PREDICTION OF INUNDATION DUE TO KABUYANDA DAM FAILURE AND ITS IMPACT ON THE COMMUNITIES OF ISINGIRO DISTRICT, WESTERN UGANDA

BY

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DECLARATION

I hereby declare that this dissertation is my original work and has never been presented to any university for any other degree award.

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APPROVAL

We hereby certify that this dissertation has been prepared under our supervision and is now ready for submission with our approval.

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DEDICATION

This research work is dedicated to my parents, Mr. & Mrs. Osegge.

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ACRONYMS

DEM : Digital Elevation Model
DMRVPI : District Multi-Risk Vulnerability Profile for Isingiro
EP & R : Emergency Preparedness and Recovery
EPP : Emergency Preparedness Plan
ESIA : Environmental and Social Impact Assessment
ESMP : Environmental and Social Management Plan
FEMA : Federal Emergency Management Agency.
GIS : Geographical Information Systems
HEC : Hydrologic Engineering Center
HEC-RAS : Hydrologic Engineering Center River Analysis System
HEC-HMS : Hydrologic Engineering Center Hydrologic Management System
GeoRAS : Geographic River Analysis system
ICODS : Interagency Committee on Dam Safety
IDCRP : Irrigation Development and Climate Resilience project
MAAIF : Ministry of Agriculture, Animal Industry and Fisheries
MEMD : Ministry of Energy and Mineral Development
MoFED : Ministry of Finance and Economic Development
MoH : Ministry of Health
MoLG : Ministry of Local Government
MWE : Ministry of Water and Environment
NEMA : National Environment Management Authority
NFA : National Forestry Authority
O&M : Operational and Maintenance
OPM : Office of the Prime Minister
PMF : Probable Maximum Flood
RAP : Resettlement Action Plan
UWA : Uganda Wildlife Authority
UTM : Universal Transverse Mercator

ABSTRACT

Globally, dams are indispensable in overcoming hindrances posed by climate change through ensuring sustainable water supply for irrigation. However, in case of failure, Dam floods cause devastating effects in fatalities and financial losses. The study focused on predicting the flood extent in case of Kabuyanda dam failure, determining the exposure of land use types, estimate the damages/losses resulting from the inundation in the eventuality of the dam failure and establish possible flood mitigation measures in Isingiro district. A cross-sectional survey design was adopted following both qualitative and quantitative approaches. Hydrologic Engineering Center River Analysis System model was used to predict flow simulation while depth-damage stage, and replacement values were considered for risk analysis. The data used was acquired from Uganda Beareau of statistics, Ministry of education and sports, Ministry of health, Ministry of water and environment, National risk and vulnerability atlas for Uganda, key informant interviews, and google earth. Geo-spatial analysis, descriptive statistics, and Nvivo software were used to analyze the data. The study revealed that in the eventuality of a dam failure, the spatial extent of floodwater would inundate approximately 1,745.65 hectares of land totaling 43.20% of the Kabuyanda flood plain (4040.60 hectares) with flood velocity and depth ranging between 11.99 m/s to 0 m/s and 0-8.4 m respectively. About 5, 756 people, 319.15 hectares of croplands, 178 roads, 8 schools, police post, and a medical center are exposed to potential dam-break inundation and damage with loss estimate totaling approximately 4,158,130,546 UGS**.** Flood preparedness will be more vital than response and recovery. Low flood zone and uphill regions are suggested as evacuation centers; river banks for forestry and flood fringe for crop cultivation. Conclusively, elevation within the flood plain determines water surface movement, damageability while losses depend on flood velocity and depth. Therefore, flood emergency preparedness strategies are a prerequisite in protecting the downstream population, reducing the damages and losses that could to result from potential dam failure. The estimated cost is 1,670,738 USD (5,912.992,392 UGX) towards meeting the activities to mitigate an inundation disaster in Kabuyanda irrigation scheme in the Isingiro notably evacuation and resettlement from the flood danger spots.

CHAPTER ONE: INTRODUCTION

1.1 Background to the study

With the ever-increasing population, drought, and limitations in water supply, there have been recent cases of multiple menaces that are a hindrance to sources of livelihoods notably the agricultural sector. Some parches of the world especially in Australia, Sub-Saharan Africa, and associated cattle corridors are characterized by prevailing conditions that make life almost unbearable notably unreliable rainfall for most months of the year, extremely hot temperatures, and shortage of surface water as well as declining levels of agricultural development (Brown & Graham, 1988). Moreover, with the increasing unprecedented rainfall patterns due to climate change (K. Khosravi et al., 2019)Therefore, to address such challenges, growing creativity, innovation, and technological advancement came up with multiple strategies and among the best approaches aimed at ensuring the supply of water is the establishment and construction of drainage infrastructures often referred to as dams as part of climate resilience projects purposely directed to increasing farmers access to irrigation facilities, to increase water for production for improved food production and thus, livelihood improvement amidst changing climatic pattern (K. Khosravi et al., 2019).

Globally, dams of varied capacities, sizes, and designs have been and are still being constructed majorly classified based on construction material (concrete, Earth fill, Rock fill) and capacity notably small, medium, and large (Ge et al., 2019). Dam construction is mounting swiftly around the world for the drive of providing electricity, flood control, Water storage, recreation as well as navigation (K. Khosravi et al., 2019)Dams provide a wide range of economic, environmental, and social benefits notably dams create reservoirs that supply water for many uses, including industrial, domestic as well as farm purposes (Shahrim & Ros, 2020). Flood control dams impound floodwaters and then either release it under control below the dam or store or divert the water for other uses and leave alone this, dams provide enhanced environmental protection as well as a stable system of inland river transportation (Kizza & Mugume, 2006).

However, dams that were established to be of great support and serve the purposes to which they were constructed have instead turned out to be a menace to the population. Nakachumeti valley dam in Napak broke in 2019 due to poor maintenance, claiming 5 lives, 3 settlements and some cultivated mature crop land gardens that got flooded (Kizza & Mugume, 2006). Similarly, in the past decades, dams have broken elsewhere leading to catastrophic floods and consequently severe impacts downstream (Guha-Sapir et al., 2011). New technologies, and designs, the possibility of dam failure cannot be eliminated because, dams have been failing in association with spillway capacity, landslide, Seismic resistance, Quality of design, Nature of the foundation, Quality of construction, Monitoring, maintenance and human factors (Monlton, 1989). In modern continents like USA and Europe, dam failure is mainly naturally triggered through induced extreme rainfall, snowmelt, deposition in to the reservoir due to erosion elsewhere which cause overtopping, structural overstressing as well as surface erosion that later intensify hydrologic failure (Ogie et al., 2020).

In Sub-Saharan Africa, thousands of reservoirs are evident on the landscape which attracted development programs to allow for small scale community-based irrigation. This was clear when several of them had gotten destroyed by 2012 merely due to poor management, un restricted land use at their vicinity, poor design and many more (Arshad et al., 2019). However, in East Africa, human-induced failure modes are on the lead notably miss-operation, scheduled volume release, multiple land use at the command area, community terrorist attacks (Guha-Sapir et al., 2011) .In Uganda, Kagamba Bulky Water Project dam in Rakai district and Nakachumeti in Napak had part of their water escape off the reservoir partly due to human negligence (Ogie et al., 2020).

Floods resulting from dam failure are categorized as the most devastating disasters in terms of fatalities and monetary losses (Ran et al., 2021). In the 20th century, nearly 200 dam failures have occurred in the world claiming about 8000 lives and millions of dollars' damages (Umaru et al., 2010). Some notable dam failures include the Vaiont dam which broke in Italy in 1963 and killed about 2000 people downstream, Machhu II dam failure, India in 1979- about 2000 people died and multiple infrastructures destroyed down at the catchment (Elalu, 2020). Malpasset Concrete dam in France broke down in 1959 leading to repercussions of over 433 casualties, in Southern Germany the failure of a dam in 1999 caused 4 deaths and damaged properties worth billions of euros (Arshad et al., 2019). St. Francis Dam in California, 1928 (Rogers, 2006), Teton Dam in Idaho, 1976 (Arthur, 1977), Johnstown dam in Pennsylvania (United States) in 1889, and Buffalo Creek Dam in West Virginia, 1972 (Mohammadi et al., 2014). Floods caused by Asian river dams claim the most lives and affect more people than any other region in the world (Sonwa et al., 2012). In 2010, approximately one-fifth of the territory of Pakistan was flooded, affecting 20 million people and claiming close to 2,000 lives and the economic losses were estimated to be around US$ 43 billion. One year later, another monster flood struck South-East Asia. The flood event extended across several countries and a few separate limited flood events affected parts of the same countries: Thailand, Cambodia, Myanmar, and Viet Nam. Meanwhile, the Lao People's Democratic Republic also sustained flood damage, with the death toll reaching close to 3,000 while the 2014 dam floods in South-East Europe killed 80 people and caused over US$ 3.8 billion in economic losses (Sonwa et al., 2012).

In Africa, floods caused 3,310 deaths and affected more than 27 million people by 2015 (Arshad et al., 2019). Although Africa accounts for only 5% of the deaths, found statistics portray worrying trends particularly in the wake of climate variability (Ghimire & Sharma, 2021). Besides, multiple predictions were made about inundation resulting from dam failure notably on Friday, January 2017; Kariba dam in Zimbabwe broke down due to heavy rainfall beyond the maximum carrying capacity of the river, over accumulation resulting in recognizable destructions and a greater impact to over 2 million people (Arshad et al., 2019). (Ge et al., 2019), notes that the Bill dam in Somalia collapsed and caused multiple destructions which is a global concern today often disastrous to Infrastructure, human life, plantations, and farmlands while on 19th September 2012 (Ogie et al., 2020).

In Uganda, dam failure is not prominent as it is in other countries in Sub Saharan Africa. However, some dams were constructed with various targets explicitly facilitate irrigation farming, control floods, provide water for various activities, and generate Hydroelectric power (Ogie et al., 2020). Nalubaale and Kira dams were constructed and maintained by Eskom Uganda limited which was involuntarily decommissioned in 1999 when Kira dam started operating. However, due to increased rains, water levels were pushed to an average of 12m resulting in a lot of misting and water showers that led to floods in 2016 which called for the construction of flood gates (Kizza & Mugume, 2006). In Karamoja, the government recently constructed valley dams worth sh3.86b to provide an emergency source for water for livestock in this drought-prone area of Uganda. However, this did not last when two of them were washed away by excessive rains leading to great destruction (OPM, 2020). Similarly, Kagamba bulky Water Project dam in Rakai district and Nakachumeti in Napak collapsed in 2019. In Uganda, dam failure is mainly attributed to improper management, inadequate operation as well as land use at the upper dam vicinity command area which increases silting leading to rising water elevation surface hence spill over and over topping (OPM, 2020).

Besides, Isingiro lies within the cattle corridor whose climatic patterns presents difficulties to agricultural activities especially during the long dry spell and thus, necessitating the climate resilience project, one of which involves the construction of a dam. However, there is limited pertinent information that can adequately guide dam operation and human activities within the flood plain and the command area. Moreover, there is a need in the disaster management paradigm to shift from the traditional mitigation and emergency response focus towards prevention and preparedness in case of dam failure. Therefore, appropriately defined and functioning flood extent determination, situational analysis of land use at risk, estimation of potential damages and losses dam flood disaster management plan is a prerequisite to protecting the population downstream against the possible dam flood hazard.

1.2 Problem Statement

Flooding is one of the most common hydrological hazards affecting multitudes of communities and land uses occurring in almost every rainy season in Isingiro district. According to the District Multi-Risk Vulnerability Profile for Isingiro (DMRVPI), between 2015-2019, about 1000 people were displaced, 200 died, farmlands damaged, and economic life halted**.** The ministry of water and environment with backing from the World Bank is preparing the Irrigation Development and Climate Resilience project (IDCRP) in Kabuyanda Sub County involving the construction of an earth-fill dam with a height of 33.8 m and the reservoir storage capacity of 8.8 million m^3. This would lead to control of flooding in this area however, according to World Bank OP4.37 Dam Safety Policy and the International commission of large Dams (ICOLD), Kabuyanda dam is classified as a large and high hazard dam located in a zone of high seismic activity with meteorological hazards like hailstorms, strong winds, floods and lightning, and geological hazards such as landslides, rock fall, soil erosion, and earthquakes likely to cause serious impacts to the dam (Plan et al., 2019). Also, human livelihood activities such as farming, deforestation and overgrazing as well as oversights, negligence, poor design, improper construction, operation and inadequate maintenance would lead to spillover, increase in water levels, blockages, and damage of dam infrastructure. As such, dam failure is likely to cause death, damage and loss of critical infrastructure and facilities as well as other devastating effects. The previous studies did not predict possible dam failure inundation extents, land use and population exposed to potential dam failure inundation and yet this is crucial to allow timely assembly and temporal flood defenses, resistance measures, emergency planning, and post-flood recovery, installation of flood warning systems and mechanisms. Therefore, the study focused on predicting the extent of flooding in the floodplain, mapping the elements exposed to the dam flood and estimating the potential damages and losses resulting from the inundation.

1.3 Objectives of the study

1.3.1 General objective

The overall objective of the study was to determine the extent of dam flood occurrence in Kabuyanda floodplain- Isingiro district.

1.3.2 Specific objectives

(i) To predict the spatial flood extent of flooding in case of dam failure.

(ii) To assess the elements at risk in case of dam failure inundation.

(iii) To determine the potential damages and losses of elements at risk due to dam failure inundation.

(iv) To establish the mitigation measures that can be put in place to reduce the possible damages and losses resulting from dam failure?

1.4 Research questions

From the specific objectives of this research study, a number of research questions to guide the investigations were posed.

(i) What will be the extent and coverage of the flood in Kabuyanda flood plain in case of earth dam failure?

(ii) What is the level and status of exposure of the elements at risk to potential earth dam Flood Hazard?

(iii) What are the estimated damages and losses of elements at risk in case of earth dam failure?

(iv) What mitigation measures can be put in place to reduce the possible damages and losses resulting from earth dam failure?

1.5 Significance of the Study

The study findings may ensure alertness and response actions among the local communities as well as various national disaster management authorities on the availability of accurate and timely meteorological and hydrological forecasting information.

The findings of the study will provide a basis for restricting land use by dam engineers depending on susceptibility to floods.

The findings of the study are of great benefit to the communities of Isingiro District and the country at large in strengthening National Policy for Disaster Preparedness and Management through creating awareness in the communities on flood risk reduction measures, enforce river bank management programs and gazette flood basins.

The findings of the study provide general information about the area as well as the dam including the potential inundation area in case of the any eventuality of dam failure. The flood management Plan will provide the relevant contact details for the stake holders to be contacted in case of a flood disaster situation as well as providing the emergency evacuation strategies.

The findings are key in development planning and decision making, and in providing information to all stakeholders at various levels and capacities on the multiple prediction of inundation extents in the area.

1.6 Scope of the study

The study was conducted in Kabuyanda flood plain in Isingiro District-South Western Uganda, in the sub-counties of Kabuyanda, Kikagate, and Kabuyanda Town Council. However, within Ntungamo District, only Rukoni East Sub County was anticipated to be affected. This floodplain was chosen due to its low elevation, proximity to the dam site at the downstream dam outflow water path, and the multiplicity of land uses.

The research investigation concentrated on determining and predicting the areal coverage of the inundation in case of earth dam failure, map the land use types at risk and quantify the damages and losses that can result from the inundation. However, 3 scenarios were considered namely flood extent without the dam, with the dam and due to dam failure. This was intended to build a comparative analysis of flood coverage from these events whilst field data collection was scheduled between April and May 2021.

1.7 Conceptual Framework

The conceptual framework in this study illustrates the links between inundation characteristics, exposure status, and how they determine the damageability of elements at risk (Figure 1.1). Dam flood characteristics are independent variables, and land-use at-risk exposure and damage are dependent variables. Location of the dam uphill, its geometry, construction materials, geologic, meteorological hazards, engineering issues, and human land use increase the likelihood of dam failure. In case of dam failure, an elevation that determines the interaction of water with the flood plain, distance from the river, and land use types lead to different flood zones, flood depth, and velocity hence exposure status of the elements at risk. The flood characteristics act as the basis for damage and loss estimation. Land use exposure to the flood hazard, resultant damage, and loss estimates call for an intervention (flood management) that should be implemented based on the predicted dam flood characteristics.

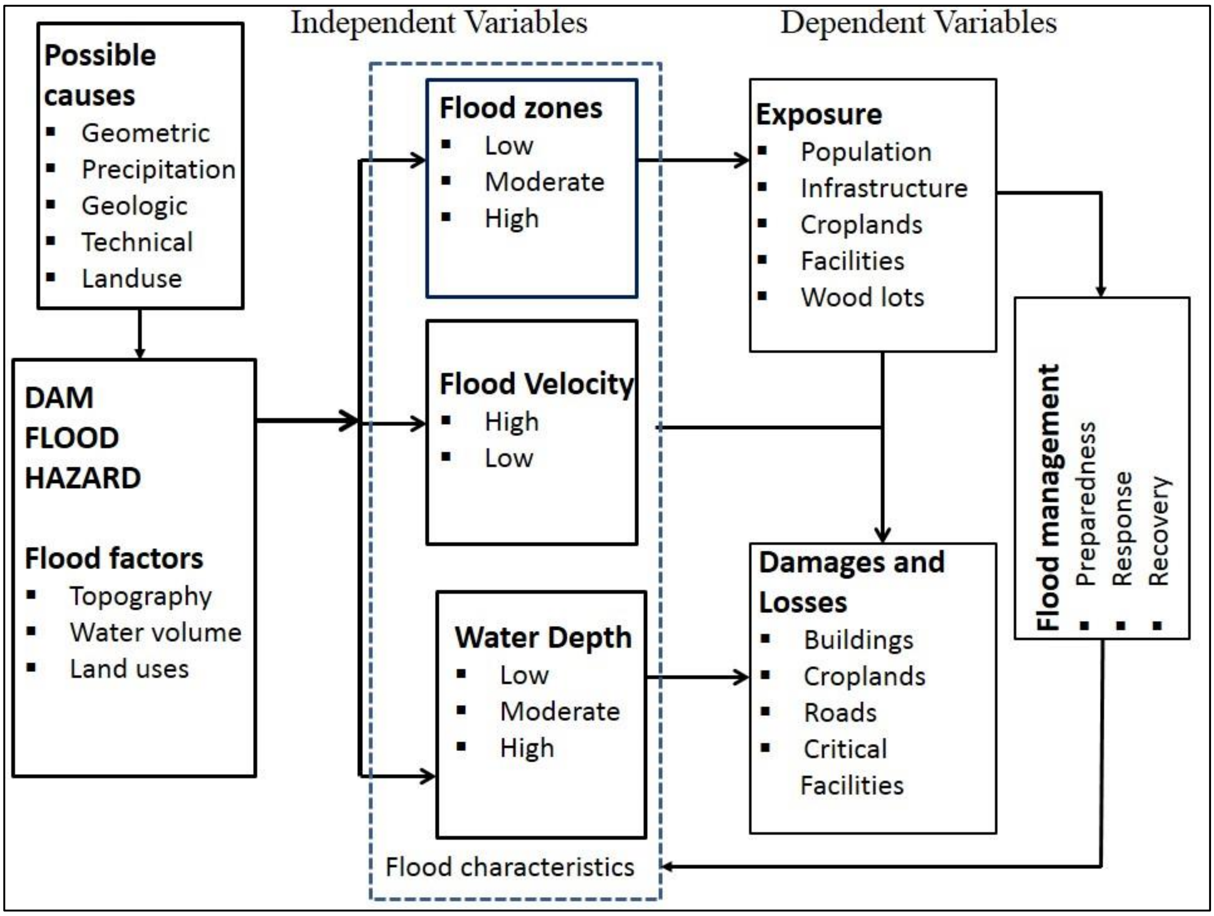


Figure 1. 1: Conceptual framework

Source: Author's own conceptualization.

CHAPTER TWO: LITERATURE REVIEW

2.0 Introduction

This chapter encompasses a review of literature on causes of dam failure, flood hazard mapping, and extents, land use flood impacts, and points out some of the findings by other researchers on models developed to predict the coverage of floods as well as flood management in terms of emergency preparedness, response and recovery strategies.

2.1 Causes of Earth dam failure

Dam failure is a calamitous type of structural failure characterized by the sudden, rapid, and uncontrolled release of impounded water or the likelihood of such an uncontrolled release (Shahrim & Ros, 2020).

Dam failure inundation can be defined as the rapid unrestrained release of water from the reservoir leading to severe inundation downstream (Diman & Tahir, 2012). Globally, in the 20th century, approximately 200 dam failures have occurred, claiming about 8000 lives and millions of dollar damages (Umaru et al., 2010). Most dams break due to overtopping or quality problems, accounting for over 80% of failures (Umaru et al., 2010). Dam failures due to overtopping occur in the wet season (Aboelata, 2005). Deficient spillway capacity mainly accounts for overtopping (Owen et al., 2020). Therefore, the probable location at risk is the spillway followed by the downstream slope (Ge et al., 2019). In addition, the erodibility of the downstream slope material is one of the controlling factors for the erosion process over time and hence determines whether a dam eventually fails or not (Ran et al., 2021). The foundation may be another potential cause because the strength depends on the quality of the construction material. As a result, the foundation settlement will cause the dam to crest and reduce the freeboard of the dam (Yang et al., 2018). The study will focus on other origins of overtopping materials like land-use activities related to livelihoods such as farming, deforestation, and overgrazing that can trigger secondary impacts through erosion and sedimentation hence heightening overtopping scenarios.

In addition, failure arises when soil particles are carried away locally, usually in suspension, by the hydrodynamic forces of the flowing water in the embankment or the foundation, from the embankment to the foundation, or around and into conduits through the embankment. Internal erosion can occur in both granular and cohesive embankments (Smith, 1994). The above study made a sub-optimal decision by neglecting rainfall by assessing a no-rainfall scenario which this study will emphasize since climate variability drives flood events (Van Niekerk & Viljoen, 2005). The most common quality problem is internal erosion in the foundation, and quality problems like sliding or overturning, which is also closely related to the foundation (Diman & Tahir, 2012). Therefore, quality problems at the foundation linked to design and material of the poor type leading to internal erosion and structural instability confirm that foundation plays a key role for Earth fill dams that rely on gravity, arch, or buttress resistances (Kizza & Mugume, 2006). These are consistent with the finding of ICOLD (1995) that foundation problems with internal erosion (21%) and insufficient shear strength (21%) are the two most common causes of earth-fill concrete dam failures. Key considerations are attached to dam maintenance, inspection, and structural plans after the dam completion as well as coordination which is unheard of in the above researches. The operation of dams is a major issue especially during a period of heavy rainfall (Brown & Graham, 1988). Besides, dam flooding or a spill occurs when the reservoir elevation reaches its maximum (Van Niekerk & Viljoen, 2005). In addition, it worsens the flood conditions on the river system leading to increasingly destructive floods downstream of the dam as what happened to Ahning Dam Kedah, at the Pedu-Muda area and Timah Tasoh Dam, Perlis, Malaysia (Azmeri & Isa, 2018). Animal burrows in an embankment or dike can lead to nearly continuous holes through the embankment or a limited length of holes (FEMA, 2005). The resultant control influencing overtopping is insufficient spillway capacity (Elalu, 2020). The single most adverse factor for internal erosion is cracks caused by differential settlement, shrinkage, interfaces with an abutment or embedded structures, or hydraulic fracturing (Ghimire & Sharma, 2021). Cracks in the embankment dam are grouped into three: desiccation cracks, transverse cracks, and longitudinal cracks. Desiccation cracking in embankment dams is caused by the drying and shrinking of embankment soils (high plasticity clay), particularly during an extended period of low reservoir levels. Desiccation cracks do not persist to a great depth, so they only become an issue for reservoir levels near the crest level (Ghimire & Sharma, 2021). The failure of Holland Dam Site A in 1997 was possibly due to the concentrated leak erosion in desiccation cracks (Chereni et al., 2020).

2.2 Flood modeling and elements at risk (Land use) exposure mapping

Flood Inundation Mapping is a vital tool for engineers, planners, and government agencies used for municipal and urban growth planning, emergency action plans, flood insurance rates, and ecological studies (Azmeri & Isa, 2018). By understanding the extent of flooding, decision-makers can allocate resources, prepare for emergencies, and generally improve the quality of life (S. Khosravi & Heydari, 2013). In a dam flood-prone region, accurate flood risk and susceptibility mapping are imperative since it can extend the lead time for issuing disaster warnings and allow sufficient time for habitants in hazardous areas to take appropriate action (Sonwa et al., 2012). However, accurate prediction of the spatial distribution of dam floods is a complex task to undertake due to insufficient key inputs of spatial data constrained by costs and availability (Güneralp & Seto, 2008). Models of flood propagation are classified as conceptually and empirical-based models on system analysis (Ran et al., 2021). Therefore, specifying the sources of danger of a sudden flood and to locate the highly hazardous areas is imperative and to achieve this, application of hydrological-hydraulic modeling should be based on approaches aimed at mapping areas prone to inundation at various hazard zones (Dutta et al., 2006). Unfortunately, this is quite complex in ungauged environments and where expensive and time-consuming hydrological-hydraulic simulations are not probable, utilization of an effective tool to map areas prone to flooding is essential (Arshad et al., 2019). Moreover, identifying an area at high risk of flooding is very important in small hydrological basins where the flood warning time is short (Mohammadi et al., 2014).

Flood hazard extent maps aid in predicting flood coverage and provide life-loss estimates for use in dam safety risk assessments (Mudavanhu, 2015). The life loss estimation model with simulation modeling utilized readily available GIS information on population and structures from Census data deriving 2km length, 500m on both riversides' inundation extent, and 3000 population loss estimates (Mudavanhu, 2015). The USU model reveals a narrow understanding of flood repercussions by clinging to population loss and ignoring other elements at risk. Considerations should be attached to other land use at risk depending on the nature of the dam and multiple land use downstream. Estimating areas vulnerable to flooding is based on the principle of categorizing the region on the degree of hazard (flood free zone, low, moderate, high and very high). This procedure is possible in a GIS environment where thematic maps are processed for every parameter. The linear combination of the thematic maps and the selection of the weights yield the map of hazardous areas (Aronica & Thieken, 2009). For the estimation of the flood-hazard areas in the six thematic-layer factors (variables) were created using a GIS Arc Map environment that is the slope, flow accumulation, elevation, land use, rainfall intensity, and geology while mapping flood vulnerable areas in the river basin of Koiliaris (Thompson et al., 1997). All of these variables were geo-referenced to the Greek Coordinate System EGSA'87. The produced raster maps were 20 ×20 m, 400 m 2 raster unit where five different hazard classes were identified based on the Jenk's Natural Breaks method that allows one to determine these classes statistically by finding the adjacent feature pairs between which there is a relatively large difference in data value (Chereni et al., 2020).

Hybrid models based on recent artificial intelligence technology like the algorithm-based artificial neural network (ANN-GA) and the adaptive-network-based fuzzy inference system (ANFIS) were employed for flood forecasting in a channel reach of the Yangtze River in China (Cobbinah & Addaney, 2021). An empirical linear regression model was used as the benchmark for comparison of their performances that is water levels at a downstream station forecasted by using known water levels at the upstream station (Luino et al., 2009). LISFLOOD-FP was developed based on a raster inundation model to take advantage of high-resolution topographical data sets (Cobbinah & Addaney, 2021). The model solves the 2D shallow water (also known as Saint Venant or depth-averaged) equations of free surface flow, and from this, the findings revealed flood extents for 1998 and 2000 for Severn River in the U.K simulated (Lyu et al., 2019).

The Hydrologic Engineering Center-River Analysis System (HEC-RAS) model provides information on dam floods. The operation involves obtaining open channel flow, the cross-sectional area of the flow, the wetted perimeter, the hydraulic radius, the Manning's roughness value and the friction slope (Ran et al., 2021). For the case of Severn dam in the U.K, HEC-RAS and HEC-Geo RAS models were used. The simulation results revealed the intensities of flood coverage from the river and critical facilities like roads and housing as elements exposed to the hazard (Dutta et al., 2006). Moreover, earth dam failures are extremely disastrous, killing multiple lives and destroying property (Umaru et al., 2010). The extent of evident losses to these dam’s ranges from complete failures resulting from property losses to relatively minor deterioration that may or may not call for remedial work (Yang et al., 2018). A distorted physical model based on Ürkmez Dam in Izmir, Turkey, was built to study sudden partial dam-break flows (Ge et al., 2019). The distorted model had a horizontal scale of 1=150 and a vertical scale of 1=30, containing dam reservoir, dam body, and downstream area from dam body to Ürkme.

2.3 Flood damage and loss estimation

Flood damage refers to all the multiplicities of harm caused by flooding that includes detrimental effects on people, their health, and properties; on public and private infrastructure, ecological systems, cultural heritage, and economic activities (Dutta et al., 2006). Flood reimbursements have amplified overtime time, and risk to floods remain to upsurge as a result of increasing urbanization in flood-prone areas, lack of integration between land-use planning and flood risk management, and storm water infrastructure unable to deal with intensified runoff loads (Pistrika et al., 2014). Globally, immense flood damage to buildings is characteristically analyzed using stage damage functions (McBean et al., 1986; Smith, 1994; Dutta et al., 2001; Meyer and Messner, 2005; Messner et al., 2007). This methodology is suitable by using flood stage height (water depth), either as percentage damage or loss to building structure and contents. Considerable uncertainty is inherent in stage–damage functions. For example, data for both actual direct structural and content damages for residential buildings from the 1986 flood in Sydney, Australia, show considerable scatter (Smith, 1994). Luino et al., (2009) developed a flood damage estimation model utilized by land insurance companies in managing flood-related damage data. Potential loss assessment implies knowledge of the event, exposed asset values, and the degree of damage. Following a widely shared simplifying assumption, the flood water level was the only factor indicating event magnitude. Ogie et al., (2020) considered the worth of economic losses connected to direct damages to goods being dependent on the number and the value of the units of each element in the area and the degree of damage to the exposed units (varying from 0=undamaged to 1=completely destroyed). The central idea in the traditional approach for direct flood damage and loss estimation in monetary terms is depth-damage functions or loss functions which relate flood depth with the extent of damage that usually is the maximum possible damage in the flood-prone area (Pistrika et al., 2014). The damage-depth methodological function encompasses water depth as the only conditioning factor for direct damage assessment. The estimation of direct damages to the built environment involves two related steps that are; the analysis of structural damage caused by the flood effects to determine flood actions over the building resistance, and valuation of the physical damages by costing to convert structural damage to economic estimates, insight in the building's pre-disaster market value and, the replacement cost required. Estimation of flood loss is complex for all areas of flood risk management (Luino et al., 2009). For loss estimations, the determinant is the comparison and multiplications of central values with potential damage classes. These can be empirical curves founded on damages from a historical flood or flood events in a specific site and signify damage from that event. Unlike synthetic functions based on one or two parameters, for example, water depth, duration, and warning time (Penning-Rowsell and Chatterton, 1977; Parker et al., 1987), empirical stage–damage functions will include the influence of many physical factors on buildings (notably velocity, water depth, sedimentation, contamination, debris load, duration of inundation and warning time). The damage value obtained from historical data is required to estimate damage for subsequent flood as well as losses. However, attaining loss data is a dare shared for most dam flood modelers and evaluators. Multiple parameters contribute to flood damages that is to say water depth (Wijayanti et al., 2017), inundation period (Guha-Sapir et al., 2011) and contamination, debris load (Dutta et al., 2006). Building construction and material type, warning time, and previous experience with flooding also influence flood damages (Smith, 1994).

2.4 Flood mitigation, planning and management measures

Flood mitigation is defined as sustained, organized, and well-directed actions taken and implemented to reduce or eliminate the long-term risks to people and property from flood hazards (Heidari, 2009). Flood mitigation and management purposes ensure dam flood safety, minimize downstream floods, and maintain the operational capacity of reservoirs once a flood is over (Veeravalli, 2020). The flood management and mitigation strategies aim at minimizing the likelihood and enormousness of flooding and complement flood defenses (Ogie et al., 2020). However, the time frame for decision-making is usually short, information available is generally sparse, and the predictability of the meteorological situation is limited (Arshad et al., 2019).

Dam flood mitigation is a tactic process that is growing in importance worldwide corresponding to the increasing emphasis on the desire to learn, adapt and live with floods and create sufficient space for the water (Veeravalli, 2020). The flood management strategy includes pre-flood measures, flood forecasting, and post-flood measures (Yang et al., 2018). Pre-flood measures provide the natural, institutional and social infrastructure for the viable management of flood risk and strategies for preventive flood management for notably technical measures to control and manage the flood (small dams and projects on the retention and stabilization of river banks); planning of settlements; and economic measures for the regulation, promotion, and communication (Bubeck et al., 2012). Most importantly, to institute a sustainable flood management program, a complete strategy for disaster management is essential to effectively lessen the impact of natural disasters (Billa et al., 2006). It is commonly known as "the disaster management cycle" composed of two phases; before flood occurrence (prevention and preparedness) and after flood occurrence like relief, rehabilitation, and reconstruction (Billa et al., 2006). Pre-flood mitigation and planning are possible through regulation and flood plain maintenance of river channels, ditches, and streams as the perfect preventive measures to minimize waste dumping through building and construction regulations (Mabuku et al., 2019). A flood-preparedness plan is a series of activities, including emergency response planning and training, raising public awareness, flood forecasting, warning, setting development policy, land use regulation, flood proofing, alternative plans, and local social structure strengthening (Ogie et al., 2020).

Similarly, during the disaster prevention phase, GIS is used to manage the large volume of data needed for the hazard and risk assessment, planning of evacuation routes, for the design of centers for emergency operations, and integration of satellite data with other relevant data of disaster warning systems (Billa et al., 2006). In the disaster relief phase, GIS is extremely useful in combination with GPS in search and rescue operations in areas that have been devastated and where it is difficult to orientate. In the rehabilitation phase, GIS is used to organize the property damage, post-disaster census information, and evaluation of sites for reconstruction (Arshad et al., 2019). Flood forecasting and Warning System (FFWS) includes; planning a network of telemetric stations for recording rainfall, meteorological parameters, and river flow (Kourtis et al., 2021). This system can also provide a direct warning system for developing an evacuation plan (Azmeri & Isa, 2018). A well-designed FFWS needs a hydro-meteorological data acquisition and transmission system that allows the real-time storage of rainfall, water level, and discharge data at a central dam station (Linortner, 2021). Threat recognition based only on the observed water-level data cannot be considered adequate for flood warning purposes in watersheds characterized by short hydrological response time (Linortner, 2021). Therefore, the FFWS must include a forecast modeling system capable of predicting flows and stages from the measurements provided by the hydro-meteorological data acquisition and transmission system along with the physiographic features of the watershed (Arshad et al., 2019). Apart from pre-flood measures, it is essential to have a satisfactory flood warning system. The first milestone is the beginning of the precipitation that causes the dam flood, while the last is the exceedance of a water level threshold at which property damage, injuries, or loss of life occur (Arshad et al., 2019). The time between the beginning of precipitation and the threshold exceedance is the maximum potential warning time. During the response-warning time, actions such as data collection, evaluation, notification, and decision-making are vital (Owen et al., 2020). In addition, it conducts construction and maintenance of embankments, floodwalls, regulators, pumping stations and providing good forecasting and warning through the Flood Forecasting and Warning Center (D. S. Parihar et al., 2022). Moreover, studies reveal the relevance of residential consultation and public perception in determining opinions for designing a flood management plan (Azmeri & Isa, 2018). These involved close interaction with the community residents, officials and direct the local community advisory committee. Therefore, it is critical to recognize the opinions within the most possible disciplinary and professional framework (Veeravalli, 2020). Furthermore, during the mitigation time, efforts are made to prevent hazards from developing into flood disasters or to reduce the effects of the flood post-flood measures promote the fast re-establishment of the affected regions through measures of alleviation, re-establishment of the damaged infrastructure, and the revision of the effectiveness of the flood-prevention system (Kourtis et al., 2021). Therefore, local authorities that have adopted a program of readiness and a plan for mitigating the consequences can respond much more effectively in the case of a flood (Bubeck et al., 2012). Recently, the Hazards US Multi-Hazard (HAZUS MH) flood model, a natural hazards loss-estimation software, was developed to quantify the human, property, financial and social impacts of flooding under existing conditions and given possible mitigation measures like relocation, land-use planning, structural modifications and warning (Azmeri & Isa, 2018).

Narrowing down to Uganda, it is clear that the accomplishment of early warning depends on a multi-sectorial and interdisciplinary response and evaluation. However, the link between the community-based approach, national and global early warning systems is relatively weak due to inadequate early warning leading to untold losses, yet having an integrated system that captures the risk knowledge, monitoring, evaluation services, dissemination, and communication response capability will support making the early warning information. The majority of the people affected either did not receive the early warning information or received it too late to implement a positive response (Ogie et al., 2020).

