

# Architectural Adaptation Strategies to Mitigate Perennial Pluvial Floods in Port Harcourt Metropolis

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Article History	Abstract
Thesis Paper	
Received: 02-02-2026	
Accepted: 28-02-2026	<i>Perennial pluvial flooding presents significant challenges to the urban environment of Port Harcourt Metropolis, impacting infrastructure, public health, and overall urban functionality.</i>
Published: 09-03-2026	<i>This research investigates architectural adaptation strategies aimed at mitigating the negative effects of recurrent flooding, focusing on the impact of perennial pluvial flooding on residential buildings in Port Harcourt Metropolis, with the intent on identifying vulnerable areas, assessing the impact of perennial pluvial flooding on building performance, and evaluating existing mitigation measures.</i>
<p>Copyright © 2026 The Author(s): This is an open-access article distributed under the terms of the Creative Commons Attribution 4.0 International License (CC BY-NC) which permits unrestricted use, distribution, and reproduction in any medium for non-commercial use provided the original author and source are credited.</p>	<i>Blue-Green Infrastructure (BGI) Theory and Resilience Theory guided the theoretical framework of this study. The methodology integrated both primary and secondary data sources. With a population of 1,416, a sample frame of 708, and a sample size of 512 determined using the Taro Yamane method, the study employed field observations, surveys, and statistical analysis, including descriptive statistics. Additionally, Geographic Information Systems (GIS) were used to identify flood-prone areas within the metropolis. The findings highlight highly vulnerable areas, such as Rumuewhara New Layout/Eneka (elevation 17.1m) and NTA/Apara Link Road (elevation 13.5m), where floodwaters can reach depths of up to 200mm. Over 90% of respondents identified streets in Obio/Akpor Local Government Area (LGA) as the most affected in the metropolis. Moderately and low-flooded areas display community-driven mitigation efforts, such as flood barriers, but government strategies are found to be lacking. The findings also revealed that flooding negatively impacts building safety, aesthetics, comfort, and durability, with 80% of respondents reporting moderate damage and 25% highlighting severe effects on structural integrity. The study recommends a comprehensive Flood Resilient Design Framework (FRDF) involving a multi-faceted approach to mitigate perennial pluvial floods in Port Harcourt Metropolis, including architectural adaptations, urban planning and policy changes, community engagement, and infrastructure development.</i>
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**A Thesis Submitted to the Department of Architecture, Rivers State University, Nkpolu-Oroworukwo, Port Harcourt in Fulfilment of the Requirements for the Award of Doctor of Philosophy (Ph.D.) Degree in Architecture of the Department of Architecture.**

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 Dr. T. D. Pepple  
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May, 2025

***DECLARATION***

I, **OKEY-EJIOWHOR, Caleb Happiness** (PG.2020/00487), hereby declare that the work in this thesis titled “Architectural Adaptation Strategies to Mitigate Perennial Pluvial Floods in Port Harcourt Metropolis” is my work, and has not been previously submitted to this, and any other university to the best of my knowledge, for the award of Doctor of Philosophy (PhD), or any other degree.

**Signature:** \_\_\_\_\_

**Date:** \_\_\_\_\_

***CERTIFICATION***

We the undersigned, certify that this work carried out by OKEY-EJIOWHOR, Caleb Happiness (PG.2020/00487), under the supervision of Dr. Tonye Dagogo Pepple and Dr Anthony Enwin in the Department of Architecture, Faculty of Environmental Sciences, Rivers State University, Nkpolu-Oroworukwo, Port Harcourt has met the partial requirement for the award of Doctor of Philosophy degree in Architecture.

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***DEDICATION***

This work is being dedicated to the Almighty God for making it a success.

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I want to first of all thank the Almighty God for his provision, direction, and grace throughout this academic journey.

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### INTRODUCTION

#### 1.1 Background of the Study

One of the most prevalent natural disasters in Nigeria is perennial flooding. Many states are increasingly experiencing annual flooding during the rainy season, and a growing body of evidence links these events to climate change. Climate change refers to the periodic modification of Earth's climate brought about by atmospheric changes and interactions with various geologic, chemical, biological, and geographic factors within the Earth system (Intergovernmental Panel on Climate Change [IPCC], 2021; Jackson, 2021).

It is becoming clear that climate change has influenced many water-related variables contributing to perennial floods, such as rainfall intensity and patterns (IPCC, 2021). While a warming world may not directly cause floods, it exacerbates factors that do. For instance, heavier precipitation events are linked to climate change. A warmer atmosphere holds more water vapor, leading to increased precipitation intensity. According to the Clausius Clapeyron equation, for every 1°C of warming, saturated air contains approximately 7% more water vapor, which may lead to higher rainfall intensity under the right conditions (Richard, Thorsten, & Deborah, 2020). Global warming has been shown to significantly increase the number of record-breaking rainfall events (Eran & Reto, 2021).

Climate change manifests through rising sea levels, desertification, crop failure, and flooding, all of which pose significant threats to humanity (United Nations Human Settlements Programme [UN-Habitat], 2020). These impacts, particularly perennial flooding, are evident in the Port Harcourt Metropolis, Rivers State.

Urban flooding in Nigeria is a growing concern, affecting approximately 20% of the population annually (Terence, Ayodele, & Samuel, 2020). Flood sources include rivers, canals, overwhelmed drainage systems, and excessive rainfall. Flooding occurs when water overflows its normal boundaries, inundating land that is usually dry (Subir, Amlan, & Priyanka, 2019). Perennial floods refer to the recurring overflow of water over dry land, often linked to climatic and environmental factors.

Recent flooding events, such as the 2010 Sokoto flood, 2011 Ibadan flood, and widespread 2012 flooding, underscore the severe environmental challenges Nigeria faces (National Emergency Management Agency [NEMA], 2021). Furthermore, the three primary types of floods are coastal (storm surge), fluvial (river), and pluvial (surface).

Coastal floods, resulting from extreme tidal conditions and storm surges, are the leading causes of flooding in low-lying coastal areas (Andrew, Samuel, & Caitlyn, 2020). Fluvial or river floods occur when excessive rainfall or snowmelt causes rivers to overflow, with severity depending on factors such as precipitation, soil saturation, and terrain (Andrew, Samuel & Caitlyn, 2020). Pluvial floods occur when intense rainfall overwhelms urban drainage systems or flows over impervious surfaces, causing water accumulation in urban areas, even those above coastal and river floodplains (Terence, Ayodele & Samuel, 2020).

Additionally, pluvial flooding accounts for 41% of flooding incidents nationwide (Terence, Ayodele & Samuel, 2020). However, understanding the types and causes of flooding provides clarity for detecting the problems associated with perennial pluvial flooding and identifying architectural adaptation strategies to mitigate its impacts.

Therefore, this study seeks to analyze the determinants of flooding in Port Harcourt Metropolis, focusing on architectural adaptation strategies to mitigate and curtail perennial pluvial flooding. Hence in systematically reviewing the challenges faced by residents, this study aimed to propose solutions for the recurring flooding issues in the metropolis of Port Harcourt.

#### 1.2 Statement of Problem

Perennial pluvial flooding in Port Harcourt Metropolis urgently requires effective, research-based solutions to mitigate damage, protect residents' health and livelihoods, and improve urban functionality.

In urban centres like Port Harcourt Metropolis, perennial pluvial flooding has become a recurring challenge, particularly during the rainy season, resulting in significant economic losses and disruption to daily life (Proverbs & Brebbia, 2016). These floods disrupt daily activities, hinder economic growth, and compromise urban functionality, highlighting the limitations of current flood management strategies and urban planning practices in addressing the specific challenges posed by pluvial flooding (Hammond et al., 2015). Rapid urbanization, inadequate drainage systems, and the absence of climate-resilient architectural designs further exacerbate the vulnerability of residents to health risks, property loss, and displacement (Akukwe & Ogbodo, 2015). This issue requires urgent attention, as it impacts not only the physical environment but also the social and economic well-being of the city's population (Formetta & Feyen, 2019). However, despite the critical nature of this problem, there has been limited focus on

incorporating architectural adaptation strategies to mitigate pluvial flooding in Port Harcourt Metropolis (Durowoju, 2019). This study seeks to identify and propose effective architectural solutions to address these challenges, contributing to a more resilient and sustainable urban environment in the metropolis.

### 1.3 Aim and Objectives of the Study

#### 1.3.1 Aim of the Study

This study aims to investigate how architectural adaptation strategies will enhance pluvial flood disaster resilience capacity in residential buildings in Port Harcourt Metropolis.

#### 1.3.2 Objectives of the Study

The objectives of the research are to:

1. Identify the areas within Port Harcourt Metropolis that are most vulnerable to perennial pluvial flooding.
2. Examine the impact of perennial pluvial flooding on the architectural quality and performance of residential buildings in Port Harcourt Metropolis, focusing on safety, functionality, aesthetics, comfort, and durability.
3. Analyze the architectural strategies currently employed to address pluvial flooding in Port Harcourt Metropolis.
4. Evaluate the effectiveness of existing architectural and urban planning strategies in mitigating the risks associated with perennial pluvial floods.
5. Propose a Flood Resilient Design Framework (FRDF) for Port Harcourt Metropolis, that integrates innovative architectural adaptation strategies, stakeholder involvement, and actionable policy recommendations to enhance urban resilience and minimize flood-related risks.

### 1.4 Research Questions

1. Which areas within Port Harcourt Metropolis are most vulnerable to perennial pluvial flooding?
2. What is the impact of perennial pluvial flooding on the architectural quality and performance of residential buildings in Port Harcourt Metropolis, considering safety, functionality, aesthetics, comfort, and durability?
3. What architectural strategies have been adopted in Port Harcourt Metropolis to address the challenges posed by pluvial flooding?
4. How effective are the existing architectural strategies in mitigating the risks of perennial pluvial flooding in Port Harcourt Metropolis?
5. What flood-resilient architectural design framework can be developed for Port Harcourt Metropolis to enhance flood mitigation and resilience?

### 1.5 Significance of the Study

This study played a crucial role in addressing the persistent problem of perennial pluvial flooding in Port Harcourt Metropolis, providing insights into how architectural adaptation strategies can enhance resilience against flood-related challenges. Port Harcourt Metropolis, a city often

affected by severe flooding during the rainy season, faces frequent disruptions to its infrastructure, economy, and the daily lives of its residents. This research focused on finding architectural solutions to mitigate the adverse effects of flooding and reduce the damage caused to buildings and public spaces. The significance of this research lay in its potential to develop practical, context-specific solutions that can improve flood resilience in Port Harcourt Metropolis.

Beyond reducing infrastructural damage, the findings of this study will have a direct impact on the safety and well-being of the residents. Perennial flooding posed serious risks to public health, property, and economic stability.

The study also holds significant implications for urban planning and policy development. However, in evaluating existing architectural strategies and proposing new solutions, the research will guide urban planners, architects, and policymakers in making informed decisions about flood risk management.

Furthermore, this study aimed to address a knowledge gap in the existing literature by focusing on architectural adaptations specific to the unique urban characteristics of Port Harcourt Metropolis. While there is considerable research on flooding in Nigeria, few studies have concentrated on architectural solutions for urban flood management. This study provides valuable data and context-specific strategies that can be applied directly to Port Harcourt Metropolis and other cities facing similar flood risks, ensuring the research's broader applicability.

Finally, while the primary focus of this study is Port Harcourt Metropolis, the findings have the potential to benefit other urban centers worldwide that face similar flood challenges due to climate change. The strategies developed in this research can serve as a model for other cities looking for effective architectural adaptations to reduce flood risk. The global relevance of this study underscores its importance in the context of growing environmental concerns and the need for resilient urban infrastructure.

### 1.6 Scope of the Study

This research focused on exploring architectural adaptation strategies to mitigate the persistent problem of recurrent pluvial flooding in Port Harcourt Metropolis, Nigeria. The primary goal was to assess how architectural practices and design solutions could reduce the risk of flooding and enhance the resilience of buildings and infrastructure within the city.

The study area encompasses Port Harcourt local government area and parts of the Obio/Akpor local government areas. Key areas included in the study are Rukpokwu, Eneka, Nkpolu, Eliowhani, Elingbu, Rumuodomaya, Rumuokoro, Rumuodara, Mgbuoba, Rumuola, Rumuogba, Umurolo, Mgbuosimini, Diobu, Old Port Harcourt township, and Abuloma.

This research deliberately narrowed its scope to pluvial flooding, a type of flooding that arises from intense rainfall exceeding the capacity of urban drainage systems, resulting in surface water accumulation and subsequent damage to properties and infrastructure. By exploring pluvial flooding in the context of Port Harcourt Metropolis, this study sought to identify effective architectural adaptation strategies to mitigate its impacts and enhance the resilience of urban communities

Findings from this research may not be universally applicable to all urban environments in Nigeria, given the differences in flood patterns, topography, infrastructure, and socio-economic contexts that exist across various regions. The unique combination of factors contributing to pluvial flooding in Port Harcourt Metropolis, such as its coastal location, high rainfall intensity, and urban development characteristics, may not be representative of other urban areas in Nigeria. Therefore, caution should be exercised when attempting to generalize the results of this study to other contexts, and further research may be necessary to adapt the findings to specific urban environments with distinct flooding profiles.

This research examined specific flood-prone areas within Port Harcourt Metropolis, identifying those most vulnerable to severe flooding during the rainy season. It assessed how perennial pluvial flooding impacts the architectural quality and performance of buildings, focusing on safety, functionality, durability, and aesthetics. Particular attention was given to residential buildings located in selected areas in the flood-affected zones.

Additionally, the study evaluated existing architectural strategies designed to address flooding. It assessed the effectiveness of these strategies, such as flood-resistant building materials and elevated structures, which had been implemented by various stakeholders in the public and private sectors.

Another critical component of this research was the development of a Flood Resilient Design Framework (FRDF). This framework will integrate architectural adaptation strategies, urban planning practices, and policy recommendations. The aim was to provide a comprehensive, adaptable approach that can be applied to Port Harcourt Metropolis and potentially other urban areas facing similar flooding challenges in Nigeria and beyond.

While the primary focus was on Port Harcourt Metropolis, the insights gained from this study could have broader applications for other Nigerian cities that experience similar flooding issues. The study focused on architectural solutions specifically for mitigating perennial pluvial flooding.

Ultimately, the scope of the study is aimed at identifying practical and sustainable architectural solutions that can help reduce the impacts of perennial pluvial flooding, contributing to the long-term resilience and sustainability of Port Harcourt Metropolis.

## 1.7 Limitations of the Study

This study, which focused on architectural adaptation strategies to mitigate perennial pluvial flooding in Port Harcourt Metropolis, had some limitations that were to be considered. Firstly, the study was limited to selected areas within Port Harcourt Metropolis. This research focused on specific urban zones in Port Harcourt Metropolis, which, while representative of areas significantly affected by pluvial flooding, may not capture the full complexity and variability of flooding dynamics in other parts of Rivers State or different urban environments in Nigeria. Consequently, the study's findings might have limited generalizability to other contexts, where factors such as topography, infrastructure, and socio-economic conditions may differ. This limitation underscores the need for caution when applying the research outcomes to other urban areas, and highlights the potential for future studies to explore flooding dynamics in diverse contexts.

Furthermore, it was difficult to fully engage all relevant stakeholders such as residents, urban planners, and policymakers in the research process. Stakeholder engagement was critical for gaining insights into the current situation and proposed solutions, but logistical issues and limited willingness to participate affected the breadth of perspectives incorporated into the study. This, in turn, influenced the development of the Flood Resilient Design Framework (FRDF), which will not fully reflect the diversity of opinions or needs of all stakeholders.

Finally, the study faced financial and resource constraints that limited the scale of interventions assessed and the practicality of implementing all proposed strategies, particularly on a large scale.

## 1.8 Study Area

The study area, depicted in figure 1.1, is situated in Rivers State, Nigeria, and encompasses various towns across Port Harcourt city and Obio/Akpor local government areas. The Port Harcourt Metropolis originally include the local government areas of Port Harcourt City, Obio/Akpor, and Eleme. The study area comprised numerous towns, such as Rukpokwu, Eneka, Nkpolu, Eliowhani, Elingbu, Rumuodomaya, Rumuokoro, Rumuodara, Mgbuoba, Rumuola, Rumuogba, Umurolu, Mgbuosimini, Diobu, Old Port Harcourt township, and Abuloma, which are grouped into 13 zones: Rumukwurushi, Rumuodara, Elekahia, Eligbolo, Bori Camp, Bodo, Orogbum, Golf Course, Mgbuoba, Rumuepirikom, Mgbuosimini, Amatagwolo, and Town (Akukwe, Okpala-Okaka & Ojeh, 2015).

### 1.8.1 Geography of the Study Area

The study area is situated in Rivers State, Nigeria, within the Niger Delta region, between Latitude 4°45'N and Latitude 4°55'N, and Longitude 6°55'E and Longitude 7°05'E.

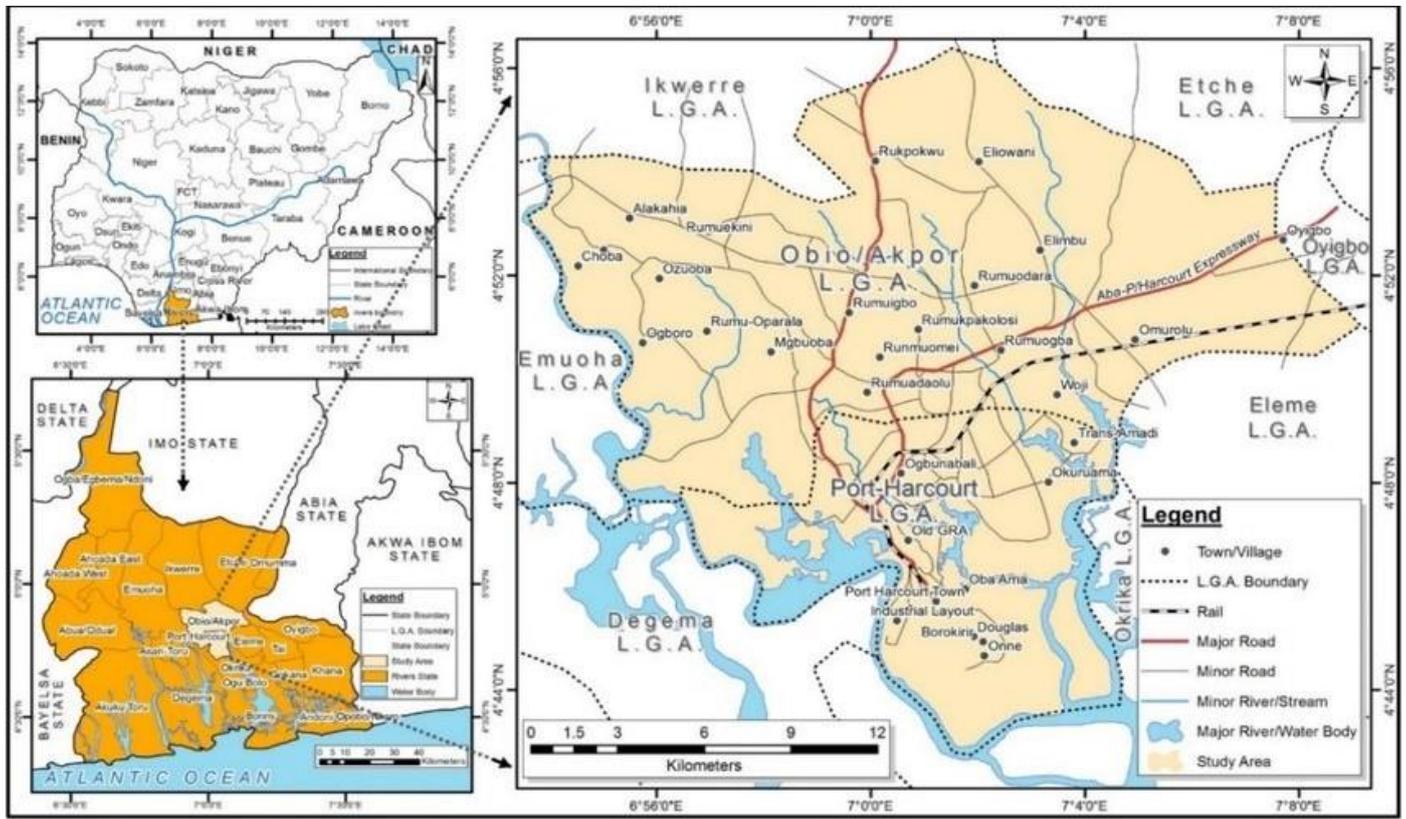


Figure 1.1: Port Harcourt Metropolis; Obio/Akpor and Port Harcourt City LGAs  
(Source: Ogbozige et al, 2020)

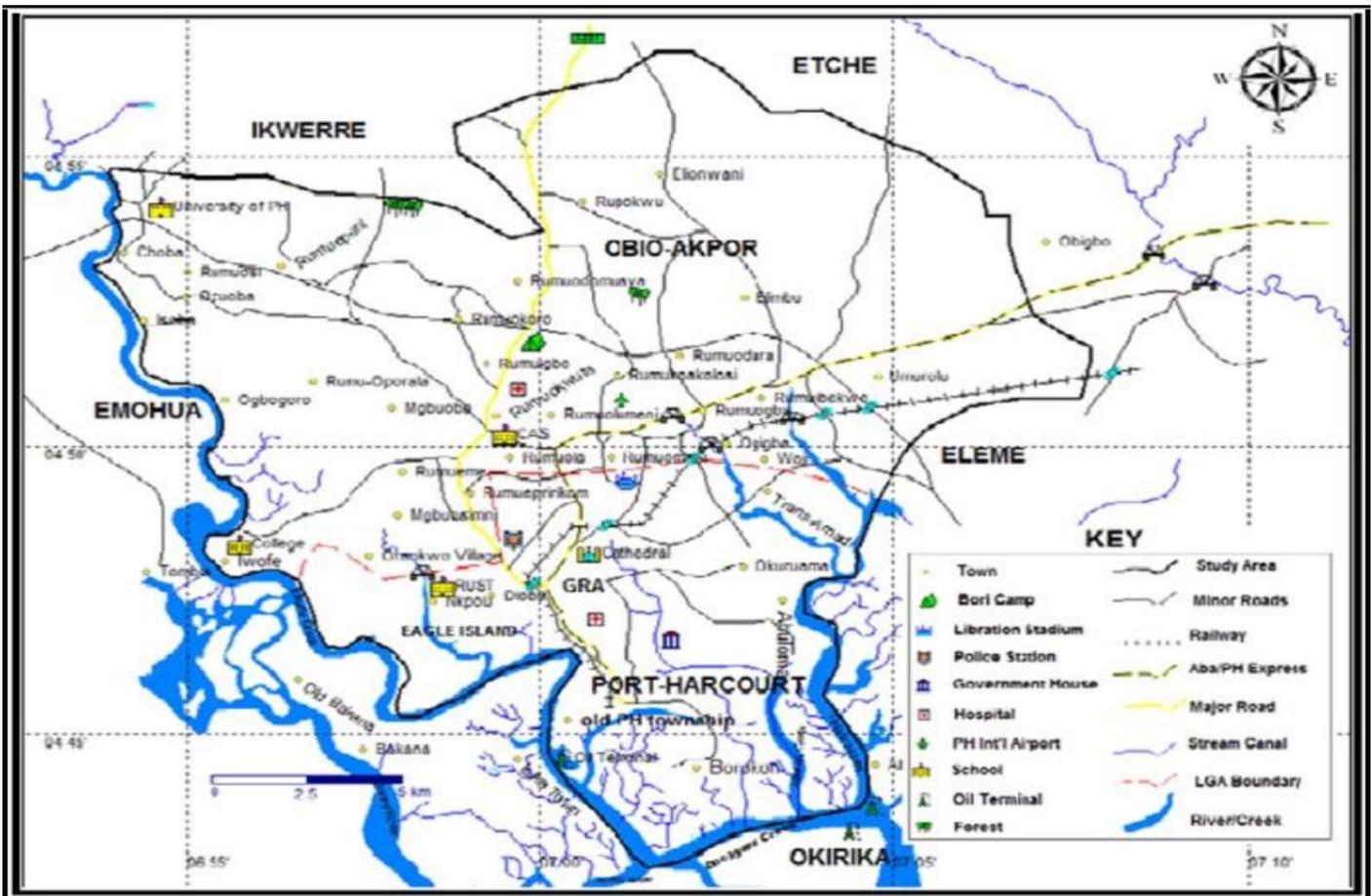


Figure 1.2: Map of Port Harcourt metropolis; Obio/Akpor and Port Harcourt LGAs  
(Source: Effiong et al, 2022)

Port Harcourt Metropolis, located at the mouth of the Bonny River and approximately 25 km from the Atlantic Ocean, plays a significant role in the urbanization process in the Niger Delta region of Nigeria. It lies within two local government areas Port Harcourt and Obio/Akpor covering a total area of 664 km<sup>2</sup>, which includes cosmopolitan areas that contribute to the city's urban sprawl. The city is strategically positioned, making it easily accessible through land, air, and sea transport, which has greatly influenced its development. As an urban hub, Port Harcourt serves as a major center for industrial activity, including oil and gas exploration, with an increasingly diverse population drawn from various parts of Nigeria. The 2006 census recorded a population of 1,017,461, and this number has grown exponentially, with estimates suggesting a population of over 2.6 million by 2024 (Ogba & Okon, 2012; Paulinus, Agba & Ekanem, 2015; Udo & Orji, 2023).

The city's population density and rapid urban expansion have been driven by economic opportunities in the industrial, commercial, and service sectors, especially in the wake of the oil boom in the 1970s. As a result, Port Harcourt faces challenges related to urban planning, housing, environmental sustainability, and infrastructure development. Given its significance as a port city and its proximity to major oil reserves, urban planners and policymakers have had to adapt strategies to accommodate a growing population and ensure that developmental policies address the environmental and social impacts of rapid urbanization.

### **1.8.2 Climate and Weather Patterns**

Port Harcourt's climate is classified as Af in the Köppen system, which means it experiences tropical rainforests with year-round warmth and significant moisture. The city's climate features two major seasons: the rainy season and the dry season. According to Adebayo and Oladipo (2021), characterized by stable temperatures ranging from 26°C to 28°C throughout the year. Although temperatures rarely fluctuate, they can drop to 18°C or rise to 37°C in extreme cases. The city experiences significant rainfall, with an annual average of 2815 mm and approximately 295 rainy days per year. Port Harcourt receives ample sunshine, with an average of 3162 hours annually, and daylight hours vary from 11 hours 50 minutes to 12 hours 22 minutes daily.

### **1.8.3 Temperature and Seasonal Trends**

Port Harcourt's warmest period spans from February to April, with average daily temperatures consistently ranging between 28°C and 28°C. During these months, daytime temperatures typically peak around 32°C, while nighttime temperatures remain relatively warm, rarely dipping below 24°C. In contrast, the coolest temperatures in Port Harcourt

are usually recorded between July and September. Although still relatively warm, average daily temperatures during this period range from 26°C to 26°C. Notably, even during these cooler months, daytime temperatures often reach 29°C, while nighttime temperatures rarely drop below 22°C. Overall, Port Harcourt's tropical climate is characterized by high temperatures throughout the year. On average, the city experiences 329 days with temperatures above 25°C, indicating a predominantly warm and humid environment. Conversely, temperatures never drop below 0°C, reflecting the city's proximity to the equator (Copernicus Climate Change Service, 2022). This constant high humidity has implications for public health, as it supports the spread of waterborne diseases and vector-borne diseases like malaria (Eze, 2022).

### **1.8.4 Rainfall and Precipitation**

Port Harcourt experiences its wettest period during the months of June, July, and September. These months are characterized by significant rainfall, with an average of 29 rainy days and 365 mm (14.4 inches) of precipitation per month. This prolonged rainfall is a hallmark of the city's tropical monsoon climate, bringing much-needed moisture to the region. In contrast, the city's driest months occur from January to February and again in December. During these periods, Port Harcourt receives substantially less rainfall, with an average of only 55 mm (2.2 inches) of precipitation per month. These relatively dry months offer a brief respite from the region's otherwise high levels of rainfall, making them ideal for outdoor activities and travel.

### **1.8.5 Cloud Cover and Sky Conditions**

Port Harcourt experiences significant seasonal variations in cloud cover, which influences its overall climate. From November to March, the city experiences relatively clear skies, particularly in December, which is the clearest month. However, cloud cover increases significantly during the rainy season, with April being the cloudiest month of the year. During this period, the skies are often overcast, which limits sunshine and can affect the city's solar energy potential (Eze, 2022). This extended cloud cover also affects the quality of air and visibility, particularly in areas with high traffic or industrial emissions.

### **1.8.6 Monthly Sunshine Hours**

Port Harcourt experiences its sunniest period during the months of March, April, and December. Throughout these months, the city enjoys an abundance of sunshine, with an average of 9 hours and 19 minutes of direct sunlight per day. This prolonged sunlight makes these months ideal for outdoor activities, such as exploring the city's parks and gardens or taking a stroll along the riverside. In contrast, the city's least sunny months occur from June to September. During this period, Port Harcourt receives significantly less

sunlight, with an average of only 8 hours and 7 minutes of direct sunshine per day. Although still relatively sunny compared to many other cities, these months mark the beginning of the wettest season in Port Harcourt, with increased cloud cover and rainfall.

### 1.8.7 Wind and Air Movement

Wind speeds in Port Harcourt exhibit mild seasonal variation. The windiest months occur from June to October, with August being the peak of wind activity. These winds

are typically gentle, with sustained speeds that have minimal impact on daily life. The dry season, which lasts from November to March, is characterized by relatively calm winds, particularly in December when wind speeds are at their lowest (Weatherspark.com, 2016). While wind patterns play a role in dispersing air pollutants in Port Harcourt, the city's heavy industrial activity, including the refining of oil and gas, often results in air pollution, contributing to health issues like respiratory diseases.

