# DAM MANAGEMENT INFORMATION SYSTEM

## A CASE OF KALOMO DISTRICT - SOUTHERN PROVINCE ZAMBIA


By

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Dissertation submitted in partial fulfilment of the requirements for the award of the Master of Engineering Degree in Geo-Informatics and Geodesy


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## APPROVAL

This dissertation of Mr. Hantambo Stanley has been approved as fulfilling the requirements for the award of the Master of Engineering in Geo-informatics and Geodesy by the University of Zambia.

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**ABSTRACT**

Management Information Systems have proved to be an important component for delivering consistent and effective management of water reservoirs such as Dams. Many institutions around the world have developed management information systems to make information accessible to governments, stakeholders and users for decision making and planning purposes. In Zambia, the Department of Water Resources Development (DWRD) being the agency in charge of water resources infrastructure development such as dams, lacked a dam management information system. This was an overarching challenge to policy makers and practitioners to plan and make informed decisions. It was for this reason that a Dams Management Information System (DMIS) was developed. This study was aimed at developing an application for storing and retrieving the country's dams and making collective dam information easily accessible to all stakeholders. The study focused on dams in Kalomo District, Southern Province because the district has the largest number of dams in the country. An applied research methodology was followed in this study. The resulting database was designed and developed following the analysis of existing data, user expectations and requirements. The interface consisting of dam portal contains primary information on dams which include dam architectural plans, title deeds reports on disasters, inspections, rehabilitation works, hydrological data, field inspections reports and construction details. The final results of the study showed a successful integration of MySQL database backend, MS-Access front-end and a Geographical Information System for desktop mapping; implementing thematic visualization for making inferences. The interaction between the application system and its users was evaluated in form of system's ability to function. The functions were suitable, well structured, with applicable data on dams making the system more user friendly. Linkages of tools such as ArcGIS, QGIS, MySQL database and MS access proved to serve effectively in decision support for water managers.

**Keywords:** Dam Information System, Management Information Systems, GIS, MySQL database

# DEDICATION

I dedicate this work to the memory my mother, (Justina Hantambo), who always encouraged and believed in my ability to be successful in education. Although you are gone, your belief in me has made this uneasy journey possible.

# ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| 7NDP | Seventh National Development Plan |
| AfDB | African Development Bank |
| API | Application Programming Interface |
| DBMS | Database Management System |
| DWRD | Department of Water Resources Development |
| GIS | Geographical Information System |
| GWAN | Government Wide Area Network |
| ICT | Information Communication Technology |
| LAN | Local Area Network |
| MIS | Management Information System |
| NDMIS | National Dams Management Information System |
| SSA | Sub Saharan Africa |
| WAN | Wireless Area Network |

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# CHAPTER ONE: INTRODUCTION

## 1.1 Introduction

This chapter brings out the problem background and justification of the study, problem statement, aim of the study and the objectives as well as the significance of the study. The scope of the study is also discussed.

## 1.2 Problem Background and Justification

Jean et al (2012) has posited that for many countries especially in Sub Saharan Africa (SSA), have more recently realised that agriculture is, as it were, the strategic engine of growth and poverty reduction as such it's deliberately coming back on the development agenda. As a result, donor communities and governments in developing countries are looking again for sound investments in the sector especially in water harvesting structures such as dams. Therefore, the provision of data on the dams is vital to all stakeholders if agriculture is to thrive.

In its quest to revamp the dwindling economy resulting from low copper prices on the international market, Zambia has identified agriculture as one of the key sectors to bring about economic development. As the country diversifies into the agricultural sector in order to boost its economy, the ever-increasing demand for water cannot be overemphasized (Nkhuwa et al, 2013). In Zambia rapid agricultural, industrial and population growth puts more pressure on the available water resources thereby prompting for mechanisms to manage water resources. In view of this, Nyambe (2000) has shown that management of water resources is critical if equitable access by marginalized poor, especially women and children are considered. Low precipitation due to adverse effects of climate change has put more pressure on available water resources. Southern Province is one such area that has been affected. This has prompted both the public and private institutions to focus on water harvesting structures such as dams. For this reason, the Ministry of Water Development, Sanitation and Environmental Protection through the Department of Water Resources Development (DWRD ) which is responsible for undertaking the water resources and infrastructure development in order to secure the provision of quality water to meet the social and economic requirements of the country, has embarked on construction and rehabilitation of dams.

Richter et al (2010) has indicated that globally, there are millions of people whose livelihoods depend largely on dams or rivers. There are many private and public dams in Zambia providing water for various uses ranging from household, livestock to irrigation purposes. For the DWRD to ensure efficiency, better quality and facilitating equitable access, the challenge has been providing timely delivery of information to all stakeholders on the state and condition of the dams as well as available water quantities. Vembu et al (2006), has also observed that although many institutions have been generating databases and working in collaboration with each other in order to arrive at a common conclusion and share results, in times of emergency data from institutions has not been readily available due to poor maintenance of existing information.

## 1.3 Problem Statement

The Department of Water Resources Development being the agency in charge of water resources infrastructure development related to dams and groundwater exploration does not have a management information system for water resources management such as dams. Thus, information on dam facilities has not been easily accessible to policy makers. Lacking also is providing information on how the dams have impacted communities where they were built. This has been a challenge to policy makers and practitioners to plan and make informed decisions. It is for this reason that a Dams Management Information System (DMIS) was developed to provide information on the country's dams and how they are impacting not only the farming communities but all users at large including decision makers.

## 1.4 Aim of the Study

This study was aimed at developing a database for managing the country's dams so as to make collective dam information easily accessible to all stakeholders. To accomplish this purpose, the study had the following specific objectives.

## 1.5 Research Objectives

The main objective of this study was to develop a GIS based prototype for easy storing and retrieving the country's dam data for the DWRD.

## 1.6 Specific Objectives

1. To investigate the current dams information system available at the DWRD.
2. To develop the Dam Management Information System (DMIS).

3. To use GIS to visualize DMIS parameters and make inferences from the representations (decision support system - DSS)
4. Compare current approach to the previous manual workflows (speed, efficiency, likelihood of adoption, etc.)

## 1.7 Research Questions

The questions to be answered by the study are:

1. What are the existing systems for managing dams at DWRD?
2. How will the National Dam Management Information System (NDMIS) impact efficiency in water resource management?
3. How will GIS be used to visualise the DMIS data and make inferences from the representations?
4. Is the developed system better than the previous manual workflows in terms of speed, efficiency?

## 1.8 Significance of the study

The study selected Kalomo District out of many districts in Zambia. This is largely because Kalomo district has the prevalent number of dams in the country and is one area which has in the recent past produced largest quantities of maize grains compared to other major agricultural regions in the country. Additionally, Kalomo district mainly depends on dams to support the little rainfall in the areas for both domestic and commercial farming.

Deployment of a reliable and dependable Management Information System across the network of dams in Kalomo district eliminated the flaws in manual management of dam data and ensured that the Department of Water Resources Development and other consumers of data share data and other related services with all stakeholders for planning and evidence-based decision-making purposes. Many stakeholders will have chance to view the data and see how they are impacting the communities. This has not only benefited the Department of Water Resources Development but the community at large in making informed decisions and improve their livelihood and improve agriculture and livestock activities in the area.

## 1.9 Scope of Study

This project report was limited to review the literature on developing dam's management system. The research was mainly developing the geodatabase for dams in Kalomo and looking at modalities of making the data on dams accessible and available across all departments, agencies and stakeholders of the Department of Water Resource Development in Kalomo using Information Technology.

## 1.10 Organisation of the Dissertation

Chapter 1 brings out the problem background and justification of the study, problem statement and the objectives for developing the Dam Management Information System for DWRD. The chapter highlights the significance and scope of the study.

Chapter 2 presents literature on Management Information Systems and Dam Management Information Systems and describes similar studies. The MIS architecture is described.

Chapter 3 presents the techniques which were used in order to achieve the set objectives. The chapter is divided into four sections namely Study design, System Development Lifecycle, System Design and is followed by Testing and Deployment.

Chapter 4 presents the study results on the prototype of the developed Dam Management Information System (DMIS) and its functionalities in terms of speedy and efficiency compared to previous manual workflows. The use of GIS in the visualisastion of DMIS parameters are presented.

Chapter 5 presents the discussion on the findings of the study and compares the developed system with current workflows at DWRD.

Chapter 6 presents the summary of the research findings according to the research questions and research objectives. The chapters also brings out recommendations on what needs to be prioritised going forward. The organisation of the dissertation is summarised in Figure 1.1.

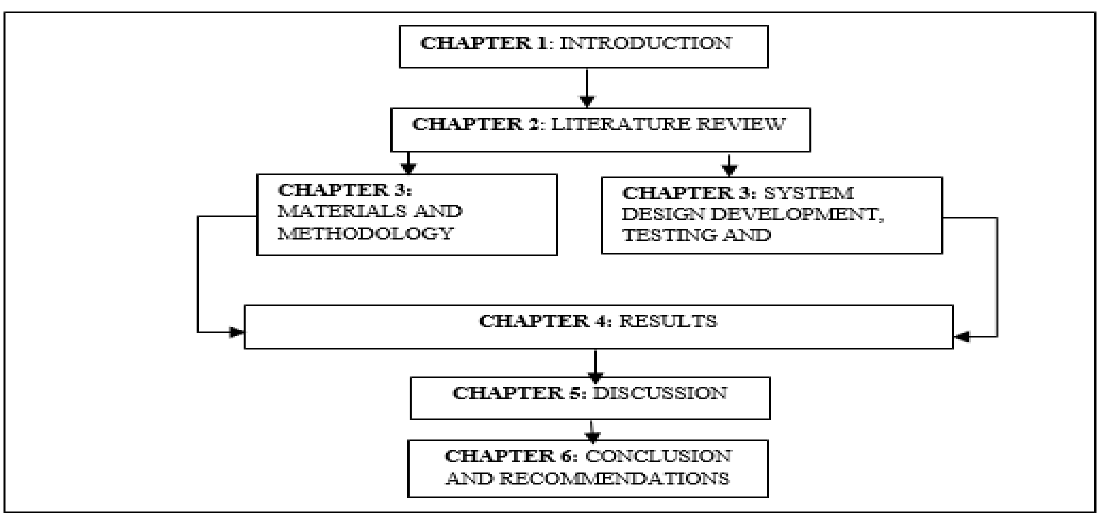



Figure 1.1 : **Dissertation Chapter Summary**

Source**:** Formulated by author (2017).

# CHAPTER TWO: LITERATURE REVIEW

## 2.1 Introduction

This chapter is aimed at providing an overview of databases with emphasis on dam management information systems. Section 2.0 provides an overview of Kalomo district. Section 2.1 describes the effects of climate change and how it has impacted Zambia. The background on dam management information and situation analysis on dam management is provided in section 2.2 and 2.3 respectively. Section 2.4 describes the current workflows while section 2.5 describes Geographical information system. Section 2.6 and 2.7 brings out literature on Management Information Systems and Dam Management Information Systems respectively. The MIS architecture is described in section 2.8.

## 2.2 Brief Overview about Kalomo

Kalomo district with an area 8,374 km² is in the Southern Province of Zambia (See Figure 2.1). According to the census population of 2010 as conducted by the central statistical office, Kalomo has 188, 693 people and of which 51.3 percent is represented by females and 48.7 are male (CSO, 2010). Agriculture is the primary economic activity in the area with a combination of small scale and commercial farms across the province (Sichingabula, et al.1997). Further, Kalomo District compared to other major agricultural regions in the country, has more abundant land, but with very less rainfall due to increased draught('SPARS - ZAMBIA', 2019). Kalomo mainly depends on dams to support the little rainfall in the areas for both domestic and commercial farming. In total, Kalomo has 113 registered dams and 192. 078 cattle (Sichingabula el, 1997).

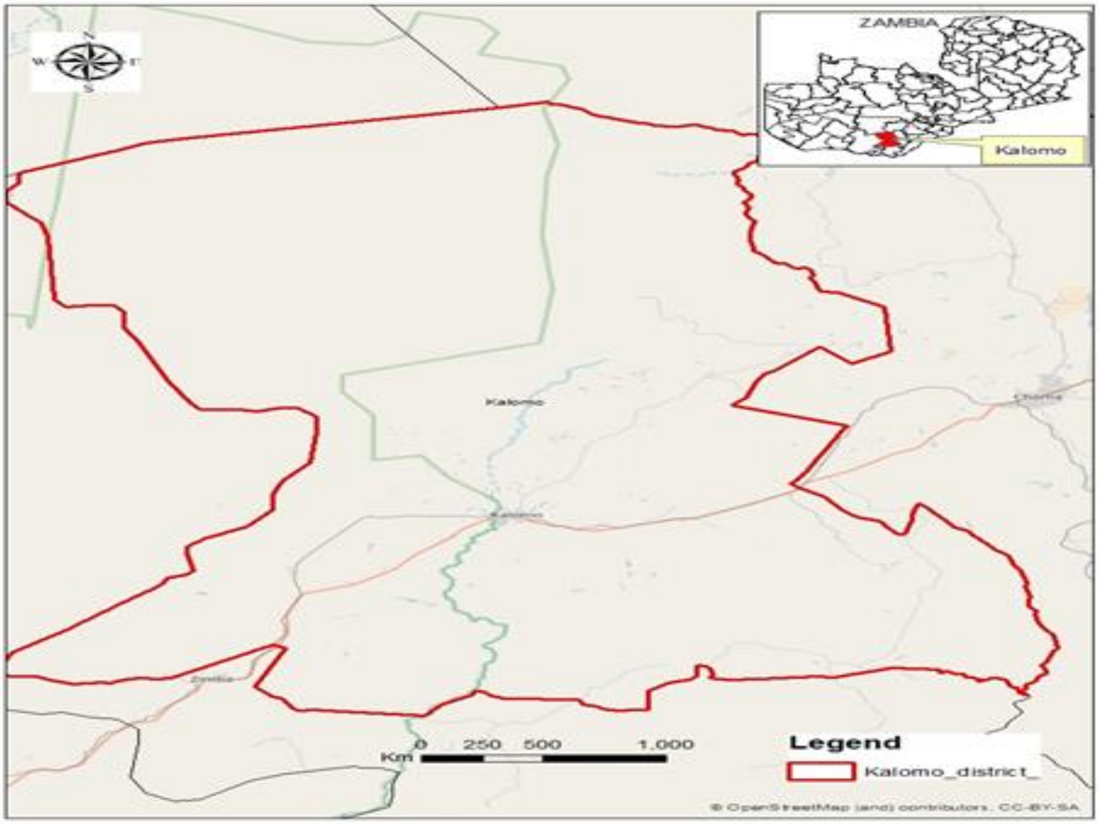



Figure 2.1 : **Location Map of Kalomo District**

Source: Openstreet Map, (2017).

According to City Population Portal as accessed in 2019, the total area of crops planted during the year 2014 in southern province was 360,160.32 hectares which constituted 18.98% of the total the national area cultivated in Zambia in the year under review. The net production stood at 688,122 metric tons representing 16.89% of the total agricultural production in the country for the year under review (R-SNDP, 2017). Sorghum was the major crop in the province with 4,695 metric tons, constituting 40.62% of the national output.

Government in its 7th National Development Plan has prioritised agriculture as a key economic sector together with tourism as key contributors to wealth creation and job creation (R-SNDP, 2017). In the past decade, due to average rainfall caused by climate change and lack of water resources management system, Kalomo's agricultural activities have greatly declined (Sector Profile, 2010). The average rainfall in Zambia is about 240 mm per year and per capita water availability is also decreasing rapidly (Sector Profile, 2010). However, considering these facts, adoption of dam management will help address the pending challenges as water allocation will be adequately directed to economically viable areas and it will easy planning and quality decision.

Water Management Crises in Kalomo is due to rapid growth of industrial and agricultural sectors to meet ever increasing communal demands for water resources. Kalomo has been facing serious water management problem (SPARS - ZAMBIA, 2019). These factors are among many contributors of poverty in the area. Shortage of adequate water for the agricultural sector are losing their strength. It is urgently required to encourage farmers and agriculture sector by providing reasonable resources and funding. For instance. Crop yield in Pakistan is still very less because most of the farmers are using traditionally old farming techniques (Morales, 2015). Proper water resource management may improve the crop yield and productivity. Awareness among farmers, proper water management and institutional setup can seriously improve the agricultural productivity (Adedeji et al, 2014).

## 2.3 Climate Change in Zambia

Zambia is a land-linked country located on the central plateau of the southern African region, with a land area of 752,612 square kilometres and a population of over 16 million (CSO, 2010). Zambia uniquely stands out as one of the prime tourism destinations in Africa because of its vast natural water resources from waterfalls, lakes, dams and rivers. Zambia's water resources hold about 35 percent of natural water resource in Southern Africa. This gives Zambia a comparative advantage in the SADC region in the hydro power generation and agricultural sector. Despite having 35 percent of natural water resource, Zambia's Kalomo District has not been spared from the hard-hitting challenges of climate change.

The Zambian government has prioritized Agriculture from over dependency on mining, but this has so far been proved to be a huge challenge due to climate change affecting food security, wildlife, forestry, water and energy, health and infrastructure, thereby affecting the economic, social, and environmental dimensions of sustainable development efforts. According to Zambia Action Report (2016), Zambia is ranked the 34th in the world as the most vulnerable climate change and 69th least ready to adapt to climate change. The increased drought over the past decade has encouraged construction of small dams in many parts of Zambia including Kalomo District for drought relief. Dams have for a long-time been reservoir to harvest water for livestock and agricultural purposes for the people of kalomo. Additionally, lack of data on dam life usage and effects on climate change in the area is another huge challenge. There is very little data on dam water resource management.

Climate change is a number one cause of hunger and food shortage in Africa and the world at large (Wheeler and Braun, 2013 and;  Misra, 2014).Zambia, just like any other country in the world has been experiencing the effects of climate change (Kalantary,2010). This has resulted in extreme weather conditions, droughts, rising temperatures and unpredictable rainfall patterns. It has been predicted that these extreme weather patterns will get even worse in the future if no adequate mitigation measures are put in place. Jain (2007) suggests that climate change has negatively impacted on the Zambian economy and consequently people's livelihoods more especially those living in rural areas whose livelihood is purely dependent on agriculture. According to the monthly bulletin (2017) on climate change, from the Ministry of National Development Planning, the impact of climate change will cost Zambia approximately 0.4 percent (US$7.1 billion) of its annual economic growth between 1991-2011. The aggregated estimated total GDP loss by sector was in the range of US$ 4,330-5,440 million with the following sector GDP losses: Agriculture ($2,200 – 3,130m), Energy related ($270 – 450m), Health ($460m), and Natural Resources ($1,400m) (ZCAR, 2017).

