MODELLING POTENTIAL DISASTER SITES FOR CITY OF NAIROBI, KENYA

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Key words: Geology, Fault lines, Seismology, GIS, Hazard modeling, Nairobi.

ABSTRACT

This paper is an attempt to determine the potential disaster sites within the city of Nairobi and its environs. Nairobi sits close to the eastern flanks of the great rift valley and recent revelations that the valley may be expanding at a rate of (2-3) mm per year due to tensional forces in the crust (Waithaka, 20001). The high heat flow beneath the crust is represented by the geothermal activities at Olkaria, Bogoria and Kapedo in Turkana District (M.lbs – Von Seht et al., 2000) and the high seismicity around Lake Magadi is evidence of a continental plate break-up (Prodehl et al., 1991) Recent geodynamic studies based on the International GPS Service (IGS) indicate that the African plate has moved northwards by 7 cm into the European plate between 1993 and 2000. This proximity to the active rifting system and general behaviour of the African plate calls for continuous assessment of the tectonic state of the City.

The geological map of Nairobi area (scale 1: 125,000) was manually digitized to create a digital base for subsequent GIS analysis. A topo-cadastral map of Nairobi scale (1:20,000) was also digitized and superimposed onto the geological digital map. Seismic data for the period 1994 to 1999, obtained from the Department of Geology, at the University of Nairobi were also incorporated into the data-base. Preliminary results indicate that the faultlines are affecting a good number of plots in the western side of Nairobi including the prime areas of Karen and Langata. The results also indicate that there are virtually no faultlines in the eastern side of Nairobi. Seismology data indicate very minimal earthquake activity in the general area of Nairobi but high activity in the Ongata Rongai/Ngong areas of the western parts of the city and Lake Magadi area. Further research is being undertaken to include analysis of remote sensed data, old landfill sites, caves, old quarries and height of buildings to produce a more representative model for disaster mitigation in the city.

1. INTRODUCTION

The International Decade for National Disaster Reduction (IDNR) was declared by the United Nations General Assembly in December 1989 as an international promotional mechanism for the period 1990 – 2000 when special attention would be encouraged to foster international cooperation to reduce the global effects of natural disasters. The main objective of the decade was “the reduction of loss of life, property damage, and social economic disruption caused by natural disasters, through concerted international action, especially in developing countries’. In order to achieve this objective the following goals were declared for the decade;

- To improve the capacity of each country to mitigate the effects of natural disasters with special attention being given to assisting developing countries in the assessment of **disaster damage potential**, and in the **establishment of early morning systems and disaster-resistant structures**.

- To device appropriate guidelines and strategies for applying existing scientific and technical knowledge, taking in account cultural and economic diversity;

- To foster scientific and engineering endeavour aimed at addressing critical gaps in knowledge in order to reduce loss of life and property.

- To disseminate existing and new technical information related to measures for the assessment, prediction and mitigation of natural disasters; and

- To develop measures for the assessment, prediction and mitigation of natural disasters through programmes of technical assistance and technology transfer through demonstration projects, education and training, and to evaluate the effectiveness of theses programmes. (Olavi et al; 1996). This study was undertaken to fulfill some of the above objectives.

Problem Statement

The problem however, is that the analysis of natural disasters is a complex issue, requiring a large input of geospatial data. Previous studies on disaster mitigation in the study area (i.e. Kenyan Rift Valley and environs) have approached the phenomenon in a piece-meal manner, often according to the professional interest and preferences of the respective researchers. These include Elizabeth Shah (1986) and her study of seismicity of Kenya, C. J. Swain (1977) on Gravity and seismic measurements of Kenya, Brian Howard Baker (1970) and his work on Tectonics of the Kenya Rift valley, Ochieng' (1992) and his research on Seismic Energy Mapping and Strain Release Pattern of Kenya. More recently, the Kenya Rift International Seismic Project (KIRSP) Prodehl et al., (1994 – 1999) carried out extensive Seismic survey of the Kenyan Rift Valley and observed very high and frequent sensitivity around Lake Magadi: The Department of Geology has also launched a continuous seismology programme to monitor earthquake activities in Kenya since 1994 and publishes its results annually (Hollnack, 1996). There has therefore been a lot of duplicity on disaster mitigation studies without a comprehensive assessment of the impact of these indicators (i.e. measured earthquakes, faultlines, gravity anomalies etc.) on the existing engineering structures and the built environment; neither has there been a proper evaluation of the geological parameters in siting of dams, large buildings, Airports etc. The results of such studies have been limited in application, and often lack capacity for multiple integration.

