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DEPARTMENT OF GEOSPATIAL AND SPACE TECHNOLOGY

OPEN SOURCE WEB BASED SPATIAL INFORMATION SYSTEM FOR MONITORING AND EVALUATING OF DEVELOPMENT PROJECTS

Case Study: North Maragoli Ward, Vihiga County, Kenya

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F56/87608/2016

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Research Study submitted for the Degree of Master of Science in Geographic Information System, in the Department of Geospatial and Space Technology

July, 2018

This research is submitted with our approval as University supervisor:

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July, 2018

Declaration

I, **Lusala Logedi Victor**, hereby declare that this project study is my original work. To the best of my knowledge, the work presented here has not been presented for a project study in any other university.

LUSALA LOGEDI VICTOR	……	……
Name of student	**Signature**	**Date**

This project has been submitted for review with our approval as university supervisor.

MR. OKUMU BENSON	……	……
Name of supervisor	**Signature**	**Date**

Dedication.

To my sons Kyle and Dylan

Acknowledgement

My sincere special thanks goes to my supervisor Mr. Okumu Benson of the Department of Geospatial and Space Technology in the School of Engineering for his dedicated support and guidance throughout the project. In addition, special thanks to my colleague Dennis Wekesa for his unmatched assistance in programming and scripting.

Special thanks is also accorded to Mr. Morgan Asena, Director ICT –Vihiga County for his guidance in Data collection.

Special thanks goes to my Dad, who was my primary field guide in data collection as well my entire family for keeping me in prayers and constant support.

And above all, for life, good health and wisdom throughout the entire course, To God be the Glory.

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Acronyms

CIDP …… County Integrated Development Plan

GIS……. Geographic Information System

GUI……..... Graphic User Interface

HTML…… Hypertext Markup Language

M&E…… Monitoring and Evaluation

QGIS…… Quantum GIS

SIMS……. Spatial Information Management System

SIS……. Spatial Information System

VGI……. Volunteered Geographic Information

WFS……...Web Feature Service

WMS……. Web Map Service

ABSTRACT

Web based Geographic Information System has added a new dimension on how spatial information is shared, displayed, processed and disseminated in an easy and quick way which in turn assists different decision makers and stakeholders interested in spatial related development projects. On the other hand, the use of Open Source Geographic Information System (GIS) software presents a cost-effective means of implementing, operating and maintaining spatial information over the web with the similar capabilities and features of commercial GIS software. The County Government of Vihiga has embarked on a governance transformation aimed at having development activities (from design, planning, implementation to monitoring and evaluation) undertaken on a GIS platform. Until recently, no effort had been made to spatially make available, on a web platform, development projects to different stakeholders to enable monitoring and evaluation. As part of ensuring different users are able to appreciate the appropriateness of GIS in enhancing Monitoring and evaluation of projects, there is need to develop a user-friendly system for thin clients[1] to enable them be part of the daily running of County Government projects as well as ensure accountability by the relevant departments. The main objective of this study is to develop an Open Source Web-based Spatial Information System aimed at providing collection, storage and dissemination of development projects to enable monitoring and evaluation. The methodology adopted in developing the system included User needs assessment and data collection of development projects from the County Government of Vihiga, data analysis and development of a database management system using QGIS and PostgreSQL /PostGIS as the Spatial Database Management System, System used GeoServer as the Map Server, publishing of digital layers as dynamic maps using Open Layers, OpenStreetMap and Google earth and development of an interactive Graphic User Interface framework which is interactive and can perform queries using Node.js. This GUI integrated all the components of the Spatial Information System in one platform easily accessed on a web browser. Scripts and codes were generated using the freely available Javascript Libraries (Open Layers and Node.js). The installation of these libraries involved a HTML (North_Maragoli.html) document which was a reference to library location in the server system hosted locally. The resultant OpenStreetMap can be embedded into the county website for visualization and thin client spatial analysis. The results of the study was a n working Spatial Information System with capabilities spatial analysis and querying of projects. This system is envisioned to assist the county governments with similar projects in enhancing monitoring and evaluation as well as promote transparency and accountability as they seeks to improve service delivery at the county level. The system has the potential to be scaled up to the World Wide Web level. The availability of this system on the World Wide Web is envisioned

[1] A thin client is a user who only visualizes information on the client side and depends on the web map server side to perform all spatial analysis that he has requested

encourage multi-stakeholder interaction aimed at facilitating data exchange, stakeholder participation in monitoring and evaluation of projects and improve decision making

CHAPTER 1: INTRODUCTION

1.1 Background

We live in a society where information is created, distributed, integrated, used and manipulated for the enhancement of economic, political and cultural activities. In order to realise the full potential in any information-based society, it's a requirement that technologies, infrastructures, applications and services be accessible and usable by anyone, anywhere, anytime, whether it be for business or individual use (Botterman, 2003). The use of the Internet as a distributed computing environment has made it possible for spatial data visualization in a faster way that enables quicker interpretation of geographical phenomena that is viewed as complex and identification of spatial patterns within a geographical location (Green, 2010). Specifically, Web Map Service (WMS) and Web Feature Service has made it much easier to publish, visualize, and exchange any geospatial data over the Internet (Mount *et al*, 2009). The integration of data with spatial information allows for more complex data processing, analysis, and modelling. Layered information, displayed as maps, can assist in the understanding of complicated strategic, spatial, and informational relationships (Ginter, 2013). Web based Mapping, in the context of development projects, allows for visual assessment of the spatial distribution of development projects by different stakeholders (Evans and Sabel 2012). The widespread adoption of GIS technologies and the strong advancements in computer science has led the user experience to be strongly enriched. Through a user-centric spatial exploratory paradigm, user is able to interactively investigate spatial data and their relationship with an aim of building new knowledge (Borruso, 2010). This study therefore seeks to explore web-based mapping as an extended GIS tool that can provide an interactive spatial information system that enables multi user collaboration and data sharing of development projects taking place in Vihiga County from any location with internet connectivity.

1.2 Problem Statement

Until recently, no effort has been made to spatially make available, on a web platform, development projects to different stakeholders in Vihiga County. On documents such as the County Integrated Development Plan (CIDP), hundreds of projects ranging from bridges, roads, building of health and learning institutions, market construction among others are taking place at different locations within the county, some planned, others ongoing while others are complete. This has made monitoring and evaluation of the projects a challenge due to a number of reasons. Firstly, the spatial data for these development projects is not well maintained in a central database that can enable easy retrieval and dissemination to different users. Secondly, there lacks any georeferenced static maps publicly available for these projects that can enable one to easily perform spatial analysis. Thirdly, information describing these projects such

as texts that are available and documented have not been linked to the spatial location of these projects (if any has been digitized). With the mentioned problems, there lacks a central system where the primary stakeholder, Vihiga residents, can not only visualize and track progress but also interact with these projects to perform oversight role of monitoring and evaluation yet they are the beneficiaries. Potential investors have also been locked out from viewing investment opportunities available and prioritised by the projects being embarked by the county. This has led to lack of accountability and transparency as often witnessed by introduction of 'ghost projects' which are available on paper but not reflected on the ground. To address these challenges, the County Government of Vihiga has embarked on a transformation program that will ensure all the activities are on a GIS platform (Business Daily, 2018). This means that the county appreciates the power of GIS as a decision-making tool for Governance in addition to the requirement by the County Government Act No 17 of 2012 which requires preparation of County Spatial Plans be anchored on a GIS platform. Therefore, to enable provision of information and GIS enabled tools that can enhance transparency, accountability and assist in decision making by the county government, there is need to address how available data on projects is collected and integrated into a well-designed spatial database that can be accessed through an appropriate web platform that will facilitate thin clients to perform spatial analysis. In summary, this study aimed at addressing the following questions:

- How can a web-based spatial information system for county development projects that offers an integrated information retrieval for monitoring and evaluation be developed?
- How can non-spatial data about the projects be incorporated into a centralized spatial database in a structured way?
- How can a thin-client spatial analysis tools be developed and integrated into the system?

1.3 Objectives

The overall objective of the study was to develop a web based spatial information system for monitoring and evaluation of development projects using open source software.

The specific objectives included:

i. To identify development projects and their integration into the GIS platform.
ii. To create a centralized database that contains spatial and non-spatial data of development projects in North Maragoli Ward, Vihiga County.
iii. To generate digital layers that connect to the centralized database for spatial information management for monitoring and evaluation.
iv. To publish digital layers on a web platform with capabilities of Thin Client spatial analysis.

1.4 Justification for the Study

Kenya has an estimated 51.1 million internet users as at September 2017 and this numbers are continuing to soar (CIO East Africa, 2018). This signifies the demand for information disseminated through the internet. Coupled with the Freedom to Information and the constitutional requirement for public participations at all levels of government projects (Nizam *et al*, 2015). County Government of Vihiga has a mandate to explore digital means by which information can be shared among different stakeholders. A web based spatial information system will present a conducive environment through which stakeholders can interact with the county through actual visualization of development projects that are spatial in nature. This will not only fulfil the requirements of the law but also build on project ownership by residents, enhance transparency and accountability, support decision making as well as attract investments. It is envisioned that this web based spatial information system is successful and can be replicated to cover the entire county to an extent be used by other counties keen on reaping the benefits that come with it.

Essentially, there is a very visible gap that is in existence in terms of information sharing between the county government and the residents/stakeholders that requires an integrated environment to eliminate. The spatial information system has capitalized on the wide coverage and increasing use of internet across the county and Kenya at large to enable quick and efficient dissemination of data in an effort to fill the existing information gap as well as provide users with an interactive web based visual platform.

1.5 Scope of work

This study covered North Maragoli Ward of Vihiga County. The output is an interactive web-based platform which showcases the need and benefits of a spatial information system and provides a basis for rolling out the system to cover the entire county. This study used open source applications to develop the system due to resource limitations and a relatively small geographical area that enabled collection of data due to time limitations.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

The Constitution of Kenya 2010 created 47 independent county governments under the devolved system of governance. These governments were meant to bring services closer to the people, spur growth and development thereby addressing inequity that has existed since Kenya got its independence. The functions that were devolved by the central government to the county government include Agriculture, Health Services, Transport, Trade and Development, County Planning and Development among others. To manage these functions, a county government is required to develop County Integrated Development Plan (CIDP) whose product is the County Spatial Plan anchored under a GIS platform. Essentially, GIS is an integral tool for planning at county level. Therefore, exploring the capabilities of GIS using information and communication technology is important in enhancing management of county activities. In appreciating the use of GIS as a tool for M&E, this section outlines the different components in and information System, elements of M&E, GIS and its role in M&E, a successful case study of GIS application in M&E, Web GIS and Spatial Information Management Systems and its relevance in this study, open source software this study adopted and appreciating the efforts made by the county government in application of GIS.

2.2 Information Systems

A system consists of a set of elements or components that work together to perform one or more functions which are meant to accomplish a set of objectives. These Components are generally people, hardware and software (Bhise, 2013). An information system primarily deals with manipulation of data. It receives data from a defined source, processes the data according to instructions given by a user and ultimately, produces a desired output which is used for decision making. For information system to work, they require database which offer a long-term memory and contains entities and relationships (Mannino, 2001). The other important component of an information system which include people, procedures, input and output data, Software and hardware work collectively to achieve the intended objective.

2.3 Monitoring and Evaluation

This is considered as a powerful management tool whose application can be used to improve the way organizations undertaking projects achieve results. It essentially serves as a dialogue between stakeholders on matters development whose end result is to offer feedback of how a project has performed in meeting its objective (Goergens and Kusek, 2010). Monitoring involves collecting data for the purpose of measuring the progress of a project vis-a-vis the objectives. As a task, it's periodically recurring in nature from when the project begins in the planning phase until completion with the aim of improving project design. Therefore, monitoring allows for

the documentation of results, processes and experiences that provides stakeholders with early indicators of progress or lack thereof in achieving project objectives which is used for decision making. The data collected from monitoring process is applied and used for evaluation (Gudda, 2011).

Evaluation on the other hand uses data collected from monitoring process to systematically and objectively measure how well a specific intervention has met expected objectives and/or the extent to which changes in results can be attributed to the intervention (Berhanu Gebremedhin., Getachew and Amha, 2010).

Kusek and Rist, 2004 have identified and described a step-by-step approach in monitoring and evaluation that a number of developing countries have used in designing and constructing M&E systems. These steps include:

Step One: *Conducting a Readiness Assessment*
Step Two: *Agreeing on Outcomes to Monitor and Evaluate*
Step Three: *Developing Key Indicators to Monitor Outcomes*
Step Four: *Gathering Baseline Data on Indicators*.
Step Five: *Planning for Improvements—Setting Realistic Targets*
Step Six: *Monitoring for Results*
Step Seven: *Evaluative Information to Support Decision-making*
Step Eight: *Analyzing and Reporting Findings*
Step Nine: *Using the Findings*
Step Ten: *Sustaining the M&E System within the Organization*

It's at Step Eight that GIS comes in as a powerful tool that can transform how findings are represented through visual representations such as maps. The use of maps to represent M&E findings in any project provides a clear communication to various stakeholders of diverse backgrounds. This study therefore explored how GIS can be integrated into and support M&E using the internet as a communication medium for dissemination and processing of spatial information for development projects in Vihiga County.

2.4 Geographic Information System

Geographic Information System (GIS) is a tool for working on and managing geographic information. Developed in the 1970s, it has grown to be used widely for different purposes mainly due to its technical and processing capabilities. Geographical Information Systems (GIS) are people, Hardware and software tools that facilitate the transformation of raw geographic data into useful information (Burrough, McDonnell and Lloyd, 2015). The continuous evolution of technology has led to geodata, map processing and map outs being shared by different users in different locations. The internet which is an interconnection of thousands of telecommunication networks has become and enabling technology in GIS data access, processing and dissemination of not only

geographic information but also knowledge. It is this connectivity technology that has led to the evolution of centralized GIS systems to distributed GIS systems which web GIS runs on.

2.5 Use of GIS in Monitoring and Evaluation

The use of maps in Monitoring and Evaluation (M&E) dates back to 1854 where a Doctor by the name of John Snow who represented cholera outbreak in London using points on a map to represent locations where deaths occurred. This led him to identify the source of the disease as a contaminated water pump through analysis of the distribution of these points. As an intervention, he removed the handle and was able to contain the further spread on the disease. (Johnson, 2008). This approach clearly demonstrates how spatial analysis was used long before technology and GIS came into being to monitor an epidemic and inform a decision.

With the increasing application of GIS in the field of monitoring and evaluation of projects has led to many benefits such as savings on project running costs, enhanced communication between different stakeholders, improved record management of projects and most importantly better decision making. The fundamental difference between M&E and GIS is that whereas M&E is temporally focused where changes and outcomes that occur over time are measured while GIS is spatially oriented to identifying where the outcomes are occurring in space (Catherman, 2013). This study therefore merged GIS and M&E into one tool that uses the internet to not only display useful project information but also support additional spatial analysis capabilities that will result to successful monitoring and evaluation of a project.

2.6 Case Study: GIS and HIV: Linking HIV Databases in Rwanda

According to a report by MEASURE Evaluation 2014, Rwanda was regarded as one of the pioneers in using evidence in developing highly effective and cost-friendly strategies for HIV Programmes. A comprehensive strategy for performing monitoring and evaluation activities that are directed to preventing, detecting and treating HIV/AIDs has been clearly outlined in the National Strategy Plan for HIV (2009-2012). However, in 2011 a new important tool was added to the M&E strategy: Geographic Information System (GIS). Through GIS, greater utilization of data was achieved through linking of geographic mapping with data from different sources. This linkage was done at multiple levels. Through GIS-based HIV monitoring, it became possible to enhance by far the value of data gathered. The use of computer processing and spatial software capabilities enabled value addition to raw data for traditional M&E. GIS-based monitoring therefore enhanced monitoring in health care, including HIV health care programs and in addition improved monitoring in data-poor environments by making greater use of the limited available data, as well as making that data more accessible. (MEASURE Evaluation, USAID, PEPFAR, 2014).

2.6.1 GIS and Data Integration for M&E

GIS manages data using a geographic (spatial) context whereby the geographic element enables the linkage of data sets as well as perform analysis. Computer-based GIS have become invaluable research tools for epidemiologists and public health programs in higher-income nations however with the recent changes in the availability of GIS resources (software, human resources, and data) has widened the application of GIS in a wide range of environments. The low cost of GIS software (including availability of open source software) and increased availability of data has made it much easier for GIS to bring data into M&E interventions within a variety of contexts. The application of GIS in tracking health Data has one key advantage; the complete use of the full power of computers. GIS has provided alternative to user of paper where information was mainly on paper format and individuals could consume and interpret not much of the information. On the other hand, GIS has provided individuals with greater data processing capabilities through use of computers and visual inputs such as maps and satellite imagery.

It's also important to note the capacity of GIs to link and integrate data from multiple sources and across multiple levels (from the local communities to government). This character of GIS has facilitated a deeper understanding of issues at the local level and has informed decision making at the national level. Integrating data from multiple sources (e.g. some 490 facilities in Rwanda) enabled sophisticated spatial analysis to be undertaken without dependence on multiple charts and tables. This in turn revealed underlying patterns displayed on a map that otherwise charts or graphs could not show. Through analysis, GIS-based M&E was able to use all data, including raw data from different sources, to provide deeper understandings to how programs run. On the contrary, without GIS, the insights would otherwise be concealed within the data or would be too time-consuming to generate. (MEASURE Evaluation, USAID, PEPFAR, 2014).