The Zambian government has prioritized Agriculture from over dependency on copper, but this has so proved to be a huge challenge due to climate change affecting Agriculture and food security, wildlife, forestry, water and energy, health and infrastructure, thereby affecting the economic, social, and environmental dimensions of sustainable development efforts. The total contribution of the agricultural sector to GDP on average is 9.8 percent in the period 2006 to 2015. During the period under review, output for 13 of the 18 major crops declined. This was largely attributed to erratic rainfall and lack of dam water resource management which negatively affected the yield rates.

## 2.4 Background on Dam Management

Water harvesting structures such as dams have been in existence from time immemorial to provide water for various uses (Brown, 1965, Horlacher, et al., 2012 and Jean et al, 2012). Even now these dams are still being built and serving the same purpose (Zarfl et al, 2014). The World Commission on Dams (2012) reports that some dams and aqueducts that were constructed by Romans to supply water for drinking are still in existence to date. The reports further indicate that from the early 19$^{th}$ century, various regions of the world witnessed dam construction for various water uses mainly for irrigation of crops as well as household consumption. Horlacher, et al (2012) has also noted that the increase in dam construction around the world in the 20th century was owing to high demand in energy and water supply as well as the flood control. This trend has not retarded but it has rather increased due to popular demand for agricultural products from growing human and livestock population (Fahim, 2015).

It can also be mentioned that although agriculture is becoming number one priority for economic development in many countries, its major input rain-water is becoming scarce due to climatic variations. As shown by Jean et al, (2012) one of the factors leading to increase in the number of water storage reservoirs is reduced rainfall or droughts and the dams have been seen as the best solution to the problem. The report by the World Commission on Dams also notes that in order to cushion water scarcities to meet agriculture demand, many countries have resorted to use of dams as it were (WCD, 2000 and Richter et al, 2010).

## 2.5 Situational Analysis on Dam Management

Currently, the Department of Water Resources Development has no automated management information system to store data on dams apart from manual based processes. The only automated system available is for boreholes. However, as for dams, all the data is currently stored on a standalone computer in an MS Excel Spreadsheet. This method of data storage makes it quite difficult to store, access and retrieve data in most of the times especially when requested by users within the department and by other stakeholders. This is because the database on standalone computer is not distributed or shared due its technological limitations (Afërd and Shaqiri, 2015). It can only be accessed by one user at a time and within an institution. Data cannot remotely be uploaded or accessed. Another bigger challenge is that when electricity is not available, the data can-not be entered and accessed on the standalone computer (Heeks and Bhatnagar, 1999). Even in worst case scenario, in case the computer crushes, data recovery is a night mere because the standalone computer can-not provide back-up and back out measures.

Users to access, retrieve and upload the data, they will have to travel long distance from one station to where the computer is housed. This in the end compromised the integrity of the data because it lacks consistency and standards for quality decision making. Interestingly, Vembu et al (2006) observes that even though many institutions have been generating databases and working in collaboration with each other in order to arrive at a common conclusion and share results, in times of emergency data from institutions has not been readily available due to poor maintenance of existing information.

## 2.6 Current Workflows

Throughout the country, information on dams is acquired through field inspections by Provincial Offices. The collected data is then entered into existing excel sheets on a standalone computer which are stored on the computer as softcopy and then printed out and filed as hard copies (Kang'omba and Bäumle 2013). Thus, the DWRD relies on these manual ways and hard copy records of data for dams. As earlier noted however, these manual processes of recording and retrieving data are very tedious and time consuming especially when reports are requested on short notice. This makes it difficult for members of the public including donors to access the existing information on dams.

## 2.7 Geographic Information System (GIS) and its Role in Decision Making

According to ESRI (2017), Geographical Information System is defined as a framework for gathering, managing and analysing data. Okello (2017) has also defined GIS as a database for input, storage, manipulation, and output of geographic information. This is very evident that GIS essentially was designed to handle and manipulation of large geographically referenced data to support users to make smarter business decisions (Wheeler, 2018). Hundreds and thousands of organisations have adopted the use of GIS because of its open APIs abilities to integrates with many data types for easy and rich analysis of spatial data such as locations (Okello, 2017). It helps to organise layers of information into visualisation using maps and images for communication, sharing and solving complex problems (Morehouse, 1992). GIS can be desktop based, web-based, Mobile Phone or developer based. For the purpose of this study, GIS concentrated on desktop -based platform.

The adoption of server-based GIS solution provides an easy access of spatial data by users and decision makers in real time anywhere to support planning and immediate decision making without much needed technical skill through summarised dashboards (Morehouse, 1992). The strength of a GIS lies in its ability to combine both visualization and analytical functions, GIS can integrate diverse sources of information that create patterns and relationships that might otherwise be missed. In Zambia, according to the smart Zambia plan on smart cities, GIS will be the main tool to provide visualisation data.

It can be inferred that in order to make better use of spatial information and to support better spatial decision making, GIS systems are more suitable systems for Spatial Decision Support Systems (SDSS) development (Jarupathirun and Zahedi 2005).

As noted earlier, GIS has materialised as a strong instrument in the management of spatial data and has become a major topic of intense interest for many disciplines ranging from academic to government institutions. Bernhardsen (2002) suggests more promising benefits gained when GIS is implemented and suitably selected when undertaking various tasks. Depending on how the system is used and information is applied the benefit to cost ratio ranges from 1:1 to as much as 4:1.

There is a relationship between the objectives and the benefits as indicated in the Figure 2.2.

| Objective level | Map production | Map production and internal use of data | Map production, internal use of data and shared use of data |
|---|---|---|---|
| Tasks | • storage<br>• manipulation<br>• maintenance<br>• presentation | • map production<br>• planning<br>• facility maintenance<br>• project management | • map production<br>• project<br>• planning<br>• facility maintenance<br>• coordination<br>• general service<br>• facility management<br>• economic planning<br>• service and information |
| Benefit/cost ratio: | 1:1 | 2:1 | 4:1 |

Figure 2.2 : Relationship between objectives and benefits of using GIS

Source: Adapted from Bernhardsen (2002).

Bernhardsen (2002) further shows that GIS has intangible benefits such as enhancement of decision making in administration, planning and operations. The same is true with information access and service to the public.

The use of GIS in mapping of both geographic and non-geographic features cannot be over-emphasized. In most cases people often asks questions which involves geography. (E.g. where? When? and so on) the answers obtained are geographic data. GIS has now taken the centre stage in providing geographic data in many endeavours of humans (ESRI, 2007). Such data has played a key role in improving human's standard of living by making information on geographic features readily available.

Deeprasertkul and Chitradon (2012) suggests that “GIS systems have been developed and applied for managing water resources, monitoring floods, disasters and sometimes solving water insufficiency in agricultural areas”. In view of this claim, the dam management information system can be used by policy makers and other stakeholders in their planning and decision making processes in water resources management.

## 2.8 Definition of Management Information Systems

Adoption of enterprise Management Information Systems (MIS) by public institutions can play a key role facilitating and attaining efficient decision making in an organization (Bhatnagar, 2003). MIS is an organizational method of providing past, present and future information relating to internal and external operations (Afërd and Shaqiri, 2015). MIS supports planning, control and operation functions of an organization by furnishing uniform information in the proper time frame to assist the decision makers (Mishra et al, 2015).

A Management Information System is made up of five major components and these include people, business processes, data, hardware, and software (Kadam and Sutar, 2017). These components must work seemly to achieve the organizational objective.

### 2.8.1 People

This is the most important component of Management Information System. Every system is built to satisfy user needs and requirements (Afërd and Shaqiri, 2015). People are the owners of the systems and without their involvement in the development of the system at every stage, the system developed is a failed system (Heeks, 2003). This is a number one reason why most public projects fail despite spending so much money and time developing them (Danish, 2006). People in this case are the users who run and manage the information system by recording the day to day business transactions or activities and interpret it for planning and informed decision making for senior management (Dumas et al, 2005). The users are usually qualified professionals such as engineers, accountants and planners (Haag and Cummings, 2009).

### 2.8.2 Business Procedures

Information systems are a means to an end, not an end in themselves. This means that Information systems are powerful valuable tools but not magic. If you automate a business process that is wrong, you end up with an automated mess (Laudon and Laudon, 2016). Business Procedures defines work flow in a business environment on how to execute a task. Business Procedure are standard operating procedures that guides the operation of the system or business for both internal and external (Kadam and Sutar, 2017). It is from the business procedure that one can understand dos and don’ts according to steps are defined to be done, by whom, when, where, and how.

### 2.8.3 Data

Data is a very important component in Management Information System (Masrom and Ismail, 2008). Transaction recorded is stored in the data warehouse and is retrieved for further manipulation for informed decision making by top management. Data stored can help provide trends or behavior which can help in planning and monitoring and evaluation and for future decision making. Data is recorded from day to day business transactions in the database. A database is a place where data is collected and from which it can be retrieved by querying it using one or more specific criteria (Sumner 1999 and Nayak et al.,2012). For a bank, data is collected from activities such as deposits, withdrawals. Data on dam use, number of farmers in the area, rainfall patterns and other related trends is very important for this research study.

### 2.8.4 Hardware

The physical infrastructure that connects the various components of the management Information System is the hardware. Hardware may include server, computer, printer, network devices, smartphone and storage (Ryker and Nath, 1998). The hardware provides the computing power for processing data. It also provides networking and printing capabilities. The hardware speeds up the processing of data into information.

### 2.8.5 Software or Application

This is the actual business programs that run on the hardware to support the business operations of an organization as required by users. Software can be broken down into two categories and these include System Software and Applications Software (Sumner 1999). System software refers to the operating system such as Microsoft Windows, Mac OS, and Ubuntu. Applications software refers to specialized software for accomplishing business tasks such as ArcGIS, MS Office, Banking System and Oracle. Application software is designed for specific tasks, such as handling a spreadsheet (Ryker and Nath, 1998).

## 2.9 Dam Management Information Systems

A well-designed information system for dams has the huge potential for internal and external benefits. The information management systems provide data to guide decision makers to make informed decisions and it also guides policy direction (Heeks, 2003). Donia (2013), has shown that in order for managers to make key informed decisions on integrated management of water supply systems, the use of Decision Support System (DSS) cannot be overemphasized. A DSS has been defined by Donia (2013), as a computer based tool consisting of modelling subsystems, databases subsystem and graphical user inter face subsystems.

The increase in cases of dam damages owing to natural disasters such as weather variations, earthquakes and/or dam aging around the world has seen many countries developing computer based DSS for the management and operations of dams (Donia 2013). For example, in order to address the dam safety issues in Korea, Korea water Resources Corporation developed a “Korea Dam Safety Management System”- (KDSMS) aimed at enhancing efficient and consistent management of dam safety (Jesung et al, 2009).

Due to increasing concerns and demands in dam safety monitoring and management in China, a Dam Safety Monitoring and Management Information System (DSMMIS) was developed with the intent of monitoring dam safety projects and managing dam safety monitoring information appropriately and on time (Yang et al, 2009).

Tan et al, (2009) has shown works on development of dam safety management information system for hydropower stations in the Yuanshui Drainage Area in China's Changsha province.

In Egypt, the Aswan High Dam reservoir Management System was developed as a DSS for management of the facility (Donia, 2013).

Although literature has shown that most of the developed dams management information systems have focused mainly on dam safety particularly on single dams and in some cases on a few hydropower dams (Tan et al., 2009, Yang et al.,2009, Jesung et al., 2009, Rodrigues et al.,2002 and Donia,2013), the comprehensive management information systems covering dams countrywide are limited.

### 2.9.1 Increasing Information Availability

Automation of dam management has the potential to reduce administrative issues of handling dam information. The automation of water resource management in Kalomo will help stakeholders to have access to data in real time as required and government can disseminate rules and regulation and procedures to citizens of Kalomo districts on the utilization of water resources mainly for the economic benefits of the area. Rahim and Pawanteh (2011) has suggested that availability and access to information promotes a knowledgeable society in which people are able to make very informed decision in planning for various activities.

### 2.9.2 Promotes Public Participation

Dam management will be an integrated system allowing multiple accesses to the database using the internet by different users across the country, the system will promote participation. The United Nation agenda 2030 for Sustainable Development Goals (SDGs), calls for open governance system were people are free to access and engage government in their day to day affairs (UNDESA, 2016). Participation helps in restoring the relationship between government and stakeholders and wins the confidence of government (Chipeta, 2018). Public participation has the capacity to expand opportunities for civic engagement on water resource management between government and stakeholders including increased possibilities for citizens to participate in decision-making processes and service delivery to make societies more inclusive (Azab et al., 2009). Public participation helps people to freely engage and express their opinion to government through the use of information technology such as web portals on policy issues and decision-making (Palvia & Sharma, 2007).

### 2.9.3 Improve decision making

One major function of an MIS is to aid and improve decision making. It does so by providing accurate information fast which is then used by managers for making crucial decisions. By improving decision making, it also works to improve the bottom-line and profitability of the business (Nayak et al., 2012).

### 2.9.4 Efficient operations

Nayak et al (2012), has further shown that MIS improves operational flow by providing required information at right time. The managers are able to perform their tasks with higher ease and that improves the productivity of the business (Chipeta,2018).

### 2.9.5 Better communication and connectivity

A central MIS helps improve the entire communication channel and provides better connectivity throughout the organization across all levels of management (Van, 2012). Bhargava (2009) describes Management Information System **(**MIS) as a planned system of gathering, storing and distributing data in the form of information needed in order to carry out effective and efficient functions of management. This implies that functions of management become critical whenever data is improperly collected, stored or disseminated. It is therefore imperative to ensure that data is obtained and stored in a way that will make decision making easy.

Furthermore, Bhargava (2012) illustrates management, information and system as follows;

1. Information as data that is processed and presented in a way which supports a decision maker.
2. Management as the skill of having things done successfully via other people in formally organised groups.
3. System is defined as a set of elements which are joined together to achieve a common objective. The elements are interrelated and interdependent.

## 2.10 Management Information Systems (MIS) Architecture

Deployment of Management Information Systems should be guided by the concept of Enterprise Architecture according to John Zachman who is frequently referred to as the “father” of Enterprise Architecture (Ahuja & Neena, 2008). Enterprise architecture is a blueprint showing the current and future position of an organisation. Enterprise Architecture helps to fully optimize an organisation so that it can perform more far better and more efficient than before using Management Information System (FCIO, 2002).

Enterprise Architecture can be defined as a model of an organization that depict its current and future structure and processes aligned with its core goals and strategic direction using information technology (Fischer et al, 2007). Lack of well-defined Enterprise Architecture for Management Information System can affect successful deployment and adoption of the project by users (Fischer et al, 2007). Ebrahim and Iran (2005), proposed a four-layer MIS Architecture as shown in Figure 2.3.

### 2.10.1 E-government Layer

The E-governmenet layer shown in figure 2.3 makes sure that the database of the MIS is integrated across all users, departments, agencies of an organisation regardless of its geographical location. They are so many users or consumers of data, during design of a management Information System it is very important consider would be users of datasets and therefore provide necessary measure to enable multiple access or window to the database using API (Ebrahim & Iran, 2005). System Integration or database sharing improves real time access to resources, reduces service-processing costs, and enables delivery of better quality of service (Wimmer, 2002). A web portal facilitates interaction between public organisations and citizens (Ndou, 2004 & Heeks, 2003). A portal is an example of e-government layer, it linked to different sources of information (back end) and it has the potential to reduce overhead and improve information flow and such as the need to visit various government institutions, spending so much time in ques, complete and submit bulk forms just to access data (Ebrahim & Irani, 2005). Government is a very complex organization with hundreds of agencies, departments, directorates, commissions, and regulatory bodies; a sharing of database or integration of management information systems will allow multiple access to the system at once in real time just with a few clicks on the internet (Atabakhsh et al., 2004 and Fan et al., 2014).

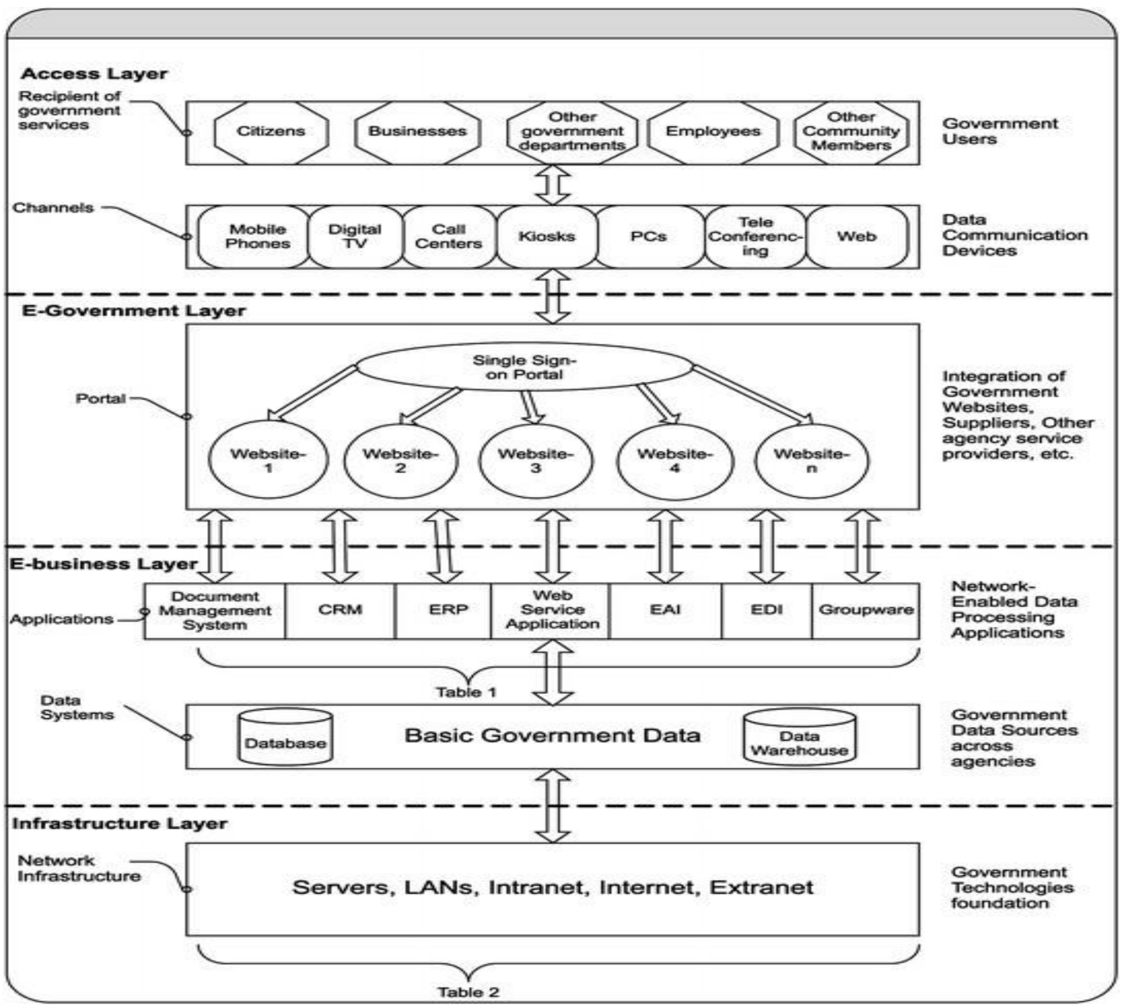



Figure 2.3: MIS Architecture

Source: Ebrahim and Irani, (2005).

