MANAGEMENT STRATEGY FOR THE ANNUAL FLOOD RISK OF INFORMAL SETTLEMENTS IN SOUTH AFRICA: CASE STUDY OF ALEXANDRA TOWNSHIP, GAUTENG PROVINCE.

by

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DECLARATION

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Management strategy for the annual flood risk of informal settlements in South Africa: Case

Study of Alexandra township, Gauteng Province.

I declare that this dissertation is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

I further declare that I submitted the dissertation to an originality-checking software to ensure that it falls within the university's accepted requirements for originality.

I further declare that I have not previously submitted this work, or part of it, for examination at Unisa for another qualification or at any other higher education institution.

Masombuka

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11/09/2024

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ABSTRACT

Floods are natural catastrophic events that cause severe consequences for humans. Floods cause damage to infrastructure, roads, and result in life loss. Alexandra Township is prone to floods. Between 2016 and 2018, heavy rain has caused the Jukskei River to burst its banks. A Geographic Information System (GIS) tool is utilized to map out locations that are vulnerable to floods. Using an aerial shot and a 1:100-year floodline as the base map layer in ArcGIS, a spatial analysis of the regions that are vulnerable to floods was carried out. The outcomes charted the susceptibility of properties located in floodplains.

Affected families were given questionnaires as part of a quantitative survey technique to determine community coping mechanisms, indicators, and factors that contribute to flood susceptibility. In addition, a qualitative survey was conducted to round out the data collected from the quantitative survey. In order to gather information on indicators, flood experience, adaptability, and mitigation strategies, key informant interviews were carried out with disaster management authorities in the research region. To study the physical landscape and the effects of flooding, field observations were conducted. Secondary data were obtained from the South African Weather Service and maps.

The absence of planning has resulted in inadequate dwelling unit layout and structure, making people more susceptible to other hazards beyond floods. Their socioeconomic background and dense population have made them more vulnerable because they depend on each other for daily survival. Recommendations were given based on the study's main conclusions. This study makes several adaptation and mitigation suggestions which may be applied to lessen inundation susceptibility whilst avoiding flood-related negative consequences. The study shows that locals were not totally unaware of the floods, but public sharing activities are still required. The following are the main suggestions for this research:

- The community should be regularly updated on the disaster awareness program and given more attention.
- To better manage and prepare for floods, household socio-economic conditions must be considered.

- Authorities must deter and prevent people from settling in dangerous areas close and along the riverbanks.

Flooding is a natural occurrence that will always happen after a heavy rain. Although we cannot stop floods from happening, we can control or reduce how vulnerable households are to them. This can be done by preventing floods from reaching people and preventing people from being affected by floods. The community will benefit in the long run from preventing floods, even though it can be a lengthy project because it involves expensive technological investments such as trapping excess water using a dam or building canals.

Additionally, since there is no other land available for development or the construction of residential properties except the Jukskei River, squatter communities have also sprung up there. We can conclude that changes in land cover classes and population change are strongly correlated. The case studies made it abundantly evident that the use of ArcGIS is crucial in the collection of data for flood management. The research study's conclusions could be used as standard procedures to develop a more focused, well-informed intervention program that will aid in determining how recurrent flooding affects communities and in managing flood disasters.

KEY TERMS:

Flood disasters, permanent strategy, early warning, Alexandra Township, socio-economic, vulnerability.

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LIST OF ABBREVIATIONS

ADRC: Asian Disaster Reduction

ARF: Areal reduction factor

COJ: City of Johannesburg

CV: Co-efficient of variation

DEA: Department of Environmental Affairs

DEM: Digital elevation model

DMP: Disaster Management Plan

DWS: Department of Water Sanitation

EMS: Emergency management service

GIS: Geographic information system

GJMC: Greater Johannesburg Metropolitan Council

HECRAS: Hydrologic Engineering Centre-River Analysis System

IPCC: Intergovernmental Panel Climate Change

MAP: Mean annual precipitation

NDMC: National Disaster Management Centre

NDMF: National Disaster Management Framework

NGO: Non-governmental organization

P-value: Probability value

SALGA: South African Local Government Association

SAPS: South African Police Service

SAWS: South African Weather Service

SCS-SA: Soil Conservation Service South Africa

SMS: Short message service

SPSS: Statistical Package for Social Science

Stats SA: Statistics South Africa

UN: United Nation

UNICEF: United Nations International Children's Emergency Fund

UNFCCC: United Nations Framework Convention on Climate Change

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

Utmost events like floods are devastating. Floods can damage structures and roads and result in life loss. The bursting of the Jukskei River beyond its banks between 2016 and 2018 due to heavy rain has resulted in 13 people losing their lives, homelessness for 130 people, and a child still missing Eyewitness News (EWN, 2016). According to the report from the Natural Disaster Management Centre, almost 15 000 families from different provinces were affected by floods and an additional 74 deaths were recorded, resulting in damage amounting to R1 billion (Makinana and Magwaza, 2011). Informal settlements remain unsightly common throughout South Africa, especially in the major cities (Salami et al., 2017). During the rainfall season, some parts of South Africa, such as Pretoria, Ekurhuleni and Johannesburg, experience heavy floods (News24, 2018). According to the City of Johannesburg, Gauteng province is one of the provinces where heavy rainfall occurs from time to time during the summer period and results in flash floods (Hill, 2016). Alexandra township, also situated in Johannesburg, was used in this investigation as a case study.

Marutlulle (2017) defines informal settlements as residential areas with substandard building codes, a lack of basic utilities, and occupants without tenancy security. Due to their location on steep slopes and floodplains where stormwater flows easily along natural valleys, these informal settlement locations are frequently vulnerable to various hazards. Additionally, there is a deficiency in early warning systems and preparedness (Musyoki et al., 2016). Furthermore, in cases where the warning is issued, residents have fewer options for reducing losses on time. They occupy vacant land which is often the only place where they can afford to live and is usually at the edge of the river and near industrial areas (Seyoum, 2011). The residents are aware of the dangers linked with settling in a location that is prone to disaster, however, they, in most cases, are poor and tend to use materials like corrugated iron and wood to build their houses, which are easily destroyed by floods (Salami et al., 2017). There is no proper planning for these structures, nor do they comply with construction standards (Parkinson, 2003).

This situation needs a new approach to manage the risk associated with floods. The 2014 Intergovernmental Panel on Climate Change (IPCC) reports that some planned adaptations (of human activities) are taking place globally and can be improved through complementary actions at different levels, like safeguarding susceptible populations, by promoting the diversification of the economy and providing financial assistance, policy and legal frameworks, information, and other resources. Extensive adaptation is required to reduce vulnerability to floods, In South Africa, this adaptation is occurring at a slow pace (Department of Environmental Affairs, 2016). Unpredicted floods may exceed the capacity of natural and engineered systems that control floods. According to (Department of Environmental Affairs, 2019) the study additionally examined strategies for adaptation which could be well-thought-out to lessen the effects of floods and to make development more sustainable by combining flood adaptation and mitigation measures into a sustainable development strategy. Complementary mitigation and adaptation in the water division need to tackle the primary effects of flooding on water resources since doing so will make it easier to pinpoint the regions that the hydrological system is most likely to affect (UNFCCC, 2006). Flooding has a variety of detrimental effects on both economic activity and human settlements which have been experienced in many parts of the world (Rahman, 2014).

The formation of landscapes is attributed to floods in various parts of Africa. Floods have struck Mozambique on several occasions, most notably in 2000, which impacted the lives of 500,000 people, and as a result, 700 people died in the incident. Flooding is common in Zimbabwe, especially when it's a season of rain (Christie and Hanlon, 2001). According to Mudavanhu (2014), flooding in Zimbabwe has caused damage to crops and infrastructure, human causalities, and a high prevalence of diseases like cholera and malaria. According to Reliefweb (2019), 33 deaths have been reported, over 100 people are missing, and 1600 households have been affected by the flooding. In April 2019, floods created great damage, people were injured, and buildings were destroyed in Kwa-Zulu Natal province of South Africa. The flood resulted in about 70 deaths caused by collapsing buildings, sinkholes, and mudslides (News24, 2019). When considering the background provided, it is apparent that it is imperative to produce a holistic approach to flood risk management that can successfully deal with this issue in informal settlements. Additionally, there is very not enough information and inadequate comprehension of the causes of flooding and the probability of occurrence (Salami et al., 2017).

Generally speaking, flood frequency analysis (FFA) is a method of projecting forthcoming frequencies using statistical and probability methods (probability of hydrological events occurring) based on information contained in hydrologic records (Singo et al., 2012). The exceedance probability of floods is expressed in numerical format, starting from higher percentage to lower, for example, 50%, 20%, 10%, 5%, 2%, 1% and 0.5%. The exceedance probability shows the likelihood that a given level will be reached in a given year. The primary goal of a flood frequency analysis is to calculate the interval at which a hydrologic event of a specific size will recur. For example, structures such as dams, ditches, culverts, and bridges are designed based on frequency analysis of flood events (Van der Spuy and Rademeyer, 2021). Thus, flood frequency analysis is based on the determination of flood frequency curves for streamflow and river flows.

1.2 PROBLEM STATEMENT

Floods are one of the natural disasters faced by people in Alexandra informal settlement. The large number of people moving to Johannesburg for better lives has led them to settle in flood plain areas, exposing themselves to flash floods (Holloway et al., 2013). Floods disrupt lives each year and result in personal tragedies and property damage. Families are frequently left homeless, often without insurance or any other assistance (Mort et al., 2018). Houses, bridges, and roads are more vulnerable to flooding and landslides are triggered on account of soil becoming saturated (Bizimana and Sonmez, 2015). There is a loss of life and livestock caused by drowning (Munyai, 2015). According to News24 (2019), a severe flash flood occurred in the Alexandra area due to the overflow of the Jukskei River, resulting in deaths and property damage.

When there are no adaptive measures in place, the vulnerability of the people in the community increases (Nojavan et al., 2018). The Alexandra township is vulnerable because the township is characterised by poor drainage systems which are not properly maintained. Furthermore, as shelter becomes scarce, people resort to building their shacks in sewer lines and manholes (Exstrum, 2016). One of Alexandra's biggest problems is its excessive population growth; the city's infrastructure is built to support a maximum of 70,000 residents, but as more people have moved there over time, the city's population has continued to rise Greater Johannesburg Metropolitan Council (GJMC, 2000). According to Statistics South Africa (Stats SA) (2011), the Alexandra township population is estimated to be around 179 629. The Jukskei River, which is shallow and contaminated and occasionally experiences cholera outbreaks, is one of the risk factors for the densely populated area. Jukskei riverbanks will inevitably flood, more so during the rainy season, and such can have a negative impact on the residents of Alexandra.

However, based on the literature review and available information, it has not been sufficiently stated how communities play a part in disaster management, despite extensive research done on the Alexandra community. Collins (2009) also pointed out that additional research is required to integrate physical and social research because many studies regarding catastrophes have concentrated more on computer prediction software. In order to estimate community exposure and adaptation strategies to flash floods, as well as to identify the most suitable flood inundation model that could be used in the management of flash floods in Alexandra Township, this study seeks to analyse the current situation.

1.3 RATIONALE AND SIGNIFICANT OF THE STUDY

The research intends to benefit both dwellers and policymakers in disaster management. According to the City of Johannesburg (2016), measures to deal with disasters are in place but the responsibility of the public on those measures are not clearly defined. Therefore, this research expects to empower the community with improved wisdom about disaster management and public involvement (Dube et al., 2018). This site-specific study offers a better understanding of flooding because it is based on a place where flooding occurs virtually every time it rains. The results of the study would be of benefit to the Johannesburg municipality in their attempt to improve service delivery to their residents located on the floodplain. In addition, the municipality would be better equipped to adapt to deviations from the status quo and gain a thorough insight into the underlying causes of the issue (floods) they are currently experiencing. Residents would have the means to react constructively to the effects of flooding, and policymakers would be able to address the problems brought on by floods by taking a comprehensive approach. Additionally, the study would be considered a tool for the municipality and residents to use as part of an early-warning system for disaster preparedness.

1.4 AIM AND OBJECTIVES

1.4.1 Aim of the study

The study aims to provide an appropriate strategy that could be applied in the management of annual flood risk in informal settlements to prevent life loss and property damage.

1.4.2 Objectives

The specific objectives of the study are:

I. Investigate the risks associated with floods and evaluate housing structure.

II. Profile the flood risk to determine the floodlines in Alexandra informal settlement, to ascertain practical and efficient ways to reduce the risk to life and property.

III. Examine the existing and future adaptation options in order to minimise the impacts of floods.

1.5 RESEARCH QUESTIONS

The study was conducted to address the following research questions.

I. How does flooding affect the living conditions of the community?

II. What is the flood risk and position of the actual floodlines in Alexandra?

III. Which adaptation techniques should the community and municipality implement?

IV. How should the flood impacts be reduced?

1.6 RESEARCH OUTLINE

The six chapters that make up this dissertation are arranged and presented as follows:

Chapter 1 consists of the background and problem statement, significance, and rationale of the research study, and the study's aim and objectives. Furthermore, it provides the research questions and a description of the study.

Chapter 2 outlines the thorough literature review, which encompasses studies from the developing world to highlight the severity of floods.

Chapter 3 outlined the methodology of the research which includes the research design, sampling method, method of data collection, and analysis as well as ethical considerations of the study.

Chapter 4 focuses on the presentation and analysis of the questionnaire data obtained from communities residing along riverbanks. In addition, field observation and interviews with the community leader and the City of Johannesburg Municipality Disaster Management Unit were done.

Chapter 5 outlines the findings and discussions of the analysis of the results based on the observations, interviews with the people residing on the riverbank, community leaders and City of Johannesburg Municipal Disaster management.

Chapter 6 outlines the conclusions, recommendations and future prospects for the study.

1.7 DESCRIPTION OF THE STUDY

1.7.1 GENERAL INFORMATION ON ALEXANDRA

The study area is located between (28° 6' 47.66'' E and 26° 1' 52.8'' S). Alexandra, also known as Alex or Gomorra, is a township located 12 km northeast of Johannesburg in the Gauteng province of South Africa. The township is separated by the Jukskei River where the eastern side is not developed, and the western side is more developed. One of the most impoverished and crowded cities in the nation is Alexandra. The squatters occupying every square kilometre of vacant land cause reduced water penetration into the soil, which raises surface runoff (McGrane, 2016). According to Stats SA, the total population in Alexandra is 179,624 and the population density is 25,979 persons/km^2 and the total number of households is 63,737. Figure 1-1 indicates the location of Alexandra within the City of Johannesburg and Figure 1-2 indicates the Jukskei River (white in colour) crossing the township and the distributions of rainfall stations and positions. The Stjwetla informal community (grey in colour), which is located in the old Alex on the north-west and partially east banks of the Jukskei River, is the focus of this study (see Figure 1-3).

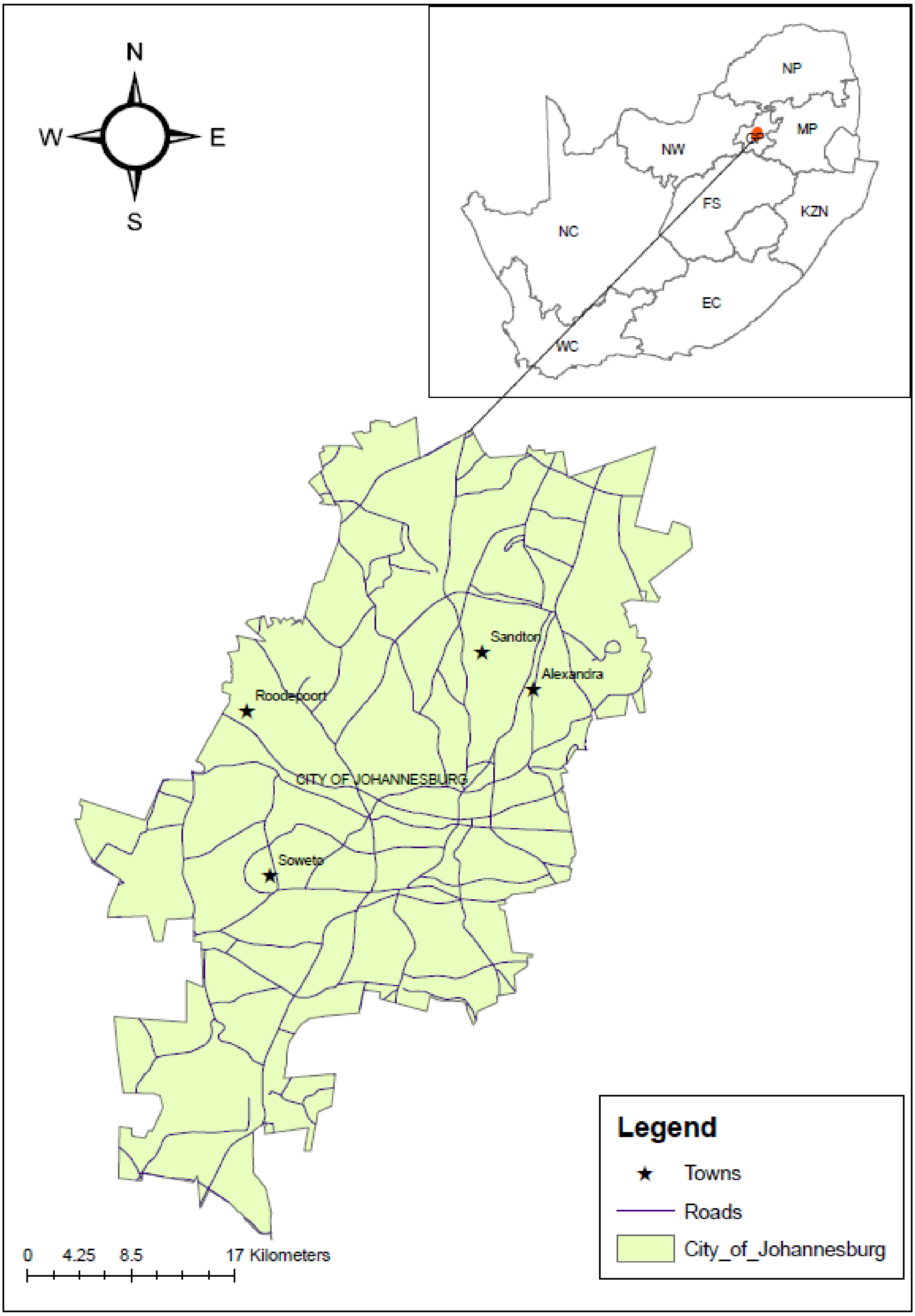


Figure 1-1: Location of Alexandra township.

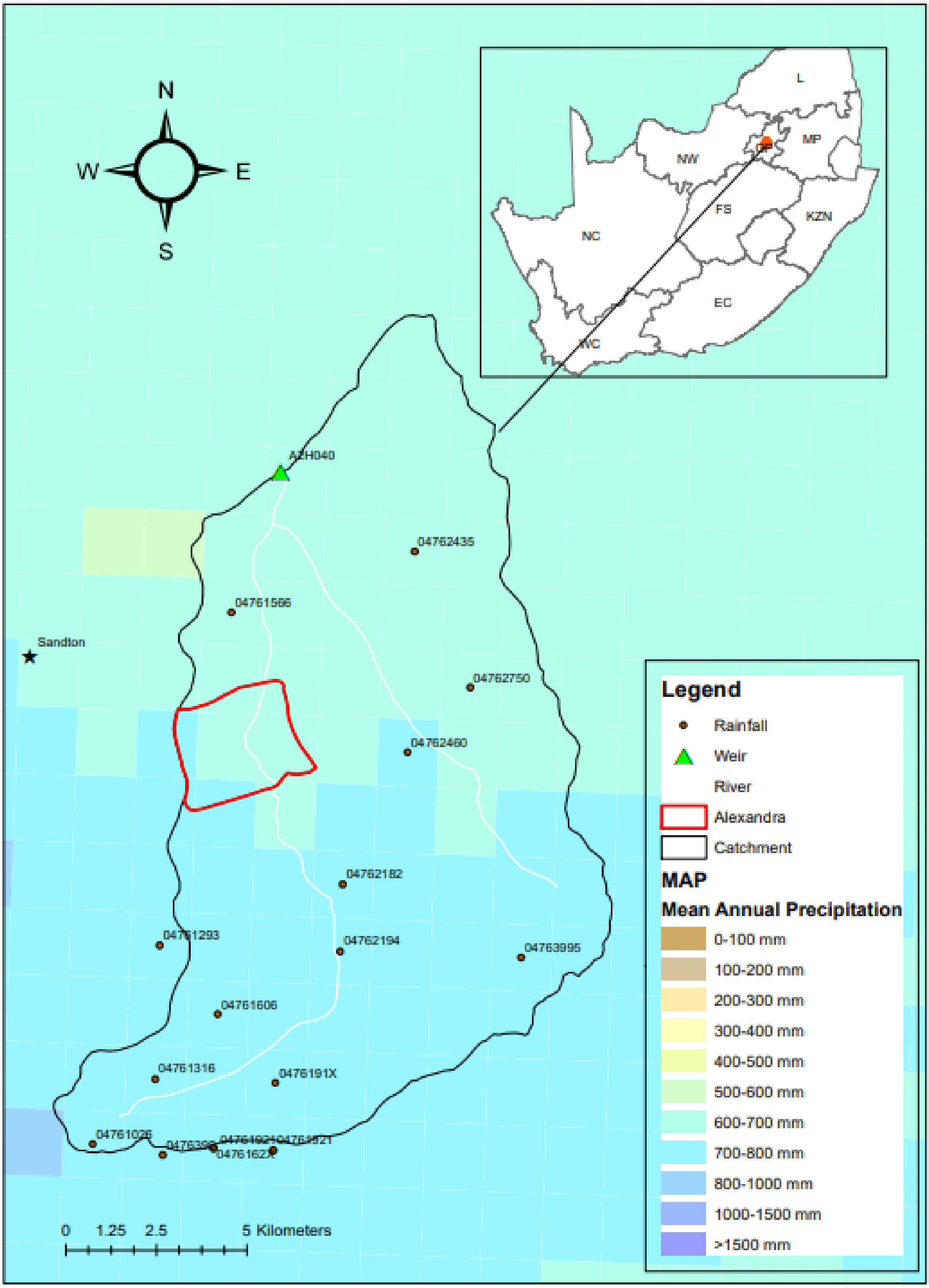


Figure 1-2: Rainfall stations near Alexandra and rainfall pattern.

Figure 1-3: Area of interest (Stjwetla section (grey colour section) within Alexandra Township).

Images 1-1 and 1-2 (below) shows that during high rainfall season, these built structures are exposed to floods since they are located below the floodline.

Image 1-1: Building structures near the riverbanks (Eyes Witness News, 2016)

Image 1-2: Jukskei River flooding (SA people, 2016)

1.7.2 CLIMATE AND RAINFALL

Alexandra Township has a dry climate, which is characterized by high evaporation rates, and as a result, the area receives rainfall during the summer, which peaks in January and February, and the annual precipitation (MAP) is around 713 mm. Humidity is higher during wet months than during dry months. The summers are generally very warm, and the winter is moderate with dry and sunny days, and during the night it is chilly (Dyson, 2009). According to New et al., (2000) South Africa when compared to other African nations, their rainfall stations network is comparatively dependable, but in the last quarter of the 20th century, there has been a decline in the number of active reliable rainfall stations. A total of 15 rainfall stations were considered and subjected to data quality and homogeneity to thoroughly screen each rainfall station to determine if there are missing or unreliable data. As a result, one rainfall station was functional for this study, and the station number is 0476399. To establish a rainfall pattern (precipitation totals and dispersion during a specific period) and flood pattern (It entails analysing past data to find patterns in the frequency of floods that may be used to comprehend and forecast future flood occurrences), rainfall data was extracted from South African Weather Service (SAWS) and Hydstra data bank used by Department of Water and Sanitation. Ideally, it is preferable to have each station data record length equal to or more than 30 years. The rainfall stations with location, record length from 1989-2022 and data quality enabled the use of the station. The annual rainfall was graphically represented (Figure 1-4) to show long-term trends, and the results indicate which year was the wettest.

