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Assessment and Mitigation of Flood Risk in Urban Settlement: A Case of Ethekwini Metropolitan Area

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ABSTRACT

Flooding is one of the most destructive natural hazards globally, with impacts intensified by climate change and systemic gaps in disaster risk governance. This study assesses the vulnerability of the eThekwini Metropolitan Area (EMA) in KwaZulu-Natal, South Africa, to recurrent flood disasters. Using an indicator-based methodology, the research analyses quantitative data across five dimensions: socio-economic, physical, health and wellbeing, institutional and governance, and environmental factors. The aim is to identify structural weaknesses and inform inclusive, long-term mitigation strategies. In April 2022, KwaZulu-Natal experienced a devastating flood disaster that illustrates the region's exposure and fragility to floods, leading to a 0.7% drop in national GDP, disrupted manufacturing and agriculture, and reversed post-COVID economic recovery. EMA's coastal location, prevalence of informal settlements, and limited infrastructure amplify its flood risk. Findings reveal inadequate preparedness, slow recovery, unequal distribution of incentives, and prolonged lack of essential services, such as clean water and healthcare, in affected communities. The research highlights how climate-induced hazards compound vulnerabilities, affecting livelihoods, public health, and service delivery. Institutional fragmentation and reactive planning hinder effective risk reduction. The study recommends a multi-stakeholder approach to flood mitigation, emphasising coordinated governance, equitable recovery, and proactive investment in resilient infrastructure and community engagement. This research contributes a localised vulnerability assessment framework and actionable insights for urban flood mitigation in climate-sensitive regions. By integrating diverse vulnerability indicators and emphasising inclusive planning, it offers a strategic foundation for enhancing resilience and reducing future flood impacts in South Africa's urban settlements.

Keywords: Flood Vulnerability; Disaster Risk Management; Informal Settlement; Climate Change; Resilience

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INTRODUCTION

Flooding is one of the most destructive natural hazards, which could be a result of heavy rainfall, storm surge or dam burst and river overflow. These risks are intensified by climate change, leading to more frequent and severe floods. The economic impact of floods comes in several forms, which may include infrastructural damage, property and crop losses, disruption of business operations, spread of water-borne diseases leading to increased healthcare costs and reduction in productivity as people fall ill. The United Nations Disaster Risk Reduction confirms that, for every 1^0C global warming, extreme daily precipitation event is expected to intensify by seven percent.[1] Climate change is undermining the ability to achieve the

[1] UNDRR, " Implementing the Sendai Framework," United Nations, 2023, https://www.undrr.org/implementing-sendai-framework/drr-focus-areas/climate-action-and-disaster-risk-reduction.

2030 Agenda for sustainable development as well as the Sendai Framework for Disaster Risk Reduction (SFDRR).[2]

The devastating flood disasters in South Africa have been attributed to climate change and the inability of the governmental agencies to effectively apply disaster risk management strategies.[3] Flooding not only poses an immediate threat to life and property but also has profound and lasting impacts on the economy. The cost accrued to floods alone in January 2021 was estimated to be over R50 million.[4] The flood disaster in KwaZulu Natal (KZN) in 2022 led to a decrease in GDP by 0.7%.[5] The flooding was documented as having a negative impact on manufacturing industries.[6] Manufacturing is the largest industry in KZN, accounting for one-fifth of National manufacturing production. The damage to factories and the destruction of logistics and supply chains reduced national manufacturing output by 5.9%. Trade, catering and industry were also impacted. Agriculture, forestry, and fishing activities decreased by 7.7%. This disaster dragged the post-COVID recovery of the GDP in quarter one of 2022 (Q1:2022) by R1,148 billion.[7]

Current mitigation efforts to climate-induced flood disaster risk are insufficient, and risk analytics are inadequate for effective preventive action to reduce the impact of floods on communities. Long-term actions are becoming inadequate in current developmental planning, as the continuing increase in the number of extreme weather events and the impact on livelihoods, access to proper healthcare and population displacement has become overwhelming due to the underestimated cost-benefit of rapid climate change.[8] Disadvantaged communities suffer disproportionately from the adverse effects of climate change, reducing their ability to cope and recover from the impacts of climate-change-induced natural flood hazards, pushing them further into poverty and inequality. The frequency of flood disasters in KZN has been attributed to climate change and the absence of proactive disaster risk reduction strategies.[9]

This research assesses the vulnerabilities of individuals in the eThekwini metropolitan area, an urban settlement in KwaZulu-Natal, to flood disasters using the indicator-based approach. This approach uses available data to provide a logical image of the vulnerability of the area under review.[10] The socio-economic, physical, health and well-being, institutional and governance, and environmental factors that lead to vulnerabilities of the individuals in the study area are used to develop mitigation strategies that effectively incorporate climate change and long-term developmental planning in flood disaster risk reduction. The following sections of this research provide a comprehensive literature review relevant to the study, materials and methods adopted for the research, results obtained, discussions and conclusions.

LITERATURE REVIEW

This section provides a comprehensive review of literature pertinent to the study. The review structure is in two phases: the conceptual review, which examines key concepts vital to the research and the empirical review, which examines research findings relevant to the study to highlight consistencies and gaps in current knowledge.

Conceptual Review

The main purpose of this is to review literature related to floods in urban areas, their impacts, vulnerabilities, and resilience, as well as the various FRM strategies adopted to minimise the damages accrued to risk. This review utilised relevant publications from journal articles and books and critically analysed these to identify themes, debates and gaps. To achieve a holistic literature search, the ways

[2] UNDRR, " Implementing the Sendai Framework."
[3] Bethuel Sibongiseni Ngcamu, "Application of the Disaster Management Cycle and Climate Change: Studying Flood Disasters in South Africa," *Social Sciences & Humanities Open* 8, no. 1 (2023): 100657, https://doi.org/10.1016/j.ssaho.2023.100657.
[4] Barry Maher et al., "South Africa - Disaster Risk Finance Diagnostic," 2022.
[5] StatsSA, "Publications Statistics by Place Statistics by Theme," Stats SA, 2022, http://www.statssa.gov.za/?p=11361.
[6] StatsSA, "Publications Statistics by Place Statistics by Theme."
[7] StatsSA, "Publications Statistics by Place Statistics by Theme."
[8] UNDRR, " Implementing the Sendai Framework."
[9] Ngcamu, "Application of the Disaster Management Cycle and Climate Change: Studying Flood Disasters in South Africa."
[10] Hajar Nasiri, Mohd Johari Mohd Yusof, and Thamer Ahmad Mohammad Ali, "An Overview to Flood Vulnerability Assessment Methods," *Sustainable Water Resources Management* 2, no.3(September 26, 2016): 331–36, https://doi.org/10.1007/s40899-016-0051-x.

communities manage disaster risk were reviewed. In addition, disaster management in SA, in particular the National Disaster Management Framework, was examined.

Urban Floods and Impacts

Historically, floods were viewed as external natural events, prompting technical flood control responses. However, evolving perspectives now recognise flood disasters as outcomes of interactions between natural hazards and societal vulnerabilities.[11] This shift has led to the adoption of Flood Risk Management (FRM), which integrates community vulnerability into flood planning.[12] Urbanisation has tripled flood risk, especially in densely populated areas, resulting in infrastructure damage and economic losses.[13] Climate-related disasters and anthropogenic climate change further intensify these impacts.[14]

Williams et al. project increased flood frequency and severity, noting that rapid urbanisation and climate change undermine urban resilience. Seemuangngam and Lin similarly highlight how land use changes heighten flood vulnerability.[15] Floods produce varied economic, social, and environmental consequences, influenced by factors such as flood duration, depth, location, and the vulnerability of affected populations. Waghwala and Agnihotri also emphasise the role of urbanisation in increasing flood exposure.[16] Yari et al. report that most flood-related deaths occur in densely populated, less developed countries, where preparedness is limited.[17] In contrast, countries with greater resources possess stronger capacities to anticipate and respond to flood events, reducing mortality and damage.

