University of Nairobi

School of Engineering

DEPARTMENT OF GEOSPATIAL AND SPACE TECHNOLOGY

Development of a Web-based Informal Cadastre for an Informal Settlement in Nairobi

A Case Study of Mukuru Sinai Settlement

By

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DECLARATION

I Tom Mumo Okongo, hereby declare that this project is my original work. To the best of my knowledge, the work presented here has not been presented for a degree in any other University.

TOM MUMO OKONGO …… …..…….

Name of Student Signature Date

This project has been submitted for examination with my approval as university supervisor.

Mr. JASPER N. MWENDA ……..…….. .....……

Name of supervisor Signature Date

DEDICATION

I dedicate this project to my wife Barbra, my son Charles and my mother Felister Ndindi

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Foremost I thank the Almighty God for the good mind, health and strength to undertake the course and the project. He made way when there seemed to be no way and refreshed me throughout my study period. I acknowledge the assistance and support of my supervisor Mr. Jasper Mwenda with honor and gratitude. His constructive encouragement and willingness to give important advice were consistent.

I am greatly indebted to various authors whose publications I have used and also cited. I commend them for their superb works, which have enabled me to work on this project. Special thanks to my classmates, for being so supportive and of great encouragement to my academic life. Memories of the great times we bonded will forever be in my mind. Lastly, I give sincere thanks to my mother Ndindi for being a mum with a difference throughout, and my wife Barbra for her love and emotional support.

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LIST OF ACRONYMS

KENSUP: Kenya Slum Upgrading Project

KISIP: Kenya Informal Settlement Improvement Program

GLTN: Global Land Tool Network

SDGs: Sustainable Development Goals

UN: United Nations

PAP: Project Affected Persons

OGC: Open Geospatial Consortium

WFS: Web Feature Service

WMS: Web Map Service

WPS: Web Processing Service

PHP: Hypertext Preprocessor

HTML: Hypertext Mark-up Language

CSS: Cascading Style Sheets

HTTP: Hypertext Transfer Protocol

ABSTRACT

Informal Settlements are commonly found in urban areas in developing countries. They emerge due to inadequate housing that is affordable to the many migrants moving to the city in search of employment and business opportunities. The settlements face the challenge of security of tenure. The existing records which constitute their manual informal cadastre of the settlement are usually manual and incase of fire they easily get destroyed. Developments in the web and mapping technologies have created the drive towards building web based systems for information management and for visualization. The main objective of this project is to develop a web based informal cadastre for an informal settlement. It aligns the settlement into the continuum of rights with an anticipation of upgrading by the government in the near future. The study developed a Postgres/PostGIS database, used open geospatial technologies to create a web mapping application which was hosted online on a web page domain where the informal cadastre was accessed. Test results of the Web-based Informal Cadastre indicated that it was possible to search a structure in the settlement using a structure number, users were able to view and download data, and update of the attribute data of a structure online.

CHAPTER 1: INTRODUCTION

1.1 Background

A major feature nowadays in most of urban areas in developing countries is the presence of informal settlements. They proliferate as more populations are moving to the cities in search of employment opportunities. Lack of adequate and low cost housing leads many to move into informal settlements where residential structures exist and at a low rent. Even as industrialization is increasing in most African countries, the remuneration for the workers remains low and they end up settling in the informal settlements near the industries where the cost of living is low (Karanja and Makau, 2008). These settlements are dynamic in their existence (Wayumba *et al.*, 2015) as their populations grow and residents constantly immigrate and migrate. This nature is motivated by the fact that most of the informal settlements exist on land whose ownership is not by the residents (Odongo, 2017) resulting in insecure tenure.

At the onset of the 21st century Kenya responded to the challenge by partnering with the UN-HABITAT and as a result came up with the Kenya Slum Upgrading Project (KENSUP). Later on after the incoming of a new constitution Kenya initiated another program to complement KENSUP – Kenya Informal Settlement Improvement Program (KISIP) (Anderson and Mwelu., 2004). Despite these projects informal settlements continue to exist and experience insecurity of tenure and related problems. Studies show that, in Sub-Saharan Africa, more than 60% of urban dwellers live in informality and poverty (GLTN, 2015). Enhancement of tenure security in the informal settlements would improve the livelihoods of the residents which is in line with the Sustainable Development Goals (SDGs) goal number 11 target 11.1 (UN, 2015). Web technology developments are providing platforms for developing land information systems for handling Cadastral operations and this comes with benefits of increasing access to the cadastral services by different interested stakeholders as well as users.

Development of an informal Cadastre for the settlement which is accessible on the web would enhance access of information on the settlement by stakeholders involved in projects as well as the residents and improving livelihoods. This is part of the information systems that enable the residents of the settlement to some form of tenure security and offer a record of their operations

that are useful to decision makers when carrying out settlement upgrading (UN Habitat, 2003). The study area for this project is Mukuru Sinai settlement. The settlement is located in Nairobi County, Makadara Sub-county, in Viwandani ward. It emerged in 1980 as a result of displacement of residents of Kayaba by factory construction (Karanja and Makau, 2018). The land under the settlement is on an electricity wayleave. Sections of the settlement that were under the pipeline and railway reserves were cleared to pave way for the companies to undertake their planned developments on the land. The locational map figure 1 shows the selected study area.

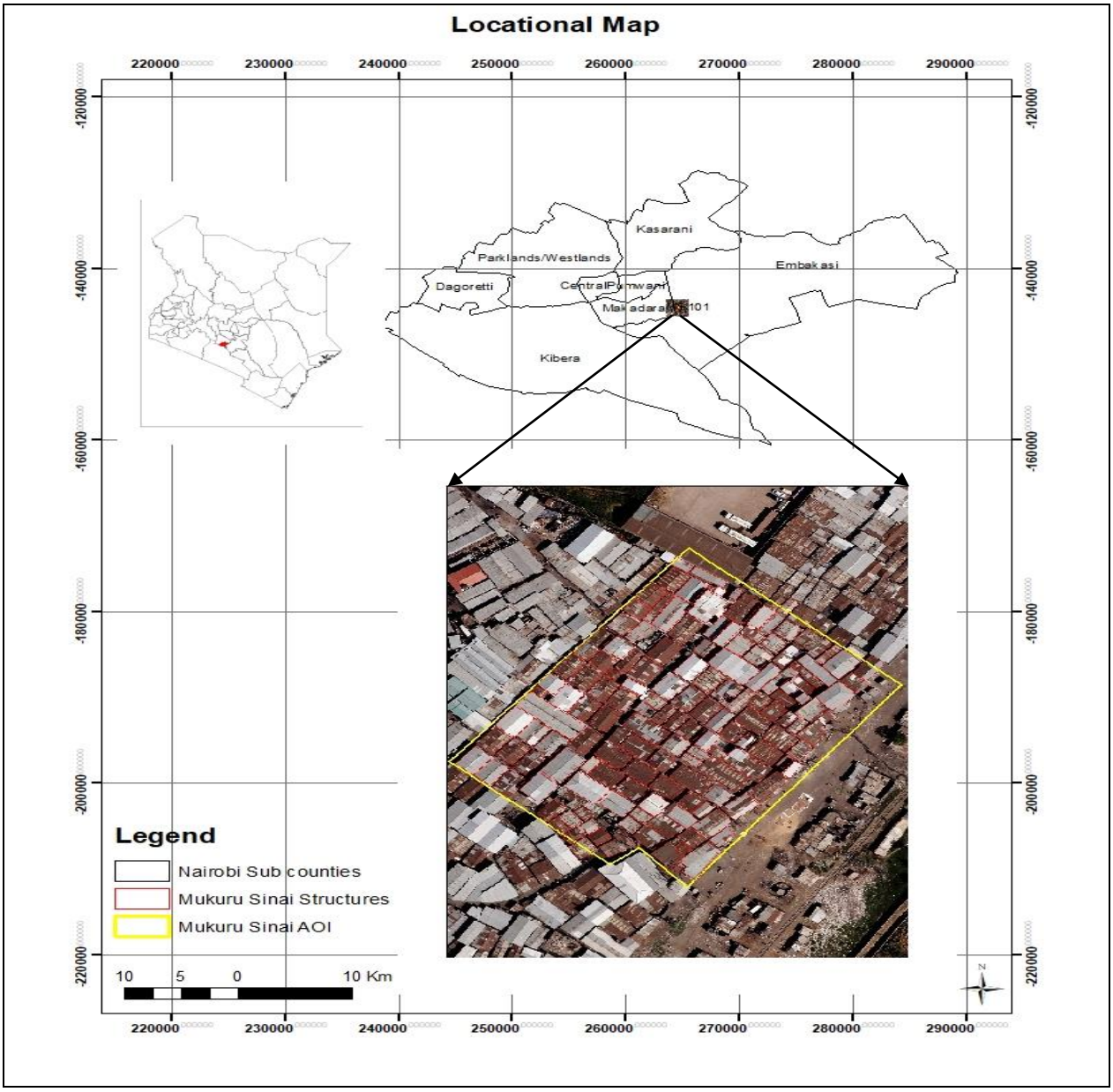

Figure 1.1 Locational Map (Source, Own)

1.2 Problem Statement

As the City of Nairobi grows with more populations, the presence of informal settlements remains evident in all its surrounding residential areas. The settlements host more than half of the city residents. At the centre of problems that the dwellers in these informal settlements face is insecurity of tenure. Despite the introduction of the eviction guidelines (GoK, 2009) there are still reports of evictions. Studies show that insecurity of tenure is closely linked to poverty and therefore enhancement of tenure security is one of the ways to improve livelihoods in these settlements (Williamson, 2015; Durand-lasserve and Selod, 2007). The informality in Mukuru Sinai, arises from the absence of land ownership by the residents. This has resulted in the rise of challenges whenever programs on improving sanitation and provision of social amenities are intended to be carried out in the settlement. In one of the projects on relocation programme by World Bank to pave way for the Railway reserve, there were challenges in establishing the persons affected by the project (PAPs) and the process led to slow accomplishment of the project. It resulted in court cases where records were tempered with and non-residents included in the list of PAPs.

Informal settlements have a number of informal transactions that occur regularly. These are the transfer of ownership of the structures by informal sale agreements, clearing of the structures to pave way for replacements of the power poles, and change in the type of structure to add entry storeys on the existing one. Records of the transactions are kept in manual files which are stored by the settlement elders. In case of a fire break out in the settlement, these records can be destroyed hence creating the possibility of disputes when restoring the structures. It also becomes difficult to establish the affected persons in such times. The design and development of a web-based informal cadastre for the settlement will enhance the transparency of the transactions in the settlement and ensure that records are accessible to residents, stakeholders of different projects that offer basic amenities - provision of last mile electricity connections - as well as enable future projects within the area to be carried out with ease. The Web-based Informal Cadastre becomes a basic entry into the continuum of rights (GLTN, 2015) with anticipation of future upgrading of the settlement through the government KISIP project.

1.3 Objectives

The main objective of this study is to develop a Web-based Informal Cadastre for Mukuru Sinai Settlement in Nairobi County.

The specific objectives are namely to:

a) Design an Informal Cadastre for Mukuru Sinai Settlement
b) Develop a Web-Mapping Application for Mukuru Sinai Settlement

1.4 Justification for the Study

The proliferation of informal settlements in the urban areas in Kenya has been on the rise since the beginning of the 20th Century. This has been due to increased populations living in the urban centres and it gives rise to other needs on provision of basic amenities. Populations within the informal settlements are usually not controlled and keep on increasing as long as there are available structures to reside in. Tracking of the records of residents of the settlement is usually a difficult task and this opens the challenge of insecurity. It also becomes difficult to plan for the residents in terms of provision of the services needed. The Kenya Power and Lighting Company has been connecting informal settlements to electricity through *Stima Mtaani* programme, part of the Last Mile Connectivity project which aims at connecting 70% of the population to electricity with Mukuru Sinai being a beneficiary. Establishing the number of structures was a visible challenge which left a number of structures unconnected to electricity. The informal cadastre will enable the company to determine the number of structures to connect to. This in turn will build the economy of the settlement by supplying reliable electricity to small business in the settlement.

Dynamism in the informal settlements is common due to their nature and the tenure insecurity involved and absence of a transparent informal cadastre. This study seeks develop a web-based informal cadastre, useful to access records of the residents of the settlements, virtually to users. It will offer a number of benefits to the settlement including, enumerating the residents of the settlement which in return is useful for planning and future upgrading of the settlement. This would support of KISIP programmes which might probably be extended to this settlement after the selected pilot settlements are completed (Anderson and Mwelu, 2004). The project when

replicated in the other informal settlements in Nairobi County, will be useful when planning on programmes relating to upgrading and development. The residents of the settlement will use the informal cadastre as an entry into the continuum of rights.

The settlement is occasionally affected by fires which destroy structures and cause challenges in identification of affected persons or households especially when there is need to provide help to victims. Rescue team from the fire station usually find difficulties accessing the different parts of the settlement due to absence of a reliable map. Therefore the presence of a map with access routes to the settlement would ensure efficient movement to access locations within the settlement. Organizations that offer support in times of disaster including the Kenya Red Cross would be able to access the web informal cadastre and approximate the number of people affected as well as the required items to support them. Organizations that have running projects in the settlement will also benefit by using the web-based informal cadastre to locate and track progress of their projects.

1.5 Scope and Limitations of the Study

The study involved design and development of a web-based informal cadastre for Mukuru Sinai Settlement. The structures of the settlement in this project were used to form the spatial unit in the informal cadastre and thus forming the basic unit. The ownership details were of residents of the structures in the settlement. The open source mapping and web-mapping technologies were used to design the web page for the Informal Cadastre and create the web application for access via internet.

1.6 Organization of Report

Chapter one is the general introduction of the project, problem statement, the objectives and justification of the study as well as its scope. Chapter two is made up of the literature review of the themes in the study. Chapter three presents the study area, the methodology applied to meet the project objectives, the materials used, and the test of application functionalities. Chapter four is made up of the results of the project and Chapter five is the conclusion which summarizes the project, outlines the conclusions made in the study as well as the recommendations.