2.6.2 Integration of GIS in M&E of HIV

In 2010, MEASURE Evaluation came up with a proposal of linking and integrating HIV data using a GIS platform. Envisioned as a six-month, small-scale mentorship project, the intervention initially had a few participants tasked to advance two teaching goals: the technical skills of linking data via geography; and the ability to use GIS data for evaluating and making decisions on HIV programs (MEASURE Evaluation, USAID, PEPFAR, 2014). The key objective of the proposal was to show how the GIS approach builds on, and can be integrated into, existing activities in the HIV program. In the long run, GIS was integrated to the broad HIV program and fully became a tool to analyse and display data and after the end of MEASURE project, in 2014, Rwandan health agencies responsible for HIV programming adopted GIS as a tool for monitoring HIV activities and used it to enhance data collection and analysis on HIV.

2.7 Web GIS

To realise Web GIS, access to and sharing of geospatial data plays an important role. The element of online data access has enabled GIS users to with standalone GIS software to access and share data over the internet. However, the growing need to view and analyse data over the internet has facilitated the development of Web GIS as a system for online GIS processing where GIS users can access and operate different GIS applications (Peng and Tsou, 2003) from any location supporting web browsers (Geospatial World, 2018). Therefore, Web GIS is a type of distributed geographic information system whose components include a GIS server and a client (web browser, desktop/mobile application) using web technology to communicate between the server and the client (Enterprise.arcgis.com, 2018). The functionality of a Web GIS is dependent on 5 essential elements: a web application, digital base maps, operational layers, tasks and tools, Geodatabase. These five elements are enabled in a three-tier system architecture consisting of presentation, business logic and data tiers which offers a strict system functionality (Kwon, Bouju and Claramunt, 2005).

2.8 Spatial Information Systems (SIS)

Spatial information systems (SIS) is a representation of a wide variety of concepts, techniques, and technologies that are associated with capturing, managing, displaying and analysing spatial information. SIS greatly involves the integration of technologies such as geographic information systems (GIS), the internet and relational database management systems (RDBMS). This integration enables spatial information system to create a linkage between numerous databases therefore making it possible to visualise and view data in a spatial context. It is therefore possible to integrate previously external databases that was used within an organization to the SIS in order to allow generation of an additional layer of information that enables one to perform spatial analysis that was previously impossible. The stored data in the SIS can also enable production of maps that are critical in decision making and better visualization of spatial relationships. in order for the spatial information system to work, it's important to appreciate its ability to relate different layers of information in a defined spatial context and be able to reach conclusions about the spatial relationships.

2.9 Relevance of Spatial Information System

Spatial Information Systems allows storage of same referenced layered information (maps and other data) making it possible to perform complex spatial analysis by using location and arrangement of object as a feature (Hilton, 2007). The information retrieval capabilities allow a user to locate an object or area and retrieve the attribute information related to the object from a database. Using visual guides such as aerial/satellite imagery, cadastre it is possible to perform a query within the SIS and get relevant information about a particular project that is spatial in nature. For thick clients within a Web GIS, SIS offers topological modelling for identification and analysis of relationships that are spatial in nature (Egenhofer, 2011). These models include Conditions of

adjacency (what is next to what), containment (what is enclosed by what) and proximity (how close something is to something else) (Shamsi, 2005).

2.10 Open Source Software for Geospatial Applications

Open Source Software is an executable program that allows one to perform anything with the code except ripping off the author. Ripping off in this case means passing the author's code as one's personal code (E-education.psu.edu, 2018). The application of Open Source software in GIS must conform to the Open Geospatial Consortium Standards. In the context of Web GIS, standards that Open Source Software must conform to include;

i. Web Mapping Service: This provides a simple HTTP interface that enables one to request geo-registered map images located in one or more distributed geospatial databases within the spatial information system. The request defines the area of interest as well as the geographical layers to be processed while the response to the request consists of one or more geo-registered map images, in different formats (JPEG, PNG), displayed in a web browser application. In addition, WMS also adds extra functionality to the returned images such as transparency to allow layers from multiple servers to be combined or not (Opengeospatial.org, 2018).

ii. Web Feature Service: Once a request has been made, this feature defines the necessary operations required to manipulate information about geographic features (points, lines, and polygons). Through the WEB, these operations allow execution of transactions such as query, create, update or delete on the available spatial data (Regula Stopper (Overall), 2018).

iii. Web Coverage Service: This is a service that allows serving of geographic features (raster) over the Web. The feature describes a set of coverages, means to describe the structure of coverage in terms of resolution and bands as well as the means to extract the data. Therefore, a client is not only allowed to get the source of the raster data but also download it for later visualization as well as analysis (Geoserver.geo-solutions.it, 2018).

2.11 Previous Efforts in Application of GIS in Vihiga County.

From 2008 to 2017, Emuhaya Constituency being one of Vihiga County constituencies rose to the limelight by becoming the first constituency to apply GIS and Geographic information in planning and development. The then Member of Parliament and current Governor His Excellency Dr. Wilber Ottichillo, was able to mainstream geoinformation in community management and development. In 2003, the Government of Kenya introduced the Constituency Development fund drawn from Kenya´s national kitty and is meant to foster economic growth

at the constituency level. (Namano, 2014). The use of these funds called for sound planning and management at constituency level. Upon the preparation of 2008-2015 strategic plan for Emuhaya Constituency, it became important to meet the set objectives of the strategic plan through Geographic Information technologies. Under the leadership of Dr. Ottichillo, Kenya's first Constituency Development Information System (CDIS) was developed. This CDIS served as a model for other constituencies to emulate. The goal of the CDIS was to create a 'smart system' that enabled storage, management, analysis, manipulation and display of Emuhaya's constituency spatial data for improved development planning & management, food security and poverty alleviation.

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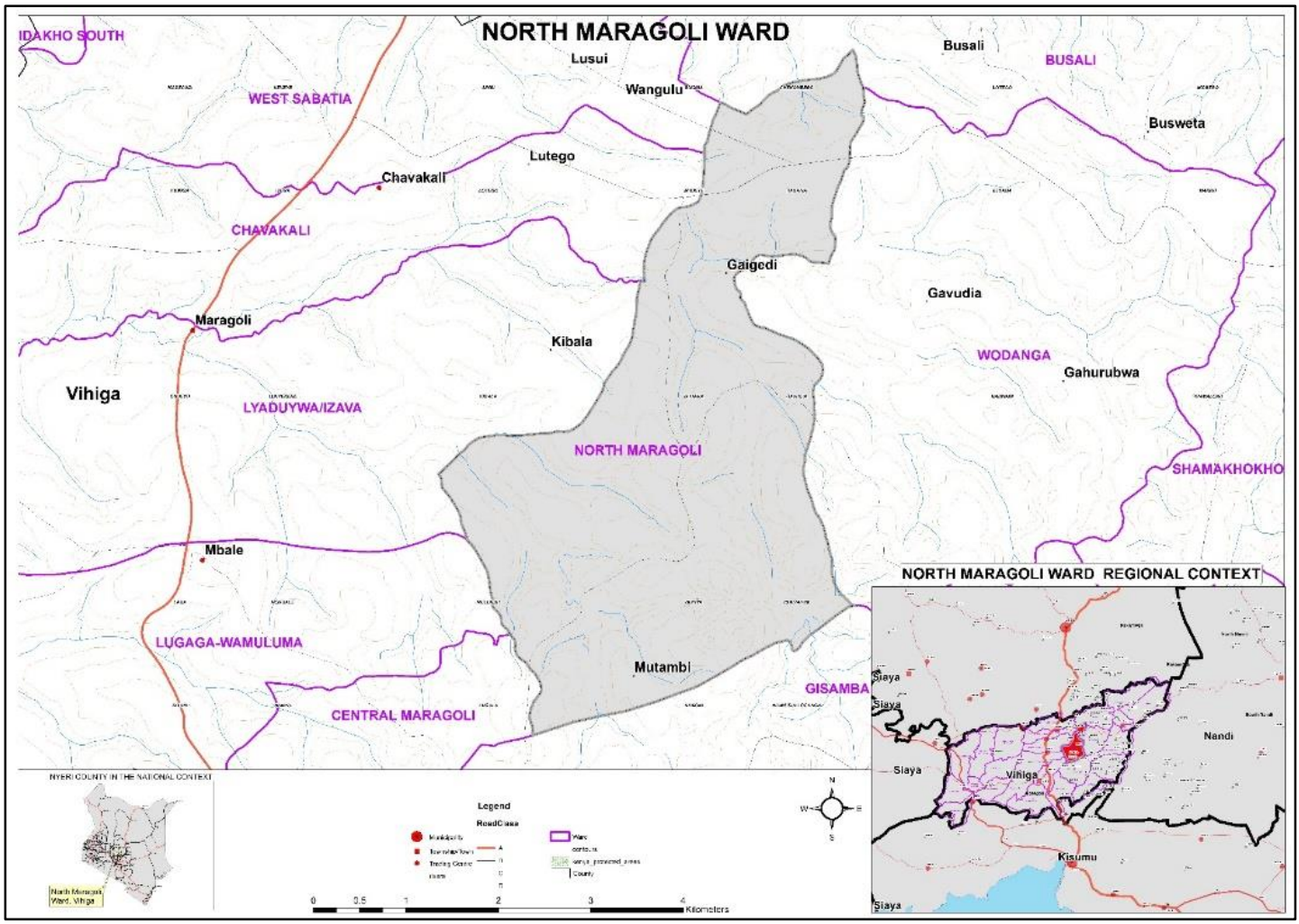
CHAPTER 3: MATERIALS AND METHODS

3.1 The Study Area

North Maragoli County assembly ward is one of the wards in Sabatia constituency in Vihiga County. It measures an area of approximately 16.3 Sq. Km and a population of 18,487 persons (2009 Population Census). It comprises of Kigama, Kivagala, Digula, Mudete and Mulundu Sub–Locations and is accessed by the main Kisumu-Kapsabet- Eldoret road. The Mudete- Gisambai road cuts across the ward while numerous access and feeder roads service the ward. The ward consists of 14 primary schools, 3 secondary schools, a market centre, health centres among others. The most prominent facility is the Mudete Tea Factory which processes tea from the wider tea catchment area of Vihiga. The National, Regional and Locational context of the study area is shown in the Map 1 below:



Map 1: The Study Area, Source*:* Author, 2018

3.2 The Methodology

It is envisioned that this Open Source Web based spatial information system will be used by both thick and thin clients. To accommodate the two clients, a rudimentary approach to developing the system was used. This approach, within a web environment, will allow users of the system to spatially visualize and interact with spatial data relating to development projects within the study area. The methodological approach involved carrying out a user needs assessment, data collection based on the user needs assessment, data analysis, development of the spatial information system and implementation of the system. A methodological work flow diagram is provided under Figure 1. Below;

Conceptual Methodological Approach to Conducting the Study

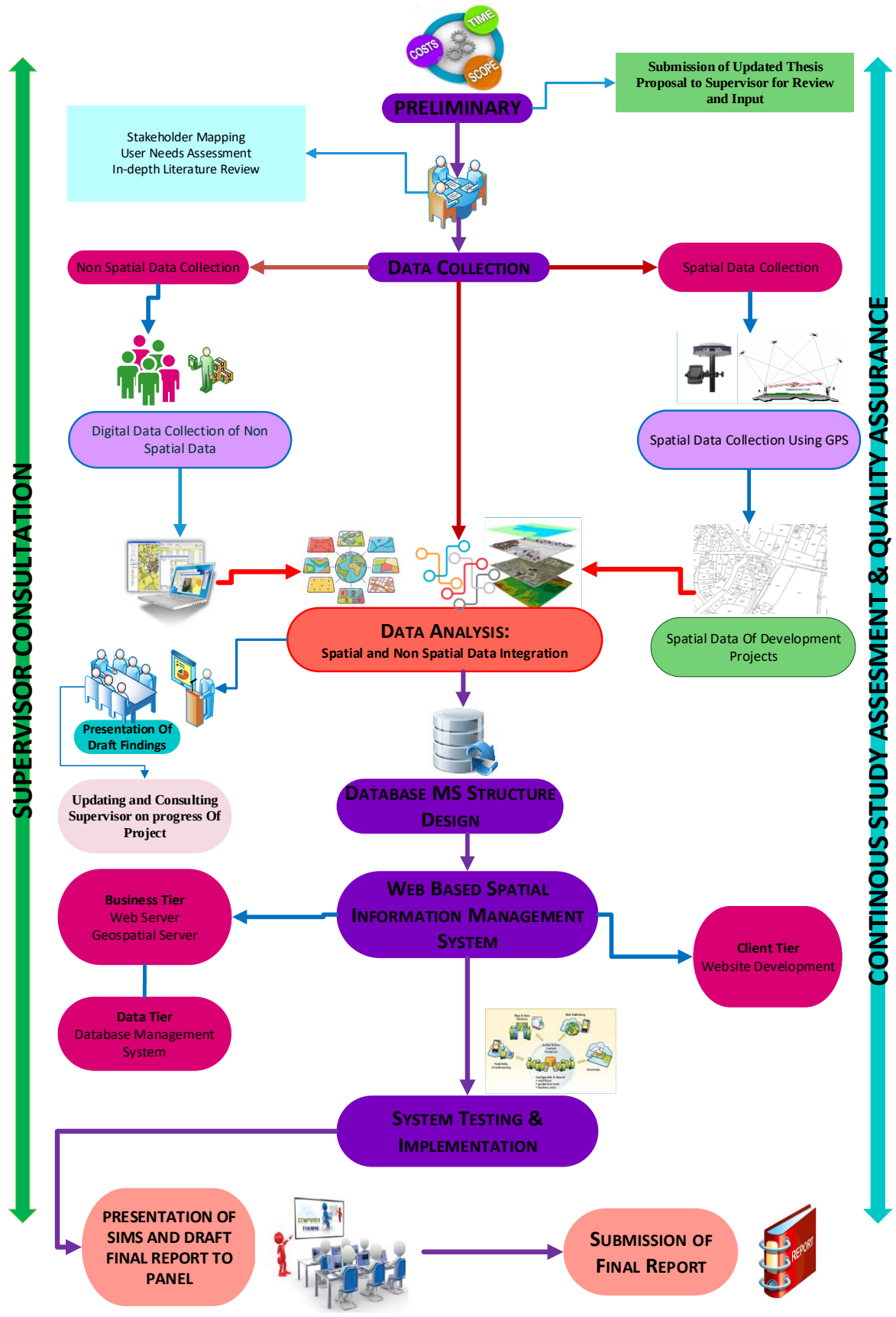


Figure 1: Study Conceptual Methodology Flow Diagram, Source: Author, 2018

3.2.1 User Needs Assessment

In order to fully understand the requirements for SIMS from a broad number of stakeholders interested in County Development projects, this study started with a thorough and structured needs assessment interview process. The stakeholders interviewed included but not limited to County ICT Director, Ward Administrator as well as Staff from various departments within the county, local population as well as professionals from the County. These one on one interviews provided an understanding of the current developments and efforts towards incorporating GIS into county planning system as well as the expectations of general public.

3.2.2 Data Collection

Upon completion of user needs assessment, data collection was conducted based on the findings of the user needs. The North Maragoli ward representative was helpful in identifying location of ongoing projects. The data, both spatial and non-spatial data, was collected from the county departments of information, communication and technology and Infrastructure who are carrying out a number development projects within North Maragoli ward. Spatial data collected included GPS coordinates of projects. On the other hand, non-spatial data obtained from the mentioned county departments included contract details, contractor details, start and end dates etc. Eventually, the spatial data was processed to correspond to the attributes of the non-spatial data as shown in section 4.3.

3.2.3 Data Analysis

Once the spatial and non-spatial data was collected, analysis was carried out using Quantum GIS software and Microsoft Excel. The final analysed data was exported into Postgre/PostGIS database management system. This analysis involved downloading GPS points, linking the points to corresponding non-spatial data and identifying relations that informed the composition of the database. Primary keys and Foreign keys for the relation were identified and a relational database was developed. Postgres/ PostGIS was used as the database management system. A detailed Approach for developing the database is described in section 3.4 below.

3.2.4 Database Design and Development

The goal of the database design and development process is to produce an operational database for the web based spatial information Management system. Database design involved requirement analysis, conceptual design, logical design and physical design.

3.2.5 Development of the Spatial Information Management System

Once the development of the database is complete, there was need to present this database in a system that can be used by the residents of Vihiga. Therefore, to develop the spatial information management system, digital layers were generated from the spatial data collected using Geoserver as the Web Map server. The digital

layers were presented as dynamic maps using Open Layers with capabilities of reading spatial data from PostGIS as well as OpenStreetMap and Google earth to enhance spatial representation. For an interactive Graphic User Interface, Node.js was used to design and develop a website with capabilities of spatial analysis and querying of projects on a web browser. This GUI integrated all the components of the spatial information system and presented it in a visual way that enables interaction and navigation to projects using icons and menus thus used for monitoring and evaluation. This system was hosted locally.

