UNIVERSITY OF NAIROBI

School of Engineering

DEPARTMENT OF GEOSPATIAL AND SPACE TECHNOLOGY

Application of GIS in Road Reserves Mapping

Case Study: Kayole – Mananja – Masinga (C438) Road in Machakos County.

NJOKA, DAVID MURIMI

F56/75066/2014

A Project Report submitted in partial fulfillment of the requirements for the Degree of Master of Science in Geographic Information System, in the Department of Geospatial and Space Technology of the University of Nairobi

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DECLARATION OF ORIGINALITY

Name of student:	DAVID MURIMI NJOKA
Registration:	F56/75066/2014
Faculty/School/Institute:	Engineering
Department:	Geospatial and Space Technology
Course Name:	Master of Science in Geographic information System
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NJOKA, DAVID MURIMI 04/09/2023

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DR. S. M. MUSYOKA 04/09/2023

Name of Supervisor Date

ABSTRACT

A functioning road infrastructure accelerates socio - economic developments. In Kenya, the most used mode of transport is by road. However, some key challenges are facing the road sub-sector in that road reserves are narrow and many are facing encroachments. This is due to lack of concise information on road reserves since the traditional manual system of road reserves information management in form of hard copy maps and records, which is still in use today, is not only less effective and efficient but also time consuming especially during road reserves information retrieval. Therefore, there is need to develop a modern road reserves management geodatabase that will facilitate effective and efficient road reserves information collection and dissemination, so as to protect the road reserves in order to support long term sustainable development of the road infrastructure.

The first step in developing a modern road reserves management geodatabase was collection of relevant datasets, both spatial and non-spatial. In this case, registry index maps, ground control surveys and topographical maps were collected. The datasets used were obtained from different sources and with different data properties and coverage. These datasets obtained were then edited and harmonized together. This involved confirming and ensuring that the datasets were congruent in terms of scales, projection, georeferencing and all the other harmonization aspects. Querying criteria was built to allow the road reserves information transfer.

As a result, using AutoCAD and Arc map softwares, the topographical data and the registry index maps, the road reserve along Kayole – Mananja (C438) road was therefore mapped and a geodatabase for road reserves mapping was designed.

Essential geographical information to the users was retrieved from the geodatabase when subjected to queries. This study proved that GIS is a very critical technological advancement in the management and development of the road infrastructure. It was realized that through the created geodatabase, it was possible to identify encroachments on the road at the area of study.

Finally, it is recommended that the road reserves information geodatabase designed should be shared through the web and mobile GIS platforms for faster and easier access of the information.

DEDICATION

This project is dedicated to my loving wife and my beloved children

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The completion of this work was made possible with both the cooperation and assistance of many people whom I sincerely wish to acknowledge.

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Wishing you all God’s blessings.

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LIST OF ABBREVIATIONS AND ACRONYMS

GCPs ……………………………………………………………………..Ground Control Points

GIS…………………………………………………………...Geospatial Information System

GNSS……………………………………………………..Global Navigation Satellite System

KENHA…………………………………………………...Kenya National Highways Authority

KURA…………………………………………………………...Kenya Urban Roads Authority

KERRA…………………………………………………………..Kenya Rural Road Authority

PID……………………………………………………………….Preliminary Index Diagrams

RIM……………………………………………………………. ……..Registry Index Maps

SOK………………………………………………………………………….Survey of Kenya

CHAPTER 1: INTRODUCTION

1.0 Background

Transportation as a way of taking goods, services and people from one place to another plays a very important role in life today. It has played this important role in most societies in the past. The adequacy of a society's transportation system is a fair index of socio - economic development of communities .The road transportation network has quickly developed in Kenya since the most used mode of transport is by road. This situation arises due to the annual increase in the volume of vehicles on the road.

With the introduction of digital cartography, many new ways have been developed to perform spatial analysis in desired formats, specifications and standards and especially for the management of the road infrastructure. This new way of performing spatial analysis better constitutes a Geospatial Information System, GIS. GIS is therefore a computer system which can assemble, store, aid in querying a database and present georeferenced geospatial data so as to help in smooth and quick decision making. Its main components are hardware, software, data, personnel, procedures, and network.

A road reserve can be described as the full width of a road, including the carriageways, shoulders, drains, backslopes, the air space above it and all other areas from boundary to boundary. It is the total area between boundaries shown on a survey plan, preliminary index diagram or on a registry index map.

Roads in Kenya are mainly classified as either national government roads or county government roads. The establishment of Kenya Rural Roads Authority, KERRA, Kenya Urban Roads Authority, KURA and Kenya National Highways Authority, KENHA is provided for by the Kenya Roads Act, 2007.These Agencies were established to deal with matters of the national government roads. These authorities and county governments are mandated to deal with various matter related to their respective road networks including maintenance of the road reserves. Road widths in Kenya varies from 9 metres, 15metres, 18metres, 25metres, 30metres up to 60 metres.

1.1 Problem Statement

A functioning road infrastructure accelerates socio - economic developments in communities, societies and in countries. Road transportation is the most commonly used type of transport in Kenya. Despite its vital role, the subsector is facing some key challenges which includes:

- Road reserves are narrow and many are facing encroachments. This is due to lack of concise information on road reserves.
- The traditional manual system of road reserves information management in form of hard copy maps and records, which is still in use today, is not only less effective and efficient but also time consuming especially during road reserves information retrieval.

Therefore, there is need to develop a modern road reserves management database that will facilitate efficient road reserves information collection and dissemination, so as to protect the road reserves in order to support long term sustainable development of the road infrastructure.

1.2 Objectives

The main objective of the study is therefore to create a GIS database for road reserve mapping and management with an aim of providing a proper up to date road reserves information collection, storage and dissemination platform.

Specific Objectives

1. To carry out mapping of the existing road widths, road furniture and assets with their locations and chainages and land parcels abutting the road reserve.
2. To design a GIS geodatabase for the road.

1.3 Justification for the Study

There have been several challenges facing the management of road reserves information in the country which includes.

1. Many cases of encroachment on road reserves and
2. A manual system currently in use, which is in form of hard copy maps, being time consuming and less effective.

However, there seems to lack a single answer which is most appropriate and sufficient to tackle the management of the road reserves information problems thereby necessiting the need to come up with a modern road reserves management geodatabase that will facilitate efficient road reserves information collection and dissemination. Furthermore, the need to provide road reserve boundary information to facilitate smooth decision making during actual road construction and general road maintenance initiated the necessity for carrying out the study.

1.4 Scope of Work

The work for this study is limited to Kayole – Mananja - Masinga (C438) road and its immediate environs. The case study for this project is also limited to topographical data collected and road reserve information along the road. Land parcel sizes, land parcel ownership, land use, road reserve boundaries, widths and chainages will be considered for road reserves dataset in this study.

CHAPTER 2: LITERATURE REVIEW

2.0 Road Reserve Boundaries

A road reserve can be described as the full width of a road, including the carriageways, shoulders, drains, backslopes, the air space above it and all other areas from boundary to boundary. It is the total area between boundaries shown on a survey plan, preliminary index diagram or on a Registry Index Map.

Roads in Kenya are mainly classified as either national government roads or county government roads. The establishment of KeRRA, KURA and KeNHA is provided for by the Kenya Roads Act, 2007.These Agencies were established to deal with matters of the national government roads. These authorities and county governments are mandated to deal with various matter related to their respective road networks including maintenance of the road reserves. Road widths in Kenya varies from 9 metres, 15metres, 18metres, 25metres, 30metres up to 60 metres.

To many people, the distinction between a road reserve and the physical road is unclear. The physical road formation is supposed to be contained within the legal road reserve. Where a new road is to be created, surveyors play a vital role. More often than not, legal road reserves have been used to host several public facilities and utilities e.g. electricity power lines, Optic fibre cables and several other road resources as shown in Figure 2.0 below.

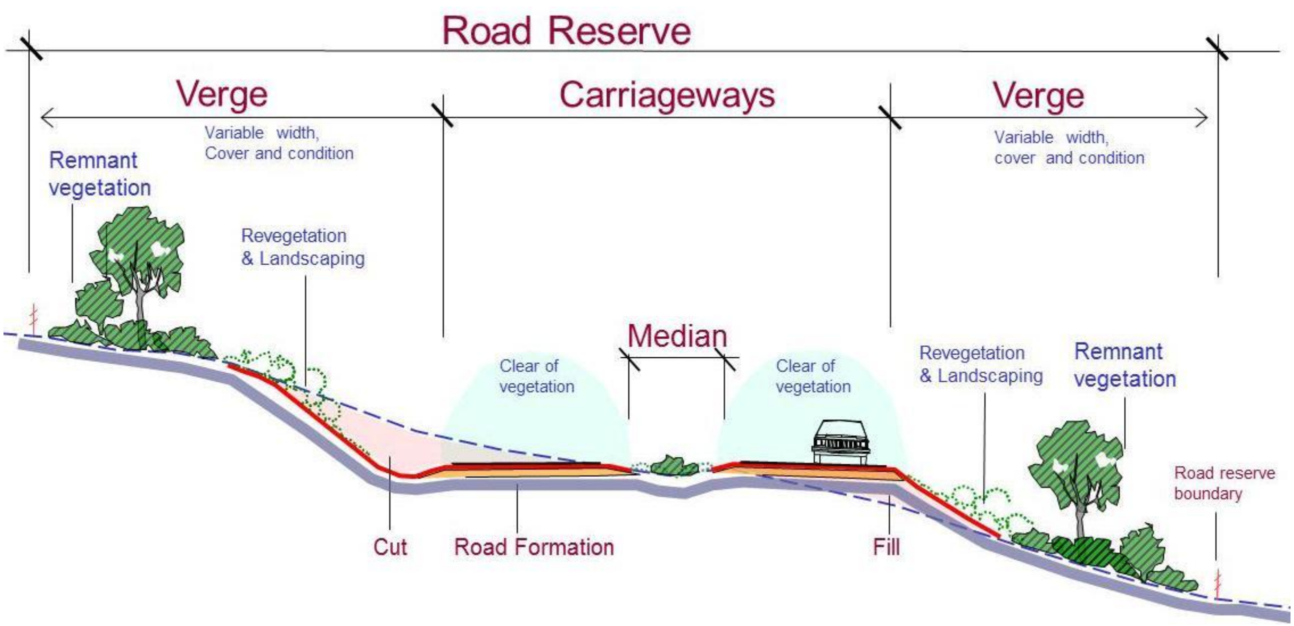

Figure 2.0 A diagram depicting a road reserve

2.1 Mapping and Demarcation of the Road Reserves

Mapping is the transformation of survey measurements into a visual representation that can be used to support a given decision. Mapping was traditionally done using field survey techniques (ground survey methods) using among others, the traditional optical instruments like total stations and theodolites. With advancement in technology, various mapping techniques such as aerial photogrammetry, remote sensing emerged that are more accurate and efficient. These methods have been used in the parcel boundary mapping. The survey techniques used have captured data as imagery, photographs, survey plans and so on depending on the mapping methods used. The data is henceforth processed to give deliverables such as topographical maps, cadastral maps, engineering drawings and so on depending on the intended purposes. Boundary demarcation survey on the other hand is an activity to accurately survey and build a boundary marker along the boundary line. The boundary markers define the boundary delineated in the cadastral maps. The existence of the boundary survey markers gives physical appearance of the boundary line in the field preventing the ambiguity (Sutisna & Handoyo, 2006). The survey marks used to define the boundary depends upon whether the boundary is fixed or approximate. In an approximate boundary, the boundary is generally demarcated by natural features such as river, watershed, and ridges. On other hand, for fixed boundary, it is defined by coordinates referenced to a particular geodetic reference system. Here, the physical survey marks including beacons, and marker posts are used to define the boundary line.

2.2 Road Classification

Roads are generally classified and categorized according to the functions they serve. Refer to table 2.0 below.

Table 2.0 Road classification **(Source KRB)**

S/ no	Road class	Function	Agency	Recommended Standard road width (Metres)
1	Class A roads	Roads that connect cities of international importance, crossing international boundaries.	KENHA	40 - 60 meters and above
2	Class B roads	Roads that connect National centers and urban centers.	KENHA	40 Meters
3	Class C roads	Roads that connect provincial important centers, towns to each other.	KeRRA	30 - 40 Metres
4	Class D roads	Roads that connects important centers to each other.	KeRRA	20 - 30 Metres
5	Class E roads (Minor roads)	Roads that links minor or local shopping centers and markets	County Governments	Less than 20 Meters

2.3 Way leaves

A way leave can be defined as an agreement between an owner of a piece of land and another land owner or a person providing a service, where the owner of the land gives consent to the service provider the right to access, use and maintain or install services in his land. Section 49 of Kenya Road Act states inter alia……. *"no person or body may do any of the following things without the responsible Authority's written permission or contrary to such permission— (a) erect, construct or lay, or establish any structure or other thing, on or over or below the surface of a road reserve or land in a building restricted area; (b) make any structural alteration or addition to a structure or that other thing situated on or over, or below the surface of a road or road reserve or land in a building restriction area; or (c) give permission for erecting, constructing, laying or establishing, any structure or that other thing on or over, or below the surface of, a road or road reserve or land in a building restriction area, or for any structural alteration or addition to any structure or other thing so situated."* (Kenya Roads Act, n.d.).

It is worthwhile noting that road agencies responsible for managing roads are the ones that regulates granting of way leaves along and across road reserves for any roadside developments thereby ensuring that they are legally protected from encroachments.

2.4 Building Lines (Set Back Distances)

The Kenyan Physical and Land use Planning Act, 2019 stipulates that a buiding line is a restriction which specifies that buildings are not allowed to be situated within a certain distance from the road reserve boundary for preserving the road and road side amenities. The Act further specifies that building line for permanent structure in the abutting plots should be 6m or 9m from the road reservation of 6-18m or above 18m respectively. This building line specification ensures that road reserves are protected from encroachments during construction of buildings and structures.

2.5 Boundaries and Cadastral Maps

2.5.1 Fixed Boundaries

A boundary where the dimensions and boundaries of a parcel are defined by reference to a plan verified by the office or authority responsible for the survey of the land, and a note is made in the register, the parcel shall be deemed to have had its boundaries fixed under Section 19 of the Land Registration Act (No.3 of 2012). Such boundaries are defined by series of boundary beacons whose spatial details are referenced with respect to a national coordinate system. In survey plan necessary for registration of fixed boundary parcels, beacons are appropriately marked and described. The bearings and distances between the turning points except for irregular boundaries are well indicated. According to Survey Act Cap 299, Kenya survey is based on two national coordinate systems; Cassini-Soldner and UTM coordinate systems. Presently, there are attempts to modernize the National Coordinate System that is uniform and continuous to conform to Kenya Geodetic Reference Frame (KENREF) by GNSS methods in line with the United Nations Global Geospatial Information Management (UN_GGIM). The preliminary designs and construction of Continuously Operating Reference Stations (CORS) are on-going.

2.5.2 Approximate Boundaries

These are “general boundaries” of a parcel of land defined by existing physical features that may be characteristically irregular in alignment or variable in width. They include but not limited to hedges, fences, stones, walls, and water bodies. The Land Registration Act (No.3 of 2012), specifies that the registration and management of “approximate boundary” parcels in Kenya requires cadastral maps and plans such as Preliminary Index Diagrams (PIDs), Registry Index

Maps (RIMs) and Registry Index Maps-Range. Approximate boundaries are not surveyed accurately and are appropriate in areas where the accuracy is of little concern (Mumbone, 2015).

