University of Nairobi

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DEPARTMENT OF GEOSPATIAL AND SPACE TECHNOLOGY

DEVELOPING A GEODATABASE FOR RURAL ELECTRIFICATION AUTHORITY

CASE STUDY: PART OF MACHAKOS COUNTY

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A Project submitted in partial fulfillment for the Degree of Master of Science in Geographical Information Systems, in the Department of Geospatial and Space Technology of the University of Nairobi

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Declaration

This is to certify that the work is entirely my own and not of any other person, unless explicitly acknowledged (including citation of published and unpublished sources). The work has not previously been submitted in any form to the University of Nairobi or to any other institution for assessment for any other purpose.

Nancy Bochaberi Ondicho   Date   03.06.2014

This project has been submitted for examination with our approval as university supervisor(s).

Dr.-Ing. S.M.Musyoka

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Name of supervisor   Date

Dedication

I dedicate this to my Late father Zablon M. Ondicho for the love and inspiration in my years of education. Also dedicate to my family members, for their love, support and motivation throughout the entire duration of the master's project. May the Almighty God abundantly bless you all.

Acknowledgement

Abstract

Rural Electrification Authority (REA) was established to accelerate the pace of rural electrification in Kenya. It is among the development goals set out in the Vision 2030 by the government whose target is to achieve 100% electricity connectivity. In order to supply electricity to customers, geospatial data or information is necessary to support effective engineering design. The analogue maps produced are neither georeferenced nor interactive and the CAD drawings which are finally handed over to Kenya Power for operation and maintenance lack accuracy. The Design Department in REA faces many challenges, including time spent searching for information, organizing data, difficulties finding accurate location of facilities, duplication of work, and difficulties in updating data. Therefore, the project objective was to set up a geodatabase that will support activities in the Design Department and demonstrate how it can be used. This involved georeferencing CAD drawings and Topographic maps, converting CAD data to geodatabase feature classes, geodatabase design, and base map creation and design. These tasks were useful in assigning geographic coordinates to spatial data, providing better management of data, base map creation and design, and accuracy enhancement of CAD features. This project provided a basic understanding of how to work with CAD drawings in GIS, and outlined procedures and methodologies for geodatabase design and creating a base map for the facilities from CAD data.

The database was created using a ready to use geodatabase data model; The ArcGIS MultiSpeak Data Model template used in electric utilities which was downloaded from ESRI Support Centre. Some of the findings indicated that the development and use of a geodatabase would greatly enhance the operation of REA. However it is also evident that with proper policy and information sharing among the stakeholders, more and even better results can be achieved.

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GLOSSARY

DBMS Database Management System

KP Kenya Power

AP Angle Points

 HT High Tension Cable

 LV Low Voltage Cable

TX Transformers

FDB Facility Database

GIS Geographic Information System

GoK Government of Kenya

GPS Global Positioning System

KNBS Kenya National Bureau of Statistics

OH (OHL) Overhead (Line)

REA Rural Electrification Authority

REM Rural Electrification Master Plan

REP Rural Electrification Programme

kWh Kilowatt Hour

SLA Service Level Agreement

AM/FM Automated Mapping/Facilities Management

CHAPTER 1: INTRODUCTION

1.1 Background

The Government established Rural Electrification Authority (REA) under section 66 of the Energy Act, No.12 of 2006 to accelerate the pace of rural electrification in the country. The objective was to streamline the implementation of the rural electrification programme so as to facilitate the achievement of the aforementioned national development goals. To achieve these objectives, the Authority has the mandate of extending electrification services to rural areas, developing rural electrification master plans, managing the rural electrification programme fund, mobilizing resources for rural electrification and promoting the development and use of renewable energy. In addition, GoK targets as set out in the Vision 2030 is to achieve 100% electricity connectivity by 2030. (National Energy Policy, 2013)

Further, statistical reports show that as at June 2013 the Government through Kenya Power (KP) and REA had provided electricity supply to 23,167 out of the existing 25,873 public facilities in the country. Also,the cumulative capital expenditure since inception of Rural Electrification Programme (REP) in 1973 was KShs45billion of which KShs 36 billion was generated from internal sources and the balance of KShs 9 billion was from Development Partners. The number of customers connected under the Rural Electrification Programme (REP) rose significantly to stand at 453,544 as at June 2013 from 382,631 as at June 2012. Units of electricity sold increased by 5million from 308 million kWh in 2011/12 to million 313 million kWh in 2012/13.

In REA the Design Manual, it specifies that purpose of survey is to provide geospatial data or information necessary to support effective engineering design required for connecting customers to electricity supply. Project Implementation Process in the Rural Electrification Authority is done after funds have been allocated to projects identified as load centers from Corporate Planning Department. The proposed route survey is then used for design and cost estimation, generation of project drawings, bills of quantities and materials necessary for the successful implementation of the Project. The drawings are then forwarded to Cartography Department for the production of maps as per built drawings. During the survey land owners give consent for construction of the power line to proceed as proposed where the proposal encroaches into their land. Assessment and records are made for all the properties damaged. REA hands over

completed projects to KP for operation and maintenance based on the Service Level Agreement (SLA). The summary of project implementation is shown in Fig. 1.1 below.
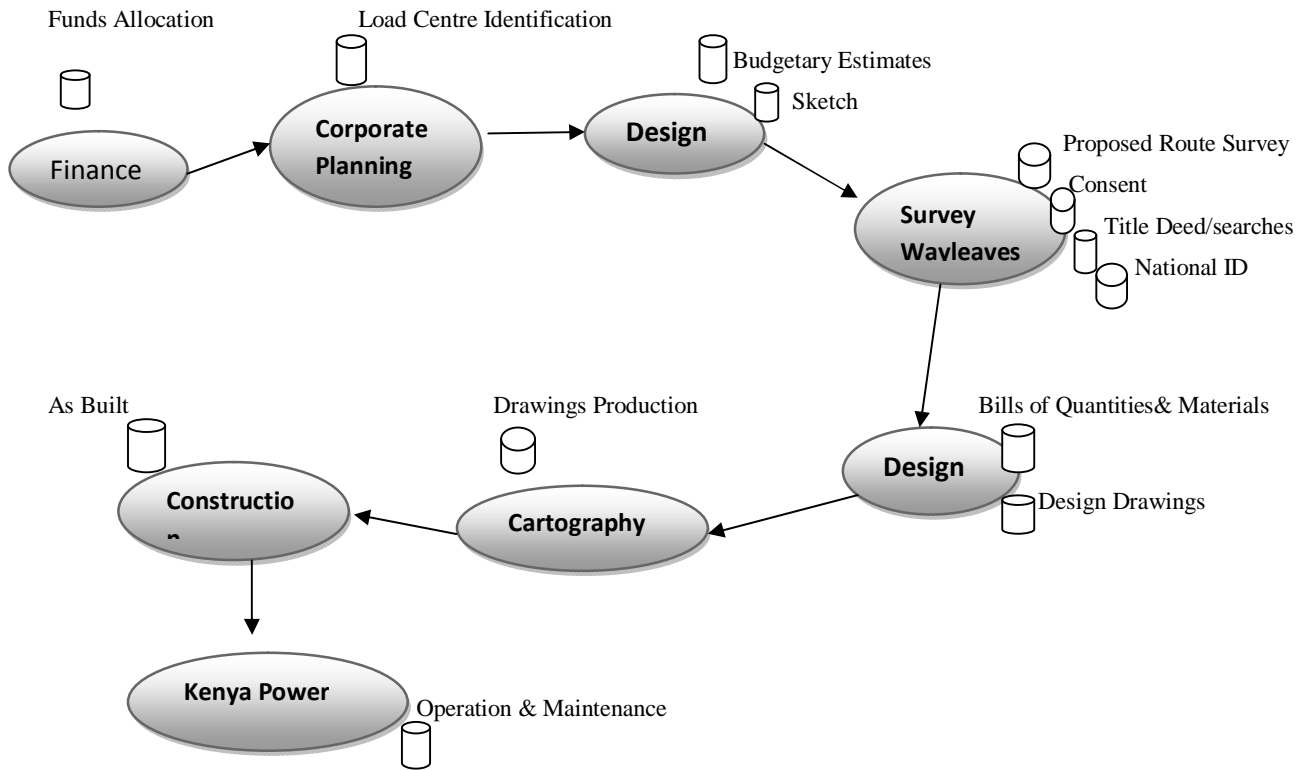
Fig. 1.1 Project Implementation Process in the Rural Electrification Authority

1.2 Problem Statement

Rural Electrification has faced challenges in high costs of connection due to scattered population settlements in the rural areas leading to long distribution lines. The non-controlled sub-division of arable land has escalated this problem including harsh terrains and inaccessibility due to under developed infrastructure. Physical plans in most cases do not provide an infrastructure corridor for electricity reticulation causing high compensation demand by public institutions and land owners during acquisition of way leaves. Operating costs are also high for off grids in rural areas due to low population density. Improvement of the Geographical Information System (GIS) utility database by completing the digitizing and mapping of the grid network is among the key areas that will help in the expansion of the national power distribution grid to connect one million new customers in 5 years starting from 2009. (National Energy Policy, 2013)

The design Department of REA is the custodian of survey records. The records are poorly managed due to lack of proper book keeping system that is reliable. It is difficult to update information despite the fact that even more spatial information records is being collected with the increased number of customers. The records are kept in paper form and this has made storage and retrieval a big challenge. Some records have been lost in the process while some have been destroyed. This is a great hindrance towards delivering effective power supply to the people of Kenya. Tracing a power line distribution history is also not an easy task as information relating different route survey plans are not easy to retrieve.

Planning in distribution system takes time and involves a lot of bureaucracy hence a system that can efficiently capture, store, retrieve and manage such data. GIS offers the above capabilities with the benefit of making it possible to update such a database timely.

Figure 1.2 A photograph of Spatial information records in REA (Taken by Author)

1.3 Objectives

The general aim of this research is to provide insight in the development and assessment of a geodatabase in a rural electrification environment. By investigating ways to assess or evaluate progress of the development of a geodatabase, this research may contribute to the improvement of the overarching REA framework. A conceptual roadmap for the geodatabase can be used to harmonize this process.

Furthermore the geodatabase creates possibilities for making new connections and comparisons by crosscutting existing boundaries between different disciplines, time periods and geographical areas. In this way this research aims to contribute to new trends and innovations in REA. This is necessary for maintaining the high quality of the existing level of GIS expertise and knowledge within REA and it is of vital importance for keeping in touch with the frontline developments in the national and international arena of electricity distribution. The concepts of a geodatabase are complex and comprehensive; therefore the research has a relatively large theoretical body. The objectives for this research are formulated as follows:

Overall Objective

The main aim of the project is to set up a geodatabase for effective distribution of electricity for the rural Kenya.

Specific Objective
i.   To create a GIS database that will support design activities.
ii. To demonstrate how the geodatabase can be used.

1.4 Justification for the Study

A guide for REA on how to create, manage, exchange common and other specific datasets for the common good of the organization is therefore crucial. Complexity of electrical distribution system and necessity of accurate up-to-date information of the network assets is a reasonable intention for introducing new method of information technology in REA.

The geodatabase will recommend the data structures, formats, descriptions, components and content that will be available. The description will try to minimize some confusion, about definitions, duplication in data handlings, and disagreements as to who must do what, and how it must be done, in REA.

Geographical Information System (GIS) offers the aforementioned in the management of facilities for engineering, construction operations, and maintenance and services purposes. With the aid of GIS, variety of information can be better organized on a computer system linking the database to spatial information. This will makes it more beneficial over the traditional database. Moreover GIS has the functionality of having information as layers, which helps in a systematic and refined manner of managing voluminous data. The spatially referenced data provides useful reference for setting up of new facilities, necessary information on land use pattern for planning optimum expansion of network and other network operations and maintenance. The database can also handle non-spatial queries as done with any other normal DBMS. For this reason GIS has become in effect, one of the tools for generating, arranging and managing geospatial information in a database that can support decision making.

1.5 Scope of work

The scope of the project will cover the following operations;

i) Geometric and Attribute data acquisition

ii) Design and creation of spatial database using ArcGIS software

iii) Perform spatial analyses i.e. query generation using ArcGIS software based on information need.

iv) Presentation of the required information in form of customized map and non-spatial data.

1.6 PROJECT STRUCTURE

The project report starts with a background of the problem and introduction to the research in first chapter, outlining the problem statement, justification of the project, project objectives and scope of the work. The review of relevant literature is presented in Chapter two, journals, reports and books are given as sources of information on the development and maintenance of a geodatabase. Next the geodatabase theories and models will be discussed. Chapter 3 starts with describing the theories behind assessment of a geodatabase and it presents the framework for this research, including the approach, models and instruments used including their coherence. The fourth chapter presents the results and analysis. The final chapter outlines the conclusions of the research including recommendations and a conceptual roadmap.

CHAPTER 2: LITERATURE REVIEW

2.0 INTRODUCTION

This chapter starts with a review of a Technical Report on GIS Development which examined sources of available GIS data, selected suitable data for the proposed GIS for REA and gave recommendation for regular backups of the GIS Database of the REM Project.

The chapter reviews theories and concepts of the GIS database models and of a geodatabase development was subject of reflection. The models and components used were discussed and this section is used as fundament of the geodatabase assessment theory and approach in chapter three. The literature review concludes with a synthesis that outlines the connection of the body of knowledge related to the research problem and questions.

Todayøs electricity production and distribution is utilizing GIS technology in the management of facilities for engineering, construction, and operation purposes. According to the Data Dictionary (2010), the typical GIS based requirements of production and distribution of electricity are;

- Update GIS databases with design and as-built data.
- Produce standard and custom map products.
- Integrate computer-aided design (CAD) drawings with the GIS network.
- Integrate with other enterprise systems such as work management systems, outage management systems, document management systems, materials management systems, and customer information systems.
- Analyze installed network for capacity planning and capital improvement projects.
- Manage feeder system, conduit systems, and inspection operations.

The ArcGIS Electric Distribution Model supports these typical business needs by providing an implementation that focuses on operations and maintenance portions of the facility life cycle and provides a crucial visual component. ArcInfo combines data and application behavior modeling. As a result, the ArcGIS model not only includes an essential set of electric device, structure, circuit segment, and customer information feature classes and properties, but also includes rules and relationships that define object behaviors. The core object technology and applied ArcGIS electric distribution model result in significantly less configuration and customization effort for overall implementation per site. ArcGIS MultiSpeak® Data Model Data Dictionary (2010)

2.1 RURAL ELECTRIFICATION AUTHORITY

2.1.1 Introduction

The arrangement between Rural Electrification Authority (REA) and Kenya Power (KP) is that REA builds lines, and then hands them over to Kenya Power upon commissioning for operations and maintenance. A recent agreement between the two organizations that geo-referenced drawings for commissioning of projects be handled only in soft copy which is GIS based and so the Kenya power can use the files to enhance their operations as well as their existing FDB. This has emphasized the need to establish a Geographical Information System (GIS). Evolution of technology, coupled with the ever increasing scope of work and data being handled by REA has since necessitated the adoption of GIS.

REA as an entity has to adopt existing standards and data models, or to develop its own, which the required spatial datasets will have to adhere to, enabling the various applications and software in use. This will ensure easy data exchange between the master data source, between applications and users, and also on new datasets or changes made by some REA environments. The dissemination of these datasets will also be a critical success factor (Figueroa, et al. 2006).

2.1.2 Rural Electrification Master Project

The importance of GIS in management of data within the Energy sector in Kenya goes as far back as 2007, when the country was paid a technical visit by GIS experts on invitation of the Ministry of Energy under the Rural Electrification Management (REM) Project (Technical Report on GIS Development November 2008). The purpose of the technical visits was to examine sources of available GIS data and select suitable data for the proposed GIS.

The GIS data of the 1997 Master Plan were available from three different sources:

- DGN Files at the Ministry of Energy;
- Excel Files at the Ministry of Energy;
- SGD Files at KPLC.

After their retrieval and verification, these data converted and implemented into the REM GIS Database as described in the following sections.

DGN files are the format for the software program called õMicrostation CAD Drawingö distributed by the company Bentley. The problem with these DGN files is that they contained

only graphical information. It was found that a conversion into GIS data would be very complicated including extensive manual conversion work and it is difficult to predict if the result would be acceptable. It was suggested to keep these DGN files only as backup. For the time being, no effort should be made to convert these files.

These excel files show the data for the market places which were collected during the surveys of the 1997 Master Plan. The data were presented in one excel file per zone, thus altogether 12 excel files. The market places are enumerated by the defined project numbers.

The conversion exercise into ESRI shape files (GIS data) was successful. These data are now available as 12 layers for the original 12 zones of the 1997 Master Plan. Unfortunately, in these excel files, the coordinates of a few (less than 3%) locations / market centers were not correct and cannot be visualized.

The SGD files (referring to the Facilities Database at KPLC) consist of the grid of the projects defined in the 1997 Master Plan. KPLC originally received these data (unknown format, possibly DGN or DXF files) from Ministry of Energy and converted them into DFX files (AutoCAD). The Consultant now converted them into the ESRI shape file format, thereby preparing the grid data in four layers;

- 33 kV existing grid;
- 33 kV proposed grid;
- 11 kV existing grid;
- 11 kV proposed grid.

The grid and the locations proposed within the 1997 Master Plan are now included in the GIS Database of the REM. With these data it is possible to evaluate the progress of realization of the 1997 Master Plan and to use them as basis for the REM Project.

It was therefore strongly recommended considering and implementing at least the following guidelines:

- One GIS user should be selected as the õGIS Administratorö being responsible for the maintenance of the GIS Database of the REM Project. He/she defines the most up-to-date version of the GIS Database and organises the work of all GIS users.
- Regular backups of the GIS Database of the REM Project should be made by the GIS Administrator.

2.1 GEOGRAPHIC INFORMATION SYSTEM

GIS can be defined as integrated sets of data, hardware, software design and focus on the real issues rather than trying to understand the data, also analyse power system networks in less time, more economically and more accurately. Database which is the most important asset of an organization plays a central role in the operation of planning, can be divided into two main various data types: spatial data that describe the location and the shape of geographic features and spatial relationship of map features and attribute data which is the descriptive information of the map features. The two most frequently used GIS models of spatial data are raster and vector. Vector data are based on co-coordinating the system where geographic object is represented by points, lines and polygon. Vector data are more suitable for features that have discrete boundaries such as roads. Raster data consists of a regular grid of cells or pixels where each cell contains a value representing information such as elevation. Each set of cells constitute a layer which is called coverage and several thematic layers can logically constitute a complete database. The raster data model is the most suitable format for arithmetic operations among cells. A mathematical procedure called topology is used for representing spatial relationships among the objects. GIS software and hardware are used as tools for storing, analyzing, interpreting, updating and displaying information.