3.2.6 Testing and Implementing the System

Once the development of the spatial information system was complete, the system was tested by querying individual projects and visualizing the outputs. This yielded a positive result making the system successful and implementable.

3.3 Materials and Tools

The study entirely used open source tools. These tools included;

- QGIS for spatial data analysis
- Postgres/PostGis as the Database Management System.
- Geoserver Web Map Server.
- Open Layers, OpenStreetMap and Google Earth to present digital layers as dynamic Maps
- Node.js as the javascript cross platform for server side programming that allowed the building of Web based Spatial Information System.
- Notepad+++ for writing Scripts and codes
- Microsoft Office Package for capturing non-spatial data and report writing
- Internet connection for Online resources and tutorials

3.4 Database Design

3.4.1 Introduction to the Organization: Vihiga County

Vihiga County is one of the 47 devolved County Governments in Kenya tasked with spurring growth and development through resources allocated to it by the Central Government as well as own revenue generation. It spurs growth and development by undertaking development projects in different **locations** within the county. Each **department** proposes different projects as identified through public consultations by North Maragoli residents[2] to be undertaken by the County in different locations (to ward level) and are prioritized in the County Integrated

[2] North Maragoli resident include locals, investor or any other individual who would benefit from the project directly or indirectly.

development plan. Budgetary allocation is attached to each **project** and a **contractor** is then identified and issued with a **contract** to undertake the projects.

Part of the organization we are designing the Conceptual Database for

Vihiga County is a large entity undertaking different transactions. Other than projects, it offers services, collects revenues, undertakes development projects, consultancies and feasibility studies among others**.** Therefore, creating a database for all these activities that occur within the county is not only difficult but goes beyond the scope of the Msc. Project which is restricted to a certain Geographic Information. The design of this particular conceptual database was strictly on development projects that are spatial in nature. With this focus, the study narrowed down the entities to most basic forms and on the other hand, there is not much information available on the North Maragoli resident whereas most of the data collection was derived from Contracts being undertaken.

Major Entities and relationships

The **Department Entity** is one of the major entities of this database. Other than the basic information of the department, the entity branched off to subclasses representing the different tasks[3] performed under the County.
The **Project Entity** is the second of the entities of the database. It contains information about the project identified by North Maragoli residents and documented in the CIDP to be undertaken by the department responsible.
The **Contract Entity** contains information about the project implementation, what it entails, duration, and the outputs
The **Contractor Entity** on the other hand shows who the contract was awarded to and the services being offered.
Other entities include **Employee Entity**, **Resident Entity** and **Ward Entity** where the projects take place.

[3] For example, Physical Planning Lands and Housing department is mandated with undertaking tasks related to physical planning, land related matters and housing.

3.4.2 External Model: User Groups, Data Views and Operations

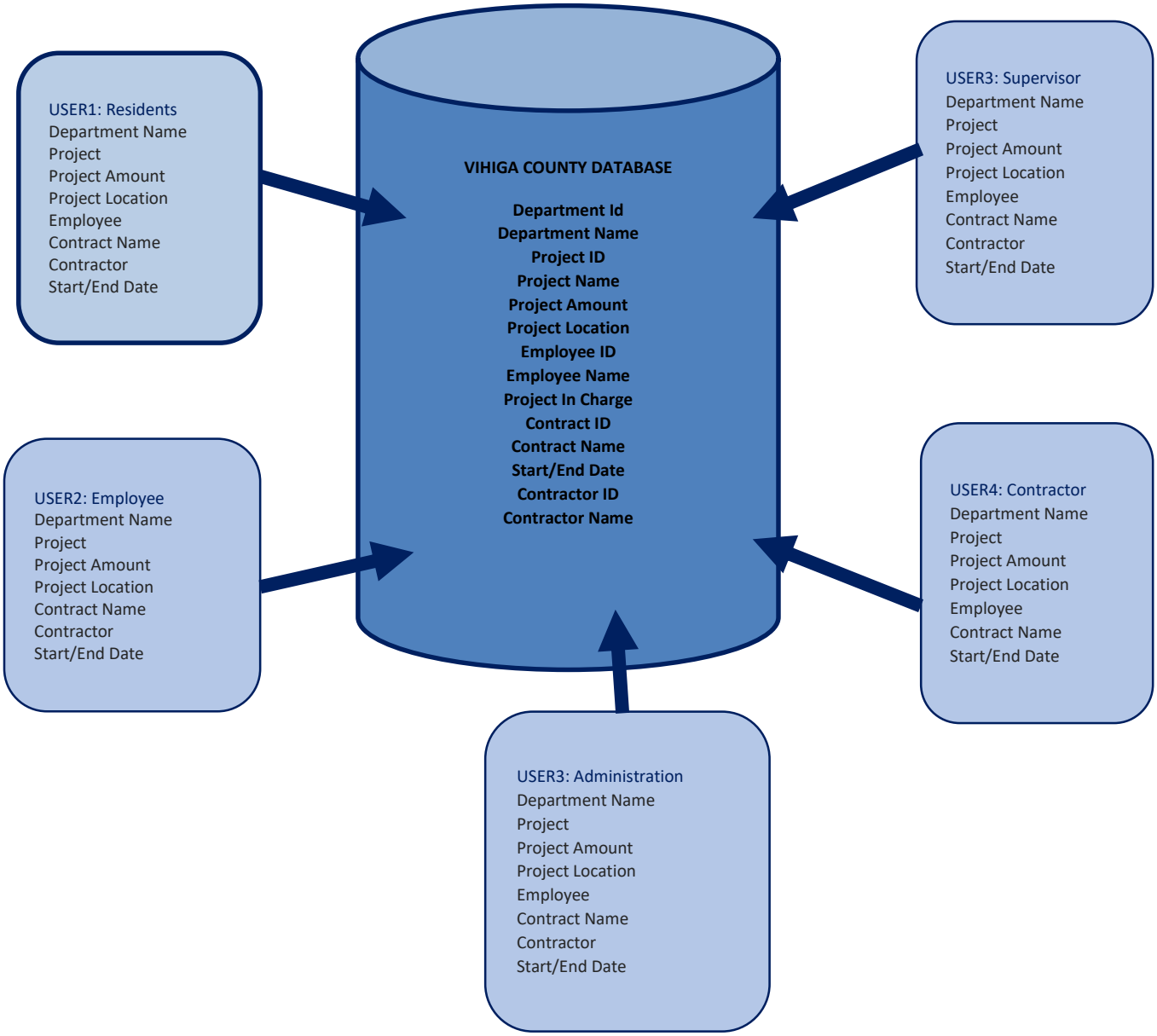


Figure 2: Database Design-External Model Diagram, Source: Author, 2018

3.4.3 Conceptual Database Design: ER Modelling

3.4.3.1 Entity Set Explanation

i. Department (Strong/Central Entity)

This entity stores information relating to each individual department in the County Government. It contains Name of the department, the budget that has been allocated. Entry such as County Executive in Charge (CEC) as well as Chief Officer in charge. One department is in charge of many Projects.

Candidate Keys

i. *Department ID (Primary Key)*
ii. *Name*

Attribute	Department ID	Name	Budget	No. of Projects	Employee
Description	Uniquely Identifies the Department	Name of the Department	Development Budget.	Number of Projects	EmployeeID
Domain	varchar	varchar	Amount	Integer	Varchar
Primary Key	Yes	No	No	No	No
Unique	Yes	Yes	No	No	Yes

Table 1: Department Entity

ii. Project

This entity contains information about the projects being undertaken by different departments in the county. Entries are inserted every time a project is proposed and a budget allocated for it. One department can have many projects under its jurisdiction, while a project can have many contracts to be performed. On the other hand, residents of North Maragoli can propose many projects to be undertaken in their ward.

Candidate Keys

i. *Project ID (Primary Key)*
ii. *Name*

Attribute	Project ID	Name	Budget	Department	Contracts
Description	Uniquely Identifies the Project	Name of the Project	Project Budget	DepartmentID	contracts being undertaken
Domain	Varchar	Varchar	Amount	Varchar	Varchar
Primary Key	Yes	No	No		No
Unique	Yes	Yes	No	No	Yes

Table 2: Project Entity

iii. Contract

This entity keeps track of all contracts under each project, the contractor awarded, start and end date and the contract amount. One contract can only be given to one contractor while one employee can over see many contracts.

Candidate Keys

i. Contract ID (Primary Key)
ii. Title

Attribute	**Contract ID**	**Title**	**Contract Amount**	**Contractor Awarded**	**Project**
Description	Uniquely Identifies the Contract	Title of the Contract	Contract Amount	Name of Contractor	ProjectID
Domain	Varchar	Varchar	Amount	Varchar	Varchar
Primary Key	Yes	No	No	No	No
Unique	Yes	Yes	No	No	Yes

Table 3: Contract Entity

iv. Contractor

This entity stores information about all contractors undertaking contract works within North Maragoli ward. One contractor can only work on one contract at a time.

Candidate Keys

i. Contractor ID (Primary Key)
ii. Name

Attribute	**Contractor ID**	**Name**	**Specialty**	**Contract**
Description	Uniquely Identifies the Contractor	Name of the Contractor	Speciality of contractor	ContractID
Domain	Varchar	Varchar	Varchar	Varchar
Primary Key	Yes	No	No	No
Unique	Yes	Yes	No	Yes

Table 4: Contractor Entity

v. Employee

This entity comprises of employee details such as his/her name, role played in county etc. Many employees work in one department while one employee is in charge of many contracts. An employee can supervise contractors in the county.

Candidate Keys

i. Employee ID (Primary Key)

ii. Name

Attribute	**Employee ID**	**Name**	**Gender**	**Department**	**Role**
Description	Uniquely Identifies the Employee	Name of the Employee	Male or Female	DepartmentID	Role of Employee
Domain	varchar	varchar	varchar	varchar	varchar
Primary Key	Yes	No	No	No	No
Unique	Yes	Yes	No	No	No

Table 5: Employee Entity

vi. Resident

This entity keeps track of residents who are interested in tracking progress of development projects in North Maragoli Ward. Residents also include investors keen on availability of investment opportunities as shaped by development projects being undertaken.

Candidate Keys

i. National ID/Passport Number (Primary Key)

ii. Name

Attribute	**Resident NationalID/Passport Number**	**Name**	**Ward**	**Gender**
Description	Uniquely Identifies the Resident	Name of the Resident	WardID	Male or Female
Domain	varchar	varchar	varchar	varchar
Primary Key	Yes	No	No	No
Unique	Yes	Yes	Yes	No

Table 6: Resident Entity

vii. Ward

This entity describes the location where contracts are done. Many Contracts can be done in one ward.

Candidate Keys

i. Ward ID (Primary Key)

ii. Name

Attribute	**Ward ID**	**Name**	**Sub County**	**Population**
Description	Uniquely Identifies the Ward	Name of Ward	Sub county where Ward is Located	Total Population of the Ward
Domain	varchar	varchar	varchar	Integer
Primary Key	Yes	No	No	No
Unique	Yes	Yes	No	No

Table 7: Ward Entity

3.4.3.2 Relationships Set Explanation

The table below summarizes the relationship sets between entities:

Relationship set	**Entities involved**	**Implication**	**Cardinalities**
'Implements'	Department Projects	One department implements many projects	One to Many
'Consists'	Project Contract	One project consists of Many contracts e.g. a roads projects can have different contracts under it	One to Many
'Works in'	Employee Department	Many employees work in one department	Many to One
'In charge of'	Employee contract	One employee is in charge many contracts	One to Many
'Supervises'	Supervisor contractor	One supervisor supervises many contractors	One to Many
'Reside'	Residents Ward	Many residents reside in one ward	One to one

'Performs'	Contractor Contracts	One Contractor performs one contract at a time	One to One
'Tracks'	Governor Projects	Governor tracks many projects being run by different departments	One to Many
'Clears'	Supervisor Contractor	One Supervisor clears Many Contractors	One to Many
'Done in'	Contracts Ward	Many contracts can be done in on ward	Many to One

Table 8: Relation Set Explanation

3.4.4 Conceptual Modelling: E-R Diagram

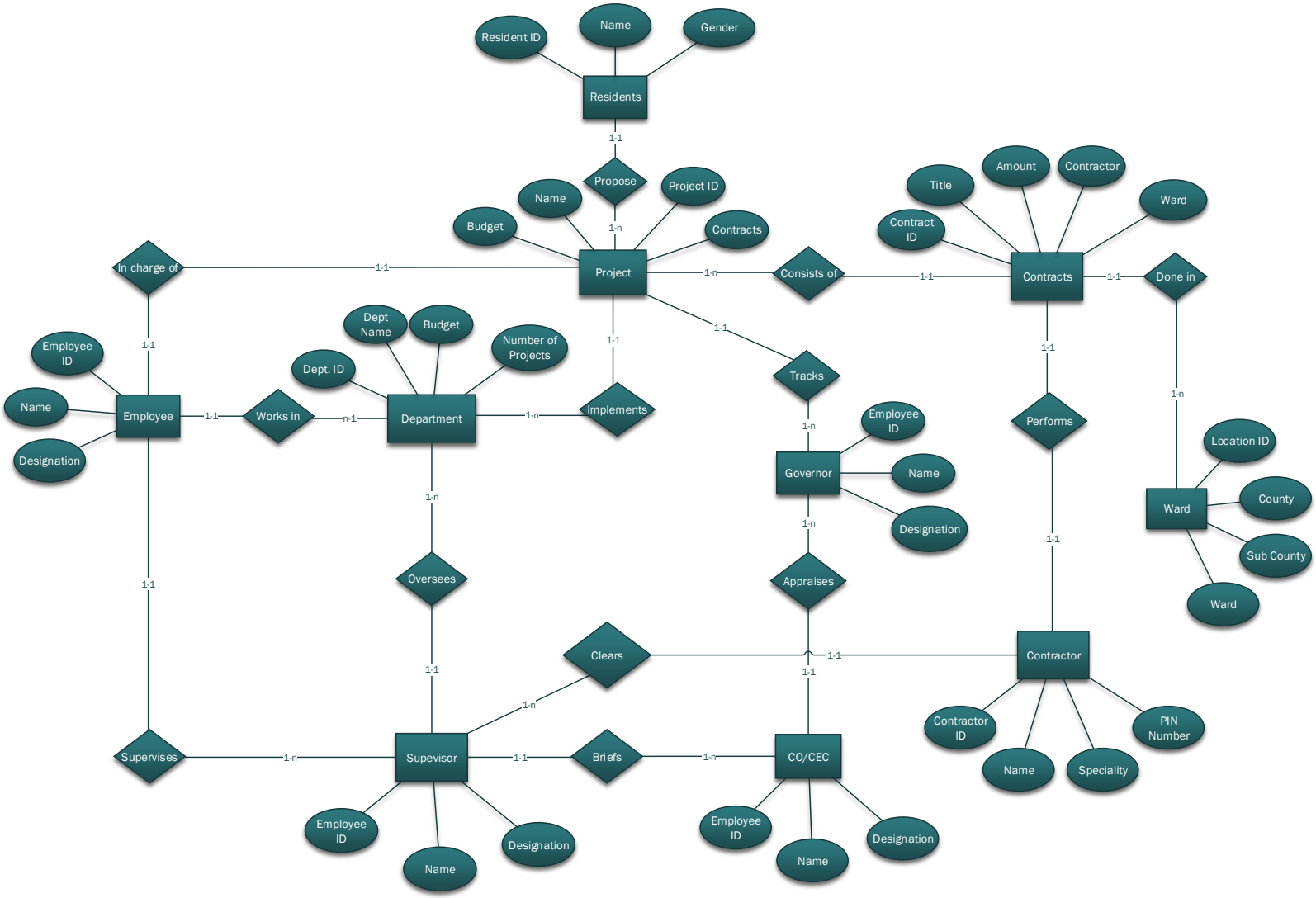


Figure 3: Database Design-Conceptual Model (E-R) Diagram, Source: Author, 2018

3.4.5 Logical Design: Data Normalization

In order to fully represent the Conceptual Model of the database, Conceptual model was transformed into a 'logical mode' that the DBMS can fully use. This was achieved through logical design. The main aim of the logical design was to create tables that correctly represents operations around Vihiga County for ease of relating within the DBMS. These relations contain entities and attributes arranged in a non-redundant manner as well as foreign keys which were incorporated within the tables so as to create relationships among the entities. Therefore, logical design ensured that data can be input and manipulated easily as well as certain requirements are satisfied through production of reports and queries.