#### 2.10.1.1 Access Layer

When planning for a Management Information System, it is very important to consider how users will be able to receive the services. Access Layer refers to different data communication platforms/devices that will enable recipient of services access these services conveniently. They are increased newer platforms that are user friendlier such as Smart Phones, Tablets, PCs, Smart TVs, Kiosks, Web-based platforms. Access layer provides a condusive platform for users to access various services using a single window of access on the internet anywhere in real time (Ebrahim & Iran, 2005). This should be well planned during the deployment process of MIS.

#### 2.10.1.2 Infrastructure Layer

Deployment of Management Information System requires adequate and reliable ICT Infrastructure. ICT Infrastructure is the transportation platform that distribute services and be able to be accessed by different users using different access platforms such as mobile phone, tablets and PCs online (ITU, 2009). Electronic distribution and access of services online within and between public sector organizations can be very expensive and unreliable without prescribed standards of hardware devices (Wilkinson and Reinhardt, 2005). Therefore, this layer focuses on technologies that should be in place when deploying MIS in an organisation (United Nations, 2002).

A reliable and available MIS depends on adequate ICT Infrastructure. The potential of these technologies is to support necessary standards and protocols through network and communication infrastructure approaches such as Storage devices, intranet, extranet, and internet, LAN, WAN, PCs, Laptops, and Mobile Phones (Bhatnagar, 2003; ITU, 2009).

#### 2.10.1.3 E-business Layer

This layer uses ICT applications and tools to facilitate knowledge sharing and information processing that takes place both w10ithin and across government departments (Ebrahim & Iran, 2005). This layer integrates the front-end e-government layer applications in the government portal with back-end activities such as common databases. This layer is used as a foundation that holds a single e-government portal and it also supports the relationship and interaction between G2G, G2B, and G2E (Abdalla, 2012). It provides a seamless, automatic and real-time communication between different systems at both data and process level. Traditionally, government departments, agencies and local authorities have maintained isolated databases that are not connected to each other (Siau, 2017). This creates barriers of data transmission and communication with government institutions and pose a huge implementation challenge for e-government in developing countries and use of a single porta (Al-Hashmi & Darem, 2008). Integrating different government databases, processes and applications is very critical because e-government depends on the existing government data, systems and processes (Nkwe, 2012). For instance, if a citizen performs a transaction at a local department or agency, the information and results of the transaction should be viewed across all government departments and agencies that are linked to the government web portal.

# CHAPTER THREE: MATERIALS AND METHODOLOGY

## 3.1 Introduction

The chapter is aimed at highlighting the techniques which were used in order to achieve the set objectives. The chapter is divided into six sections. The first one is section 3.1 were study design is discussed and this is followed by section 3.2 which highlights the System Development Lifecycle. Section 3.3 discusses the System Design and is followed by Testing and Deployment in section 3.4. The dams database is highlighted in section 3.5 and finally section 3.6 describes the System Deployment and Implementation.

## 3.2 Study Design

An applied research methodology was followed in this study. Applied research is a methodology which can be used to solve specific practical problems in industry. It is aimed at gathering knowledge with the goal of producing useful materials or devices to meet specific, renowned requirements (Hedrick et al., 1993 and Bickman et al., 2009). Using applied research methodology, a prototype for the application was developed.

## 3.3 Data collection and Analysis of work procedure

The researcher took time and visited the Department of Water Resource Development DWRD, both at the head office in Lusaka and Kalomo district office. The researcher observed the business processes and workflow on how data on dams was being handled. This stage involved analysing the existing business process, in how data was handled, processed, stored and retrieved and shared using data flow diagrams (DFD).

According to Hermans et al (2011), data flow diagrams are used to graphically represent the flow of data in a business organization and describes the processes that are involved in the workflow from data capturing, manipulation, storage, and distribution between or within the business organisation and other stakeholders.

### 3.3.1 Collecting data on the available database

The existing databases for dams at the DWRD were studied. The data on dams was saved mainly in form of hardcopy files as well as excel formats. The user requirements were identified and analysed based on the existing formats. This followed gathering the available data on dams particularly those in Kalomo district of Southern Province.

### 3.3.2 Research Setting

This project focused on developing a Dams Management Information system that incorporates information on dams distributed across the country with emphasis on those in Kalomo district in Southern Province.

### 3.3.3 Data Collection

Chaleunvong (2009), has indicated that there are various techniques used in data collection and the five common ones include the following;

- Using existing information;
- Observing;
- Interviewing (Face to face);

- Administering written questionnaires and;
- Focused group discussions

The use of available information and interviews were the data collection techniques used in this study. The data collection tools included excel forms as wells as the interview guide (See Appendix A1). The existing data in excel formats on dams was made available by officers in charge of dams at DWRD. The officers from DWRD provided data on user requirements and what type of data was vital for the system to capture.

### 3.3.4 Data Analysis

The data was analysed using various tools which were linked to give updated information. The interface was developed for easy execution of commands such as querying, reporting, data entry, and many more. The database makes use of GIS ArcMap for visualization and making inferences (Anselin,1996). Microsoft access as front end for displaying forms and reports, Microsoft excel for making dashboards and other open source platforms such as MySQL for database storage and connection to the servers. MySQL Open Data Base Connector was also used to link the DMIS database to MySQL, ArcGIS and Excel. The Figure 3.1 shows the 4-tier integration of ArcGIS, Microsoft Access, Microsoft Excel and MySQL in the operations of the national dams' management information system.

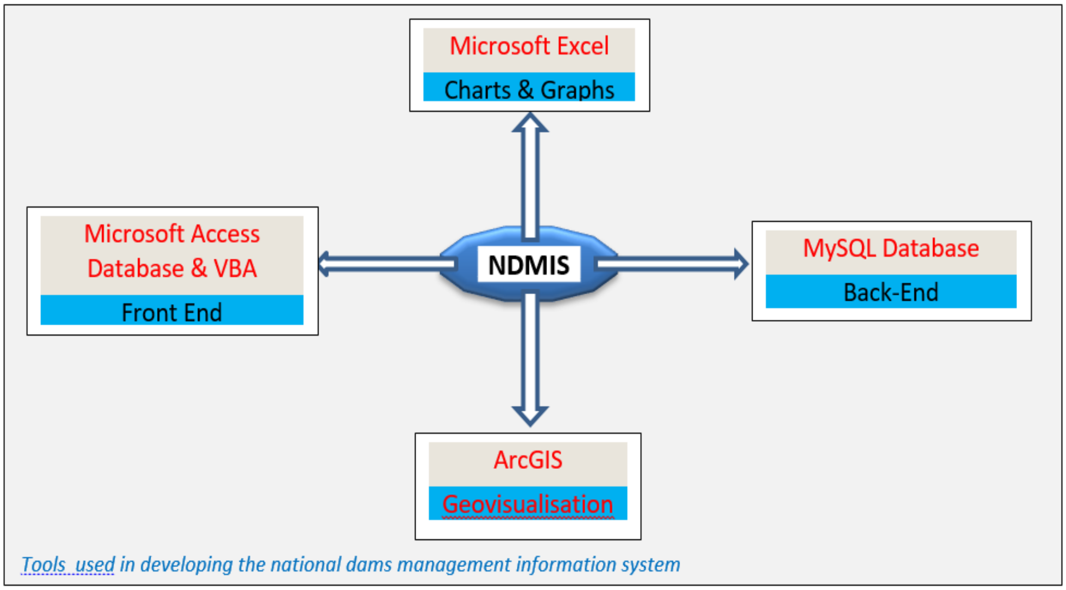



Figure 3.1 : Tools used in developing the National Dams Management Information System

Source: Formulated by Author (2017).

### 3.3.5 Sample Size

The research was focused on dams in Kalomo district Southern province and this provided a proof of concept for other dams located across the country. A total of 213 dams in Kalomo district were entered into the system.

## 3.4 System Development Lifecycle

The systems development life cycle (See Figure 3.2), also referred to as the application development life-cycle, is a methodology used in systems engineering, information systems and software engineering to describe a process for planning, creating, testing, and deploying an information system (Ambler, 2001). The researcher adopted this approach because of its consistence application development and ensures the project delivers required expectation.

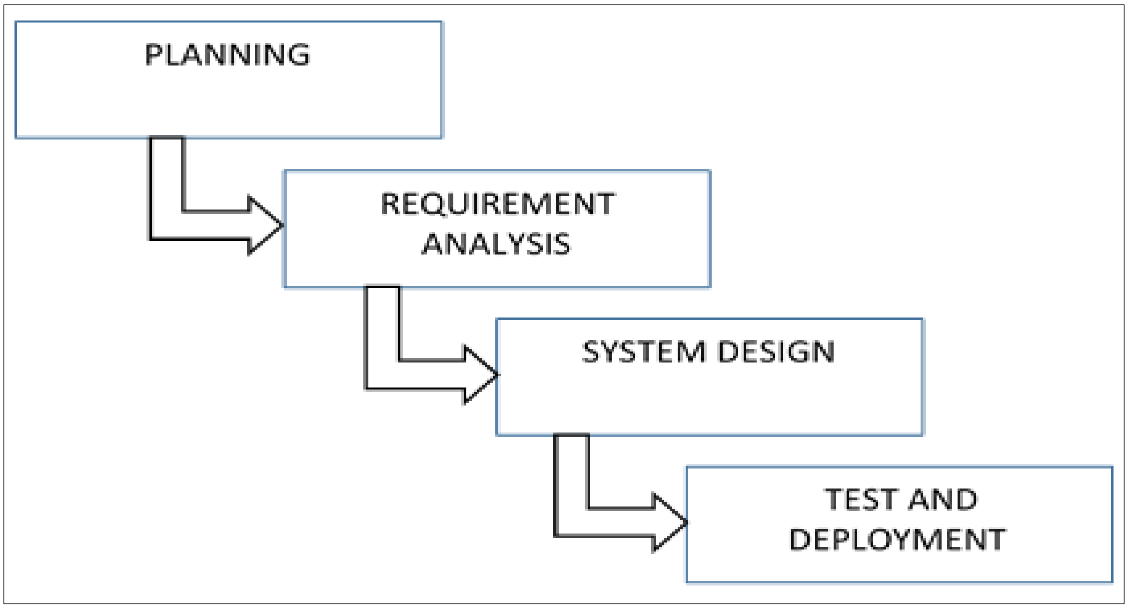



Figure 3.2: SDLC Stages

Source: Formulated by Author (2017)

### 3.4.1 Planning

This was the preliminary stage in the systems development Life cycle as shown in Figure 3.2. The purpose of this phase was to identify if there was need for DWRD to proceed with the development of a new system to achieve its strategic objectives. According Pavel (2004), Planning or preliminary stage is used to investigate the benefits of the project, costs involved and time. It is at this stage that investigates whether the current business processes have a problem to determine whether there is need to proceed with the new project to better up or improve the way business is currently being conducted. It is during this stage that the project can get an approval to a go-ahead or not.

During the planning stage, the researcher developed a research proposal which was presented to the School of Engineering, Department of Geomatics. After the presentation, the researcher was given acceptance by the Department of Geomatics. The researcher further made a presentation at Department of Water Resource Development, Ministry of Water Development, Sanitation and Environmental Protection and an approval was given to conduct the research in Kalomo Districts. A research plan was however drawn, and research time frame was determined, cost and benefits.

After the system was presented to both parties, a system request from the Department of Water Resource Department was presented to the researcher with a brief summary of the business need, and how the system proposed will create business value for the organization and the community of Kalomo District. The researcher was assigned a technical person in charge of dams from the department DWRD Headquarters in Lusaka and Kalomo District Office as key contact personnel for the project. The following were the considerations by the researcher during the planning stage:

■ Technical feasibility (Can we build it?)

■ Economic feasibility (Will it provide business value?)

■ Organizational feasibility (If we build it, will it be used?)

### 3.4.2 Requirement Analysis and Requirements

During this stage in the system development lifecycle, the researcher answered the following questions:

- Who will use the system,
- What will the system developed do
- Where and when will the system be used.

The researcher investigated current systems in the DWRD, indenting improvement opportunities, and developed a concept for the new system. The stage was developed to guide the researcher's efforts. Such a strategy usually includes a study of the current system (called the as-is system) and its problems according to NTT (2014), and envisioning ways to design a new system (called the to-be system). The To-Be Model was a prototype of the system of the Dam Management System with emphasis of dams in Kalomo district as a model. To achieve the above objectives, the following steps were undertaken

### 3.4.3 The requirements gathering step

During this undertaking, the researcher conducted on site visits and interviews on key staff in the DWRD in Kalomo and Lusaka to familiarize on the workflows. The researcher also interviewed the beneficiaries of the dams in the communities both at small and large scale (farmers and livestock owners). Due to financial constraints group workshops were not conducted but questionnaires were mainly used to capture much needed information (See Appendix A1).

A prototype as a system concept was developed and used as a basis to develop a set of business requirements that describes how the business will operate if the new system were developed.

### 3.4.4 The analyses of requirements

During analysis requirement stage, the researcher visited the Department of Water Resources Development in Lusaka and the District office in Kalomo to familiarize with the current business operation. The researcher observed the workflows at DWRD headquarters offices. This was backed by follow up interviews with member of staff from management and operation level on workflows on dams. This was very key to get the much needed business requirement and investigate current business operation and analyse the gap (problem) and determine if there was need to develop a new system to bring efficiency and betterment of the operation in the organisation.

### 3.4.5 Business System Requirement Document

A business system requirement document was generated describing all the necessary business workflows, data needs and models. The requirement document was approved by DWRD from Lusaka to help the research during system development stage. If this stage is wrong, the system developed will also have problems. The system requirement document was reviewed several times with key technical user team which was assigned to work with the researcher during the entire research period. After several review meetings with the key users, a go ahead was given to proceed to the development stage of the system. The business requirement document is a key deliverable in this stage of SDLC because it describes what business requirements the new system should address or meet.

## 3.5 System Design

The design stage decided how the system was going to operate having met all necessary requirements such as hardware, software, and network infrastructure; the user interface, forms, and reports; programs, databases. This stage depended heavily on the previous two stages more importantly the business requirement stage. All the elements defined in the business requirement documents were developed as user requirements.

### 3.5.1 Hardware

The analysis and design stage determined exactly how the system would operate and the Table 3.1 gives an overview of what was used.

**Table 3. 1**: Summary of Hardware and Software Specifications

| No | Description | Specification |
|---|---|---|
| 1 | Hardware | |
| 1.1 | Storage | 100 GB |
| 1.2 | Computer Processor | 3.0 Ghz i9 dual core |
| 1.3 | RAM | 8GB dual Core |
| 2 | Software | |
| 2.1 | Database | MySQL SERVER |
| 2.2 | OBDC | MS |
| 2.3 | Access | MS |
| 2.4 | VBA | MS |
| 3 | Internet Connection | |
| 3.1 | GWAN, NDMIS | Wide Area Network Access, VB |

Source: Formulated by Author (2017)

During design stage, the system was going to be distributed using already existing network as deployed by Smart Zambia under the Government Wide Area Network connecting government provincial centres. The researcher provided a high end laptop computer which was used as a server to host the application development. The specification of the computer were customised to meet required hardware specification to avoid blade server costs.

The server was then connected to the GWAN for easy of the application access across government. GWAN made the distribution of the application very cost efficient because the cost of internet connection was already taken care of, security issues, access control and Private IP addresses.

### 3.5.2 Software

The investigations took advantage of various software on the market as described in the Table in 3.2.

**Table 3. 2:** Software Specification

| No | Name | General Use | Acquisition | Version |
|---|---|---|---|---|
| 1 | ArcGIS | Data Visualization, Geo-processing, Spatial Analysis and Map Production | Proprietary | 10.3.1 |
| 2 | MySQL workbench | Database Schema design and Entity Relationship Diagrams | Open Source | 5.0 |
| 3 | MySQL | Database(Back-End) | Open Source | 5.0 |
| 4 | Microsoft Access | User Interface, Forms and Auto Reports | Proprietary | Office 2016 |
| 5 | Microsoft Excel | Data Manipulation, Charts and Graphs | Proprietary | Office 2016 |
| 5 | VBA | Programming | Proprietary | Office 2016 |
| 7 | ODBC drivers | Connections to other platforms | Open Source | 5.3.1 |

**Source:** Formulated by Author (2017)

### 3.6 Testing and Deployment

The prototype developed was tested by officers from the Surface Water Section at the DWRD. The officers included those in charge of Water Infrastructure Development such as dams and District Water Development Officers. The officers were trained on the execution of functionalities in the system. During this stages, the application underwent some changes to suite the user needs. The non-spatial database proved beyond doubt that it could work to suite the study objectives. For the Spatial database ArcGIS was used for visualisations and it proved successful.