Climate Change and Flood Risk

Floods are influenced by multiple factors, including weather and humanitarian conditions, linking climate change and flooding complex way. Nonetheless, Seneviratne et al. emphasise that climate change significantly affects water-related variables contributing to floods.[18] This supports Morita's findings that global climate change alters rainfall patterns.[19] While global warming may not directly cause floods, it intensifies many contributing factors. Denchak outlines key mechanisms by which climate change elevates flood risk: warmer air holds more moisture, leading to heavier rainfall; stronger storms occur more frequently, and rising sea levels amplify storm surges.[20] Tabari adds that extreme precipitation increases with water availability, rising by 6–7% per degree of temperature increase, aligned with saturation concentration.[21]

UNEP reports that higher global temperatures inject more energy into the Earth's system, increasing evaporation and cloud formation.[22] Warmer air retains more moisture, resulting in longer, more intense rainfall events. UNEP also notes a 1.1% rise in global average temperature since the last century,

[11] Viveca Norén et al., "Flood Risk Assessment – Practices in Flood Prone Swedish Municipalities," *International Journal of Disaster Risk Reduction* 18 (September 2016): 206–17, https://doi.org/10.1016/j.ijdrr.2016.07.003.
[12] Jochen Schanze, "Flood Risk Management–a Basic Framework," in *Flood Risk Management: Hazards, Vulnerability and Mitigation Measures* (Springer, 2006), 1–20.
[13] Farhat Rafiq et al., "Urban Floods in India," *International Journal of Scientific & Engineering Research* 7, no. 1 (2016): 721–34.
[14] Canesio Predo, "Adaptation of Community and Households to Climate-Related Disaster: The Case of Storm Surge and Flooding Experience in Ormoc and Cabalian Bay, Philippines," *EEPSEA Climate Change Technical Reports/IDRC. Regional Office for Southeast and East Asia, Economy and Environment Program for Southeast Asia*, 2010.
[15] Apinan Seemuangngam and Han-Liang Lin, "The Impact of Urbanization on Urban Flood Risk of Nakhon Ratchasima, Thailand," *Applied Geography* 162 (January 2024): 103152, https://doi.org/10.1016/j.apgeog.2023.103152.
[16] Rupal K Waghwala and P G Agnihotri, "Flood Risk Assessment and Resilience Strategies for Flood Risk Management: A Case Study of Surat City," *International Journal of Disaster Risk Reduction* 40 (2019): 101155.
[17] Arezoo Yari et al., "Risk Factors of Death from Flood: Findings of a Systematic Review," *Journal of Environmental Health Science and Engineering* 18, no. 2 (2020): 1643–53.
[18] Sonia I. Seneviratne et al., "Changes in Climate Extremes and Their Impacts on the Natural Physical Environment," in *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* (Cambridge University Press, 2012), 109–230, https://doi.org/10.1017/CBO9781139177245.006.
[19] M. Morita, "Quantification of Increased Flood Risk Due to Global Climate Change for Urban River Management Planning," *Water Science and Technology* 63, no. 12 (June 1, 2011): 2967–74, https://doi.org/10.2166/wst.2011.172.
[20] M. Denchak, " Flooding and Climate Change: Everything You Need to Know," NRDC, 2019, https://www.nrdc.org/stories/flooding-and-climate-change-everything-you-need-know.
[21] Hossein Tabari, "Climate Change Impact on Flood and Extreme Precipitation Increases with Water Availability," *Scientific Reports* 10, no. 1 (August 13, 2020): 13768, https://doi.org/10.1038/s41598-020-70816-2.
[22] United Nations Environment Programme (UNEP), *Climate Change and Africa: Addressing the Challenges* (Nairobi: UNEP, 2020).

suggesting that extreme flooding will intensify in urban areas built on floodplains and low-lying coastal zones.[23]

Da Silva, Alencar, and de Almeida agree that climate change complicates flood management due to temperature variability and escalating impacts.[24] Therefore, decision-makers, disaster managers, and stakeholders must integrate climate change considerations into urban flood risk planning to address the growing severity of flood events.

Flood Vulnerability

Unplanned and rapid urbanisation increases the vulnerability of urban poor communities to floods.[25] The increase in vulnerability is also attributed to the dense concentration of important, crucial physical assets, energy installations, functioning industries and infrastructure such as bridges, roads, tunnels and more. The annual risk of floods in SA is 83.3%, with a high population vulnerability as a result of its geographical location and economic factors.[26] These findings were authenticated by Munyai et al., in their research on the vulnerability and adaptation to flood hazards in rural settlements of the Limpopo province in South Africa.[27] Coastal cities such as Durban are susceptible to river flooding and storm surge, which increases vulnerability.

Several vulnerability drivers are hidden and remote from their triggering events. These drivers of vulnerability include biophysical, social and economic vulnerabilities.[28] Communities are vulnerable to flood disasters that significantly impact infrastructure and the livelihood of communities.[29] The research on two communities in Limpopo province by Musyoki et al. indicated that an increase in the level of education, household incomeand access to grants decreased vulnerability of households to flood.[30] This authenticates a review of the elderly, poor and marginalised groups in societies by Otto, which found that these groups are more vulnerable to the effects of flooding because of their low human, social and financial coping capacities.[31] Coastal cities are susceptible to river flooding and storm surge, which increase vulnerability.[32] Knowledge of the study area vulnerability factors is key in reducing disaster risk and promoting a culture of resilience, while also assisting in targeted and cost-effective mitigation measures and enhanced efficacy in FRM.

Disaster Resilience

To understand and influence how stakeholders respond to disaster risk and disasters, it is important to have a combined knowledge of the hazards people experience and their perceptions. Irrespective of the community structure, resilience to disasters can be built through effective decision-making rooted in

[23] United Nations Environment Programme (UNEP), *Climate Change and Africa: Addressing the Challenges*.

[24] Lucas Borges Leal da Silva, Marcelo Hazin Alencar, and Adiel Teixeira de Almeida, "Multidimensional Flood Risk Management under Climate Changes: Bibliometric Analysis, Trends and Strategic Guidelines for Decision-Making in Urban Dynamics," *International Journal of Disaster Risk Reduction* 50 (November 2020): 101865, https://doi.org/10.1016/j.ijdrr.2020.101865.

[25] David A Williams, "Worship Music as Spiritual Identity: An Examination Of Music In The Liturgy Among Black And White Adventists In The United States From 1840 To 1944," *Andrews University Seminary Studies (AUSS)* 56, no. 2 (2019): 15.

[26] Bongumusa M Zuma et al., "Flood Disaster Management in South Africa: Legislative Framework and Current Challenges," in *International Conference on Applied Life Sciences* (IntechOpen, 2012).

[27] Rendani B. Munyai et al., "Vulnerability and Adaptation to Flood Hazards in Rural Settlements of Limpopo Province, South Africa," *Water* 13, no. 24 (December 7, 2021): 3490, https://doi.org/10.3390/w13243490.

[28] E. Mavhura and S. B. Manyena, "Integrating Disaster Risk Reduction into Development Planning in South Africa," *International Journal of Disaster Risk Reduction* 39 (2019): 101–8.

[29] Agnes Musyoki, Reuben Thifhulufhelwi, and Florence M. Murungweni, "The Impact of and Responses to Flooding in Thulamela Municipality, Limpopo Province, South Africa," *Jàmbá: Journal of Disaster Risk Studies* 8, no. 2 (January 13, 2016), https://doi.org/10.4102/jamba.v8i2.166.

[30] Musyoki, Thifhulufhelwi, and Murungweni, "The Impact of and Responses to Flooding in Thulamela Municipality, Limpopo Province, South Africa."

[31] Daniel Otto, "Lived Experience of Climate Change - a Digital Storytelling Approach," *International Journal of Global Warming* 12, no. 3/4 (2017): 331, https://doi.org/10.1504/IJGW.2017.084784.