Emengini (2004) noted that knowledge about physical assets of the enterprise is necessary to make strategic and operation decisions. Thus, to take wise decisions vital to the operations, growth and management of electricity distribution facilities, information must be collected and analyzed to its full extent, such information contributes not only to efficient services, but also to the operation and maintenance of assets, and to the sensible planning of extensions and new works. This information helps in spatial decision making and it makes the information easily updateable and can cater for the needs of maintaining large power infrastructure. GIS can effectively be used to manage and monitor information on the distribution of electricity to end-users including information describing their spatial and non-spatial attributes such as geographical location and electricity use.

(Sipes, 2007) shows a transition in recent years from the ways in which utility companies which have previously been engaging GIS as departmental solution to an enterprise solution where data is accessible by thousands of people.

However, GIS is not only a computer system designed to produce maps, but also a powerful tool of geographical analysis.

The earliest efforts at automation during the 1970s and early 1980s were focused around producing digital maps. Since this was largely a graphics-driven task, most utilities chose Computer Aided Design/Drafting (CAD) software as the basis for systems which came to be called Automated Mapping/Facilities Management (AM/FM). A number of approaches geared to map reproduction were taken, based around the CAD technology of the era.

Data are the foundation of a utility GIS. While it is difficult to generalize, it is common for the cost of data to be 60 to 80 per cent of the total first cost of an AM/FM/GIS solution. Utility data automation is complicated by the diverse quantity and quality of the source documents, the detailed facilities and base-map data that may be necessary to support application requirements, the existence of segregated departmental databases containing existing facilities records, and even the lack of standards for cartography among different departments and geographical regions of a company. Accordingly, any attempt to generalize about the cost of data capture is nearly certain to be misleading. That said, the graph presented in Figure 1 gives a range of expected data capture costs in terms of US$ per customer served from several utilities surveyed .(Meyers et al,2009)

2.2.1 GIS and databases

Geographic Information Systems are based on the interaction between a geometrical and a tabular interface used to manage and analyze spatial data. When working with GIS it is important to define a database design and structure that allows the user to be consistent while moving from the storage to the data analysis phase.

2.2.2 Structure and naming of the data

A good database-design allows finding data, and speeds up data processing. Updating and modeling data play a very important role in GIS and therefore have to be taken into consideration while designing a database. Deciding the relations between data and the names of the dataset are also crucial steps in the database design phase. Names have to be understandable and unique for every single dataset.

2.2.3 Data type used in the database

ArcGIS allows the user to work mainly with vector, raster and tabular data. The different formats are chosen based on the availability of the data and on the phase of the GIS process. When talking about spatial analysis or relations, we can use topology from the vector environment or the cell by cell model of the raster environment. Tabular data are mainly used for reclassification and arithmetical calculations.

2.2.4 Data acquisition

Many sources are used in the data acquisition phase ó from free databases available on the Internet to local public databases. It is important in the data acquisition phase to verify the source and the main characteristics of the dataset and to keep always in mind the quality of the dataset.

2.2.5 Data Standardization

GIS work mainly with spatial data relation; the spatial environment of these systems is based on coordinates. To make spatial data comparable they have to share the same spatial references. When working with geometric features and raster dataset, layers should share a standard coordinate system and the same resolution. To gain these setups especially when data from different sources are used, operations on geotransformation are in most cases needed.

2.2.6 Creation of Metadata

Metadata are õdataö about the dataö, a small description of the datasets to make data understandable by everyone who wants to use them. Data production can get very laborious using GIS and enormous amounts of data can be created. Keeping track on what and where things are is very important during the creation and the use of the database. When using ArcGis, every dataset has a page where data about the data can be saved and reviewed every time needed.

2.2.7 Use of data

Database Administration involves the overall design and management of the database, archiving, consistency checks, developing/maintaining, retrieval functionality, migration, and monitoring.

The database must be checked periodically and updated by one person who has the responsibility of maintaining the structure and updating the metadata. Download and upload of new dataset should be integrated in the structure, thatøs why it is always important to have a common platform where the data can be saved and the users are able to have easy access to the database, Riccardo et al (2004).

Tveite (1997) in his study on Migrating CAD maps to GIS the experience of the City of Regina described this process of schema mapping and data conversion, and the transition from using paper records, to CAD maps, to departmental GIS, and finally to multi-user enterprise GIS-based asset data repository is described traditional CAD models, GIS models emphasize the definition and use of semantic rich object-based models that are linked to Relational DBMS to store and manage the attribute data. The study revealed that by integrating spatial and non-spatial data, GIS models can enable efficient and automated data verification and validation; both are critical for ensuring the quality and reliability of the asset data. Moreover, the client-server architecture of most GIS software enables browser-based thin clients to efficiently access the data over Intranet/Extranet networks. The browser-based architecture can support the mass deployment of spatial data across various departments and stakeholders within municipalities in a cost-effective manner. The project team adopted the ESRI ArcGIS architecture, and started by developing a geodatabase for domestic and storm sewer data. The ESRI geodatabase data model is an object-relational schema that includes relational tables, feature classes, relationship classes, topologies, geometric networks, raster datasets and raster catalogs, and data semantics and behavior rules. The geodatabases data model enables the implementation of validation rules to enforce integrity constraints on the data, and employs relational DBMS SQL functions to support data access, update, and management processes. The geodatabase data model allows the definition of õcustom objectsö that embody user-defined semantics. For example, instead of representing a sewer as a generic line feature, a custom sewer feature can enforce subtypes, domains, and relationship rules to ensure the validity of the feature. The geodatabase model also enables the implementation of more complex spatial relationships such as networks, topologies, and terrains. The definition of the Domestic Sewer Line (DSLine) feature class. Three subtypes in the DSLine Feature Class were defined: Main, Trunk and Force. All three subtypes have the same attributes, but are classified differently because of their diameter. Domains (or range of valid numbers or list values) were defined on the fields in the feature class. Two Coded Value Domains were

defined: Pipe Material and Main Pipe Diameter. The Pipe Material domain is attached to the Material field in the Feature Class, while the Main Pipe Diameter domain is attached to the Diameter field in the Main subtype (Weston et. al., 2001). A geometric network was then created to establish connectivity rules and cardinality for each object in the model. These rules establish which features can be connected, and the restrictions of the number of edges connecting to a junction, or the number of junctions connecting to an edge. Some examples of the types of rules and cardinality applied were: a manhole must connect to at least two mains, a coupling can only have two pipes connected to it, and an end cap can only have one pipe connected to it.

After the geodatabase schema was designed, domestic and storm sewer data were converted from the AutoCAD drawings into the geodatabase schema. The objects (or features) and attributes were already established in AutoCAD with attributes, attribute domains, layers and blocks (or symbols). Data were exported from AutoCAD to ESRI shape files, and then imported to the geodatabase using ESRIøs Arc Catalogøs Simple Data Loader. After the data were loaded, a validation was performed to identify the number of existing errors such as not falling into a featureøs applied domain, or the violation of network connectivity and cardinality rules. Network analysis tools were also used to determine if there were ±holesø or disconnected areas in the network topology.

After migrating the domestic and storm sewer data into the geodatabase and correcting the errors flagged in the validation process, the data maintenance of these layers (changes, additions, or deletions) were mainly performed in ESRIøs ArcMap. Junction subtypes (manhole, fitting, etc) and attribute information were also added and edited in ArcMap. At a later stage, the water distribution system and pavement layers were added to the geodatabase. In addition to infrastructure layers, the geodatabase also included other corporate layers such as parcels, land use, digital elevation maps, and aerial ortho-corrected photos

The entity-relationship (ER) approach (or ER diagrams, initially proposed by Chen [Chen76]) has been the most popular diagrammatic representation for data modeling in the last decade. The expressiveness of the original ER model has been extended in many directions to capture more real-world semantics in the diagrams. The latest direction in real world modeling for computer representation is the object-oriented approach. Object-oriented methods add encapsulation and behavior to the traditional structuring mechanisms of semantic data models.

2.3 ELECTRICITY DISTRIBUTION MODEL

Today's electric utilities are realizing the benefits of GIS technology in the management of facilities for engineering, construction, and operation purposes. The typical requirements of these utilities reflect business needs to:

- Update GIS databases with design and as-built data.

- Produce standard and custom map products.

- Integrate computer-aided design (CAD) drawings with the GIS network.

- Integrate with other enterprise systems such as work management systems, outage management systems, document management systems, materials management systems, and customer information systems.

- Analyze installed network for capacity planning and capital improvement projects.

- Manage feeder system, conduit systems, and inspection operations.

The ArcGIS Electric Distribution Model supports these typical business needs by providing an implementation that focuses on operations and maintenance portions of the facility life cycle and provides a crucial visual component.

The object technology at the core of ArcInfo combines data and application behavior modeling. As a result, the ArcGIS model not only includes an essential set of electric device, structure, circuit segment, and customer information feature classes and properties, but it also includes rules and relationships that define object behaviors. The core object technology and applied ArcGIS electric distribution model result in significantly less configuration and customization effort for overall implementation per site.

2.3.1 Electric Distribution

ArcGIS MultiSpeak® Data Model Data Dictionary (2010) describes what an Electric distribution is by explaining how power delivered by electric utilities is transmitted from generating plants to industrial sites and the substations that distribute power to residential and commercial users. The Dictionary also explains that the utility business is thus divided into these two areas - transmission and distribution. Transmission networks connect generators to substations through transmission networks. The distribution system delivers power from substations to residential and commercial users. Therefore, REA covers the aspects of the electric utility business dealing with distribution. Distribution represents about 35 percent to 50 percent of a utility's investment.

The mission of the utility is to provide power to consumers at an appropriate voltage with a certain degree of reliability. Distribution components typically include:

- Sub-transmission circuits with voltage ratings that range between 12.47 and 345 kV
- Distribution substations that convert energy from transmission network levels to lower primary system voltages
- Feeders, or primary circuits, that operate between 4.16 and 34.5 kV and supply load to specific geographic areas.
- Distribution transformer rated from 10 to 25000 KVA that transform primary voltage to utilization voltage
- Secondary circuits that carry current from the transformer along the street
- Service drops that carry current from transformers to customer point of utilization.
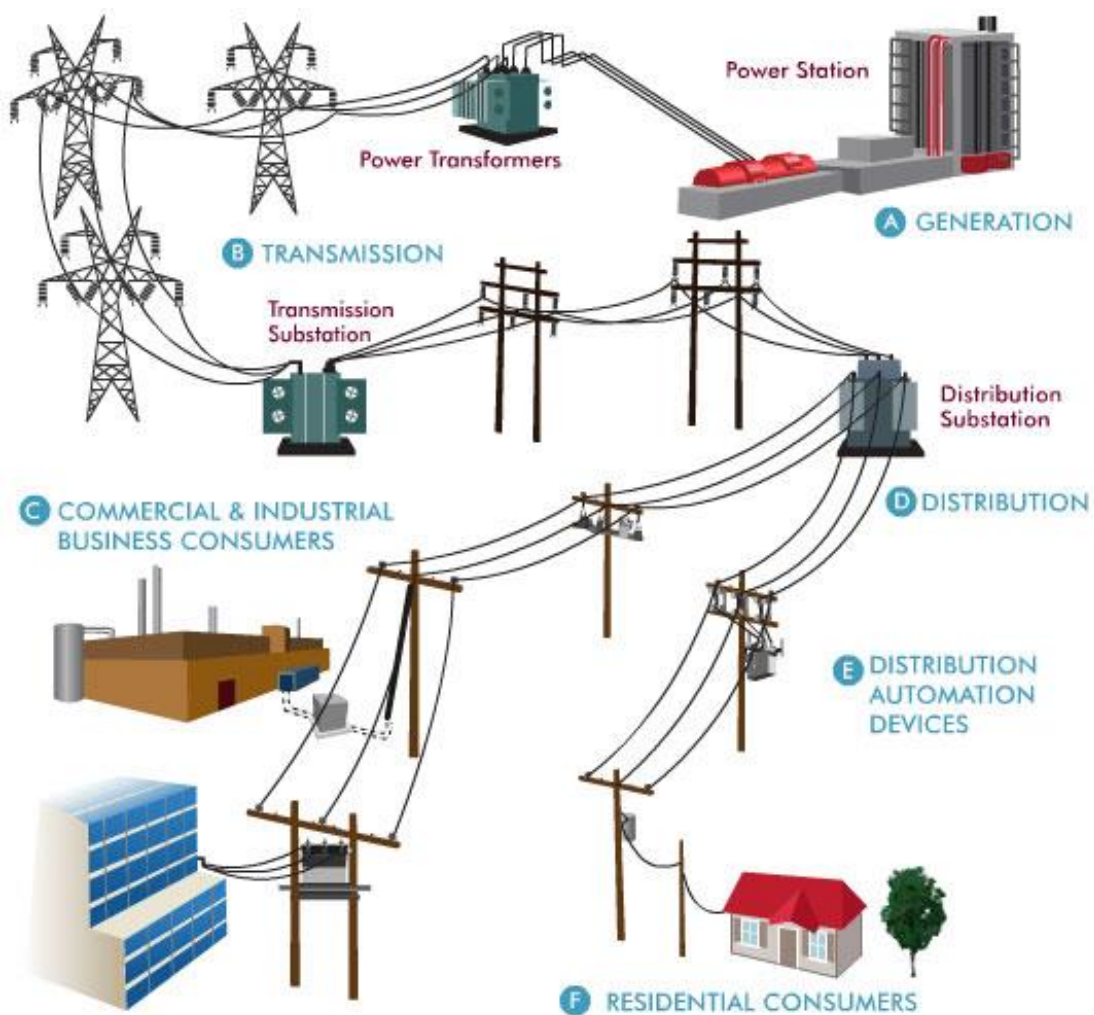
Figure 2.1: A typical Electric Power Distribution Components (Courtesy Oncor.com)

2.3.2.0 Electric distribution system components

Typical primary overhead distribution systems are operated as radial circuits from the substation outward. In overhead systems, structures such as poles and H-frames support the primary and secondary conductors. Surface structures like pads enclose and protect electric devices on the ground. The electric utility infrastructure is also composed of devices such as transformers and fuses and circuit segments, such as overhead and underground conductors.

These components fall into four general logical categories: circuit segments, structures, devices, and customer and service.

2.3.2.1 Circuit Segments

This subsystem contains classes and properties that describe the conductors that transmit and distribute electric current. Circuit segments can be categorized as simple or complex edges and objects. The inherent behavior of complex edges is very different in ArcGIS Electric Distribution than the traditional ArcInfo topology model. The ArcGIS Electric Distribution system automatically maintains the relationships between complex edges, any attached devices, and other edges so you can choose how you want to physically segment your network. For instance, it makes sense to physically segment electric lines between fuses and switches since, among other things, it is important to keep circuit data on lines, depending on which side of the fuse they are on. For example, if you place a fuse on an overhead primary that originally was associated with CircuitID 001, it may be that the overhead primary west of the fuse is part of CircuitID 001, but the overhead primary east of the fuse is now associated with CircuitID 005. At the same time, it is not necessary to physically segment electric line segments at splices.

Once your network is in place and you move an electric line segment, any attached switches, fuses, transformers, and other portions of the network automatically move with it. ArcFM Energy determines whether a complex edge should be split based on the type of junction (device) being added. As with most of the subsystems discussed in this document, a common set of properties is defined in a toplevel abstract class. All subclasses beneath the abstract class *ElectricComplexEdge* inherit these properties.
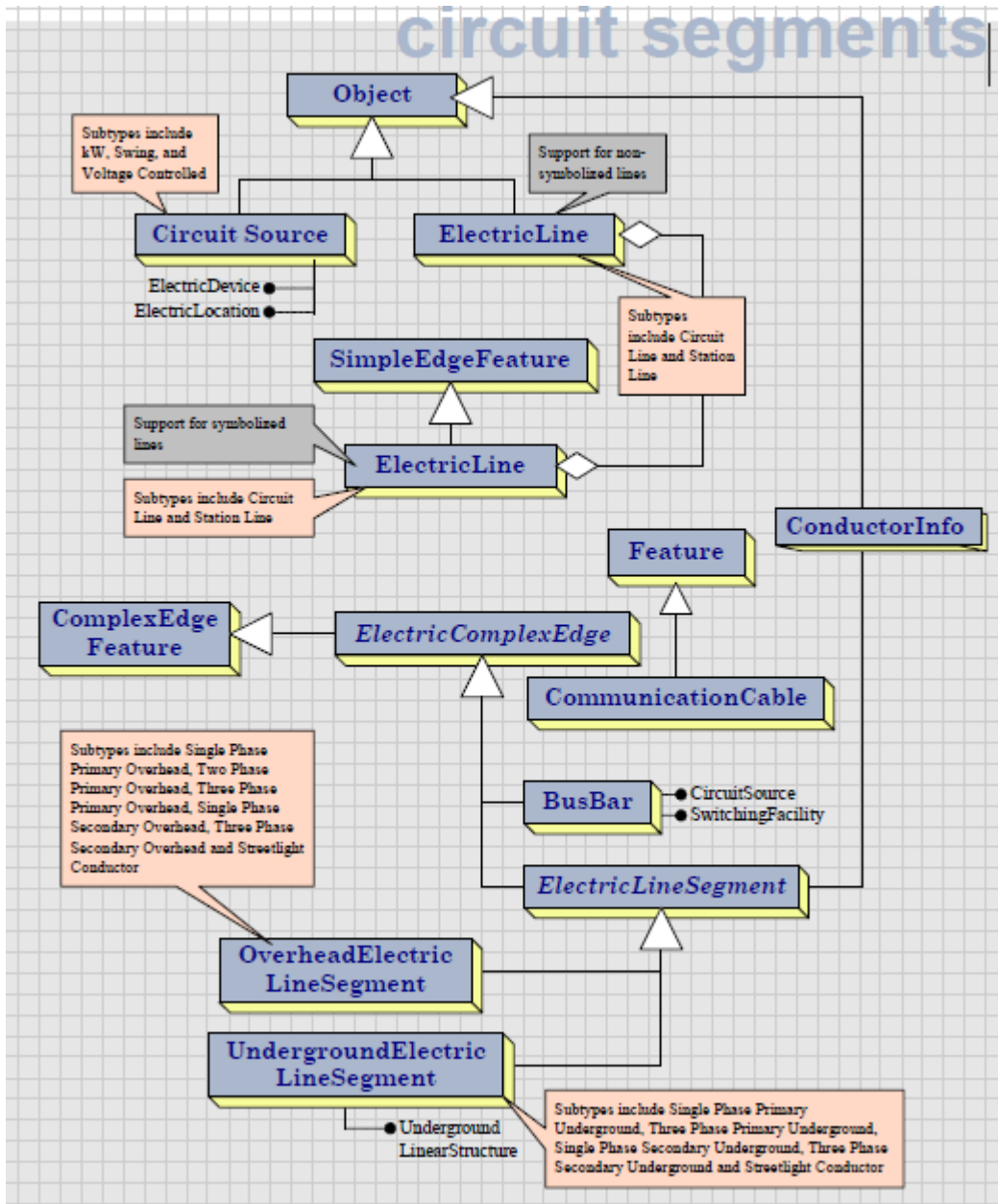
Figure 2.2: Circuit Segments