According to Anselin (1996), GIS is a powerful tool for data visualisation, geoprocessing, spatial analysis and map production. GIS was used for visualising dams and make inferences. This is because the software has the ability to interact with other third-party software tools such as Microsoft Access/Excel and SQL server to provide a user-friendly interface which allows graphical display of imagery results. The database was shared on the internet to allow multiple access for easy sharing across different users located in different geographical locations. The assessment was chosen to demonstrate the capabilities of the GIS decision support system. It was evident that the test results compared with other tools indicated that GIS system provides versatile and reliable means of visualising dams.

#### 3.6.1 MySQL SCHEMA

To show the relationships in the database, MySQL workbench was used to create the entity relationship diagrams (ERD). The database schema describes the organization of data and represents the relationship between various tables in a database (Suehring 2002 and Deshpande et al 2005).

MySQL Workbench is an open source unified visual tool used by database developers, architects, and database administrators. It offers data modelling, SQL development, and all-inclusive administration tools for server configuration, user administration and backup. MySQL Workbench is available on Windows, Linux and Mac OS X. (Lee and Zheng, 2015)

Though MySQL workbench can be used for the initial table design, it is quite a new product on the market and many people seem to have gotten used to table design in MySQL (Yang and Cao, 2016). Thus in this project MySQL workbench was only used to produce the entity relationship diagrams (ERD). The ERD is shown in appendix A2. This was done through the procedure known as reverse schema. It allows one to import an SQL script into the work environment and then link the tables outlining the existing relationships between them.

Further, MySQL workbench also has multiple notations that one can switch to fairly very easily to suite the notation they are more comfortable with. These include birds foot, standard, Unified Modelling Language (Yang and Cao, 2016). Copies of each of these were printed and stored for future use in case of any amendments or modifications, and also for basic troubleshooting later on.

### 3.6.2 MS Access

Microsoft access was used as front end graphical user interface. This was successfully linked to the tables in MySQL database which was used as Backend using the Open Database Connector (ODBC). The ODBC open source drivers were downloaded from dev.mysql.com the official site for MySQL products through the

ODBC option. ODBC enables the connection of a MySQL database to other software platforms (Yang and Cao, 2016) as shown in the Figure 3.3.

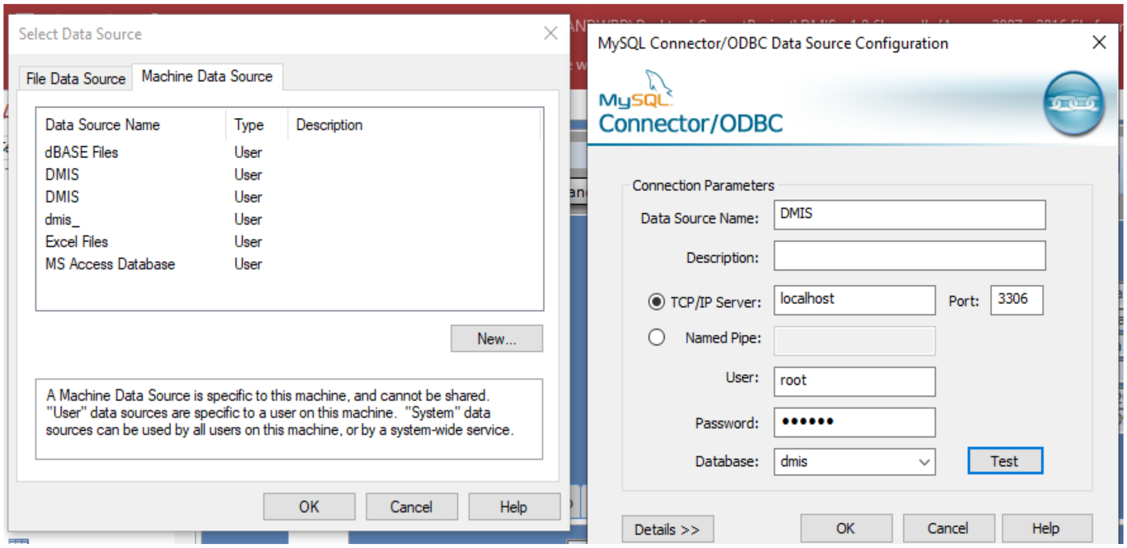



Figure 3.3 : **ODBC Connection**

Source: Formulated by Author (2017)

### 3.6.3 Interface design

- Forms (data entry, image connections, VBA Programming code).A database system is used by people with different technological capabilities. Whether one is technologically advanced or not, a good database system has forms which make data entry easier for the database users.
- Thus a user is given a friendly interface with which to work with. A good form is one that is intuitive to the user. Good form design ensures that tools are located easily and intuitively by the user.
- Forms can also be designed to ascertain quality assurance and quality control. For instance, the use of dropdowns. At times it becomes very necessary to

restrict the data that can be entered on a form to a list of acceptable values from which one can select from. E.g. the recording of a dam's district or province location. Best practice is to allow the user to select a particular province or district from the list of available ones.

### 3.6.4 Cascaded dropdowns

Another feature on forms that makes data entry a lot easy are cascaded dropdowns. For example, if a user is updating location information for a dam, upon selecting the name of the province the dam lies in, to select the district the form will filter and allow the user to select from a list of districts that are within that particular province, then by extension, a constituency that lies in that particular district, and finally a ward that lies in the particular constituency.

### 3.6.5 Visual Basic for Application (VBA) and Controls

All the features that appear on forms and related to the tables of the database are known as controls. These features enables developers to come up with full-fledged applications using Microsoft access. Figure 3.4 shows part of programming codes.

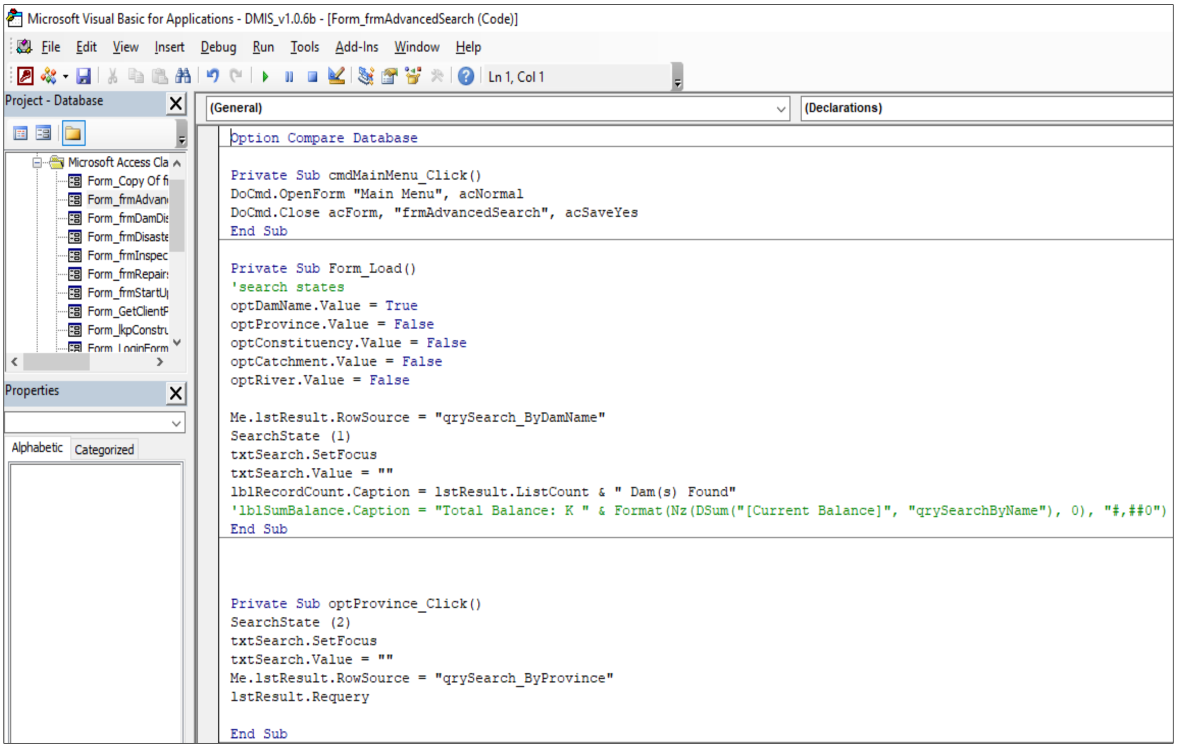



Figure 3.4 : **Programming Code-VBA**

Source: Formulated by Author (2017)

### 3.6.6 User tiers/ user groups

All users accessing the system have specific tasks that they are assigned to work on. Thus it is not necessary for everyone to have access to all features of the database. This is clearly seen in the issue of security for example. Some users have restricted access to certain portions of the database. What enables this to be achieved are user tiers or user groups. Thus users can have an interface designed that restricts them to access only their assigned work tasks.

### 3.6.7 Queries

In database notation it is important to note that the word query should not be mistaken for the word query used to mean objection to something. A 'query' in database notation simply refers to a stored procedure for segregating particular desired data from the bulk source domain (Yang and Cao, 2016). Thus queries can be filtered from one table in the database or even a combination of multiple tables from the database.Some important queries that were created included reports.

### 3.6.8 Reports

Once dam's data was entered into the database, reports were produced automatically. MS access has the capability of storing reports that can be opened up at any point in time by the click of a button. All these were automatically generated using the parameters correctly entered.

### 3.6.9 MS Excel

At DWRD headquarters, most of the dam data was previously stored in excel sheets. The excel document consisted of hundreds of records of data, thus manual entering of data into the system was not feasible and had to be done in much simpler and much quicker ways. Once the database and user interface design were completed, there was then a need to have this data imported/transferred into the database.

However, before this could be done, it was imperative that the data first be examined before being directly imported into the new database. There exists a popular saying in database administration, "Garbage in, garbage out". This saying simply conveys the idea that any system, no matter how large is only as good as the data stored in it. So if fed with garbage- totally wrong and inconsistent data, no proper analysis can ever be generated from it by way of reports etc. Thus a series of techniques had to be implored during the cleaning of the data which was discovered to contain quite a number of inconsistencies.

### 3.6.10 The Dams database (Management Information System)

The system application backend was MySQL (Suehring,2002). The database, Dam Management Information System (DMIS) table's schema were successfully designed in MySQL server as shown in Figure 3.5.

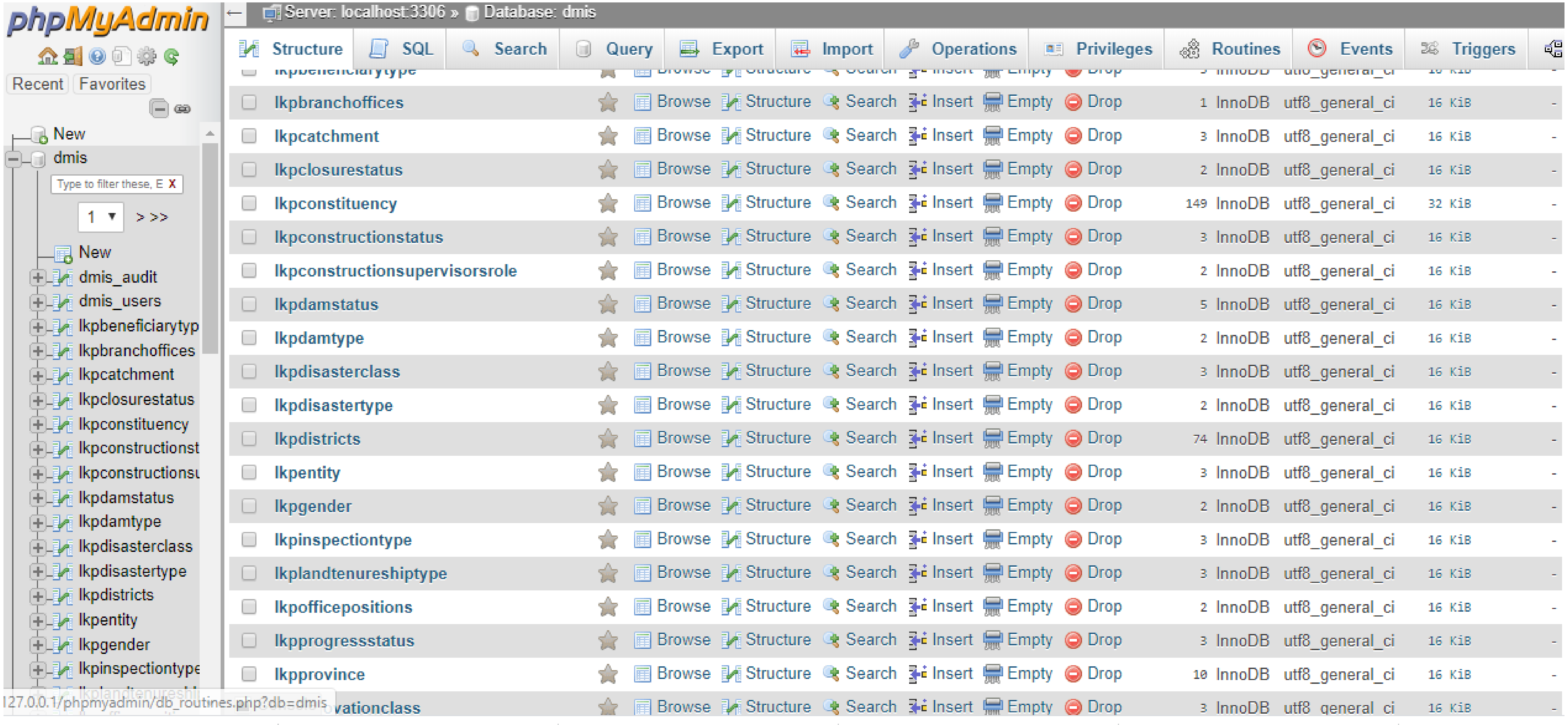


Figure 3.5 **: MySQL database**

Source: Formulated by Author (2017)

### 3.6.11 System Users and Access Control

The provincial government offices are the remote users who will be accessing the system for data update and access using the Government Wide Area Network. These officers will be required to capture data as defined by the dam management information system about the status of dams. The remote and local users will have access to the database of the system in real time as demanded by management for planning and decision making. However, the system will have access level whereby only the super users will have more access privileges. The system administrator will be the ones to consolidate the data about dams and the data about the provincial office will further be shared to the system administrator at the head office who will consolidate all the data as updated by all provinces about dam for a national dam management report. The data fields captured by Dam Management Information System is as shown in the schema design in Appendix A3.

### 3.6.12 System Deployment and Implementation

The researcher deployed the system after successful User Testing and Acceptance was concluded with the Department of Water Resource Development in Lusaka and Kalomo. Deployment plan was drawn as shown in Figure 3.6.

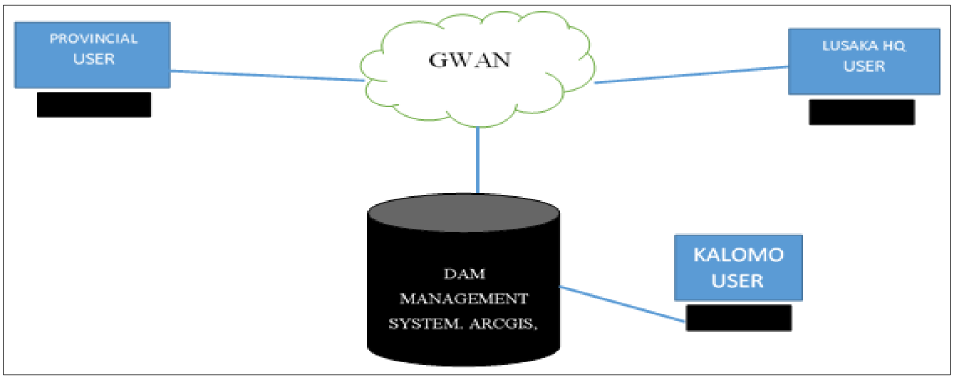



Figure 3.6 **: System Deployment Plan**

Source: Formulated by Author (2017)

### 3.6.13 Government Wide Area Network (GWAN)/ Internet

The emergence of the internet has changed the way society and businesses operate. It has allowed download, upload, and update of live data and images on shared databases. The data on the database will be shared and accessed by different users and decision makers in provincial offices in real time regardless of geographical location with easy.

The Internet Infrastructure required to make the integration of the database across all provincial office for the National Dam Management System in the areas was already made easier and available by government of the republic of Zambia in most of the provincial offices across the country through Smart Zambia. The government of the republic of Zambia deployed Government Wide Area Network GWAN across most government provincial offices including Southern Province and Kalomo District. The deployment of the dam management information system did not require internet costs. This is because internet connection through the already exist GWAN network deployed by Smart Zambia was already available. The existing network connect in most provincial centres, will make upload and access of data captured in the Dam Management System be accurate as it will have defined standard parameters to prevent data duplication and misinterpretation that can affect decision making processes. Additional application such as Google maps and ArcGIS are examples of internet-based databases that will allow users to share live geographical datasets and maps across the world for easy spatial planning and decision making. GIS and google maps are powerful tools that have allowed storage, analyses, update and generation of visual geographic information sets. The internet has contributed to work efficiency and improved the management of data for decision making.

# CHAPTER FOUR: RESULTS

## 4.1 Introduction

This sections presents the study results on the prototype of the developed Dam Management Information System (DMIS) and its functionalities in terms of speedy and efficiency compared to previous manual workflows. The use of GIS in the visualisastion of DMIS parameters are presented.

## 4.2 Graphical User Interface

The prototype of DMIS was successfully developed and the implementation proved that it was capable of executing many tasks as desired. In order to open the application, the user was required to input the username and password as shown in Figure 4.1.

