University of Nairobi

School of Engineering

WEB BASED MAPPING OF WATER SUPPLY SITUATION IN MATHARE VALLEY

BY

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Declaration

I, Lilian Wangui Ndungu 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 Institution of Higher Learning.

Lilian Wangui Ndungu 08/07/2015

Name of student Date

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

J N Mwenda 08/07/2015

Name of supervisor Date

Dedication

My appreciation goes to my parents Moses Ndungu, Grace Wanjiru, my Siblings Irene Wambui, Sam Wamathai and Eric Kuria for their support and encouragement throughout my studies, and to my daughter Valeria Grace Wanjiru for being my inspiration.

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Abstract

Informal settlements are home to an increasing number of the urban poor. The lack of basic services, from sanitation and waste removal to water and electricity, has resulted in untenable conditions for the poor. Despite the importance of water supply and improved sanitation for achieving progress in the Millennium Development Goals, the water supply situation in Kenya's informal settlements is still dismal. The needs of people living in informal settlements are often neglected or unmet due to lack of proper data on the situation on the ground to aid in decision making. Without basic knowledge on the geography and resources in a slum, it is very difficult to make informed decisions on improving the quality of life of slum dwellers. According to the Nairobi City Water and Sewerage Company, lack of clear maps is one of the hindrances to proper service provision in the informal settlement, and this project aimed to fill that gap (NCWSC, 2009).

The objective of this study was to investigate water supply situation in Mathare Informal Settlement and its constituent villages in Nairobi and present this information in a Web based interface. Availability of this information to the Nairobi City Water and Sanitation Council (NCWSC) and other stakeholders would allow them to make informed decisions on availability, use and administration of resources such as water in the slums. The study was conducted based on existing information aggregated from different sources. The data was then represented in Webpage showing specific information and maps for each area/informal settlement and covered the 20 villages that constitute Mathare Informal Settlement and point data showing the water resources location such as kiosks, wells and yard taps.

Questions that were answered in this study include the state of the water supply situation, the cost of water, time taken to fetch the water and the user's perception of the water quality. This project has proved that Web mapping is a useful tool for representing spatial and non-spatial information and the level of the detail in the study goes to show that such an undertaking should be considered for the entire country. In this study the integration of spatial and tabular information into a Web based resource has proved to be a powerful tool in visualizing, querying and communicating the availability, location and spread of water resources in the informal settlements.

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Acronyms

AJAX	Asynchronous JavaScript and XML
APHRC	African Population and Health Research Centre
API	Application Programming Interface
CSV	Comma-separated values
CSS	Cascading Style Sheet
DU	Dwelling unit
GIS	Geographical Information System
GLTN	Global Land Tool Network
ICT	Information and Communications Technology
KODI	Kenya Open Data Initiative
KDHS	Kenya Demographic and Health Survey report
KML	Keyhole Mark-up Language
MDG	Millennium Development Goals
NCWSC	Nairobi City Water and Sewerage Company
NGO	Non-Governmental Organization
UN	United Nations
UN-HABITAT	United Nations Human Settlements Programme
UN ECOSOC	United Nations Economic and Social Council
UNFPA	United Nations Population Fund
WAMP	Windows, Apache, MySQL, and PHP
WIS	Water Information System
UN WWAP	United Nations World Water Assessment Programme
WSSCC	Water Supply and Sanitation Collaborative Council
WSTF	Water Services Trust Fund

CHAPTER 1: INTRODUCTION

1.1 Background

With the rising number of urban poor living in informal settlements in developing countries, new solutions are needed to deliver basic services to residents. While cities provide opportunities for many, city life can also present conditions of overcrowded living, inadequate access to basic services, congestion, unemployment or underemployment, lack of social and community networks, stark inequalities, crippling social problems such as crime and violence, and particular vulnerability to health problems, economic shocks, and the risks related to climate change and natural disasters, particularly for the poor. To accommodate these rising demands from new residents, many cities struggle to address the demands, but often fall short. This is often due to resource constraints, but also due to capacity constraints, lack of urban planning and management and lack of political will.

Meeting this challenge will require new thinking and innovations in service delivery through use of Information and Communications Technology (ICT), new partnerships and new financing opportunities, an expanded role for NGOs and the private sector, and new technological solutions. There is also an important role for better urban planning and management to anticipate the influx of new city residents and their needs and how to meet them. Water is vital to life, and supply of water is critical especially to informal settlements where population density is high. Most of the dwellings in informal settlements do not have water supply or sanitation facility and if available, it is mostly located outdoors. Many of the informal settlement dwellers have to cover long distances to access water or even a sanitation facility.

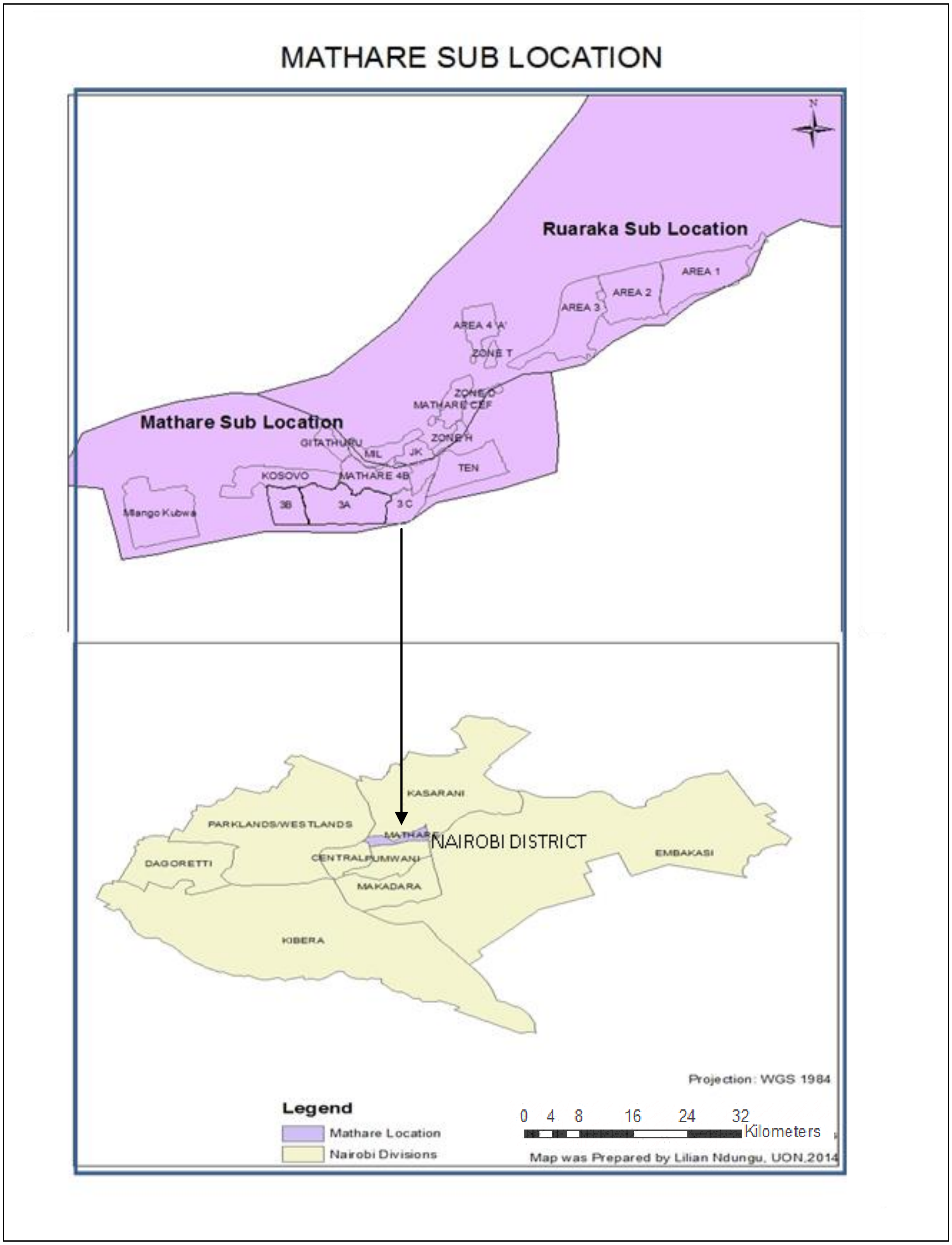
Lack of clean water leads to water borne diseases being prevalent in these areas. For most of the slum dwellers who are low income earners, it is often an issue of deciding whether to buy food, other necessary provisions or water. Due to their large size and lack of extensive data on the extent of these informal settlements, meeting water and sanitation needs of their occupants becomes challenging. Therefore there is need for detailed information on the size of the constituent villages, existing legal water sources, the water situation, water problems currently being experienced, time taken to fetch water and the user’s perception of the quality of water.

This can be achieved through a Web based information system to show the current situation, existing resources and the gaps in provision of water in these areas.

This project focuses on Mathare Informal Settlement which is one of Nairobi's low income informal settlement areas in Kenya. It is located approximately 3 km from Nairobi's Central Business District. It is bordered by two main highways, Juja Road and Thika Road. Mathare Informal Settlement covers an area of approximately 73 hectares and comprises of a number of different smaller informal settlements (also called villages) which stretch over two administrative divisions of Nairobi (Starehe and Kasarani). Much of Mathare was formerly a quarry and some of the Informal Settlements are built on steep slopes of "carved-out" rock. The Mathare and Gitathuru rivers which traverse the settlement are part of the larger Nairobi River watershed. These two rivers are a central feature of economic life in Mathare. The villages in Mathare slum are a dynamic set of informal communities with different histories, strong community networks and changing population characteristics (Pamoja Trust, 2009).

The exact number of informal settlements in Nairobi is difficult to determine, as new informal settlements are known to develop while others are demolished to pave way to new high rise buildings or commercial investments. Mathare Valley has about 500,000 inhabitants. It is reportedly the second biggest informal settlement in Kenya after Kibera (WSTF, 2010). The Mathare Valley Squatter settlement dates back to colonial days. Today single mothers occupy 90% of the shacks in the valley. Mothers with six to eight children reside in tiny, dirty-floored shacks (no bigger than the average bathroom). The tin roofs leak and the floors turn muddy when it rains. These shacks are jammed next to each other, filling every available space. Latrines are few if any and no space to build any. Open, foul-smelling sewerage ditches flow by the edges of the huts (WSTF, 2010). Apart from having no access to basic amenities like clean water, food, clothing, shelter and healthcare, the residents do not have proper roads that can allow for any emergency services. The makeshift housing structures are either made out of mud or metal.

Figure 1.1: Study area: Mathare Informal Settlement



1.2 Problem Statement

Nairobi's informal settlements are mostly unplanned, resulting in inadequate infrastructure (roads, water, sanitation, sewerage, drainage, and electricity), temporary and haphazard building solutions, poor housing, high occupation density, and very low levels of public services. Clean water, adequate sanitation, and hygiene are visibly substandard. This was confirmed in a recent consumer survey done by the Nairobi City Water and Sewerage Company (NCWSC) which illustrated the informal settlement residents' general discontent with services in water provision (NCWSC, 2009). The continuing expansion and densification of settlements render upgrading and service improvements altogether urgent, as well as more complicated and expensive. Part of Nairobi City Water and Sewerage Company strategic plan, includes improvement of service provision in the informal settlements. Proper information is required to guide the Company and its stakeholders to make informed decisions when improving service delivery in informal settlements.

One of the gaps identified in the strategic plan is lack of proper information and clear maps to aid in decision making (NCWSC, 2009). This project provides detailed information on the water supply situation in Mathare Valley in a Web map, which shows the spread of resources in form of maps, the location of these resources in point form and water supply information of the area. Using this information, decision makers such as the NCWSC can tell at a glance, which villages are adequately supplied and which are facing water shortages. The Web map will also provide information on the overall water situation of each village such as the main water sources, main water problems, time taken to fetch water, the user's perception of the water quality and will also allow querying of the information provided. NCWSC has specific guidelines on water charges in informal settlement and the Web map also provides additional information on what residents are currently paying for water.

1.3 Objectives

1.3.1 Overall objective

The main objective of this project is to create a Web based water resources map for Mathare Valley Informal Settlement.

1.3.2 Specific objectives

The specific objectives of this project will be:-

i) To demonstrate the use of Geographic Information System (GIS) and Web based maps in the spatial representation of water resources in the informal settlement. The Web maps will supplement information available to decision makers from the NCWSC and their stakeholders to assist them make informed choices when upgrading water resources in the slums.

ii) To demonstrate how spatial and non-spatial data can be combined, represented and queried in a Web interface. The Web map combines spatial and non-spatial data and information, and uses queries to allow for selective display of required information for each village in Mathare Informal Settlement, thereby providing greater accessibility to the data and information on water resources.

1.4 Justification

The understanding of the level of urbanization or its scale in developing countries is challenged by differences in the definition of "urban" and in turn, the lack of reliable data (Giok *et al.*, 2007). One of the major reasons given by water and sanitation agencies for their failure to extend services to informal settlements and squatter settlements has been the lack of baseline data about these settlements. A survey and documentation of physical and economic conditions, as well as social actors and relationships is very important because this will show what already exists and what needs to be improved on. It must also be noted that, in the absence of such documentation, realistic and cost effective planning cannot take place (Hasan, 1997). Since lack of clear maps is one of the hindrances to proper service provision in the informal settlement, this project will provide baseline data and maps on water supply situation in the slums thereby allowing for proper decision making. This will be achieved by highlighting the plight of the people living in

Mathare and specifically the water situation to allow for equitable distribution of resources such as funds for water projects, and to help urban planners in informal settlement upgrading programs. The use of a Web interface allows for global access of the information and mapping the slums by village allows greater level of detail and information at area level.