2.5.3 Cadastral Maps

Cadastral maps include survey plans, registry index maps (RIMs), Preliminary index diagrams (PIDs) and Registry Index Maps-Range (Provisional). They form basis of registration of land parcels as well as it is the indicator of the location and geometric size and shape of a parcel of land. They are also used to demarcate the lost or interfered with boundaries. In boundary disputes, cadastral maps are instrumental in providing parcel number and geometrical shape and position of land parcel. Land Surveyors, therefore interpret these maps and restore lost boundaries to a considerable level of success (Peter & Wanyoike, 2001).Peter and Wanyoike further indicated that some of the RIMs are not conclusive on the precise position of the boundary, which causes confusion to map users, especially in solving boundary disputes. In other words, the ordinary map users do not know the limit to which such maps can be used and that encourages apathy in them.

2.6 National Geodetic Control Network and Datum Conversions

Kenya uses several geodetic coordinates systems which include; The Cassini-Soldner coordinate system; the Universal Traverse Marcator coordinate system and the East African war system coordinate system. According to Survey Act Cap 299, Kenya survey is based on two national coordinate systems; Cassini-Soldner and UTM coordinate systems.

2.6.1 Cassini-Soldner Coordinate System

Cassini-Soldner is a local coordinate system that uses Clarke 1858 reference ellipsoid and it's referenced to 1950 Arc Datum and the unit of measurements is feet. It is a plane (grid – coordinates) with orthogonal axes. The coordinate system in this projection originates at the intersection between the equator and the odd meridians such as 35°E, 37°E, 39°E, and 42°E to cover the entire Kenya. In Kenya, before 1950, cadastral surveys were based on Cassini-Soldner projection (system). As a result of emergence of modern technology that is mostly in use such as Global Positioning System (GPS) and usually in UTM projection, cadastral maps are often being re-projected to UTM.

2.6.2 Universal Transverse Mercator (UTM) Coordinate System

The Universal Traverse Mercator projection is based on the Transverse Mercator (TM) with secant cylinder. This is based on ellipsoid that is divided into 60 zones of the same size, numbered 1- 60, starting at the International Date Line (IDL) at longitude 180° and proceeding east. Each zone has a 60° longitudinal width and overlaps the adjacent zone by 00 30″. It covers from 80°S to 84°N. Polar wards of the UTM are covered by Universal Polar Stereographic (UPS) system. It is important to note that UTM is a conformal projection and therefore it preserves angle and shape of small areas. It is important to note that in Kenya, UTM coordinate system uses Clarke 1880 reference ellipsoid that is referenced to 1960 Arc Datum and it falls in Zones 36 and 37 with their central meridians being 33°E and 39°E respectively. The reference ellipsoid to which UTM is used in Africa is based on Clarke 1880. Finally, it is important again to note that like Cassini coordinate system, UTM coordinate system is also plane (grid – coordinates) with orthogonal axes.

2.6.3 Transformation of Coordinates between Cassini-Soldner and UTM

In Kenya, for example, survey has been done based on various map projections- Cassini-Soldner projection based on Clarke 1858 ellipsoid (datum) and UTM projection based on Arc 1960 datum. Cadastral surveys in Kenya before 1950 were based on Cassini-Soldner projection. With emergence of modern survey technology and application softwares that utilizes UTM projection the re-projection is inevitable to enable interoperability of data. Datasets such as topographical maps, GPS technology, and GIS system utilize UTM projection. The integration and harmonization of data surveyed in Cassini-soldner with data surveyed in UTM projection in a GIS software requires the computation and application of datum shift parameters through coordinate transformation. Transformation is a mathematical operation for changing coordinates from one coordinate reference system to another characterized by change in datum. This transformation is generally expressed as (x, y) = f (u, v) where u-v and x-y are different planes. (Iliffe & Lott, 2000).

The various coordinate transformation models in survey include 3D and 2D transformation models. In 3D transformation model for instance, Bursa Wolf model; coordinate transformation between geodetic reference frame to form 3D similarity transformations involves three small Euler values of the rotations in few arc seconds and scale parameter. The general mathematical transformation formular is given by :(Mitsakaki, 2004).

X2 = (1+k).R.X1 + tx

The transformation includes: X1 and X2 which are a source and a target coordinates of the two coordinate systems respectively, three translations components tx, ty, tz. R is rotation matrix consisting of three small Euler rotations angles x, y, z and scale factor from unity (1+k) between the two systems. Further, a 2D coordinate transformation model is a model that is applicable in relatively small network less than 100 square kilometers. This transformation is a plane-to-plane transformation where both systems differ in scales along the axes, orientation and position of their origins.

2.7 Georeferencing and Digitization

Geo-referencing is linking the image features to their true ground coordinates under appropriate coordinate system. Geo-referencing fundamentally permits the computation of the transformation parameters which may be used to compute ground coordinates from the digitizer coordinates. Geo referencing and digitization techniques are well anchored in Land Registration Act, cap 300 to facilitate the geo-referenced boundaries as well as digitization of land records for easy road reserves management etc. These techniques are very useful in utilization, sharing and incorporation of different set of survey data. Geo-referencing enable data to be converted into the same datum.

2.8 Legal Requirements

Legal documents play a critical role in land survey. It provides the guidance of how the land surveys are supposed to be done. There are several land laws in Kenya which include; the National Land Commission Act, 2012; The Land Registration Act, 2012; The Land Act, 2012. and the Community Land Act, 2016. These land laws are important to have clear understanding of the common boundaries between land portions in order to avoid disputes. Land laws aims at building sound and undisputable land parcels ownership. The boundary of a parcel of land is supposed to be established in accordance of these laws where applicable. It is therefore necessary that the land surveyor responsible for establishment or re-establishment of the property to apply the requirements stipulated in these statutory documents. Further, land laws particularly Survey Act, Cap 299 describes the role of a land surveyor in property boundary establishment and further states how these boundaries are demarcated and maintained on the ground. The common boundary between the road reserve and the abutting land parcel, just like any land boundary need to be accurately and precisely established, marked and maintained. The road agencies who are the custodians of the road reserves are obliged to maintain boundary markers indicating the common boundary between road reserves and the abutting parcels of land. There is lots of interference with the boundary markers such as hedges leading to encroachment to the road reserves. The road agencies therefore use concrete marker posts to demarcate the common boundary instead of fuzzy live hedges that are very susceptible to interference by the owners of abutting land parcels. The land registration Act, 2012 stipulates that a matter regarding boundary is to be dealt with using cadastral maps and survey plans depending on the type of boundary that exist; Approximate boundary or fixed boundary. However, position accuracy of the "approximate" boundary is noisy and sometimes do not geometrically tally with those shown on cadastral maps. These maps especially PIDs were developed from unrectified aerial photographs inheriting distortions and lacked uniform scale. This resulted into non-conformal in geometry of the features mapped. Land Registration Acts further spells out penalties, fines or imprisonment, for any person who interferes with the common boundary markers.

2.9 Overview of GIS

Geospatial Information System is a computer system which can assemble, store, aid in querying a database, and present georeferenced geospatial data so as to help in smooth and quick decision making. Its main components are hardware, software, data, personnel, procedures, and network. The workflow in GIS involves:

1. **Collecting GIS Data**

Data used in GIS is collected by several ways among them: Classical field surveys, GPS, LiDAR mapping, scanning and geo-referencing analogue maps; validation of data, quality control, excel data, secondary shape files, among other data.

2. **Maintaining and Editing GIS Data**

Several ways are used in order to maintain the GIS data in a n optimal condition by way of ensuring effective management, control and manipulation of spatial and non-spatial and attribute data.

3. **Analyzing GIS Data**

Spatial and attribute queries, spatial analysis, computational analysis, multi-criteria analysis among others are ways in which GIS data is analyzed to ensure better retrieval of information.

4. **Displaying/Presentation**

Maps, charts and graphs, reports and Web maps are ways in which GIS data is displayed and presented.

2.10 GIS and Road Inventorying

The features that can be mapped into the GIS database include: land assets (camps and weighbridges); Road Signage; Culverts and Bridges; Road Streetlights; Survey Marker Posts (if they exist); Guard Rails and Bumps; Road condition (if there are potholes, blocked culverts etc.); Accident prone zones if any; Road corridor (reserve extent) condition i.e. encroachments etc.

GIS can be used to carry out an inventory and map the existing and proposed road assets within the road corridor this requires the use of handheld GPS devices enabled with GIS mapping applications. Alternatively, smartphones (android enabled) can be used. This data can be stored in the database and/or used to develop a prototype system of linking the collected field data to a GIS geodatabase in real-time. With a GIS portal the public can be involved in reporting incidents like potholes, blocked culverts etc. this can inform an agency in due time and help in speedy response mechanisms. The ultimate goal is to have a harmonized and centralized database showing an agency assets, roads condition, accident hotspots and measures to be put in place to safeguard them.

2.11 Land Surveyors and Road Reserves Mapping

An organization of surveyors in the United Kingdom defines a surveyor as a professional who provides expert advice on property and construction, including valuation, management, development, and sustainability. The Organization further defines a chartered surveyor as a qualified professional who has met rigorous standards of education, training, and ethical practice. Chartered surveyors have a wide range of skills and expertise, and may specialize in areas such as building surveying, quantity surveying, land surveying, property management, or environmental assessment.

Further, in Kenya, Institution of Surveyors of Kenya (ISK) defines a surveyor as a professional who is trained in the science and art of measuring and mapping the physical features of the earth, as well as planning, designing, and managing land and water resources. From these definitions among others, a surveyor can be defined as a professional person who has acquired certain academic qualification, skills and expertise to competently execute survey activities within technical requirements. The conventional and contemporary responsibility of a surveyor can be understood under the philosophy of surveying. The responsibility of surveyor is the provision of accurate geospatial information (Ezeomedo, 2019).It is important to note that survey has advanced from purely classical survey techniques with integration of new and developing technologies such as Global Positioning System, Light Detection and ranging (LiDAR), Un-manned Aerial Vehicle (UAV), and Remote Sensing (RS), Satellite imagery, Laser mapping and fast computing to create complex layers of interconnected geographic information. The professionals who use these new technologies are known as Geospatial/Geomatic Engineers. These professionals as well as Classical Surveyors play an integral role in ensuring that road reserves are well protected and optimally managed.

CHAPTER 3: MATERIALS AND METHODS

3.0 Area of Study

The spatial extent of the area of study is 21.82 Km^2. According to UTM projection, this area is in zone 37 south M. Kayole - Mananja – Masinga (C438) road is situated in Masinga Constituency in Machakos County. It starts on A2 (Nairobi – Nyeri Highway near Kambiti) and passes through Mananja township to Masinga township. This Study covers a section between Kayole and Masinga Townships and measures approximately 10 kilometers. Much of the economic activity is indigenous cattle rearing and Sand Harvesting with minimal mixed farming while pronounced farming is around Masinga Township. Refer to figures 3.0 & 3.1.

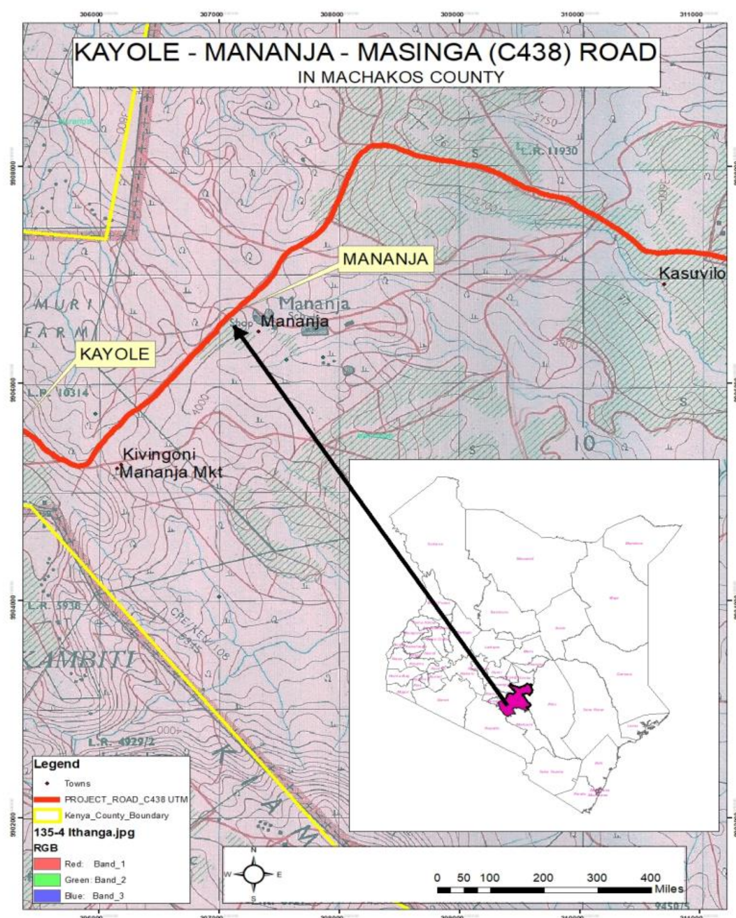

Figure 3.0 Area of Study, C438 Road

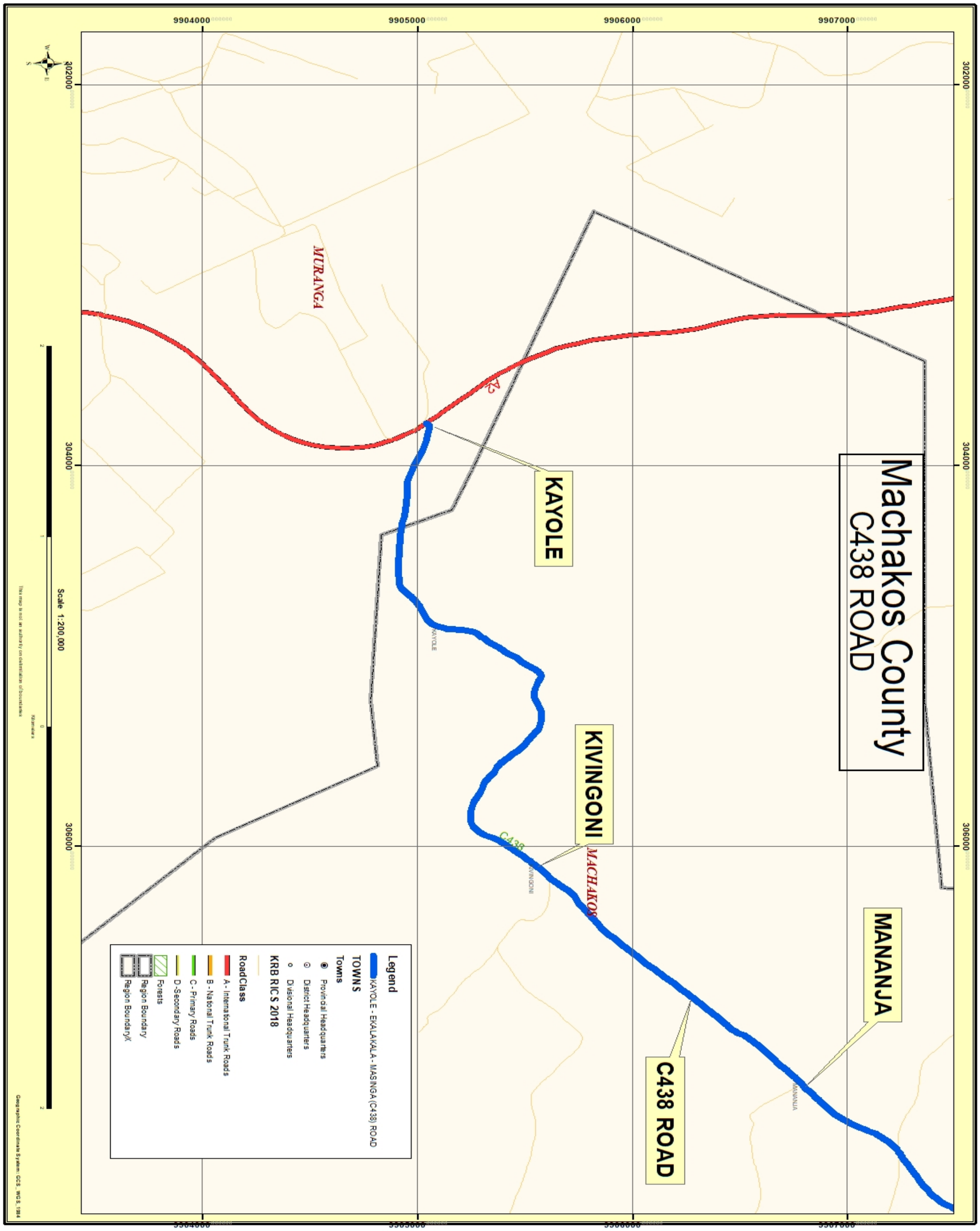

Figure 3.1 a locational map showing Kayole – Mananja – Masinga, C438 Road

3.1 Methodology.

The figure 3.2 below, illustrates in a nutshell the approach used in this research study. The first step was collection of relevant datasets for the study, both spatial and non-spatial. In this case Registry Index maps, Ground control surveys and topographical maps were collected. The datasets used in this study were obtained from different sources and with different data properties and coverage as summarized in table 3.0 below. The datasets obtained was then edited and the goedatabase was created for efficient data management. There was data harmonization; this involved confirming and ensuring that the datasets were harmonized in terms of scales, projection, georeferencing and all the other harmonization aspects. Querying criteria was built to allow the road reserves information transfer. Finally the results were displayed in form of maps and reports and further, there was analysis of results by way of discussions. Conclusions and recommendations were also done.