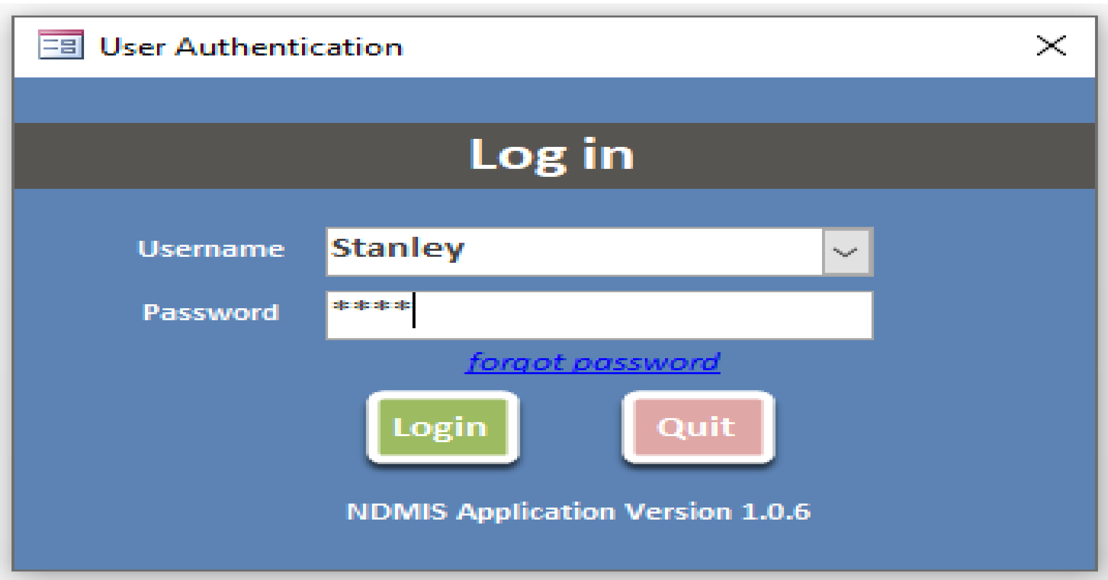



**Figure 4. 1**: Application User Login Interface

Source: Formulated by Author (2017)

When successfully logged in the system main menu is displayed. The main menu has key features or forms allowing users to perform differently tasks with easy. The forms included among others 'view dams', 'advanced search', 'System Access control' and Update lists. General reports provided automated reports on all dams by location, province, constituency, size, age, ownership, unoperational dams as well as province summary report. The main menu display is as illustrated in Figure 4.2.

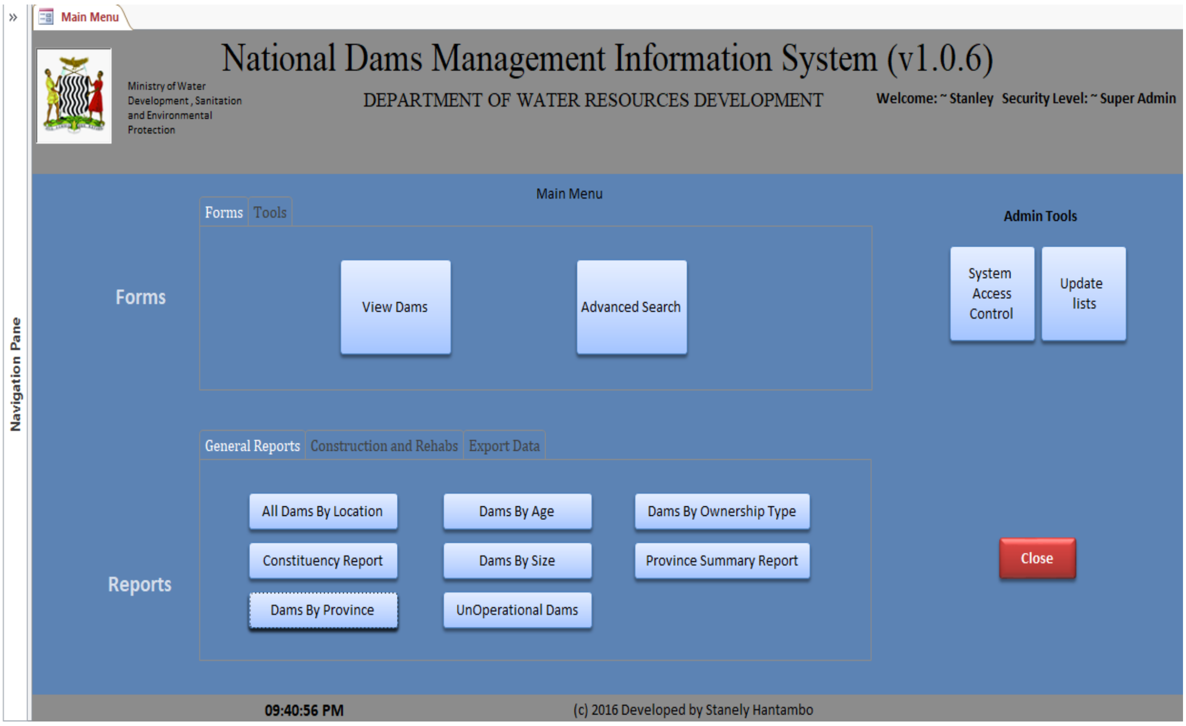



**Figure 4. 2:** System Main Menu Interface

Source: Formulated by Author (2017

## 4.3 View Dams

The view dam's button opens up the Dam portal. This is the main data entry form which enabled users to successfully undertake data entry. Most of the fields were designed with cascaded drop down as a control measure aimed at avoiding incorrect data entry. This has enabled quick entry of data into the system. Most of the dam data was captured in dam portal. Figure 4.3 illustrates the dam portal interface.


**Figure 4. 3:** Main data Entry Form Interface

Source: Formulated by Author (2017)

## 4.4 Dam Identification Numbers

The Dam Identification Numbers or Dam IDs were generated automatically by the system using VBA. For example if the dams is located in Southern province in Zambezi catchment on a river with stream order/level of 0; The system was designed to select the province code, in this case Southern province has a code of Zero nine (09) according to Central Statistical Office, Next is the abbreviations for the sub basin codes, Zambezi sub catchment (CZ01). This was followed by the stream order/level on which the dam was built level 0 (L0) and finally the system generated unique Ids (S1) for the dam entered first. The results clearly demonstrated that the developed application generated dam Identification codes that were unique and no dam was assigned more than a code. This would be applicable to any province. Therefore, the dam's assigned code with information described above was as shown in the Figure 4.4 and the View Dams Forms in Figure 4.3.

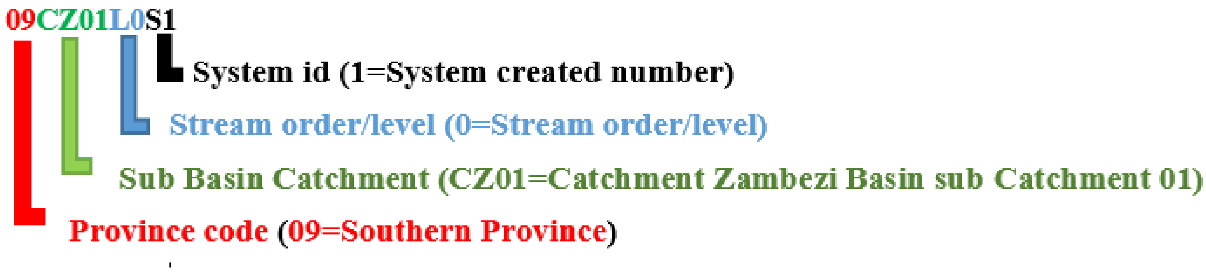
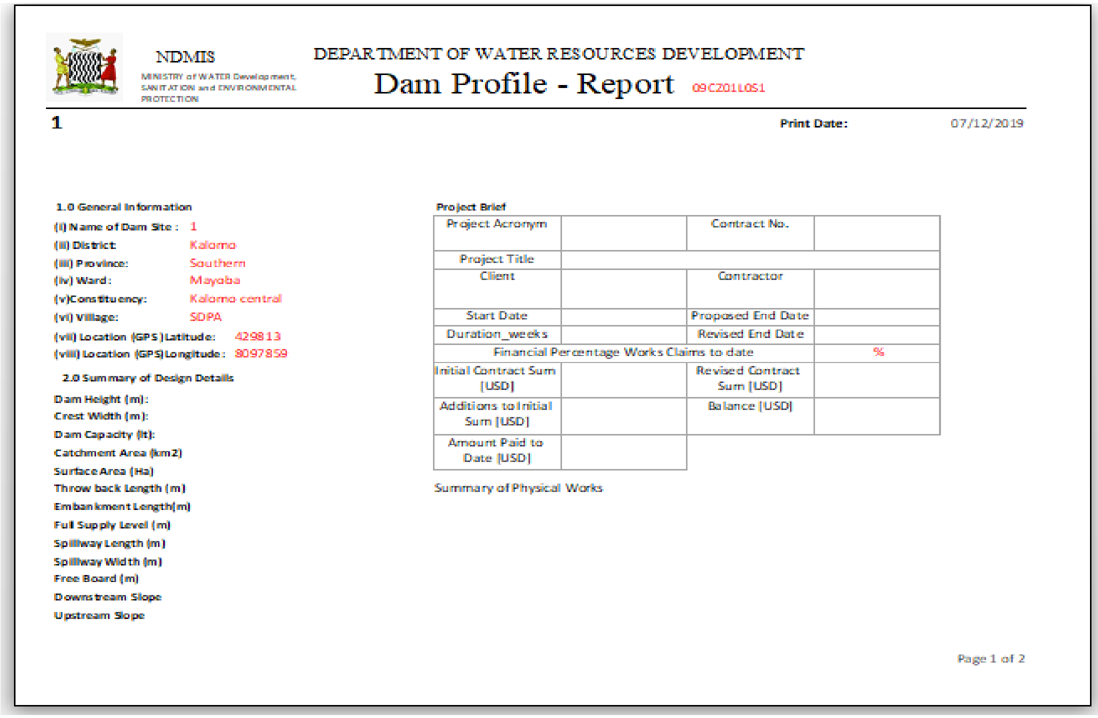



**Figure 4. 4**: Dam ID Combination

Source: Formulated by Author (2017).

### 4.5 Profile Report

The application demonstrated that it was able to create automated reports which were able to be printed or shared. The information contained on each report included the dam inspection, the rehabilitation or maintenance works and the general information of a particular dam. Figure 4.5 shows the print profile report.


NDMIS

MINISTRY of WATER Development, SANITATION and ENVIRONMENTAL PROTECTION

DEPARTMENT OF WATER RESOURCES DEVELOPMENT

Dam Profile - Report 09C201L0S1

1

Print Date: 07/12/2019

1.0 General Information

(i) Name of Dam Site : 1

(ii) District: Kalomo

(iii) Province: Southern

(iv) Ward: Mayoba

(v)Constituency: Kalomo central

(vi) Village: SDPA

(vii) Location (GPS)Latitude: 429813

(viii) Location (GPS)Longitude: 8097859

2.0 Summary of Design Details

Dam Height (m):

Crest Width (m):

Dam Capacity (lt):

Catchment Area (km2)

Surface Area (Ha)

Throw back Length (m)

Embankment Length(m)

Full Supply Level (m)

Spillway Length (m)

Spillway Width (m)

Free Board (m)

Downstream Slope

Upstream Slope

Project Brief

| | | | |
|---|---|---|---|
| Project Acronym | | Contract No. | |
| Project Title | | | |
| Client | | Contractor | |
| Start Date | | Proposed End Date | |
| Duration_weeks | | Revised End Date | |
| Financial Percentage Works Claims to date | | | % |
| Initial Contract Sum [USD] | | Revised Contract Sum [USD] | |
| Additions to Initial Sum [USD] | | Balance [USD] | |
| Amount Paid to Date [USD] | | | |

Summary of Physical Works

Page 1 of 2

**Figure 4. 5:** Dam Profile Report

Source: Formulated by Author (2017).

## 4.6 Dam Inspections Form

The designed dam inspections form proved to work successfully. The form had various fields for comprehensive data collection during dam monitoring and inspections. The form is as shown in figure 4.6.


**Figure 4. 6:** Inspection Form Interface

Source: Formulated by Author (2017)

## 4.7 Disaster Occurrence Form

Sometimes dams may pose a threat to the humans and environment in case of dam break. In order to take care of data capture in case of such eventuality, the application was designed with the disaster occurrence form to record various parameters. Figure 4.7 illustrates the disaster occurrence form.

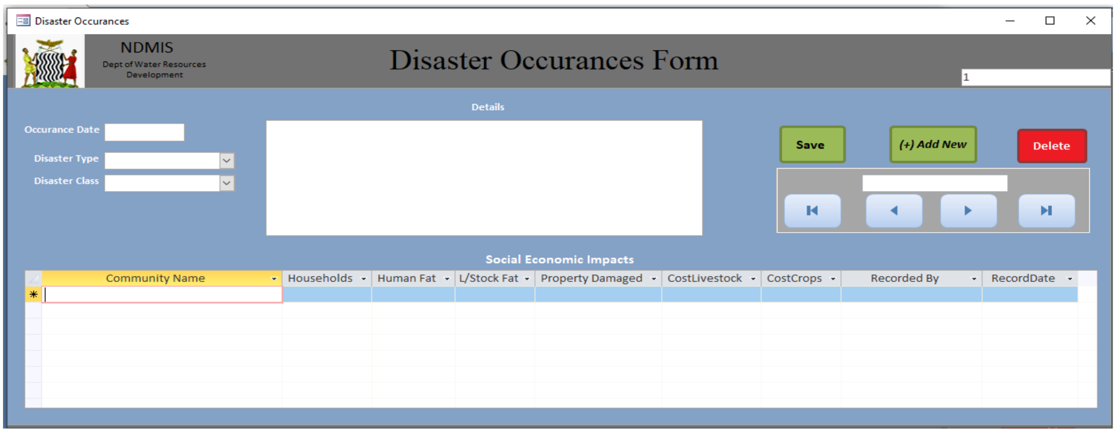



**Figure 4. 7**: Disaster Occurrence Interface Form

Source: Formulated by Author (2017).

## 4.8 Rehabilitation and Maintenance

The rehabilitation and maintenance form is a data entry form that was specifically designed to capture data during rehabilitation and dam maintenances. The fields included the funding agency, Project cost, contractor name, start date, proposed end date and other details. The application stored data each time the form was entered with data. This meant that the system could store as much information as possible on one particular dam under rehabilitation or maintenance. Figure 4.8 shows the rehabilitation and maintenance form.

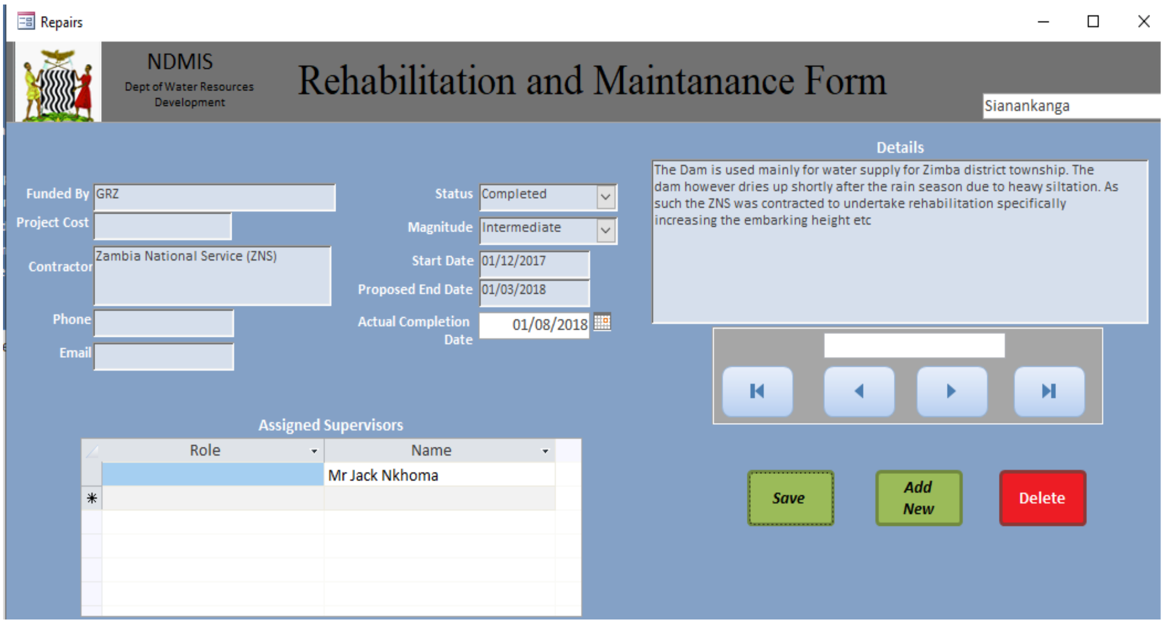



**Figure 4. 8:** Rehabilitation and Maintenance Form Interface

Source: Formulated by Author (2017)

## 4.9 All dam Location Report

They system successfully generated automated reports of all dams by location such as by Province, district and constituency. The total number of dams that were entered in a province were displayed in the report. For example, Southern Province and Kalomo district in particular had 216 dams entered into the system and the

Dams in Zambia location report was generated automatically as shown in Appendix B1. The dams by constituency reports is attached in the appendix B2

This made workflows much easier for the DWRD because reports can be shared with stakeholders including decision makers within shortest possible time.

### 4.10 Spatial Representation of Dams

The developed database was linked to other platforms such as ArcGIS and Microsoft Excel in order to visualise DMIS parameters and make inferences from the representations (decision support system). Thus the backend database, MySQL was successfully linked to both ArcGIS and Excel. This provided real time data connection to MySQL thereby updating the DMIS. Figure 4.9 illustrates the successful linking of MySQL tables to Arc catalogue in ArcGIS.