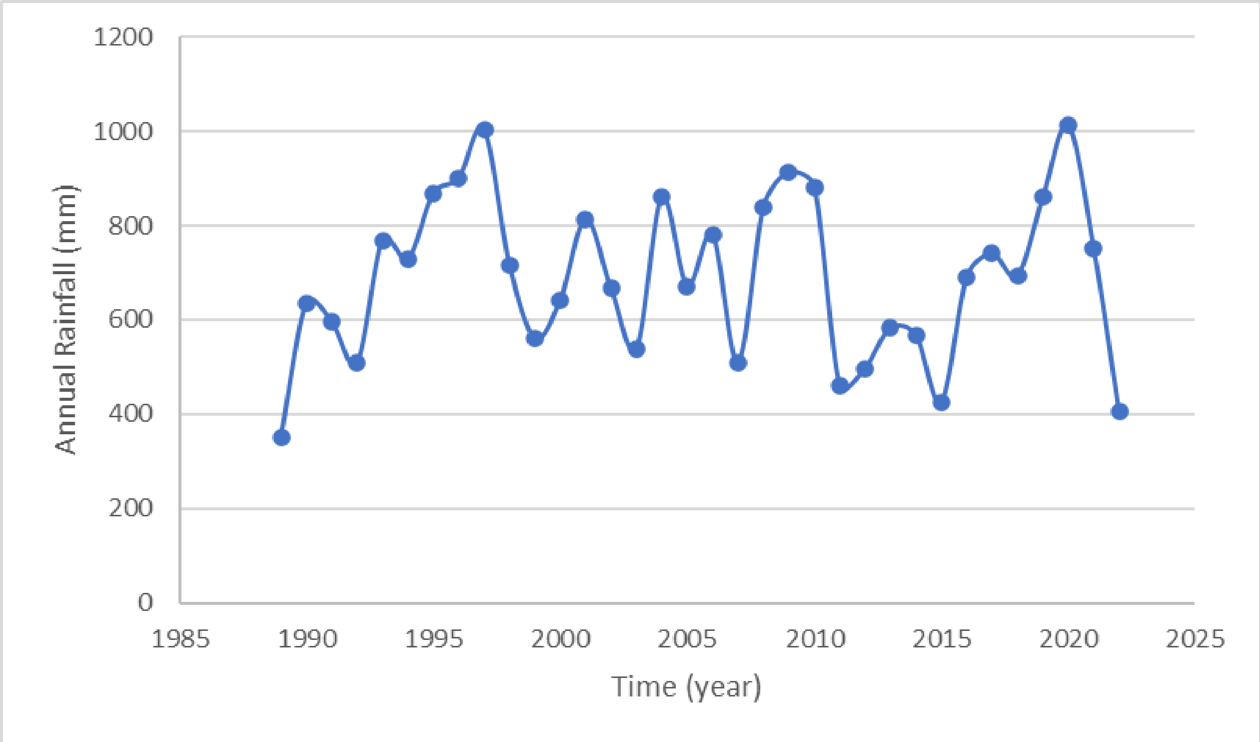


Figure 1-4: Annual rainfall for Alexandra (Data from SAWS and Hydstra: 1989-2022)

CHAPTER 2: LITERATURE REVIEW

2.1 INTRODUCTION

This chapter explores the relevant literature on management strategies for annual flood risk. It describes floods and their impact, floods in developing countries, early warning, disaster management and permanent strategies. It also looks at international experience on the annual flood risk in informal settlements with a focus on the developing world. The main purpose is to develop an understanding of theoretical concepts relevant to this research.

2.2 CAUSES AND IMPACTS OF FLOODS

With the growth of informal settlements encroaching on flood-prone regions in the low-elevated sections and along the Jukskei River's riverbanks, Alexandra Township has a long history of flooding. The majority of the study area's informal homes are situated below the 100-year floodline (Mawasha and Britz, 2020) (See Figure 4-2). A major level of flooding that has a one in a hundred chance of being equalled or exceeded in any given year is known as a 100-year flood-line. The phrase is only a statement of likelihood; it does not imply that these circumstances will always exist at 100-year intervals or, for that matter, that a 100-year flood will always occur inside a certain 100-year window. While the 100-year floodline is frequently utilized as a benchmark, it does not always represent the highest floodline that might occur (Munyai, 2015). The majority of informal settlements are situated below a 100-year floodline, as shown in Figure 4-2. This emphasizes the necessity of appropriate intervention plans, which can be accomplished through accurate mapping of risks, hazards, and vulnerabilities. It is challenging to prevent, control, and efficiently monitor flooding in the township without this knowledge.

“Floods are one of the most common and widely distributed natural risks to life and property”, (Balica, 2012). The most unfortunate aspect is that rainfall is one of the main factors contributing to floods, and since it happens naturally, it cannot be stopped. One kind of urban pluvial flood is urban flash flooding. Surface runoff is the typical symptom of this type of flood, which is typically brought on by strong, prolonged rainstorms or storms (Few, 2003; Diakakis et al., 2016; Miller and Hutchins, 2017). Urban flash floods may also result from other events including glacier melting, dam breaks, rainwater buildup in low-lying regions with high water tables, insufficient stormwater drainage (Few, 2003), and an abrupt release of water from a reservoir or a sewage system malfunction (Yu et al., 2016). Although flash floods typically have localized effects, they have the capacity to do significant harm (Karagiorgos et al., 2016; Pharoah et al., 2016). Because flash floods are sudden, large-volume local floods brought on by intense rainfall, they have a short lead time (Pharoah et al., 2016).

When significant amounts of water spill onto normally dry land, flooding results. Floods happen when there is a lot of rain, when waves from the ocean crash onto land, when snow melts quickly, and when levees and dams fail. A flood may occur over a short or long period of time. It may last days, weeks, and even longer (Miller and Hutchins, 2017). In terms of weather-related natural disasters, flooding is the most common and widespread. Flooding is a natural phenomenon which occurs when the volume of water in the channel is high enough to overwhelm the capacity of the floodplain to discharge it. The likelihood of flooding is increased by human activities such as urbanisation, deforestation, land degradation and blocking of natural channels. The destructive power of floods varies in terms of flood type and exposure of communities; hence, the methods for their prediction, mitigation, and protection also differ by type (Karagiorgos et al., 2016).

Flooding has both good and negative effects, but this research concentrates on the latter because there are no mitigating strategies in place. Understanding hazards demands a better comprehension of the various forms and reasons for inundating, as well as their likelihood of occurrence, depth, and velocity (Jha et al., 2011). Flood effects are worsened by the development of floodplains and the absence of long-term flood prevention techniques. Furthermore, problems associated with floods, like significant material loss and a high mortality rate, continue to increase even though much effort of massive risk reduction and large amounts of money are being invested in flood defences worldwide (Jongman, 2018). The financial toll that severe weather events (of which floods are a major category) can damage resources and disrupt communication and livelihood systems, resulting in suffering for millions of people, human deaths, loss of livestock, and sewerage overflow from pit latrines which become a serious health hazard (Sakijege et al., 2012).

Flooding is considered as the most upsetting natural hazard in Africa. Tropical cyclones and severe storms result in extreme rainfall, which leads to localized flooding. Once floods and flash floods are experienced, properties are damaged, lives are lost and many illnesses are spread, including cholera, dengue fever, and malaria (Rahman, 2014). Over the decade 2000-2010, floods in Africa are estimated to have caused damage worth US$4 billion, killed close to 15550 people, and destroyed nearly 15 million shelters (United Nations, 2010). According to UNDP (2012), communities' economic development may also be delayed by flooding because of the negative effects that response and rehabilitation costs may have on investments in infrastructure and other development-related activities. Excessive rainfall is the primary cause of abnormal flooding, for example, because of tropical cyclones. Human factors also contribute to land degradation, deforestation of watersheds, growing population intensity along riverbeds, inadequate drainage, especially in cities, poor land use planning, zoning, and control over development in flood plains. In addition, natural and man-made dam failures can result in flooding (Miguez et al., 2015).

According to reports, the February 2000 floods that devastated a large portion of Southern Africa were the worst in living memory. Floods are powerful and can destroy everything they encounter, especially gauging stations and dams (Dam Safety Emergency Plan, 2010). Floods can cause a slowdown or even a downturn of the economy as destruction can reduce production, delay the movement of goods, interrupt the provision of essential services, increase unemployment, reduce household income, and limit fiscal revenues. The destructive impact of floods can also result in the diversion of resources, interruption of investment funds for disaster response, and lengthened periods of recovery and rehabilitation. When society is already undergoing socio-economic difficulties, floods can trigger civil and political unrest (Munyai, 2015).

2.3 FLOODS IN DEVELOPING COUNTRIES

The consequences of natural catastrophes can be evident anywhere throughout the globe, but developing countries tend to suffer more from flood impacts than developed countries with fewer informal settlements (Ritchie et al., 2019). Individuals who frequently relocate to flood-prone areas are more exposed to flooding. The discussion below was only for selected developing countries.

2.3.1 South Africa

Flooding does have several advantages. According to Singo et al. (2012), flood water is crucial for the general flushing and cleaning of the river system as well as the recharge of aquifers. Strong low flows for several seasons typically ensue intense flooding in the area, allowing aquatic communities to recuperate (State of Rivers Report, 2001). Extremely high flows have the potential to completely alter a river's course and destroy long-established native vegetation. The world's most productive farmland is created by flooding, according to Maluleke (2003), because silt rich in nutrients is left behind after floodwaters regress.

According to Hill (2016), between 1980 and 2010 South Africa experienced more than seventy major floods resulting in 1068 fatalities. The following discussions include the difference between the flood of 2000 and the annual flooding. In February 2000, some parts of South Africa felt exceptional, continuous rainfall for five weeks caused by a tropical depression and the flood events are becoming more frequent and larger. Furthermore, the loss of draining marshland and grassland contributed to more run-off (Smithers et al., 2000).

Although it may seem strange given that South Africa is located in a semi dry region of the world, the number of studies on floods in the country has increased recently. In the annual rainy season, unexpected rainfall has resulted in flooding, displacing hundreds of people, and damaging homes, particularly in undeveloped areas (News24, 2019). In South Africa, informal and unorganized settlement problems impact the reasons behind people's bad settlement choices (Holloway et al., 2013). Flooding's consequences have been harsher in places where homes and other structures impede floodplains. The flood impact tends to force people on the riverbanks to flee for their lives (Singo et al., 2012). The flood victims may feel the economic impact of spending money to replace or fix their homes and may lose potential income for many days (Sillah, 2015).

According to *The Sowetan* (2009), during the rainy season, the country recorded several incidents. In Orlando West, thirty people were displaced; in Lenasia, 200 people had to evacuate their homes due to flooding, and about fifty houses in Klipspruit were submerged in water. *The Star* (2010) substantiated the Sowetan statement and recorded other floods that happened mostly in the township of Soweto. After more than 100 shacks and houses in the informal settlement of Klipspruit flooded, more than 200 residents had to be evacuated. There are floods in many parts of South Africa. The regular occurrence of heavy rainfall in Gauteng province is the cause of flooding. In 2000, there were floods in the northeastern parts of South Africa due to excessive precipitation. These floods had detrimental impacts on society and the economy. The Limpopo, Crocodile, and Sabie rivers in Mpumalanga, South Africa, were among the areas impacted (Niekerk et al., 2018). Grobler (2003) notes that the cost of the flooding was estimated at around 300 million rands in February 2000 in South Africa.

2.3.1.1 Eastern Cape Case Study

During the period between 9 and 12 April 2022, the Province of the Eastern Cape experienced disruptive heavy rains in several District Municipalities. Settlements in Port St Johns and Nyandeni were the most affected. The water and sanitation infrastructure were also affected albeit with minor damages which were fixed with the allocated maintenance budget. The Elundini, Senqu and Walter Sisulu Local Municipalities were also affected. Chris Hani District Municipality confirmed that although the floods were severe, water and sanitation infrastructure was not affected, only housing, roads, and bridges. The Amathole District Municipality reported all their Local Municipalities, namely Raymond Mhlaba LM, Great Kei Local Municipality M and Ngqushwa Local Municipality, being affected by heavy rains and strong winds between December 2021 and April 2022 leading to localized flooding of vulnerable settlements, water infrastructure, roads, low-lying areas, and bridges. Amathole District Municipality estimated a total need of R21,984,200.00 for all the damages caused by the disaster. Planning adaptation strategies requires an understanding of future flood risk, which calls for an impact estimation method that takes into consideration multiple flooding causes.

2.3.1.2 Kwazulu-Natal case study

Between April and May 2022, the KwaZulu-Natal (KZN) province received above normal rainfall (<300 mm) which caused flooding in different parts of KZN. Areas like Jozini, eThekwini, Mtubatuba, Ulundi, Nongoma and KwaDukuza were affected. The floods destroyed roads, factories, dwellings, schools, mobile network communications as well as electrical and water distribution systems. According to the authorities, about 461 people died, and others had to be relocated. About 87 were still missing weeks after the devastating rains. Business operations were disrupted, and livelihoods were destroyed. The cost of the damage was estimated to be close to R20 billion.

This is not the first major flooding event that has occurred in KwaZulu-Natal. Since 2010, this Province has experienced floods in November of 2011, July of 2016, February, May and October of 2017, March, April and November of 2019, February and November of 2020 and February of 2021. Most of these floods were classified and declared as disasters corresponding to the Disaster Management Act of 2002.

2.3.2 India

According to Stecko and Barber (2007), nearly 400 000 km^2 of India's land is prone to floods and each year, the country experiences floods. In the past, India witnessed many of the largest, most catastrophic floods, which permanently damaged people's livelihoods. In India the region of the north of the country is more susceptible to floods, the states affected are Assam, Bihar, Uttar Pradesh, and West Bengal. The above-mentioned states have been extensively impacted by flooding, bringing severe damage to the economy and over 25.5 million people have been affected, resulting in people drowning in floodwater or being killed by falling rocks from landslides (CNN, 2019). According to UNICEF (2017), the government of these states find it challenging to provide housing and assistance to the expanding population. The rising threat is directly and indirectly associated with population growth (Mondal, 2019).

India experiences the following types of flooding:

2.3.2.1 Coastal flood

According to Few et al. (2003), windstorm events and cyclonic activities like hurricanes and tropical cyclones are linked to coastal floods. Storm surges caused by wind often exacerbate catastrophic flooding near the coast. A dome of water is produced during a storm or hurricane by the suction from the storm's low pressure area and powerful winds that lead to the accumulation of surface water. If this gets close to a coastal area, the dome may be forced towards the land due to the rising sea floor level that is typically found in inshore waters. This causes the body of water to rise and creates a wave that inundates the coastal zones.

2.3.2.2 Flash flood

According to Penna et al. (2013), flash floods are characterized as floods that happen within under six hours of the onset of a lot of rainfall. They are typically linked to cloud bursts, storms, and cyclones and necessitate prompt, localized warning and action in order to minimize damage. Topography, catchment condition, high rainfall intensity and duration are some of the contributing factors to this type of flooding. For instance, a riverbed that initially held very little or no water would eventually collect heavy rainfall within a catchment with steep slopes, as noted by Van der Waal and Rowntree (2015).

2.3.2.3 River flood

Among the most common categories of natural disasters is river flooding, which is brought on by precipitation over a sizable catchment area. Unlike flash floods, these floods often build up gradually or seasonally over days or weeks (Debashreen, 2000). A river like the Jukskei usually floods part of its floodplain. It may flood a sizable portion of its floodplain less frequently and, on average, only once every 100 years reaches a significant depth (Dodds and Whiles, 2010).

2.3.3 China

China is one of the nations most impacted by natural disasters, according to Ritchie et al. (2019). Over 200 million people experience a significant unfavourable event annually that results in fatalities and displacement. These create a significant danger to economic development, property, and life. Severe weather such as heavy rainfall, thunderstorms, and hail across southern China, trigger deadly floods. Areas along the Yangtze and Huai Rivers have been hit hard; particularly the middle reaches, where the Yangtze River converges with numerous rivers. This region is a low-lying plain with lakes and record-high rainfall. Due to the high demand for land and food in China, most of the cities in China convert their lakes into land for the development process and more dams have been built along the Yangtze River, reducing the amount of water (Liu et al., 2013).

2.3.4 Mozambique

According to studies (Conversation Media Group, 2019; UNDP, 2012), it is likely that Mozambique will be severely impacted by climate change because of its location, which exposes it to cyclones, floods, and drought. The country is positioned along the equator, where northern and southern air masses responsible for rainfall converge. The substantial downpour floods the business focal point of Maputo, after heavy rain in the region, the riverbanks burst, causing flooding in most parts of the country (Floodlist, 2019). Different researchers conducted studies about floods that hit the country, and the reports show that more than 500 people died during the February 2000 floods, and despite the fact that there were no significant disease outbreaks or severe malnutrition, 45,000 people were saved. (Alshehri et al, 2014; Baez et al., 2010). According to Floodlist (2019), on 25 April 2019, heavy rainfall caused severe flooding that resulted in at least 38 people being killed and 20720 displaced. This flood caused huge material damage where almost 32000 house structures were partially destroyed, and 3000 houses were completely destroyed. The harm incorporates schools and well-being focuses on various regions, just as more than 30000 hectares of crops (Humanity Road, 2019).

2.3.5 Nigeria

During the rainfall season, Nigeria suffers from seasonal flash floods whereby rivers overflow. Floods are primarily the result of meteorological conditions, specifically rainfall-related weather phenomena and events. In the rural areas or overcrowded communities where there are no streamflow drainage systems, these floods end up being deadly to the community. In September 2012, heavy rain resulted in flash floods and caused over 100 people being displaced and property damage in poor areas of Nigeria (Adebayo, 2014). According to Yavinsky (2012), climate change and poor town planning worsened the situation.

2.4 FLOOD MANAGEMENT STRATEGY

2.4.1 Disaster management

The government is in charge of making decisions regarding the creation of economic policies, policies for reducing disasters, and policies for implementing them. In order to have no fatalities and no house structural damage, the concept of disaster management must be a well-oiled machine (Sillah, 2015). Disaster management can be characterized as an expert body in charge of making strategic, operational and arrangement exercises which aim to mitigate loss of life and improve crisis readiness (WCDMC, 2016). According to the City of Johannesburg (2016), disaster management's primary goal is to bring about improvements in reaction, training and mitigation plans before disaster incidents can occur so that the impact of the next disaster event can be decreased by implementing well-formulated strategies, policies and also improved coping capacities.

Flood disaster management is known to be complicated and requires careful handling by involving as many parties as possible, including the community (Dube et al., 2018). Simplified, the disaster management cycle (see Figure 2-1) illustrates how all actions and measures taken in disaster management both before and after the event are interconnected. The two components of the measure are risk management and crisis management.

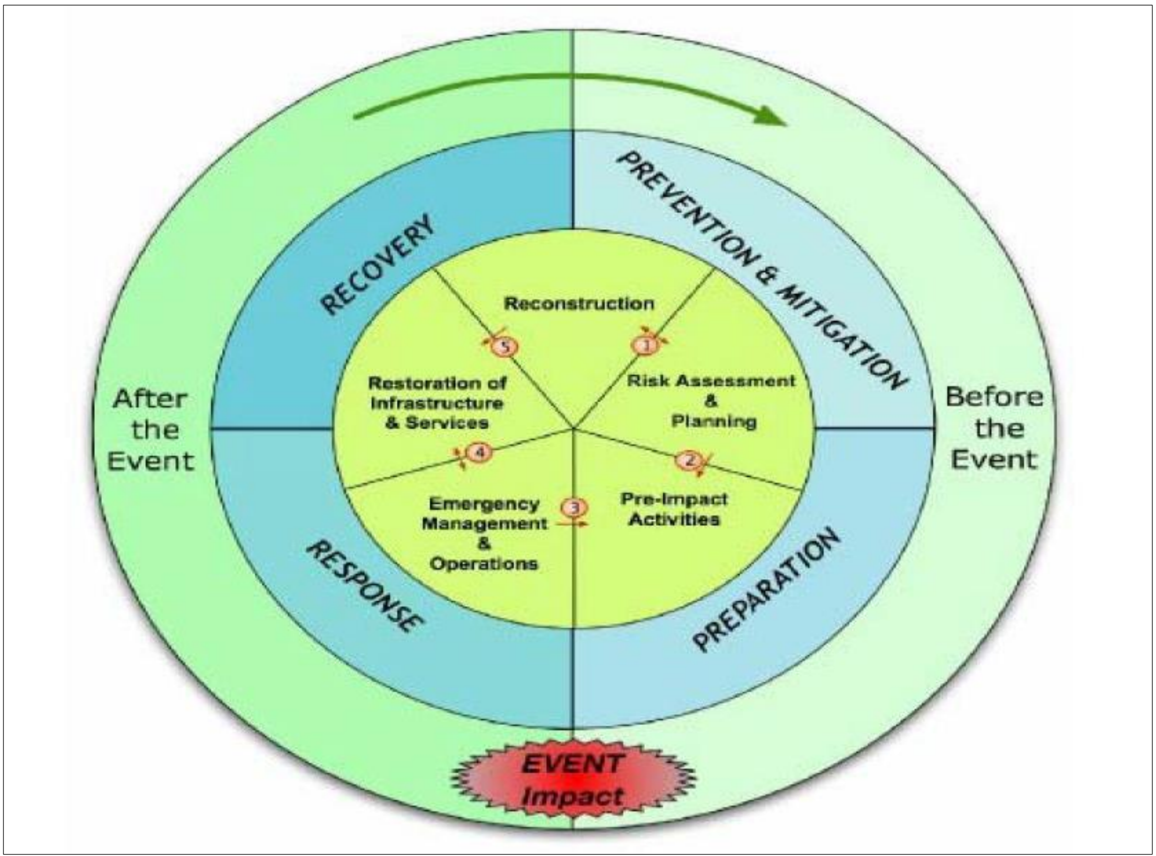


Figure 2-1: Disaster Management cycle (Adopted from Anon, 2010)

2.4.2 Early warning

Weather events can strike a community suddenly or gradually, and both have the capacity to wipe it out. Early warning is crucial because it lessens the number of fatalities caused by floods. Because they are centred on people, early warning systems are considered a crucial part of risk management for disaster strategies. The community is aware of the potential for flooding, but they still need to be regularly informed. Early warning systems' primary function is to alert the public when a flood is imminent, as opposed to flood forecasting systems, which evaluate flood risk (Smith et al., 2016). In order for the system to be effective and functional, timely alerting mechanisms must be tracked and evaluated in real-time, and early alerts must be transmitted and disseminated to vulnerable communities (Rogers, 2010).

There are four elements in the early warning system:
1. Assessment and knowledge of flood risks,
2. Local alerting and warning systems for hazards,
3. Distribution and communication of flood risks,
4. Public response capabilities.

Improvements in cutting edge innovation, enhanced risk management and forecasting, and unwavering quality of satellite information have resulted in the transformation of early warning (Okazawa et al*.,* 2011). In addition, increased reliability, and lead time for forecasts of high impact weather events have made a major contribution to prompt early warning. Because alarm systems are designed to benefit local communities on the ground and to educate their actions, responsible organizations must understand how local communities can cope and respond to disasters (Anderson-Berry et al*.,* 2018). In order for lives to be saved and economic damage to be reduced from natural disasters, a warning system must be in good working condition. Communication, before and after disasters, is imperative in all spheres of government and community. Early warning enables timely preparation and information being disseminated to all people involved. The use of word-of-mouth and whistleblowing to signal or indicate that floods are coming can be regarded as significant techniques to this day to be used by communities (Few, 2003).