2.5 Study gaps identified in the Literature

Flood mapping and prediction has been done in consideration to flood characteristics. The mostly considered parameters during flood mapping are water surface extents and depth (Pistrika et al., 2014). Therefore, the possible inundation velocity was considered for this study in flood mapping as well as a basis for damage and loss estimation. Analysis of possible dam failure inundation damage and loss estimation using both extent and depth has been studied widely. In this study efforts were made to consider flood velocity during inundation mapping. In addition, most of the studies do assess only one scenario at ago, this study assessed flood events for three scenarios namely possible flood extent without the dam, with fully functioning dam and with a broken dam. Multiplicity of studies consider general flood extent as a single zone while some classify the flood extent to five zones, yet over classification does not allow effective risk and vulnerability analysis (Sonwa et al., 2012). Therefore, there was need to reclassify the flood to three zones to allow accurate damage and loss assessments.

CHAPTER THREE: METHODOLOGY

3.0 Introduction

This chapter entails a description of background information on the study area and the methods that were used in data collection, sampling techniques as well as analysis including the study design and strategy.

3.1 Description of the study area

3.1.1 Location

The study was conducted in Kabuyanda floodplain, Isingiro district in South Western Uganda in Ankole sub-region at 00°50′S 30°50′E, covering a total land area of approximately 3,010 km^2, altitude is about 1800 m above sea level (Figure 3.4). Isingiro District is bordered by Kiruhura in the North, Rakai in the East, Tanzania in the South, Ntungamo in the West, and Mbarara District in the Northwest. It falls within the broad zone known as Uganda's "cattle Corridor" which stretches from the South West to the North East of Uganda.

The area is dominated by pastoral rangelands and resource variability. This project will affect three Sub-Counties of Kabuyanda, Kikagate, and Kabuyanda Town Council (Figure 3.4). Within Ntungamo District, only Rukoni East Sub County will be affected (Plan et al., 2019). The irrigation area served by the dam has an area of 3,663 Ha (90 Km^2) and extends southwards the dam at the sides of River Mishumba.

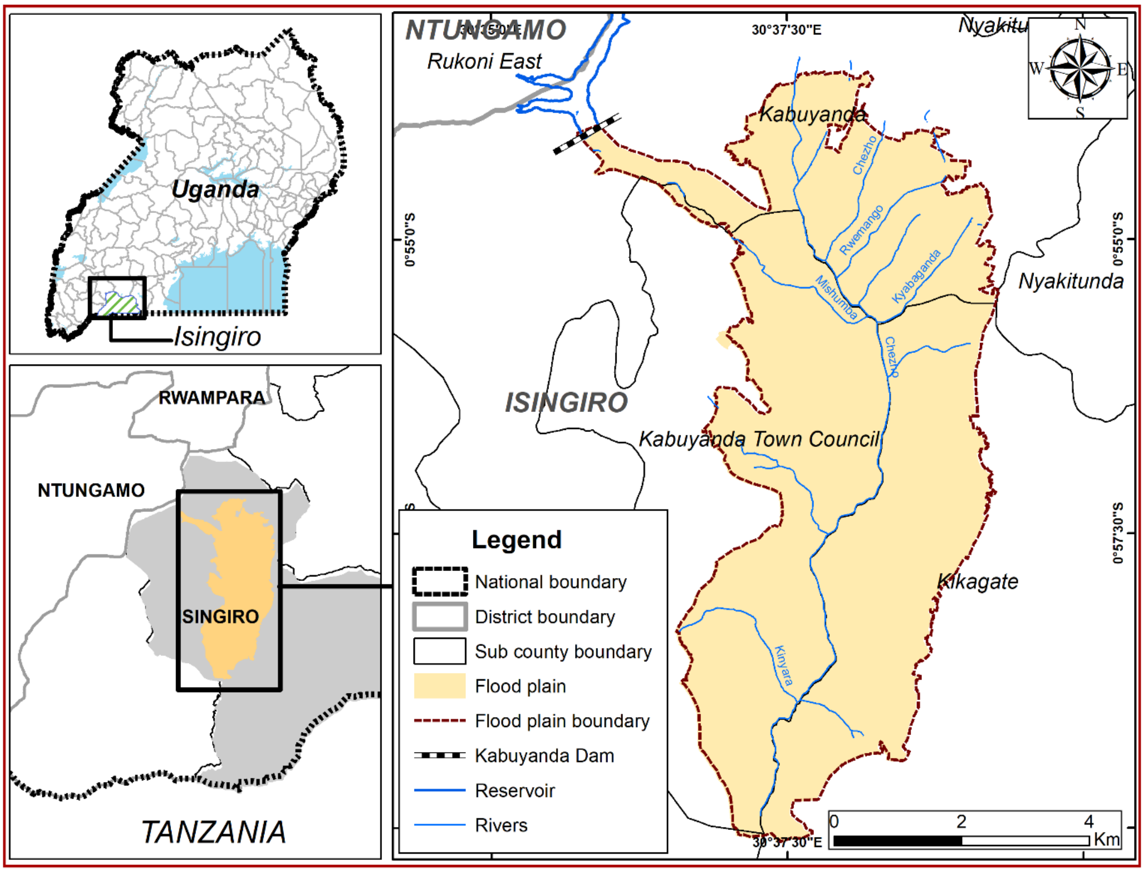


Figure 3. 1: Location of the study Area

3.1.2 Description of Kabuyanda Earth Dam

Kabuyanda Dam site is located approximately 5 km North-West of Kabuyanda Town, the coordinates of the dam site are (UTM, WGS84): E 233’602; N 9’899’313. The dam site is on the seasonal Mishumba River, a tributary of the Kagera River which drains part of the Rwoho Central Forest Reserve and later joins the Kagera River along the Uganda-Tanzania border (Figure 3.1). The dam is to drain an area of about 90 Km^2.The irrigation area to be served by the dam has about 3,663 ha, and extends southwards from the dam bordering the banks of the Mishumba River (Figure 3.1). The area suffers from low access to water and electricity, with occasional border conflicts arising when pastoralists cross into Tanzania, and vice versa, in search of water and pasture during the dry seasons. The dam attributes include a 25m high and reservoir with a storage capacity of approximately 8.8 million cubic meters to provide water for irrigation, Flow regulation for drought and flood control functions; and Restoration of degraded upstream sub-catchments. In the detailed design, the main geometrical characteristics of Kabuyanda earth fill dam are: Max dam height from foundation: 33.80m, Max dam height from the river bed: 26.45m, Max crest length (length of dam): 314m, Base width (upstream to downstream toe): 160m, Upstream slope: 2.25:1+2.5:1+2.5:1(h/v), Downstream slope: 2.25:1+2.5:1(h/v) and Top width of Dam: 9m (MoWE, 2019)

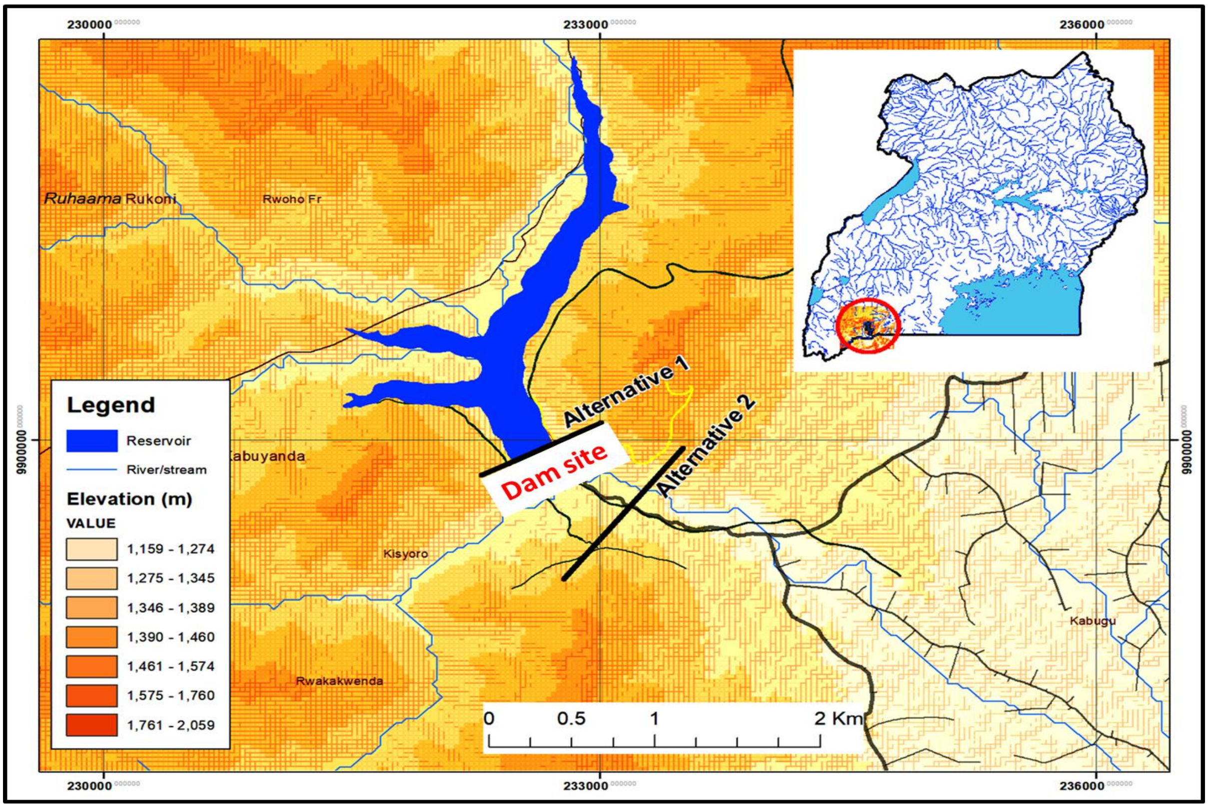


Figure 3. 2: Location of Kabuyanda Dam

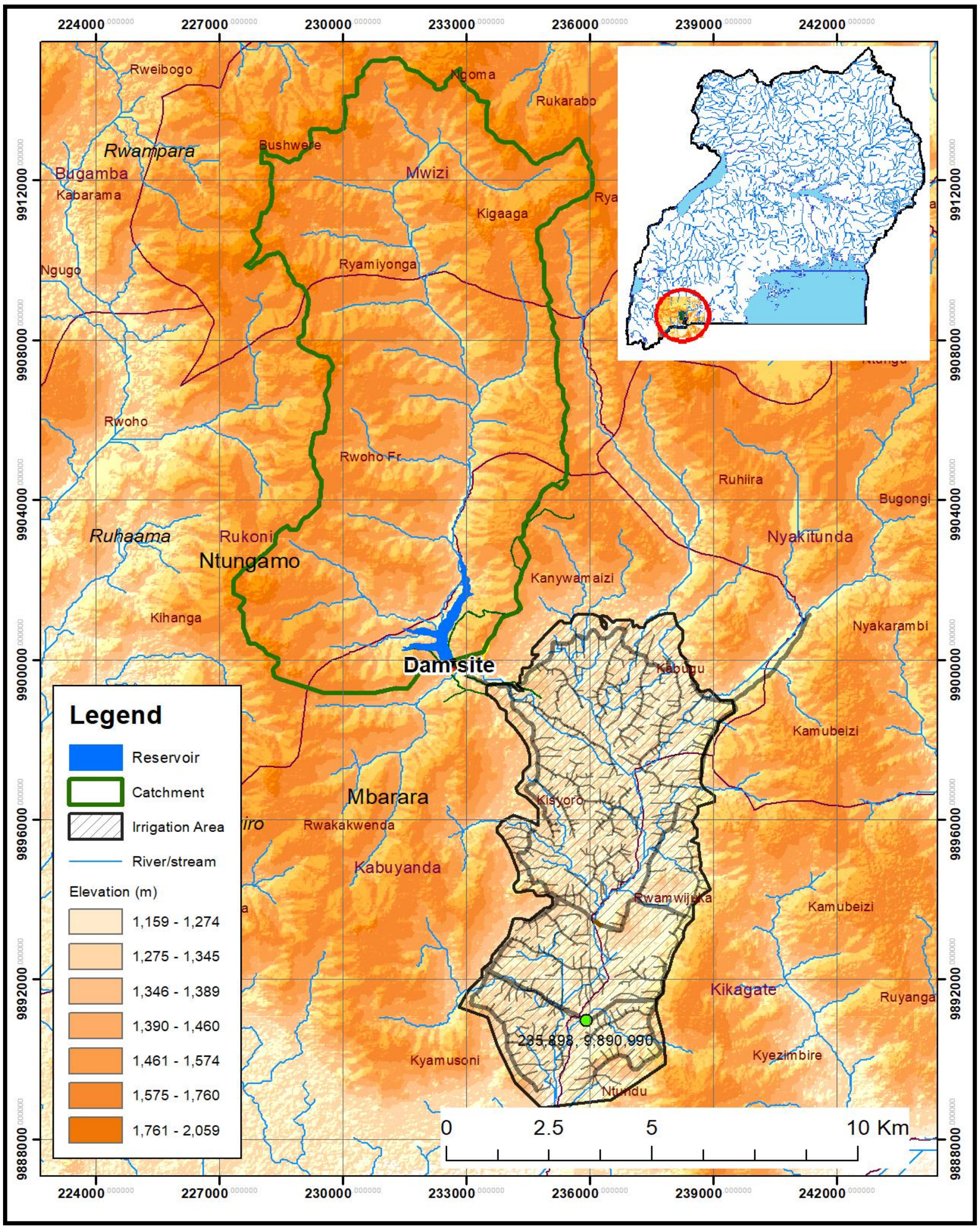


Figure 3. 3: Location of Kabuyanda Dam catchment area

3.1.3 Elevation

Isingiro District is located in the Western plateau surface of Uganda characterized with steep hills, deep valleys, gently sloping hills and flat plains and lies between altitudes of 1200m-1,800m above sea level (Figure 3.4). Areas west of the district around Nyakitunda, Nyamuyanja, Ngarama, Kabingo and Kabuyanda hills having the highest altitudes up to 1,800m towards Mbarara and Ntungamo district border whereas the low altitudes are along areas east of the district around Endiizi, Rushasha sub-counties bordering with Rakai district (NECOC, 2017). The entire flood plain lies at a low altitude of less than 1,200m above sea level (Figure 3.4).

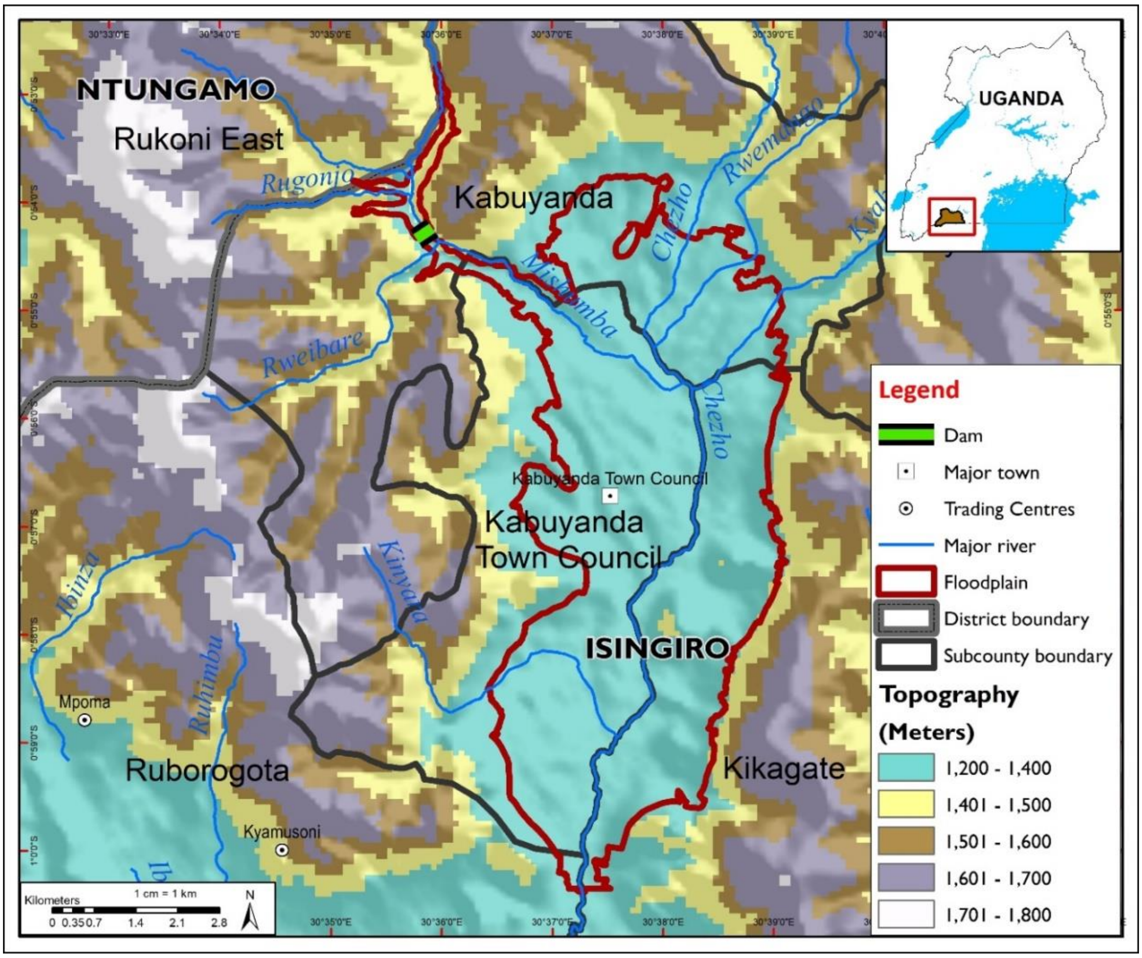


Figure 3. 4: Elevation of Kabuyanda flood plain

3.1.4 Geology

From the geological mapping undertaken by the Geological Surveys and mines (2012), the areas west of the district (around Nyakitunda, Nyamuyanja, Kabuyanda sub counties) are dominated by mudstone, shale and phyllites with oncolite and stromatolite rock patches. Lower areas occupied by Lake Nakivale catchment system are predominantly papyrus swamp with flood plain mud. Mid areas of the district especially the Ngarama hills are dominated by quartzitic sandstones and laterites. Areas further East towards the border with Rakai district and National border with Tanzania are occupied by mica schist with quartzitic interbeds especially in Endiizi sub-county. Some patches of Alluvium lacustrine deposits form the Masha areas especially along the Rwizi River catchment system (MEMD, 2019).

3.1.5 Climate

Isingiro District lies 0.6^0 south of the equator hence the region experiences generally hot and humid climate with average monthly temperatures varying between 27°C- 31°C. The temperature maximum is consistently above 30°C and sometimes reaches 38°C (Cobbinah & Addaney, 2021). Average minimum temperatures are relatively consistent and vary between 16°C and 18°C in the hilly areas of Nyakitunda, Nyamuyanja, Ngarama, Kabingo and Kabuyanda sub-counties. The relative humidity is higher during rain seasons with maximum levels prevalent in May whilst the lowest humidity levels occur in dry seasons with minimum levels occurring in December and January. The average monthly humidity is between 60% and 80% with rainfall totals averaging 1,063mm per year with two seasons namely March to May and August to December. This means that the rest of the months receive little or no rain at all (NEMA, 2018). This implies that some areas experience dry spells especially Masha sub-county and Kikagati while some parts of Bukanga are sometimes unfortunate as they are hit by hail storms especially at the beginning of the September to November wet rainy season. The warmest month of the year is often July and August and the lowest average temperatures in the year occur in June (Ogie et al., 2020).

3.1.6 Drainage

Isingiro District lies in the Lake Victoria basin sharing both River Kagera and River Rwizi catchments. Besides, numerous permanent and seasonal rivers pour into River Kagera including Kitezo, Muhurubuki and Oruchinga. Lake Nakivale occupies the northern flat areas of the district being shared by five sub-counties which include Kabingo, Isingiro Town council, Ngarama, Kashumba and Rugaaga (Ocheng, 2019). These major rivers (River Kagera and River Rwizi) and Lake Nakivale are supplied by a network of numerous secondary rivers as well as seasonal rivers that provide momentous amounts of surface water to supplement the ground water resources. Generally, the mid parts of the district around Kabingo, Kabuyanda Town council, Ngarama, Kashumba and Rugaaga sub-counties are poorly drained and flood prone (MEMD, 2019). The major wetland systems include Oruchinga stretching from Ngarama to Isingiro Town council, Bigasha wetland forming border between Ngarama and Kashumba, Ikariro wetland system located south of the district in Endiizi sub-county bordering with Tanzania, and the greater Rwizi River- Lake Nakivale wetland system that forms Lake Nakivale Ramser site (MEMD, 2019).

3.1.7 Population and Ethnicity

Isingiro district has a total population of 492,116 with the biggest percentage as rural residents (89%) and the remaining percentage are urban residents (11%), 48% and 52% are male and female respectively. About 99% form the household population and only 1% (3,789) is Non-household (UBOS, 2017). Kashumba sub-county consists of the largest population with Nakivale refugee settlement alone with 57,168 and the rest of the sub-county having 21,883. On the other hand, Kaberebere Town council had the least population (6785). In terms of ethnicity; the area is dominated by Bantu Tribes; Banyankole, Bakiga, Banyarwanda and patches of Tanzanian Nationals (MEMD, 2019).

3.1.8 Vegetation

Isingiro is endowed with protected areas that is Rwoho and Kyahi central forest reserves in Kabuyanda sub-county (Isingiro district) and Masha sub-county (Ntungamo) as well as thorny bushes and rangelands, grassland savannah dominated by acacia trees (NEMA, 2018). The district has two forest reserves under NFA and one natural forest which is privately owned. The district embarked on an afforestation plan. In the financial year 2007/08, 119,965 trees were planted and as such, 120 Hectares land were afforested by 2010 (Ocheng, 2019).

3.1.9 Economic activities

Agriculture is the backbone of Isingiro District. Approximately 90% of the households are engaged in subsistence agriculture and the major crops include banana, sweet, potatoes, bananas, maize, cassava, sweet, Irish potatoes, beans, and vegetables. A considerable number of the population is involved in livestock production especially rearing cattle and goats. Mining is also done mainly quarrying to obtain aggregate and stones for the construction industry. Mining of economic mineral ores such as cassiterite is also carried out in Mwerasandu and Kikagati (Ocheng, 2019). Besides, those who generate income from trading regularly sell crops like beans, maize, sorghum, bananas, and coffee. Majority of the household heads in the area earn less than UGX 100,000 per month. The most common assets owned by households in the project area include land, house, radio, domestic animals, cell phone and bicycle while other assets owned include solar panels, motorcycles and television sets (MoWE, 2020).

3.2 Research Design

The study adopted a cross-sectional design where data was collected from the field during a single field as well as hydraulic flood modelling and mapping using digital interpretation with the help of HEC-RAS and GIS. Qualitative and quantitative approaches were employed during data collection. Quantitative data was collected and quantified to estimate the possible damages and losses. Qualitative data was obtained through key informant interviews with the District disaster preparedness officer, District environment officer, IDCRP supervisor, GISO, Health Official, Town council chairperson, Town council disaster response chairperson, Chief police officer, District planning officer and District Natural Resources officer

3.2.1 Sample Design

The study was restricted to three sub counties notably Kabuyanda, Kikagati and Kabuyanda town council. The study areas were purposively selected based on the fact that they are located within R. Mishumba flood plain. The dam project will affect these three Sub-Counties of Isingiro though a small section of Rukoni East sub-county in Ntungamo district will be affected. In addition, results from the Participatory assessment show that floods occur in this area during rainy seasons every year and the most affected sub-counties included areas around Rugaaga, Kashumba, Isingiro TC, Oruchinga wetland system in Kajaho trading centre in Kikagate sub-county Isingiro TC, Kabuyanda, and Kabingo sub-counties (DMRVPI, 2017). Ten key informants were purposively selected for interviews which included the District disaster preparedness officer, District environment officer, IDCRP supervisor, GISO, Health Official, Town council chairperson, Town council disaster response chairperson, Chief police officer, District planning officer and District Natural Resources officer. The selection of key informants was based on technical expertise and knowledge on disaster management which was central to this study.

3.2.2 Data collection

The research investigation involved collection of both primary and secondary data. Primary data was collected through field mapping of elements at risk and key informant discussions while Secondary data was in form of remote sensing data thrrough developing inundation extent maps.

3.3 Determination of the spatial areal extent of Kabuyanda floodplain due to earth dam failure

The flood hazard extent was determined through modeling and simulation with the help of HEC-RAS and HEC-Geo-RAS.

3.3.1 Flood Hazard extent maps for the three scenarios

The technique employed for flood hazard mapping was digital interpretation using HEC-RAS and GIS to conduct hydraulic modeling and flood mapping. Therefore, the flood extent was determined using hydrological models notably HEC-RAS and HEC-Geo-RAS downloaded from the U.S Army Corps of Engineers Portal (https://www.hec.usace.army.mil/software/hec-ras/). HEC-RAS was used in flood plain determination and to assume and simulate steady gradually varied flow scenario, HEC-Geo-RAS was used to process geometric data for import into HEC-RAS and to process simulation results exported from HEC-RAS.

3.3.2 Model Data inputs

The major inputs to the model for flood mapping were rainfall data, Digital elevation model, River Geometries as well as dam design dynamics especially reservoir water capacity, Probable Maximum Flood, dam dimensions and fetch attributes which are explained below.

3.3.2.1 Digital Elevation Model

The Shutter Radar Elevation Mission (SRTM) Digital elevation model (DEM) for Isingiro district was the main source for topographic characteristics in determining water passages, directions and levels in case of dam failure (Figure 3.5). The SRTM DEM 30m was downloaded from USGS website; http://glovis.usgs.gov/web-link) in its innate format and later re-projected to a UTM 36S coordinate system, converted to contours and later used as input raster layer to create Triangulated irregular network (TIN) with the help of Arc GIS 10.5 spatial analysis tool (Figure 3.5). For geometry data preparation, TIN or TERRAIN is used. However, for this stydy, the TIN was used as the surface attribute because of its detailed display of various classification elevation differences to allow creation of more refined cross section data for estimation of water flow paths on the left and right overbank.

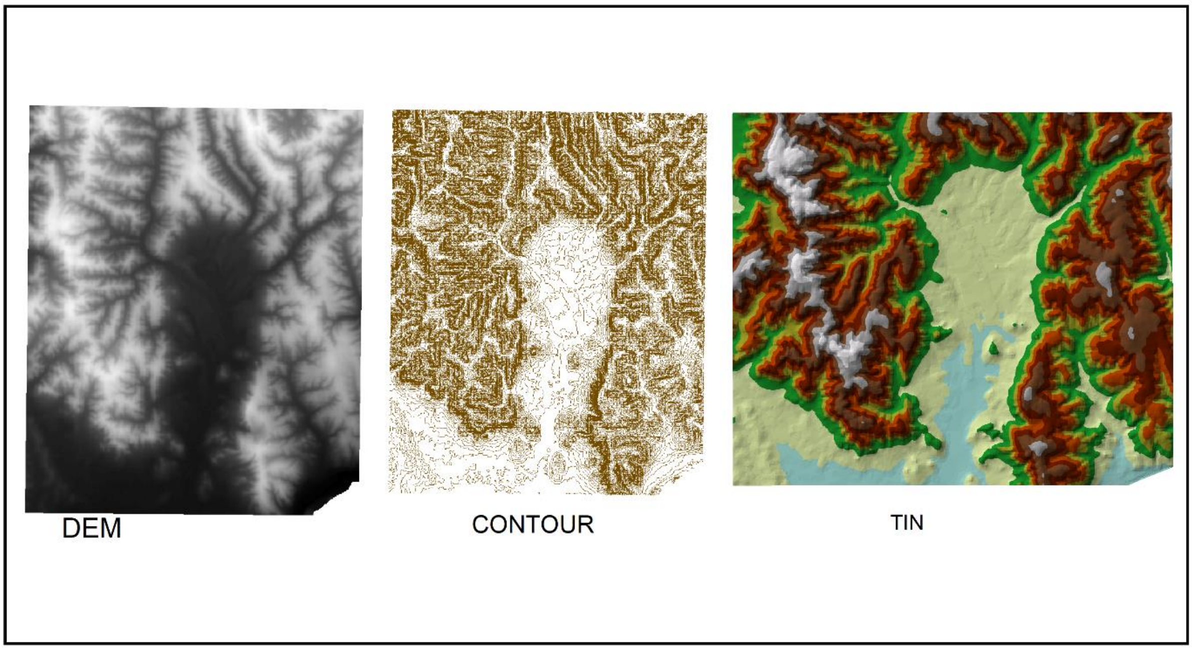


Figure 3. 5: Conversion of the DEM-Contours-TIN

3.3.2.2 Rivers

The river data sets for Uganda (2019) were obtained from Uganda energy sector GIS working group open data site developed and maintained by the Uganda energy sector GIS working group website; http://data-energy-gis.opendataarcgis.com/. The shape file was loaded in ArcGIS 10.5 and the rivers that fall within the study area were clipped out using Geo processing clipping tools in GIS environment. However, for specific accurate geometric creation, River Mishumba was digitized from high resolution images of Google earth and processed in Arc-GIS for conversion to shape file using data management conversion tool. The river dataset was used because it was freely available for download and detailed display for modeling to create geometry data through digitization for export to HEC-RAS.

3.3.2.3 Hydrological Data

Hydrological data used to simulate the flood occurrence for the three scenarios was rainfall data and Probable Maximum Precipitation (PMP). Rainfall data for 2019-2020 was obtained from NASA power climatology. This was used to simulate flood occurrence without the dam (Appendix 1) while for Kabuyanda Dam, the dam breach inflow hydrographs generated from Probable Maximum flood level (PMF) with Dam slip water level propagation parameters modeled from HEC-HMS was entered in the culvert data editor in the inline structure and used for breach analysis (fully functioning dam and broken dam), extracted from the dam design hydrological study report. Precipitation data from NASA power was preferred because of missing measured rainfall data for certain months from Isingiro district weather station especially for January, February, May, June and September for both years which was pertinent for the first scenario analysis.

3.3.2.4 Geometry Data

Geometry data required for simulation included all the characteristics of the river system and entire flood plain such as main river centerlines, banks, cross sections (XS cut lines), cross sectional plots and flow paths (Appendix III) which were used in the identification of river connectivity network, over bank area connection, extract elevation transects, and centre of mass flow respectively. Geometry data was extracted through digitizing features from the TIN as the main surface parameter using HEC-Geo-RAS extension embedded in Arc-GIS (10.5 Version). A total of 158 XS cut lines were drawn from left to right overbank across the bank line, centre line and flow paths. The prepared data was then exported to HEC-RAS for simulation (Figure 3.6). However, for the second scenario of dam extent with a fully functioning dam, the dam structure was considered an obstruction to water flow during the digitization process.

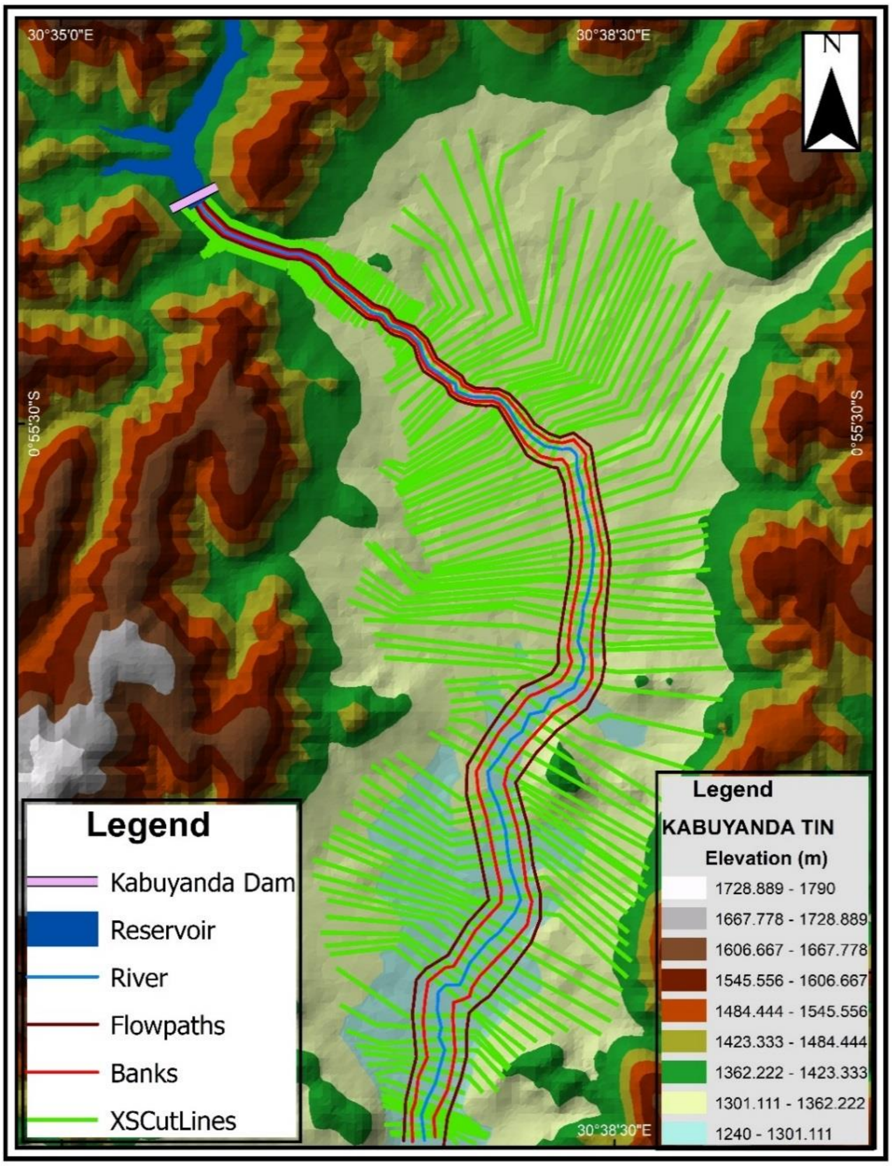


Figure 3. 6: Kabuyanda Flood plain Geo-RAS Geometry data

3.3.2.5 Dam Design dimensions

Kabuyanda proposed dam design dimensions were extracted from MoWE Dam design report (2019). Dam design characteristics that were used to perform the simulation included foundation parameters, reservoir water carrying capacity, water level hydraulic channel calculations, Effective fetch calculations, and height of the dam measured from downstream toe to the crest (Appendix IV). These were entered to the storage, inline and lateral structure data editor in HEC-RAS model. The justification for using this data is that it is accurate in estimating water behavior in the reservoir and its movement through the spill way.

3.3.2.6 HEC-RAS and HEC-Geo-RAS Model set up

Hydrologic Engineering Centre (HEC)-River Analysis System (RAS) was developed by the Hydrologic Engineering Centre for the U.S. Army corps of Engineers. HEC-RAS is a one-dimensional steady flow hydraulic model designed to aid hydraulic engineers in channel flow analysis and floodplain determination (Brunner, 2008). The results of the model can be applied in floodplain management and flood insurance studies. Steady flow describes conditions in which depth and velocity at a given channel location do not change with time. Gradually varied flow is characterized by minor changes in water depth and velocity from cross-section to cross-section. The primary procedure used by HEC-RAS to compute water surface profiles assumes a steady, gradually varied flow scenario, and is called the direct step method.

Therefore, to determine the flood-prone areas and extents in the flood plain for the three scenarios, Arc GIS 10.5 was used. HEC-GeoRAS was utilized to process geospatial data in ArcGIS using a graphical user interface (GUI) which prepares geometric data for export in to HEC-RAS. The digital terrain model (DTM) of River Mishumba and sub streams in Arc Info TIN format was used to create the import file. This was followed by creating a series of line themes vital for developing geometric data which included cross section cut lines, left and right channel banks, flow path centerlines and the river centerline as well as land use and storage areas (dam reservoir capacity). DEM for Kabuyanda flood plain was added as map layer and browsed to add Triangular Irregular Network (TIN) upon which slope was deduced. Four Raster layers (Stream centerline, Bank line, Flow path and Cross-section cut lines) were generated in Arc GIS by digitizing and Manning’s N values (0.1) for both left and right bank lines and (0.2) for the stream centerlines was added to represent Geometric Data for modeling in HEC-RAS, saved and exported to HEC-RAS model to create peak flow data, surface elevations and water surface profiles. The high-water surface elevations for the various flow scenarios were exported back to Arc GIS where the RAS output file was converted to compatible format (XML), imported to display the feature classes (River 2D, XS-Cut lines and Bounding Polygon) to the new data frame. Reclassification of the flood prone areas was done using elevation as the input Raster which displays old values (elevation) and new values for classification. Therefore, 1, 2 and 3 values were assigned to high, moderate and low flood intensities respectively and the output here was flood hazard extent map with different intensities.