DeptName	PrjctName	CntctName	Employee	CntctrName	WardName
Transport and Infrastructure	Routine Maintenance of Roads, Construction of bridges,	Grading, gravelling road re-shaping, Bridge Construction	Staff1, Staff2, Staff2, Supervisor1, Supervisor2, Supervisor1	Contctr1, Contctr2, Contctr3, Contctr4	North Maragoli,

Table 9: Table before Normalization

i. Identification of Primary Keys

DeptID	DeptName	PrjctID	PrjctName	CntctID	CntctName	EmplyID	EmplName	CntctrID	CntctrName	WardID	WardName
VCG_T_INFR_003_2018	Transport and Infrastructure	**RD_VCG_003_1_2018_19**	Routine Maintenance of Roads	**RD_VCG_003_1_SW_012_2018_19, RD_VCG_003_1_SW_013_2018_19**	Grading, gravelling road, Bridge Construction	**VCG_001, VCG_006 VCG_034, VCG_024**	**Wilbur, Moses, Carol, Esther**	**VCG_SW_CNTCTR_023, VCG_SW_CNTCTR_045**	**Ferrod Construction, Thamsin Enterprises**	**VCG_WRD_003**	**North Maragoli**
VCG_EDUCTN_004_2018	Education	**EDUCTN_VCG_004_1_2018_19**	Construction of ECD complexes	**EDUCTN_VCG030_2017_2018, EDUCTN_VCG037_2017_2018**	Mukomba_ECD_Complex, Digula_ECD_Complex	**VCG_001, VCG_009 VCG_045, VCG_064**	**Wilbur, Timothy, Faith, Desmond**	**VCG_SW_CNTCTR_043, VCG_SW_CNTCTR_039**	**Building Systems Ltd, Design and Build Ltd**	**VCG_WRS_003**	**North Maragoli**

Table 10: Identification of Primary Keys

ii. Normalization to 1NF

Relation 1: Department

DeptID(PK)	DeptName	Budget	NumPrjcts
VCG_T_INFR_003_2018	Transport and Infrastructure	**150,000,000**	**2**
VCG_EDUCTN_004_2018	Education	**120,000,000**	**2**

Table 11: Relation 1: Department

Relation 2: Project

PrjctID(PK)	PrjctName	Budget	Contracttype	Department (FK)
RD_VCG_003_1_2018_19	Routine Maintenance of Roads	**66,000,000**	Grading, Gravelling Roads and Bridge Construction	**VCG_T_INFR_003_2018**
EDUCTN_VCG_004_1_2018_19	Construction of ECD complexes	**90,000,000**	Building Construction	**VCG_EDUCTN_004_2018**

CntctID(PK)	CntctName	Amount	Ward	EmplyID(FK)	FirstName	EmplyRole
T_INFR_VCG049_2017_2018	Routine Maintenance of Simboyi_Mutambi Road	10,000,000	North Maragoli	VCG_001	Wilbur	Supervisor

T_INFR_VCG049_2017_2018	Routine Maintenance of Simboyi_Mutambi Road	10,000,000	North Maragoli	VCG_034	Carol	Technical
T_INFR_VCG044_2017_2018	Routine Maintenance of Mbale Stalls_Chugi_Kisangula Road	12,000,000	North Maragoli	VCG_001	Wilbur	Supervisor
T_INFR_VCG044_2017_2018	Routine Maintenance of Mbale Stalls_Chugi_Kisangula Road	12,000,000	North Maragoli	VCG_024	Esther	Technical
T_INFR_VCG052_2017_2018	Routine Maintenance of Kiritu_Chanderema_Jemovo Road	14,000,000	North Maragoli	VCG_001	Wilbur	Supervisor
T_INFR_VCG052_2017_2018	Routine Maintenance of Kiritu_Chanderema_Jemovo Road	14,000,000	North Maragoli	VCG_034	Carol	Technical
T_INFR_VCG056_2017_2018	Construction of Mulimukho Bridge	10,000,000	North Maragoli	VCG_001	Wilbur	Supervisor
T_INFR_VCG056_2017_2018	Construction of Mulimukho Bridge	10,000,000	North Maragoli	VCG_034	Carol	Technical
EDUCTN_VCG030_2017_2018	Mukomba_ECD_Complex	4,000,000	North Maragoli	VCG_009	Timothy	Supervisor
EDUCTN_VCG030_2017_2018	Mukomba_ECD_Complex	4,000,000	North Maragoli	VCG_O45	Faith	Technical

EDUCTN_VCG037_2017_2018	Digula_ECD_Complex	5,000,000	North Maragoli	VCG_009	Timothy	Supervisor
EDUCTN_VCG037_2017_2018	Digula_ECD_Complex	5,000,000	North Maragoli	VCG_064	Desmond	Technical

Table 12: Relation 2: Project

iii. Normalization to 2NF

Relation 3: Employee

EmplyID	FirstName	Last Name	EmplyRole	Department (FK)
VCG_001	Wilbur	Otichillo	Supervisor	**VCG_T_INFR_003_2018**
VCG_009	Timothy	Wanyonyi	Supervisor	**VCG_EDUCTN_004_2018**
VCG_034	Carol	Esendi	Technical	**VCG_T_INFR_003_2018**
VCG_024	Esther	Mudasi	Technical	**VCG_T_INFR_003_2018**
VCG_045	Faith	Mudanyi	Technical	**VCG_EDUCTN_004_2018**
VCG_064	Desmond	Atigala	Technical	**VCG_EDUCTN_004_2018**

Table 13: Relation 3: Employee

Relation 4: Contract

CntctID	CntctName	StrtDate	EndDate	Amount	Project (FK)	Technical (FK)	Ward (FK)
T_INFR_VCG 049_2017_2018	Routine Maintenance of Simboyi_Mutambi Road	1/07/2017	31/08/2018	10,000,000	**RD_VCG_003_1_2 018_19**	VCG_034	VCG_WRD_003
T_INFR_VCG 044_2017_2018	Routine Maintenance of Mbale Stalls_Chugi_Kisa ngula Road	1/07/2017	31/08/2018	11,000,000	**RD_VCG_003_1_2 018_19**	VCG_034	VCG_WRD_003
T_INFR_VCG 052_2017_2018	Routine Maintenance of Kiritu_Chanderem a_Jemovo Road	1/07/2017	31/08/2018	10,000,000	**RD_VCG_003_1_2 018_19**	VCG_034	VCG_WRD_003
T_INFR_VCG 056_2017_2018	Construction of Mulimukho Bridge	1/07/2017	31/12/2018	6,000,000	**RD_VCG_003_1_2 018_19**	VCG_034	VCG_WRD_003

EDUCTN_VCG030_2017_2018	Mukomba_ECD_Complex	1/07/2017	31/12/2018	4,000,000	**EDUCTN_VCG_004_1_2018_19**	VCG_O45	VCG_WRD_003
EDUCTN_VCG037_2017_2018	Digula_ECD_Complex	1/07/2017	31/12/2018	5,000,000	**EDUCTN_VCG_004_1_2018_19**	VCG_064	VCG_WRD_003

Table 14: Relation 4: Contract

Relation 5: Ward

WardID	WardName	Popltn
VCG_WRD_003	North Maragoli	5,000

Table 15: Relation 5: Ward

Relation 6: Resident

ResiID	Ward (FK)	ResiName	Gender
24776889	**VCG_WRD_003**	**Victor Logedi**	**Male**
20457899	**VCG_WRD_003**	**Francis Omwami**	**Male**
25895478	**VCG_WRD_003**	**Mary Mwenesi**	**Female**

Table 16: Relation 6: Resident

iv. Normalization to 3NF

Relation 7: Contractor

CntctrID	CntctrName	Address	City	Speclty	Supervisor (FK)	CntctID
VCG_SW_CNTCTR_023	Ferrod Construction	53174	Nairobi	Civil Works	**VCG_001**	**T_INFR_VCG049_2017_2018**
VCG_SW_CNTCTR_024	Twiga Ltd	23675	Nairobi	Civil Works	**VCG_001**	**T_INFR_VCG044_2017_2018**
VCG_SW_CNTCTR_026	Thamsin Enterprises Ltd	320	Maragoli	Civil Works	**VCG_001**	**T_INFR_VCG052_2017_2018**
VCG_SW_CNTCTR_045	Topclass Contractors	12345	Mbale	Civil Works	**VCG_001**	**T_INFR_VCG056_2017_2018**
VCG_SW_CNTCTR_043	Building Systems Ltd	13452	Nairobi	Building Works	**VCG_009**	**EDUCTN_VCG030_2017_2018**
VCG_SW_CNTCTR_039	Design and Build Ltd	2356	Kisumu	Building Works	**VCG_009**	**EDUCTN_VCG037_2017_2018**

Table 17: Relation 7: Contractor

3.4.6 Logical Design: Data Integrity

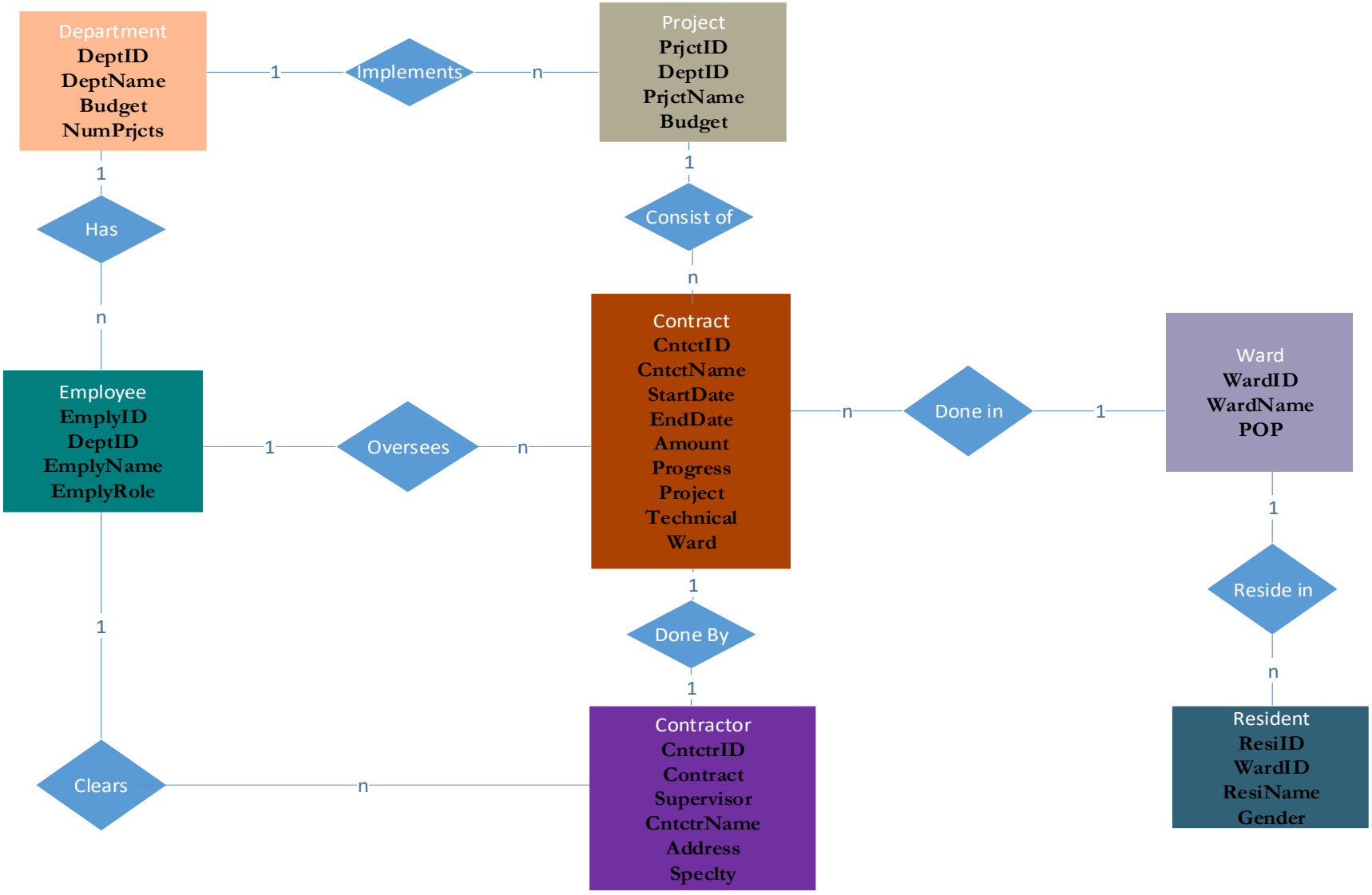


Figure 4: Database Design-Logical Design-Data Integrity, Source: Author, 2018

CHAPTER 4: RESULTS

4.1 Database Creation and Implementation

4.1.1 Creating Database North Maragoli

```
CREATE DATABASE northmaragoli;
```

4.1.2 Results:

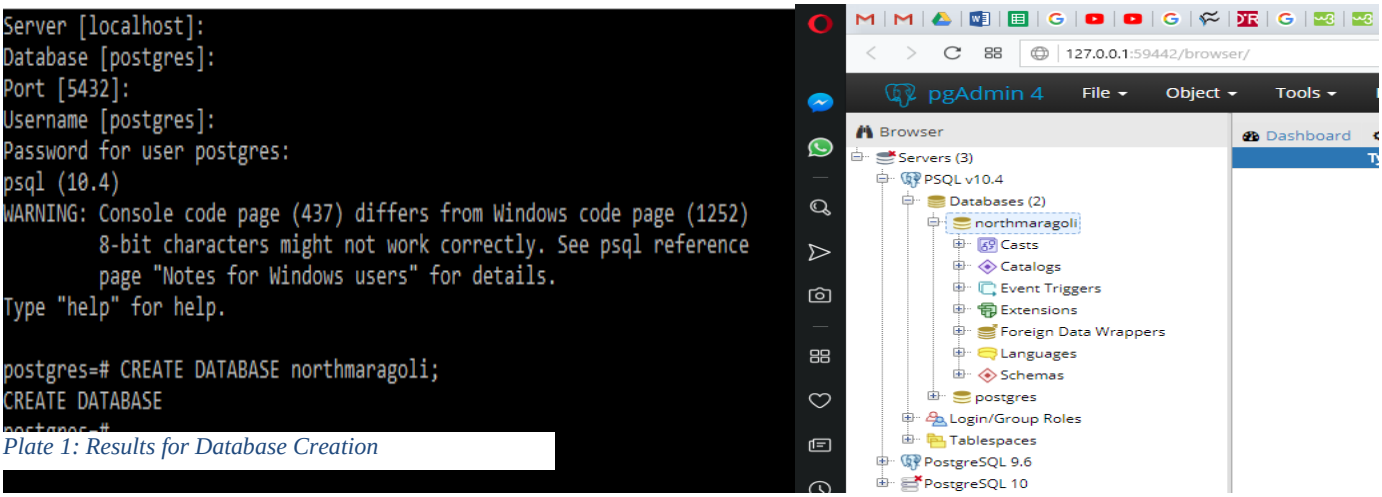


Plate 1: Results for Database Creation

4.1.3 Creating Non-Spatial Relational Tables with Constraints and inserting data.

i. Department.

```
CREATE TABLE Department_VCG (
    DeptID varchar(100) NOT NULL,
    DeptName varchar(100) NOT NULL,
    Budget int NOT NULL,
    NumbPrjcts int NOT NULL,
    PRIMARY KEY (DeptID)
);
```

Inserting data

```
INSERT INTO Department_vcg (deptid, deptname, budget, numbprjcts)
VALUES ('VCG_EDUCTN_004_2018', 'Education', '120000000', '11');
```

ii. Employee

```
CREATE TABLE Employee_VCG (
    EmplyID varchar(100) NOT NULL,
    FirstName varchar(100) NOT NULL,
    LastName varchar(100) NOT NULL,
    EmplyRole varchar(100) NOT NULL,
    Department varchar(100),
    PRIMARY KEY (EmplyID),
    FOREIGN KEY (Department) REFERENCES Department_VCG(DeptID)
);
```

Inserting data

```
INSERT INTO employee_vcg (emplyid, firstname, lastname, emplyrole, department)
VALUES ('VCG_001', 'Wilbur', 'Otichillo', 'Supervisor', 'VCG_T_INFR_003_2018');
```

iii. Project

```
CREATE TABLE Project_VCG (
    PrjctID varchar(100) NOT NULL,
    PrjctName varchar(255) NOT NULL,
    Budget int NOT NULL,
    Contracttype varchar(255) NOT NULL,
    Department varchar(100),
    PRIMARY KEY (PrjctID),
    FOREIGN KEY (Department) REFERENCES Department_VCG(DeptID)
);
```

Inserting data

```
INSERT INTO project_vcg (prjctid, prjctname, budget, contracttype, department)
VALUES ('RD_VCG_003_1_2018_19', 'Routine Maintenance of Roads', '50000000', 'Grading, Gravelling Roads,
bridge construction', 'VCG_T_INFR_003_2018');
```

iv. Contractor

```
CREATE TABLE Contractor_VCG (
    CntctrID varchar(100) NOT NULL,
    CntctrName varchar(255) NOT NULL,
    Address int NOT NULL,
    City varchar(50) NOT NULL,
    Speclty varchar(50) NOT NULL,
    Contract varchar(100),
    Supervisor varchar(100),
    PRIMARY KEY (CntctrID),
    FOREIGN KEY (Contract) REFERENCES Contract_VCG(CntctID),
    FOREIGN KEY (Supervisor) REFERENCES Employee_VCG(EmplyID)
);
```