CHAPTER 2: LITERATURE REVIEW

2.1 Definitions

In carrying out the literature review of the project the following were main definitions of interest.

2.1.1 Informal Settlements

A description of informal settlements has not been fully developed and different authors and organizations have defined them with regard to what they are, and their characteristics. The global organization concerned with human habitation and settlement - UN Habitat - categorizes informal settlements into two; squatter and illegal land development settlements (Lamba, 2005). Squatter settlement being where land has been occupied without permission of the owner; and the latter where occupation is legal but unauthorized land developments have occurred (i.e. building extension without building permits, change of land use that breach zoning plans, subdivisions without regard to services and infrastructure).

South Africa has dealt with informal settlements in different contexts for a while leading to publication of a handbook. According to the Informal Settlements Handbook of the Western Cape Department of Housing and the City of Cape Town informal settlements are 'residential areas that do not comply with local authority requirements for conventional (formal) townships.' They are often termed as squatter or unplanned settlements. They occur in land which has not been designated for residential use. They proliferate due to the fact that urbanization is faster than the ability of government to provide residential land, infrastructure and homes. Sessional Paper No 3 of 2009 Land Policy (GoK, 2009) outlines the essence of informal as the absence of security of tenure and planning.

Nabutola (2004) refers to an informal settlement as a dwelling put up without authority of the owner of the land, usually without a formal design and without conforming to any specifications in the existing laws and regulations in the country they are in. The settlements lack access to electricity connection, clean water and sewer line. Public infrastructure especially roads and railway are rare. In the case of Mukuru Sinai, the access road to the settlement is Lunga Lunga road which is also made to service the industries. The railway only passes through the settlement

without a station nearby. Connections to electricity have not been done and access to sewerline and remains a dream. There is no security of tenure to land and entry into and development in the settlements is easy and unregulated.

This project focuses on informal settlements that lack tenure security. The definition adopted outlines that informal settlements are dwellings put up on a piece of land without permission/authority of the owner or without conforming to the conventional system of the country. They are characterized by shanty structures and rare social services (Nabutola, 2004).

2.1.2 Cadastre

A Cadastre refers to up to date parcel based land record which captures the interests in the parcel commonly known as the 3Rs (FIG, 1995). These are the rights, restrictions and responsibilities that exist on the each of the basic unit (parcel).

2.1.3 Informal Cadastre

An Informal Cadastre refers to a type of cadastre that considers interests on land without necessarily aligning to the conventional land recording system (Odongo, 2017). In this case the basic unit of the Cadastre is not necessary a land parcel. In this study this concept is applied to capture the structure in the settlement as the basic unit upon which rights are enjoyed.

2.2 Emergence of informal settlements in Kenya

A common driving force behind the growth of informal settlements is the desire for many people in countryside to move to the urban areas to seek employment and business opportunities. In the cities especially within developing countries, low cost housing is usually inadequate. In Kenya informal settlements date back to the colonial period when the British colonial government introduced policies on containment, labour supply, public health and racial segregation of the natives in reserves and occupying the White Colonial Settlements. In case of Nairobi, informal settlements have gradually grown since 1902 when the city was founded (Syagga et al., 2001). Efforts to clear (demolition of slums in Nairobi 1970) the slums have been in place since independence. Demolitions were later replaced by the upgrading concept. The concept has been adopted although the reality on the ground is that the slums remain and have actually thrived and grown in size and numbers.

2.3 Types/Categories of informal settlements

Informal settlements in Kenya can be classified in four broad categories depending on the land tenure system and history of evolution of the settlement:

(i) Informal Settlements situated on government land;

These are settlements located on land that has not been alienated or allotted to anyone. In the current devolved system of governance the land belongs to the county government. Examples of such informal settlements in Nairobi include Mathare, Kibera, Huruma and Kariobangi. Such areas, tenure security is lacking and other utility services are rare.

(ii) Informal Settlements on private land;

This category comprises settlements developed on land belonging to private citizens and the inhabitants have no ownership rights whatsoever. Such settlements in Nairobi include Mukuru Kwa Njenga, Mukuru Kwa Reuben and Mathare.

(iii) Settlements on indigenous land;

These informal settlements arise in areas where urban centers expand quickly and overtake what was indigenous freehold land. This almost always happens without consent from indigenous inhabitants. In Kenya these settlements include the ones in Kisumu (Manyatta, Nyalenda, Obunga and Dunga). Such areas, tenure security is already secured through land adjudication and in most cases owners have been issued with title deeds. The only problem is that original owners are long dead and descendants have not transferred ownership.

(iv) Settlements on private land owned by absentee Landlords.

These kind of informal settlements are peculiar at the Coastal region in Kenya. The land where the settlements are located is owned by absentee landlords[1] mostly of British or Arab origin and also Kenyan politicians. This situation was created in the Ten-mile Coastal strip, when in 1908,

[1]Absentee landlords are owners of land who were issued with certificates of ownership and they went away and rarely visit the land.

unclaimed land was declared government. Successful claimants were issued with certificates of ownership and who are forestated above.

2.4 Web Mapping Technology

Web mapping is highly supported by the availability of internet platform. Applications are developed and availed on the internet where users can access services available of these applications. Data for the services are stored on the web server and requests are made through web browser by clients using Hypertext Transfer Protocols (HTTP). Web technologies are supported by the framework of the Open Geospatial Consortium[2] (OGC) which has standards for open geospatial and location based services. The standards are based on the International Organization for standardization (ISO) ISO/TC211. Services that follow the OGC standards are Web Map Services (WMS), Web Feature Services (WFS) and Web Processing Services (WPS). This study uses this technological framework to develop a Web-based informal Cadastre which offers the search service to clients with results showing contents of data stored in a geodatabase connected through the internet on a web server.

2.5 Case Studies on Web based Cadastre Projects

The growth in geospatial technologies that are available have enabled more research to explore on ways to manage land information digitally. Land information is shared through web services and countries globally are actively involved in developing systems that support online land transactions. In this sub-section there are a number of case studies where web based cadastre and land information systems have been researched on and prototype systems developed. In this study the methods used to develop the web based systems and benefits they offer are discussed.

2.5.1 Development of a Web-based Cadastral Survey Project Management Information System in Support of the Lands Management Bureau of the Philippines

The Department of Environment and Natural Resources (DENR) spearheaded the implementation of the project which came following an Executive Order No. 192. The project

[2] The Open Geospatial Consortium (OGC) is an international not for profit organization committed to making quality open standards for the global geospatial community.

aim being to provide immediate and substantial benefits to the poor as cadastral survey of the entire country was to be completed based on the Cadastral Act of 1913 and Public Land Act of 1936. A complete cadastral survey was to provide comprehensive data on resources, for land management and speed up land related projects for the people. A web based system to manage the projects was proposed to actualize the project.

The system development involved the following steps:
(a) System analysis;
(b) Database design;
(c) System design and development;
(d) Evaluation and modification; and
(e) Integration and operationalization
On completion the system enhanced transparency, improved project planning and productivity (Vicente, 2014).

2.5.2 Web Based Land Information System for Nintavur Divisional Secretariat Division (DSD) – Sri Lanka.

The study was to show how open source geospatial technologies are usable in development of a Land Information System and also create a framework for a Web-based GIS for the Land Information System. The Web based system was used to improve efficiency in land management and to hasten decision making process in land disputes. It explored the use of HTML, CSS and JavaScript to develop the client-side viewer and a combination of PHP scripting language, Map Server and Postgres SQL database to develop the WebGIS Land Information (Kaleel and Zahir, 2016).

The resultant Web GIS system had client viewer and several server components. Client viewer was designed using HTML, CSS and JavaScript. The Map Server was to handle client requests and perform map service functions. The Web GIS offered feature services, navigation services and map display and in so doing enabling faster decisions on land issues by the administrators at the Division.

2.5.3 Web based Cadastral Information System for Land Management, Nigeria

The study was carried out to analyze the cadastral information management process in Ekiti State, Nigeria. A Web based prototype was developed based on a survey on the desire by professionals and public users towards access of information and services on the web through web browsers. The overall objective being to ease access to cadastral information by public users and improve on participatory approach in land management (Taiwo *et al*, 2016). The system allowed professionals to log in on personalized pages, this would be accessed from the links on the homepage. Data used for the research and its accomplishment was in the following layers;

a) Ekiti State Boundary
b) Ekiti State Land Governance Assessment Boundary map,
c) Road map
d) Towns and
e) Parcel Layer.

The results of the research showed that if embraced, the system would benefit land owners in hastening the procurement process. The professionals would benefit by facilitating easy and faster land registration and management. Finally the government would benefit by having reduced land disputes thus saving costs of solving such cases.

2.5.4 Web based Land Information System for Guwahati City, India

Following the increase population and more upcoming urban areas in India, incidences of unplanned development activities emerged. In order to address this challenge, the city of Guwahati was selected as the area of study and a digital database accessible on the web was developed base on the approach of integrating Remote Sensing and GIS. The resulting Land Information System was then designed in web supported format (Sarma *et al.*, 2003). The data used for the study was; Satellite data in digital format, Analog data in the form of maps and, field data collected from various sources.

The methodology applied involved, digitization of the city cadastral map, processing of satellite data and its classification, ownership information of plots in the city were assigned accordingly and these formed a database. It was then converted into a web supported format. As a result it made it more accessible by many users and more efficient. It also had ability to offer multiple

query facilities where users could concurrently information on any plot of interest. In overall the web based system offered a platform for data extraction useful in decision making and in the city (Sarma *et al*., 2003).

2.5.5 Web based Information System for Aboriginal Land Management, Canada

Land Management in Aboriginal territories was enhanced by the development of a web-enabled spatial information system that provided a platform for access and analysis of land management information by interested users. Methods used to build the prototype were based on ArcIMs which served as the spatial server. The area selected for the project was Yukon where data was available. The steps taken for the system implementation were;

a) User requirements analysis,
b) Data collection,
c) Data processing,
d) Database design and updating, system architecture design,
e) Users interface design,
f) Map hyperlinks and lastly
g) Query implementation.

Data collected composed of spatial data and parcels attribute data within the territories. The developed prototype allowed users to interactively access services such as, browse, analyze and share information pertaining to the land use in the territories through the client viewers created (Mao *et al.*, 2005).

2.5.6 Web based Geo-Spatial and Village Level Information Extraction System using FOSS, India.

Majority of the population in India reside in the rural areas. This comes along with the need for cost effective geospatial tools. The use of open geospatial tools was a fit for purpose as well as being cost effective to the population (Kodge and Hiremath, 2012) in developing the web based information system. In this study, the free open source software tools used were the GeoServer with a set of Apache web server, POSTGIS and POSTGRESQL for the spatial database, and PHP which facilitated the querying of the database. The web based spatial information system

was developed through the GeoServer and tested at local network http://localhost:8080/ GeoServer port.

The system developed had the following advantages to the users;

i. Centralized control over data and model, this lowered the costs in system operation and maintenance
ii. It offered simple user friendly interface for access by the users without need for professional GIS knowledge
iii. The system also enhanced stakeholders and public participation in planning and decision making process.

In this case study it emerged that the use of open geospatial tools offer an advantage to data analysis which help in providing a new dimension of data during the decision making process for complex problems. The open source tools lower the cost of building systems as they are capable of being modified to user need.

2.5.7 A Web-Based Pilot Implementation of the Africanized Land Administration Domain Model for Kenya - A Case Study of Nyeri County

The project was aimed at customizing the Land administration domain Model to suit the Kenyan context in a pilot system. The web-based system captured the process of change of user as an example of the processes in land administration in Kenya. The system was anticipated to reduce the common errors experienced under the paper-based system therefore improving confidence of clients that visit the land offices seeking services on land administration processes (Kuria et. al., 2016)

CHAPTER THREE: MATERIALS AND METHODS

3.1 Introduction

This chapter describes the materials used for the study, the methods and procedures adopted to carry out the study. The sub sections include the materials needed, the data collection and preparation, the technologies required in carrying out the project, the analysis done on the data and the end generation of results of the study.

3.2 Project Data Requirements

This study in developing an informal cadastre used two types of data: spatial data and attribute data of structures. The spatial datasets entailed the structures which form the Mukuru Sinai Settlement. Structures served as the basic unit in the informal cadastre. The attribute data was made up of the personal details of the residents who live in the structures, their tenure rights, restrictions and responsibilities.

3.3 Materials and tools

Materials used for the project was satellite imagery of the settlement, and data collection tool using a questionnaire. Geospatial Technologies used were, ArcGIS for spatial data preparation, Microsoft Excel for preparing the attribute data of the settlement structures, Postgres/PostGIS database for storage of the datasets, GeoServer for the hosting of the database online, Hypertext Preprocessor (PHP) scripting for web application development and HTML, CSS and JavaScript for the web page design and a domain for enabling access of the informal cadastre on a web page.

3.4 Methods

The study selected 146 Structures out of the approximately 2000 Structures in the settlement. Methods applied involved those for designing the database which were external modeling, conceptual modeling, logical modeling and the physical modeling. The end database was populated with the datasets for the area of study and tested by querying. A web application was developed using Hypertext Preprocessor scripts which enabled the search and retrieval of data

and its packaging from the web server and allow the display on the web map window. Users needed to register to the web application page and login in order to access exploratory tools of the cadastre and to be able to query the cadastre.

3.5 Data preparation

(i) Spatial data

This was made up of structures in the settlement. They were created by digitization of georeferenced aerial image of the study area. ArcGIS 10.5 was used in creating the shapefile named as Mukuru Sinai Structures and digitized structures were captured as polygons. Digitization involved screen tracing of the rooftop of each structure and a unique number was assigned to it in the attribute table as shown in Figure 2. The area of each structure was also calculated using the geometry calculation tool on the attribute table. The area was calculated in square meters for each structure. The structures would form the basic unit of the Informal Cadastre.