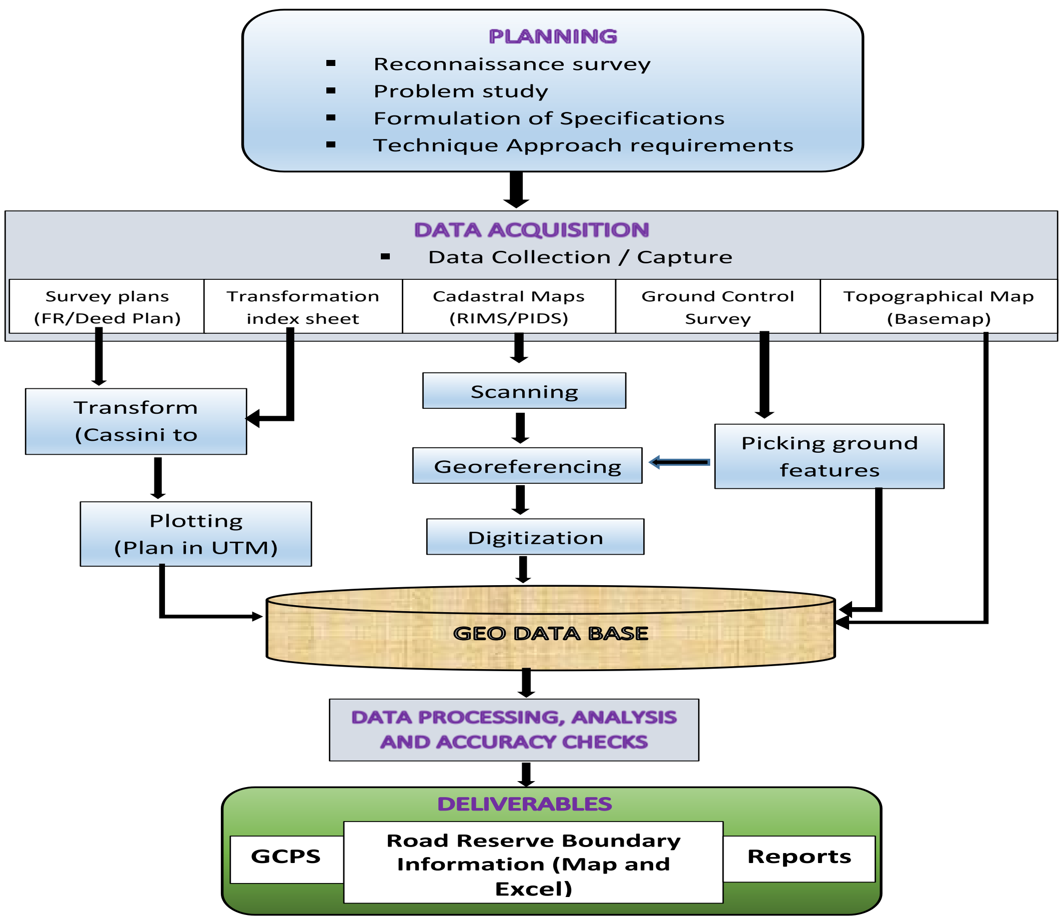

Figure 3.2: The methodology flow schematic diagram

3.2 Datasets, Sources and Coverage

Data Acquisition

The datasets used in this study were obtained from different sources and with different data properties and coverage as summarized in table 3.0 below.

Table 3.0 The datasets, data sources and data coverage

DATASETS	DATA SOURCE	COVERAGE
Registry Index Maps (Ndithini/Mananja/block 1 sheet 1,2&3) (1:2,500)	Survey of Kenya Regional Office in Machakos	Kayole – Masinga Road and its environs
Road network Shape file and road data	KeRRA	Kayole - Masinga road and its environs
Topographical data	Excel, CSV Comma delimited	Kayole - Masinga road and its environs
Topographical map (1:50,000)	Survey of Kenya Offices, Nairobi	Kayole - Masinga road and its environs

3.3 Software, Equipment and Personnel Requirements

Equipment and Software Requirements

The methodological procedure accomplishment for successful realization of the objectives of this study required various equipment, software and personnel among others as illustrated in table 3.1 below

Table 3.1: Equipment and Software Requirements

STAGE	EQUIPMENT/ SOFWARE	ITEM	SPECIFICATIONS/ DESCRIPTION	USE
Data Acquisition and Collection	Equipment	Set of GNSS	Stonex	Static Observations and Ground picking of features
	Software	Situoli Geo Office	Supports RINEX data	Post processing of static data
Data Preparation, Processing and Analysis	Equipment	Scanner		Conversion of analogue datasets into digital format
		Hard Disk	1 TB	Storage of data and information
		Flash Disk	16 GB	Transfer of data
	Software	Microsoft Office-excel		Transformation of data from cassini to UTM
		ArcMAP	ArcMap10.7.1	Georeferencing, digitization, analysis of data and production of maps
Output/ Deliverables	Equipment	Printer		Printing of the documents and road reserve boundary maps

Personnel

Personnel involved in the task were as follows:

- One Lead surveyor
- One Survey assistant
- Office Attendant
- One driver
- Six support staff

3.4 Data Collection.

Data collection involved field works, site visits and gathering of registry index maps (RIMs) and carrying out topographical surveys.

3.4.1 Datum Used

The projection and datum for the survey works used was UTM Projection, Arc 1960 datum. Static GNSS observations were carried out using control points tied to the national grid. This was done in order to densify control points at the project road.

3.4.2 Data Collection and Capture Methods

To identify the relevant National Geodetic network controls covering the target road, the team used the national topographic sheets at scale of 1:50,000. These sheets show the location of the Survey of Kenya pillars and controls. The team also liaised with the county surveyors on the exact locations and status of these controls.

After identifying National Geodetic network controls that were eligible for use on the target roads, the team monumented controls along the target roads with a set of three (3) at every five (5 km) interval. By using the Stonex GNNS receivers, the team observed the monumented controls using static modes for at least 2 hours.

To identify the relevant Cadastral Maps/Registry Index Maps covering Kayole – Mananja – Masinga (C438) road, the team visited land owners with land parcels abutting the road to obtain parcel numbers. The team also got assistance from the local administration to identify registration sections of the area. After identifying the relevant plans, the team visited Ministry of Lands, Survey Office at Machakos and Survey of Kenya to purchase them.

The actual ground measurement of the road reserve width was done by measuring fence to fence, fence to hedge or hedge to hedge depending on physical boundary features to obtain the existing road reserve width. Similarly, to confirm conformity and identify any encroachment, scaling of the same road reserve boundary on the cadastral plans and registry index maps was done. This was crucial especially in detecting encroachment and areas of potential encroachment.

The team also picked the road centerline, road junctions, fences and hedges, power poles and culverts using GNSS receivers. Road junctions and parcels boundaries of clear defined boundaries such as schools were carefully picked to be used for georeferencing especially points that coincide with the RIMs.

Identification of the utility services such as power lines and water pipes on the road side was done as they have direct influence on the road construction and also to ascertain if they are encroaching on the road reserve.

3.4.3 The Data Capture Process

Digital data was captured as shown in figure 3.3 below

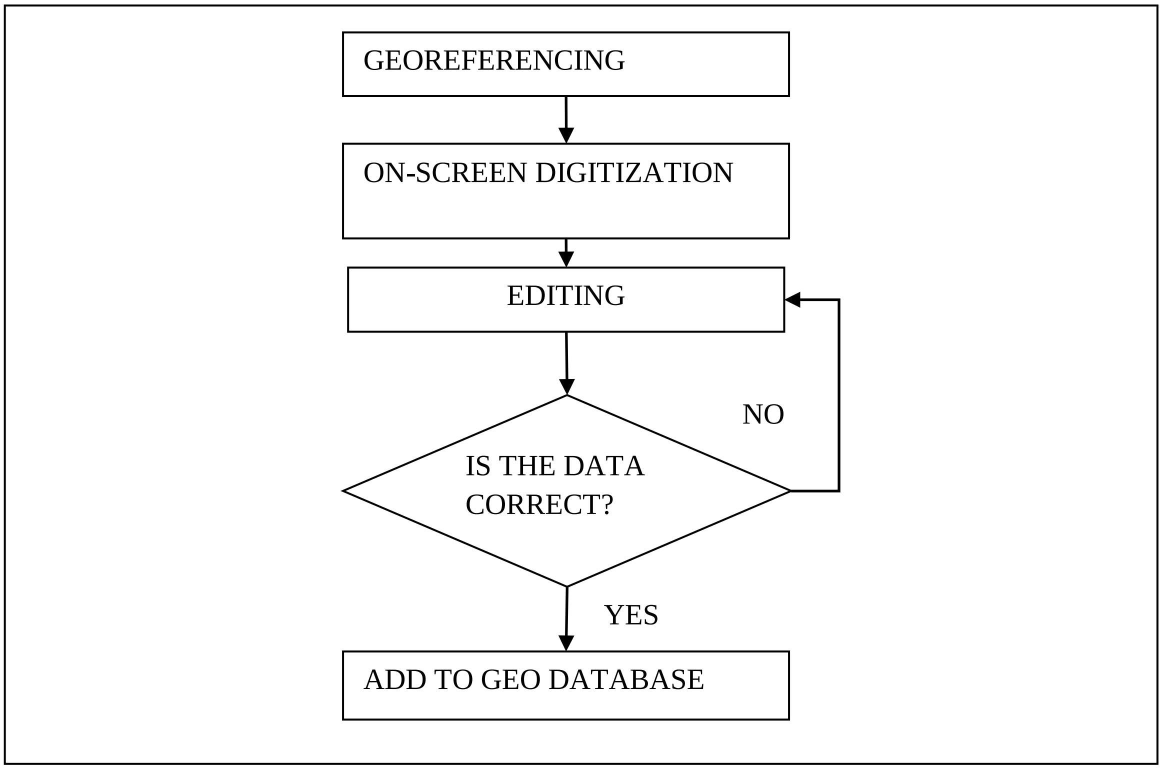

Figure 3.3: Data capture process in a flowchart

3.5 Geo-referencing.

Geo-referencing involved linking the image features to their true ground coordinates under appropriate coordinate system. Geo-referencing fundamentally permits the computation of the transformation parameters which may be used to compute ground coordinates from the digitized coordinates.

Geo referencing and digitization techniques are well anchored in Land Registration Act, 2012 to facilitate the geo-referenced boundaries as well as digitization of land records for easy road reserves information management. These techniques are very useful in utilization, sharing and incorporation of different set of survey data. Geo-referencing enable data to be converted into the same datum.

3.5.1 Georeferencing Process

Map images were loaded into ArcGIS software as outlined in figure 3.4 below. A georeferencing tool from arc toolbox was chosen. Projection used was specified first. The projection specified was the Universal Transverse Mercator and Arc 1960 datum as shown in figure 3.5 below. To rectify the image, the image was zoomed into a better view by dragging boxes and clicking on a control location. The resulting geo-referenced images matched perfectly well forming a seamless display of the area of study.

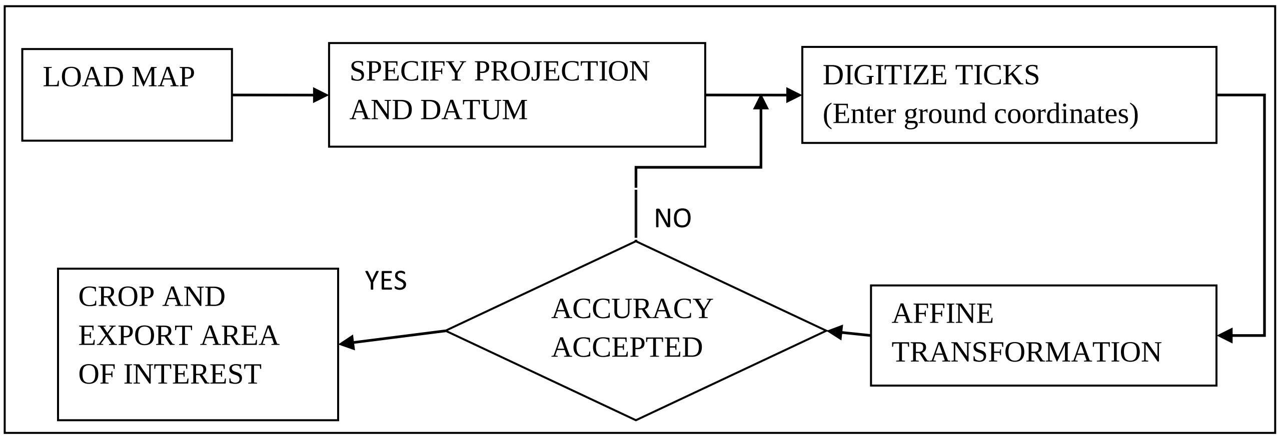

Figure 3.4 Georeferencing process in a flowchart

3.5.2 Projection Specification

The projection used during georeferencing was specified first as shown in figure 3.5 below. The projection specified was Universal Traverse Mercator (UTM). Zone specified was 37 (36°E – 42°E Southern hemisphere) and Arc 1960 as the reference coordinate system specified. Planar units specified were Meters.