3.3.3 Data processing and analysis

The data was processed in ArcGIS 10.5. The downloaded DEM was pre-processed using “*fill sinks*” algorithm to eliminate artifacts in the original DEM and the flood plain Geometry was processed in HEC-GeoRAS extension in ArcGIS. Besides, the original river was first automatically generated using DEM by hydrological module of ArcGIS through several calculation process of filling depression, flowing direction and flow accumulation. This was then followed by obtaining the real river from Google Earth (Landsat eye alt 2021-10 m, Elevation digitization range-1.5 Km), enlarged to the finest resolution in order to draw the center lines, modification of the original DEM with gradual elevation slope. The modified DEM was used to rebuild the river network later converted to KML files and revised for river accuracy according to the real river in Google earth manually. The simulated data on flood inundation was analyzed using geo-spatial analysis with the aid of ArcGIS 10.5 spatial analysis software with HEC-GeoRAS extension tool and HEC-RAS 5.0.7 software application as well as display of flood hydrographs from the HEC-RAS analytical tool while Result presentation vector maps were used to display the data. Qualitative data obtained from key informant interviews was analyzed using descriptive narratives and quotes.

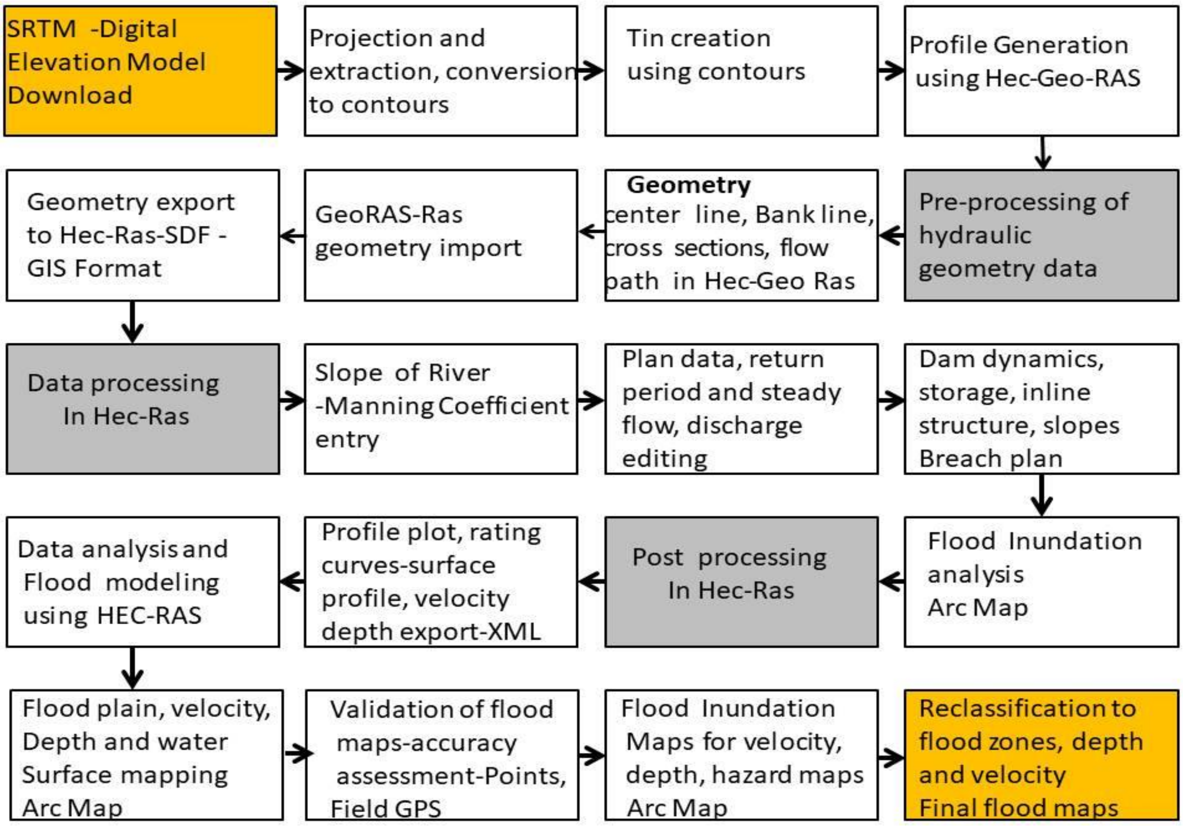


Figure 3. 7: Data processing and analysis

3.3.4 Validation of the flood maps and error checking

To validate the accuracy of flood maps, cHECK-RAS validation tool was utilized to confirm the equanimity of the input and output results from HEC-RAS. Output extents, steady flow, geometry, check flood way, profiles and plan data were used during the verification of hydraulic estimates, from which the report was generated (Table 4.3).

Selected areas where flood waters reach in the flood plain during flood events were mapped and marks of previous flood water on buildings within Mishumba valley were obtained as well and compared with the simulated depth and extent to confirm whether it matches with the percentage increase from dam inundation. In addition, the dam flood extent was exported to a high-resolution image of Google Earth (Landsat eye alt 2021-10m, Elevation digitization range-1.5 Km) and measurements were mapped at sample critical areas on the either side of the main river. TIN classes and maximum water volume were obtained and entered to cHECK-RAS for computational analysis estimates.

3.4 Assessment of the exposure status of Elements at Risk to Kabuyanda floodplain

Elements at risk is about exposure to the hazard, what is there that can be damaged or destroyed, injured or killed and hampered or interrupted (Westen, 2013). Exposure refers to the situation of people, infrastructure, housing, production capacities and other tangible human assets located in hazard-prone areas (UNISDR, 2017). The elements at risk anticipated to be affected in case of dam failure include Population, croplands, tree plantations/wood lots, critical facilities (schools, health units, water sources and police stations), Infrastructure (road network and buildings). The flood hazard map was superimposed with the elements at risk to determine their exposure status in a GIS environment.

3.4.1 Datasets

The datasets used to determine the exposure of the elements at risk included population, schools, health units, water sources and police stations. The human population dataset for 2017 was extracted from Uganda Bureau of Statistics (UBOS), schools dataset from the Ministry of Education and Sports (MoES) Schools database for 2017, health facilities dataset from the Ministry of Health (MoH) database for health facilities for 2017, water sources dataset from the Ministry of Water and Environment (MoWE) water resources database for 2017 and the police posts dataset were extracted from the Uganda Police Force database for

2017. However, recent detailed data sets for road networks, farm lands, tree plantations and houses within Kabuyanda flood plain were not available in the respective ministry data base. Therefore, roads, crop lands, tree plantations and residential houses data sets were digitized from high resolution images of Google Earth -Landsat eye, Elevation digitization range of 1.5 Km (Figure V) with the capability to identify the smallest land surface details to determine the quantities that would be lost to the flood in case of dam failure.

3.4.2 Data Analysis

The flood extent was exported to Google earth and converted to digitizable format for correction. The Google earth image was zoomed to its finest resolution to obtain smallest landscape detail to allow digitization. Post processing of the digitized datasets was undertaken with the help of ArcGIS 10.5 and HEC-GeoRAS extension tool. The obtained data with flood zone intensity classes was analyzed using quantitative techniques of Geo-Spatial analysis and computations using RAS-calculator and extraction of attribute tables to Microsoft excel and the use of descriptive statistics whilst the results on exposure were presented in vector maps and graphs inform of frequencies and percentages.

3.5 Estimation of potential damages and losses resulting from Dam failure

3.5.1 Damages

Due to scarce accurate soil data for simulating flood arrival time and duration, casualties of the population during the flood event were not considered for analysis. Similarly, only buildings, farmlands, critical facilities and road network were analyzed for the possibility of damages and losses. The methodology adopted for damage estimation presents the analytical criteria of sub division of the classes to three classes. Class/category1 was composed of elements that would be completely destroyed within the High flood intensity zone characterized by flood water levels of over 5.55m, class 2 is composed of elements at Risk that will be moderately damaged based on a state description of location in the high flood zone with flood velocity and depth ranging between 1-5m/s and 2.55-5.55 m respectively (Table 3. 2). However elements located in the moderate flood zone with flood water level and velocity below 2.55m and 1m/s are considered to experience a slight/minor damageability rate or none at all.

Table 3. 1: Damage categorization scale and classes for estimation

Class	**Damage degree/state**	**Flood Characteristics**		
		Flood Zone Intensity	**Depth (m)**	**Velocity (m/s)**
1	Completely damaged	High	Over 5.55	over 5
2	Moderately damaged	High	2.55-5.55	1-5
3	Slight/Minor/No damage	Moderate	0.00-2.55	0-1

3.5.2 Losses

The flood damage and loss average costs were parameterized to depth-damage function to element location, quality and type to derive the potential damage degree classes/categories. Therefore, the estimated unit cost value of cropland was obtained from the DMRVPI, (2015), UNVA and multiplied by the total damages of each element at risk to derive total estimated loss value whilst placement/reconstruction value were derived from the available economic data on reimbursement due to flood damage to buildings from Uganda Living Standards Surveys by UBOS (2018), and the estimated costs for constructing primary schools was extracted from MoES-department of finance data base of 2019 (Table 3.4) . These datasets were used on account that they are often used for dam disaster analysis.

3.5.2.1 Loss estimation of Residential Buildings to dam failure inundation

To estimate the monetary value of potential damage to the residential buildings, a replacement price matrix is required considering the locational differences in prices. Due to the difference in economic growth and living standard, there are differences in price among different jurisdictions. Data used for replacement costs was extracted from the Statistical Abstract of 2018 (Table 3.2). It should be noted that this replacement price matrix can be updated from time to time based on national price and consumer monitoring mechanisms.

Table 3. 2: Replacement Price Matrix for residential buildings for Western Uganda

Region	**Replacement Prices in Uganda shillings**					
	Typologies of Residential Buildings					
	Steel	Wood frame	Mud pole	Concrete	Unburnt bricks with cement	Unburnt bricks with mud
Units (moderate two bed roomed house ~10mx10m)	(sheets)	(No)	(ft)	(sqft)	(No)	(No)
Western	**3,800,000**	**220,000**	**240,000**	***10,700,000***	**5,790,000**	***570,000***

Source: Uganda Living Standards Surveys by UBOS (2018) produced in Statistical Abstracts.

3.5.2.2 Loss estimation of Crop lands

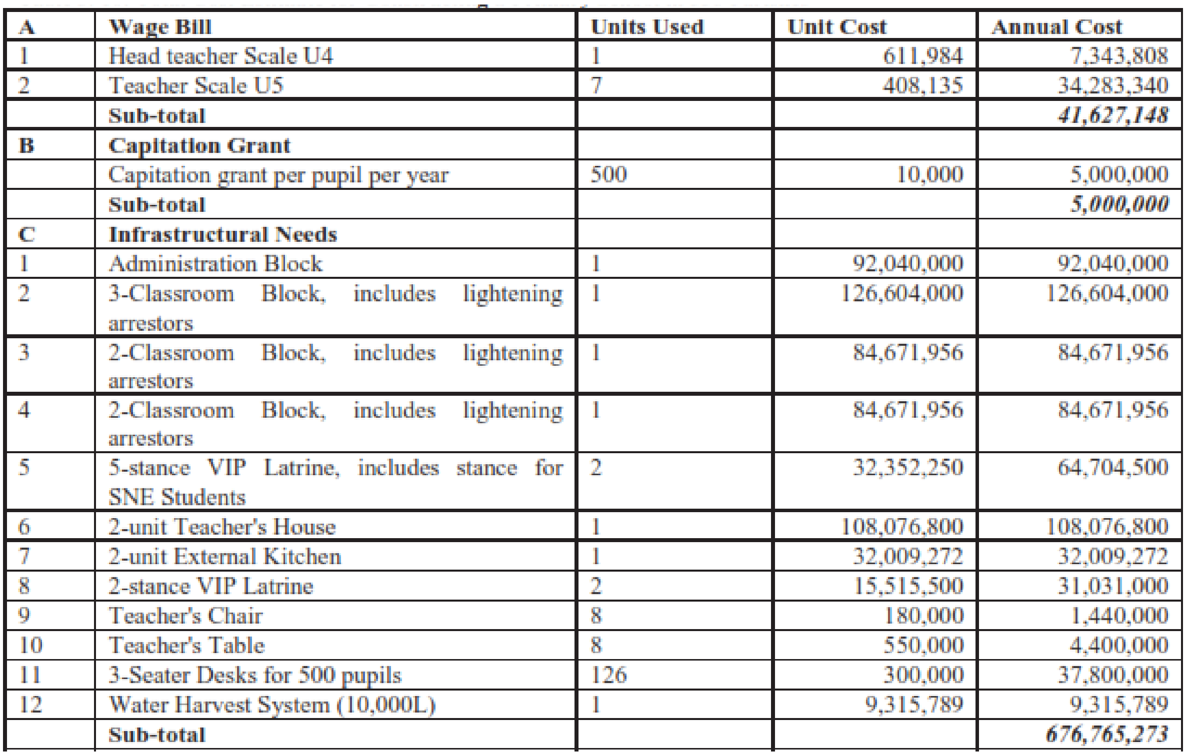
The major crops cultivated in the flood plain include banana, sweet potatoes, maize, cassava, Irish potatoes, beans, and vegetables. However, only banana plantations were considered for damage and loss analysis. The effects were examined by considering flood inundation depths for the cropped areas, Stage-damage functions quantifications and damage rate variation of flood depth. To estimate the potential losses resulting from crop damage, the regional replacement price matrix for major crops was derived using the real price from the national price recording system and multiplied by the total damage value (Table 3.3).

Table 3. 3: Replacement Price matrix of crop lands for Uganda

	Replacement costs in Uganda shillings				
Region	**Banana**	**Maize**	**Millet**	**Sorghum**	**Rice**
Western	2,000,000	2,000,000	3,000,000	2,000,000	4,000,000
Eastern	1,600,000	1,200,000	2,800,000	1,650,000	3,700,000
Northern	1,000,000	1,500,000	2,800,000	1,650,000	3,550,000
Central	1,100,000	1,650,000	3,000,000	1,750,000	3,950,000

Source: National Risk and Vulnerability atlas for Uganda (2019).

Table 3. 4: Total estimated costs for replacement and construction of new schools in Uganda



A	Wage Bill	Units Used	Unit Cost	Annual Cost
1	Head teacher Scale U4	1	611,984	7,343,808
2	Teacher Scale U5	7	408,135	34,283,340
	Sub-total			***41,627,148***
B	**Capitation Grant**			
	Capitation grant per pupil per year	500	10,000	5,000,000
	Sub-total			***5,000,000***
C	**Infrastructural Needs**			
1	Administration Block	1	92,040,000	92,040,000
2	3-Classroom Block, includes lightening arrestors	1	126,604,000	126,604,000
3	2-Classroom Block, includes lightening arrestors	1	84,671,956	84,671,956
4	2-Classroom Block, includes lightening arrestors	1	84,671,956	84,671,956
5	5-stance VIP Latrine, includes stance for SNE Students	2	32,352,250	64,704,500
6	2-unit Teacher's House	1	108,076,800	108,076,800
7	2-unit External Kitchen	1	32,009,272	32,009,272
8	2-stance VIP Latrine	2	15,515,500	31,031,000
9	Teacher's Chair	8	180,000	1,440,000
10	Teacher's Table	8	550,000	4,400,000
11	3-Seater Desks for 500 pupils	126	300,000	37,800,000
12	Water Harvest System (10,000L)	1	9,315,789	9,315,789
	Sub-total			***676,765,273***

Source: NPA computations based on MoES cost estimates (ESSP 2017/2018-2019/2020)

3.5.3 Data Analysis

The depth-damage function to elements at Risk was performed in Arc-GIS software. The superimposed elements at Risk datasets with the flood zone, depth and intensity zones were clipped out basing on the damage categorization scale and the attribute table quantifications extracted, exported and analyzed in Excel to generate the damage estimate statistics. For loss estimates, the replacement values were multiplied by the damage estimates to derive total estimated losses for the selected elements at Risk and the analysis was done in Excel and the data presented in tables and graphs.

3.6 Mitigation measures to reduce the damages and losses resulting from dam failure

Key informant interviews were conducted for the 10 purposively selected stakeholders known to be involved in the district disaster management programs, these included District disaster preparedness officer, District environment officer, IDCRP supervisor, GISO, Health Official, Town council chairperson, Town council disaster response chairperson, Chief police officer, District planning officer and District Natural Resources officer. The key informants were requested to give their opinions on the mitigation measures through providing solutions to reduce the damages and losses likely to result from potential dam failure.

Figure 3. 8: Key informant interviews held in Kabuyanda headquarters

3.6.1 Data Analysis

The responses for this section were jotted on paper and organized as word documents. The transcriptions from key informants were analyzed using NVivo qualitative data software. The data was coded and summarized to obtain the level of suggestion frequency (Figure 4. 20). The data was displayed using NVivo Word cloud. Narratives and quotes were also used to analyze data for this section.

Table 3. 5: Summary of methodology

Objective	Data and Sources	Method	Analysis
To determine the spatial areal extent of Kabuyanda floodplain in case of earth dam failure.	SRTM-DEM-USGS Geoportal: http://glovis.usgs.gov/web-link). Rivers dataset-Uganda energy sector Gis working group website; http://data-energy-gis.opendataarcgis.com/. Rainfall data-NASA Geometry data(Xs lines, stream centreline, flowpath, banklines) from Hec-GeoRas Dam design geometry from detailed dam design report, (MoWE)-Arvee Associates	-Flood hazard mapping/modeling-Hec-RAS-Steady flow hydraulic computation simulation -Geometry creation-Hec-GeoRAS	-Geo-Spatial Analysis-Hec-Ras inundation Surface flow analysis-Geo Computations Vector and Raster map display
To assess the exposure status of elements at risk to Kabuyanda floodplain.	-Population dataset-UBOS (2017) -Schools dataset - MoES 2017, -Health facilities –MoH, -Water sources- MoWE, -Police stations dataset - Uganda Police Force -Digitized datasets -roads, plantations, buildings, farmlands from Google earth	Superimposition – dataset theme overlays and masking Dataset digitization from high resolution images of Google Earth	Geo-Spatial Analysis computations Descriptive statistics
To determine the potential losses and damages of elements at risk due to earth dam failure.	Digitized datasets from Google earth (croplands, treelots, buildings, roads) Datasets from UNRA, MoES -Cost replacement average cost value-Uganda Living Standards Surveys by UBOS (2018), MoES, NRVAU	-Stage damage involving depth – velocity and zone intensity function multiplication matrix	- Descriptive statistics (frequencies and percentages)

To establish the mitigation measures that can be put in place to reduce the possible damages and losses resulting from earth dam failure?	-Key informant interview	-Interview using key informant interview guide	NVIVO qualitative data analysis, quotes and narratives.

CHAPTER FOUR: PRESENTATION OF FINDINGS

4.1 Introduction

This chapter presents analysis and interpretation of findings. The results presented are in line with specific study objectives, that is, to determine the extent of inundation in case of dam failure, map the elements at risk, estimate the possible damages, and establish mitigation measures. Flood prediction was assessed for the Kabuyanda Irrigation scheme, business as usual before the dam construction, and in case of dam failure/or failure after its completion.

4.2 Prediction of the spatial flood extent in Kabuyanda floodplain

Flood mapping assessment for Kabuyanda flood plain for three scenarios (without the dam, with a fully functioning dam and a broken dam) was conducted and the results are hereby presented.

4.2.1 Flood extent without the dam

The flood extent of Kabuyanda floodplain without the dam was assessed, and the results are thereby presented (Figure 4.1). The results reveal that 650 hectares (6.5 km^2) of land out of approximately 4040.60 hectares (40.40 km^2) of the total land area of the Kabuyanda flood plain is subject to flooding during the wet spells prior to dam construction. The highest inundation was simulated to be experienced in Kabuyanda Sub County covering 250 hectares of land which accounts for 6.1% of the total land area of Kabuyanda flood plain, followed by Kabuyanda town council with 210 hectares (5.2%) of the total land area, while Kikagate sub-county constitutes the least inundation with only 190 hectares (4.7%). Therefore, without the dam infrastructure, the floods extent covers 6.5 km^2 of the total 40.40 km^2 which accounts for 16% of the flood plain (Figure 4.1).

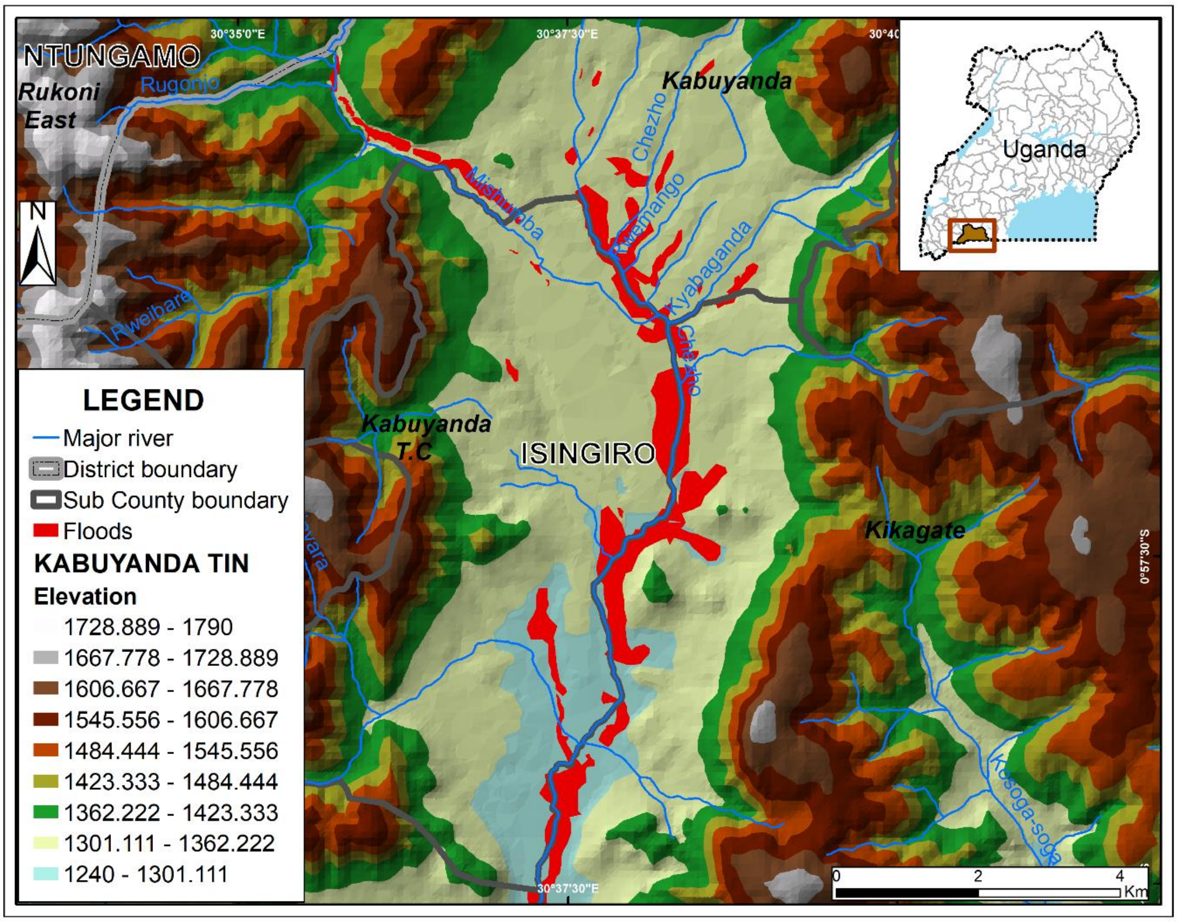


***Figure 4. 1:	Flood extent in Kabuyanda flood plain without the dam***

4.2.2 Flood extent with the fully functioning dam

Similarly, the flood extent of the Kabuyanda floodplain with the fully functioning dam was predicted (Figure 4.2), and the results revealed that 400 hectares (4.0 km^2) of land out of approximately 4040.60 hectares (40.40 km^2) of the total land area of the Kabuyanda flood plain is subject to flooding during the wet spells prior to dam construction. The highest inundation was simulated to be experienced in Kabuyanda town council covering 1.7 km^2 which accounts for 4.3% of the total land area of Kabuyanda flood plain, followed by Kabuyanda Sub County with 1.5 km^2 (3.7%) of the total land area, while Kikagate sub-county constitutes the least inundation with only 0.8 km^2 (1.9%). Therefore, with the dam in place, the flood extent will reduce to 400 hectares accounting for only 9.9% of the flood plain and thus the area subject to flooding will reduce by 6.1% (2.5 km^2).

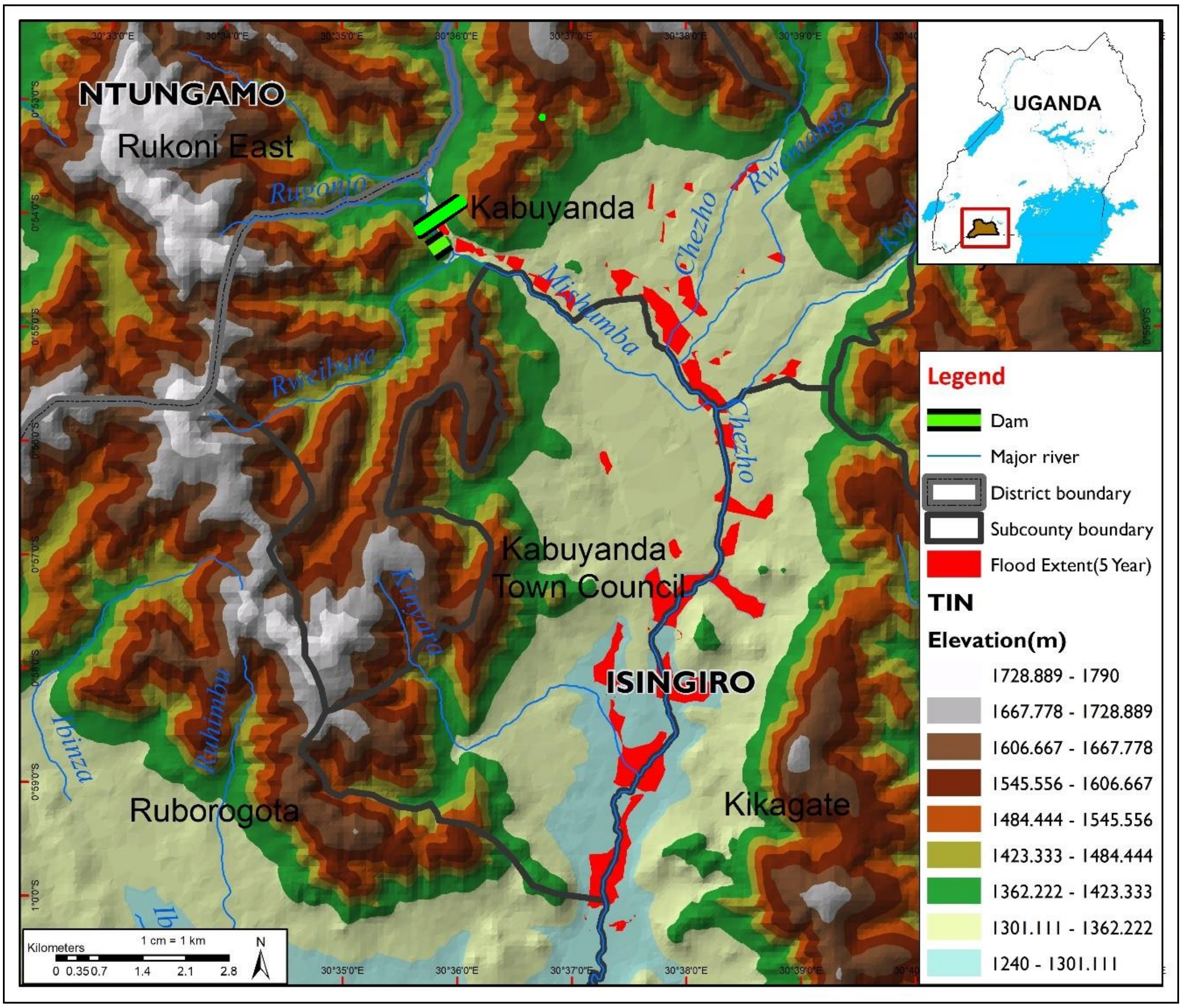


Figure 4. 2: Flood extent in Kabuyanda flood plain with the dam

4.2.3 Flood extent due to dam failure

The simulation results (Figures 4.3) revealed that in the eventuality of dam failure/failure, the spatial extent of flood water would amount to approximately 1,745.65 hectares (17.43 km^2) of land totaling 43.20% of the flood plain (4040.60 hectares). The computations showed that flooding due to dam failure would be experienced in Kabuyanda Town council covering 9.5 km^2 which accounts for 23.53% of the flood plain, followed by Kabuyanda Sub County with 4.5 km^2 of its land lost to the flood swallowing up 11.1% of the flood plain. Kikagate Sub County will experience the lowest inundation covering 8.4% of Kabuyanda flood plain with 3.42 km^2 of land inundation loss. The HEC-RAS model results in figure 4.3 show that flood severity for all the scenarios will be experienced in Kabuyanda town council owing to its elevation (between 1280-1330 m above sea level) at the flood plain, leave alone covering the largest area, a reversible fact attributed to Kabuyanda flood plain having most of its area located at a higher elevation at the vicinity of major hills.

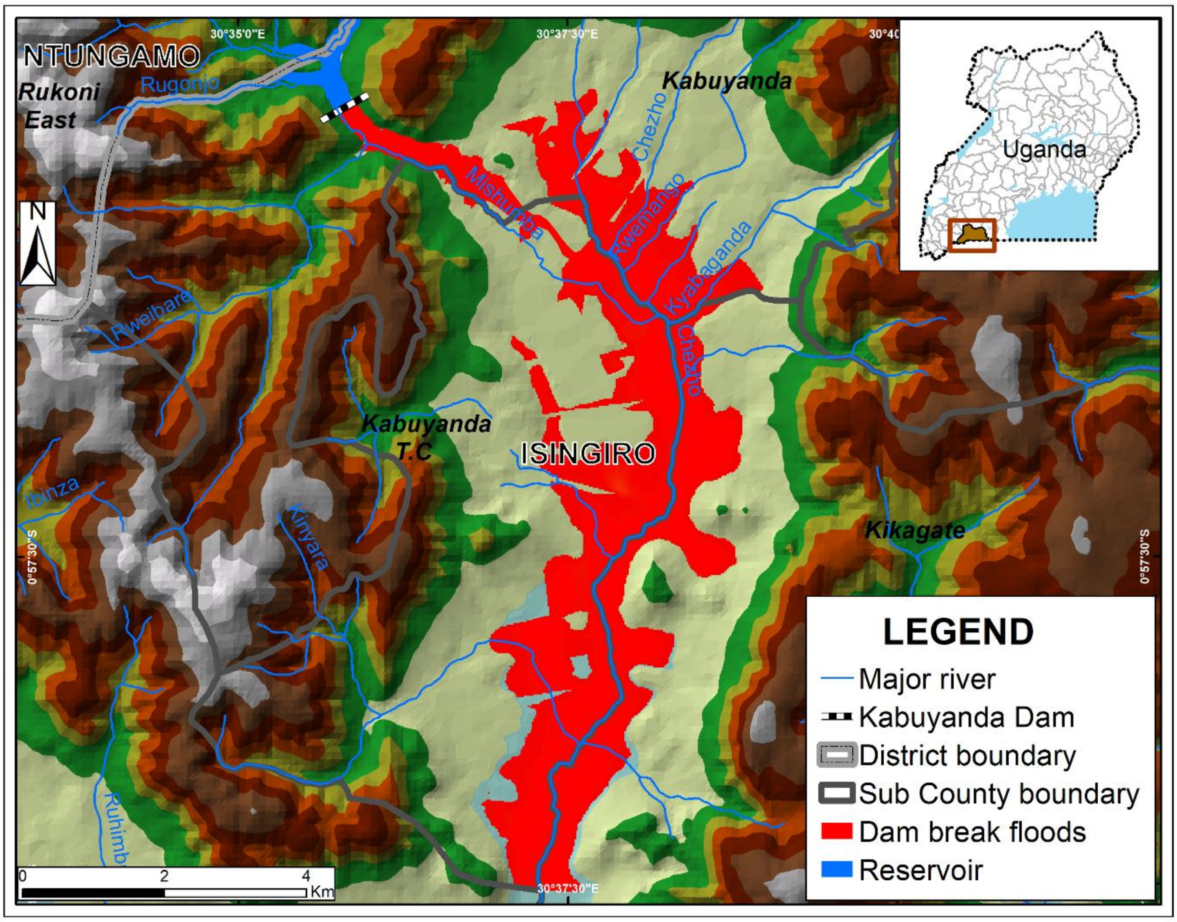


Figure 4. 3: Flood extent in Kabuyanda flood plain in case of dam failure

The results from the three flood scenarios were used as comparison parameters of increase and decrease in the land area (Table 4.1). The results revealed that the area to be flooded would slightly decrease with a fully functioning dam from 6.5 km^2 (650 hectares) to 4.00 km^2 (400 hectares). This also implies that the dam will reduce flooding in the flood plain land area by 6.1% that is from 16% flood plain (without the dam) to 9.9% land area of the flood plain (with a fully functionining dam). The comparative results also depict a great increase of land to be flooded in the eventuality of dam failure from normal rainfall and river bank flooding in the flood plain sub counties. Figure 4.2 indicates that besides normal flooding from the rivers bursting their banks, in case of dam failure, the inundated area will immensely increase by 9.0% in Kabuyanda town council equating to 2.4 km^2 of land while in Kabuyanda Sub County, the flooded area will increase by 17.4 % and the least increase of 6.5% will be experienced in Kikagate sub county. Therefore, the flooded area will greatly increase by 32.9 % in all the three sub counties.

Table 4. 1: Inundation extents in Kabuyanda Floodplain

SUB COUNTIES	SCENARIOS						Inundation Area change			
	Without Dam		**With Dam**		**Dam failure**		**Without and with dam**		**Without Dam and Dam failure**	
	Area Km^2	Area %	Area Km^2	Area %	Area Km^2	Area %	Area Km^2	Area %	Area Km^2	Area %
Kabuyanda	2.5	6.1	1.7	4.3	4.5	11.1	0.8	1.8	7	17.4
Kabuyanda TC	2.1	5.2	1.5	3.7	9.5	23.5	0.6	1.5	2.4	9
Kikagate	1.9	4.7	0.8	1.9	3.4	8.4	1.1	2.8	1.5	6.5
TOTAL	**6.5**	**16.0**	**4.0**	**9.9**	**17.4**	**43.0**	**2.5**	**6.1**	**10.9**	**32.9**

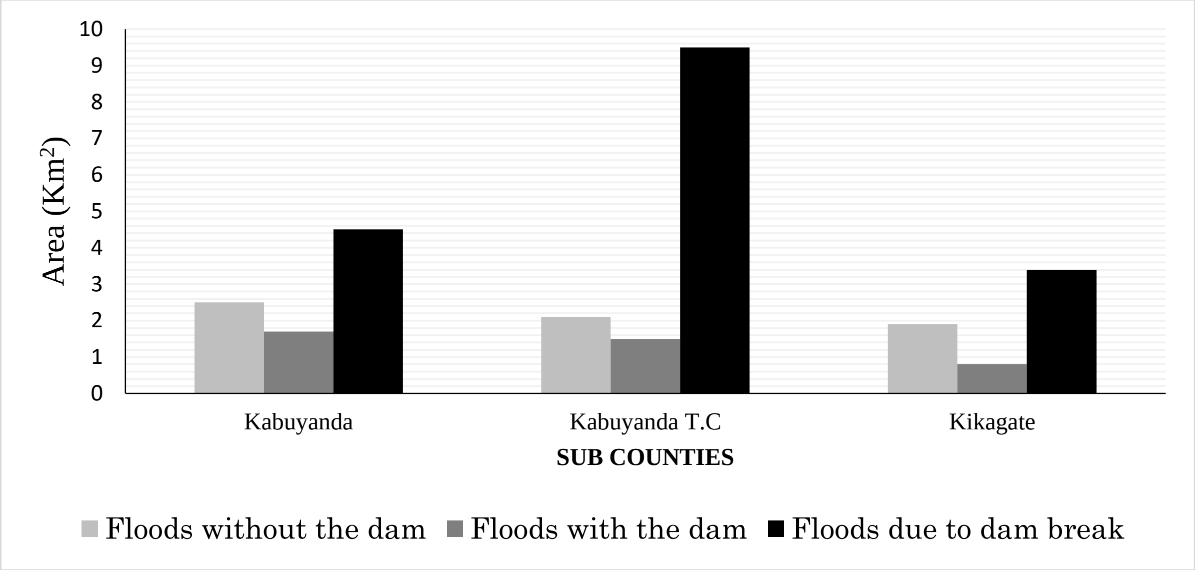


Figure 4. 4: Inundation land area due to dam failure

Further analysis and classification of the flood was carried out in Arc map software using spatial analyst tool to reclassify the flood into flood intensity zones using unique values derived from elevation differences quantified by considering the flood depth (D) and velocity (V) in combination (D×V product) divided by the delineated flood plain. Dam inundation extent was classified into three flood zones, mapped and the intensities were apportioned to different sub counties (Figure 4.3). It is clear that the distribution of the three flood zones (low, moderate and high) is determined by flow depth and velocity as well as the interaction of the flood water with the landscape (Figure 4.4). The land area at lower elevation (below 1300m above sea level) and at close proximity to the river valley was classified as a high danger intensity zone from which dam failure will most likely cause loss of human life and mass demolition of property and hence the disaster will be of a severe nature and cause overwhelming devastation. Area exposure to floods depreciates considerably outward the river channel boundary. The areas somewhat far from the river valley, owing to higher elevation places them almost outside the ferocious inundation wave fronts and therefore considered low flood free zone and the damages experienced are likely minimal restricted to few owners' property whilst the moderate flood zone acts as a transitional area from which damaged will neither be low nor high. Therefore, the severity of the flood decreased as flood water flows away from the main river valley.