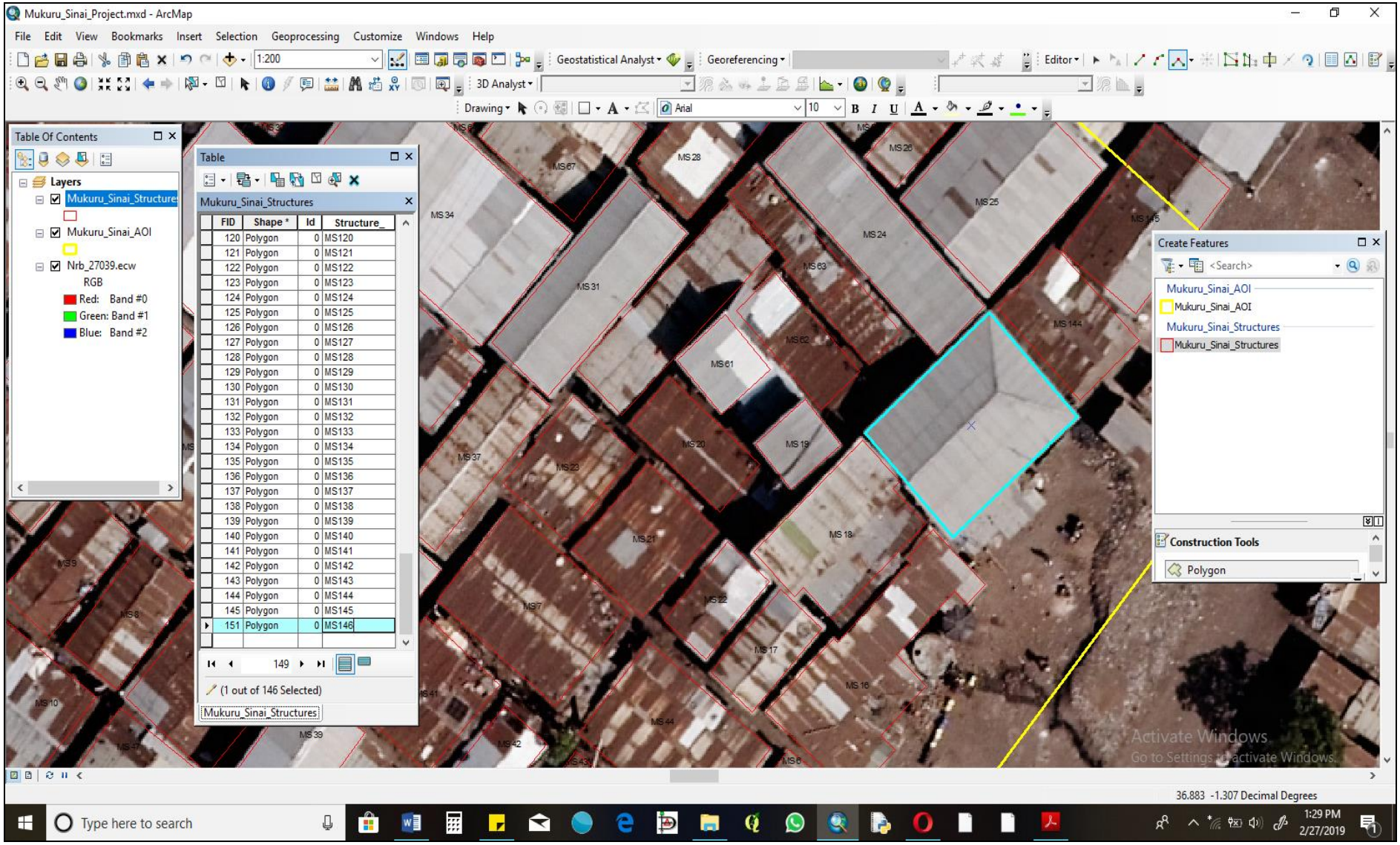

Figure 3.1 Digitizing Settlement Structures and Labelling

Table 3.1 Structure Attribute Data

Structure Number	Structure Owner (SO)/Tenant (T)	Full Name	ID number	Nationality	Structure use e.g Residential, church, school	Mode of Acquisition e.g Inherited	Number of Structure owners	Previous Residence	Years lived in the Settlement
MS1	T	Peter Musao	11772891	Kenyan	Residential	N/A	1	Upcountry	3
MS2	T	Lydia Atieno	30293812	Kenyan	Residential	N/A	1	Upcountry	7
MS3	T	John Kamau	28372982	Kenyan	Residential	N/A	1	Upcountry	7
MS4	T	Peter Wambua	28910292	Kenyan	Residential	N/A	1	Upcountry	5
MS5	T	George Kaini	46920393	Kenyan	Residential	N/A	1	Upcountry	8
MS6	T	Johnstone Shida	29382019	Kenyan	Residential	N/A	1	Upcountry	4
MS7	T	Felister Kamene	33283029	Kenyan	Residential	N/A	1	Upcountry	8
MS8	T	Francis Kiplagat	21923202	Kenyan	Residential	N/A	1	Upcountry	3
MS9	T	Judy Karimi	28304045	Kenyan	Residential	N/A	1	Upcountry	6
MS10	T	Gideon Njogu	21293002	Kenyan	Residential	N/A	1	Upcountry	5
MS11	SO	John Makau	22930493	Kenyan	Residential	Purchase	1	Upcountry	6
MS12	T	James Musungu	18293022	Kenyan	Residential	N/A	1	Upcountry	2
MS13	T	Wallace Kamau	29384902	Kenyan	Residential	N/A	1	Upcountry	9
MS14	T	Jonah Odhiambo	29384039	Kenyan	Residential	N/A	1	Upcountry	3
MS15	T	Joan Kadenge	24882901	Kenyan	Residential	N/A	1	Upcountry	12

ii) Ownership details

Ownership details were made up of the information of the residents of the settlement. These were acquired using a questionnaire and by way of interviews with the residents of the settlement in the sampled area of study. Details for the residents included their tenure status, whether they were structure owner or a tenant. The questionnaire is in appendix II. The data collected was entered into an Excel sheet, a portion of the table is shown in Table 1.

3.7 Database Development

The database for the cadastre was designed using the four stages of database modelling.

a) External Modeling/ User needs Assessment

This stage involved the identification of the stakeholders of the informal cadastre of the settlement. Based on the ongoing upgrading interventions by the government in informal settlements in selected pilot settlements, personnel involved in the project were interviewed to capture their views for a web based cadastre. The Mukuru Sinai residents and settlement leaders were also interviewed in an open ended unstructured setup. The outcome of the process enabled the mapping of the user needs to be considered in the resultant web based cadastre.

b) Conceptual Modeling

This level was based on the external model. The stakeholders identified were used to create entities and relationships established. The conceptual model was actualized in an entity relationship diagram drawn using Dia software. Each entity was allocated a primary key.

c) Logical Modeling

This stage involved the design of skeleton tables of the entities created in the conceptual modelling. The tables were generated using pgADMIN which is the user interface for Postgres/PostGIS database. The tables were normalized to conform to the First, Second and Third Normal Forms eliminating redundancy in the database while maintaining data integrity.

d) Physical Modeling

This was to create the actual database of the settlement. The database was based on the logical model design. It was actualized on the pgADMIN of the Postgres/PostGIS database. The attribute data was then uploaded to the database named Mukuru_Sinai_Informal_Cadastre.

3.8 Web Mapping Application Development

The Web Application architecture was made up of the following components;

i. Web browser

This is the client viewer part of the system, accessible once a user is connected to the internet through a browser. Users can search and view information of the Informal Cadastre as well as download materials. It was designed using HTML, CSS and JavaScript.

ii. Postgres/PostGIS Database

The database was used to store the spatial and attribute data collected for the settlement. The resultant database was connected to the GeoServer where the spatial data would be visualized. The web server was used to store the data and Hypertext Preprocessor scripts would then be used to query the database for data required by users on the client side when viewing or searching for a structure or its associated attribute data. Client side through a web browser would be enabled by the web application developed and hosted on a web domain.

iii. Web Application

The Web Application was designed using Hypertext Preprocessor. PHP is an open source general purpose scripting language that is server-side useful for development of web applications. This scripting language can easily be embedded directly into the HTML code. The informal cadastre needed a web application with the abilities of searching the database, visualizing data, updating data and the capability of downloading the data from the application. This capabilities were enabled using PHP scripts embedded in the html code for the web page.

The Web mapping application for the informal Cadastre was developed using scripts. The scripts were then integrated and hosted on a web page where users would access the data. Both non-spatial data collected and the spatial data generated from the aerial imagery would then be visualized online.

In order to use the GeoServer, in visualizing the data in form of feature service, map service or process service, the GeoServer was started from the start button. On the browser the GeoServer homepage was launched upon typing http://localhost:8080/geoserver. Log in was done as an Admin. A workspace was created and labelled as Mukuru_Sinai_Settlement as shown in Figure 3.2. A store was also created and connection to the PostGIS database (Mukuru_Sinai_Informal_Cadastre) done as shown in Figure 3.3. Lastly the layer was created and styling done as shown in Figure 3.4.