2.3.2.2 Structures

Structure is the abstract class that contains common characteristics, or attributes, for all electric structures involved in the distribution or transmission of electricity. The Structure class was created as a general top-level class for any type of facility structure. The subsystem structure contains non-network (non-spatial) features and related objects. You can create associations between a support structure and the Inspection object class to capture information about

maintenance, for example. The subsystem structure also includes objects to manage information about the lifecycle of a structure.
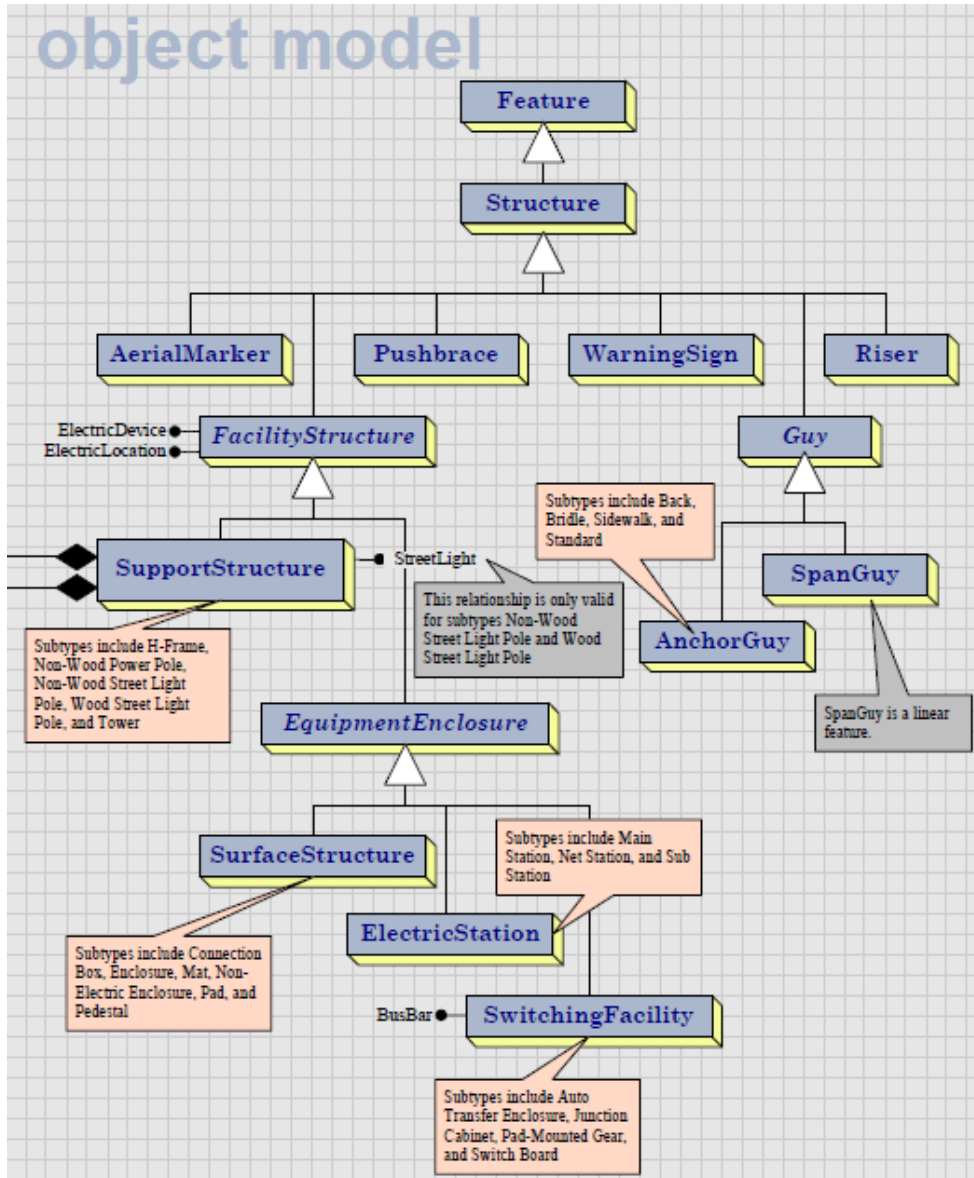
Figure 2.3: Structure

2.3.2.3 Devices

Electric devices help ensure consistent service within the distribution network. The device subsystem contains simple junction features and object classes. Devices features participate in the network and objects are the units and controls associated with those devices.
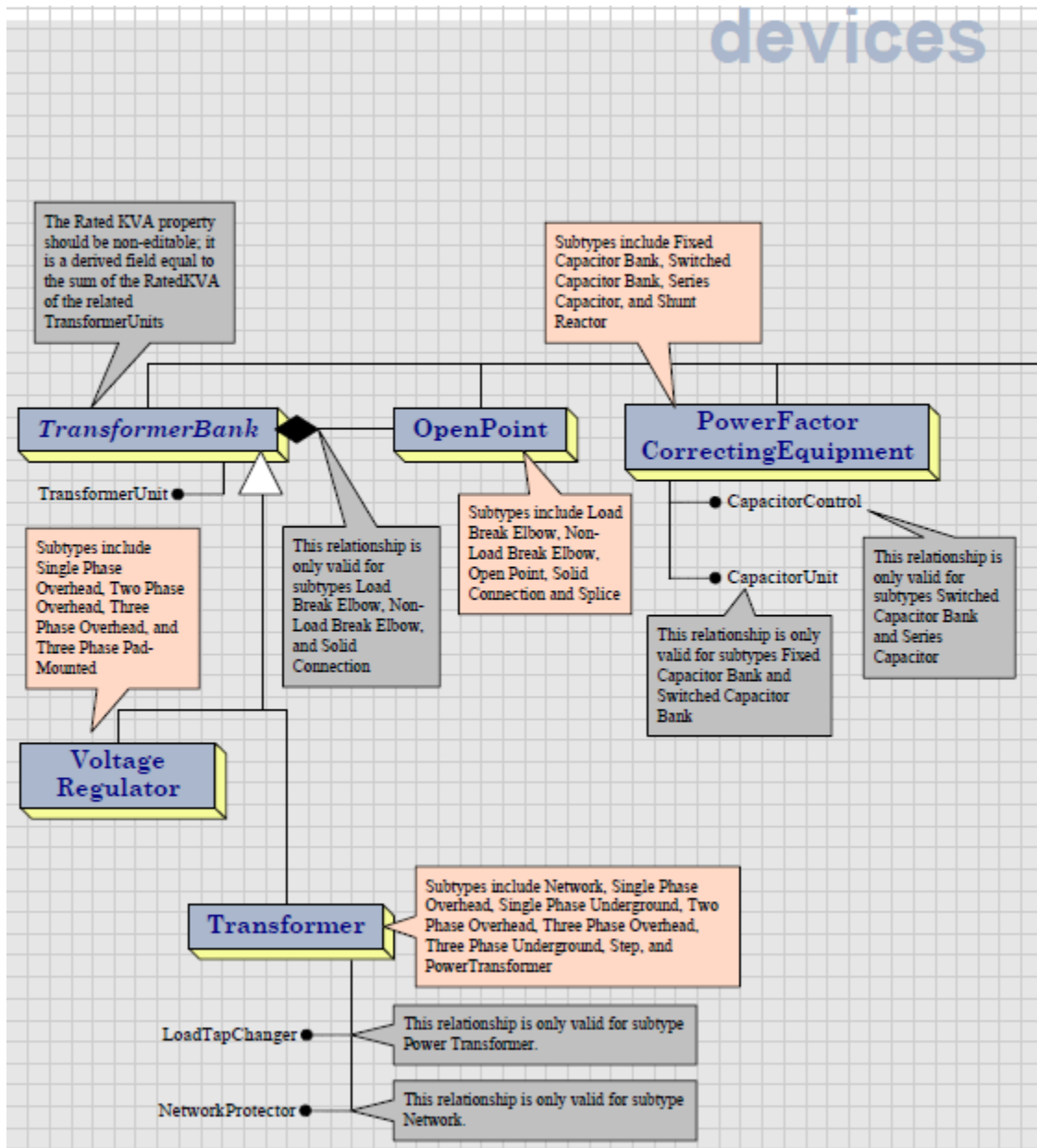
Figure 2.4 Devices

2.3.2.4 Customer and Service

Residential, commercial, and industrial customers, resellers, as well as special devices such as streetlights, constitute the loads on the electrical system. Simple junction features are the electric locations (for example, primary meters and service points). Objects contain customer information and information about generators of alternate sources of electricity. Primary meters, delivery points, and generators may be associated with a structure

CHAPTER 3.0 METHODOLOGY

This chapter identifies the materials and tools used to achieve the objectives of the project. It also discusses the process of creating the GIS database using an Electric Distribution model.

3.1 AREA OF STUDY

The area of study shown in (Fig 3.1) below was Mwala Constituency in Machakos County covering an area of approximately 5953 km^2. It lies between UTM coordinates- Northings: 9803447 m & 9913778m and Eastings: 263386m &3737318 m.

The choice of the study area was due to the availability of the data sets and its accessibility for field verification.

Map of the study area
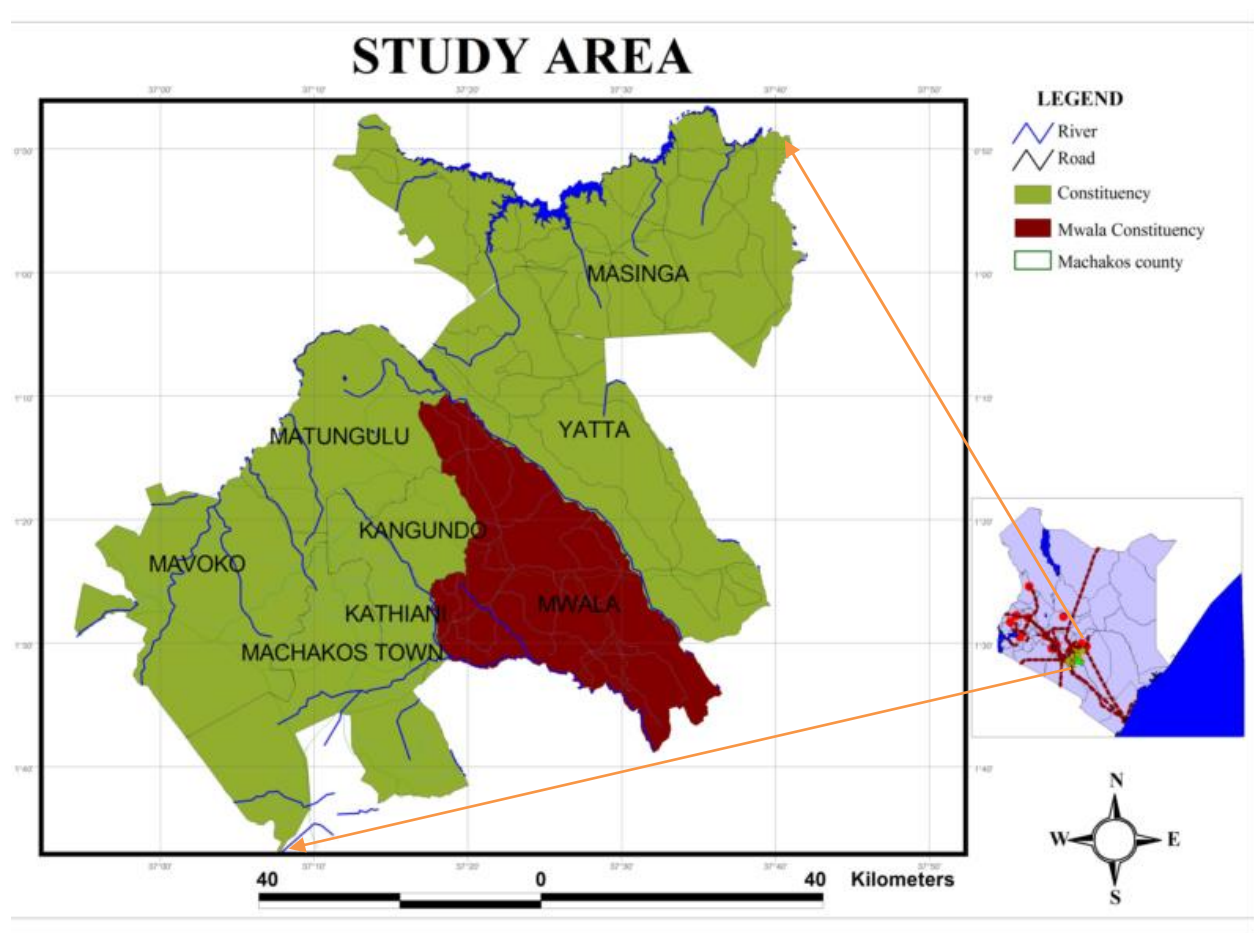
Figure 3.1 **Machakos County Map**

3.2 DATA AND DATA SOURCE

A survey of available data commenced once needed data was identified in the needs assessment. This task made an inventory and document mapped, tabular and digital data within the energy sector as well as data available from other sources, such as Survey of Kenya, Kenya Power and Kenya National Bureau of Statistics. The documentation prepared at this point was sufficient to evaluate each potential data source for use in the geodatabase. Information collected at this point will also form part of the metadata for the resulting GIS database. Table 3.3 below, shows the collected data, the source the use, type and the format as collected.

Table 3.3 Data and Data Sources

Spatial Data	Map Use	Data Source	Representation	Format
Parcels	Land Owner	Survey of Kenya	Polygons & related annotation	DWG
Secondary Distribution Network	Power Distribution Lines	Kenya Power	Lines &related annotation	DWG
County Map	Constituency Boundaries	Kenya National Bureau of Statistics	Polygons & related annotation	Shapefile
Topographic Maps	Basemap	Survey of Kenya	Scanned Image	JPEG (Raster)
Primary Distribution Network	Power Distribution Lines	REA	Points, Lines & related annotation	DWG

3.3 SOFTWARE

A number of application software packages were used for data processing. Some of the packages are ArcGIS, AutoCAD, ArcGIS MultiSpeak Microsoft Visio, Global Mapper and Microsoft office package. The packages were used for georeferencing, mosaicking, geodatabase design and modeling, operation and spatial analysis and queries.

Table 3.4 Software

Software	Use	Source
AutoCAD 2007	CAD data extraction	AUTODESK
ArcGIS 10.1	Data organization& topology building	ESRI
Global Mapper13	Cropping & Mosaicking	
ArcGIS MultiSpeak Microsoft Visio	Modeling	ESRI
Microsoft Access	Modeling	Microsoft Office
Microsoft Excel	Statistical analysis	Microsoft Office
Microsoft Word	Project report writing	Microsoft Office

3.4 HARDWARE

Several devices as shown in the table below, (Table 3.5) were used, some installed with the above mentioned software. The hardware use ranged from data collection such as the GPS units and the camera. Others were used in the data storage and analysis such as the hard drives and the laptop.

Table 3.5 Hardware

Hardware	Specifications
Laptop	HP 4GB RAM i5
External Hard Disc	Sony 1 TB
Handheld GPS receiver	Garmin, with
Digital camera	Sony (Carl Zeiss), 4Mega pixels resolution
Memory stick	16 GB
Printer	HP Laser Printer