In the world of property valuation, real estate managers have not been able to present objective valuation of such properties due to lack of data on the geological status of the plot – Insurance Agencies cannot place realistic premiums on buildings and structures on such plots due to lack of geological information.

As observed by Ananaba (1991) good economic judgment requires that potentially active seismic zones and faultlines (such as the rift valley) identified, mapped and carefully assessed , and where possible, avoided when siting major structures. It is therefore desirable to have a comprehensive data-base where relationship between geological features and measurements (e.g. seismological data, gravity, faultlines, landslides etc.) and the built environment can be assessed.

Currently, a combination of Geographic Information System (GIS), Global Position System (GPS) and remote sensed data, provide one of the most cost-effective tools for analyzing multispectral data associated with natural disaster mitigation. Once we have the relevant data-base and an information system that can cater for geospatial data, it becomes relatively easy to develop hazard zonation maps and mitigation strategy (Sarat et al., 1996). It is therefore the intention of this study to construct and maintain a comprehensive geospatial data-base for Nairobi area, based on GIS, GPS and remote sensing technology for hazard mitigation and early morning system.

The Study Area

The City of Nairobi is located approximately at the junction of 36.5° longitude and 1.5° south latitude at an altitude of 1676 m (5500ft) above mean sea level and an average temperature of (21 – 22)° C. The total population of the city is 3 million people with a annual growth rate of 5.5. per cent. The growth of Nairobi is related to the construction of the Uganda railway from Mombassa to Kisumu on Lake Victoria between 1896 and 1901. On 24th May 1899, the railhead reached Nairobi, a place known by the Maasai as Nakusontelon, i.e.: “the beginning of all beauty”, although Preston described it as a bleak, swampy stretch of soppy landscape devoid of human habitation of any sort but streaming with thousands of wildlife of every species” (Miller, 1971). Nakusontelon was bisected by a small stream, which the Masai called Uaso Nairobi (a place of cold water), and it is this name, which was eventually adopted for modern Nairobi.

Geological Setting

The geological history of Nairobi has been dominated by volcanic activity whereby a thick succession of alkaline lavas and associated tuffs began accumulating in mid-miocenne time and continued into the upper Pleistocene.
Practically the entire Nairobi area is covered by these volcanic rocks derived from the Rift Valley region and estimated to accumulate in volume to more in volume to more than 250 cubic miles (1,042 cubic km) and covering an area of nearly 1,200 square miles (3000 km^2).

In the present area, the extent of the lava flows beneath the cover of Limuru Trachytes, has been estimated to form a major part of geology of western areas of Nairobi. Volcanism began with the extrusion of Kapiti phonolite which has been dated at 13 Ma. The eruptive products of the volcanoes provide the most topographic expression of Nairobi.

The main geologic formations in Nairobi area are, undifferentiated Ngong volcanic material (Tva_3), Tva_1 (Basanites), Tva_2 (Tephrites), Tvp2 (Kandizi phenolites), Tvt_2) Nairobi Trachytes), which covers most of the Karen area; $Tvtf_2$ (middle and upper Kerichwa valley tuffs) which cover Wilson Airport area, Tvp_3 (Nairobi phonolites – of lower Trachyte Division) which cover most of eatern parts of Nairobi, including Jomo Kenyatta International Airport (JKIA). The CBD and the rest of the city is covered in various form of Trachytes, (Saggerson, 1991). A full digital map showing all the geological formation of Nairobi is presented in Figure One.