1.5 Scope of Work and Limitations

1.5.1 The scope of the study

The study was conducted based on existing information aggregated from different sources. This information includes maps (shape files for waypoints and polygons) and tabular data. The study covers twenty villages that make up the part of Mathare Valley settlement scheme namely Kosovo, 3A, 3B, 3C, 4A, 4B, Number 10, Gitathuru, MIL, Zone JK, Zone G, Zone H, Zone D, Zone T, Area 1, Area 2, Area 3, CEF, Mabatini and Mlango Kubwa. The data was then represented in a Webpage showing specific information for each area/informal settlement which includes the study area covered, villages that constitute Mathare Informal Settlement, point data showing the water resources location such as kiosks and yard taps, tables showing water situation, fetch duration, user perceived water quality and cost of water for each area.

The main indications to determine the proportion of households with access to improved water supply included households with direct connection (piped water) to the dwelling or plot such as a yard tap, access to public stand pipe such as through a water kiosk and public taps, access to non-piped water such as a borehole or well, protected spring, rain water collection and finally access to a water kiosk (public, communal, private). Secondary data used in this project was aggregated from different sources and therefore may not have been a very accurate representation of the current situation on the ground. However it attempts to exhibit in a small way, how large amounts of spatial and non-spatial data can be integrated and represented on the Web. This project aims to represent the data as an informative tool whose data can be used for further analysis and interpretation.

1.5.2 Limitations

Most of the areas in informal settlements are served by unlicensed water vendors and leaks which are not covered in this project. However for each area, the informal water sources are listed. This project mainly covers points of sale for water (water kiosks with communal or yard taps) connections provided by a water service provider within the area and any other public or communal water source point such as tanks, boreholes, standpipes among other sources which are collectively referred to as formal water sources in this project. Evaluation of water quality was based on user's perception and no scientific testing of water sample was done to determine the quality due to time, financial and equipment limitations.

1.6 Summary of Project Contents

This project is divided into five chapters namely the introduction, literature review, materials and methods, discussion and analysis of results, and conclusions and recommendations. References used in the study and an appendix have also been included. Chapter One gives a background, explains the problem, provides justification for the project and defines the overall and specific objectives. Chapter Two provides a review of the state of water supply, cost of water, accessibility and water quality. The section also covers a review of the use of GIS and web maps as a visualization and information dissemination tool. A background on what Web maps are and mapping tools in construction of GIS systems are discussed. Current efforts in mapping slum resources in Kenya are also explained. Chapter Three provides an overview of the study area, the data and tools used, and the methodology, tables generated as inputs for the Web map and data processing to create the Web maps. In Chapter Four, the Web map outputs have been displayed and a summary of findings for the entire area has been provided to give an overview of the water supply situation in Mathare Informal Settlement as a whole. Conclusions from the study and recommendations based on findings are discussed in Chapter Five. Area level maps and queries used have been listed in the appendix. All references used in the project have also been listed in the References Section.

CHAPTER 2: LITERATURE REVIEW

2.1 Lack of water in informal settlements

According to the UN-HABITAT (2003), an informal settlement is a heavily populated urban settlement characterized by substandard housing and squalor. While informal settlements differ in size and other characteristics from country to country, most lack reliable sanitation services, supply of clean water, reliable electricity, timely law enforcement and other basic services. Informal settlement residences vary from shanty to poorly built and deteriorated buildings (UN-HABITAT, 2007). In the context of this study, the Water Services Trust Fund (2010) definition has been adopted where informal settlements: are often referred to as “urban informal settlements”. Informal Settlement residents are called “informal settlement dwellers” or “squatters”. Most informal settlements are un-planned, often illegal, urban settlements with high population densities, poor service levels, and low incomes associated with lack of social cohesion.

The land occupied by the residents of these informal settlements is owned by the Municipality, the Government or by private individuals and in some cases; the land was allocated to the squatters. The water supply and sanitation situation in most informal settlements is poor (WSTF, 2010). Examining access to water services in informal settlements spurs an appreciation of the multidimensional nature of the problem, including low incomes, poverty, infrastructural limitations, asset ownership and housing quality. Moreover, developments in the informal settlements concern every aspect of the Millennium Development Goals (MDGs). According to World Water Development Report (WWDR) (UN WWAP, 2003), although water has come to be recognized as a fundamental and inalienable human right that should be accessible to all individuals; access to this resource continues to elude many people around the world. Approximately, 2.2 million people in developing countries die each year from diseases associated with the lack of access to sufficient and clean water (WSSCC, 2004). Residents in informal settlements often depend on a small number of house/yard connections, springs and wells.

2.2 Access to water in informal settlements

Access to water is affected by the time it takes to get to the water point, the time it takes to fetch the water and water shortages which are determined by the number of people accessing water from a specific source. The United Nations Economic and Social Council (UN-ECOSOC) report (1997), established that only about 24% of all households in informal settlements have access to piped water, in the form of public water taps or water piped into the residence, which can be compared against 92% in non-informal settlement areas of Nairobi as a whole. An estimated 75 per cent of Informal Settlements residents purchase their water from resellers at water kiosks operated by community groups or individual entrepreneurs, and in some cases from pushcart vendors. Water kiosks are the main water source in informal settlements (NCWSC, 2009). Since water is a very rare commodity for informal settlement dwellers, they often tend to drink rain water which is usually trapped by gutters from the roofs of their shelters.

Rain water is usually safe for drinking if it is boiled before consumption and stored in clean containers but because of the ignorance of the informal settlement dwellers; they fail to do so, thus the water becomes a hazard in their lives. Improving access to safe water implies less burden on people, mostly women, to collect water from available sources (WSTF, 2010). Due to poverty and poor living conditions in the informal settlements, water availability is a huge problem. The main indication to determine the proportion of households with access to improved water supply should include households with direct connection (piped water) to the dwelling or plot, access to public stand pipe shared by a maximum of two households and access to non-piped water such as a borehole or well, protected spring or rain water collection (WSTF, 2010).

Water should be affordable, offered at adequate quantity that is available without excessive physical effort and time. Vendor-provided water which is a common source of water in informal settlements is not considered as an improved water supply source. Provision and access of water in informal settlements comes with major challenges. Adding a water connection to a building leads to an increase in rent. The landlord faces the problem that if they implement a water infrastructure, increases in rent leads to loss of tenants. Poverty in informal settlements means that most of the residents might opt for a cheaper house without a water source. This means that they have to go for long distances to fetch water, (NCWSC, 2009). Many utilities are challenged by unaccounted-for water (due to illegal connections, leakages, bribes and vandalism), which along with the lack of confidence in financial returns from investing in service extension to low-income areas leads to less investments in water services provision in such areas.

2.3 Quality of water in informal settlements

A supply of clean water is absolutely necessary for life and health, yet almost 2 billion people lack access to adequate water supply or can only obtain it at high prices. In areas where residents have access to a water source, it is necessary to consider the quality of the water. Clean water prevents infection from many diseases. The lack of clean and safe water supplies in informal settlements has led to unhygienic food, poor sanitation, and increase in diseases; thus, poor nutrition and well-being in general (Sholkamy, 1996). Due to the lack of water, informal settlement dwellers are forced to use polluted water for basic needs leading to diseases which can lead to many deaths of innocent lives (UNFPA, 2001). According to United Nations Economic and Social Council, the deprivation of water and sanitary facilities resulting in severe water-borne diseases is one main concern for informal settlement dwellers (UN-ECOSOC, 1997). Each year, 4 billion cases of diarrhoea are reported, and 2.2 million people die from it (Camdessius, 2003). Comprehensive approach to water is needed to address the water concerns in informal settlements because just having clean drinking water is not enough.

A Kenya Demographic and Health Survey report (KDHS) (2008-2009), stated that over 50% of hospital visits in Kenya for illnesses are related to insufficient water supply, sanitation and hygiene and these diseases are the main cause of children under five hospitalizations and mortality. A survey conducted by the African Population and Health Research Centre (APHRC)(2002), found that compared to other areas in the country, informal settlement residents in Nairobi suffer worse health and reproductive health conditions than their non-slum counterparts. The quality of water is determined by measuring the level of contaminants in the water, by physical and chemical factors such as the alkalinity and also by the salts and minerals present in the water. To evaluate the quality of water, laboratory testing of water samples by a qualified analyst is required. Due to the lack of time and resources to conduct extensive testing of water samples in a laboratory, user perception on the quality of water was adopted in this study to represent water quality.

2.4 Cost of water in informal settlements

In many cities, households in informal settlements are rarely connected to the network and can only rely on water from vendors at up to 200 times the tap price (UN-HABITAT, 2003). According to NCWSC (2009), Kiosk vendors sell water in 20 litre jerry cans at 2 to 5 Ksh each (about Ksh 100 to 250 per m^3). This price is well above NCWSC's average price of Ksh 45/m^3, which includes the lower block tariff of 12 Ksh/m^3 applicable to households consuming under 10 m per month. NCWSC's official price for water in informal settlements is a subsidized KSh10/m^3 and although resellers add their own margins, this rate is not always accurately billed. Consequently, informal settlement residents are the highest-paying consumers in the city per cubic meter (NCWSC, 2009). On average, poor non-connected households spend a higher share of their monthly income on water. In Nairobi, as in most African cities, lack of access to modern water services is a contributing factor to poverty since households spend limited income on expensive water.

Discussions with informal settlement residents indicate that few households are able and willing to invest in house or yard connections. Most households are poor and simply lack the financial resources to invest in a house connection and to pay the monthly water bill. Others, who can afford, are not willing to invest in a house connection because of the insecurity of tenure (NCWSC, 2009). Water kiosks are in many cases the most technically feasible and sustainable solution for these informal settlements (WSTF, 2010). However problems of unreliability hinder use of tap water from the kiosks since it takes time for residents to get to the kiosk. The kiosks do not also have specific operating hours, thereby inconveniencing residents and forcing them to look for alternative sources of water (WSTF, 2010). This would mean that they would have to pay for more expensive informal water sources whose prices depend on demand.

2.5 Using GIS, Satellite Imagery and Internet to map resources

A Geographic Information System (GIS) is a computer system capable of assembling, storing manipulating and displaying geographically referenced information (data identified by its location). The GIS system allows data capturing, integration and data modeling. GIS applications are tools that allow users to create interactive queries, analyze spatial information, edit data in maps and present the results of all the operations in a defined interface. GIS can relate unrelated information by using their location as the key identifier. Modern GIS technologies use digital information, for which various digitized data creation methods are used to convert hard copy maps into a digital format. GIS allows for representation of spatial information in the form of maps. Applications of GIS can reveal links between different sources of information, when it is presented on a map and can find out relationships between features that are not readily apparent in spreadsheets or statistical packages. GIS often creates new information from existing data resources which is very useful for decision making and can lead to better management. Using GIS maps can provide a basis for detailed plans for development. Mapping is a useful tool to gather information about existing conditions in deprived urban areas.

Through mapping, communities have been more knowledgeable about their situation, and empowered to challenge and find solutions to the issues they face. This also offers a platform to monitor service provision and to gather all available information in one place (Cain *et al.*, 2002). The GIS information which has been generated locally can be used to lobby government units such as counties for further allocation of resources. GIS consists of four components: data input, data storage and retrieval, data analysis and data reporting. Users of GIS information start by collecting a variety of information. This could be water point locations, number of people using a water resource or description of water resources. This could also be uploading of digital or printed maps into the GIS. The data is then stored in the GIS where it can be retrieved to edit or update. This information can then be used to analyze different layers or themes of data already stored in the system. Finally a report can be produced in the form of a graphic map, with different themes, making it visual for those relying on maps.

Until a few years ago, GIS was a complex tool only used by trained experts. GIS software was expensive and required substantial training. In recent years, the proliferation of internet access and broadband connections has resulted in maps and satellite imagery becoming more available to the public. Companies such as ESRI, Google and Microsoft offer those with internet access the ability to create maps with different layers, print out these maps and visualize selected information on top of them. This has brought GIS to the average computer user and resulted in even more geo-spatial data being shared. The broadening use of GIS from its applications by professionals to its application by the broader public has extended the use of GIS in urban planning. A local example of this kind of participation is in the Kibera slum where Map Kibera has offered the public the opportunity to map their own surroundings, giving them a more visual understanding of their neighborhood and allowing them to be a part of their community upgrade. It also gives the community the option of expressing their needs (Primoz, 2011).

However the maps produced are an overview of the resources without going into details. Another example from India shows that having a map, slum dwellers can more confidently and convincingly talk to the municipality about the problems affecting their community (Hoyt *et al.*, 2005). By placing these maps online the slum dwellers can then share information about their community around the world and potentially get more visibility for the conditions they live in. The use of high-resolution satellite images, such as those available through Google Earth, Bing and QuickBird can easily be used to help map a slum and give a rough estimation of the number of residents living in the area and the resources available (Nolte *et al.*, 2010). The resolution of satellite imagery can vary depending on the altitude of the satellite and is sometimes supplemented with aerial photography, especially where cloud coverage is a problem (Martinuzzi *et al.*, 2005).