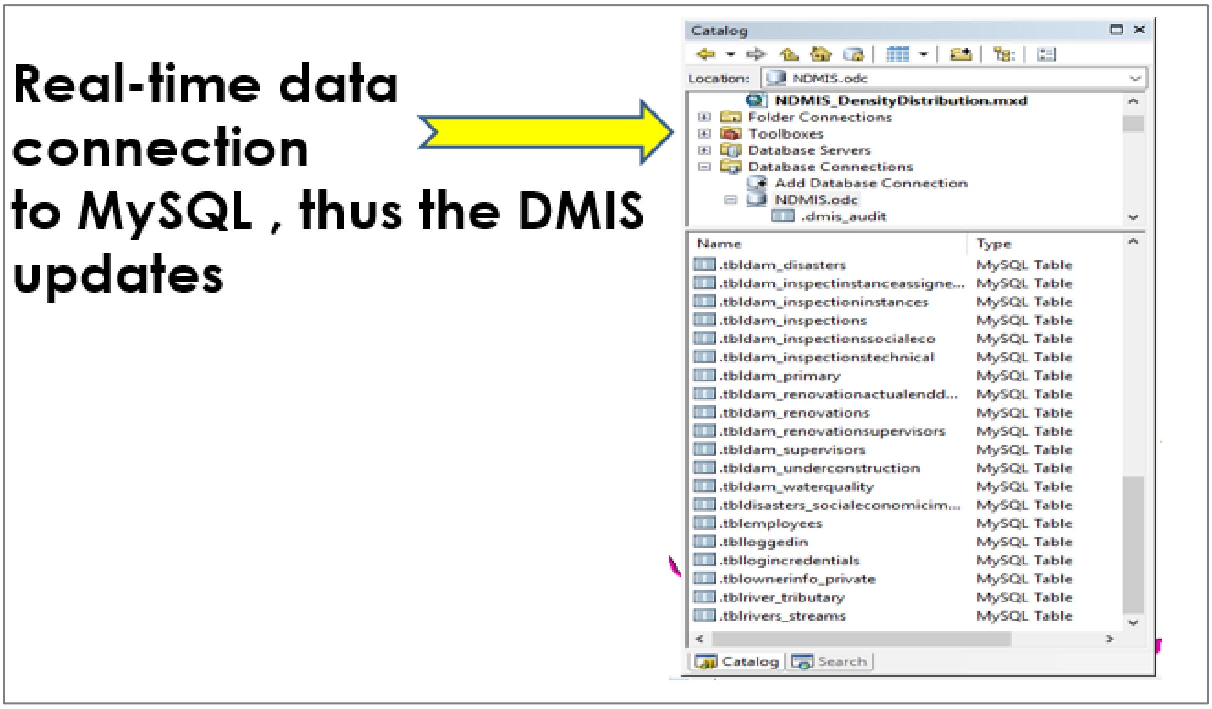



**Figure 4. 9:** Linking of MySQL tables to Arc Catalogue

Source: Formulated by Author (2017)

Kalomo district was segregated into three constituency namely Dundumwezi, Kalomo Central and Mapatizya. The dams that were entered into the DMIS application were displayed in ArcMap. The number of dams in each constituency were shown as demonstrated in Figure 4.10.

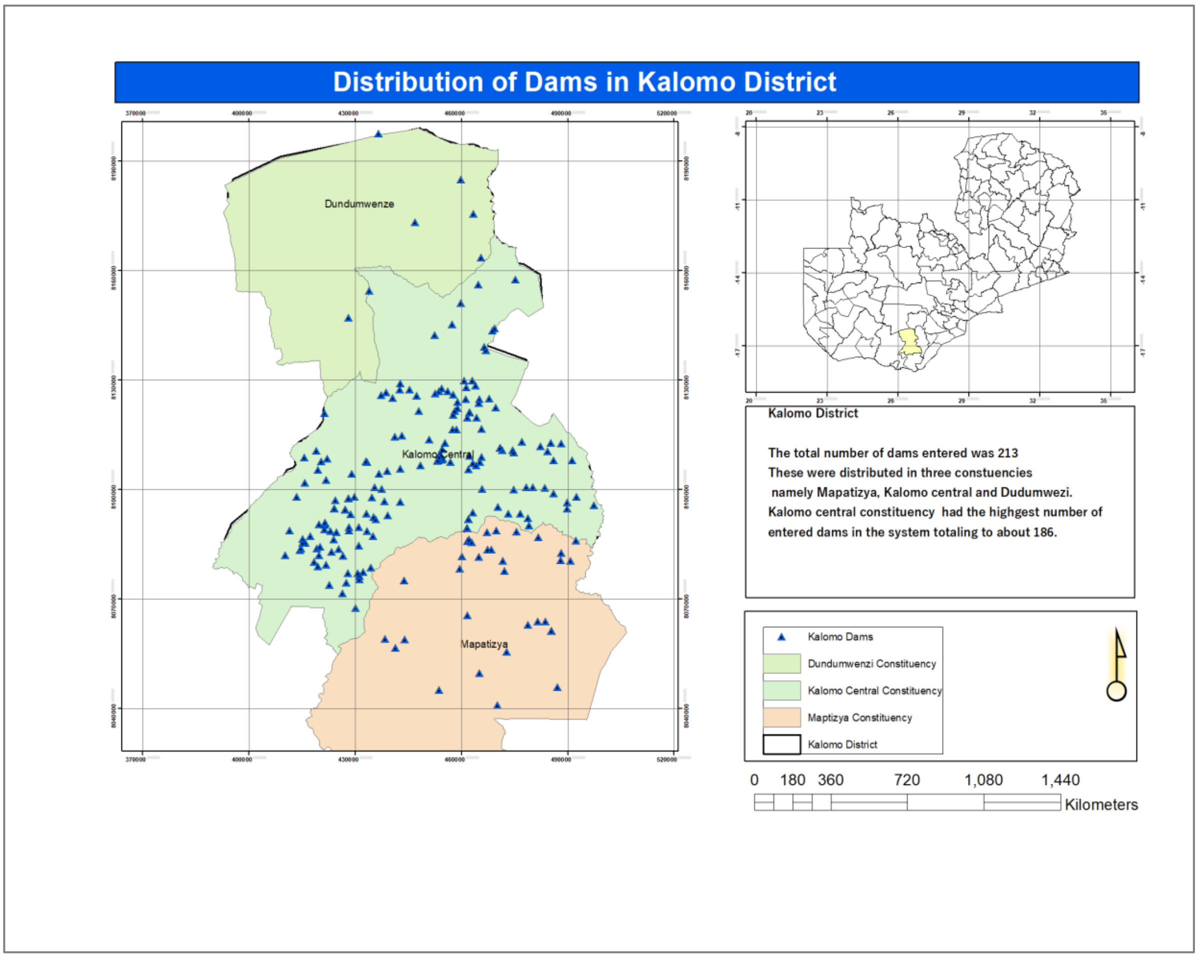



**Figure 4. 10:** Spatial distribution of dams

Source: Formulated by Author (2017)

Furthermore, ArcMap made it possible to visualise dams and make inferences from the representations. For instance, the dams were grouped by dam types, catchment, ownership etc. It was possible to tell the number of dams which are privately owned and in which catchment or constituency they are in. This type of information is vital to policy makers in making informed decisions. Figure 4.11 illustrates the attributes in the dams' data that was entered in Kalomo district.

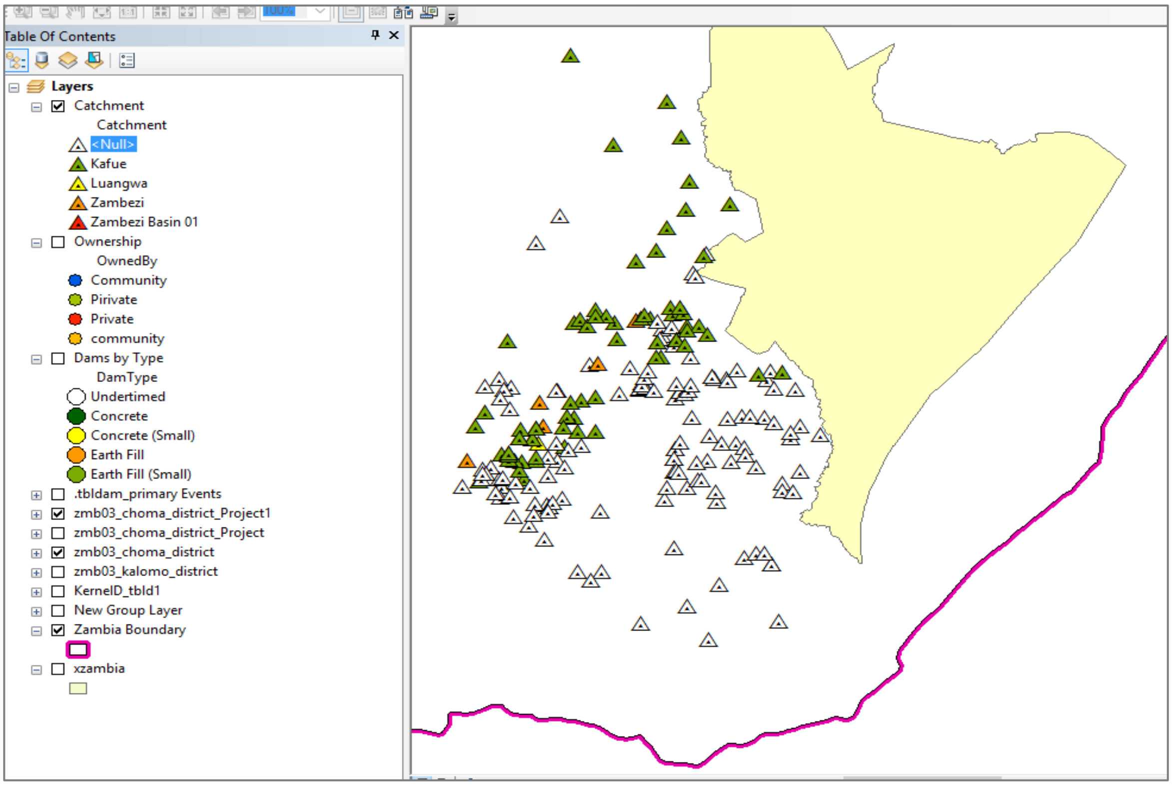



**Figure 4. 11**: Spatial distribution of dams

Source: Formulated by Author (2017)

Similarly, the DMIS database and MySQL tables were also linked to Microsoft Excel in order to make updated dash boards for decision makers to make informed decisions. From the available dam data that was entered in the application during the study, it was revealed that there were more dams in Kalomo Central Constituency at 80% followed by Mapatizya at 17% and the least was Dundumwezi with only 3%. Figure 4.12 illustrates the dash board created using excel from the database.

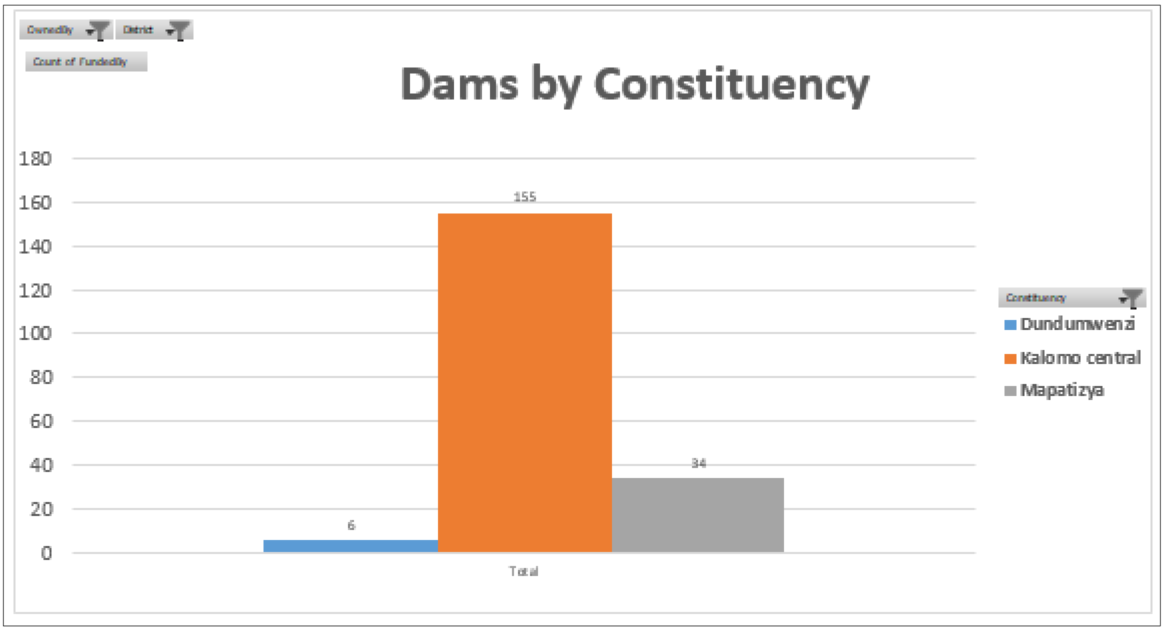



**Figure 4. 12:** Dashboards-dams by constituency

Source: Formulated by Author (2017)

# CHAPTER FIVE: DISCUSSION

The study results have indicated that the developed Dam Management Information System proved beyond doubt that, if well populated with reliable dam's data it could store and provide timely information to policy makers. Its role therefore, cannot be overstated. As argued by Donia (2013), a reliable data resource can be used by policy makers for evidence based decision making in order to improve water management.

The current set up at DWRD, data on dams management has been stored on standalone machines from province to province posing high risk on manipulation and loss. Heeks and Bhatnagar (1999), has shown that in case of electricity outage, there is a high risk of data loss and availability of the system. According Afered and Shaqiri (2015), standalone desktop systems have technological limitation from security. This in the due course affects the quality of decisions made by policy maker in addressing water challenges faced by the communities. Collection and input of dam's data has equally been a challenge due to different formats that the data is submitted from remote offices within DWRD. Transforming data from one format to another takes away valuable time and this affects the data quality submitted. There are so many key stakeholders in the sector that consume data on dams and water management, lack of real time data access affects business operation of not only DWRD but other Government Spending Agencies, for example the agriculture, energy sector and many more. This results in crushing of similar projects in the same communities robbing the much needed financial resources which could have been used to finance a project in another community.

However, the development of the National Dams Management Information System for the DWRD has led to the establishment of a distributed database which stores large volume of data from different provinces and districts in a well-structured predefined format. This has greatly improved decision management and services operation because data is accessed anytime from anywhere. Heeks (2003) in his study says MIS guides in planning and sound policy direction. Many studies in the literature reviewed show focus mainly on dam safety management. Although literature has shown that most of the developed dams management information systems have focused mainly on dam safety particularly on single dams and in some cases on a few hydropower dams (Tan et al., 2009, Yang et al., 2009, Jesung et al., 2009, and Donia, 2013), the comprehensive management information systems covering dams countrywide are limited. This study looked beyond information on dam safety ranging from general details of the dams, technical and routine inspections, to social economic impact assessments during varying times of the year as well as when disaster strikes. The developed Dams Management Information System brought efficiency in business operation in the DWRD. As suggested by Bellotti and Bly (1996), MIS facilitates easy sharing and storage of data across different user groups, this promotes operation efficiency and time management. This is particularly true because the Dams Management Information System can now generate automated reports on dams by province, district, constituency, ward, etc. The data on various parameters can be shared by various users within a short period.

# CHAPTER SIX: CONCLUSION AND RECOMMENDATIONS

## 6.1 Introduction

This final chapter presents the summary of the research findings according to the research questions and research objectives. The chapters also brings out recommendations on what needs to be prioritized going forward.

## 6.2 Conclusion

Arising from the analysis and the discussion of results in this applied research study, the conclusion drawn were as follows;-

i. Adoption of Dam Management Information System by DWRD in service delivery can bring out many benefits to all stakeholders;
ii. DMIS can facilitate easy storage and sharing of data across diverse users leading to efficiency in data and time management;
iii. Storage of dams data in hardcopies and excel format can be quiet tedious for officers responsible for data management at DWRD especially when it comes to dams data sharing with key stakeholders;
iv. Linkages of tools such as ArcGIS, QGIS, MySQL database and MS access can serve effectively as decision support for water managers and;
v. This DMIS provides a new approach transforming how dam's data is managed and used that fuses physical and socioeconomic data and notifies GIS that mixes spatial and temporal information.

## 6.3 Recommendations

The study recommends that the following be considered;

1. Effecting this database requires leadership and management support in sharing dam's data services and ongoing participation of all stakeholders involved.
2. Data collection on dams to be continued in all districts across the country.
3. The system application should be evaluated regularly so as to improve its functionality, existing parameters and data structure, usability and ease of learning the system.
4. In future studies, there is need to design and capture real time data of water levels on the country's major dams especially the ones used for hydropower generation into the system. During the research study, the system design and implementation did not include water levels real time data capture due to limited financial resources and time.
5. The DWRD needs to form a dedicated team that will be undertaking routine field inspections on dam's facilities to assess the conditions and make informed decisions.