2. MATERIALS AND METHODS

2.1 Materials

The materials used for the study included a geological map of Nairobi (scale 1:125,000) and its associated literature (Saggerson, 1991); two topographical maps of Nairobi ,i.e Nairobi and environs scale 1:50,000 and Nairobi Central Business District topo-cadastral map, scale 1:20,000.

2771 Seismographic points covering the whole country form 1994 – 1999 obtained from the department of Geology, at the University of Nairobi. These points are described in details by Hollnack (1996). Each of the seismic points are presented in terms of code, year of occurrence, date, time, latitude, longitude, depth, origin, number allocated to the point, root mean square value (rms) and the magnitude of the earthquake.

Other data that were considered but have not been analyzed are panchromatic black-and-white photographs, satellite Landsat and SPOT remote sensed data and other auxiliary information such as heights of buildings, old landfill sites, old quarries and general landform situation in the city.

2.2 Methodoly

The geological map was digitized manually to create a digital base-map for subsequent GIS analysis. All the features on the map were digitized and assigned colours similar to the map. The geographical grid values were converted to Kenya UTM grid automatically by the mapinfo software so that all features could be registered in the UTM system. This map formed the basis of further analysis of all subsequent thematic data.

The Nairobi city map was also manually digitized on a UTM grid system available on the map. The resultant map shows all the residential areas, industrial areas, roads, railway lines and al infrastructure of the city. This is the most detailed map available covering the Central Business District of Nairobi. The Nairobi and environs map was scanned and produced at a scale of 1:50,000 and it covers a much wider area than the CBD topo-cadastral map.

Seismographic data were incorporated into the data-base by coordinates after conversion from geographicals to UTM. In total 2771 points were entered covering the whole of

Kenya and parts of Tanzania. The rest of the information about seismographic stations were entered as attributes.

Data Integration

The mapinfo GIS software was used to correlate all the above data by layering onto the digital geological map. A comparative analysis was undertaken to determine the relationship between faultlines and seismographic stations to the built-up areas of Nairobi. The main objective was to assess which parts of Nairobi are affected by faultlines and seismicity. These areas are considered potential disaster sites and are recommended for special treatment during design and construction of engineering structures.

Results

The preliminary results indicate that there are numerous faultlines towards the western edge of the city (Fig. 1.0) passing through some prime plots in Karen and Lang'ata area. The Ngong/Ongata/Kiserain area show a lot of seismicitiy and numerous faultlines. Lack of seismicity on the faultlines within Karen/Lang'ata area however implies that the faultlines are not active.

No faultlines were observed within the Central Business District (CBD) of the city and towards the eastern end. Seismicity in the city is also minimal (Fig. 4.0) and all the points are below magnitude 4.0. The most notable observation for seismic data is that Lake Magadi is the most seismic area in Kenya. This corroborates the findings of the KRISP study of 1994 – 1999 (Prudehl et al., 1994) and since the area is only 100 km due south of Nairobi; this high seismic activity can easily affect the city.

The use of GIS as a tool for the hazard modelling is much more effective that the single approach where each spatial variable is analyzed on its own. By using the several options of the software, it was easy to transform coordinates, assign colours, enter additional attributes and carry out multiple correlation through layering.

Further Work

As indicated before, the results presented here are not exhaustive as several sources of data have not been considered. Further research is being undertaken to include identification and mapping of faultlines and other lineaments with remote sensed data. Elsinga and Verstappen (1989) observed that stereo SPOT Satellite data showed faultlines that were not available even on the geological maps, and recommended the use of these data for lineaments analysis. Global Position Measurements shall also be undertaken to eliminate scaling errors.

Height of buildings within the city will be incorporated in the data-base as part of the modelling strategy. Old land fill sites, old quarries and location of caves shall be mapped from aerial photos as a means of assessing geotechnical status of buildings and other engineering structures.

CONCLUSION

The preliminary results presented here show that there is great potential in the use of GIS technology in disaster modellilng and hazard mitigation. The problem in the less developed countries lack adequate historical geological/geomorphic data for development of realistic models. The effort by the department of geology at the University if Nairobi in collecting and publishing Seismologiy data for the region is commendable.