[32] Alice Newton and Juergen Weichselgartner, "Hotspots of Coastal Vulnerability: A DPSIR Analysis to Find Societal Pathways and Responses," *Estuarine, Coastal and Shelf Science* 140 (March 2014): 123–33, https://doi.org/10.1016/j.ecss.2013.10.010; Rendani B. Munyai, Agnes Musyoki, and Nthadeuleni S. Nethengwe, "An Assessment of Flood Vulnerability and Adaptation: A Case Study of Hamutsha-Muungamunwe Village, Makhado Municipality," *Jàmbá: Journal of Disaster Risk Studies* 11, no. 2 (June 24, 2019), https://doi.org/10.4102/jamba.v11i2.692.

knowledge, through experience and perceptions.[33] The efforts of governments in Southern African countries to cope with the impact of flooding in communities are often limited and affected by people's perception of floods, which influences response.[34] This is in line with the findings of Masud et al., who demonstrated that when an individual can perceive flood risk and understand the seriousness of the issues confronted, it would prompt more noteworthy attitude change.[35]

Community-Based Disaster Risk Management (CBDRM)

CBDRM emphasises the critical role of communities in understanding and reducing disaster risk. As the most affected stakeholders, communities offer valuable insights into how vulnerabilities are created and can be addressed.[36] Van Niekerk et al. argue that meaningful knowledge about vulnerability, exposure, and resilience emerges when those directly impacted are involved in the process.[37] CBDRM is a participatory approach that engages communities in identifying, assessing, managing, and planning for hazards and vulnerabilities.[38] It empowers local populations to address disaster-related challenges from their own perspective. Community members often serve as the first line of defense, making education and sensitisation vital for reducing loss of life and property.[39] Direct consultation helps identify specific vulnerabilities and needs. However, challenges persist, including limited resources and the absence of disaster risk reduction (DRR) legislation at sub-national levels. For DRM to be inclusive and effective, active community involvement is essential.

Disaster Risk Management (DRM)

Globally, communities are experiencing an increase in disaster frequency, which is largely driven by climate change and extreme weather events.[40] This trend underscores the urgent need for resilient communities and improved disaster risk management (DRM). Effective DRM depends on learning from past events and adopting best practices, yet poor knowledge sharing and limited access to information continue to hinder performance.[41] Technological advancements are reshaping disaster management, with tools like crowdsourcing, social media (e.g., Twitter), and Volunteer Geographical Information (VGI) enhancing data collection and public engagement.[42] In least developed and developing countries, mobile technology has proven life-saving despite limited technical and human capacity.[43]

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[33] Ziyanda Nkombi and Gideon J. Wentink, "The Role of Public Participation in Disaster Risk Reduction Initiatives: The Case of Katlehong Township," *Jàmbá: Journal of Disaster Risk Studies* 14, no. 1 (February 28, 2022), https://doi.org/10.4102/jamba.v14i1.1203; Adhianty Nurjanah et al., "The Role of Stakeholders as Disaster Communicators at Disaster-Prone Tourist Attraction Objects," *Komunikator* 15, no. 2 (November 20, 2023): 247–58, https://doi.org/10.18196/jkm.20158.

[34] Musyoki, Thifhulufhelwi, and Murungweni, "The Impact of and Responses to Flooding in Thulamela Municipality, Limpopo Province, South Africa."

[35] Muhammad Mehedi Masud et al., "Community Responses to Flood Risk Management–An Empirical Investigation of the Marine Protected Areas (MPAs) in Malaysia," *Marine Policy* 97 (2018): 119–26.

[36] Dewald van Niekerk and Christo Coetzee, "African Experiences in Community-Based Disaster Risk Reduction," 2012, 333–49, https://doi.org/10.1108/S2040-7262(2012)0000010023.

[37] Dewald Van Niekerk et al.,"Community-Based Disaster Risk Management," in *Handbook of Disaster Research* (Springer,2017),411–29.

[38] Andre Krummacher, "Community Based Disaster Risk Management (CBDRM)-Panel Remarks by Andre Krummacher," *Community Based Disaster Risk Management (CBDRM).*, 2014; Nkombi and Wentink, "The Role of Public Participation in Disaster Risk Reduction Initiatives: The Case of Katlehong Township."

[39] Krummacher, "Community Based Disaster Risk Management (CBDRM)-Panel Remarks by Andre Krummacher."

[40] World Health Organization, "Global Health Achievements 2023," 2023, https://www.who.int/news-room/spotlight/global-health-achievements-2023.

[41] Krisanthi Seneviratne, David Baldry, and Chaminda Pathirage, "Disaster Knowledge Factors In Managing Disasters Successfully," *International Journal of Strategic Property Management* 14, no. 4 (December 31, 2010): 376–90, https://doi.org/10.3846/ijspm.2010.28; Rina Suryani Oktari et al., "Knowledge Management Practices in Disaster Management: Systematic Review," *International Journal of Disaster Risk Reduction* 51 (December 2020): 101881, https://doi.org/10.1016/j.ijdrr.2020.101881.

[42] Marta Poblet, Esteban García-Cuesta, and Pompeu Casanovas, "Crowdsourcing Tools for Disaster Management: A Review of Platforms and Methods," in *International Workshop on AI Approaches to the Complexity of Legal Systems* (Springer, 2013), 261–74; Giovanni Iacovitti, "How Technology Influences Information Gathering and Information Spreading," *Church, Communication and Culture* 7, no. 1 (January 2, 2022): 76–90, https://doi.org/10.1080/23753234.2022.2032781; Anne B. Nielsen et al., "Social Media and Crowdsourcing in Disaster Risk Management: Trends, Gaps, and Insights from the Current State of Research," *Risk, Hazards & Crisis in Public Policy* 15, no. 2 (June 22, 2024): 104–27, https://doi.org/10.1002/rhc3.12297; Ian McCallum et al., "Technologies to Support Community Flood Disaster Risk Reduction," *International Journal of Disaster Risk Science* 7, no. 2 (June 17, 2016): 198–204, https://doi.org/10.1007/s13753-016-0086-5.

[43] McCallum et al., "Technologies to Support Community Flood Disaster Risk Reduction."

Doocy et al., emphasise that flood monitoring, mitigation, and communication with vulnerable populations can significantly reduce mortality.[44] South Africa's Disaster Management Act and National Policy promote decentralised disaster risk reduction (DRR),[45] but Phaswana warns that legislation alone does not guarantee effective practice.[46] Strong governance structures are essential for collaborative flood risk management.[47] However, DRM in South Africa often follows a top-down approach, excluding community input and fostering stakeholder dissatisfaction.[48] Interdepartmental coordination is weak, and technical solutions are frequently implemented without local consultation or adequate training, leading to failed interventions.[49] Zuma et al. found national-level flood response adequate, but district municipalities lacked capacity and skills.[50]

Musyoki et al. observed that local governments typically engage only post-disaster, with short-term measures prevailing due to limited strategic planning capacity.[51] This research proposes enhancing stakeholder coordination and participation to improve DRM effectiveness in the eThekwini Metropolitan Area (EMA). Long-term resilience requires inclusive governance, community engagement, and sustained investment in capacity-building.

Empirical Review

Flood-related disasters in EMA have been frequent and more intense. The increased influx of people to EMA has led to overpopulation, poor infrastructure and a lack of resources responsible for the severe impacts of floods as a result of climate change.[52] EMA has the largest number of informal settlements in South Africa, leading to increased flood vulnerability among the population.[53] Records reveal that there has been at least one major flood event from 2017 to 2022 with increasing frequency.[54] Reports express concern about insufficient funding for disaster interventions and an ineffective transition towards a climate-resilient economy.[55] The 2020 flood disaster in KZN showed a lack of disaster preparedness, mitigation and over subscription to disaster response and recovery with no robust capacity and coordination in assessing key stakeholders.[56] Findings by Masamba and Molaiwa in the Assessment of the 2023 flood disaster in KZN found that response interventions were swift and effective; however, there were several gaps in the post-disaster management.[57] They included extremely slow human settlement interventions, delays in finalising and verifying damages and costs, leading to delays in completing funding applications, which affects the flow of funds and implementation of interventions, fragmented coordinating and reporting structures, leading to slow and clumsy communication and poor disaster management planning. While restoration of major economic infrastructure and basic services, as well as

[44] Shannon Doocy et al., "The Human Impact of Floods: A Historical Review of Events 1980-2009 and Systematic Literature Review," *PLoS Currents* 5 (2013): ecurrents-dis.