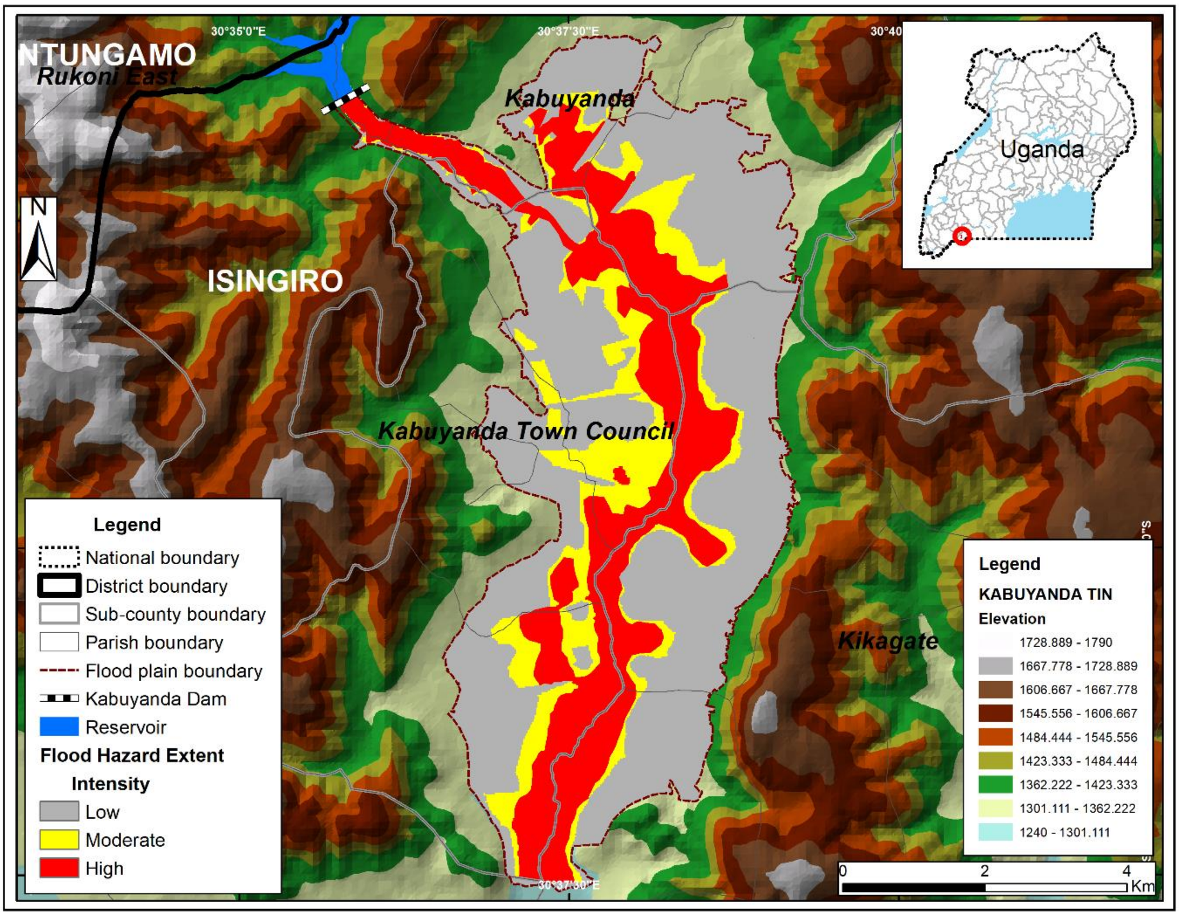


Figure 4. 5: Inundation extent zones in case of Dam failure

Out of the total land area of 1,745.65 hectares (43.20%) exposed to the dam flood, 1111.02 hectares (27.47%) of land in Kabuyanda flood plain is located in the high flood intensity zone (Table 4.5). Kabuyanda town council accounts for the largest portion of the high flood zone with 533.31 hectares (13.19%) followed by Kabuyanda sub county with 340.55 hectares (8.42%) of the flood plain while Kikagate sub county accounts for the lowest high flood zone area of 237.16 hectares representing 5.86% of the high flood zone. 15.69% (634.63 hectares) of land is situated in the moderate flood zone and of this, Kabuyanda town council accounts for 10.33 % (417.51 hectares), followed by Kabuyanda sub county with 2.76 (111.72

hectares) and Kikagate with the least area of 105.40 hectares (2.60%). The remaining 56.84% (2294.94 hectares) of the land area is located in the low flood intensity zone. The largest land area (20.52%) which is approximately 829.45 hectares in the low flood zone is located in Kikagate Sub County, followed by Kabuyanda town council with 18.82% (760.67 hectares) and Kabuyanda sub county with the least area of 704.82 (17.44%) located in the low flood zone.

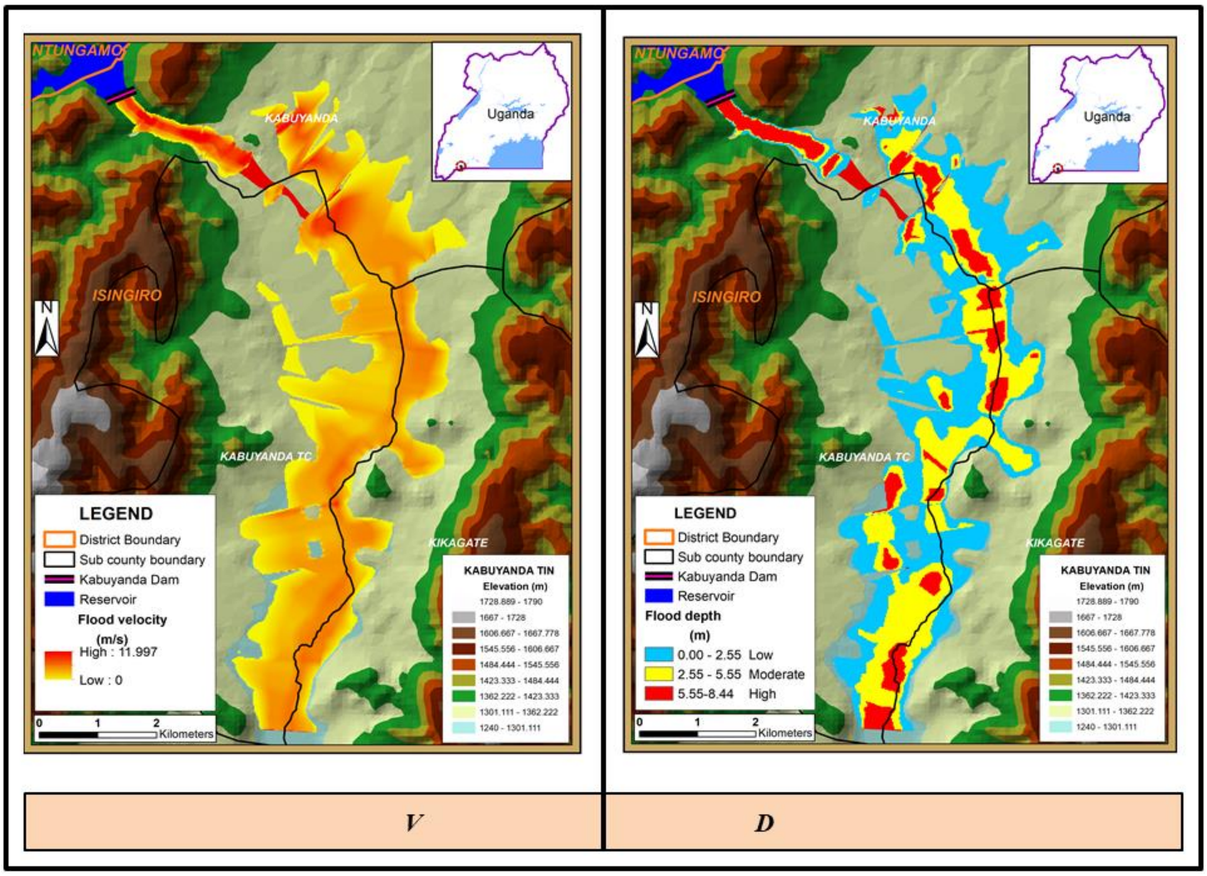
Table 4. 2: Dam failure Inundation extent in Kabuyanda Floodplain

Sub counties	**Flood Zones (intensities)**					
	High		**Moderate**		**Low**	
	Area (ha)	**Area (%)**	**Area (ha)**	**Area (%)**	**Area (ha)**	**Area (%)**
Kabuyanda	340.55	8.42	111.72	2.76	704.82	17.44
Kabuyanda Town Council	533.31	13.19	417.51	10.33	760.67	18.82
Kikagate	237.16	5.86	105.40	2.60	829.45	20.52
TOTAL	**1111.02**	**27.47**	**634.63**	**15.69**	**2294.94**	**56.84**

4.2.4 Flood Velocity and Depths

Velocity and depth results imported from HEC-RAS were visualized through creation of velocity grid on flood plain point prefixed with “v” and intersecting water surface grid with terrain surface and depth grid clipped from the bounding polygon prefixed with “d” respectively. Figure 4.6 obtained from HEC-RAS steady flow flood simulations reflect flood velocity and depths distribution resulting from Kabuyanda dam failure. To begin with, figure 4.6 velocity distribution constitutes of high and low scenarios from the flood vicinity to the most low-lying sections of the flood plain. Flood velocity is characterized by being high to low ranging from 11.997 to 0 m/s. The model results clearly depict that the flood velocity shall be high especially in the first 6 km of the upper river reach closer to the dam at the onset of dam failure especially in Kabuyanda Sub County with its western part being raised. Mild velocity of approximately 5-8 m/s is experienced at the river channel from mid-stream to downstream section of the river reach at Kikagate Sub County mostly in Kashaka village.

The flood speeds reduce subsequently ranging between 0-0.10 m/s away from the river valley. The depth of flood water due to potential dam failure ranges from 0-8.4 m with the lowest depth being 0.00 m mostly in Kikagate and some areas of Kabuyanda town council. The highest flood depths was 8.44 m to be experienced in areas at close proximity with the dam and areas with low elevation (Figure 4.6). The results indicated that at the very commencement of dam failure, areas with relatively steep elevation in Kabuyanda sub county exclusively Kagoto I, Kagoto II and Nyamiyada village in Kanywamaizi parish as well as Akatesani village in Central parish in Kabuyanda town council shall be characterized with maximum flood depths of over 5m within the first 3 minutes immediately after dam-break. However, due to high flood water velocity of about 11.997 m/s speed movement downstream, water accumulation constantly shifts to areas with lower elevation notably Ekisanga village in Kabuyanda sub county, Katembo, Kashaka and Nyampikye II villages in Kabuyanda town council with the flood depth between 2.32-4.12 m along the stream channel whilst with continuous water flow downstream, low flood depths of less than 2.55m shall be evident in villages with raised elevation and those far from River Mishumba main channel notably Kaaro I, Kigarama, Rwembera II in Kabuyanda town council as well as Kabugo II in Kabuyanda sub county.



V=Velocity, D= *Depth*

Figure 4. 6: Flood velocity and Depth

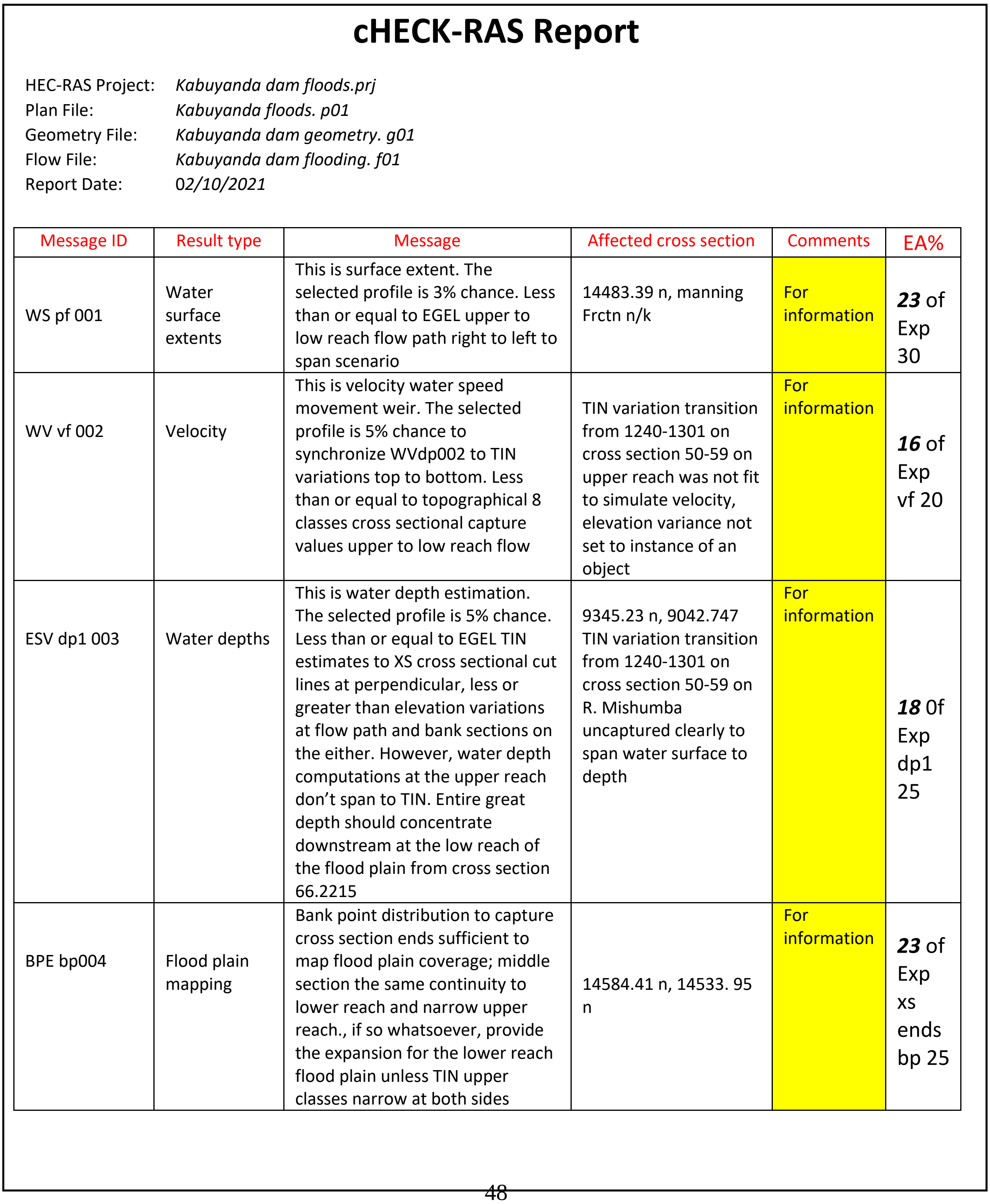
Flood velocity and depth are dependent on the conditioning factors of elevation below 1300m (Figure 4.6) and distance from the main river valley. Flood velocity ranges between 11.99 m/s to 0 m/s represented in a red and yellow coloration respectively. Kagoto I, Kagoto II and Nyamiyada in Kabuyanda sub county as well as Akatesani in town council are characterized by very high flood velocities within the first 6 Km below the dam of 11.99 m/s whilst low flood speeds below 1m/s are experienced at the lower river reach. Moderate flood velocity can be clearly seen a long the stream channel with low elevation but as the water spills over to raised valley sides, the speed reduces. Variations in flood depth are determined by elevation differences in that higher inundation rates are noticed in lower areas after maximum water flow. This signifies that although some areas within the flood plain are very far from the dam, lower elevation leads to greater flood depth notably Kashaka village in Kabuyanda town council is 14 km and Kagunga village in Kikagate Sub County is 12.7 km away from the dam yet portray greater inundation.

Figure 4. 7: Upstream section of Kabuyanda Dam anticipated to experience high Velocity

4.2.5 Validation of Flood maps

The flood results of extent, depth and velocity exported from HEC-RAS were validated using cHECK-RAS validation tool and the results are presented in table 4.3

Table 4.3: cHECK-RAS flood map validation report



cHECK-RAS Report

HEC-RAS Project: *Kabuyanda dam floods.prj*
Plan File: *Kabuyanda floods. p01*
Geometry File: *Kabuyanda dam geometry. g01*
Flow File: *Kabuyanda dam flooding. f01*
Report Date: *02/10/2021*

Message ID	Result type	Message	Affected cross section	Comments	EA%
WS pf 001	Water surface extents	This is surface extent. The selected profile is 3% chance. Less than or equal to EGEL upper to low reach flow path right to left to span scenario	14483.39 n, manning Frctn n/k	For information	***23*** of Exp 30
WV vf 002	Velocity	This is velocity water speed movement weir. The selected profile is 5% chance to synchronize WVdp002 to TIN variations top to bottom. Less than or equal to topographical 8 classes cross sectional capture values upper to low reach flow	TIN variation transition from 1240-1301 on cross section 50-59 on upper reach was not fit to simulate velocity, elevation variance not set to instance of an object	For information	***16*** of Exp vf 20
ESV dp1 003	Water depths	This is water depth estimation. The selected profile is 5% chance. Less than or equal to EGEL TIN estimates to XS cross sectional cut lines at perpendicular, less or greater than elevation variations at flow path and bank sections on the either. However, water depth computations at the upper reach don't span to TIN. Entire great depth should concentrate downstream at the low reach of the flood plain from cross section 66.2215	9345.23 n, 9042.747 TIN variation transition from 1240-1301 on cross section 50-59 on R. Mishumba uncaptured clearly to span water surface to depth	For information	***18*** Of Exp dp1 25
BPE bp004	Flood plain mapping	Bank point distribution to capture cross section ends sufficient to map flood plain coverage; middle section the same continuity to lower reach and narrow upper reach., if so whatsoever, provide the expansion for the lower reach flood plain unless TIN upper classes narrow at both sides	14584.41 n, 14533. 95 n	For information	***23*** of Exp xs ends bp 25

FMAExpts-arc in Asc=Fpd, vm, wse and WD, Overall PMVA to TIN was ***80***perc of possible 100perc

The results show that the flood maps scored above average percentage of 80%. The percentage in cHECK-RAS flood map validation tool for water extents, velocity mapping, water depths and flood plain mapping is 30, 20, 25 and 25% respectively. The results from the report showed that water surface extents, velocity mapping, water depths and flood plain mapping had 23%, 16%, 18% and 23% respectively which totals to 80% map validation accuracy. Therefore, the flood maps were fit to perform the dam flood hazard scenario analysis. The most accurate flood parameter was flood plain mapping, velocity, depth and water surface extent. The results revealed that some cross sections and TIN variations had errors that needed adjustments only if it was below average. In addition, the critical flood extent points were mapped and the results showed that the longest water surface coverage was 1,975 m from the river whilst the shortest was 158 m. On the other hand, the computations showed that when approximately 8.8 Mcm^{3}of water is poured to 40.3 km^2 of land with less than 8 TIN elevation classifications, the maximum and minimum elevation of 1700 m and 1200 m respectively, then the maximum flood water surface extent distance from the river centerline at the lowest point should not exceed 2000m and not less than1500 m. The maximum distance recorded for this study was 1,975 m, hence fitting in to the accuracy specification. The estimated recent flood depth mark on the buildings at the most critical location in Kagoto1 was 1m, the maximum flood depth for dam flood is 8m; this in reference to the flood percentage increase is valid.

4.3 Exposure status of Elements at Risk to dam failure Inundation

The elements at risk anticipated to be affected by dam failure were broadly categorized as human population, croplands, critical facilities (schools, health units and police stations), vegetation (tree plantations) and Infrastructure (road network and buildings)

4.3.1 Human Population exposed to dam Flood Hazard

The results reveal that a total of 5,756 people in Kabuyanda flood plain are exposed to the flood in the eventuality of dam failure with 2,428 and 3,328 people found in the high and moderate flood zones respectively (Table 4.3). The largest population exposed to the dam flood is located in Kabuyanda town council with a population of 3,704 people (64.35%), followed by Kabuyanda sub county with 1,504 people (26.20%) exposed to the dam flood hazard while the least population exposure to the potential dam failure flood hazard is located in Kikagate sub county with 544 people (9.45%). In Kabuyanda town council, the largest population exposure is found in central parish with 1,924 (33.43%) people, followed by Iryango with 932 people (16.19%), Kisyoro with 848 people (14.73%) and northern with no population at all exposed to the flood hazard. Kabugu parish accounts for the largest population in Kabuyanda Sub County with 1,080 people (18.76%), Kanywamaizi with 408 people (7.09%) and the least population exposed to the dam flood hazard in Kabuyanda sub county is found in Kagara parish with only 20 people which accounts for 0.35% exposure. The overlay results also revealed that the lowest population exposure is located in Kikagate Sub County with the largest exposure located in Rwamwijuka with 536 people (9.31%) and the least population exposure mapped in Ntundu parish with 4 people (0.14%). Therefore, the results reveal that the largest human population exposed to the dam flood hazard in Kabuyanda flood plain is located in Central parish in Kabuyanda town council having 33% exposure status whilst the least population exposure is in Northern parish having no exposure.

Table 4. 3: Human population exposed to dam flood hazard

Sub Counties	**Parishes**	**Exposure by Flood zones**		**Total Exposure**		**Total Sub county Exposure Flood zone**		**Total Exposure**	
		High	**Moderate**	**No**	**(%)**	**High**	**Moderate**	**No**	**(%)**
Kabuyanda	Kagara	20	0	20	0.35				
	Kanywamaizi	260	148	408	7.09				
	Kabugu	728	352	1,080	18.76	1,008	500	1,508	26.20
Kabuyanda T.C	Central	668	1,256	1,924	33.43				
	Kisyoro	284	564	848	14.73				
	Iryango	336	596	932	16.19				
	Northern	0	0	0	0.00	1,288	2,416	3,704	64.35
Kikagate	Rwamwijuka	132	404	536	9.31				
	Ntundu	0	8	8	0.14	132	412	544	9.45
TOTAL		**2,428**	**3,328**	**5,756**	**100**	**2,428**	**3,328**	**5,756**	**100**

4.3.2 Croplands exposed to the dam Flood Hazard

The results show that a total of 155 crop gardens, approximately 339.15 hectares of land under crop in Kabuyanda flood plain is exposed to the dam flood hazard (Figure 4.4). The largest portion of this cropland of 184.26 hectares (71gardens) while 154.3 hectares (84 gardens) are situated in the high and moderate flood hazard zones respectively. The computation results reveal that the biggest cropland areas exposed to the potential dam flood inundation are situated in Kabuyanda town council with 176.09 hectares (51.92%), followed by Kikagate with 98.38 hectares (29.01%) while the least croplands exposed to the flood hazard are situated in Kabuyanda sub county with 64.68 hectares accounting for only 19.07% exposure (Figure 4.4). The results also reveal that Kabuyanda town council has most of its crop lands in the high flood hazard zone of 64.64 hectares (41.89%), Kikagate with 52.38 hectares (33.95%) while the least area cropland exposure to the high flood zone is situated in Kabuyanda Sub County with 37.28 hectares (24.16%). The largest farmlands exposed to the dam flood hazard in the moderate flood zone is situated in Kabuyanda town council with 111.45 hectares (60.16% exposure), followed by Kikagate sub-County with 46.41 hectares (25.05%) situated in the moderate flood zone and Kabuyanda sub-County with the least cropland exposure to the moderate flood zone.

Table 4. 4: Crop lands exposed to the dam flood hazard

Sub counties	**Flood zones**						**Total Exposure**		
	High			**Moderate**					
	No	**Area (ha)**	**Area (%)**	**No**	**Area (ha)**	**Area (%)**	**No**	**Area (ha)**	**Area (%)**
Kabuyanda	25	37.28	24.16	23	27.4	14.79	48	64.68	19.07
Kabuyanda T.C	46	64.64	41.89	40	111.45	60.16	86	176.09	51.92
Kikagate	13	52.38	33.95	8	46.41	25.05	21	98.38	29.01
Total	**84**	**154.3**	**100**	**71**	**185.26**	**100**	**155**	**339.15**	**100**

Figure 4. 8: Croplands exposed to dam flood hazard in Kabuyanda flood plain.

4.3.3 Tree plantations/wood lots (Eucalyptus) exposed to the dam flood hazard

The results reveal that a total of 441 tree plantations (131.64 hectares) are exposed to the dam flood hazard in the eventuality of dam failure with 89.96 hectares (266 tree plantations) and 41.68 hectares (175 tree plantations) located in the high and moderate flood zones respectively (Figure 4.5). The results also depict that in the high flood zone, the largest tree plantations are located Kabuyanda sub county amounting to 61.39 hectares (46.63%), Kabuyanda town council with 53.62 hectares (40.73%) whilst the least tree plantation exposure to the high flood zone was found to be in Kikagate with 16.63 hectares and having 12.63% exposure to the high flood zone (Figure 4.5). The largest tree lots exposed to the dam flood hazard in the moderate flood zone are situated in Kabuyanda town council with 24.22 hectares (58.11% exposure), followed by Kabuyanda Sub County with 13.5 hectares (32.39%) situated in the moderate flood zone and Kikagate Sub County with the least tree lots of 3.95 hectares accounting for only 9.50% exposure.

Table 4. 5: Tree plantations/wood lots exposed to the dam flood hazard

Sub counties	High			Moderate			Total Exposure		
	No	**Area (ha)**	**Area (%)**	**No**	**Area (ha)**	**Area (%)**	**No**	**Area (ha)**	**Area (%)**
Kabuyanda	105	40.12	44.60	63	13.5	32.39	168	53.62	40.73
Kabuyanda T.C	108	37.17	41.32	82	24.22	58.11	190	61.39	46.6
Kikagate	53	12.67	14.08	30	3.96	9.50	83	16.63	12.63
Total	**266**	**89.96**	**100**	**175**	**41.68**	**100**	**441**	**131.64**	**100**

4.3.4 Buildings /houses exposed to the dam flood hazard

The buildings dataset of Kabuyanda irrigation command area was digitized from high resolution images of Google Earth and the results were quality-checked with the households collected by UBOS during the 2014 Census. The dataset was then overlaid with the flood extent map and the buildings exposed to the dam flood computed accordingly as showed in figure 4.6.

Figure 4.6 shows that the highest number of buildings exposed to the dam flood hazard are located in the parishes of central in Kabuyanda town council with 481 buildings (33.43%), Kabugu in Kabuyanda Sub County with 270 buildings (18.76%), Iryango in Kabuyanda town council with 233 buildings (16.19%). Moderate buildings exposed to the dam flood hazard are situated in the parishes of Kisyoro in Kabuyanda town council with 212 buildings (14.73%), Rwamwijuka in Kikagate Sub County with 134 buildings (9.31%) as well as Kanywamaizi in Kabuyanda Sub County with 102 buildings (7.09%). The least buildings exposed to the flood hazard are located in the parishes of Ntundu in Kikagate Sub County with only 2 buildings (0.14%), Kagara in Kabuyanda Sub County with 5 buildings (0.35%) and Northern in Kabuyanda Sub County with no buildings exposed to the flood hazard (0%). Figure 4.6 discloses that the highest number of buildings exposed to the dam flood in the high flood zone are located in the parishes of Kabugu, central, Iryango and Kisyoro with 182, 167, 84 and 71 buildings respectively whilst the lowest number of buildings within this zone were mapped in the parishes of Kanywamaizi, Rwamwijuka and Kagara with 65, 33 and only 5 buildings respectively. It was discovered that parishes of Northern and Ntundu had no buildings located in the high flood zone. The results reveal that in the moderate flood zone, the highest number of buildings is located in Kabuyanda town council in the parishes of Central, Iryango and Kisyoro with 314, 149 and 141 buildings as well as Rwamwijuka in Kikagate Sub County with 101 buildings whilst e lowest number of buildings exposed to the flood in this zone are located in the parishes of Kanywamaizi (37 buildings) Ntundu (88 buildings) and Kabugu (2 buildings). However, no buildings in Kagara and Northern parishes were found located in the moderate flood zone. The findings generally reveal that the highest number of buildings exposed to the dam flood hazard is located in Central parish while no buildings at all are exposed to the flood in the parish of Northern, all in Kabuyanda town council.

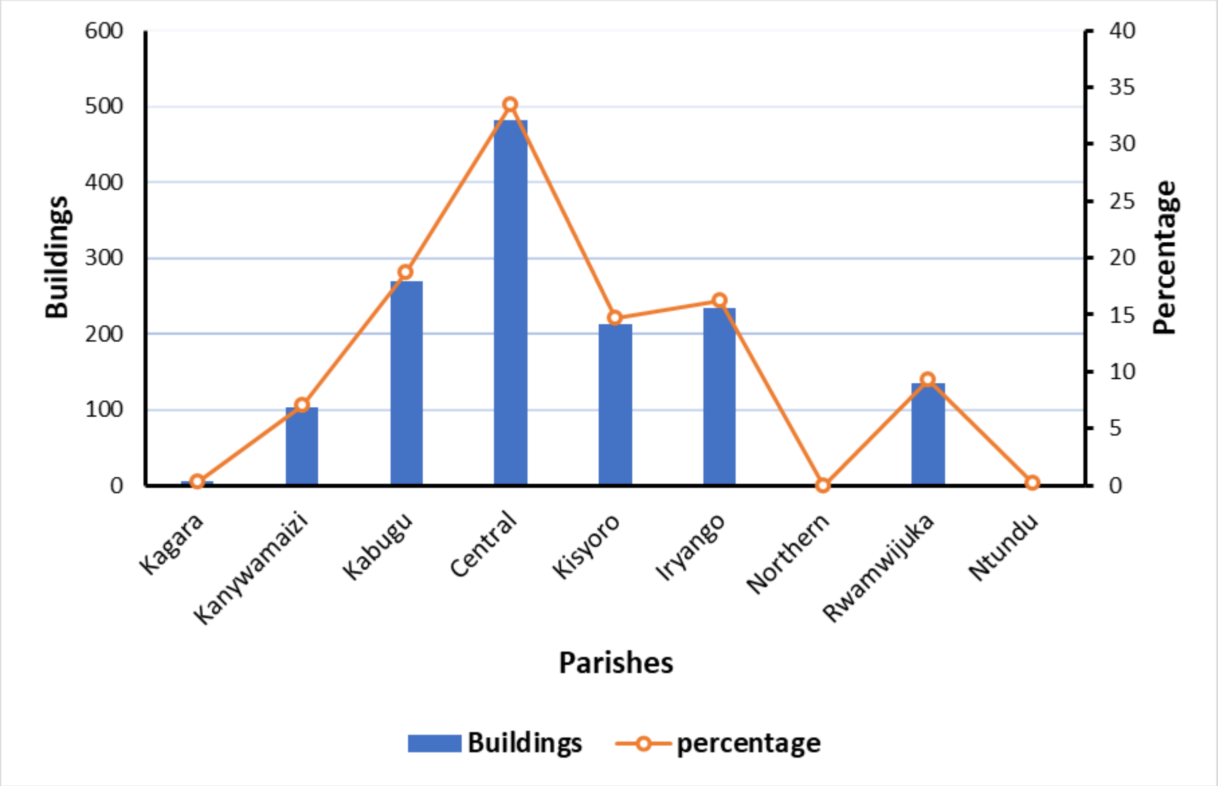


***Figure 4. 9:* Buildings exposed to dam flood hazard**

Figure 4. 10: Some of the buildings exposed to dam flood hazard in Kabuyanda flood plain

4.3.5 Road Network exposed to the Dam Flood Hazard

The roads that were mapped from the entire delineated flood plain are spread over the three flood zones and the results indicated that a total of 70 roads are located in the high flood zone while 108 roads were mapped being situated in the moderate flood intensity zone which implies that more roads in the study area are located in the moderate flood zone (Table 4.6). The summary statistics confirmed that the total road length was 26.1 km(70 roads) and 21.01 km (108nroads) in the high and moderate flood zones respectively with the highest number road exposure mapped in Kabuyanda town council with 83 roads accounting for 49.35% exposure, Kabuyanda Sub County with 47 roads (28.25%) while Kikagate Sub County accounts for the least percentage of 10.55% with 48 roads being exposed. Kabuyanda town council consists of the biggest number of roads situated in the high flood zone with 25 roads , Kikagate with 23 roads while the lowest number of roads is in Kabuyanda sub county with only 22 roads but with somewhat greater length of 10.16 km. Variations were also recorded in the moderate flood zone where the highest number of roads exposed to the dam floods in this zone is located in Kabuyanda town council with 58 roads (14.87 km), Kabuyanda and Kikagate Sub County account for the least road number all with 25 roads but with varying total road length of 3.15 km and 2.99 km respectively. 178 roads will be lost to the flood in the eventuality of dam failure approximating to the road length of 47.11 km.