2.6 Role of Web based technologies in information dissemination

The main aim of information management is to preserve, store, organize and retrieve existing information in order to help people access and therefore generate new information (Hagler, 1997). Therefore an information system solves the problem of obtaining data from different users and aggregating it, then providing it to other users. The emergence of new technologies such as the World Wide Web allows for users from all over the world to access information from different sources easily as long as they have an internet connection (UNDP, 2011). In developing countries, the number of internet users had doubled from 974 million in 2009 to 1.9 billion in 2014. Internet user penetration has reached 78% in developing countries (ITU, 2014). Many potential users of both geospatial and statistical data seem to be intimidated by an array of figures. Decision and policy-makers have busy schedules and sometimes lack background in statistics. These are some of the reasons that could be attributed to underutilization of data.

The advent of Web browsers brings us to a step closer to addressing this dissemination challenge. Through bringing together multiple data sets from the Web, updating it dynamically and adding data context along with the numbers, complex data can be presented in an easy and understandable way. This would allow decision makers understand, at a glance, the presented information, and enable them to make decisions and conclusions. Recently, there has been a drive towards opening up public access to various data by use of Web interfaces and maps. This effort has reached Kenya with Websites such as Kenya Open Data Initiative (KODI, 2014). On that site, the Kenya Government is making their data available to anyone with access to the internet. This willingness to openly share information is now becoming commonplace within developing countries and is supported through the donor community (KODI, 2014). Mapping slum communities makes it easier to identify which families need assistance, which need basic services and how they should be assisted.

Web based technologies have been applied in this project to create the Web map. Mapping can be used for addressing environmental issues or for addressing food poverty, or to identify flood or fire prone areas, it also strengthens the community and opens the opportunity for discussion (Water Aid, 2005). Hard data in itself is not an effective tool for communicating trends and issues. However, using a map provides a visual and simple way of representing information. Use of a Web interface increases the number of people who access this information since it is not limited by geographical distance. A map can be presented as evidence in court to stop evictions. It can be reprinted by International Advocacy Groups to raise awareness. It can be presented to City Planners, as a puzzle to be solved. Maps therefore, are important tools for raising awareness on the situation of a slum at an international level.

2.7 Web maps in visualizing information

Web maps are tools that reference a set of map and GIS services that compose a useful map for use on a Web application. Web maps are useful because they can be shared and used through a Web connection without the user having to install any GIS software. Users can simply use their Web browser or mobile phone to access and use these GIS Web maps. Web mapping is the process of using maps delivered by geographical information systems (GIS). Since a Web map on the World Wide Web is both served and consumed, Web mapping is more than just Web cartography, it is both a service activity and consumer activity. Web GIS emphasizes Geo data processing aspects that are more involved with design aspects such as data acquisition; and server software architecture such as data storage and algorithms, than it does the end-user reports. Web mapping usually involves a Web browser or other user agent capable of client-server interactions.

In traditional cartography, when dealing with printed maps or interactive maps distributed on offline media (CD's and DVD's), a map update caused serious efforts, triggering a reprint or re-mastering as well as a redistribution of the media, (WolfGang *et al.*, 2012). With Web maps, data and product updates are easier, cheaper, and faster, and can occur more often. Perhaps owing to this, many Web maps are of poor quality, both in symbolization, content and data accuracy. Web maps can combine distributed data sources. Using open standards and documented Application Programming Interfaces (API's) one can integrate different data sources, if the projection system, map scale and data quality match. The use of centralized data sources removes the burden for individual organizations to maintain copies of the same data sets, (WolfGang *et al.*, 2012).

Web maps can easily deliver up to date information. If maps are generated automatically from databases, they can display information in almost real-time. They do not need to be printed, mastered and distributed. Software and hardware infrastructure for Web maps is cheap. Web server hardware is cheaply available and many open source tools exist for producing Web maps, therefore product updates can easily be distributed. Because Web maps distribute both logic and data with each request or loading, product updates can happen every time the Web user reloads the application.

2.8 Mapping tools in constructing Web based GIS systems

An important part of the implementation of a GIS system is constructing the base maps. The base maps in the GIS systems can be constructed using desktop mapping programs or Web mapping applications. Maps are an important component in GIS systems. Many GIS systems use maps as their user interfaces. Through maps GIS system users obtain a way to work with the geographic data in the GIS system. Furthermore, the product of a GIS system most often takes the form of a map (a graphical presentation of the geographically referenced data). Implementation of a GIS system often involves mapping programs for constructing the set of maps in the system. Available Web mapping services offer a straightforward way to build maps for Web based GIS systems. External data sources can be integrated into the Web mapping services to build complete GIS systems.

With the launching of Google maps, GIS developers are provided with a powerful Web mapping service for constructing GIS base maps. Google maps offer three types of maps (the standard street map, the satellite map, and the hybrid map) of the world at various resolutions. Besides, the Google maps provide a very interactive user interface with navigation on the map simply achieved by performing “drag and drop” on the map using the mouse. Unlike other mapping applications, Google maps perform with high responsiveness. The functionality of the mapping application is based on a number of scripts such as JavaScript, HTML, PHP and SQL modules, which are loaded from the Google’s site then executed on the client side (Web browser). The fact that Google maps functions on the client side make it even possible for Web developers to add in their own map imagery. Among all the advantages that Google maps has, the most meaningful one for Web developers is the application programming interface (API). The Google maps API library consists of a number of JavaScript modules. The API library offers methods which enable Web developers to embed Google maps in their own Web applications. Google maps API is freely available and having all the advantages previously mentioned, it was selected as the platform for implementation of this project.

2.9 Current efforts in mapping slum resources

A number of technology solutions, being developed in Kenya by local software entrepreneurs attempt to address the needs of the local population and provide solutions to many of the issues faced by those people by mapping the resources available. The two examples discussed portray the impact of information in improving service provision and decision making. M-Maji (Mobile Water in Swahili) is a mobile-based platform for sharing information about water availability in slums. M-Maji provides a mobile-based platform for water vendors to advertise their water availability, price and location. The water buyers then query M-Maji to find the closest and cheapest available water.

Kenya-based Spatial Collective is another mapping project that helps slum communities collect data and visualize it through GIS mapping. The spatial analysis of various GIS data and maps, allows the slum communities to see available resources, current and future needs, trends and solutions – all of which local civil society organizations can use to encourage city authorities to provide basic services. A specific case is noted in which people moved their structures so that a municipal water pipe might be laid, and agreed to do so only because they were convinced they could replace their informal structures. These maps of informal communities in which no one has legally recognized property rights are providing some record of occupancy and community-accepted boundaries, allowing a degree of stability (GLTN, 2010).

CHAPTER 3: MATERIALS AND METHODS

This chapter discusses the steps used in data preparation for both tabular data and shape files, the development of the database tables and the web maps. The software and hardware used in data processing are also described in this chapter.

3.1 Data and Tools

Data was obtained from the Water Services Trust Fund and the Majidata programme. The data obtained was in digital form which contained information on water and sanitation, demographics and socioeconomic information and information on water supply situation, water availability, problems in water access, cost of water, time taken to fetch water and water quality was extracted. The data was in tabular and shape file formats.

Tabular Data

Data was extracted and aggregated from different sources combined into five tables to answer the questions of water supply situation, water availability, problems in water access, cost of water, time taken to fetch water and water [1]quality based on the user's perception. Since the tables were large the extracted information has been represented in the data processing section showing the aggregated information.

Base maps

In this study, Google maps were used as the base maps for the Web interface. The map was accessed from Google repository as a simple Web map service. Google provides APIS which when included in the Web map, allow for access to a specified section of the map. The map shows an aerial view of the area, roads, demarcations and local names. Google maps allow for an easy overlay with other datasets.

[1] Evaluation of water quality scientifically was not conducted. The quality of water is solely based on user perception as this affects how they use the water. For example for washing and cooking only if quality is poor and treating the water for drinking if the quality is considered to be poor. This is due to time and financial limitations of conducting scientific tests.

Spatial data

Shape files containing GPS coordinates (Latitude, Longitude) of area boundaries and location of water resources were obtained for the twenty areas that make up Mathare Informal Settlement.

3.2 Data identification and collection

The variables of the study which are water supply situation, water availability, problems in water access, cost of water, time taken to fetch water and the quality of water, were determined to cover the objectives of the study and they were checked for consistency and formatted to ease understanding. The data was formatted in Ms Excel.

3.3 Software and Hardware

Software

JavaScript V3 and J-Query Application Programming Interface (API) were used to support using Google maps as the base maps. Asynchronous JavaScript and XML (AJAX) were used to plot polygons and waypoints. Pre-processing of data was done using ArcGIS and Google earth. JavaScript and PHP programming languages were used to create the Web interface text. Google chrome Web browser was used to display the Web maps. The database was hosted on WAMP server. WAMP is a free tool that combines Apache, MySQL and Python to provide compact database management. Google maps have been used as it is easy to use and easily understood by many online users. Users will not need any training to use the application. Google's Web based applications require minimal administration and no ownership costs.

Hardware

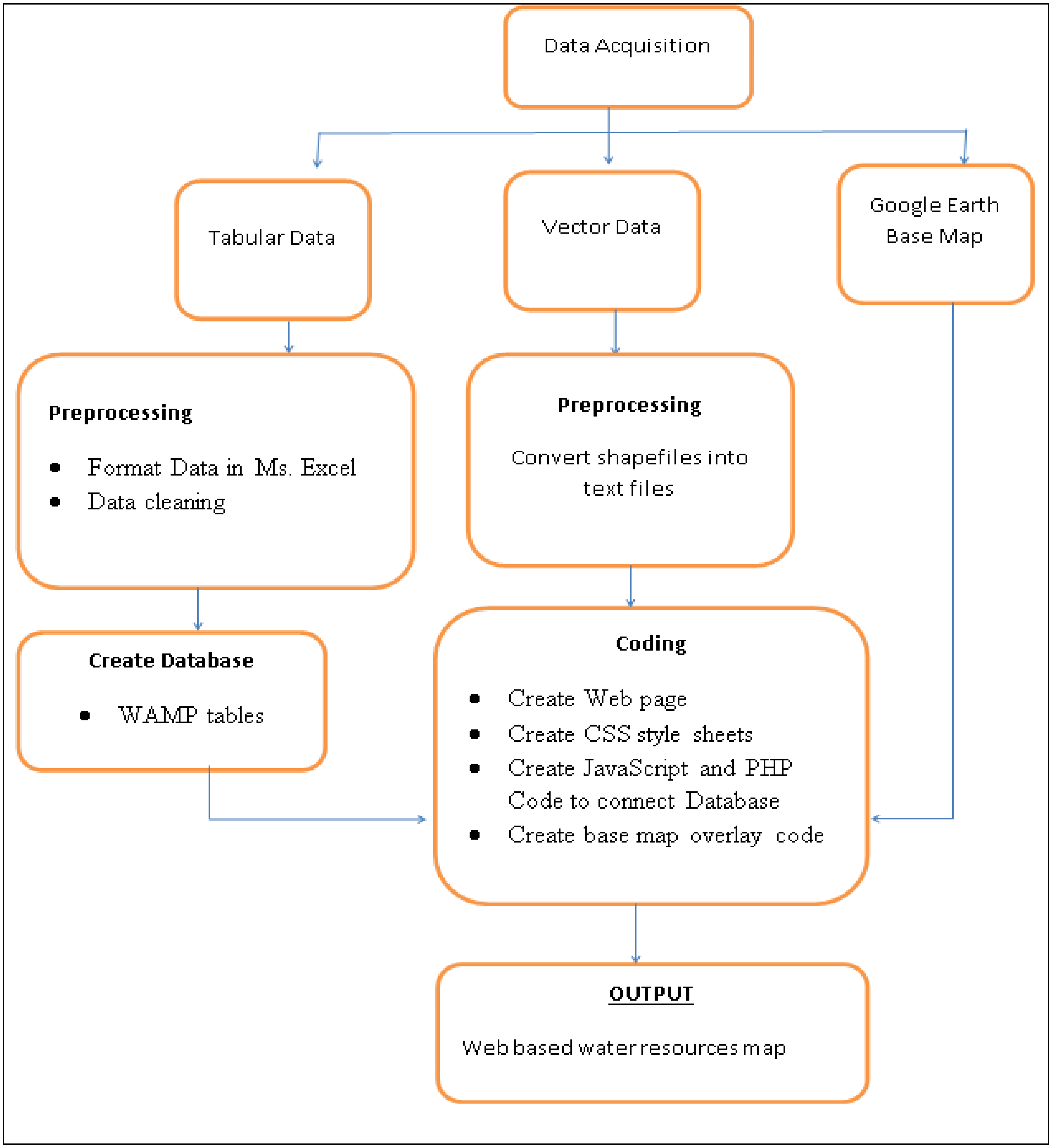
A computer with the following specifications was used:-

- 2.0 GHZ processor
- 80GB hard disk
- 2GB RAM and 17" inch monitor
- Internet connection

3.4 Data processing

The methodology for data processing for Mathare Informal Settlement involved data acquisition, pre-processing which resulted in clean harmonized datasets for use in the database and for populating the Web map interface.

Figure 3.2: Flowchart of the methodology for data processing



Data processing for tabular data

The first task was data formatting and cleaning which was done using Ms Excel spread sheets. The data was edited to fit the scope of this project which is data for the 20 villages that constitute the Mathare Valley informal settlement. Five tables were created covering the water sources, water supply situation, and time taken to fetch water, water quality and cost of water. Proper naming of the columns and calculation of percentages was done.

Creating polygons and point data

Using ArcGIS the shape files were loaded and saved as layers. The layers were then converted into KML file format. The KML format allows for easy selection of coordinates to a text based format which is uploaded to the database as a table with unique identifier, area name and a string of comma separated latitude longitude pairs. A sample of the points and polygon tables are listed in the appendix.