[45] Munyai et al., "Vulnerability and Adaptation to Flood Hazards in Rural Settlements of Limpopo Province, South Africa."

[46] Nkhelebeni Phaswana, "Contradiction or Affirmation? The South African Language Policy and the South African National Government," in *Black Linguistics* (Routledge, 2005), 129–43.

[47] Doret Botha and Dewald Van Niekerk, "Views from the Frontline: A Critical Assessment of Local Risk Governance in South Africa," *Jàmbá: Journal of Disaster Risk Studies* 5, no. 2 (January 23, 2013), https://doi.org/10.4102/jamba.v5i2.82.

[48] T T Monyepao and D E Uwizeyimana, "The Effects of the Top-down Management Approach on Employees' Attitude Towards the South African National Government Intervention in Limpopo Province," *Administratio Publica* 26, no. 2 (2018): 91–117.

[49] OCHA/UNDP, "Innovation in Disaster Management - Leveraging Technology to Save More Lives," 2023, https://www.undp.org/sites/g/files/zskgke326/files/2024-03/innovation_in_disaster_management_web_final_compressed.pdf.

[50] Zuma et al., "Flood Disaster Management in South Africa: Legislative Framework and Current Challenges."

[51] Musyoki, Thifhulufhelwi, and Murungweni, "The Impact of and Responses to Flooding in Thulamela Municipality, Limpopo Province, South Africa."

[52] British Broadcasting Cooperation, " Durban Floods: Is It a Consequence of Climate Change?," British Broadcasting Cooperation, 2022, https://www.bbc.co.uk/news/61107685.

[53] United Nations, " UNITAC x EThekwini : Using AI to Map Informal Settlements in EThekwini, South Africa," 2022, https://unitac.un.org/news/unitac-x-ethekwini-using-ai-map-informal-settlements-ethekwini-south-africa.

[54] Godfrey Mashamba and Thokozile Molaiwa, "Rapid Assessment of the Government ' s Intervention on the April 2022 Flood Disaster in Kwazulu-Natal , Eastern Cape and North West March 2023" (Pretoria, South Africa, 2023); Caroline C. Olanrewaju and Maliga Reddy, "Assessment and Prediction of Flood Hazards Using Standardized Precipitation Index—A Case Study of EThekwini Metropolitan Area," *Journal of Flood Risk Management* 15, no. 2 (June 3, 2022), https://doi.org/10.1111/jfr3.12788.

[55] NDMC, *National Disaster Management Contingency Plan for 2021-2022 Summer Season* (Pretoria, South Africa, 2021).

[56] Elmon Mudefi, "Disaster Management 'Deeds' in the Context of April 2022 KwaZulu-Natal Floods: A Scoping Review," *International Journal of Disaster Risk Reduction* 98 (November 2023): 104122, https://doi.org/10.1016/j.ijdrr.2023.104122.

[57] G. Mashamba and T. Molaiwa, " Rapid Assessment of the Government's Intervention on the April 2022 Flood Disaster in Kwazulu-Natal , Eastern Cape and North West March 2023. Pretoria, South Africa.," 2023.

social services, progressed on the 2022 flood disaster, new bouts of flood disaster continue to occur with more frequency and intensity, setting back concluded interventions.

Management of flood risk requires a holistic approach which covers the pre- and post-disaster phases, which should allow for human dignity and security, uninterrupted education, proper management of psychological and mental health of the affected and all other factors that may impact the economic well-being of families in particular and the country as a whole. The mitigation strategies in this research consider all aspects of the mitigation of flood risk.

THEORETICAL FRAMEWORK

There are several disaster management frameworks. Disaster Management Cycle (DMC) is the most learnt literature on Disaster Management (DM). The cycle comprises five phases with interlinked activities and is categorised into distinct phases: pre-disaster and post-disaster.[58] These interlinked activities were created to assist disaster management officials in mitigating physical and human risk and losses associated with natural risk-induced disasters.[59] The DMC has been criticised for lacking contemporary management concepts, making it lack more value and relevance to the outcomes in the process of DM. Findings by Sawalha indicate that worldwide DM stakeholders, including academics, still rely on the traditional DM life cycle to manage disasters, unrecognising that each disaster is a unique incident and should be treated differently.[60] The DMC has also been criticised for not sufficiently accommodating climate change, which is the most modern trigger of natural-induced disasters.[61] Research conducted by Ngcamu showed that DMC had not been fully applied by the governmental officials before, during and after the devastating April 2022 flood disaster in KZN, in which EMA was the hardest hit.[62] The findings show that the lack of proper implementation of the DMC to mainstream climate change was the cause of the 2022 flood disaster.

South Africa is one of the countries in Africa with a genuine legal framework on DRR, as demonstrated during the coronavirus pandemic.[63] However, the country's response to the 2021/2022 flood disasters in three provinces, including KZN, was inefficient as there were disaster-related losses with a very severe impact on the economy, social, cultural, health and environment. Findings from the Flood Relief Fund (2022) showed that the government provided social relief; however, the reconstruction process was too slow, speed and quality of delivery in critical areas were very slow, showcasing weakness in intergovernmental processes and coordination.[64] The Sendai Framework for Disaster Risk Reduction (SFDRR) is a framework aimed at improving DRR measures and policies with seven global targets, which include reducing direct disaster economic loss, damage to critical infrastructure and the number of affected people, as well as increasing access to early warning systems, international cooperation and availability of multi-hazard early warning.[65] Reports on the overview of disaster management systems in South Africa indicate the need for South Africa to move towards DRR and align with the SFDRR to improve its capabilities and respond more effectively to disasters, increase resilience and promote sustainable development in the face of increasing disaster risk.[66]

METHODOLOGY

This research utilised the quantitative research methodology approach. This research methodology is used to test the importance of the research hypothesis.[67] In this approach, the focus is on collecting, testing and

[58] Prince Kumar, "Comprehensive Overview of the Disaster Management Cycle : Stages and Understanding the Disaster Management Cycle Pre-Disaster : Preparedness , Prevention , and Mitigation During-Disaster : Response and Relief Post-Disaster : Rehabilitation , Reconstructio," 2023.

[59] I. H. Sawalha, "A Contemporary Perspective on the Disaster Management Cycle.," *Foresight* 22, no. 4 (2020): 469–82, https://doi.org/https://doi.org/10.1108/FS-11-2019-0097.

[60] Sawalha, "A Contemporary Perspective on the Disaster Management Cycle."

[61] Daniel L. Swain et al., "Attributing Extreme Events to Climate Change: A New Frontier in a Warming World," *One Earth* 2, no. 6 (June 2020): 522–27, https://doi.org/10.1016/j.oneear.2020.05.011.

[62] Ngcamu, "Application of the Disaster Management Cycle and Climate Change: Studying Flood Disasters in South Africa."

[63] South African Governemnt, "Concept Note International Dialogue Series On Disaster Management Systems," South African Government, 2023, https://www.gov.za/sites/default/files/gcis_document/201409/275340.pdf.

[64] South African Governemnt, "Concept Note International Dialogue Series On Disaster Management Systems."

[65] UNISDR, "Sendai Framework for Disaster Risk Reduction 2015– 2030" (Geneva, 2015).

[66] Elias Sithole, "Overview of Disaster Management System in South Africa," Cooperative Governance, RSA, 2023.

[67] Sujata Mehta, "Types of Research Methodology," Eduvoice, 2023.

measuring numerical data from a large sample of participants. The data collected was analysed using statistical analysis and comparisons. Number-based research measures attitudes, performance and behaviour in numbers, making data easier to interpret. These data can effectively be converted into charts and graphs, making it difficult for the researcher to influence the interpretation of the results. It measures the relationship between variables.[68] This study used a quantitative research methodology to obtain the objective opinions of a large number of respondents in the study area regarding Flood Risk Management (FRM).

Research Design

This research utilised a case study research design. A case study research design entails the in-depth examination of a specific case for a period of time.[69] This study focused on flood disasters in EMA and intensively sought to understand how flood risk can be managed. The design was selected by the researcher to gain an in-depth understanding of the study area in its real-world context, and with the hope of acquiring new knowledge regarding the study area that will activate the research and provide more understanding of the real issues causing floods.