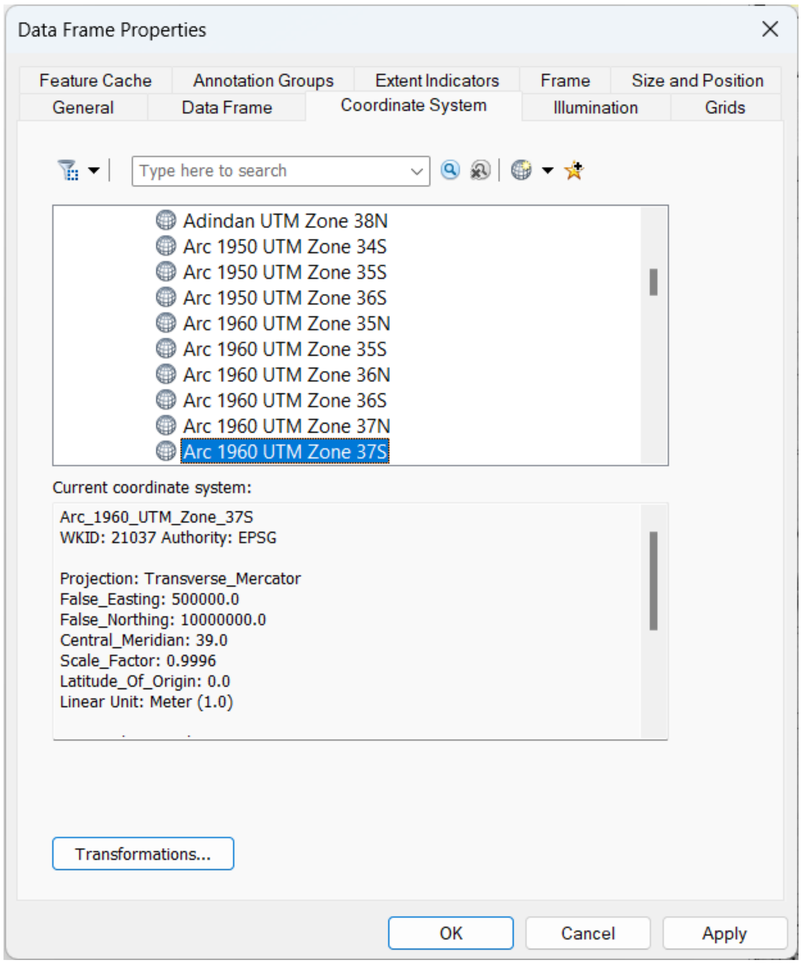

Figure 3.5 Specifying projection

3.6 On-screen Digitization.

Digitization is the conversion of raster data into vector data. On-screen digitization was performed on the geo-referenced image in ArcGIS and AutoCAD environment. Line, point and area features were digitized as shown in figure 3.6 below.

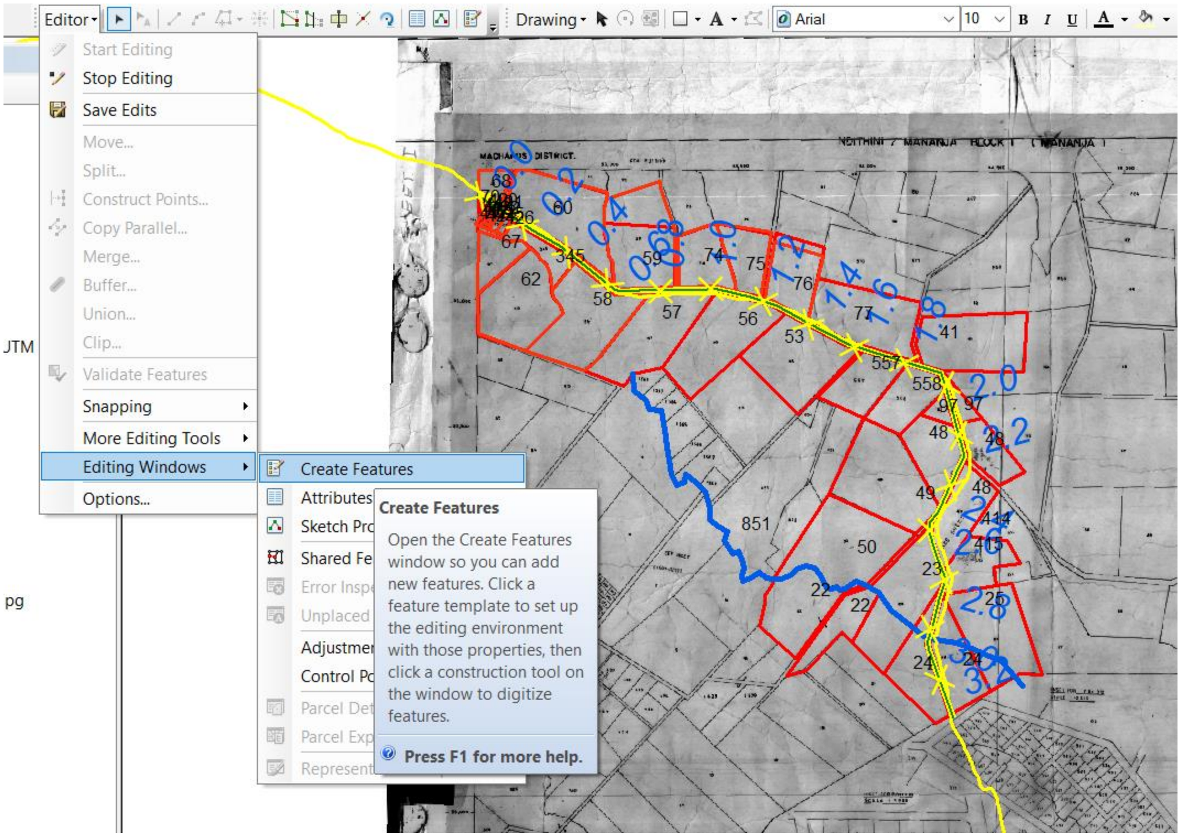

Figure 3.6 Specifying on-screen digitization.

3.7 Editing

Editing of the Vector data (digitized features) were then performed using the edit tool. The tasks such as to create task (create new feature), modify task (reshape feature, modify feature, extend or trim feature and cut polygon), and topology task (reshape edge and modify edge) were utilized. Undershoot and overshoots were edited as shown in figures 3.7& 3.8 below.

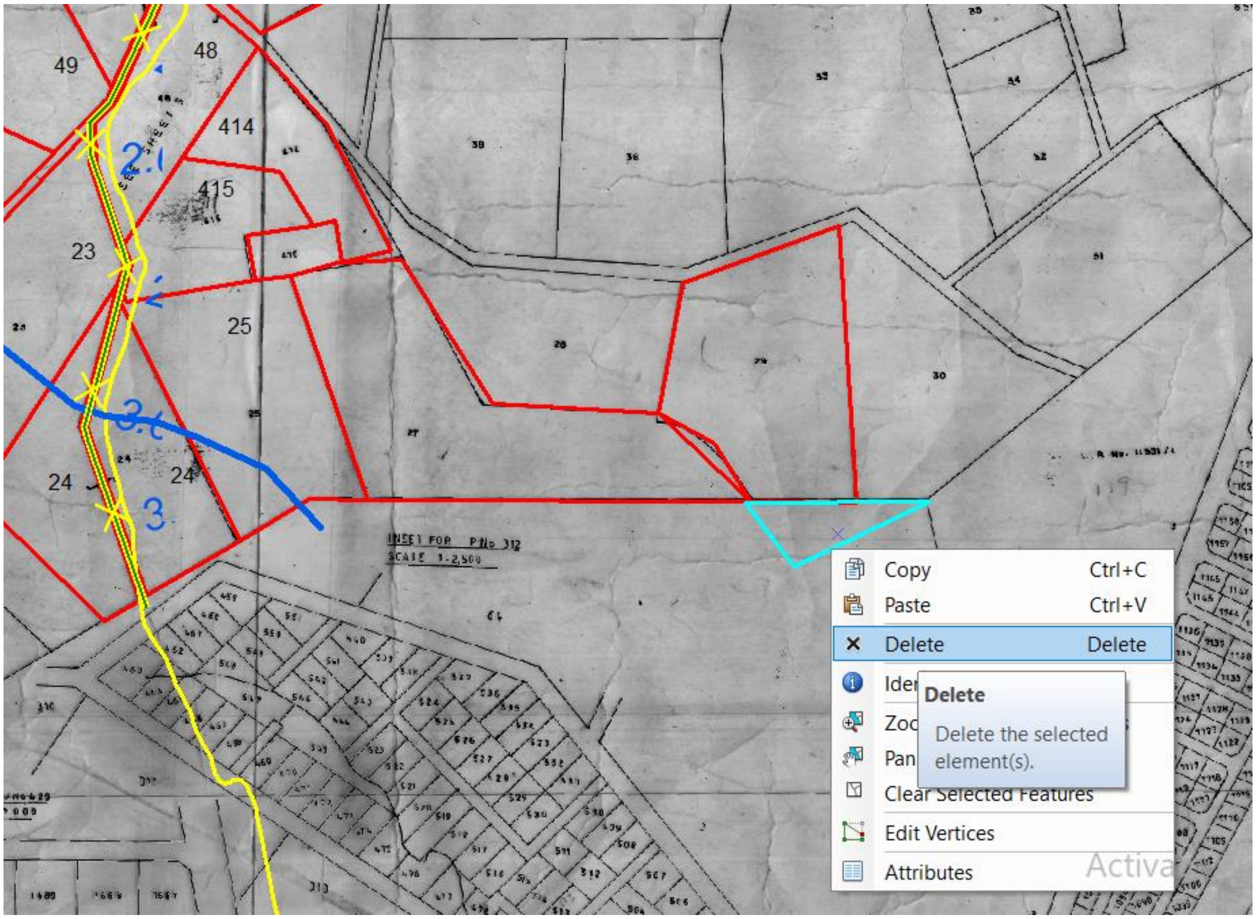

Figure 3.7 Specifying on-screen editing (deleting) unnecessary polygons.

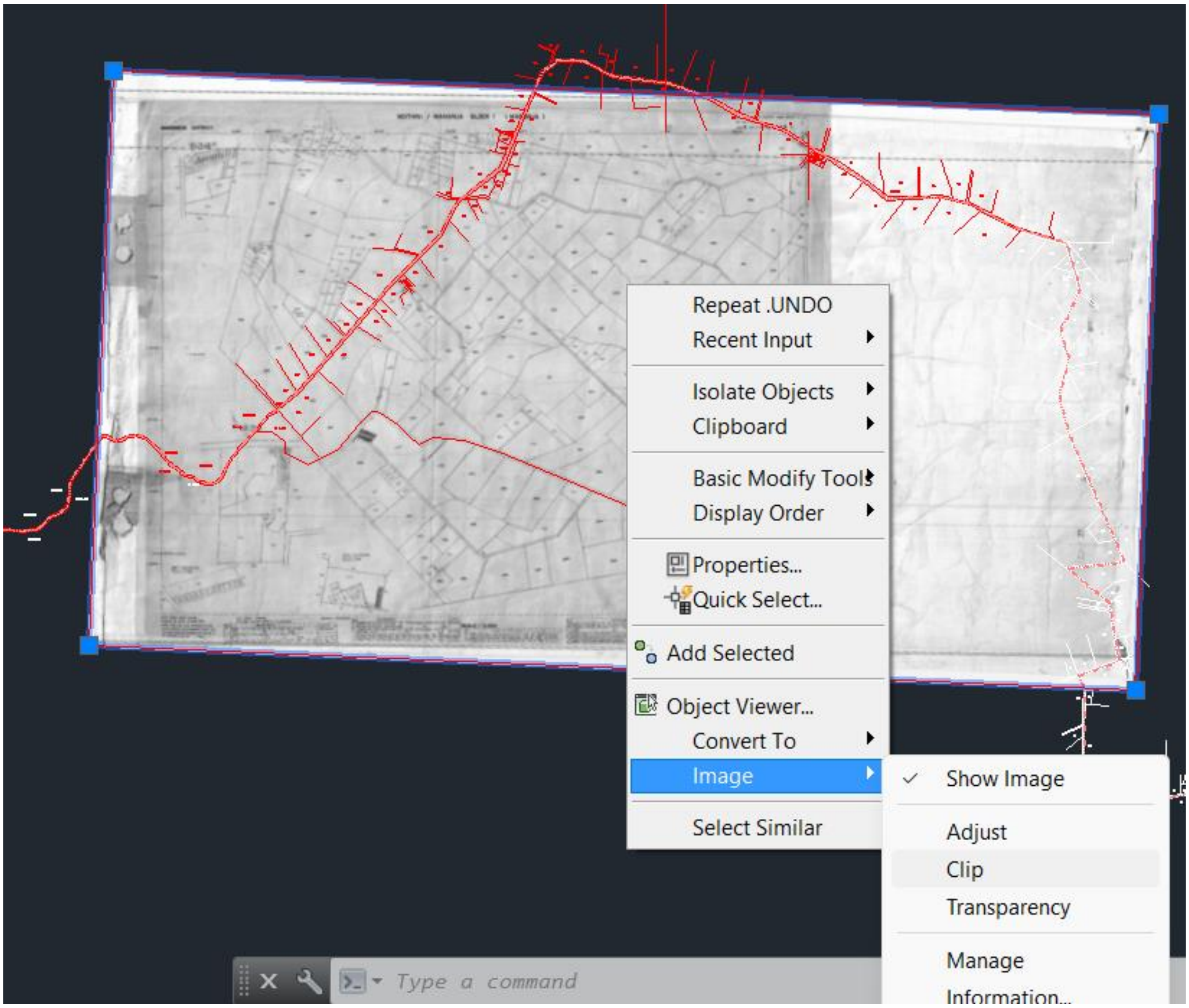

Figure 3.8 Image clip inorder to remove the unnecessary sections and enable better mossaicking

3.8 Data Processing

After field observations, the data was downloaded using Stonex Assistant software and post processing done using Situoli Geo- Office software. Topographical data picked was plotted using Autodesk Civil 3D and ArcGIS arc map. Common points were used for georeferencing of the R.I.Ms. Comparison of existing road reserve width with the authentic road reserve width as indicated in cadastral plans was done whereby the variation between the two explains whether there is encroachment or not.

3.8.1 Scanning

The Registry index maps, Survey plans and the topo sheets used for this study were scanned. It is a way of converting hardcopy registry index maps, surveys plans and topo sheets into raster images which allows digitization. The result of the scanning process is therefore a raster image of the original map. For this study, the raster image was saved as (Joint Photographic Experts Group) JPEG as it doesn’t distort image quality.

3.8.2 Georeferencing

In this exercise, common points on the ground and on the RIM were used for georeferencing. These were road junctions and parcels with clear defined boundaries such as schools that coincide with the RIMs. as shown in figure 3.9 below.

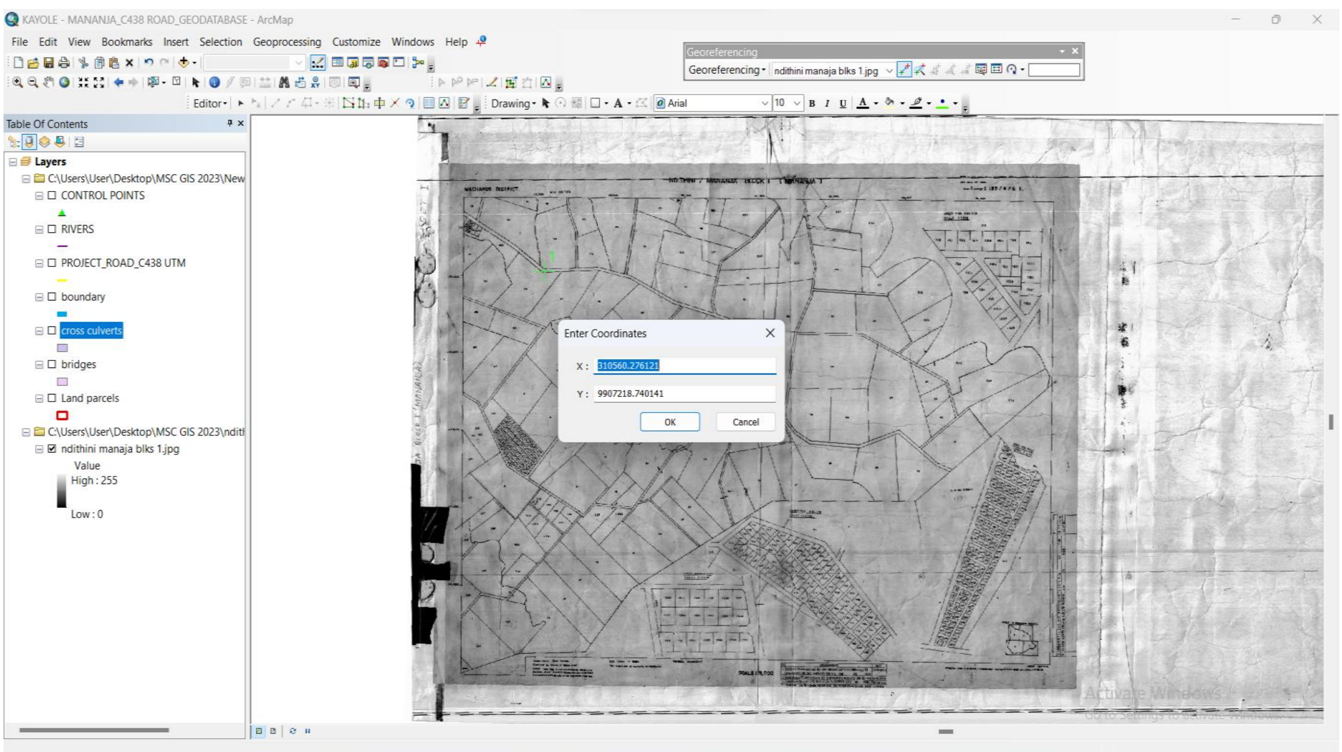

Figure 3.9 Georeferencing process in arc map

3.8.3 Mosaicking

Mosaicking involves combining multiple scanned maps into a single composite image.This is done to allow continuity of features between different maps. This is possible after the scanned maps have been georeferenced such that they are in the same coordinate system. This was done after all the images were well georeferenced as shown in figure 3.10 & 3.11 below.