3.5 **METHODOLOGY FLOW CHART**

The development of the geodatabase design began with the identification of the data, assessment and evaluation to determine the suitability for their use and whether they met the project objectives. All the steps involved in the process were related to each other as each process lead to another. The data collected and the tools used determined the process of developing the geodatabse hence influencing the results of the study.The process that was used is as illustrated in the flow chart shown in Fig. 3.2below.

```
                    ┌─────────────────────────────┐
                    │   DATA IDENTIFICATION       │
                    └─────────────────────────────┘
                                │
┌──────────────────┐           ▼
│ SPATIAL DATA     │   ┌─────────────────────────────┐     ┌──────────────────┐
│  • CAD data      │──▶│    DATA ASSESSMENT          │◀────│  NON SPATIAL     │
│  • Shape files   │   └─────────────────────────────┘     │  DATA            │
│  • Scanned       │           │                           └──────────────────┘
└──────────────────┘           ▼                                    │
       │           ┌─────────────────────────────┐                  │
       │           │  DATA PREPARATION &         │                  │
       │           │  GEOSPATIAL DATA            │                  │
       │           └─────────────────────────────┘                  │
       ▼                       │                                    ▼
┌──────────────────┐           ▼                           ┌──────────────────┐
│  SPATIAL DATA    │─ ─ ─▶ ┌───────────────────────┐       │  ATTRIBUTES      │
└──────────────────┘       │  ArcGIS ENVIRONMENT   │       └──────────────────┘
                           └───────────────────────┘
                                │
                                ▼
                    ┌─────────────────────────────┐
                    │  DATA PROCESSING            │
                    │  -Geometry repair           │
                    │  -Topological controls      │
                    │  -Clear duplicate objects   │
                    └─────────────────────────────┘
                                │
                                ▼
                    ┌─────────────────────────┐      ╭──────────────────╮
                    │  DATABASE DEVELOPMENT   │─ ─ ▶ │  ELECTRIC        │
                    └─────────────────────────┘      │  DISTRIBUTION    │
                                │                     │  MODEL           │
                                ▼                     ╰──────────────────╯
                    ┌─────────────────────────┐
                    │       RESULTS           │
                    └─────────────────────────┘
                                │
                                ▼
                    ┌─────────────────────────┐
                    │  INTERPRETATION OF      │
                    └─────────────────────────┘
                                │
                                ▼
                    ┌─────────────────────────┐
                    │  CONCLUSIONS &          │
                    │  RECOMMENDATIONS        │
                    └─────────────────────────┘
```
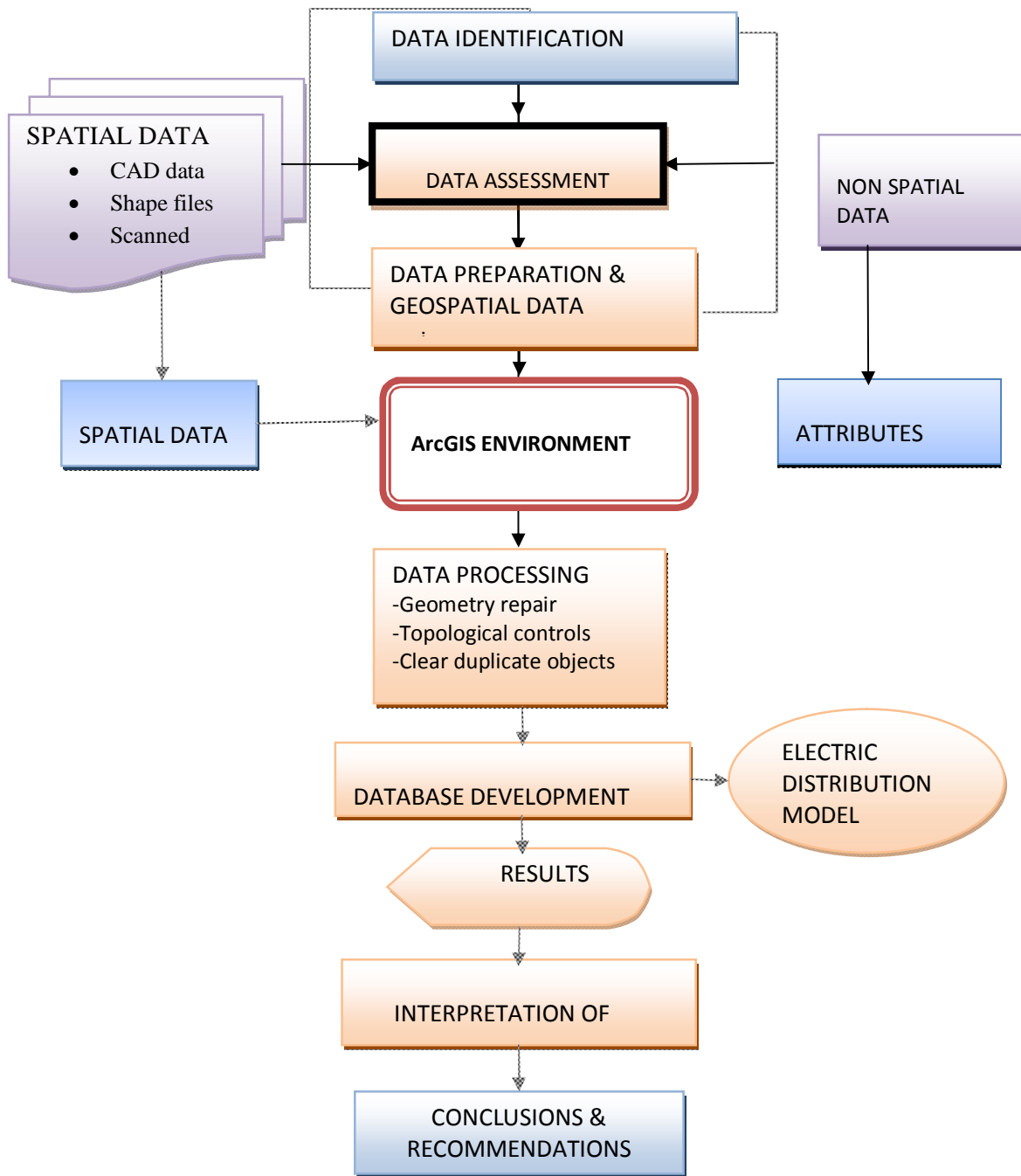
Fig. 3. 2 Methodology flow chart

3.5.1 Data Identification

Data identification was based on the project data needs where some of the key aspects of each data theme were defined. Determining how each data set would be used for editing, modeling and analysis that would represent the proposed work flow.

3.5.1.1 Topographic maps

Four scanned topographical maps namely, Wamunyu (150/3), Kangundo(149/4), Machakos (162/2) and Kisau (163/1) were identified, (See Appendix A). These were used as base map for the project's study area. They also provided information for general orientation and acted to aid in database decision making. Fig. 3.3 below shows an excerpt of one of the toposheets used.
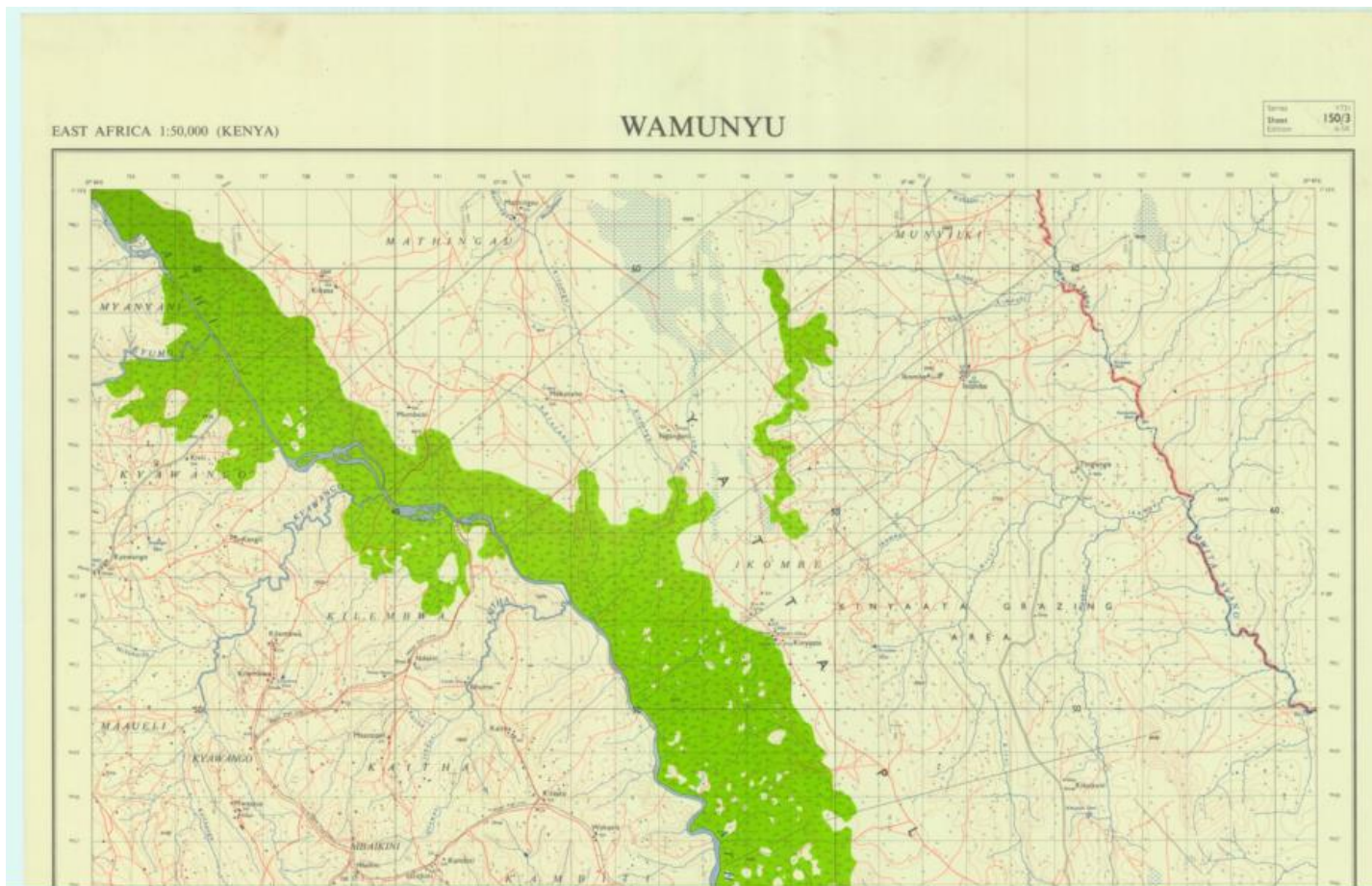
Fig. 3.3 Part of Wamunyu (150/3)

3.5.1.2 Proposed route survey

The proposed route survey below (Fig 3.4) is an AutoCAD drawing which has spatial data collected for the engineering design purpose by the surveyor. Parcel data is in CAD drawings showing boundary information from digitized from RIM submitted for designed.
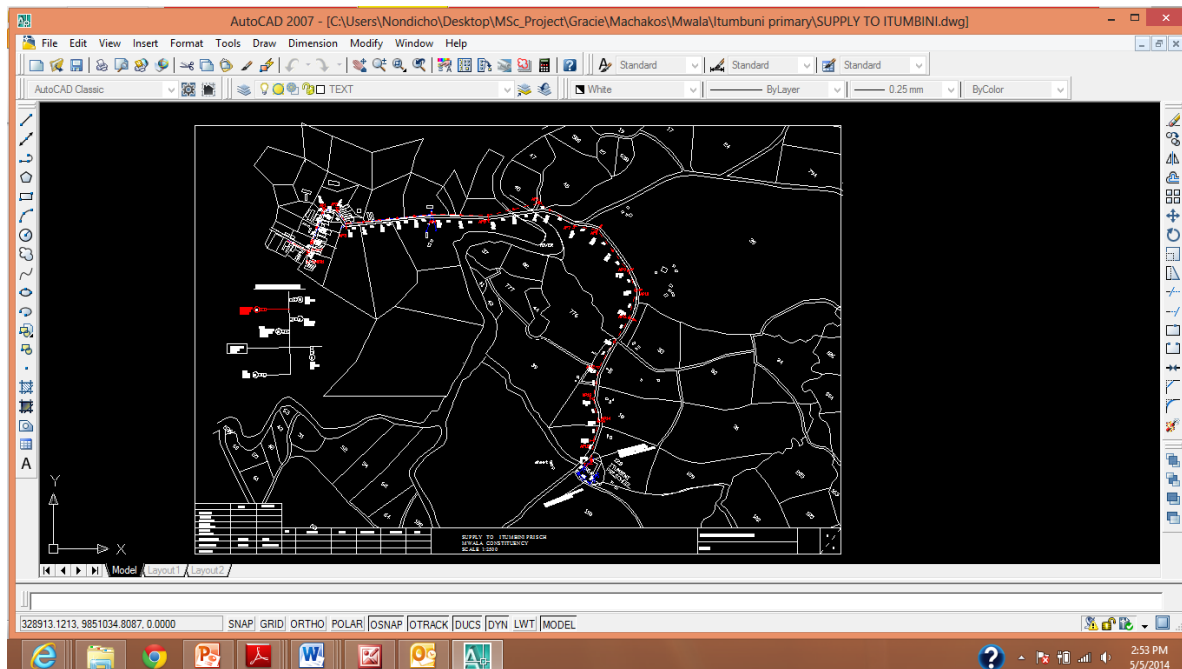
Fig.3.4 Proposed Route Survey

3.5.1.3 The design plan

The designed plan shown in (Fig 3.5) below was also a CAD drawing that had been designed on the proposed route survey drawing. The design drawing has electric structures such as the proposed transformer (1x 50 kva) poles and distribution lines.
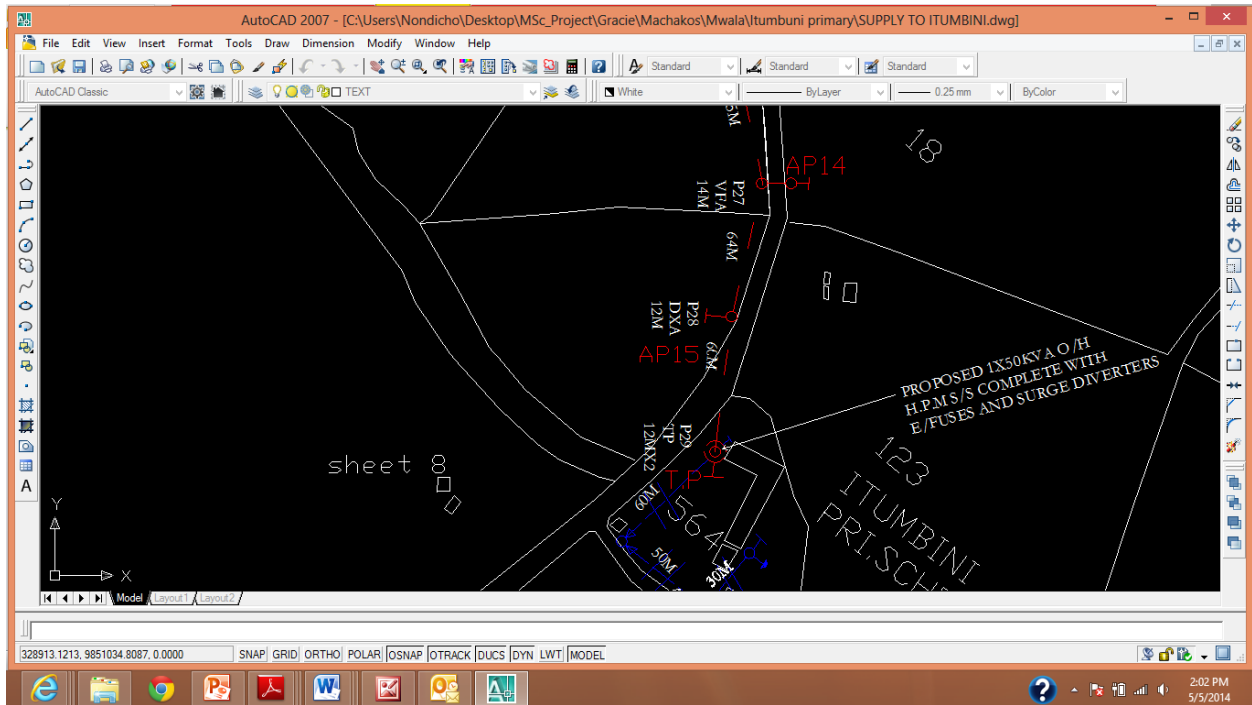
Fig. 3. 5.A designed Plan

3.5.1.4 Secondary distribution network

The secondary and primary distribution network is in AutoCAD drawings which was necessary for the existing power distribution network. It consists of Transmission Substations and distribution Transformers. The grid data are available in the REM GIS Database.

Currently, roughly 95% of the medium voltage grid (11 kV and 33 kV) has been tracked, also by using up to date information from the field work in counties covered by the micro studies. The MV grid in the layers below in (Fig. 3.7) gives a good but not a complete representation of the entire existing distribution grid of KP. This layer was prepared based on the Transmission Substations. Additionally to the original layer, it contains data regarding the technical equipment of each substation like the apparent power of the transformers and the available voltage levels. This layer is used for evaluating the capabilities of these substations to connect electricity nearby rural areas.
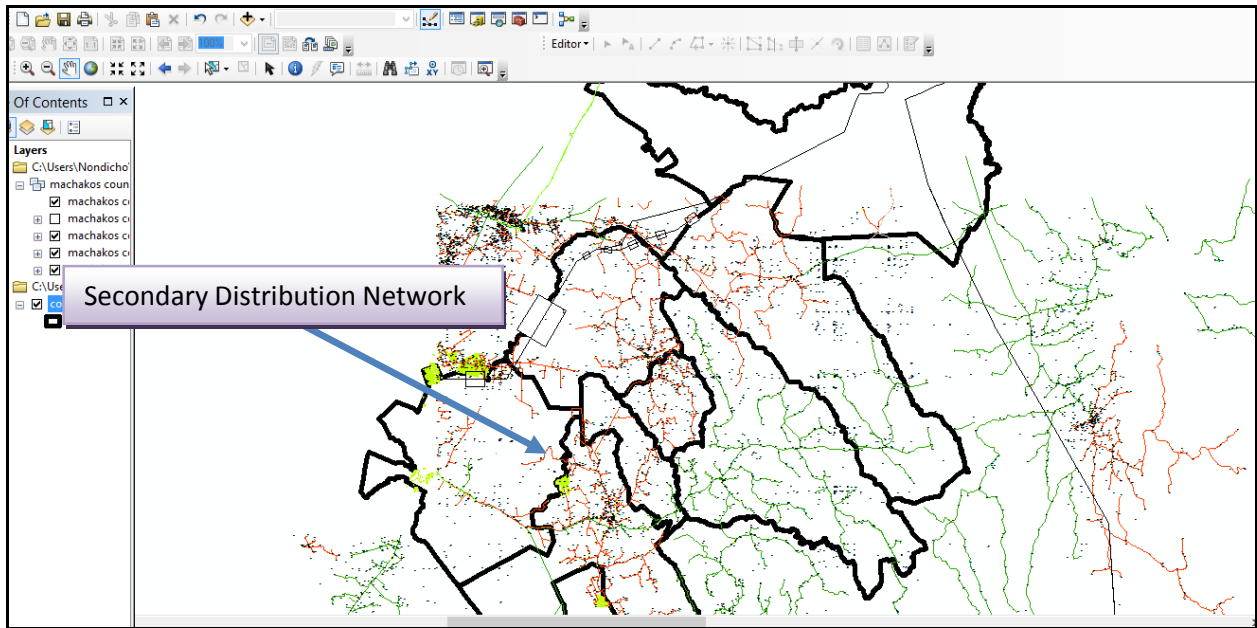
Fig. 3.6 Medium Voltage (MV) Grid

The (Fig. 3.7) shows a Secondary Distribution transformer Substation number 01515 with 100kva rating and a Secondary line section
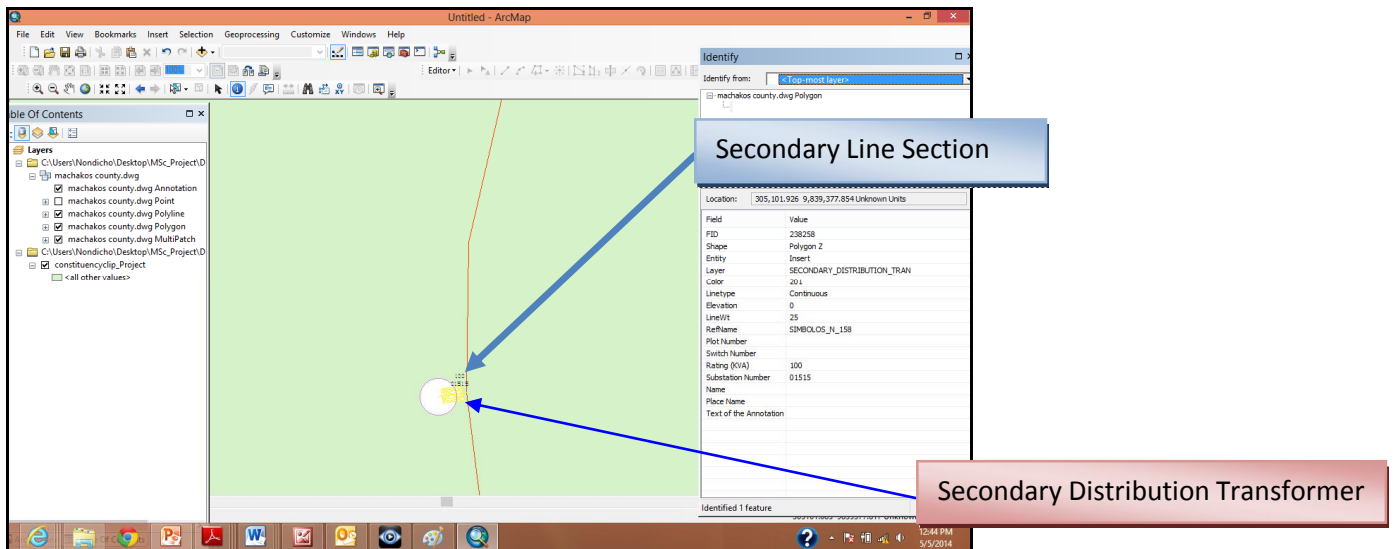
Fig. 3.7 Enlargement of the MV Grid

3.5.2 Data assessment

The datasets were assessed to determine their suitability for use and whether they met the projectøs objectives. This was achieved by determining their spatial representation such as in which coordinate systems they were acquired, the scale and resolutions, sources and formats.