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# APPENDICES

Appendix A. 1: Data Collection Questionnaire

**EXISITNG DAM SITES QUESTIONNAIRE**

*URGENT INFORMATION REQUIRED HILIGHTED BY: RED CELLS*

| | | |
|---|---|---|
| 1 | GENERAL INFORMATION | |
| 1.1 | Name of dam: | |
| 1.2 | Type of site: | |
| 1.3 | Dam wall length (m): | |
| 1.4 | Dam wall height (m): | |
| 1.5 | Province: | |
| 1.6 | District: | |
| 1.7 | Constituancy: | |
| 1.8 | Ward: | |
| 1.9 | Chief: | |
| 1.10 | Village: | |
| 1.11 | Agriculture block: | |
| 1.12 | Agriculture camp: | |
| 1.13 | Contact Person: | |
| 1.14 | Contact Details: | |
| 1.15 | E-mail Address: | |
| 1.16 | Date visited (dd/mm/yy) | |
| 2 | GEOGRAPHIC LOCATION DETAILS | |
| | Dam site: | |
| | GPS coordinates (Position Format : **Decimal Degrees & UTM**, Map Datum : **Arc 1950**, Elevation: **above mean sea level-masl**) | |
| | Position Format: Decimal Degrees | |
| 2.1 | Latitude (South): | |
| 2.2 | Longitude (East): | |
| 2.3 | Elevation (masl): | |
| | Position Format: UTM | |
| 2.4 | East: | |
| 2.5 | South: | |
| 2.6 | Sheet: | |
| 2.7 | Elevation (masl): | |

| | | |
|---|---|---|
| 2.8 | **Description of direction and distance from point of interest (from office, road junction etc.)** | |
| 2.9 | **Ownership of land where site is located** | |
| | **Privately owned land contact details (only if the land is owned privately)** | |
| 2.10 | **Name of owner:** | |
| 2.11 | **Contact details:** | |
| 2.12 | **ecological/archeological/cultural/historical site near the dam site?** ***Relevant for rehab*** | |
| 2.12 | **Type of site 1 only if yes in 2.12:** | |
| 2.13 | **Name of site 1:** | |
| | **Position Format: Decimal Degrees** | |
| 2.14 | Latitude (South): | |
| 2.15 | Longitude (East): | |
| 2.16 | Elevation (masl): | |
| | **Position Format: UTM** | |
| 2.17 | East: | |
| 2.18 | South: | |
| 2.19 | Sheet: | |
| 2.20 | Elevation (masl): | |
| 2.21 | **Type of site 2 only if yes in 2.12:** | |
| 2.22 | **Name of site 2:** | |
| | **Position Format: Decimal Degrees** | |
| 2.23 | Latitude (South): | |
| 2.24 | Longitude (East): | |
| 2.25 | Elevation (masl): | |

| | | |
|---|---|---|
| | **Position Format: UTM** | |
| 2.26 | East: | |
| 2.27 | South: | |
| 2.28 | Sheet: | |
| 2.29 | Elevation (masl): | |
| **3** | **HYDROLOGICAL DETAILS** | |
| 3.1 | **Name of River/Stream:** | |
| 3.2 | **Tributary of:** | |
| 3.3 | **Main Catchment:** | |
| 3.4 | **Type of river stream (Perennial or Non-Perenn** | |
| 3.5 | **Catchment Area ($km^2$):** | |
| 3.6 | **Dam Capacity ($m^3$):** | |
| 3.7 | **Dam Surface Area when full ($km^2$):** | |
| 3.8 | **Is there an existing flow gauging station or weir upstream or downstream of the site?** | |
| 3.9 | **Details of existing flow gauging:** | |
| 3.10 | **Are there dams upstream within this catchmen** | |
| 3.11 | Name of existing dam 1: | |
| 3.12 | Name of existing dam 2: | |
| 3.13 | Name of existing dam 3: | |
| 3.14 | Name of existing dam 4: | |
| 3.15 | Name of existing dam 5: | |
| 3.16 | Name of existing dam 6: | |
| 3.17 | Name of existing dam 7: | |
| 3.18 | Name of existing dam 8: | |
| 3.19 | Name of existing dam 9: | |
| 3.20 | Name of existing dam 10: | |

*If there are more than 10 dams in the upstream catchment add under comments below as items 3.21 to 3.30*

**4 SOCIO-ECONOMIC DATA**

**Beneficiaries:**

**Current (to be completed for all sites):**

| | Name of community/village/ institution | Type of water use | Population | Households | Animal Population | Irrigation Area (ha) | Other sources of access to | Water use conveyance system | Current Water Use |
|---|---|---|---|---|---|---|---|---|---|
| 4.1 | | | | | | | | | |
| 4.2 | | | | | | | | | |
| 4.3 | | | | | | | | | |
| 4.4 | | | | | | | | | |
| 4.5 | | | | | | | | | |
| 4.6 | | | | | | | | | |
| 4.7 | | | | | | | | | |
| 4.8 | | | | | | | | | |
| 4.9 | | | | | | | | | |
| 4.10 | | | | | | | | | |
| 4.11 | | | | | | | | | |
| 4.12 | | | | | | | | | |
| 4.13 | | | | | | | | | |
| 4.14 | | | | | | | | | |
| 4.15 | | | | | | | | | |
| 4.16 | | | | | | | | | |
| 4.17 | | | | | | | | | |
| 4.18 | | | | | | | | | |
| 4.19 | | | | | | | | | |
| 4.20 | | | | | | | | | |

**5 REHABILITATION**

***Only to be filled in for rehad site***

| | | |
|---|---|---|
| 5.1 | **Has the dam been breached?** | |
| 5.2 | **Has the breach taken place in the embankment or spillway?** | |
| | **If the dam has not breached what is the reason for the rehabilitation:** | |
| 5.3 | Not enough freeboard left between the spillway and the crest? | |
| 5.4 | Signs of piping through the embankment? | |
| 5.5 | The spillway has been damaged/eroded? | |
| 5.6 | Extensive tree growth on the embankment? | |
| 5.7 | The outlet pipe is no longer functioning? | |
| 5.8 | The dam has silted up? | |
| 5.9 | **Has any human settlement taken place in the dam basin since the dam was breached?** | |

**6 ADDITIONAL COMMENTS**

*REHABILITATION), the secondary item no. in the 2nd column (for example "1" for "5.1 Has the dam been breached") and adding the comment in the 3rd column*

| | Main item no. | Secondary item no. | Comment |
|---|---|---|---|
| 6.1 | | | |
| 6.2 | | | |
| 6.3 | | | |
| 6.4 | | | |
| 6.5 | | | |
| 6.6 | | | |
| 6.7 | | | |
| 6.8 | | | |
| 6.9 | | | |
| 6.10 | | | |
| 6.11 | | | |
| 6.12 | | | |
| 6.13 | | | |
| 6.14 | | | |
| 6.15 | | | |
| 6.16 | | | |
| 6.17 | | | |
| 6.18 | | | |
| 6.19 | | | |
| 6.20 | | | |

Source: Formulated by Author (2017).

## Appendix A. 2: Entity Relationship Diagram

ERdiagram_UML.pdf

Appendix A. 3: Database Schema Design

| Theme | Fields | Description |
|---|---|---|
| Dam Informatio n | DamID | Unique ID assigned to each dam – Primary Identity |
| | DamName | Name of the Dam |
| | DamType | Type of dam whether Earth fill, concrete etc |
| | ConstructionDate | Date of dam construction |
| | Funded By | Who funded the construction of the dam |
| | Owned By | Who has legal ownership and responsibility over the dam? |
| | Land Tenure | Who is the legal owner of the land the dam sits on? |
| | X Location on Stream | GPS location on the stream (Northings) |
| | Y Location on Stream | GPS location on the stream (Eastings) |
| | Stream/ River Name | Name of Stream or River dam was constructed on |
| | Province | Province location of the dam |
| | District | District location of the dam |
| | Constituency | Constituency location of the dam |
| | Ward | Ward location of the dam |
| | Village | Village location of the dam |
| | Catchment | Catchment location of the dam |
| Tributary Information | Record AID | Unique ID auto assigned for dams on tributaries |
| | Dam ID | Unique ID for the dam |
| | Tributary | Name of the tributary |
| | Stream/River | Name of parent Stream/River |
| | Branch Off Level | Branch Level of the tributary |
| Construction Project | Construction AID | Unique ID auto- assigned for all construction projects |
| | Dam ID | Unique ID of the dam |
| | Start Date | Official Date for launch of construction works |
| | Proposed Completion | Target date when constructions works are to be completed |
| | Current Status | Is the project completed, on halt or ongoing? |
| | Project Budget | What is the total budget for the construction project |
| | Contractor ID | Unique ID for the assigned contractor |
| Construction Supervisors | Supervisor AID | Unique ID auto assigned to all supervisors on projects |
| | Construction ID | Unique ID for the specific project under construction |
| | Assigned Staff Role | The Man No. for the member of staff assigned |
| | | The specific role assigned that member of staff |
| Completed Constrction Projects | Completion AID | Unique ID auto assigned by for each project completed |
| | Dam ID | Unique ID for the dam that has been completed |
| | Date Completed | Date officially completed |
| Dam Parameters | DamID | UniqueIDfor the dam |
| | DamHeight | The dams height |
| | Crest Length | The length of the dams crest |
| | CrestWidth | The width for the crest |
| | SpillwayWidth | The spillway width |
| | DamCapacity | The maximum capacity/ volume of the dam |
| | XDamLeftCorner | GPS location X for the dam wall's left corner |
| | YDamLeftCorner | GPS location Y for the dam wall's left corner |
| | XDamRightCorner | GPS location X for the dam wall's right corner |
| | YDamRightCorner | GPS location Y for the dam wall's right corner |
| | Evaluation Date | Date when these measurements were taken |

| Theme | Fields | Description |
|---|---|---|
| Inspection Instances | Instance AID<br>Dam ID<br>Inspection Date<br>Inspection Details<br><br>Allocated Budget | Unique ID assigned to every inspection instance<br>Unique ID of the dam inspected<br>Date of inspection<br>Inspection Details (eg water quality monitoring, routine inspections, deformation monitoring etc)<br>Funds allocated for the exercise to be carried out |
| Water Quality Monitoring | Record AID<br>Dam ID<br>Inspection Instance ID<br>Collection date<br>Collection time<br>Sampling Point<br>PH<br>Turbidity<br>Electric Conductivity<br>TSS<br>TDS<br>Chlorides<br>Fluorides<br>Nitrates<br>Nitrites<br>Arsenic<br>Residue Chlorine<br>Coliform<br>Faecal Coliform<br>Ammonia<br>Collected By | Unique ID assigned each water quality monitoring exercise<br>Unique ID for the dam<br>Unique ID for the specific inspection instance<br>Date the water quality readings were taken<br>Time the readings were made<br>The name of the sampling point<br>PH recorded<br>Turbidity recorded<br>Electric Conductivity recorded<br>TSS recorded<br>TDS recorded<br>Chlorides recorded<br>Fluorides recorded<br>Nitrates recorded<br>Nitrites recorded<br>Arsenic recorded<br>Residue Chlorine recorded<br>Coliform recorded<br>Faecal Coliform recorded<br>Ammonia recorded<br>Member of staff who made the collections |
| Social Economic Impact Assessments | Record AID<br>Instance ID<br>Dam ID<br>Inspection Type<br>Beneficiary Type<br>Name<br>Human population<br>Animal population<br>households<br>Peasant Farmers<br>Small scale farmers<br>Large scale farmers<br>Fish farmers<br>Water use per day<br>Livestock use<br>Fish farming<br>Irrigation<br>Hydropower<br>Inspected by | Unique ID assigned each social eco. Impact assessment<br>Unique ID for the inspection instance<br>Unique ID for the dam<br>(whether routine inspection, special inspection etc)<br>whether community, village school etc<br>Name of community/village/school etc<br>What is the total human population of the area?<br>What is the total animal population of the area?<br>How many households in total exist in the area?<br>Number of peasant farmers using the dam<br>Number of small scale farmers using the dam<br>Number of large scale farmers using the dam<br>Number of fish farmers using the dam<br>Amount of water the community uses each day<br>Is the dam being used for water for livestock?<br>Is the dam being used for fish farming?<br>Is the dam being used for irrigation purposes<br>Is the dam being used for hydro power generation<br>Member of staff who carried out the evaluations |

| Theme | Fields | Description |
|---|---|---|
| Deformation monitoring | Record AID | Auto assigned ID for all deformation monitoring exercises |
| | inspection ID | Unique ID for the inspection |
| | Dam ID | Unique ID for the dam |
| | Inspection Date | Date of Deformation monitoring exercise |
| | Inspected By | Member of staff carrying out the exercise |
| | Dam Height | Measured dam's height |
| | Crest Length | Measured dam's crest's length |
| | Crest Width | Measured width |
| | Spillway Width | Measured spillway width |
| | Dam Capacity | Measured dam capacity |
| | X Dam Left Corner | Measured X dam left corner |
| | Y Dam Left Corner | Measured Y dam left corner |
| | X Dam Right Corner | Measured X dam Right corner |
| | Y Dam Right Corner | Measured Y dam Right corner |
| | General Comments | General comments for the exercise |
| General Inspections | Record AID | Auto ID assigned each general inspection instance |
| | Instance ID | Unique inspection Instance ID |
| | Dam ID | Unique ID for the dam |
| | Inspection Date | Date the exercise was carried out |
| | Inspected By | Member of staff who carried out the inspection |
| | Inspection Type | Was it a routine inspection, special inspection etc |
| | Water Level | Dams measured water level |
| | Cracks | Where there any cracks observed in the dam's wall? |
| | Floods | Were there any floods at the dams site at inspection time? |
| | Breach | Was any dam breach of any sort observed? |
| | Siltation | Was any significant siltation observed? |
| Disaster Occurrences | Disaster AID | Auto ID assigned each disaster occurrence |
| | Dam ID | Unique Dam ID |
| | Occurrence Date | Date of disaster occurrence |
| | Disaster Type | Is the disaster a flood, breach, drought etc |
| | Disaster Class | What is the magnitude of the disaster (eg Minor, Major, Severe) |
| | Details | More detailed report giving extra details |
| Disaster Occurrences- Social Economic Impact Assessments | Record AID | Auto ID assigned each Social Eco Impact Evaluation |
| | Disaster ID | Unique ID for the disaster being evaluated |
| | Dam ID | Unique ID for the dam |
| | Community Name | Name of Community affected |
| | Affected Households | Number of households affected by the disaster |
| | Human Fatalities | Number of Human lives lost |
| | Livestock Fatalities | Number of livestock lost |
| | Property Cost | Cost of Physical Property damaged by the incident |
| | Livestock Cost | Cost of Livestock lost by the incident |
| | Crops Cost | Cost of Crops damaged |
| | Recorded By | Member of staff who carried out the evaluations |
| | Evaluation Date | Date of evaluation |

| Theme | Fields | Description |
|---|---|---|
| Rehabs and Upgrades | Rehabs AID<br>Dam ID<br>Start Date<br>Proposed Completion<br>Classification<br>Allocated Budget<br>Contractor<br>Project Status | Auto ID assigned each repair activity<br>Unique ID for the dam<br>Official launch date of rehab works<br>Proposed completion date for the works<br>Magnitude of works eg major, minor<br>Funds allocated for the project<br>Name of Contractor assigned works |
| Contractors | Contractor AID<br>Contractor Name<br>Phone<br>Email<br>Designation | Auto ID assigned to all contractors<br>Name of the Contractor<br>Phone Number<br>Email<br>Is the Contractor a local contractor or foreign |
| Supervisors | Repair ID<br>Staff Name<br>Role | Unique ID for the repair works being carried out<br>Name of member of staff<br>The assigned role in the project |
| Completed Works | Record AID<br>Repair ID<br>Dam ID<br>Date of Completion | Auto ID assigned each repair work upon completion<br>Unique ID for the repair work which was being carried out<br>Unique ID for the dam<br>Actual Date of completion of works |

Source: Formulated by Author (2017).

Appendix B. 1: Location of Dams Report

NDMIS

MINISTRY of WATER, SANITATION and ENVIRONMENTAL PROTECTION

DEPARTMENT OF WATER RESOURCES DEVELOPMENT

Dams In Zambia - Location Report

**Luapula Province** Total Number of Dams: 1

Mansa District

| Name of Dam | DamID | Constr.Date | Owned By | Constituency | Ward | Village |
|---|---|---|---|---|---|---|
| | | | | Bahati | Mansa | thycjsdbh |

**Lusaka Province** Total Number of Dams: 1

Kafue District

| Name of Dam | DamID | Constr.Date | Owned By | Constituency | Ward | Village |
|---|---|---|---|---|---|---|
| Namankutu | 05CK01L0S2 | | Communal | Kafue | Kafue | Muyasansunka |

**Southern Province** Total Number of Dams: 214

Kalomo District

| Name of Dam | DamID | Constr.Date | Owned By | Constituency | Ward | Village |
|---|---|---|---|---|---|---|
| | | | | Mapatizya | Luyaba | tyghsj bh scj |
| | | | | Kalomo Central | Choonga | |
| 1 | 09CK01L3S1 | | Pirivate | Kalomo central | Mayoba | SDPA |
| 1 | | | Private | Kalomo central | Mayoba | Happy Rest# 3159 |
| 10 | | | Pirivate | Kalomo central | Mayoba | Hudson Farm |
| 12 | 09CZ01L1S1 | | Private | Kalomo central | Mayoba | Hudson Farm |
| 16 | | | Pirivate | Kalomo central | Mayoba | Hudson Farm |
| 2 | | | Private | Kalomo central | Mayoba | Happy Rest# 3159 |
| 2 | 09CL0S2 | | Pirivate | Kalomo central | Mayoba | SDPA |
| 2 | | | Pirivate | Kalomo central | Mayoba | Hudson Farm |

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| | | | | | | |
|---|---|---|---|---|---|---|
| 3 | | | Private | Kalomo central | Mayoba | Happy Rest# 3159 |
| 3 | 09CL053 | | Pirivate | Kalomo central | Mayoba | SDPA |
| 3 Corner | | | Private | Kalomo central | Mayoba | Van Berg |
| 4 | | | Private | Kalomo central | Mayoba | Happy Rest# 3159 |
| 5 | | | Pirivate | Kalomo central | Mayoba | Hudson Farm |
| 6 | | | Private | Kalomo central | Mayoba | Happy Rest # 816 |
| 7 | | | Private | Kalomo central | Mayoba | Happy Rest# 3159 |
| 8 | | | Pirivate | Kalomo central | Mayoba | Hudson Farm |
| 8 | | | Private | Kalomo central | Mayoba | Happy Rest# 3159 |
| Alex Wii | | 01/01/1970 | Private | Kalomo central | Simayakwe | Alex will farm |
| B. Williams | | | Private | Kalomo central | Choonga | Chikoli B settlements |
| Barkitha | | | Community | Kalomo central | Choonga | Farm 624 |
| Big Dam Mazuba | | | Private | Kalomo central | Mayoba | Mazuba Farm |
| Bird Estate | | | Private | Kalomo central | Namianga | Farm |
| Bruce 2 | | | Pirivate | Kalomo central | Siachitema | Bruce Danquet Farm |
| Buche Buche | | | Private | Kalomo central | Sipatunyana | Farm 8 luyala |
| Bulls | 09C201L155 | | Private | Kalomo central | Mayoba | Van Derm |
| Camp Dam | | | Private | Kalomo central | | Farm |
| Camp 6 Dam | | | Pirivate | Kalomo central | Zimba | Foresythes Estate |
| Chakufola | | | Private | Kalomo central | Kalonda | Chakufola farm |
| Chakwiza / Mapanza T Dam | | | Pirivate | Kalomo central | Zimba | Zimba Town |
| Chalaluka | | | Community | Kalomo central | Nachikungu | Situngwani |
| Chalimongela | | | Community | Mapatizya | Mbwiko | Chalimongela |
| Chaluza | | | Community | Kalomo central | Chawila | Ndandula |
| Chandula Bazomba | | | Community | Kalomo central | Nachikungu | Siabowa |
| Chawila | | | Community | Kalomo central | Chawila | Chawila |
| Chawila | | | Community | Kalomo central | Chawila | Chawila |