Inserting data

```
INSERT INTO Contractor_vcg (CntctrID, CntctrName, Address, City, Speclty, Contract, Supervisor)
VALUES ('VCG_SW_CNTCTR_023', 'Ferrod Construction ', '53174', 'Nairobi', 'Civil Works',
'T_INFR_VCG049_2017_2018', 'VCG_001');
```

v. Ward

```
CREATE TABLE Ward_VCG (
    WardID varchar(100) NOT NULL,
    WardName varchar(255) NOT NULL,
    Popltn int NOT NULL,
    PRIMARY KEY (WardID)
);
```

Inserting data

```
INSERT INTO Ward_vcg (WardID, WardName, Popltn)
VALUES ('VCG_WRD_003', 'North Maragoli', '15000');
INSERT INTO Ward_vcg (WardID, WardName, Popltn)
VALUES ('VCG_WRD_004', 'Central Maragoli', '13000');
```

vi. Resident

```
CREATE TABLE Resident_VCG (
    ResiID int NOT NULL,
    resiName varchar(100) NOT NULL,
    Gender varchar(100) NOT NULL,
    Ward varchar(100),
    PRIMARY KEY (ResiID),
    FOREIGN KEY (Ward) REFERENCES Ward_VCG(WardID)
);
```

Inserting data

```
INSERT INTO Resident_vcg (ResiID, ResiName, Gender, Ward)
VALUES ('24776889', 'Victor Logedi', 'Male', 'VCG_WRD_003');
```

4.1.4 Results

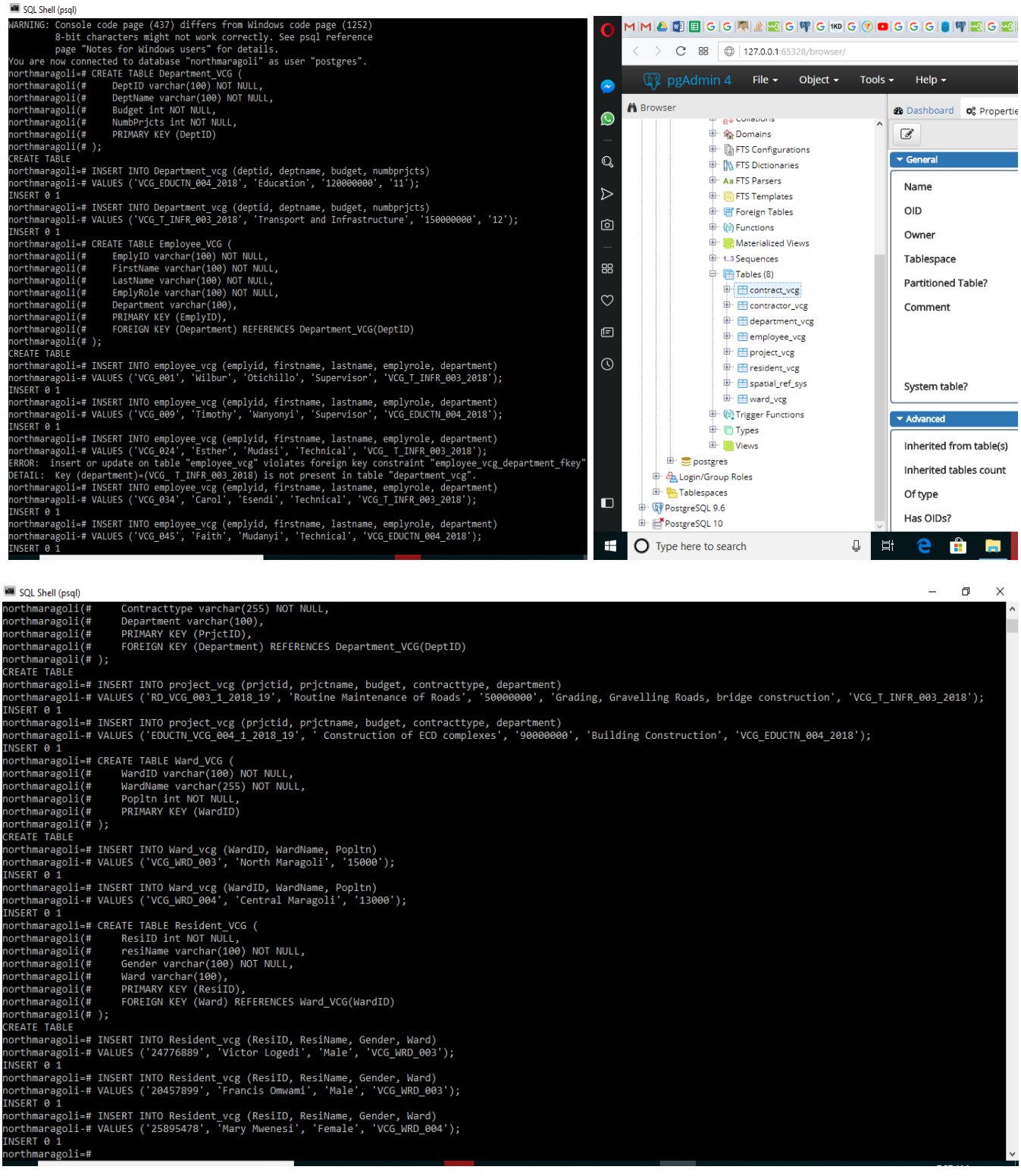
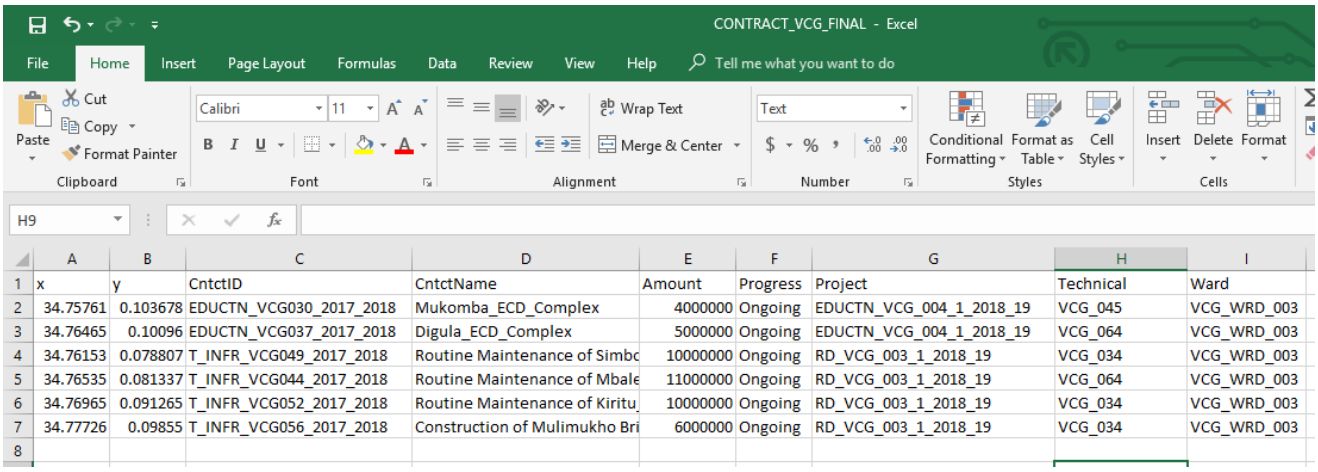


Plate 2: Results for Creating Non-Spatial Relational Tables with Constraints and inserting data

4.1.5 Creating Spatial Relational Tables.

To create the spatial relational table, data collected from the field was exported into excel and saved as CSV which was imported into QGIS.



	A	B	C	D	E	F	G	H	I
1	x	y	CntctID	CntctName	Amount	Progress	Project	Technical	Ward
2	34.75761	0.103678	EDUCTN_VCG030_2017_2018	Mukomba_ECD_Complex	4000000	Ongoing	EDUCTN_VCG_004_1_2018_19	VCG_045	VCG_WRD_003
3	34.76465	0.10096	EDUCTN_VCG037_2017_2018	Digula_ECD_Complex	5000000	Ongoing	EDUCTN_VCG_004_1_2018_19	VCG_064	VCG_WRD_003
4	34.76153	0.078807	T_INFR_VCG049_2017_2018	Routine Maintenance of Simbc	10000000	Ongoing	RD_VCG_003_1_2018_19	VCG_034	VCG_WRD_003
5	34.76535	0.081337	T_INFR_VCG044_2017_2018	Routine Maintenance of Mbale	11000000	Ongoing	RD_VCG_003_1_2018_19	VCG_064	VCG_WRD_003
6	34.76965	0.091265	T_INFR_VCG052_2017_2018	Routine Maintenance of Kiritu_	10000000	Ongoing	RD_VCG_003_1_2018_19	VCG_034	VCG_WRD_003
7	34.77726	0.09855	T_INFR_VCG056_2017_2018	Construction of Mulimukho Bri	6000000	Ongoing	RD_VCG_003_1_2018_19	VCG_034	VCG_WRD_003
8									

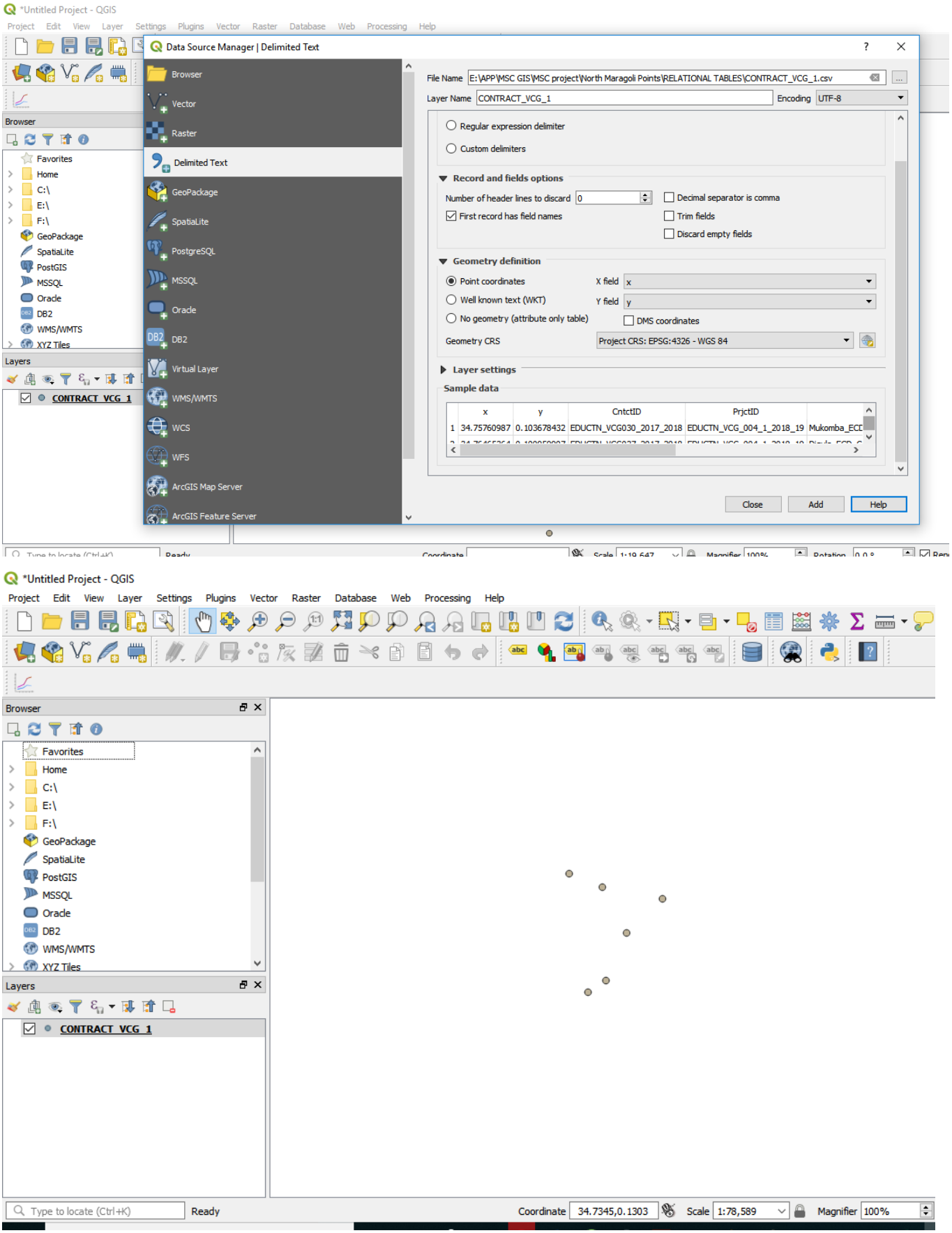


Plate 3: Importing Field Data into QGIS

Exporting Layer as shapefile *contract_vcg.shp*

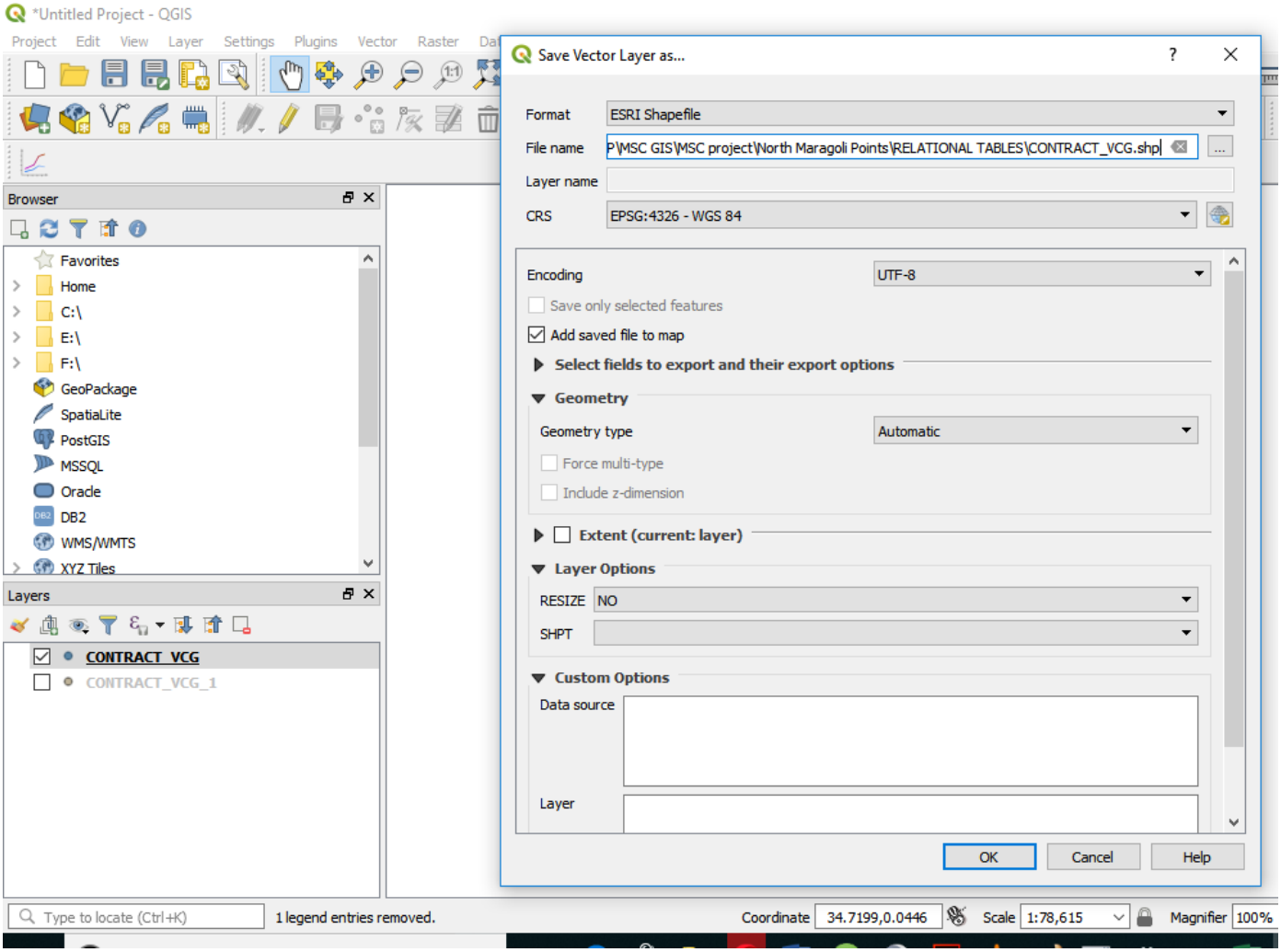
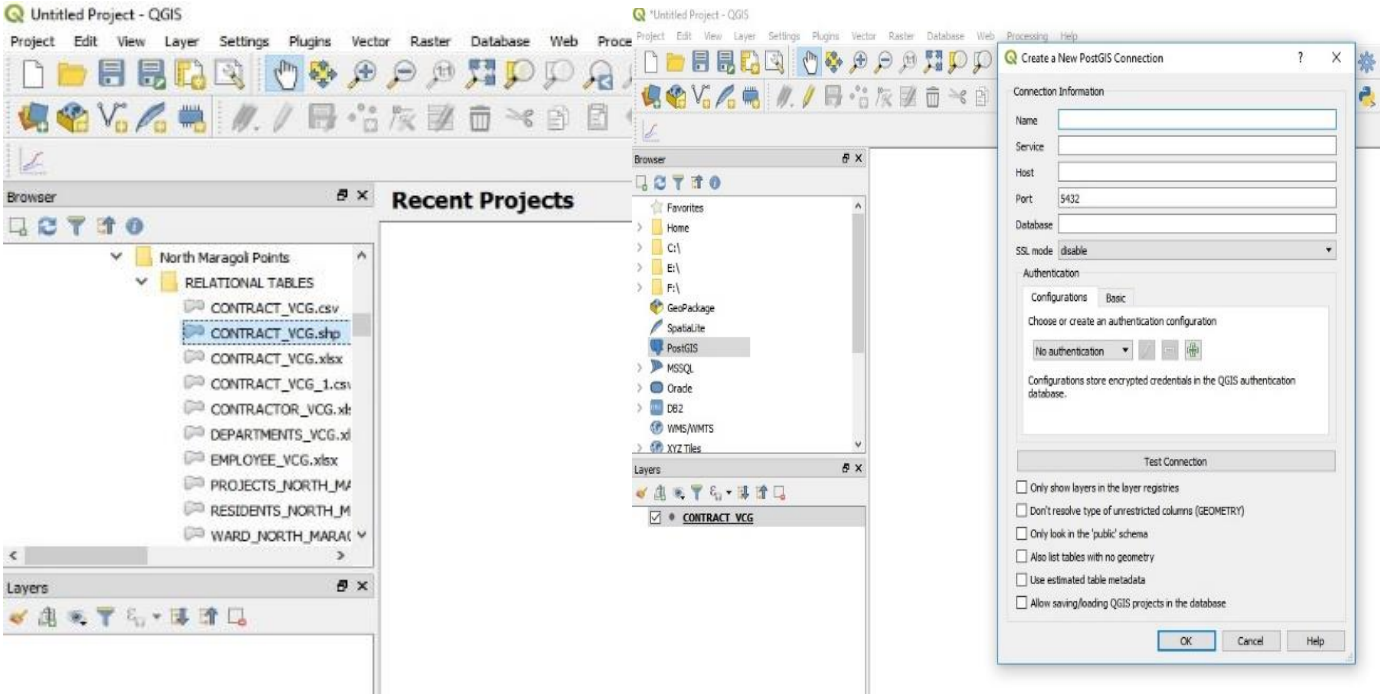