**Table 1.1: Monthly Average Temperatures in Port Harcourt**

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
<b>Maximum</b>	36°C (97°F)	37°C (99°F)	35°C (95°F)	34°C (93°F)	34°C (93°F)	32°C (91°F)	31°C (88°F)	31°C (88°F)	32°C (89°F)	32°C (90°F)	33°C (92°F)	34°C (94°F)
<b>Mean maximum</b>	34°C (94°F)	35°C (96°F)	34°C (93°F)	33°C (92°F)	33°C (92°F)	32°C (89°F)	30°C (87°F)	31°C (87°F)	31°C (88°F)	32°C (90°F)	32°C (91°F)	33°C (93°F)
<b>Average high</b>	33°C (91°F)	33°C (92°F)	32°C (90°F)	31°C (89°F)	31°C (87°F)	29°C (85°F)	28°C (83°F)	28°C (83°F)	29°C (84°F)	30°C (86°F)	30°C (87°F)	32°C (90°F)
<b>Daily mean</b>	27°C (82°F)	28°C (83°F)	28°C (83°F)	28°C (82°F)	27°C (81°F)	26°C (80°F)	26°C (78°F)	26°C (78°F)	26°C (79°F)	26°C (79°F)	27°C (81°F)	27°C (81°F)
<b>Average low</b>	24°C (75°F)	25°C (77°F)	25°C (78°F)	25°C (77°F)	25°C (77°F)	24°C (76°F)	24°C (75°F)	24°C (75°F)	24°C (75°F)	24°C (75°F)	24°C (76°F)	24°C (75°F)
<b>Mean minimum</b>	21°C (70°F)	22°C (73°F)	24°C (75°F)	24°C (75°F)	24°C (75°F)	23°C (74°F)	23°C (73°F)	23°C (73°F)	23°C (73°F)	23°C (74°F)	23°C (74°F)	22°C (71°F)
<b>Minimum</b>	18°C (65°F)	21°C (70°F)	23°C (74°F)	23°C (74°F)	23°C (74°F)	22°C (73°F)	22°C (73°F)	22°C (72°F)	23°C (73°F)	23°C (74°F)	23°C (73°F)	21°C (70°F)

Monthly average temperatures with daily means, minimums and maximums for period, average high and low temperatures in Port Harcourt, Nigeria. Generated using Copernicus Climate Change Service information. Data for period from January 2017 to June 2022.

*Nomadseason.com (2022)*

**Table 1.2: Monthly Average Precipitation in Port Harcourt**

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
<b>Average precipitation mm (inches)</b>	43 (1.7)	69 (2.7)	186 (7.3)	241 (9.5)	284 (11.2)	362 (14.2)	360 (14.2)	302 (11.9)	374 (14.7)	343 (13.5)	199 (7.8)	52 (2.1)
<b>Average precipitation days (≥ 1 mm)</b>	12	14	27	25	28	28	29	28	30	30	28	16

Monthly average precipitation and precipitation days in Port Harcourt, Nigeria. Generated using Copernicus Climate Change Service information. Data for period from January 2017 to January 2022.

*Nomadseason.com (2022)*

**Table 1.3: Monthly Sunshine Hours in Port Harcourt**

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
<b>Mean monthly sunshine hours</b>	250	267	275	273	266	249	248	258	240	252	271	308
<b>Mean daily daylight hours</b>	11h 52m	11h 57m	12h 4m	12h 12m	12h 19m	12h 22m	12h 21m	12h 15m	12h 7m	11h 59m	11h 53m	11h 50m

Mean monthly sunshine duration, average sunshine hours per day and mean daily daylight hours in Port Harcourt, Nigeria. Generated using Copernicus Atmosphere Monitoring Service information. Data for period from January 2017 to January 2022.

*Nomadseason.com (2022)*

### 1.8.8 Implications for Urban Development

The climate and weather patterns in Port Harcourt are important factors for urban development, particularly regarding infrastructure and public health planning. The city's frequent rainfall requires well-maintained drainage systems to prevent flooding, and its high humidity levels demand adequate housing and sanitation systems to mitigate the spread of diseases. Furthermore, the tropical climate with high temperatures and humidity levels presents challenges in terms of energy consumption, particularly air conditioning, and water management for residents and industries. Urban planners need to consider these climatic factors when designing sustainable urban spaces that accommodate the city's growing population while minimizing environmental impacts.

Urban planning also needs to incorporate the effects of seasonal weather on the city's economy. For instance, the agricultural sector benefits from consistent rainfall, but heavy rains in the rainy season can damage crops, especially in low-lying areas, resulting in loss of revenue. Meanwhile, the oil and gas industry in Port Harcourt has to account for weather disruptions that may delay projects or impact production during the rainy season (Paulinus, Agba & Ekanem, 2015).

### 1.9 Definition of Terms

**Architectural Adaptation Strategies:** These refer to design and construction approaches employed to modify buildings and infrastructure to withstand or mitigate environmental challenges (Schnädelbach, 2010). In the context of this study, these strategies involve architectural techniques, materials, and designs aimed at reducing the impact of pluvial floods in urban areas.

**Perennial Pluvial Floods:** This term describes recurring flooding caused by heavy and prolonged rainfall, leading to water accumulation in areas with inadequate drainage systems. Unlike riverine or coastal flooding, pluvial floods occur independently of water bodies and are common in urban areas with poor water runoff management (Prokić et al., 2019).

**Flood Mitigation:** This encompasses the measures and practices designed to prevent or reduce the adverse impacts of flooding. Flood mitigation strategies may include infrastructure improvements, drainage system enhancements, and the adoption of resilient building designs (Sandink & Binns, 2021).

### 1.10 Structure of the Thesis

This thesis was organized into six chapters, each focused on specific aspects of the research. Chapter 1 introduced the study. It covered the background of the research, the statement of the problem, the research aim, objectives, and questions. It also included the justification for the study, limitations, delimitations, scope, study area, definitions of key terms, and the thesis structure.

Chapter 2 provided a detailed review of existing literature written by various authors on the subject. This chapter placed the study in context, highlighting what was already known and identifying gaps that the research aimed to address.

Chapter 3 explained the methodology and techniques used in the study. It described the philosophical framework, research paradigms, design, and the reasoning behind the choice of research instruments. It also detailed the methods of data collection, analysis, and measures taken to ensure the accuracy and reliability of the findings.

Chapter 4 presented the analysis and interpretation of the data. It provided an organized account of the responses and insights from participants, focusing on how the findings related to the research questions.

Chapter 5 discussed the findings in relation to the research objectives. It examined their significance, connected them to existing knowledge, and explored their implications for understanding the research problem.

Chapter 6 concluded the study by summarizing the key findings, drawing conclusions, and providing recommendations. This chapter also reflected on the study's limitations and contributions to knowledge while offering suggestions for future research.

LITERATURE REVIEW

In the literature review, this section explores prior research and academic contributions related to the topic. It helps identify gaps in the existing body of knowledge, highlight areas that need further investigation, and positions the current study within the broader academic context.

2.1 Theoretical Framework

Theoretical models provide a conceptual basis for understanding complex phenomena and guiding research investigations. In the context of mitigating perennial pluvial flooding and enhancing urban resilience, two key theories were used to provide significant insights into the architectural adaptation strategies to mitigate perennial pluvial floods in Port Harcourt Metropolis. These theories include: Blue-Green Infrastructure (BGI) Theory, conceptualized in sustainable urban design practices and advanced by scholars like Ahern (2013), and Resilience Theory, introduced by Holling (1973).

These theories provide a robust foundation for developing architectural adaptation strategies and informing urban planning policies. They not only address the technical aspects of managing urban flooding but also emphasize the importance of ecosystem-based approaches and systemic adaptability. In Port Harcourt Metropolis, where rapid urbanization has exacerbated flooding risks, the integration of these theories is critical to creating sustainable, resilient urban environments.

The following sections provide an in-depth examination of these theories, emphasizing their principles, relevance, and application to the study area.

2.1.1 Blue-Green Infrastructure Theory

Blue-Green Infrastructure (BGI) Theory advocates for the integration of water management (blue) and vegetative systems (green) to address urban stormwater challenges. It

encompasses a range of sustainable urban drainage approaches, including green roofs, rain gardens, bioswales, permeable pavements, retention ponds, and wetlands. These features not only manage stormwater but also deliver ecosystem services like flood mitigation, water purification, and habitat creation (Ahern, 2013; Lennon, 2015).

Ahern (2013) emphasizes the multifunctionality of BGI, highlighting its capacity to simultaneously address flooding, enhance biodiversity, and improve urban aesthetics. This is particularly relevant to Port Harcourt, where urbanization has led to the loss of permeable surfaces, exacerbating pluvial flooding. The application of BGI features in architectural designs, such as incorporating green roofs or permeable pavements, can significantly reduce surface runoff and enhance flood management.

Further, the treatment train approach, as detailed by Qin, Li & Chen. (2013) and Liu, Li, & Qin, (2014), demonstrates how combining multiple BGI measures can amplify their effectiveness in mitigating flood risks. For instance, rain gardens and bioswales can slow and filter runoff before it enters larger retention systems, ensuring comprehensive stormwater management.

The European Commission (2021) defines green infrastructure as “a strategically planned network of natural and semi-natural areas designed to deliver a wide range of ecosystem services.” The U.S. Environmental Protection Agency (EPA, 2022) underscores its cost-effectiveness, stating that green infrastructure is “a resilient approach to managing wet weather impacts that provides numerous community benefits.” These perspectives validate BGI’s applicability in Port Harcourt, where effective stormwater management strategies are urgently needed to address recurring floods.

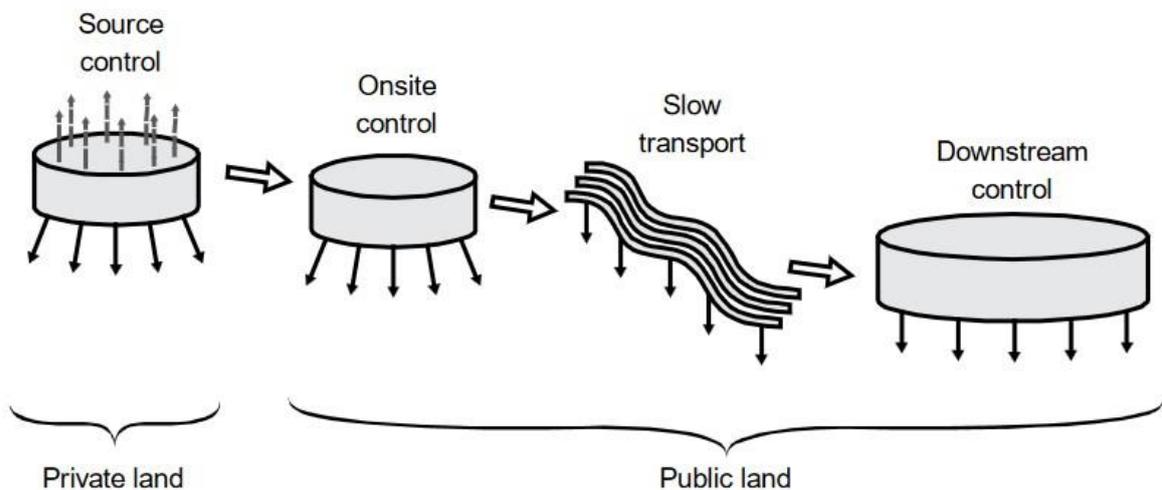


Figure 2.1: Key Elements of Blue-Green Infrastructure for Stormwater Management

Source: Czyża & Kowalczyk, (2024)

Additionally, in addressing the challenges of stormwater management and adapting to climate change, Blue-Green Infrastructure (BGI) is gaining significant attention. This system combines natural and engineered elements such as green spaces (e.g., parks, forests) and water elements (e.g., ponds, wetlands) to mitigate the adverse effects of urbanization. In particular, BGI serves as an effective adaptation strategy by managing extreme weather events like floods, reducing urban heat, and enhancing biodiversity (Keesstra, van Beek & de Leeuw, 2018; Tzoulas, Korpela & Venn, 2020).

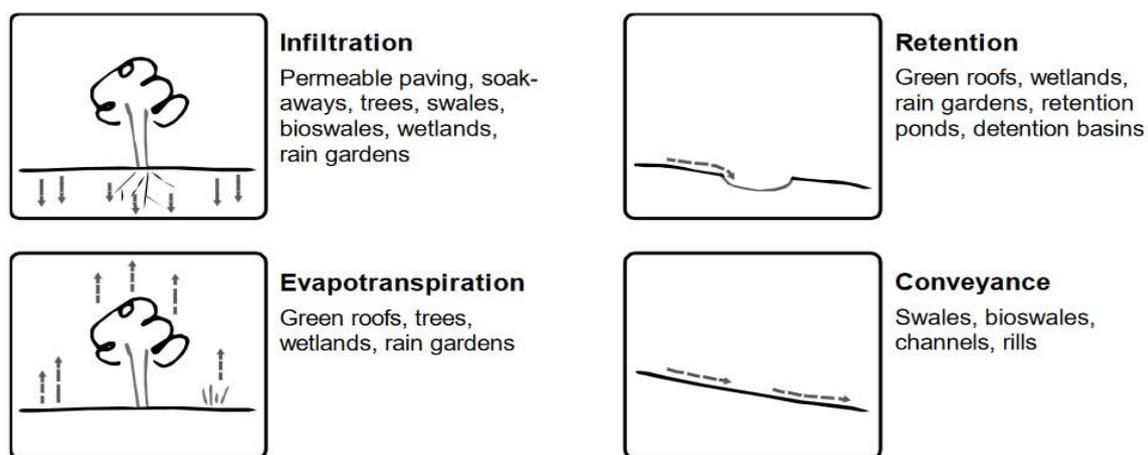
The integration of blue and green infrastructure provides various ecosystem services, including cooling through evapotranspiration, water storage, peak discharge attenuation, and groundwater recharge (Kabisch, Qureshi & Haase, 2017). Moreover, when combined with grey infrastructure (traditional, hard-engineered solutions like sewer systems), BGI contributes to a more resilient urban environment that is better equipped to handle the challenges posed by climate change (Fletcher, Shuster & Hunt, 2015; Vardoulakis, Dimitriou & Carson, 2019).

Studies highlight the importance of green infrastructure in mitigating the Urban Heat Island (UHI) effect, particularly

in cities where reduced vegetation and water bodies intensify heat waves and high temperatures. A study by Lee, Lyu & Jang, (2020) confirms that urban areas with integrated green infrastructure, including parks, green roofs, and permeable surfaces, show a significant reduction in surface temperatures. Similarly, Nouri, Goh & Mohammed, (2021) further emphasize that these green interventions can effectively lower urban temperatures, improving climate resilience and public health. Urbanization-related challenges, such as increased heatwaves, can be mitigated through such ecological solutions, as evidenced by various city-based case studies (Lee, Lyu & Jang, 2020; Nouri, Goh & Mohammed, 2021).

These systems not only help in temperature regulation but also in managing stormwater runoff and reducing flood risks, which are crucial as urbanization and climate change increase the frequency and intensity of such events (Rahman, Haque & Islam, 2019; Lanza, Preti & Lupo, 2020).

Thus, in incorporating BGI into urban planning and development, cities (Port Harcourt) can reduce the impacts of climate change while improving the quality of life for their inhabitants (Mitchell, 2018).



**Figure 2.2: Hydrological Processes in Blue-Green Infrastructure for Urban Flood Mitigation**

*Source: (Sørensen, 2018)*

### 2.1.2 Resilience Theory

Resilience Theory, introduced by Holling (1973), explores the capacity of systems to absorb disturbances and reorganize while undergoing change to retain essential functions. This theory has evolved to include urban resilience, particularly in the context of climate change and natural hazards (Meerow & Newell, 2019).

In urban flooding scenarios, resilience involves three critical dimensions: resistance, recovery, and transformation. Resistance focuses on minimizing flood impacts through proactive measures like flood-proof architectural designs. Recovery emphasizes quick

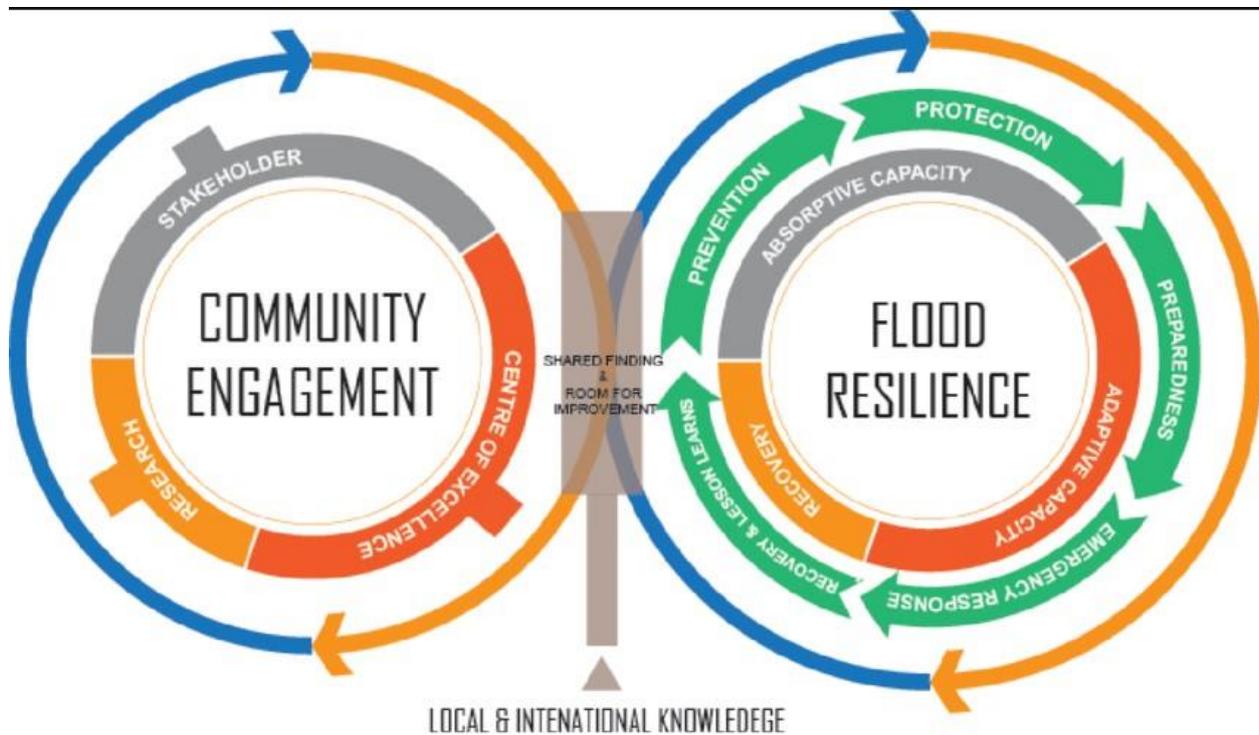
restoration of functionality after flood events, while transformation involves long-term adaptability to changing climatic conditions.

Holling’s foundational work highlights the adaptive capacity of systems, a principle crucial for designing buildings and urban spaces that can withstand and recover from flooding. Meerow and Newell (2019) extend this by defining urban resilience as “the capacity of urban systems to survive, adapt, and thrive despite chronic stresses and acute shocks.”

In Port Harcourt, resilience-thinking can inform architectural strategies such as elevated foundations,

modular designs, and adaptive building materials that resist water damage. Dong, Yang & Li, (2022) note that resilient urban planning integrates local knowledge, community participation, and innovative designs to create flood-resistant cities. For example, incorporating flexible drainage systems and multi-functional spaces can enhance a city's ability to manage flooding while maintaining its socio-economic vitality.

Zhang, Wu & Wang, (2023) provide a case study of urban resilience in flood-prone regions, emphasizing the integration of nature-based solutions and community-driven approaches. These insights are particularly relevant to Port Harcourt, where engaging local communities in flood mitigation strategies can enhance their effectiveness and sustainability.



**Figure 2.3** Relationship between Flood Resilience and Community Engagement.

(Source: Roslan, Jamaludin & Mohamad, 2015).

## 2.2 Conceptual Framework

The conceptual framework for Architectural Adaptation Strategies to Mitigate Perennial Pluvial Floods in Port Harcourt Metropolis brings together diverse concepts and methodologies designed to address the persistent challenges posed by urban flooding. The framework considers how urban architecture and urban planning can adapt to reduce flood risks, promote resilience, and ensure sustainability in the face of changing climate conditions.

### 2.2.1 Floods: Definition and Types

Oxford Dictionary defines a flood as an overflow of a large amount of water beyond its normal limits, especially over what is normally dry land. A flood is the accumulation of too much water which rises to overflow land that is not normally submerged (Mukhopadhyay, 2010). Flooding can comprise overflow of a river as a result of prolonged seasonal rainfall, rainstorms, snowmelt, dam-breaks, accumulation of rainwater in low-lying areas with a high water table, or inadequate storm drainage. Floods could also be caused by the intrusion of seawater onto coastlands

during cyclonic/tidal surges (Handmer, Penning-RowSELL, and Tapsell, 1999; Stoltman, Lidstone, and DeChano, 2004). Floods have been noted to cause about one-third of all deaths, one-third of all injuries, and one-third of all damage from natural disasters (Askew, 1999).

Flooding in various parts of Nigeria has forced thousands of people away from their homes, destroyed businesses, polluted water resources, and increased the risk of diseases (Jeb and Aggarwal, 2008; Etuonovbe, 2011; Olorunfemi, 2011). The occurrence of floods in Nigeria is not a recent phenomenon (Ayoade, 1979; Ayoade and Akintola, 1980; Olaniran, 1983; Ologunorisa and Terso, 2006; Adeloye and Rustum, 2011). The recent occurrences of flooding in Nigeria such as the Sokoto flood in 2010, the Ibadan flood in 2011, the Lagos flood in 2011, most parts of the country in 2012, and the recent flooding of 27 states in 2022, have shown that flooding is one of the major environmental problems faced in Nigeria. Widespread flooding killed more than 500 people in Nigeria in 2022, left around 90,000 homes underwater, and blocked food and fuel supplies. The floods have hit 27 of Nigeria's 36 states and impacted

around 1.4 million people (NEMA). Nigerian authorities said flooding caused by heavier-than-usual rains had been building and intensified after water releases from the Lagdo dam in neighbouring Cameroon.

To plan for floods, one has to understand the type or types of floods that might be encountered. Each one has a different impact in terms of its duration, how it occurs, how it is forecast, the damage it causes, and the type of protection needed.

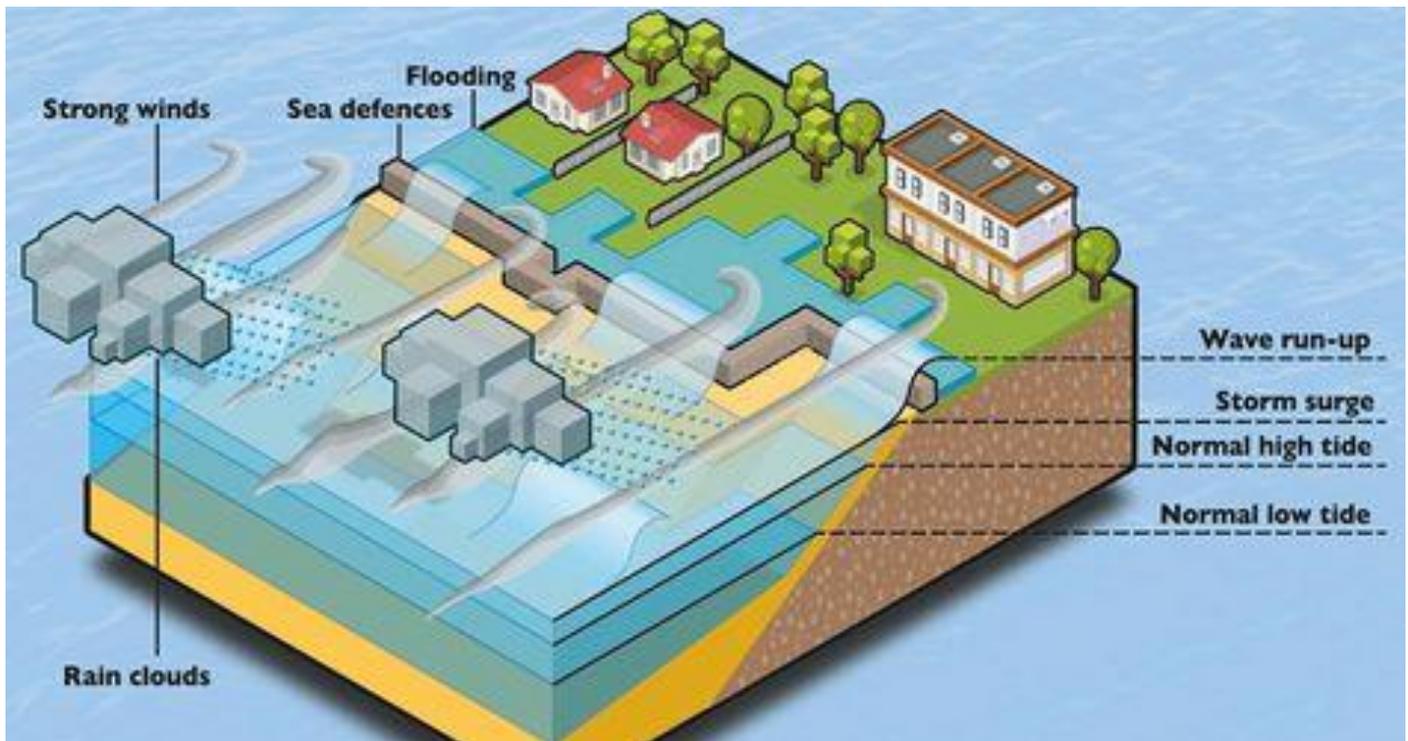
### 2.2.1.1 Coastal (Surge) Floods

A coastal flood, as the name suggests, occurs in areas that lie on the coast of a sea, ocean, or other large body of open water. It is typically the result of extreme tidal conditions caused by severe weather. Storm surge — produced when high winds from hurricanes and other storms push water onshore — is the leading cause of coastal flooding and often the greatest threat associated with a tropical storm. In this type of flood, water overwhelms low-lying land and often causes devastating loss of life and property. (Maddox, 2021)

Coastal flooding is categorized into three levels:

1. Minor: A slight amount of beach erosion will occur but no major damage is expected.
2. Moderate: A fair amount of beach erosion will occur as well as damage to some homes and businesses.
3. Major: Serious threat to life and property. Large-scale beach erosion will occur, numerous roads will be flooded, and many structures will be damaged. Citizens should review safety precautions and prepare to evacuate if necessary.

The severity of a coastal flood is determined by several factors, including the strength, size, speed, and direction of the storm. The onshore and offshore topography also plays an important role. To determine the probability and magnitude of a storm surge, coastal flood models consider this information in addition to data from historical storms that have affected the area, as well as the density of nearby development.



**Figure 2.4 Coastal Flood Diagram.**

*Source: Gilliland, (2017).*

### 2.2.1.2 Fluvial (River) Floods

Fluvial, or riverine flooding, occurs when excessive rainfall over an extended period causes a river to exceed its capacity. It can also be caused by heavy snow melt and ice jams. The damage from a river flood can be widespread as the overflow affects smaller rivers downstream, often causing dams and dikes to break and swamp nearby areas. (Maddox, 2021)

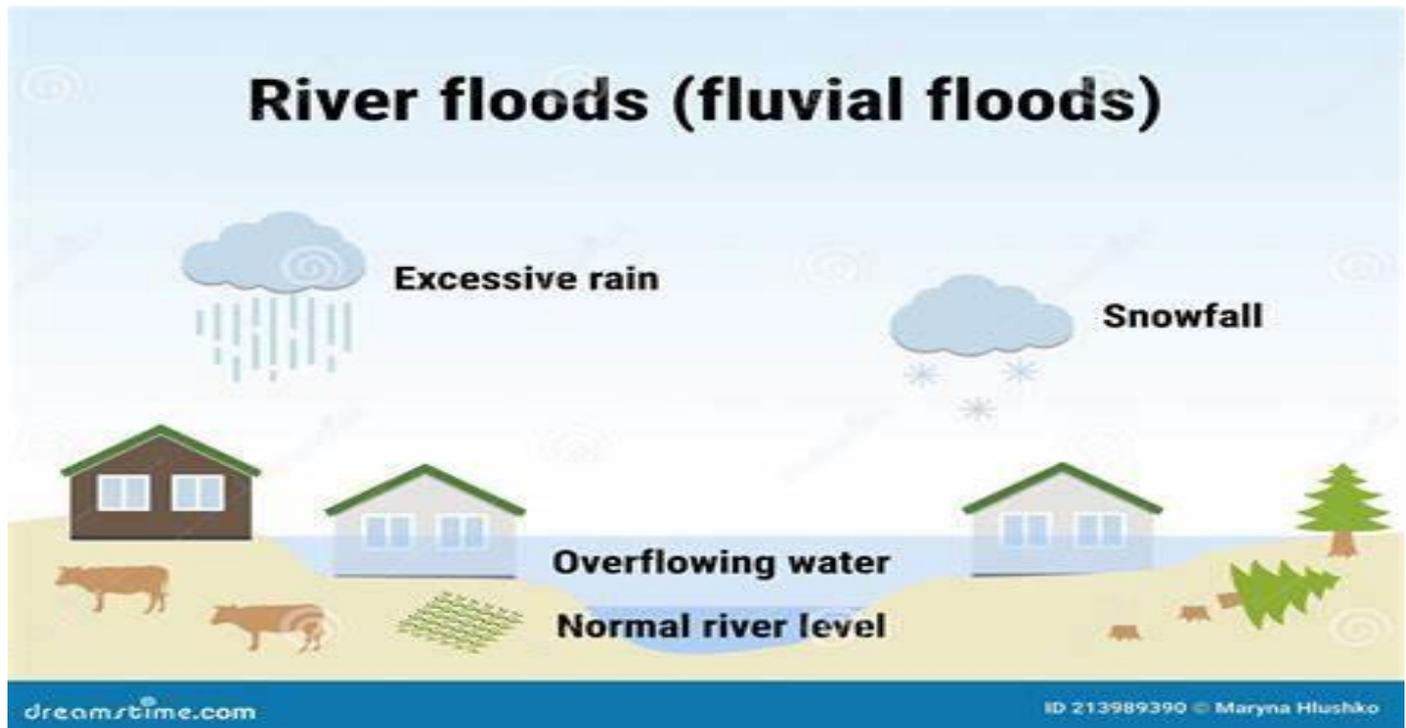
There are two main types of riverine flooding:

1. Overbank flooding occurs when the water rises and overflows over the edges of a river or stream. This is the most common and can occur in any size channel — from small streams to huge rivers.
2. Flash flooding is characterized by an intense, high-velocity torrent of water that occurs in an existing river channel with little to no notice. Flash floods

are very dangerous and destructive not only because of the force of the water but also the hurtling debris that is often swept up in the flow.

The severity of a river flood is determined by the amount of precipitation in an area, how long it takes for precipitation to accumulate, the previous saturation of local soils, and the

terrain surrounding the river system. In flatter areas, floodwater tends to rise more slowly and be more shallow, and it often remains for days. In hilly or mountainous areas, floods can occur within minutes after heavy rain. To determine the probability of river flooding, models consider past precipitation, forecasted precipitation, current river levels, and temperatures.