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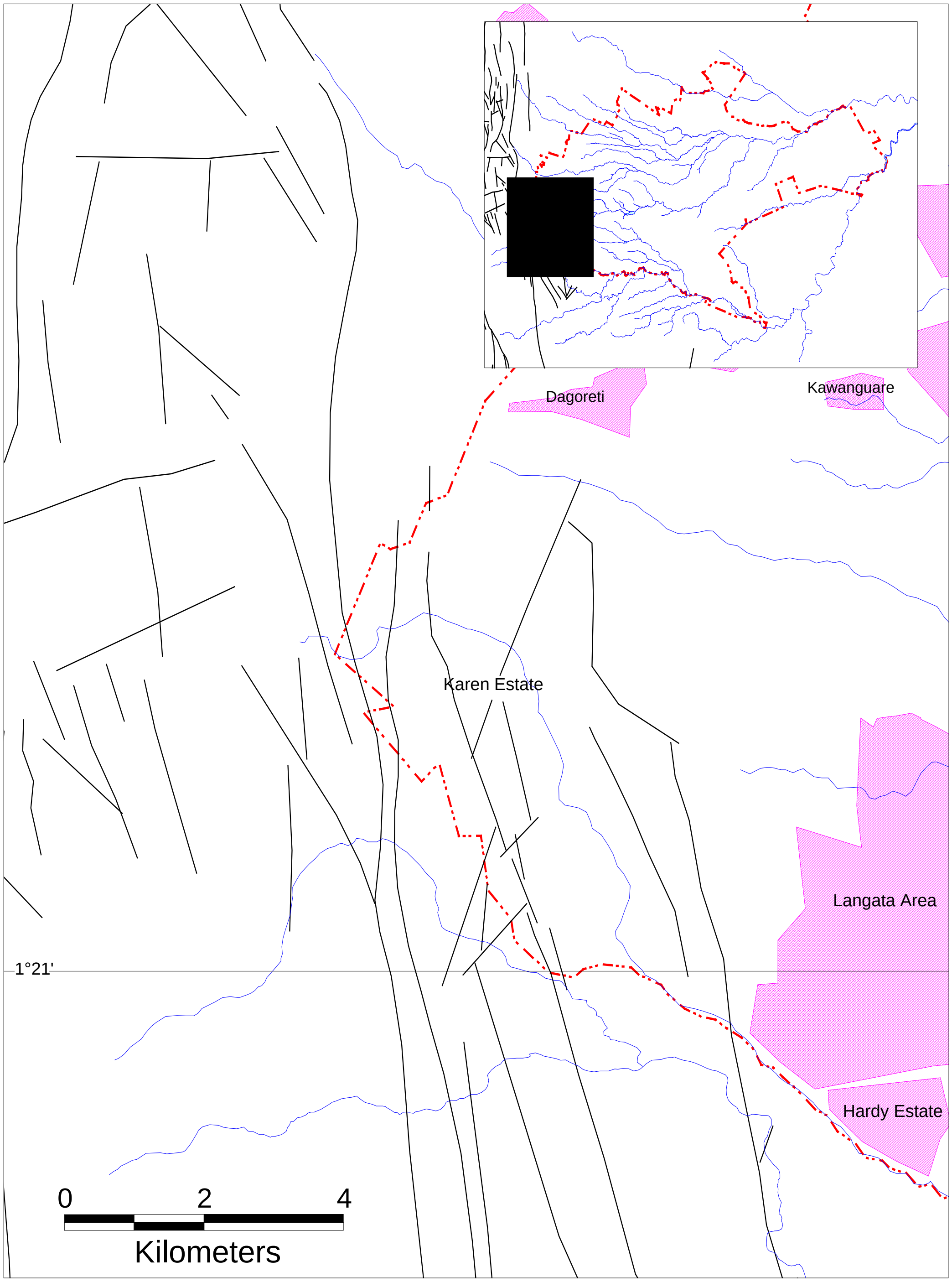


Fig.1.0: Map showing position of fault lines in Karen/Langata area of Nairobi.