Database creation

The database was created using WAMP Server, which is a Web development platform that allows creation of Web applications and databases. For each table in the database, the variable characteristics such as data type and size were determined and created. The excel data was converted, comma-separated, value formatted and uploaded to the database to populate the tables. Five tables namely Water supply, Quality, Fetch duration, Water sources and Water payment were created. The database was used to store the tables containing user feedback. It was then connected to the Web interface to allow loading of information from each village. A table with points and waypoints was also created and loaded to the database.

Creating the Web map

The Web map HTML code was developed using Dreamweaver to create the page, section it into header and body. Programming languages used include JavaScript and PHP to create the home page on which the map and tables are displayed. Function calls have been coded on the home page to call other scripts, the Google base map and the Cascading Style Sheet (CSS) style renderer. For each of the tables namely:- Water supply, Quality, Fetch duration, Water sources and Water payment, a corresponding PHP file was created to connect the database tables to the Web interface. Once an area is selected from the drop down list, the corresponding data from the tables in the database is loaded and the polygon and point are also plotted on the Google base map area. A drop down list that dynamically fetches the Area names and Area ID's was added to the home page. In the summaries, several drop-down lists allow selection of variables which are then used to query the database, and the results are displayed in the form of Web maps and tables. When clicked, the points show information on the type of water source represented at that point. A CSS was using to enable ease of style rendering to the page. The CSS was used to set the fonts, styles, sizes and any other page formatting applied on the page. Hosting of maps on a Web platform was done using the Google maps API V.3 which allows for use of Google maps as the base maps over which to overlay our polygon, point and image data. AJAX was used to create code that allows the Web interface to recognize coordinates and not treat them as just a set of values. The database and the Web map are hosted on local host to allow for simulation.

The Web Interface with Google Base Map

The Web interface shows the name of the Web map and a drop down button which allows the user to select an area/village and get information on water supply, water payment, water quality and time taken to fetch the water. The Area viewer is loaded with a Google base map, selected slum village map with its points, water supply, water payment, water quality and time taken to fetch water data. The Web interface was named Mathare WIS (Water Information System). The Web map has tabs for water supply, water status, water payment, water quality, time taken to fetch water and summaries allowing for selective viewing and querying of data. A sample of the results is listed in the Appendix.

Adding Google base maps

To use Google base maps, a unique API key is generated from the Google developers' Website on the Google API's console. The Key provides a link to the JavaScript file that includes all of the symbols and definitions needed for using the Google maps API. Some scripts are created and added to the header section of the HTML code to define the specific options of the base map such as zoom level, map type (terrain, hybrid, satellite). A code is added to initialize once the page is loaded so that the base map is also loaded with the specifications indicated in the code. This ensures that the default page has some data and is not blank in the map area. In the body of the HTML code, a container (known as the DIV tag) is created and its size defined with a unique identifier which ensures that the Google maps are loaded in that container.

CHAPTER 4: DISCUSSION AND ANALYSIS OF RESULTS

In this chapter, the results are discussed by displaying the database tables, web map outputs, complex queries and aggregate results for Mathare Informal Settlement. The database is the source of the information displayed on the Web page. The Web map outputs were developed by creating scripts that query the database and display the results through the web interface. In the area specific Web maps, the user selects an area from a drop down list and the selected area map and water points are displayed. Information on the type of water point available at a specific location can be displayed by clicking on the point. Information on water supply situation, water quality, time taken to fetch water and water payment data for the area is displayed in the form of formatted tables after being retrieved from the database. The complex queries allows comparison of different sets of information and provides aggregates of all areas in Mathare Informal Settlement that meet the selected criterion, and some supplementary information in the form of tables. The analysis of results has been done through using charts and supplementary information explaining the charts has been provided to analyze the results.

4.1 Mathare Informal Settlement Database

This section displays the tables that comprise the Mathare Informal Settlement database. After the database was created in the PHP administration panel, the schema was set up in preparation for creation of table and their respective variables. To develop the database, the data was first cleaned for data uniformity and normalized to remove redundancies in Microsoft Excel and converted to text based format. The variable characteristics such as size, data type, collation, attributes, null and default values were set. Some of the terms used in the database include a dwelling unit, which in this study was used to describe a household. A household could be composed of different houses that house the same family unit. For example, a family may rent two housing units. In this case the family is considered as one dwelling despite occupying more than one housing unit. Since the data is secondary data, no formula was required in determination of sample size and data was used as acquired. Table 4.1 provides information on the sample size and the total area population and the specific area names.

Table 4.1 shows areas covered, the sample size and number of dwelling units in the informal settlement.

Table 4.1: Mathare Informal Settlement villages

Area Name	**Area Sample Size**	**No of Dwelling units**
Area-2	78	2582
CEF-Mathare 4 A	59	1620
Gitathuru	52	862
JK-Mathare 4 A	48	750
Kosovo-Mathare	91	2953
Mabatini	78	2597
Mathare 3 A	78	2205
Mathare 3 C	60	1638
Mathare 3 B	60	1644
Mathare 4A-Zone D	32	484
Mathare 4A-Zone G	36	441
Mathare 4A-Zone H	36	588
Mathare 4A-Zone T	24	375
Mathare 4B	78	2711
Mathare North-A1	133	7924
Mathare North-A2	134	7681
Mathare North-A3	142	7924
MIL-Mathare 4A	64	1688
Mlango Kubwa	154	8938
Ten	78	2420

Source: WSTF (2010)

Water Supply situation

Tables 4.2 and 4.3 give an overview of the water supply situation by displaying all the existing water sources, main water source and main water problems being faced in each area.

Table 4.2: Water sources in Mathare Informal Settlement

Area Name	Formal Sources	Informal Sources	Main Water Source
Area 2	Yard taps, borehole	Unprotected spring	Shared yard tap
CEF-Mathare 4 A	Indoor connection	None	Shared Ablution block
Gitathuru	Shared yard tap	Leaks	Shared Yard tap
JK-Mathare 4 A	Yard taps	Water resellers	Water resellers
Kosovo-Mathare	WSP kiosk,	Water resellers, Leaks	WSP Kiosk
Mabatini	Shared yard tap, Communal tap	Water resellers, Rain water, Storage tank	Shared yard tap
Mathare 3 A	Yard taps	None	Shared Ablution block
Mathare 3 C	Shared yard tap	Water resellers, Leaks	Shared Ablution block
Mathare 3 B	Shared yard tap	Rain water, Leaks	Shared yard tap
Mathare 4A-Zone D	Communal	Rain water	Shared Ablution block
Mathare 4A-Zone G	Shared yard tap.	Rain water, Leaks	Shared Ablution block
Mathare 4A-Zone H	None	Rain water	Shared Ablution block
Mathare 4A-Zone T	Shared yard tap	Rain water	Shared yard tap
Mathare 4B	Individual yard tap	None	Individual yard tap
Mathare North-A1	Shared yard tap	Leaks	Shared yard tap
Mathare North-A2	Indoor connection, Shared yard tap	None	Shared yard tap
Mathare North-A3	Indoor connection, Shared yard tap	Water resellers, Rain water, Leak	Shared yard tap
MIL-Mathare 4A	Shared yard tap	Water resellers, Rain	Shared yard tap
Mlango Kubwa	Yard taps	Leaks	Shared yard tap
Ten	Yard taps	Shallow well, Rain	Shared yard tap

Source: WSTF (2010)

Table 4.3: Main Water Problems in Mathare Informal Settlement

Area Name	**Main Water Problems**
Area 2	Long distance.
CEF-Mathare 4 A	No major problems.
Gitathuru	Poor water quality.
JK-Mathare 4 A	Low water quantity
Kosovo-Mathare	Irregular supply.
Mabatini	Price of water.
Mathare 3 A	Low water quantity
Mathare 3 C	Irregular supply.
Mathare 3 B	Poor water quality.
Mathare 4A-Zone D	Low water quantity
Mathare 4A-Zone G	Poor water quality.
Mathare 4A-Zone H	No major problems.
Mathare 4A-Zone T	Low water quantity
Mathare 4B	Low water quantity
Mathare North-A1	Low water quantity
Mathare North-A2	Interruptions in supply (including water rationing).
Mathare North-A3	Poor water quality.
MIL-Mathare 4A	Poor water quality.
Mlango Kubwa	Irregular supply.
Ten	Interruptions in supply (including water rationing).

Source: WSTF (2010)

Water Availability

Table 4.4 contains information on the availability of water in terms of frequency in supply.

Table 4.4: Water Availability in Mathare Informal Settlement

Area Name	**24hr Supply**	**Supply Information**	**Water Rationing**	**Water Days Per Week**
Area 2	Yes	N/A	Only at times	7
CEF-Mathare 4 A	Yes	N/A	No	7
Gitathuru	No	N/A	No	7
JK-Mathare 4 A	No	Inconsistent supply	No	7
Kosovo-Mathare	No	Irregular hours	Yes	7
Mabatini	No	Lasts for 5 days	Yes	5
Mathare 3 A	No	Irregular supply	Yes	5
Mathare 3 C	No	Irregular supply	Yes	6
Mathare 3 B	No	Irregular supply	No	7
Mathare 4A-Zone D	No	Irregular supply	Yes	5
Mathare 4A-Zone G	No	Lasts for 4 days	Yes	4
Mathare 4A-Zone H	No	N/A	Only at times	5
Mathare 4A-Zone T	No	Irregular	Yes	6
Mathare 4B	No	N/A	Only at times	7
Mathare North-A1	No	Irregular supply	Yes	3
Mathare North-A2	Yes	N/A	Only at times	7
Mathare North-A3	No	Lasts for 4 days	Yes	4
MIL-Mathare 4A	No	Lasts 4 days	Yes	4
Mlango Kubwa	No	Irregular	Yes	7
Ten	No	24 hr. supply	Only at times	7

Source: WSTF (2010)

Water Quality

Table 4.5 it contains percentages showing the percentage of people in each of the response category.

Table 4.5: Water Quality in Mathare Informal Settlement

Area Name	Good (%)	Fair (%)	Poor (%)	It Varies	No Opinion
Area 2	60	27	1	12	0
CEF-Mathare 4 A	68	25	2	5	0
Gitathuru	44	25	4	27	0
JK-Mathare 4 A	67	15	0	19	0
Kosovo-Mathare	66	22	2	10	0
Mabatini	71	13	5	12	0
Mathare 3 A	56	19	9	15	0
Mathare 3 C	48	48	0	3	0
Mathare 3 B	72	13	7	8	0
Mathare 4A-Zone D	88	6	0	6	0
Mathare 4A-Zone G	64	22	6	8	0
Mathare 4A-Zone H	53	28	6	14	0
Mathare 4A-Zone T	54	21	21	4	0
Mathare 4B	46	28	4	22	0
Mathare North-A1	68	13	5	14	0
Mathare North-A2	56	24	2	18	0
Mathare North-A3	71	18	1	10	0
MIL-Mathare 4A	72	8	2	17	2
Mlango Kubwa	65	17	5	13	0
Ten	54	27	3	17	0

Source: WSTF (2010)

Payment of Water

Tables 4.6, 4.7 and 4.8 provide information on payment of water in terms of the percentage of the respondents in each category.

Table 4.6: Payment of water in Mathare Informal Settlement

Area Name	Yes (%)	No (%)
Area 2	88	12
CEF-Mathare 4 A	15	85
Gitathuru	100	0
JK-Mathare 4 A	83	17
Kosovo-Mathare	95	5
Mabatini	100	0
Mathare 3 A	51	49
Mathare 3 C	95	5
Mathare 3 B	88	12
Mathare 4A-Zone D	13	88
Mathare 4A-Zone G	64	36
Mathare 4A-Zone H	61	39
Mathare 4A-Zone T	33	67
Mathare 4 B	100	0
Mathare North-A1	98	2
Mathare North-A2	95	5
Mathare North-A3	99	1
MIL-Mathare 4 A	84	16

Source: WSTF (2010)

Water payment based on cost information is represented in Table 4.7 is based on the area sample, the number of dwelling units in the sample who fall under each category and the percentage represented. The payments were categorized in the tables into eight ranges depending on the answers given for each area. The cost is the amount of money paid for the water per twenty litre container. Table 4.8 provides information on the specifics of how the water is paid for, if it is included in the rent, per container or though meter readings.

Table 4.7: Payment based on cost in Mathare Informal Settlement

Area Name	**Ksh1 (%)**	**Ksh2 (%)**	**Ksh3 (%)**	**Ksh4 (%)**	**Ksh5 (%)**	**Ksh 6-10 (%)**	**Ksh 16-20 (%)**	**Ksh 31 Or More (%)**
Area 2	0	31	35	0	12	1	0	0
CEF-Mathare 4 A	0	2	2	0	0	0	0	2
Gitathuru	0	90	4	0	4	0	0	0
JK-Mathare 4 A	13	50	17	0	4	0	0	0
Kosovo-Mathare	0	76	8	0	0	0	0	3
Mabatini	1	54	32	0	13	0	0	0
Mathare 3 A	0	29	19	0	3	0	0	0
Mathare 3 B	0	57	7	0	0	0	0	3
Mathare 3 C	27	48	8	0	12	0	0	0
Mathare 4A-Zone D	0	0	0	0	0	0	0	0
Mathare 4A-Zone G	3	44	6	0	0	0	3	6
Mathare 4A-Zone H	6	6	6	0	3	0	0	17
Mathare 4A-Zone T	0	0	0	0	0	0	0	0
Mathare 4B	1	94	3	1	1	0	0	0
Mathare North-A1	0	4	12	1	19	0	1	5
Mathare North-A2	0	1	1	0	16	2	0	1
Mathare North-A3	0	6	17	0	11	1	0	1
MIL-Mathare 4A	0	77	5	0	3	1	0	0
Mlango Kubwa	1	21	18	1	18	0	0	3
Ten	0	73	15	0	8	0	0	0

Source: WSTF (2010)

Table 4.8: Method of water payment in Mathare Informal Settlement

Area Name	Per 20-litre container (%)	Cost Included In Rent (%)	Per 10-litre Jerry can (%)	Per meter readings (%)
Area 2	61	8	0	0
CEF-Mathare 4A	2	6	1	0
Gitathuru	51	0	0	1
JK-Mathare 4A	40	0	0	0
Kosovo-Mathare	76	6	1	1
Mabatini	78	0	0	0
Mathare 3 A	40	0	0	0
Mathare 3 C	57	0	0	0
Mathare 3 B	37	13	0	3
Mathare 4A-Zone D	0	4	0	0
Mathare 4A-Zone G	19	2	1	0
Mathare 4A-Zone H	13	3	6	0
Mathare 4A-Zone T	0	8	0	0
Mathare 4B	78	0	0	0
Mathare North-A1	50	74	1	4
Mathare North-A2	27	97	0	1
Mathare North-A3	49	87	0	4
MIL-Mathare 4A	54	0	0	0
Mlango Kubwa	90	58	0	3
Ten	75	3	0	0

Source: WSTF (2010)

Time taken to fetch water

The fetch duration was categorized based on a range of minutes shown in the table below. Fetch duration is the time taken to fetch water.