**Figure 2.5** *Depiction of River Floods (Fluvial Floods).*

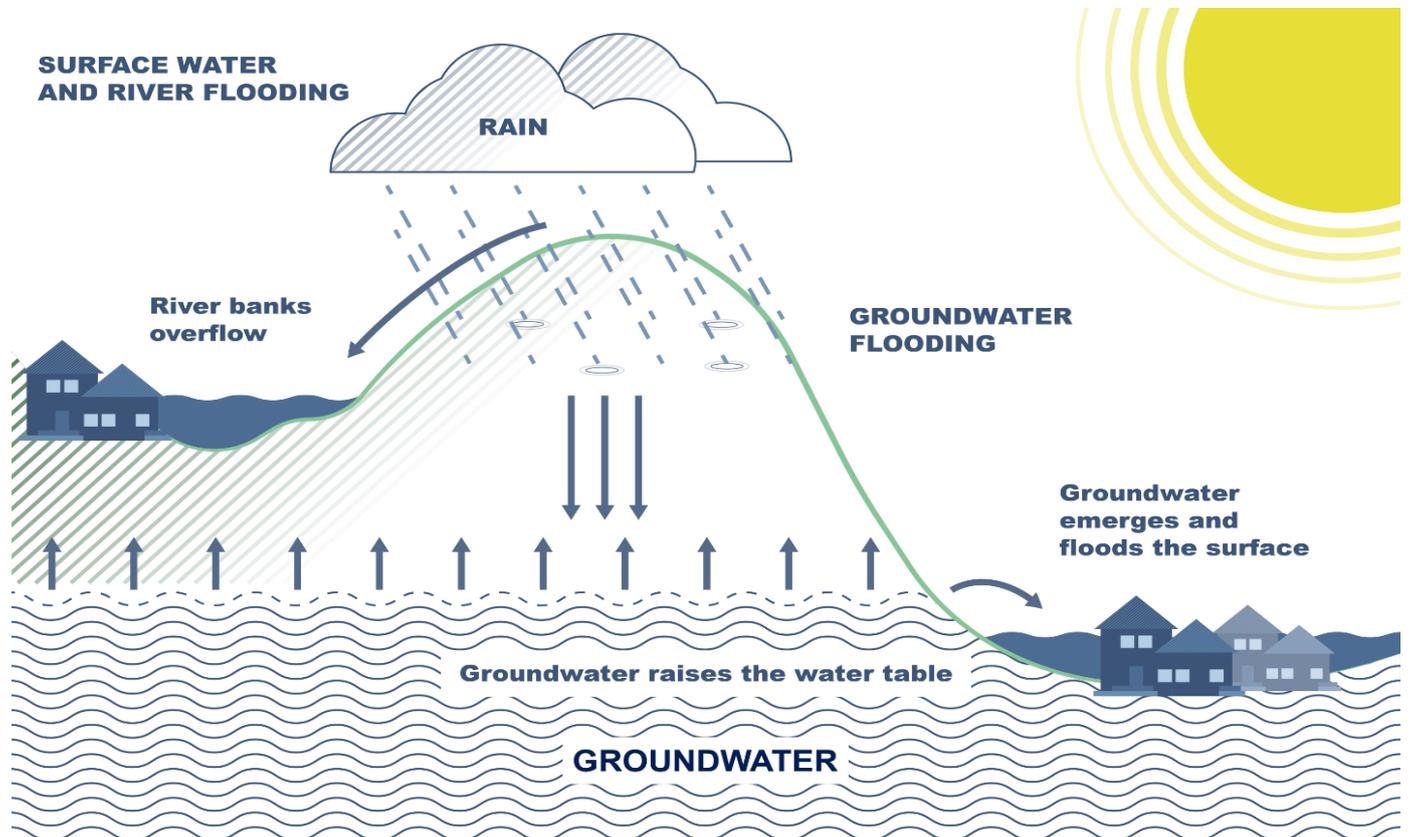
*Source: Maryna Hlushko, (2021).*

### 2.2.1.3 Groundwater Floods

Groundwater flooding is a lesser-known type of flooding. It is the emergence of groundwater at the ground surface away from perennial river channels and can also include the rising of groundwater into man-made ground, including basements and other subsurface infrastructure. (Macdonald et al., 2012) Flooding from groundwater can happen when the level of water within the rock or soil underground – known as the water table – rises. When the water table rises and reaches ground level, water starts to seep through to the surface and flooding can happen. This means that water may rise up through floors or underground rooms such as cellars or basements. Water doesn't always appear where you would expect it to - such as valley bottoms – it may also emerge on hillsides (*What Is Groundwater Flooding?*, 2019). Groundwater flooding takes much longer to develop than river flooding, often appearing days, weeks, or even months after heavy or prolonged rainfall. This type of flooding can persist for weeks or even months. It is most common in areas with chalk bedrock

but can also occur in places with sand and gravel, like river valleys.

To understand groundwater and basement floods, one needs to first understand groundwater. An estimated 40km<sup>3</sup> of water runs across the surface of the earth per year, some of it gets collected in surface reservoirs like rivers and streams that flow back into the ocean while the rest seeps into the ground to recharge groundwater systems or aquifers. There is about 35 times as much water that seeps into the groundwater systems than there is in surface reservoirs. With the increase in frequency and duration of rainfall due to climate change, groundwater aquifers increase in size by absorbing more water. With increased groundwater comes higher groundwater table or artesian conditions. If the groundwater table exists behind a basement wall, then the wall will be subject to hydrostatic pressure which can force large quantities of water through wall cracks or joints and lead to basement flooding (Brisibe et al., 2021).



**Figure 2.6** Depiction of Groundwater Floods.

*Source: projectgroundwater.co.uk, (2023).*

#### 2.2.1.4 Pluvial (Surface) Floods

Pluvial or surface water flooding occurs when intense rainfall overwhelms the natural or man-made drainage systems, causing water to accumulate on the surface rather than flowing into rivers or other water bodies. This form of flooding is typically independent of overflowing water bodies and is often associated with extreme precipitation events, which have been increasingly recognized as a growing hazard in many urban areas (Kundzewicz, Hoozemans & Svensson, 2022). Unlike traditional flood risks, pluvial flooding can impact even elevated areas that are not directly near rivers or coastal zones, challenging the common misconception that flood risks are limited to proximity to water bodies (Maddox, 2021).

There are two primary types of pluvial flooding:

1. **Saturated Drainage Systems:** In urban environments, heavy rainfall can exceed the capacity of drainage systems, causing water to overflow onto streets and properties. This is most common in areas where rainfall intensity surpasses the designed capacity of urban stormwater systems, leading to localized flooding (Núñez, Fernandez & Gómez, 2021).
2. **Runoff from Impermeable Surfaces:** When rain falls on hard, impermeable surfaces like asphalt or concrete, water cannot be absorbed into the ground. This runoff can quickly accumulate, leading to surface flooding,

particularly in densely built-up areas (Piroozfar, Sarlak & Erdem, 2020).

Pluvial flooding frequently interacts with other forms of flooding, such as coastal and riverine floods, exacerbating the overall flood risk. Although pluvial floods are typically shallow, even a few centimeters of water can cause significant damage to property and disrupt daily life. While this type of flooding is distinct from flash flooding often caused by rapid runoff from a river or stream both types share similar causes in terms of high-intensity rainfall (Falconer, Smith & Jones, 2022). In particular, the frequency of these rainfall events appears to be rising, which may be linked to broader climate change patterns, leading to more frequent and severe flood events in urban centers (World Bank, 2023).

The Niger Delta region, including Port Harcourt Metropolis, is particularly vulnerable to pluvial flooding due to its low-lying topography, intense rainfall, and urbanization. Various studies have highlighted that a combination of environmental factors, such as land-use changes, deforestation, and urban sprawl, contribute to the severity of pluvial floods in this region (Kenny, Booth & Austin, 2021). Notably, while rainfall is a key driver of these floods, it is often the result of a complex interplay of topographical and anthropogenic factors that exacerbate the flood risk.

In response to these recurring flood events, Nigeria has taken steps to address disaster management through the National Emergency Management Agency (NEMA), established by the NEMA Act (12 as amended by Act 50 of 1999). NEMA is tasked with disaster response, policy formulation, risk assessment, and providing relief efforts. The agency's focus extends to areas at risk of pluvial

flooding, working alongside state-level entities such as the Rivers State Emergency Management Agency (SEMA) to mitigate flood-related hazards (Ogu & Adekola, 2022). Understanding flood-prone areas is essential to creating effective prevention and mitigation strategies, a task which requires collaboration between government bodies and local communities.



*Figure 2.7 Depiction of Surface Water Floods (Pluvial Floods).*

*Source: Hlushko, (2021).*

### 2.2.2 Causes and Impacts of Perennial Pluvial Floods in Port Harcourt Metropolis

Several studies have identified the causes of perennial pluvial flooding in Port Harcourt Metropolis and have attributed it to one or all of the following; topography, soil/vegetation/river alteration, increased heavy rainfall, uncontrolled waste dumping, land use change, and unplanned urbanization (Oriola, 1994; Onokerhoraye, 1995; Parker, 1999; Folorunsho and Awosika 2001; Ologunorisa, 2004; Ogba and Utang, 2008; Adedoye and Rustum, 2011). Perennial pluvial flooding in Port Harcourt Metropolis can be attributed to a combination of these factors. Based on available literature and data, the causes of perennial pluvial flooding in Port Harcourt Metropolis include:

**Heavy Rainfall and Climate Change:** Because of climate change, rainfall variation is projected to continue to increase. Precipitation in southern areas is expected to rise and rising sea levels are expected to exacerbate flooding and submersion of coastal lands (Beyioku, 2016). Port Harcourt Metropolis experiences high levels of rainfall throughout the year, with particularly intense rainfall

during the wet season. Heavy and prolonged rainfall events overwhelm the drainage systems, leading to water accumulation and subsequent flooding. Climate change exacerbates the situation, with changing rainfall patterns and an increased frequency of extreme weather events contributing to more intense and frequent floods.

**Inadequate Drainage Infrastructure:** The city's drainage infrastructure has not kept pace with rapid urbanization and population growth. The existing drainage systems often lack sufficient capacity and are unable to efficiently manage the volume of water during heavy rainfall. Additionally, inadequate maintenance and the dumping of solid waste into drains contribute to blockages and hinder the flow of water (Chiadikobi et al., 2011).

**Encroachment on Waterways and Floodplains:** Uncontrolled urban expansion and improper land use practices, such as construction on floodplains and encroachment on natural waterways, disrupt the natural flow paths of water (Oriola, 1994). This reduces the storage capacity for excess water and increases the risk of flooding. The loss of natural buffers, such as wetlands and floodplains, further exacerbates the impacts of flooding.

**Deforestation and Soil Erosion:** Unregulated deforestation, particularly in upstream areas, leads to increased surface runoff and soil erosion (Adeloye & Rustum, 2011). The removal of vegetation reduces the ability of the land to absorb water, resulting in enhanced runoff and sediment transport. Deforestation also contributes to the clogging of drains and water channels with sediment, further impeding drainage systems (Ogba & Utang, 2008).

**Inefficient Waste Management:** Improper waste disposal practices, including the dumping of solid waste into drains and water bodies, obstruct the flow of water and exacerbate drainage issues (Folorunsho & Awosika, 2001). Blocked drains and water channels reduce the capacity of the drainage systems, leading to increased flood risks.

**Lack of Urban Planning and Regulation:** Inadequate urban planning and zoning regulations have contributed to haphazard development, particularly in flood-prone areas. The absence of strict regulations on land use and construction standards has allowed for the encroachment on floodplains and the development of infrastructure that is not resilient to flooding (Oriola, 1994).

### 2.2.3 Floods: Some Major Flood Events in Nigeria

By studying the past, we learn about the present and are able to plan for the future (Angelakis et al., n.d.). Since 2012, Nigeria has experienced numerous significant flood events that have caused substantial damage, loss of life, and disruption to communities and economies. These events highlight the critical need for improved flood management, infrastructure, and preparedness strategies. The major flood events featured the different types of floods. But for this study, the focus was on the part of pluvial floods. This detailed review, therefore, delved into the major flood events of 2017 and 2021, examining their causes, impacts, and the lessons learned to better prepare for future occurrences.

#### 2.2.3.1 The 2017 Floods

The 2017 floods in Nigeria were a devastating natural disaster that impacted several regions of the country, resulting in about 18 deaths, displacement of communities, and widespread damage to property and infrastructure. These floods were primarily triggered by intense and prolonged rainfall, which overwhelmed rivers, reservoirs, and drainage systems, leading to severe inundation across many states.

#### Causes of the 2017 Floods

The primary cause of the 2017 Nigerian floods was heavy and sustained rainfall during the rainy season. Nigeria's geographical location and climatic conditions make it prone to seasonal flooding, especially during the peak months of

the rainy season from June to September. In 2017, the intensity of the rains was unusually high, exacerbated by climate change factors, which contributed to the extreme weather patterns observed. Another contributing factor was poor urban planning and inadequate drainage infrastructure in many cities and towns. Rapid urbanization without corresponding improvements in infrastructure led to clogged drainage systems, which could not handle the volume of water. This situation was further aggravated by deforestation and land degradation, which reduced the land's natural ability to absorb and manage rainfall (Sullivan, 2022).

#### Impact on Affected Regions

The floods of 2017 affected numerous states across Nigeria, with particularly severe impacts in Benue, Kogi, Niger, and Lagos States.

**Benue State:** One of the worst-hit areas, Benue State, experienced severe flooding that displaced over 100,000 people. The flooding was so severe that it submerged entire communities, destroying homes, farmlands, and critical infrastructure. The state capital, Makurdi, saw significant portions underwater, leading to the displacement of thousands of residents who sought refuge in temporary camps and shelters (Olujobi, 2024).

**Kogi State:** Kogi State, located along the confluence of the Niger and Benue rivers, also experienced catastrophic flooding. The rise in water levels of both rivers led to widespread inundation, displacing thousands and causing extensive damage to property and agricultural lands. The flooding disrupted transportation and communication networks, hampering relief efforts.

**Niger State:** In Niger State, the floods resulted in the displacement of many communities, particularly those situated along riverbanks. The swollen rivers led to the destruction of homes and farmlands, severely impacting the livelihoods of residents who rely on agriculture.

**Lagos State:** As Nigeria's economic hub, Lagos was not spared from the flooding. Urban areas in Lagos experienced significant waterlogging, leading to traffic congestion, property damage, and disruptions to business activities. The city's drainage systems were overwhelmed, highlighting the urgent need for infrastructural improvements to mitigate future flood risks.

**Rivers State:** Residents of Port Harcourt, the capital city of Rivers State, reported that they were counting their losses after three days of continuous rainfall which started in the early hours of 22<sup>nd</sup> July 2024. The 2017 floods caused widespread flooding and destruction of property. According to reports, three people lost their lives in various parts of the city due to the flooding. Areas such as D-Line,

Diobu, Elekahia, and Ada-George were identified as being the hardest hit. Besides the loss of property, many victims were temporarily displaced from their homes. (TVC News, 2017).

### Humanitarian Response and Relief Efforts

The scale of the disaster prompted a swift response from both the Nigerian government and international organizations. The Federal Government, through the National Emergency Management Agency (NEMA), coordinated relief efforts, providing emergency assistance to affected populations. This included the distribution of food, clean water, medical supplies, and temporary shelters to those displaced by the floods.

International humanitarian organizations and local NGOs also played a critical role in the response. They assisted in conducting needs assessments, delivering aid, and supporting the establishment of temporary camps for displaced persons. These efforts were crucial in alleviating the immediate suffering of those affected and preventing further health crises due to waterborne diseases and poor sanitary conditions.

### Long-Term Implications and Lessons Learned

The 2017 floods underscored the urgent need for comprehensive flood management and mitigation strategies in Nigeria. The disaster highlighted the vulnerabilities of urban and rural communities to extreme weather events and the consequences of inadequate infrastructure and poor environmental management.

In response to the floods, there were calls for improved urban planning, investment in resilient infrastructure, and the implementation of early warning systems to better prepare for and respond to future flood events. Enhancing community awareness and preparedness through education and training programs was also recognized as a critical component in reducing the impact of such disasters.

The floods also emphasized the importance of addressing broader environmental issues, such as deforestation and land degradation, which contribute to increased flood risks. Reforestation and sustainable land management practices were identified as necessary measures to enhance the natural resilience of the environment to heavy rainfall and flooding.



*Plate 2.1 Flooding of Federal Road Safety Commission Port Harcourt Office along Aba Road.*

*Source: Echendu, (2021)*

#### 2.2.3.2 The 2021 Floods in Port Harcourt

Residents reported that on 21st September 2021, the capital city of Rivers State, Port Harcourt, experienced severe flooding due to torrential rains. Among the most impacted were the Federal Road Safety Corps (FRSC) office and the Port Harcourt Shopping Mall (SPAR). The rains, which

began at dawn and continued for several hours, overwhelmed the FRSC's Port Harcourt Zonal Office on Aba Road. Business operations at SPAR were heavily disrupted as staff scrambled to protect merchandise from floodwater that submerged the ground floor of the mall on Azikiwe Road. Numerous cars were also submerged on

major roads throughout the city, leaving many commuters stranded and residents facing significant property losses.

Several respondents and victims blamed the flooding on inadequate drainage systems in the city. Additionally, some criticized the Rivers State Government for the rapid and concurrent construction of road projects concentrated in the capital city and the reclamation of waterways that previously absorbed floodwater. The most affected areas included Station Road, Abali Motor Park, Rivers State Judiciary Complex, Ikwerre Road, Ada George, and Sanni Abacha Road. One resident highlighted that the

government's unrestrained land reclamation on waterways that used to absorb floodwater had exacerbated the situation. They remarked, the water will always find its level. The result is what we are seeing now. The affected areas may have been prone to flooding in the past, but the experience today is unprecedented. (Vanguard, 2021)

Ultimately, the consensus among many was that urbanization and the indiscriminate construction over natural waterways were the primary causes of the severe flooding in Port Harcourt.



*Plate 2.2 Flooding of Port Harcourt Mall Flood along Azikiwe Road.*

*Source: Vanguard Newspaper, (2021)*

## 2.2.4 Nature-Based Mitigation and adaptation Strategies for Flooding

Flooding is a recurring and devastating natural disaster that affects communities worldwide. As the frequency and severity of floods continue to increase due to climate change, urbanization, and land use changes, there is a growing need for effective mitigation and adaptation strategies (Intergovernmental Panel on Climate Change [IPCC], 2019). Nature-based solutions, which utilize natural ecosystems and processes to mitigate the impacts of flooding, are gaining recognition as a valuable approach to reducing flood risk (United Nations Office for Disaster Risk Reduction [UNDRR], 2019).

### 2.2.4.1 Definition and Types of Nature-Based Mitigation and Adaptation Strategies

Nature-based mitigation and adaptation strategies for flooding involve the use of natural ecosystems, such as wetlands, forests, and floodplains, to reduce the risk and impacts of flooding (World Bank, 2019). These strategies can be divided into two main categories: mitigation and adaptation.

**Mitigation strategies:** These aim to reduce the likelihood and severity of flooding by restoring or preserving natural ecosystems that can absorb and filter floodwaters (European Commission, 2019).

Examples of mitigation strategies include:

- I. Wetland restoration: Restoring wetlands can help to absorb and filter floodwaters, reducing the risk of flooding downstream (Mitsch & Gosselink, 2015).
- II. Floodplain management: Allowing floodplains to flood naturally can help to reduce the risk of flooding in nearby communities (Tockner & Stanford, 2002).
- III. Green infrastructure: Incorporating green infrastructure, such as green roofs and permeable pavements, into urban design can help to reduce stormwater runoff and alleviate flooding (Fletcher et al., 2015).

**Adaptation strategies:** These strategies focus on reducing the vulnerability of communities to flooding by promoting sustainable land use practices, improving flood forecasting and warning systems, and enhancing community resilience (International Union for Conservation of Nature [IUCN], 2019).

Examples of adaptation strategies include:

- I. Ecosystem-based adaptation: This approach involves restoring and preserving natural ecosystems, such as mangroves and coral reefs, to provide natural barriers against flooding and storm surges (Adger et al., 2005).
- II. Flood-resilient agriculture: Implementing flood-resilient agricultural practices, such as agroforestry and conservation agriculture, can help to reduce the vulnerability of agricultural communities to flooding (Ziervogel et al., 2016).

#### 2.2.4.2 Benefits of Nature-Based Mitigation and Adaptation Strategies

Nature-based mitigation and adaptation strategies for flooding offer numerous benefits, including:

- I. Reduced flood risk: By restoring and preserving natural ecosystems, these strategies can help to reduce the likelihood and severity of flooding (World Bank, 2019).
- II. Improved water quality: Natural ecosystems can help to filter and purify floodwaters, improving water quality and reducing the risk of waterborne diseases (Mitsch & Gosselink, 2015).
- III. Enhanced biodiversity: Nature-based strategies can help to preserve and restore natural habitats, promoting biodiversity and ecosystem services (IUCN, 2019).
- IV. Increased community resilience: By promoting sustainable land use practices and enhancing community awareness and preparedness, nature-based strategies can help to increase community resilience to flooding (UNDRR, 2019).

- V. Cost-effective: Nature-based strategies can be more cost-effective than traditional engineering approaches, which often require significant investment in infrastructure (European Commission, 2019).

#### 2.2.4.3 Challenges and Limitations

While nature-based mitigation and adaptation strategies for flooding offer numerous benefits, there are also challenges and limitations to consider, including:

- I. Land availability: Restoring and preserving natural ecosystems often requires significant land areas, which can be a challenge in densely populated urban areas (Fletcher et al., 2015).
- II. Community engagement: Nature-based strategies often require community engagement and participation, which can be time-consuming and challenging to achieve (IUCN, 2019).
- III. Funding: Implementing nature-based strategies can require significant funding, which can be a challenge for communities with limited resources (World Bank, 2019).
- IV. Policy and regulatory frameworks: Nature-based strategies often require supportive policy and regulatory frameworks, which can be lacking in some countries (European Commission, 2019).

Nature-based mitigation and adaptation strategies for flooding offer a valuable approach to reducing flood risk and promoting community resilience. By restoring and preserving natural ecosystems, these strategies can help to reduce the likelihood and severity of flooding, improve water quality, and enhance biodiversity. While there are challenges and limitations to consider, the benefits of nature-based strategies make them an important tool in the fight against flooding.

#### 2.2.5 Floods: Sponge City Concept

The Sponge City Concept is a innovative approach to urban flood management that has gained significant attention in recent years (Fletcher et al., 2015). The concept involves designing cities to absorb and filter rainwater, reducing the burden on drainage systems and minimizing the risk of flooding (Li et al., 2019). This report provides an overview of the Sponge City Concept, its benefits, and examples of its implementation in cities around the world. The Sponge City Concept is a holistic approach that integrates urban planning, architecture, and engineering to create sustainable and resilient cities (Wuhan Municipal Government, 2019). The concept has been recognized as a key strategy for mitigating the impacts of urbanization on flood risk (Fletcher et al., 2015).

##### 2.2.5.1 Sponge City: Definition

A sponge city is an urban area designed to absorb and filter rainwater, reducing the burden on drainage systems and

minimizing the risk of flooding (Fletcher et al., 2015). The concept is inspired by the natural water cycle, where rainwater is absorbed by the soil, filtered by vegetation, and slowly released into waterways (Mitsch & Gosselink, 2015). Sponge cities aim to replicate this process through the use of green infrastructure, such as parks, green roofs, and permeable pavements (Li et al., 2019). Green infrastructure is a key component of sponge cities, as it provides a range of ecosystem services, including stormwater management, air quality improvement, and habitat creation (Benedict & McMahon, 2006). The use of green infrastructure in sponge cities can also help to mitigate the urban heat island effect, improve air quality, and enhance biodiversity (Taha, 1997).

The concept of sponge cities is not new, but it has gained significant attention in recent years due to its potential to mitigate the impacts of urbanization on flood risk (Fletcher et al., 2015). The concept has been implemented in several cities around the world, including Chicago, Rotterdam, Singapore, Copenhagen, and Wuhan (City of Chicago, 2019; City of Rotterdam, 2019; Urban Redevelopment Authority of Singapore, 2019; City of Copenhagen, 2019; Wuhan Municipal Government, 2019). These cities have implemented a range of green infrastructure initiatives, including green roofs, rain gardens, permeable pavements,

and urban parks, to reduce stormwater runoff and improve water quality.

### 2.2.5.2 Sponge City: Examples

As cities around the world face increasing challenges related to urbanization, climate change, and water management, the concept of the "sponge city" has gained significant attention (Li et al., 2019). A sponge city is an urban area that is designed to absorb and filter rainwater, reducing the risk of flooding and improving water quality. Here are five examples of cities that are implementing sponge city initiatives:

**Chicago, USA:** Chicago's Green Infrastructure Plan aims to reduce stormwater runoff and improve water quality through the use of green roofs, rain gardens, and permeable pavements (ProQuest, n.d.). The plan, which was launched in 2014, includes a range of initiatives, such as the creation of green infrastructure in public spaces, the implementation of green roofs on private buildings, and the use of permeable pavements in urban areas (City of Chicago, 2014). According to a study by the University of Illinois, Chicago's green infrastructure plan has the potential to reduce stormwater runoff by up to 70% (University of Illinois, 2018).



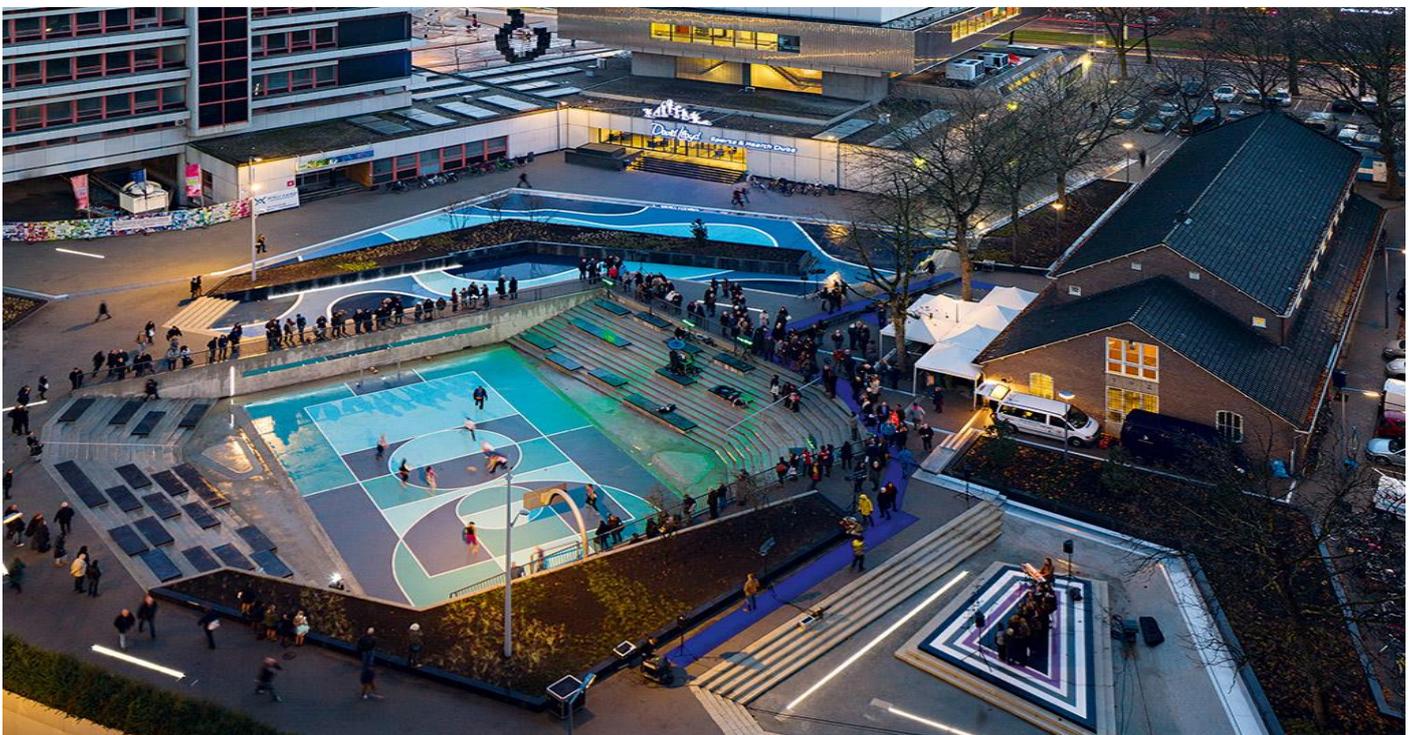
*Plate 2.3 One Central Park, Chicago*

*Source: Cook, (2014)*

**Rotterdam, Netherlands:** The Netherlands, literally translating to "low-lands," is famously situated below sea level. To cope with this unique challenge, the country has developed and implemented numerous innovative strategies to coexist with water, minimizing the risk of flooding over the years (Jonkman & Kelman, 2005). Rotterdam's Water Management Plan includes the creation of green roofs, urban parks, and flood-resistant construction to reduce the risk of flooding (City of Rotterdam, 2019). The plan, which was launched in 2013, aims to make Rotterdam a "water-resilient" city by 2025 (City of Rotterdam, 2013). According to a study by the Delft University of Technology, Rotterdam's water management plan has reduced the risk of flooding in the city by up to 50% (Delft University of Technology, 2019).

The Water Square Benthemplein in Rotterdam, Netherlands, is a pioneering example of urban design that combines public

space and stormwater storage (Salinas et al., 2014). This innovative square holds a twofold strategy, serving as both a public space and a stormwater storage facility. By integrating these two functions, the square provides a unique solution to urban flooding and climate change resilience. As part of Rotterdam's strategy to increase climate resilience through adaptive measures, the Water Square Benthemplein showcases a new approach to urban design (City of Rotterdam, 2019). The square's design allows it to store excess rainwater during heavy rainfall events, reducing the burden on the city's drainage system and minimizing the risk of flooding. In addition to its functional benefits, the Water Square Benthemplein also demonstrates a new model for funding high-quality public spaces. The square was largely financed by water management departments and innovation subsidies, highlighting the potential for collaborative funding approaches to support urban design initiatives (Zevenbergen et al., 2018).



*Plate 2.4 Benthemplein Water Square, Rotterdam.*

*Source: Salinas et al., (2014)*

**Singapore:** Singapore's Urban Redevelopment Authority has implemented a range of green infrastructure initiatives, including green roofs, rain gardens, and permeable pavements, to reduce stormwater runoff and improve water quality (Urban Redevelopment Authority of Singapore, 2019). The initiatives, which were launched in 2014, aim to make Singapore a "City in a Garden" by 2030 (Urban Redevelopment Authority of Singapore, 2014). According to a study by the National University of Singapore, Singapore's green infrastructure initiatives have reduced stormwater runoff by up to 30% (National University of Singapore, 2020).

The Singapore Green Plan 2030 is an ambitious initiative launched on February 10, 2021, with the goal of advancing

Singapore's national agenda on sustainable development (Zheng, 2021). The plan is built around five key pillars: City in Nature, Sustainable Living, Energy Reset, Green Economy, and Resilient Future. Under the City in Nature pillar, the plan aims to add 1,000 hectares of green spaces by 2035 and double the annual tree planting rate (Zheng, 2021).