2.5 FLOOD VULNERABILITY

Musyoki et al*.,* (2016) state that to lessen a community's weakness, there is a need to increase household income and the level of education. Ways of increasing income will be through job creation in different sectors like mining, tourism, agriculture, and small business empowerment. Better earnings can help the community at large to afford all types of equipment or resources for dealing with flooding. South Africa has one of the highest rates of unemployment worldwide and it is a national crisis. Furthermore, Stats SA (2016) indicated that the employment and absorption rate remained unchanged in the fourth quarter of 2016. The real gross domestic production (GDP) dropped by 0.6 % in the third quarter of 2016, and negative contributors to the GDP were the mining, communication, and tourism sectors. Furthermore, raising educational standards helps people become more knowledgeable and better equipped to handle floods.

There are several ways to be vulnerable, one way is to be exposed to flooding due to a flood-prone location and occupation of vacant land which has little resistance to floods (Salami et al., 2017). According to Thinda (2009), people's vulnerability and institutional capacity vulnerability are the two categories of disaster vulnerability. Individuals' susceptibility to disasters is referred to as their vulnerability, while the capacity of important institutions, such as hospitals, to manage the aftermath of a disaster, is referred to as institutional capacity vulnerability. Developing nations are more susceptible than developed ones due to their faster rates of development and population growth, which increase the likelihood of disaster effects. While the impoverished are obliged to survive in informal settlements in order to be close to their places of employment and shopping, the rich choose to live in hazardous environments (Williams et al., 2019). Raphela (2011) corroborated that in informal settlements, there could be ten times as many people living in 150,000 km^2 as in established areas. Most buildings on land that is prone to flooding or steep slopes stay exposed.

According to Wisner et al. (2004), the adjective vulnerable is the source of vulnerability and is further defined as *"*characteristic of a person or group in terms of their capacity to anticipate, cope with, resist, and recover from the impact of natural disasters. It involves a combination of factors that determine the degree to which someone's life and livelihood is put at risk by discrete and identifiable events in nature or society*"*. According to Tucker et al*.* (2014), many scholars acknowledge that vulnerability consists of three components which are as follows: degree of exposure, susceptibility, or inability to cope and response capacity of a population. The region's susceptibility to natural disasters determines a community's vulnerability to flood risk. It is anticipated that the risk will significantly rise in the years that follow.

Numerous mitigation strategies have been put forth and implemented in South Africa. For example, meteorologists from the South African Weather Service have developed strategies that involve tracking the paths of tropical storms and using radar and satellite images to provide early warnings when heavy rainfall is predicted (Singo et al., 2011). However, during periods of rainfall, the degree of flood vulnerability continues to increase. In South Africa, prevention, reduction, and mitigation are far more important than response and recovery. Although awareness campaigns and housing quality improvement programs have been established by the South African government, they are insufficient. According to Le Roux and Van Huyssteen (2010), the provinces of KwaZulu-Natal, the North-West, the Eastern Cape, and Limpopo are the most vulnerable in South Africa. This does not, however, eliminate the risk of flooding in other provinces of South Africa.

Munyai, (2015) highlighted that the notion of vulnerability assessment encompasses varying levels of risk, including aspects related to the physical, social, and economic domains. Buildings, livelihoods connected to infrastructure, agriculture, roads, communication networks, and other societal operations are all linked to physical vulnerability. Social vulnerability is linked to women, children, individuals with physical disabilities, the impoverished, and refugees. The assessment of economic vulnerability is linked to risk hazards and their impact on financial resources and procedures.

2.6 DISASTER REDUCTION

The best approach to lower the risk of disaster in a community is to collaborate with the locals to assess their capacities and vulnerabilities in order to create an action plan. Furthermore, improving the economic and social network may contribute to a reduction in the vulnerability of the community (Thinda, 2009). Risk awareness is important because it aids in disaster risk reduction (Van Huyssteen et al., 2009). The way in which vulnerable individuals perceive the risks they face influences the way in which knowledge is gathered and applied. When people are unaware of the risks to their lives and property, they are more susceptible (UNISDR, 2013). The flood risk can never be eliminated completely, but the risk to the community can be properly managed (Van Huyssteen et al., 2009).

According to UNISDR (2013), risk only materializes when there is a susceptibility to the danger that floods present. If the community has no idea about the disaster management plan, it becomes impossible for the community to execute the strategy. The consequence is that ordinary citizens in the society are still unable to help minimize the risk of the disaster (Manyena et al., 2013). According to UNISDR (2013), when the communication framework is working properly it can minimize loss of property and life.

One way to define disaster reduction is as a methodical process for identifying, assessing, and lessening the threat of flooding. The goal of the catastrophe decrease system is to address environmental and other hazards that can set off the system, as well as to reduce socioeconomic vulnerabilities to disasters (Mata-Lima et al., 2013). As a result, disaster reduction is now more closely linked to methods that characterize initiatives to attain sustainable development (Mata-Lima et al., 2013). The following systematic diagram (Figure 2-2) shows different disaster components that lead to natural disasters in the community.

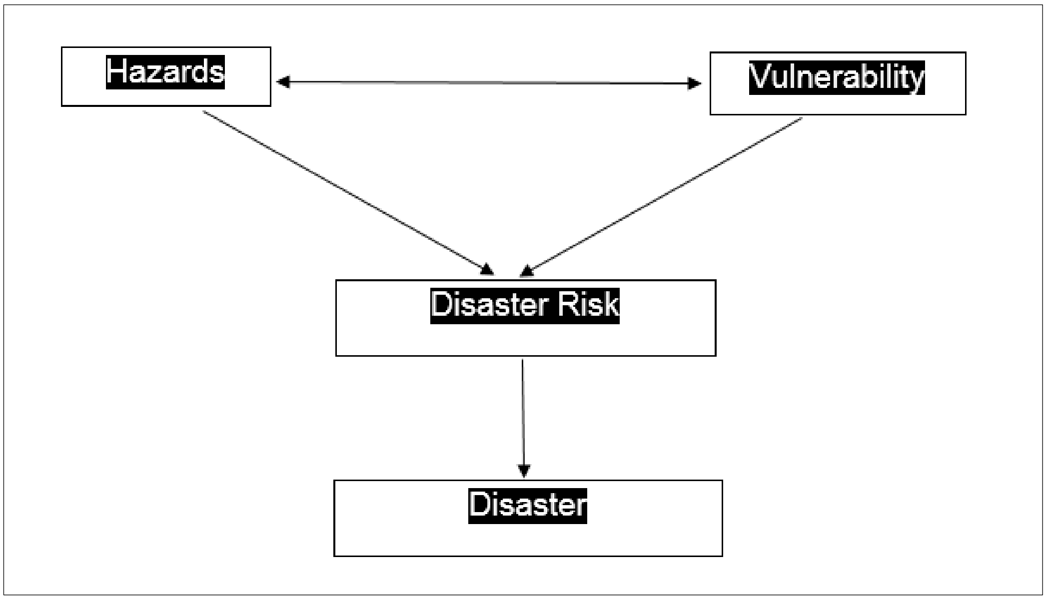


Figure 2-2: Disaster risk component (Adopted from Eschborn, 2001)

2.7 FLOOD CONTROL MEASURE

Typically, flood control strategies are described as either structural or non-structural. The purpose of structural measures is to manage water flow both within and outside of urban settlements in order to lower the risk of flooding. They are an adjunct to non-structural measures that try to prevent flooding by managing urban development and planning appropriately. The current policies, practices, and policies related to urban planning and management need to be linked to a fully integrated strategy (Wang et al., 2022). Since structural and non-structural measures complement one another, strategies that combine both will be the most successful. In order to achieve a balance between long- and shortterm investments in flood risk management, it is also critical to recognize the extent and features of current risks as well as likely future changes in risk.

Structural mitigations, or physical adjustments or actions to protect against risks or disasters, are a part of structural measures. The range of structural measures includes more organic and sustainable complementary measures like wetlands and natural buffers, as well as more inflexible, engineered structures like drainage channels and flood defences. When implemented correctly, structural measures can be very effective, as demonstrated by the Dutch sea defences and the Thames barrier (EU, 2017).

Some of the Structural measures include:

i. Conveyance.
ii. Flood storage.
iii. Drainage storage.
iv. Flood defence.

A group of mitigation and adaptation strategies known as non-structural measures (NSMs) do not employ conventional structural measures. In the absence of hard engineering structural measures, they are intended to protect people from flooding and to lessen the impact of flooding on people and assets exposed to risks (Ogie et al., 2019). While they are less expensive than structural measures, their effectiveness is dependent on knowledge of flood hazards and appropriate flood forecasting systems, such as alerts prior to emergency evacuation plans. Non-structural measures help reduce risk by increasing people's ability to deal with flooding in their surroundings.

Wang et al., 2022 stated that in the absence of expensive structural measures, the early warning system, an example of a non-structural measure, can be thought of as the first line of defence for individuals. In some circumstances, non-structural solutions have shown to be the most successful way to reduce the effects of flooding.

Non-structural measures include:

i. Flood awareness campaigns.
ii. Health planning and awareness campaigns.
iii. Land use planning and flood zoning.

2.8 PREPAREDNESS AND MITIGATION

According to Twigg (2004), in order to protect the community against disaster, preparedness and mitigation are commonly employed. All parties involved in the integrated emergency management system are involved in preparation measures. According to Twigg (2004), preparedness is the state of being ready or able to act in advance of a disaster, usually by anticipating them, warning against them, taking preventative measures when they threatens, and making plans for a suitable response. Preparedness includes the design and regular inspections of warning systems or evacuation plans or more steps considered during the catastrophe notification episode to reduce likely damage to property (Mamogale, 2011). Sometimes, weather events that could cause destruction are happening upstream of the community, and people may not be aware of them. Along with the population at risk, officials also need to be educated and trained. Mitigation is defined as steps taken to reduce potential disasters. As the cost of disaster continues to rise, it is necessary to take sustainable action (Alshehri et al., 2015).

Mitigation strategies such as planning regulations, usage of land, and structural building standard codes are necessary to prevent or minimize actual damage from hazards. Planning and regulations can prevent landslides and flood-prone developments, saving both money and lives. Commitments by city and local leaders to the implementation of mitigation measures are necessary because they have a role to play and a contribution to make (UNISDR, 2013). Mitigation actions consist of three actions and are as follows:

- Local plan and regulations.

  The usage of land or comprehensive plans reflects the community's priorities, values and desires as articulated through a community engagement process. In addition, the action plan must be able to detect the current patterns of development and the forthcoming developments should they occur. The policies and regulations that guide construction away from the flood zone should be part of the plan (Tasantab, 2019).
- Structure and infrastructure projects.

  This action includes changing the current structure in order to shield them from hazards or to eliminate them from the danger zones (Tasantab, 2019).
- Natural system protection

This action consists of vegetation management, stream restoration, sediment and erosion control that can assist by minimizing damage and losses and preserving or restoring the functions of the natural system (Tasantab, 2019).

2.9 STRATEGY

In most cases, floods cannot be alleviated, but there is a way for people to stay safe. Strategy is defined as a premeditated plan to accomplish desired goals and objectives (Barad, 2018). Planning is imperative to reduce the consequences of floods because floods and rainfall cannot be prevented. People often prepare for future events by creating contingency plans based on past experiences that they know will happen. These tactics rely on the presumption that the event will proceed according to a well-known pattern (Jha et al., 2011). The approach for extreme occurrences is perceived as precedent in action before, during and after the event (Lidskog and Sjodin, 2015).

UNISDR (2013) indicated that there are various tactics that can be used to lessen the number of fatalities and property damage; some of the types are as follows:

- Moving the structure of the building from the floodplain zone to higher ground.
- Raising the building so that water can go under it.
- Making watertight walls and roofs to avoid penetration.
- Improve the drainage system.
- Installing a tube barrier in the river to prevent water going downstream.

Dube et al. (2018) state that the two most important resources for surviving a disaster are social structure and income. Dube et al., (2018) added that the effects of tragedy are felt less by people who are financially stable because they can employ suitable mitigation measures and they have a faster recovery time, whereas poor people cannot even afford to employ mitigation measures.

2.10 FLOOD ANALYSIS

According to Lastra et al. (2008), Saint-Venant equations are used to calculate water surface profiles in a variety of channel networks where flow conditions are roughly unidirectional. The HEC-RAS (Hydrologic Engineering Centre-River Analysis System) is a hydraulic model that was developed for undertaking one-dimensional steady and unsteady flow as well as two-dimensional unsteady flow hydraulic simulations. The equation energy is written as follows:

$$Z_2 + Y_2 + a_2 V_2^2 = \frac{z_1}{2g} + Y_1 + a_1 V_1^2 + \frac{h_e}{2g} \text{ ....2.1}$$

where: Z_1, Z_2 = Elevation of the main channel inverts (m); Y_1, Y_2 = Depth of water at cross sections (m); V_1, V_2 = Average velocities (total discharge /total flow area); a_1, a_2 = velocity weighting coefficients; g = gravitational acceleration; he = energy head loss (m) which is calculated or evaluated by manning formula and contraction. When there is a rapid change in the water surface profile, the momentum equation is utilized.

$$he = L\overline{S_f} + C\left(\frac{a_1 v_1^2}{2g} - \frac{a_2 v_2^2}{2g}\right) \text{ .... 2.2}$$

Where h_e = Energy head loss; L = Discharge weighted reach length; S_f = representative friction slope between two sections; C = Contraction coefficient; a_1, a_2 = velocity weighting coefficient; g = gravitational acceleration; V_1, V_2 = Average velocities (total discharge /total flow area).

The HEC-RAS user interface simplifies the model's use to undertake hydraulic simulations efficiently and effectively. The interface provides functions pertaining (but not limited) to; file management, data entry and editing, geographical information system (GIS) interfaces, river analyses, tables, and graphs for presenting data input and output, mapping of inundations, animated water propagation, writing conveniences and online support (Brunner & CEIWR-HEC 2016).

The HEC-RAS model allows for the merging of hydrology and hydraulics. One of the aspects of hydrology is the estimation of design flood peaks and hydrographs. This is then used to simulate the hydraulic conditions of the river section being analysed resulting from the hydrology. The model calculates various hydraulic properties of the simulated flow including the water surface and energy-grade line elevations, flow velocities and inundation areas (Dyhouse et al., 2017). This information is important for low flow applications consisting of (but not limited to) the design of extraction weirs or gauging stations as well as high-flow applications consisting of (but not limited to) the evaluation of flood lines for the design of bridges or culverts, scour protection placement and community development.

2.11 FLOOD ESTIMATION METHODS

The first and most important piece of information is that, inevitably, different flood frequency estimation methods would give different results and that there is no single calculation method that can be presumed to be better than any of the other methods (van der Spuy and Rademeyer, 2021). The fixed characteristics of the catchment (primarily its size); the properties that can change from flood to flood (primarily those of storm rainfall); and the moisture status of the catchment before the storm (primarily soil moisture status and river flow) are the main factors that determine the magnitude of a flood (Van der Spuy and Rademeyer, 2021). Throughout the years, a variety of techniques and models have been created in an attempt to replicate the processes that turn rainfall into flood runoff. These techniques can all be broadly categorized into three main approaches for estimating flood frequency:

- Statistical analysis of observed flood data.
- Deterministic methods, where the statistical properties of the flood are assumed to be the same as that for the storm rainfall, which is then used in more complex conceptual rainfall-runoff models.
- Empirical methods, or experience diagrams, where mathematical models are developed to fit the available data. All the methods make use of or are developed from, available data. In South Africa, rainfall data can be obtained from the South African Weather Services (SAWS) and other hydrological data from the Department of Water Affairs.

2.11.1 Deterministic methods

Catchment characteristics and storm rainfall are used as input for deterministic methods. The conversion of storm rainfall into streamflow considers the catchment characteristics that have an important role in the determination of factors such as storm loss and hydrograph shape. These include catchment area and steepness as well as main watercourse length and slope.

The Direct Runoff Hydrograph (DRH), Synthetic Unit Hydrograph (SUH), Soil Conservation Science (SCS) and Rational methods were used to calculate the flood peaks in the deterministic analysis.

2.11.2 Empirical methods

Flood peak discharges from the empirical methods are obtained mainly through the use of catchment characteristics and a rainfall parameter (MAP) in some methods. The Midgley and Pitman (1967) (MIPI), Midgley and Pitman (1971) (HRU 1/71), and Catchment Parameter (2002) (CAPA) methods are some of the methods that are being used.

2.11.3 Statistical methods

The main objective of statistical analyses is to make "some sense" out of collected data. This is achieved by summarising the data, estimating certain parameters, and then choosing an appropriate theoretical distribution with which probabilities can be calculated; this technique is known as statistical inference. The statistical methods involved the use of the observed inflow AMS record. The record’s data were statistically analysed and it was found that a Log Pearson III (LP III) and General Extreme Value (GEV) distributions gave the best fit against the annual maximum flood peaks plotted using the Cunane (1978) and Z-set (van der Spuy, 2022) plotting positions.

Trends in a time series can be found using a variety of statistical techniques. These techniques might be parametric or non-parametric. According to Anderson (2001), non-parametric techniques are typically chosen over parametric ones. A few of the non-parametric techniques are discussed below.

Runoff precipitation, management strategies, and planning objectives are three primary uses of hydrological modelling. The first step in each of these applications is rainfall throughout the catchment area, finding surplus runoff after accounting for all abstractions, and then simulating runoff hydrographs using the chosen hydrological models. There are several techniques for hydrological flood modelling. The majority of these models use arbitrary formulae and relationships as the foundation for runoff forecast and flood projection (Moliere et al., 2002).

2.11.4 Mann Kendall

A non-parametric technique called Mann Kendall (MK) ranks every piece of data in the series in chronological order. The most popular technique for identifying trends in time series, especially environmental ones like hydrological time series, is Mann Kendall (MK) (Kundewicz and Robinson, 2000). The rationale is that MK works well with hydrological time series that have gaps in them and does not require a continuous record. Furthermore, testing for randomness versus trend in climatological time series has been a common use of this approach (Zhang et al., 2001).

The MK test's data that has been seasonally adjusted (x_1–x_n) are a sample of n independently dispersed variables with the same distribution, according to the null hypothesis H_0 (Yu et al., 1993). To eliminate fluctuations in values caused by the time of year, According to Hisdal and Tallaksen (2003), data that has been seasonally adjusted is achieved by dividing the standard deviation by the mean value of each individual record. In a two-sided test, the alternative hypothesis H_1 states that the distributions of x_k and x_j are not the same for all k, j. The following two equations are used to calculate the test statistic S.

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sgn\,(xj - x_k) \quad \text{2.3}$$

Which is calculated as the sum of the positive and negative differences. If S is a positive number, observations taken later in time are typically larger than observations taken earlier. Laterally made observations typically have a smaller sample size than earlier observations if S is a negative number.

$$sgn\,(x_J - x_k) = \begin{cases} +1\; if(x_j - x_k) > 0 \\ \;0\; if(x_J - x_k) = 0 \\ -1\; if(x_j - x_k) < 0 \end{cases} \quad \text{2.4}$$

Which, calculated by, has a variance of S and a mean of zero:

$$Var(S) = \left\lfloor \frac{n(n-1)(2n+5) - \Sigma_t t(t-1)(2t+5)}{18} \right\rfloor \quad \text{2.5}$$

As per Hirsch and Slack (1984), this equation is exponential normal, where it is the time interval of any given length and $\sum_t$ is the sum of all ties.

CHAPTER 3: METHODOLOGY

3.1 INTRODUCTION

The primary goal of this chapter is to discuss the research methods that were employed to obtain data during the research project. The discussion covers the research design, data analysis method, matters linked to ethics in research, and the source of data used and sampling size.

3.2 RESEARCH DESIGN

According to Balakumar et al. (2013), research can be defined as a planned, structured, systematic investigation to obtain facts about a research problem. According to some researchers, the choices made when organizing the study such as those regarding sampling, sources, and data collection methods make up the research design (Creswell, 2014).

To address the research objective, this study used a mixed research approach that incorporates both quantitative and qualitative techniques. These two methods apply to this study primarily because the methodology emphasizes insider perspectives (Johnson et al., 2007). Speaking with or watching people who have been flooded helped to achieve the qualitative component because first-hand knowledge yields the most insightful information and it better serves the interests of the social group to interpret their social world (Darling-Hammond et al., 2019). A case study methodology was chosen since it addresses what-where-how questions. Data that was quantitative was examined using the ArcGIS and HECRAS software for floodlines and rainfall data. ArcGIS and HECRAS have vast competencies to work broadly on spatial data for different purposes.

According to Bell (2005), a researcher using a qualitative approach is more interested in gaining unique insights than in analysing data statistically. With the use of documents, photos, observations, interviews, and case studies, the methodology pursues to deliver a comprehensive thoughtfulness of the subject matter and maintains that it is crucial to comprehend the significance that individuals attribute to events that occur in their surroundings. From their own frame of reference, the researcher can then offer comprehensive descriptions, of relationships, systems, and people. In addition, it is critical for a researcher to evaluate, contextualize, and confirm specific hypotheses. Furthermore, the methods would enhance confidence in the findings and increase the understanding within the community. Public participation would strengthen the community's knowledge, and site visits (observation) would determine the vulnerability of the community. The building's height, vulnerability, and the existence of barriers in front of the door are all considered relevant factors. With a focus on gathering secondary and primary data, the data gathering techniques were examined in relation to various methods and the goals they were meant to address. To determine the flood risk, field visits were used to gather data through observations, photographs, and both structured and unstructured interviews. The secondary data would include the City of Johannesburg floodline report and delineated floodline for 1:100-year recurrence.

3.3 RAINFALL DATA COLLECTION AND ANALYSIS

The continuous surface rainfall was produced by interpolating using the inverse distance weighting (IDW) approach. In many regions of the world, studies of spatial rainfall have made extensive and effective use of the IDW interpolation approach (Ndlela, 2015). Furthermore, the IDW approach makes the significant assumption that the distance between neighbours which may be described as a distance reverse function of each point from surrounding points determines the rate of correlations and similarities between them. The rainfall was estimated by averaging the rainfall measured at the station’s location. The Thiessen polygon method for determining the average rainfall is convenient, particularly for repeated calculations (the method is available in ArcGIS), and also the study area was calculated for various probabilities of exceedance. The rainfall station that was considered for the study is listed in the table 3-1 below.

Table 3-1: Description of rainfall station (0476399) used.

Start Year	End Year	SAWS number	Altitude	Longitude	Latitude	Station name
1989/06	2022/12	0476399	1684	2814	-2604	Jan Smuts

It is necessary to examine the data set for uniformity and insufficient data. If data is inconsistent, it needs to be adjusted; if it is missing, it should ideally be replaced. Instrumental failure or unrecorded data could be the reason for missing data. A number of techniques, to fill in the gaps in rainfall data, several techniques can be applied, such as the arithmetic average, the normal proportion method, the reciprocal inverse weighting factor, and the artificial neutral network. Due to the arithmetic mean's ease of use, simplicity, and ability to solve any system of equations, it was used in the study to patch the missing rainfall data. A data series' missing values complicate analysis and raise concerns about its quality. It is crucial to take into account whether gaps are caused by defective equipment or are random. As long as the gaps in the data are not too big, there are a few techniques available to patch the incomplete data.

Although rainfall is often considered the most important factor for floods, what happens to the rain once it is on the ground can be even more important. Catchment characteristics such as shape, catchment steepness, soil permeability, and river slope and land vegetative cover can all impact how rainfall is absorbed by the ground. Summertime is when the majority of the rainfall in the study area occurs, and the study adopted a quantitative method by analysing and predicting the rainfall trend and mapping flood vulnerability by overlaying the calculated floodlines onto a map of Alexandra. The delineation of the structures at risk of flooding and warning systems was analysed qualitatively through communication with the community.

Trend analysis was performed on the rainfall time series of the homogeneous rainfall stations located within each cluster. Conventional trend tests, such as the Mann-Kendall test, were used to identify trends in the study area's yearly rainfall data from 1989 to 2022. When doing trend tests, the alternative hypothesis states that there is a substantial trend in the time series, whereas the null hypothesis (H_0) states that there is no trend. Either H_0 is accepted or denied depending on the crucial value at a certain significance level (usually the 5% level of significance). It is important to note that the failure to reject H_0 does not imply that the absence of a trend has been established. It indicates that there is insufficient data to draw the conclusion that a trend exists (Helsel and Hirsch, 2002).