Plate 4: Exporting layer as Shapefile

Importing the Shapefile *CONTRACT_VCG.shp* into PostGIS through QGIS

i. Creating New PostGIS connection


Untitled Project - QGIS
Project Edit View Layer Settings Plugins Vector Raster Database Web
Browser
Recent Projects
North Maragoli Points
RELATIONAL TABLES
CONTRACT_VCG.csv
CONTRACT_VCG.shp
CONTRACT_VCG.xlsx
Layers
*Untitled Project - QGIS
Create a New PostGIS Connection
Connection Information
Name
Service
Host
Port
5432
Database
SSL mode
disable
Authentication
Configurations
Basic
Choose or create an authentication configuration
No authentication
Configurations store encrypted credentials in the QGIS authentication database.
Test Connection
Only show layers in the layer registries
Don't resolve type of unrestricted columns (GEOMETRY)
Only look in the 'public' schema
Also list tables with no geometry
Use estimated table metadata
Allow saving/loading QGIS projects in the database
OK
Cancel
Help
Favorites
Home
GeoPackage
SpatiaLite
PostGIS
MSSQL
Oracle
DB2
WMS/WMTS
XYZ Tiles
CONTRACT_VCG

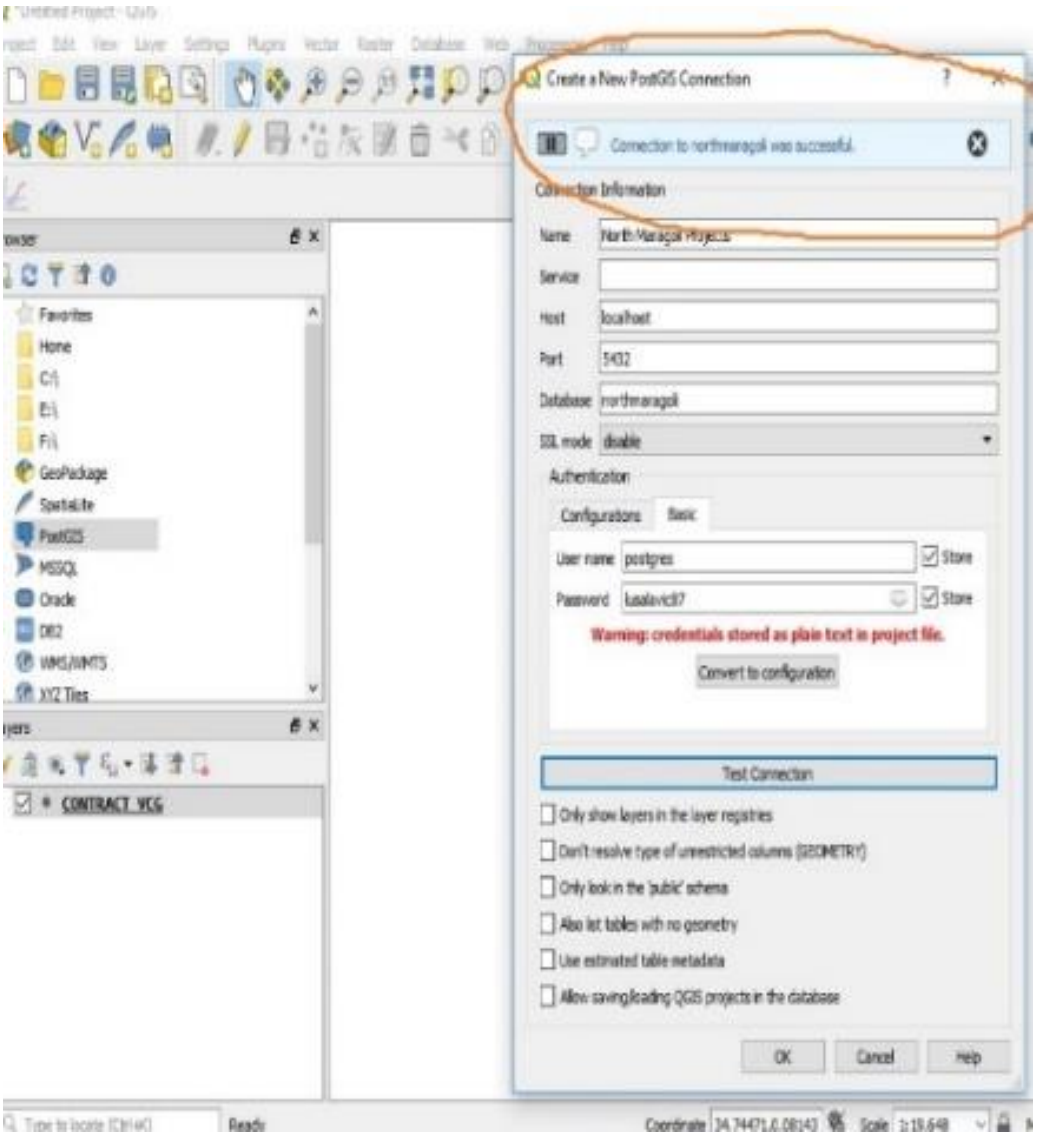


Plate 5: Creating New PostGIS Connection

ii. Confirming Connection and Importing Layer file through the DB manager into northmaragoli Database in PostgreSQL

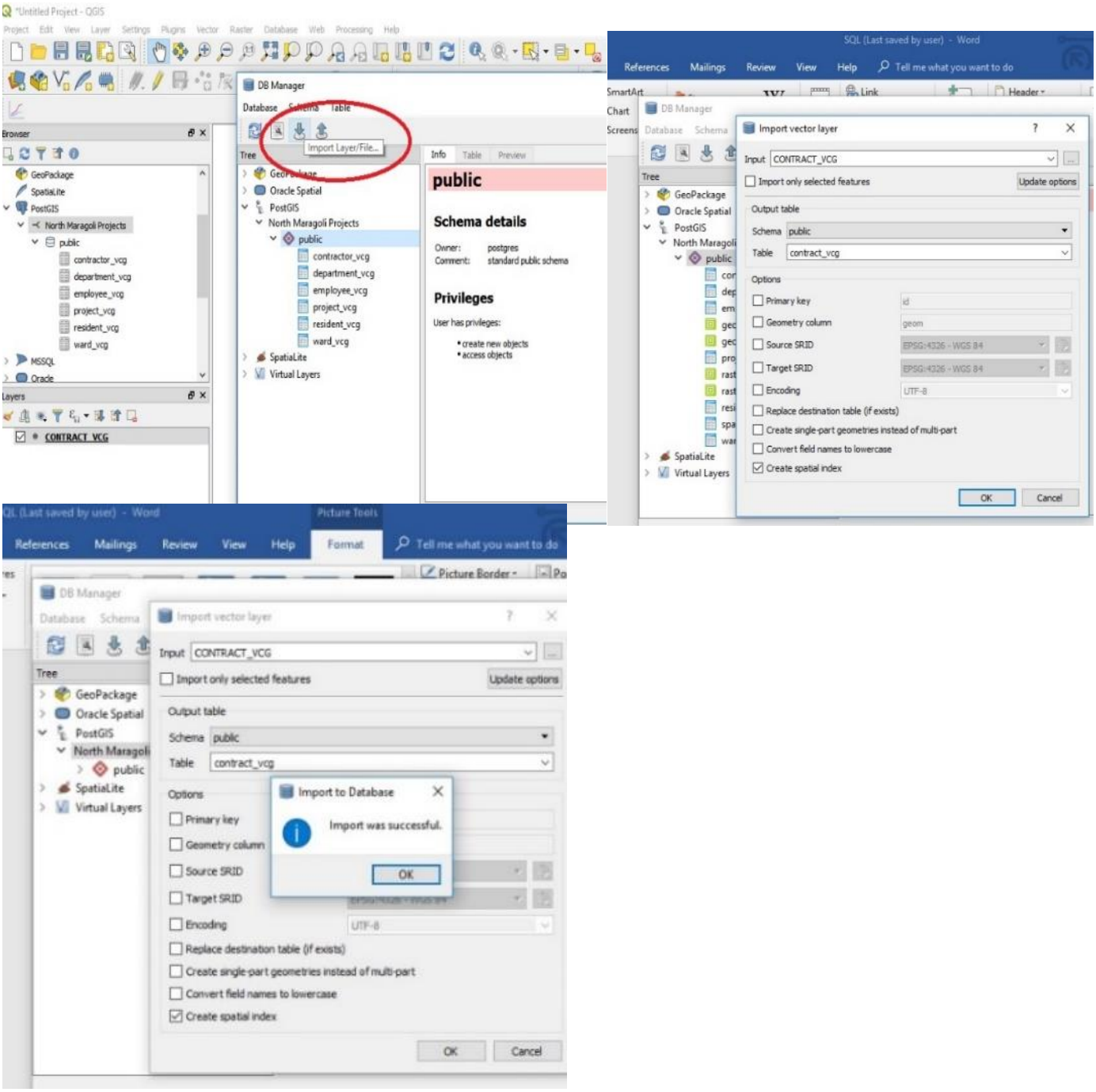


Plate 6: Importing Layer File into (North Maragoli) Database in PostgresSQL

1. *Adding Constraints* into Spatial Table *contract_vcg*

a. Primary Key and Foreign Keys

```
ALTER TABLE Contract_vcg
ADD PRIMARY KEY (CntctID);

ALTER TABLE Contract_vcg
ADD FOREIGN KEY (Ward) REFERENCES Ward_VCG(WardID);
```

2. *Adding New Columns* into Spatial Table contract_vcg

```
ALTER TABLE contract_vcg
ADD start_date date,
ADD end_date date;
```

3. *Updating data* into New Columns

```
UPDATE contract_vcg
SET Start_date = '2017-07-01',
       End_date = '2018-06-30'
WHERE id >= 1;
```

4.1.6 Results

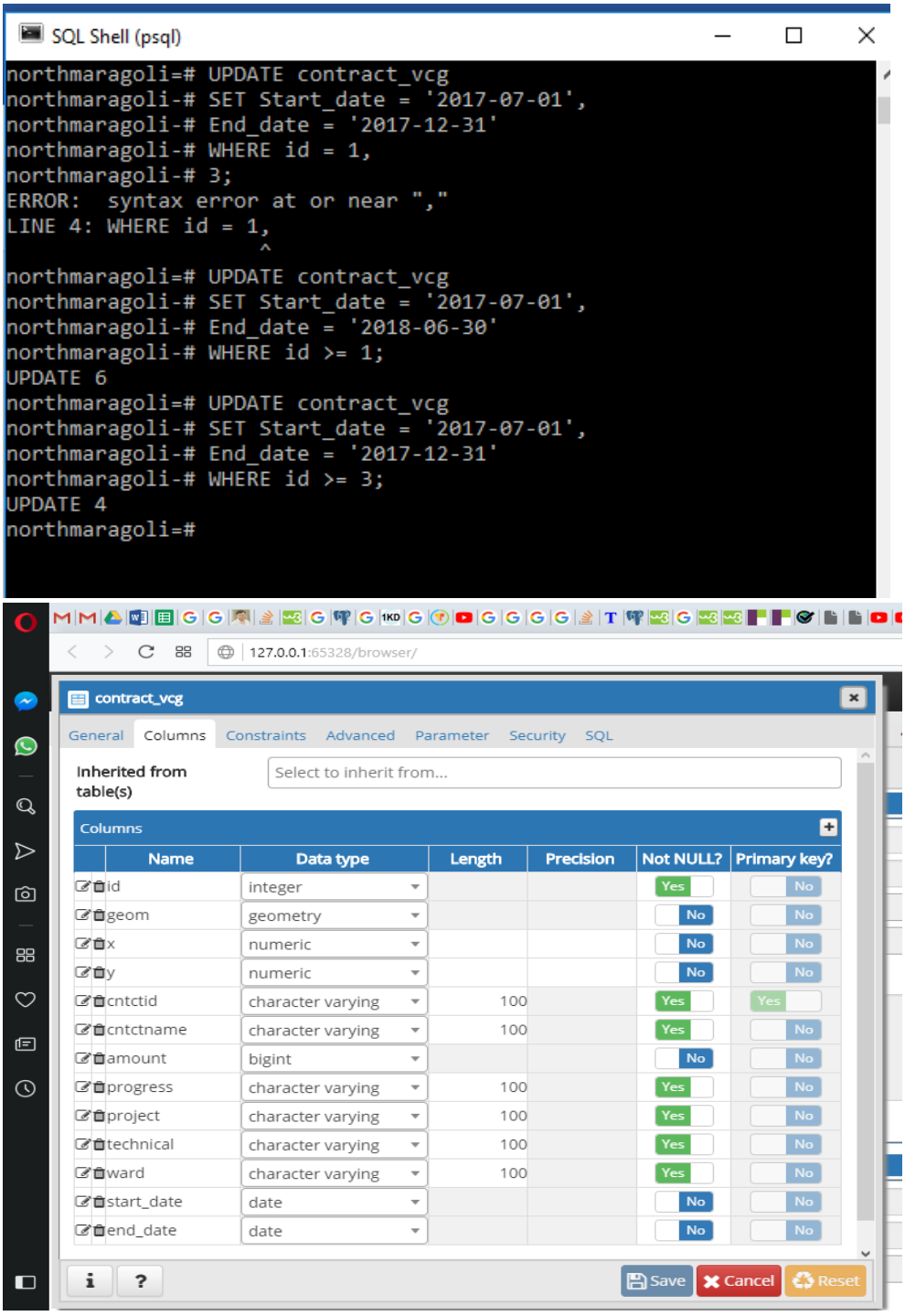


Plate 7: Results for Creating Spatial Relational Tables: Adding Constraints, Adding New Columns and Adding data into Columns

4.2 Generating Digital Layers

GeoServer was used as the Map Server and the Workflow consisted of the following;

i. Creating a new Workspace

This included giving the work space a name and a URI associated with the Project.