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| | | | | | | |
|---|---|---|---|---|---|---|
| Chifusa | 09C201L152 | | Community | Kalomo central | Siachitema | Chifusa |
| Chikoli B | | | Communal | Kalomo central | Choonga | Chikoli B settlements |
| Chilundika | | | Community | Mapatizya | Chiiidi | Napaisha |
| Chilundu | | | Private | Kalomo central | Kalonda | Van Berg |
| Chilundu | | | Private | Kalomo central | Mayoba | Vanbery Farm |
| chiyongolo | | | Community | Kalomo central | Nachikungu | Siamakando |
| Chris Kens Dam | | | Private | Kalomo central | Namianga | Chris Kens |
| Chuundwe | | | Community | Kalomo central | Zimba | Chuundwe |
| Compound Dam | | | Private | Kalomo central | | Farm |
| Dabali | | | Community | Kalomo central | Chawila | Dabali |
| Dam 7 Luyala | | | community | Kalomo central | Sipatunyana | Farm 7 (4004) |
| Daphan | | | communal | Kalomo central | Mayoba | Daphan Settlement |
| Deko | | | Community | Kalomo central | Nachikungu | Simachela |
| Five 5 | | | Pirivate | Kalomo central | Zimba | Zambezi Raunch |
| Four (4) dam | 09C201L251 | | Private | Kalomo central | Zimba | Highland Estates |
| Gala | | | Community | Mapatizya | Chiiidi | Moono |
| Grandat Dam | | | Private | Kalomo central | Namwianga | Farm 1757 |
| Gungu Dam | 09C201L259 | | Private | Kalomo central | Choonga | David Mcleans Farm |
| Hamaleka Farm | 09C201L251 | | Private | Kalomo central | Mayoba | Hamaleka Farm |
| Hamanyanga | | | Pirivate | Mapatizya | Zimba | 3377 |
| Hambwalula | | | Private | Kalomo central | Mayoba | Hambwalula Tarm |
| Handalata T Dam | | | Community | Kalomo central | Nachikungu | Moomba |
| HH Dam Training Ce | | | Private | Kalomo central | Choonga | HH Farms |
| HH Mayoba | | | Private | Kalomo central | Mayoba | HH Farm |
| Hugo Dam | | | Private | Kalomo central | Simayakwe | Alex will farm |
| Janika | | | Pirivate | Mapatizya | Zimba | F 3377 / A |
| Janki | | | Community | Kalomo central | Chawila | Siasilumba |

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| | | | | | |
|---|---|---|---|---|---|
| Kabeleka | 09CL0S4 | Pirivate | Kalomo central | Mayoba | Kabeleka 3261 |
| Kaboota | | Pirivate | Kalomo central | Zimba | Luezi Launch |
| Kaboota 17 | | Pirivate | Kalomo central | Zimba | Foresythes Estate |
| Kabwekasalala | 09C201L2S2 | Community | Kalomo central | Siachitema | Munansangu |
| Kala 3 | | Private | Mapatizya | Chiiidi | Kala 3 Farm |
| Kala 4 | | Private | Mapatizya | Chiiidi | Kala Farm |
| Kalala | | Communal | Dundumwenzi | Mabombo | Nkowa |
| Kalemu | | Communal | Dundumwenzi | Kalemu | Mutinta |
| Kalima | | Community | Mapatizya | Simwatachela | Simwatachela |
| Kalomo Weir | | Private | Kalomo central | Choonga | Magrimond |
| Kalundu | | Pirivate | Mapatizya | Zimba | F 3377 |
| Kalundu Farm | | Pirivate | Kalomo central | Zimba | Kalundu Farm |
| Kanyameza Peter Makoto | | Pirivate | Kalomo central | Namianga | Far Enough 383A |
| Kapondo | | Community | Mapatizya | Simwatachela | Kayuni |
| Kasabelo | | Pirivate | Kalomo central | Zimba | Foresythes Estate |
| Kasulama | | Pirivate | Kalomo central | Zimba | Highland Estates |
| Katundulu | 09C201L2S2 | Community | Kalomo central | Kalonda | Settlement C |
| Kaulu | | Private | Mapatizya | Chiiidi | Kala Ranch |
| Kayama | | Private | Kalomo central | Chawila | Kayama Farm |
| Kayobo | | Community | Mapatizya | Chiiidi | Chikamba |
| Kazemba | 09C201L1S2 | Private | Kalomo central | Zimba | Hamadudu |
| Kemkers | | Private | Kalomo central | Mayoba | Kemkers Farm |
| Kumbs | | Communal | Kalomo central | Choonga | Daphan Settlement |
| Leon Dam | 09C201L1S1 | Private | Kalomo central | Mayoba | Deep South Tob. Farm |
| Lifwalale | | Community | Kalomo central | Zimba | Lifwalale |
| Limbuwa | | Community | Kalomo central | Nachikungu | Limbuwa |
| Liwelu – Welu | | Pirivate | Kalomo central | Zimba | Liwelu welu Farm |

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| | | | | | |
|---|---|---|---|---|---|
| Lugobo | | Community | Kalomo central | Chawila | Lugobo |
| Luwezi Ng'andu | | Private | Kalomo central | Mayoba | Ng'andu |
| Luyala | | Private | Kalomo central | Sipatunyana | Luyala Farm |
| Luyala | | Private | Kalomo central | Sipatunyana | Farm 3 luyala |
| Lwambi | | Communal | Kalomo central | Namianga | Settlements |
| Mabele | | Private | Mapatizya | Chiiidi | Kala 3 Farm |
| Mabulu | | Private | Kalomo central | Mayoba | Vanbery Farm |
| Machona | | Private | Kalomo central | Sipatunyana | Machona |
| Madubansi / Chibomba | | Pirivate | Mapatizya | Zimba | F 5077 / 5076 |
| Mailoni | | Community | Mapatizya | Chiiidi | Siasungo |
| Makangala | | Pirivate | Kalomo central | Zimba | Foresythes Estate |
| Makulu | | Private | Kalomo central | Kalonda | Van Berg |
| Makwalantila/ Ndyamazhini | | Community | Kalomo central | Zimba | Makwalatila |
| Man'gwato | | Community | Kalomo central | Chawila | Kanchele |
| Manzi Atuba | 09C201L1S2 | Community | Kalomo central | Siachitema | Sindunda |
| Mashaba Dam | | Private | Kalomo central | Kalonda | Sitrafor farm |
| Masizi | | Community | Mapatizya | Luyaba | Luyaba |
| Mawana | | Private | Kalomo central | Mayoba | Mailos Farm |
| Mayobo | | Community | Mapatizya | Chiiidi | Chikamba |
| Maziba Dam | 09CK01L2S1 | Private | Kalomo central | Zimba | Nahuhati Farm |
| Maziba Dam | | Private | Kalomo central | Mukwela | Deep South Tob. Farm |
| Mcleans Dam | 09C201L1S1 | Private | Kalomo central | Choonga | David Mcleans Farm |
| Mcleans Dam 2 | 09C201L2S1 | Private | Kalomo central | Choonga | David Mcleans Farm |
| Middleton Dam | | Private | Kalomo central | | Farm |
| Mililo | | Pirivate | Kalomo central | Namianga | Vergnoeg SA |
| Monde Dam | | Community | Kalomo central | Simayakwe | Monde |
| Mowiko | | Private | Mapatizya | Mbwiko | Kwandu |

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| | | | | | |
|---|---|---|---|---|---|
| Mpundu 1 | | Private | Kalomo central | Mayoba | Mpundu F # 3232 |
| Mpundu 2 | | Private | Kalomo central | Mayoba | Mpundu F # 3231 |
| Muchindu | | Community | Mapatizya | Luyaba | Muchindu |
| Muhundi | | Community | Kalomo central | Nachikungu | Tambula |
| Mukangala | | Private | Mapatizya | Chiidi | mukangala |
| Mukaziwa Dam | | Private | Kalomo central | Namwianga | Mukaziwa Farm |
| Mukaziwa Dam 2 | | Private | Kalomo central | Namwianga | Mukaziwa Farm |
| Mukaziwa Dam 3 | | Private | Kalomo central | Namwianga | Mukaziwa Farm |
| Mukaziwa Dam 4 | | Private | Kalomo central | Namwianga | Mukaziwa Farm |
| Mukaziwa Dam 5 | | Private | Kalomo central | Namwianga | Mukaziwa Farm |
| Mukaziwa Dam 6 | | Private | Kalomo central | Namwianga | Mukaziwa Farm |
| Mulamfu | | Community | Mapatizya | Mulamfu | Mulamfu |
| Mulibu | | Community | Dundumwenzi | Bbilili | Mulibu |
| Muliwana | | Private | Kalomo central | Mayoba | Muliwana Farm |
| Mulunje | | Community | Kalomo central | Nachikungu | Mulunje |
| Mulwazi T dam | | Community | Kalomo central | Simayakwe | Siabowa |
| Munakanyemba | | Community | Kalomo central | Chawila | Mweebo |
| Muntanga T-Dam | | Private | Kalomo central | Mukwela | Farm |
| Munyeke | | Communal | Dundumwenzi | Chamuka | Sibwendele |
| Mupengu | | Community | Mapatizya | Mulafu | Sianamalembi |
| Mupengu | | Community | Mapatizya | Mulamfu | Sianamalembi |
| Museta | | Community | Kalomo central | Chawila | Museta |
| Muzya | | Community | Kalomo central | Zimba | Muzya |
| Mweebo | | Private | Kalomo central | Choonga | Mweebo Farm |
| Mweemba Dam | | 11 | Kalomo central | Simayakwe | Alexwell Farm |
| Mweemba Dam | 09C201L1S1 | Private | Kalomo central | Simayakwe | Alex will farm |
| Nabbobwe | 09C201L2S2 | Community | Kalomo central | Siachitema | Settlement B |

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| | | | | |
|---|---|---|---|---|
| Nabuyani | Private | Kalomo central | Namianga | Farm # 1760 |
| Nabuyani??? | Private | Kalomo central | | Farm |
| Nakowa | Community | Mapatizya | Zimba | Mantanyani |
| Nanjili | Pirivate | Kalomo central | Siachitema | Bruce Danquet Farm |
| Nanyemu | Communal | Dundumwenzi | Chilala | Nachiyanta |
| Nchelebe Weir | Private | Kalomo central | Mayoba | Muliwana Farm |
| Ndongo | Private | Kalomo central | Namianga | Ndongo |
| Neal Dam | Pirivate | Kalomo central | Zimba | Luezi Launch |
| New Dam | Private | Kalomo central | Mayoba | Happy Rest# 3159 |
| New Dam | Private | Kalomo central | Kalonda | Van Berg |
| Ng'andu | Private | Kalomo central | Namianga | Ng'undu |
| No. 1 Dam | Private | Kalomo central | Kalonda | Thomas Nell Farm |
| One (1) Dam | Pirivate | Kalomo central | Zimba | Foresythes Estate |
| Pikinini | Private | Kalomo central | Kalonda | Van Berg |
| Pot dam | Private | Kalomo central | Mayoba | Muluwana Farm |
| Raphael | Private | Mapatizya | Chiiidi | Siasungo |
| Safali | Community | Mapatizya | Siamafumba | Siangoyo |
| Samona | Private | Kalomo central | | Farm |
| Samona dam | Private | Kalomo central | Kalonda | Samoan F 1753 |
| Sejili | Communal | Kalomo central | Siamyakwe | Siambala |
| Seven Fountain Dam | Private | Kalomo central | Namianga | Farm 356/ 66F |
| Siachiba | Community | Mapatizya | Simwatachela | Siampimpi |
| Siachifwa | Community | Kalomo central | Zimba | Namadula |
| Siachitema | Community | Kalomo central | Siachitema | Siachitema Mission |
| Siadunka Wier | Communal | Kalomo central | Choonga | Kalomo River |
| Siakabaza | Community | Mapatizya | Chiiidi | Siakabaza |
| Siakabezi | Community | Kalomo central | Chawila | Siakabezi |

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| | | | | | |
|---|---|---|---|---|---|
| Siakasasa | | Private | Kalomo central | Mayoba | Siakasasa farm |
| Siakasasa | | Community | Mapatizya | mulamfu | Siakasasa |
| Siamabele | 09C201L1S7 | Community | Kalomo central | Zimba | Musozya |
| Siamabele | | Community | Kalomo central | Siachitema | Siamabele |
| Siamafumba | | Community | Mapatizya | Siamafumba | Nkobe |
| Siampondo | | Community | Mapatizya | Siamafumba | Siampondo |
| Siamwela | | Community | Kalomo central | Simayakwe | Simuchula |
| Siananakanga | 09C201L1S6 | Community | Kalomo central | Zimba | Kalangu/ Kalamba |
| Siandeke Dam | 09C201L1S8 | Private | Kalomo central | Choonga | David Mcleans Farm |
| Siankanga Dam | | Private | Kalomo central | Choonga | Siankanga Farm |
| Siansungule Weir | | Communal | Kalomo central | Mayoba | Siansungule |
| Siapwazya | | Private | Kalomo central | Kalonda | Van Berg |
| Sibuku | | Pirivate | Kalomo central | Zimba | Foresythes Estate |
| Sichikwenkwe Dam | 09CK01L1S1 | Private | Kalomo central | Choonga | David Mcleans Farm |
| Sikaanga Mbwiza | | Pirivate | Kalomo central | Zimba | Luezi Launch |
| Sikabondo | | Private | Kalomo central | Chawila | Sikabondo |
| Sikalaye | | Community | Mapatizya | Chiiidi | Malweza |
| Sikasukwe | | community | Kalomo central | Chawila | Farm 6 luyala |
| Sikweya | | Community | Kalomo central | Chawila | Sikweya |
| Simachiila | | Communal | Kalomo central | Nachikungu | Simachila |
| Simalundu | | Community | Mapatizya | Siamafumba | Simalundu |
| Simatanga | | Private | Kalomo central | Mayoba | Simatanga Farm |
| Simusunge | | Community | Mapatizya | Siamafumba | Simusungu |
| Simwami | | Community | Kalomo central | Zimba | Simwami |
| Simwanda | | Community | Dundumwenzi | Naluja | Chilumbwe |
| Sindowe | | Community | Kalomo central | Zimba | Sindowe |
| Small Dam Mazuba | | Private | Kalomo central | Mayoba | Mazuba Farm |

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| | | | | | |
|---|---|---|---|---|---|
| Sosibery | | Private | Kalomo central | Mayoba | Vanbery Farm |
| Sosibery | | Private | Kalomo central | Mayoba | Van Berg |
| Tambula | | Community | Kalomo central | Nachikungu | Tambula |
| Tema Farm | | Private | Kalomo central | Nabuyani | Tema Farm |
| Thomas Nell | | Private | Kalomo central | Kalonda | Thoms Nell |
| Transformer | | Pirivate | Kalomo central | Namianga | Vergnoeg 5A |
| Twin Fountain Kanyemeza | | Private | Kalomo central | Namwianga | Twin fountain Farm |
| Twin Fountain Lemba | | Private | Kalomo central | Namwianga | Twin fountain Farm |
| Twin Fountain Lemba2 | | Private | Kalomo central | Namwianga | Twin fountain Farm |
| Twin Fountain Mabalani | | Private | Kalomo central | Namwianga | Twin fountain Farm |
| Twin Fountain Mayoba2 | | Private | Kalomo central | Namwianga | Twin fountain Farm |
| Twin Fountain Siakafuma2 | | Private | Kalomo central | Namwianga | Twin fountain Farm |
| Twin Fountain Sikafuma | | Private | Kalomo central | Namwianga | Twin fountain Farm |
| Yusa Farm | 09CK01L1S1 | Private | Kalomo central | Mayoba | Elias Miyanda |
| Zibanga | | Community | Kalomo central | Zimba | Mukwalantila |

216 Dams on record

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Source: Formulated by Author (2017)

Appendix B. 2: Dams by Constituency Report

NDMIS

MINISTRY of WATER, SANITATION and ENVIRONMENTAL PROTECTION

DEPARTMENT OF WATER RESOURCES DEVELOPMENT

Dams In Zambia - Constituency Report

| Constituency | Ward | Dam Name | Dam ID | Dam Type | Owned By | Province |
|---|---|---|---|---|---|---|
| Bahati | Mansa | | | | | Luapula |
| Dundumwenzi | Bbilili | Mulibu | | | Community | Southern |
| Dundumwenzi | Chamuka | Munyeke | | | Communal | Southern |
| Dundumwenzi | Chilala | Nanyemu | | | Communal | Southern |
| Dundumwenzi | Kalemu | Kalemu | | | Communal | Southern |
| Dundumwenzi | Mabombo | Kalala | | | Communal | Southern |
| Dundumwenzi | Naluja | Simwanda | | | Community | Southern |
| Kafue | Kafue | Namankutu | 05CK01L05213 | | Communal | Lusaka |
| Kalomo central | | Camp Dam | | | Private | Southern |
| Kalomo central | | Compound Dam | | | Private | Southern |
| Kalomo central | | Middleton Dam | | | Private | Southern |
| Kalomo central | | Nabuyani??? | | | Private | Southern |
| Kalomo central | | Samona | | | Private | Southern |
| Kalomo Central | Choonga | | | | | Southern |
| Kalomo central | Chawila | Chaluza | | | Community | Southern |
| Kalomo central | Chawila | Chawila | | | Community | Southern |
| Kalomo central | Chawila | Chawila | | | Community | Southern |
| Kalomo central | Chawila | Dabali | | | Community | Southern |
| Kalomo central | Chawila | Janki | | | Community | Southern |
| Kalomo central | Chawila | Kayama | | | Private | Southern |
| Kalomo central | Chawila | Lugobo | | | Community | Southern |
| Kalomo central | Chawila | Man'gwato | | | Community | Southern |

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Source: Formulated by Author (2017)