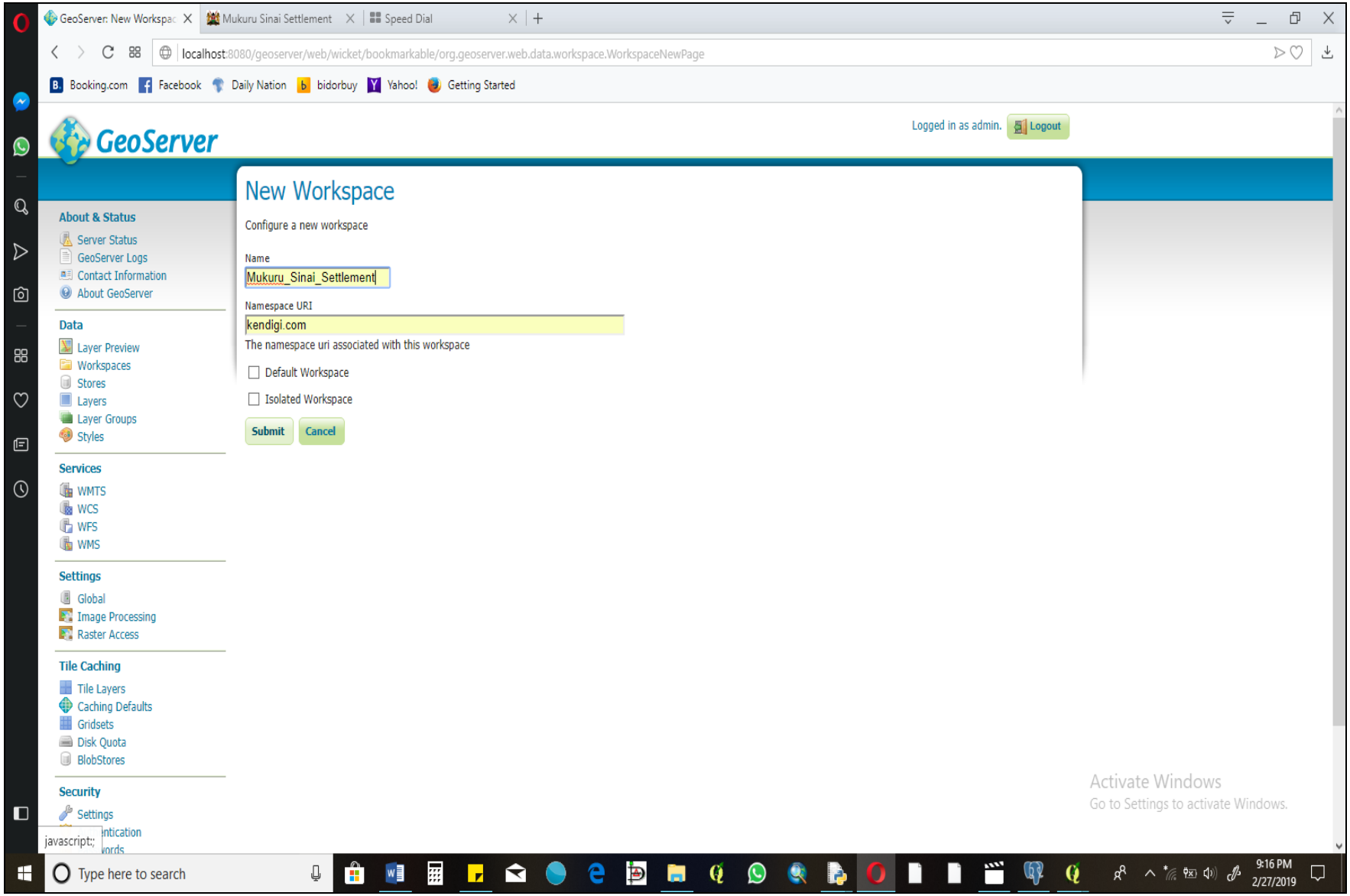

Figure 3.2 Creating a Workspace

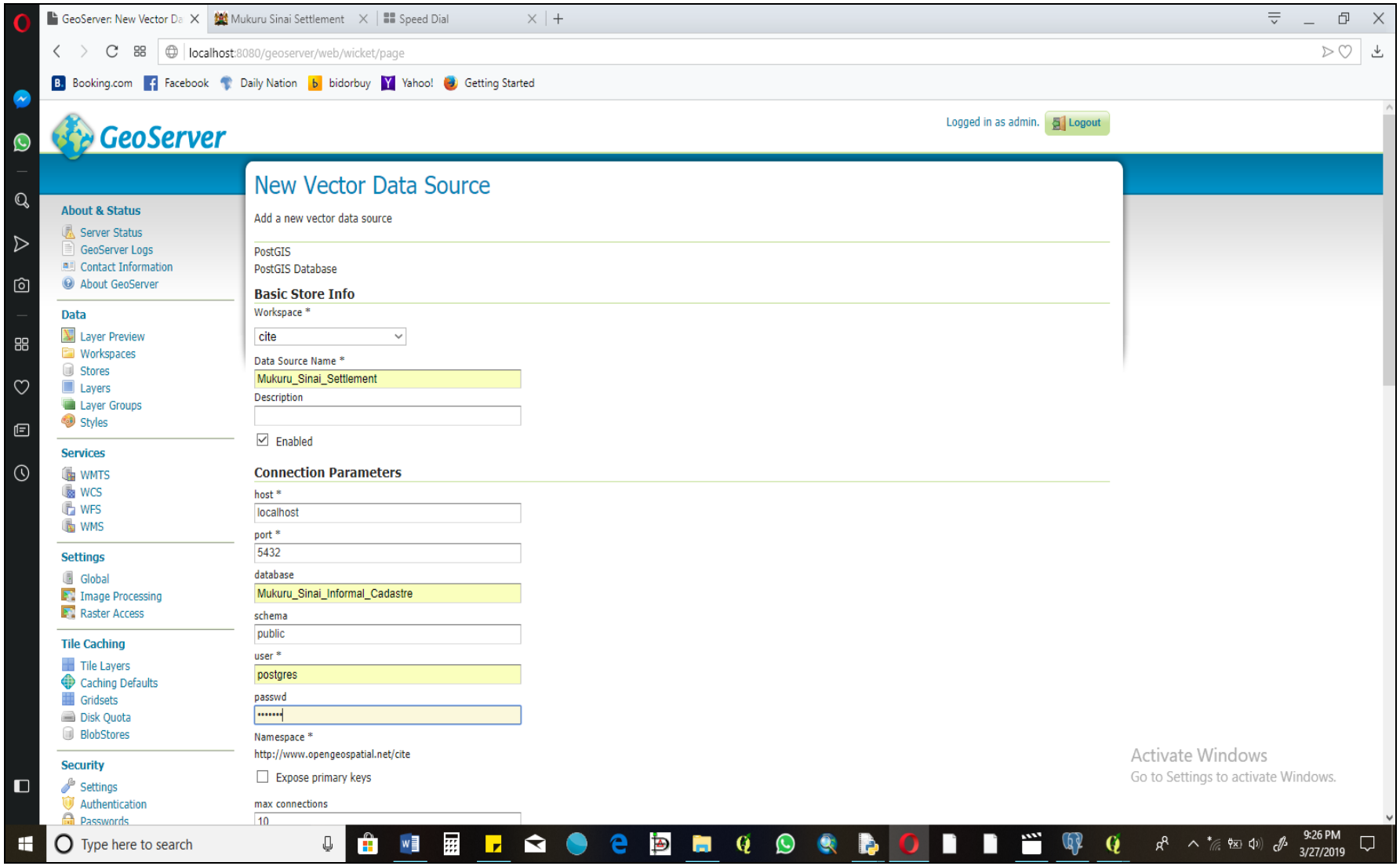

Figure 3.3 Connecting to PostGIS Database

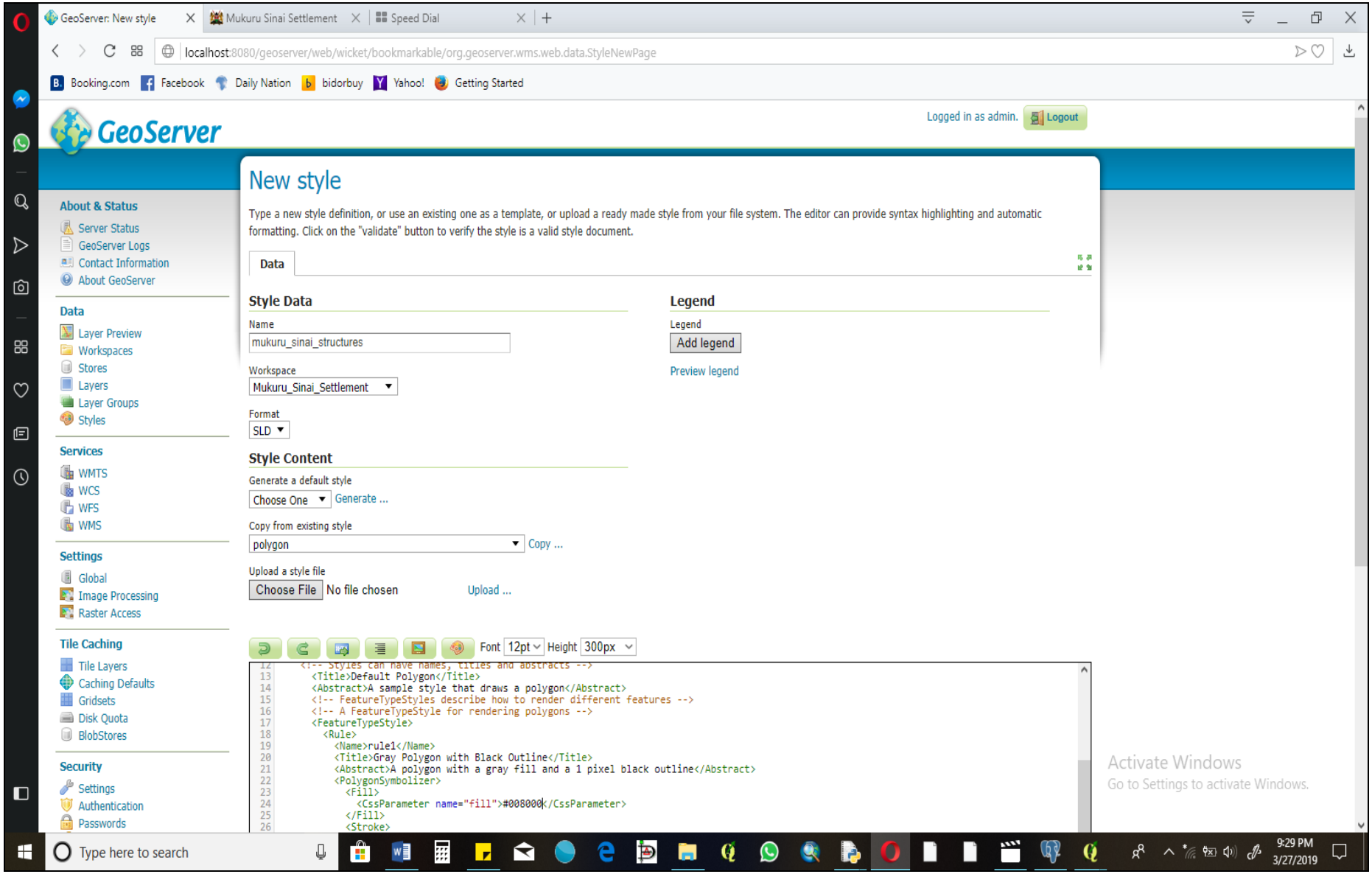

Figure 3.4 Styling the Layer

c) The User Interface

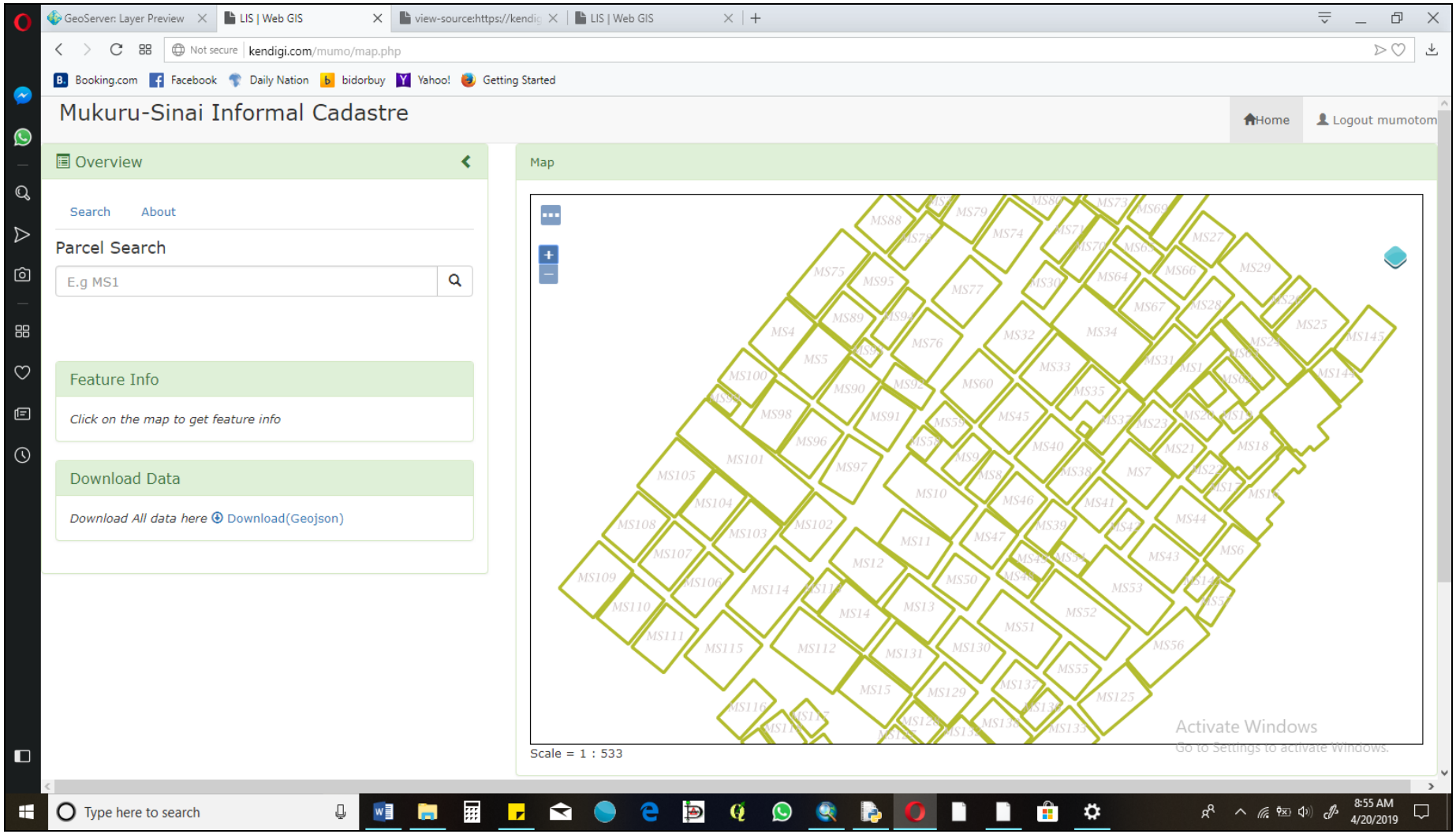

Figure 3.5 Web-based Informal Cadastre User Interface

After configuring the GeoServer, PHP scripts embedded in a web page html code was hosted on Kendigi.com server which had offered that domain for the web page. The domain enabled the access of the Informal Cadastre online at http://Kendigi.com/mumo. Figure 15 shows the user interface of the web based cadastre.

3.9 Testing the Web Application

The Web application upon completion was hosted on the web through a domain acquired from Kendigi.com limited and the web page with a Universal Resource Locator (URL) as www.http://kendigi.com/mumo/. On searching the page, it opens to a registration and login page as shown below.

The application allow login after registration. Users require to be connected to the internet using a computer of a mobile phone, and using a browser of choice for instance Opera Mini, type the URL address that holds the Mukuru Sinai Settlement informal cadastre. The user has to insert a valid email address e.g. mumotom@gmail.com and a password of choice, then click on the Register button. The Application will store the credentials for verification when logging in. The Web Mapping Application by default saves the user as an ordinary user. In order to access the Informal Cadastre, the user then will enter the credentials and click on login. In the event the information (email and password) used do not match those used in the registration, the user is denied access. Successful login opens the Informal Cadastre interface where the user has access to the different available resources of the cadastre.

The users of the informal cadastre are categorised into two;
(i) Ordinary users
(ii) Administrator users
Ordinary users are automatically registered into the web application database upon provision of login credentials.

Administrator user rights are on the other hand specifically assigned by the database administrator. They have the following rights and privileges in the online cadastre.

a) View data

This involves the browsing of the information on the user interface the history, the structures in the settlement and their respective attribute details.

b) Search for specific information

The user is able to search for a structure in the settlement using the structure number for instance MS100. The searched structure would appear on the map window on the user interface.

c) Download data

Attribute data and spatial data in the cadastre can be downloaded for other uses by the user.

The test for Informal Cadastre functionalities was carried out and the results are discussed in chapter four under test results sub-section. Search for a structure was done using structure number MS100 and its attribute data viewed on the user interface page. Data download of the information in the cadastre was also done.

Data download from the cadastre

The users are able to download data once logged into the cadastre. The script to download data was coded to enable the packaging of the spatial data and attribute data into GeoJSON format and zipped in a zip file.

Updating the informal cadastre

This is a right for administrator user. To update the attribute data, the user needs to login into the cadastre. On the interface go to search the structure that requires update, below the search box the update-attribute link shall appear. Click on it and it shall open a form where to edit the details. After filling all the necessary fields, click save. The same can be repeated as many times as it may be required. The php script was coded to enable updating of the PostgreSQL.

CHAPTER FOUR: DISCUSSION OF RESULTS AND FINDINGS

4.1 Introduction

In this part of the project, the results are and findings of the project are interpreted and discussed in line with the specific objectives in chapter one: Design of an Informal Cadastre for Mukuru Sinai Settlement, Development of a Web-Mapping Application for Mukuru Sinai Settlement, and Testing the application. The results begin with those on design of the database for the informal cadastre and end at the resultant Web based Informal Cadastre of the study area.

4.2 Results

The results are generated from the project activities which were composed of the following stages. First there was the development of the database for the informal cadastre. In actualizing this database, spatial data was created, attribute data was collected from the structures. Secondly the Web Mapping Application was designed and developed, a domain was acquired and the application hosted online to realize the web based informal cadastre. Finally the Web based cadastre was tested on its functionalities. The sub sections below are a summary of the results and the findings.

4.2.1 Database Design and Development

The database for the settlement entailed two main types of data; spatial data and attribute data. The spatial data of the settlement was made up of structures in a selected part of the settlement to make up of 146 structures. The structures were digitized from an aerial imagery of 10cm resolution. Each structure was labelled with a unique number for identification. The first structure was labelled MS1 which meant Mukuru Sinai 1, and so on until the 146^{th} structure. The labelling was adopted from relating the concept of the formal cadastre, the basic unit which is normally a parcel with a unique number. Figure 4.1 shows the map of the digitized structures.