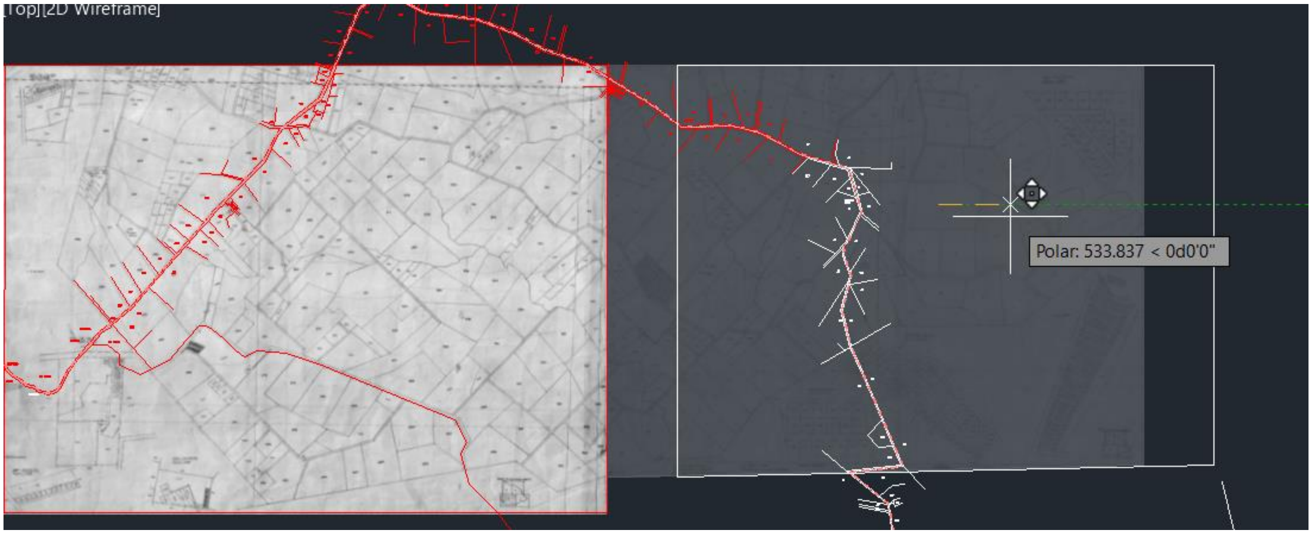

Figure 3.10 The mosaicking process which involves georeferencing,clipping,moving images towards each other

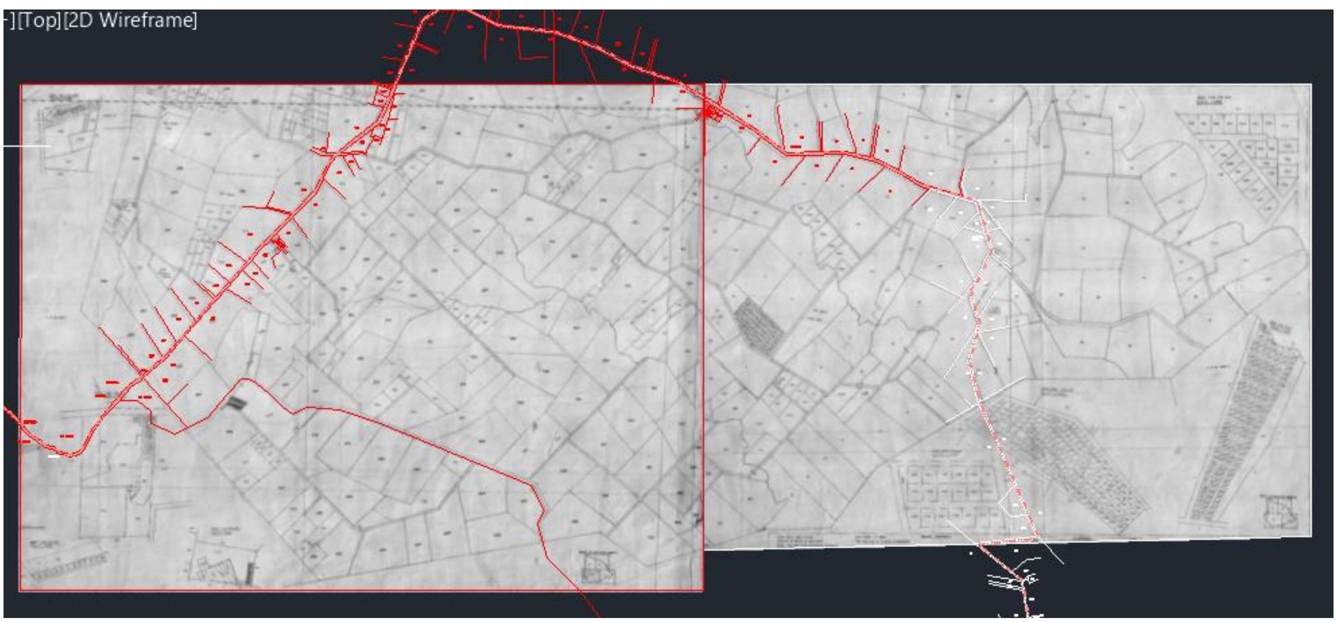

Figure 3.11 Mosaicked images

3.8.4 Digitizing

Digitizing involves tracing points, polylines and polygons from the scanned images using a computer software e.g. AutoCAD. The most common types of errors include spikes, undershoots, overshoots, missing lines etc. Digitization also involved correcting those inherent errors mentioned above. Refer to figure 3.12 below for the digitization process.

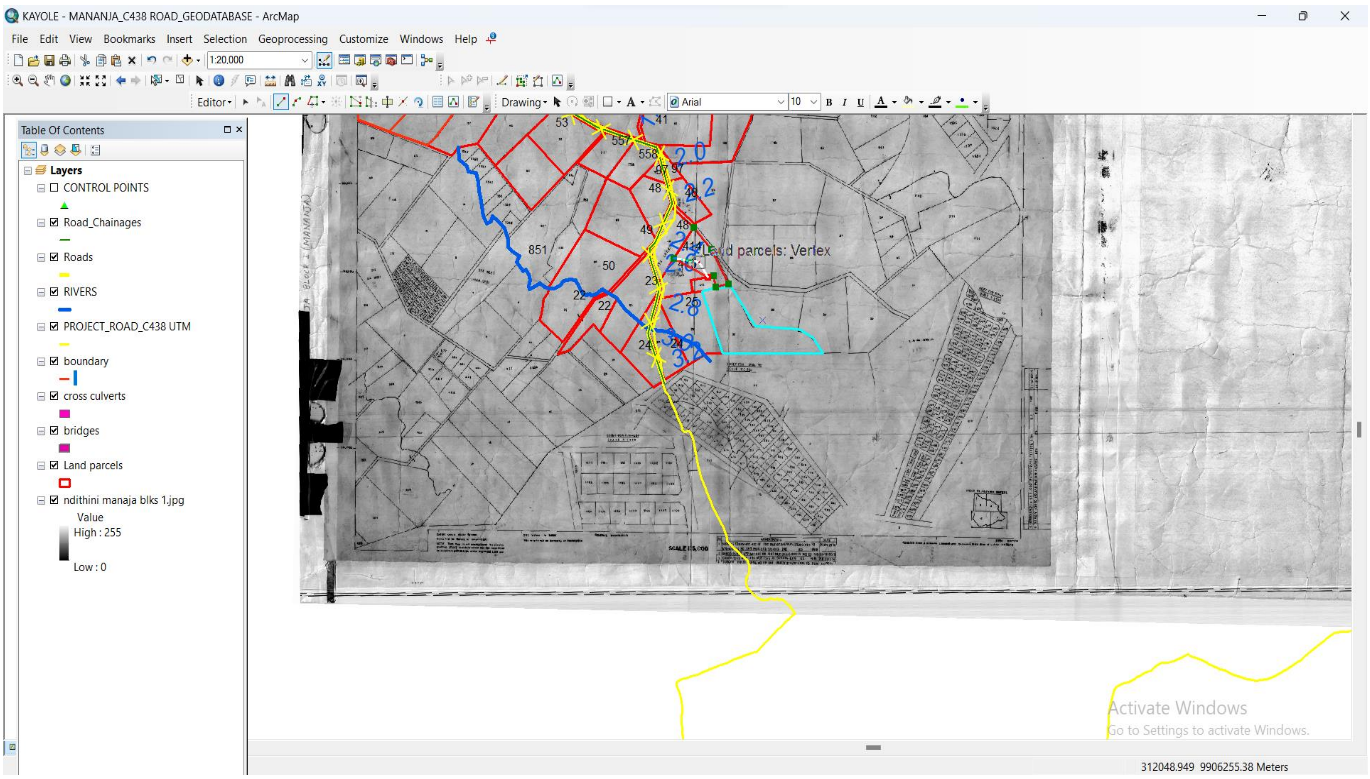

Figure 3.12 Specifying On-screen Digitization.

3.8.5 Creating Chainages

A chainage in surveying refers to a distance measured in a specified unit along an imaginary line. More often than not it is measured in metres.Defining Chainages along Kayole - Mananja road involved creating points along the road at every 200metres as shown in figures 3.13,3.14,3.15 & 3.16 below.This helps to locate land parcels and road assets easily.