The Sustainable Living pillar focuses on reducing carbon emissions, keeping the environment clean, and saving resources. Some of the targets include reducing household water consumption to 130 liters per capita per day, expanding the rail network to 360km, and tripling cycling paths to 1,320km (Zheng, 2021).

The Energy Reset pillar aims to increase the use of cleaner energy and improve energy efficiency. Targets include increasing solar energy deployment by five-fold, greening 80% of buildings, and reducing energy consumption in HDB towns by 15% (Zheng, 2021).

The plan also emphasizes the importance of a Green Economy, seeking green growth opportunities to create new jobs and transform industries (Ministry of Sustainability and the

Environment, 2021). Finally, the Resilient Future pillar focuses on building Singapore's climate resilience and enhancing food security.

The Singapore Green Plan 2030 is a "living plan" that will evolve over time, taking into account technological developments and public feedback (Ministry of Sustainability and the Environment, 2021).



**Plate 2.5 Singapore Green Plan 2030: 1,000ha more green spaces & tripling cycling paths to 1,320km**

*Source: Zheng, (2021)*

**Copenhagen, Denmark:** Copenhagen's Cloudburst Management Plan includes the creation of green roofs, urban parks, and flood-resistant construction to reduce the risk of flooding (City of Copenhagen, 2019). The plan, which was launched in 2012, aims to make Copenhagen a

"cloudburst-resilient" city by 2030 (City of Copenhagen, 2012). According to a study by the Technical University of Denmark, Copenhagen's cloudburst management plan has reduced the risk of flooding in the city by up to 40% (Technical University of Denmark, 2020).



**Plate 2.6 Copenhagen Cloudburst Management Plan**

*Source: Tauhid, (2021)*

**Wuhan, China:** Wuhan's Sponge City Initiative aims to reduce flood risk and improve water quality through the use of green infrastructure, including green roofs, rain gardens, and permeable pavements (Wuhan Municipal Government, 2019). The initiative, which was launched in 2016, aims to make Wuhan a "sponge city" by 2030 (Wuhan Municipal Government, 2016). According to a study by the Wuhan University, Wuhan's sponge city initiative has reduced flood risk by up to 20% (Wuhan University, 2020).

The Wuhan Xinyuexie Park plays a vital role in the east eco-corridor of the Optics Valley Center Area, connecting Jiufeng Forest Park with Baoxie Lake (Tauhid, 2018). As the primary recreational space in the new Optics Valley CBD area, the park must incorporate several key functions:

- I. Provide recreational space for various user groups, promoting an active lifestyle.
- II. Preserve and enhance the natural stormwater corridor by integrating the Sponge City concept (Tauhid, 2018).
- III. Offer opportunities for public access and environmental education, consistent with restored habitat areas.
- IV. Establish connections between existing and restored hills and water bodies.

By serving these purposes, the park can fulfill the city's needs beyond merely improving its image and value (Tauhid, 2018). Upon completion, the park will be well-integrated into the Optics Valley city context, serving communities and user groups while improving local conditions (OBERMEYER Engineering Consulting, n.d.).



*Plate 2.7 Wuhan Sponge City Initiative*  
*Source: OBERMEYER, (n.d.)*

### 2.2.5.3 Sponge City: Benefits

Sponge cities offer numerous benefits, including reduced flood risk, improved water quality, enhanced biodiversity, mitigated urban heat island effect, and improved public health (Li et al., 2019). The use of green infrastructure in sponge cities can also help to improve air quality, reduce noise pollution, and enhance aesthetic value (Benedict & McMahon, 2006). Additionally, sponge cities can provide opportunities for physical activity, social interaction, and community engagement, which can help to improve public health and well-being (Sallis et al., 2016).

**Reduced Flood Risk:** One of the primary benefits of sponge cities is the reduced risk of flooding. By incorporating green infrastructure, such as green roofs, rain gardens, and permeable pavements, sponge cities can

absorb and filter rainwater, reducing the burden on drainage systems and minimizing the risk of flooding (Fletcher et al., 2015). This can help to protect homes, businesses, and infrastructure from flood damage, reducing economic losses and improving public safety.

**Improved Water Quality:** Sponge cities can also improve water quality by reducing stormwater runoff and filtering out pollutants and sediments (Li et al., 2019). Green infrastructure, such as green roofs and rain gardens, can absorb and treat stormwater runoff, reducing the amount of pollutants and sediments that enter urban waterways. This can help to improve the quality of urban waterways, making them safer for recreation and aquatic life.

**Enhanced Biodiversity:** Sponge cities can also enhance biodiversity by providing habitat for urban wildlife and

promoting ecosystem services (Mitsch & Gosselink, 2015). Green infrastructure, such as parks and green spaces, can provide habitat for urban wildlife, such as birds, bees, and butterflies. Additionally, sponge cities can promote ecosystem services, such as pollination, pest control, and climate regulation.

**Mitigated Urban Heat Island Effect:** Sponge cities can also mitigate the urban heat island effect by reducing the temperature in urban areas (Taha, 1997). Green infrastructure, such as green roofs and urban parks, can provide shade, reduce the amount of impervious surfaces, and promote evapotranspiration, all of which can help to reduce the temperature in urban areas.

**Improved Public Health:** Sponge cities can also improve public health by providing opportunities for physical activity, social interaction, and community engagement (Sallis et al., 2016). Green infrastructure, such as parks and green spaces, can provide opportunities for physical activity, such as walking, cycling, and playing sports. Additionally, sponge cities can promote social interaction and community engagement, which can help to improve mental health and well-being.

**Improved Air Quality:** Sponge cities can also improve air quality by reducing air pollution and promoting ecosystem services (Benedict & McMahon, 2006). Green infrastructure, such as green roofs and urban parks, can absorb and filter air pollutants, reducing the amount of particulate matter and other pollutants in the air.

**Reduced Noise Pollution:** Sponge cities can also reduce noise pollution by providing a natural barrier between urban areas and noise sources (Benedict & McMahon, 2006). Green infrastructure, such as green roofs and urban parks, can provide a natural barrier between urban areas and noise sources, reducing the amount of noise pollution in urban areas.

**Enhanced Aesthetic Value:** Sponge cities can also enhance aesthetic value by providing a natural and beautiful environment (Benedict & McMahon, 2006). Green infrastructure, such as parks and green spaces, can provide a natural and beautiful environment, enhancing the aesthetic value of urban areas.

#### 2.2.5.4 Sponge City: Implementation and Challenges

Implementing sponge city initiatives can be challenging, requiring significant investment in infrastructure and community engagement (Li et al., 2019).

Some of the challenges include:

**Cost:** Implementing green infrastructure can be expensive, requiring significant investment in materials and labor (Fletcher et al., 2015). The cost of implementing green

infrastructure can be a significant barrier for cities, particularly those with limited budgets. However, the long-term benefits of green infrastructure, such as reduced flood risk and improved water quality, can outweigh the initial costs.

**Community engagement:** Sponge city initiatives require community engagement and participation, which can be time-consuming and challenging to achieve (Mitsch & Gosselink, 2015). Community engagement is critical to the success of sponge city initiatives, as it helps to build support and ownership among local residents. However, engaging with the community can be challenging, particularly in cities with diverse populations and competing priorities.

**Policy and regulatory frameworks:** Sponge city initiatives require supportive policy and regulatory frameworks, which can be lacking in some cities (Li et al., 2019). Policy and regulatory frameworks play a critical role in supporting the implementation of sponge city initiatives. However, in some cities, these frameworks may not be in place, or may even create barriers to implementation.

**Maintenance and upkeep:** Green infrastructure requires regular maintenance and upkeep, which can be challenging to ensure (Fletcher et al., 2015). Maintenance and upkeep are critical to the long-term effectiveness of green infrastructure. However, ensuring that maintenance and upkeep are carried out regularly can be challenging, particularly in cities with limited resources.

Overcoming these challenges will require innovative solutions and collaborative approaches. Cities can learn from each other's experiences and share best practices in implementing sponge city initiatives. Additionally, cities can engage with local communities, stakeholders, and experts to build support and ownership for sponge city initiatives.

Furthermore, cities can also explore innovative financing mechanisms, such as green bonds and public-private partnerships, to support the implementation of sponge city initiatives. Governments can also provide incentives, such as tax credits and grants, to encourage private sector investment in green infrastructure.

In conclusion, implementing sponge city initiatives can be challenging, but with innovative solutions and collaborative approaches, cities can overcome these challenges and create more sustainable and resilient urban environments.

#### 2.2.6 Flood Risk Management (FRM) and Planning

Effective flood risk management in Port Harcourt involves identifying areas prone to pluvial floods and incorporating architectural adaptations to reduce vulnerability. This includes strategies such as elevating buildings to keep them above the floodplain, creating detention ponds, and

designing drainage systems that direct water flow away from urban areas (Kundzewicz, Hoozemans & Svensson, 2019). Comprehensive flood risk management involves a cross-disciplinary approach, where architects collaborate with urban planners, engineers, and environmental scientists to design solutions that address both structural and non-structural aspects of flood mitigation (Kundzewicz, Hoozemans & Svensson, 2019). Urban planning must incorporate policies that mandate flood resilience measures, ensuring that new developments adhere to flood-proofing standards.

### **2.2.7 Sustainable Architecture**

Sustainable architecture is another essential element in mitigating flooding. This approach includes using eco-friendly building materials, energy-efficient systems, and low-impact construction techniques. Sustainable architecture in Port Harcourt could integrate water collection and recycling systems, solar power, and green roofs to help manage both floodwater and energy use (IPCC, 2022). Moreover, sustainable designs should prioritize the reduction of impervious surfaces, increasing water infiltration into the ground. Climate-resilient architecture, by anticipating the increasing frequency and intensity of rain events due to climate change, ensures that new buildings are capable of withstanding both current and projected flood risks (Sovacool, Kivimaa & Mitchell, 2017).

### **2.2.8 Integrated Water Management (IWM)**

The integration of Integrated Water Management (IWM) in architectural strategies ensures that water systems are designed to manage both stormwater and wastewater. IWM encourages the use of permeable surfaces, retention ponds, and bioswales to capture rainwater and prevent flooding, while also ensuring that the water is reused effectively. However, in designing buildings that contribute to water retention and filtration on-site, Port Harcourt's architecture can play a vital role in flood mitigation. Rainwater harvesting systems, for example, can store runoff for later use, reducing the immediate volume of water flowing into the city's drainage systems during a storm event (Ochoa, González & Latorre, 2022).

### **2.2.9 Community Engagement in Design**

The success of flood resilience strategies depends significantly on community engagement. Participatory design involves the local population in planning processes to ensure that flood mitigation measures are contextually appropriate, acceptable, and sustainable. In Port Harcourt, involving local communities, residents, and stakeholders in architectural decisions can lead to solutions that address local flood patterns and the specific needs of different neighborhoods (Roslan, Ali & Rahman, 2015).

Additionally, community-driven solutions often promote greater ownership and ensure long-term maintenance of flood resilience measures.

### **2.2.10 Policy and Governance**

Effective flood mitigation and architectural adaptation require strong policy frameworks and governance mechanisms. In Port Harcourt, local authorities must develop zoning laws and building codes that enforce flood-resistant construction practices. Additionally, urban governance must prioritize the inclusion of flood resilience measures in development plans and urban regeneration projects. Collaboration between different sectors, such as urban planning, environmental management, and infrastructure development, is critical for ensuring that flood resilience becomes an integral part of the city's architecture and urban landscape (Sovacool, Kivimaa & Mitchell, 2017).

The Architectural Adaptation Strategies to Mitigate Perennial Pluvial Floods in Port Harcourt Metropolis involve a multifaceted approach integrating blue-green infrastructure, resilience theory, sustainable design principles, and community engagement. This framework highlights the importance of interdisciplinary collaboration in urban planning, emphasizing the role of architecture in adapting to flood risks while enhancing the overall quality of urban life. The framework serves as a guideline for creating a resilient, sustainable, and flood-resistant urban environment in Port Harcourt, helping the city respond effectively to the increasing challenges posed by climate change and urbanization.

## **2.3 Empirical Review**

Port Harcourt Metropolis, a major city in the Niger Delta region of Nigeria, is frequently affected by perennial pluvial floods that have significant negative impacts on the environment, infrastructure, and livelihoods of its residents. Perennial pluvial floods are floods that occur every year, usually as a result of a combination of factors such as rainfall, topography, and land use changes. This Thematic Empirical Review aims to synthesize the existing literature on architectural adaptation strategies to mitigate perennial floods in Port Harcourt Metropolis.

### **2.3.1 Adaptation Strategies**

The Intergovernmental Panel on Climate Change (IPCC, 2007) defines adaptation as the process of adjusting natural or human systems in response to current or anticipated climatic conditions or their effects, with the goal of reducing harm or taking advantage of potential benefits. Adaptation to climate change is generally categorized into two types. The first type, adaptation strategies, involves long-term measures designed to address and prepare for

climate change impacts (Thomas et al., 2007). The second type, coping strategies, consists of short-term actions taken at the household level to mitigate the immediate effects of climate-related events such as floods (Thomas et al., 2007; DFID, 2008).

Adaptation strategies can be further divided into two categories: proactive (or anticipatory) and reactive (De Bruin, 2011). Proactive adaptation involves planning and implementing measures in anticipation of future climate changes, while reactive adaptation involves responding to and managing the impacts of climate change after they have occurred (Shongwe et al., 2014). For example, reactive adaptation might include measures like controlling soil erosion, building irrigation dams, developing new crop varieties, and adjusting planting and harvesting schedules. In contrast, anticipatory adaptation might involve developing climate-resilient crop varieties, conducting research and development, and implementing policy measures such as tax incentives and regulations

In practice, most adaptation measures tend to be reactive, as they are often implemented in response to problems as they arise rather than in anticipation of future issues (Bierbaum et al., 2013). This tendency reflects the immediate nature of many challenges faced by communities and the need for urgent responses to mitigate their impacts.

According to Brody et al. (2009), structural mitigation strategies involve the construction or modification of physical infrastructure to protect people, buildings, and the environment from the impacts of flooding. These strategies are designed to prevent or minimize the intrusion of floodwaters into areas where they could cause damage, effectively serving as barriers between the water and the built environment. The effectiveness of these structural measures in reducing flood damage has been supported by various studies (IPCC, 2014; Queensland Government, 2018). Such strategies aim to manage flood damage by controlling factors such as water height, flow rate, and seepage into structures (Queensland Government, 2018).

### **Structural And Non-Structural Measures**

Structural and non-structural measures are not limited to just mitigation strategies. They play roles in various stages of disaster management, including preparedness, response, and recovery.

#### **Structural Measures**

Examples of structural mitigation strategies include the construction of dams, levees, sea walls, and detention basins. Other techniques involve modifying natural and artificial waterways, such as widening, deepening, or realigning canals, rivers, and floodplains, as well as

dredging rivers and lakes and building embankments. These measures require significant financial investment and are often implemented by government agencies or through collaborative efforts between communities and authorities (IPCC, 2014; Queensland Government, 2018).

Ologunorisa (2010) categorizes structural flood mitigation strategies into three main types. The first category encompasses engineering schemes, which include both small-scale interventions, such as minor embankments and soil retention measures, and large-scale projects, such as major flood control infrastructure, significant sea walls, and substantial dam constructions. The second category consists of flood abatement schemes, which utilize natural methods, such as afforestation, to manage land use and mitigate flood impacts. These schemes aim to manage flood runoff at the upstream catchment level to reduce its downstream effects (Ologunorisa, 2010). The third category is flood-protection schemes, which focus on modifications to buildings to enhance their resilience to flooding. These can include both permanent and temporary alterations to a building's structure and design to withstand flood conditions, often referred to as building adaptation strategies (Ologunorisa, 2010).

#### **Non-Structural Measures**

In contrast, non-structural mitigation strategies are policies and regulatory measures designed to manage flood risks through planning and prevention rather than physical construction. These strategies focus on regulating land use and reducing the exposure of people and assets to flood hazards. Non-structural measures include floodplain zoning, flood insurance, public relief funds, flood forecasting and warning systems, weather modification, and loss-bearing and acceptance (Ologunorisa, 2010). These approaches have been adopted in various countries around the world to complement structural measures and provide a comprehensive approach to flood management (Creach et al., 2020; Queensland Government, 2018; Brody et al., 2009).

Additional non-structural strategies involve evacuation plans, relocation efforts, and other measures aimed at moving people and property out of harm's way during flood events. These strategies are crucial for minimizing the risk to human lives and reducing property damage when floods occur (Lumbroso & Davison, 2016; Kolen, Slomp & Jonkman, 2013; Priest, 2007). By integrating both structural and non-structural approaches, communities can better prepare for, respond to, and recover from flooding, thereby enhancing overall resilience to these natural hazards.

#### **2.3.2 Architectural Adaptation Strategies**

To mitigate the impacts of perennial pluvial flooding in Port Harcourt Metropolis, researchers have proposed various architectural adaptation strategies that are largely Structural

measures. Permeable pavements, for example, have been identified as an effective strategy for reducing surface runoff and increasing infiltration (Efe and Opoko, 2020). Blue roofs have also been proposed as a way of reducing runoff, increasing evapotranspiration, and improving thermal performance (Sarai and Oloke, 2021). Other strategies include the use of rain gardens, retention basins, and elevated buildings. Rain gardens are vegetated depressions that collect and filter runoff from impervious surfaces, while retention basins are designed to temporarily store and release stormwater runoff (Enaruvbe et al., 2021). Elevated buildings are designed to raise the ground floor of buildings above flood levels, reducing the exposure of buildings to floodwaters (Akande et al., 2020).

Architecture in general can be adapted to some degree, as buildings can always be modified manually in some manner. Brand's book *How Buildings Learn* provides insight into the different levels of adaptation that can be expected and how they apply over various periods (Brand, 1994). Therefore, the term Adaptive Architecture must be considered in this broader context, and the distinction between adaptable and adaptive architecture is as follows: Adaptive Architecture refers to buildings that are purposefully designed to adapt, whether automatically or through human intervention, to their environment, occupants, and objects within them (Schnadelbach, 2010).

To manage potential climate hazards, such as extreme storms and flooding, that could impact water quality, infrastructure, and safety, the Environmental Resilience Institute in Indiana suggests adaptation strategies. These strategies include the use of green infrastructure techniques to mitigate recurrent flooding. One or more methods may

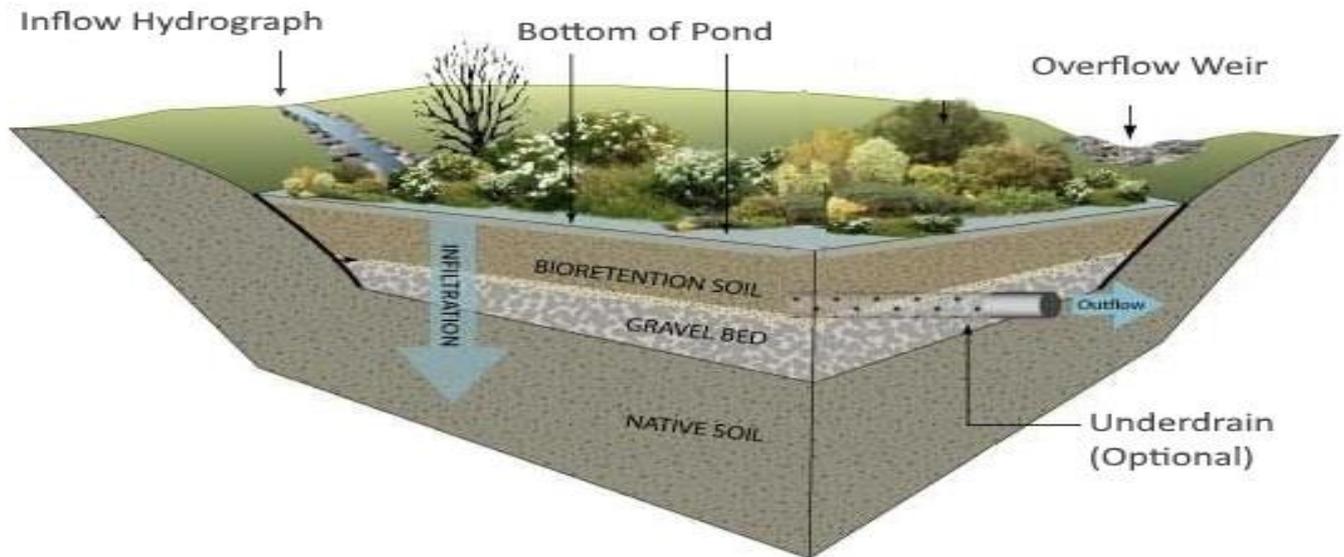
be employed for adaptation purposes (Environmental Resilience Institute, Indiana).

### 2.3.2.1 Use of Bioretention to Collect Stormwater Runoff

Bioretention is a form of landscape feature that is specially designed to collect, store, and allow the infiltration of stormwater runoff on-site (Davis et al., 2012). When it rains, water falling on surfaces like rooftops, driveways, or parking lots is directed towards a shallow depression, which enables runoff to pool before slowly infiltrating the ground (Dietz, 2007). This depression, which is filled with a filter bed, is typically planted with vegetation that can withstand water-tolerant conditions (Hunt et al., 2017). As stormwater runoff accumulates, it will gradually travel through the filter bed, where it will either be absorbed into the ground or discharged via an underdrain (Davis et al., 2012). This method is commonly used in both residential and commercial areas as it is a cost-effective and efficient way of managing stormwater (EPA, 2017). Bioretention can be used to help reduce the volume and peak flow rate of stormwater runoff, which can help prevent downstream flooding and erosion (Hunt et al., 2017). The use of vegetation within the bioretention area can help improve the quality of the runoff by removing pollutants and nutrients (Dietz, 2007). Small-scale bioretention areas, also known as rain gardens, are often found in residential settings (EPA, 2017). These features are typically designed to manage stormwater runoff from rooftops or other small impervious surfaces (Hunt et al., 2017). They are often planted with native vegetation that is adapted to the local climate and soil conditions, which can help reduce maintenance needs and enhance biodiversity in the area (Dietz, 2007).



**Figure 2.8 Bioretention Pond in a Residential Property**  
(Source: [mixnew15.bitbucket.io](https://mixnew15.bitbucket.io), 2023)

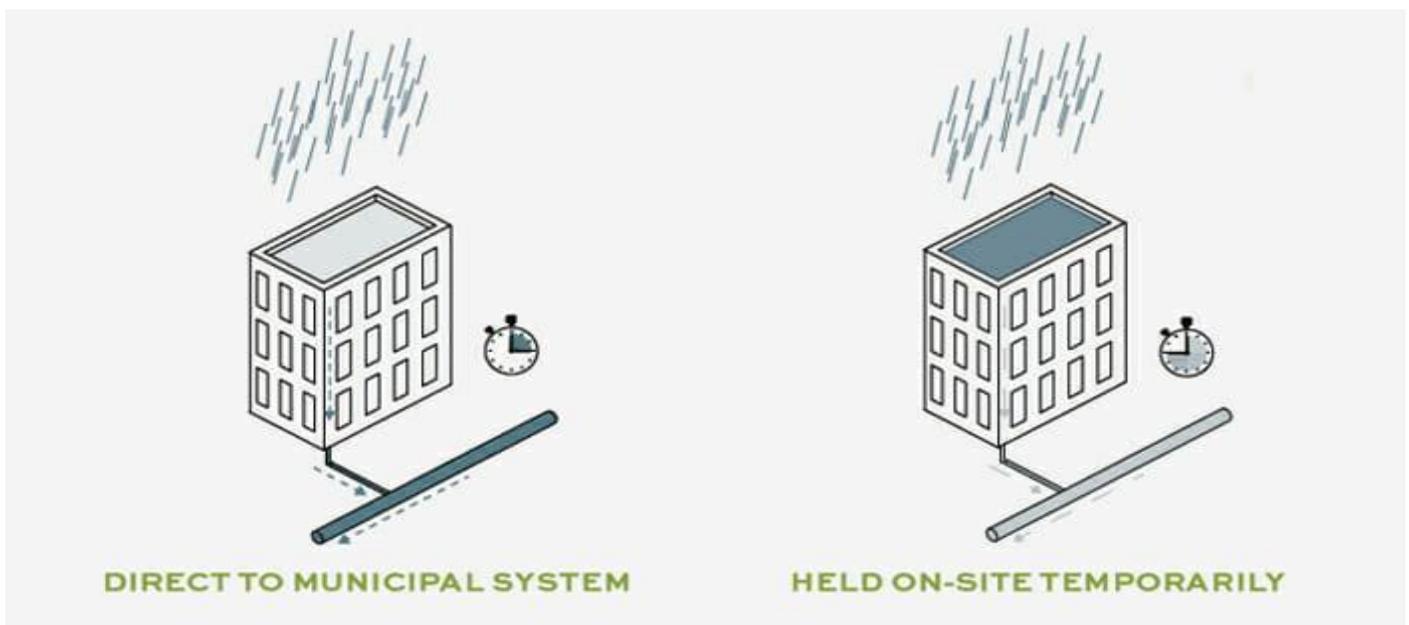


**Figure 2.9 Section Through a Typical Bioretention Pond.**  
 (Source: *encycloall.com*, 2023)

### 2.3.2.2 Use of Blue Roof to hold Precipitation

One of the strategies that can be used to manage stormwater runoff is the installation of a blue roof. A blue roof is a roof explicitly designed to capture and slowly release rainwater, in order to slow the rate of runoff and reduce the potential for related flooding (BKS Architects, n.d.). According to Wong (2017), a blue roof is designed to retain and manage stormwater by temporarily holding it on the roof surface or in engineered trays. The roof can hold up to eight inches of precipitation, and it functions similarly to a vegetated roof, but without the need for soil or vegetation (Carter & Fowler, 2009). The stored water is then slowly released at a controlled rate to the drainage system after the storm event, reducing the

peak discharge rate of runoff and allowing for evaporation (Wong, 2017). This process is regulated through a flow restriction device that is located around the roof drain, which controls the discharge rate of water and ensures that the water is slowly released into the drainage system (Carter & Fowler, 2009). Blue roofs can be used in various settings, including commercial, industrial, and residential buildings, to manage stormwater effectively (Wong, 2017). They are particularly useful in areas where there is limited space for other green infrastructure practices, such as bioretention areas or rain gardens (EPA, 2017). In addition to managing stormwater, blue roofs offer other benefits, such as reducing the urban heat island effect by reflecting sunlight and reducing the need for air conditioning during the summer months (Taha, 2017).



**Figure 2.9 Blue Roof (Source: *bskarch.com*, 2014).**

### 2.3.2.2 Use of Permeable Pavement

To manage stormwater runoff effectively, one strategy is to use permeable pavement that allows water to flow through and be temporarily stored before being discharged (Fletcher et al., 2018). Permeable pavement includes pavements and pavers that have void spaces that permit runoff to flow through them (Dietz, 2007). After the runoff flows through the pavement, it is stored in an underground stone base before infiltrating into the ground or discharging from an underdrain (Bean et al., 2007). Permeable pavers are particularly efficient at removing heavy metals, oils, and

grease in the runoff (Barrett, 2008). In addition, permeable pavement also helps remove nutrients such as phosphorous and nitrogen (Dietz, 2007). As runoff infiltrates through the porous surface, soil and engineered media filter pollutants (Fletcher et al., 2018). The void spaces in the permeable pavement surface and reservoir layers provide storage capacity for runoff, thereby reducing peak volume (Bean et al., 2007). By implementing permeable pavement systems, we can effectively manage stormwater runoff and mitigate the negative impacts of urbanization on water quality, while also providing a durable and functional pavement surface (Barrett, 2008).



Figure 2.11: Permeable Concrete Paver (Source: [thepavercompany.com](http://thepavercompany.com), 2022).

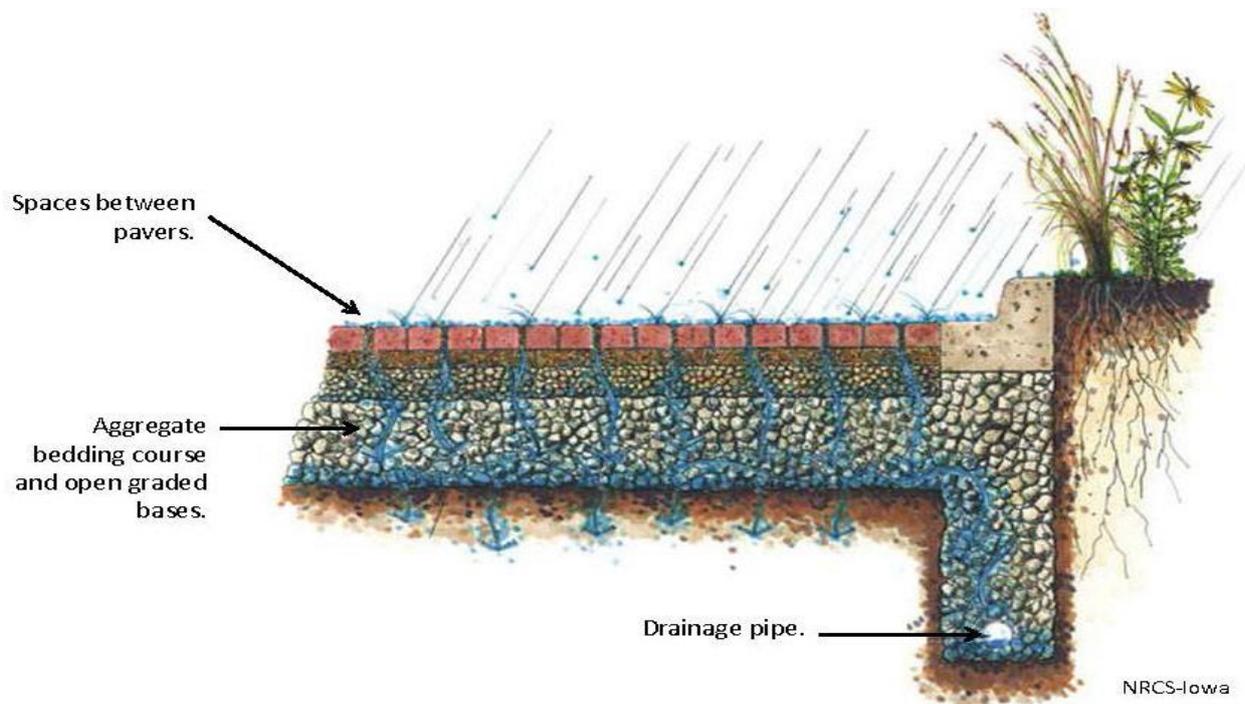


Figure 2.12: Permeable Concrete Paver Section (Source: [metrobloms.org](http://metrobloms.org), 2017).