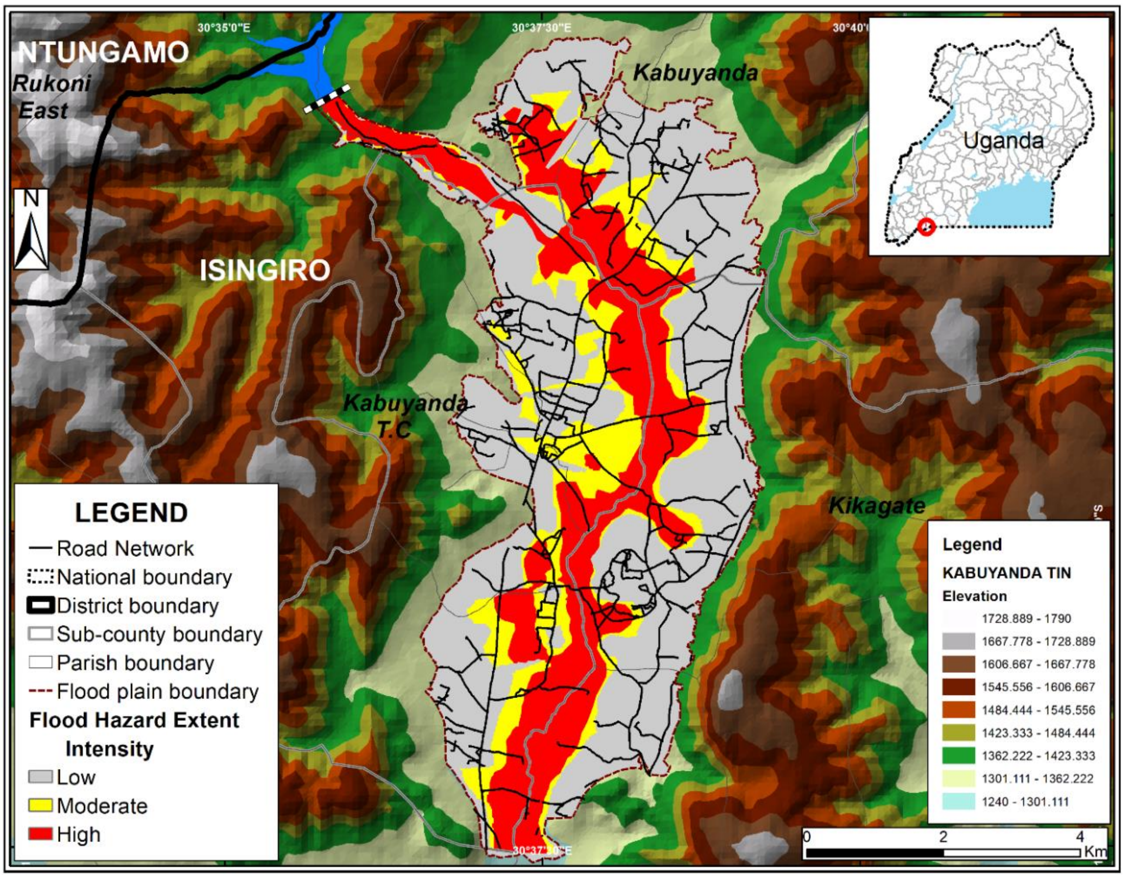


Figure 4. 11: Road network exposed to dam flood hazard

Table 4. 6: Road network exposed to the dam flood hazard

S.C	**Parishes**	**Exposure by Flood zone**				**Total exposure**			**Flood zone**				**Total exposure**		
		High		**Moderate**					**High**		**Moderate**				
		No	**Km**	**No**	**Km**	**No**	**Km**	**%**	**No**	**Km**	**No**	**Km**	**No**	**Km**	**%**
Kabuyanda	**Kagara**	1	0.41	2	0.1	3	0.51	1.08	22	10.16	25	3.15	47	13.31	28.25
	Kanywa maizi	9	4.31	9	1.19	18	5.5	11.67							
	Kabugu	12	5.44	14	1.86	26	7.3	15.50							
Kabuyanda T.C	**Central**	7	3.28	24	6.6	31	9.88	20.97	25	8.38	58	14.87	83	23.25	49.35
	Kisyoro	10	1.71	23	4.12	33	5.83	12.38							
	Iryango	8	3.39	11	4.15	19	7.54	16.01							
	Northern	0	0	0	0	0	0	0							
Kikagate	**Rwamwi juka**	19	7.18	21	2.6	40	9.78	20.76	23	7.56	25	2.99	48	10.55	22.39
	Ntundu	4	0.38	4	0.39	8	0.77	1.63							
	TOTAL	**70**	**26.1**	**108**	**21.0**	**178**	**47.11**	**100**	**70**	**26.1**	**108**	**21.01**	**178**	**47.11**	**100**

SB=Sub Counties

Figure 4. 12: Roads in Kanywamaizi parish exposed to the dam flood

Further analysis of the road network exposed to the dam flood hazard was narrowed down to parish level specific to road length (Figure 4.13). The longest road lengths exposed to the dam failure flood hazard are located in the parishes of Central with 9.88 km (20.97%), Rwamwijuka with 9.78 km (20.76%), Iryango with 7.54 km (16.01%), Kabugu with 7.3 km (15.50%) as well as Kanywamaizi with 5.5 km. The results also revealed that the shortest road length exposed to the dam flood was mapped in the parishes of Kagara and Ntundu with the road length of 0.51 km and 0.77 km having 1.08% and 1.63% exposure respectively(Table 4.6). However, Northern parish does not have any of its roads exposed to the dam failure inundation (Figure 4.13) owing to its location at the foot hills of raised grounds where the dam flood inundation water surface flow may not cause severe impacts.

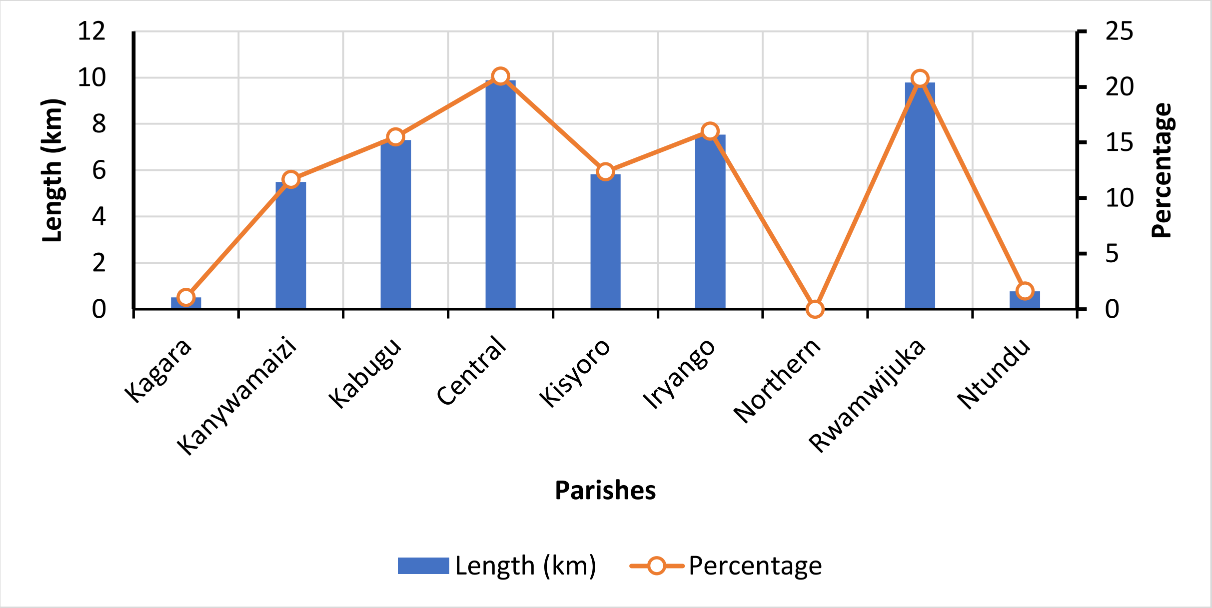


Figure 4. 13: Road lengths exposed to dam flood hazard

4.3.6 Critical Facilities exposed to the Dam Flood Hazard

The schools, health facilities, water sources and police posts datasets were superimposed with the flood hazard extent map (Figure 4.13) and the results are presented in table 4.5.

The findings here divulge that a total of 8 schools are exposed to the dam flood inundation with 2 schools (Kabuyanda parents’ school and Katooma primary school) situated in the high flood zone in the parishes of Kisyoro and Kanywamaizi in Kabuyanda town council and Kabuyanda Sub County respectively. Out of the 6 schools in the moderate flood zone, 5 are situated in Kabuyanda town council and only 1 in Kabuyanda Sub County (Table 4.7).

A total of 19 water sources are exposed to dam flood hazard. 8 in Kabuyanda town council and 1 in Kikagate Sub County located in the high flood zone while 4 water sources in Kabuyanda Sub County, 5 in Kabuyanda town council and 1 in Kikagate are located in the moderate flood zone. The overlay results also reveal that only Kabuyanda police post at central parish in Kabuyanda town council is exposed to the flood hazard in the moderate flood zone (Figure 4.14). Kabuyanda health Centre IV in Kabuyanda town council is located in the moderate flood zone. The results clearly signify that Kabuyanda town council has most critical facilities exposure to dam failure inundation.

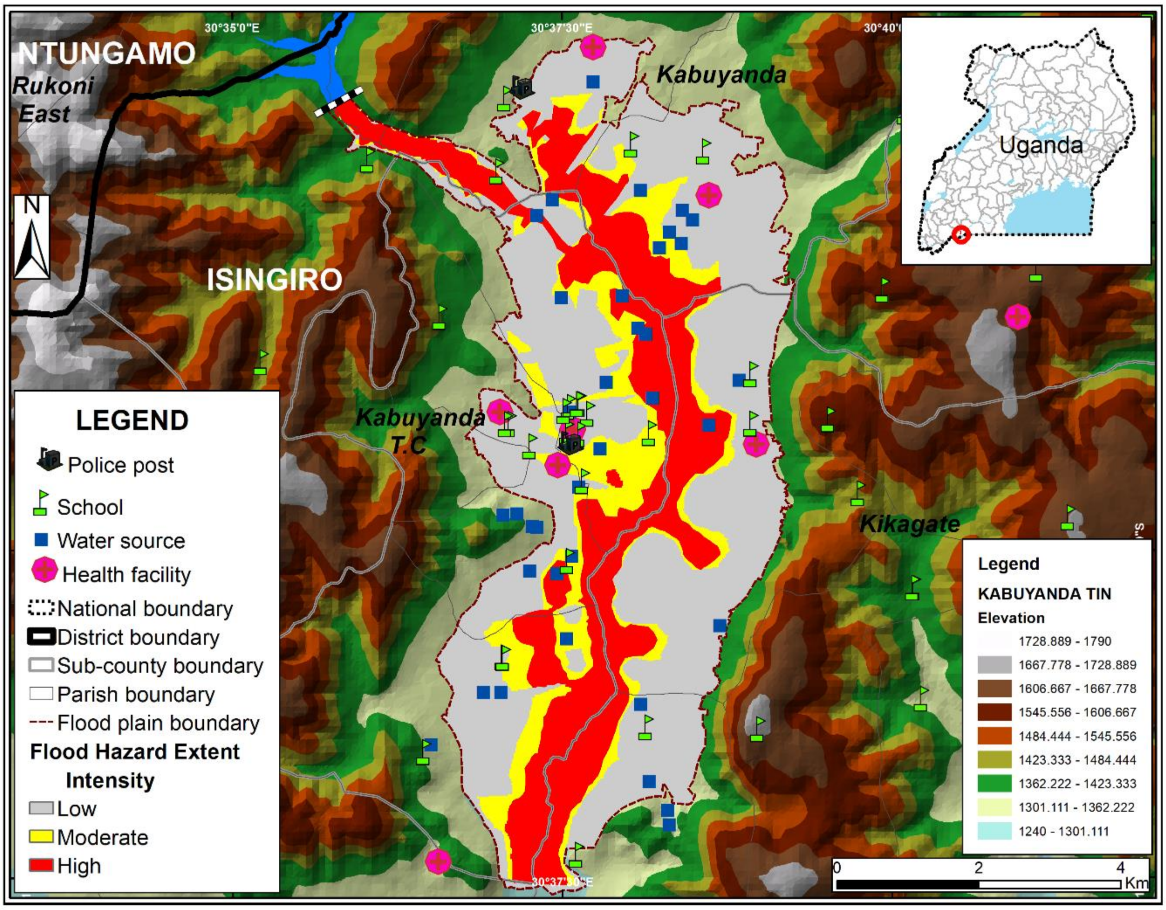


Figure 4. 14: Critical facilities exposed to dam flood hazard

Table 4. 7: Critical facilities exposed to dam flood hazard

	Schools			**Water sources**			**Police posts**			**Health centers**		
Sub Counties	**Flood zone**			**Flood zone**			**Flood zone**			**Flood zone**		
	H	**M**	**T**	**H**	**M**	**T**	**H**	**M**	**T**	**H**	**M**	**T**
Kabuyanda	1	1	2	0	4	4	0	0	0	0	0	0
Kabuyanda TC	1	5	6	8	5	13	0	1	1	0	1	1
Kikagate	0	0	0	1	1	2	0	0	0	0	0	0
TOTAL	**2**	**6**	**8**	**9**	**10**	**19**	**0**	**1**	**1**	**0**	**1**	**1**

H=High M=Moderate T=Total exposure

4.4 Estimating potential damages and losses due to Earth Dam failure

4.4.1 Estimation of potential damages

The elements at risk which were assessed for potential damage due to earth dam failure included infrastructure (residential buildings and roads), croplands and critical facilities.

4.4.1.1 Estimation of potential damage to Residential Buildings

Damageability status of residential buildings to Kabuyanda flood plain was assessed using flood zone-depth-velocity function computation and grouped to three classes and the results are hereby presented in table 4.6 and figure 4.10.
Results of the analysis indicated that a total of 1,465 residential buildings are likely to be damaged by the dam flood hazard in case of dam failure. Mapping results further revealed that 136 (9.2%), 406 (27.7%) and 923 (63.1%) residential buildings will be completely, moderately and slightly/not damaged at all respectively in the event of dam failure. The biggest percentage of buildings likely to be destroyed in case of a flood hazard was mapped in Kabuyanda town council with 63.2% (926 buildings), followed by Kabuyanda Sub county with 25.7% (377 buildings) whilst Kikagate with only 11.1% (162 buildings) accounting for the smallest portion of damage to residential buildings. However, although the biggest percentage damage to buildings were mapped in Kabuyanda town council, the highest number of those that are likely to be completely and severely damaged are located in Kabuyanda Sub County with 82 buildings (60.3%), followed by Kabuyanda town council with 38 buildings (27.9%) and Kikagate with the lowest number of 16 buildings accounting for 11.8%. Similarly, Kikagate sub County was mapped with the lowest percentage of buildings likely to experience a slight/minor or no damage at all of 1.6% (15 buildings) , followed by Kabuyanda sub county with 19.2% (177 buildings) and Kabuyanda town council with 79.2% (731 buildings) accounting for the highest slight/minor damageability to residential buildings. The damageability classes and quantities are reflected in table 4.6 below.

Table 4. 8: Estimated damage to residential buildings

SUB COUNTY	**PARISHES**	**Classes**													
		C.D		**M.D**		**SN.D**		**C.D**		**M.D**		**SN.D**		**Grand Total**	
		No	**(%)**	**No**	**(%)**	**No**	**(%)**	**No**	**(%)**	**No**	**(%)**	**No**	**(%)**	**No**	**(%)**
Kabuyanda	Kagara	2	1.5	1	0.2	2	0.2	82	60.3	118	29.1	177	19.2	377	25.7
	Kanywamaizi	45	33.1	32	7.9	25	2.7								
	Kabugu	35	25.7	85	20.9	150	16.3								
Kabuyanda T.C	Central	27	19.9	55	13.5	399	43.2	38	27.9	157	38.7	731	79.2	926	63.2
	Kisyoro	6	4.4	49	12.1	157	17.0								
	Iryango	5	3.7	53	13.1	175	19.0								
	Northern	0	0.0	0	0.0	0	0.0								
Kikagate	Rwamwijuka	16	11.8	131	32.3	13	1.4	16	11.8	131	32.3	15	1.6	162	11.1
	Ntundu	0	0.0	0	0.0	2	0.2								
Total								**136**	**100**	**406**	**100**	**923**	**100**	**1,465**	**100**

C.D=*completely damaged*, ***M. D***=*moderately damaged*, ***SN. D***=*Slight/minor/No damage*

Furthermore, damageability to residential buildings by parish was investigated and the results are also shown in figure 4.10. The results indicated that the highest number of buildings likely to be completely damaged are located in the parishes of Kanywamaizi with 45 buildings (33.1), Kabugu with 35 buildings (25.7), central with 27 buildings (19.9%) and Rwamwijuka with 16 buildings (11.8%) whilst the parishes with the lowest percentage of completely damaged buildings included Kisyoro with 6 buildings (4.4%), Iryango with 5 (3.7%) and Kagara with only 2 buildings (1.5%) to be completely damaged. However, Ntundu and Northern have no buildings located to the completely damaged class. Similarly, the results showed that with buildings that will be moderately damaged, the highest percentage was mapped in Rwamwijuka with 131 buildings (32.3%), Kabugu with 85 buildings (20.9%), central with 55 buildings (13.5%) as well as Iryango, Kisyoro, Kanywamaizi, and Kagara with 53 (13.1%), 49 (12.1%), 32 buildings (7.9%) and only 1 building (0.2%) respectively. In the slight/minor damage class Central, Iryango, Kisyoro, Kabugu, Kanywamaizi, Rwamwijuka, Kagara and Ntundu had 399 buildings (43.2%), 175 buildings (19.0%), 157 buildings (17.0%), 150 (16.3%), 25 buildings (2.7%), 13 buildings (1.4%), 2 buildings (0.2%) and 2 buildings (0.2%) respectively

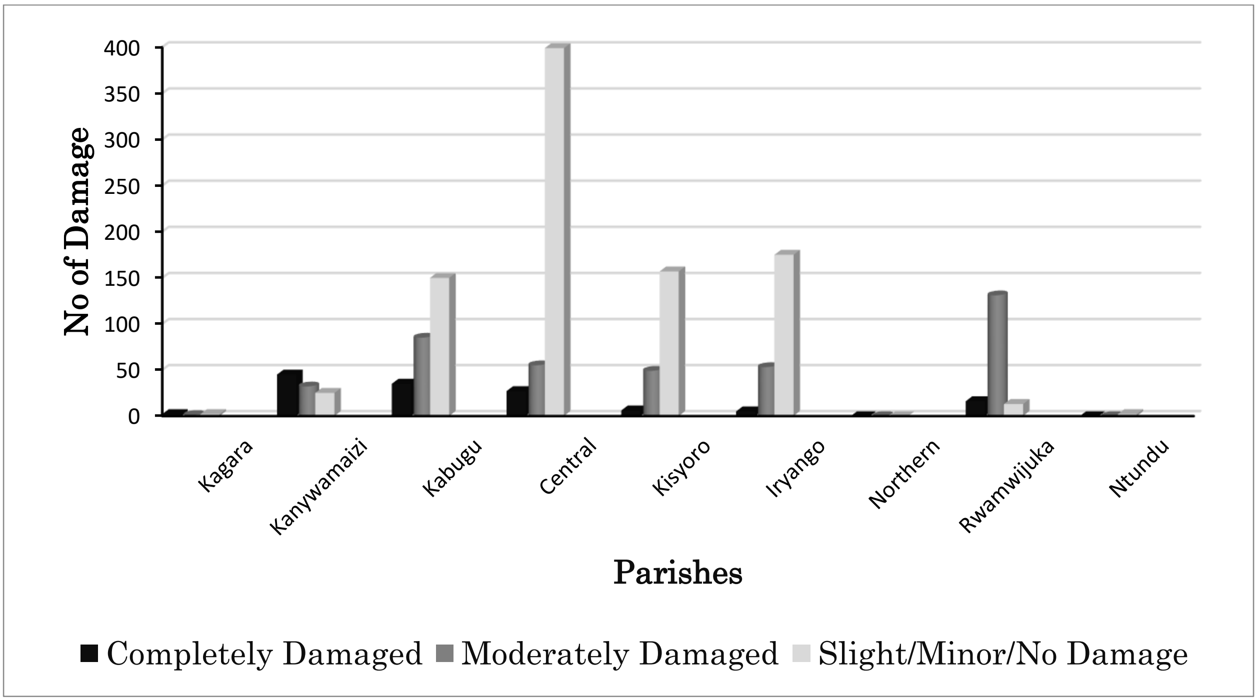


Figure 4. 15: Estimated damage to residential buildings by parish

4.4.1.2 Estimation of potential damage to schools

The results indicate that a total of 10 schools are likely to be damaged by the dam failure flood hazard with highest number located in Kabuyanda town council that is 7 schools, 2 in Kabuyanda Sub County and 1 in Kikagate. Only one school is likely to be completely and moderately damaged in Kabuyanda Sub County and Kabuyanda town council respectively. However, 8 schools are expected to experience minor/slight or no damage at all and the highest number was 6 in Kabuyanda town council and 1 in both Kabuyanda Sub County and Kikagate.

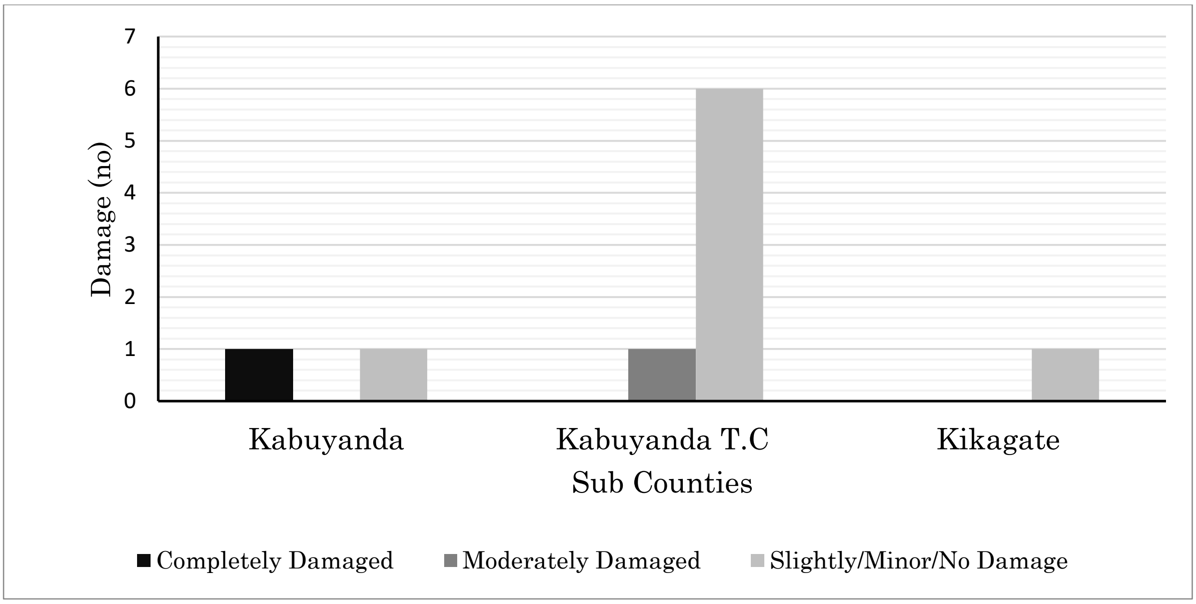


Figure 4. 16: Estimated damage to schools

4.4.1.3 Estimation of potential damage to Roads

The results in figure 4.12 reveal that 178 roads with approximately 47 km are likely to be destroyed by potential dam flood hazard with Kabuyanda town council, Kabuyanda sub county and Kikagate with 23.2 km (83 roads), 13.3 km (47 roads) and 10.3 km (48 roads) respectively. The results also show that 3.4 km (23 roads) would be completely destroyed with 2.1 km (8 roads); 1.2 km (12 roads) and 0.1 km (3 roads) mapped in Kabuyanda town council, Kabuyanda Sub County and Kikagate respectively, 6.7 km (61 roads) will be moderately damaged with 3.6 km (22 roads); 1.8 km (20 roads) and 1.3 km (19 roads) mapped in Kabuyanda town council, Kabuyanda Sub County and Kikagate respectively. However, roads that will likely not be damaged or rather be minimally damaged were 94 (37 km) in Kabuyanda town council, Kabuyanda Sub County and Kikagate with a distance of 17.6 km (53 roads); 10.3 km (20 roads) and 9.1 km^2 (19 roads) respectively.

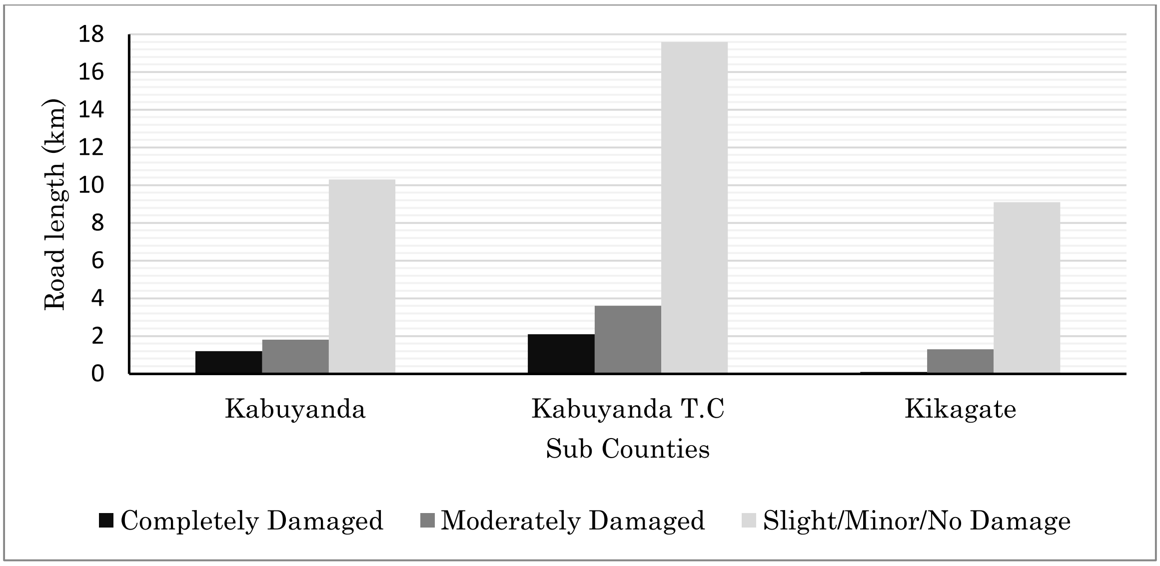


Figure 4. 17: Estimated damage to road network

4.4.1.4 Estimation of potential damage to croplands

The estimate assessments show that approximately 338.9 hectares of croplands would be damaged in the event of dam failure. The analysis in table 4.6 revealed that about 32.1 hectares (9.4%) of the area under croplands would be completely damaged in the eventuality of dam failure, 90.6 hectares (26.7%) moderately destroyed while 216.2 hectares (63.7%) would experience minor or slight damage (Table 4.9). A majority of the crop lands subject to complete damage were mapped in Kabuyanda town council, followed by Kabuyanda and Kikagate Sub County with 15.1 hectares (47%), 10.8 hectares (33.6%) and 6.2 hectares (19.3%) respectively. Most of the crop lands likely to experience moderate damageability status were mapped in Kikagate with 52.3 hectares (57.7%), Kabuyanda town council had 20.5 hectares (22.6%) and Kabuyanda Sub County with 17.8 hectares (19.6%) accounting for the least crop damage in the moderately damaged category. However, multiple crop lands that would experience slight/minor or no damage at all are located in Kabuyanda town council with 140.4 hectares (64.9%) while 39.8 hectares (18.4%) and 36 hectares (16.7%) were mapped in Kikagate and Kabuyanda Sub County respectively. Therefore, the overlay results reveal that in all the damageability categories, in case of dam failure a total of 176 hectares (51.9%) of crop lands are likely to be damaged accounting for the highest crop land damage area by sub county followed by Kikagate with approximately 98.3 hectares (29%) while the least damages to crop lands are likely to be experienced in Kabuyanda sub county with approximately 48 gardens (64.6%) accounting for 19.1% of the total estimated crop land damage.

Table 4. 9: Estimated damage to Crops

SUB COUNTIES	Damage categories											
	Completely Damaged			Moderately Damaged			Slightly/Minor No Damage			Total		
	No	Area (ha)	Area (%)	No	Area (ha)	Area (%)	No	Area (ha)	Area (%)	No	Area (ha)	Area (%)
Kabuyanda	7	10.8	33.6	10	17.8	19.6	31	36	16.7	48	64.6	19.1
Kabuyanda T.C	11	15.1	47.0	20	20.5	22.6	55	140.4	64.9	86	176	51.9
Kikagate	2	6.2	19.3	6	52.3	57.7	13	39.8	18.4	21	98.3	29.0
Grand Total	**20**	**32.1**	**100**	**36**	**90.6**	**100**	**99**	**216.2**	**100**	**155**	**338.9**	**100**

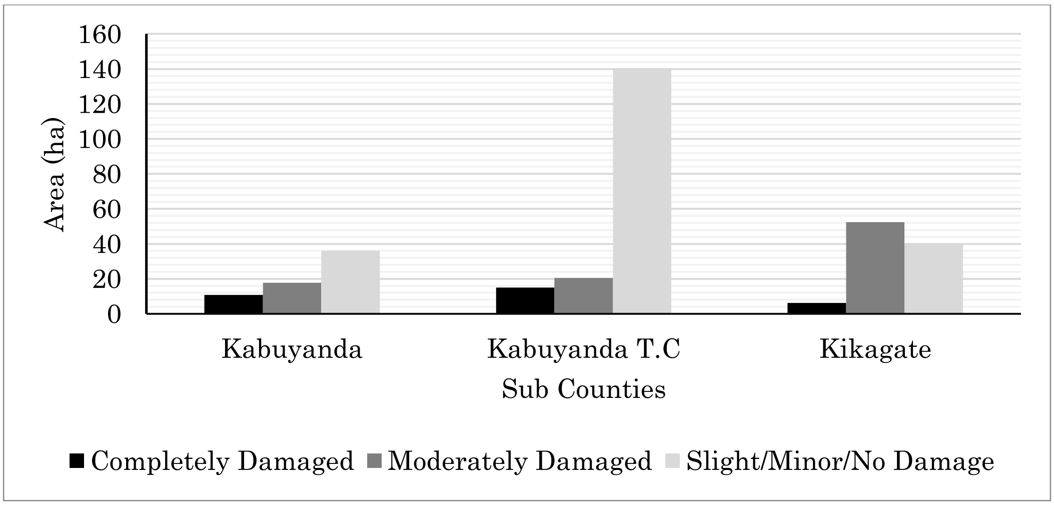


Figure 4. 18: Estimated damage to croplands

4.4.2 Estimation of potential losses to dam failure inundation

4.4.2.1 Loss estimation to residential buildings in the flood plain

The loss to residential buildings for multiple levels was computed basing on the building type, material as well as location and the results are shown in table 4.7 and figure 4.13. Results of the analysis indicated that the total loss to residential buildings is estimated to be 2,202,600,000Ugsh with 1,444,500,000 and 758,100,000Ugsh losses resulting from the damage of permanent and semi-permanent buildings respectively. The computational assessments show that a bigger loss of residential buildings in monetary terms is expected to be in the parishes of Iryango with 548,140,000 UGX, Central with 486,900,000Ugshs, Kabugu with 457,800,000 UGX and Kisyoro with 313,310,000 UGX whilst the smallest loss is expected to be in the parishes of Ntundu with 1,140,000 UGX, Kagara with 2,850,000U

UGX, Kanywamaizi with159,440,000Ugshs and Rwamwijuka with 233,020,000 UGX (Figure 4. 19). However, just like other assessments, Northern parish does not have any losses to buildings given its location of approximately 2 km off the floodplain inundation zones.

Table 4. 10: Buildings and their estimated loss

	Building type					
	Permanent		Semi-Permanent		Total losses	
PARISHES	**No**	**Loss (UGX)**	**No**	**Loss (UGX)**	**No**	**Loss (UGX)**
Kagara	0	0	5	2,850,000	5	2,850,000
Kanywamaizi	10	107,000,000	92	52,440,000	102	159,440,000
Kabugu	30	321,000,000	240	136,800,000	270	457,800,000
Central	21	224,700,000	460	262,200,000	481	486,900,000
Kisyoro	19	203,300,000	193	110,010,000	212	313,310,000
Iryango	41	438,700,000	192	109,440,000	233	548,140,000
Northern	0	-	0	-	0	-
Rwamwijuka	14	149,800,000	146	83,220,000	160 d	233,020,000
Ntundu	0	-	2	1,140,000	2	1,140,000
Grand Total	**135**	**1,444,500,000**	**1,330**	**758,100,000**	**1,465**	**2,202,600,000**

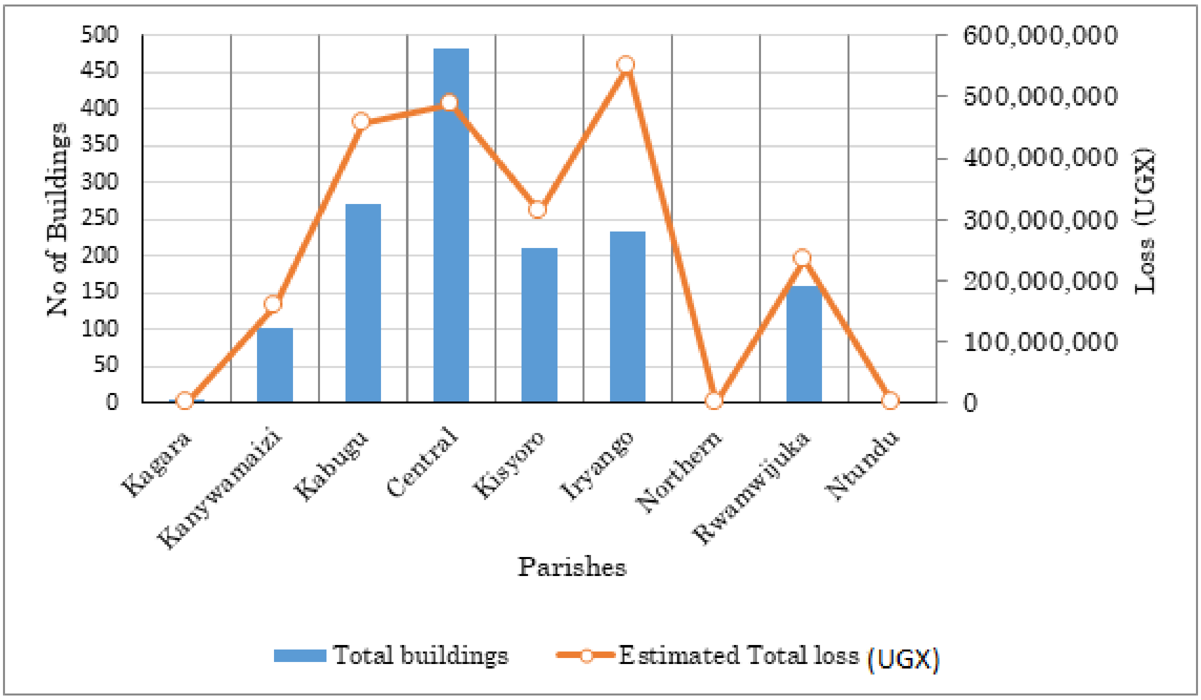


Figure 4. 20: Total buildings and estimated loss

4.4.2.2 Loss estimation for croplands in the flood plain

The results show that the total loss in monetary value in Uganda shillings to the permanent croplands (banana plantations) is estimated to amount to 602 million shillings in the entire Kabuyanda floodplain in any eventuality of a dam failure inundation hazard (Table 4. 11). The estimated loss to crop land was computed to be 176million (88 acres), 164million (82 acres) and 140million (70 acres) shillings in Kabuyanda town council, Kikagate and Kabuyanda Sub County respectively. The damage-stage computation assessments revealed that the bigger loss of croplands in monetary terms is expected to be in Kabuyanda town council with 176million UGX, followed by Kikagate sub county with approximately 164million shillings while the smallest loss to crop lands was computed in Kabuyanda sub county with about 140 million shillings.

Table 4. 12: Total crop land area and estimated loss

SUB COUNTIES	Total area (Acres)	Estimated Loss (UGX)
Kabuyanda	70	140,000,000
Kabuyanda town council	88	176,000,000
Kikagate	82	164,000,000
Total	301	602,000,000

4.4.2.3 Loss estimation for schools in the flood plain

The computation assessments revealed that a total of 2 schools are located within the high flood depth velocity zone and therefore expected to be completely destroyed (Figure 4. 21). In monetary terms, the results of the analysis revealed that the total loss of schools is expected to amount to a sum of 1,353,530,546 UGX. A total loss of 676,765,273 UGX could be lost in the two schools that is Kabuyanda parent's school and Katooma primary school in Kabuyanda Sub County and Kabuyanda town council respectively. These loss estimates included all the physical infrastructure and all the content in the school setting including classrooms, stance latrines, seater wooden desks, office furniture, assorted relevant school instructional teaching and learning materials, Games and Sports materials, Science Lab equipment, chemicals and apparatuses that are expected to be buried by the flood or completely washed away by the high velocity flood water.

Table 4. 13: Total schools and estimated loss

SUB COUNTIES	Schools (no)	Loss (UGX)
Kabuyanda	1	676,765,273
Kabuyanda town council	1	676,765,273
Kikagate	0	-
Total	**2**	**1,353,530,546**

4.4.3 Mitigation measures to reduce the damages and losses resulting from dam failure

The responses from the key informant interviews were analyzed using NVIVO software. The results depicted multiplicity of strategies that can be implemented to reduce the damages and losses resulting from potential dam inundation. Evacuation programs, flood plain management, quality dam construction, floodplain zoning, installation of early warning systems and resettlement activities were frequently mentioned with 9 transcription frequency. Strengthening of disaster management committees, planning for disaster relief activities, community sensitization programs and tree planting at the “loodway” had a frequency coding of 8. Flood gates, river flow and dam reservoir behavior forecasting, identification of more vulnerable communities and educating communities on disaster preparedness had transcription frequency of 5. However, first aid services, establishment of community emergency recovery sensitization programs, land use policies and regulations and flood gates had the lowest transcription frequency of 2 from all the 10 key informants. The analysis depicts that most of the mitigation measures suggested by the respondents are deviated to preparedness than response and recovery.