The attribute data was made up of ownership details of the persons residing in the structures, the 3Rs (Rights, Restrictions, Responsibilities) for the structure resident as could be applicable. The structure attribute entails the personal details of the structure residents, their tenure status and the

length of their stay in the settlement. A dummy register for the study area was created to form the attribute data. Tables 4.1 and 4.2 show a portion of the dummy attribute data tables.

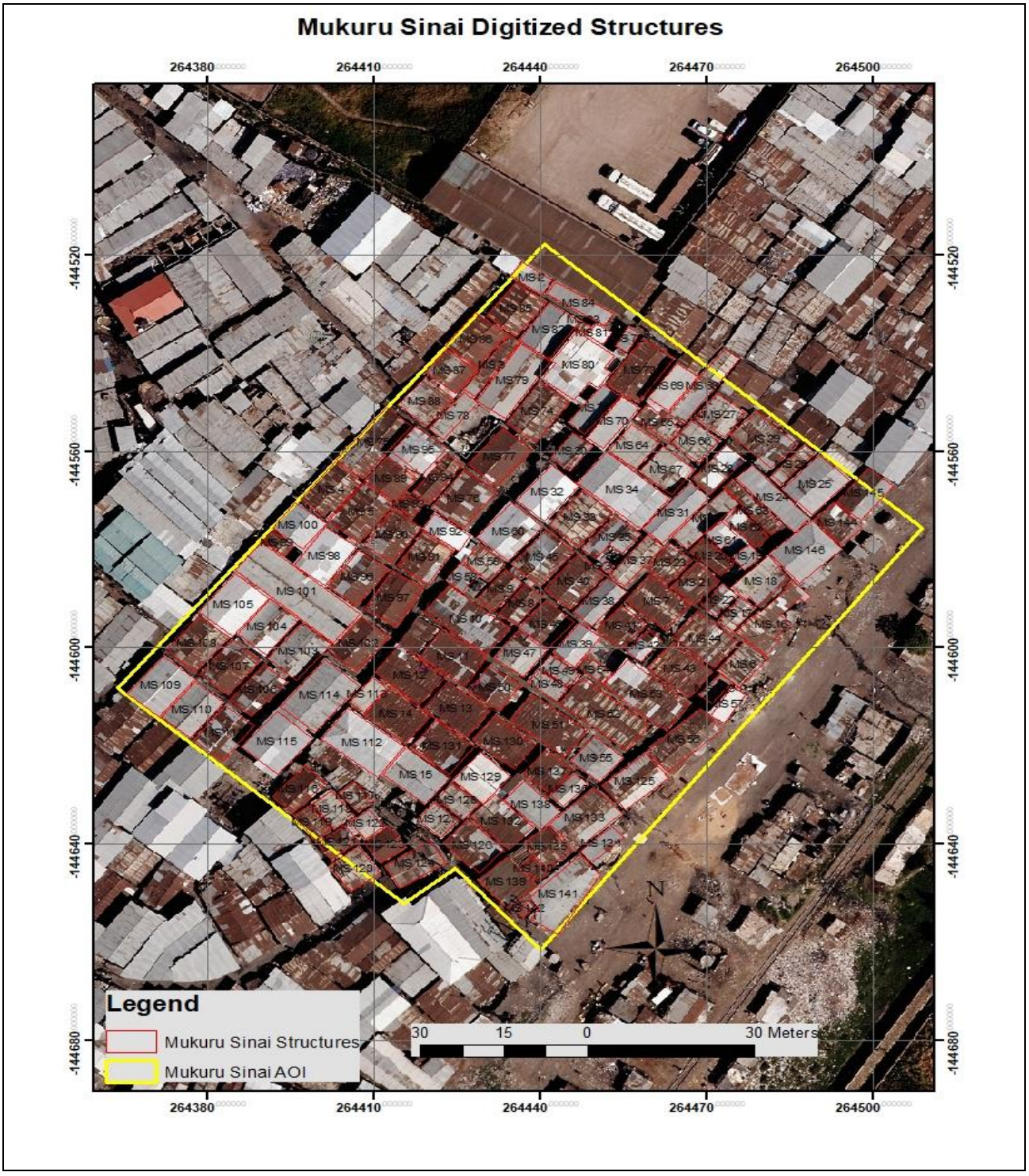

Figure 4.1 Mukuru Sinai Digitized Structures (Source, own)

Table 4.1 Rights, Restrictions and Responsibilities

	Rights	**Responsibilities**	**Restrictions**
Structure Owners	Occupation	Create paths into the structures	Sale of the land
	Receive rent		
	Access to social amenities		
Tenants	Occupation	Pay rent	
	Access to social amenities		

Table 4.2 Ownership Details (Source: Fieldwork)

Structure Number	**Structure Owner (SO)/Tenant (T)**	**Full Name**	**ID number**	**Nationality**	**Structure use e.g Residential, church, school**	**Mode of Acquisition e.g Inherited**	**Number of Structure owners**	**Previous Residence**	**Years lived in the Settlement**
MS1	T	Peter Musao	11772891	Kenyan	Residential	N/A	1	Upcountry	3
MS2	T	Lydia Atieno	30293812	Kenyan	Residential	N/A	1	Upcountry	7
MS3	T	John Kamau	28372982	Kenyan	Residential	N/A	1	Upcountry	7
MS4	T	Peter Wambua	28910292	Kenyan	Residential	N/A	1	Upcountry	5
MS5	T	George Kaini	46920393	Kenyan	Residential	N/A	1	Upcountry	8
MS6	T	Johnstone Shida	29382019	Kenyan	Residential	N/A	1	Upcountry	4
MS7	T	Felister Kamene	33283029	Kenyan	Residential	N/A	1	Upcountry	8
MS8	T	Francis Kiplagat	21923202	Kenyan	Residential	N/A	1	Upcountry	3
MS9	T	Judy Karimi	28304045	Kenyan	Residential	N/A	1	Upcountry	6
MS10	T	Gideon Njogu	21293002	Kenyan	Residential	N/A	1	Upcountry	5
MS11	SO	John Makau	22930493	Kenyan	Residential	Purchase	1	Upcountry	6
MS12	T	James Musungu	18293022	Kenyan	Residential	N/A	1	Upcountry	2
MS13	T	Wallace Kamau	29384902	Kenyan	Residential	N/A	1	Upcountry	9
MS14	T	Jonah Odhiambo	29384039	Kenyan	Residential	N/A	1	Upcountry	3

a) External Modelling

Based on the user needs assessment carried out, the stakeholders identified were, the Settlement tenants, structure owners and settlement leaders.

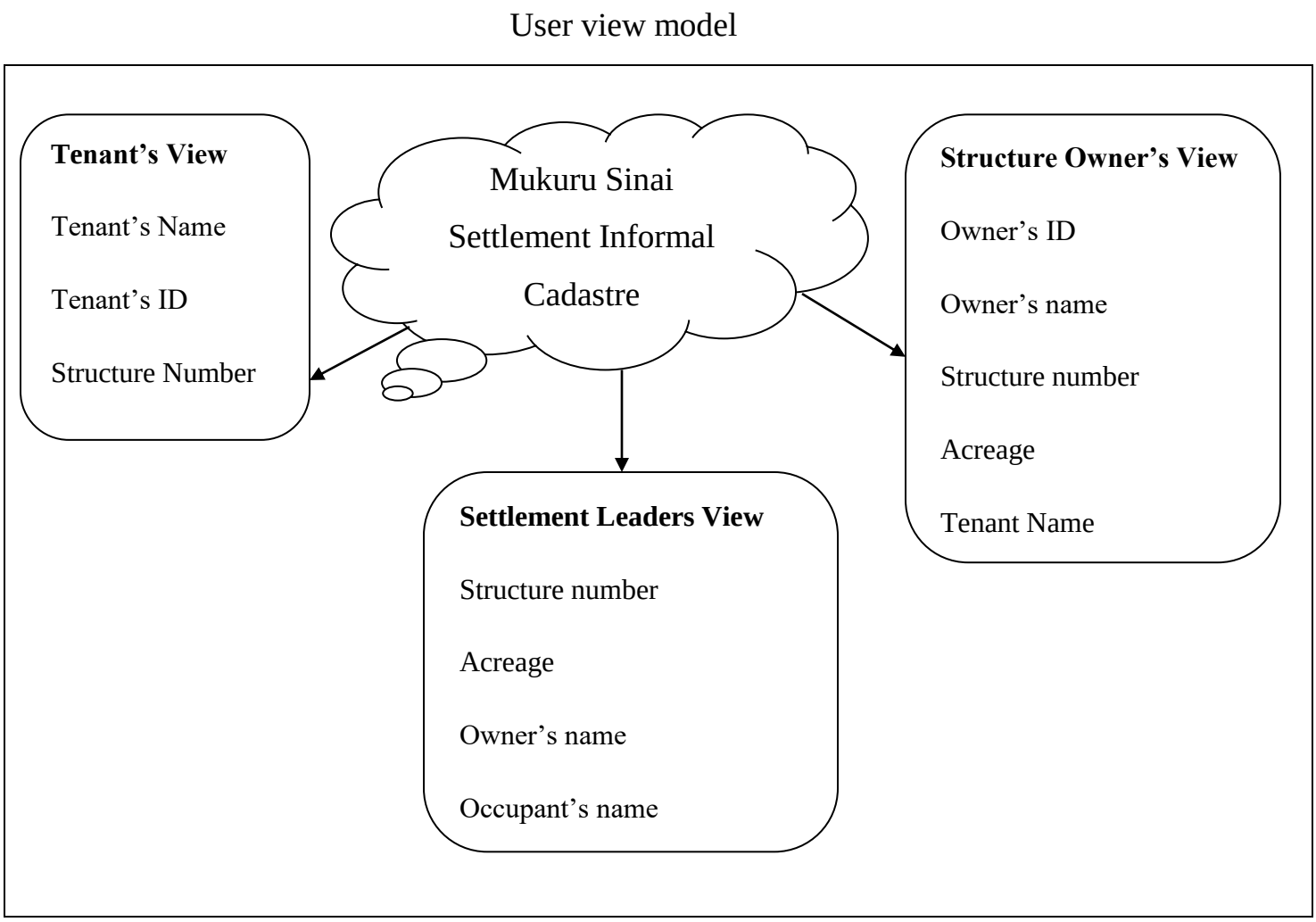

Figure 4.2 External Model

b) Conceptual Modelling

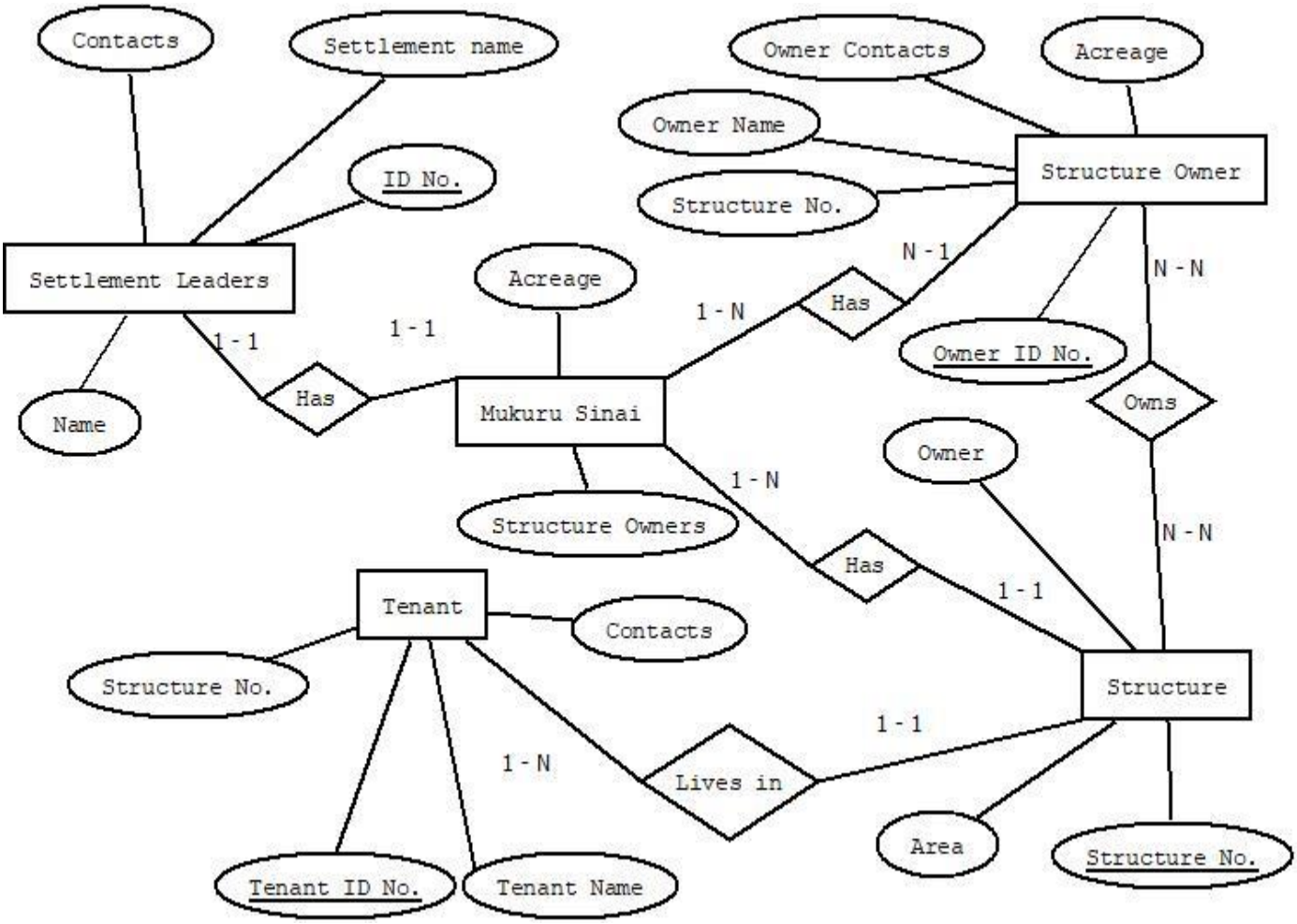

Figure 3.3 Entity Relationship Diagram

Mukuru Sinai was the main entity. The settlement is made up of structures. The structures are owned by structure owners. The structure is either occupied by the structure owner or a tenant. The Conceptual model above has entities with attributes, and the key attribute is underlined.

c) Logical Modelling

The following skeleton tables were created based on the conceptual model in figure 8 using pgAdmin 4.