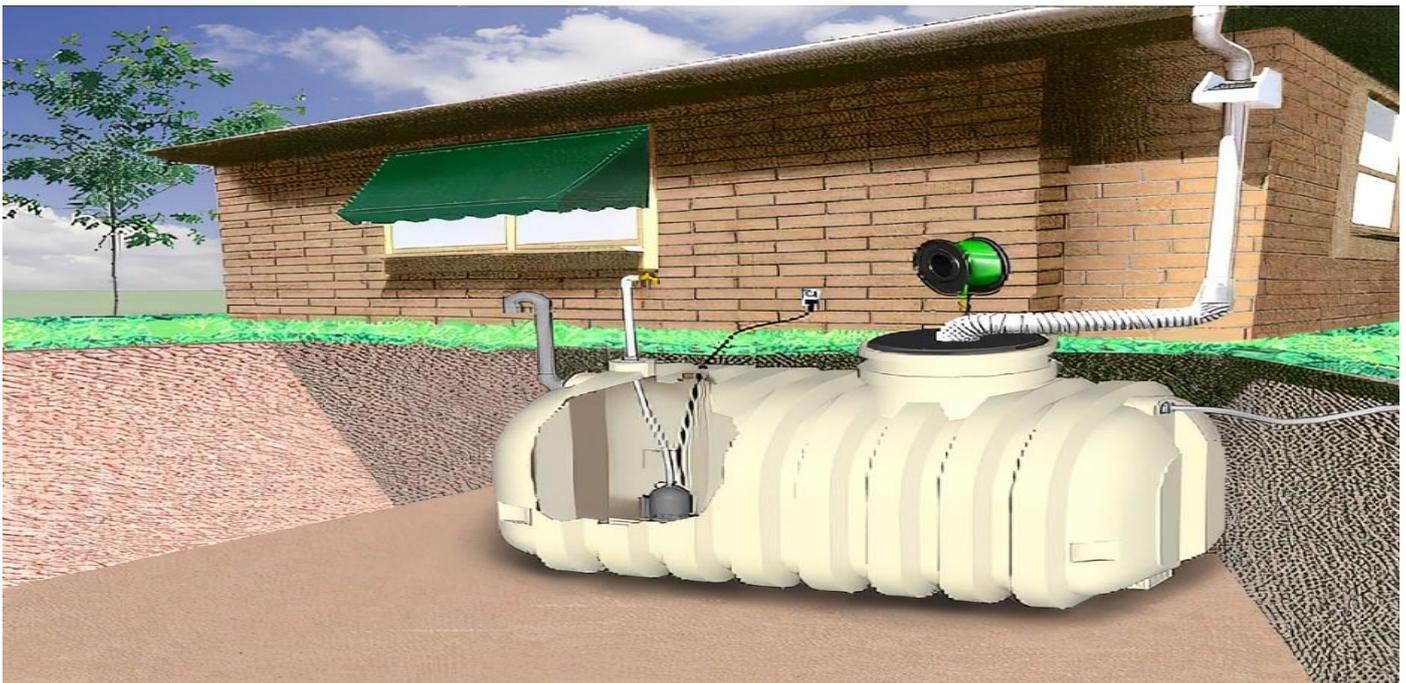
### 2.3.2.3 Use of Underground Storage Systems

Underground storage systems are an effective way to manage stormwater runoff by detaining it in receptacles located beneath the surface of roadways, parking lots, or athletic fields (EPA, 2017). They can also be used in private compounds (Wong, 2017). These systems have varying designs, including culverts, engineered stormwater detention vaults, or perforated pipes, and they slowly release the detained runoff (Fletcher et al., 2018). Compared to other green infrastructure practices, underground storage has the advantage of not occupying additional surface area, making it particularly useful in areas where space is limited (Dietz, 2007). These systems are usually designed to store large volumes of runoff and can have a significant impact in reducing the risks of flooding and peak discharges (Wong, 2017). By holding back large volumes of water, underground storage systems provide time for water to percolate into the soil or to be slowly released through other green infrastructure practices (EPA, 2017). This helps to minimize the impact of large storm events on downstream areas and protect critical infrastructure (Fletcher et al., 2018). These tanks come in

different materials, including polyethylene tanks, fiberglass tanks, and concrete tanks (ASCE, 2014).

#### Polyethylene Tanks

Polyethylene underground water tanks have gained popularity due to their numerous advantages (Aladenola & Adekitan, 2012). Firstly, these tanks are lightweight, making them easy to transport and install (Khan et al., 2015). They require less labour and equipment during installation, resulting in cost savings (Ariaratnam et al., 2013). Additionally, their flexibility allows them to withstand ground movements, reducing the risk of cracking or damage (Hufenus et al., 2016). On the downside, polyethylene tanks have limitations in terms of capacity (Khan et al., 2015). They are available in smaller sizes, making them more suitable for residential or small-scale applications (Aladenola & Adekitan, 2012). Moreover, they are not as durable as concrete tanks and may be susceptible to punctures or damage from sharp objects (Hufenus et al., 2016). Cost is another consideration, as polyethylene tanks can be relatively more expensive compared to other materials (Ariaratnam et al., 2013). However, their lower installation and maintenance costs may offset this initial investment (Khan et al., 2015).



**Figure 2.13: Polyethylene Underground Rain Tank**  
(Source: rainharvest.co.za, 2013). **Fibreglass (GRP) Tanks**

GRP (glass reinforced plastic) underground water tanks are lightweight in nature, making them easier to handle and install compared to concrete tanks (Al-Sharif, 2017). Their lightweight construction also reduces transportation costs (Khan et al., 2015). Additionally, fibreglass tanks are highly resistant to corrosion, making them suitable for long-term use without the risk of rust or degradation (Awad et

al., 2014). Another advantage is their versatility in terms of shape and size (Al-Sharif, 2017). Fibreglass tanks can be customised to fit specific requirements, allowing for a tight fit in limited spaces. They also have excellent insulation properties, helping to maintain water temperature (Khan et al., 2015). However, fibreglass (GRP) tanks do have some disadvantages to consider as well. They can be more

expensive compared to other options such as plastic tanks (Ariaratnam et al., 2013). Also, if they are exposed to UV light, they can degrade over time and weaken the structure

(Awad et al., 2014), however, if installed underground, this will minimize the UV rays affecting it (Al-Sharif, 2017).



**Figure 2.14 Fibreglass (GRP) Underground Rain Tank**

*(Source: rainharvest.com, 2019).*

### Concrete Tanks

Concrete underground water tanks can be constructed precast or in situ (Kumar et al., 2017). They have their own set of advantages and disadvantages. One of the major advantages of concrete tanks is their durability (Al-Sharif, 2017). They are known for their strength and longevity, with the ability to withstand harsh weather conditions and external forces (Khan et al., 2015). Concrete tanks also have a larger capacity, making them suitable for commercial or industrial applications (Ariaratnam et al., 2013). Another advantage of concrete tanks is their thermal properties. They have excellent insulation,

which helps to maintain the temperature of the stored water (Kumar et al., 2017). Along with advantages, there are some disadvantages to consider with concrete underground water tanks. Firstly, concrete tanks are heavy and require heavy machinery for installation, resulting in higher installation costs (Al-Sharif, 2017). They also have a longer installation time compared to other options (Khan et al., 2015). Another drawback is the possibility of cracks or leakages over time. Concrete is prone to cracking due to ground movement or settling, which can lead to water loss or contamination (Ariaratnam et al., 2013).



**Figure 2.15: Concrete Underground Rain Tank (Source: Rain Brothers, 2023).**

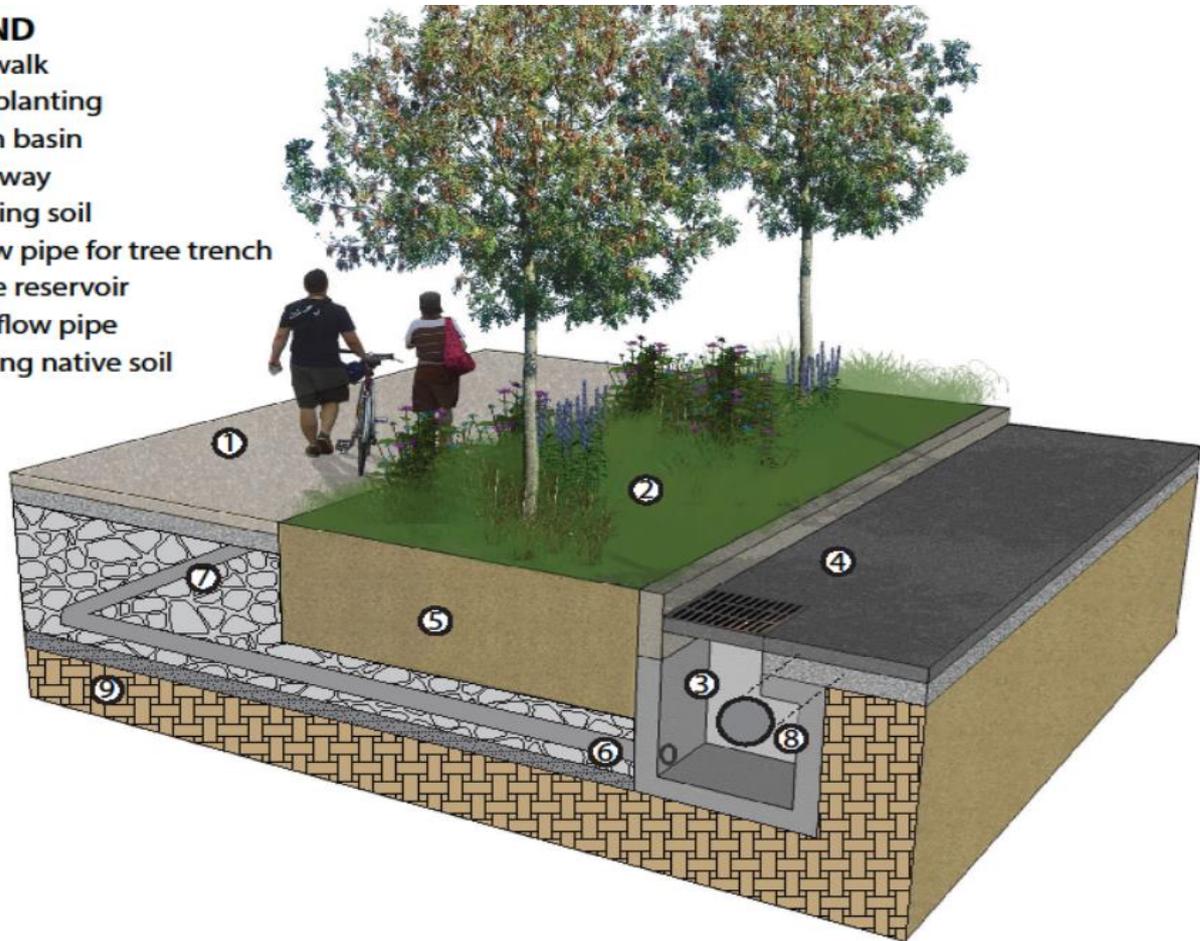
### 2.3.2.4 Use of Stormwater Tree Trench

A stormwater tree trench is an effective technique to collect and filter stormwater runoff (Cunningham, 2017). This is achieved by a line of trees that are planted in an engineered trench that is designed to hold and infiltrate runoff (Dayton, 2013). The trees appear like any other planted tree on the surface level, however, they are planted in a trench that is specially engineered with layers of soil and gravel (Lefevre

et al., 2016). The trench filters and temporarily stores stormwater runoff, allowing it to slowly infiltrate into the ground (Cunningham, 2017). By doing so, stormwater tree trenches improve water quality and reduce the volume of runoff, providing multiple benefits (Dayton, 2013). These trenches are increasingly being used as a green infrastructure practice to help reduce the negative impacts of urbanization on natural hydrologic systems (EPA, 2017).

#### LEGEND

1. Sidewalk
2. Tree planting
3. Catch basin
4. Roadway
5. Planting soil
6. Inflow pipe for tree trench
7. Stone reservoir
8. Overflow pipe
9. Existing native soil



*Figure 2.16: Section Through a Stormwater Tree Trench (Source: Winchester, 2024).*

### 2.3.2.5 Use of Retention Pond

A way to manage stormwater is through the implementation of a retention pond (EPA, 2017). It is considered a more traditional type of stormwater infrastructure, which has been integrated into grey infrastructure design (Schueler, 1994). A retention pond is an engineered basin designed to store runoff and release it at a controlled rate while maintaining a level of ponded water (Wu et al., 2016). The basin is designed to reduce pollutants and sediment loads as the runoff is retained in the pond (Hunt et al., 2017). Adding sustainable elements to the design of retention ponds can increase water quality and decrease peak discharges (Dietz, 2007). Vegetated forebays may be added to increase sediment removal as well as provide habitat (Brunner et al., 2017). A further improvement to traditional retention ponds is the use of an iron-enhanced sand filter bench that

removes dissolved substances such as phosphorus from runoff (Collins et al., 2010). Retention ponds have been widely used as a stormwater management practice (EPA, 2017). They are designed to temporarily store stormwater and allow pollutants and suspended solids to settle out before the water is released into waterways (Wu et al., 2016). The basin can also provide recreational benefits and enhance the aesthetics of the surrounding environment (Dietz, 2007). However, the effectiveness of retention ponds can be limited by their size, and they may not provide long-term water quality benefits (Hunt et al., 2017). Adding sustainable elements to the design of retention ponds can help improve their overall effectiveness (Brunner et al., 2017). For example, using a vegetated forebay can increase sediment removal, while the use of an iron-enhanced sand filter bench can help remove dissolved substances such as phosphorus from runoff (Collins et al., 2010)



**Figure 2.17: Section Through a Stormwater Retention Pond**  
(Source: Western Environmental Liner, 2020).

### 2.3.2.6 Use of Extended Detention Wetlands

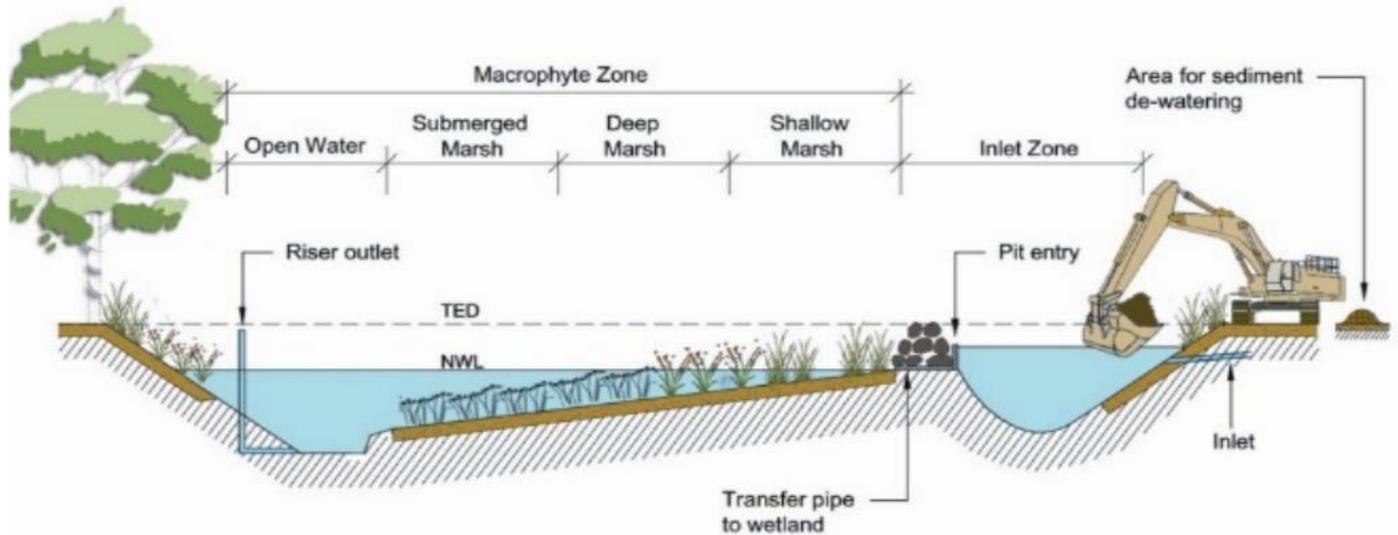
Extended detention wetlands are a valuable green infrastructure practice that can provide a range of benefits including flood mitigation, water quality improvement, and ecological benefits (Mitsch & Gosselink, 2015). These wetlands are designed to store floodwater during a storm and release it slowly to reduce peak flows, which can help to prevent flooding (Wu et al., 2016). The extended detention period provides additional flood storage capacity while also enhancing water quality and providing ecological benefits (Hunt et al., 2017). Extended detention wetlands can be created, restored, or enhanced existing wetlands (EPA, 2017). These wetlands are typically designed as a flood mitigation strategy but can also provide ecological and water quality benefits (Mitsch & Gosselink, 2015). Although extended detention wetlands can require large land areas, they offer significant flood storage benefits (Wu et al., 2016). As stormwater flows into the wetland, it is slowed down and allowed to remain in the wetland area for an extended period (Hunt et al., 2017). This extended detention period enables the wetland to provide increased flood storage and water quality benefits (EPA, 2017). Extended detention wetlands are different from the preservation of existing wetlands, but the two practices are often considered together as part of a watershed-based strategy (Mitsch & Gosselink, 2015). Wetlands can be enhanced to create an extended detention period, which provides additional flood storage capacity while also improving water quality and providing ecological benefits

(Wu et al., 2016). Enhancements such as adding vegetation and creating shallow pools can also increase the ecological value of the wetland (Hunt et al., 2017).

The vegetation in the wetland can remove pollutants from the water, while the shallow pools can provide a habitat for aquatic wildlife (Mitsch & Gosselink, 2015). Wetlands are densely vegetated water bodies that use sedimentation and filtration to provide treatment of surface water runoff (EPA, 2017). Wetlands generally consist of an inlet zone (sediment basin) a macrophyte zone, which is a shallow, densely vegetated area; and a high-flow bypass channel, which is typically a wide vegetated swale from the inlet pond around the side of the wetland (Wu et al., 2016). Wherever possible wetlands should be the last stage of the SuDS management train and should be one of the last treatment stages, otherwise, there's a risk of extensive siltation (unless there is upstream treatment) (Hunt et al., 2017). They remove fine sediments, metals, particulates, and dissolved nutrients (Mitsch & Gosselink, 2015). Wetlands mainly treat polluted runoff, provide attenuation, and deliver biodiversity and amenity (EPA, 2017). Increasingly they're also being used as a valuable educational resource (Wu et al., 2016). Wetlands can be constructed on a variety of scales (Hunt et al., 2017). In highly urbanized areas, wetlands can have a hard edge or be part of the streetscape or other hard landscaping features and furniture (Mitsch & Gosselink, 2015). They must be appropriately sized for the catchment to ensure the hydraulics support water treatment (EPA, 2017). Upstream

components both control the flow and level of siltation allowing wetlands and ponds to polish the runoff (Wu et al., 2016). This is achieved by ensuring water flows slowly through the wetland over an extended period of time (known as the residence time) (Hunt et al., 2017). An

important mechanism is also the breakdown of oils by natural organisms (Mitsch & Gosselink, 2015). They need a good supply of oxygen which means the permanent water must be shallow enough so that oxygen can reach the bottom of the wetland (EPA, 2017).



**Figure 2.18 Section Through a Constructed Extended Detention Wetland**  
(Source: WSUD Engineering, 2012).

### 2.3.4 Challenges and Limitations of Architectural Adaptation Strategies

Despite the potential benefits of architectural adaptation strategies, several challenges and limitations have been identified. One major challenge is the high initial cost of implementing these strategies, which may make them unaffordable for many people and organizations (Efe and Opoko, 2020). In addition, there is often a lack of public awareness and acceptance of these strategies, which may limit their effectiveness (Akande et al., 2020). Other challenges include limited space availability, the need for regular maintenance and monitoring, and the potential for unintended consequences such as increased air pollution from blue roofs (Sarai and Oloke, 2021).

### 2.3.5 Policy and Governance Implications

The success of architectural adaptation strategies in mitigating perennial pluvial flooding in Port Harcourt Metropolis depends on effective policy and governance. Researchers have emphasized the importance of stakeholder engagement, multi-sectoral collaboration, and the development of regulatory frameworks that promote resilient urban design and construction practices. For example, Enaruvbe et al. (2021) argue that effective governance requires the involvement of all stakeholders, including government agencies, NGOs, and community groups, in decision-making processes related to flood management. Additionally, they suggest the need for regulations and incentives to promote the adoption of architectural adaptation strategies.

Overall, the existing literature on architectural adaptation strategies to mitigate perennial pluvial floods in Port Harcourt Metropolis provided valuable insights into the challenges, limitations, and opportunities associated with flood management in the city. However, further research is needed to evaluate the effectiveness of these strategies in the local context and to explore the potential for their integration with other approaches such as nature-based solutions.

### 2.3.6 Urban Drainage and Water Management Systems

Perennial pluvial flooding is a recurring problem in urban areas, causing damage to infrastructure, disrupting economic activities, and posing health risks to residents (Marsalek et al., 2016). Urban drainage and water management systems play a critical role in curbing perennial pluvial flooding by managing stormwater runoff and preventing flooding (EPA, 2017). This empirical review section provides an overview of urban drainage and water management systems as they relate to curbing perennial pluvial flooding, including their components, functions, challenges, and innovative solutions.

#### 2.3.4.1 Components of Urban Drainage and Water Management Systems for Curbing Perennial Pluvial Flooding

Urban drainage and water management systems for curbing perennial pluvial flooding consist of various components, including:

**1. Stormwater drainage systems:** These systems collect and convey stormwater runoff from urban surfaces, such as roads, sidewalks, and buildings (Wu et al., 2016).

**2. Green infrastructure:** This includes natural or engineered systems that mimic natural processes to manage stormwater runoff, such as green roofs, rain gardens, and urban wetlands (EPA, 2017).

**3. Flood control structures:** These structures, such as levees, dams, and floodwalls, help prevent flooding by controlling the flow of stormwater runoff (Marsalek et al., 2016).

**4. Water treatment plants:** These facilities treat wastewater and stormwater runoff to remove pollutants and contaminants before discharging the treated water into waterways (Metcalf & Eddy, 2014).

#### **2.3.4.2 Functions of Urban Drainage and Water Management Systems for Curbing Perennial Pluvial Flooding**

Urban drainage and water management systems for curbing perennial pluvial flooding perform several critical functions, including:

**1. Flood control:** These systems help prevent flooding by collecting and conveying stormwater runoff away from urban areas (Wu et al., 2016).

**2. Stormwater runoff management:** Urban drainage and water management systems manage stormwater runoff by reducing peak flows and improving water quality (EPA, 2017).

**3. Water quality protection:** These systems help protect water quality by removing pollutants and contaminants from stormwater runoff and wastewater (Marsalek et al., 2016).

**4. Public health protection:** Urban drainage and water management systems help protect public health by preventing the spread of waterborne diseases and reducing exposure to pollutants and contaminants (Metcalf & Eddy, 2014).

#### **2.3.4.3 Challenges Facing Urban Drainage and Water Management Systems for Curbing Perennial Pluvial Flooding**

Urban drainage and water management systems for curbing perennial pluvial flooding face several challenges, including:

**1. Aging infrastructure:** Many urban drainage and water management systems are aging and in need of repair or replacement (EPA, 2017).

**2. Climate change:** Climate change is altering precipitation patterns, leading to more frequent and intense storms that

can overwhelm urban drainage and water management systems (Wu et al., 2016).

**3. Urbanization:** Urbanization is leading to increased impervious surfaces, which can increase stormwater runoff and overwhelm urban drainage and water management systems (Marsalek et al., 2016).

**4. Funding constraints:** Urban drainage and water management systems require significant funding to maintain, repair, and upgrade, which can be a challenge for municipalities with limited budgets (Metcalf & Eddy, 2014).

#### **2.3.4.4 Innovative Solutions for Urban Drainage and Water Management Systems for Curbing Perennial Pluvial Flooding**

Several innovative solutions have been proposed to address the challenges facing urban drainage and water management systems for curbing perennial pluvial flooding, including:

**1. Green infrastructure:** Green infrastructure, such as green roofs, rain gardens, and urban wetlands, can help manage stormwater runoff and reduce the burden on urban drainage and water management systems (EPA, 2017).

**2. Smart drainage systems:** Smart drainage systems, which use sensors and real-time monitoring to optimize drainage system performance, can help reduce flooding and improve water quality (Wu et al., 2016).

**3. Water-sensitive urban design:** Water-sensitive urban design, which incorporates urban design principles that reduce stormwater runoff and improve water quality, can help reduce the burden on urban drainage and water management systems (Marsalek et al., 2016).

**4. Decentralized water management:** Decentralized water management, which involves managing water at the local level through decentralized systems, can help reduce the burden on urban drainage and water management systems (Metcalf & Eddy, 2014).

Urban drainage and water management systems are critical components of urban infrastructure, playing a vital role in managing stormwater runoff, preventing flooding, and protecting water quality. However, these systems face numerous challenges, including aging infrastructure, climate change, urbanization, funding constraints, and institutional and regulatory challenges. To address these challenges, innovative solutions such as green infrastructure, smart drainage systems, water-sensitive urban design, and decentralized water management must be implemented. Additionally, public education and awareness, environmental justice and equity, and technological advancements are essential for ensuring the

sustainability and resilience of urban drainage and water management systems. Ultimately, a holistic and integrated approach to urban drainage and water management is necessary to protect the health, safety, and well-being of urban residents, while also preserving the environment and promoting sustainable urban development.

## **2.4 Literature Gap**

The literature gap in this empirical review is the lack of research on the effectiveness of architectural adaptation strategies in mitigating perennial pluvial floods in Port Harcourt Metropolis. While the review discusses various architectural adaptation strategies, such as permeable pavements, blue roofs, and underground storage systems, it notes that further research is needed to evaluate the effectiveness of these strategies in the local context.

Additionally, the review highlights the need for more research on the integration of architectural adaptation strategies with other approaches, such as nature-based solutions, to address perennial pluvial flooding in Port Harcourt Metropolis.

Overall, the literature gap suggests that there is a need for further research on the effectiveness of architectural

adaptation strategies in mitigating perennial pluvial floods in Port Harcourt Metropolis, as well as on the potential for integrating these strategies with other approaches to achieve more effective and sustainable flood management outcomes.

Finally, while several studies propose recommendations, none have developed a comprehensive Flood Resilient Design Framework (FRDF) tailored to Port Harcourt Metropolis. The proposed FRDF should integrate innovative architectural adaptation strategies, stakeholder involvement, and actionable policy recommendations into a unified system. Existing research does not synthesize these components into a cohesive framework that addresses the city's specific vulnerabilities and promotes long-term resilience. This gap represents a critical opportunity for this study to contribute substantively to the discourse on urban flood resilience in Port Harcourt.

Thus, in addressing these gaps, the proposed research can bridge existing knowledge deficits and advance practical solutions for managing perennial pluvial flooding in Port Harcourt metropolis.

**METHODOLOGY**

This section outlines the various techniques employed to collect the relevant data for this study. It describes the sources of data and the methods used to gather information from the selected areas of Port Harcourt Metropolis. It utilized an “ex-post-facto” research which implies that the researcher did not manipulate or modify actions or behaviours that have already occurred. Reliance was on how floods, especially the 2021 floods, affected mitigation measures in the study area.

**3.1 Research Philosophy, Approach and Design**

This study adopted a pragmatic research paradigm, which is suitable for addressing real-world problems like urban flooding. A pragmatic approach allows the combination of qualitative and quantitative methods, focusing on practical solutions that are grounded in evidence. This paradigm helped to explore both the causes and potential solutions to pluvial flooding through empirical data collection and analysis. Additionally, the research design for this study focused on investigating architectural strategies that can mitigate the persistent issue of pluvial flooding in Port Harcourt Metropolis. The design aimed to explore sustainable architectural interventions and how they could be integrated into urban planning practices to reduce the adverse effects of flooding. However, this research combined both qualitative and quantitative approaches to gather comprehensive data and insights on the architectural strategies that can mitigate the persistent issue of pluvial flooding in Port Harcourt Metropolis.

This study adopted a mixed-methods research design, combining both qualitative and quantitative research techniques. The qualitative aspect of this research explored in-depth insights into the architectural features and flood mitigation measures from both expert and community perspectives. Case study research was used to examine specific neighborhoods within Port Harcourt Metropolis that are particularly vulnerable to pluvial flooding. Additionally, through direct observations and interviews with residents, urban planners, and local officials, the study gathered rich, descriptive data on the effectiveness of current flood mitigation strategies.

Expert interviews also formed a key part of the qualitative research, targeting professionals such as architects, environmental scientists, urban planners, and flood management experts. These interviews provided expert insights into the most feasible and effective architectural strategies for mitigating pluvial flooding. In addition, focus group discussions were conducted with a range of local stakeholders, including residents, community leaders, and policymakers. These discussions gathered diverse opinions

on the current state of flood mitigation efforts and explore potential new strategies.

The quantitative component of the study provided objective data to complement the qualitative findings and offered statistical evidence on flood risks and mitigation strategies. Surveys were administered to residents, property owners, and local government officials in flood-prone areas of Port Harcourt Metropolis. The survey gathered data on the level of awareness among residents about pluvial flooding, current flood mitigation measures in place, and their views on various architectural strategies for flood prevention. The survey used a mix of Likert scale questions to measure attitudes and perceptions, along with close-ended questions. This approach allowed for the quantification of public knowledge and opinions, as well as the identification of patterns in attitudes towards flood resilience.

In addition, spatial analysis and mapping using Geographic Information System (GIS) tools was employed to map stratified flood-prone areas in Port Harcourt Metropolis, and analyzed the relationship between urban development patterns, existing infrastructure, and the architectural features that influence flooding.

Finally, the study incorporated flood impact data analysis. This involved doing an urban flood vulnerability assessment of the selected areas in Port Harcourt Metropolis. It is essential for developing effective flood risk reduction and management strategies. Statistical tools were used to analyze this data and explore the relationship between specific architectural features and the occurrence of flooding.

**3.2 Population and Sampling**

In order to develop effective architectural adaptation strategies to mitigate perennial pluvial floods in Port Harcourt Metropolis, it became essential to understand the characteristics of the population affected by flooding in the study area. This area focused on the population and sampling method used in this research.

The population consisted of residents and stakeholders in the flood-prone areas of Port Harcourt Metropolis. A well-designed sampling strategy is crucial to ensure that the sample is representative of the population, allowing for generalizable findings. This section outlined the population characteristics, sampling frame, sampling technique, and sample size determination, providing a foundation for the data collection and analysis that followed.

**3.2.1 Population**

The targeted population for the study on Architectural Adaptation Strategies to Mitigate Perennial Pluvial Floods

in Port Harcourt Metropolis include various stakeholders and groups directly or indirectly involved in addressing pluvial flooding challenges. Stratified sampling technique was used to get the population into 6 key stakeholder groups.