Table 4.9: Time taken to fetch water in Mathare Informal Settlement

Area Name	**0-2 Min (%)**	**16-30 Min (%)**	**3-8 Min (%)**	**9-15 Min (%)**	**31-60 Min (%)**
Area 2	22	3	56	19	0
CEF-Mathare 4A	39	3	49	8	0
Gitathuru	21	2	58	19	0
JK-Mathare 4A	19	6	58	17	0
Kosovo-Mathare	29	0	63	9	0
Mabatini	23	3	62	13	0
Mathare 3 A	10	9	38	40	3
Mathare 3 C	13	2	68	17	0
Mathare 3 B	28	3	52	17	0
Mathare 4A-Zone D	50	3	38	9	0
Mathare 4A-Zone G	31	8	42	19	0
Mathare 4A-Zone H	36	3	47	14	0
Mathare 4A-Zone T	100	0	0	0	0
Mathare 4B	14	1	68	17	0
Mathare North-A1	62	1	26	11	0
Mathare North-A2	80	2	12	6	0
Mathare North-A3	70	2	23	4	0
MIL-Mathare 4A	20	2	59	19	0
Mlango Kubwa	50	1	34	15	0
Ten	22	3	56	19	0

Source: WSTF (2010)

4.2 Mathare Informal Settlement Area Specific Web Maps

After development of the database and web interface, the results for each area in Mathare Informal Settlement can be accessed through the web interface, with tabs showing information on the water supply, status of the water points, water payment and water quality information. Below is a sample output of a web map output for Mathare Informal Settlement Area 2, after being hosted on the local host. The result is achieved after executing the queries to load each village map and corresponding data from database and the Google base map. Screenshots of data from the other tabs is available under appendix A. Web maps for all the twenty villages have been listed under Appendix A. Samples of the queries used to load the areas and the summaries have also been appended in the appendix. Summaries queries results appear in the Summaries tab on the Web page and involve complex queries which covering many tables to extract information.

Figure 4.1: Query on time taken to fetch water in Area 2 of Mathare Informal Settlement

4.3Aggregate findings for the Entire Mathare Informal Settlement

This section presents an analysis of results for the entire area using charts and tables and therefore giving an overview of the water supply situation in Mathare Informal Settlement as a whole. Supplementary information providing an analysis of the charts results has been included.

4.3.1 Water Supply Situation

The water supply situation was based on the respondent's perception and in most areas was termed as good or fair based on the information collected despite the myriad problems faced. Most of the areas had access to a formal water source which was supplemented by an informal water source due to the irregularity in water supply.

Frequency of water supply

The water supply frequency was based on water available throughout the day, and if not, if the water was rationed and how many days per week the residents got water if the supply is irregular. If water is not available 24hours a day, the supply information provides a detailed description why there is no water throughout the day. The lack of a 24 hour supply was attributed to irregular supply due to rationing, interruptions in water supply and low water pressure. This in turn meant that the main water problem in most areas was that the quantity of formal water sources supplied was not sufficient to the residents hence creating the need for establishment of more formal sources of water in the areas.

Figure 4.2: Water supply frequency (24hr) in Mathare Informal Settlement

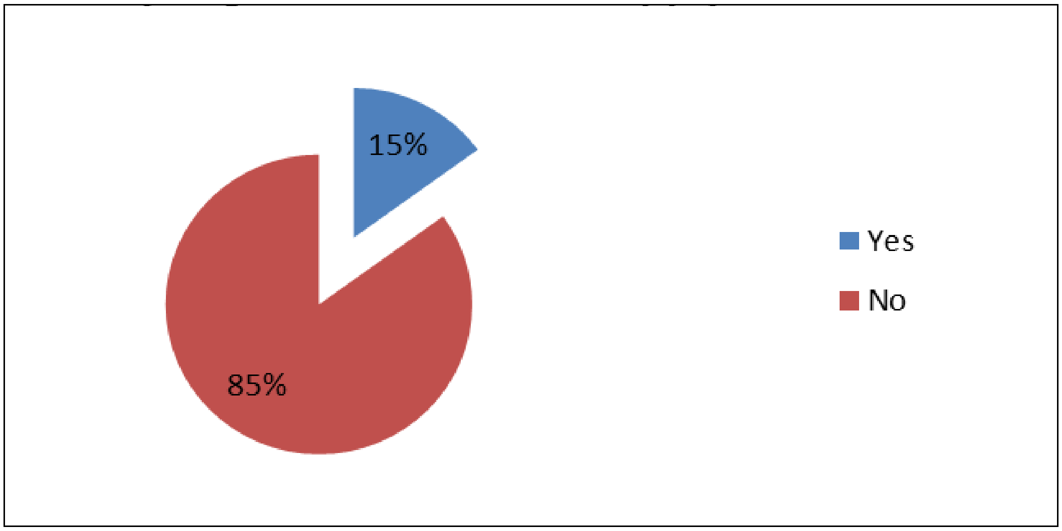
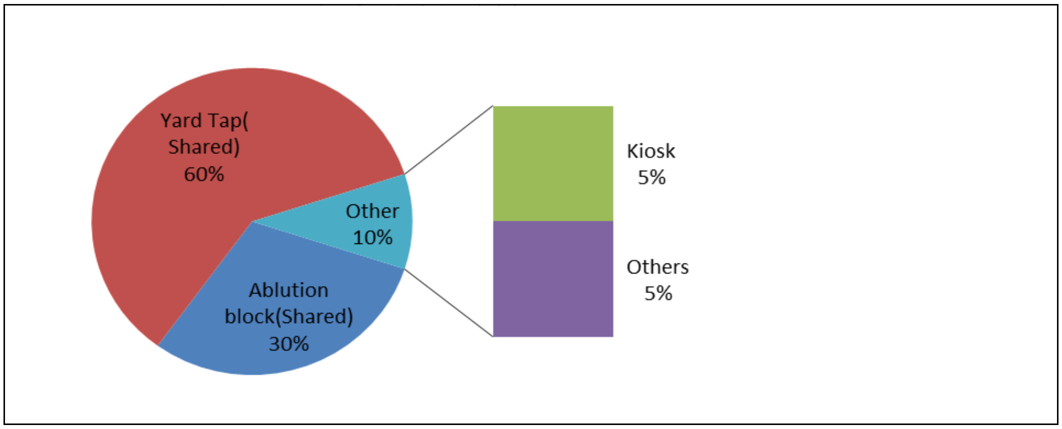
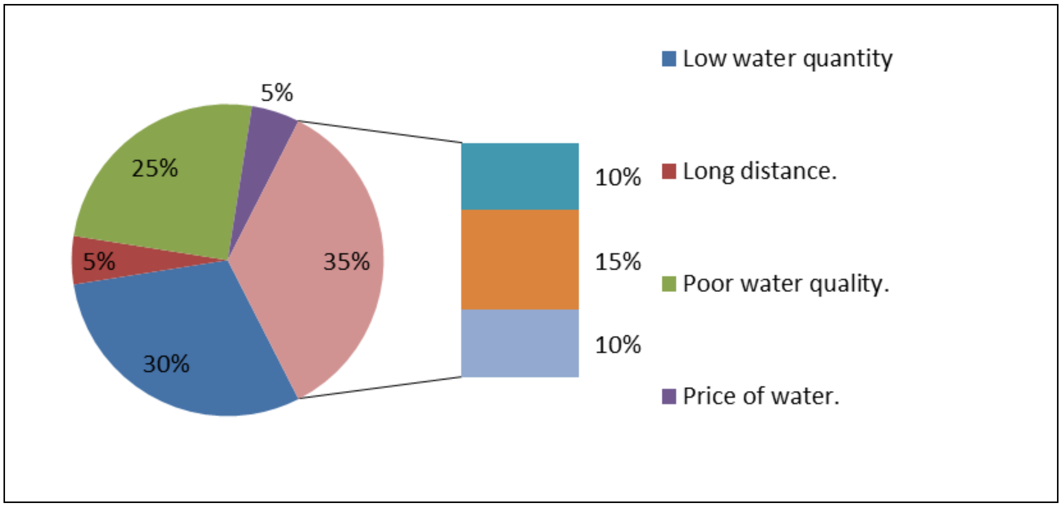


Figure 4.3: Main Water Sources in Mathare Informal Settlement



The Main Water sources were shared yard taps and ablution block.

Figure 4.4: Main Water Problems in Mathare Informal Settlement

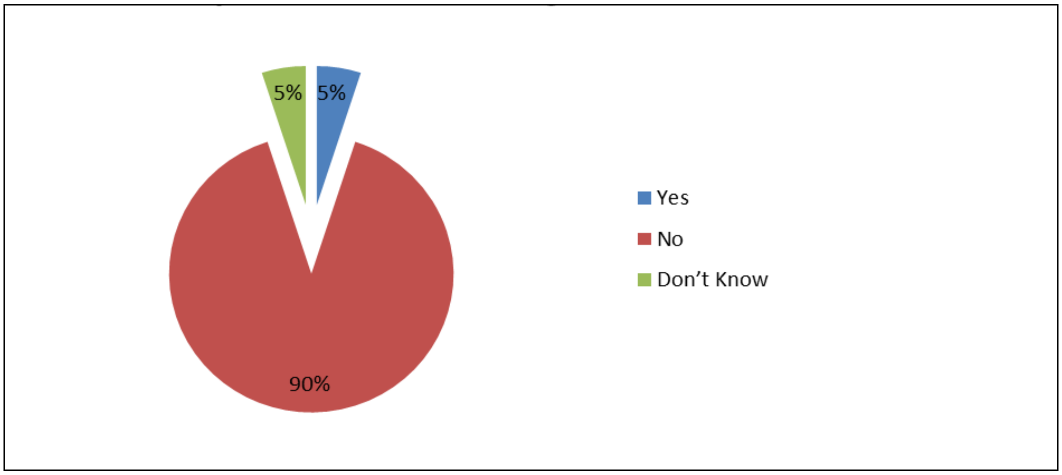


The problems that the residents face were varied with low quantity being the main problem. This could be due to the irregularity of supply, low water pressure and rationing.

Legality of Connections

From the study, 90% of the connections in Mathare Valley are illegal. These could be in the form of leaks or illegal connections and lack of specific hours of operation of the formal water kiosks which forces residents to look for alternative sources of water.

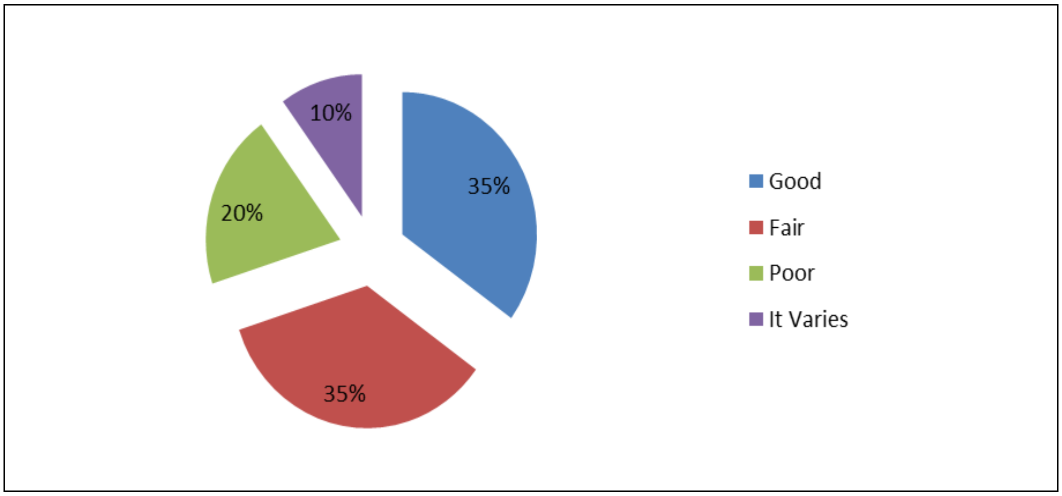
Figure 4.5: Legality of connections in Mathare Informal Settlement



Water Pressure

Water pressure determines the time taken to fetch water from the tap. Opinion on water pressure is varied with the 70% of the residents regarding the pressure of the water as good and fair.