Study Area

The EMA, created in the year 2000, is one of the 11 municipalities located in the KZN province of South Africa. KZN is in the Southeast of the country, with a long shoreline on the Indian Ocean. The EMA is sprawled over approximately 2297km^2 and extends from the Tongati river in the North to the aMahlongwa river in the south. Bounded on the eastern edge by 98km of Indian coastline, the EMA extends 50km inland to the west at Cato Ridge. It is bordered in the North by Ilembe municipality, and south and west by Ugu and uMgungundlovu district municipalities, respectively, comprising approximately 37 cities and towns, featuring a rugged topography with hills and valleys.[70]

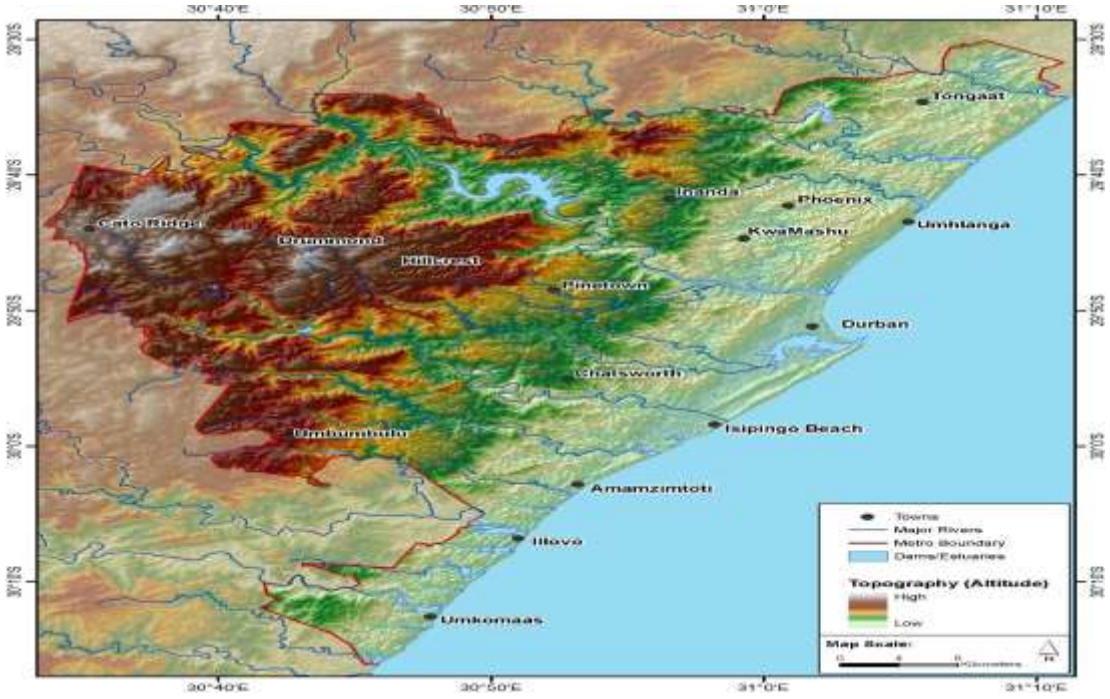

Figure 1: Map showing the topography of the eThekwini Metropolitan Area (EMA)

[68] S. Mehta, "Types of Research Methodology," Eduvoice, 2023, https://eduvoice.in/types-research-methodology/#:~:text=Some common types of research,research%2C and case study research.

[69] P. Leady and J. Ormrod, *Practical Research - Planning and Design* (New York: Pearson, 2010).

[70] Jane Turpie et al., "Promoting Green Urban Development in Africa : Enhancing the Relationship between Urbanization ," The World Bank, 2017.

The EMA, also known as Durban, has a sub-tropical climate with wet, humid summers and mildly dry winters.[71] As the largest city in the KZN province and the third largest city in SA, with a population of approximately 3 987 648, the EMA accounts for 34.7% of the total KZN province population, with 50.3% women and 49.7& men.[72] EMA is the main economic seat in KZN and contributes over half of the province's employment, income and output. Durban has a port which is the busiest cargo port in South Africa and the busiest container port in the Southern hemisphere.

Sampling Technique and Sampling Size

A sample of the research that offers large and meaningful data to represent the entire population in solving the problem of the research was used. Thus, the representative sample can make precise conclusions about the population, based on the information obtained. Care was taken to determine an appropriate sample size that was not too small to lack the precision to provide reliable answers to the investigated questions and affect performance, and not too large to cause a waste in time and resources. Thus, the research focused on four strategically located townships as representative of the entire study area. This enabled the capture of meaningful and relevant data. The sampled respondents are residents of the study area, purposively drawn, and aimed at targeting respondents directly involved, who could produce data relevant to the study. The population sample for the quantitative data was drawn based on period of stay in the study area, age of respondent, ownership of property in the study area and frequent visits to communal centres.

The Metropolitan SDF expound that sample size is determined by considering the population size, sample error or level of precision, degree of variability in the attributes being measured, and confidence level or risk, as well as the study purpose. This research utilised the published Tables. The Table entails three components that include determination of the margin of error the researcher is willing to tolerate, determination of the confidence level for the margin of error and an estimation of the percentage of the sample that will respond in a given way.[73] The positive and negative deviations allowed on the survey results for the sample are known as the confidence level. The confidence interval or margin of error and the confidence level determine the data accuracy. For this research, sample size determination was achieved through the use of the Krejcie and Morgan sample size table.[74]

Based on the population of the selected cities/towns in the study area, the questionnaire respondents were determined using a ratio of 1:2:3:4. The larger the population, the more the respondents. Using this reasoning, the questionnaire distribution is shown in Table 1.

Table 1: Quantitative sample size

Urban Suburb	Participant Category Urban Residents	Population	Sample size
uMlazi Township (South-West)	South-West of Durban	404,811	154
Inanda Township (North)	North of Durban	158,619	115
Clare Estate (Central)	Durban central	5,996	77
Cato Manor Township (West)	West of Durban	6,190	38
Total		575,616	384

For a total population of 575,616, there is thus a margin of error (confidence interval) of +/- 5% percent, 95% confidence level for the margin of error and a 50% chance the sample contains the required characteristics, where the sample size for the research, according to the Krejcie and Morgan 1970 sample size Table, was 384.

[71] Debra Roberts and Sean O Donoghue, "Urban Environmental Challenges and Climate Change Action in Durban , South Africa," *Environment and Urbanization* 25, no. 2 (2013): 299–319, https://doi.org/10.1177/0956247813500904.

[72] Metropolitan SDF, " Ethekwini Metropolitan KZN, COGTA," 2021, https://www.cogta.gov.za/ddm/wp-content/uploads/2020/07/Metro-Profile_Ethekwini.pdf.

[73] J. W. Creswell and J. D. Creswell, *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*, 5th ed. (London: Sage, 2017).

[74] R. V. Krejcie and D. W. Morgan, "Determining Sample Size for Research Activities," *Educational and Psychological Measurement* 30 (1970): 607–10.

Data Collection Procedure

Structured questionnaires were used to collect information from purposively sampled residents of the study area, whose livelihoods and property are affected yearly by flood disasters. This provided the researcher a quantitative or numeric description of attitudes and trends of a population through the study of a sample of that population.[75] Secondary data with historical literature reviews were employed to review existing research on flood disasters and flood disaster risk management to understand the current flood disaster in the study area. In addition, the knowledge gap identified needed to be filled to further understand the issues potentially important for further exploration, using primary data. These secondary data include historical reports of rainfall variables from the SAWS, newspaper publications and articles and geographically referenced data from the Geographic Information System (GIS).

Research Instrument

The questionnaire survey was partitioned into three sections. Section one, which captured the socio-economic factors of the population, obtained the demographic information such as gender, age, marital status, and education, occupation, household size, years of community residency, and ownership status, in addition to basic income. Section 2 obtained information on the impacts of floods, which were viewed through two scenarios vis-à-vis impacts on property and impacts on individuals. This captured the physical factors as well as the health and well-being of the study area. The third section captured information on flood management in the study area needed for the institutional and governance factor. The secondary data is used to obtain information on the environmental factor consisting of topography and land-use/land-cover using GIS and Remote Sensing.