3.5.3 Data preparation, organization and Georeferencing

The four topographic map sheets were georeferenced in ArcGIS, and then cropped in Global Mapper software. The sheets were then mosaicked to cover the area of study as shown in the (Fig. 3.8) below
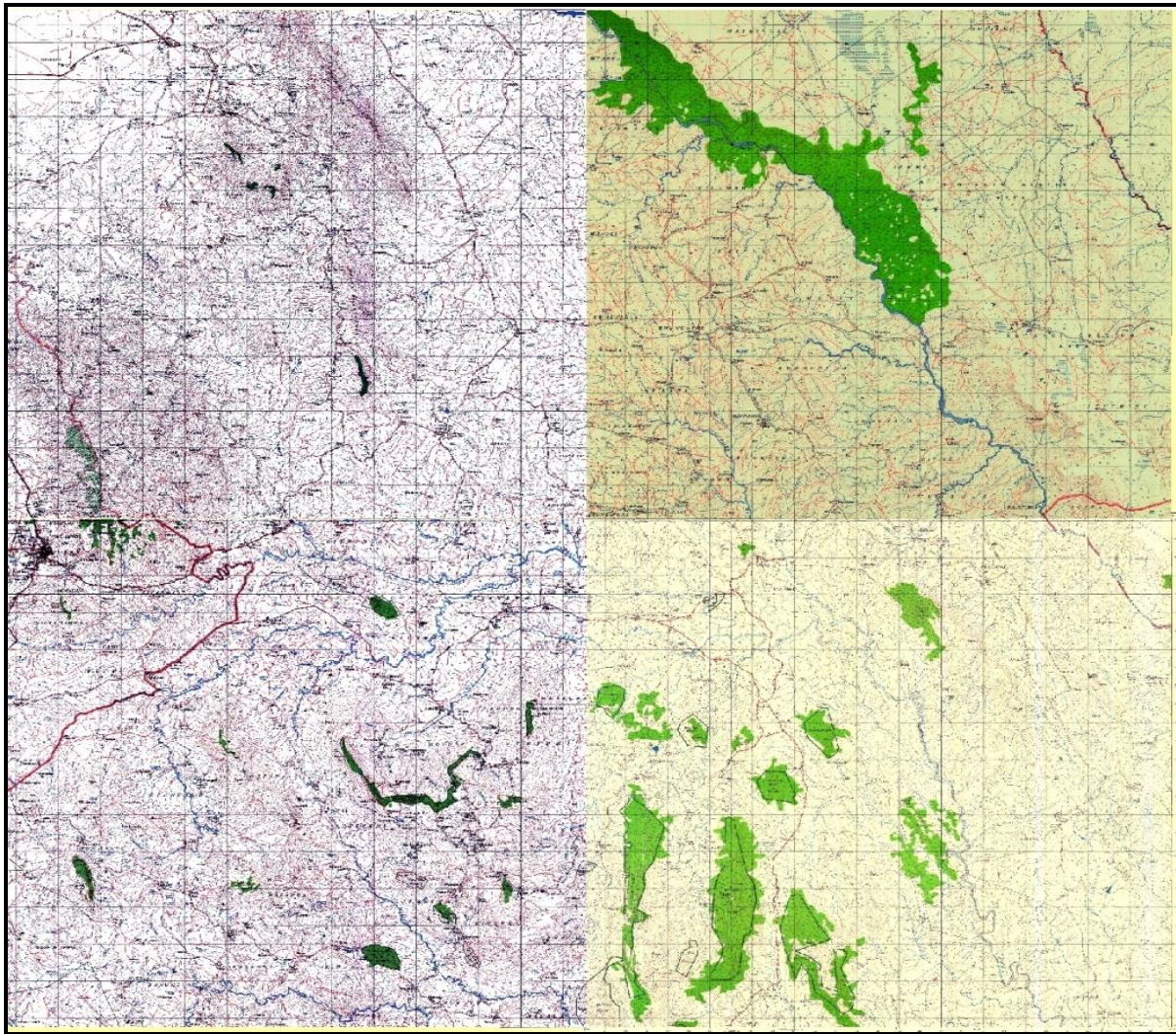
Fig. 3.8 Mosaicked Topographic Maps

Data organization was achieved by putting data in their respective layers and in appropriate building blocks (points, lines and polygons) and formats. Georeferencing of the shapefiles and the CAD drawings was done by using the following parameters: UTM Arc 1960 Zone 37M and in metric units.

3.5.4 Data Processing

This was necessary in order to clean up the spatial data of any topological and geometric errors. Undershoots were extended, offshoots trimmed and geometry repair done on CAD data in ArcGIS environment.

3.6   DATABASE DESIGN

This was found to be the most critical phase of a Database life Cycle as it ensured that the final product meets requirements. A properly designed database was found to be to be critical as it provided access to up to date and accurate information. Because a correct design was essential to achieving the objectives in working with a database, investing the time required to learn the principles of good design was worthwhile.

3.6.1 Choice of appropriate Database system

Relational databases are more constrained in their capabilities especially with regard to storing and representing some fairly common data structures. Object-Oriented approach made it impossible for applications to share data and made data recoverability, manageability, and scalability impossible as well. A hybrid of object Oriented and relational databases was adopted. ArcGIS software uses the same model. Object-relational database approach allows complex objects (maps, vector graphics, and photographs, even whole tables) to be defined within a relational structure and held as items (Bloor, B. 2003, 2004).

The advantages of object databases combined with the advantages of relational databases were considered and found to be enormous and include:

  Good transactional performance

  Complex data management

  Ease of management

  Rapid development

Flexible query capability

Standard data access interface

Suitability for business intelligence applications

This hybrid opens up the possibility of having a single database engine, with a single set of data definitions appropriate for all applications (Bloor, B. 2004).

To construct a data model, the ArcGIS electric distribution data model was used as a guide for determining the objects, attributes, and classes for the design.

3.6.2 Database design phases

The approach that was used to design the database is called the ANSI-SPARK (American National Standard Institute- Standards Planning and Requirement Committee) design methodology. The design focused on data needs and involved the following phases:-

- Identification of entities
- Creation of an external model
- Creation of a Conceptual model
- Creation of a Logical model
- Creation of a Physical model
- Pilot Geodatabase
- Full Implementation

However, for the purpose of this project a portion of data was used to test the geodatabase

A summary of the same is given in the (Fig. 3.9) below:
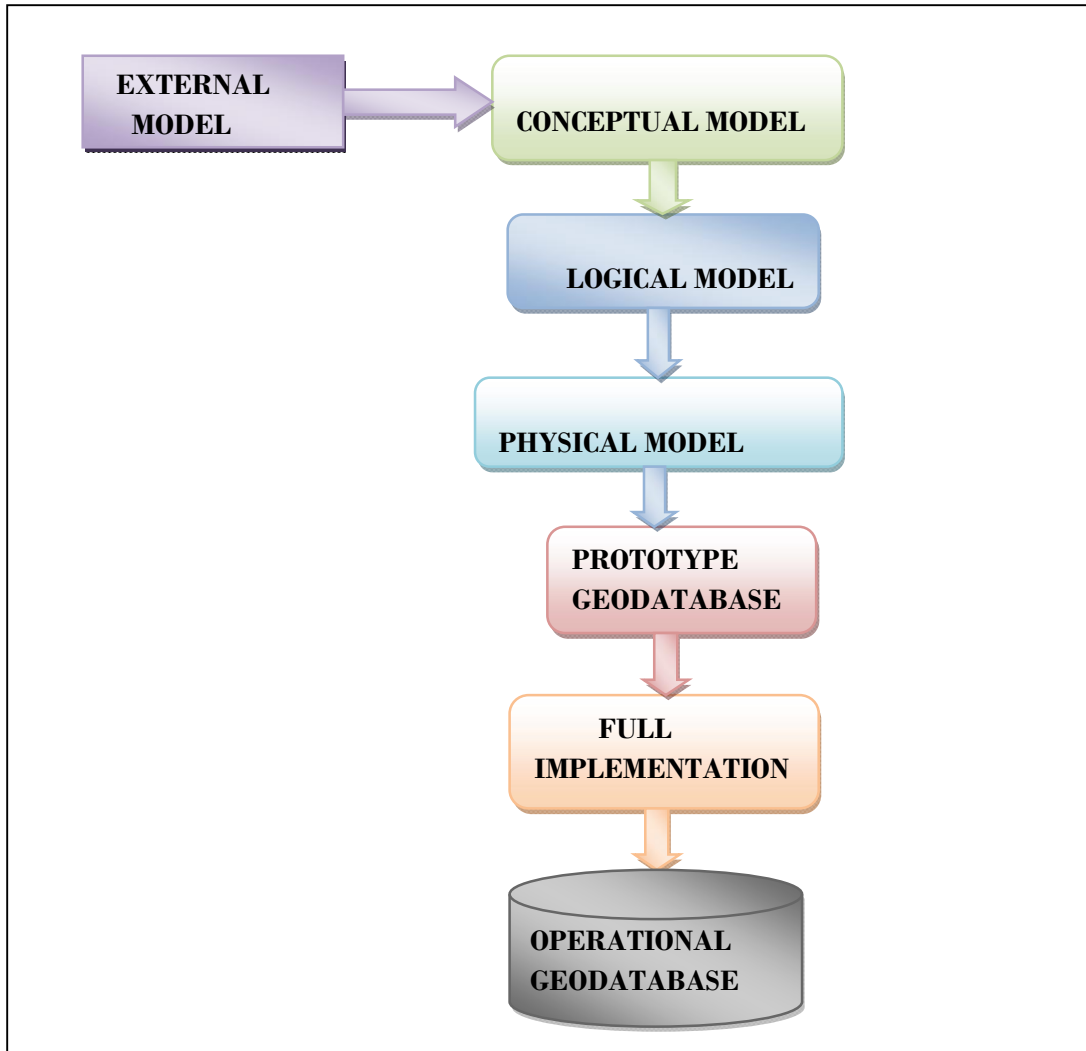
Fig.3.9 Phases of a Database design

3.6.3 External Modeling (User Need Assessment)
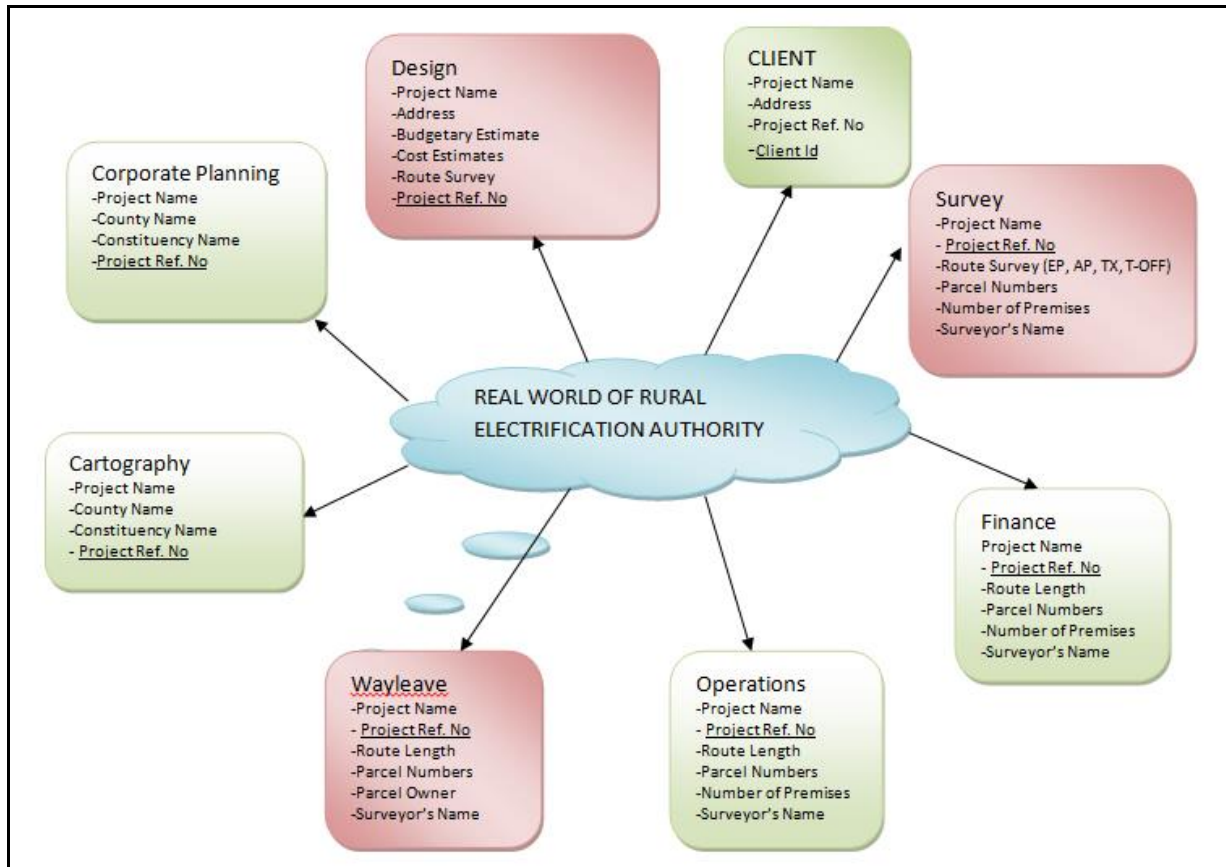
Fig. 3.10 Organizational functions

The Design Department is the custodian of survey records and therefore handles all the spatial information. It is considered the potential user of the geodatabase. To achieve the objective of the external model, the Design Department's needs for the spatial database was first analyzed, its information needs was identified and the necessary data acquired. The function of the department was determined and was found to entail the following (Table 3.6). The results were in a formal and detailed database requirements specification as shown in (Fig. 3.10) above.

Table 3. 6. An Analysis and Identification of data

User	Function	Information Needs/Data Required	Do the functions produce or use the data.	Type of work supported by the department.
Design	1. Carrying out Preliminary cost estimates of rural electrification prioritized projects 2. Identification of sites with H.V distribution lines for installation of transformers	1.Distance from the existing distribution line to the load 2.Position of H.V;TX; Switches ,Fuses; S/Station	Use Data	Preparation of schemes and project budgets
Survey	Engineering survey	1.Position of Angle Points 2.Topography details	Produce data	Provide spatial data
Design	Design, costing and production material schedules	1. Proposed Route Survey. 2.Pole scheduling	Use and Produce Data	Electrical Designs
Cartography	Production of working and as per built drawings		Reproduce data	Data Storage & Management
Wayleaves	1.Wayleaves acquisition 2. Damage assessment during Engineering Survey and Construction 3. Overseeing the compensation to damages	Parcel Boundaries Road	Use and produce data	

3.6.4 Conceptual Modeling

Conceptual modeling is the synthesis of all the external models into an E-R diagram showing all the entities involved their attributes and relationships. A correct conceptual model is necessary for an efficient database structure devoid of redundancy. This was achieved by identifying and describing the objects and specifying object relationships. The diagram below (Fig. 3.11) illustrates samples of entities that were identified and their relationships.

Fig. 3.11 Conceptual model (E-R Diagrams)

During the Identification of entities, the following entities were identified and used in designing the external model.

- Parcel
- Poles
- Angle Points (AP)
- High Tension Cable (HT)
- Low Voltage Cable (LV)
- Transformers (TX)
- Substation
- Fuse
- Switch

3.6.5 Logical Model

In order to implement the database design as defined by the system independent conceptual model, it was necessary to map in a system-specific model. Logical data modeling is the process by which the conceptual schema is consolidated, refined and concerted to a system-specific logical schema. The entities identified were used to form an object- relation database in ArcGIS 10.2. The relation name and its attributes were established as follows:

Poles [REA_No.. Project Name, Pole ID; Pole _ Type; Pole _Class; Pole _Height ; Treatment _Type ; Date _Manufactured; Inspection Date; Description]

Transformer [REA_No. Project Name, Transformer Number, Rating, Manufacturerí í .]

Fuse [REA_No. Project Name; Phase, Position, Rated, Voltage í í í í í í í í í í í í ..]

Substation [REA_No.. Project Name, Substation Number; Load connection; í í í í]

HT Line (Cable) [REA_No, Phase_ code, Conductor_ length, conductor_ neutral,í í í . ,_]

LV Line (Cable) [REA_No, Phase code, Conductor_ length, conductor_ neutral, construction í í í .,]

Angle Points [REA_No., AP No. Project Name, Description]

Parcels [REA_No., Project _Name, Parcel_ID; Owner; Owner _ID, Area, Description].

Proposed Route Survey [REA_No. Project Name, Length; Description]

The entities were organized into themes using ArcGIS 10.2.

3.6.6 Physical Modeling

Physical modeling is both hardware and software specific and dependent and requires consideration of how files will be structured for efficient access from the disc. It is prudent that the resulting physical model provides efficient physical data storage structures for the data.