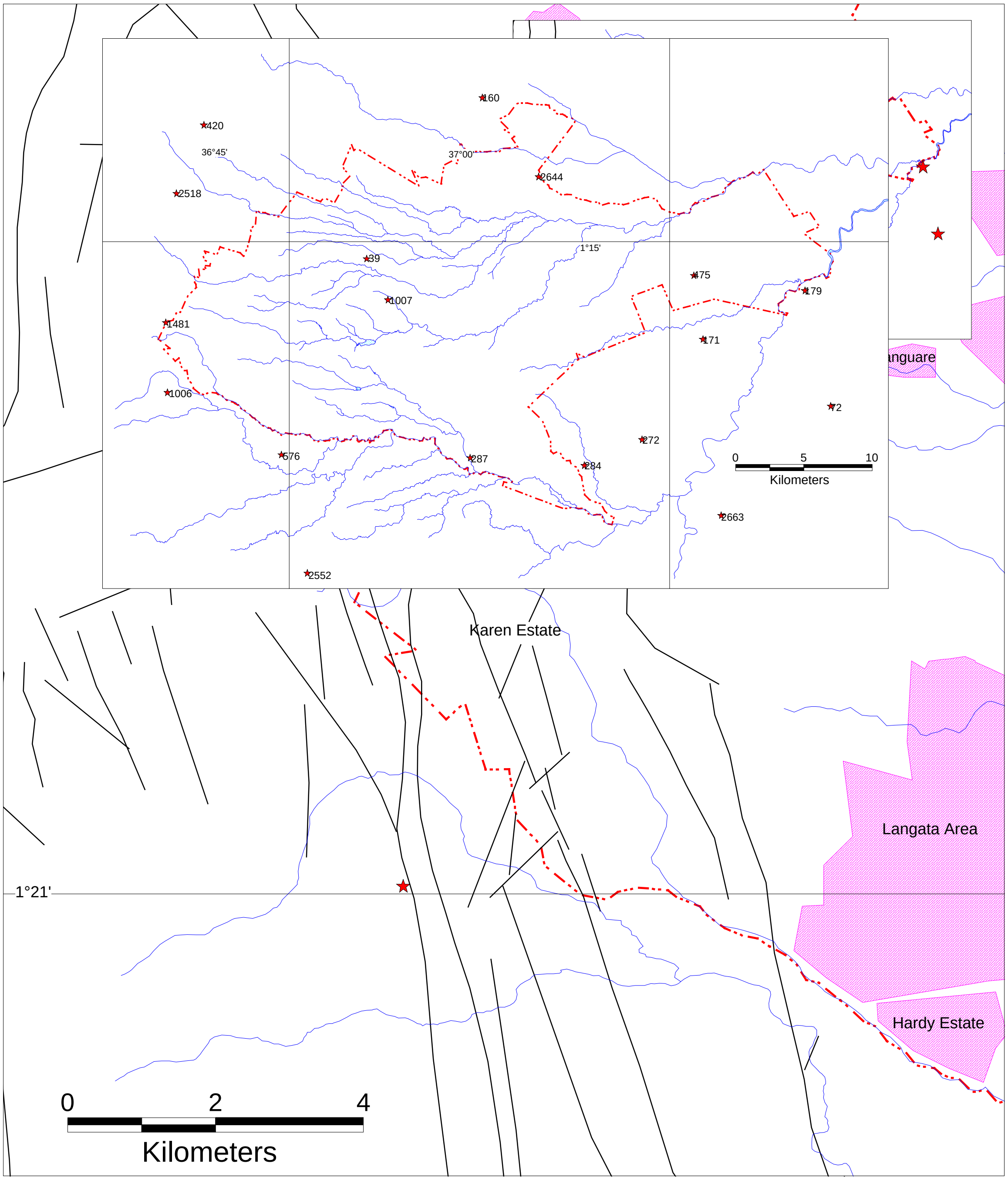
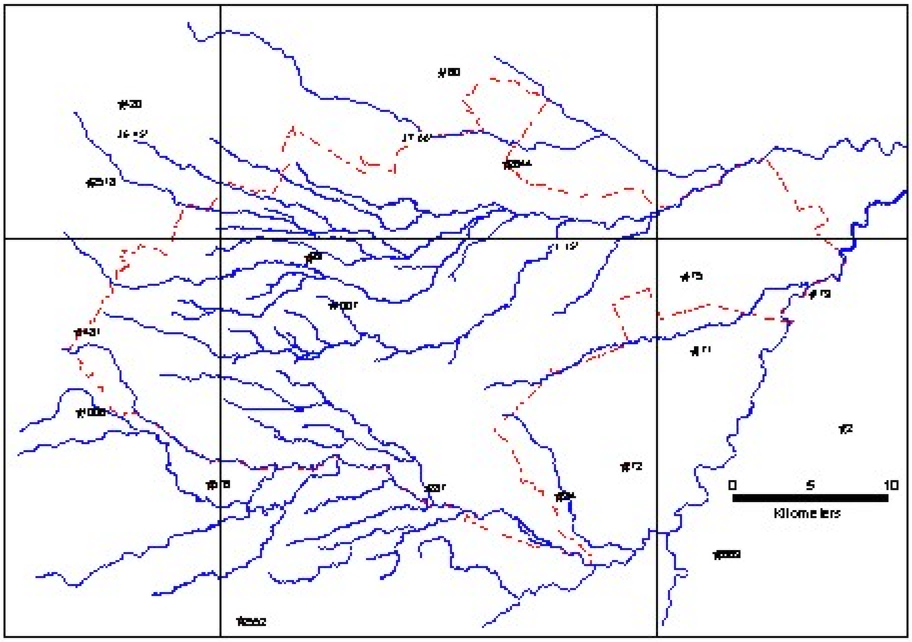