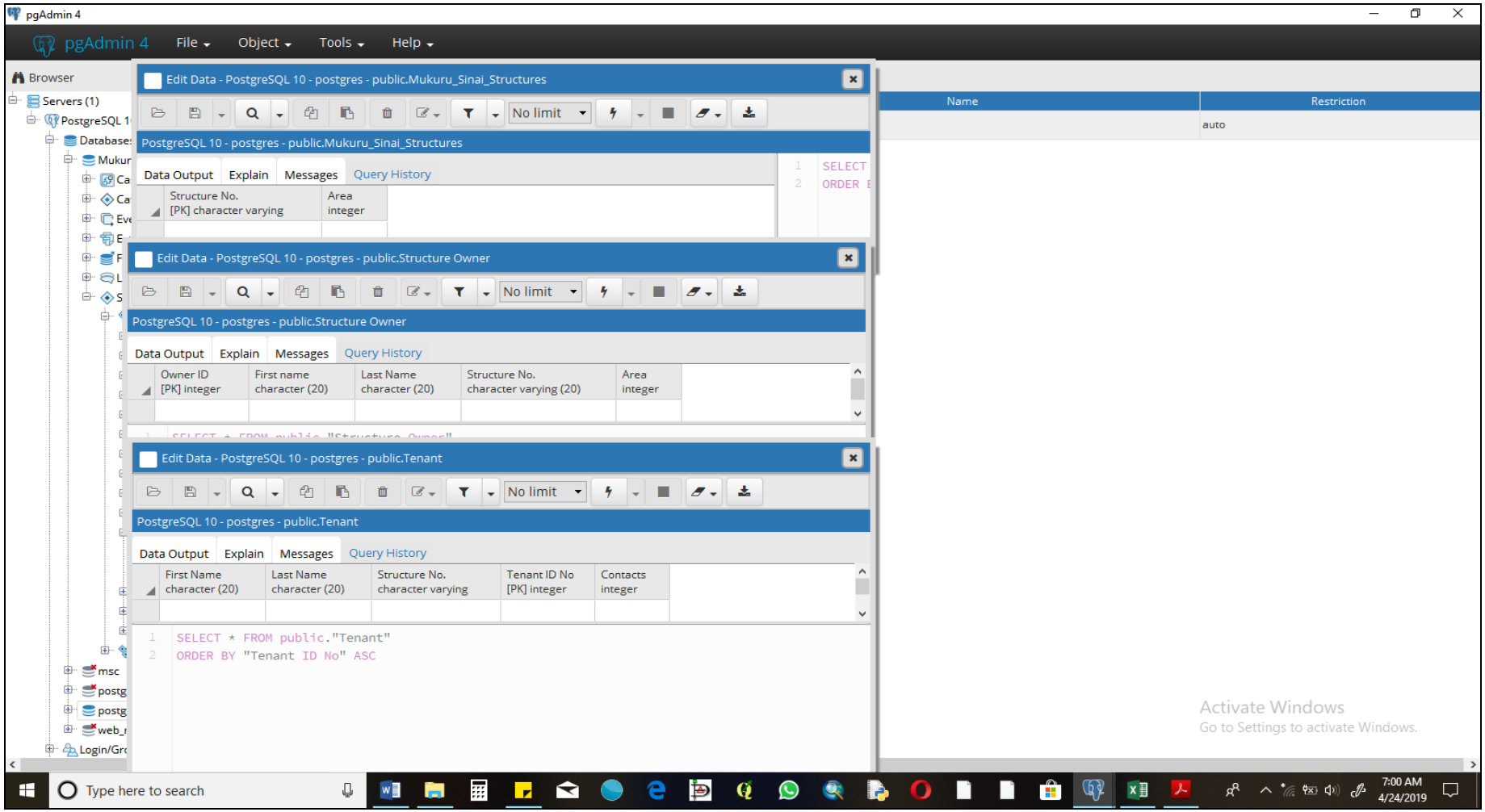

Figure 4.4 Skeleton Tables of the database

d) Physical Modelling

a) Creating the database

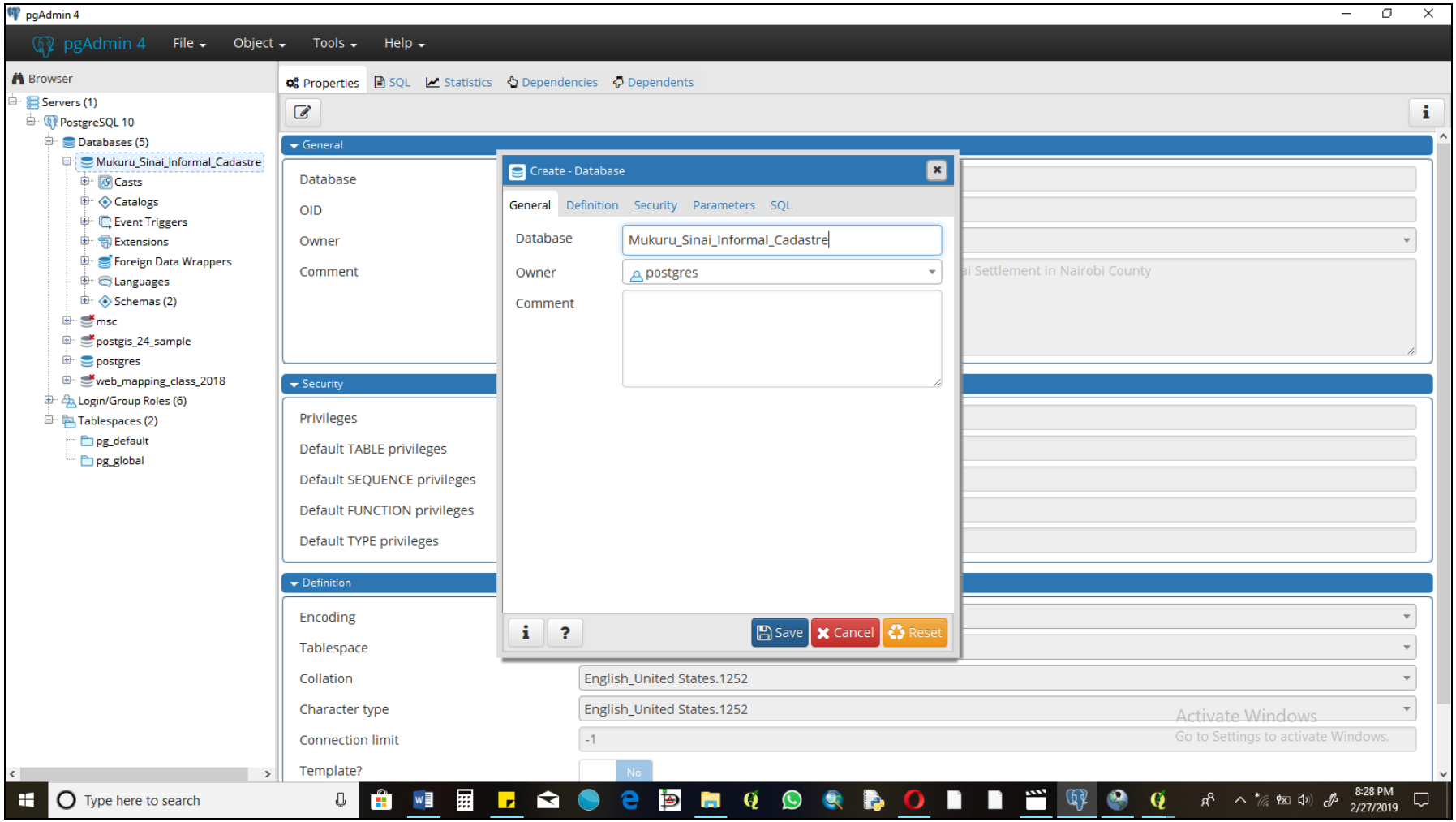

Figure 4.5 Creating Postgres/PostGIS Database

The database for the informal cadastre was created and name *Mukuru_Sinai_Informal_Cadastre*. Under the extensions, the PostGIS extension and topology were also added to enable the database capture both non-spatial and spatial data. The Tables designed in the logical modeling were created ready to be populated with data.