Rainfall data is necessary to verify if floods existed in a certain year. The rainfall of the catchment was quantitatively determined from different stations within the catchment. Past rainfall and present rainfall trends give an indication of how changes have been occurring. The direction and extent of potential future changes can be inferred from an examination of historical observed rainfall data trends and fluctuations.

The first step in the hydrological study is to access good quality hydrological information; nevertheless, precipitation data is repeatedly incomplete. Jamal (2017) highlighted that some weather stations tend to have incomplete data records because of instrumental failure. According to (Shabalala et al., 2019) a basic arithmetic average of data from nearby stations with high-quality and trustworthy data can be used to fill in the gaps in the data. When the mean annual precipitation of the surrounding stations is known, the first method—known as the arithmetic mean—is employed and is within 10% of the missing data station. When the average yearly precipitation of one of the three adjacent stations is 10% higher than the rainfall station with insufficient information, the second method the normal ratio method is employed. The study used the rainfall utility software, which patches and extends rainfall data using a regression approach. The benefit of this approach is that projections can be produced in cases where the control data is also missing. It is easier to comprehend how current precipitation patterns diverge from past trends and to recognize the modifications that have occurred over time when previous trends in precipitation are examined. In order to determine the curve of the precipitation over the previous 30 years, this study analysed the records. Additionally, the rainfall data in tables and graphs were analysed using the quantitative research methodology. A graph was prepared between hydrological years and annual maximum rainfall using Microsoft Excel. Visual inspections of simple arithmetic calculations and time series plotting were performed, and this assisted in indicating trends in the plotted data.

3.4 METHOD FOR FLOOD ESTIMATION

No water level gauging is done in the study area and therefore a statistical analysis could not be done. Deterministic and empirical methods were used in the flood frequency analysis. The Rational and SCS-SA methods were specifically developed for small catchments. In such cases, their results may be used as the benchmark for comparing other methods results especially where results from statistical analyses are not available. The results of the Rational method are recommended for the study site and the results are less conservative than those of the other applicable methods. However, they were calculated using a method that was developed for a small catchment.

3.5 FLOODLINE MAPPING

The investigation was undertaken to determine the extent of the 1:100 year floodline of the study site. This informed whether there are dwellings that are at risk of being flooded during this event. It would further determine whether there are any areas that should be avoided for further housing developments. GIS mapping procedure to generate floodlines for floodline investigations and detailed contour data are required to produce accurate floodline delineations. Such contour data includes a detailed cross-sectional survey of the watercourse and surrounding floodplain and/or contour data at 5 m intervals. In this case, contour data at five-metre intervals were applied. This resolution (cell size: 5,5) is of course, but it can provide a useful indication of the areas at risk of flooding. The primary factor in selecting the Stjwetla area is that it is the area most impacted by floods.

The area flooded by the flood event with a 1:100 year return period was measured using one-dimensional hydraulic modelling using the HEC-RAS model (US Army Corp of Engineers). Contour data at 5 m intervals was imported into ArcMap and used to create a digital elevation model (DEM) that serves as the surface for the hydraulic simulation. Elevations and other topology pertinent to the hydraulic simulation were extracted from the DEM using HEC-Geo RAS, an ArcMap extension that connects to the HEC-RAS model directly. After that, the HEC-RAS model was used to import the data and model the hydraulics of the previously determined peak discharge value. After exporting the HEC-RAS results, ArcGIS was used to finalize the floodline delineation. The hydraulic model must take the roughness of the floodplain and channel surfaces into consideration. The right Manning's n value selection is crucial for the computation of water surface profiles to be correct. Many factors, such as surface roughness, channel irregularities, alignment, size and shape, scour and deposition, vegetation, obstructions, stage and discharge, seasonal changes, temperature, suspended materials, and bed load, influence the highly variable value of Manning's n. The data acquired from field visits and the area's land use (GeoTerraImage) map served as a foundation and guide. Manning’s n values of for channel and overbanks were chosen for all the cross sections as contained in Chow’s table (see table 4-3) (Chow, 1959). The Department of Agriculture and Environmental Affairs (DAEA) South African National Landcover (2013 - 2014) provided the land cover data used for this purpose. The dataset was assembled in 2015 by Geoterra Image (Pty) Ltd.

The proof of flooding in the selected households were images which were taken by residents, the municipality, and newspapers. The disaster management team that dealt with previous disasters were questioned to determine their opinions related to possible solutions regarding flood disasters. It was imperative to seek this kind of information from the disaster management team since they work with this information and they are involved in compiling the plan for disaster management.

3.6 SURVEY OF FLOOD RISK

3.6.1 Structured questionnaires

A quantitative method was utilized in the study whereby in-person questionnaires were administered. The questionnaire contained questions where respondents were asked to choose the most appropriate option and there were also a few open-ended questions to capture data not covered by the other questions (Appendix D). The questionnaire was constructed in a manner that it could produce quantitative data for comparison purposes in establishing people's perception of risk associated with floods. The questionnaire was about the residents to gain insight into their coping strategies during floods, receiving flood information and their age, gender, occupation, and address.

The target population were residents of Stjwetla in Alexandra Township. The researcher recognized pertinent individuals who meet the criteria to be considered respondents; these are councillors, municipal officials, community organizations and household heads aged 18 years and above within the study area.

The questionnaire for individual households was be grouped into five questions.

- General issues
- Livelihood
- Disaster impacts
- Coping strategies
- Property

The authorisation was requested from the councillor to carry out a study with residents and once the councillor granted permission (Appendix A); residents were shown the permission letter and the next step was to make respondents aware of the objectives of the study. To avoid respondents losing interest in taking part in the research, questions are well formulated, clear, and easy to understand.

3.6.2 Semi-structured interviews

A semi-structured interview helps create the impression that the researcher is not overly involved and that participants are free to offer their own observations. A predetermined list of questions that focused on the individual as well as their struggles were part of the semi-structured interviews used in this study. The interviewer probed responses when needed, and the order of questions varied among respondents (Jamshed, 2014). Garrett (2016) highlights that this technique is appropriate because it allows for the probing of more information and is ideal for investigating behaviours, views, principles, opinions, and motivations pertaining to intricate and sometimes delicate subjects. It also creates a platform for the interviewer and interviewee to have a focused discussion. One (1) councillor and four (4) municipal officials were interviewed through semi-structured interviews.

The steps that were followed before the interview:

First step: The purpose of the interviews with officials was explained over the phone when they were scheduled.

Second step: Prior to the interviews, questionnaires were sent via email.

Third step: Each interview lasted between 20-40 minutes.

3.6.3 Administration of Questionnaires

The questionnaire was administered to determine different aspects from respondents. Interviewer administered questionnaires were conducted with close-ended questions, which guaranteed that all questions were answered, avoiding blank spaces and resulting in an increase in participation. Questionnaires are the most used instrument of research. Due to financial limitations and time, at least one hundred (100) households were randomly targeted for the questionnaire.

Using a street shape file superimposed on a Google map, a systematic sampling technique was used to create the randomised sample of participating houses. Sampling is a method used to classify a population subgroup that is reflective of all people during the data gathering process. Furthermore, Mathers et al. (2007) state that in order for samples to characterize the entire population, one needs to involve a statistician.

Sampling has two benefits, which are lower cost and quicker data collection than the assessment of the whole population. According to Fridah (2002), the main reason for sampling is feasibility. To have more precise and accurate information, one needs to employ the use of sampling. Time and money can be invested to produce higher-quality research and more comprehensive information by using sampling.

In general, sampling methods are divided into two types: samplings that are both non-probability (non-random) and probability (random). Non-probability sampling is defined as a method where the researcher's judgment is the deciding factor and no participant's chances of being selected for a sample can be calculated (Alvi, 2016). Probability sampling means that everyone in the population has an equal chance to be included in the study or sample and is also characterized as a process by which a sample from a large population is selected using a probability theory method for participants to be considered a probability sample; they must be selected using a random selection method (Alvi, 2016). Teddlie and Yu (2007) highlight that one of the characteristics of probability sampling is that the technique aims at achieving representativeness and comparability. According to Leedy and Ormorod (2001), certain participants in the community have minimum to no possibility of being chosen for the study's participant sample. This type of sampling (random) is useful in circumstances where one needs to reach a targeted sample without hassle, targeting only people who are directly involved or affected by floods (Palinkas et al., 2011). The residents who were impacted by the floods or experienced its effects are more relevant to the study because they have pertinent information that the study needs.

3.6.4 Analysis of Questionnaires

Wright (2003) notes that “conducting data analysis is like drinking a fine wine. It is important to swirl and sniff the wine, to unpack the complex bouquet and to appreciate the experience. Gulping the wine doesn’t work”. According to Egger (2010), data analysis is the process of establishing or finding beneficial information by interpreting the raw data. Raw data cannot easily be interpreted but one needs to analyse and interpret the data. The data from questionnaires were coded and labelled using Statistical Package for Social

Science (SPSS) and GNU PSPP computer-aided analysis and cross-tabulations of descriptive statistics, and the final product was graphs and tables for interpretation. According to Cooksey (2020), descriptive statistics organize and summarise raw data, where graphs, tables and calculations are being used to describe the data in the form of average and percentages.

The software was employed because it is the most used package for analysing survey data that provides detailed information, and it is user-friendly and analyses multiple response questions (Cohen et al., 2003). These were to shed light on the socio-economic characteristics like poverty level and literacy. The following indicators were discussed: flood frequency occurrence, awareness, emergency services and early warning systems. In the meantime, the responses to the open-ended questions were qualitatively analysed and used to develop arguments on various topics as well as comprehend the scope and severity of the flood event.

3.6.5 Pilot study

According to Eldridge et al. (2016), a pilot study is a preliminary investigation that is conducted on a smaller scale to see if the main study's components can cooperate. A pilot study is conducted to get crucial information that can help in improving the large-scale study. According to Van Teijlingen and Hundley (2001), a pilot study raises the likelihood of a successful main study but does not ensure it. According to Stopher (2012), the reason a pilot study is necessary is that problems pertaining to respondents' varying interpretations will inevitably arise; therefore, it is necessary to address these issues prior to conducting the main study. Therefore, it's important to pay attention to how questions are worded in order to prevent needless misunderstandings.

Following a thorough comprehension of the research topic by the researcher, queries, methods, and strategies to be used, the pilot study is conducted (Calitz, 2009). Five households participated in the pilot study, which gave the researcher insight into the timing, language, and behaviours of the other respondents. Also, it was undertaken to test the measuring tool, which is a questionnaire. According to Du Plooy (2004), pilot studies are regarded as beneficial because they can be used to assess the validity and reliability of the methods in the study. Two field workers received training in administering questionnaires as well as in analysing community behaviour. The field workers were trained for one day on how to conduct a survey. The instruction concentrated on how to approach the participants and formulate questions, particularly those intended for translation, how to not lead your respondent's answer and how to conclude the interview.

3.7 THE HOUSING STRUCTURE

3.7.1 Data collection

This was accomplished by asking residents to describe the building materials they used to construct their homes in questionnaires. The questions were broken down to look into the most common materials used for walls, floors, and roofs.

3.7.2 Analysis of data

Data without a proper analysis means nothing. Therefore, the researcher needs to make sure that important results are generated by the given data. Since the data consisted of closed-ended questions, such questions are intended to produce data that are effortlessly quantified and final in nature. They also permit researchers to classify participants into groups based on the choices they have made. Coding of data is simple but extra care must be taken in the coding process in order to uphold reliability. Furthermore, the housing structure data were coded, and frequency tables were produced, these tables were then used to understand the coefficient correlation between two different variables. The effects of flooding were contrasted with home construction. This provided the researcher with the chance to investigate the extent of the damage to the housing units. This demonstrated that casual structures (metal sheets) tend to suffer more losses than formal homes (bricks). Coding the material used to build homes into two categories: bricks and shoddy material (such as plastic, mud, metal, and timber). To analyse this information, a statistical package for social science was required, because the package is able to interpret the outcomes and show data tables quickly (Arkkelin, 2014). The statistical package involves three (3) procedures namely, coding, data entry and analysis. It was ideal to transfer data onto a single grid to make the assessment easier and archiving of the responses. This helped the researcher assess the degree of destruction to the home's structure in connection to building materials. The purpose of the data analysis is to support researchers when drawing a conclusion (Arm Treasure Data, 2015).

To assess the link between the responses, the researcher employed the chi-squared test of independence and descriptive statistics. The mixed method's quantitative approach is supported by the chi-squared test in this investigation. The statistical significance threshold for the chi-squared test was set at $p < 0.05$. Chi-squared (symbolically represented as χ^2) is the most popular usage of tests in hypothesis testing. A hypothesis is a conjecture that, based on potential testing, may or may not be true. The Chi-Square test calculates the difference between the estimated and existing results when the number of variables in the relationship and the sample size are taken into consideration.

In these tests, degrees of freedom are used to determine whether a particular null hypothesis can be rejected in light of all the data gathered during the investigation. The outcome is more dependable with the larger the sample size.

The formula for the Chi-Square test:

$$\chi^2 = \sum \frac{(0-E)^2}{E} \quad \text{......} 3.1$$

Where:

χ^2= is the chi-square test statistic

$\sum$= is the summation operator (meaning take the sum)

O= Observed value

E= Expected value

The observed values are those that are collected or observed by the analyst and the expected values are the end results based on the null hypothesis.

Trend detection: The most popular technique for analysing natural time series data, like hydrological time series data, is the Mann-Kendall method. In light of this, this study employs the Mann-Kendall method to find patterns and variances in extensive hydrological time series information. The two parameters of MK, the significance level and the gradient magnitude estimation, represent the trend's magnitude as well as its strength and direction, respectively. Trend varies between -1 and 1; it is a positive number when the trend increases and a negative number when the trend decreases. Mann Kendall test was conducted using the ProUCL software package providing statistical and graphical tools needed.

3.8 VALIDITY AND RELIABILITY

In qualitative research, reliability and validity are frequently referred to as trustworthiness, where deeper analysis and observation lead to reliability (Elo et al., 2014). According to Jackson (2015), validity can be defined as the indicator used to assess what it intends or claims to measure. The findings are expected to be valid if all the approaches and methods are in place such as to investigate, check and theorise. Bless et al., (2006) define reliability as the measuring instrument that yields the same results each time it is applied, in short, its consistency, dependability and accuracy. The research design must be able to yield reliable and valid results.

Validity and reliability are terms used in the research to assess the quality of research. When you are generating a research design it is imperative to contemplate validity and reliability. The information acquired during the field visits strengthens the reliability of the study's conclusions. The measures which were employed to guarantee the reliability and validity of the information gathered are as follows:

- Ensuring validity by testing questionnaires in the pilot phase. Questions for the questionnaire were carefully and precisely worded. In addition, by ensuring that there are enough participants and that they are representative of the sample population.
- Ensure reliability throughout the procedure of data collection; it was critical that the results are precise and reproducible. Pilot studies are usually used to test reliability.
- There are different kinds of validity, face, construct, content, and criterion validity. The study utilizes construct validity and face validity. To guarantee the authenticity and dependability of the gathered information, the subsequent protocols were employed: When two distinct parties reviewed the questionnaires, internal validity was used. The first party being supervisors who are familiar with the topic and can evaluate the questions. The second party was someone (a statistician) who is a professional in question construction.
- Furthermore, the testing of reliability was done using Cronbach Alpha. According to Bobbitt (2021) definition, “Cronbach Alpha is a way to measure the internal consistency of survey or questionnaire, values of Cronbach Alpha ranges from 0 and 1. With higher values indicating that the survey is more reliable”. The calculated Cronbach Alpha is 0.78 and this score is considered to be good (Appendix C). The

calculation was done through the GNU PSPP Statistical Analysis Software, it recites the input, processes it in accordance with the instructions given, and a graphical display window with a standard end product file.

In addition, the integrity of the research is determined by precise data collection.

3.9 ETHICAL CONSIDERATIONS

Ethical considerations are crucial in research because they guarantee respect for all involved. In this research, the researcher endorsed the ethical principles of the University of South Africa (UNISA, 2016). In order to guarantee ethically acceptable research and to comply with UNISA's ethical policy, the research proposal was submitted to the Ethics Committee and an ethical clearance certificate was granted (Appendix H). Complying with the regulations of the University of South Africa, standardization and uniformity were adopted during the study for all respondents. The study depended on the use of human subjects for completion. Consent to conduct the study in the Alexandra community has been granted by the City of Johannesburg (Appendix A). Since qualitative research requires the researcher to be part of the private environments of research participants, it was prudent to adhere to research ethics in order to increase the response rate. The author considered the following aspects specifically:

- Issues of informed consent (Appendix B)
  Which is the willingness of individuals to engage in the exercise of their preference. All participants were briefed about the aims and objectives of the study.
- Confidentiality
  According to the Oxford Dictionary, “confidentiality is the state in which you anticipate someone to keep information private”. The data which were collected were strictly confidential and the results were for academic purposes only.
- Anonymity of the participants.
  This means that the identity and responses of the research participants cannot be identified and this was respected in the study.

Since everyone taking part in the study was a volunteer, they could all leave at any time. Additionally, they were (and still are) guaranteed complete confidentiality of both their identities and data. There was no psychological abuse or legal risk posed to study participants. Hard copies of all the data were kept in the researcher's office and on his personal computer.

CHAPTER 4: RESULTS PRESENTATION AND ANALYSIS

4.1 INTRODUCTION

This chapter discusses the findings/results of the study and explores the finding's effort in addressing the study's research questions. The discussion includes the demographic characteristics of the population, floodline mapping, housing structure and local knowledge about floods. The abovementioned information was gathered from municipal officials and members of the community.

Walking around the study area that was designated as a flood-prone area, was the first task during the fieldwork. Before contacting residents for interviews, the researcher studied the neighbourhood by taking a walk around the study area. During the fieldwork, the researcher respectfully and politely approached residents to ask permission to enter their homes. People who were present in a house were randomly chosen and approached. After greeting the respondents in their native tongue, they were instructed to express their preference for the interview's language.

After spending 18 days in the field, 97 households were sampled, compared to the original plan of sampling at least 100. Some people were not interested in forming part of the study, others wanted to be compensated for taking part in the study, and others felt that they were not relevant to the study, despite the assurance that the aim of this research is to offer education, and it's not linked or affiliated with the local municipality or any organizations. After some thought, the researcher determined that the information gathered was adequate because the stories were already producing dense narratives and painting a clear picture of the situation.

4.2 RAINFALL VARIABILITY

The intensity of the flood is mostly determined by the deepness, area spread, and period of the rainfall as well as by changes in intensity over time and space in the catchment. The graph below shows that the study area's rainfall variability has increased over the past several years, with some years exhibiting extremely high peaks and lows that, in turn, resemble catastrophic climatic events like floods. Occasionally, there are brief periods of intense rainfall that result in flooding. The fluctuation of rainfall is making the rainy season unpredictable, which has an impact on the livelihood. The five highest rainfall events occurred during 1995, 1996, 1997, 2009 and 2010, mainly associated with the typical pattern of summertime precipitation in the highveld. Residents showed a good insight into the cause of the flooding, by indicating that floods are caused by heavy rainfall. The examination of patterns was conducted by using a Mann-Kendall test, where the end results are confidence coefficient with a value of 0.9500, level of significance with a value of 0.0500, standard deviation of (S) with a value of 67.4413, standardized value of (S) with the value of -0.3559, MK test value (S) with the value of -25 and p-value of 0.3610 which represents the evidence against the null hypothesis, based on the results the p-value is greater than level of significance, it suggests insufficient evidence to reject the null hypothesis. This indicates that there is no statistically significant trend in the data (**Figure 4-1**). Rainfall variability is causing the rain season to be unpredictable, which ends up affecting the community. A helpful statistic is the co-efficient of variation, which shows how far the standard deviation differs from the mean. The calculated CV is 0.21 or 21%. Since the CV is lower than 1, it is considered to be low-variance and within the acceptable range of coefficient variation.

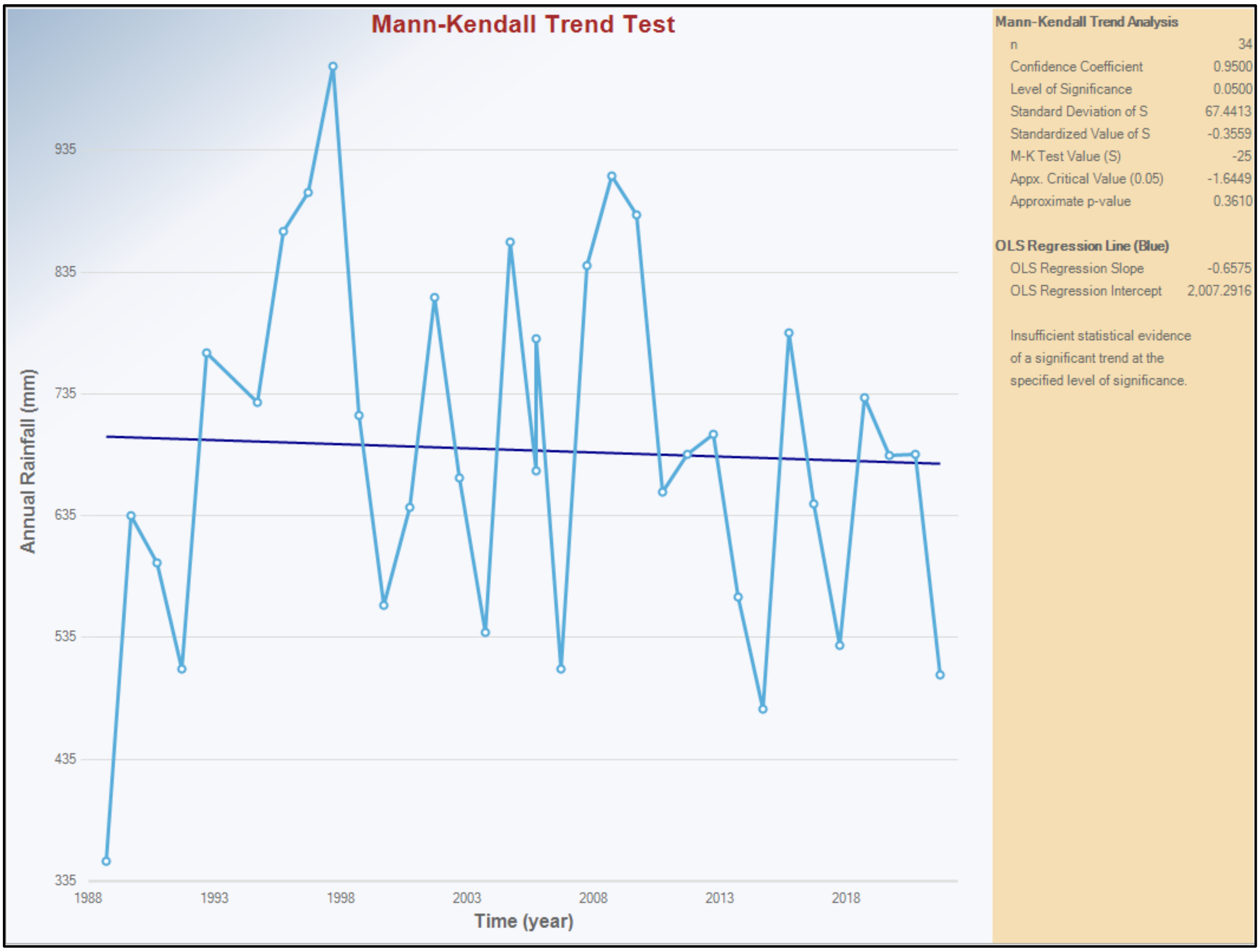


Figure 4-1: Annual Rainfall Variability for Station 0476399.

4.3 SOCIO-DEMOGRAPHIC CHARACTERISTICS

According to the sociodemographic data, more females than males were included in the sample. Due to the dissertation's scope, it must be highlighted that the research did not directly involve any groups in the community addressing issues like belief systems, gender identity, employment, and women's empowerment. Future research could focus on these populations (and others) to learn more about their coping strategies and responses to disasters.