Fig.2.0: Map showing Location of fault lines and earthquake points around Karen/Langata area of Nairobi.



CODE	YEAR	DATE	TIME	LATITUDE	LONGITUDE	DEPTH	ORG	NO	RMS	MAGNITUDE
39	1994	511	95545.9	-1.26100	36.80100	10	Com	2	0.2	
72	1994	620	80732.2	-1.35800	37.10600	10	Com	3	0.2	2
160	1995	1119	220010.6	-1.15500	36.87700	10	Com	1	0	1.2
171	1995	125	34255.6	-1.31400	37.02200	10	Com	1	0	1.9
179	1995	128	14245.3	-1.28200	37.08900	10	Com	1	9.9	2.3
272	1996	11-Mar	150628.2	-1.38000	36.98200	10	NAI	1	0	0.9
284	1996	12-Apr	103148.3	-1.39700	36.94400	11.7	NA	I	2	2.1
287	1996	16-Apr	143732.3	-1.39200	36.86900	16.7	NAI	2	0.2	1.4
420	1996	917	12755	-1.17300	36.69400	17.4	NAI	2	0	1.7
475	1996	226	131321.5	-1.27200	37.01600	10	NAI	1	0	1.3
576	1997	326	131635.3	-1.39000	36.74500	11.5	EAF	5	0.7	4.4
1006	1998	314	64911.5	-1.34900	36.67000	10	Nai	1	0	2.0
1007	1998	314	135712.6	-1.28800	36.81500	10	Nai	1	0.1	1.7
1481	1998	514	233346.1	-1.30300	36.66900	10	Nai	1	0	2.2
2518	1998	915	70826.8	-1.21800	36.67600	30.3	EAF	2	0	1.5
2552	1998	112	103429.6	-1.46800	36.76200	10	EAF	1	0	1.5
2644	1999	21	9581.7	-1.20700	36.91400	10	EAF	1	0	1.5
2663	1999	217	211440.4	-1.43000	37.03400	0	EAF	2	6.9	2.4