**Residents of Flood-Prone Areas:** Based on the work of Wizor & Mpigi, (2020) on the 25 most-flooded roads in Port Harcourt Metropolis. Using purposive sampling technique, 13 regions (streets/roads) were chosen from the 25 most-flooded roads/streets in Port Harcourt Metropolis. 4 streets/roads were chosen from low-flooded areas, 5 from moderately-flooded areas, and 4 from high-flooded areas. A total of 13 streets/roads were considered for this research. However, Residents from these 13 selected flood-prone areas in Port Harcourt Metropolis form a key part of the population. These individuals provided valuable insights into local experiences with flooding, awareness of flood risks, and opinions on both existing and potential architectural strategies for flood mitigation. Also using purposive sampling technique, From each of the 13 areas, 20 compounds were selected, with one respondent per compound, resulting in a total of 260 respondents from this group.

**Urban Planners and Architects:** Professionals such as urban planners and architects are integral to the study, offering expert opinions on design and urban development strategies aimed at reducing flood risks. The research focuses on members of the Nigerian Institute of Town Planners (Rivers State branch), which has 570 members,

and the Nigerian Institute of Architects (Rivers State branch), comprising 240 fully registered members. These professionals provide insights into the most effective architectural solutions for mitigating pluvial flooding.

**Government Officials:** Officials from relevant state ministries in Port Harcourt also form part of the population. These include the Rivers State Ministry of Urban Development and Physical Planning, with 84 staff members, River State Ministry of Housing with 134 staff, and the Rivers State Ministry of Environment, with 102 staff members. Their perspectives on flood management practices, policies, and regulations are crucial for understanding the institutional framework required to implement architectural adaptation strategies.

**Community Leaders:** Community leaders from the 13 selected flood-prone areas were included to represent the views of the broader community. These leaders play a critical role in advocating for local concerns and influencing decision-making processes related to flood mitigation. Two leader or such as street chairman and a member were selected from each flood area, making a total of 26 stakeholders in this category.

In summary, the total targeted population for this study is 1,416 individuals, encompassing residents, professionals, government officials, and community leaders who are directly or indirectly involved in addressing the challenges posed by pluvial flooding in Port Harcourt Metropolis (See Table 3.1)

*Table 3.1: Population of the Study*

<b>Population of the Study</b>	
<b>Stakeholders</b>	<b>Populations</b>
Residents of flood-prone areas	260
Nigerian Institute of Town Planners, Rivers State branch	570
The Nigerian Institute of Architects (Full Members)	240
Rives State Ministry of Urban Development	84
Rivers State Ministry of Environment	102
River State Ministry of Housing	134
Community Leaders of flood prone areas	26
<b>Total</b>	<b>1416</b>

*Source: Fieldwork (2024)*

### 3.2.2 Sample Frame

The sample frame for this study, "Architectural Adaptation Strategies to Mitigate Perennial Pluvial Floods in Port Harcourt Metropolis", was thoughtfully developed to include a broad range of stakeholders with diverse roles and experiences related to flood mitigation. The approach ensured a balanced representation of opinions from individuals and institutions who are directly impacted or involved in addressing flooding challenges in the study area.

The study employed a purposive sampling technique, targeting 50% of the total population from six key stakeholder groups. This sampling approach was chosen to ensure that the sample was representative of the population most affected by pluvial flooding, while also allowing for in-depth analysis and rich data collection. By focusing on a significant proportion (50%) of the population, the study aimed to capture diverse perspectives and experiences, enhancing the validity and reliability of the findings. The purposive sampling technique enabled the researcher to selectively target participants who were most knowledgeable about the research problem, thereby providing valuable insights into the causes, impacts, and potential solutions to pluvial flooding in the study area.

Residents of flood-prone areas constituted a significant portion of the sample frame, with 130 participants selected from a population of 260. This group provided firsthand accounts of the flooding issues they faced, offering valuable insights into the effectiveness of existing measures and highlighting the areas requiring improvement for better flood resilience.

The Nigerian Institute of Town Planners (Rivers State Branch) represented the largest group in the sample, with 285 participants selected out of 570. Town planners bring critical expertise to the study as they are responsible for urban development and zoning regulations. Their contributions helped evaluate how planning practices can mitigate flooding in urban areas.

The Nigerian Institute of Architects played a crucial role, contributing 120 participants from its total membership of 240.

Architects are vital in designing buildings and infrastructure to withstand flooding. Their input focused on assessing existing designs and recommending solutions tailored to the challenges posed by recurrent pluvial flooding in the region.

Officials from the Rivers State Ministry of Urban Development and Physical Planning were also included, with 42 selected from a population of 84. This group represents government involvement in urban planning and policy-making, ensuring that the study reflected institutional perspectives and strategies currently in place to manage urban flooding.

The Rivers State Ministry of Environment contributes 51 participants from a population of 102. Their expertise provides an understanding of the environmental dimensions of flooding, including its causes, impacts, and the role of sustainable practices in mitigating its effects.

The Rivers State Ministry of Housing contributes 67 participants from a total population of 134. Their specialized knowledge offers valuable insights into the environmental aspects of flooding, encompassing its underlying causes, consequences, and the importance of sustainable practices in addressing its challenges.

Finally, community leaders from flood-prone areas are represented by 13 individuals from a total of 26. These leaders provide collective insights on how floods affect local communities and the social and cultural dimensions of flood management. Their involvement ensures that community needs and priorities are well-represented in the findings.

In total, the sample frame includes 708 participants, drawn from a population of 1,416 across the seven stakeholder groups. By incorporating inputs from residents, professionals, government agencies, and community leaders, the study ensures a comprehensive understanding of the flooding problem. This diversity strengthens the analysis and helps develop practical, inclusive, and sustainable architectural strategies to address pluvial flooding in Port Harcourt Metropolis (See Table 3.2).

**Table 3.2: Sampling Frame using half Population of the Study**

<b>Sample frame using half population of the study</b>		
<b>Stakeholders</b>	<b>Populations</b>	<b>Sample Frame</b>
Residents of flood-prone areas	260	130
Nigerian Institute of Town Planners, Rivers State branch	570	285
The Nigerian Institute of Architects (Full Members)	240	120
Rivers State Ministry of Urban Development	84	42
Rivers State Ministry of Environment	102	51
Rivers State Ministry of Housing	134	67
Community Leaders of flood prone areas	26	13
<b>Total</b>	<b>1416</b>	<b>708</b>

*Source: Fieldwork (2024)*

### 3.2.3 Sample size

The sample size for the research “Architectural Adaptation Strategies to Mitigate Perennial Pluvial Floods in Port Harcourt Metropolis” was determined using the Taro Yamane formula. This statistical approach ensures the selection of a representative sample that accurately reflects the target population while minimizing sampling error. The study drew participants from seven key stakeholder groups, resulting in a total sample size of 512 individuals from an initial sample frame of 708. The Formula for Taro Yamane method is statistically given as follows:

$$n = \frac{N}{1+N(e)^2}$$

Where n = sample size

N = Population size

e = Level of significance or allowable error

1 = a constant

However, for each stakeholder, the estimated sample size was obtained for the sample frame of the population, for example, using the residents of flood prone area with a sample frame of 130 stakeholder for illustration, the Taro Yamane formula is thus substituted.

$$\begin{aligned} n &= \frac{130}{1 + 130 (0.05)^2} \\ &= \frac{130}{1 + 130 (0.0025)} \\ &= \frac{130}{1.325} = 98 \end{aligned}$$

*Table 3.3: Sample Size using Taro Yamane Method*

<b>Sample Size using Taro Yamane</b>		
<b>Stakeholders</b>	<b>Sample Frame</b>	<b>Sample Size</b>
Residents of flood-prone areas	130	98
Nigerian Institute of Town Planners, Rivers State branch	285	166
The Nigerian Institute of Architects (Full Members)	120	92
Rivers State Ministry of Urban Development	42	41
Rivers State Ministry of Environment	51	45
Rivers State Ministry of Housing	67	57
Community Leaders of flood prone areas	13	13
<b>Total</b>	<b>708</b>	<b>512</b>

*Source: Fieldwork (2024)*

The Residents of Flood-Prone Areas constituted a significant portion of the sample size, with 98 participants selected from a sample frame of 130. The Nigerian Institute of Town Planners, Rivers State Branch had the largest sample frame of 285 members, from which 166 were selected. From the Nigerian Institute of Architects (Full Members), 92 individuals were selected from a sample frame of 120. The Rivers State Ministry of Urban Development and Physical Planning had a sample frame of 42 participants, with 41 selected for the study. The Rivers State Ministry of Environment had a sample size of 45 individuals, drawn from a sample frame of 51. While the Rivers State Ministry of Housing has a sample size of 57 selected from a sample frame of 67.

Finally, the Community Leaders of Flood-Prone Areas, representing grassroots stakeholders, had all 13 members included in the sample size.

In summary, the total sample size of 512 participants encompassed a diverse range of stakeholders, ensuring the study benefited from a broad spectrum of expertise, experiences, and perspectives. This approach enhances the reliability of the findings and supports the development of effective architectural adaptation strategies to mitigate pluvial flooding in Port Harcourt Metropolis.

#### **3.2.4 Sample Technique**

The sampling technique adopted for the study was a combination of stratified and purposive sampling methods. Stratified sampling was employed to divide the population into six key stakeholder groups: residents of flood-prone areas, members of the Nigerian Institute of Town Planners (Rivers State branch), the Nigerian Institute of Architects (full members), officials from the Rivers State Ministry of Urban Development and Physical Planning, Ministry of Environment, Ministry of Housing, and community leaders of flood-prone areas. This approach ensured that all relevant groups were adequately represented in the study.

Within each stratum, purposive sampling was used to select individuals based on their knowledge, experiences, and direct involvement in issues related to flooding and its strategies for mitigation. The sample size of 512 participants was determined using Taro Yamane's formula, which accounts for population size and desired precision level. This process resulted in the proportional selection of participants from each group, including 98 residents of flood-prone areas, 166 members of the Nigerian Institute of Town Planners, 92 architects, 41 officials from the Ministry of Urban Development and Physical Planning, 45 officials from the Ministry of Environment, 57 officials from the Ministry of Housing and 13 community leaders.

Thus, this sampling technique ensured that the study captured diverse perspectives from stakeholders directly

affected and involved in addressing pluvial flooding in Port Harcourt Metropolis. The combination of stratification and purposive selection allowed for a detailed and contextually rich analysis of architectural adaptation strategies to mitigate perennial floods

### **3.3 Instrumentation and Data Collection**

This section outlined the instrumentation and data collection methods employed in this research, including the design and administration of surveys, interviews, and observational studies. The data collection instruments were carefully developed and validated to ensure that they captured the necessary information to address the research questions and objectives. This chapter provided an overview of the data collection process, including data collection techniques, and instrumentation used to gather both qualitative and quantitative data.

#### **3.3.1 Instrumentation**

This research utilized a variety of tools to collect comprehensive data on strategies for architectural adaptation to address recurring urban floods in Port Harcourt Metropolis. The instruments employed included well-structured questionnaires, interviews, and Geographic Information System (GIS) tools, each tailored to extract specific information from relevant stakeholders actively involved in flood management in the city.

The structured questionnaire served as the main instrument for data collection, featuring both closed and open-ended questions. Its purpose was to gather diverse insights from key groups such as government officials, urban developers, architects, residents of affected neighborhoods, and community leaders in areas susceptible to flooding. The questionnaire was organized into sections.

The initial part captured demographic data, including variables like age, gender, education, and professional background. The bio-data of respondents, including demographic characteristics, can inform flood mitigation strategies by identifying vulnerable populations, understanding risk perception and behavior, and designing effective communication strategies. Demographic characteristics can influence how people access and respond to information about flood risk and mitigation strategies, as well as the types of interventions that are most effective in promoting flood mitigation behaviors. Analyzing bio-data can help evaluate the equity and effectiveness of flood mitigation strategies and identify areas for improvement. For example, bio-data can be used to develop targeted communication strategies, adapt flood mitigation strategies for working individuals, and promote flood mitigation behaviors among households with dependent children. By using bio-data, researchers can develop more effective flood mitigation strategies that take

into account the diverse needs and perspectives of different populations.

The latter section addressed the central research themes, including:

1. Which parts of Port Harcourt are most at risk of frequent urban flooding?
2. How does recurring flooding affect the structural integrity, functionality, and comfort of buildings in Port Harcourt?
3. What architectural measures are currently in use to tackle flooding challenges?
4. To what extent are existing architectural interventions effective in reducing flood risks?
5. What innovative and resilient architectural design framework can be proposed for enhancing flood mitigation in Port Harcourt Metropolis?

The questionnaire allowed for in-depth quantitative and qualitative evaluations, providing a broad overview of planning and development practices in the city.

Moreover, GIS tools were essential for collecting and analyzing geographical data from the selected flood-prone areas. Through the use of applications such as ArcGIS, the research examined the spatial patterns of flooding, their vulnerability, and their relationship with urban development. These analyses offered a clearer understanding of the geographical distribution of flooding and complemented the questionnaire results, contributing to actionable recommendations for mitigating flood impacts in Port Harcourt Metropolis.

### 3.3.2 Data Collection

This study employed a mixed-methods approach, integrating both qualitative and quantitative methods to gain an understanding of flood risks and mitigation strategies. Field Observations focused on flood-prone areas, examining drainage systems, building elevations, and construction materials, providing a baseline for adaptation strategies. Document Review was conducted using government reports, urban planning documents, and flood management policies to understand the historical and policy context of flood mitigation in Port Harcourt Metropolis.

Additionally, Surveys were used to gather both expert and community perspectives. Semi-structured interviews were conducted with professionals, including architects, urban planners, and flood management experts, to gain expert insights into effective architectural strategies. Focus group discussions with community leaders were held to explore local views on current flood mitigation measures and potential solutions. Surveys were distributed to residents, property owners, and local government officials to assess

their awareness of pluvial flooding and their opinions on architectural strategies for flood prevention. The surveys combined Likert-scale and close-ended questions, providing statistical data on public knowledge and attitudes.

Finally, GIS mapping was used to create flood risk maps, correlating urban development patterns and architectural features with flood vulnerability. This spatial analysis identified areas most at risk and informed where adaptation measures should be prioritized.

Thus, combining these methods, help to gather rich qualitative and quantitative data to guide the development of effective architectural strategies for flood mitigation in Port Harcourt Metropolis.

### 3.4 Analytical Techniques for Data Collected/ / Analysis

The data obtained from the survey and GIS assessments were carefully organized and prepared for analysis. Responses from the structured questionnaire were initially sorted according to the demographic characteristics of respondents and the study's key research objectives. Descriptive statistical techniques, such as frequency distributions, percentages, and graphical representations, were utilized to interpret the responses. These methods facilitated the identification of participants' views on recurrent pluvial flooding in Port Harcourt Metropolis.

In addition, spatial data analysis was conducted using ArcGIS. The GIS software was instrumental in visualizing and analyzing specific flood-prone areas within the study region. However, in mapping these vulnerable locations, ArcGIS provided valuable spatial context to the survey findings, enabling an understanding of the challenges and solutions related to pluvial flood mitigation in Port Harcourt Metropolis.

The integration of descriptive statistics and GIS analysis ensured that the data was examined from multiple perspectives, contributing to well-rounded insights into strategies for addressing flooding issues in the study area.

### 3.5 Validity and Reliability of Research Instruments

To guarantee the accuracy and dependability of the tools used in this study, a thorough validation process was undertaken. The consistency of the structured questionnaire was evaluated using the test-retest technique. This approach involved administering the same set of questions to a small group of urban planners and other relevant stakeholders within Port Harcourt Metropolis at two different times. This allowed for an assessment of the uniformity in responses, ensuring the questionnaire effectively captured participants' views and experiences related to pluvial flooding and its

mitigation. The variations observed between the two rounds of responses were reviewed, and modifications were made to improve the questionnaire's reliability.

Additionally, the GIS tools utilized in this research, particularly ArcGIS, were rigorously tested by a certified GIS specialist before being deployed for data collection. This preliminary evaluation ensured the software's capability to accurately extract and analyze spatial data related to pluvial flooding within the study area. The GIS tools were also assessed to confirm their reliability in providing consistent results throughout the study. This step

was critical in verifying that the spatial data collected was both precise and dependable.

However, in employing the test-retest method for the questionnaire and subjecting the GIS tools to expert evaluation, the study ensured that all research instruments were both valid and robust. These efforts ensured the collection of high-quality, reliable data that was essential for developing effective architectural strategies to mitigate recurring pluvial flooding in Port Harcourt Metropolis. The combined validation process enhanced the credibility of the research findings and supported the study's objectives.

**DATA PRESENTATION AND ANALYSIS**

**4.1 Data Presentation**

The primary and secondary data collected and returned from the field was tabulated and compiled while both descriptive and inferential statistics were used for the analysis. However descriptive statistics such as frequency distribution tables, bar graphs, line graphs and pie charts were used to analyse the characteristics of the data.

**4.2 Analysis and Discussions**

**Demography of Respondents Architectural Adaptation Strategies To Mitigate Perennial Pluvial Floods in Port Harcourt Metropolis**

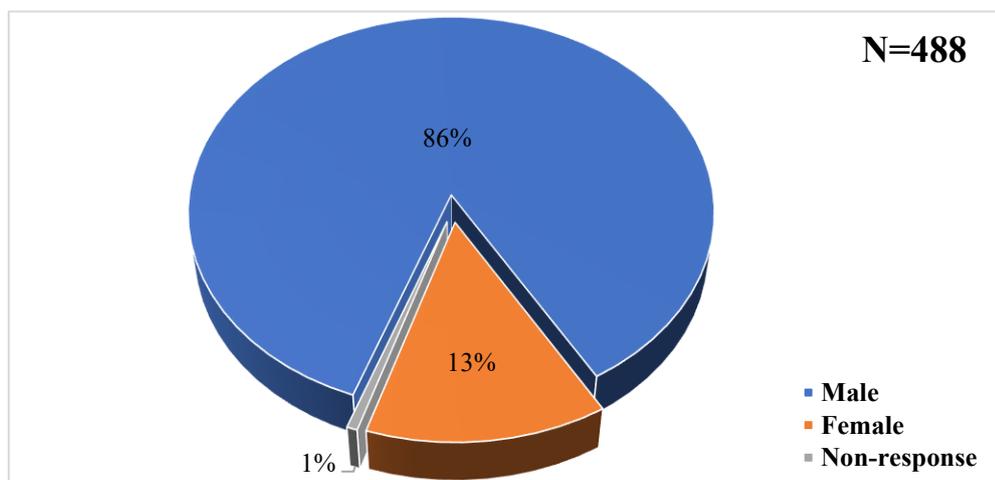
*Table 4.1: Questionnaire Analysis*

<b>Questionnaire Analysis</b>		
<b>Questionnaire</b>	<b>Frequency (F)</b>	<b>Percentages (%)</b>
No of Questionnaire Returned	488	95%
No of Questionnaire Not Returned	24	5%
<b>Total Questionnaire Sampled</b>	<b>512</b>	<b>100%</b>

*Source: Fieldwork (2024)*

Table 4.1 shows the analysis of the questionnaire responses on the level of participation and data collection efficiency for the research on Architectural Adaptation Strategies to Mitigate Perennial Pluvial Floods in Port Harcourt Metropolis. However, out of the total 512 questionnaires distributed, an impressive 95% (488) were completed and returned by the respondents. This high return rate demonstrates strong engagement and commitment from the participants, ensuring a robust dataset for the study.

Conversely, only 5% (24) of the questionnaires were not returned, indicating a minimal loss of data and underscoring the effectiveness of the distribution and follow-up process. The near-complete response rate enhances the reliability and representativeness of the result, providing a foundation for analyzing architectural adaptation strategies to address flooding challenges in the study area. This high participation level underscores the importance and relevance of the research topic to the respondents, further validating the study's conclusions and recommendations.



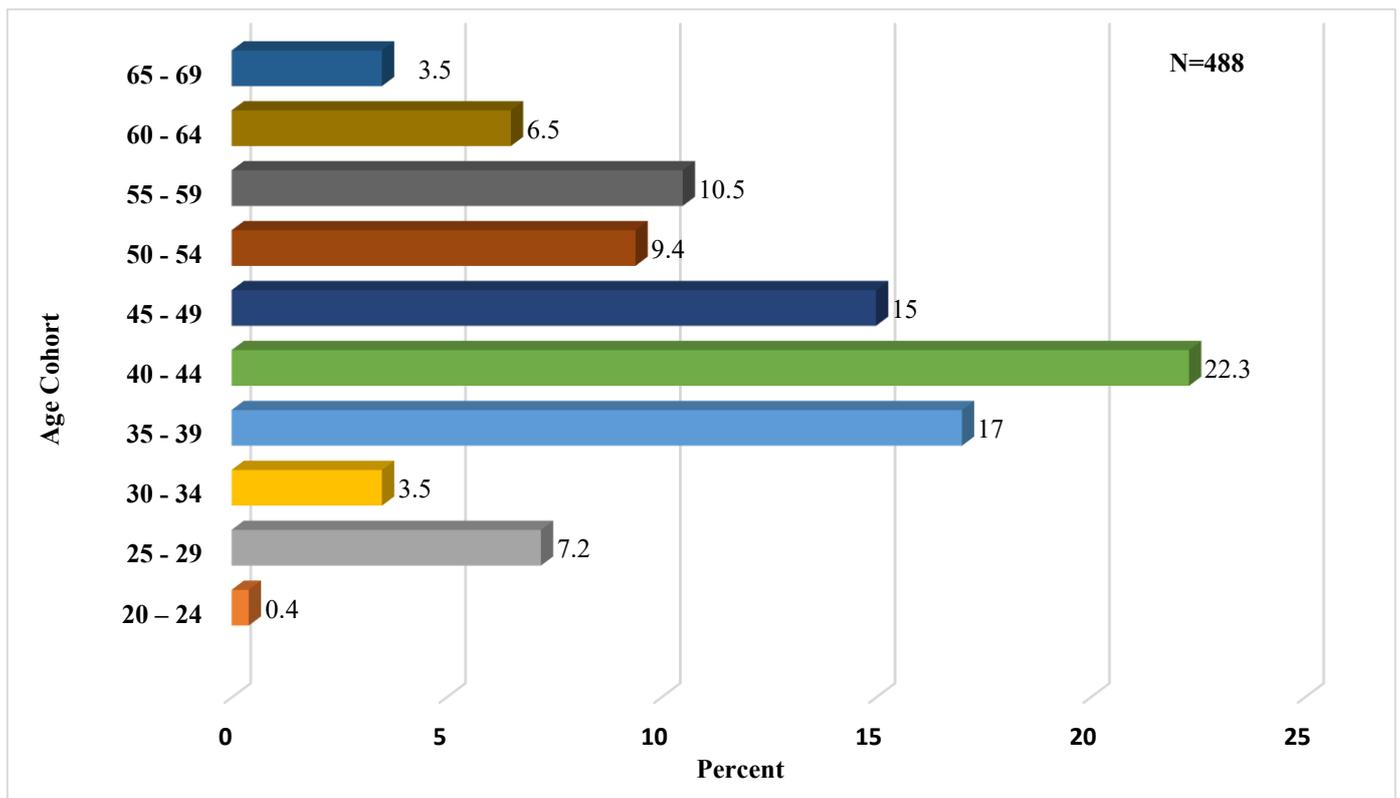
**Fig. 4.1: Percentage Distribution of Gender of Respondents**  
(Source: Generated by Researcher)

Figure 4.1 shows the gender distribution of respondents in the study on architectural adaptation strategies to mitigate perennial pluvial floods in Port Harcourt Metropolis. However, the result reveals a notable disparity, with a higher proportion of male participants. Specifically, 86% of the respondents were male, while 13% were female, and 1% did not provide gender information. This data suggests that men were more likely to engage with the topic of flooding and architectural solutions in the region. Various factors, such as societal roles, cultural norms and the specific nature of this research, may have contributed to the higher male representation in the study.

The relatively small percentage of female participants highlights potential gaps in gender representation when discussing environmental and urban challenges like flooding. Women, particularly in many communities, often play vital roles in resilience building and addressing environmental issues, and their perspectives may offer critical insights into the challenges posed by floods. The underrepresentation of women could result in missing

views on important factors such as household safety, community engagement, and the role of women in flood mitigation strategies. Future studies may consider developing targeted outreach approaches to encourage more female participation, ensuring a more comprehensive understanding of the impact of floods on various demographic groups.

Additionally, the 1% non-response rate for gender is minimal but underscores the importance of complete participation in demographic data collection. The gender distribution in this research suggests that, although the study predominantly reflects male perspectives, efforts should be made to balance the participation of men and women. Thus, in fostering a more inclusive research environment, future studies can ensure that the voices of both genders are adequately represented in the design and implementation of flood mitigation strategies, which ultimately contribute to creating more resilient communities in Port Harcourt Metropolis.



**Fig. 4.2: Percentage Distribution of Age of Respondents**

*(Source: Generated by Researcher)*

Figure 4.2 presents the age distribution of respondents in the research on architectural adaptation strategies to address persistent pluvial floods in Port Harcourt Metropolis. The result reveals a varied demographic composition, with the largest share of respondents falling within middle-aged groups.

The group aged 40-44 years represented the highest percentage, accounting for 22.3% of respondents, closely

followed by those in the 35-39 age range, who made up 17%. These two age groups together form a substantial portion of the sample, suggesting that people in these age brackets are more engaged with issues related to flooding and the architectural solutions needed to address it. This may reflect their heightened responsibility for property and community well-being, which increases their awareness and concern about flood risks and mitigation measures.

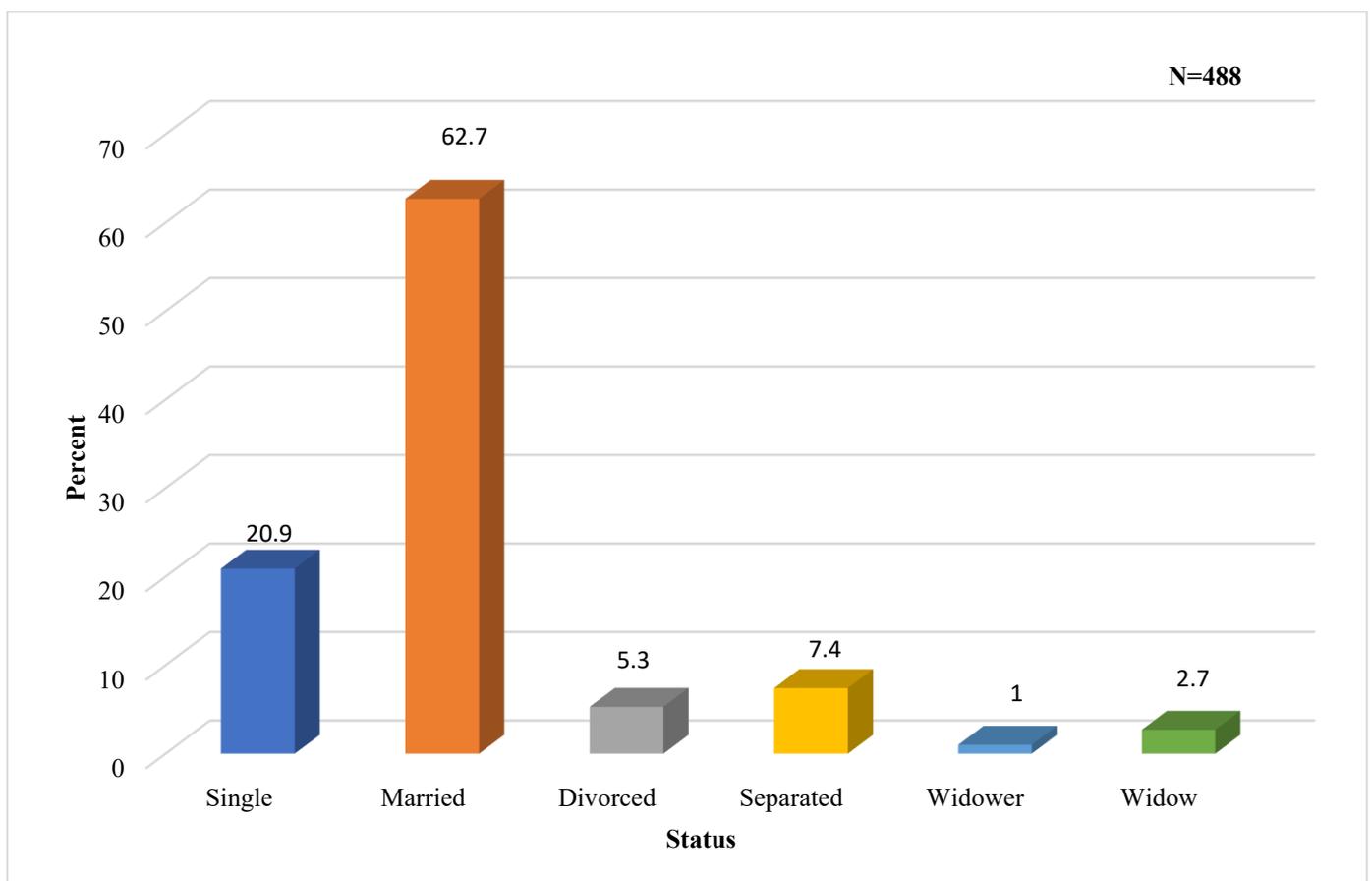
Other age groups, particularly those between 45 and 59 years, also represented significant portions of the sample. Respondents aged 45-49 years accounted for 15%, while those aged 55-59 years made up 10.5%. The participation from these age ranges shows that middle-aged and older adults are equally involved in discussions on flooding and architectural adaptation, likely due to their investments in property and longer-term concerns about environmental changes and their impacts on living conditions.

The younger age groups, particularly those between 20 and 34 years, represented a much smaller portion of respondents. Those aged 20-24 years made up just 0.4%, while 7.2% were in the 25-29 range and 3.5% in the 30-34 range. This suggests a lower level of engagement from younger people in flood mitigation issues. This may be attributed to factors like limited ownership of property or a

reduced sense of urgency regarding flood risks, as they may not yet directly feel the impacts of flooding or its long-term consequences on infrastructure.

The elderly population (aged 60-69) made up a smaller share of the responses, with 6.5% in the 60-64 group and 3.5% in the 65-69 range. Although the proportion is lower, this still reflects a certain level of involvement from the older demographic, though perhaps with less direct involvement in urban planning or architectural changes.

In conclusion, the data highlights that the majority of respondents are middle-aged, with less participation from younger and older age groups. This suggests that when designing flood mitigation strategies or policies, it might be necessary to target younger and older populations more effectively to ensure their voices are heard and their needs considered.



**Fig. 4.3: Percentage Distribution of Marital Status of Respondents**

*(Source: Generated by Researcher)*

Figure 4.3 presents the marital status of respondents in this research. However, the result highlights a diverse representation, with the majority of participants being married (62.7%). This suggests that individuals who are married, possibly with family responsibilities, are particularly engaged in concerns related to flood mitigation, likely due to the potential impact of flooding on their homes and loved ones. Married respondents are likely to have a

stronger interest in ensuring the safety and sustainability of their living spaces.