Validity, Reliability and Trustworthiness

Strategies employed in this research to strengthen validity, reliability and trustworthiness included: multiple data in the form of questionnaires, an extensive literature review, and satellite images from observations; logical link between the research instruments and the study objectives; multi-site survey; collection and analysis of relevant and sufficient data which portrayed a true reflection of the research problem; transparency and consistency of data collection affirmed data validity; clear and transparent decisions during data analysis; reproduceable result findings during data analysis and transferability of research findings to other similar settings and contexts.

Data Analysis

Descriptive and inferential statistics were used. Descriptive statistics were used to generate summaries of the sample in a data set. This was to show what is typical for the sample. Inferential statistics were used to make inferences on the trends, relationship with other variables and impact of flooding on the population. The quantitative data were analysed using SPSS v. 29.

Ethical Considerations

This study secured ethics clearance from the Research Ethics Committee (IREC) of the Durban University of Technology (DUT). Authorisation to collect data from the study area was obtained from the relevant authorities of the eThekwini metropolitan municipality. Ethical considerations taken in this research aimed to ensure voluntary participation and address participant anonymity and confidentiality. The reason for the research was clearly communicated, and the confidentiality of responses was maintained.

PRESENTATION OF FINDINGS

This section focuses on the analysis and interpretation of the results from the measurement instruments.

Socio-economic Factors

This is composed of multiple factors that interact and influence one another. They include education, income, employment status, access to healthcare, home ownership, and family structure, just to mention

[75] John W Creswell, *Research Desing: Qualitative, Quantitative and Mixed Methods Approaches*, vol. 54 (United State of America: Sage Publications, 2014).

a few.[76] They can influence the overall well-being of an individual or community. Socio-economic factors of a community affect its ability to prepare for, respond to and recover significantly from a flood disaster.[77] These factors are captured in the demographic information of the study area.

Demographic Information

Root causes of flooding in the study area can be learnt from knowing the demographics. Table 2 shows the demographic information of 384 respondents who participated in the survey from the selected cities in the study area.

Table 2: Demographic Information

Demographic	Frequency	Percentage
Gender		
i. Male	160	41.7
ii. Female	224	58.3
Age		
i. 18-24 years	130	33.9
ii. 25-34 years	42	10.9
iii. 35-50 years	105	27.4
iv. 51-70 years	88	22.8
v. Above 70	5	1.4
Marital status		
i. Single	290	75.5
ii. Married	52	13.5
iii. Divorced	10	2.6
iv. Separated	19	4.9
v. Widowed	13	3.4
Education		
i. No formal education	78	20.3
ii. Primary education	48	12.5
iii. Secondary education	179	46.6
iv. Tertiary education	80	20.8
Occupation		
i. Public sector worker	64	16.7
ii. Self-employed	83	21.6
iii. Retired	22	5.7
iv. Unemployed	215	56
Household size		
i. Below 5	137	35.7
ii. 6-8	199	51.8
iii. 9-12	37	9.6
iv. Above 12	11	2.9
Property type		
i. Brick house	160	41.7
ii. Mud house	85	22.1
iii. Wooden house	139	36.2
Ownership status		
i. Owner	230	59.9
ii. Renting	72	18.8

[76] E P Havranek et al., "Social Determinants of Risk and Outcomes for Cardiovascular Disease: A Scientific Statement from the American Heart Association. 2015;132(9):873–98.," *Circulation* 132, no. 9 (2015): 873–79, https://doi.org/doi:10.1161/CIR.0000000000000228.

[77] Vladimir M. Cvetković and Vanja Šišović, "Understanding the Sustainable Development of Community (Social) Disaster Resilience in Serbia: Demographic and Socio-Economic Impacts," *Sustainability (Switzerland)* 16, no. 7 (2024), https://doi.org/10.3390/su16072620.

iii. Sharing	82	21.4
Basic income/month		
i. Below R3500	227	59.1
ii. R3500-R7000	107	27.9
iii. R7001-R10000	34	8.9
iv. Above R10000	16	4.2

Physical Factors

This describes the ability of the built environment to withstand impacts. It is also represented in the monetary value of the physical assets. This research uses the impacts of floods on property to get information on physical factors.

Impacts of Flood on Property

This section of the questionnaire comprised questions that assessed the impacts of the flood on the properties of the residents in the study area. These questions were used in analysing the exposure of the individual property and community to flood disasters. It also highlights the physical vulnerability of the study area and assesses the general characteristics of the flood hazard, such as its frequency and duration. This is shown in Table 3.

Table 3: Impact of flood on property

Information on the property	Frequency	Percentage
Age of property		
i. Below 5 years	76	19.9
ii. 6-10 years	129	33.6
iii. 11-20 years	135	35.2
iv. Above 20 years	44	11.5
Flood frequency on the property		
i. Once in a while	202	52.6
ii. All the time	182	47.4
Duration of flood inside the property		
i. 0-1 hour	19	4.9
ii. 2-4 hours	69	18.0
iii. 5-7 hours	70	18.2
iv. 8-10 hours	60	15.6
v. Above 10 hours	58	15.1
vi. Not Applicable	108	28.1
Estimated cost of damage to property		
i. Up to R1000	36	9.4
ii. R1001-R2000	74	19.3
iii. R2001-R4000	85	22.1
iv. R4001-R6000	94	24.5
v. Above R6000	62	16.1
vi. N/A	33	8.6

Health and Well-being

Several factors influence the health and well-being of an individual. These could be broadly categorised into social, economic and physical. The impacts of floods on individuals are used to obtain information on the health and well-being of the individuals in the study area.

Impacts of Floods on Individuals

Floods have a far-reaching effect on the individual and the community at large. This section of the questionnaire sought to identify the factors that increase the vulnerability of the community members to floods in the study area. Also assessed were the impact of floods on social (healthcare, education and population density), economic (livelihood) and technical (access to media and internet) factors that may increase vulnerability as a result of floods. In this section, respondents had to answer the questions using a 6-point response scale (agree, disagree, strongly agree, strongly disagree), neither agree nor disagree (neutral), and an option was provided for those who were unsure. Table 4 analyses the responses to the questions.

Table 4 – Impact of flood on individuals

Variables	Frequency	Percentage
Overpopulation is a contributing factor to floods		
i. Strongly agree	72	18.8
ii. Agree	201	52.3
iii. Neutral	14	3.6
iv. Not sure	49	12.8
v. Disagree	41	10.7
vi. Strongly disagree	7	1.8
Poor infrastructure (drainage system, waste management, roads, water, etc.)		
i. Strongly agree	101	26.3
ii. Agree	259	67.4
iii. Neutral	3	0.9
iv. Not sure	19	4.9
v. Disagree	2	0.5
vi. Strongly disagree	0	0
The infrastructure is affected due to a flood disaster		
i. Strongly agree	161	41.9
ii. Agree	210	54.7
iii. Neutral	5	1.3
iv. Not sure	2	0.5
v. Disagree	3	0.8
vi. Strongly disagree	3	0.8
Water sources in the community are affected		
i. Strongly agree	47	12.2
ii. Agree	183	47.7
iii. Neutral	24	6.3
iv. Not sure	85	22.1
v. Disagree	35	9.1
vi. Strongly disagree	10	2.6
Poor access to clean drinking water		
vii. Strongly agree	65	16.9
viii. Agree	177	46.1
ix. Neutral	15	3.9
x. Not sure	43	11.2
xi. Disagree	78	20.3
xii. Strongly disagree	6	1.6
Access to healthcare facilities is disrupted		
i. Strongly agree	75	19.5
ii. Agree	211	54.9
iii. Neutral	20	5.2

iv. Not sure	33	8.6
v. Disagree	33	8.6
vi. Strongly disagree	11	2.9
Healthcare provision is interrupted during floods		
i. Strongly agree	73	19.0
ii. Agree	205	53.4
iii. Neutral	23	6.0
iv. Not sure	32	8.3
v. Disagree	41	10.7
vi. Strongly disagree	10	2.6
Increase in disease outbreaks during flood disaster		
i. Strongly agree	32	8.3
ii. Agree	171	44.5
iii. Neutral	37	9.6
iv. Not sure	79	20.6
v. Disagree	47	12.0
vi. Strongly disagree	19	4.9
Floods impact livelihood negatively		
i. Strongly agree	95	24.7
ii. Agree	272	70.8
iii. Neutral	2	0.5
iv. Not sure	6	1.6
v. Disagree	8	2.1
vi. Strongly disagree	1	0.3
Respondents who lost property to floods		
i. Yes	250	65.1
ii. No	134	34.9

Institutional and governance factors

This involves how flood disaster is managed by disaster management stakeholders in the study area. This information is obtained by assessing the flood management practices employed in the study area.