The socio-demographic data are given in **Table 4-1**. The average respondent's age is 30-45 years. It is believed that older people are more vulnerable than the youth. However, the outcome of the research indicates that the dwellers are mostly young adults. In South Africa, people aged between 18 and 35 are considered as the youth of the country. Most of the respondents (95%) have indicated that they fall within the educational level Grade 0-12, a portion of the participants lack formal education and about 5% of the dwellers had some tertiary education. The poll generally shows that most of the study's respondents do not have tertiary qualifications. Most of the dwellers have lived in the study area for an average of four years or longer, with 6% having lived in the area for two or less (one) years. 4% of the study's respondents have dwelled in the area for two to four years. Most of the respondents did not have any members with disabilities, only one household indicated that they have members with disabilities.

The results show that 66% of the participants in the research area have 3-5 members in a household, and 28% have between 1-3 members, and 6% have more than 5 members. According to the 6% of respondents who have dwelled in the area for one to two years, there is regular migration into and out of the area. This may be because people from other parts of South Africa or Africa travel to Johannesburg in search of employment opportunities.

Table 4-1: Socio-demographic characteristics of respondents in Stjwetla area.

Catergory	Characteristics	Total No. of respondents	% of respondents
Gender	Female	59	61
	Male	38	39
Age	18-30	27	28
	30-45	54	56
	45-above	16	16
Education	Grade 0-12	92	95
	Diploma	5	5
	Degree		
Total number of dwellers	(1-3)	27	28
	(3-5)	64	66
	5-above	6	6
How long have you stayed in this area	(1-2)	6	6
	(2-4)	4	4
	4-above	87	90

4.4 ESTIMATED FLOOD MAGNITUDE

The investigation's goal was to ascertain the extent of the 1:100-year floodline of the study site rivers. This indicates whether there are dwellings that are at risk of being flooded during this event. According to the delineated mapping (**Figure 4-2**) that is based on the floodplain, the results suggest that many dwelling units are built below the floodline. It further determined whether there are any areas that should be avoided for further housing developments. For floodline investigations, detailed contour data are required in order to produce accurate floodline delineations (Govender, 2021). In this case, contour data at five metre intervals was applied and this resolution provided a useful indication of the regions that are in danger of inundation. According to Liu et al., 2015 an important indicator for determining how vulnerable residential structures are to flash floods is the buildings' horizontal distance from the riverbanks. The proximity of residential buildings from riverbanks with a horizontal distance from the stream centerline was measured to be approximately 5.5 m using ArcGIS. These sections were reported and mapped out. The model then performs a successful calculation throughout the interior points and keeps the distance constant. The Jukskei River basin in Stjwetla Township is considered to have a steady river flow for the purposes of this research project. Since time-dependent flows are excluded from the energy calculation, a steady flow river is one that has been considered to flow steadily along the reach (Salimi et al., 2008). An unsteady flow is more complex and demands more data than a steady flow.

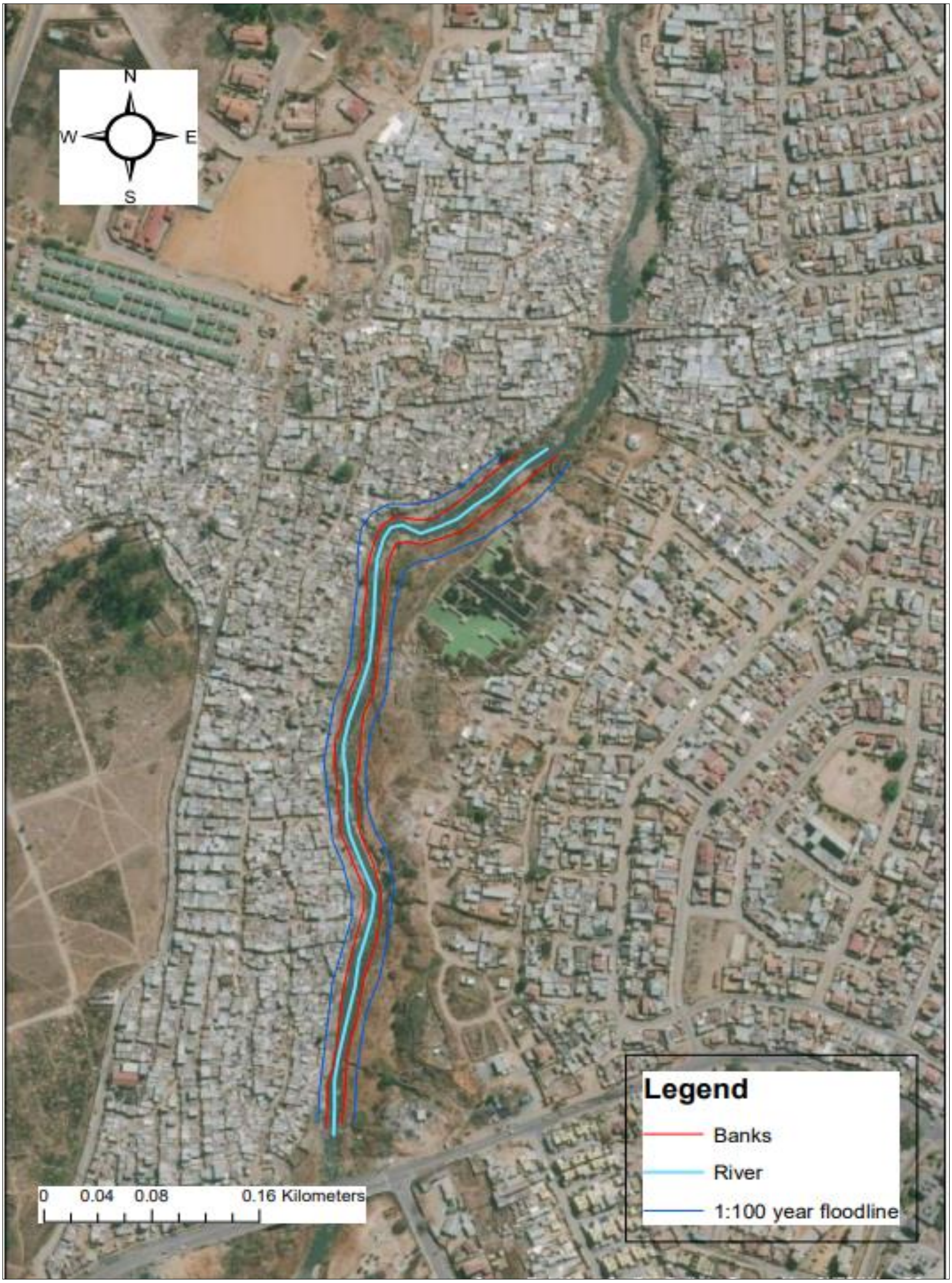


Figure 4-2: Delineated floodline for Stjwetla area.

4.4.1 Design flood estimation

The flood frequency analysis of the project site was undertaken to estimate flood peaks using several accepted methodologies. The rational method is a straightforward technique that replicates flood peaks using storm rainfall and catchment characteristics. The approach has been successfully applied to larger catchments, despite the general recommendation that it can only be used for catchments smaller than 15 km^2 (Van der Spuy and Rademeyer, 2021). It was found that the Rational method was the most appropriate for the project site for reasons that included its applicability to small catchments (as is the case in this study) and its performance in relation to the SCS-SA method (a method developed for small catchments). The 1:100-year design flood peak of the main catchment is estimated as **120 m^3/s**, see **Table 4-2**. The Rational method requires the vegetation types as a percentage of the total catchment area, and the vegetation is classified according to the description from Geoterra Image (Pty) Ltd (2015). Catchment characteristics and storm rainfall are used as input to the methods. The conversion of storm rainfall into flow takes into account the catchment characteristics that play a vital part in the determination of storm-loss and hydrograph shape, encompassing the primary watercourse's distance, gradient, and drainage basin and its steepness. When the exceedance probability (return period) decreases and the storm's duration decreases, the storm's intensity increases. For a given exceedance probability, the storm rainfall duration must match the time of concentration (t_c) in order to produce the largest possible flood peak. By splitting up the storm rainfall P by the critical storm duration D—which can be ½t_c, t_c, or 2t_c—the rainfall intensity i is found. I (mm/hr) = P (mm)/ D(hr), in short rainfall intensity is the amount of water (in mm) received during a rainy period divided by the duration of the shower.

To determine the average precipitation intensity over the catchment, the rainfall intensity must be multiplied by the ARF for the duration of interest. The average rainfall intensity is the value that is used in the Rational method. The catchment area can be accurately determined by using ArcGIS, providing the correct projection used. Alternatively, a planimeter can be used to estimate the catchment area from 1:50 000 or 1:250 000 (larger catchments) topographical maps.

The workable rational equation is given by:

$Q_P = 0.278\, C_P\, I_P\, A$……………………………………………………………………………4.1

P – exceedance probability

Q_p - peak flow (m^3/s)

0.278 - conversion factor

c_p - Runoff coefficient (dimensionless)

I_p - average rainfall intensity (mm/hour)

A – effective catchment area (km^2)

The duration of a water particle's journey from the furthest point in the catchment to the outlet is known as the time of concentration (t_c). When extreme events occur, the storm duration is thought to be comparable to the concentration period. Both overland and natural flow components can be present during a time of concentration.

Natural channel: DWS also uses this equation to determine the time of concentration for channel flow, which is more helpful in rural areas.

$$t_c = \tau \left[\frac{0.87 \times L_1^2}{1000 \times S_L}\right]^{0.385} \quad \text{.......} 4.2$$

where:

t_c time of concentration (hour)

τ correction factor

L_1 length of natural channel (km)

S_L mean channel slope (m/m)

Using the above equation, the calculated time of concentration for the study area is 1.5 hours. The input values are as follows:

$\tau = 1.1$

$L_1 = 24.7$

$S_L = 0.21110$

The catchment slope is determined by overlaying a grid of at least 50 squares over the catchment. The horizontal distance between the contour intervals is then measured for each grid point. In the grid method, the catchment slope is defined as the average slope perpendicular between the nearest contour lines, through each grid-point.

The longest watercourse is the path that a water particle will take from a location on the catchment border to the catchment outflow, given the longest time. The natural channel (L_1) and overland flow (undefined channel, L_2) make up this distance. The separation between the catchment border and the natural channel's upstream end. With GIS, this distance may be measured with great accuracy. For ease of reference, the Map with grids is provided in Appendix G.

The runoff coefficient is an integrated value representing a number of factors, influencing the rainfall-runoff relationship. It reflects that part of the storm rainfall contributes to the peak flood runoff at the outlet of the catchment. The runoff coefficient is given by:

$C1= (C_s + C_p + C_v)$ ……………………………………………………………………...4.3

Where:

C_s = Steepness of the catchment

C_p = Permeability of soil (%)

C_v = Vegetation (%)

Table 4-2: Rational method input

Catchment	**A (km²)**	**Conversion factor**	**Runoff Coefficient**	**Rainfall intensity (mm/hour)**
Main Catchment	61	0.278	0.287	683

4.4.2 Flood extent estimation (steady flow)

The area flooded by the 1:100-year return period of a flood event was measured using one-dimensional hydraulic modelling. Contour data at 5-meter intervals was imported into ArcMap to generate a digital elevation model (DEM), which was then used to create a surface for the hydraulic simulation. Elevations and other topology pertinent to the hydraulic simulation were obtained from the DEM using HEC-Geo RAS, an ArcMap extension that connects to the HEC-RAS model directly. The HEC-RAS model was then used to import this data and model the hydraulics of the previously determined peak discharge value. After that, ArcGIS received the HEC-RAS output for the last floodline delineation. Note that this study's floodlines are based on a 5 m resolution digital elevation model (DEM). Because there is not so much detailed information available using spatial data at this resolution, the resulting floodlines are regarded as high level. On the other hand, Mkhulisa (2016) states that the high level floodline delineations are thought to be adequate in identifying the areas that could be flooded during the 1:100-year design flood event.

The study area is characterized by relatively high and low-elevation areas (valleys), as Figure 4-3 illustrates. As a result, compared to communities and low-elevation locations for infrastructure, those situated in high-elevation areas are less vulnerable to periodic flooding. The Jukskei River, which is positioned in the east side and central regions of the study area and has an elevation of 1519 meters above sea level, is clearly the location of the lowest elevation, as indicated by the DEM. The township's elevation steadily rises toward its northern and western regions, reaching its maximum elevation of 1657 meters above sea level. Since those areas remain submerged for the majority of the flood period, it is evident from the DEM that the eastern and central portions, which have the lowest elevations, are more susceptible to periodic flooding than the higher areas.

The banks line (Red) was created by RAS Geometry from the HEC-GeoRAS toolbar. This creates a “Banks” layer in ArcMap. The riverbanks are drawn by starting an edit session to edit the “Banks” layer. It is advisable to draw the left bank of each stream first and then the right bank. These must be drawn from upstream to downstream. At times it is difficult to see where the bank positions need to be due to poor quality imagery and/or due to discrepancies between imagery and spatial information. The resultant riverbank lines are shown in the **Figure 4-3**. Notice that the Jukskei River banks and its bank lines are all separate lines that do not touch each other. In order to determine the study area's relief and slope, as well as to create and present ground level contours and serve as the foundation for dynamic flood mapping, a DEM of Alexandra Township was utilized. In order to evaluate the area's overall topography and to draw attention to low- and high-lying areas, contour lines were added to the elevation model.

The township's height steadily rises toward its northern and western ends, with the greatest elevation occurring at 1586 meters above sea level. Since these areas are frequently submerged during the flood period, it is clear from the DEM that the lowest elevation in the eastern and central regions accounts for why these areas are more vulnerable to frequent floods than higher places. A given amount of water would cause less flooding in a valley that is wide and level than it would in one that is narrow and steeply sloped (Thieken et al., 2005).

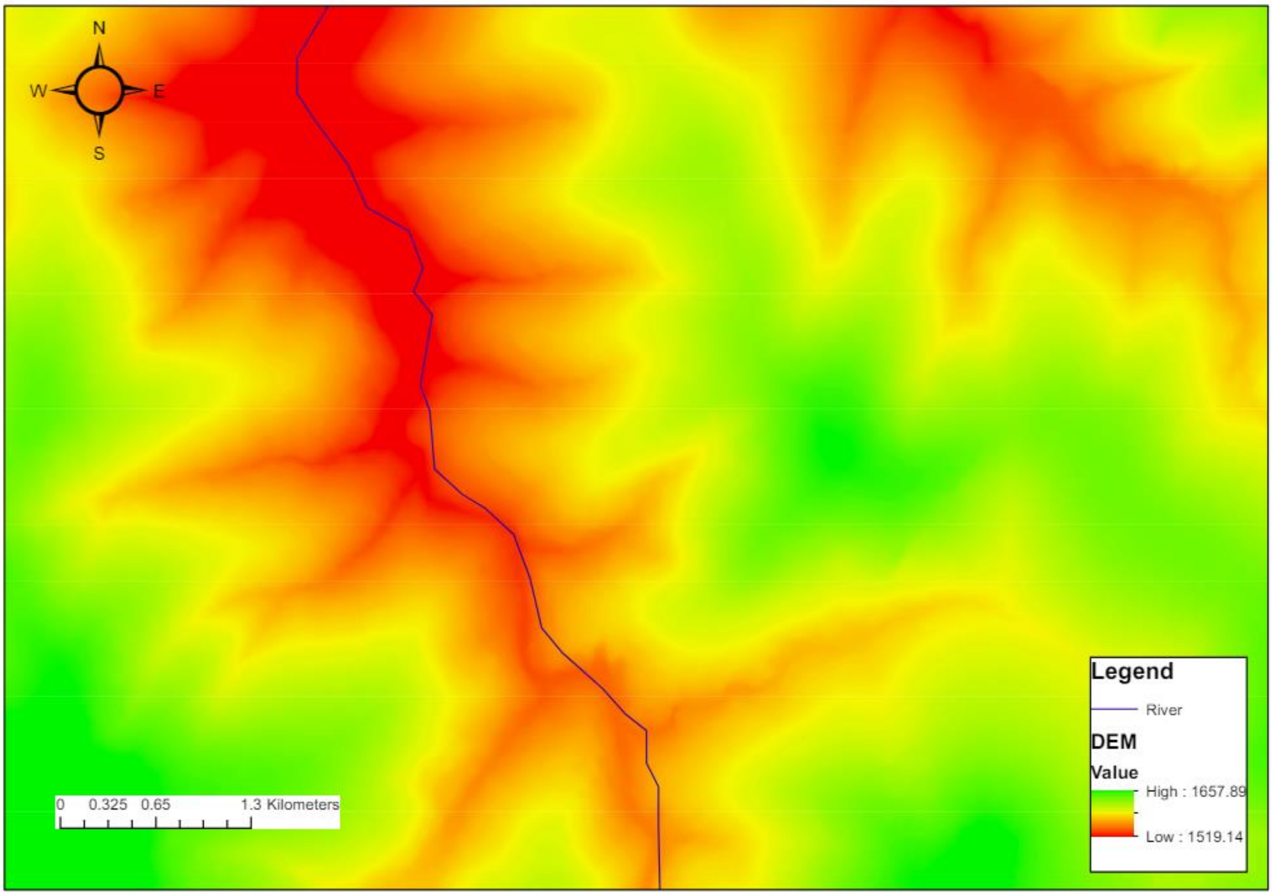


Figure 4-3: DEM (Digital Elevation Model) created from contours.

The hydraulic model must take the roughness of the floodplain and channel surfaces into consideration. In this instance, the surface roughness within HEC-RAS was described using Manning's n values (Chow, 1959). The Department of Agriculture and Environmental Affairs (DAEA) South African National Landcover (2018 - 2020) provided the most recent land cover data needed for this purpose. Therefore, selecting appropriate Manning's N-values is very important for accurate computation of water surface profiles. The general Manning's n values that were used in the study for the modelled river reach and surrounding floodplain are shown in Table 4-3.

Table 4-3: Manning's n Values (Chow, 1959; GeoTerraImage, 2014)

Manning's n	Description
0.005	Bare non-vegetated areas
0.050	Sparse vegetation
0.035	Grassland
0.200	Built area
0.085	Intact vegetation

Figure 4-4 shows an imagery layer providing a comprehensive indication of the regions that are susceptible to flood risk and already inundated. Most flooding extents occurred during the 1:100- years' return periods. Most of these housing structures were informal. The floodline serves as a guide to help with safe house layout, but it does not set fixed flood water levels. Regarding the river flow direction, Jukskei River passes through the Stjwetla community from the direction of Ellis Park (Johannesburg) to the direction of Steyn City before joining the Crocodile River.

Figure 4-4: Viewing simulation results in RAS Mapper for Stjwetla area.

To find regions where flood overtops occur, cross-sections were made at an angle to the river, and they were stretched to reach the maximum watershed elevation. According to **Figure 4-5**, the results show that the cross-section plots have not been overtopped, this approach is a good way to ensure that none of the cross-sections are overtopped by simulated water. The HEC-RAS software describes the shape of the stream, its elevation, and its relative location by analyzing several input parameters for each cross-section. Additionally, using the locations of the stream banks, three sections of the left floodway, the main channel, and the right floodway were identified in each cross-section.

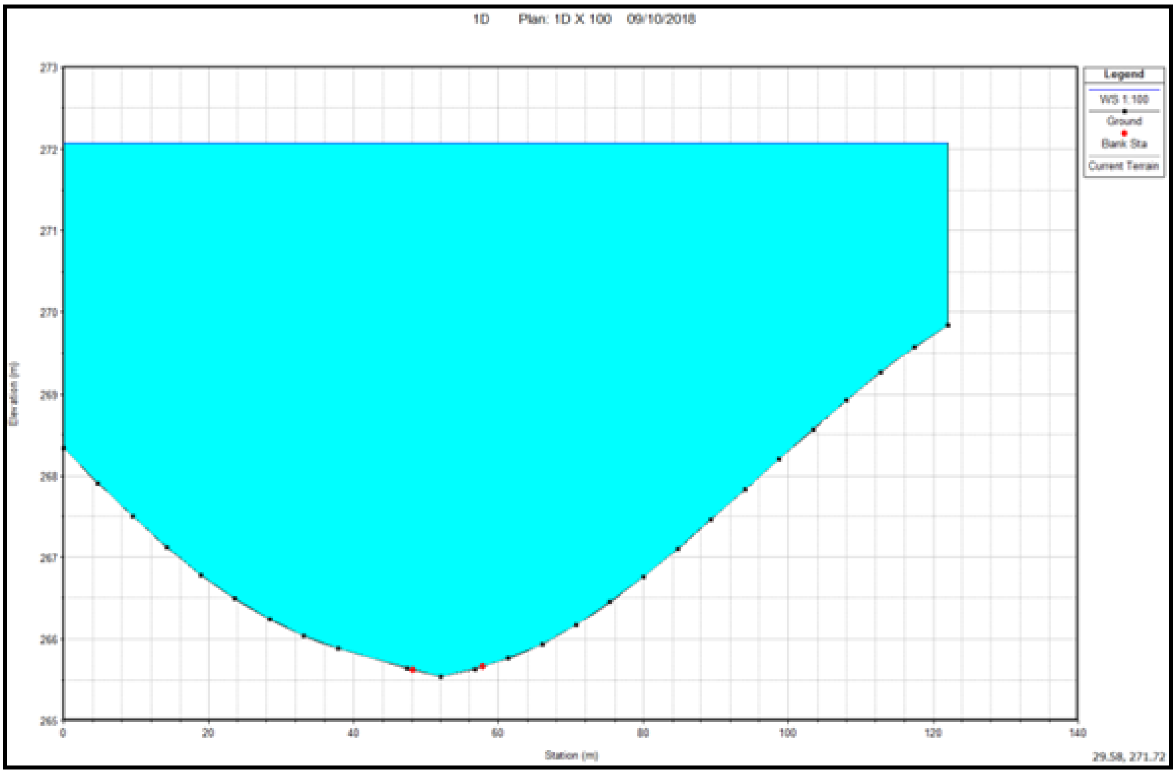


Figure 4-5: Viewing simulation results in cross-section view – cross-section not overtopped.

A set of connected channels with uniform flow that is predetermined and is also perpendicular to the flow, and discrete cross-sections spaced at regular intervals. **Figure 4-6** below, provides a side view of the watercourse long sections. Generally, the upstream side of the river/s is on the right of the Profile Plot window and the downstream side is on the left. One can view one or more watercourses at the same time in this option.

Due to differences in hydraulic variables, HEC-RAS separates a cross-section into various divisions. For instance, in a floodway, the wetted boundary was higher than the main channels.

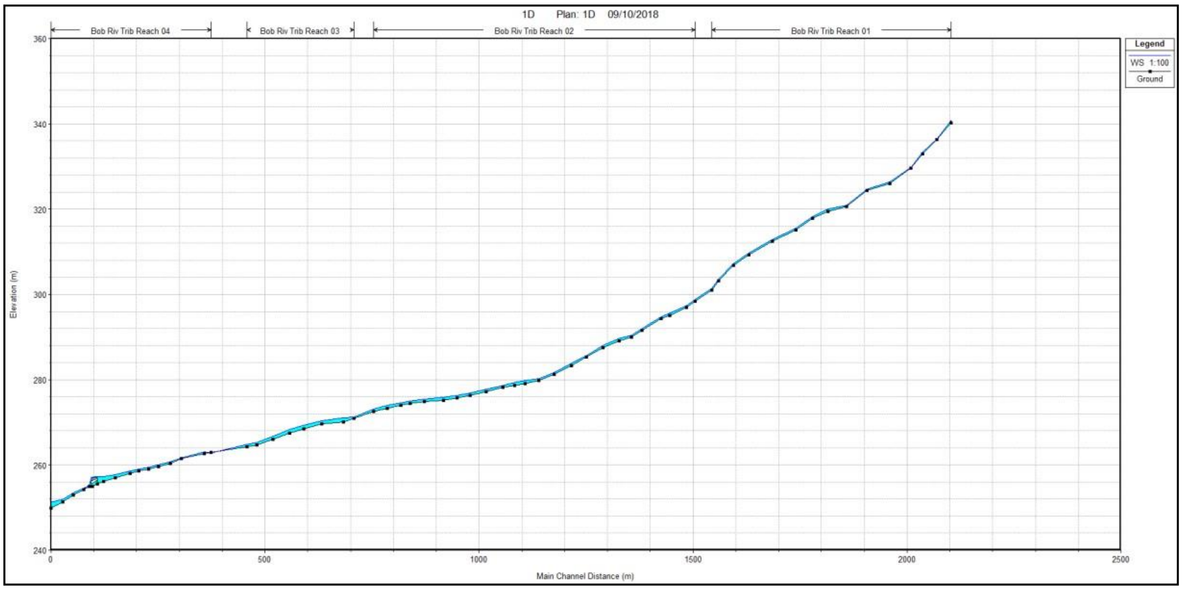


Figure 4-6: Viewing simulation results in long section view.