ii. Creating New Store

This involved creating a new store and connecting to the Postgis database

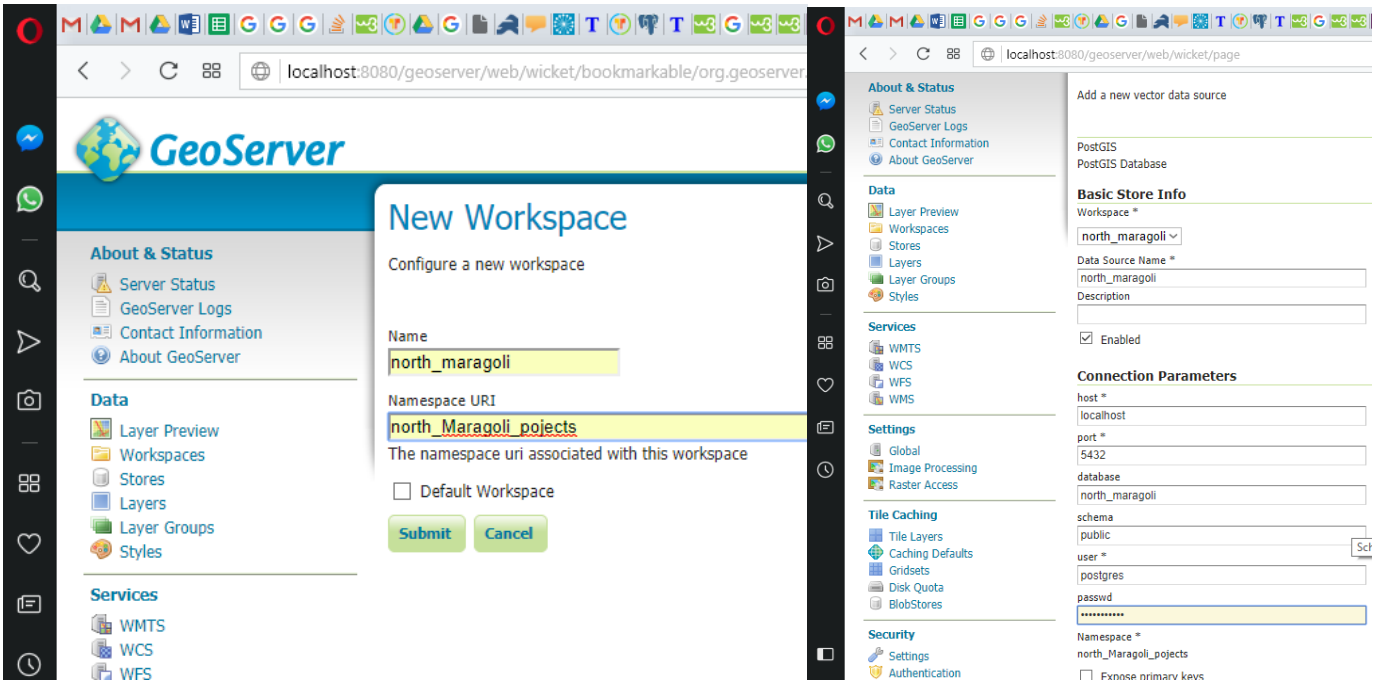


Plate 8: Results for Generating Digital Layers; Creating a new Workspace and Store on Geoserver

The layers were added and ready for publishing

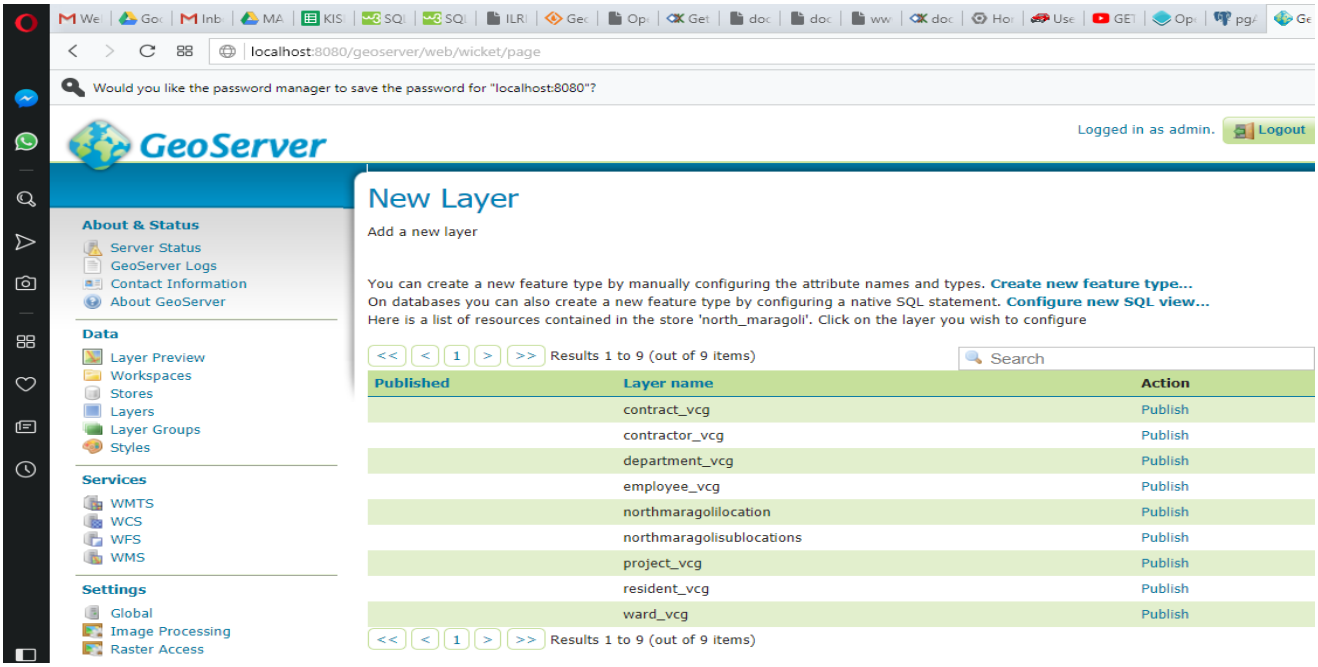
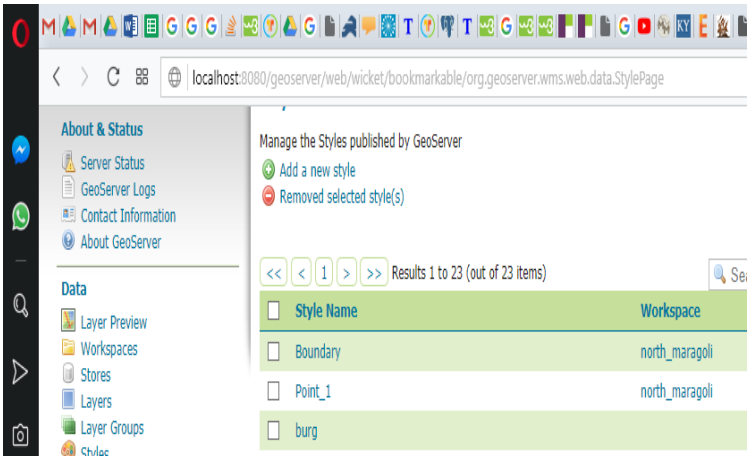
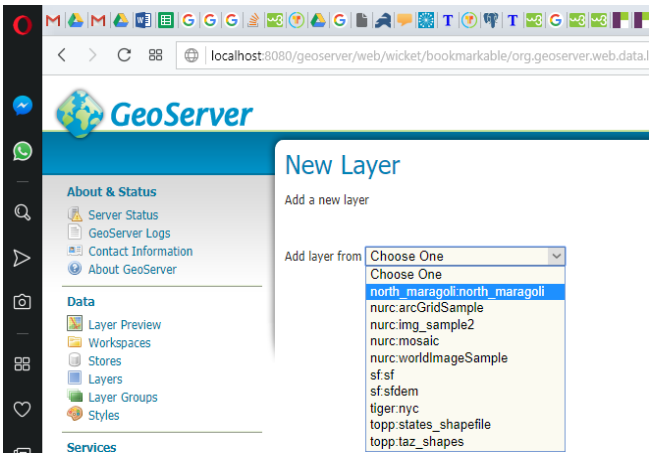


Plate 9: Results for Generating Digital Layers; Adding New Layers on Geoserver

4.3 Styling and Publishing the Layers





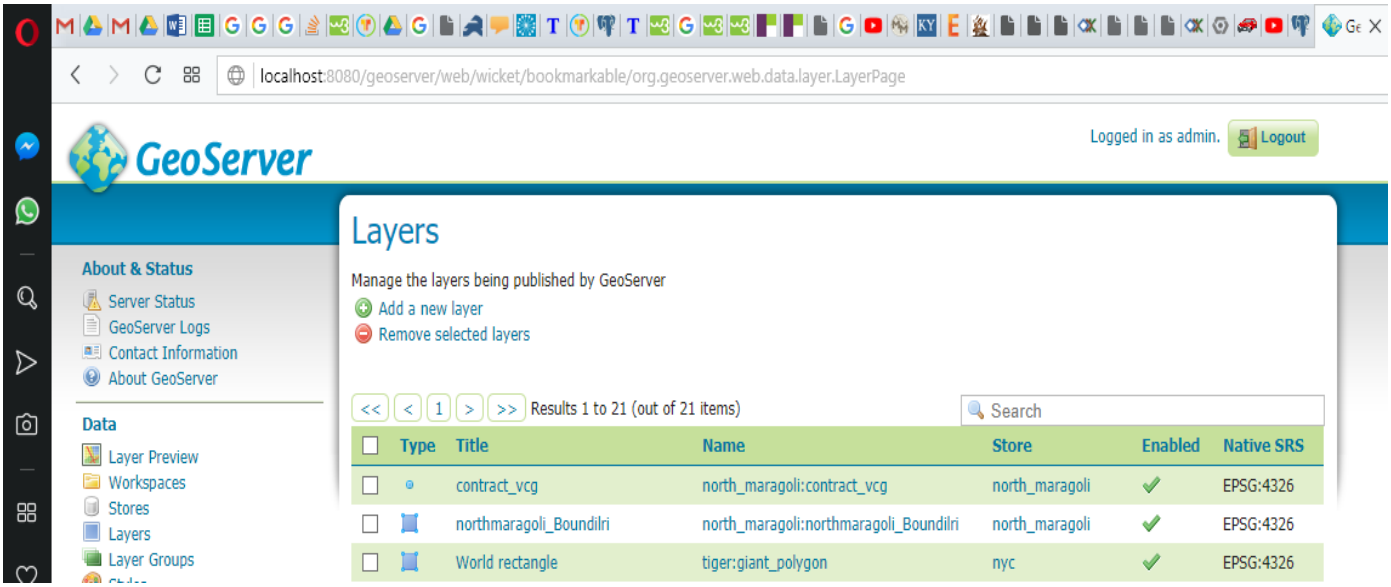


Plate 10: Results for Generating Digital Layers; Styling and Publishing Layers

A preview of how the layers will appear on Open Layers was successful.

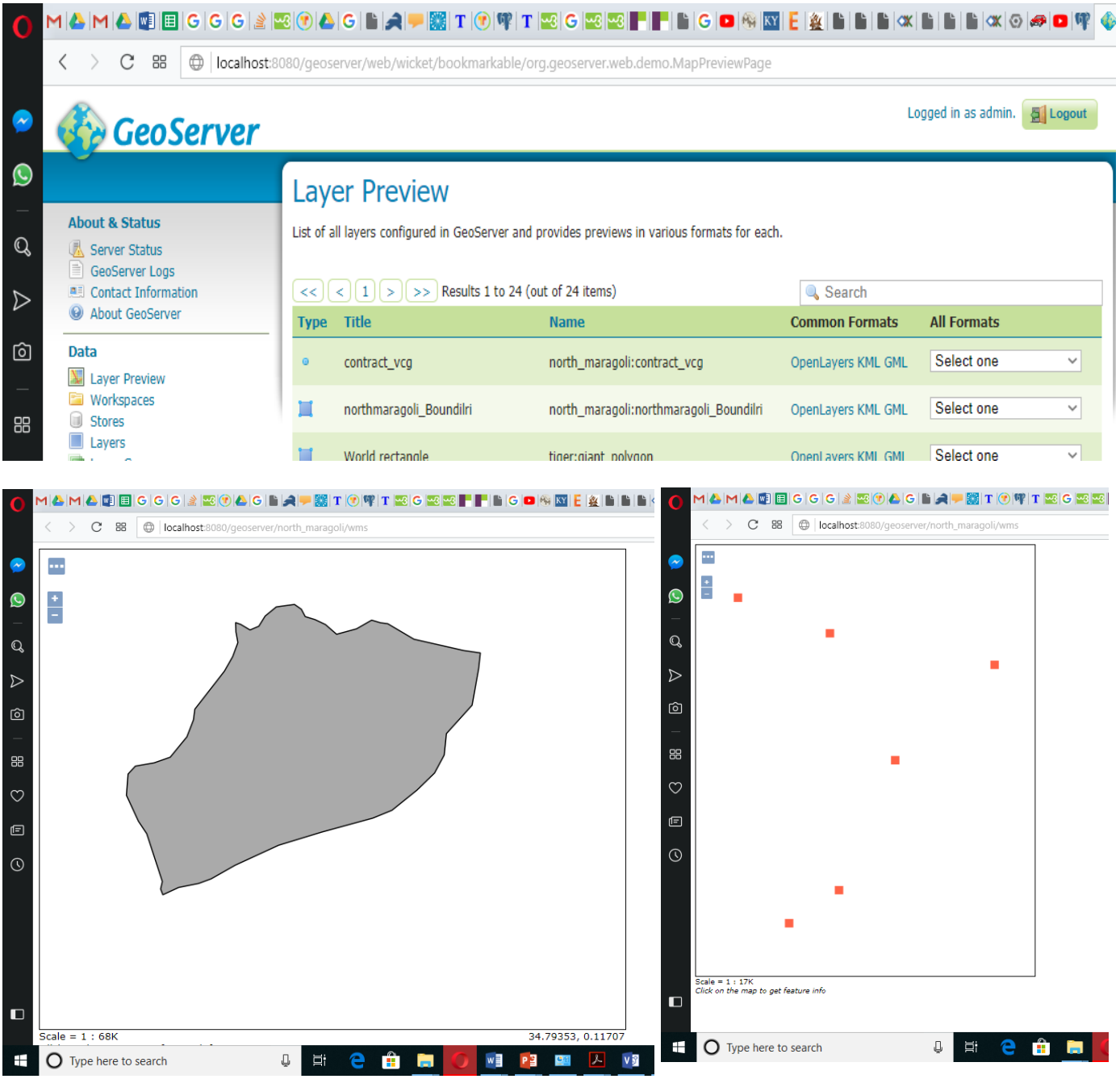


Plate 11: Results for Generating Digital Layers; Styling and Publishing Layers

To verify the spatial projection, the published layers KML files were overlayed on Google Earth.

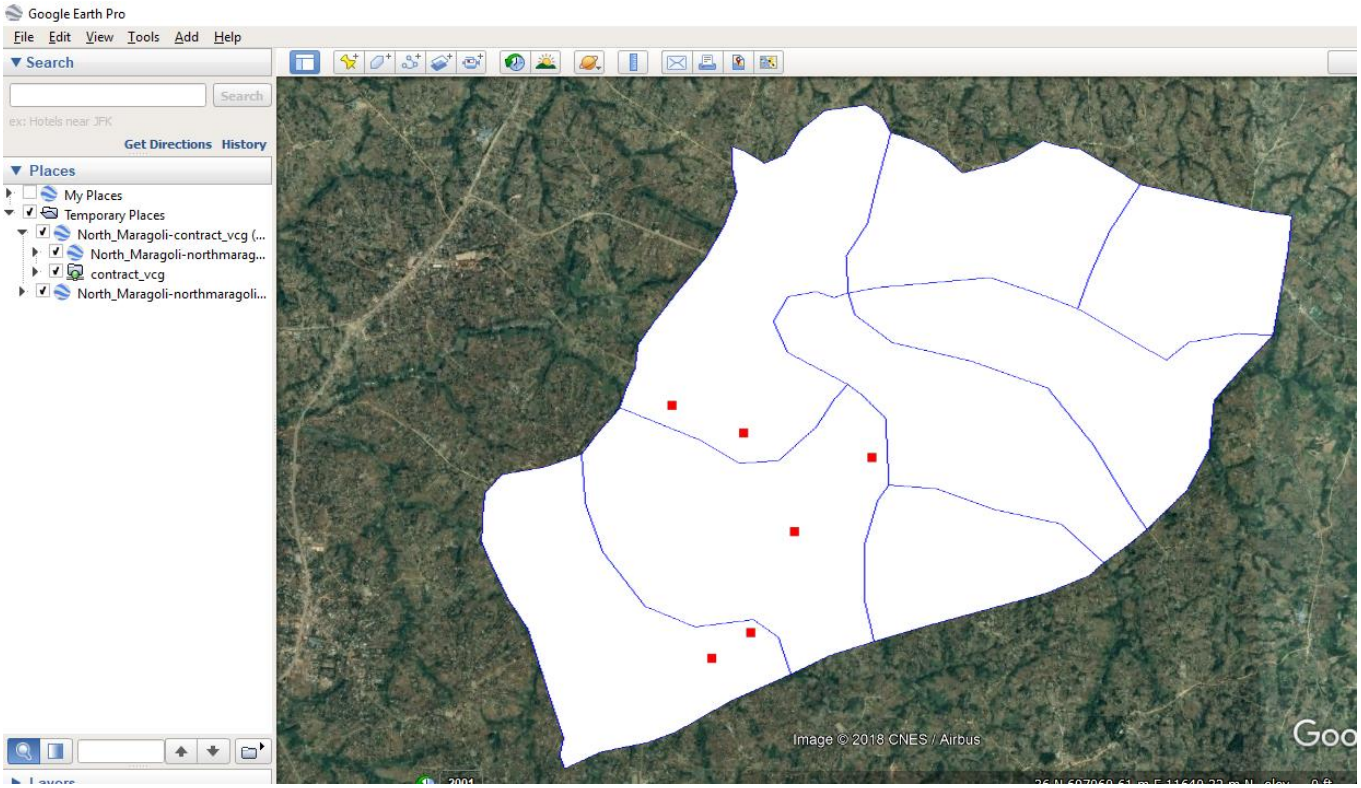


Plate 12: Results for Generating Digital Layers; Verifying Spatial Projection on Google Earth