To construct a data model, the ArcGIS electric distribution data model was used as a guide for determining the objects, attributes, and classes for the design. The objects in the logical data model were then matched to objects in a geodatabase. The geometry types of discrete features were determined and the relationships between features specified. The attribute types for objects were then implemented. The following schemas shown in (Table 3.5) below were used to represent the various relations:

Tables 3. 7 Relations in ArcGIS Distribution Model and Proposed Empty Schemas

Relation 1: Poles:-

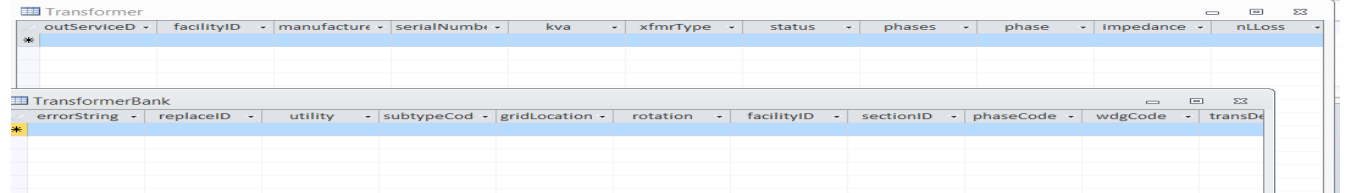| Pole ID	REA_No	Proj_ Name	Pole _ Type	Pole _Class	Pole _Height	Treatment _Type	Date _Manufactured	Description
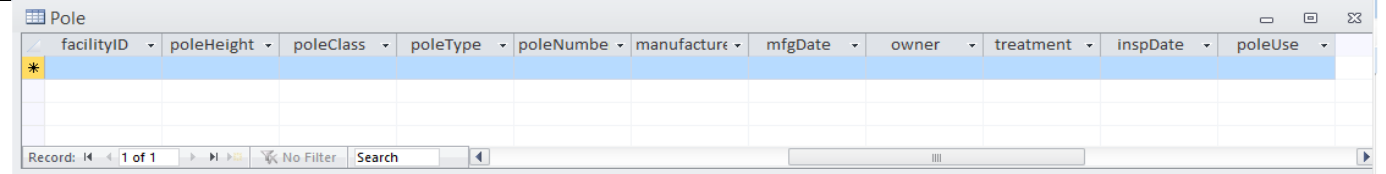
Relation 2: Transformer

Transf_ID	REA_No	Proj_ Name	Rating	Phasecode	Pole _Height	xfmr _Type	manufactured	Description

Relation 3: HT Cable, ,

Phase _code	REA_No,	Conductor_ length	conductor_ neutral

Relation 4: LV Cable

Phase _code	REA_No,	Conductor_ length	conductor_ neutral

Relation 6: Substation

Substation_Number	REA_No..	Project Name	Load connection					

3.6.6.1 Creation of Feature Datasets

In the newly created File Geodatabase (Fig.12), Feature datasets were created with all the features and tables, named and spatial references defined respectively. The feature datasets are organized in such a way that related feature classes into common dataset for building a topology, a network dataset.
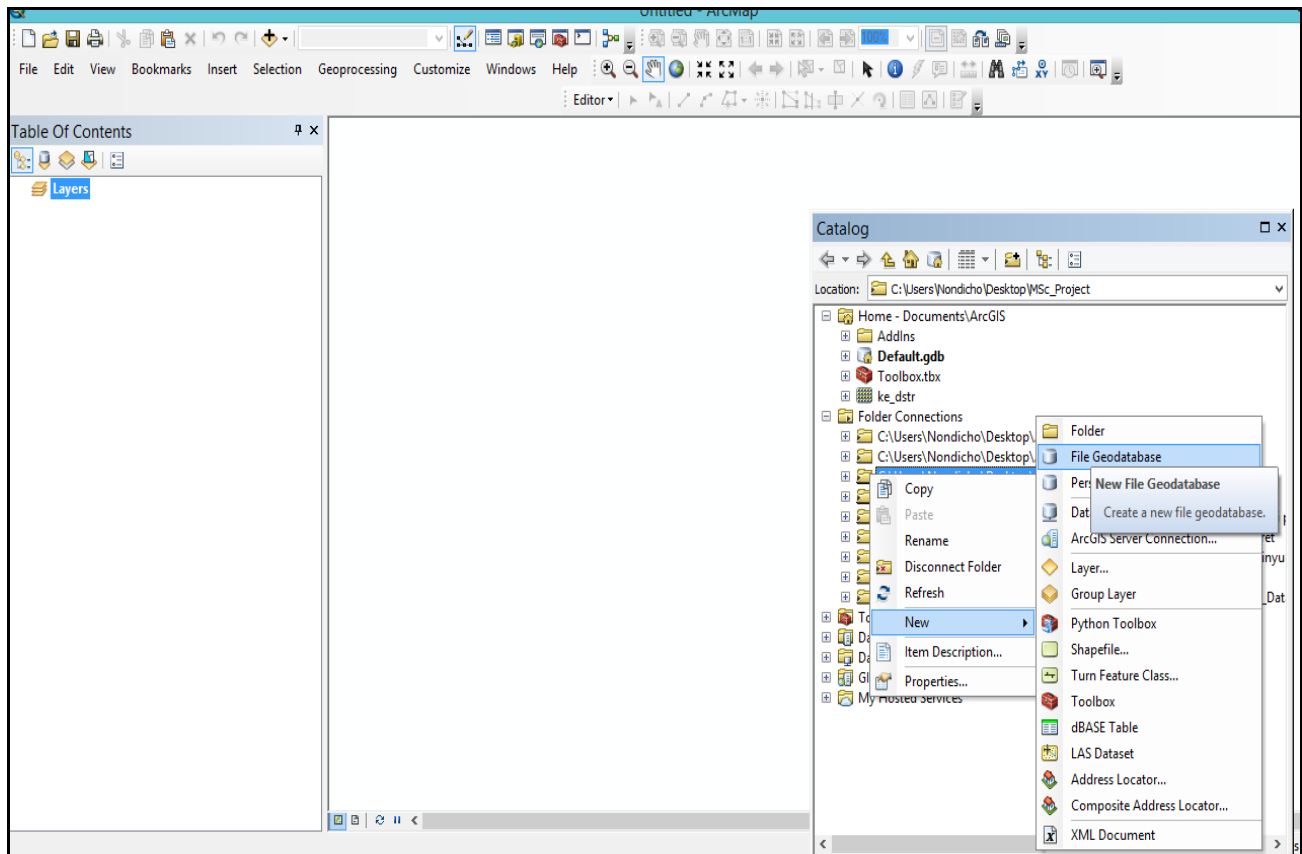

Fig. 3.12 Creating a File Geodatabase

3.6.6.2 Creation of Feature Classes

T-offs, transformers, premises, primary schools, parcels, roads, power line were built in the new feature dataset. Feature classes are homogeneous collections of common features, each having the same spatial representation, such as points, lines, or polygons and a common set of attribute columns for example, a line feature class for representing the road centerlines and a point feature class representing a transformer's position. The feature classes in the geodatabase are points, lines, and polygons.

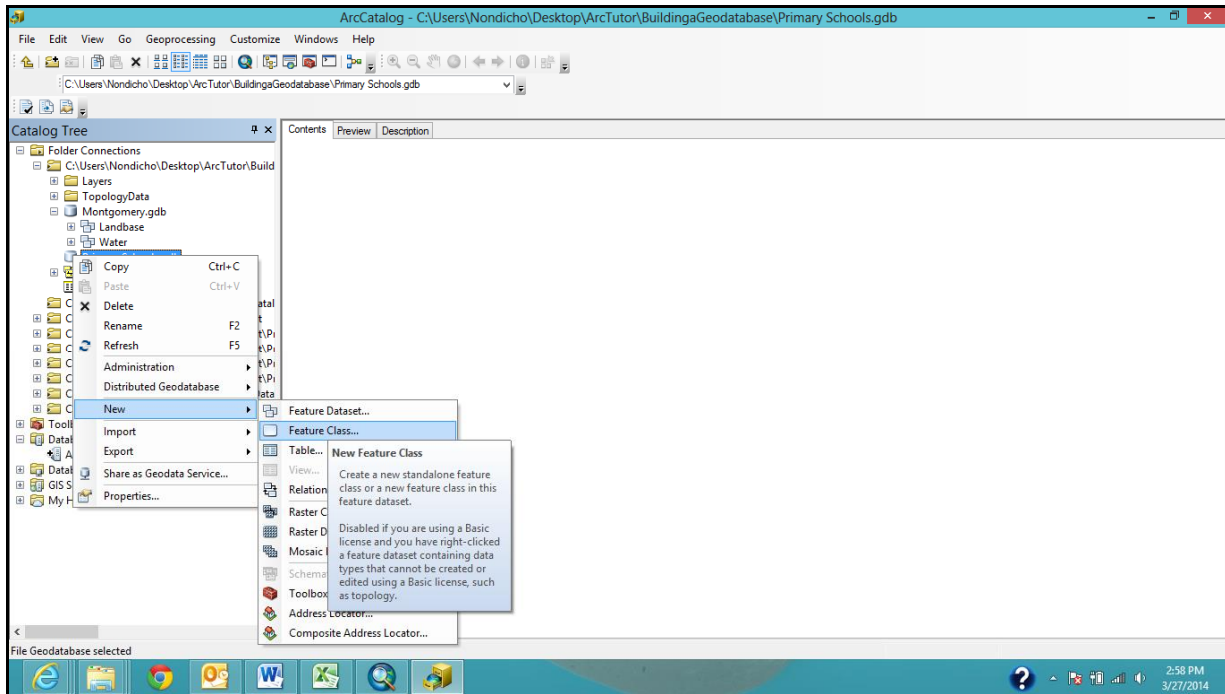**Fig. 3.13: Feature Class Creation**

Through ArcCatalog wizard window a Geodatabase is created and appears as a new node under a feature dataset. It inherits the coordinate system of the feature dataset in which it is created. Once a geodatabase has been created, its properties can viewed, add new attributes to its feature classes and tables, and associate other feature classes as shown (Fig.14).
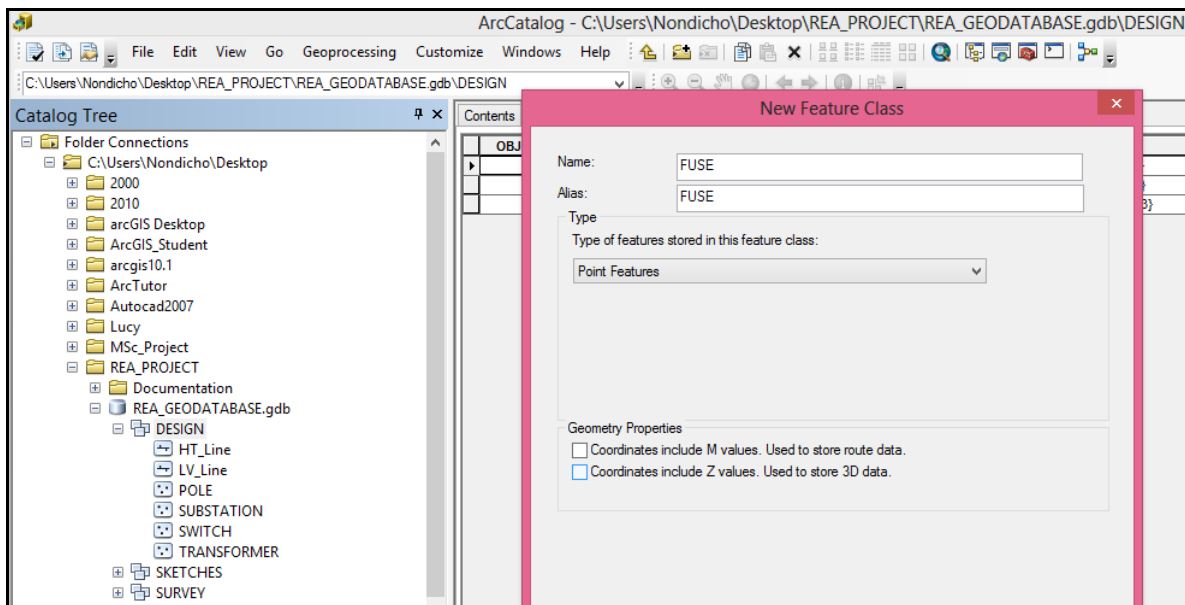
Fig. 3.14 Feature class creations.

3.6.6.3 The Electric Distribution Model

Each of these feature classes were further divided into subtypes. Subtypes are integer-valued attribute that are used within a feature class or a table to emulate a class hierarchy. Subtypes inherit all the properties of the feature class. Various validation rules (e.g. domains, relationship rules) was then be applied to individual sub-types. See Appendix B

The object technology at the core of ArcInfo combines data and application behavior modeling. As a result, the ArcGIS model not only includes an essential set of electric device, structure, circuit segment, and customer information feature classes and properties, but it also includes rules and relationships that define object behaviors. The core object technology and applied ArcGIS electric distribution model result in significantly less configuration and customization effort for overall implementation per site.

3.6.6.4 Importing schema

The steps involved in using an ArcGIS data model are very similar to importing and modifying any existing geodatabase design as shown in (Fig.3.15) below. The appropriate data model was downloaded from the Esri Support Center, then imported the schema and set up the appropriate spatial reference for its contents into the created empty test geodatabase as a file geodatabase.

Fig. 3.15 Importing the Schema

3.6.6.5 Populating the geodatabase

Some of the existing datasets was loaded into a new, empty geodatabase as shown in (Fig.3.15).

Fig. 3.16 Populating the geodatabase

The design was tested and refined as appropriate.

3.7 PILOT IMPLEMENTATION

This was necessary for evaluation of the database design, procedures and alternatives of the system.

3.7.1 Prototype geodatabase

A test of the prototype design was done by building a sample geodatabase of design using a file geodatabase.

- Maps were generated, key applications ran, and editing operations performed to test the design's utility.
- Based on the prototype test results, the design was revised and refined.
- With a working schema, a set of data was loaded to check out production, performance, scalability, and data management workflows.

3.8 FULL IMPLEMENTATION

This will involve the creation of special storage-related constructs to house end-user tables. Other issues for consideration will be; Performance, Security, Backup and recovery, Integrity, Company standards and Concurrency controls.

Testing and evaluation

It is of necessity that the geodatabase was tested and fine-tuned for performance, integrity, concurrent access, and security constraints. Fine-tuning was based on reference manuals to accomplish the modification of both the physical design and the logical design.Upgrade or change DBMS software or hardware is also necessary from time to time to cope with the dynamism the systems.

3.9 OPERATIONAL GEODATABASE

At this stage the Database is considered operational
System evaluation process may commence and the developer should be ready for unforeseen problems may surface.

Maintenance and evaluation
The following maintenance types will be vital:

- Preventative maintenance

- Corrective maintenance

- Adaptive maintenance

- Assignment of access permissions

- Generation of database access statistics to monitor performance

- Periodic security audits based on system-generated statistics

- Periodic system usage-summaries

4.0 RESULTS AND DISCUSSION

4.1 RESULTS

In Fig. 4.1, the resulting geodatabase was created showing the REA_Geodatabase with Feature classes and feature datasets in ArcCatalog.
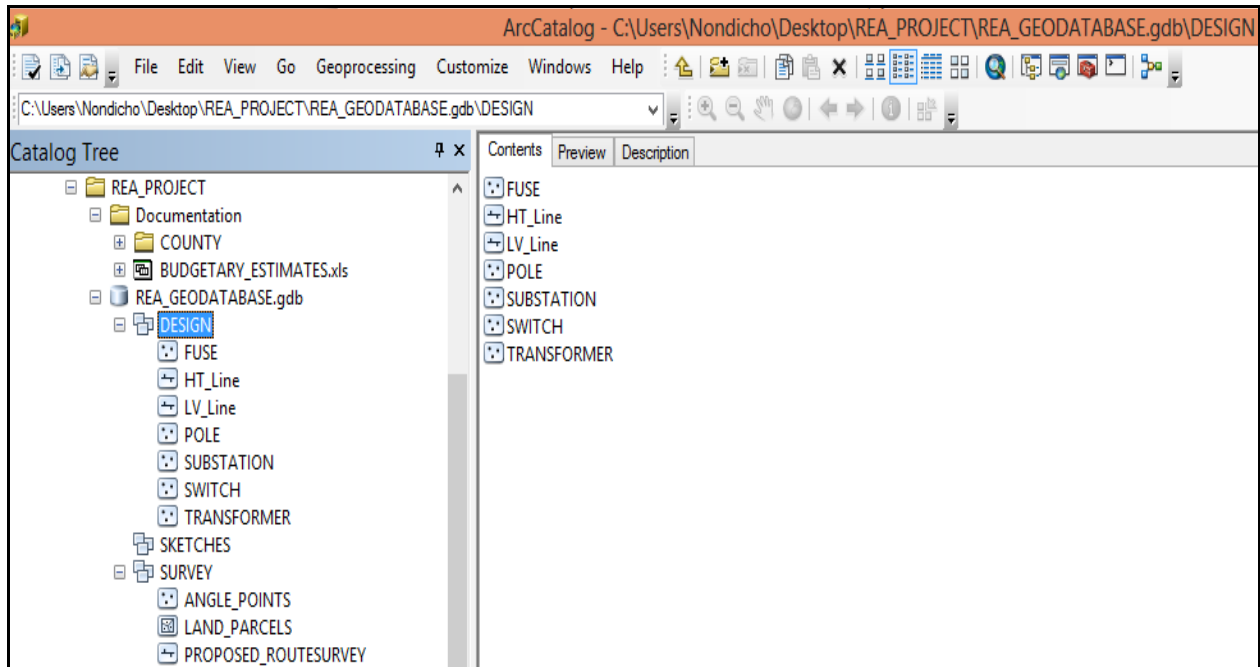

Fig. 4.1 REA_Geodatabase

The resulting Geodatabase that was obtained can be combined and map non-spatial data with spatial data in a meaningful way as shown in Fig. 4.2 below.
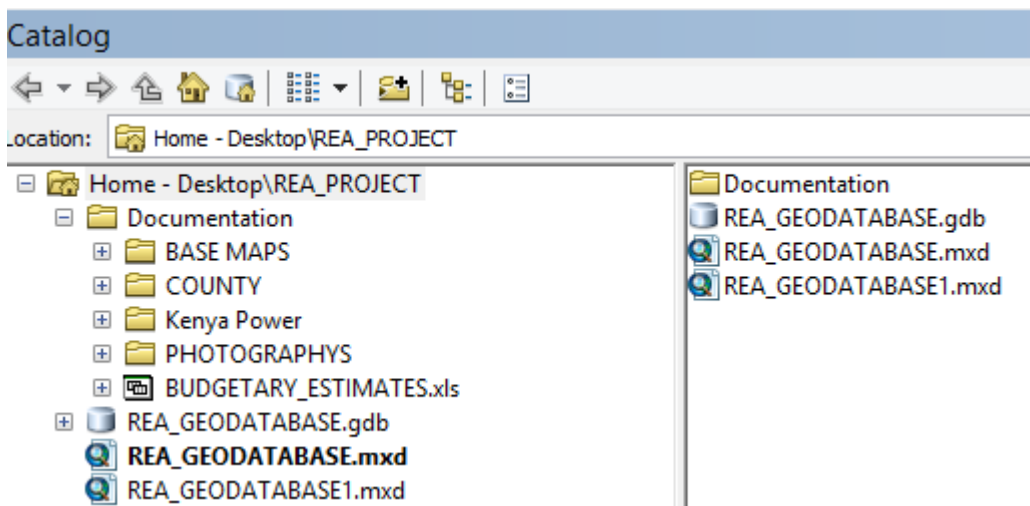
Fig. 4.2 Mapped non-spatial data

In Fig. 4.3, the base map (parcel and topographic maps) were overlaid with the electricity distribution network, hence revealed the spatial distributions and locations of electricity distribution facilities. The facilities on ground such as 11kv line, power transformer, distribution transformer, transmission station etc, were shown and the extents at which they occur were also revealed.