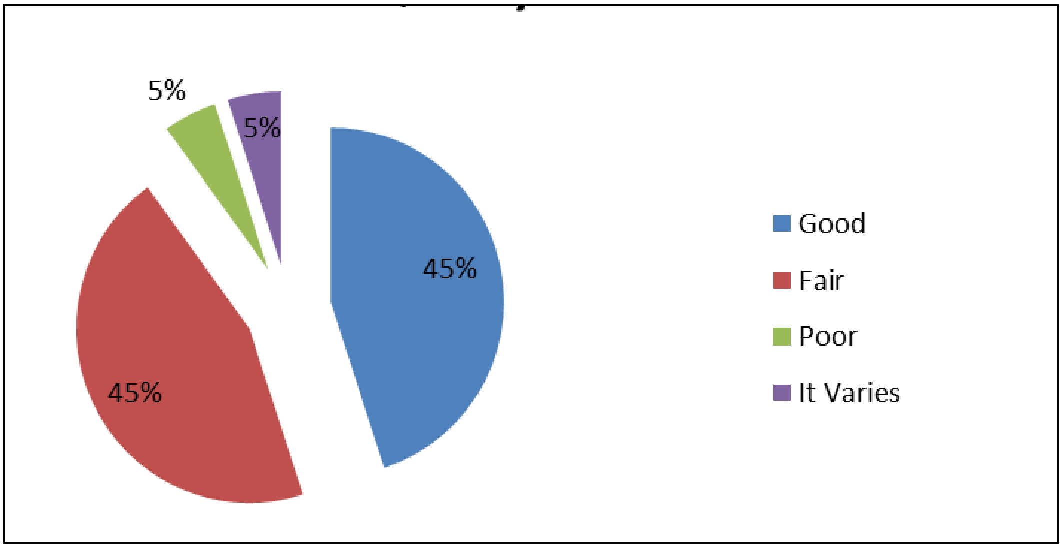
Figure 4.6: Water pressure in Mathare Informal Settlement



4.3.2 Water Quality

The quality of water was evaluated based on the user's perception and how they use their water. Residents considered the water quality good if it was used for drinking and cooking, and fair or poor if it was only used for other purposes such as washing clothes and cleaning the house. Due to variability in the water source, residents responded that the water quality varies where on some days the quality might be good while on others the quality is fair or poor. The values given are a percentage representation of the sample. Water quality of informal sources was termed as good. However, no scientific tests were conducted to prove water quality and therefore the results represented here are based on each interviewee's perception of the quality of water and may not necessarily be accurate. Information on the quality of informal water sources was not available.

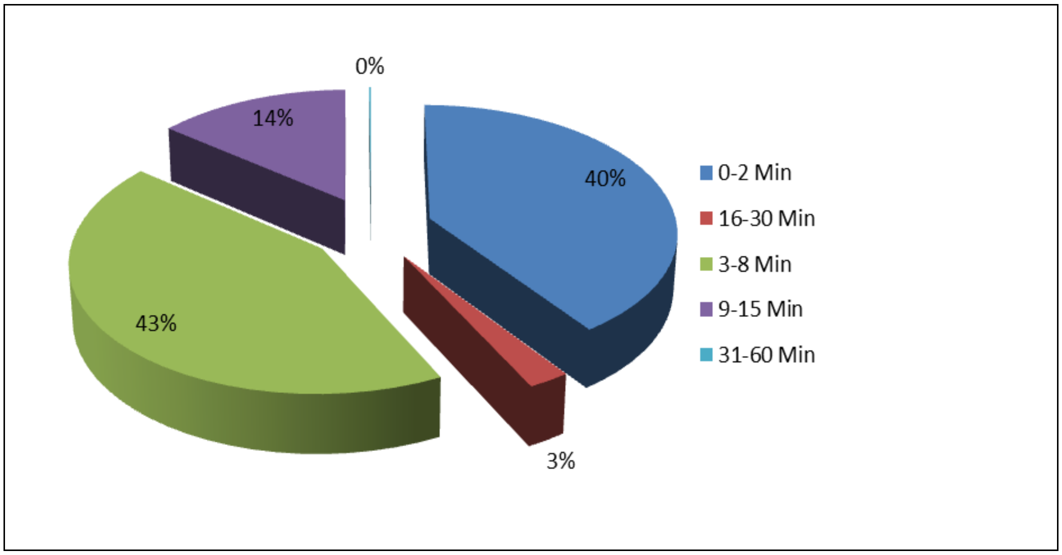
Figure 4.7: Water quality in Mathare Informal Settlement



4.3.3 Time Taken To Fetch Water

The time taken to fetch water was mainly between 0 - 8 minutes. This would mainly be attributed to the fact that most of the formal water sources are outdoors and shared. The distance to the water source, the queue on the water source and the water pressure would all affect the time taken to fetch water. However, it is observed that the higher the time taken to fetch water the greater the water access problems. This question was used to approximate roughly the distance taken to fetch water. This can in turn be used to determine which areas do not have nearby water sources. In areas where residents have to queue for a long time to fetch water, more time is taken to fetch water, would still be indicative of an area that has a water shortage or problem.

Figure 4.8: Time taken to fetch water in Mathare Informal Settlement



4.3.4 Water Payment

The overall payment issue was considered with respondents giving a yes or no answer and the percentage of the sample population for each category was calculated. Residents in most of the areas were paying for their water and in some cases below all the residents interviewed were buying their water. Water was paid for in different ways with over half of the respondents paying for their water per 20 litre container.

Table 4.10: Amount paid for water in Mathare Informal Settlement

Ksh Paid for water per 20L	People paying (%)
Ksh 16-20	0.25
Ksh 31 or more	3.39
Ksh 6-10	0.63
Ksh1	3.51
Ksh2	68.09
Ksh3	23.37
Ksh4	0.50
Ksh5	16.58

Table 4.11: Payment method in Mathare Informal Settlement

Water payment Method	People paying (%)
Meter readings	1.12
Flat rate per month	0.53
It is included in the rent	24.42
10Litre Jerry can	0.66
Per 20-litre container	59.21
Not paying for water	14.06

From Table 4.10 and Table 4.11, 86% of the respondents in Mathare Informal Settlement are paying for water, with more than half paying two shillings per 20 liters. This is due to the fact that most formal water sources especially water kiosk charge for water based on prices set by the Nairobi City Water and Sewerage Company.

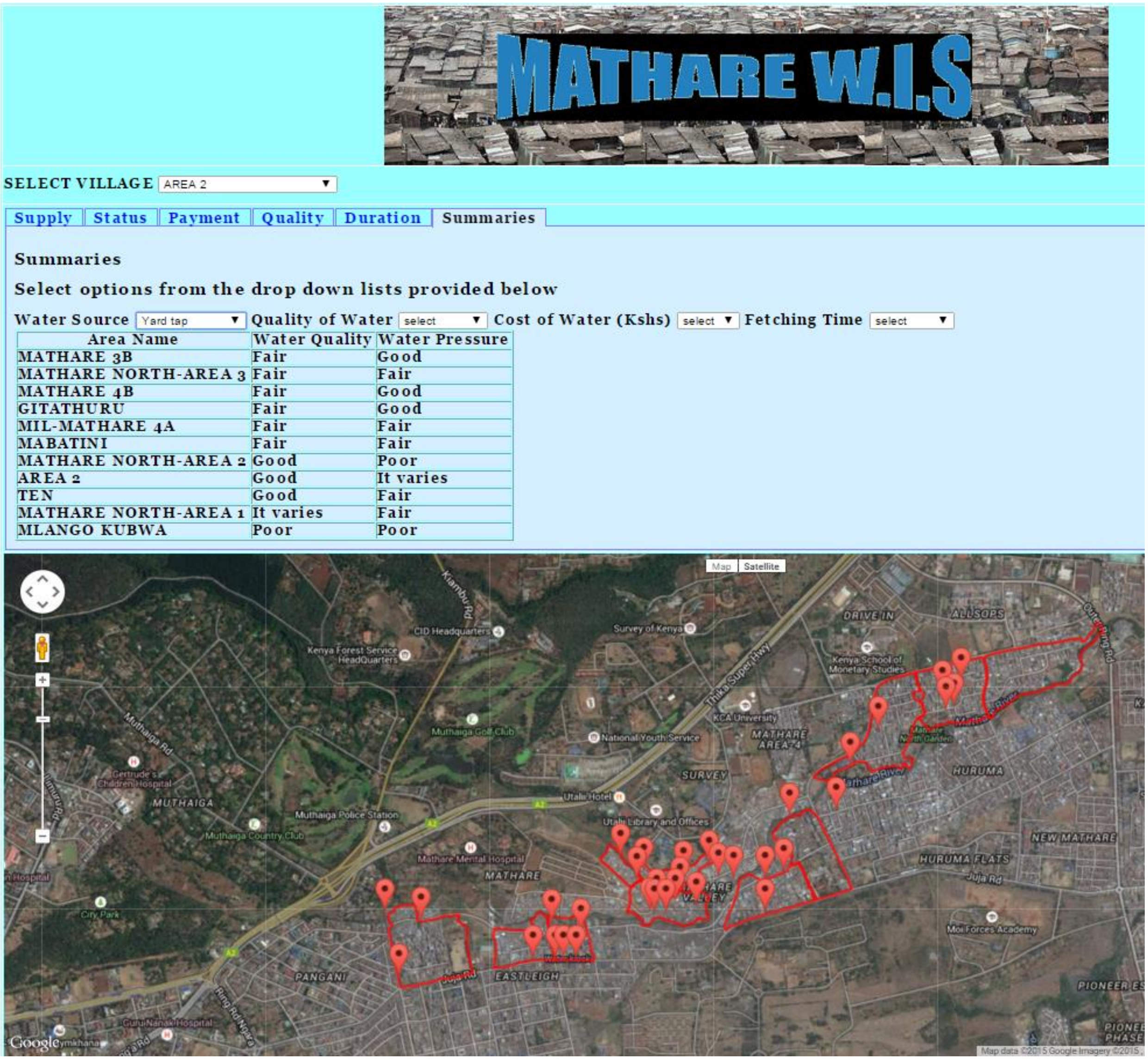
4.3.5 Interactive Queries

The summaries section provides the user with more interactive options to query the database. Four tabbed sections have been used to display the water source, water quality and a comparison of the fetching time and cost of water. When the water source is selected, all the area maps and points that fall in the selected category are displayed, and a table is loaded showing the water quality and water pressure in all the selected areas. In the water quality tab, the selected area maps and points are displayed, while tables showing the detailed supply information, water pressure, the water supply frequency and main water source are also displayed. When the fetching time and cost of water is selected, a table showing the water problems and sources within the selected categories is loaded, together with respective area maps and water points. All the tables produced also display the area names to allow easy assessment of the different factors.
The summaries tab shows aggregate information for the entire Mathare Informal Settlement and can be used to run queries for all the water sources (ablution block, yard tap, communal tap, water resellers and WSP kiosk).

The options for water quality include good, fair, poor, it varies and no opinion. The cost of water includes options for Ksh. 1, 2, 3, 4, 5, 6, 16 and 31. Fetching categories included are 0 to 2 minutes, 3 to 8 minutes, 9 to 15 minutes, 16 to 30 minutes and 31 to 60 minutes. Selecting a water source in the drop down list results in a table displaying the areas using the source, water quality and water pressure. The polygon and point maps for the selected area are also loaded. The water quality drop down list provides aggregate results for all the areas in terms of the supply information, water pressure, and frequency of supply, main water source; the maps and points in each category. The cost of water and fetching time drop down lists are linked to allow comparison between the different costs of water for different fetching time. The resulting table shows the main problems and water source in those areas; the maps and points in each category. This would allow an evaluation of the main problems where, for example, the cost of water is high and the fetching time is also high. The data for these categories was automatically loaded from distinct values in the database. The tables to be loaded for each category were selected to provide data that allows for ease of comparison between different selections. The following summaries and results were achieved through querying the database and represent some of the results that can be achieved through the summaries tab. The actual queries used to query the database have been listed in Appendix A.

1. From the results, 60% of the areas considered the yard tap as their main water source, what is the water quality and water pressure?

Figure 4.9: Water quality and pressure in areas using a yard tap as the main water source



Area Name	Water Quality	Water Pressure
MATHARE 3B	Fair	Good
MATHARE NORTH-AREA 3	Fair	Fair
MATHARE 4B	Fair	Good
GITATHURU	Fair	Good
MIL-MATHARE 4A	Fair	Fair
MABATINI	Fair	Fair
MATHARE NORTH-AREA 2	Good	Poor
AREA 2	Good	It varies
TEN	Good	Fair
MATHARE NORTH-AREA 1	It varies	Fair
MLANGO KUBWA	Poor	Poor

In areas where the yard tap was the main water source the water quality and water pressure was mainly good or fair.

2. From the results, where the residents deemed the [2]quality of their main water source as good (90%), how was the water pressure and consistency of supply?