A multi-cross section plot in three dimensions inside the reach is called the X-Y-Z plot. The **Figure 4-7** below, indicates several watercourses and the view of the plots can be rotated on various axes by adjusting the rotation angle x. This graphic figure makes it evident that the facilities, especially those in low-elevation locations, are situated near rivers and are subject to 100-year floods. The flood-prone region map also helps to identify flood-affected areas and to forecast areas that will likely flood owing to high water levels during flooding. The blue colour in **Figure 4-7** represents the water surface and the red line represents the riverbanks.

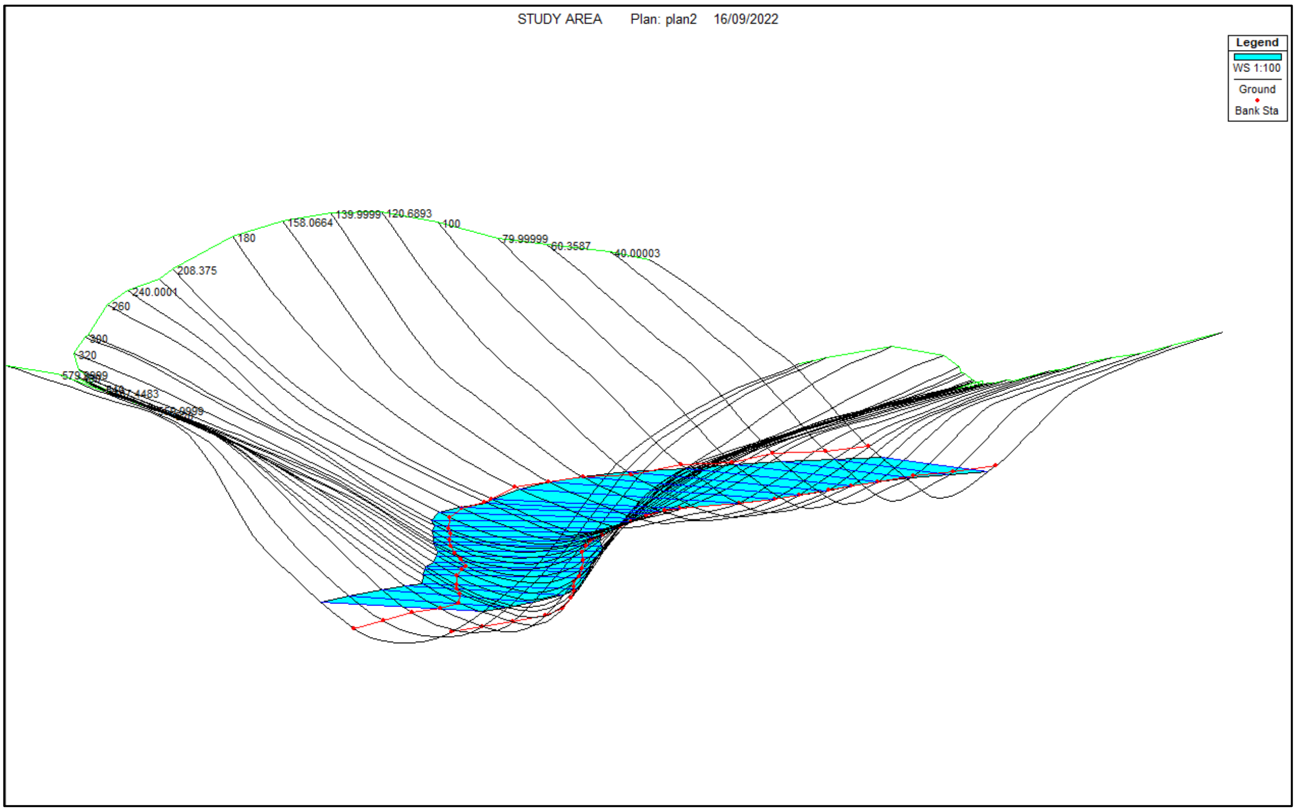
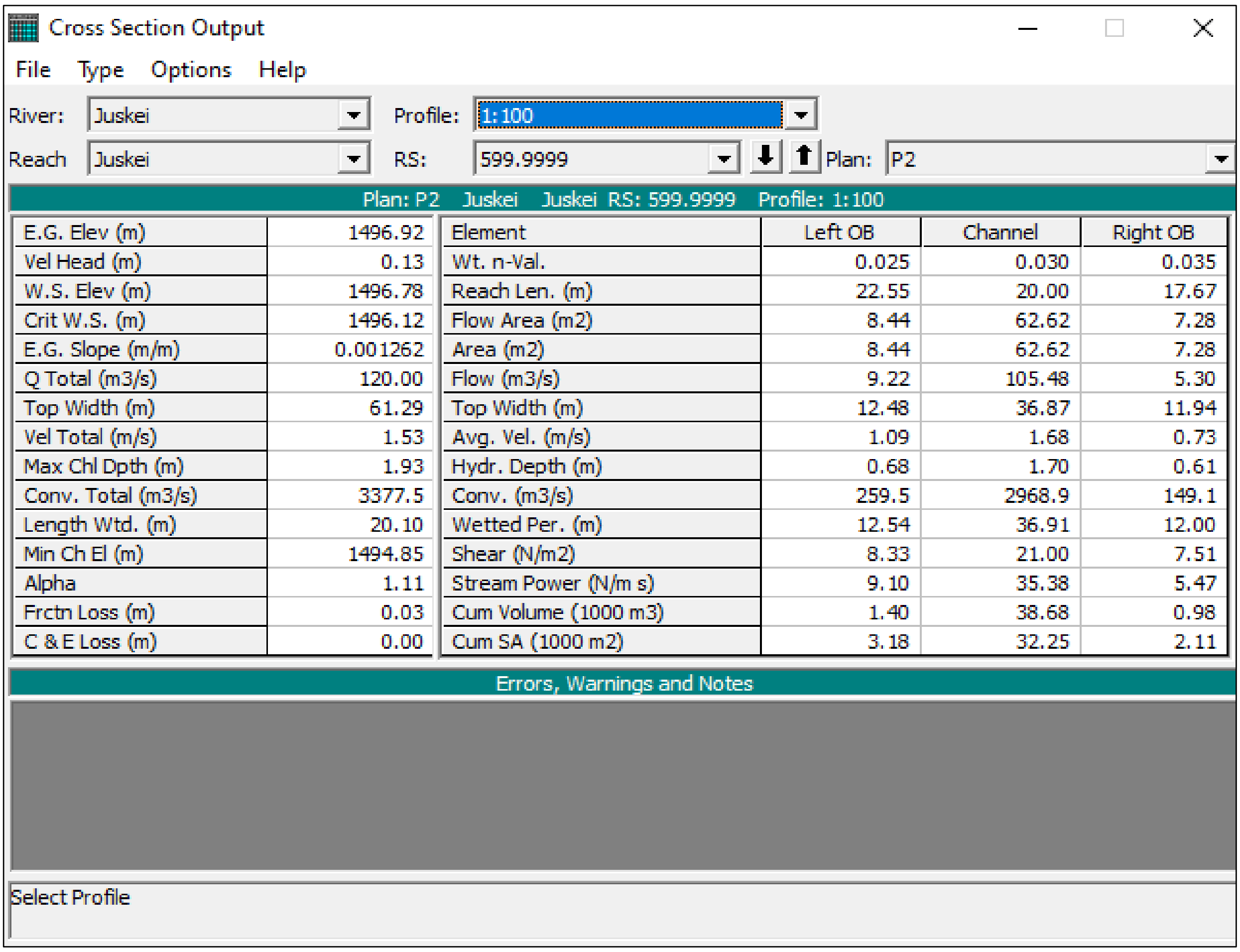


Figure 4-7: Viewing simulation results in X-Y-Z perspective plots.

The detailed output table, **Figure 4-8,** shows hydraulic information at a single profile. Useful information such as water surface elevation, and maximum channel depth can be viewed here. One is also able to view specific variables for the Left OB (left floodplain) Channel and Right OB (right floodplain). The model reports on errors, warnings and notes in the Errors, Warnings and Notes portion of the Cross Section Output window. Warnings and notes should be taken cognizance of, and warnings should be addressed where possible. Warnings are often a result of inadequate or bad data. Errors require the user's attention as these indicate that there is a flaw in the model that needs to be resolved in order for the model to undertake an acceptable simulation. Errors, warnings, and notes are labelled, and color coded for ease of referral.



		Element	Left OB	Channel	Right OB
E.G. Elev (m)	1496.92	Wt. n-Val.	0.025	0.030	0.035
Vel Head (m)	0.13	Reach Len. (m)	22.55	20.00	17.67
W.S. Elev (m)	1496.78	Flow Area (m2)	8.44	62.62	7.28
Crit W.S. (m)	1496.12	Area (m2)	8.44	62.62	7.28
E.G. Slope (m/m)	0.001262	Flow (m3/s)	9.22	105.48	5.30
Q Total (m3/s)	120.00	Top Width (m)	12.48	36.87	11.94
Top Width (m)	61.29	Avg. Vel. (m/s)	1.09	1.68	0.73
Vel Total (m/s)	1.53	Hydr. Depth (m)	0.68	1.70	0.61
Max Chl Dpth (m)	1.93	Conv. (m3/s)	259.5	2968.9	149.1
Conv. Total (m3/s)	3377.5	Wetted Per. (m)	12.54	36.91	12.00
Length Wtd. (m)	20.10	Shear (N/m2)	8.33	21.00	7.51
Min Ch El (m)	1494.85	Stream Power (N/m s)	9.10	35.38	5.47
Alpha	1.11	Cum Volume (1000 m3)	1.40	38.68	0.98
Frctn Loss (m)	0.03	Cum SA (1000 m2)	3.18	32.25	2.11
C & E Loss (m)	0.00				

Figure 4-8: Viewing simulation results in cross-section tables.

The **Figure 4-9** below is a map with the resultant inundation boundary shapefile that was exported from HEC-RAS. Using Figure **4-9**, floodlines are drawn using the shapefile as a guide to depict the maximum flood water extent. The resultant delineated floodlines are shown in **Figure 4-10**. Floodlines are typically left open-ended in areas where there are inflows from tributaries unless their design flood values have been estimated and simulated. Notice how there are dwellings adjacent to the river that are at risk of being flooded by the simulated 1:100-year event. There are many areas that are inundated across the site as many of the houses have been constructed below the floodline.

Figure 4-9: Shapefile of inundation extent plotted in ArcMap.

Figure 4-10: Delineation of the 1:100-year floodline in Stjwetla area.

4.5 FLOOD COPING STRATEGIES AND STRUCTURE OF HOUSES

The study examined the various adaptation strategies used by locals to lessen floods through residential structures to evaluate the adaptation strategies. For this kind of assessment, cross-tabulations were used. The education level of households and their coping mechanisms were compared. To determine whether there is a correlation between these two characteristics, the education level was recoded. Moving to a higher position was the most practical coping mechanism, regardless of their educational background. This simply indicates that local coping mechanisms did not necessitate the use of technical or specialized abilities. According to **Table 4-4**, the most preferred coping strategy of the respondents was relocating to a higher place. The second group preferred to be rushed to a safe area, which is an area away from a floodplain, provided that the speed of the water is not hectic. The other group preferred to be relocated (moved out of the study area) as a safe strategy. Given that the table below was 4x4, the Chi-square test was appropriate to determine the significance of the relationships. It is also an appropriate option in the event of one or more of your variables being quantitative because several statistics tests are used. Statistical tests are used to quantify the difference between two or more groups and to ascertain whether a predictor variable has a statistically significant association with an outcome variable. The p-value (probability value) could not be used because the warning that followed stated that the percentage of expected value was less than 50%. So, by examining the values in the table, there is a relationship significance since it is a contingency table.

Table 4-4: Comparing coping strategy and education level in Stjwetla area.

Educational level and Coping strategy						
		Relocate to high property	Temporal Relocation	Evacuate	Rush to safe area (Churches)	Total
Grade 0-7	Count	26	13	0	13	52
	%	52	26		22	
Grade 8-12	Count	12	9	3	16	40
	%	30	23	7	40	
Diploma	Count	5	0	0	0	5
	%	100				
Degree	Count	0	0	0	0	0
	%					
Total		43	22	3	29	

A cross-tabulation was conducted between residents who have been flooded and residents who are prepared to leave the area as a coping mechanism if it is judged unsafe.

It was clear that most participants wanted to move out of the area. 88% of respondents who have experienced flooding affirmed this relationship, and only 22% indicated that they have not experienced floods, refer to **Table 4-5** below.

People's perceptions of the risk of flooding greatly influence the steps they will take to reduce it. For instance, a person is not as probable to take action to reduce the risk that they will encounter if they believe the risk from that hazard is low (Martin et al., 2009).

Table 4-5: Flood experienced and willingness to relocate.

	MOVE OUT				
			YES	NO	TOTAL
EXPERIENCED FLOODS	YES	Count	56	8	64
		%	88	22	
	NO	Count	19	14	33
		%	58	42	
	TOTAL		75	22	97

According to Thieken et al., (2005), most people who are in danger of disaster around the world are poor people, because the materials used to build their homes are usually insufficient to withstand extreme weather conditions or natural disasters. Through observation and interviews, the researcher determined the different kinds of housing structures in the study area. The quality of the housing structure demonstrates that most of the dwelling units are in a poor state and congested. Furthermore, these houses are built on a floodplain. Most of these are built from bricks and the roof is from metallic sheets, as can be seen in **Images 4-1** and **4-2**.

Image 4-1: **Some of the brick houses**

Image 4-2: Some of the houses with metallic sheet roofing

The floors in these houses are cement. A cross-tabulation was done to see if the wall material of a house and the effects of flooding were related. Most of the homes in the study area are built inside the Jukskei River's floodplain and are inundated or washed away during high water events. This demonstrated that compared to formal dwellings (made of bricks), informal structures (made of metallic sheets) suffered greater losses. The materials used in the homes were recoded into two classes for cross-tabulation: temporary (metal sheets and cardboard) and permanent (cement and bricks). According to **Table 4-6**, 69% of respondents used bricks material for their house structure and 22% of respondents used mud and 9% used metallic sheets. With regards to the material used for roofing, 92% of respondents used metallic sheets for their roofing and 8% used plastic for roofing. 76% of respondents used cement material for their floor and 24% used mud as their material.

A cross-tabulation was created to see if there was any correlation between the materials used for housing and the effects of flooding (loss of priceless items). According to the results, house units with proper structural materials experienced less flood impacts on their valuable items than house units with shoddy materials. The yes and no answers differed significantly from one another (x^2= 23.74, df = 4, P≤0.001). In all tests of significance, if $p < 0.05$, then there is a statistically significant relationship between the two variables. The respondents were asked about the flood impacts on the household, considering the material used for their houses. A positive significant P-value of ≤ 0.00 is displayed in Table 4.7.

Table 4-6: Quality of the house structure and materials used in Stjwetla area.

Quality of the house	Materials used	Total Number of respondents	% of respondents
House structure	Mud	21	22
	Bricks	67	69
	Timber		
	Metalic sheet	9	9
Roofing	Plastic	8	8
	Metalic sheet	89	92
	Tiles		
	Grass		
Floor	Mud	23	24
	Cement	74	76
	Bricks		
	Wood		

Table 4-7: Chi-Square tests output on question flood impacts and types of material

Chi-Square Tests

	Value	df	Asymptotic Sig. (2-tailed)
Pearson Chi-Square	23.74	4	.000
Likelihood Ratio	29.23	4	.000
Linear-by-Linear Association	17.38	1	.000
N of Valid Cases	97		

Source: Output from GNU PSPP

4.6 LOCAL KNOWLEDGE ON FLOOD VULNERABILITY

Investigations were conducted into the views and decisions of the general public with reference to the causes, effects, possible solutions, coping mechanisms, and adaptive techniques for managing floods in both individual households and communities. Additionally, this study also evaluated public knowledge of flood vulnerability from a broad perspective. This is significant because it helps determine how much the community knows about flooding. According to **Table 4-8**, 94% of respondents indicate flooding as a major environmental problem.

Table 4-8: Resident's view on the flood in Stjwetla area.

Characteristics	Yes	No
Flooding as a major environmental problem	91	6
% of respondents	94	6
Do you get form of help during flooding	100	
% of respondents	100	

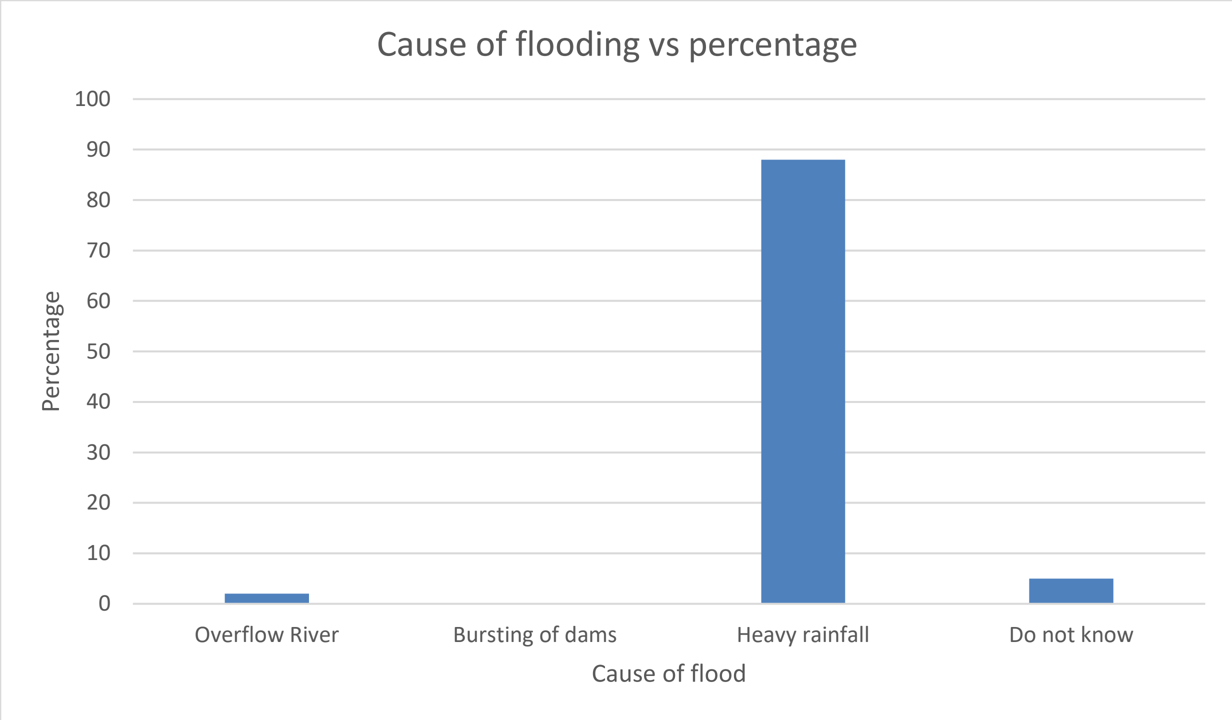


Figure 4-11: Individual's perceptions about the cause of flooding in Stjwetla area.

A survey was given to households to find out how they perceived the elements affecting flood vulnerability in order to determine the factors that determine the cause of flooding in the study area. Participants were asked to determine the reason behind the Stjwetla flooding. According to **Figure 4-11** above, many residents in the study area thought that flooding was brought on by persistent rainfall, even though the location of their houses exposed them to floods. Few respondents said that the flooding is caused by a river that is overflowing in addition to the other explanations. The participants were questioned about the cause of flooding in their property (factor 1) and the usage of different strategies of coping (factor 2) during floods. The correlation between these variables (What causes floods in our area and how did you cope) was conducted. **Table 4.9** shows that between the two variables, there is a correlation that is significant at the 2-tailed 0.01 level. It is extremely likely that there is a link between the two variables since the association is highly significant at the significance level of 0.000. The interpretation of these results (Pearson correlation -0.504) implies that changes in one parameter cause changes in the other in the opposite way.

Table 4-9: Correlations between two variables.

Correlations

		What cause floods in your area	How did you cope
What cause floods in your area	Pearson Correlation	1	-.504**
	Sig. (2-tailed)		<.001
	N	97	97
How did you cope	Pearson Correlation	-.504**	1
	Sig. (2-tailed)	<.001	
	N	97	97

**. Correlation is significant at the 0.01 level (2-tailed).

Source: Output from GNU PSPP

This question (3-G on the questionnaire) tested the participant's understanding of the forces that drew them to this area despite its history of flooding. The informal settlement of Stjwetla is situated in the Jukskei River's flood zone. When asked if respondents knew they lived in a place where disasters, especially flooding, could affect them. Some (6%) residents said they were unaware they lived in a flood-prone location, while other residents (94%) who answered the survey acknowledged that they were aware of the risk of disasters in their area. The respondents were questioned again, this time about their reasons for moving to the informal settlement of Stjwetla, and most of the respondents (59%) said that the area is convenient and accessible to work. While 21% responded that the area is affordable, 4% of the respondents indicated that they wanted to be closer to relatives and lastly, 13% of the respondents indicated that they have nowhere to go (**Figure 4-12**).

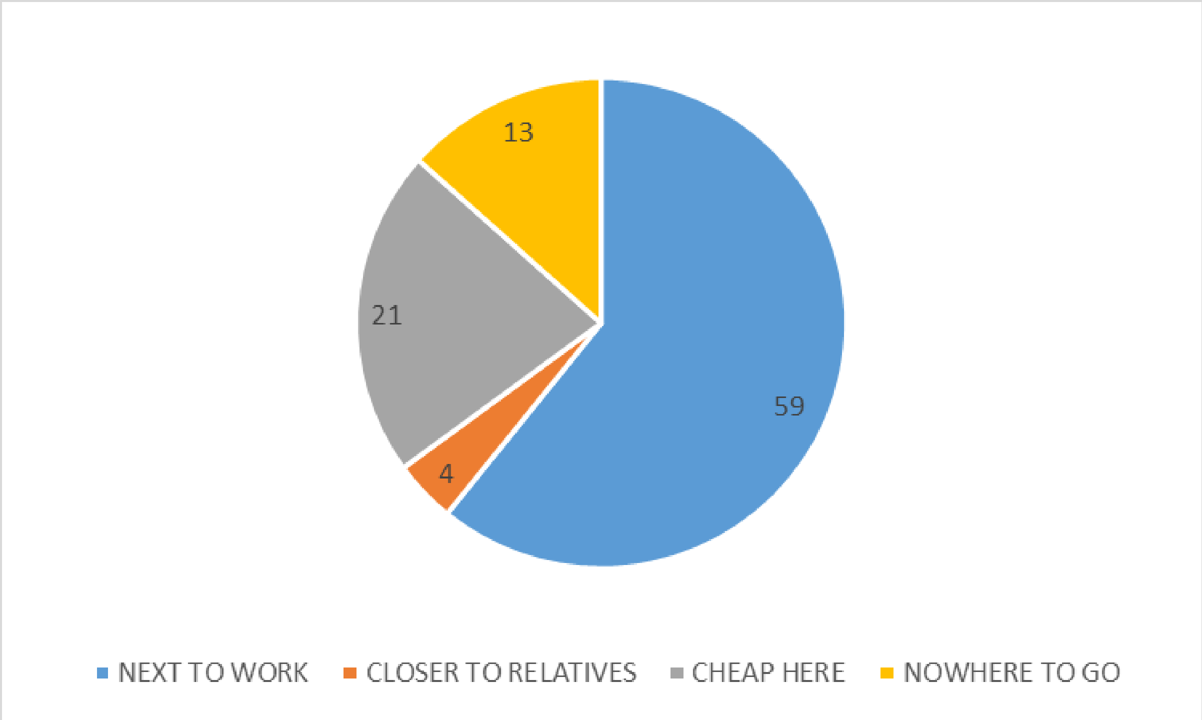


Figure 4-12: Reasons for moving to Stjwetla area.