To successfully display the published layers in an open source web application on a browser, a client mapping library, Open Layers was used. The base layer selected was OpenStreetMap. The following html code was used;

```
<!DOCTYPE html>
<html>

<head>
    <title>Single Image WMS</title>
    <link rel="stylesheet" href="https://openlayers.org/en/v4.6.5/css/ol.css" type="text/css">
    <!-- The line below is only needed for old environments like Internet Explorer and Android 4.x -->
    <script
src="https://cdn.polyfill.io/v2/polyfill.min.js?features=requestAnimationFrame,Element.prototype.classLi
st,URL"></script>
    <script src="https://openlayers.org/en/v4.6.5/build/ol.js"></script>
</head>

<body>
    <div id="map" class="map"></div>
    <script>
        var layers = [
            new ol.layer.Tile({
                source: new ol.source.OSM()
            }),
                      new ol.layer.Image({
                //extent: [-13884991, 2870341, -7455066, 6338219],
                source: new ol.source.ImageWMS({
                    url: 'http://localhost:8080/geoserver/North_Maragoli/wms',
                    params: { 'layers': 'North_Maragoli:northmaragolilocation' },
```

```
                ratio: 1,
                serverType: 'geoserver'
            })
        }),
                  new ol.layer.Image({
            //extent: [-13884991, 2870341, -7455066, 6338219],
            source: new ol.source.ImageWMS({
                url: 'http://localhost:8080/geoserver/North_Maragoli/wms',
                params: { 'layers': 'North_Maragoli:northmaragolisublocations' },
                ratio: 1,
                serverType: 'geoserver'
            })
        }),
                  new ol.layer.Image({
            //extent: [-13884991, 2870341, -7455066, 6338219],
            source: new ol.source.ImageWMS({
                url: 'http://localhost:8080/geoserver/North_Maragoli/wms',
                params: { 'layers': 'North_Maragoli:contract_vcg' },
                ratio: 1,
                serverType: 'geoserver'
            })
        })
    ];
    var map = new ol.Map({
        layers: layers,
        target: 'map',
        view: new ol.View({
            center: [4099485,-142884],
            zoom: 9
        })
    });
</script>
</body>

</html>
```

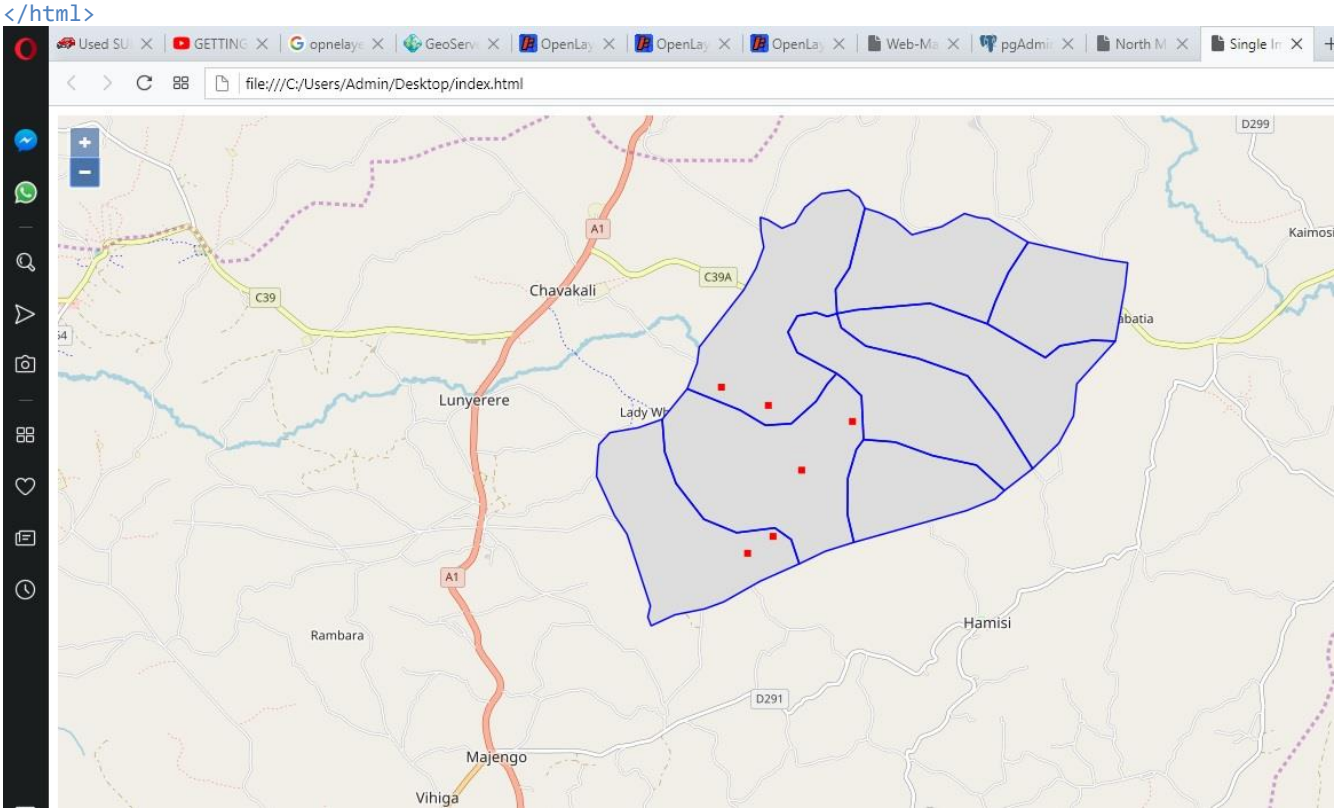


Plate 13: Results for Generating Digital Layers; Displaying Published Layers on an Open Source Web Application.

To effectively develop a web-based spatial information system and deploy the database with capabilities of thin client spatial analysis, Node.js cross-platform for server side programming was used since it can extend and be modified to enable integration into the Postgresql creating a runtime environment capable of executing JavaScript code outside the normal browser. The following Java Script code was used.

```
// USE STRICT
// const myCustomColour =
// var greenIcon = new L.Icon({
//   iconUrl: "images/marker-icon-red.png",
//   shadowUrl: "images/marker-shadow.png",
//   iconSize: [25, 41],
//   iconAnchor: [12, 41],
//   popupAnchor: [1, -34],
//   shadowSize: [41, 41]
// });

// new L.marker(
//   [
//     parseFloat(AllReadingLocations[i]),
//     parseFloat(AllReadingLocations[i + 1])
//   ],
//   { icon: greenIcon }
// )

///// Base map
var OpenStreetMap = L.tileLayer(
  "http://{s}.tile.openstreetmap.org/{z}/{x}/{y}.png"
);
var WorldImagery = L.tileLayer(
  "http://server.arcgisonline.com/ArcGIS/rest/services/World_Imagery/MapServer/tile/{z}/{y}/{x}"
);

///// Configuration de la map
var map = L.map("map", {
  layers: [OpenStreetMap], /// fond de base
  center: [0.081337304, 34.76535228], /// coordonnées
  zoom: 13 //// zoom par defaut
});
var markerset = false;
var markerId;
function addMarker(x, y) {
  if (!markerset) {
    markerId = new L.marker([parseFloat(x), parseFloat(y)]).addTo(map);

    markerset = true;
  } else {
    var newLatLng = new L.LatLng(x, y);
    markerId.setLatLng(newLatLng);
  }
}
/////layers de base
var baseLayers = {
  "Open Street Map": OpenStreetMap,
  "World Imagery": WorldImagery
};

// ///// layers from Geoserver (format WMS)
 ///// layers from Geoserver (format WMS)
```

```
                var mLocation = L.tileLayer.wms("http://localhost:8080/geoserver/North_Maragoli/wms", {
                    layers: 'North_Maragoli:northmaragolilocation',
                    format: 'image/png',
                    transparent: true,
                    version: '1.1.0'
                }).addTo(map);

// ///// layers from Geoserver (format WMS)
 var mSublocation = L.tileLayer
   .wms("http://localhost:8080/geoserver/North_Maragoli/wms", {
     layers: "North_Maragoli:northmaragolisublocations",
     format: "image/png",
     transparent: true,
     version: "1.1.0"
   }).addTo(map);
// ///// layers from Geoserver (format WMS)
 var mContract = L.tileLayer
   .wms("http://localhost:8080/geoserver/North_Maragoli/wms", {
     layers: "North_Maragoli:CONTRACTS_POINT",
     format: "image/png",

     transparent: true,

     version: "1.1.0"

   }).addTo(map);

// ///// layers from Geoserver (format WMS)

 var northMaragoli = L.tileLayer

   .wms("http://localhost:8080/geoserver/North_Maragoli/wms", {

     layers: "North_Maragoli:northmaragoliward",

     format: "image/png",

     transparent: true,

     version: "1.1.0"

   }).addTo(map);

var overlays = {

   "Location": mLocation,

   "Sublocation": mSublocation,

   "Contracts": mContract,

   "North Maragoli ward":northMaragoli

};

//http://localhost:8080/geoserver/North_Maragoli/wms?service=WMS&version=1.1.0&request=GetMap&layers=Nor
th_Maragoli:northmaragolisublocations&styles=&bbox=34.7384834289551,0.0676368549466133,34.8189468383789,
0.133537143468857&width=768&height=628&srs=EPSG:4326&format=application/openlayers

L.control.layers(baseLayers, overlays).addTo(map);
```

The Layers with Capabilities of thin Client spatial Analysis was successfully published as shown

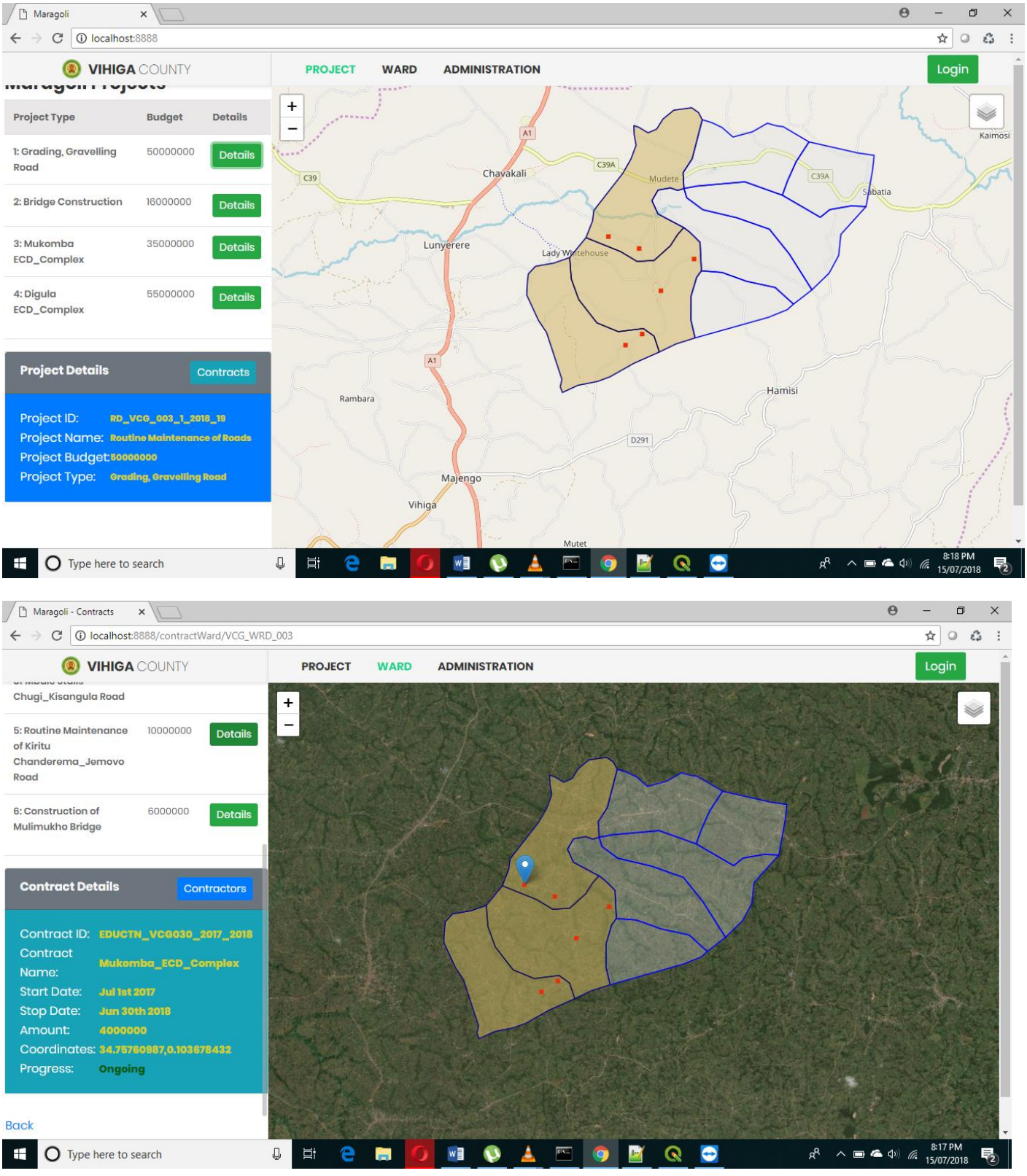


Plate 14: Results for Publishing Digital Layers; Published On A Web Platform with Capabilities of Thin Clients Spatial Analysis

4.4 Discussion of Results.

4.4.1 Identification of Development Projects and Their Integration into GIS Platform.

Although development projects in Vihiga County have not been incorporated into GIS platform, it is important to note that a data collection process has been initiated on every project and a data bank with a database will be created. This study identified projects taking place in North Maragoli Ward through field data collection. The attribute data collected in turn informed the development of the relational database system.

Plate 15: Example of Contract Information from the field, Source Authors Field Data, 2018

4.4.2 Creation of a Centralized Database Containing Spatial and Non-Spatial Data Of Development Projects in North Maragoli Ward, Vihiga County.

Once Data was collected from the field, a centralized database was designed and created. This database can be expanded and used by the County Government in management of all their development Projects data effectively leading to the following:

i. Mass storage of Data
ii. Removal of Duplication due to the mass data available
iii. Allow multiple users to access and view the database at different access levels.
iv. Ensure Data protection since data can be stored on different servers.
v. Provide integrity of Information
vi. Assure Platform Independence

4.4.3 Generation of Digital Layers that Connect to the Centralized Database for Spatial Information Management For Monitoring and Evaluation.

The study was able to achieve this objective and the digital layers that connect to the centralized database were successfully generated. This demonstrates the ability of the digital layers to be expanded to cover a wider geographical area to the extent of the entire county and link the digital layers to data contained in the centralized database.

4.4.4 Publishing Digital Layers on a Web Platform with Capabilities of Thin Client Spatial Analysis.

The study was able to publish the digital layers on a web platform successfully using Node.js which is a free and open source cross platform for sever side programming that allowed the building of the spatial information system. This approach enabled querying of non-spatial data from Postgresql, compilation of

the queried results into an html page and publishing/displaying of the results on the Web Browser using command prompt. The published results were on a hosted locally. However, to allow multiple users Local Area Networks, Wireless Local Area Networks and Wide Area Networks can also be used. A query form/tab for thin client spatial analysis was also created and tested to show queried results.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion.

The study has shown that it is possible to develop a web based spatial information system for monitoring and evaluation of development projects in North Maragoli Ward using open source software. This web-based spatial information system for county development projects offers an integrated information retrieval for monitoring and evaluation of projects taking place in North Maragoli. The spatial information system allows for non-spatial data about the projects to be incorporated as relations into a centralized database that is relational and managed using a Database Management System (DBMS). Finally, thin client spatial analysis tools for querying information were developed and integrated into the system.

The biggest challenge in developing the system was experienced in data collection due to the expansive and unfriendly terrain of the study area as well as reluctance in sharing project information by county officials visited. This presents an opportunity for exploration in enhancement of information sharing especially concerning public projects.

5.2 Recommendations.

Although this was an academic scientific study with North Maragoli as the study area, the successful results of this study can be implemented beyond the academic scope. It is important to note that, the choice of Vihiga County as a study area is due to the Government's commitment on using GIS in management of all county government affairs. Therefore, the spatial information system in this study can be explored as part and parcel of the County Government's plans on GIS and is highly recommended for adoption by not only the County Government of Vihiga but other County Governments as well. This study therefore recommends further studies in development of an information system that incorporates all projects from National Government, County Government, Constituency Development Fund, donor funded and private sector in an effort to provide a single platform where this information is publicly available with an aim of eliminating duplication of projects and enhancing information sharing for development and efficient use of resources.

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