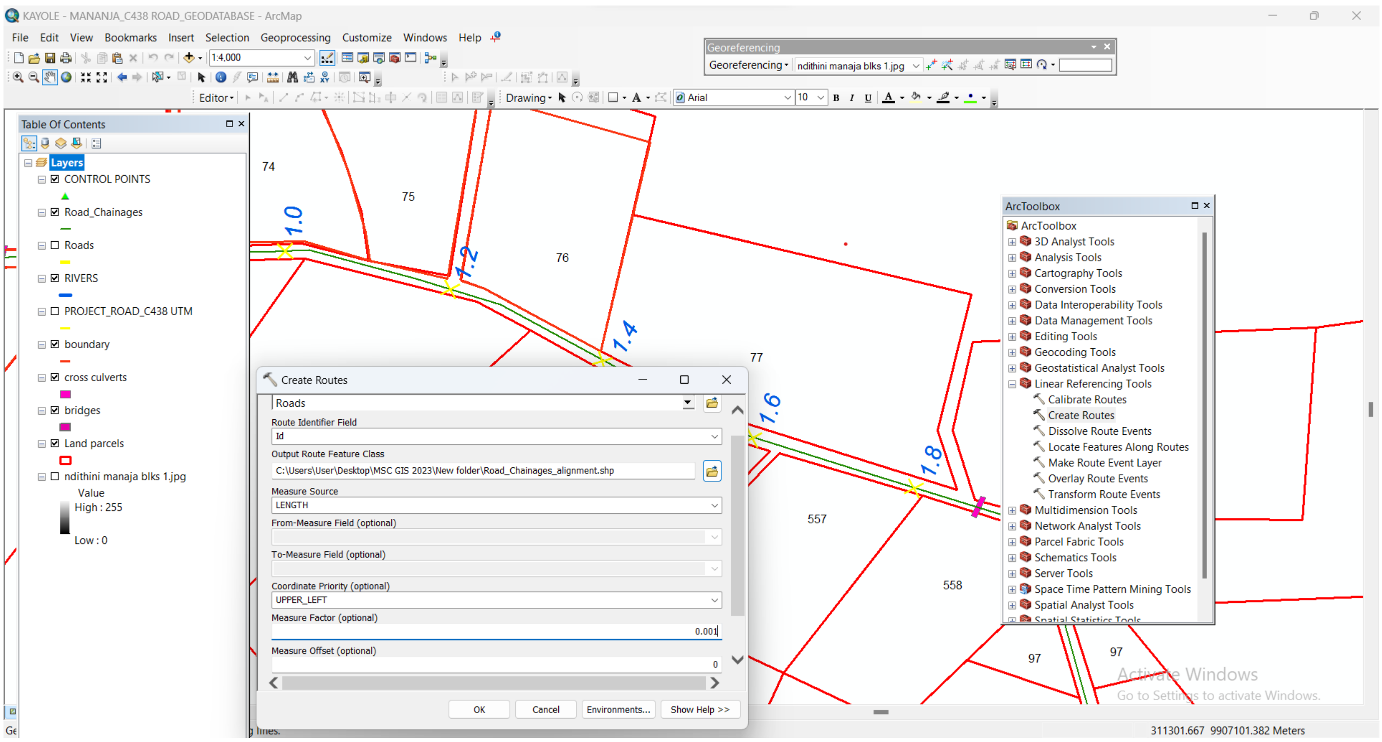

Figure 3.13 Creating chainages in arc map

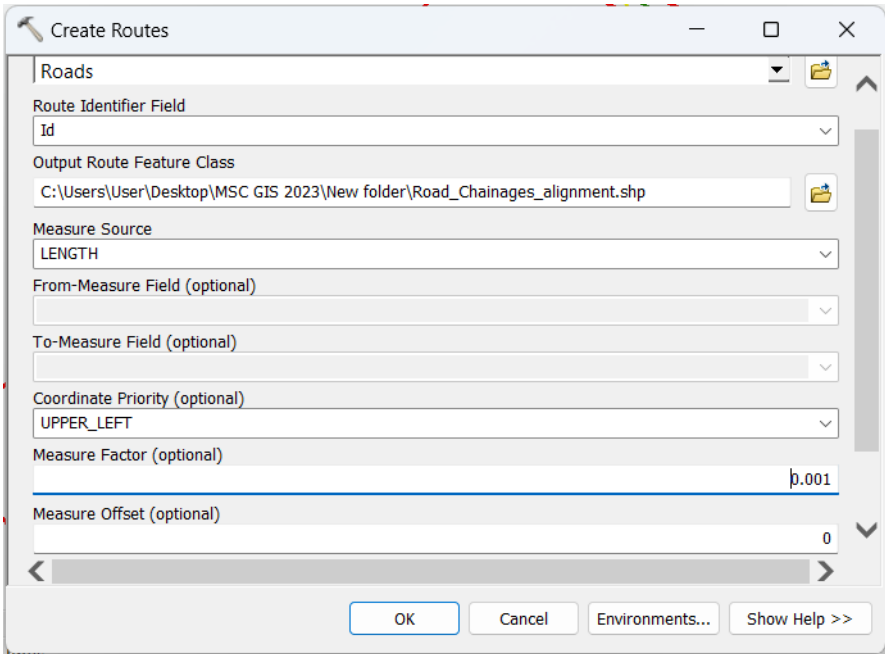

Figure 3.14 Creating chainages in arc map

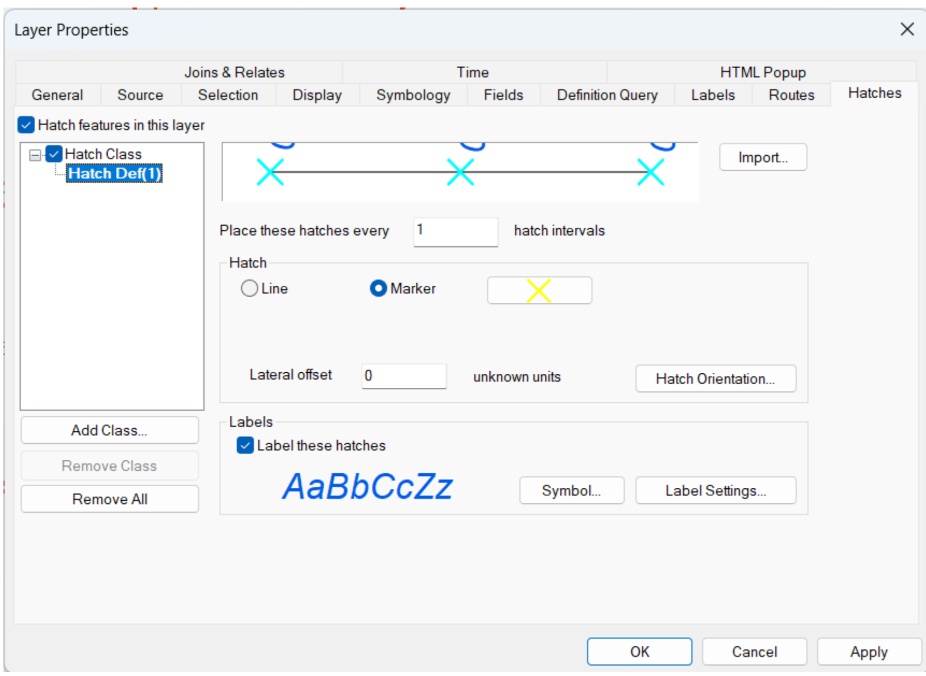

Figure 3.15 Creation of hatches for display of chainages

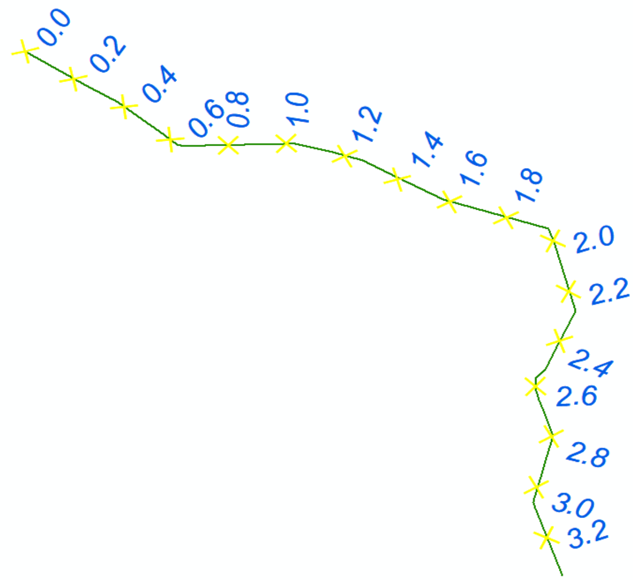

Figure 3.16 Showing chainages created.

3.9 Mapping

3.9.1 Existing Road Reserve Widths

Most sections of the road is abutted by farms whose boundaries are defined by fences made of barbed wires and planted hedges. Other sections have fence or hedge on one side of the road reserve. Some areas with no physical boundaries were also noted. The existing road reserves widths for the road sections was as shown in table 3.1 below.

Table 3.1 the road reserve widths

Road name	Section	Existing road reserve width
Kayole – Mananja (C438) Road	Km 0 - km 2	20m. This is a fixed boundary section
Kayole – Mananja (C438) Road	Km 2 - km 10	16m to 20m. This is a general boundary section

3.9.2 Encroachment

Land boundaries as shown in the Registry Index Maps are both general boundaries and fixed boundaries which are defined by physical features such as fences and hedges which are legally acceptable. The authentic road reserve width as indicated in the cadastral plans varies as tabulated in table 3.2 below. The cadastral plans covering the area of study are at scale of 1:2,500 on comparison of the actual ground measurement of road reserve width boundaries and the cadastral plans, encroachments were noted as referred in table 3.2 below.

Table 3.2 existing widths against authentic widths

Road name	Section	Existing road reserve width	Authentic road reserve width
Kayole – Mananja (C438) Road	Km 0 - km 2	20m. A fixed boundary section	16m to 20m
Kayole – Mananja (C438) Road	Km 2 - km 10	16m to 23m.General boundary section	18m to 20m

It was also noted that some power poles and power lines are within a few metres to the existing road centerline. It was also noted that encroachment was widespread along the entire road at the area of study.

3.9.3 Road Reserve Awareness

The parcel owners abutting the road were aware of the road reserve widths and were cooperative in relaying the relevant information concerning the boundaries. Some of the residents are aware of the road reserve widths and are willing to relocate their boundaries to conform to the authentic road reserve width as would be provided after adjudication. Others have built temporary structures which serves as kiosks within the road reserve.

3.9.4 Road Alignment

The road alignment on the ground was found to concur with the alignment as indicated in the cadastral maps. The road junctions on the ground were well fitting to the corresponding junctions on the RIMs.

3.9.5 Map Compilation

Compilation of Road reserve boundary maps were finally done on a standard layout template, as shown in figure 3.17 below, from the digitized information. Additional details such as chainages, market centres and schools were shown on maps to enable ease of interpretation of road reserve widths along the road.

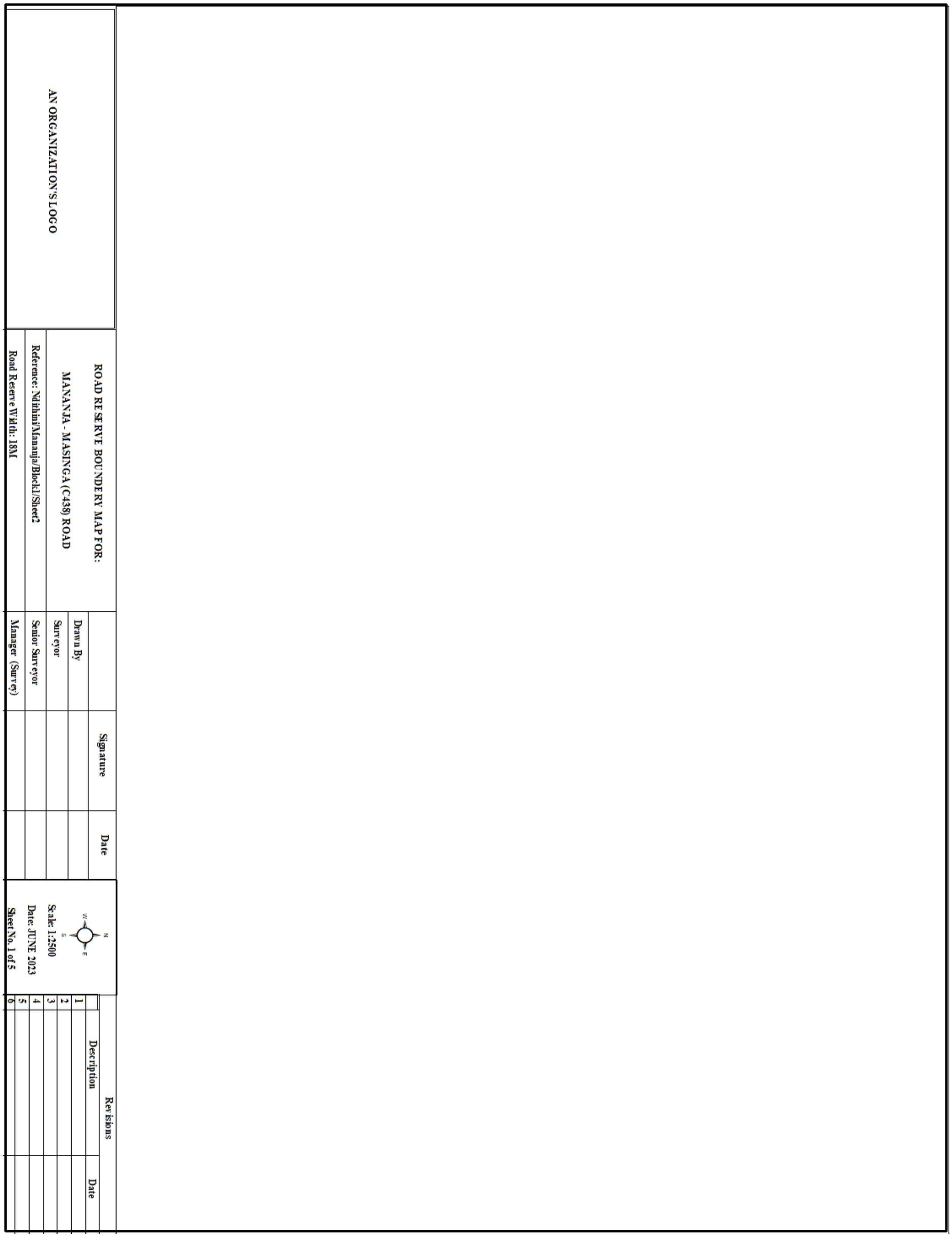

Figure 3.17 a standard drawing template for road reserves mapping.

CHAPTER 4: RESULTS AND DISCUSSIONS

4.0 Results

This chapter focuses on describing the results and analysis carried out in the study thus exhibiting how GIS can be applied in mapping of road reserves.

In view of the set objectives the following results were attained:

- The GIS application created provided a proper up to date road reserves information collection, storage and dissemination platform.

- The database will provide essential information to road agencies in terms of managing the road reserves, through querying the database.

4.1 Road Reserve Boundary Map

Road reserve boundary maps covering the area of study was created. The map contains roads, road assets and land parcels with chainages and locations along Kayole - Mananja - Masinga (C438) Road. Refer to figure 4.0, 4.1, 4.2 and 4.3 below.