The most outstanding mitigation measures were evacuation (Figure 4.26) and resettlement programs for residents at the high flood zone (loodway) to seemingly flood free zones, zoning through restricting land use in the flood plain and emphasizing use of material during construction, foundation and close monitoring of river Mishumba flow and reservoir water behavior forecasting (Figure 4. 22). The district environmental officer noted that, ***"with dam flood prediction already done through mapping, it is incumbent that all the people settled within the area anticipated to experience great depth and velocity close to the dam be advised to relocate to quite safer and low flood risk regions".***

Similarly, the district natural resource officer suggested that, ***"all the households settled and carrying out crop cultivation very close to the dam should relocate off the dam, and also the environmental authorities should ensure that land use zoning is strictly implemented for example tree planting could be done at the most susceptible zone while crop cultivation somewhat close to the flood fringe and settlement be restricted to the low flood zone. However, roads and houses close to the river valley at water passage section can be reinforced with resilient material like concrete walls for houses and embankment gabions for roads to withstand extreme flood water".*** The IDRP area supervisor noted that, ***"To begin with, no dam is constructed to fail, the engineering works often commence after multiple surveys and dam analysis have been conducted. However, based on the nature of the area, it is important to expect a dam flood hazard. But there is a solution to everything, I have supervised multiple areas of the dam, and what I deem important to mitigating possible dam flooding is mainly fighting the flood before it happens notably construction of concrete walls along the river banks at the most critical high flood zone as shown in the mapping results. This will help keep the water within the river course with minimal***

chances of river bank bursting. Secondly, as the process of dam construction is soon starting, it is important for the dam construction company to ensure quality dam construction with material that can hold water well without causing any cracks and seepage defaults. It is also important to monitor the flow of River Mishumba in to the reservoir is critical to monitor water levels so as to predict possible overtopping occurrence. The disaster management committee representative mentioned that**, *"for the dam drainage infrastructure, it is pertinent to put in place early warning systems after its completion for timely alerts. Land use restriction and formulation of flood plain regulations are also pertinent in safe guarding the downstream population from the possible dam flood hazard. Sometimes, the ruralites tend to be very mindless on the impact of encroaching on the river system especially for cultivation. Unless strict laws are formulated, then flooding will worsen due to river bank disturbance. Besides, evacuation of the population from the danger zones is as well very pertinent as well as resettling the population off the fragile population is paramount. As I conclude, weather forecasting to monitor water levels in the dam, diversion works and strengthening post disaster relief programs, is something you cannot do away with".***

Other key informants had not very different views though the explanations were based on their area of specialization. The responses from all the key informants were categorized in to three flood phases with the key stake holders as adapted from NRVAU.

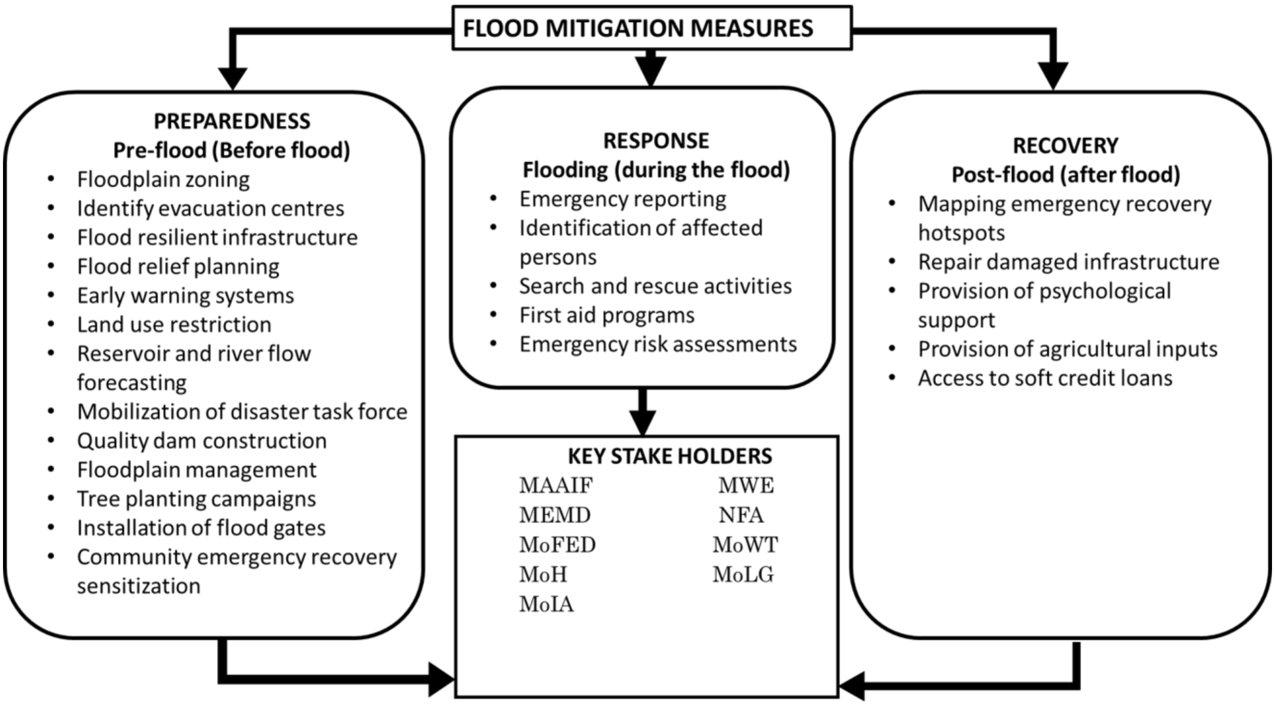


Figure 4.20: Summary of mitigation measures from key informants

Figure 4. 21: Rating of mitigation measures on NVivo word cloud

In line with the NVivo analysis, the major mitigation measure from the key informants was evacuation during the flood in case of dam failure as the best recovery strategy. Therefore, with the methodology adapted from the DMRVPI and NRVAU, during flooding the main evacuation centers include schools, health units, police stations, schools and play grounds as temporal areas. For this study, the major education centers, health units, police stations, education centers located at the flood fringe and low flood zone were mapped as temporal rescue sites in the emergency of dam flood inundation and the possible safe routes leading to these areas as possible evacuation routes (Figure 4. 23).

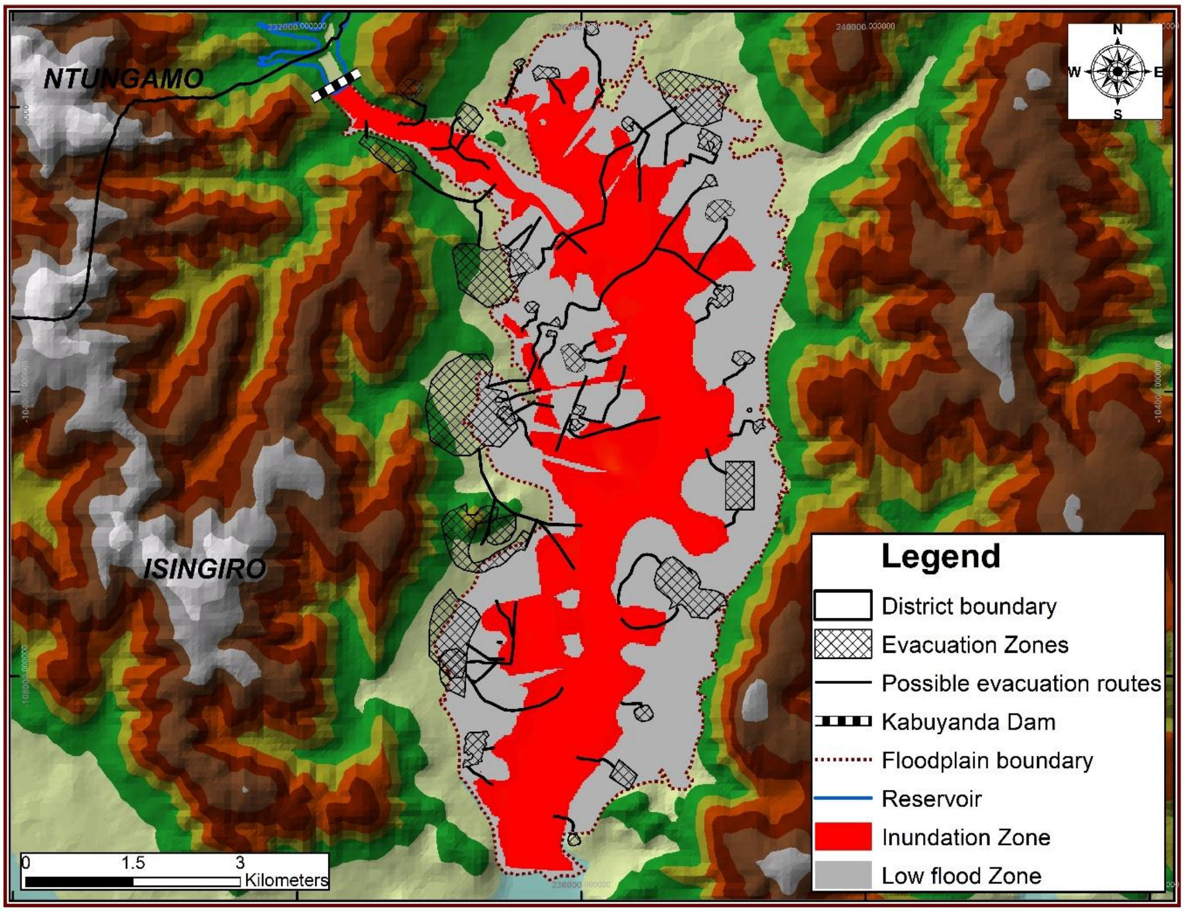


Figure 4.22: Possible evacuation Zones and routes during inundation

CHAPTER FIVE: DISCUSSION OF FINDINGS

5.0 Introduction

This chapter presents a discussion of the study findings following the study objectives.

5.1 The spatial flood extent of Kabuyanda floodplain in case of earth dam failure

Dam flood hazard mapping and flood assessment results in this study depicted prodigious variations for the three scenarios without and with the dam failure after its completion. The study revealed that flooding due to the Mishumba River bursting its banks during the wet spells exposes 4 Km^2 of Kabuyanda flood plain to floods. However, with a fully functioning dam in place, the flood extent is anticipated to slightly reduce by only 6.1%.

The simulation results revealed that in the eventuality of dam failure, the spatial extent of floodwater amounts to 1,745.65 hectares and a recognizable inundation land area increase due to dam flooding by 30.59%. This implies that dam flood hazard area coverage greatly surpasses normal river bank floods often experienced in the area and thus will result to mega damages. These findings are a reflection of those of Ardales et al., (2015), Ge et al., (2019)and Ogie et al., (2020). Similarly, Elalu (2020) noted that compared with normal floods that inflict the communities of Mishumba valley, the potential dam failure floods ought to be characterized by instant occurrence, a vast quantity of flow, and powerful impulsive force.

Reclassification and categorization of the dam flood hazard revealed the spatial distribution of the flood in Kabuyanda constituting three different flood intensity zones; high, moderate, and low. The flood hazard zone distribution can be attributed to the flood conditioning factors in the flood plain, which implies that the land area of villages at lower elevation (below 1300 m) and at proximity to river Mishumba main channel are at a high danger intensity zone from which dam failure will most likely cause loss of human life and mass destruction of property.

The reverse is true where the flood inundation reduces considerably outward the river channel boundary. The areas far from the river valley, owing to higher elevation place them almost outside the ferocious inundation wave fronts and therefore experience low inundation hence the damages experienced will likely be minimal. This is a signal that the severity of the dam flood increase as floodwater flows downstream and decreased as the water flows off the river valley. The findings in the current study are consistent with the dam impact assessments conducted in Kabuyanda IDCRP. Plan et al., (2019), noted that any eventuality cases of dam failure would result to direct and indirect losses within the main Mishumba valley just below the dam where discharge is expected to be sufficient. Similarly, a study by Barasa et al., (2019) involving the development of an emergency preparedness plan for Kabuyanda noted that emergency rescue attempts are dependent on the severity of the floodwaters mostly within the high and moderate flood zones where the deadliest damages to human life and property are expected to occur. This was attributed to the fact that at the very commencement of dam failure, areas within the steep valley sides in Kabuyanda Sub County shall be characterized with maximum flood depths ranging from of over 5m immediately after dam-break.

The depth of the floodwater in some villages was found to be high despite being located far from the dam. This was attributed to lower elevation where water accumulation will result into extremely inundation in these areas. This is in line with Kizza & Mugume (2006), Yoshikawa et al (2009) and Ardales (2016) as well as Elalu (2020) who noted that although some areas are located far from the dam, lower elevation will result into inundation. Thus, the population in these areas is at high risk when a dam failure occurs. The flood depth in the study by Elalu (2020) ranged from 0.0001 m to 13.2m whilst 0.0001m to 8.4m was recorded in the current study.

The results established that flood wave velocity is expected to be severe within the first 6 Km from the dam at the onset of the dam failure and decrease considerably as floodwater spreads over the flood plain. This implies that areas adjacent to the dam spillway will be characterized by high flood velocity at the onset of dam failure compared to those far from the dam. The mainstream channel within the high flood zone was simulated to be characterized by high flood velocity which keeps on dropping as the water flows sideways the main channel. Therefore, it can be argued that the high velocity is due to the narrow valley in the upper reach of the Mishumba River but as the water coincides with the relatively flat flood plain areas, the velocity is substantially checked. This also signifies that the greater the flood velocity and depth, the greater the potential for damage to infrastructure and life loss as people unable to evacuate may be trapped and emergency responders may not be able to access the area. The results are reflective of those by Brown et al; (2017) who noted that depth and velocity affect the potential for damage to structures, loss of life, and impacts on the environment, and as the depth of water inside structures increases, the damage increases. Similarly, Kizza and Saith (2006) in their study of the Owen Falls Dam failure simulation in Uganda noted that damage close to the dam due to high velocity is severe while those several miles downstream might be negligible.

5.2 Exposure status of Elements at Risk to Kabuyanda Flood Plain

The results showed that a total population of approximately 5,756 is exposed to the potential earth dam flood hazard with the highest exposure mapped in Kabuyanda town council with a total of 3,704 people. This was attributed to the concentration of multiple households at the vicinity of the main river Mishumba valley for agricultural activities given the fertile alluvial soil deposits. The implication of this is that given the multiple human population exposure to floods, multiple causalities are anticipated to result in the eventuality of dam failure. Several other studies have reported that greater dam flood deaths and injuries are a direct reflection of the human population exposure concentration in highly vulnerable flood passage zones, (Messner et al., 2007). The elderly (65+) comprises 13.1% and 7.4% of the directly and indirectly affected groups respectively implying that special attention needs to be given to these people during the implementation of the Resettlement Action Plan and the project in general.

The current study results indicated that roughly 339.15 hectares of croplands are exposed to the dam flood hazard. Although the greatest cropland exposure was mapped in the moderate flood zone where damage and losses are somewhat negligible, exposure of 154 hectares (84 gardens) to dam flood hazard could result to mega cropland damages hence affecting the major source of life. The Local Government Development Plan for Isingiro (2015/2016 – 2019/2020) specifies that the economy is entirely informal, with the majority of the people engaged in the production of crops and livestock products at a subsistence level. The above results are in line with earlier publications in the National Housing and Population Census (2014), which pointed out that Isingiro District, has 87.6% of the district’s population engaged in crop growing and a mere disaster can cause serious severe famine in the area.

The study revealed that a considerable quantity of residential houses is exposed to the dam flood hazard. A total of 1,439 buildings were mapped exposed to the dam flood hazard and this was too attributed to the concentration of agricultural activity at the river valley channel vicinity with fertile soils. Given the fact that flood depth and velocity are high in this zone, a greater percentage of residential buildings is subject to flood in the eventuality of dam failure. This situation implies that most residents are at a risk of being left homeless and therefore making costly evacuation an excludable fact. The results are similar to those of Brown & Graham, (1988)who noted that buildings exposure is dependent on its current location to flood velocity and depth zone, from which their damage will result to displacement hence evacuation demands.

A total of 8 schools, 4 water sources in Kabuyanda Sub County and Kabuyanda police post at the central parish in Kabuyanda town council is exposed to the flood hazard. This implies that critical facilities account for the least element at risk exposure to potential dam-break flood hazard. However, although the exposure quantity is low, the greatest attention ought to be attached attributed to the fact that the destruction of one may double the cost of replacing a single element at risk. Ministry of water and environment evaluation report for Kabuyanda under the development of emergency preparedness plan (2019) brought to the limelight that although the exposure of critical facilities to potential dam flood disaster presents the least number, it is worrying given the multiple infrastructures and offered services notably health center with biomedical equipment, structures, accommodation facilities and patients to mention but a few.

5.3 Estimation of potential damages and losses due to Earth Dam failure

Pronounced quantities of land-use types were mapped expected to be completely, moderately, and slightly damaged by the flood. A total of 1,465 residential buildings are exposed to potential dam failure inundation. This implies that in the event of dam failure, damage of 542 residential buildings downstream could result in multiple displacements especially within the high flood zones approximating 1,542 resident displacements and casualties. Damage to croplands implies that in the event of dam failure, destruction of the major staple crop (Matooke) could lead to food insecurity and an immense repercussion on food production in the district and the country at large given the fact that Isingiro is one of the largest producers of Matooke in the country worsened by the long gestation period, on average of one and a half years it takes to have mature stands of Matooke from the inception of planting. This is also an indicator of famine and direct impact on the community’s major source of income as well as a direct implication on government expenses on disaster management and relief program. The current study findings are in agreement with (Elalu, 2020) who reported that the probable dam failure upstream could harm the major source of livelihood; crop cultivation consequently instigating high rates of hunger in the already dry area, another disaster management, and recovery burden.

The analysis of results revealed a prediction of damage to Kabuyanda parents’ school and Katooma primary schools. Although enrolment in these schools is deemed low (approximately 500 pupils), the destruction could starve them of resources leading to diminishing school enrolment and permanent closure or overcrowding in the nearby schools, reduce efficiency but with the long distance to the alternative education centers, alteration, and discontinuity of study activities is expected and unavoidable as well as loss of learning hours, loss of qualified personnel, the outbreak of waterborne diseases, great absenteeism and low syllabus coverage leading to poor academic performance, leave alone food insecurity but pull out from school and sometimes children involuntary pushed to early marriages. These challenges compromise children’s rights and access to quality education. In a study by Mudavanchu (2014), dam floods leave a trail of destructions which may have a repercussion on pupils’ education getting to a level where it cannot be salvaged, schooling could be canceled and drop out as well as absenteeism may occur. Similarly, Ardales et al (2015) argued that school infrastructure destruction by floods leads to brain drain coupled with dilapidated learning infrastructure which impedes the quality of education offered to learners hence affecting performance and female learners are further exposed to early marriage.

A road distance of approximately total 47 km was predicted to most likely be damaged by the dam flood. Although it is infeasible to have precise quantification of real road damage prediction, depth and velocity variations of floodwater were parameterized to be determinants of flood road damage. Besides, previous studies indicated that the major cute parameter is the type and nature of the road that could determine flood damage, (Pyatkova et al., 2015). However, given the nature of the roads (dry weather), the analysis predicted that the propagation of the flood intensity and depth of the water not ignoring flood duration could lead to detrimental damage to most roads in the Kabuyanda sub-county where velocity is expected to be high and the Town council where long flood depth duration will have a huge effect as well. Therefore, it is clear that 23 roads (3.4 km) located at the pathway of high-velocity water and lower areas of the flood plain will be disfigured, gullied, and swallowed by the flood. These findings imply that since transport networks underpin economic activity by enabling the movement of people and goods, damage to roads will impede local mobility, transportation of agricultural produce, and education standstill culminating in unbalanced economic and social dimensions. Moreover, the peak wet spells that burst R. Mishumba banks often disrupt transportation of agricultural produce to Isingiro and Mbarara districts. This situation is expected to worsen in case of dam failure as some roads will be impassable.

The study revealed an estimated loss of approximately 4,158,130,546 UGX in the eventuality of dam failure. The estimated resettlement action plan for buildings lost to dam construction and possible floods amount to 2.6 billion UGX. The slight difference was attributed to the fact that the ministry survey focused on the entire project area that is settlements located at the proposed dam site and the irrigable area. The findings of the current study are in line with previous risk assessments by OPM (2020) that the potential average annual loss for major crops and residential buildings in the Isingiro district range between 266-594m and over 2,352UGX respectively. These findings imply that a supplementary budget worth 5 billion UGX is required for recovery action in the area. Therefore, possible dam flooding could threaten to undo decades of development gains and prospects in the area.

5.4 Mitigation measures to reduce the damages and losses resulting from dam failure

The study established multiple mitigation strategies that are pertinent in reducing the damages and losses resulting from potential dam failure inundation notably preparedness, response and recovery. This can be attributed to the past experiences of floods in the area and priorities attached to flood mitigation. Therefore, flood preparedness mitigation strategies ought to be implemented than other phases because of the complexity in dealing with flood occurrences. Most of the time, despite continued efforts to reduce flood damages, they still continue to pose the greatest threat among all natural hazards especially during wet spells. Dam floods are rarely occurring events but often result to devastating repercussions, yet hard to deal with. Therefore, it is pertinent to prepare for the possibility of occurrence rather than fighting with flood water once dam failure occurs. This implies that, all the mitigation strategies should be geared to community-based preparedness approaches rather than flood prevention and total stoppage. These findings are related to observations by Sivakumar (2015), who reported that, given the complexity in determining possible dam failure and arrival time, the best approach to damage reduction is prior preparedness to flooding (pre-flood strategies) than merely waiting for the flood for response and recovery. The best approach that can be implemented to achieve this is integrating policies that aim at keeping the population, buildings and other developments away from the possible high flood velocity and depth areas notably flood preparedness plan, flood plain regulation and zoning, land use restriction, development and redevelopment. This result relates to the view that reduction in susceptibility to damage can be achieved by keeping people and development off the flood hazard area (Yoshikawa et al; 2009; Sivakumar, 2015).

The study findings reveal that pre flood mitigation measures are hard to implement. This is because, the approach involves huge financial investment which could be constrained by corruption, owing to the past disaster program implementation, floods inclusive. This resonance with the findings by Samuel et al. (2009) who indicated that post recovery approaches to flood management usually demand bulk financial investment which can be subject to corruption. Unfortunately, the scenario of flood response and recovery is an excludable fact. On the other hand, given the difficulty in implementing sound preparedness and flood preventive measures, response and recovery are a necessity. Kabuyanda flood plain covers a considerable area of approximately 4040.60 hectares Therefore, unless a streamlined and effective implementation of both preparedness, response and recovery measures that are community based are fronted, dam flood mitigation remains a myth.

CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS.

6.0 Introduction

This chapter presents conclusions and recommendations based on the study objectives. The recommendations encompass areas connected to policy and future research needs.

6.1 Conclusion

The simulation results for the three scenarios depict change in the flood extents. The area flooded without the dam is anticipated to reduce after dam construction. On the other hand, the inundated land is predicted to increase by 32.9% in the eventuality of dam failure. Similarly, the extent, velocity and depth of the flood is anticipated to vary over space in the flood plain. The simulation results revealed that pronounced elevation variations within the floodplain determine various flood zones.

The major land uses exposed to potential dam failure inundation are human population (5,756), residential buildings (1,439), croplands (mainly banana-3339.15 hectares), tree lots (131.64 hectares), road infrastructure (47 km) and critical facilities (8 schools, 9 water sources, 1 police post and health centre). The overlay results show that the highly exposed element at risk is population, residential buildings, roads and croplands.

The damageability of elements at risk varies based on damage categories or classes depending on depth -stage and zone location. Generally, residential buildings, roads, croplands and schools are susceptible to complete, moderate and minor/slight or no damage at all status. Therefore, it is anticipated that damage of elements at risk will amount to a monetary loss of approximately 4,158,130,546UGX for elements assessed for risk analysis.

Emergency preparedness, response and recovery plans are vital in the reduction of exposure, damages in the area in case of dam failure. In cases where the flood preparedness strategies deem un effective and weak enough to fight against flood water, response to the flood scenario is important through the implementation of rescue attempts. On the other hand, it is incumbent to focus on to how the communities will recover from the flood repercussions.

6.2 Recommendations

In line with the objectives in this study, a number of recommendations are made to lessen and address the effects of potential dam flooding.

Land use restriction should be implemented in line with predicted flood extent zones, depth and flood velocity pathways. The high flood zone and the areas expected to have great depth and high food wave velocity at the lower elevations within the main Mishumba valley should be demarcated and left free of settlement and crop cultivation but used for forestry while concentration of land use should be encouraged at the flood free zone (low flood susceptibility zone).

The engineers and dam management committee should integrate flow control mechanism of R. Mishumba during the wet spells, consider strong basement construction material and support the communities to embrace tree-planting campaigns. Establishment of tree nurseries in Kabuyanda is vital to sustain tree planting initiatives aimed at re-vegetating hills and manage land use close to the reservoir to reduce surface runoff that is likely to affect water levels in the dam.

There is urgent need to form and empower the community response and rescue committees, functionality of early warning systems, monitoring signs of dam failures, emergency information and communication systems, identify space for the establishment of evacuation centers, strengthen and support health facilities through the construction of general and pediatric wards and fitted with necessary accessories.

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APPENDICES

Appendix 1: Rainfall data

PARAMETER	YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
RH2M	2019	67.75	68.75	68.94	78.31	85.12	79.06	70.69	71.12	75.5	84.69	85.5	84.62	76.69
RH2M	2020	79.56	80.06	84.12	86.94	87.12	84.12	80.88	79	78.56	82.75	85.88	80.38	82.44
precipitation	2019	39.9	71.7	70.5	136.5	192.9	77.4	65.7	103.2	99.9	289.8	143.1	176.7	**1,492.85**
precipitation	2020	75.3	115.8	274.2	219.6	120.9	70.8	124.8	65.1	106.5	198.6	169.8	87.6	**1,653.45**

Source: NASA power Precipitation data

Slip Surfaces Analyzed : 321 of 405 converged

Slip Surface : 43

Factor of Safety : 1.807

Volume : 990.08804 m³

Weight : 16,257.863 kN

Resisting Moment : 4, 74,041.65 kN·m

Activating Moment : 2,62,236.37 kN·m

Resisting Force : 6,554.9346 kN Activating

Force : 3,627.9777 kN

Slip Rank : 1 of 405 slip surfaces

Exit : (152, -0.3) m/s

Entry : (69.06546, 23.417977) m

Radius : 65.324254 m

Center : (124.0229, 58.729991) m

Appendix 11: Steady seepage with Maximum Flood Level

Dam f portions	**X**	**Y**	**PWP**	**Base Level Water prop**	**Frictional Strength**	**Cohesive Strength**	**Suction Strength**	**Base Material**
Slice 1	69.157835	23.275031 m	-10.543053	2.1824545 kPa	1.5281711 kPa	0 kPa	0 kPa	Rip Rap
Slice 2	69.364901	22.956847 m	-7.4229884	5.5124043 kPa	3.859827 kPa	0 kPa	0 kPa	Rip Rap
Slice 3	70.354403	21.519863 m	4.7700756	17.459807 kPa	9.5623981 kPa	4.66 kPa	0 kPa	Shell

Slice 4	71.489707	19.905642 m	15.369322	34.640786 kPa	7.2436672 kPa	17.67	0 kPa	Core
Slice 5	73.7502 m	17.135871 m	9.8066254	69.349632 kPa	22.380745 kPa	17.67	0 kPa	Core
Slice 6	76.0752 m	14.367309 m	-8.3780315	102.30792 kPa	38.455018 kPa	17.67	0 kPa	Core
Slice 7	77.238725	13.155268 m	-19.915359	120.16884 kPa	45.168498 kPa	17.67	0 kPa	Core
Slice 8	78.163725	12.209245 m	-29.798382	135.41463 kPa	50.899014 kPa	17.67	0 kPa	Core
Slice 9	80.161209	10.390029 m	-52.514062	143.62135 kPa	53.983717 kPa	17.67	0 kPa	Core
Slice 10	83.461205	7.5551335 m	-45.924967	146.89555 kPa	91.790529 kPa	0 kPa	0 kPa	Filter
Slice 11	86.575194	5.2464109 m	-28.079843	150.20946 kPa	113.19095 kPa	4.66 kPa	0 kPa	Shell
Slice 12	90.025198	2.9865414 m	-15.516056	164.62966 kPa	124.05735 kPa	4.66 kPa	0 kPa	Shell
Slice 13	92.414296	1.5672524 m	-3.31498 kPa	177.33768 kPa	133.63352 kPa	4.66 kPa	0 kPa	Shell
Slice 14	94.414291	0.52052187 m	6.6652616	200.53078 kPa	121.14062 kPa	0 kPa	0 kPa	Filter
Slice 15	95.897991	-0.22949563	14.014918	215.52808 kPa	125.9194 kPa	0 kPa	0 kPa	Filter
Slice 16	97.516232	-0.9530569 m	21.153738	225.10209 kPa	99.472256 kPa	1 kPa	0 kPa	Foundation 1
Slice 17	100.45711	-2.1750657 m	33.260773	237.28824 kPa	99.510845 kPa	1 kPa	0 kPa	Foundation 1
Slice 18	103.39799	-3.233462 m	43.702256	247.48018 kPa	99.389135 kPa	1 kPa	0 kPa	Foundation 1
Slice 19	106.33886	-4.1365333 m	52.574964	255.59768 kPa	99.020794 kPa	1 kPa	0 kPa	Foundation 1
Slice 20	109.27974	-4.8909115 m	59.954125	261.453 kPa	98.277566 kPa	1 kPa	0 kPa	Foundation 1
Slice 21	112.75019	-5.5822258 m	66.733284	276.43823 kPa	102.27994 kPa	1 kPa	0 kPa	Foundation 1
Slice 22	116.23698	-6.1113171 m	71.923084	288.57939 kPa	105.67034 kPa	1 kPa	0 kPa	Foundation 1

Appendix I11: Geometry data-cross sectional data (XS Cut lines) and manning values

HEC-RAS MANNING VALUES

River	Reach	River Station	Fractn (n/K)	n	#1	n #2	n #3
1	River Mishumba	Upper Reach	14584.41 n	0.02	0.03	0.04	
2	River Mishumba	Upper Reach	14559.33 n	0.02	0.03	0.04	
3	River Mishumba	Upper Reach	14533.95 n	0.02	0.03	0.04	
4	River Mishumba	Upper Reach	14503.92 n	0.02	0.03	0.04	
5	River Mishumba	Upper Reach	14483.39 n	0.02	0.03	0.04	
6	River Mishumba	Upper Reach	14466.61 n	0.02	0.03	0.04	
7	River Mishumba	Upper Reach	14431.26 n	0.02	0.03	0.04	
8	River Mishumba	Upper Reach	14410.92 n	0.02	0.03	0.04	
9	River Mishumba	Upper Reach	14389.66 n	0.02	0.03	0.04	
10	River Mishumba	Upper Reach	14364.46 n	0.02	0.03	0.04	
11	River Mishumba	Upper Reach	14346.64 n	0.02	0.03	0.04	
12	River Mishumba	Upper Reach	14326.56 n	0.02	0.03	0.04	
13	River Mishumba	Upper Reach	14301.46 n	0.02	0.03	0.04	
14	River Mishumba	Upper Reach	14282.91 n	0.02	0.03	0.04	
15	River Mishumba	Upper Reach	14261.86 n	0.02	0.03	0.04	
16	River Mishumba	Upper Reach	14243.45 n	0.02	0.03	0.04	
17	River Mishumba	Upper Reach	14220.7 n	0.02	0.03	0.04	
18	River Mishumba	Upper Reach	14197.78 n	0.02	0.03	0.04	
19	River Mishumba	Upper Reach	14181.82 n	0.02	0.03	0.04	
20	River Mishumba	Upper Reach	14160.94 n	0.02	0.03	0.04	
21	River Mishumba	Upper Reach	14138.05 n	0.02	0.03	0.04	
22	River Mishumba	Upper Reach	14115.05 n	0.02	0.03	0.04	
23	River Mishumba	Upper Reach	14090.61 n	0.02	0.03	0.04	
24	River Mishumba	Upper Reach	14069.91 n	0.02	0.03	0.04	
25	River Mishumba	Upper Reach	14033.3 n	0.02	0.03	0.04	
26	River Mishumba	Upper Reach	14004.16 n	0.02	0.03	0.04	
27	River Mishumba	Upper Reach	13972.51 n	0.02	0.03	0.04	
28	River Mishumba	Upper Reach	13943.79 n	0.02	0.03	0.04	
29	River Mishumba	Upper Reach	13918.41 n	0.02	0.03	0.04	
30	River Mishumba	Upper Reach	13889.85 n	0.02	0.03	0.04	

31	River Mishumba	Upper Reach	13860.81	n	0.02	0.03	0.04
32	River Mishumba	Upper Reach	13827.25	n	0.02	0.03	0.04
33	River Mishumba	Upper Reach	13792.16	n	0.02	0.03	0.04
34	River Mishumba	Upper Reach	13764.74	n	0.02	0.03	0.04
35	River Mishumba	Upper Reach	13725.6	n	0.02	0.03	0.04
36	River Mishumba	Upper Reach	13693.3	n	0.02	0.03	0.04
37	River Mishumba	Upper Reach	13663.01	n	0.02	0.03	0.04
38	River Mishumba	Upper Reach	13629.52	n	0.02	0.03	0.04
39	River Mishumba	Upper Reach	13591.87	n	0.02	0.03	0.04
40	River Mishumba	Upper Reach	13547.05	n	0.02	0.03	0.04
41	River Mishumba	Upper Reach	13511.25	n	0.02	0.03	0.04
42	River Mishumba	Upper Reach	13463.91	n	0.02	0.03	0.04
43	River Mishumba	Upper Reach	13414.84	n	0.02	0.03	0.04
44	River Mishumba	Upper Reach	13348.59	n	0.02	0.03	0.04
45	River Mishumba	Upper Reach	13294.97	n	0.02	0.03	0.04
46	River Mishumba	Upper Reach	13241.74	n	0.02	0.03	0.04
47	River Mishumba	Upper Reach	13165.89	n	0.02	0.03	0.04
48	River Mishumba	Upper Reach	13085.38	n	0.02	0.03	0.04
49	River Mishumba	Upper Reach	13001.05	n	0.02	0.03	0.04
50	River Mishumba	Upper Reach	12937.54	n	0.02	0.03	0.04
51	River Mishumba	Upper Reach	12835.33	n	0.02	0.03	0.04
52	River Mishumba	Upper Reach	12714.05	n	0.02	0.03	0.04
53	River Mishumba	Upper Reach	12638.87	n	0.02	0.03	0.04
54	River Mishumba	Upper Reach	12526.29	n	0.02	0.03	0.04
55	River Mishumba	Upper Reach	12462.2	n	0.03	0.04	0.05
56	River Mishumba	Upper Reach	12381.1	n	0.03	0.04	0.05
57	River Mishumba	Upper Reach	12300.29	n	0.03	0.04	0.05
58	River Mishumba	Upper Reach	12216.21	n	0.03	0.04	0.05
59	River Mishumba	Upper Reach	12117.19	n	0.03	0.04	0.05
60	River Mishumba	Upper Reach	12015.68	n	0.03	0.04	0.05
61	River Mishumba	Upper Reach	11913.18	n	0.03	0.04	0.05
62	River Mishumba	Upper Reach	11841.5	n	0.03	0.04	0.05
63	River Mishumba	Upper Reach	11750.48	n	0.03	0.04	0.05
64	River Mishumba	Upper Reach	11672.85	n	0.03	0.04	0.05
65	River Mishumba	Upper Reach	11612.51	n	0.03	0.04	0.05
66	River Mishumba	Upper Reach	11521.91	n	0.03	0.04	0.05
67	River Mishumba	Upper Reach	11427.56	n	0.03	0.04	0.05
68	River Mishumba	Upper Reach	11354.76	n	0.03	0.04	0.05
69	River Mishumba	Upper Reach	11187.07	n	0.03	0.04	0.05
70	River Mishumba	Upper Reach	11129.08	n	0.03	0.04	0.05
71	River Mishumba	Upper Reach	11062.6	n	0.03	0.04	0.05
72	River Mishumba	Upper Reach	10971.28	n	0.03	0.04	0.05
73	River Mishumba	Upper Reach	10897.52	n	0.03	0.04	0.05
74	River Mishumba	Upper Reach	10813.52	n	0.03	0.04	0.05
75	River Mishumba	Upper Reach	10758.27	n	0.03	0.04	0.05
76	River Mishumba	Upper Reach	10657.86	n	0.03	0.04	0.05
77	River Mishumba	Upper Reach	10551.23	n	0.03	0.04	0.05
78	River Mishumba	Upper Reach	10462.74	n	0.03	0.04	0.05
79	River Mishumba	Upper Reach	10373.41	n	0.03	0.04	0.05
80	River Mishumba	Upper Reach	10291.12	n	0.03	0.04	0.05
81	River Mishumba	Upper Reach	10144.87	n	0.03	0.04	0.05
82	River Mishumba	Upper Reach	10027.02	n	0.03	0.04	0.05
83	River Mishumba	Upper Reach	9946.806	n	0.03	0.04	0.05
84	River Mishumba	Upper Reach	9847.863	n	0.03	0.04	0.05
85	River Mishumba	Upper Reach	9779.899	n	0.03	0.04	0.05
86	River Mishumba	Upper Reach	9731.866	n	0.03	0.04	0.05
87	River Mishumba	Upper Reach	9691.515	n	0.03	0.04	0.05
88	River Mishumba	Lower reach	9042.747	n	0.02	0.03	0.04
89	River Mishumba	Lower reach	8977.704	n	0.02	0.03	0.04
90	River Mishumba	Lower reach	8859.702	n	0.02	0.03	0.04
91	River Mishumba	Lower reach	8567.291	n	0.02	0.03	0.04
92	River Mishumba	Lower reach	8453.299	n	0.02	0.03	0.04
93	River Mishumba	Lower reach	8375.701	n	0.02	0.03	0.04
94	River Mishumba	Lower reach	8223.878	n	0.02	0.03	0.04
95	River Mishumba	Lower reach	7885.918	n	0.02	0.03	0.04
96	River Mishumba	Lower reach	7747.599	n	0.02	0.03	0.04
97	River Mishumba	Lower reach	7623.125	n	0.02	0.03	0.04
98	River Mishumba	Lower reach	7441.803	n	0.02	0.03	0.04
99	River Mishumba	Lower reach	7288.921	n	0.02	0.03	0.04
100	River Mishumba	Lower reach	7076.918	n	0.02	0.03	0.04
101	River Mishumba	Lower reach	6806.991	n	0.02	0.03	0.04
102	River Mishumba	Lower reach	6622.221	n	0.02	0.03	0.04