Fig. 4.0 Map showing location Earthquake points around Nairobi

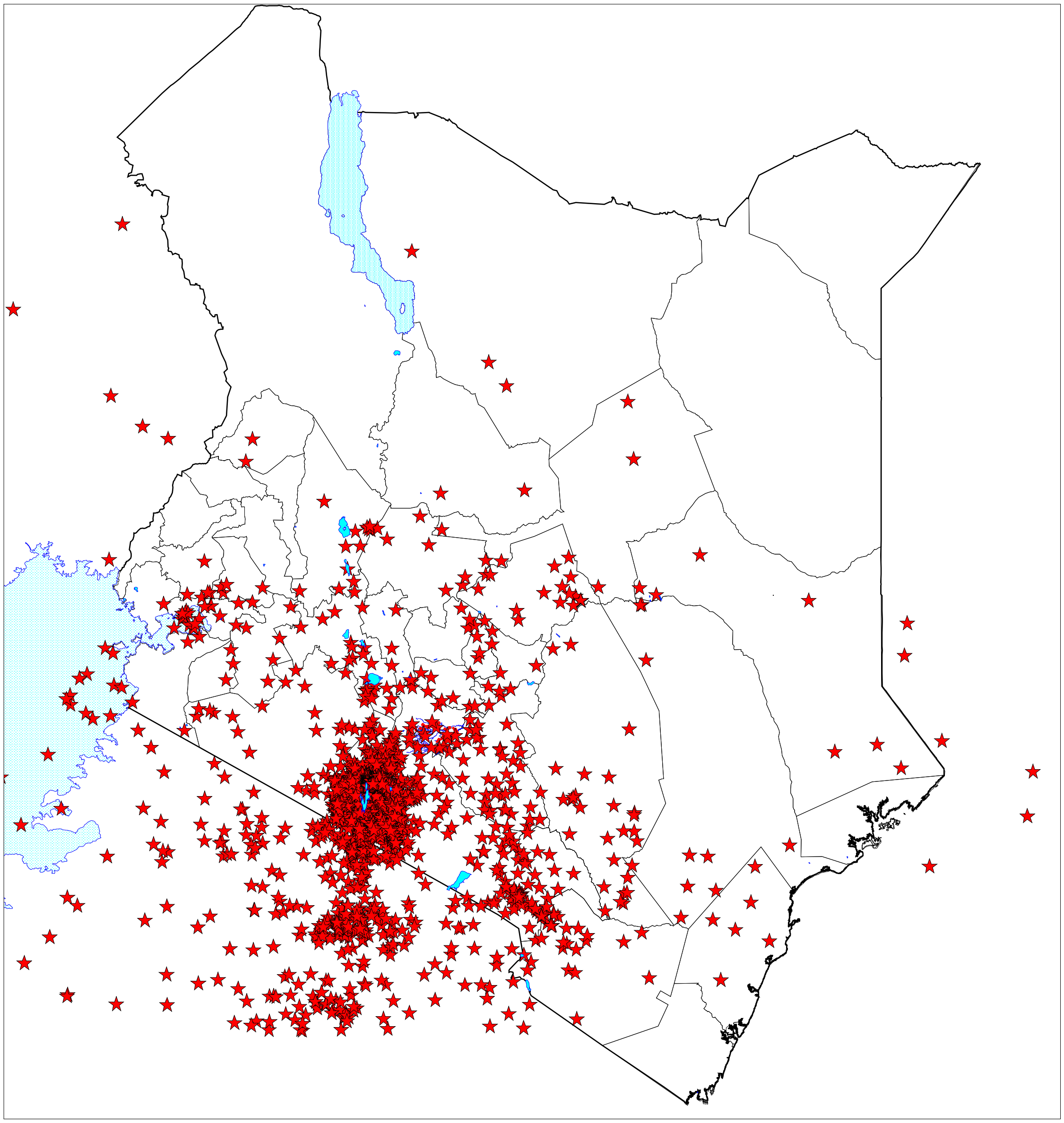


Fig. 5.0: Map showing the distribution of earthquake points in Kenya.