b) Loading data

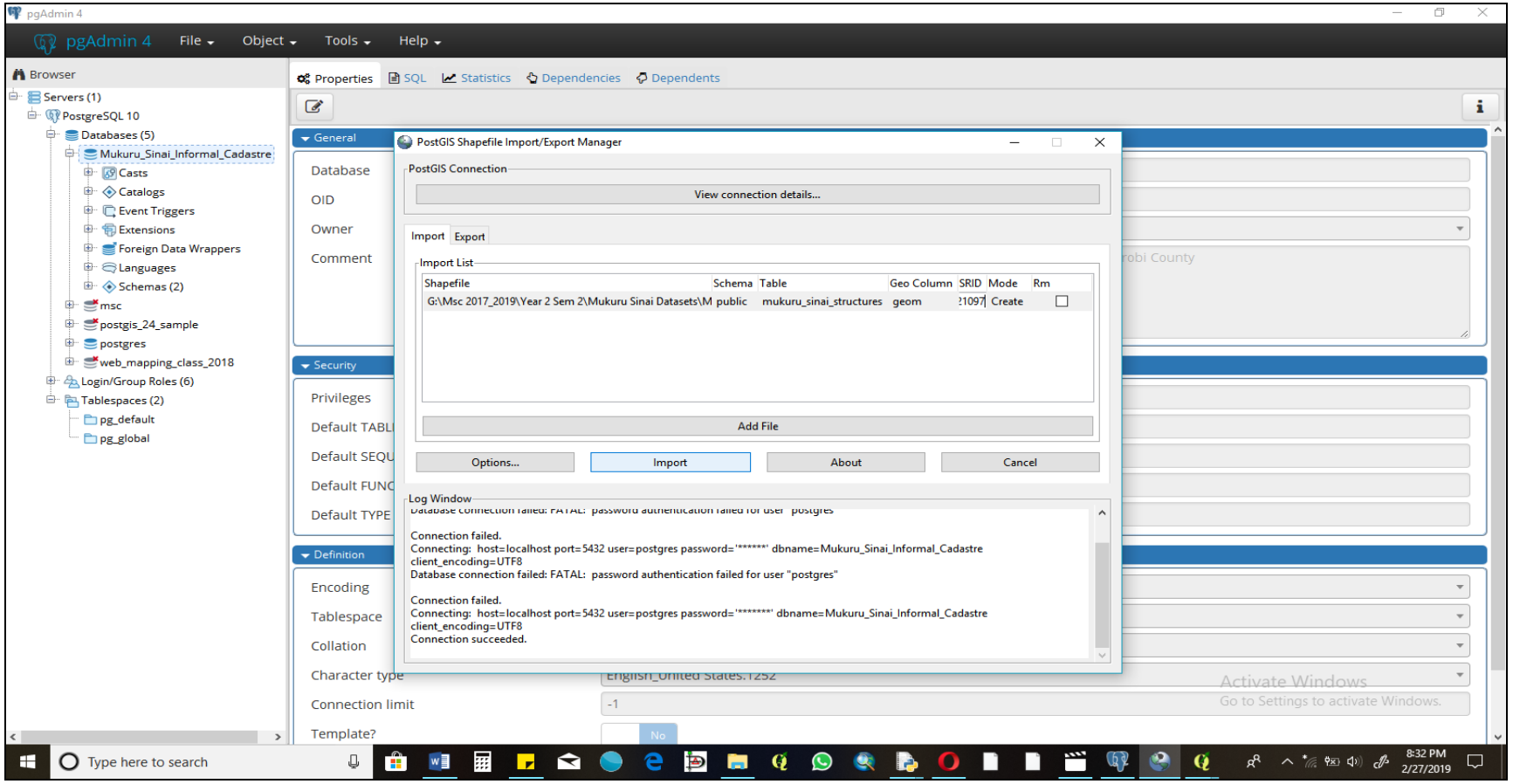

Figure 4.6 Loading data into the PostGIS database

4.2.2 Web Mapping Application

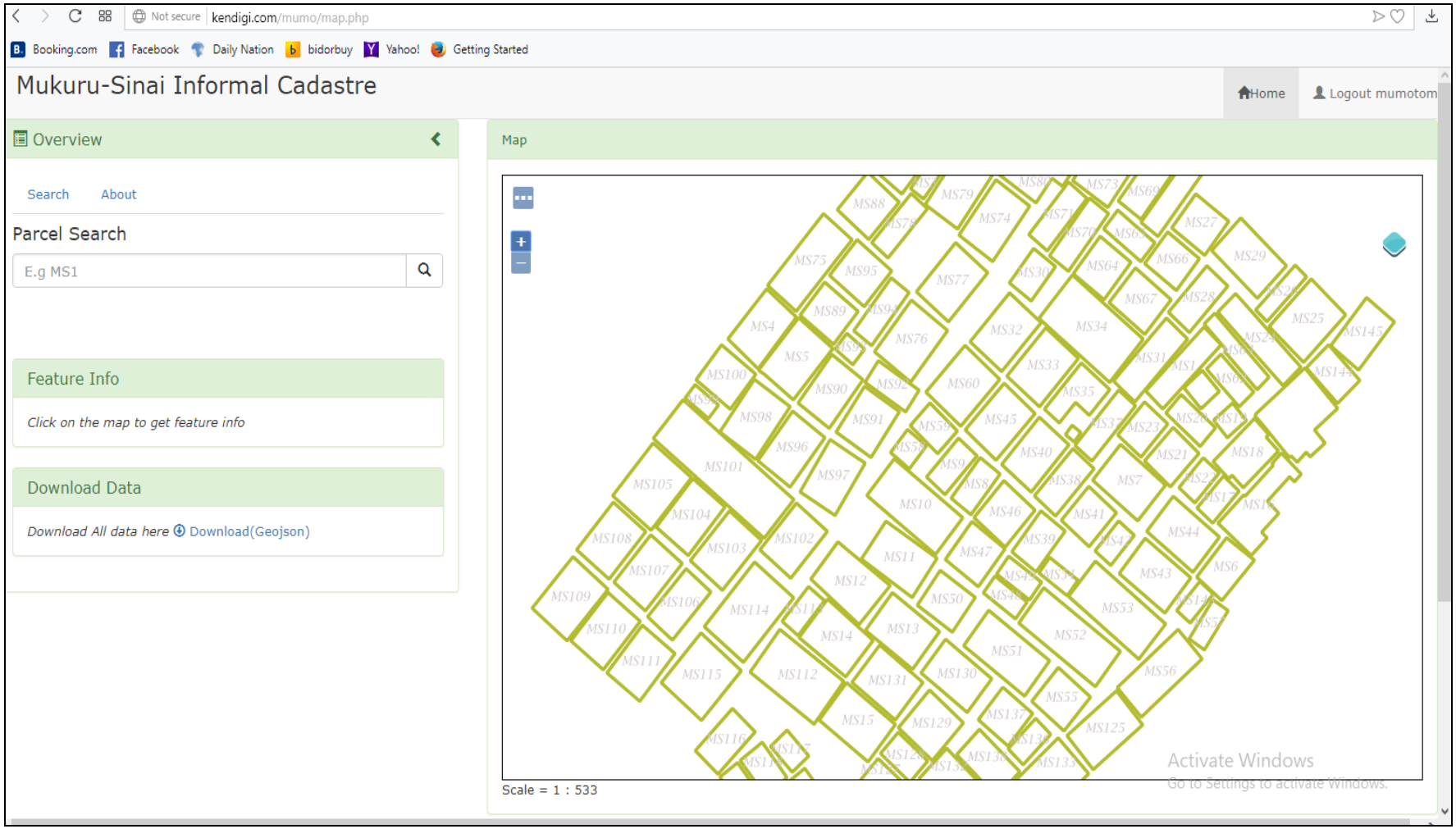

Figure 4.7 User Interface of Informal Cadastre

4.2.4 Test Results of the Web Cadastre

The results on the functionalities of the Web based Informal Cadastre were based on the following possible queries by the user.

a) How do I log into the Web based Informal Cadastre?

The Informal Cadastre allows both ordinary users and super users to register, log in and log out of its user interface. Registration is done using an email address and a password of choice. Registration is mandatory, else one cannot be able to log in. The user will require the email they registered with and the password to log in. Upon typing the credentials, the user would click on the log in button which will sign into the Informal Cadastre user interface page. Lastly, once the user has finalised their operations on the cadastre, they will browse to logout button on the top right to exit from the user interface. An alert shall appear that indicates that the user shall be redirected into the home page – the log in/Registration page – in a few seconds.

b) Search for a structure MS100 in Informal Cadastre

A user could be in need of seeking information for a specific structure. Using the search function this would be actualized. The user will need a structure number e.g. MS100. Upon clicking on the search button, the structure shall appear on the map window as shown in figure 19.

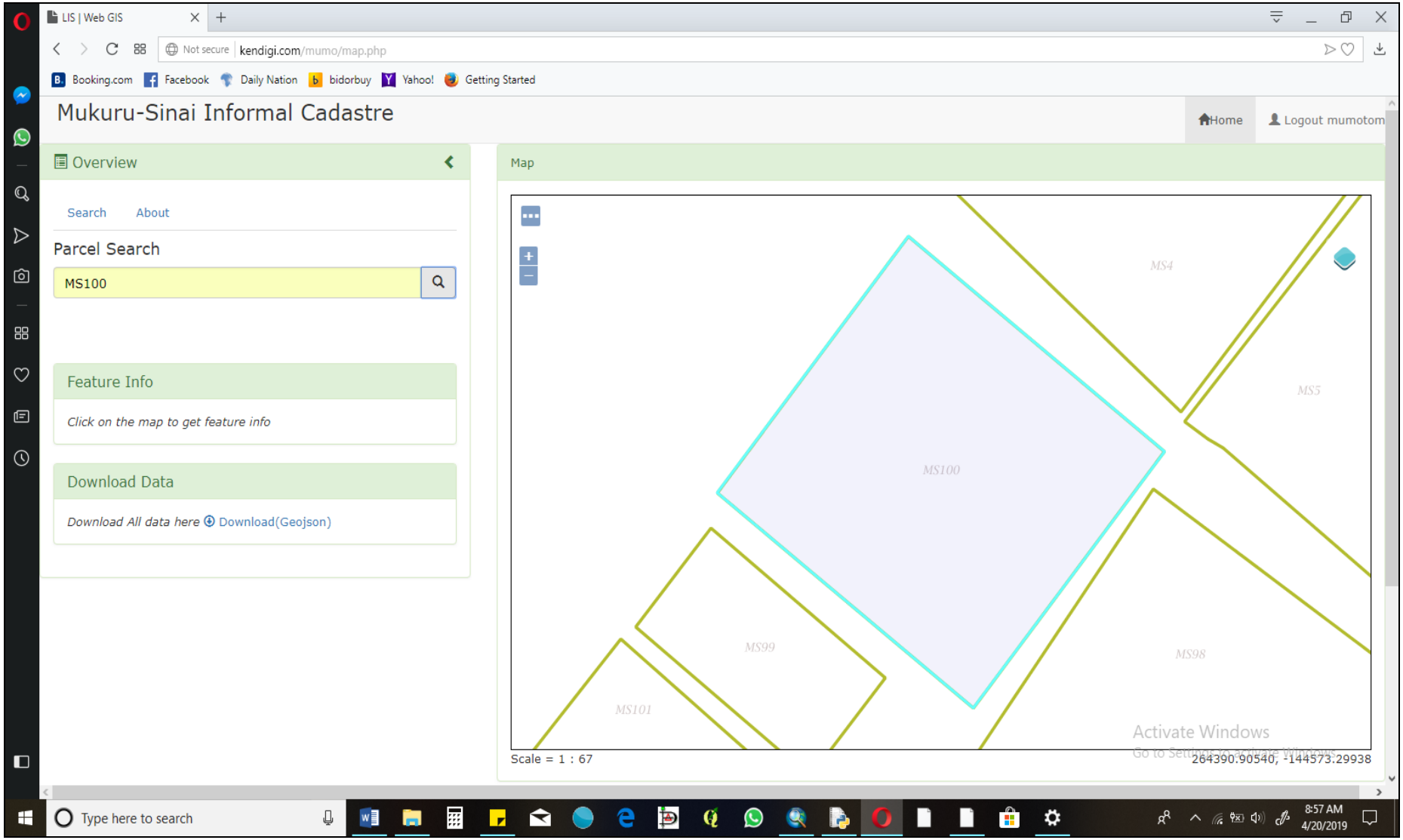

Figure 4.8 Search of Structure MS100

c) How do I view attribute information of a structure?

The user is able to view attribute data of the searched structure by clicking on the highlighted structure. Immediately the attribute data of the structure shall appear on the feature information sub section on the left side of the user interface window.

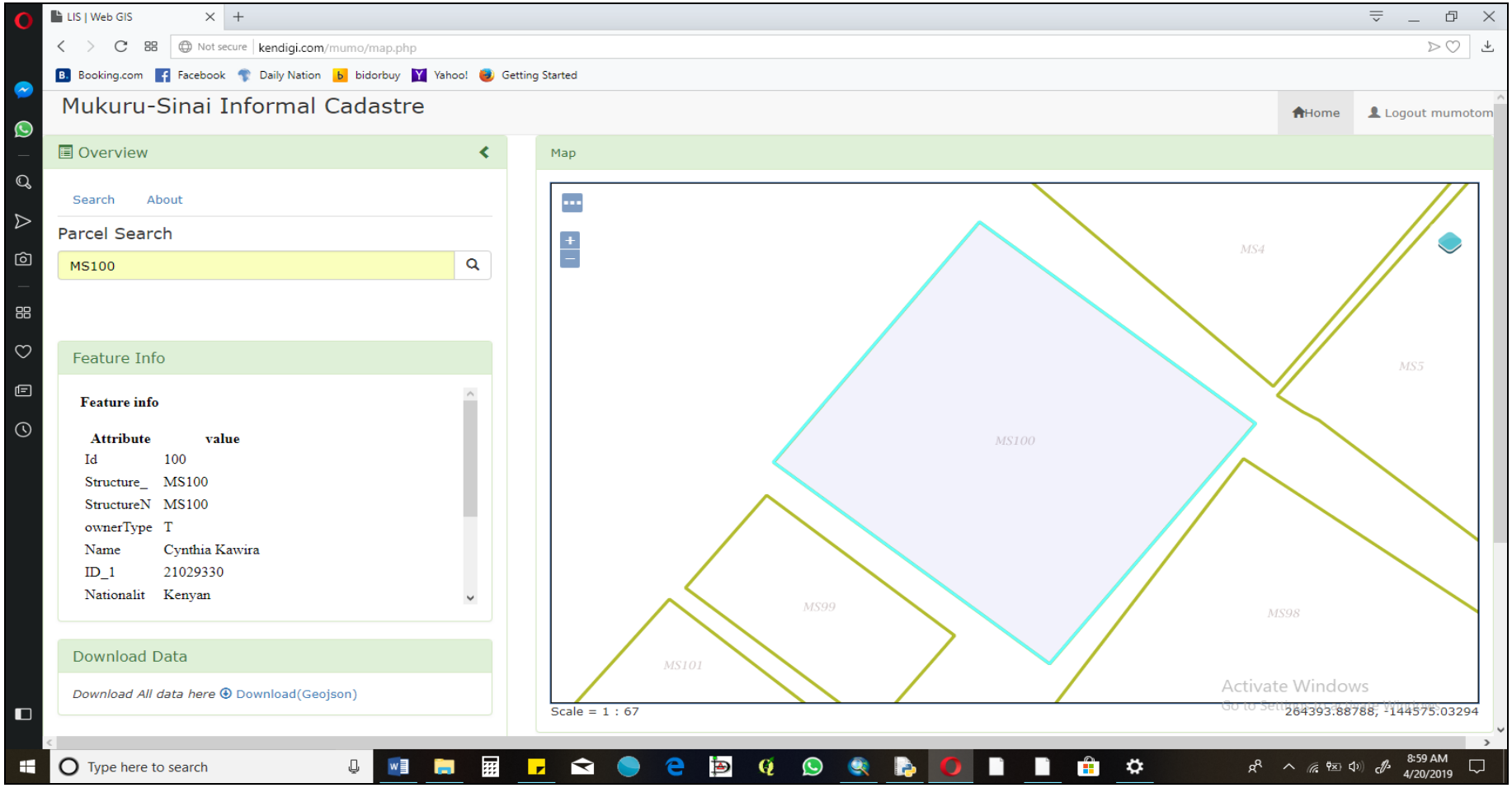

Figure 4.9 Viewing Structure Attribute data

d) How can I download Data from the informal cadastre?

The user can download data from the cadastre for other use. This is by clicking on the download data link. A zipped file shall pop up on the top right side of the User interface window. Figure 4.10 shows data download.

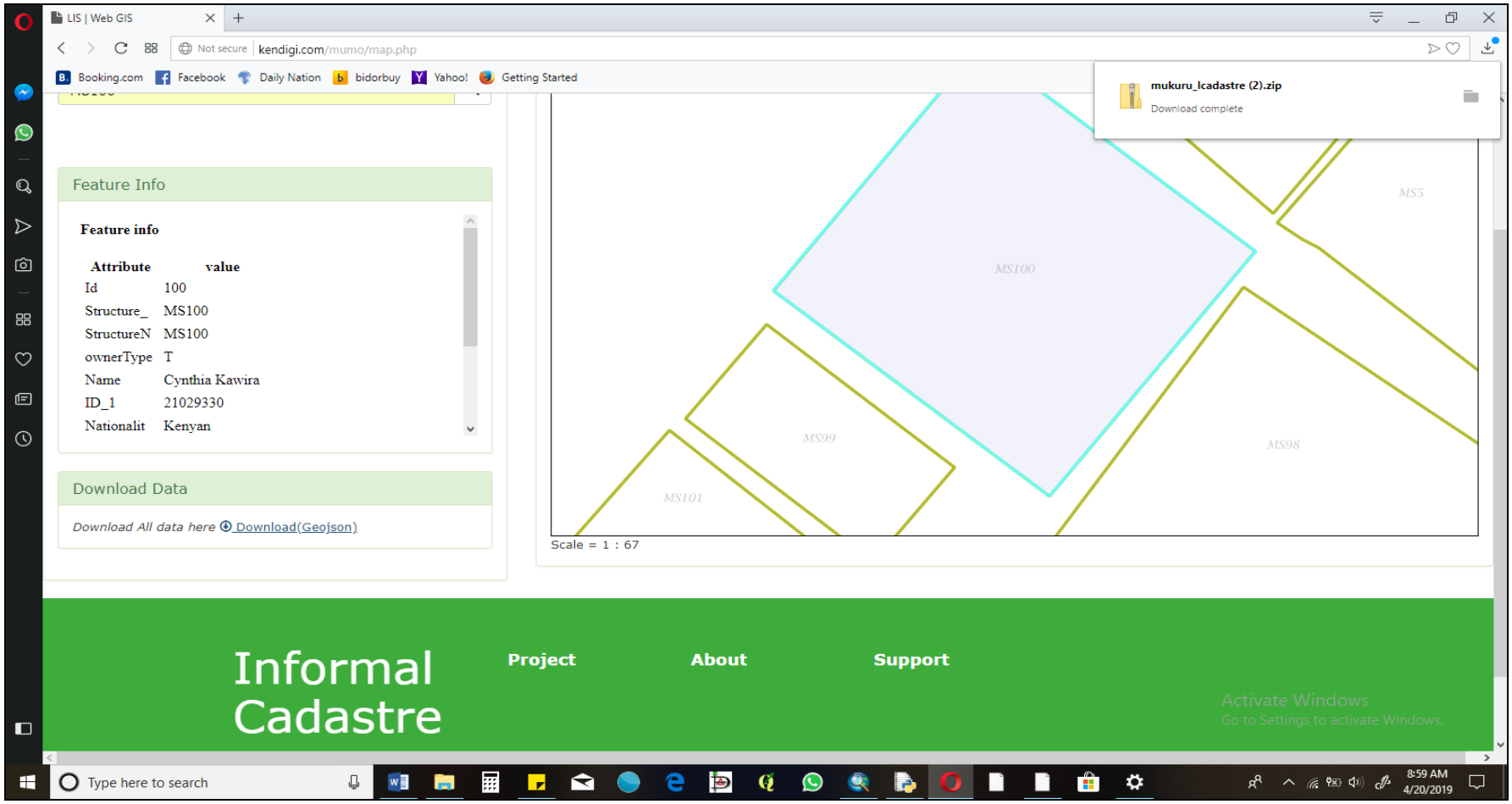

Figure 4.10 Data Download

e) How can I update attribute information for a structure?