Overlay Operation

The essence of overlay operation is to superimpose two or more data layer that occupies the same location (Sun et al, 2001). The base map was superimposed with the electricity distribution network. The result of the overlay operation is shown in Fig. 4.3.
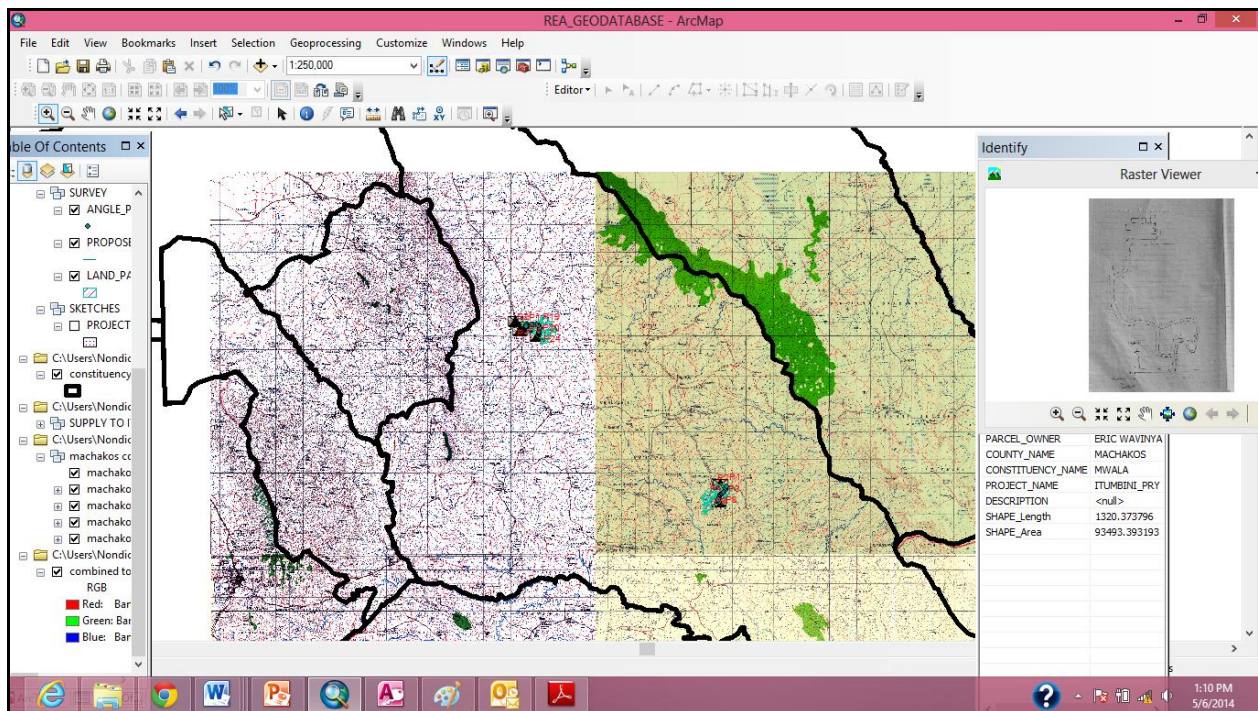
Fig. 4.3 Visualizing a Geodatabase

Spatial Query

A common goal when working with the geodatabase system tables is to find all the items related to a specific item. Examples of this include finding the contents of a feature dataset, finding which feature classes participate in a topology or a geometric network, and finding which datasets are included in a replica. Since all items and relationships are stored in the same tables, a single query can be used for all these cases. In Fig.4.4, the following steps can be used to

perform this query; using the select by feature tool. Spatial query was carried out to get all information about a given electricity distribution facility located in a given area.
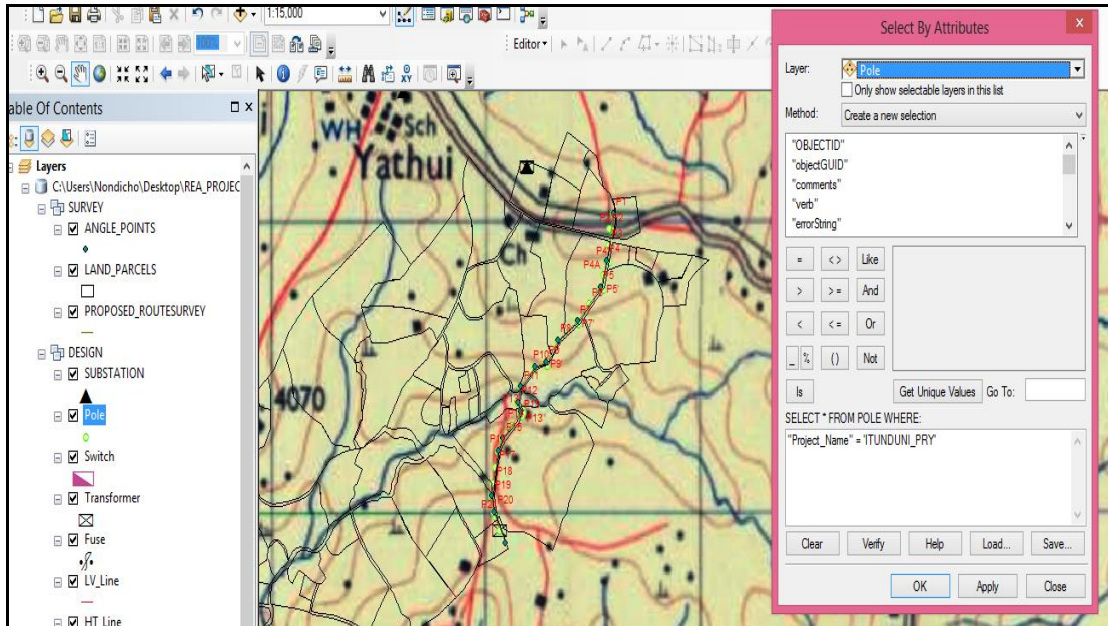
Fig. 4.4 Spatial Query

In this case, the system was queried to search and display all available information about the existing distribution transformer located or poles within "Itunduni Primary" area. The result was displayed as shown in (Fig.4.5) below

Fig. 4.5 Results of a spatial query

Aspatial Query

This task was carried out in order to know the location(s) of a given facility with a known attribute. For example, the location(s) of all the distribution transformers with capacity 15mva along a certain Road in Mwala could be known as provided by the system. The result is shown in Table 4.1 below.

Table 4.1 Attribute Table of the selected poles

Pole

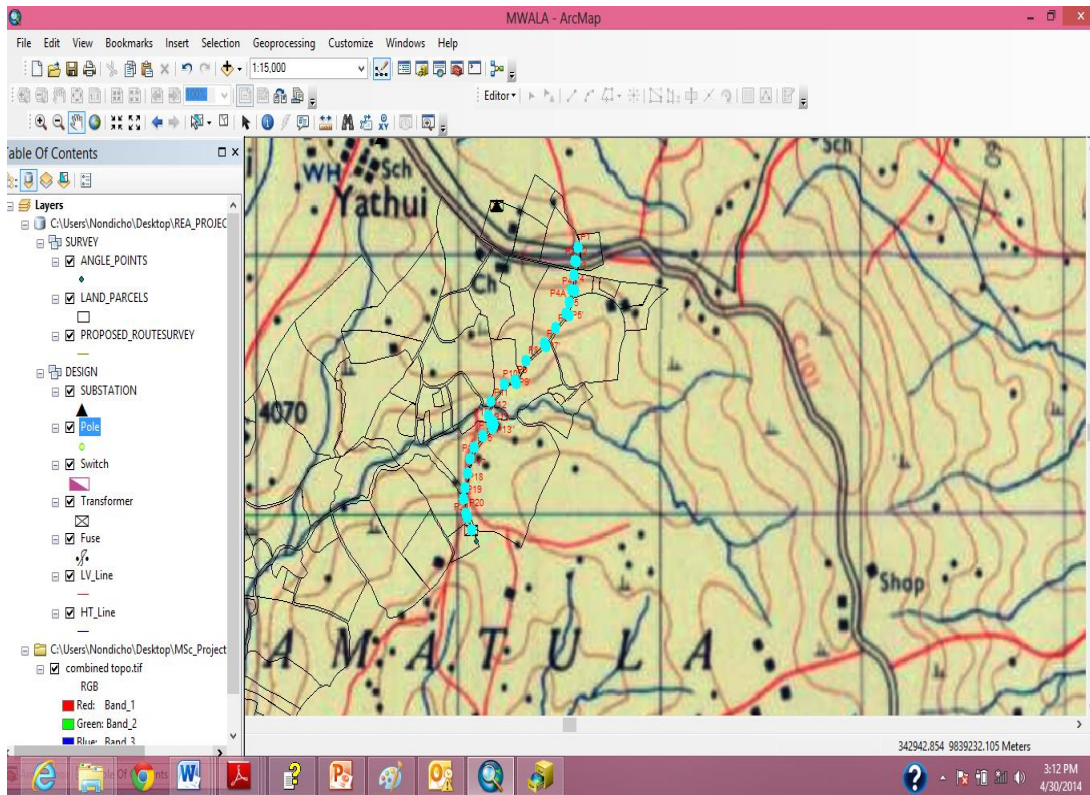| OBJECTID*	SHAPE*	REA_No	Project_Name	County_Name	Constituecy_Na	Pole Type	Pole Number	Pole Heigh	Description	Owner	Treatment Type	Ve
52	Point M	REA-07113/1406050	ITUNDUNI_PRY	MACHAKOS	MWALA	WOOD-TREATED	<Null>	<Null>	TP	REA	NATURAL	<Null>
53	Point M	REA-07113/1406050	ITUNDUNI_PRY	MACHAKOS	MWALA	WOOD-TREATED	P21	12	TP	REA	NATURAL	<Null>
54	Point M	REA-07113/1406050	ITUNDUNI_PRY	MACHAKOS	MWALA	WOOD-TREATED	P20	12	DXA	REA	NATURAL	<Null>
55	Point M	REA-07113/1406050	ITUNDUNI_PRY	MACHAKOS	MWALA	WOOD-TREATED	P19	14	VFA	REA	NATURAL	<Null>
56	Point M	REA-07113/1406050	ITUNDUNI_PRY	MACHAKOS	MWALA	WOOD-TREATED	P18	12	INT	REA	NATURAL	<Null>
57	Point M	REA-07113/1406050	ITUNDUNI_PRY	MACHAKOS	MWALA	WOOD-TREATED	P17	12	INT	REA	NATURAL	<Null>
58	Point M	REA-07113/1406050	ITUNDUNI_PRY	MACHAKOS	MWALA	WOOD-TREATED	P16	12	DXA	REA	NATURAL	<Null>
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60	Point M	REA-07113/1406050	ITUNDUNI_PRY	MACHAKOS	MWALA	WOOD-TREATED	P14	12	INT	REA	NATURAL	<Null>
61	Point M	REA-07113/1406050	ITUNDUNI_PRY	MACHAKOS	MWALA	WOOD-TREATED	P13	14	VS	REA	NATURAL	<Null>
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72	Point M	REA-07113/1406050	ITUNDUNI_PRY	MACHAKOS	MWALA	WOOD-TREATED	P7	12	DXA	REA	NATURAL	<Null>
73	Point M	REA-07113/1406050	ITUNDUNI_PRY	MACHAKOS	MWALA	WOOD-TREATED	P6	12	INT	REA	NATURAL	<Null>
74	Point M	REA-07113/1406050	ITUNDUNI_PRY	MACHAKOS	MWALA	WOOD-TREATED	P5'	14	VFA	REA	NATURAL	<Null>
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77	Point M	REA-07113/1406050	ITUNDUNI_PRY	MACHAKOS	MWALA	WOOD-TREATED	P4	12	DXA	REA	NATURAL	<Null>
78	Point M	REA-07113/1406050	ITUNDUNI_PRY	MACHAKOS	MWALA	WOOD-TREATED	P4'	12	DXA	REA	NATURAL	<Null>
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4.2 DISCUSSION

The spatial search operation for this project was carried out through query generation to retrieve information stored in the database pertaining to certain systematically defined attributes within the database to answer some spatially related questions. This operation involved the link between the database and the composite map of the project area. Queries were generated to provide answer to the application use of GIS in managing REA facilities and the results displayed in form of hardcopy map. This will provide users with a high-level, declarative query language with as its most important use the formulation of queries.

These results demonstrated some of the capabilities of GIS in handing and managing electricity distribution spatial data. With GIS, one can manipulate and carry out tasks that are vital in management of electricity for proper and efficient results. When new facilities are installed, the geodatabase and graphical (map) components can be updated easily to accommodate the new features. So, map revision and digital mapping become easy in GIS environment.
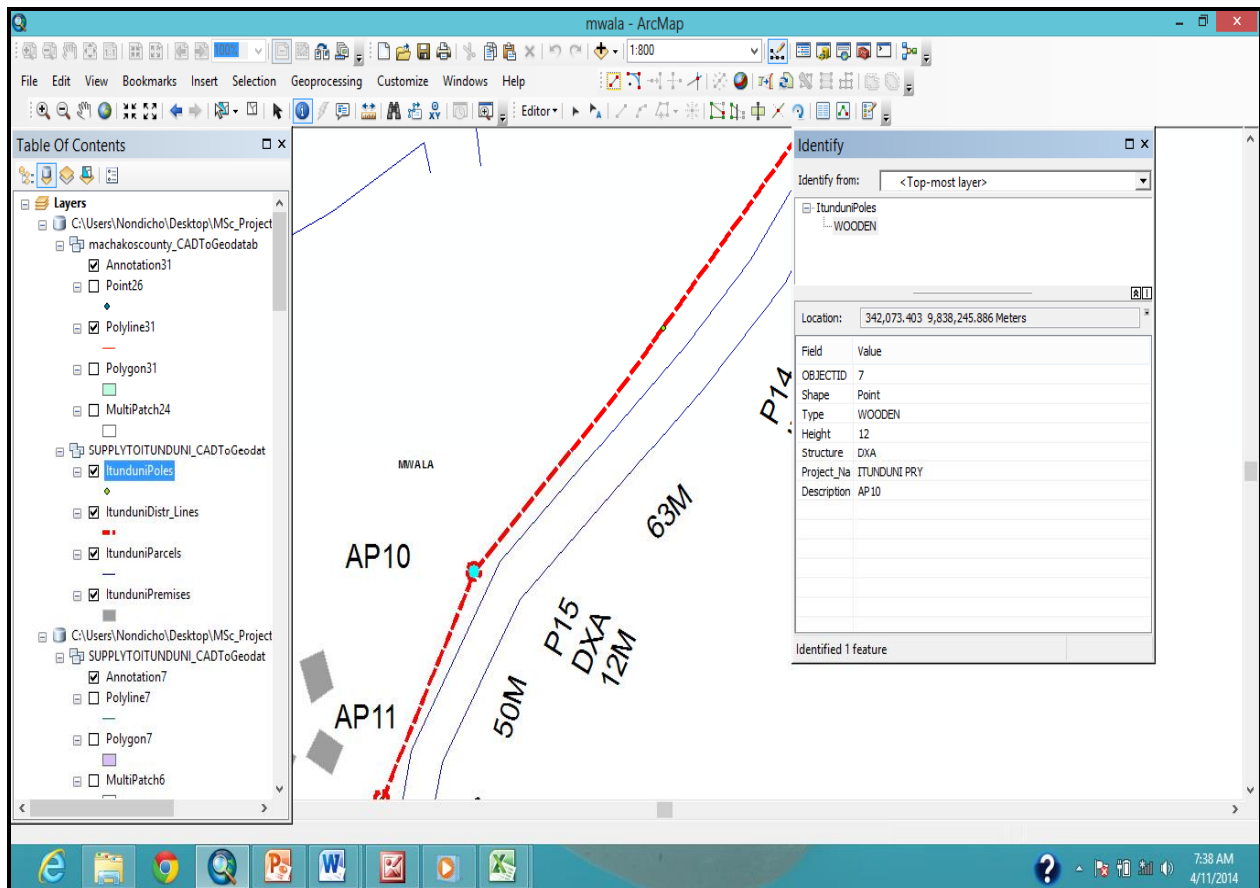
Fig. 4.6 Results of a spatial query

The result in Fig. 4.6, revealed the attributes of the pole in Itunduni. The identify results table displayed, shows descriptive information about the object. The pole a point feature class that describes a pole support structure; Double Cross Arm (DXA) whose height is 12m. In Fig. 4.5, the selected poles along Itunduni Primary Project were displayed in blue circles. Their associated records were highlighted in blue color on the attribute of Pole table.

- A summary of the large records in paper format or analogue records will be converted into Documentation of the work flow in design.
- Basemaps ̶ Photographs and any other records in databases in excel and access may be linked to the geodatabase.
- The database can also support the storage and manipulation of large datasets; the result may be to find simple tasks in minutes.

- A geodatabase can be instructed to guard for data correctness; for instance data entered into the database does not contain obvious errors.

- Support the use of a data model, a language with which one can define a database structure and manipulate the data stored in it.

- Include data backup and recovery functions, to ensure data availability at all times for safeguard against loss of data in case of calamities.