Single respondents represented 20.9% of the sample. While fewer in number, this group still contributes to the overall understanding of flood-related issues. The younger and unmarried participants may have different motivations, such as concerns about the overall livability of urban environments or future stability in flood-prone areas. This

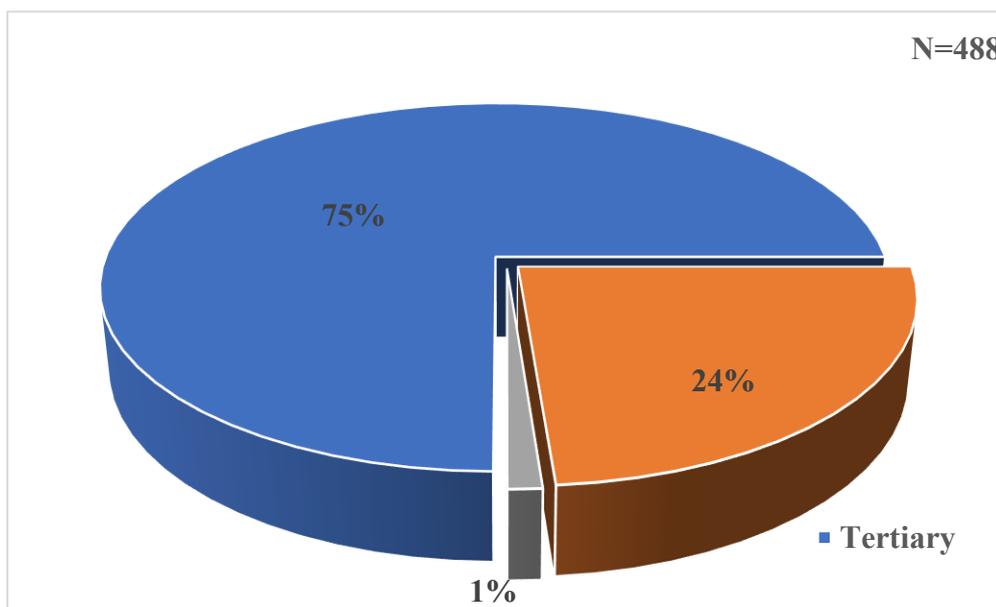
group may be more concerned with the long-term prospects of urban development, even if they don't yet own property.

Divorced and separated respondents made up 5.3% and 7.4% of the sample, respectively. These individuals may have particular concerns about housing security, especially regarding the resilience of their living spaces and the protection of assets in case of flooding. For this group, architectural solutions could address both personal safety and the preservation of property.

Widowed and widower respondents, although fewer at 1% and 2.7%, respectively, also bring unique perspectives. These participants might have heightened concerns for ensuring the durability and safety of their homes, particularly in the absence of a partner who may have

shared these responsibilities. Their involvement emphasizes the importance of considering the needs of all community members when addressing urban flood resilience.

In summary, while married individuals form the largest group in the study, representing a substantial portion of homeowners and family-oriented respondents, there is significant involvement from singles, divorced, separated, and widowed participants. This range of marital statuses underscores the widespread concern about flooding and the need for architectural adaptations that benefit all segments of the population. These results highlight the importance of creating inclusive, community-wide solutions for urban flooding challenges.



**Fig. 4.4: Percentage Distribution of Educational Attainment**

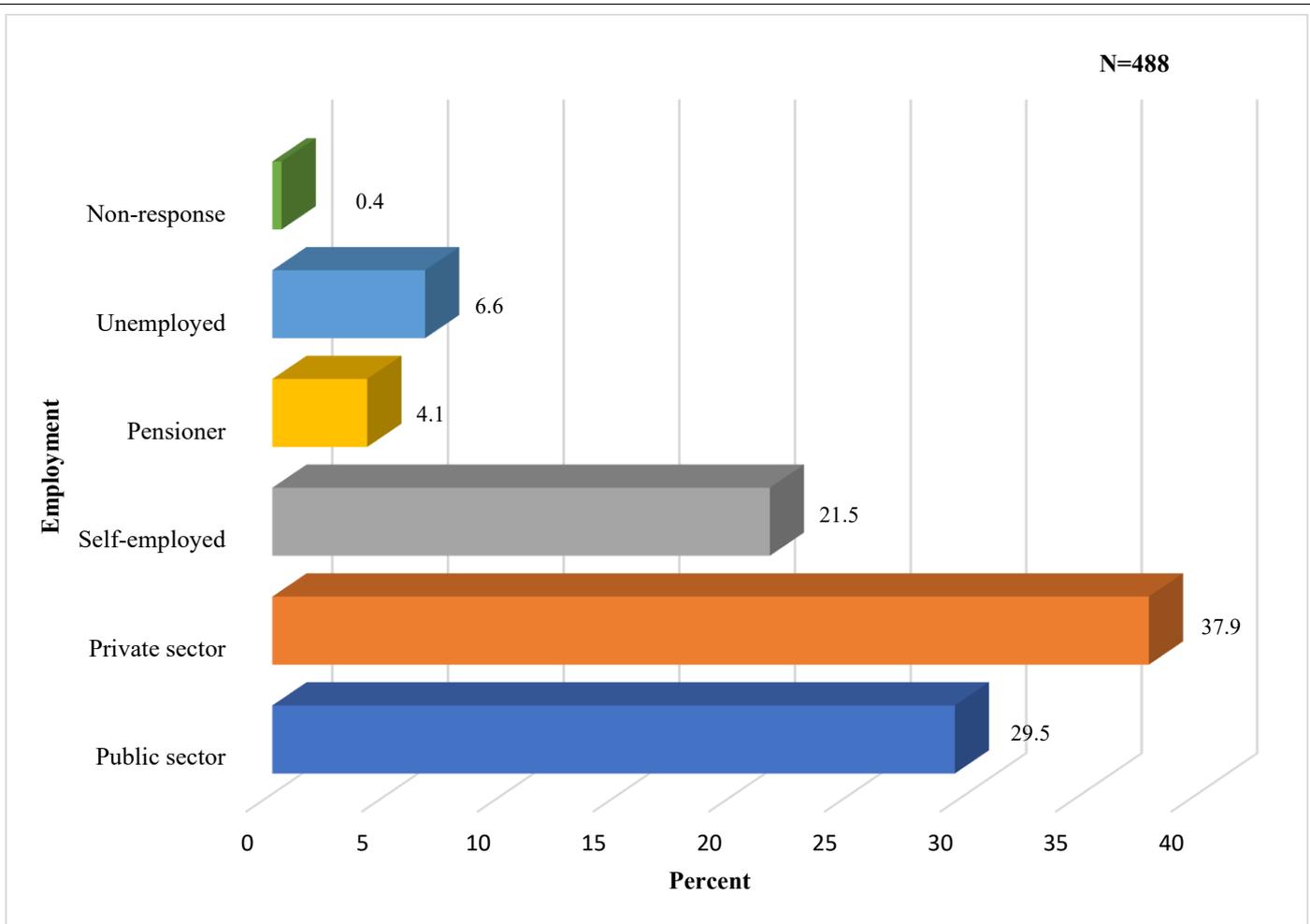
*(Source: Generated by Researcher)*

In Figure 4.4 shows the Percentage Distribution of Educational Attainment. However, a large proportion of the respondents, 75%, hold tertiary education. This suggests that most individuals in the sample are well-educated, which likely enhances their ability to grasp complex issues such as urban flooding, sustainable development, and the technical aspects of flood mitigation. This group may also be more inclined to support scientifically grounded solutions and policies related to urban planning and infrastructure.

A substantial 24% of respondents have completed secondary education. While this group may not have the in-depth technical knowledge of those with tertiary education, they likely possess general awareness about urban environmental issues. Their opinions and insights could be shaped by broader societal conversations and awareness campaigns regarding flooding and urban resilience. They may offer practical ideas based on their experiences and observations in their communities.

A smaller percentage, 1%, have only completed primary education. Despite their limited formal education, this group may still provide important perspectives, particularly based on lived experiences of flooding and its impacts on everyday life. Their insights might emphasize simple, accessible solutions or community-driven approaches to address flooding in a way that does not require specialized knowledge.

Additionally, the data indicates a relatively well-educated sample, predominantly consisting of individuals with tertiary or secondary education. This educational background is likely to influence their ability to contribute to discussions on the challenges and potential solutions for perennial flooding in the region. However, it is essential to include the perspectives of all education levels, ensuring that both expert and community-based knowledge contribute to the design of effective flood mitigation strategies.



**Fig. 4.5: Percentage Distribution of Employment Status of Respondents**  
(Source: Generated by Researcher)

### Employment Status of Respondents

Fig. 4.5 presents the percentage distribution of the employment status of respondents. The analysis reveals that a significant proportion, over 88%, of respondents are employed, indicating a predominantly active workforce within the sample population. This suggests that most individuals are engaged in economic activities, which could influence their perceptions and involvement in issues like architectural adaptation strategies for flood mitigation.

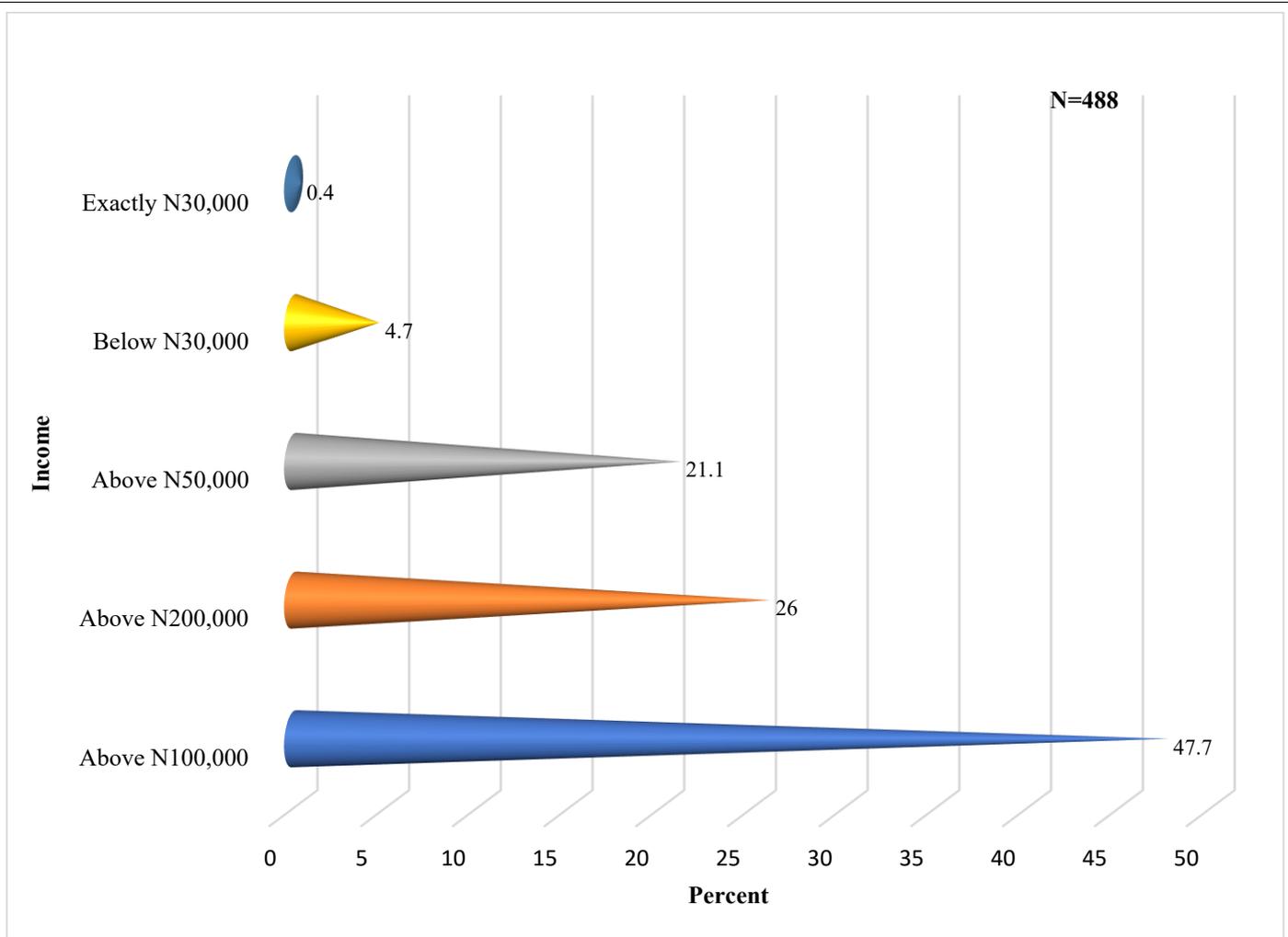
Among the employed respondents, a considerable portion, 37.9%, are employed in the private sector. This group likely represents individuals working in various industries, including construction, retail, and service sectors, which may influence their understanding of and interest in urban development and flood mitigation strategies from a practical standpoint. The private sector workforce's involvement is essential, as they may have a direct role in implementing or supporting architectural solutions to flooding.

Additionally, 29.5% of employed respondents work in the public sector, which includes government jobs and public administration roles. These individuals might have greater

exposure to policies, planning, and decision-making processes regarding urban infrastructure, including flood control and architectural strategies. Their contributions could reflect a more formal perspective, shaped by their professional experiences in public service and governance.

A notable 21.5% of respondents reported being self-employed. This category may include entrepreneurs, tradespeople, and small business owners who operate independently. Self-employed individuals often have unique insights into local challenges and may offer practical, community-based solutions to flooding and other urban issues, driven by firsthand experience in their respective businesses.

Furthermore, 4.1% of respondents are pensioners, and 6.6% are unemployed. While the proportion of pensioners is relatively small, this group may offer valuable historical perspectives on the evolution of flooding issues in the metropolis, based on their long-term experience of the urban environment. Unemployed individuals, while a minority, may provide insights into the challenges faced by those outside the formal labor market, potentially emphasizing the socio-economic dimensions of flood impacts.



**Fig. 4.6: Percentage Distribution of Income Level of Respondents**  
(Source: Generated by Researcher)

Figure 4.6 presents the income distribution of the respondents, with a clear indication of varying income levels. A substantial portion of respondents, 47.7%, reported earning more than N100,000, suggesting that nearly half of the participants fall within a moderate to high-income bracket. This could imply financial stability or engagement in sectors that offer relatively higher salaries. Another 26% of respondents claimed to earn over N200,000, positioning them in a higher income range, likely reflecting individuals in specialized, managerial, or senior-level roles.

In contrast, 21.1% of respondents reported earnings above N50,000, placing them in a lower-middle income category. This group might include individuals working in entry-level or mid-tier positions. A smaller portion, around 5%,

reported earning the national minimum wage of N30,000 or less, indicating a portion of the population in lower-wage jobs. Despite the low percentage of those earning minimum wage, it highlights the economic disparity present within the community. Thus, the data suggests that most respondents earn above the minimum wage, but there is still a significant gap between income levels, reflecting the diverse economic status of the population. This income variation is important for understanding how individuals might approach or be affected by architectural strategies aimed at mitigating flooding.

**Research Question (1): Which areas within Port Harcourt Metropolis are most vulnerable to perennial pluvial flooding?**

**Table 4.2: Criteria for Classification**

Depth of Floodwater	Extent of Floodwater	Classification
20 – 40cm	200 – 400m	Lowly Flooded
41 – 80cm	401 - 600m	Moderately Flooded
Above 80cm	Above 600m	Highly Flooded

(Source: Wizer & Mpigi, 2020)

In line with this ex-post facto research, Table 4.2 shows criteria for classification according to Wizer & Mpigi, (2020), in their research conducted in Port Harcourt Metropolis utilizing Geographic Information System (GIS) technology to identify and map 25 most flooded flood-prone areas categorizing them as lowly, moderately and highly flooded area. However, 8 regions were classified as lowly flooded (20–40 cm; 200–400 m), 9 as moderately flooded (41–80 cm; 401–600 m), and 8 as highly flooded

(above 80 cm; Above 600 m); based on the depth of inundation and extent of floodwater. Notably, all identified areas have high population concentrations, emphasizing the urgent need for effective urban planning in Port Harcourt Metropolis and similar cities globally. GIS technology, leveraging tools like GPS and ArcGIS software, proved effective in pinpointing and mapping these areas, and can aid cities in mitigating flood risks and protecting residents.

**Table 4.3: GPS Coordinates of Identified Urban Flood-Prone Areas in Port Harcourt Metropolis**

S/No	Name of Street / Road	Northings	Eastings
1	Salem Close, Off Ada George Road	4.855444	6.979556
2	Omachi Road, Rumuodomaya	4.875247	6.999777
3	Abanna Street, Old GRA	4.785583	7.022028
4	Hon. Attah Close, Peter Odili Road	4.793833	7.05075
5	Nkpolu Road 1, Rumuigbo	4.853346	6.986527
6	Eneka Town	4.878167	7.029514
7	Horsefall Street, Old GRA	4.786917	7.021222
8	Evelyn's Close, GRA Phase II	4.8195	7.006917
9	Omerelu Street, GRA Phase II	4.839583	7.005639
10	Abacha Road, GRA Phase II	4.823778	7.003361
11	Orubo Close, Peter Odili Road	4.797111	7.052361
12	NTA/Apara Link Road	4.854637	6.983774
13	Obiwali Road, Rumuigbo	4.858639	6.986944
14	L.K. Anga Road, Off Peter Odili Road	4.801917	7.047389
15	Uyo Street, Rumumasi	4.838444	7.017583
16	Odani Road, Elelenwo	4.840208	7.073506
17	Diamond Valley Estate	4.796222	7.046083
18	Rotimi Amaechi Drive, GRA Phase II	4.821278	6.000972
19	BluePearl Street, Peter Odili Road	4.794083	7.019917
20	Hilltop Road, Amadi-Kalagbo	4.823806	7.023444
21	Kenka Road, Off Mgbuoba Road	4.856194	6.980361
22	Akwaka Street, Rumuodomaya	4.880281	6.994285
23	Peter Odili Road	4.804861	7.045556
24	Alalibo Road, Old GRA	4.794083	7.019917
25	Zion Street, Rumuodomaya	4.881607	6.993837

*(Source: Wizer & Mpigi, 2020)*

Table 4.3 highlight GPS coordinates of flood-prone areas in Port Harcourt Metropolis by Wizer and Mpigi (2020). However, the scholars identify 25 locations that are highly vulnerable to flooding. These areas are distributed across various parts of the metropolis, including Peter Odili Road, Rumuodomaya, Old GRA, and GRA Phase II, among others. The northings and eastings listed in the table indicate a concentration of flood-prone zones between latitudes 4.78°–4.88° and longitudes 6.97°–7.07°, suggesting a clear spatial clustering of affected areas.

Rumuodomaya stands out with several streets such as Omachi Road (4.875247, 6.999777), Akwaka Street (4.880281, 6.994285), and Zion Street (4.881607, 6.993837). The proximity of these coordinates highlights

the susceptibility of this area to flooding, likely attributed to rapid urban development and poor drainage systems. Similarly, Peter Odili Road and its adjoining streets, including Hon. Attah Close (4.793833, 7.050750) and Orubo Close (4.797111, 7.052361), have multiple flood-prone locations. The clustering of these areas indicates terrain-related challenges, coupled with insufficient drainage infrastructure.

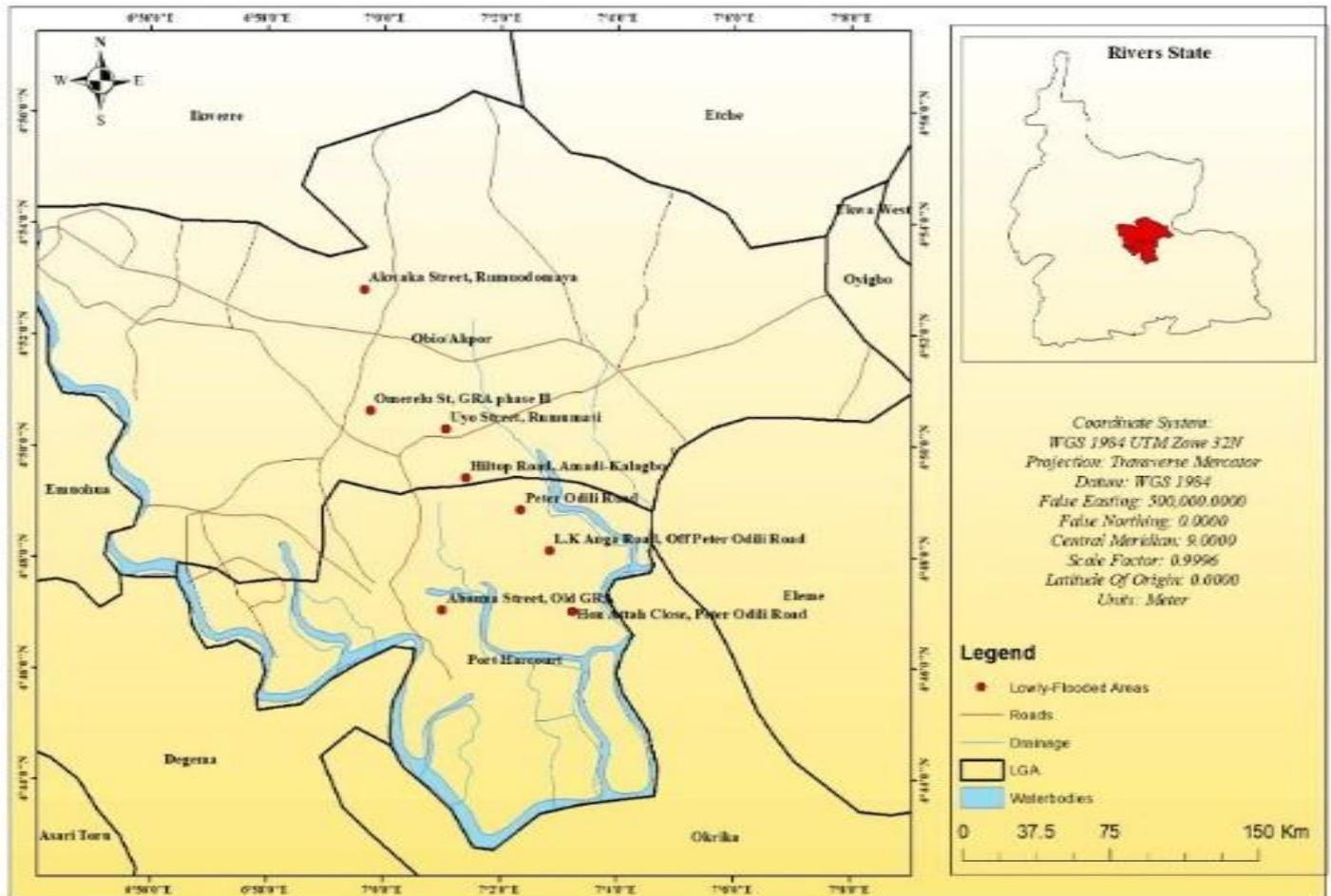
The table also reveals flood-prone streets in Old GRA, such as Abanna Street (4.785583, 7.022028) and Horsefall Street (4.786917, 7.021222). These areas may be prone to flooding due to their low-lying topography and inadequate flood management systems. In GRA Phase II, streets like Abacha Road (4.823778, 7.003361), Evelyn's Close

(4.819500, 7.006917), and Omerelu Street (4.839583, 7.005639) represent a cluster of affected zones. The pattern observed in these high-density neighborhoods highlights how urbanization impacts natural water flow and contributes to flooding.

Additional areas such as Eneka Town (4.878167, 7.029514) and Hilltop Road, Amadi-Kalagbo (4.823806, 7.023444), further illustrate the extent of flood risks in both urban and peri-urban regions. Other vulnerable zones like Rumuigbo (Nkpolu Road 1: 4.853346, 6.986527; Obiwali Road: 4.858639, 6.986944) and Mgbuoba (Kenka Road: 4.856194, 6.980361) reveal how urban growth in these areas, coupled with limited drainage capacity, contributes

to persistent flooding problems. Elenwo's Odani Road (4.840208, 7.073506) stands out as one of the farthest areas along the eastings, showing that flood issues extend beyond the city center.

Furthermore, these results underscore the need for immediate interventions to address urban flooding in Port Harcourt Metropolis. Priority should be given to improving drainage systems, implementing sustainable urban planning policies, and enforcing zoning regulations. Thus, in addressing the root causes of flooding in these identified areas, stakeholders can mitigate its impact on residents and infrastructure.



**Fig. 4.7: GPS Map of the Lowly Flooded Areas in Port Harcourt Metropolis**

*Source: Wizer & Mpigi, (2020)*

**Table 4.4: Lowly Flooded Areas in Port Harcourt Metropolis**

S/No	Name of Street / Road	Northings	Eastings
1	Abanna Street, Old GRA	4.785583	7.022028
2	Hon. Attah Close, Peter Odili Road	4.793833	7.05075
3	L.K. Anga Road, Off Peter Odili Road	4.801917	7.047389
4	Hilltop Road, Amadi-Kalagbo	4.823806	7.023444
5	Uyo Street, Rumumasi	4.838444	7.017583
6	Omerelu Street, GRA Phase II	4.839583	7.005639
7	Akwaka Street, Rumuodomaya	4.880281	6.994285
8	Peter Odili Road	4.804861	7.045556

*Source: Wizer & Mpigi, (2020)*

Figure 4.7 and Table 4.4 highlights the GPS coordinates of eight lowly flooded areas in Port Harcourt Metropolis. These areas, identified by Wizer and Mpigi, are distributed across Old GRA, Peter Odili Road, Rumumasi, GRA Phase II, Rumuodomaya, and Amadi-Kalagbo. The northings and eastings indicate that these areas lie within latitudes 4.78°–4.88° and longitudes 6.99°–7.05°, showing a spatial pattern that suggests relatively less susceptibility to severe flooding compared to other parts of the metropolis.

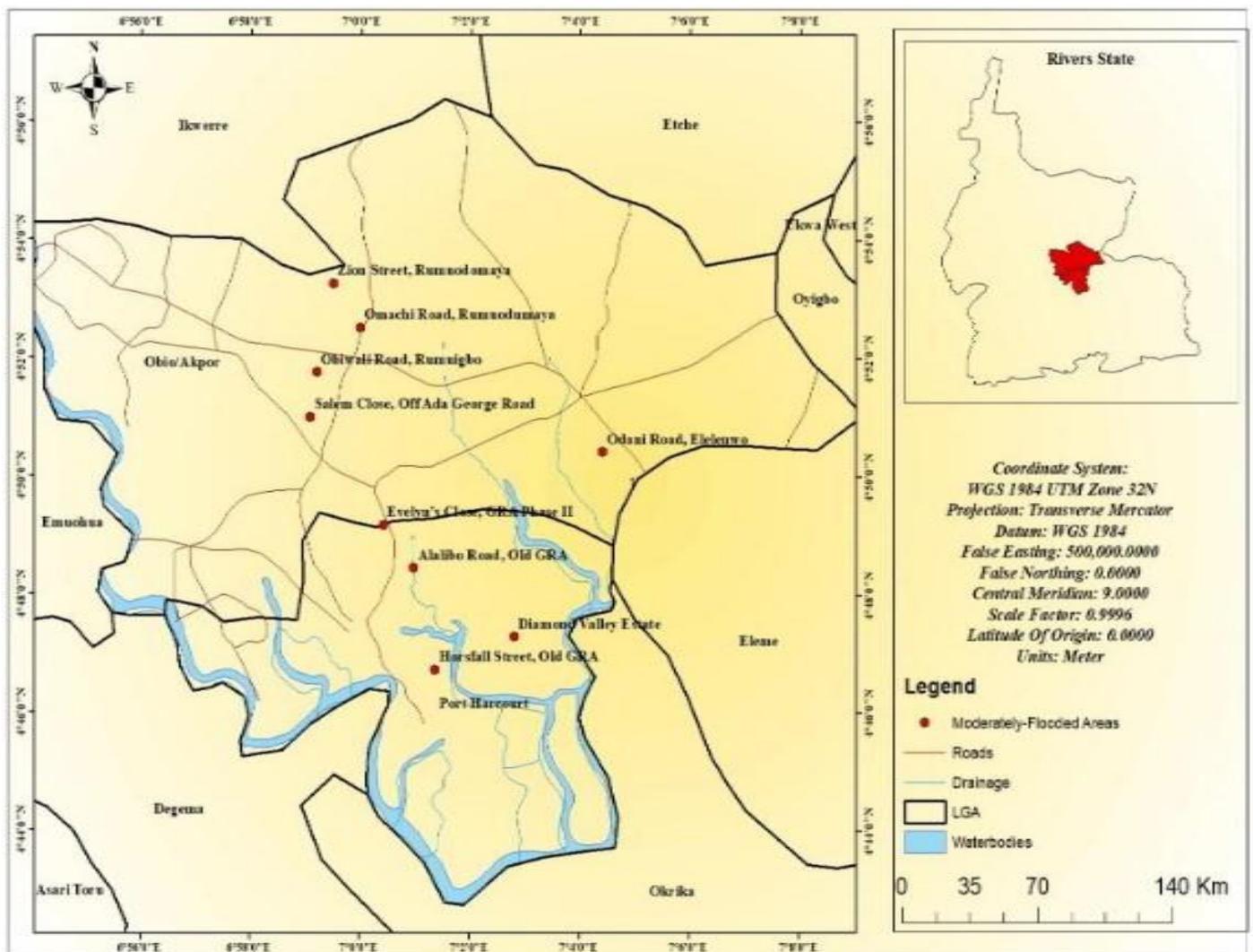
In Old GRA, Abanna Street (4.785583, 7.022028) stands out as a lowly flooded area. This could be due to its topography or the presence of better drainage infrastructure. Similarly, Hon. Attah Close (4.793833, 7.050750) and L.K. Anga Road (4.801917, 7.047389), both located near Peter Odili Road, are identified as lowly flooded areas. These areas may benefit from their proximity to major roads and better urban planning, reducing their vulnerability to severe flooding.

Hilltop Road in Amadi-Kalagbo (4.823806, 7.023444) and Uyo Street in Rumumasi (4.838444, 7.017583) also fall within the category of lowly flooded areas. Their higher

elevation or efficient water drainage systems may contribute to reduced flood risks in these locations. Similarly, Omerelu Street in GRA Phase II (4.839583, 7.005639) is less affected by flooding, likely due to its urban planning and infrastructure improvements.

Akwaka Street in Rumuodomaya (4.880281, 6.994285) and Peter Odili Road (4.804861, 7.045556) also appear in the list. Despite being located in a region with high urbanization, these areas experience relatively less flooding, suggesting that localized interventions such as proper drainage and flood control measures are effective in mitigating flooding in these specific zones.