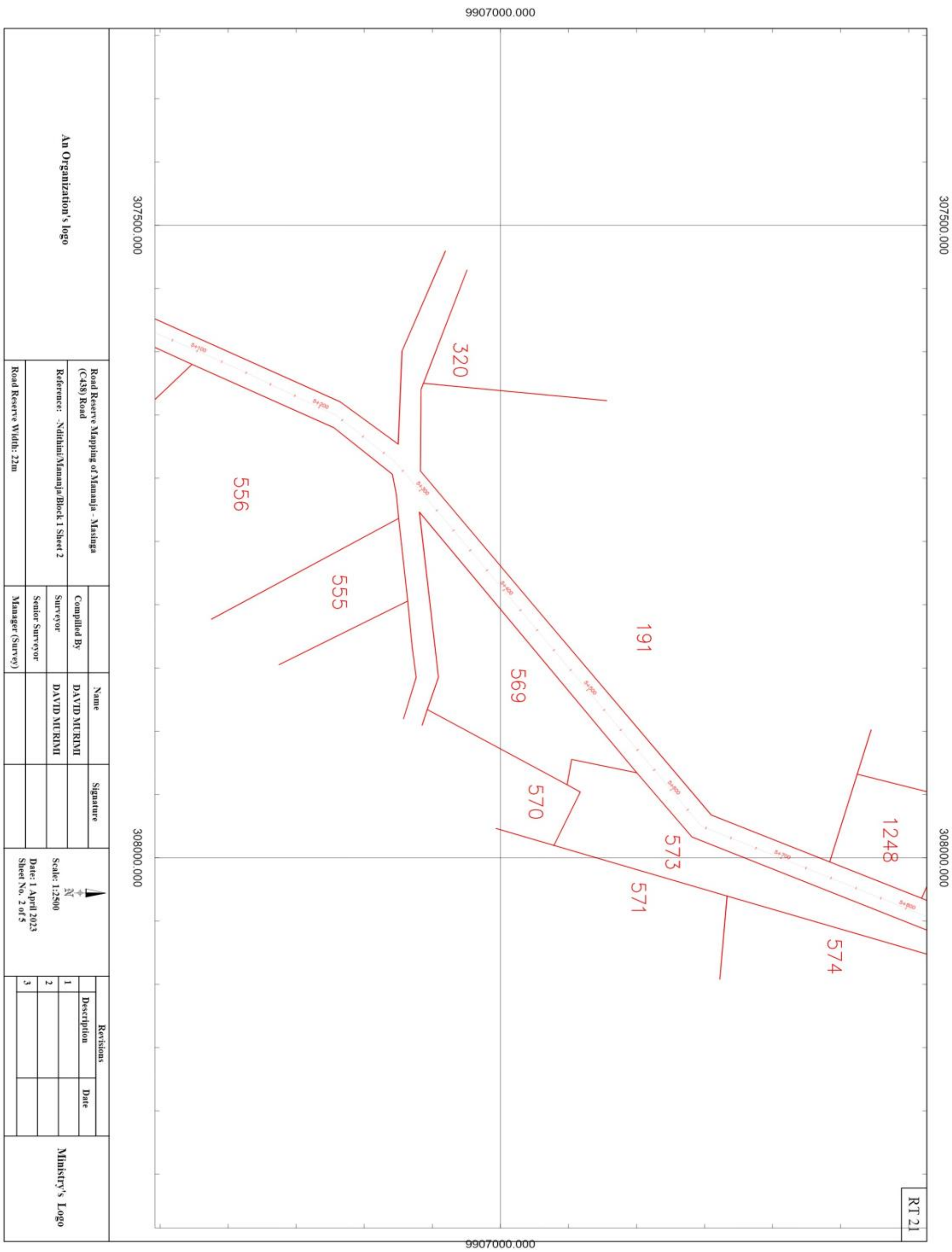

Figure 4.0 a road reserve boundary map

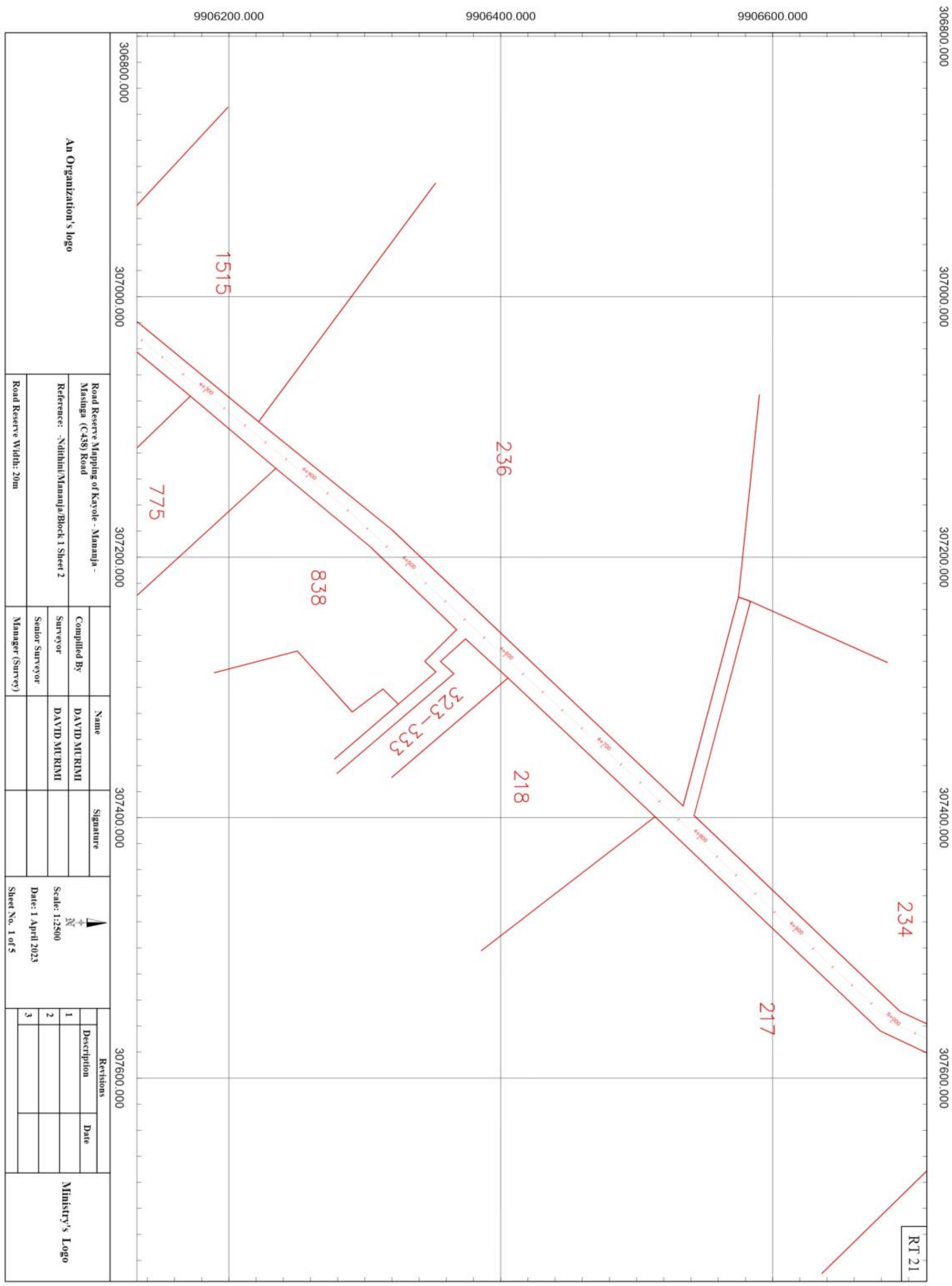

Figure 4.1 a road reserve boundary map

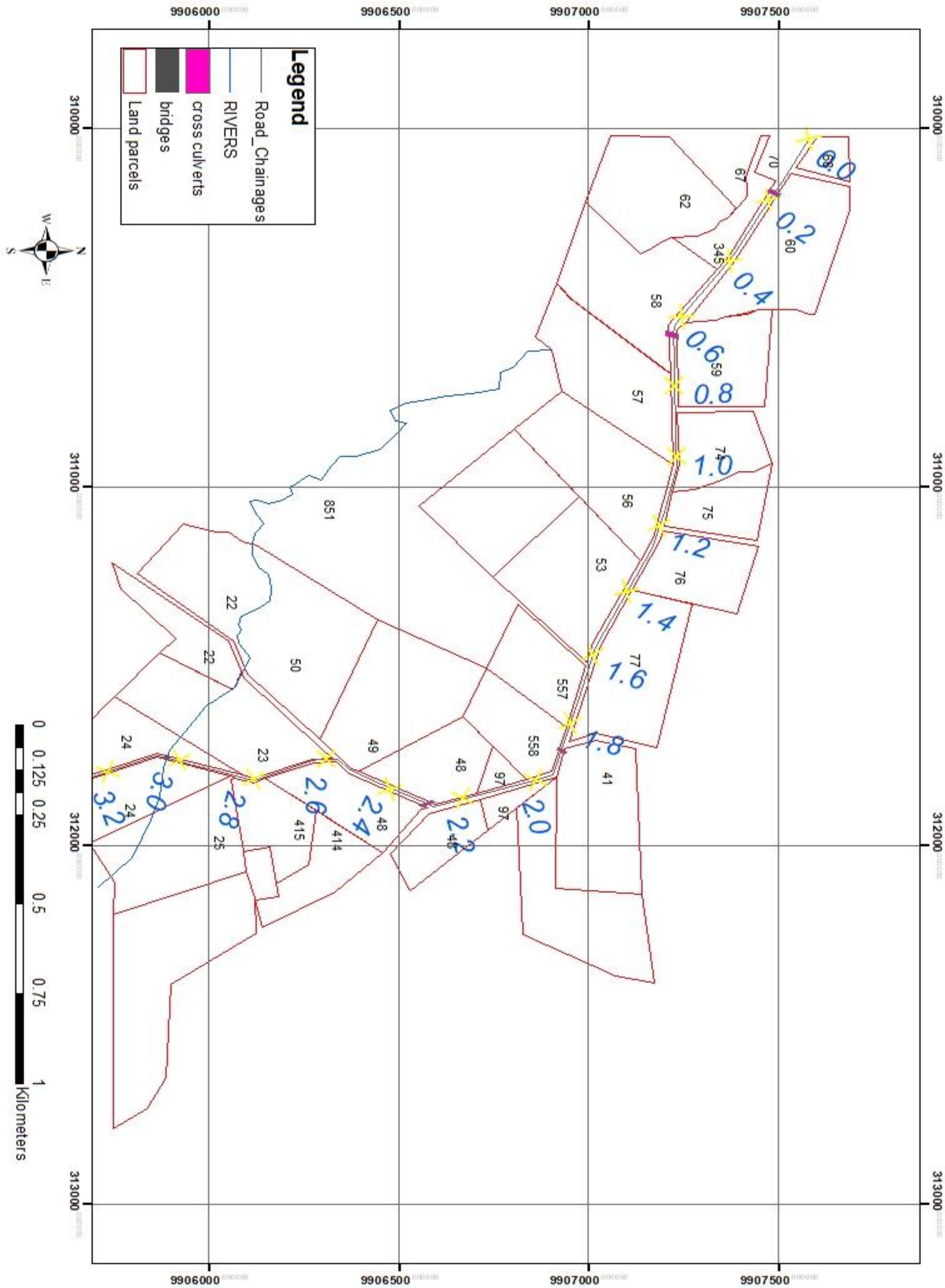

Figure 4.2 a road reserve boundary map with road reserves information

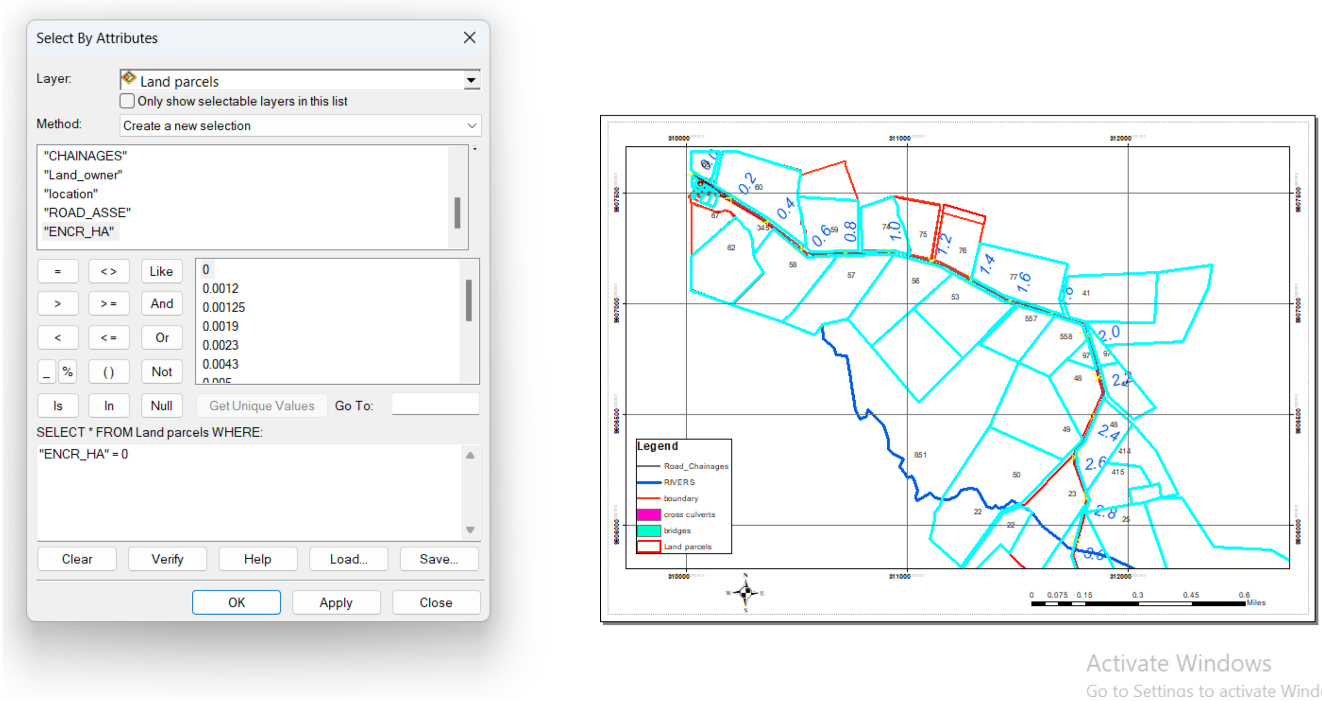

Figure 4.3 a road reserve boundary map with land parcels which are encroaching on the road reserves (colored red).

4.2 Geo-database.

A geo-database was created. It was named: GIS Geodatabase for Road reserves mapping. It contains feature classes (Land parcels, land locations, Land parcel numbers, area encroaching as well as road assets abutting the road reserve) as shown in figure 4.4 below.

Table

Land parcels

FID	Shape *	Id	PARCEL_NO	ROAD_WIDTH	ACREAGE_HA	CHAINAGES	Land_owner	location	ROAD_ASSE	ENCR_HA
41	Polygon	0	ndithini/mananja/block1/12	22	0		MUTERA JOH		NONE	0
24	Polygon	0	ndithini/mananja/block1/426	21	1	0+100	MUIMI	RHS	NONE	0
26	Polygon	0	ndithini/mananja/block1/12	19	2	0+110	MUMBUA	RHS	NONE	0.0012
27	Polygon	0	ndithini/mananja/block1/424	17	1	0+110	KAMENE	RHS	NONE	0.013
28	Polygon	0	ndithini/mananja/block1/423	21	1	0+110	NDAMBUKI	RHS	NONE	0.147
29	Polygon	0	ndithini/mananja/block1/422	26	1	0+110	MUTISO	RHS	NONE	0
30	Polygon	0	ndithini/mananja/block1/421	24	1	0+110	MAUNDU	RHS	NONE	0
31	Polygon	0	ndithini/mananja/block1/417	17	1	0+110	KILONZI	RHS	NONE	0
32	Polygon	0	ndithini/mananja/block1/418	16	1	0+110	ANDREW	RHS	NONE	0.046
33	Polygon	0	ndithini/mananja/block1/419	21	1	0+110	KAMAKIA	RHS	NONE	0
34	Polygon	0	ndithini/mananja/block1/420	18	1	0+110	ODIDI	RHS	NONE	0.0058
35	Polygon	0	ndithini/mananja/block1/70	21	2	0+110	SIMIYU	RHS	NONE	0
36	Polygon	0	ndithini/mananja/block1/68	20	5	0+110	KARENGE	LHS	NONE	0
25	Polygon	0	ndithini/mananja/block1/425	20	1	0+120	MANGA	RHS	NONE	0
23	Polygon	0	ndithini/mananja/block1/345	17	8	0+200	MUTUNGA	RHS	CROSS CULV	0.0019
22	Polygon	0	ndithini/mananja/block1/62	22	15	0+300	WAITHERA	RHS	NONE	0
21	Polygon	0	ndithini/mananja/block1/58	19	19	0+500	WAWERU	RHS	NONE	0
37	Polygon	0	ndithini/mananja/block1/60	20	15	0+500	BUTITA	LHS	NONE	0
20	Polygon	0	ndithini/mananja/block1/59	20	11	0+700	LUKAS	LHS	NONE	0
0	Polygon	0	Ndithini/mananja/block1/57	20	13	0+900	KAVINDU	RHS	CROSS CULV	0
1	Polygon	0	ndithini/mananja/block1/56	21	16	1.200	MUSYOKI	RHS	NONE	0
19	Polygon	0	ndithini/mananja/block1/74	20	6	1+000	JANET	LHS	NONE	0
18	Polygon	0	ndithini/mananja/block1/75	16	8	1+100	NJIRIRI	RHS	NONE	0.0089
17	Polygon	0	ndithini/mananja/block1/76	18	7	1+200	KANGETHE	RHS	NONE	0.0043
2	Polygon	0	ndithini.mananja/block1/53	19	10	1+400	KIKUMBU	RHS	NONE	0
3	Polygon	0	Ndithini/mananja/block1/77	19	15	1+600	NZIOKA	LHS	NONE	0
4	Polygon	0	Ndithini/mananja.block 1	18	8	1+700	MUYOKA	RHS	NONE	0
5	Polygon	0	ndithini/mananja/block1/558	21	20	1+900	AGNES	RHS	NONE	0
6	Polygon	0	ndithini/mananja/block1/41	22	13	1+900	DAVID	LHS	NONE	0
7	Polygon	0	ndithini/mananja/block1/97	18	5	2+000	EUNICE	LHS	NONE	0
8	Polygon	0	ndithini/mananja/block1/97	17	2	2+100	KAMAU	RHS	NONE	0
9	Polygon	0	ndithini/mananja/block1/48	16	12	2+200	KUNGU	RHS	CROSS CULV	0.00125
10	Polygon	0	ndithini/mananja/block1/48	22	9	2+200	KARUMBA	LHS	NONE	0
11	Polygon	0	ndithini/mananja/block1/48	21	10	2+500	KIVUITU	LHS	CROSS CULV	0
12	Polygon	0	ndithini/mananja/block1/49	18	13	2+600	KIMEU	LHS	NONE	0
39	Polygon	0	ndithini/mananja/block1/50	20	18	2+600	KIMUNDIU	RHS	NONE	0
13	Polygon	0	ndithini/mananja/block1/23	17	15	2+700	KARIUKI	RHS	NONE	0.005
15	Polygon	0	ndithini/mananja/block1/415	22	11	2+700	WAITHERERO	LHS	NONE	0
40	Polygon	0	ndithini/mananja/block1/25	19	9	2+800	BAHAKA	LHS	NONE	0
38	Polygon	0	ndithini/mananja/block1/22	20	8	3+000	KIBINDIO	RHS	NONE	0
14	Polygon	0	ndithini/mananja/block1/24	21	12	3+100	KINYUA	RHS	BRIDGE	0
16	Polygon	0	ndithini/mananja/block1/24	17	12	3+200	MURAGE	LHS	BRIDGE	0.0023

Figure 4.4 Specifying database designed

Road Reserves Information Retrieval from the Geodatabase by Queries.

A query builder is a tool in ArcGIS software used to facilitate querying of the database. It queries the database by way of selecting the required results. Query statements have to be specified first. Road reserves information retrieval was done through sructured query language,SQL and identifier tool from the geodatabase designed.See figures 4.5,4.6,4.7 & 4.8 and table 4.0 below.