Flood Management

The adverse impact of floods can be prevented or reduced by adopting efficient planning and preparation measures. Effective flood management strategies can significantly reduce the impact of flooding events on both individuals and their communities. Various approaches are used to mitigate and manage floods and their subsequent aftermath. This section explores several key variables related to flood management and preparedness to gain a comprehensive understanding of existing strategies and approaches in the study area. Table 5 analyses the responses to the questions.

Table 5 – Flood management

Variables	Frequency	Percentage
Help is received during flood disasters		
i. Yes	58	15.1
ii. No	326	84.9
Security of the community against flood disasters		
i. Strongly agree	126	32.8
ii. Agree	218	56.8
iii. Neutral	3	0.8
iv. Not sure	27	7.0
v. Disagree	8	2.1
vi. Strongly disagree	2	0.5

Response on the flood disaster by the government		
i. Strongly agree	83	21.6
ii. Agree	70	18.2
iii. Neutral	18	4.7
iv. Not sure	67	17.4
v. Disagree	109	28.4
vi. Strongly disagree	37	9.6
Any flood preventive measures by the EMA		
i. Yes	43	11.2
ii. No	341	88.8
Mitigation activities in the study area		
i. Yes	43	11.2
ii. No	341	88.8
Community participation in flood risk mitigation activities		
i. Yes	45	11.7
ii. No	339	88.3
An early warning system used for flood preparedness		
i. Yes	316	82.3
ii. No	68	17.7
Flood response plan by EMA		
i. Very good	8	2.1
ii. Good	39	10.2
iii. Adequate	26	6.8
iv. Poor	123	32.0
v. Very poor	188	49.0
Incentive for flood preparedness		
i. Yes	90	23.4
ii. No	294	76.6
Relief package after flood disasters by the government		
i. Yes	86	22.4
ii. No	298	77.6

Environmental Factors

The environmental factors will be assessed using the topography, land-use changes and closeness of homes and infrastructure close to water bodies in the study area. This information is captured using questionnaires as well as GIS and remote sensing to obtain data of the topography (land surface slope, flow accumulation, flow direction and topographic wetness), land-use changes, soil features, soil moisture and water storage.

DISCUSSION

The sample distributed for the questionnaire survey in the study area represented the study area. A 100% response rate was obtained, indicating the quantitative research lacked a non-response bias.

Socio-economic Information

The study area has 58.3% female participants, with women being 14 times more vulnerable to flood disasters than men as a result of inequitable distribution of roles, resources, and cultural norms, particularly in developing countries.[78] According to the Organisation for Economic Co-operation and Development,[79] the working age category is between 15 and 64 years. The highest age range is 18-24 years, making up 32.4% of the population. With 97% of residents in the working age (15-64 years), this implies the study area will suffer high economic vulnerability should a flood disaster occur, as

[78] Asako Okai, "Women Are Hit Hardest in Disasters , so Why Are Responses Too Often Gender-Blind," UNDP, 2022.
[79] OECD, "Working Age Population (Indicator."

approximately 97 percent residents are in the working age. In addition, disasters in the study area will result in social vulnerability. This is because the youth, who constitute the highest percentage of 32.8% of the population, are known to suffer from stress reactions, anxiety disorders, grief, and Post-Traumatic Stress Disorders (PTSD), as well as other comorbid conditions following disasters.[80] 75.5% of the population is unmarried and single, leading to high unpreparedness for flood disasters. Married individuals are generally better prepared due to their experience with frequent floods and familiarity with safety procedures.[81] Unmarried women may experience higher distress post-disaster.[82]

Only 20.3% of the population has a tertiary education. Higher education levels correlate with better disaster preparedness, response, and recovery. Educated individuals are more aware and adaptive, reducing the impacts of natural hazards.[83] 56% of the population is unemployed. Low socio-economic status (SES) affects disaster preparedness and response. People with lower SES are less prepared due to the cost of preparedness actions and suffer a slower recovery from disasters.[84] More than 50% of participants have a household size of 6-8 people. Larger households with low educational attainment and unemployment face slow and ineffective disaster response and recovery due to economic and social limitations. This may explain why disaster response and recovery may not be as effective as the efforts by disaster management practitioners. 58.3% of houses are constructed with mud and wood, making them highly vulnerable to floods. Mud houses are particularly fragile and unable to withstand natural disasters.[85] Recent studies show that most homes in SA are built with brick and concrete.[86] However, the encroachment of informal houses or backyard shacks as a by-product of formal houses is responsible for making the area more vulnerable to floods. Informal houses or backyard shacks, often built with wood and corrugated iron, are also highly vulnerable. 59.9% of residents own their homes, while 40.1% are rented. Homeowners are more likely to protect their property and prepare for disasters, whereas tenants may leave the property, leading to lower prevention and preparedness measures. More than half of the residents have a basic income below R3,500. Poor households are more vulnerable to disasters and suffer significant income losses. The April 2022 flood disaster in KZN demonstrated the high level of destruction and slow recovery rate in the study area, particularly among low-income earners. Generally, the study area faces significant vulnerabilities to flood disasters due to gender disparities, high youth population, low education levels, high unemployment, large household sizes, vulnerable housing, and low-income levels. These factors contribute to inadequate preparedness, high impact, and slow recovery from flood disasters.

Physical Information

The research emphasises the importance of assessing the vulnerability of the built environment, including physical structures, to understand the impact of floods on a community. Physical vulnerability can influence economic, social, and environmental aspects. The World Bank defines physical vulnerability as including both structural and non-structural damage to buildings and infrastructure, which can deteriorate gradually over time.[87]

The study found that 46.7% of buildings in the area are over 10 years old, contributing to high damage levels during floods. Frequent and prolonged flooding exacerbates this damage by weakening structures through hydrodynamic loads and sediment build-up. Buildings older than 20 years and constructed with natural materials are more susceptible to flood damage compared to newer buildings

[80] OECD, "Working Age Population (Indicator)."
[81] Vladimir M Cvetkovi, "Marital Status of Citizens and Floods: Citizen Preparedness for Response to Natural Disasters," *Vojno Delo*, no. January 2016 (2019), https://doi.org/10.5937/vojdelo1608089C.
[82] Michaela E Howells et al., "Maternal Marital Status Predicts Self-reported Stress among Pregnant Women Following Hurricane Florence," *American Journal of Human Biology* 32, no. 4 (July 27, 2020), https://doi.org/10.1002/ajhb.23427.
[83] Daniel M. Drzewiecki et al., "The Association between Educational Attainment and Resilience to Natural Hazard-Induced Disasters in the West Indies: St. Kitts & Nevis," *International Journal of Disaster Risk Reduction* 47 (August 2020): 101637, https://doi.org/10.1016/j.ijdrr.2020.101637.
[84] SAMHSA, " Disaster Technical Assistance Center Supplemental Research Bulletin Greater Impact : How Disasters Affect People of Low Socioeconomic Status," 2017, https://www.samhsa.gov/sites/default/files/dtac/srb-low-ses_2.pdf.
[85] Imon Chowdhooree and Kanu Kumar Das, "Indigenous Knowledge of Mud Architecture: Experiences of Surviving against Multiple Natural Hazards," *International Journal of Disaster Resilience in the Built Environment* 13, no. 4 (August 9, 2022): 451–69, https://doi.org/10.1108/IJDRBE-12-2020-0128.
[86] Capeetc, "Property Types in SA: Finding the Right Home," 2022.
[87] World Bank, *The Caribbean Handbook for Risk Information Management (CHARIM); EU-Funded ACP-EU Natural Disaster Risk Reduction Program* (Washington, DC: World Bank, 2014).