Figure 4.10 Status of water supply in areas where water quality has been termed as good

SELECT VILLAGE AREA 2

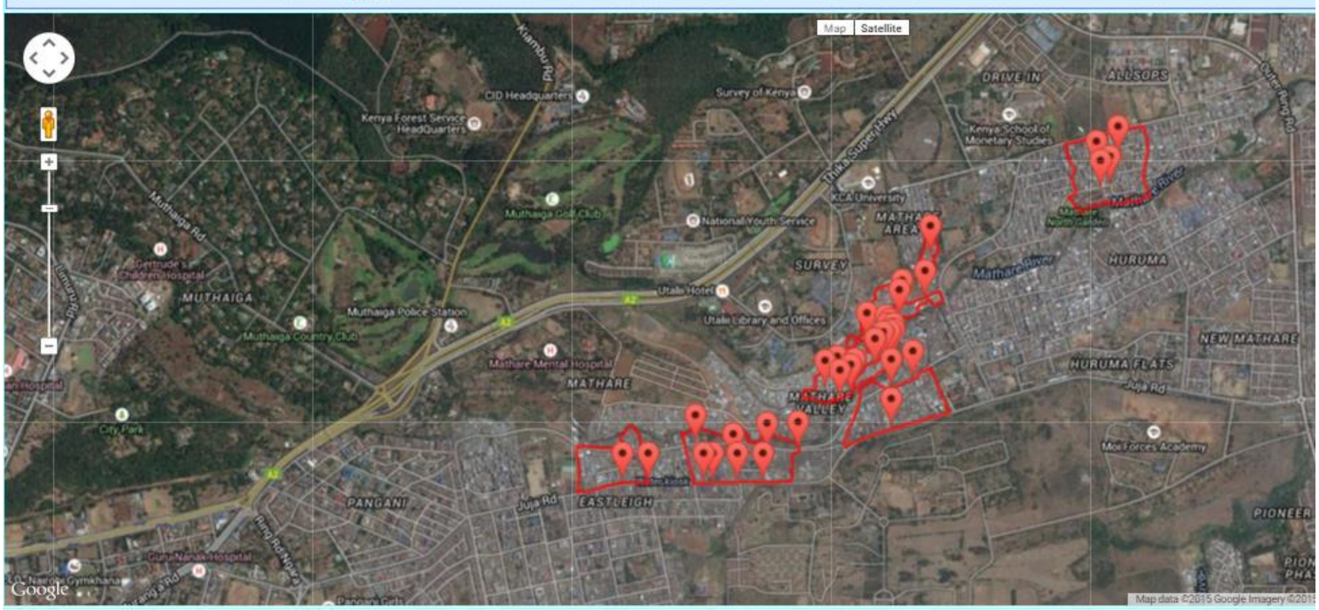
Supply | Status | Payment | Quality | Duration | Summaries

Summaries

Select options from the drop down lists provided below

Water Source select ; Quality of Water Good ; Cost of Water (Kshs) select ; Fetching Time select

Area Name	Supply Information	Water Pressure	24Hr Supply	Main Source
AREA 2		It varies	Yes	Yard tap
CEF-MATHARE 4A		It varies	Yes	Ablution block
JK-MATHARE 4A	Inconsistent supply	Good	No	Water resellers
MATHARE 2RTH-AREA 2		Poor	Yes	Yard tap
MATHARE 3 A	Irregular supply	Good	No	Ablution block
MATHARE 4A-ZONE D	Irregular	Poor	No	Communal tap
MATHARE 4A-ZONE H		Fair	No	Ablution block
MATHARE 4A-ZONE T	Irregular	Good	No	Communal tap
TEN	24 hr supply	Fair	No	Yard tap



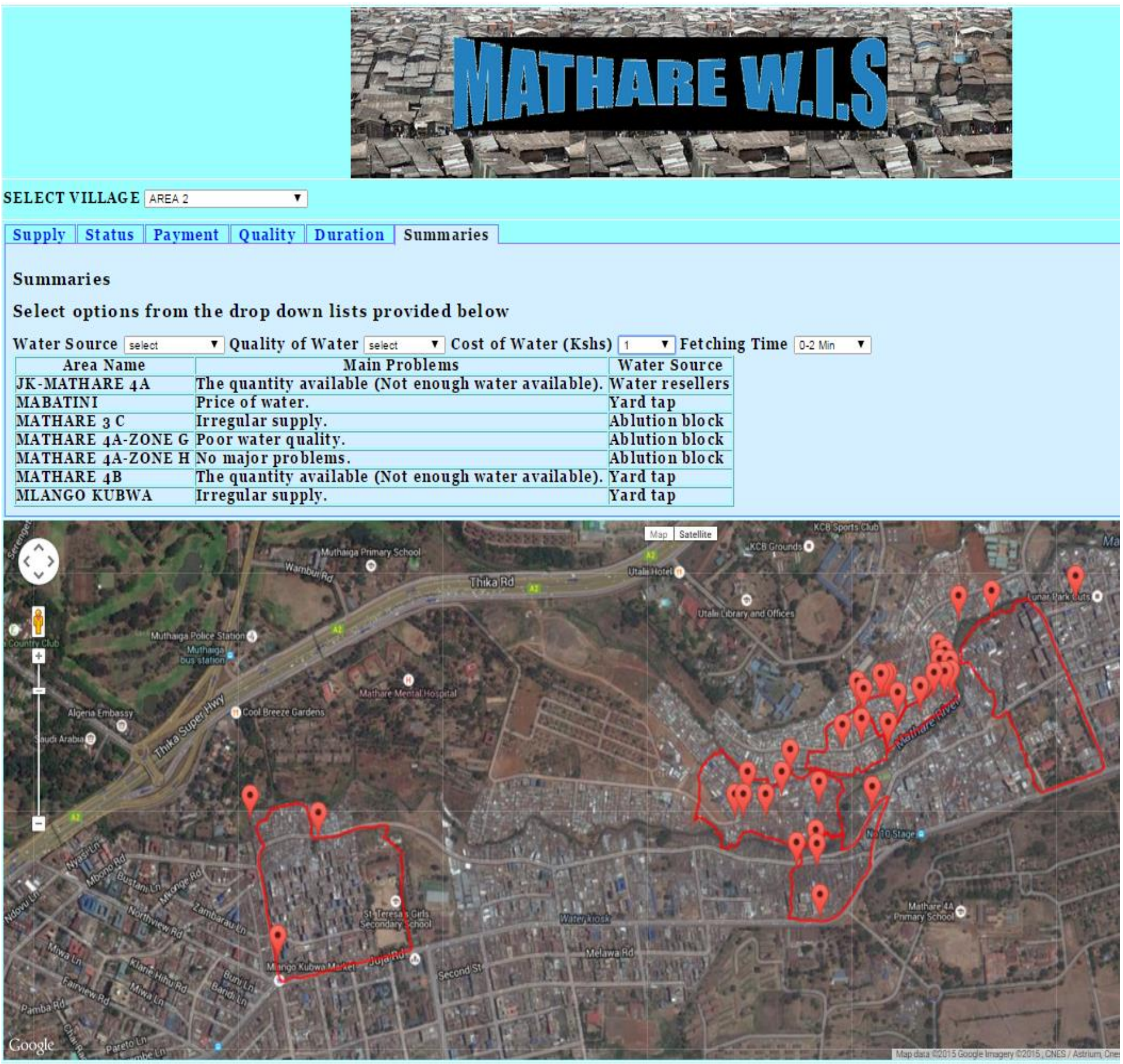
Despite residents terming their water quality as good in the areas listed in Figure 4.10 above, water supply was inconsistent and irregular.

2 Based on the use of the water i.e. if water is termed as clean it is used for drinking and cooking and if not termed clean, its used for washing and cleaning

In order to increase the interactive capabilities of the Web maps, the cost of water and fetching distance were linked so that users were able to compare the fetching time and cost of water. Maps for the selected fetching time and cost of water are displayed with their respective water points, with tables displaying the main water sources in those areas and the problems being faced.

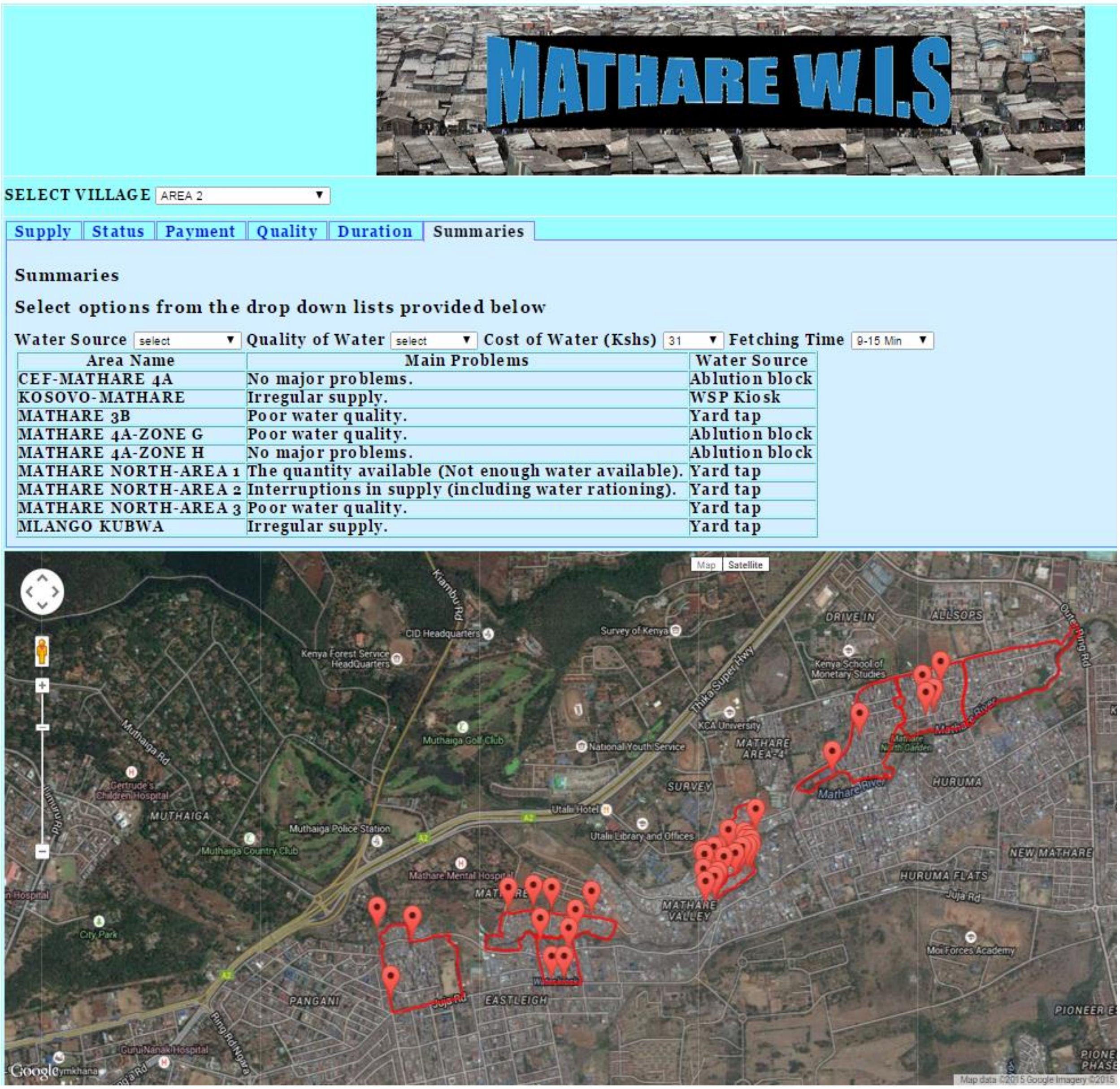
The results below show a query where residents pay Ksh1 and take 0-2 minutes to fetch water. All the areas and their water points have been loaded. The main problems faced and main water sources for selected areas are displayed in a table.

Figure 4.11: Fetching time and cost of water query 1



The results below show a query where residents pay Ksh 31 and above and take 9-15 minutes to fetch water. All the areas and their water points have been loaded. The main problems faced and main water sources for selected areas are displayed in a table.

Figure 4.12: Fetching time and cost of water query 2



Area Name	Main Problems	Water Source
CEF-MATHARE 4A	No major problems.	Ablution block
KOSOVO-MATHARE	Irregular supply.	WSP Kiosk
MATHARE 3B	Poor water quality.	Yard tap
MATHARE 4A-ZONE G	Poor water quality.	Ablution block
MATHARE 4A-ZONE H	No major problems.	Ablution block
MATHARE NORTH-AREA 1	The quantity available (Not enough water available).	Yard tap
MATHARE NORTH-AREA 2	Interruptions in supply (including water rationing).	Yard tap
MATHARE NORTH-AREA 3	Poor water quality.	Yard tap
MLANGO KUBWA	Irregular supply.	Yard tap

In areas where the residents take longer to fetch water and paid more for the water, the main problems they were facing was poor water supply in terms of quantity and quality and inconsistencies due to interruptions in water supply.

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This project has proved that Web mapping is a useful tool for representing spatial and non-spatial information. The integration of spatial and tabular information into a Web resource, as demonstrated is powerful in the visualization, querying and communication of the availability, location and spread of water resources in the slums. The role played by Web mapping applications in the dissemination of information is indisputable since it provides access to information on a global level at low maintenance cost, also allowing for coverage and representation of information in a way that is easy to comprehend. From the findings of this project, it was evident that residents of Mathare Informal Settlement face a myriad of challenges such as; long distances to water sources, inadequate supply of water due to the low pressure of supplied water, interruptions in the water supply and irregular supply and pricing that is termed as high and unaffordable to the residents.

The study found out that there is a shortage of water resources in Mathare Informal Settlement and more water resources are needed to serve the population in those areas adequately. The study has also established that despite residents terming their water quality as good, other indicators suggest that the supply was inconsistent and facing other problems such as varying water pressure. From the interactive queries, the yard taps water quality was good but the water pressure results varied. In most areas, the water quality was good but not tied to a specific water source. The cost of water and fetching time were related since the main problems faced in those areas were low quantity and long distances travelled to fetch the water. The spatial distribution in terms of water sources usage per area was visible, although the yard taps, being the main water source, was available in most areas.