- Allow the control of data redundancy

5.0   CONCLUSIONS AND RECOMMENDATIONS

This chapter concludes the project based on the objectives outlined in chapter one ,the challenges and gives recommendations on way forward for future endeavors.

5.1   CONCLUSIONS

Object-relational database management approach can be used in the design of electric power distribution. The process entailed user needs assessment and data modelling.

The main entities and the relationships among them were identified where the attributes, the primary keys were identified for each of the entities. The entities were then designed into external, conceptual, logical and physical models. These were then used to facilitate the implementation of the geodatabase in ArcGIS environment.

The Integrated geodatabase with GIS enabled the spatial and non-spatial data to be successfully fused into ArcGIS. These made it possible for queries and GIS analysis to be carried out in order to test the database.

Hyper linking of photos for the various spatial features is also possible using the hyperlink tool. This was in line with the second objective which was to demonstrate how the geodatabase can be used.

The results from these queries indicate that electric power databases can be populated and maintained using GIS and the same can be accessed and used in decision support. If fully implemented, the object- relational database will benefit the organization in the following ways:

- Good transactional performance
- Complex data management
- Ease of management
- Rapid development
- Flexible query capability
- Standard data access interface
- Suitability for business intelligence applications

The concept can be replicated in other electrification bodies using similar approach and hence the objectives of this study have therefore been achieved.

Some of the data used for this project was arbitrary in order to safeguard confidentiality.

5.3 CHALLENGES

- Limited funding during collection of data

- Poor road infrastructure in project areas

- Sparsely populated country side

- Insufficient installed generation capacity

- Low income among targeted population

5.4   RECOMMENDATIONS

- This project employed the use object-relational database method integrated with GIS in ArcGIS environment to manage electric power distribution. However, other facility management software in the market, can be explored especially those that do not require specialized software skills.

- The project's scope on the geodatabase creation was on Design department only. This scope should be expanded to include all the users of electric power or integrated with other system such as the Kenya Power's Facility Database (FDB).

- Use of different access rights should be considered to realize the success of the implementation of this prototype.

- Electrical Design Engineers should be encouraged to design on softcopies of the plans they draw so as to accelerate the move from the analogue system.

- Measuring distances and Budgetary Estimates can be determined for proposed lines in the office instead of in the field by design technician will save the department a lot of time and money.

REFERENCES

Ali NASHWAN Mohamed AIT BELAID, and Sabah EL-JENAID TS02I (2011) - Spatial Information Applications II *"Designing a Spatial Database to Facilitate Road Maintenance Tasks"* FIG Working Week 2011 Bridging the Gap between Cultures .Marrakech, Morocco.

ArcGIS MultiSpeak® Data Model Data Dictionary (2010) Revised

Baroudi Bloor International Inc., (2003, 2004) õ The Failure of Relational Database, The Rise of Object Technology and the Need for the Hybrid Databaseö

Esin Bitik and Dursun Zafer eker (2013) õ*GIS Based Gas Utility Data Model for Turkey*öIstanbul Technical University, Istanbul Asian Journal of Geoinformatics, Vol.13, No.4.

Halfawy ,M.R.; Figueroa, R. (2006). õ *Developing Enterprise Gis-Based Data Repositories For Municipal Infrastructure Asset Management "*of a collaborative initiative between the National Research Council and the City of Regina. Joint International Conference on Computing and Decision Making in Civil and Building Engineering.

Håvard Tveite (1997) õ*Data Modelling and Database Requirements for Geographical Data* õ

Igbokwe, J. I. and Emengini, E. J. (2005)   õGIS in Management of Electricity Distribution Network: A case study of Onitsha-North L.G.A.,ö Department of Surveying and Geoinformatics Faculty of Environmental Sciences Nnamdi Azikiwe University, Awka, Anambra State, Nigeria.

ITC, 2010 *GI Science and Earth Observation: a process-based approach* ITC Educational textbook Series University Of Twente Faculty Of Geo-Information Science, Enschede, The Netherlands

Meyers J R, Daniels M J, Killpack C (1996) Costs and benefits: implementing an ARC/INFO-based AM/FM/GIS.*ESRI White Paper Series*. Redlands, ESRI chapter 57

National Energy Policy, Final Draft

Olaniyi Saheed Salawudeen and Usman Rashidat (2006)*"Electricity Distribution Engineering and GIS Shape the Change*ö TS 72 ó GIS Application ó Planning Issues 13/14 XXIII FIG Congress Munich Germany.

Riccardo de Filippi, João Palma, Yvonne Reisner, Felix Herzog Agroscope FAL Reckenholz (2004) *"Spatial database for GIS for scaling up (Deliverable 8.1) "www.reckenholz.*ch Swiss Federal Research Station for Agroecology and Agriculture Reckenholzstrasse 191CH-8046 Zurich, Switzerland .

Appendix A

KANGUNDO
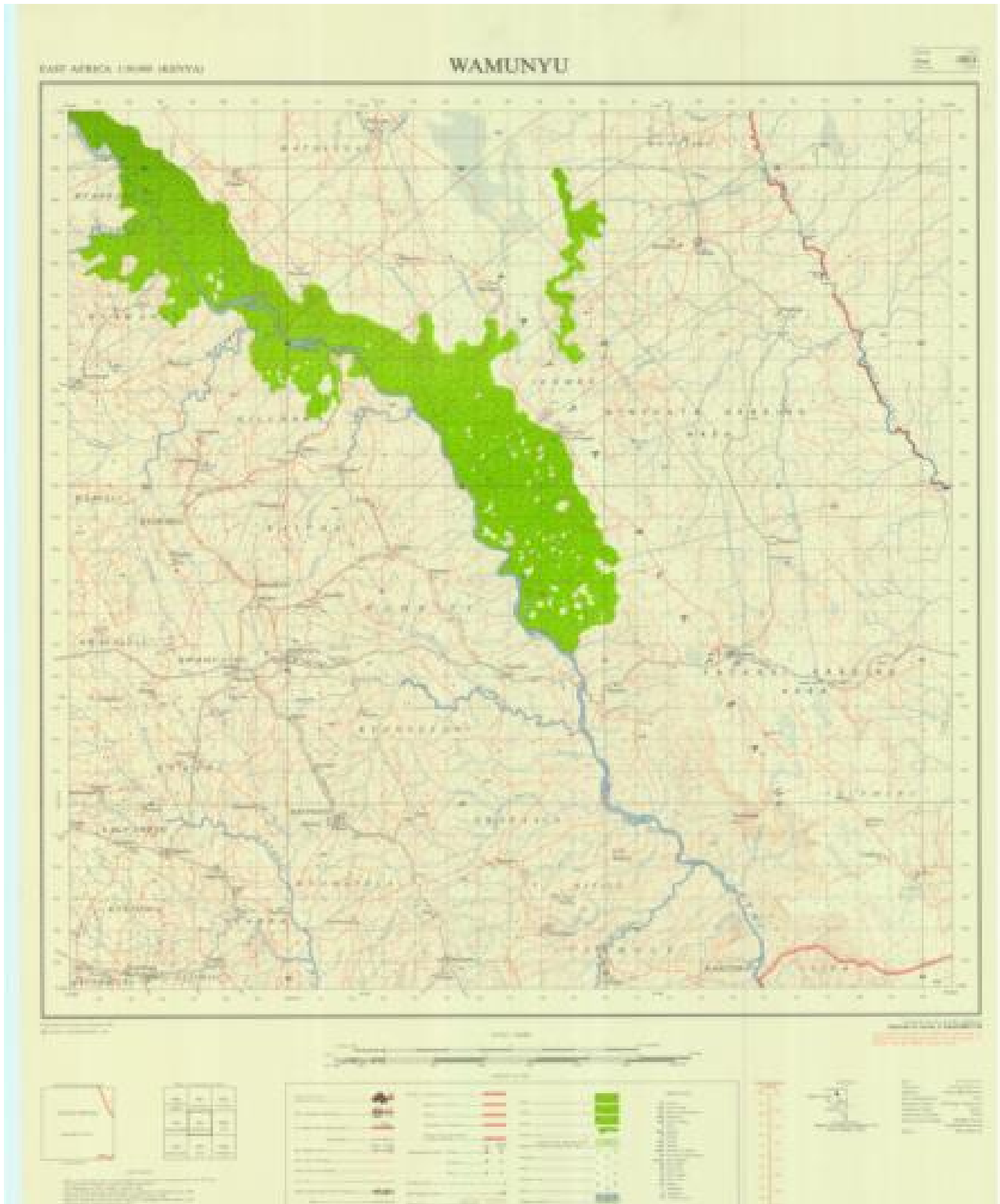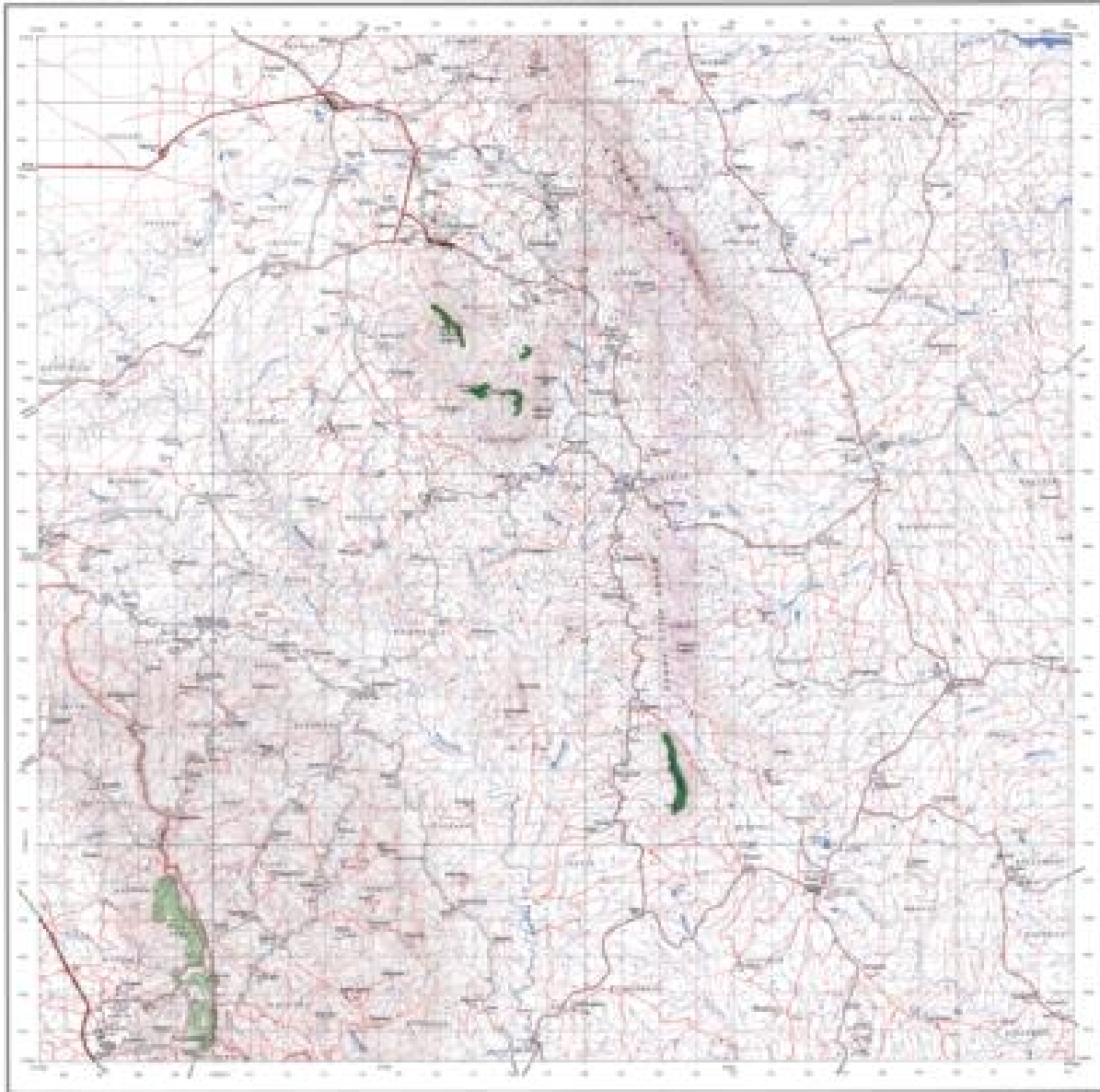
Appendix B

Tables show the feature classes and attributes in detail.

Substation

Substation is a point feature class that describes a substation location

Class Name	Substation
Type	Simple Junction Feature Class
Inherits From	*MElectricPointFeature*
Alias	Substation
Geometry	Not applicable
Attributes	**zMin** – *Minimum Source Impedance* - <text, 255> - Name of minimum source impedance. **zMax** – *Maximum Source Impedance* - <text, 255> - Name of maximum source impedance. **units** – *Impedance Units* - <text, 255> - Unit used to express impedances. Uses the *eDomainImpedanceUnits* domain. **busVolts** – *Bus Voltage Multiplier* - <double> - The bus voltage multiplier, expressed in per unit. **ohGndZ** – *Overhead Ground Impedance* - <double> - Ground impedance for a fault on an overhead section, expressed in ohms. **ugGndZ** – *Underground Ground Impedance* - <double> - Ground impedance for a fault on an underground section, expressed in ohms. **nomVolts** – *Nominal Voltage* - <double> - Nominal voltage for section. **ldAolloc** – *Load Connection Control Indicator* - <integer> - Whether the substation a load connection control point. Uses the *eDomainBooleanYesNo* domain. **ldCon** – *Load Connection* - <text, 255> - Load connection type. Uses the *eDomainConnectionTypeWyeDelta* domain. **isRegulated** – *Regulated Indicator* - <integer> - Whether the substation source is regulated. Uses the *eDomainBooleanYesNo* domain. **name** – *Substation Name* - <text, 255> - The name of the substation.
Subtypes	Not applicable
Relationships	
Notes	

Switch

Switch is an object class table that describes individual capacitor units. It is related to the *SwitchDeviceBank* feature class which provides the geographic location and participates in the geometric network.

Class Name	Switch
Type	Object class
Inherits From	*MElectricSwitchingDevice*
Alias	Switch
Geometry	Not applicable
Attributes	**switchDeviceBankID** – *Switch Device Bank ID* - <GUID> - The foreign key to the related SwitchDevice Bank feature.
Subtypes	Switch Unit (subtypeCode=1)
Relationships	SwitchDeviceBank
Notes	

Transformer

Transformer is an object class table that describes individual transformer units. It is related to the *TransformerBank* feature class which provides the geographic location and participates in the geometric network.

Class Name	Transformer
Type	Object Class
Inherits From	*MDeviceObject*
Alias	Transformer
Geometry	Not Applicable
Attributes	**manufacturer** – *Manufacturer* - <text, 255> - Transformer manufacturer. **serialNumber** – *Serial Number* – <text, 255> - Transformer serial number. **kva** – *kVA Rating* – <double> - Transformer size (in kVA). **xfmrType** – *Transformer Type* – <text, 255> - Transformer type code. **status** – *Status Code* – <text, 255> - Transformer status code. **phases** - *Phases* - <integer> - The number of transformer phases. **phase** – *Phase* - <text, 255> - The phase of the transformer. Uses the *eDomainSinglePhase* domain. **impedance** – *Impedance* - <double> - Transformer impedance. **nLLoss** - *No Load Loss* - <double> - No load loss value. **fLLoss** - *Full Load Loss* - <double> - Full load loss value. **price** – *Price* - <double> - Purchase price. **priVoltsLo** - *Primary Voltage-Low* - <double> - Transformer primary voltage (lower if dual rated). **priVoltsHi** - *Primary Voltage-High* - <double> - Transformer primary voltage (higher if dual rated). **secVoltsLo** - *Secondary Voltage-Low* - <double> - Transformer secondary voltage (lower if dual rated). **secVoltsHi** - *Secondary Voltage-High* - <double> - Transformer secondary voltage (higher if dual rated). **mfgDate** – *Date Manufactured* - <date> - Transformer manufacture date. **pcb** – PCB Code - <text, 255> - Transformer PCB code. **eaEquipment** – *EA Equipment*- <text, 255> - Description for the type of regulator in this section. **transformerBankID** – *Transformer Bank ID* - <GUID> - The foreign key to the related Transformer Bank feature.
Subtypes	Transformer Unit (subtypeCode=1)
Relationships	TransformerBank
Notes	

Fuse

Fuse is an object class table that describes individual fuse units. It is related to the *overcurrentDeviceBank* feature class which provides the geographic location and participates in the geometric network.

Class Name	Fuse
Type	Object class
Inherits From	*MElectricOvercurrentDevice*
Alias	Fuse
Geometry	Not applicable
Attributes	**linkRtg** - *Fuse Link Rating* - <double> - The current rating of the fuse link.
Subtypes	Not applicable
Relationships	overcurrentDeviceBank
Notes	

OHPrimaryLine

OHPrimaryLine is a concrete object class that describes overhead primary conductors.

Class Name	OHPrimaryLine
Type	Complex Edge Feature Class
Inherits From	*MElectricConductor*
Alias	OH Primary Line
Geometry	Polyline
Attributes	***All attributes are inherited.***
Subtypes	Single Phase (subtypeCode=1) Two Phase (subtypeCode=2) Three Phase (subtypeCode=3) Bus Bar (subtypeCode=4)
Relationships	Not applicable
Notes	

Pole

Pole is a point feature class that describes a pole support structure. It supports electrical network features, and it does not participate in the electrical geometric network.

Class Name	Pole
Type	Point feature class
Inherits From	*MPointFeature*
Alias	Pole
Geometry	Point
Attributes	**poleHeight** – *Pole Height* - <integer> - The pole height. **poleClass** – *Pole Class* - <text, 255> - The pole class. Uses the *eDomainPoleClass* domain. **poleType** – *Pole Type* - <text, 255> - The pole type. Uses the *eDomainPoleType* domain. **poleNumber** – *Pole Number* - <text, 255> - The pole number. **manufacturer** – *Manufacturer* - <text, 255> - The pole manufacturer. **mfgDate** – *Date Manufactured* - <date> - The pole manufacture date. **owner** – *Owner* - <text, 255> - The pole manufacture date. **treatment** – *Treatment Type* - <text, 255> - The pole treatment type. Uses the *eDomainPoleTreatmentType* domain. **inspDate** – *Inspection Date* - <date> - The date of last inspection. **poleUse** – *Pole Use* - <text, 255> - The pole use type. Uses the *eDomainPoleUseType* domain.
Subtypes	Not applicable
Relationships	Assembly JointUse
Notes	