with updated, flood-resistant materials.[88] Nearly 50% of residents experience frequent flooding, with floodwaters remaining on their property for up to 10 hours. This prolonged exposure increases the damage to buildings, leading to structural weakening and increased groundwater pressure on foundations. The frequent flooding also exposes residents to mental health issues such as PTSD, anxiety, and suicidal tendencies. The study area's location and topography contribute to the high frequency of floods. About 52.6% of residents report occasional flood impacts, while 47.4% experience constant flooding. Floodwaters inside properties cause significant damage to building materials and internal finishes, disrupting essential services like electricity and the internet. The depth and duration of water inside properties increase the damage, often requiring evacuation and disrupting residents' social and economic lives. Frequent flooding results in substantial financial losses for 91.4% of residents, impacting their livelihoods. The damages can amount to thousands of Rands, creating setbacks and increasing vulnerability.[89] Houses made of mud and wood are particularly at risk of severe damage. Generally, the study highlights the critical need for improved flood resilience in the built environment to mitigate the extensive physical, economic, and social vulnerabilities faced by the community.

Health and Well-being

Flooding affects vital infrastructure such as telecommunication, power, roads, schools, hospitals, and waste management. This was confirmed by 96.6% of respondents. Poor infrastructure exacerbates the impact of floods, hindering access to healthcare facilities, as validated by 74.7% of respondents. 63% of respondents reported poor access to clean drinking water, leading to water-borne diseases during floods. This is due to water sources being contaminated by sewage spills, as agreed by 59% of respondents. Additionally, 52.8% of respondents noted an increase in disease outbreaks following floods. Flooding impacts the livelihood of residents negatively, as affirmed by 95.5% of respondents. The lack of flood security was highlighted by 89.6% of respondents. This study underscores the significant impact of flooding on infrastructure, health, and livelihoods, with poor infrastructure and frequent floods contributing to increased vulnerability and disease outbreaks.

Institutional and Governance Information

The Department of Cooperative Governance and Traditional Affairs (COGTA) oversees disaster management in South Africa, coordinating efforts through the national Disaster Management Center (DMC) and its subsidiaries. In the eThekwini municipality, the DMC is responsible for managing disaster activities to reduce risks effectively. Research revealed mixed reactions to government flood disaster responses: 39.8% of respondents affirmed prompt responses, while 38% disagreed. A significant 88.8% felt there were no effective flood prevention measures, and 88.3% noted a lack of community participation in flood risk mitigation. Despite 82.3% receiving early flood warnings, 58.1% were unprepared for flood events.

Concerns about flood risks were high, with 77.1% of respondents worried about the issue. Nearly 50% believed the flood response plan was weak, and 76.6% reported no incentives for flood disaster risks. Additionally, 77.6% were disappointed with the insufficient flood relief packages. The study found that residents were more concerned about flood risks when they received incentives from the municipality. However, assistance during flood disasters was minimal, with responses often delayed by several hours.

Environmental Information

Emerging research has shown that at least one in five people around the world lives in areas directly exposed to a 1 in 100-year flood risk, and approximately 89% of this population is from lower and middle-income families all over the world.[90] This section of the questionnaire determined the vulnerability of community members to floods vis-a-vis the proximity of their homes to waterbodies, and losses they may have experienced to life, property and livelihood. The research also revealed that 82% of respondents have

[88] Md. Nawrose Fatemi et al., "Physical Vulnerability and Local Responses to Flood Damage in Peri-Urban Areas of Dhaka, Bangladesh," *Sustainability* 12, no. 10 (May 12, 2020): 3957, https://doi.org/10.3390/su12103957.
[89] Ed Hill, "South Africa – Deadly Flash Floods Hit Johannesburg," FloodList.com, 2016.
[90] Thomas K. J. McDermott, "Global Exposure to Flood Risk and Poverty," *Nature Communications* 13, no. 1 (June 28, 2022): 3529, https://doi.org/10.1038/s41467-022-30725-6.

some level of vulnerability to flood disasters due to their exposure to flood risk. Exposure to floods analysed the vulnerability of community members to floods and the flood risk they are exposed to by virtue of their proximity to waterbodies. It was determined that 52.6% of respondents have their homes close to waterbodies. On further analysis, the research showed a significant relationship between the closeness of respondents' homes to waterbodies and the impact on their health. It was also revealed that while 65.1% of respondents in the study area have lost their property to floods, only 27.9% have lost family members during flood disasters. The research additionally exposed the fact that the study area has very few functional drainage systems, as attested by 67.4% of respondents. The relationship between the functionality of drainage systems in the study area and the loss of property during flood disasters was also ascertained in the study. It showed a significant association between the functionality of drainage systems and loss of property during flood disasters.

RECOMMENDATIONS

Climate change and its consequences exacerbate the risk of floods to modern societies, particularly in the eThekwini municipality, where many residents live in informal settlements on flood plains. The survey indicates poor flood risk management, with polluted floodwaters posing severe threats to lives and livelihoods. Policy design must consider flood risk alongside other community risks, especially poverty, as many informal settlement residents earn below R3,500 per month. Flood disaster policies should avoid inadvertently reducing livelihood opportunities through restrictive regulations or resettlement programs without understanding socio-economic implications.

The study advocates a risk management approach to prevent hazards from becoming disasters, focusing on reducing vulnerability. This involves identifying, assessing, and minimising risks and eliminating inappropriate risks through suitable policies and practices. Effective flood risk management requires spatial planning, early warning systems, evacuation plans, flood-sensitive land use, disaster relief preparedness, insurance, and other risk-sharing mechanisms.

Flood reduction strategies should include sustainable development policies, housing and building codes, accurate flood forecasting, flood proofing, preparedness, education, insurance, post-disaster recovery, and floodplain zoning. Maintaining flood embankments and afforestation, along with catchment management, is crucial.

The research identifies the habitation of people on "at-risk" lands as a major problem. Relocation policies are often expensive, slow, and unachievable. Therefore, flood disaster preparedness and efficient emergency response are essential. Reliable flood forecasts and hazard maps should be circulated among stakeholders for prompt decision-making. Floodplain zoning is challenging due to population pressures and unplanned developments, but comprehensive flood management plans can minimise losses. Stakeholder participation, including public involvement at all decision-making levels, is vital. The process should be open, communicative, and inclusive, considering gender perspectives and the needs of vulnerable groups like women, children, and the elderly. Indigenous knowledge should be integrated into flood management strategies.

Successful disaster management requires collaboration among individuals, families, communities, research institutions, government, and NGOs. Transparent relationships and clear rules for stakeholder participation are necessary. The political commitment to flood risk principles and practices is critical for effective resource planning and management. Policies should be supported by appropriate legislation and regulations, covering floodplain zoning, weather forecasting, disaster response, and preparedness. Long-term political commitment is essential for implementing these policies. The prevention and preparedness strategy should involve refusing building permits in high-risk areas, prohibiting rebuilding, and having effective evacuation plans. Protective measures, such as dams, storm surge barriers, and dykes are also important. Global agendas like the SFDRR (2015-2030), the 2030 SDGs, and the Paris Agreement should be strictly followed to enhance flood risk management effectiveness. These frameworks, although adopted in South Africa, need re-evaluation for effective implementation in the study area.

CONCLUSION

The findings of this research underscore the urgent need for integrated flood risk reduction strategies that address structural inequalities, enhance infrastructure resilience, and promote inclusive governance.

Strengthening community participation, improving early warning systems, and investing in durable housing and drainage networks are critical. This study contributes a comprehensive vulnerability assessment framework, offering actionable insights for policymakers and stakeholders to build urban resilience and reduce the long-term impacts of flood disasters in climate-sensitive regions.

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