5.2 Recommendations

This section provides recommendations that have emerged from the findings of this study. They include:-

1. Web map applications can be used to present data from a larger area such as all the informal settlements in the country. This study has illustrated the use of Web maps to

represent data and information from one informal settlement interactively and the methods used can be replicated to cover more informal settlements.

2. There is need to map the water resources in all the other informal settlements to provide decision makers with comprehensive details of the water situation in informal settlements. As shown in the study, there is need to provide decision makers with tools inform decision making and how this can be achieved through combining spatial and non-spatial data in a Web platform.
3. Other resources from informal settlement such as the sanitation situation can also be represented in a Web map to portray the situation in those areas. The study has illustrated how water supply information can be represented in Web maps; however varied types of information should be represented. These include demographics, sanitation situation and other information based on needs of users and decision makers.

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APPENDIX

Appendix A: Area specific queries

Area information

The queries are used for retrieving information from the database for display on the website. This allows selective display of information based on a user's selection of a village from the drop down menu.

Water supply information

```
$strnames="Formal_sources,Informal_Sources,MainWaterSource,MainWaterProblems,Illegal_Connection,Supply24hr,Supply_Information,Water_rationing";
$strnames2="Water_days_per_week,Water_Pressure,Water_Quality,Status_of_TechnicalNW";
$res =mysql_query("SELECT $strnames,$strnames2 FROM wsupsituation WHERE AreaID ='$id';");
```

Water payment information

```
$res =mysql_query("SELECT WaterPaid,AreaSmpDUs,DUsInSmp,pcntDUs FROM wpay WHERE AreaID ='$id' ;");
```

Quality information

```
$res =mysql_query("SELECT $strnames FROM quality WHERE AreaID ='$id';");
```

Pay water information

```
$res =mysql_query("SELECT $strnames FROM fetch_duration WHERE AreaID ='$id';");
```

Area map for each village

```
$query_Contents =mysql_query("SELECT Areaname as name ,trim(poly_coord) as poly_coord FROM shapefiles WHERE AreaID ='$id';");
```

Water resource points for each village

```
$res = mysql_query("SELECT  LONGITUDE AS  'longitude',LATITUDE AS  'latitude', DESCRIPTION as detail FROM points WHERE AreaID  ='$id'") or die(mysql_error());
```

Appendix B: Interactive queries for the Entire Mathare Informal Settlement

This section shows some queries used for deriving the interactive results from the summaries tab.

Table 4.3 Water quality and pressure in areas using a yard tap

$res = mysql_query("SELECT DISTINCT wsupsituation.Areaname as area,status.Water_Quality as waterquality,status.Water_Pressure as waterpressure,shapefiles.poly_coord as polycoord,shapefiles.AreaID as areaID FROM wsupsituation,status ,shapefiles WHERE wsupsituation.AreaID=status.AreaID AND shapefiles.AreaID=status.AreaID AND wsupsituation.MainWaterSource='Yard tap' ORDER BY status.Water_Quality ASC;") or die(mysql_error());

Table 4.4: Status of water supply in areas where water quality has been termed as good

$res=mysql_query("SELECT DISTINCT status1.Areaname as area,status1.AreaID AS areaId,status1.Water_Quality1 as quality,status1.Supply_Information as information,status1.Water_Pressure as pressure, status.Supply24hr as twentyfourhr,wsupsituation.MainWaterSource as mainsource,shapefiles.poly_coord as polycoords FROM status1,status,wsupsituation, shapefiles WHERE status1.AreaID=wsupsituation.AreaID AND shapefiles.AreaID = status1.AreaID AND shapefiles.AreaID = status.AreaID AND status1.Water_Quality1='Good' ORDER BY area ASC;")or die(mysql_error());

Table 4.5: Main problems and sources where time taken to fetch water is 9-15minutes and amount paid for water is Ksh. 5

$res = mysql_query("SELECT DISTINCT wpayamount.Areaname as area,wpayamount.AreaID as AreaID, wsupsituation.MainWaterProblems as problems, wsupsituation.MainWaterSource as source, wpayamount.amountDesc as amount, fetch_duration.DurationDesc as duration ,poly_coord as polycoords FROM fetch_duration,wpayamount, wsupsituation,shapefiles WHERE wpayamount.AreaID=wsupsituation.AreaID AND fetch_duration.AreaID=wpayamount.AreaID AND shapefiles.AreaID=wpayamount.AreaID AND wpayamount.amount='9-15' AND fetch_duration.DurationRange= 5 ORDER BY wsupsituation.Areaname ASC;") or die(mysql_error());

Appendix C: Web maps for the 20 villages in Mathare Informal Settlement

This section shows the outputs on the web maps for the 20 villages covered in this study.

AREA 2

CEF-MATHARE 4A

SELECT VILLAGE CEF-MATHARE 4A

Supply | Status | Payment | Quality | Duration

Is Connection Legal	24hr Supply	Details	Days with water supply	Water pressure	Status of TechnicalNW
Yes	Yes			It varies	Good

GITATHURU

SELECT VILLAGE GITATHURU ▼

Supply | **Status** | Payment | **Quality** | **Duration**

Amount Paid	Percent Paying Drinking Water	Percent Paying Non Drinking Water
Ksh2	90.38	90.38
Ksh3	3.85	3.85
Ksh5	3.85	96.00

JK-MATHARE 4A

Water Quality	Percent
Good	32
Fair	7
It varies	9

KOSOVO-MATHARE

MABATINI

SELECT VILLAGE MABATINI ▼

Supply | Status | Payment | Quality | Duration

Area selected: MABATINI

All Formal Water Sources	All Informal Water Sources	Main Water Source	Main Water Problems	Water Quality	Water Rationing
Shared yard tap, Communal tap (managed by user group).	Water resellers using carts or bicycles, Rain water, Plastic water storage tank vendor.	Yard tap	Price of water.	Fair	Yes

MATHARE 3 A

SELECT VILLAGE MATHARE 3 A

Supply | Status | Payment | Quality | Duration

Area selected: MATHARE 3 A

All Formal Water Sources	All Informal Water Sources	Main Water Source	Main Water Problems	Water Quality	Water Rationing
Shared yard tap, Communal tap (managed by user group).	None	Ablution block	The quantity available (Not enough water available).	Good	Yes

MATHARE 3 C

SELECT VILLAGE MATHARE 3 C ▼

Supply | **Status** | **Payment** | **Quality** | **Duration**

Area selected: MATHARE 3 C

All Formal Water Sources	All Informal Water Sources	Main Water Source	Main Water Problems	Water Quality	Water Rationing
Shared yard tap.	Water resellers using carts or bicycles, Leak in distribution network of WSP.	Ablution block	Irregular supply.	Fair	Yes

MATHARE 3B

SELECT VILLAGE MATHARE 3B

Supply | Status | Payment | Quality | Duration

Area selected: MATHARE 3B

All Formal Water Sources	All Informal Water Sources	Main Water Source	Main Water Problems	Water Quality	Water Rationing
Shared yard tap.	Rain water, Leak in distribution network of WSP.	Yard tap	Poor water quality.	Fair	No

MATHARE 4A-ZONE D

SELECT VILLAGE MATHARE 4A-ZONE D ▼

Supply | Status | Payment | Quality | Duration

Area selected: MATHARE 4A-ZONE D

All Formal Water Sources	All Informal Water Sources	Main Water Source	Main Water Problems	Water Quality	Water Rationing
Communal tap (managed by user group).	Rain water.	Communal tap	The quantity available (Not enough water available).	Good	Yes

MATHARE 4A-ZONE G

Is Connection Legal	24hr Supply	Details	Days with water supply	Water pressure	Status of TechnicalNW
Yes	No	4	Lasts for 4 days	Fair	Fair

MATHARE 4A-ZONE H

MATHARE 4A-ZONE T

SELECT VILLAGE MATHARE 4A-ZONE T

Supply | Status | Payment | Quality | Duration

Water Quality	Percent
Good	13
Fair	5
Poor	5
It varies	1

MATHARE 4B

SELECT VILLAGE MATHARE 4B

Supply | Status | Payment | Quality | **Duration**

Time Taken	Percent
0-2 Min	14.10
16-30 Min	1.28
3-8 Min	67.95
9-15 Min	16.67

MATHARE NORTH-A1

SELECT VILLAGE MATHARE NORTH-AREA 1 ▼

Supply | Status | Payment | Quality | Duration

Area selected: MATHARE NORTH-AREA 1

All Formal Water Sources	All Informal Water Sources	Main Water Source	Main Water Problems	Water Quality	Water Rationing
Shared yard tap.	Leak in distribution network of WSP.	Yard tap	The quantity available (Not enough water available).	It varies	Yes

MATHARE NORTH-A2

SELECT VILLAGE MATHARE NORTH-AREA 2 ▼

Supply | Status | Payment | Quality | Duration

Area selected: MATHARE NORTH-AREA 2

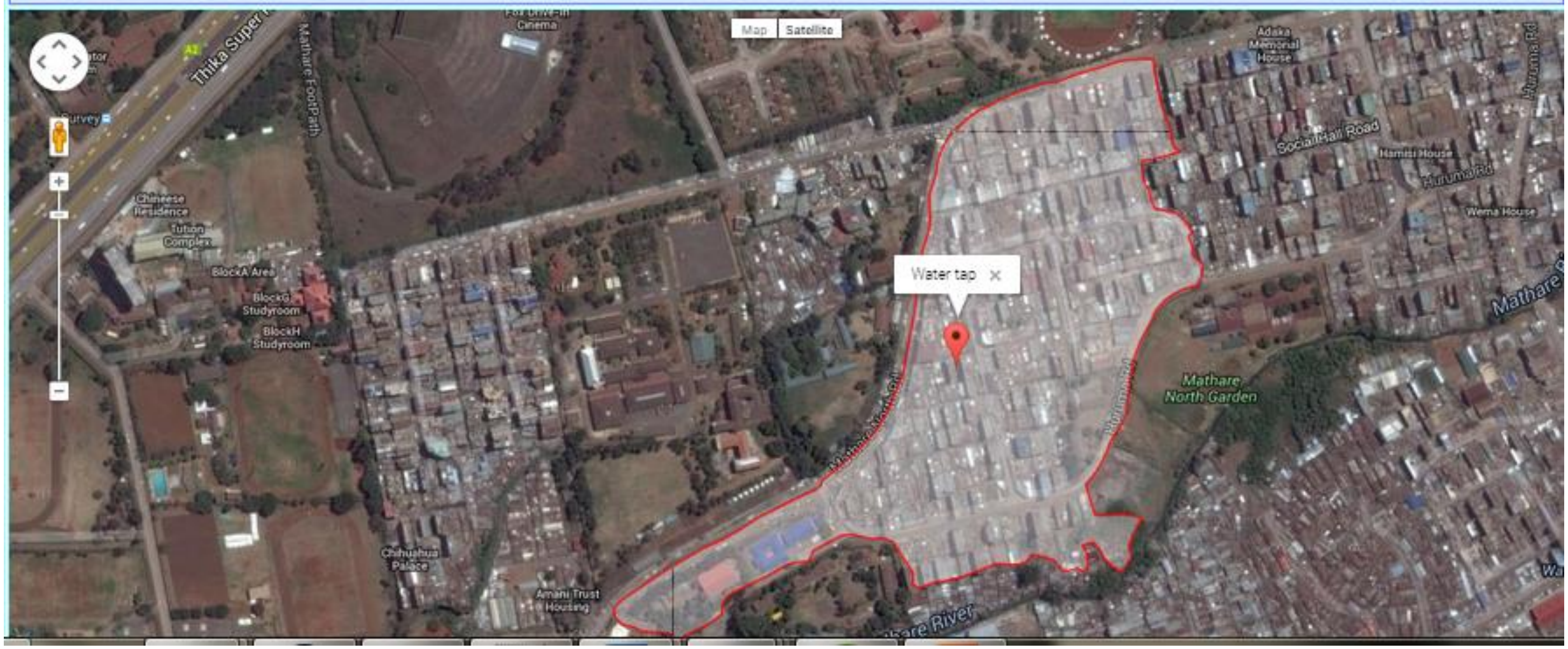
All Formal Water Sources	All Informal Water Sources	Main Water Source	Main Water Problems	Water Quality	Water Rationing
Indoor connection, Shared yard tap.	None	Yard tap	Interruptions in supply (including water rationing).	Good	Only at times

MATHARE NORTH-A3

SELECT VILLAGE MATHARE NORTH-AREA 3 ▼

Supply | Status | Payment | Quality | Duration

Amount Paid	Percent Paying Drinking Water	Percent Paying Non Drinking Water
Ksh2	5.63	5.63
Ksh3	16.90	16.90
Ksh 31 or more	1.41	1.41
Ksh5	11.27	11.27
Ksh 6-10	0.70	0.70



MIL-MATHARE 4A

SELECT VILLAGE MIL-MATHARE 4A ▼

Supply | Status | Payment | Quality | Duration

Water Quality	Percent
Good	46
Fair	5
Poor	1
It varies	11
No opinion	1

MLANGO KUBWA

SELECT VILLAGE MLANGO KUBWA

Supply | Status | Payment | Quality | Duration

Water Quality	Percent
Good	100
Fair	26
Poor	8
It varies	20

TEN

SELECT VILLAGE TEN

Supply | Status | Payment | Quality | Duration

Amount Paid	Percent Paying Drinking Water	Percent Paying Non Drinking Water
Ksh2	73.08	73.08
Ksh3	15.38	15.38
Ksh5	7.69	7.69