When asked if they had gotten help during a disaster event, 100% of the participants revealed that they had received some assistance. Participants when asked from where/whom they had received aid or support after experiencing or witnessing the disaster, many respondents (71%) said they had received it from non-governmental organizations, followed by the local municipality (16%), friends and neighbours (4%), and relatives (2%) **(Figure 4-13).** In addition, it is worth noting that some of the residents could not differentiate between the officials from non-government organizations and the local municipality.

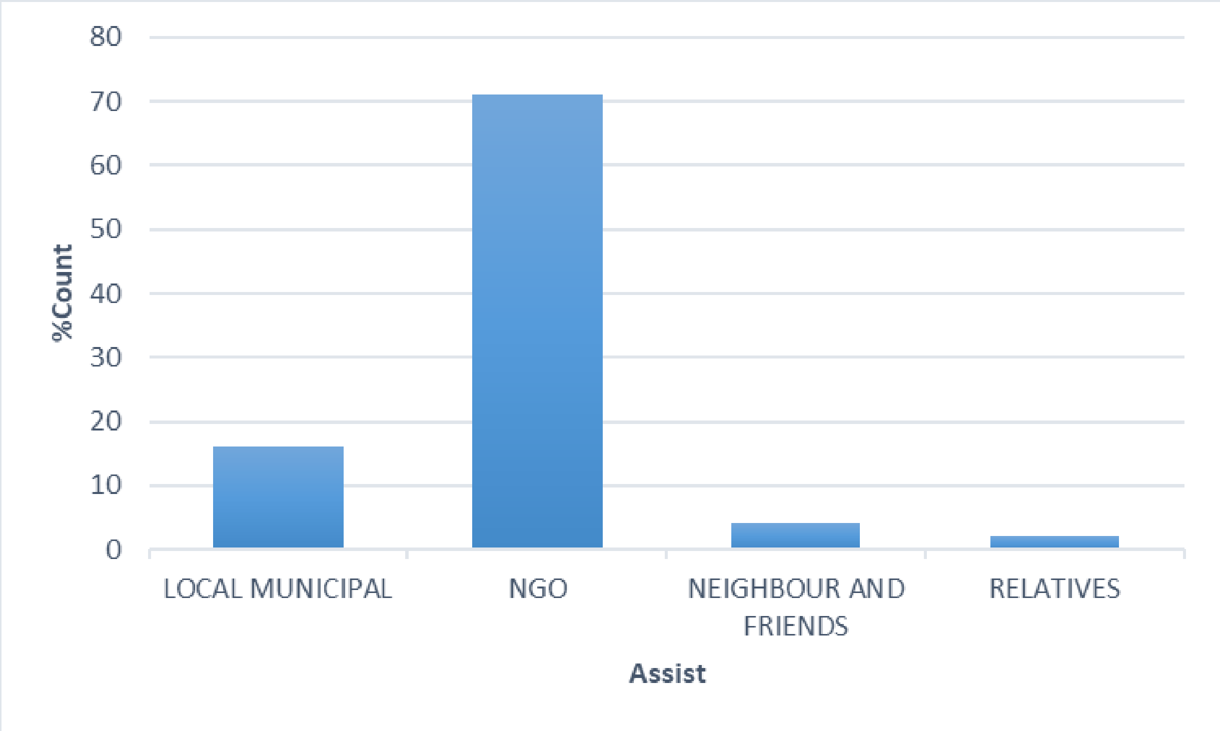


Figure 4-13: Who assists you during flooding in Stjwetla area.

The participants of the community were asked about how flooding affected them. Respondents explained how flooding damaged their valuable belongings (from the most valuable 1 to the least valuable 3) in the responses that follow (See **Table 4-10**). Numerous homes that are impacted by floods report losses on their property, including the loss of life and the displacement of household items and dwelling units. A comprehensive ranking of the most valuable items as determined by the entire population sampled in the research area was established. The participants' ranking of household items suggests that the most valuable items destroyed by floods were beds and documents. Furthermore, the participants did indicate that all the damaged items are replaceable even though it is not a straightforward or simple process to replace everything.

Table 4-10: List of valuable items (from the most valuable 1 to least valuable 3).

	Valuable level			
	1	2	3	Total number of sample
BEDS	97			97
DOCUMENTS	97			97
TV	1	31	65	97
STOVE	97			97
OTHERS				

Floods are a significant natural hazard that can cause discomfort to residents, so some households or residents have taken precautions to lessen their vulnerability to floods. The primary tools for identifying flood coping strategies were the questionnaire, interview, and field observations. These measures include:

- ✓ "First line of defence" is to prevent runoff from entering their homes, some households used bags of sand to reduce or prevent water damage (**Image 4-8**).
- ✓ The utilization of bricks and cans to put or elevate their valuable items such as beds and stoves (**Image 4-6**).
- ✓ Using cement and concrete to raise the dwelling ahead of their house to stop runoff water from entering (small veranda) commonly known as a stoep. Some create outlets at the rear of their house (**Image 4-4**).
- ✓ Positioning pipes beneath their house to route water out into the street (**Image 4-5**)
- ✓ Making furrows around their house (**Image 4-7**).
- ✓ Hole in the section of the house where water will be released (**Image 4-3**)

Image 4-3: Holes through their dwellings.

Image 4-4: Small veranda around the house.

Image 4-5: Water channel.

Image 4-6: Indoor furniture with lifted items.

Image 4-7: Furrow around the house.

Image 4-8: Bags of sand around the house.

4.7 RESPONSES FROM THE MUNICIPAL OFFICIALS

Municipal representatives from the Disaster Management Unit in the municipality were questioned through Microsoft Teams. A series of both closed-ended and open-ended questions were used to gauge the participants' thoughts on the material sought and manage the interview's flow. Most of the answers to the questions were similar.

According to Cooper and Schindler (2006), individual interviews have the benefit of facilitating the questioner to observe specific responses, which helps to clear up any uncertainty regarding the questions posed. Additionally, the interviewer can collect non-verbal data, such as adaptability and feelings of anxiety. The goal of interviews is not to identify or favour any one candidate but rather to be transparent and equitable for the good of everyone involved. The study’s research process was made easier by the officials’ eagerness to answer and voice their concerns regarding disaster management and service delivery.

The City of Johannesburg officials are aware of the dangers posed by the informal settlement of Stjwetla. According to the officials, the Jukskei River's riverbank residents' proximity to the river and the illegal dumping of waste from squatter shacks constructed on the drainage system are the primary causes of the regular floods. They went on to say that people occupied every available space, even in areas classified as flood-prone, increasing their risk of being exposed to flooding. Due to the fact that so many people reside in areas that frequently flood, they firmly believe that land invasion is one of the factors that influences and amplifies the effects of recurring flooding. Because most of the residents of the Stjwetla informal settlement are situated along rivers, the topography of the area contributes to flooding.

The following discussion is established from the municipal officials' responses. Most of the responses were similar.

4.7.1 Preparedness plans of the municipality

By taking action prior to warnings, preparation helps reduce the risk of disaster. Because of this, it is crucial to use building design codes when constructing infrastructure, such as roads and other practical facilities, and to implement erosion control measures through the work of those engaged in soil and farmland management as well as improved land-use planning (ADRC 2019). Being prepared means being ready to combat threats before they materialize. For the communities to be ready, it is essential that they comprehend the hazard (Henry, 2018).

Regarding the availability of plans for disaster management preparedness in the COJ, questions were posed to municipal participants. In response, plans were provided for the COJ along with a list of prevalent risks, including flooding. The directorate is informed by a service level agreement for the South African Weather Services. With this information, the authorities use the media and short message service (SMS) alerts to notify the appropriate parties, particularly ward councillors and neighbourhood non-governmental organizations. Sometimes, local communities aren't aware of weather events that could destroy them upstream from where they are.

Lindell et al. (2006) state that flood line delineation is the tool that ensures effective coordination and capacity improvement to block, protect against, reply to, restore from, and lessen the consequences of both man-made and natural disasters. To deal with floods, the COJ offers an emergency management service (EMS) that includes resources, gear, and personnel with the necessary training. The community's support structure also includes rescue teams, private rescue teams, and the South African Police Service (SAPS). Moreover, there is reciprocal assistance among all NGOs and churches in

Johannesburg. Churches and non-governmental organizations offer food and shelter to communities affected by flooding.

4.7.2 Prevention measures

The officials state that the Disaster Management Plan's (DMP) preventive and risk-reduction components need to be continuously implemented and upheld. Every time a significant incident or disaster occurs or is imminent in the City of Johannesburg's (COJ) jurisdiction, the emergency or reactive components of the DMP are put into action. Early warning is prioritised to minimise potential impacts of floods since most of the dwellers are more exposed, and because most of the residents in this area are unemployed, there is an abundance of people who cannot afford to build a typical house. Their vulnerability is increased because they typically lose everything during floods. The ability to provide those in need with the necessary relief is how effectiveness is determined. Food and non-food relief often show up at a disaster site without an organized system in place to ensure that those in need receive it immediately. Even with the government's best efforts to move them, people can still be found living there.

In addition, the city's Emergency Management Services (EMS) have compiled a list of preventive measures to help avoid fatalities during flooding:

- ✓ Monitoring of locations like hazardous river crossings and low-level bridges.
- ✓ Ensuring that they act without delay and do not wait to see the water rising.
- ✓ Getting away from areas with low elevation as soon as possible.
- ✓ When asked, promptly vacate the area.
- ✓ It is important to wait for authorities to declare it safe to return to flooded areas before doing so.

4.7.3 Budget

The City of Johannesburg's mayoral committee on finance included Alexandra (Stjwetla) in its budget for disaster management. The utilization of the fund is strictly controlled and audited separately for National Disaster Management Centre records. It is therefore imperative that all departments appoint designated officials who are qualified to be part of the Disaster Risk Management team. The National Disaster Management Framework determines the Disaster Fund threshold, which is a percentage of the city's overall budget that the city must implement. If assistance from the Provincial or National Government is required, the City of Johannesburg Disaster Fund threshold will be used to make that determination and request that the incident be classified as a Provincial or National Disaster. The area has had problems with stormwater management and always floods in rainy seasons.

The budget for disaster management includes money set aside for community shelter and infrastructure repairs during the initial ninety days following a disaster. In contrast to this, some residents in the previous discussion claimed that they receive no assistance from the municipality or anyone else. All that this indicates is that there is a failure to fulfil disaster management responsibilities, and the Disaster Management Act 57 of 2002 emphasizes how crucial it is to have an emergency fund in place for disaster management because disasters can strike at any time.

4.7.4 Awareness

According to municipal officials, the municipality presently conducts seasonal assessments of the community. Awareness campaigns are done in the study area and the level of awareness is high in terms of performance ranking. The effectiveness of these awareness campaigns is good because the municipality has noticed some reduction in the affected individuals. Furthermore, they highlighted that these types of activities are encouraging but not a regular practice. One of the most important aspects of a plan to protect should be anticipating the needs for a relief operation and figuring out how best to meet those needs. The planning process would only be successful if the people who would ultimately benefit from it understood what to expect and what to do in the event of a disaster. For this reason, warning and educating those who could be at risk of a disaster was a crucial component of any readiness strategy. According to this study, the COJ ran a number of flood awareness campaigns. Regarding the community's level of awareness of the risk of disaster, all officials responded by saying that it was extremely high at the time of the floods. According to the officials, means of communication before, during and after floods is by social media and media (radio and TV). Direct instruction will always have a greater impact than television, radio, or print media, Kent (1994) notes that carefully crafted and predicted messages can add value to the procedure.

4.7.5 Response and Recovery

The government and non-governmental organizations provide assistance to Stjwetla Township during flood response and recovery. According to the COJ officials, the Red Cross (NGO) and Twala Mama Africa often provide flood relief to residents. After the tragedy in November 2016, the Red Cross helped the homeless by giving them blankets, food, clothing, and toiletry packages. Community members who were interviewed agreed with the workers' claims that they obtained support from the Red Cross (NGO). Zuma et al. (2012) emphasized that the South African Local Government Association (SALGA) ought to provide training to local officials in community disaster management. But to this day these officers have not been trained.

The response from the municipal officials emphasised the importance of volunteers, more especially during flooding because the disaster response team is always in need of extra helping hands when helping the affected communities. According to the officials, help is always needed during the recovery phase. Volunteers contribute by participating in the clean-up projects, the repair and rebuild processes, and the management of the donations.

CHAPTER 5: DISCUSSION

5.1 INTRODUCTION

This chapter discusses the findings obtained from the ArcGIS analysis and interviews. With the usage of the ArcGIS Map, the floodline delineation is thoroughly discussed. The relationship between community knowledge and coping strategy is also discussed. The specific objective was to investigate the risk associated with floods, evaluate the housing structure, as well as determine floodlines. Examine the existing adaptation options concerning floods. The connection between flood effects and housing structure was discussed.

Objective 1: Investigate the risks associated with floods and evaluate housing structure. Pre-planned questions were used to conduct interviews in the research region as part of the primary data collection process. The purpose of the interviews was to identify potential risk variables and evaluate the degree of flash flood hazards in the chosen research region. Every resident of the study area (Stjwetla) is at risk of a flood disaster due to the area's low-lying terrain along riverbanks, which proves to be the primary cause of frequent floods. It was also found that the type of construction used in a home's structure affected how vulnerable it was to floods.

Objective 2: Profile the flood risk to determine the floodlines in Alexandra informal settlement, to ascertain practical and efficient ways to reduce the risk to life and property The study used the ArcGIS to delineate the mapping of the 1–100-year floodlines along the water course. These floodlines being overlaid on aerial photos, show that some homes in the study area are situated in floodplains.

Objective 3: Examine the existing and future adaptation options in order to minimise the impacts of floods. The study's findings show that various coping techniques were used in the study area. Although this study area is susceptible to flooding, it has some resilience and coping mechanisms. Most of the respondents preferred moving to a higher property as a coping strategy, which was followed by running to a safe place (a church), while some preferred the option of temporary relocation as a coping strategy, and some chose to evacuate. Creating sandbags, digging furrows around homes and on roads, moving temporarily, moving to a higher property, and rushing to a safer area (church) were all common coping mechanisms in the study area. The current level of flood vulnerability has not been reduced by any of the listed coping mechanisms; much improvement is needed to address the current flood vulnerability in the area. Their socioeconomic characteristics and their geographical topography, which is flat or plain, are the main issues that the study highlights. Most respondents were able to use affordable coping mechanisms, indicating that coping mechanisms that demand money or other financial outlays are frequently challenging to use. The study discovered that flooding incidents have motivated locals to become more initiative-taking in creating coping mechanisms to lessen the risk. The primary issue within the research region is its socio-economic features, which are primarily shaped by its relatively level or plain topography. Since the majority of respondents were able to use inexpensive coping mechanisms, it is often more difficult to use coping mechanisms that call for money or other financial outlays.

Thus, a variety of adaptation and mitigation techniques that may be used to lessen the risk of flooding while reducing its negative impacts are required in this situation. The improvement of people's living conditions must be the main priority. To prepare for the floods, communities should be urged to avoid flood-prone areas and to construct homes using sturdy materials. Implementing development controls in high-risk areas should also be prioritised.

5.2 COPING STRATEGIES AGAINST FLOOD

This section discusses the coping strategies found in the study. The study found that the sampled households used a variety of flood coping mechanisms. To rank which coping mechanisms the families preferred, the identified coping mechanisms were also graded.

The study's sample had an average educational level of 95% with some kind of formal education. However, these levels of education were inadequate for the skilled jobs market. Age and educational accomplishment are significant predictors of flood vulnerability. Most of the participants in this study had modest levels of schooling. According to Torani et al., (2019), stated that illiteracy or poor levels of education enhance danger exposure. There is a strong correlation coefficient between the education level and social position; those with higher levels of education have a greater understanding of environmental hazards and are thus better able to reduce and resist risks.

Most responders were between the ages of 30 and 45; as they are a more economically engaged generation, they are less vulnerable to flooding. Flood risk is made worse by the age and financial dependence of the elderly and young (Dube et al., 2018). Most of the respondents in this research were middle-aged, which reduced vulnerability.

This study investigated coping mechanisms as a local effort being launched and progressively embraced as a method to lessen flood vulnerability in households via people's views. The residents recognized using a higher item to climb on as a technique of self-preservation during flood disasters. Disability is a significant element influencing a person's vulnerability, according to Yande (2009). This study discovered that most respondents did not have any impaired family members, which marginally enhanced their resilience. This is because communities are more vulnerable to flooding the more handicapped people live there, making it challenging for them to respond to flooding and to relocate temporarily.

Relocation to a higher place is one of the study's most notable coping strategies; data shows that almost every household has used this coping strategy. This coping mechanism demonstrates that the study area has a serious flood problem.

It is notable that despite experiencing flooding nearly every rainy season, most of the households in this research were unwilling to move for good to safer neighbourhoods. The department head (Disaster Management Unit) had recommended that these households be relocated because they should not be there. The frequent flooding in these communities was the main driver of population relocation. However, rushing to a safe area was typically the second go-to coping strategy. For safety during flooding, families were prepared to visit their neighbours, relatives, and public buildings, but after the incident, they wanted to return to their respective residences.

It has become clear from the residents’ answers, that flooding worsens their already low socio-economic condition. The situation suggests that the residents do not have enough money to acquire solid materials to build a suitable residential area. With this knowledge, one might presume that the locals have relatively few means of defence against the effects of flooding. However, people's coping strategies also rely on their level of affordability.

5.3 IMPACTS OF FLOODS ON HOUSEHOLDS

House placement and construction materials have an impact on communities because they put them at risk of natural disasters like floods. When asked why they chose to live adjacent to the dangerous banks of the Jukskei River especially considering that this river has a history of flooding many of the residents said that they did so because they wanted to be closer to their places of employment. They also mentioned that there was no rent to be paid here. The physical devastation of residential units during a flood occurrence was one of the flood consequences that were noted. Respondents stated that damage to personal property always occurs during flood events. Furniture, bedding, and clothing are a few of the things mentioned by the people. Residents have occasionally reported losing important items such as IDs (Identity cards or books). The proximity of the homes to flood-prone areas was blamed for most of the losses to these assets. Discussions with the residents showed that some homes indirectly lost their possessions because some of their income sources became disrupted after their homes collapsed.

Even if Stjwetla township is a mostly undeveloped township, the loss or damage of valuable objects during a flood is an unpleasant experience for the locals/residents. The most treasured goods for the locals were their mattresses and bedding. These were evaluated based on how useful they were and how easily they could be replaced.

Flooding and poverty have a close association. Some respondents stated that because they are so impoverished, they were forced to move to areas that are prone to flooding in order to find sustainable means of subsistence. Some respondents stated that they not only lived in flood-prone areas but also lacked the resources to build stronger, better homes. The lightweight constructions of the buildings meant that they were easily damaged and collapsed or washed away, so when the floods came, they were often found wanting. When a community experiences flooding, it is usually discovered that the structures are defective because the household structures are easily distressed, which causes the structures to collapse. Further evidence showed that the low-income families who already lived in flood-prone areas were unwilling to permanently relocate because they moved here to be closer to work and it is also cheaper here.

The response from both municipal officials and residents are in agreement with regard to the risks linked with residing in a disaster (flood) prone area. According to the residents, the cause of flooding in the study area is brought on by persistent heavy rainfall, and municipal officials believe that the main source of flooding is the position of the resident’s settlement along the riverbanks.

5.4 FLOOD RESILIENCE AND ADAPTION

To measure adaptability, this study examined the longstanding approach taken by residents to lessen flooding through their dwellings. This part of the study also helped the investigator to determine whether individuals were prepared to leave or move to other safer areas. This evaluation was done using cross-tabulation.

The availability of resources affects the resilience capability. Given that poor people are the most vulnerable flood victims, this indicates that the Stjwetla community is not strongly resilient. Nevertheless, the most of occupants were obligated to reconstruct a portion of their residence after the calamitous flood event. In this case, resilience was available because residents could relocate, albeit in the same state and with the expectation of the same conditions the following season. This is additionally supported by their incapability to replace products destroyed by floods, due to their lack of resources.

During flooding events, people living in dwellings near the riverbanks and low-lying areas often relocate to relatives in other areas. This was seen in past floods, where shacks were destroyed and residents moved to safety, only to return once conditions improved. This indicates the limited availability of land and the need for adaptive measures to minimize the vulnerability of these populations to floods.

In the community, people are well aware of the potential risks posed by flooding, as well as other natural hazards, such as fire.

5.5 HOUSING STRUCTURE AND FLOOD EXPOSURE

Housing structures provide a dwelling to eat, sleep, relax, shelter from various weather conditions, and a place to advance family. People's ability to live in a secure place, harmony, and well respected neighbourhood as well as their physical and mental health is safeguarded by their right to adequate housing (SAHRC, 2015).

Even though structures used for informal housing are susceptible to flooding, local expertise has discovered ways to reduce the damage. It has been discovered by the locals that these buildings can let floodwaters pass through without affecting the units themselves. Additionally, since openings can be made to direct water out during flooding, building housing in flood-prone areas is made easier. According to this study, homes play a significant role in flooding, with households in unofficial structures suffering the most losses. This relationship between housing structures and flood impacts was revealed by the cross-tabulation.

Informal structures are more vulnerable to flooding than formal structures because of their poorly planned layout. Newcomers frequently lack the means to acquire sturdy materials, so they opt for whatever scrap metal and plastic they can find to construct a shelter. Most of these structures are set up on any available open land, without taking into account environmental factors, and in places that were intentionally left vacant in formal housing developments.

5.6 FLOODLINE MAPPING

An overview of the conclusions and discussions regarding the quantitative data, based on the ArcGIS application, are provided in this section. Important flood risk issues can be found with the aid of the maps. This is connected to social and economic aspects of society in addition to physical traits. The methods employed enable examination of both the factors that make the most susceptible individuals vulnerable to flooding as well as where they reside. To reduce interruption from natural catastrophes, this knowledge would be extremely helpful for land zoning, urbanization, and other development plans. The 1:100-year floodline mapping revealed that quite a number of the households were vulnerable to this flood depth, since these households are congested, it also made it difficult to distinguish individual houses on the aerial image. The majority of stand borders have fused as a consequence of pre-planning during the building of the homes, making it impossible to visibly distinguish between households. Most of these households are located on the floodplains. The findings of the study indicate that the study area's housing units are overcrowded that it was not possible to tally the quantity of units vulnerable to flood occurrence. Walking trails from the main road to the community were also exposed to a flood path.

The varying levels of risk and exposure to flooding have been found to correlate with distinct characteristics of the vulnerability of communities to flooding in the study area. The primary factor increasing people's vulnerability to flooding in the study area is their location near rivers or in the study area's lower regions, particularly with regard to vulnerability-related elements. The study discovered that populations located in low-elevation regions have a higher likelihood of experiencing flooding than those located in more raised regions. Additional areas that are susceptible to flooding were determined by utilizing local experiences. These places had insufficient or non-existent stormwater drains or diversions and were situated on low-lying, level terrain or steeper slopes. These locations were dispersed throughout the township and frequently lay outside of the zones identified by the floodline mapping as being at risk of flooding. However, to create a comprehensive flood vulnerability map, local knowledge was added to the hydrological mapping. ArcGIS Users can present vulnerability risks and hazards in more effective ways using ArcGIS mapping techniques, which can be used locally and aid in making decisions (Tran et al., 2008). Therefore, it can be said that ArcGIS is essential to the management of floods and other disasters.