Updating the cadastre in this study focused only on the attribute data. This was a right enjoyed by a super user. The user would search for the structure whose details need to be updated. Below the search button there would appear a link in blue named as **edit attribute** e.g. edit attribute MS100 as shown in Figure 4.11. This would lead to form where to change the attributes. On completion the user would click update at the bottom of the form. A message to indicate successful update shall appear. Then click close to go back to the user interface window.

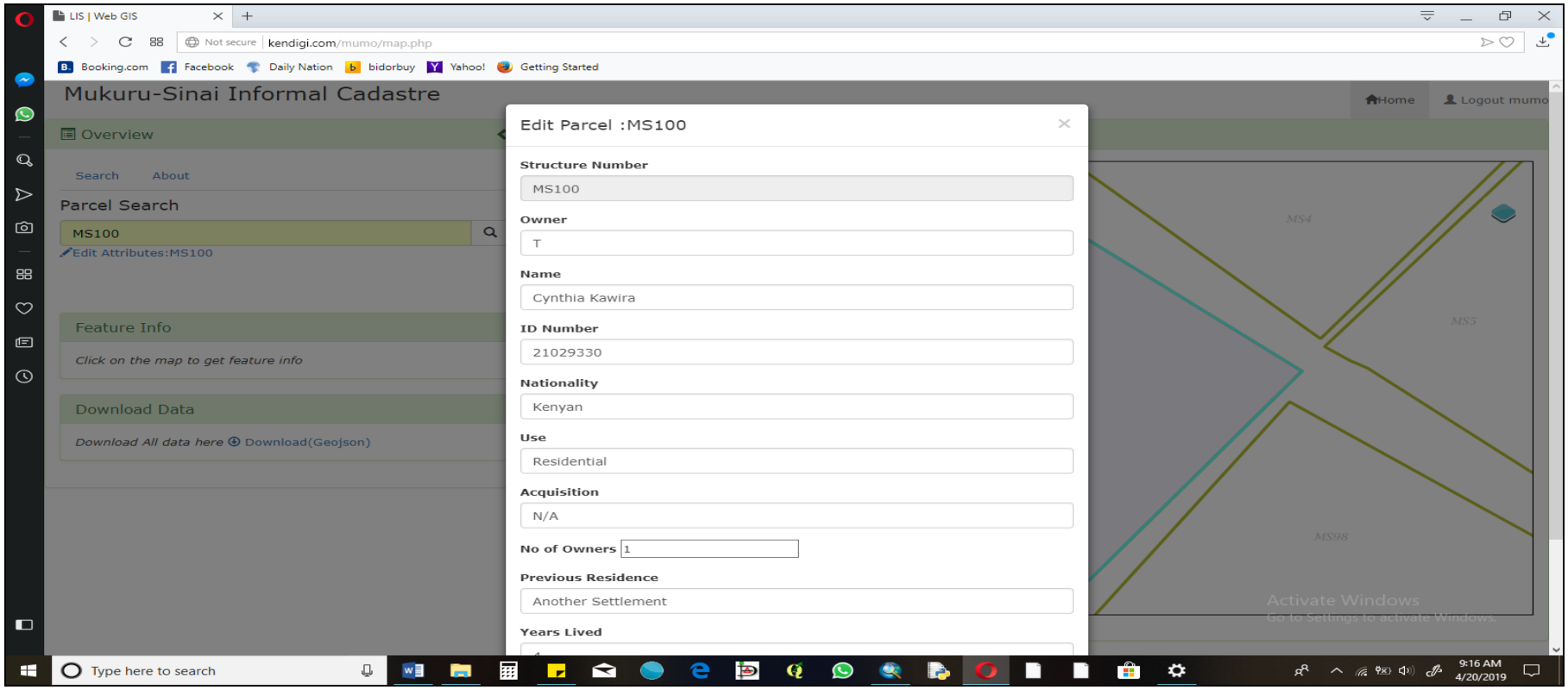

Figure 4.11 Updating Attribute Data

CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The aim of this project was to develop a web based cadastre for Mukuru Sinai settlement in Nairobi County. This was to be achieved by developing a database which was to contain structures of the settlement as the basic unit and structure attributes of the residents. A web application was developed and hosted online using a domain acquired to enable querying the database online through the informal cadastre user interface. Upon the launch of web application online it was accessible at http://kendigi.com/mumo. The informal cadastre was tested on its functionalities presented on the user interface. It was able to search a structure in the settlement, allow viewing of data, allow data download and allow attribute updating by administrative user. Based on the project it can be concluded that the development of a web based informal cadastre is solution that would enable the informal settlement to have a reliable source for their spatial and attribute data. This is useful in enabling the informal settlements to prepare towards anticipated upgrading as well as be inline with the early steps in the continuum of rights.

5.2 Recommendations

The web application developed can be adopted by interested institutions and organizations involved in projects within the informal settlements in the country to enhance their programs by creating reliable informal cadastre. Such include the Non-governmental organizations (NGOs) that work in the settlements, the KISIP program and County governments. Institutions that offer basic amenity services including water and electricity will find this project useful in developing a record of target clients for their services. Instead of having losses in water that is wrongfully tapped from their water network, they would be able to collect more funds by connecting the residents to the network. Similarly, Kenya Power will gain more by connecting the residents of the informal settlements to the national grid hence earning the company more revenue.

The Ministry of Lands and Physical Planning through the Kenya Slum Upgrading Programme that is ongoing can borrow from this concept and develop an informal cadastre for all informal settlements that would enable efficient implementation of the programme.

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APPENDIX I

MUKURU SINAI ATTRIBUTE DATA COLLECTION TOOL

This questionnaire is developed by Tom Mumo, a student persuing a Master's Degree in Geographical Information Systems at the Department of Geospatial Science and Technology in University of Nairobi. This is towards his research project entitled "DEVELOPMENT OF A WEB BASED INFORMAL CADASTRE FOR AND INFORMAL SETTLEMENT IN NAIROBI" and whereby Mukuru Sinai happens to be the area of study.

This questionnaire is a tool to facilitate the collection of data that will be used in developing the informal Cadastre for selected cluster within Mukuru Sinai Settlement. It covers, various details surrounding ownership, rights and restrictions of the residents of the settlement. This study is aimed at preparing the settlement records that will be useful in future for upgrading the settlement, an initiative at pilot level in Kenya.

Information captured in this questionnaire remains confidential and will strictly be used for academic purposes only at the University of Nairobi. Your cooperation sincere responses are much appreciated.

Yours faithfully

Tom Mumo.

ENUMERATOR DETAILS

Full Name: ……. Date: ……..

ID Number: …….

Contacts: ……..

Signature: …….

SECTION A - PERSONAL DETAILS

Name: ……..

Gender: …….

ID Number: ……..

Natinality: …….

Structure ID: …….

SECTION B – OWNERSHIP DETAILS

1. Is the respondent a structure owner (A) or a Tenant (B)
   A …… B ……

2. How many years have you been living in this settlement?
   ……..
3. Which was your previous residence?
   ……
4. What were the reasons for settling in Mukuru Sinai? ……..

SECTION C – TENURE SECURITY

a) Have you experienced eviction threats?
   ……
b) What rights do you enjoy as a tenant/structure owner?
   ……..

SECTION D – USER NEEDS IN UPGRADING

1. What would you want to be considered when upgrading the settlement?

- Roads……., Housing ……, Sanitation…….….
- Water……., Any other (state)……

- End -

Thank you for your cooperation

APPENDIX II: CODE SCRIPTS

Login Script

```
<?php
session_start();
require ('db.php');
$login=false;
$message="";
 $superuser="f";
 $_SESSION['superuser']="f";

if(isset($_POST["emailLogin"]) && isset($_POST["passwordLogin"])  ) {

  // escape string
   $userName=trim(strtolower($_POST["emailLogin"]));
   $password=trim($_POST["passwordLogin"]);
   $lastname="";

   $query="SELECT email,username as name,  superuser  FROM  mumo_users  WHERE  email  =
lower('".$userName."') AND password = lower('". $password."')";

   $result = pg_query($conn, $query);

       // check the password the user tried to login with

    while ($row = pg_fetch_row($result)) {

     if (isset($row[0])) {
      // grant access

     $lastname=$row[0];
         $login=true;

     $_SESSION['logged_in']=true;
     $_SESSION['email']=$lastname;
     $_SESSION['userName']=$row[1];
     $_SESSION['superuser']=$row[2];
```

```
            $_SESSION['lastname']=$row[1];
        $superuser=$row[2];
       $message="ok"; // log in

      } else {
       // deny access

       $login=false;
       //echo "email or password does not exist."; // wrong details
         $message="email or password does not exist."; // wrong details
       }}
}
else if ( isset($_SESSION['lastname'])&& isset( $_SESSION['logged_in'])){
      $lastname=$_SESSION['lastname'];
      //echo "ok"; // log in
       $login=true;
       $message="ok";
}
echo json_encode(array('message' => $message,'superuser'=>$row[2]));
?>
```

Data Download Script

```
<?php

//check for digits/numeric

if (!isset($_GET['d'])) {


  //echo "An SQL error occured.\n";
   echo 'Error';
   exit;

}else{
$sql="";
//$srid = '4326';
$srid = '21097';
function escapeJsonString($value) { # list from www.json.org: (\b backspace, \f formfeed)
```

```
  $escapers = array("\\", "/", "\"", "\n", "\r", "\t", "\x08", "\x0c");
  $replacements = array("\\\\", "\\/", "\\\"", "\\n", "\\r", "\\t", "\\f", "\\b");
  $result = str_replace($escapers, $replacements, $value);
  return $result;
}
$sql="SELECT structure_ as Structure_no,"
."st_asgeojson(mukuru_sinai_structures.geom) AS geojson "
." FROM mukuru_sinai_structures ";
# Connect to PostgreSQL database
require "db.php";

$rs = pg_query($conn, $sql);
if (!$rs) {
    //echo "An SQL error occured.\n";
            echo '{ "type": "FeatureCollection", "features": [ ]}';
   exit;
}
# Build GeoJSON
$output    = '';
$rowOutput = '';
while ($row = pg_fetch_assoc($rs)) {
    $rowOutput  =  (strlen($rowOutput)  >  0  ?  ','  :  '')  .  '{"type":  "Feature",  "geometry":  '  .  $row['geojson']  .  ',
"properties": {';
    $props = '';
    $id    = '';
    foreach ($row as $key => $val) {
        if ($key != "geojson") {
            $props .= (strlen($props) > 0 ? ',' : '') . '"' . $key . '":"' . escapeJsonString($val) . '"';
        }
        if ($key == "id") {
            $id .= ',"id":"' . escapeJsonString($val) . '"';
        }
    }
    $rowOutput .= $props . '}';
    $rowOutput .= $id;
    $rowOutput .= '}';
    $output .= $rowOutput;
```

```
}
$output = '{ "type": "FeatureCollection", "features": [ ' . $output . ' ]}';
//Create zip file
$zip = new ZipArchive;
if ($zip->open('mukuru_Icadastre.zip', ZipArchive::CREATE) === TRUE)
{
     //create new File
    $zip->addFile('mukuru.geojson');
    // Add a file new.txt file to zip using the text specified
   $zip->addFromString('mukuru.geojson', $output);
    // All files are added, so close the zip file.
   $zip->close();
}}
?>
```

Attribute Updating Script

```
<?php
session_start();
# Connect to PostgreSQL database
require "db.php";
$structure_=$_SESSION["plot_no"];
//check for digits/numeric
if (isset($structure_) )

{
  $owner=trim($_GET['owner']);
  $name=trim($_GET['name']);
  $id_no= $_GET['id_no'];
  $nationality=$_GET['nationality'];
  $use= trim($_GET['use']);
  $acquisition=trim($_GET['acquisition']);
  $owners=(int)$_GET['owners'];
  $previous_res=trim($_GET['previous_res']);
  $years=(int)$_GET['years'];

   $query="UPDATE owners SET (owner,name,id_no,nationality,use,acquisition,owners,previous_res,years)=".
              "('$owner','$name',$id_no,'$nationality','$use','$acquisition',$owners,'$previous_res',$years)".
       " WHERE structure_='.$structure_'";
```

```
        if (pg_send_query($conn, $query)) {
                $res=pg_get_result($conn);
                if ($res) {
                        $state = pg_result_error_field($res, PGSQL_DIAG_SQLSTATE);
                        if ($state==0) {
                          // success
                         $message="Update Successful";
                        }
                   else {
                        $message="Update Failed | Check Details Again"; // wrong details
                        }  } }}
else {
     $message = "Failed";
}
 echo json_encode(array('message' => $message));
 ?>
```

Log Out Script.

```
<?php

session_start();
if( isset($_GET['argument']) && $_GET['argument'] == 'logOut' )
{
   session_destroy();
   echo json_encode(array("page"=>"index.html"));
}
?>
```