103	River Mishumba	Lower reach	6413.087	n	0.02	0.03	0.04
104	River Mishumba	Lower reach	6185.547	n	0.02	0.03	0.04
105	River Mishumba	Lower reach	5988.699	n	0.02	0.03	0.04
106	River Mishumba	Lower reach	5891.799	n	0.02	0.03	0.04
107	River Mishumba	Lower reach	5632.233	n	0.02	0.03	0.04
108	River Mishumba	Lower reach	5366.145	n	0.02	0.03	0.04
109	River Mishumba	Lower reach	5037.705	n	0.25	0.3	0.35
110	River Mishumba	Lower reach	4927.793	n	0.25	0.3	0.35
111	River Mishumba	Lower reach	4828.372	n	0.25	0.3	0.35
112	River Mishumba	Lower reach	4728.166	n	0.25	0.3	0.35
113	River Mishumba	Lower reach	4631.004	n	0.25	0.3	0.35
114	River Mishumba	Lower reach	4335.435	n	0.25	0.3	0.35
115	River Mishumba	Lower reach	4158.668	n	0.25	0.3	0.35
116	River Mishumba	Lower reach	4090.013	n	0.25	0.3	0.35
117	River Mishumba	Lower reach	3756.224	n	0.25	0.3	0.35
118	River Mishumba	Lower reach	3597.953	n	0.25	0.3	0.35
119	River Mishumba	Lower reach	3496.718	n	0.25	0.3	0.35
120	River Mishumba	Lower reach	3360.628	n	0.25	0.3	0.35
121	River Mishumba	Lower reach	3240.364	n	0.25	0.3	0.35
122	River Mishumba	Lower reach	3052.193	n	0.25	0.3	0.35
123	River Mishumba	Lower reach	2911.013	n	0.25	0.3	0.35
124	River Mishumba	Lower reach	2785.885	n	0.25	0.3	0.35
125	River Mishumba	Lower reach	2708.918	n	0.25	0.3	0.35
126	River Mishumba	Lower reach	2536.962	n	0.25	0.3	0.35
127	River Mishumba	Lower reach	2425.888	n	0.25	0.3	0.35
128	River Mishumba	Lower reach	2335.387	n	0.25	0.3	0.35
129	River Mishumba	Lower reach	2191.086	n	0.25	0.3	0.35
130	River Mishumba	Lower reach	2050.006	n	0.25	0.3	0.35
131	River Mishumba	Lower reach	1895.047	n	0.25	0.3	0.35
132	River Mishumba	Lower reach	1627.075	n	0.25	0.3	0.35
133	River Mishumba	Lower reach	1444.054	n	0.02	0.03	0.04
134	River Mishumba	Lower reach	1260.164	n	0.02	0.03	0.04
135	River Mishumba	Lower reach	1129.119	n	0.02	0.03	0.04
136	River Mishumba	Lower reach	992.1949	n	0.02	0.03	0.04
137	River Mishumba	Lower reach	783.3875	n	0.02	0.03	0.04
138	River Mishumba	Lower reach	662.7925	n	0.02	0.03	0.04
139	River Mishumba	Lower reach	540.2328	n	0.02	0.03	0.04
140	River Mishumba	Lower reach	445.0293	n	0.02	0.03	0.04
141	River Mishumba	Lower reach	378.6594	n	0.02	0.03	0.04
142	River Mishumba	Lower reach	294.8082	n	0.02	0.03	0.04
143	River Mishumba	Lower reach	216.8494	n	0.02	0.03	0.04
144	River Mishumba	Lower reach	153.2006	n	0.02	0.03	0.04
145	River Mishumba	Lower reach	99.20635	n	0.02	0.03	0.04
146	River Shezho	Tributary	1180.451	n	0.03	0.04	0.05
147	River Shezho	Tributary	1093.71	n	0.03	0.04	0.05
148	River Shezho	Tributary	1012.03	n	0.03	0.04	0.05
149	River Shezho	Tributary	918.8026	n	0.03	0.04	0.05
150	River Shezho	Tributary	793.5311	n	0.03	0.04	0.05
151	River Shezho	Tributary	750.4226	n	0.03	0.04	0.05
152	River Shezho	Tributary	691.0597	n	0.03	0.04	0.05
153	River Shezho	Tributary	608.8555	n	0.03	0.04	0.05
154	River Shezho	Tributary	547.94	n	0.03	0.035	0.05
155	River Shezho	Tributary	479.3273	n	0.03	0.035	0.05
156	River Shezho	Tributary	405.7719	n	0.03	0.035	0.05
157	River Shezho	Tributary	329.5435	n	0.03	0.035	0.05
158	River Shezho	Tributary	265.3571	n	0.03	0.035	0.05

River Geometry

Shape *	OID *	Shape_Length	HydroID	River	Reach	FromNode	ToNode	ArcLength	FromSta	ToSta	Area (km)
Polyline	1	15087.30583	1	River Mishumba	Main	1	2	15087.31	0	15087.31	15.1
Polyline	2	345.30583	2	River Shezho	Tributary	1	2	345.31	0	345.31	1.3

River banks

Shape *	OID *	Shape_Length	HydroID	Area (Km)
Polyline	1	14759.4107	2	14.759411
Polyline	2	14865.79955	3	14.8658

River centerlines-channel, Left and Right

Shape *	OID *	Shape_Length	LineType	Area
Polyline	1	15087.30583	Channel	15.087306
Polyline	2	14571.4004	Left	14.5714
Polyline	3	14895.7464	Right	14.895746

Appendix IV: Dam design data

In the detailed design, the main geometrical characteristics of Kabuyanda earth fill dam were:

- Storage Capacity : 8.8Mm3.
- Max crest length (length of dam) : 314m.
- Max dam height from foundation : 33.80m.
- Top width of Dam : 9m.
- Upstream slope : 2.25:1+2.5:1+2.5:1(h/v).
- Downstream slope : 2.25:1+2.5:1(h/v).
- Base width (upstream to downstream toe): 160m.
- Max dam height from the river bed : 26.45m.

Foundation and weir data

River Bed	-0+18.50 to +0+12.70m – 6 -7m deep, going 1.0 m into bed rock, quartzite
Main Valley	Ch -0+18.50 to -0+145, 6m deep COT
Left Flank Bank	- 0+145 to -0+180 - 4.0 m depth - 0++180 to -0+197 – 1.0m depth or equivalent to Hydraulic head -0+197 to -0+208 - Above FRL, a nominal key trench
Right Flank Bank	+ 0+12.70 to +0+25.00 - 6.0 m depth +0+25.00 to -0+68.00 - 4 m depth +0+68.00 to -0+90.00 – 1.0 m into impervious soils or equivalent to FRL depth 0+90 to +0+106 - This stretch is above FRL, hence a nominal key trench is provided

Material	**Dam Unit weight (kN/m3)**	**Cohesion**	**Phi (deg)**	**Saturated Permeability (kx) (m/s)**	**Effective Young's modulus(kPa)**	**Poisson's ratio**	**Lambda**	**Kappa**	**Over consolidation ratio**	**Initial void ratio**
Core	16.67	17.67	20.6	4.905e-10	25000	0.3				
COT	16.67	17.67	20.6	4.905e-10	25000	0.3				
Filter	19.2	0	32	1e-04	20000	0.3				
Rock Toe	20	0	36	1e-03	30000	0.3				
Shell	14.8	4.66	37	1e-07	20000	0.3				
Rip Rap	22	100	35	1e-05	30000	0.3				
Foundation 1	19	1	26	1e-06	20000	0.3	0.09	0.03	10	0.78
Foundation 2	19.7	1	32	1e-07	20000	0.3	0.09	0.03	6	0.78
Foundation 3	19	1	32	5e-08	30000	0.3				
Foundation 4	22	100	36	5e-08	200000	0.3				

Water level hydraulic channel Barrel Centre line stations calculations

River Station (m)	Q Total	Min Ch El	W.S. Elev	Vel Chn	Flow Area	Top Width
	(m^3/s)	(m)	(m)	(m/s)	(m^2)	(m)
250	4.90	1335.20	1336.00	0.20	24.98	44.17
200	4.90	1335.30	1335.81	1.64	2.99	11.14
150	4.90	1334.49	1334.98	0.31	16.54	48.12
100	4.90	1334.52	1334.93	0.30	17.04	55.62
50	4.90	1334.43	1334.77	0.84	5.99	26.96
0	4.90	1333.95	1334.51	0.56	8.67	23.33

Dam stability values

S. No	Load Cases	Slope Side		SF_{min}	Section A	Section B	Section C
					@ Ch -44.00m	@ Ch 30.00m	@ Ch 0.00m
		Height of Dam above Ground Level			23.5 m	21.15 m	26.55 m
1	EOC	U/S		1.30	1.600	1.639	1.659
		D/S		1.30	1.540	1.567	1.548
2	FSL	D/S		1.50	1.520	1.532	1.548
3	FSL+OBE	U/S		1.20	1.308	1.395	1.317
		D/S		1.20	1.217	1.268	1.294
4	FSL+MDE	U/S		1.00	1.071	1.140	1.075
		D/S		1.00	1.066	1.010	1.134
5	RDD (FRL TO MDDL)	U/S		1.30	1.333	1.332	1.360
6	FL	D/S		1.20	1.533	1.532	1.552
7	RDD (FL TO FRL)	U/S		1.30	1.527	1.774	1.652

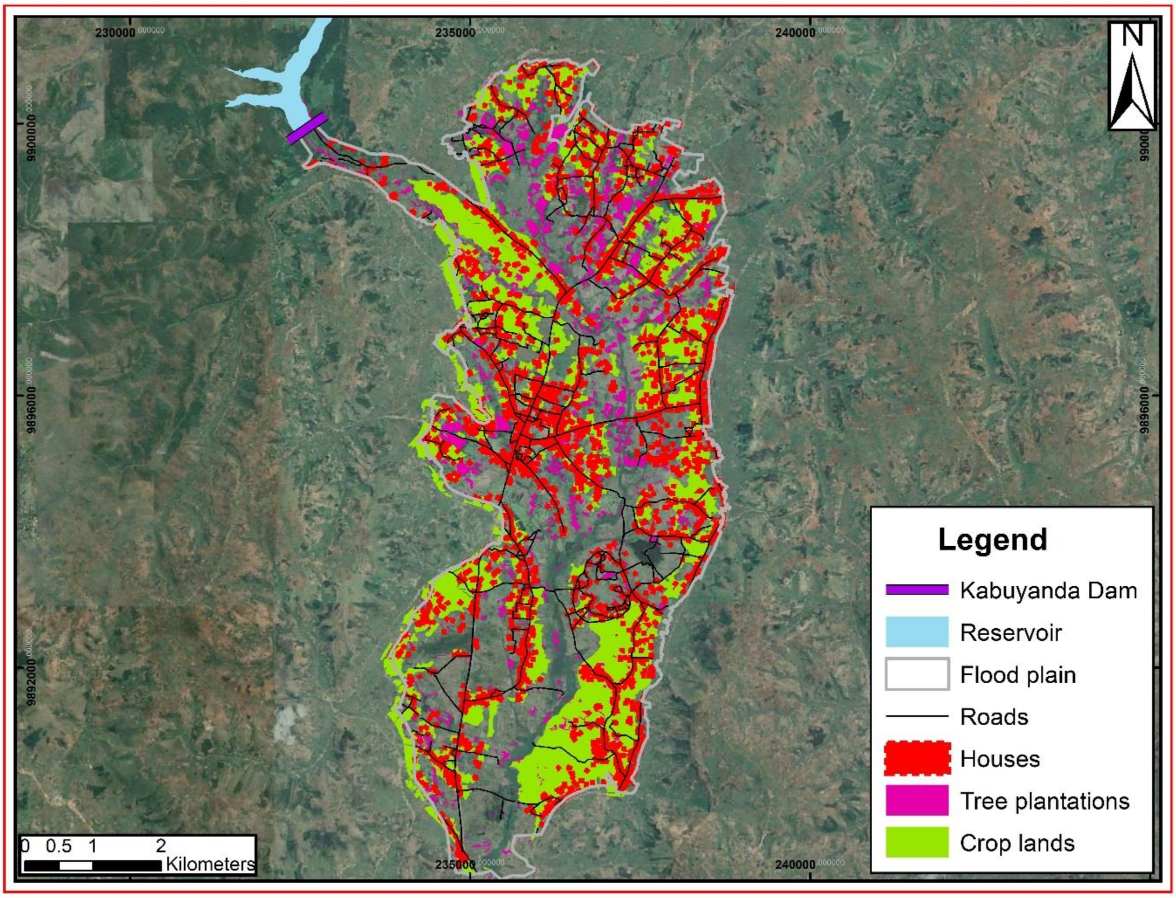
Effective Fetch calculations

□ (Degrees)	cos □	Xi	Xi cos □	Xi .cos□ □ cos □
45	0.707	93.000	65.76	46.50
42	0.743	126.000	93.64	69.59
39	0.777	156.000	121.23	94.22
36	0.809	189.000	152.90	123.70
33	0.839	341.000	285.99	239.85
30	0.866	676.000	585.43	507.00
27	0.891	666.000	593.41	528.73
24	0.914	673.000	614.82	561.66
21	0.934	721.000	673.11	628.40
18	0.951	947.000	900.65	856.57
15	0.966	952.000	919.56	888.23

12	0.978	1053.000	1029.99	1007.48
9	0.988	1108.000	1094.36	1080.89
6	0.995	1180.000	1173.54	1167.11
3	0.999	1221.000	1219.33	1217.66
0	1.000	1400.000	1400.00	1400.00
3	0.999	550.000	549.25	548.49
6	0.995	501.000	498.26	495.53
9	0.988	480.000	474.09	468.25
12	0.978	463.000	452.88	442.99
15	0.966	441.000	425.97	411.46
18	0.951	413.000	392.79	373.56
21	0.934	383.000	357.56	333.81
24	0.914	354.000	323.40	295.44
27	0.891	338.000	301.16	268.34
30	0.866	329.000	284.92	246.75
33	0.839	319.000	267.54	224.37
36	0.809	309.000	249.99	202.24
39	0.777	300.000	233.14	181.19
42	0.743	293.000	217.74	161.81
45	0.707	288.000	203.65	144.00
	27.710			15215.810

Effective Fetch		549.10
	m say	0.549
	km	
Max. Fetch		1400.00
	m say	1.400
	km	

Appendix V: Digitized datasets from high resolution image of Google Earth



Appendix VI: Crop lands

FID	Shape *	Name	tessellate	extrude	visibility	drawOrder	Area (hec)
0	Polygon ZM	Untitled Polygon	1	0	-1	0	7.21576
1	Polygon ZM	Untitled Polygon	1	0	-1	0	317.814633
2	Polygon ZM	Untitled Polygon	1	0	-1	0	0.939516
3	Polygon ZM	Untitled Polygon	1	0	-1	0	0.300291
4	Polygon ZM	Untitled Polygon	1	0	-1	0	5.835747
5	Polygon ZM	Untitled Polygon	1	0	-1	0	0.485663
6	Polygon ZM	Untitled Polygon	1	0	-1	0	0.885061
7	Polygon ZM	Untitled Polygon	1	0	-1	0	1.176462
8	Polygon ZM	Untitled Polygon	1	0	-1	0	2.117906
9	Polygon ZM	Untitled Polygon	1	0	-1	0	50.667631
10	Polygon ZM	Untitled Polygon	1	0	-1	0	5.426642
11	Polygon ZM	Untitled Polygon	1	0	-1	0	3.453693
12	Polygon ZM	Untitled Polygon	1	0	-1	0	13.009779
13	Polygon ZM	Untitled Polygon	1	0	-1	0	0.347529
14	Polygon ZM	Untitled Polygon	1	0	-1	0	12.775675
15	Polygon ZM	Untitled Polygon	1	0	-1	0	0.892113

16	Polygon ZM	Untitled Polygon	1	0	-1	0	8.893133
17	Polygon ZM	Untitled Polygon	1	0	-1	0	1.336086
18	Polygon ZM	Untitled Polygon	1	0	-1	0	0.249817
19	Polygon ZM		1	0	-1	0	14.421135
20	Polygon ZM	Untitled Polygon	1	0	-1	0	44.718777
21	Polygon ZM	Untitled Polygon	1	0	-1	0	21.051218
22	Polygon ZM	Untitled Polygon	1	0	-1	0	70.698152
23	Polygon ZM	Untitled Polygon	1	0	-1	0	60.617103
24	Polygon ZM	Untitled Polygon	1	0	-1	0	5.783524
25	Polygon ZM	Untitled Polygon	1	0	-1	0	0.290544
26	Polygon ZM	Untitled Polygon	1	0	-1	0	1.967369
27	Polygon ZM	Untitled Polygon	1	0	-1	0	2.700231
28	Polygon ZM	Untitled Polygon	1	0	-1	0	1.203177
29	Polygon ZM	Untitled Polygon	1	0	-1	0	0.392343
30	Polygon ZM	Untitled Polygon	1	0	-1	0	0.67269
31	Polygon ZM	Untitled Polygon	1	0	-1	0	0.36483
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35	Polygon ZM	Untitled Polygon	1	0	-1	0	0.139332
36	Polygon ZM	Untitled Polygon	1	0	-1	0	0.283471
37	Polygon ZM	Untitled Polygon	1	0	-1	0	6.42734
38	Polygon ZM	Untitled Polygon	1	0	-1	0	8.500883
39	Polygon ZM	Untitled Polygon	1	0	-1	0	18.066378
40	Polygon ZM	Untitled Polygon	1	0	-1	0	14.746513
41	Polygon ZM	Untitled Polygon	1	0	-1	0	49.945697
42	Polygon ZM	Untitled Polygon	1	0	-1	0	2.331284
43	Polygon ZM	Untitled Polygon	1	0	-1	0	39.204757
44	Polygon ZM	Untitled Polygon	1	0	-1	0	39.663796
45	Polygon ZM	Untitled Polygon	1	0	-1	0	5.212704
46	Polygon ZM	Untitled Polygon	1	0	-1	0	3.365166
47	Polygon ZM	Untitled Polygon	1	0	-1	0	1.561288
48	Polygon ZM	Untitled Polygon	1	0	-1	0	0.286937
49	Polygon ZM	Untitled Polygon	1	0	-1	0	0.652709
50	Polygon ZM	Untitled Polygon	1	0	-1	0	1.575513
51	Polygon ZM	Untitled Polygon	1	0	-1	0	0.463834
52	Polygon ZM	Untitled Polygon	1	0	-1	0	1.340468
53	Polygon ZM	Untitled Polygon	1	0	-1	0	0.474719
54	Polygon ZM	Untitled Polygon	1	0	-1	0	11.630021
55	Polygon ZM	Untitled Polygon	1	0	-1	0	2.653181
56	Polygon ZM	Untitled Polygon	1	0	-1	0	6.156971
57	Polygon ZM	Untitled Polygon	1	0	-1	0	2.288933
58	Polygon ZM	Untitled Polygon	1	0	-1	0	6.070532

59	Polygon ZM	Untitled Polygon	1	0	-1	0	2.12823
60	Polygon ZM	Untitled Polygon	1	0	-1	0	0.616137
61	Polygon ZM	Untitled Polygon	1	0	-1	0	0.874225
62	Polygon ZM	Untitled Polygon	1	0	-1	0	1.699319
63	Polygon ZM	Untitled Polygon	1	0	-1	0	1.405047
64	Polygon ZM	Untitled Polygon	1	0	-1	0	6.494186
65	Polygon ZM	Untitled Polygon	1	0	-1	0	3.352598
66	Polygon ZM	Untitled Polygon	1	0	-1	0	2.660946
67	Polygon ZM	Untitled Polygon	1	0	-1	0	0.436846
68	Polygon ZM	Untitled Polygon	1	0	-1	0	1.296798
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70	Polygon ZM	Untitled Polygon	1	0	-1	0	1.303161
71	Polygon ZM	Untitled Polygon	1	0	-1	0	0.758916
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73	Polygon ZM	Untitled Polygon	1	0	-1	0	1.089094
74	Polygon ZM	Untitled Polygon	1	0	-1	0	2.805824
75	Polygon ZM	Untitled Polygon	1	0	-1	0	1.607397
76	Polygon ZM	Untitled Polygon	1	0	-1	0	9.643107
77	Polygon ZM	Untitled Polygon	1	0	-1	0	20.089604
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		Polygon						
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116	Polygon ZM	Untitled Polygon	1	0	-1	0	21.323151
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122	Polygon ZM	Untitled Polygon	1	0	-1	0	0.629552
123	Polygon ZM	Untitled Polygon	1	0	-1	0	0.376655
124	Polygon ZM	Untitled Polygon	1	0	-1	0	1.223123
125	Polygon ZM	Untitled Polygon	1	0	-1	0	1.720829
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127	Polygon ZM	Untitled Polygon	1	0	-1	0	3.205475
128	Polygon ZM	Untitled Polygon	1	0	-1	0	26.524122
129	Polygon ZM	Untitled Polygon	1	0	-1	0	6.676539
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132	Polygon ZM	Untitled Polygon	1	0	-1	0	3.546986
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134	Polygon ZM	Untitled Polygon	1	0	-1	0	3.654638
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141	Polygon ZM	Untitled Polygon	1	0	-1	0	3.658427
142	Polygon ZM	Untitled Polygon	1	0	-1	0	4.126456
143	Polygon ZM	Untitled Polygon	1	0	-1	0	1.853973

144	Polygon ZM	Untitled Polygon	1	0	-1	0	3.406956
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148	Polygon ZM	Untitled Polygon	1	0	-1	0	2.367918
149	Polygon ZM	Untitled Polygon	1	0	-1	0	0.543833
150	Polygon ZM	Untitled Polygon	1	0	-1	0	0.175739
151	Polygon ZM	Untitled Polygon	1	0	-1	0	0.910579
152	Polygon ZM	Untitled Polygon	1	0	-1	0	4.193737
153	Polygon ZM	Untitled Polygon	1	0	-1	0	0.886902
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155	Polygon ZM	Untitled Polygon	1	0	-1	0	3.135706
156	Polygon ZM	Untitled Polygon	1	0	-1	0	0.738177

Appendix VII: Tree Plantations

FID	Shape *	Name	tessellate	extrude	visibility	drawOrder	Area (hac)
0	Polygon ZM	Untitled Polygon	1	0	-1	0	3.971665
1	Polygon ZM	Untitled Polygon	1	0	-1	0	0.55894
2	Polygon ZM	Untitled Polygon	1	0	-1	0	0.470552
3	Polygon ZM	Untitled Polygon	1	0	-1	0	0.52289
4	Polygon ZM	Untitled Polygon	1	0	-1	0	0.216375
5	Polygon ZM	Untitled Polygon	1	0	-1	0	0.363024
6	Polygon ZM	Untitled Polygon	1	0	-1	0	0.279742
7	Polygon ZM	Untitled Polygon	1	0	-1	0	0.259693
8	Polygon ZM	Untitled Polygon	1	0	-1	0	2.666724
9	Polygon ZM	Untitled Polygon	1	0	-1	0	0.361249
10	Polygon ZM	Untitled Polygon	1	0	-1	0	0.972449
11	Polygon ZM	Untitled Polygon	1	0	-1	0	0.833468
12	Polygon ZM	Untitled Polygon	1	0	-1	0	0.20463
13	Polygon ZM	Untitled Polygon	1	0	-1	0	1.887777
14	Polygon ZM	Untitled Polygon	1	0	-1	0	0.185515
15	Polygon ZM	Untitled Polygon	1	0	-1	0	0.340769
16	Polygon ZM	Untitled Polygon	1	0	-1	0	0.21038
17	Polygon ZM	Untitled Polygon	1	0	-1	0	2.409077
18	Polygon ZM	Untitled Polygon	1	0	-1	0	1.24632
19	Polygon ZM	Untitled Polygon	1	0	-1	0	0.528144
20	Polygon ZM	Untitled Polygon	1	0	-1	0	0.115558
21	Polygon ZM	Untitled Polygon	1	0	-1	0	0.337389
22	Polygon ZM	Untitled Polygon	1	0	-1	0	1.638409
23	Polygon ZM	Untitled Polygon	1	0	-1	0	4.377232
24	Polygon ZM	Untitled Polygon	1	0	-1	0	0.59815
25	Polygon ZM	Untitled Polygon	1	0	-1	0	8.01528
26	Polygon ZM	Untitled Polygon	1	0	-1	0	0.257515
27	Polygon ZM	Untitled Polygon	1	0	-1	0	2.705293
28	Polygon ZM	Untitled Polygon	1	0	-1	0	1.070099
29	Polygon ZM	Untitled Polygon	1	0	-1	0	0.126217
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31	Polygon ZM	Untitled Polygon	1	0	-1	0	0.163417
32	Polygon ZM	Untitled Polygon	1	0	-1	0	0.322644
33	Polygon ZM	Untitled Polygon	1	0	-1	0	0.140245
34	Polygon ZM	Untitled Polygon	1	0	-1	0	0.12292
35	Polygon ZM	Untitled Polygon	1	0	-1	0	0.028007
36	Polygon ZM	Untitled Polygon	1	0	-1	0	0.391539
37	Polygon ZM	Untitled Polygon	1	0	-1	0	0.201703
38	Polygon ZM	Untitled Polygon	1	0	-1	0	1.417792
39	Polygon ZM	Untitled Polygon	1	0	-1	0	0.057269

40	Polygon ZM	Untitled Polygon	1	0	-1	0	2.004835
41	Polygon ZM	Untitled Polygon	1	0	-1	0	0.277514
42	Polygon ZM	Untitled Polygon	1	0	-1	0	1.738748
43	Polygon ZM	Untitled Polygon	1	0	-1	0	1.030153
44	Polygon ZM	Untitled Polygon	1	0	-1	0	1.122451
45	Polygon ZM	Untitled Polygon	1	0	-1	0	0.264708
46	Polygon ZM	Untitled Polygon	1	0	-1	0	1.299693
47	Polygon ZM	Untitled Polygon	1	0	-1	0	0.300528
48	Polygon ZM	Untitled Polygon	1	0	-1	0	0.107337
49	Polygon ZM	Untitled Polygon	1	0	-1	0	0.158097
50	Polygon ZM	Untitled Polygon	1	0	-1	0	3.642299
51	Polygon ZM	Untitled Polygon	1	0	-1	0	3.543185
52	Polygon ZM	Untitled Polygon	1	0	-1	0	0.122605
53	Polygon ZM	Untitled Polygon	1	0	-1	0	0.445809
54	Polygon ZM	Untitled Polygon	1	0	-1	0	0.407925
55	Polygon ZM	Untitled Polygon	1	0	-1	0	0.793189
56	Polygon ZM	Untitled Polygon	1	0	-1	0	0.959703
57	Polygon ZM	Untitled Polygon	1	0	-1	0	1.385124
58	Polygon ZM	Untitled Polygon	1	0	-1	0	0.18245
59	Polygon ZM	Untitled Polygon	1	0	-1	0	1.743721
60	Polygon ZM	Untitled Polygon	1	0	-1	0	0.941047
61	Polygon ZM	Untitled Polygon	1	0	-1	0	1.26405
62	Polygon ZM	Untitled Polygon	1	0	-1	0	2.759195
63	Polygon ZM	Untitled Polygon	1	0	-1	0	0.538678
64	Polygon ZM	Untitled Polygon	1	0	-1	0	0.312799
65	Polygon ZM	Untitled Polygon	1	0	-1	0	0.222152
66	Polygon ZM	Untitled Polygon	1	0	-1	0	0.067476
67	Polygon ZM	Untitled Polygon	1	0	-1	0	0.2603
68	Polygon ZM	Untitled Polygon	1	0	-1	0	0.071332
69	Polygon ZM	Untitled Polygon	1	0	-1	0	1.379679
70	Polygon ZM	Untitled Polygon	1	0	-1	0	0.74943
71	Polygon ZM	Untitled Polygon	1	0	-1	0	0.183778
72	Polygon ZM	Untitled Polygon	1	0	-1	0	0.165816
73	Polygon ZM	Untitled Polygon	1	0	-1	0	0.26514
74	Polygon ZM	Untitled Polygon	1	0	-1	0	0.151547
75	Polygon ZM	Untitled Polygon	1	0	-1	0	0.194379
180	Polygon ZM	Untitled Polygon	1	0	-1	0	0.294997
181	Polygon ZM	Untitled Polygon	1	0	-1	0	0.126884
182	Polygon ZM	Untitled Polygon	1	0	-1	0	0.134172
183	Polygon ZM	Untitled Polygon	1	0	-1	0	0.176887
184	Polygon ZM	Untitled Polygon	1	0	-1	0	0.264371
185	Polygon ZM	Untitled Polygon	1	0	-1	0	0.36053
186	Polygon ZM	Untitled	1	0	-1	0	0.661121

		Polygon					
187	Polygon ZM	Untitled Polygon	1	0	-1	0	0.444883
188	Polygon ZM	Untitled Polygon	1	0	-1	0	0.72697
189	Polygon ZM	Untitled Polygon	1	0	-1	0	0.24092
190	Polygon ZM	Untitled Polygon	1	0	-1	0	0.166933
191	Polygon ZM	Untitled Polygon	1	0	-1	0	0.128502
192	Polygon ZM	Untitled Polygon	1	0	-1	0	0.200333
193	Polygon ZM	Untitled Polygon	1	0	-1	0	0.164847
194	Polygon ZM	Untitled Polygon	1	0	-1	0	0.54259
195	Polygon ZM	Untitled Polygon	1	0	-1	0	0.439218
196	Polygon ZM	Untitled Polygon	1	0	-1	0	0.250927
197	Polygon ZM	Untitled Polygon	1	0	-1	0	0.753043
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199	Polygon ZM	Untitled Polygon	1	0	-1	0	0.777944
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201	Polygon ZM	Untitled Polygon	1	0	-1	0	0.257184
202	Polygon ZM	Untitled Polygon	1	0	-1	0	0.11085
203	Polygon ZM	Untitled Polygon	1	0	-1	0	0.321919
204	Polygon ZM	Untitled Polygon	1	0	-1	0	0.767942
205	Polygon ZM	Untitled Polygon	1	0	-1	0	0.58941
206	Polygon ZM	Untitled Polygon	1	0	-1	0	0.096798
207	Polygon ZM	Untitled Polygon	1	0	-1	0	0.199307
208	Polygon ZM	Untitled Polygon	1	0	-1	0	0.055466
209	Polygon ZM	Untitled Polygon	1	0	-1	0	0.181887
210	Polygon ZM	Untitled Polygon	1	0	-1	0	0.229114
211	Polygon ZM	Untitled Polygon	1	0	-1	0	0.327577
212	Polygon ZM	Untitled Polygon	1	0	-1	0	0.458549
213	Polygon ZM	Untitled Polygon	1	0	-1	0	0.143135
214	Polygon ZM	Untitled Polygon	1	0	-1	0	0.076454
215	Polygon ZM	Untitled Polygon	1	0	-1	0	0.106976
216	Polygon ZM	Untitled Polygon	1	0	-1	0	0.155469
217	Polygon ZM	Untitled Polygon	1	0	-1	0	0.038411
218	Polygon ZM	Untitled Polygon	1	0	-1	0	0.491415
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220	Polygon ZM	Untitled Polygon	1	0	-1	0	0.185557
221	Polygon ZM	Untitled Polygon	1	0	-1	0	0.544113
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223	Polygon ZM	Untitled Polygon	1	0	-1	0	0.336286
224	Polygon ZM	Untitled Polygon	1	0	-1	0	0.081839
225	Polygon ZM	Untitled Polygon	1	0	-1	0	0.094134
226	Polygon ZM	Untitled Polygon	1	0	-1	0	0.161809
227	Polygon ZM	Untitled Polygon	1	0	-1	0	0.082888
228	Polygon ZM	Untitled Polygon	1	0	-1	0	0.341474

229	Polygon ZM	Untitled Polygon	1	0	-1	0	1.231357
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231	Polygon ZM	Untitled Polygon	1	0	-1	0	0.366422
232	Polygon ZM	Untitled Polygon	1	0	-1	0	0.629522
233	Polygon ZM	Untitled Polygon	1	0	-1	0	0.194281
234	Polygon ZM	Untitled Polygon	1	0	-1	0	0.092701
235	Polygon ZM	Untitled Polygon	1	0	-1	0	1.006515
236	Polygon ZM	Untitled Polygon	1	0	-1	0	0.190498
237	Polygon ZM	Untitled Polygon	1	0	-1	0	0.484641
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242	Polygon ZM	Untitled Polygon	1	0	-1	0	0.016102
243	Polygon ZM	Untitled Polygon	1	0	-1	0	0.059232
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258	Polygon ZM	Untitled Polygon	1	0	-1	0	0.113025
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261	Polygon ZM	Untitled Polygon	1	0	-1	0	0.21072
262	Polygon ZM	Untitled Polygon	1	0	-1	0	0.09682
263	Polygon ZM	Untitled Polygon	1	0	-1	0	0.086605
264	Polygon ZM	Untitled Polygon	1	0	-1	0	0.53655
265	Polygon ZM	Untitled Polygon	1	0	-1	0	3.365818
266	Polygon ZM	Untitled polygon	1	0	-1	0	1.998016
267	Polygon ZM	Untitled Polygon	1	0	-1	0	0.275991
268	Polygon ZM	Untitled Polygon	1	0	-1	0	0.059067
269	Polygon ZM	Untitled Polygon	1	0	-1	0	0.351019
270	Polygon ZM	Untitled Polygon	1	0	-1	0	1.200145
271	Polygon ZM	Untitled	1	0	-1	0	0.204656