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

6.1 SUMMARY

This chapter presents the study's conclusion and recommendations based on its findings. The first section provides a conclusion based on the study's findings, and the last section provides guidance for the local government and community. This study produced a number of conclusions, including those regarding household structures, gender roles, and social impacts of flooding, causes of floods, and more. According to the respondents of the study, Stjwetla flooding is brought on by persistent rain and a house being built on a floodplain. Due to a lack of information about flood mitigation techniques and insufficient resources to deal with flooding, the community is extremely vulnerable to flood disasters. The Stjwetla community is becoming more susceptible to flooding disasters, especially those who reside by the floodplain. Most members of vulnerable communities are jobless and unable to move because they would have to pay rent in any new location. The majority of Stjwetla citizens have been there for more than 20 years, and they all have different perspectives on the local government and emergency response operations.

Flooding is a global issue that requires research in order to produce literature. It occurs when the natural flow of water or the catchment area is disturbed for various reasons, such as human habitation near the flood line, rapid urbanization, and industrialization. According to recent studies, there are two main reasons why informal settlements are more likely to flood: first, because they are often made up of easily flooded shacks and mud houses; second, because they are situated near riverbanks and catchment areas. The Department of Environmental Affairs (DEA, 2016) states that South Africa is dealing with a wide range of environmental issues, such as floods, droughts, land degradation, and soil erosion. Climate change has an impact on the nation's capacity to withstand harsh weather. Some parts of the Johannesburg Municipality is affected by flooding, but those who live along flood lines many of whom are in informal settlements are the most at risk. The informal settlement was selected as the study's focal area. The study employed a random sampling method to choose participants, and a quantitative and qualitative research approach was utilized to analyse and present the findings. Flood disasters typically cause residents to lose all their possessions, and they rely heavily on institutions and the government to support them by granting them with accommodation, food, and clothing. The study's findings show that the Stjwetla community has taken precautionary steps to be ready for future flood disasters. Bags of sand around the house, building furrows around the house, having a small veranda to stop water from entering their houses during heavy rain, and creating water channels to flow out of their yards are some of the initiatives the community of Stjwetla has taken to reduce their vulnerability to floods. However, these initiatives fall short, and the community needs to be taught more flood-reduction techniques.

6.2 CONCLUSION

The study was able to emphasize a number of findings, such as the reason why floods occur, how they affect the economy and society, how gender and family patterns factor into floods, and more. The socioeconomic characteristics of Sexual identity, maturity level, relationship status, accessibility source of income (job), and financial standing were likely to have an impact on the effects of floods in this area or the respondents' capacity to make money.

Severe flash floods occurred in the Stjwetla area due to the overflow of the Jukskei River, resulting in deaths and property damage. The absence of planning has resulted in inadequate dwelling unit layout and structure, making people more susceptible to other hazards in addition to floods. Their socioeconomic background and dense population have made them more vulnerable because they depend on one another for daily survival. Through the survey, local expertise on the causes, effects, and coping mechanisms of flooding in the study area was investigated. In comparison to other natural disasters, a sizable majority of respondents in the research area—94%—considered flooding to be a serious calamity. In Stjwetla Township, flooding is mostly caused by housing construction in floodplain regions and high rainfall, according to the respondents. Furthermore, it was found that the main building materials, such as metallic sheets and cardboard, contribute to the effects of flooding in the research region.

According to the research findings, Stjwetla township's annual rainfall volume, population growth and poor drainage system are the top risk factors for flash floods. Stjwetla is illustrated by its extreme population densities with a population estimated to be 5131 in 2011 (Stats SA, 2012). This is corresponding to a density of 40670 populations per square kilometre. The annual rainfall intensity, inadequate drainage system, and population growth in the Township were found to be the primary risk factors for flash floods in Stjwetla Township.

Flooding is a natural occurrence that will always happen. Although we cannot stop floods from happening, we can control or reduce how vulnerable households are to them. This can be done by preventing floods from reaching people and preventing people from being affected by floods. The community will benefit in the long run from preventing floods, but it can also be a lengthy project because it involves more expensive technological investments (trapping excess water using dams or building canals).

Additionally, since there is no other land available for development or the construction of residential properties except the Jukskei River, squatter communities have also sprung up there. We can get the conclusion that changes in land cover classes and population change are strongly correlated. The case studies made it abundantly evident that the use of ArcGIS is crucial in the collection of data for flood management. The findings of this research study may be applied as standardized approaches to create a more targeted, well-informed intervention program that will aid in determining how recurrent flooding affects communities and managing flood disasters.

6.3 RECOMMENDATIONS

Recommendations were given based on the study's main conclusions. This study makes several mitigation and adaptation suggestions that may be put into practice to lessen flood susceptibility while avoiding flood-related negative consequences. The study shows that locals were not totally unaware of the floods, but public sharing activities are still required. The recommendations are listed below:

- Campaigns to raise public awareness and forums for disaster management are therefore greatly needed. The community should be regularly updated on the disaster awareness program and given more attention. This education campaign should cover flood preparedness since it can help reduce the consequences of flooding on homes. It is simpler to mitigate flood consequences if residents are aware of their risk.
- To better manage and prepare for floods, a lot of attention must be paid to household socio-economic conditions. This means that the local municipality should

provide special consideration and help when it comes to flood control to all households who are impacted by joblessness, bad education background, disabilities, and other disadvantages. Everyone in the community will become more resilient as a result.

- Establish a network of weather and flow measurement stations. It is important to implement a good flood forecasting in the region since it will help residents better prepare their homes for flooding. By identifying dangerous flood occurrences beforehand, the early warning system enhances disaster management. Communities may then take the appropriate precautions when flood occurrences approach. Limiting and preventing exposure to floods is the main goal of flood early warning systems.
- To deter and prevent people from settling in dangerous areas close to and along the riverbanks, the local authority needs to increase the visibility of law enforcement.
- Encourage data sharing to reduce the element of surprise when dealing with unpredictable weather conditions and prepare for them in advance, the local authority should forge a good relationship with the office of the meteorological bureau.

For future research recommendations, flood vulnerability is highly dynamic and constantly changing, so it is imperative to conduct ongoing assessments of flood vulnerability. At least one of these assessments should be carried out throughout a five-year period. Additionally, flood susceptibility varies by place. Depending on the location, as many settings have distinct physical and socioeconomic contexts. This implies that vulnerability assessments must be conducted in every community. This study was carried out at the local level without considering the issues impacting the City of Johannesburg as a whole. Thus, an evaluation of Johannesburg's flood vulnerability is necessary for the entire city.

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APPENDIX A: LETTER TO CITY OF JOHANNESBURG MUNICIPALITY

CITY OF JOHANNESBURG
METROPOLITAN MUNICIPALITY
COUNCIL LEGISLATURE

Tel: (011) 582 1590
Fax: (011) 582 1588
Cell: 082 938 8804

City of Johannesburg
Region. E
Ward 109

OFFICE OF THE COUNCILLOR LIAQUAD EBRAHIM.

10TH February 2020

To Whom It May Concern:

RE: REQUEST FOR PERMISSION TO CONDUCT A RESEARCH AT STJWETLA – ALEXANDRA TOWNSHIP

I write this letter to confirm that as a Councillor I am aware of Mr B Masombuka's request to undertake a Management Strategy for the flood risk of Informal Settlements of Alexandra along the Jukskei River.

I fully support this research and I grant him permission.

Should I be required to give any input regarding this research, please do not hesitate to contact me.

Kind regards

Thanking you

....

LIAQUAD IBRAHIM
Ward (109) Councillor.

APPENDIX B: INFORMED CONSENT FORM

Informed Consent Form

The questions that will be asked during the interview will be based on the research conducted by Bongani Masombuka (65104250), an MSc student at the University of South Africa (UNISA). The study aims to provide a strategy for the annual flood risk of informal settlements in order to prevent life loss and property damage.
I _________________________________ (name and surname) hereby agree that this researcher can record and transcribe this interview and I understand that I will not get paid in any form for participating in this interview.

Signature

____
Date

For participants/interviewees who wish to remain anonymous please place your signature below stating that you agree to the terms and conditions of this interview, which imply that the researcher can record and transcribe the interview and that no participant will be paid in any form for participating in this interview.

By signing below, you also acknowledge that participation in this study is voluntary and that you may withdraw from participating in this study at any time without any negative consequences.

Participant's signature

____
Date

I, Bongani Masombuka, look forward to speaking with you.
Thank you for your willingness to participate in this research.
Regards,
Masombuka B
(masombukab@dws.gov.za)

APPENDIX C: RESULT OF CRONBACH ALPHA

```
GET DATA
  /TYPE=TXT
  /FILE="C:\Users\MasombukaB\Desktop\Cronbachs_alpha.csv"
  /ARRANGEMENT=DELIMITED
  /DELCASE=LINE
  /DELIMITERS=","
  /QUALIFIER='"'
  /VARIABLES=
    VAR001 F1.0
    VAR002 F1.0
    VAR003 F1.0
    VAR004 F1.0
    VAR005 F1.0
    VAR006 F1.0.

RELIABILITY
        /VARIABLES= VAR001 VAR002 VAR003 VAR004 VAR005 VAR006
        /MODEL=ALPHA.
```

Scale: ANY

Case Processing Summary

Cases	N	Percent
Valid	97	100.0%
Excluded	0	.0%
Total	97	100.0%

Reliability Statistics

Cronbach's Alpha	N of Items
.78	6

APPENDIX D: RESEARCH QUESTIONNAIRE

QUESTIONS FOR RESIDENTS

1. PERSONAL INFORMATION (INTERVIEWEE)

1-A. GENDER OF HEAD OF HOUSEHOLD (PLEASE TICK)

F	M

1-B. AGE OF HEAD OF HOUSEHOLD

AGE VARIETY	PLEASE TICK
18-30	
30-45	
45-ABOVE	

1-C. EDUCATIONAL BACKGROUND

QUALIFICATION	PLEASE TICK
GRADE 0-12	
DIPLOMA	
DEGREE	
POSTGRAD	

1-D. TOTAL NUMBER OF PEOPLE LIVING IN THE HOUSE

NUMBER	PLEASE TICK
1-3	
3-5	
5-ABOVE	

1-E. ANY HANDICAP MEMBER IN THE HOUSE (PLEASE TICK)

I. (a) YES ☐ (b) NO ☐

I.I. IF YOUR ANSWER IS "YES", HOW DO YOU COPE DURING FLOODS?

……………………………………………………………………………………………

1-F. HOW LONG HAVE YOU STAYED IN THIS AREA

YEARS	PLEASE TICK
1-2	
2-4	
4-ABOVE	

2. QUALITY OF THE HOUSE

2-A. TYPES OF MATERIAL USED ON THE HOUSE

MATERIALS	PLEASE TICK
MUD	
METALIC SHEET	
TIMBER	
CEMENT AND BRICKS	

2-B STYLE OF ROOFING

MATERIALS	PLEASE TICK
PLASTIC	
METALLIC	
TILES	
GRASS	

2-C. STYLE OF FLOOR

MATERIALS	PLEASE TICK
MUD	
CEMENT	
BRICKS	
WOOD	

3. ENCOUNTER OF FLOODS AND COPING STRATEGY

3-A. HAVE YOU EXPERIENCED FLOODS IN YOUR HOUSE OR AREA (PLEASE TICK)

I. (a) YES ☐ (b) NO ☐

I.I. IF YOUR ANSWER IS "YES", BRIEFLY EXPLAIN?

…………………………………………………………………………………………..

3-B. WHAT CAUSE FLOODS IN YOUR AREA

CAUSED BY	PLEASE TICK
OVERFLOW RIVER	
BURSTING OF DAM	
HEAVY RAINFALL	
I DO NOT KNOW	

3-C. HOW DID YOU COPE?

STRATEGY	PLEASE TICK
RELOCATING	
RUSH TO SAFE AREA	
EVACUATE	
MOVED TO HIGH POSITION	

3-D. VALUABLE ITEMS THAT WERE DAMAGED DURING FLOODS (most valuable 1 to least valuable 3)

ITEMS	PLEASE TICK
DOCUMENTS	
BEDS	
STOVE	
FURNITURE	
TV	
OTHER(SPECIFY)	

3-E. IS THE DAMAGED ITEMS REPLACEABLE (PLEASE TICK)

I. (a) YES ☐ (b) NO ☐

3-F. AFTER THE INCIDENT, WHAT DID YOU NEED MOST

………………………………………………………………………………………………..

3-G. WHAT MADE YOU MOVE HERE

REASONS	PLEASE TICK
CLOSE TO WORK	
CLOSER TO RELATIVES	
CHEAP HERE	
NOWHERE TO GO	
OTHER (SPECIFY)	

3-H. IF THIS PLACE IS CLASSIFIED AS UNSAFE AND THERE IS AN OPTION TO MOVE, WOULD YOU RELOCATE (PLEASE TICK)

I. (a) YES (b) NO

☐ ☐

I.I. IF YOUR ANSWER IS "YES", WHERE?

……………………………………………………………………………………………………

3-I. DO YOU GET FORM OF HELP DURING FLOODS IN YOUR AREA (PLEASE TICK)

I. (a) YES (b) NO

☐ ☐

I.I. IF YOUR ANSWER IS "YES", WHO ASSISTS YOU

ASSISTED BY	PLEASE TICK
LOCAL MUNICIPAL	
NGO	
NEIGHBOUR AND FRIENDS	
RELATIVES	

3-J. ARE YOU AWARE OF POLICIES MEANT TO ENHANCE FLOOD COPING (PLEASE TICK)

I. (a) YES (b) NO

☐ ☐

3-K. DO YOU STRONGLY BELIEVE FLOOD IS ENVIRONMENTAL PROBLEM HERE (PLEASE TICK)

I. (a) YES (b) NO

☐ ☐

3-L. ARE YOU AWARE OF ANY RISKS ASSOCIATED WITH YOUR AREA?

……………………………………………………………………

APPENDIX E: INTERVIEW GUIDE

INTERVIEW GUIDE

QUESTIONS FOR MUNICIPAL OFFICIAL

1. **DO YOU HAVE PLANS IN PLACE WITH REGARD TO FLOODS? COPING STRATEGY EMPLOYED DURING FLOODS?**

   ……………………………………………………………………………………………………

   ……………………………………………………………………………………………………

   ……………………………………………………………………………………………………

2. **EXPLAIN ANY PREVENTION AND PREPAREDNESS MEASURES IN PLACE?**

   …………………………………………………………………………………………………..

   ……………………………………………………………………………………………….

   ……………………………………………………………………………………………….

3. **DO YOU HAVE DISASTER MANAGEMENT PLAN?**

   ……………………………………………………………………………………………….

   ……………………………………………………………………………………………….

   ………………………………………………………………………………………………

4. **DOES YOUR FINANCIAL YEAR PLAN INCLUDE ISSUES OF DISASTER MANAGEMENT PLAN?**

   ……………………………………………………………………………………………….

   ………………………………………………………………………………………………

5. **ARE THERE ANY DISASTER AWARENESS CAMPAIGN TAKING PLACE? HOW EFFECTIVE IS THE LEVEL OF AWARENESS IN THE COMMUNITY?**

   ……………………………………………………………………………………………………
   ……………………………………………………………………………………………………
   ……………………………………………………………………………………………………

   ……………………………………………………………………………………………………

6. **EXPLAIN ANY RESPONSE AND MITIGATION PLANS AVAILABLE FOR FLOOD?**

…………………………………………………………………………………………….

……………………………………………………………………………………………

……………………………………………………………………………………………

7. **WHAT ARE THE MEANS OF COMMUNICATION BEFORE, DURING AND AFTER FLOODS? ELABORATE**

…………………………………………………………………………………………….

……………………………………………………………………………………………

8. **WHAT EVACUATION PLAN DO YOU HAVE?**

…………………………………………………………………………………………….

……………………………………………………………………………………………

9. **HOW READY IS THE COMMUNITY TO UNDERSTAND AN OFFICIAL WARNING AND REACT?**

……………………………………………………………………………………………

……………………………………………………………………………………………

10. **EXPLAIN THE AREAS OF IMPROVEMENT BETWEEN THE COMMUNITY AND DISASTER MANAGEMENT TEAM?**

…………………………………………………………………………………………….

……………………………………………………………………………………………

11. **SHOULD THERE BE A DISASTER BEFALLING THIS COMMUNITY, PLEASE EXPLAIN WHETHER OR NOT THE COMMUNITY WOULD HAVE ENOUGH RESOURCES (EQUIPMENT, FUNDS AND TRAINED PERSONNEL) FOR RESCUE OR TO ADDRESS THE SITUATION AT HAND?**

……………………………………………………………………………………………

…………………………………………………………………………………………...

…………………………………………………………………………………………...

12. **IF YES, PLEASE MENTION HOW EFFECTIVE IS THE EARLY WARNING SYSTEM IN THE COMMUNITY?**

…………………………………………………………………………………………..

………………………………………………………………………………………….

13. WHAT DO YOU THINK SHOULD BE DONE TO REDUCE FLOODS EXPOSURE?

…………………………………………………………………………………………..

………………………………………………………………………………………….

APPENDIX F: CERTIFICATE OF PROOF READING AND LANGUAGE EDITING

TO WHOM IT MAY CONCERN

EDITOR CERTIFICATE

This letter serves to confirm that the following thesis/ academic work belonging to:

Mr Bongani Masombuka

titled,

MANAGEMENT STRATEGY FOR THE ANNUAL FLOOD RISK OF INFORMAL SETTLEMENTS IN SOUTH AFRICA: CASE STUDY OF ALEXANDRA TOWNSHIP, GAUTENG PROVINCE.

Was grammatically re-edited by the undersigned in July 2024.

Regards,

Dr Linah N Masombuka (nee Nkuna)

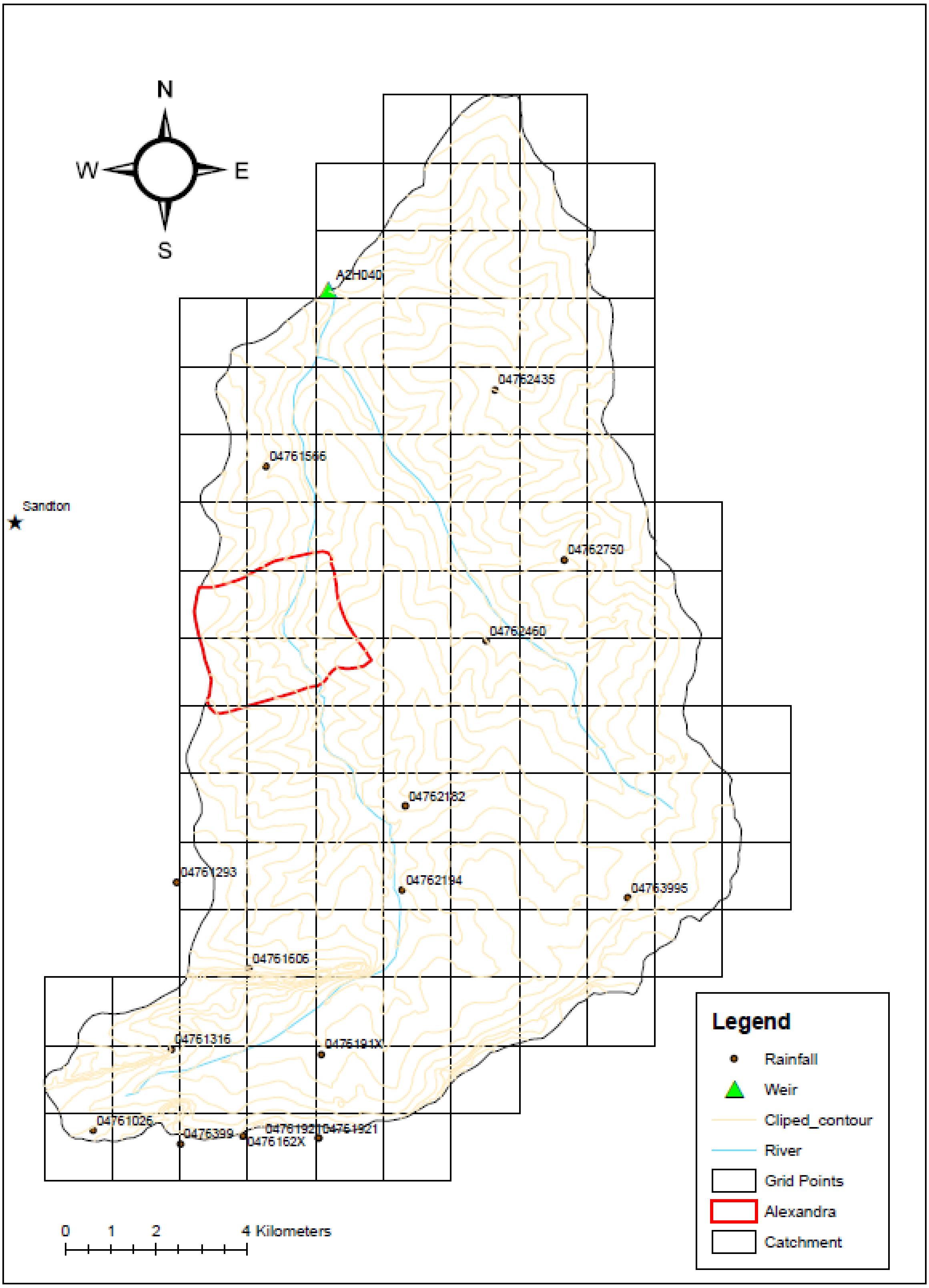
Senior Lecturer – Communication and Media studies

Department of Communication Science

Email: nkunaln@unisa.ac.za or Linahlnn@icloud.com

Cell: +27 – 0786924887 or 012 429 8053

APPENDIX G: GRID POINTS COVERING THE CATCHMENT



APPENDIX H: ETHICAL CLEARANCE

UNISA university of south africa

UNISA-CAES HEALTH RESEARCH ETHICS COMMITTEE

Date: 01/12/2021

NHREC Registration # : REC-170616-051
REC Reference # : 2021/CAES_HREC/144
Name : Mr B Masombuka
Student #: 65104250

Dear Mr Masombuka

Decision: Ethics Approval from 01/12/2021 to 30/11/2024

Researcher(s): Mr B Masombuka
bongz.bingo@gmail.com; 060-506-2684

Supervisor (s): Prof M Ilunga
ilungm@unisa.ac.za; 072-424-6104

Mrs L Craig
craigl@unisa.ac.za; 011-471-2501

Working title of research:

Management strategy for the annual flood risk of informal settlements in South Africa: Case study of Alexander township, Gauteng Province

Qualification: MSc Environmental Management

Thank you for the application for research ethics clearance by the Unisa-CAES Health Research Ethics Committee for the above mentioned research. Ethics approval is granted for three years, **subject to submission of the relevant permission letter and yearly progress reports. Failure to submit the progress report will lead to withdrawal of the ethics clearance until the report has been submitted.**

The researcher is cautioned to adhere to the Unisa protocols for research during Covid-19.

Due date for progress report: 30 November 2022
The progress report is available on the college ethics webpage: https://w2.unisa.ac.za/www.unisa.ac.za/sites/corporate/default/Colleges/Agriculture-%26-Environmental-Sciences/Research/Research-Ethics.html

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Preller Street, Muckleneuk Ridge, City of Tshwane
PO Box 392 UNISA 0003 South Africa
Telephone: +27 12 429 3111 Facsimile: +27 12 429 4150
www.unisa.ac.za

Yours sincerely,

Prof MA Antwi
Chair of UNISA-CAES Health REC
E-mail: antwima@unisa.ac.za
Tel: (011) 670-9391

Prof SR Magano
Executive Dean : CAES
E-mail: magansr@unisa.ac.za
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