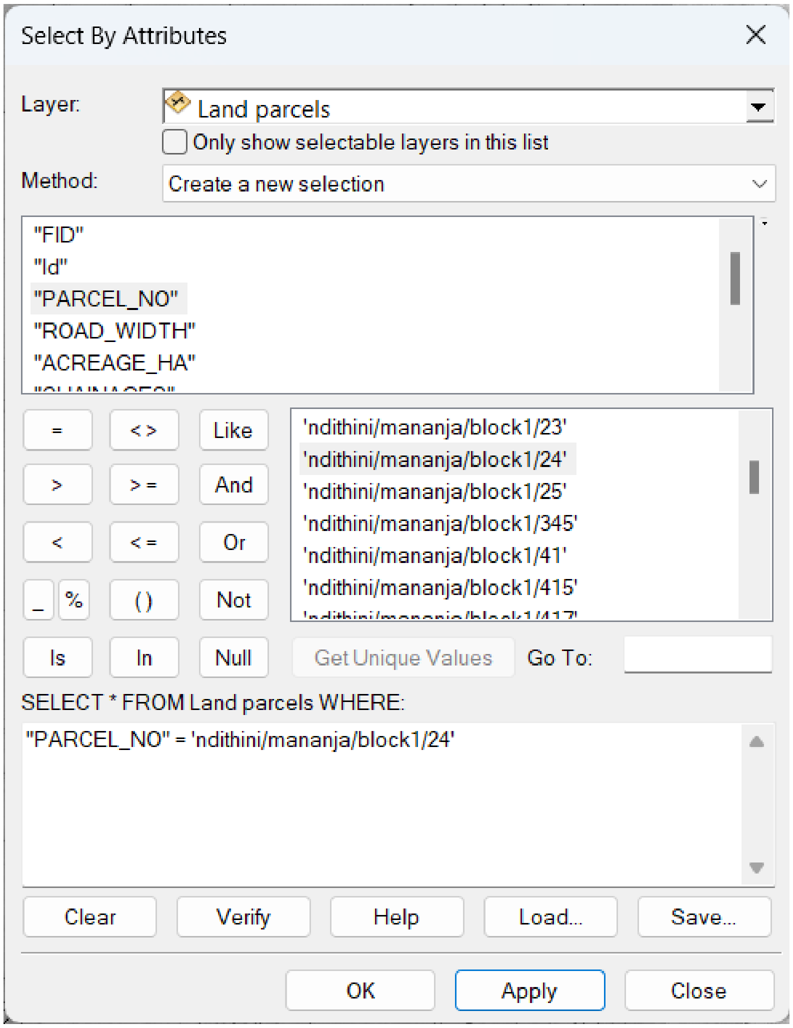

Figure 4.5 A structured query language,SQL, to get road reserves information

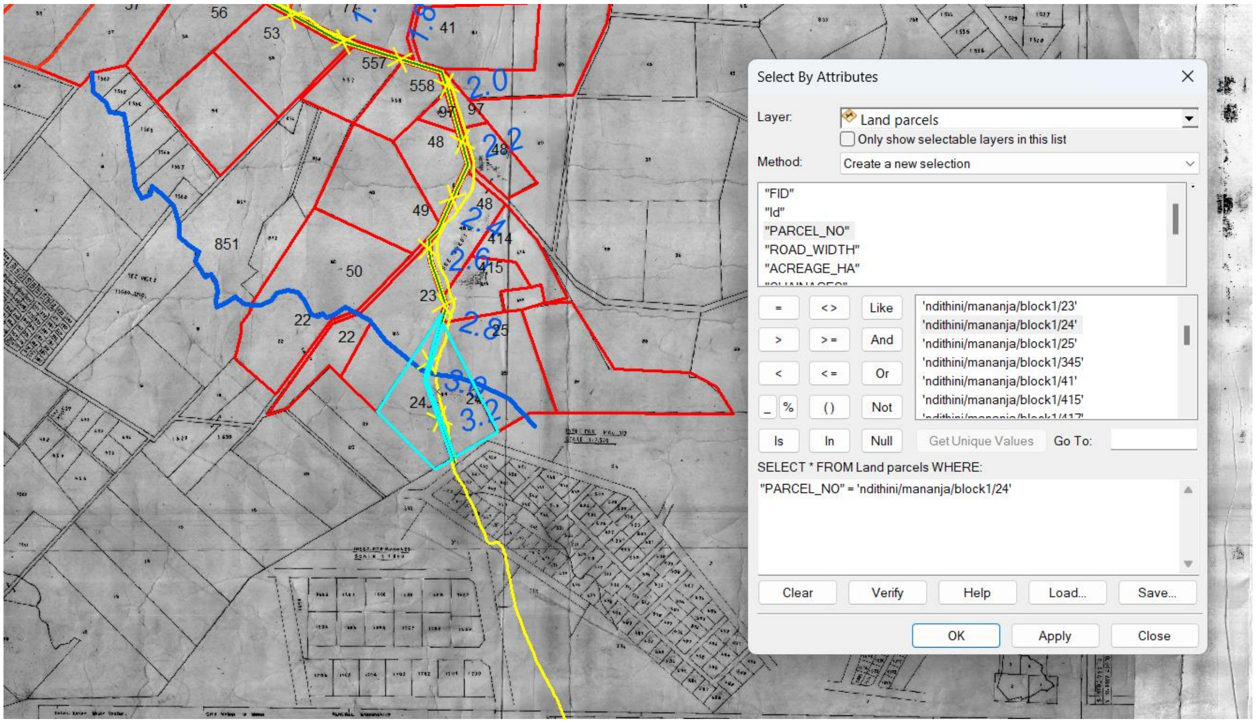

Figure 4.6 A structured query language,SQL, to get road reserves information(highlighted sections)

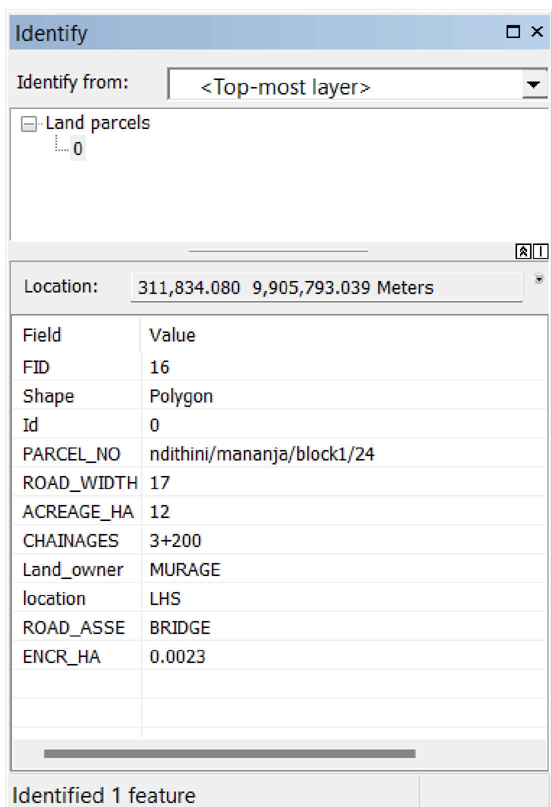

Figure 4.7 Using identifier tool to get road reserves information

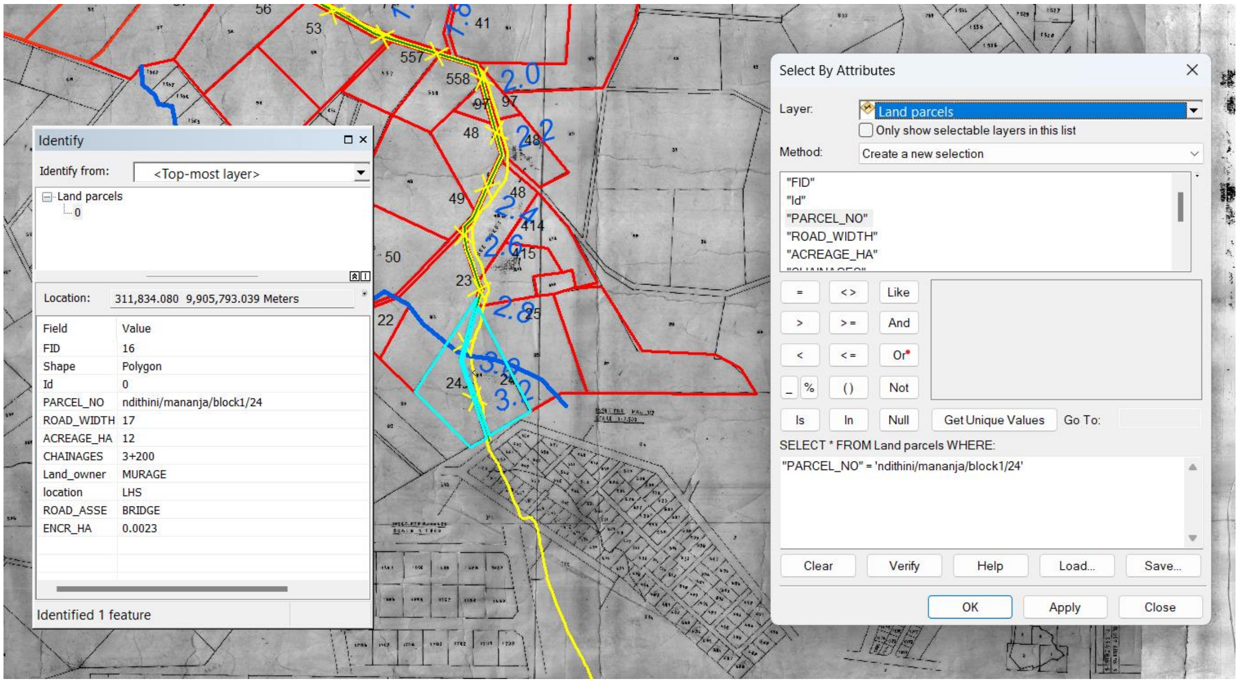

Figure 4.8 Using identifier tool to get road reserves information

Table 4.0 Showing information retrieved from the database

s/no	Road item	Road reserve information
1	Parcel no	Ndithini/Mananja/block 1/24
2	Road width	17 metres
3	Land owner	Murage
4	Road asset	Bridge
5	Chainages	3+200
6	Encroachment	0.0023ha of area encroaching on the road reserve
7	Location	311,884.080 9,905,793.039 Metres

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.0 Conclusions.

The main objective of this study; to create a GIS database for road reserve mapping and management with an aim of providing a proper up to date road reserves information collection, storage and dissemination platform was achieved.

In view of the set objectives the following results were attained:

- The GIS database created provided a proper up to date road reserves information collection, storage and dissemination platform.
- The database provided essential information to road agencies in terms of managing the road reserves, through querying the database.

Essential geographical information to the users was retrieved from the database when subjected to queries. This study proved that GIS is a very critical technological advancement in the management and development of the road infrastructure. Finally through the created geodatabase, it was possible to identify road reserve encroachment on this road.

5.1 Recommendations

After the results and discussions on application of GIS in road reserves mapping, we recommend as follows:

- Since the road infrastructure sector makes crucial contribution to economic growth and developments, road reserves management should be prioritized in order to have a sustainable development of this country. The GIS Platform is recommended to be used to manage road reserves by the local authorities and road agencies at both county and national levels.
- That the Road reserves information Geodatabase designed should be shared through the web and mobile GIS platforms for faster and easier access of the information.
- Before any development is initiated such as road construction or any other roadside development, it is critical to hire the services of a professional surveyor in order to

accurately and precisely determine the available road reserve width through mapping and demarcation. This will minimize case of encroachment on the road reserves.

- Finally Road reserve boundary demarcation should be done on sections where encroachment is noted as per the authentic road reserve width on the cadastral map. This will ensure road reserves are adequately protected by ensuring no further encroachment are carried out.

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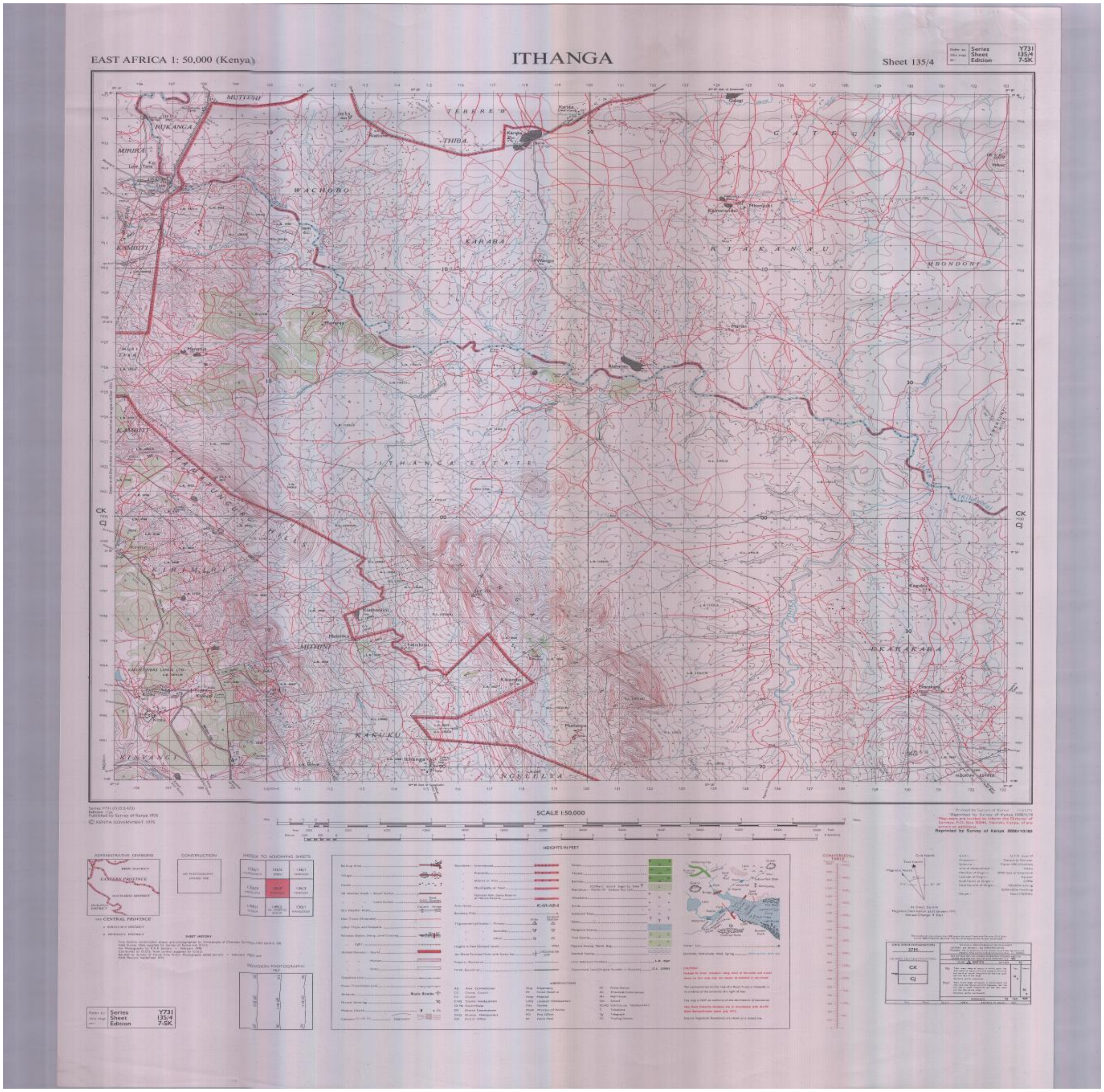
APPENDICES

Considering the amount of the road data used; Registry Index Maps, Topographical maps and topographical data were many for all of them to be put in the appendices. However for the purpose of this research project, appendix will contain the topographical map used. Refer to Appendix 1:A Toposheet,Ithanga sheet 135/4, below.

Other appendices are also hereby attached and they include:

- Appendix 2: Turntin Originality Report
- Appendix 3:Digital Repository Deposit Agreement
- Appendix 4: Student ID

Appendix 1:A Toposheet,Ithanga sheet 135/4



Appendix 2: Turntin Originality Report

Application of GIS in Road reserves mapping

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