		Polygon					
272	Polygon ZM	Untitled Polygon	1	0	-1	0	0.111848
273	Polygon ZM	Untitled Polygon	1	0	-1	0	0.274565
274	Polygon ZM	Untitled Polygon	1	0	-1	0	0.289018
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276	Polygon ZM	Untitled Polygon	1	0	-1	0	0.031709
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278	Polygon ZM	Untitled Polygon	1	0	-1	0	0.470836
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280	Polygon ZM	Untitled Polygon	1	0	-1	0	0.224403
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284	Polygon ZM	Untitled Polygon	1	0	-1	0	2.65099
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286	Polygon ZM	Untitled Polygon	1	0	-1	0	0.236537
287	Polygon ZM	Untitled Polygon	1	0	-1	0	0.128158
288	Polygon ZM	Untitled Polygon	1	0	-1	0	0.666112
289	Polygon ZM	Untitled Polygon	1	0	-1	0	1.072448
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293	Polygon ZM	Untitled Polygon	1	0	-1	0	0.085523
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295	Polygon ZM	Untitled Polygon	1	0	-1	0	0.045201
296	Polygon ZM	Untitled Polygon	1	0	-1	0	0.263179
297	Polygon ZM	Untitled Polygon	1	0	-1	0	0.079566
298	Polygon ZM	Untitled Polygon	1	0	-1	0	0.25749
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300	Polygon ZM	Untitled Polygon	1	0	-1	0	2.853485
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302	Polygon ZM	Untitled Polygon	1	0	-1	0	0.100916
303	Polygon ZM	Untitled Polygon	1	0	-1	0	0.034787
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306	Polygon ZM	Untitled Polygon	1	0	-1	0	1.554392
307	Polygon ZM	Untitled Polygon	1	0	-1	0	0.121918
308	Polygon ZM	Untitled Polygon	1	0	-1	0	1.128552
309	Polygon ZM	Untitled Polygon	1	0	-1	0	0.215987
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311	Polygon ZM	Untitled Polygon	1	0	-1	0	3.915562
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316	Polygon ZM	Untitled Polygon	1	0	-1	0	0.077418
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322	Polygon ZM	Untitled Polygon	1	0	-1	0	0.361303
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324	Polygon ZM	Untitled Polygon	1	0	-1	0	0.113159
325	Polygon ZM	Untitled Polygon	1	0	-1	0	2.612304
326	Polygon ZM	Untitled Polygon	1	0	-1	0	0.143996
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328	Polygon ZM	Untitled Polygon	1	0	-1	0	0.106455
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336	Polygon ZM	Untitled Polygon	1	0	-1	0	0.12629
337	Polygon ZM	Untitled Polygon	1	0	-1	0	0.255102
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351	Polygon ZM	Untitled Polygon	1	0	-1	0	0.570152
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353	Polygon ZM	Untitled Polygon	1	0	-1	0	0.199814
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		Polygon					
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388	Polygon ZM	Untitled Polygon	1	0	-1	0	0.113118
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390	Polygon ZM	Untitled Polygon	1	0	-1	0	0.66592
391	Polygon ZM	Untitled Polygon	1	0	-1	0	0.4314
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405	Polygon ZM	Untitled Polygon	1	0	-1	0	0.073178
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417	Polygon ZM	Untitled Polygon	1	0	-1	0	1.001226
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427	Polygon ZM	Untitled Polygon	1	0	-1	0	0.185705
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429	Polygon ZM	Untitled Polygon	1	0	-1	0	0.346899
430	Polygon ZM	Untitled Polygon	1	0	-1	0	0.118138
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433	Polygon ZM	Untitled Polygon	1	0	-1	0	0.200518
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436	Polygon ZM	Untitled Polygon	1	0	-1	0	0.458614
437	Polygon ZM	Untitled Polygon	1	0	-1	0	0.4856
438	Polygon ZM	Untitled Polygon	1	0	-1	0	0.267773
439	Polygon ZM	Untitled Polygon	1	0	-1	0	0.182072
440	Polygon ZM	Untitled Polygon	1	0	-1	0	0.104603
441	Polygon ZM	Untitled	1	0	-1	0	0.113483

		Polygon					
442	Polygon ZM	Untitled Polygon	1	0	-1	0	1.997231
443	Polygon ZM	Untitled Polygon	1	0	-1	0	0.771033
444	Polygon ZM	Untitled Polygon	1	0	-1	0	0.301842
445	Polygon ZM	Untitled Polygon	1	0	-1	0	0.119853
446	Polygon ZM	Untitled Polygon	1	0	-1	0	0.037331
447	Polygon ZM	Untitled Polygon	1	0	-1	0	0.31506
448	Polygon ZM	Untitled Polygon	1	0	-1	0	0.04732
449	Polygon ZM	Untitled Polygon	1	0	-1	0	0.241362
450	Polygon ZM	Untitled Polygon	1	0	-1	0	0.057746
451	Polygon ZM	Untitled Polygon	1	0	-1	0	0.07556
452	Polygon ZM	Untitled Polygon	1	0	-1	0	0.06318
453	Polygon ZM	Untitled Polygon	1	0	-1	0	0.143486
454	Polygon ZM	Untitled Polygon	1	0	-1	0	1.715988
455	Polygon ZM	Untitled Polygon	1	0	-1	0	0.300031
456	Polygon ZM	Untitled Polygon	1	0	-1	0	0.224733
457	Polygon ZM	Untitled Polygon	1	0	-1	0	0.058991
458	Polygon ZM	Untitled Polygon	1	0	-1	0	0.027554
459	Polygon ZM	Untitled Polygon	1	0	-1	0	0.063348
460	Polygon ZM	Untitled Polygon	1	0	-1	0	0.412612
461	Polygon ZM	Untitled Polygon	1	0	-1	0	0.100374
462	Polygon ZM	Untitled Polygon	1	0	-1	0	0.055001
463	Polygon ZM	Untitled Polygon	1	0	-1	0	0.40399
464	Polygon ZM	Untitled Polygon	1	0	-1	0	0.069597
465	Polygon ZM	Untitled Polygon	1	0	-1	0	0.055697
466	Polygon ZM	Untitled Polygon	1	0	-1	0	0.021094
467	Polygon ZM	Untitled Polygon	1	0	-1	0	0.027026
468	Polygon ZM	Untitled Polygon	1	0	-1	0	0.113947
469	Polygon ZM	Untitled Polygon	1	0	-1	0	0.20758
470	Polygon ZM	Untitled Polygon	1	0	-1	0	0.026381
471	Polygon ZM	Untitled Polygon	1	0	-1	0	0.285992
472	Polygon ZM	Untitled Polygon	1	0	-1	0	0.120991
473	Polygon ZM	Untitled Polygon	1	0	-1	0	0.128945
474	Polygon ZM	Untitled Polygon	1	0	-1	0	0.215375
475	Polygon ZM	Untitled Polygon	1	0	-1	0	0.654076
476	Polygon ZM	Untitled Polygon	1	0	-1	0	0.14493
477	Polygon ZM	Untitled Polygon	1	0	-1	0	0.439021
478	Polygon ZM	Untitled Polygon	1	0	-1	0	0.226253
479	Polygon ZM	Untitled Polygon	1	0	-1	0	0.167691
480	Polygon ZM	Untitled Polygon	1	0	-1	0	0.10516
481	Polygon ZM	Untitled Polygon	1	0	-1	0	0.09369
482	Polygon ZM	Untitled Polygon	1	0	-1	0	0.04404
483	Polygon ZM	Untitled Polygon	1	0	-1	0	0.061368

484	Polygon ZM	Untitled Polygon	1	0	-1	0	0.060201
485	Polygon ZM	Untitled Polygon	1	0	-1	0	0.276886
486	Polygon ZM	Untitled Polygon	1	0	-1	0	0.33873
487	Polygon ZM	Untitled Polygon	1	0	-1	0	0.042645
488	Polygon ZM	Untitled Polygon	1	0	-1	0	0.414824
489	Polygon ZM	Untitled Polygon	1	0	-1	0	0.086217
490	Polygon ZM	Untitled Polygon	1	0	-1	0	1.060018
491	Polygon ZM	Untitled Polygon	1	0	-1	0	0.203921
492	Polygon ZM	Untitled Polygon	1	0	-1	0	0.122409
493	Polygon ZM	Untitled Polygon	1	0	-1	0	0.045546
494	Polygon ZM	Untitled Polygon	1	0	-1	0	0.040015
495	Polygon ZM	Untitled Polygon	1	0	-1	0	0.472652
496	Polygon ZM	Untitled Polygon	1	0	-1	0	0.082211
497	Polygon ZM	Untitled Polygon	1	0	-1	0	0.132559
498	Polygon ZM	Untitled Polygon	1	0	-1	0	0.089987
499	Polygon ZM	Untitled Polygon	1	0	-1	0	0.028938
500	Polygon ZM	Untitled Polygon	1	0	-1	0	0.35793
501	Polygon ZM	Untitled Polygon	1	0	-1	0	0.123849
502	Polygon ZM	Untitled Polygon	1	0	-1	0	0.080094
503	Polygon ZM	Untitled Polygon	1	0	-1	0	0.044716
504	Polygon ZM	Untitled Polygon	1	0	-1	0	0.075858
505	Polygon ZM	Untitled Polygon	1	0	-1	0	0.050406
506	Polygon ZM	Untitled Polygon	1	0	-1	0	0.047331
507	Polygon ZM	Untitled Polygon	1	0	-1	0	0.106277
508	Polygon ZM	Untitled Polygon	1	0	-1	0	0.241349
509	Polygon ZM	Untitled Polygon	1	0	-1	0	1.054008
510	Polygon ZM	Untitled Polygon	1	0	-1	0	0.062064
511	Polygon ZM	Untitled Polygon	1	0	-1	0	0.145954
512	Polygon ZM	Untitled Polygon	1	0	-1	0	0.564499
513	Polygon ZM	Untitled Polygon	1	0	-1	0	0.390517
514	Polygon ZM	Untitled Polygon	1	0	-1	0	0.141879
515	Polygon ZM	Untitled Polygon	1	0	-1	0	0.137601
516	Polygon ZM	Untitled Polygon	1	0	-1	0	0.140949
517	Polygon ZM	Untitled Polygon	1	0	-1	0	0.030744
518	Polygon ZM	Untitled Polygon	1	0	-1	0	0.039564
519	Polygon ZM	Untitled Polygon	1	0	-1	0	0.065594
520	Polygon ZM	Untitled Polygon	1	0	-1	0	0.118339
521	Polygon ZM	Untitled Polygon	1	0	-1	0	0.428071
522	Polygon ZM	Untitled Polygon	1	0	-1	0	0.282077
523	Polygon ZM	Untitled Polygon	1	0	-1	0	0.060496
524	Polygon ZM	Untitled Polygon	1	0	-1	0	0.613265
525	Polygon ZM	Untitled Polygon	1	0	-1	0	0.28841
526	Polygon ZM	Untitled	1	0	-1	0	0.036033

		Polygon					
527	Polygon ZM	Untitled Polygon	1	0	-1	0	0.859436
528	Polygon ZM	Untitled Polygon	1	0	-1	0	0.367558
529	Polygon ZM	Untitled Polygon	1	0	-1	0	0.111656
530	Polygon ZM	Untitled Polygon	1	0	-1	0	0.145996
531	Polygon ZM	Untitled Polygon	1	0	-1	0	0.077588
532	Polygon ZM	Untitled Polygon	1	0	-1	0	0.022424
533	Polygon ZM	Untitled Polygon	1	0	-1	0	0.010755
534	Polygon ZM	Untitled Polygon	1	0	-1	0	0.008555
535	Polygon ZM	Untitled Polygon	1	0	-1	0	0.11629
536	Polygon ZM	Untitled Polygon	1	0	-1	0	0.063721
537	Polygon ZM	Untitled Polygon	1	0	-1	0	0.171983
538	Polygon ZM	Untitled Polygon	1	0	-1	0	0.615946
539	Polygon ZM	Untitled Polygon	1	0	-1	0	0.462543
540	Polygon ZM	Untitled Polygon	1	0	-1	0	0.274482
541	Polygon ZM	Untitled Polygon	1	0	-1	0	0.206102
542	Polygon ZM	Untitled Polygon	1	0	-1	0	0.071733
543	Polygon ZM	Untitled Polygon	1	0	-1	0	0.07284
544	Polygon ZM	Untitled Polygon	1	0	-1	0	0.172407
545	Polygon ZM	Untitled Polygon	1	0	-1	0	0.292206
546	Polygon ZM	Untitled Polygon	1	0	-1	0	0.39154
547	Polygon ZM	Untitled Polygon	1	0	-1	0	1.702025
548	Polygon ZM	Untitled Polygon	1	0	-1	0	1.288278
549	Polygon ZM	Untitled Polygon	1	0	-1	0	0.344786
550	Polygon ZM	Untitled Polygon	1	0	-1	0	0.148961
551	Polygon ZM	Untitled Polygon	1	0	-1	0	0.326955
552	Polygon ZM	Untitled Polygon	1	0	-1	0	0.117539
553	Polygon ZM	Untitled Polygon	1	0	-1	0	0.662862
554	Polygon ZM	Untitled Polygon	1	0	-1	0	1.358326
555	Polygon ZM	Untitled Polygon	1	0	-1	0	0.264267
556	Polygon ZM	Untitled Polygon	1	0	-1	0	0.820283
557	Polygon ZM	Untitled Polygon	1	0	-1	0	0.114544
558	Polygon ZM	Untitled Polygon	1	0	-1	0	0.071613
559	Polygon ZM	Untitled Polygon	1	0	-1	0	0.028123
560	Polygon ZM	Untitled Polygon	1	0	-1	0	0.03333
561	Polygon ZM	Untitled Polygon	1	0	-1	0	1.008098
562	Polygon ZM	Untitled Polygon	1	0	-1	0	0.505118
563	Polygon ZM	Untitled Polygon	1	0	-1	0	0.29178
564	Polygon ZM	Untitled Polygon	1	0	-1	0	0.294116
565	Polygon ZM	Untitled Polygon	1	0	-1	0	0.069926
566	Polygon ZM	Untitled Polygon	1	0	-1	0	0.012452
567	Polygon ZM	Untitled Polygon	1	0	-1	0	0.024753
568	Polygon ZM	Untitled Polygon	1	0	-1	0	0.028049

569	Polygon ZM	Untitled Polygon	1	0	-1	0	0.032373
570	Polygon ZM	Untitled Polygon	1	0	-1	0	0.048588
571	Polygon ZM	Untitled Polygon	1	0	-1	0	0.035559
572	Polygon ZM	Untitled Polygon	1	0	-1	0	0.05092
573	Polygon ZM	Untitled Polygon	1	0	-1	0	0.242766
574	Polygon ZM	Untitled Polygon	1	0	-1	0	0.071504
575	Polygon ZM	Untitled Polygon	1	0	-1	0	0.055784
576	Polygon ZM	Untitled Polygon	1	0	-1	0	0.04165
577	Polygon ZM	Untitled Polygon	1	0	-1	0	0.034559
578	Polygon ZM	Untitled Polygon	1	0	-1	0	0.210606
579	Polygon ZM	Untitled Polygon	1	0	-1	0	0.080656
580	Polygon ZM	Untitled Polygon	1	0	-1	0	0.090569
581	Polygon ZM	Untitled Polygon	1	0	-1	0	0.073852
582	Polygon ZM	Untitled Polygon	1	0	-1	0	0.113914
583	Polygon ZM	Untitled Polygon	1	0	-1	0	0.102403
584	Polygon ZM	Untitled Polygon	1	0	-1	0	0.660066
585	Polygon ZM	Untitled Polygon	1	0	-1	0	0.475924
586	Polygon ZM	Untitled Polygon	1	0	-1	0	0.121484
587	Polygon ZM	Untitled Polygon	1	0	-1	0	0.545441
588	Polygon ZM	Untitled Polygon	1	0	-1	0	0.040198
589	Polygon ZM	Untitled Polygon	1	0	-1	0	0.191417
590	Polygon ZM	Untitled Polygon	1	0	-1	0	0.201432
591	Polygon ZM	Untitled Polygon	1	0	-1	0	0.079489
592	Polygon ZM	Untitled Polygon	1	0	-1	0	0.048848
593	Polygon ZM	Untitled Polygon	1	0	-1	0	0.045968
594	Polygon ZM	Untitled Polygon	1	0	-1	0	0.62281
595	Polygon ZM	Untitled Polygon	1	0	-1	0	0.134076
596	Polygon ZM	Untitled Polygon	1	0	-1	0	0.343562
597	Polygon ZM	Untitled Polygon	1	0	-1	0	0.557002
598	Polygon ZM	Untitled Polygon	1	0	-1	0	0.042308
599	Polygon ZM	Untitled Polygon	1	0	-1	0	0.140542
600	Polygon ZM	Untitled Polygon	1	0	-1	0	0.033426
601	Polygon ZM	Untitled Polygon	1	0	-1	0	0.082053
602	Polygon ZM	Untitled Polygon	1	0	-1	0	0.034695
603	Polygon ZM	Untitled Polygon	1	0	-1	0	0.030208
604	Polygon ZM	Untitled Polygon	1	0	-1	0	0.234496
605	Polygon ZM	Untitled Polygon	1	0	-1	0	0.036509
606	Polygon ZM	Untitled Polygon	1	0	-1	0	0.211882
607	Polygon ZM	Untitled Polygon	1	0	-1	0	0.126755
608	Polygon ZM	Untitled Polygon	1	0	-1	0	0.057377
609	Polygon ZM	Untitled Polygon	1	0	-1	0	0.284588
610	Polygon ZM	Untitled Polygon	1	0	-1	0	0.040413
611	Polygon ZM	Untitled	1	0	-1	0	0.363816

		Polygon					
612	Polygon ZM	Untitled Polygon	1	0	-1	0	0.101164
613	Polygon ZM	Untitled Polygon	1	0	-1	0	0.049903
614	Polygon ZM	Untitled Polygon	1	0	-1	0	0.119535
615	Polygon ZM	Untitled Polygon	1	0	-1	0	0.159221
616	Polygon ZM	Untitled Polygon	1	0	-1	0	0.103996
617	Polygon ZM	Untitled Polygon	1	0	-1	0	0.153453
618	Polygon ZM	Untitled Polygon	1	0	-1	0	0.019248
619	Polygon ZM	Untitled Polygon	1	0	-1	0	0.10341

Appendix VIII: Roads

Shape *		Name	tessellate	extrude	visibility	Length (km)
Polyline ZM		road1	1	0	-1	6.8
Polyline ZM		road2	1	0	-1	9.9
Polyline ZM		road3	1	0	-1	1.7
Polyline ZM		road4	1	0	-1	6.8
Polyline ZM		road6	1	0	-1	16.2
Polyline ZM		road7	1	0	-1	0.9
Polyline ZM		road8	1	0	-1	1.6
Polyline ZM		road9	1	0	-1	5.1
Polyline ZM		road10	1	0	-1	0.7
Polyline ZM		road11	1	0	-1	17.2
Polyline ZM		road12	1	0	-1	10.5
Polyline ZM		road12	1	0	-1	7.4
Polyline ZM		road13	1	0	-1	3.1
Polyline ZM		road14	1	0	-1	10.1
Polyline ZM		road15	1	0	-1	9.2
Polyline ZM		road16	1	0	-1	3.4
Polyline ZM		road17	1	0	-1	1.4
Polyline ZM		road18	1	0	-1	6.3
Polyline ZM		road20	1	0	-1	5.9
Polyline ZM		road21	1	0	-1	3.6
Polyline ZM		road22	1	0	-1	2.7
Polyline ZM		road23	1	0	-1	3.2
Polyline ZM		road24	1	0	-1	6.1
Polyline ZM		road25	1	0	-1	0.7
Polyline ZM		road26	1	0	-1	5.8
Polyline ZM		road27	1	0	-1	3.9
Polyline ZM		road28	1	0	-1	5.0
Polyline ZM		road29	1	0	-1	1.6
Polyline ZM		road30	1	0	-1	2.8
Polyline ZM		road31	1	0	-1	5.1

Polyline ZM		road32	1	0	-1	2.5
Polyline ZM		road33	1	0	-1	8.7
Polyline ZM		road34	1	0	-1	2.6
Polyline ZM		road35	1	0	-1	4.1
Polyline ZM		road36	1	0	-1	2.5
Polyline ZM		road37	1	0	-1	0.6
Polyline ZM		road38	1	0	-1	0.7
Polyline ZM		road39	1	0	-1	1.0
Polyline ZM		road40	1	0	-1	0.7
Polyline ZM		road41	1	0	-1	0.9
Polyline ZM		road42	1	0	-1	3.5
Polyline ZM		road43	1	0	-1	0.6
Polyline ZM		road44	1	0	-1	3.0
Polyline ZM		road45	1	0	-1	1.8
Polyline ZM		road46	1	0	-1	2.1
Polyline ZM		road46	1	0	-1	1.0
Polyline ZM		road47	1	0	-1	0.4
Polyline ZM		road47	1	0	-1	1.1
Polyline ZM		road48	1	0	-1	1.1
Polyline ZM		road50	1	0	-1	0.6
Polyline ZM		road51	1	0	-1	0.9
Polyline ZM		road53	1	0	-1	0.9
Polyline ZM		road54	1	0	-1	0.5
Polyline ZM		road55	1	0	-1	0.5
Polyline ZM		road56	1	0	-1	0.1
Polyline ZM		road57	1	0	-1	0.2
Polyline ZM		road58	1	0	-1	0.3
Polyline ZM		road59	1	0	-1	0.1
Polyline ZM		road61	1	0	-1	0.7
Polyline ZM		road62	1	0	-1	0.5
Polyline ZM		road64	1	0	-1	0.2
Polyline ZM		road60	1	0	-1	0.7
Polyline ZM		road65	1	0	-1	1.0
Polyline ZM		road66	1	0	-1	0.5
Polyline ZM		road67	1	0	-1	0.1
Polyline ZM		road68	1	0	-1	0.1
Polyline ZM		road63	1	0	-1	0.4
Polyline ZM		road69	1	0	-1	0.0
Polyline ZM		road70	1	0	-1	0.9
Polyline ZM		road71	1	0	-1	0.2
Polyline ZM		road72	1	0	-1	0.2
Polyline ZM		road73	1	0	-1	0.5
Polyline ZM		road73	1	0	-1	0.1
Polyline ZM		road74	1	0	-1	0.4
Polyline ZM		road75	1	0	-1	0.1
Polyline ZM		road76	1	0	-1	1.1

Polyline ZM		road77	1	0	-1	0.3
Polyline ZM		road78	1	0	-1	0.0
Polyline ZM		road79	1	0	-1	0.4
Polyline ZM		road80	1	0	-1	1.4
Polyline ZM		road81	1	0	-1	1.0
Polyline ZM		road82	1	0	-1	0.4
Polyline ZM		road83	1	0	-1	0.3
Polyline ZM		road84	1	0	-1	0.4
Polyline ZM		road85	1	0	-1	0.2
Polyline ZM		road86	1	0	-1	2.1
Polyline ZM		road87	1	0	-1	0.8
Polyline ZM		road88	1	0	-1	0.7
Polyline ZM		road89	1	0	-1	0.5
Polyline ZM		road90	1	0	-1	0.4
Polyline ZM		road91	1	0	-1	2.4
Polyline ZM		road92	1	0	-1	3.8
Polyline ZM		road93	1	0	-1	1.0
Polyline ZM		road94	1	0	-1	1.0
Polyline ZM		road95	1	0	-1	0.1
Polyline ZM		road96	1	0	-1	0.5
Polyline ZM		road97	1	0	-1	2.9
Polyline ZM		road98	1	0	-1	1.5
Polyline ZM		road99	1	0	-1	1.5
Polyline ZM		road100	1	0	-1	0.5
Polyline ZM		road101	1	0	-1	0.1
Polyline ZM		road102	1	0	-1	0.7
Polyline ZM		road103	1	0	-1	0.2
Polyline ZM		road104	1	0	-1	0.4
Polyline ZM		road105	1	0	-1	0.0
Polyline ZM		road106	1	0	-1	0.6
Polyline ZM		road107	1	0	-1	0.5
Polyline ZM		road108	1	0	-1	0.2
Polyline ZM		road109	1	0	-1	0.3
Polyline ZM		road110	1	0	-1	0.1
Polyline ZM		road111	1	0	-1	0.3
Polyline ZM		road112	1	0	-1	0.1
Polyline ZM		road113	1	0	-1	0.1
Polyline ZM		road114	1	0	-1	0.1
Polyline ZM		road115	1	0	-1	0.5
Polyline ZM		road116	1	0	-1	0.2
Polyline ZM		road117	1	0	-1	0.3
Polyline ZM		road118	1	0	-1	0.9
Polyline ZM		road119	1	0	-1	0.7
Polyline ZM		road120	1	0	-1	0.3
Polyline ZM		road121	1	0	-1	0.3
Polyline ZM		road122	1	0	-1	0.3

Polyline ZM		road123	1	0	-1	0.1
Polyline ZM		road124	1	0	-1	0.1
Polyline ZM		road125	1	0	-1	0.1
Polyline ZM		road126	1	0	-1	0.1
Polyline ZM		road127	1	0	-1	0.4
Polyline ZM		road128	1	0	-1	0.2
Polyline ZM		road129	1	0	-1	0.4
Polyline ZM		road129	1	0	-1	0.5
Polyline ZM		road130	1	0	-1	0.1
Polyline ZM		road131	1	0	-1	0.7
Polyline ZM		road132	1	0	-1	0.3
Polyline ZM		road133	1	0	-1	0.1
Polyline ZM		road134	1	0	-1	0.1
Polyline ZM		road135	1	0	-1	0.1
Polyline ZM		road136	1	0	-1	0.1
Polyline ZM		road137	1	0	-1	0.2
Polyline ZM		road138	1	0	-1	0.4
Polyline ZM		road139	1	0	-1	0.2
Polyline ZM		road140	1	0	-1	0.1
Polyline ZM		road141	1	0	-1	0.9
Polyline ZM		road142	1	0	-1	0.1
Polyline ZM		road143	1	0	-1	0.1
Polyline ZM		road144	1	0	-1	0.1
Polyline ZM		road145	1	0	-1	0.3
Polyline ZM		road146	1	0	-1	0.2
Polyline ZM		road147	1	0	-1	0.1
Polyline ZM		road148	1	0	-1	0.1
Polyline ZM		road149	1	0	-1	0.0
Polyline ZM		road150	1	0	-1	0.1
Polyline ZM		road151	1	0	-1	0.1
Polyline ZM		road152	1	0	-1	0.7
Polyline ZM		road153	1	0	-1	0.3
Polyline ZM		road154	1	0	-1	0.0
Polyline ZM		road155	1	0	-1	0.0
Polyline ZM		road156	1	0	-1	0.1
Polyline ZM		road157	1	0	-1	0.0
Polyline ZM		road158	1	0	-1	0.1
Polyline ZM		road159	1	0	-1	0.2
Polyline ZM		road160	1	0	-1	0.3
Polyline ZM		road161	1	0	-1	0.1
Polyline ZM		road162	1	0	-1	0.5
Polyline ZM		road163	1	0	-1	0.1
Polyline ZM		road164	1	0	-1	0.6
Polyline ZM		road165	1	0	-1	1.5
Polyline ZM		road166	1	0	-1	0.7
Polyline ZM		road167	1	0	-1	0.2

Polyline ZM		road168	1	0	-1	0.0
Polyline ZM		road169	1	0	-1	0.1
Polyline ZM		road170	1	0	-1	0.3
Polyline ZM		road171	1	0	-1	0.1
Polyline ZM		road172	1	0	-1	0.1
Polyline ZM		road173	1	0	-1	0.2
Polyline ZM		road174	1	0	-1	0.0
Polyline ZM		road174	1	0	-1	0.1
Polyline ZM		road175	1	0	-1	0.8
Polyline ZM		road176	1	0	-1	0.6
Polyline ZM		road178	1	0	-1	2.6
Polyline ZM		road179	1	0	-1	1.4
Polyline ZM		road180	1	0	-1	0.3
Polyline ZM		road181	1	0	-1	1.0
Polyline ZM		roa182	1	0	-1	0.8
Polyline ZM		road183	1	0	-1	1.3
Polyline ZM		road184	1	0	-1	0.3
Polyline ZM		road185	1	0	-1	0.3
Polyline ZM		road186	1	0	-1	0.2
Polyline ZM		road187	1	0	-1	0.2
Polyline ZM		road188	1	0	-1	0.4
Polyline ZM		road189	1	0	-1	0.4
Polyline ZM		road190	1	0	-1	0.8
Polyline ZM		road191	1	0	-1	0.8
Polyline ZM		road192	1	0	-1	0.3
Polyline ZM		road193	1	0	-1	0.3
Polyline ZM		road194	1	0	-1	0.2
Polyline ZM		road195	1	0	-1	1.4
Polyline ZM		road196	1	0	-1	0.7
Polyline ZM		road197	1	0	-1	1.1
Polyline ZM		road198	1	0	-1	0.4
Polyline ZM		road199	1	0	-1	0.1
Polyline ZM		road200	1	0	-1	0.7
Polyline ZM		road201	1	0	-1	0.7
Polyline ZM		road202	1	0	-1	0.6
Polyline ZM		road203	1	0	-1	0.1
Polyline ZM		road204	1	0	-1	0.5
Polyline ZM		road205	1	0	-1	0.2
Polyline ZM		road206	1	0	-1	0.2
Polyline ZM		road207	1	0	-1	0.5
Polyline ZM		road208	1	0	-1	0.6
Polyline ZM		road209	1	0	-1	0.6
Polyline ZM		road210	1	0	-1	1.4
Polyline ZM		road211	1	0	-1	0.5
Polyline ZM		road213	1	0	-1	0.2
Polyline ZM		road214	1	0	-1	0.4

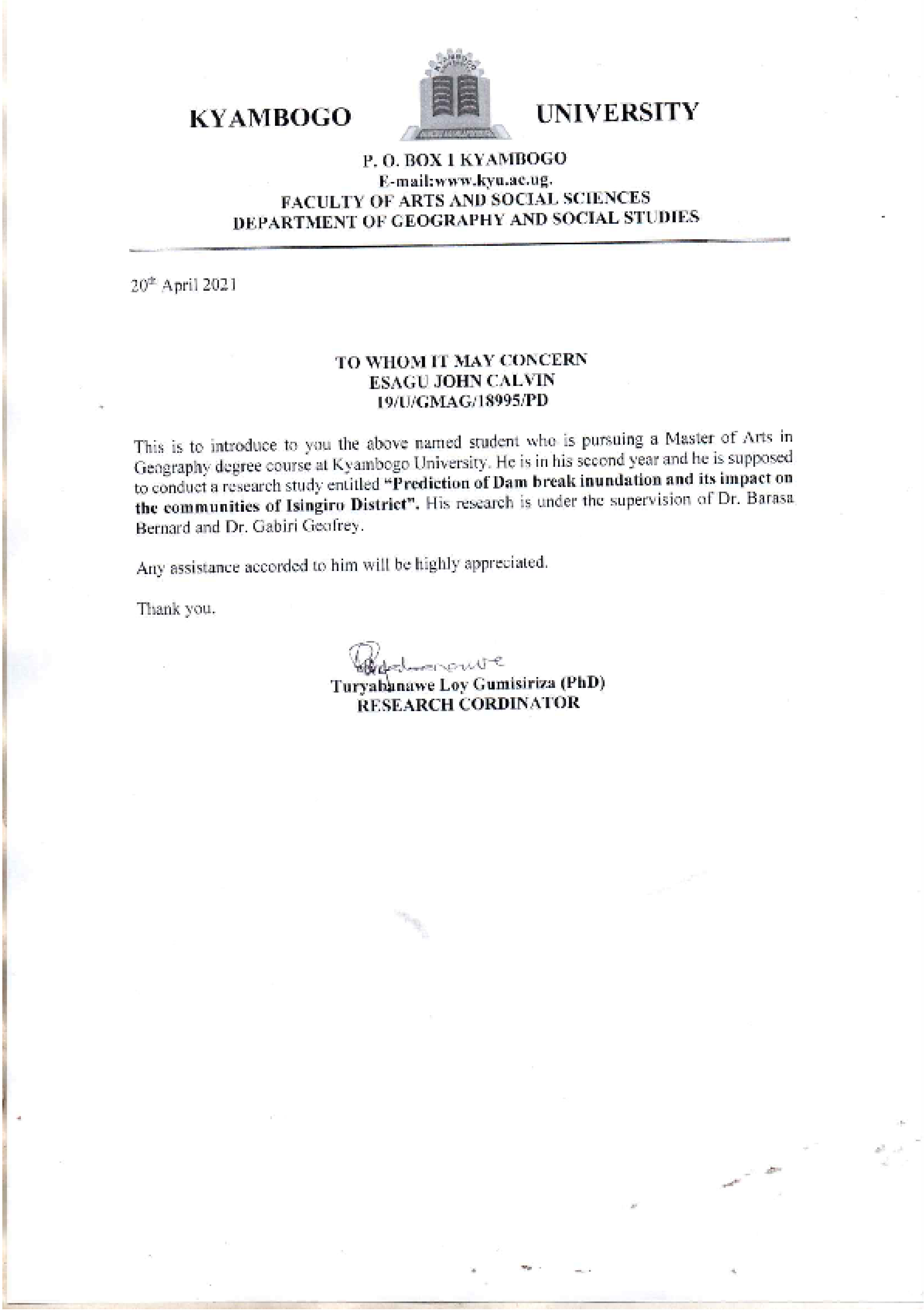
Polyline ZM		road215	1	0	-1	0.6
Polyline ZM		road216	1	0	-1	0.3
Polyline ZM		road217	1	0	-1	1.0
Polyline ZM		road218	1	0	-1	0.7
Polyline ZM		road219	1	0	-1	0.4
Polyline ZM		road220	1	0	-1	0.1
Polyline ZM		road221	1	0	-1	0.2
Polyline ZM		road222	1	0	-1	0.1
Polyline ZM		road223	1	0	-1	0.3
Polyline ZM		road224	1	0	-1	0.1
Polyline ZM		road225	1	0	-1	0.0
Polyline ZM		road226	1	0	-1	0.1
Polyline ZM		road227	1	0	-1	0.1
Polyline ZM		road228	1	0	-1	0.2
Polyline ZM		road229	1	0	-1	0.2
Polyline ZM		road230	1	0	-1	0.1
Polyline ZM		road231	1	0	-1	0.6
Polyline ZM		road232	1	0	-1	0.3
Polyline ZM		road233	1	0	-1	0.2
Polyline ZM		road234	1	0	-1	0.4
Polyline ZM		road235	1	0	-1	0.8
Polyline ZM		road236	1	0	-1	0.3
Polyline ZM		road237	1	0	-1	0.4
Polyline ZM		road238	1	0	-1	0.2
Polyline ZM		road239	1	0	-1	0.8
Polyline ZM		road240	1	0	-1	0.7

Appendix IX: Houses

FID	Shape *	tessellate	extrude	visibility	drawOrder	osm_id	code	fclass	Area (sqm)
0	Polygon	-1	0	-1	0	607353300	1500	building	86
1	Polygon	-1	0	-1	0	607353303	1500	building	185
2	Polygon	-1	0	-1	0	607353305	1500	building	227
3	Polygon	-1	0	-1	0	607353307	1500	building	214
4	Polygon	-1	0	-1	0	607354498	1500	building	182
5	Polygon	-1	0	-1	0	607354500	1500	building	170
6	Polygon	-1	0	-1	0	607354501	1500	building	100
7	Polygon	-1	0	-1	0	607354503	1500	building	101
8	Polygon	-1	0	-1	0	607354505	1500	building	153
9	Polygon	-1	0	-1	0	607354507	1500	building	48
10	Polygon	-1	0	-1	0	607355857	1500	building	78
11	Polygon	-1	0	-1	0	607355860	1500	building	100
12	Polygon	-1	0	-1	0	607356558	1500	building	61
13	Polygon	-1	0	-1	0	607356559	1500	building	45
14	Polygon	-1	0	-1	0	607356560	1500	building	56

15	Polygon	-1	0	-1	0	607356561	1500	building	37
16	Polygon	-1	0	-1	0	607356562	1500	building	24
17	Polygon	-1	0	-1	0	607356563	1500	building	27
18	Polygon	-1	0	-1	0	607356564	1500	building	27
19	Polygon	-1	0	-1	0	607356565	1500	building	76
20	Polygon	-1	0	-1	0	607356566	1500	building	37
21	Polygon	-1	0	-1	0	607356567	1500	building	99
22	Polygon	-1	0	-1	0	607356631	1500	building	165
23	Polygon	-1	0	-1	0	607356632	1500	building	220
24	Polygon	-1	0	-1	0	607356633	1500	building	199
25	Polygon	-1	0	-1	0	607356635	1500	building	106
26	Polygon	-1	0	-1	0	607358191	1500	building	38
27	Polygon	-1	0	-1	0	607358197	1500	building	87
28	Polygon	-1	0	-1	0	607358199	1500	building	86
29	Polygon	-1	0	-1	0	607358201	1500	building	128
30	Polygon	-1	0	-1	0	607358202	1500	building	92
31	Polygon	-1	0	-1	0	607358203	1500	building	81
32	Polygon	-1	0	-1	0	607358204	1500	building	107
33	Polygon	-1	0	-1	0	607358205	1500	building	105
34	Polygon	-1	0	-1	0	607358206	1500	building	222
35	Polygon	-1	0	-1	0	607358207	1500	building	69
36	Polygon	-1	0	-1	0	607358208	1500	building	79
37	Polygon	-1	0	-1	0	607359265	1500	building	50
38	Polygon	-1	0	-1	0	607359267	1500	building	156
39	Polygon	-1	0	-1	0	607359268	1500	building	95
40	Polygon	-1	0	-1	0	607359270	1500	building	104

Appendix X: Introductory letter



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FACULTY OF ARTS AND SOCIAL SCIENCES
DEPARTMENT OF GEOGRAPHY AND SOCIAL STUDIES

20th April 2021

TO WHOM IT MAY CONCERN
ESAGU JOHN CALVIN
19/U/GMAG/18995/PD

This is to introduce to you the above named student who is pursuing a Master of Arts in Geography degree course at Kyambogo University. He is in his second year and he is supposed to conduct a research study entitled **"Prediction of Dam break inundation and its impact on the communities of Isingiro District".** His research is under the supervision of Dr. Barasa Bernard and Dr. Gabiri Geofrey.

Any assistance accorded to him will be highly appreciated.

Thank you.

Turyabanawe Loy Gumisiriza (PhD)
RESEARCH CORDINATOR