In addition, the distribution of lowly flooded areas reflects a combination of factors such as elevation, drainage infrastructure, and urban planning. The identification of these zones provides valuable insights for urban planners and policymakers to replicate successful flood mitigation strategies in more vulnerable areas of the metropolis. Furthermore, maintaining and enhancing the existing infrastructure in these lowly flooded areas is critical to ensuring their continued resilience against urban flooding.



**Figure 4.8: GPS Map of the Moderately Flooded Areas in Port Harcourt Metropolis**  
(Source: Wizer & Mpigi, 2020)

**Table 4.5: Moderately Flooded Areas in Port Harcourt Metropolis**

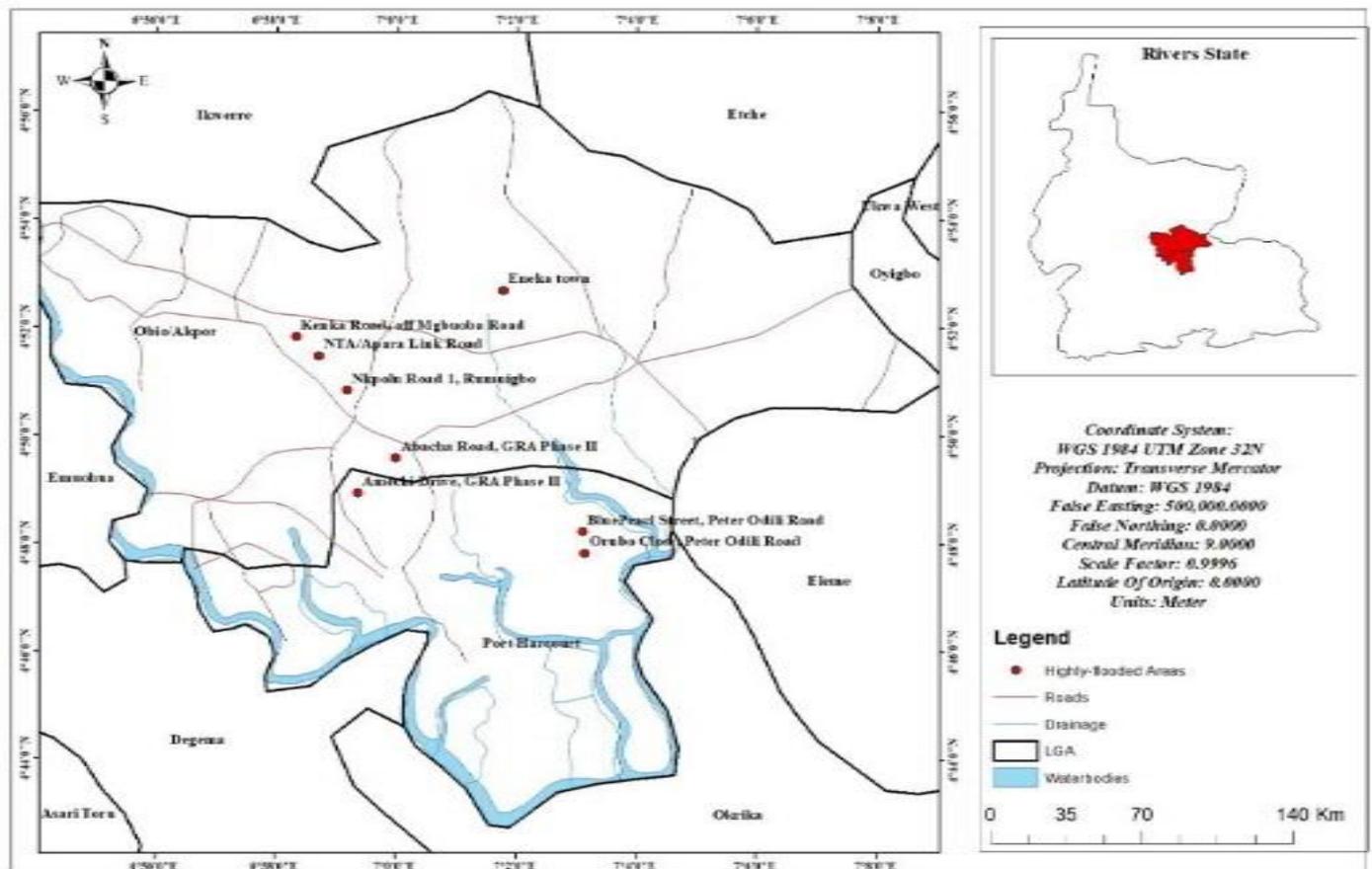
S/No	Name of Street / Road	Northings	Eastings
1	Omachi Road, Rumuodomaya	4.875247	6.999777
2	Salem Close, Off Ada George Road	4.855444	6.979556
3	Obiwali Road, Rumuigbo	4.858639	6.986944
4	Diamond Valley Estate	4.796222	7.046083
5	Zion Street, Rumuodomaya	4.881607	6.993837
6	Odani Road, Elemenwo	4.840208	7.073506
7	Evelyn's Close, GRA Phase II	4.8195	7.006917
8	Horsefall Street, Old GRA	4.786917	7.021222
9	Alalibo Road, Old GRA	4.794083	7.019917

Table 4.5 outlines nine moderately flooded areas within Port Harcourt Metropolis, spread across locations like Rumuodomaya, Ada George Road, Rumuigbo, Elemenwo, GRA Phase II, and Old GRA. These areas are situated within latitudes 4.78°–4.88° and longitudes 6.97°–7.07°.

In Rumuodomaya, streets such as Omachi Road (4.875247, 6.999777) and Zion Street (4.881607, 6.993837) experience moderate flooding, potentially due to urban development and insufficient drainage infrastructure. Similar flooding patterns occur at Salem Close off Ada George Road (4.855444, 6.979556) and Obiwali Road in Rumuigbo (4.858639, 6.986944), likely linked to challenges in stormwater management.

Diamond Valley Estate (4.796222, 7.046083) and Odani Road, Elemenwo (4.840208, 7.073506) are also affected by moderate flooding, which may stem from proximity to water sources or terrain-related factors. Additionally, Evelyn's Close (4.8195, 7.006917) in GRA Phase II and streets like Horsefall (4.786917, 7.021222) and Alalibo Road (4.794083, 7.019917) in Old GRA face similar flooding challenges.

However, these results highlight the necessity of upgrading flood control measures, including effective drainage systems, sustainable urban planning, and water retention structures, to reduce the impact of moderate flooding in these areas.



**Fig. 4.9: GPS Map of the Highly Flooded Areas in Port Harcourt Metropolis**  
(Source: Wizer & Mpigi, 2020)

**Table 4.6: Highly Flooded Areas in Port Harcourt Metropolis**

S/No	Name of Street / Road	Northings	Eastings
1	Nkpolu Road 1, Rumuigbo	4.853346	6.986527
2	Eneka Town	4.878167	7.029514
3	NTA/Apara Link Road	4.854637	6.983774
4	Rotimi Amaechi Drive, GRA Phase II	4.821278	6.000972
5	Kenka Road, Off Mgbuoba Road	4.856194	6.980361
6	Abacha Road, GRA Phase II	4.823778	7.003361
7	Orubo Close, Peter Odili Road	4.797111	7.052361
8	BluePearl Street, Peter Odili Road	4.794083	7.019917

*(Source: Wizer & Mpigi, 2020)*

Table 4.6 identifies key highly flooded areas in Port Harcourt Metropolis, each listed with its specific coordinates, indicating their precise locations within the city. Areas such as Nkpolu Road 1 (Rumuigbo), with coordinates (4.853346, 6.986527), and Eneka Town (4.878167, 7.029514) are prone to significant flooding, likely due to rapid urban expansion, poor drainage infrastructure, and the saturation of natural waterways. These locations, positioned within the city's developing neighborhoods, face severe water runoff issues, particularly after heavy rainfall, as the drainage systems in these areas are often inadequate to handle the volume of water.

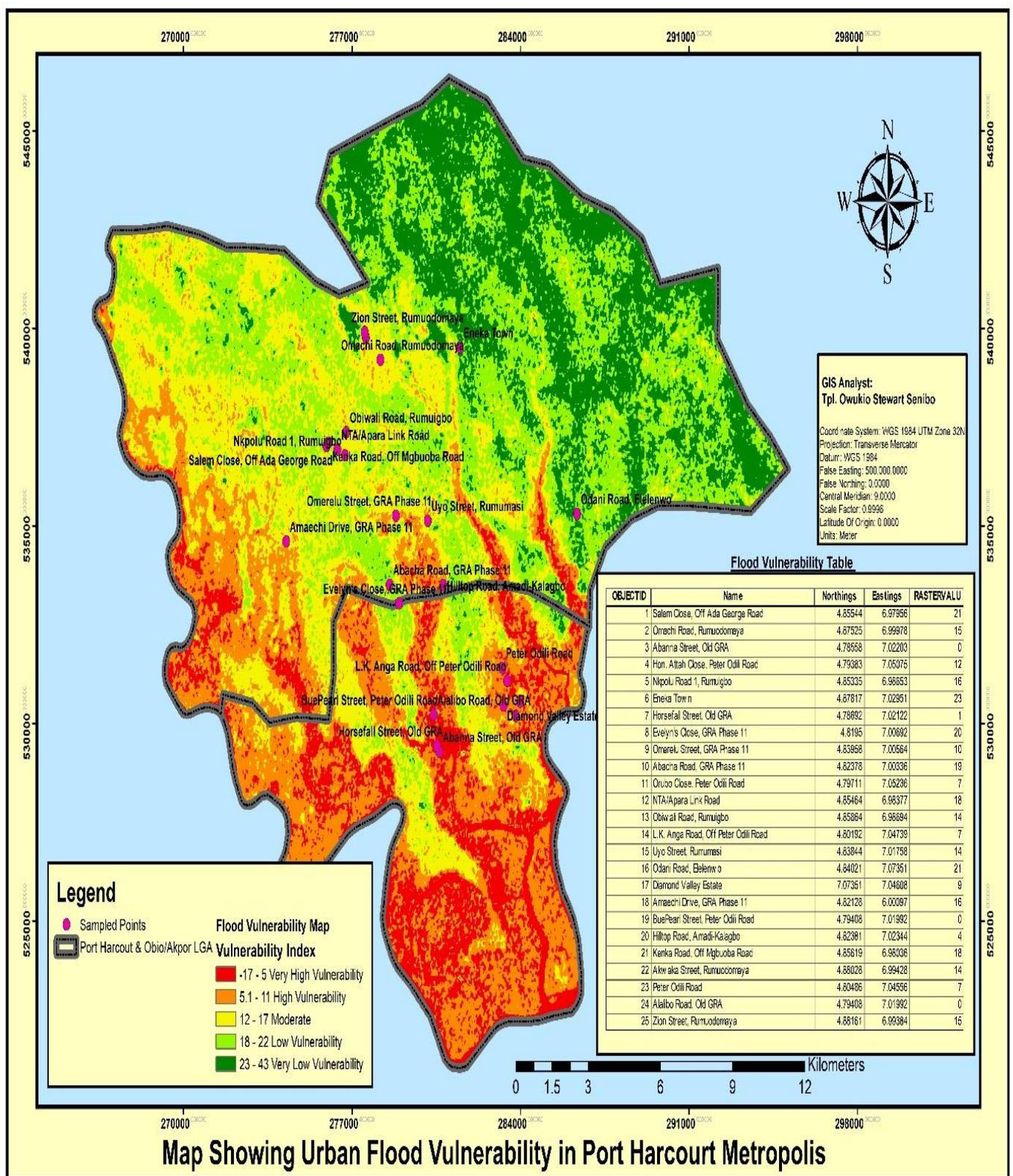
Similarly, streets like NTA/Apara Link Road (4.854637, 6.983774) and Rotimi Amaechi Drive, GRA Phase II (4.821278, 6.000972) also experience flooding, albeit in more established areas. The proximity of these roads to key commercial and residential zones in Port Harcourt suggests that urban development without the necessary flood mitigation measures contributes to the worsening flooding. These highly developed areas have large impermeable surfaces (such as roads and buildings), which do not allow water to seep into the ground, thus contributing to surface runoff and localized flooding.

Additionally, Kenka Road, off Mgbuoba Road (4.856194, 6.980361) and Abacha Road, GRA Phase II (4.823778, 7.003361) are situated in low-lying areas, where natural water flow patterns are often disrupted by

urbanization. The combination of poor drainage systems and terrain-related challenges makes these areas particularly vulnerable to flooding, especially during the rainy season. Orubo Close, Peter Odili Road (4.797111, 7.052361) and BluePearl Street, Peter Odili Road (4.794083, 7.019917) are also in areas with insufficient water management infrastructure, compounded by the surrounding development, which exacerbates the flooding risk.

However, these areas share common challenges such as inadequate drainage, poor urban planning, and rapid urbanization without adequate flood management infrastructure. The geographic coordinates show that these flood-prone areas are spread throughout the city, from residential zones to major roads, highlighting the widespread nature of the flooding problem in Port Harcourt. To mitigate the impacts of flooding, urgent measures such as improved drainage systems, better stormwater management, and sustainable urban planning are necessary to protect these vulnerable areas from future flooding events.

In furtherance of this thesis, there was a need to ground-truth the findings of Wizer & Mpigi (2020) to ascertain if the flood situation of the 25 most flooded roads in Port Harcourt Metropolis are still the same. Based on the above, a flood vulnerability map of the 25 most flooded streets/roads in Port Harcourt Metropolis was carried out using ArcGIS (Fig 4.10).



**Fig. 4.10: GPS Map of Urban Flood Vulnerability in Port Harcourt Metropolis**  
(Source: Fieldwork, 2024)

Wizor and Mpigi’s 25 most flooded streets/roads of Port Harcourt Metropolis was mapped out using ArcGIS, to find out the vulnerability of the selected flooded areas. The flood vulnerability index of the 25 sampled points in Port Harcourt Metropolis was between -17 and 43. With -17 to 5 being Very High Vulnerable, 5.1 to 11 being High Vulnerable, 12 to 17 being Moderate, 18 to 22 being Low Vulnerable, and 23 to 43 being Very Low Vulnerable. For the sake of this research, the researcher broke it down to 3 groups; Highly Vulnerable (-17 to 11), Moderately Vulnerable (12-17), and Lowly Vulnerable (18 to 43). See Fig 4.11.

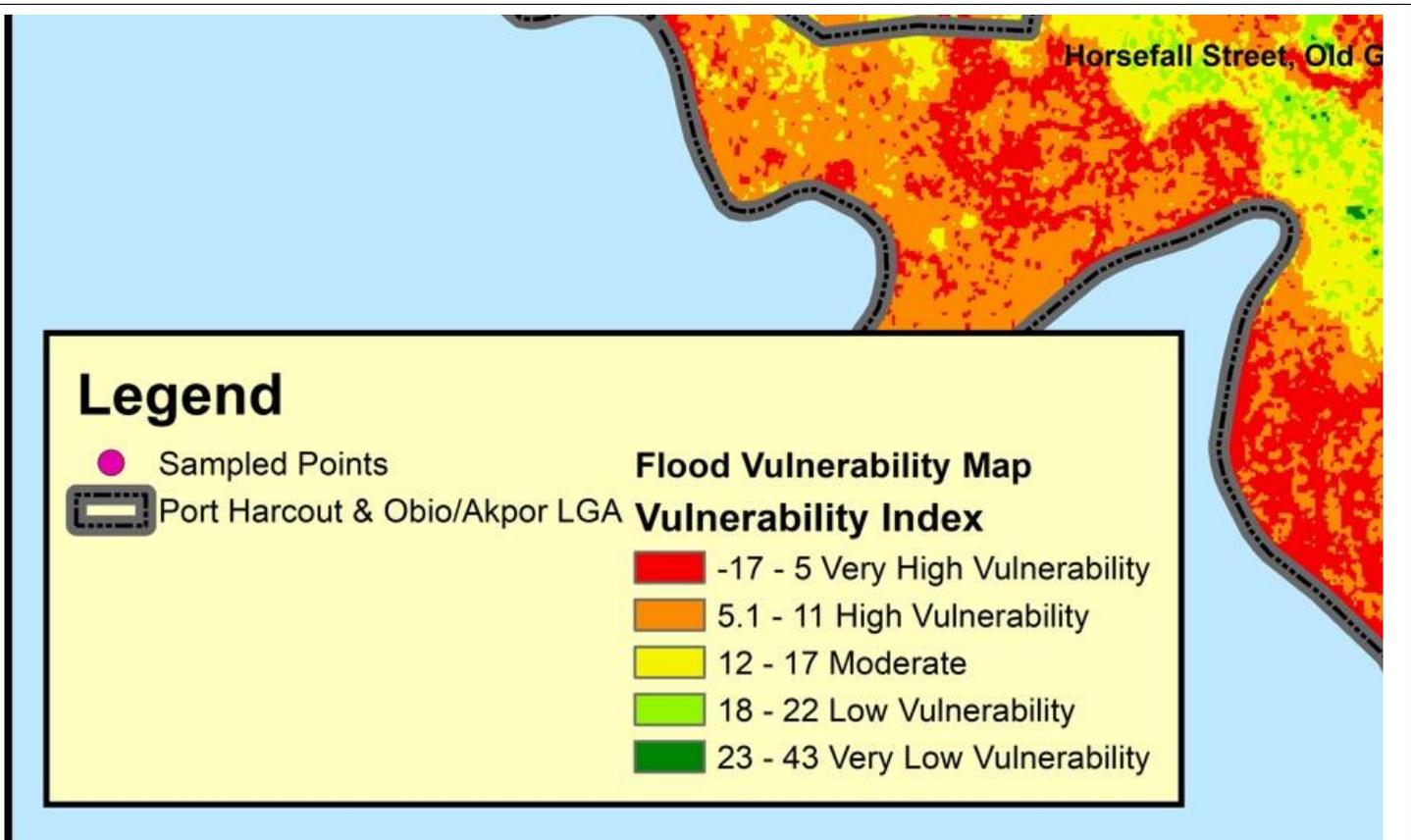


Fig. 4.11: Legend of Urban Flood Vulnerability Map of Port Harcourt Metropolis  
(Source: Fieldwork, 2024)

Flood Vulnerability Table				
OBJECTID	Name	Northings	Eastings	RASTERVALU
1	Salem Close, Off Ada George Road	4.85544	6.97956	21
2	Omachi Road, Rumuodomaya	4.87525	6.99978	15
3	Abanna Street, Old GRA	4.78558	7.02203	0
4	Hon. Attah Close, Peter Odili Road	4.79383	7.05075	12
5	Nkpolu Road 1, Rumuigbo	4.85335	6.98653	16
6	Eneka Town	4.87817	7.02951	23
7	Horsefall Street, Old GRA	4.78692	7.02122	1
8	Evelyn's Close, GRA Phase 11	4.8195	7.00692	20
9	Omerelu Street, GRA Phase 11	4.83958	7.00564	10
10	Abacha Road, GRA Phase 11	4.82378	7.00336	19
11	Orubo Close, Peter Odili Road	4.79711	7.05236	7
12	NTA/Apara Link Road	4.85464	6.98377	18
13	Obiwali Road, Rumuigbo	4.85864	6.98694	14
14	L.K. Anga Road, Off Peter Odili Road	4.80192	7.04739	7
15	Uyo Street, Rumumasi	4.83844	7.01758	14
16	Odani Road, Elelenwo	4.84021	7.07351	21
17	Diamond Valley Estate	7.07351	7.04608	9
18	Amaechi Drive, GRA Phase 11	4.82128	6.00097	16
19	BuePearl Street, Peter Odili Road	4.79408	7.01992	0
20	Hilltop Road, Amadi-Kalagbo	4.82381	7.02344	4
21	Kenka Road, Off Mgbuoba Road	4.85619	6.98036	18
22	Akwaka Street, Rumuodomaya	4.88028	6.99428	14
23	Peter Odili Road	4.80486	7.04556	7
24	Alalibo Road, Old GRA	4.79408	7.01992	0
25	Zion Street, Rumuodomaya	4.88161	6.99384	15

Fig. 4.12: Table of Urban Flood Vulnerability Map of Port Harcourt Metropolis  
(Source: Fieldwork, 2024)

*Table 4.7: Comparison of Findings for 25 Most Flooded Streets/Roads in Port Harcourt Metropolis*

S/N	Name of Street/ Road	Wizor & Mpigi classification	Flood Vulnerability Map classification	Findings
1	Abanna Street, Old GRA	Lowly flooded	Highly vulnerable	Not in agreement
2	Hon Attah close, Peter Odili Road	Lowly flooded	Moderately vulnerable	Not in agreement
3	L.K. Anga Road, off Peter Odili Road	Lowly flooded	Highly vulnerable	Not in agreement
4	Hilltop Road, Amadi-Kalagbor	Lowly flooded	Highly vulnerable	Not in agreement
5	Uyo Street, Rumuomasi	Lowly flooded	Moderately vulnerable	Not in agreement
6	Omerelu Street, GRA Phase II	Lowly flooded	Highly vulnerable	Not in agreement
7	Akwaka Street, Rumuodomaya	Lowly flooded	Moderately vulnerable	Not in agreement
8	Peter Odili Road	Lowly flooded	Highly vulnerable	Not in agreement
9	Omachi Road, Rumuodomaya	Moderately flooded	Moderately vulnerable	In agreement
10	Salem Close, off Ada George Road	Moderately flooded	Lowly vulnerable	Not in agreement
11	Obi Wali Road, Rumuigbo	Moderately flooded	Moderately vulnerable	In agreement
12	Diamond Valley Estate	Moderately flooded	Highly vulnerable	Not in agreement

*Source: (Fieldwork, 2024)*

*Table 4.8: Comparison of Findings for 25 Most Flooded Streets/Roads in Port Harcourt Metropolis (Continued)*

S/N	Name of Street/ Road	Wizor & Mpigi classification	Flood Vulnerability Map classification	Findings
13	Zion street, Rumuodomaya	Moderately flooded	Moderately vulnerable	In agreement
14	Odani Road, Elemenwo	Moderately flooded	Lowly vulnerable	Not in agreement
15	Evelyn'S Close, GRA Phase II	Moderately flooded	Lowly vulnerable	Not in agreement
16	Horsefall Street, Old GRA	Moderately flooded	Highly vulnerable	Not in agreement
17	Alalibo Road, Old GRA	Moderately flooded	Highly vulnerable	Not in agreement
18	Nkoplu Road 1, Rumuigbo	Highly flooded	Moderately vulnerable	Not in agreement
19	Rumuewhara New Layout / Eneka Town	Highly flooded	Lowly vulnerable	Not in agreement
20	NTA Aparo Link Road	Highly flooded	Lowly vulnerable	Not in agreement
21	Rotimi Amaechi Drive, GRA Phase II	Highly flooded	Moderately vulnerable	Not in agreement
22	Kemka Road, Off Mgbuoba Road	Highly flooded	Lowly vulnerable	Not in agreement
23	Abacha Road, GRA Phase II	Highly flooded	Lowly vulnerable	Not in agreement
24	Orubo Close, Peter Odili Road	Highly flooded	Highly vulnerable	In agreement
25	BluePearl Street, Peter Odili Road	Highly flooded	Highly vulnerable	In agreement

*Source: (Fieldwork, 2024)*

The findings from the Flood Vulnerability Map show the vulnerability of the 25 most flooded streets/roads in Port Harcourt Metropolis in comparison with the research conducted by Wizor & Mpigi (2020).

It shows that the lowly flooded streets of Abana Street, Old GRA; L.K. Ang Road, off Peter Odili Road; Hilltop Road, Amadi-Kalagbor; Omerelu Street, GRA Pgase II; and Peter Odili Road are considered highly vulnerable to pluvial flood. While Hon. Attah Close, Peter Odili Road; Uyo Street, Rumuomasi; and Akwaka Street, Rumuodomaya which were classified by Wizor & Mpigi (2020) as lowly flooded are moderately vulnerable.

The moderately flooded streets of Diamond Valley Estate; Horsefall Street, Old GRA; and Alalibo Road, Old GRA are considered highly vulnerable. On the other hand, Salem Close, off Ada George Road; Odani Road, Elemenwo; and Evelyn's Close, GRA Phase II are lowly vulnerable. Only 3 streets/roads are in agreement according to the findings. They are Omachi Road, Rumuodomaya; Obi Wali Road, Rumuigbo; and Zion Street, Rumuodomaya.

The highly flooded streets/roads of Nkpolu Road 1, Rumuigbo; and Rotimi Amaechi Drive, GRA Phase II are considered as moderately vulnerable. The streets/roads of Rumuewhara New Layout/Eneka Road; NTA/Apara link

Road; Kemka Road, off Mgbuoba Road; and Abach Road, GRA Phase II are considered lowly vulnerable. Only Orubo Close, Peter Odili Road; and Blue Pearl Street, Peter Odili Road are in agreement with the findings, that they are highly flooded according to Wizer & Mpigi (2020), and highly vulnerable according to the researcher's findings.

### **Causational Factors Contributing to Pluvial Flooding in Port Harcourt Metropolis**

Below are some causational factors that are responsible for the pluvial flooding of some residential areas in Port Harcourt Metropolis.

**Poor Drainage Slope of Newly Constructed Drainages:** Some newly constructed drainages in Port Harcourt Metropolis have been designed with sufficient slope to

facilitate efficient water flow, leading to stagnation and overflow. With the cancellation of the monthly environmental cleaning exercise in Rivers State, most drainages are not regularly cleaned or maintained, causing debris and sediment to accumulate and reduce the drainage capacity. Furthermore, the construction of some drainages in Port Harcourt Metropolis does not adhere to standardized guidelines, resulting in varying levels of effectiveness.

**Indiscriminate Dumping of Refuse in Existing Drainages:** Refuse and debris clog drainage channels in Port Harcourt Metropolis, reducing their capacity to carry water away from urban areas. The blockages in drainage channels cause water to back up and overflow, leading to flooding in surrounding areas and posing a significant threat to residents and infrastructure.



*Plate 4.1: Blocked Drain at Woji Junction, Port Harcourt.*

*(Source: Obihoja, 2023)*

**Impervious Surfaces (Asphalt, Concrete):** The widespread use of impervious surfaces such as asphalt and concrete in Port Harcourt Metropolis prevents rainwater from infiltrating the soil, increasing surface runoff and flooding. Impervious surfaces in the city contribute to increased stormwater runoff, overwhelming drainage

systems and leading to flooding, which poses a significant threat to residents and infrastructure. Furthermore, the extensive use of impervious surfaces in Port Harcourt Metropolis absorbs and retains heat, exacerbating the urban heat island effect and increasing the likelihood of extreme weather events, such as intense rainfall and flooding.



**Plate 4.2: Blocked Drain at Woji Junction, Port Harcourt.**

*(Source: Researcher, 2023)*

**Indiscriminate Development of New Buildings:** The rapid construction of new buildings in Port Harcourt Metropolis has led to an increase in impervious surfaces, exacerbating stormwater runoff and flooding in the city. Indiscriminate development projects in the metropolis have altered natural drainage patterns, leading to increased flood risk and vulnerability for residents and businesses. Additionally, the surge in new development has put additional strain on the city's existing drainage infrastructure, increasing the likelihood of flooding and infrastructure failure, which have devastating consequences.

**Urban Sprawl and Development:** Unplanned urban growth in Port Harcourt Metropolis has led to inadequate infrastructure, including drainage systems, thereby increasing the risk of flooding. The rapid urban sprawl in the city has resulted in the destruction of natural habitats,

such as wetlands and floodplains, which previously provided natural flood protection. Urban sprawl in Port Harcourt Metropolis has increased flood risk by altering natural drainage patterns and reducing the ability of natural systems to absorb and filter rainwater.

**Increased Rainfall Intensity:** Climate change is projected to increase the frequency and intensity of extreme weather events, including heavy rainfall, which will have devastating consequences for Port Harcourt Metropolis, particularly in terms of flooding and infrastructure damage. The increased rainfall intensity caused by climate change overwhelms the urban drainage systems in Port Harcourt Metropolis, leading to flooding, infrastructure damage, and disruption of essential services, ultimately affecting the livelihoods of residents and the overall economic development of the city.

**Table 4.9: Identified highly Flooded Areas in Port Harcourt Metropolis**

S/No	Name of Street / Road	Northings	Eastings	Classification of Flood	Elevation Above Sea Level
1	Abanna Street, Old GRA	4.785583	7.022028	Low Flooded	3.6m
2	Hon. Attah Close, Peter Odili Road	4.793833	7.05075	Low Flooded	3.9m
3	Akwaka Street, Rumuodomaya	4.880281	6.994285	Low Flooded	14.1m
4	Uyo Street, Rumumasi	4.838444	7.017583	Lowly Flooded	5.7m
5	Salem Close, Off Ada George Road	4.855444	6.979556	Moderately Flooded	12.6m
6	Obiwali Road, Rumuigbo	4.858639	6.986944	Moderately Flooded	14.1m
7	Omachi Road, Rumuodomaya	4.875247	6.999777	Moderately Flooded	12.6m
8	Odani Road, Elelenwo	4.840208	7.073506	Moderately Flooded	16.8m

9	Evelyn's Close, GRA Phase II	4.8195	7.006917	Moderately Flooded	14.7m
10	Rumuewhara New Layout / Eneka	4.878167	7.029514	Highly Flooded	17.1m
11	NTA/Apara Link Road	4.854637	6.983774	Highly Flooded	13.5m
12	Abacha Road, GRA Phase II	4.823778	7.003361	Highly Flooded	4.2m
13	Nkpolu Road 1, Rumuigbo	4.853346	6.986527	Highly Flooded	14.1m

*Source: Fieldwork, 2024*

Table 4.9 identifies 13 chosen streets/roads out of the 25 that were analysed earlier from the research conducted by Wizor & Mpigi (2020). From field observation by the researcher, the analysis of flooded areas within Port Harcourt Metropolis, as presented, highlights the varying flood classifications and elevations across different locations. The highly flooded areas include Rumuewhara New Layout/Eneka (4.878167, 7.029514; elevation: 17.1m), NTA/Apara Link Road (4.854637, 6.983774; elevation: 13.5m), Abacha Road, GRA Phase II (4.823778, 7.003361; elevation: 4.2m), and Nkpolu Road 1, Rumuigbo (4.853346, 6.986527; elevation: 14.1m). For example, in Rumuewhara New Layout, floodwaters reached a height of 200mm and required approximately 1 hour to recede (see Plate 4.3). On Emmanuel Close, an adjoining street, water levels were measured at 50mm after rainfall (see Plate 4.4).

Moderately flooded areas such as Salem Close (4.855444, 6.979556; elevation: 12.6m), Obiwali Road, Rumuigbo (4.858639, 6.986944; elevation: 14.1m), Omachi Road,

Rumuodomaya (4.875247, 6.999777; elevation: 12.6m), and Odani Road, Elelenwo (4.840208, 7.073506; elevation: 16.8m) exhibited varying water retention levels but were less severe than the highly flooded areas.

In contrast, areas classified as lowly flooded include Abanna Street, Old GRA (4.785583, 7.022028; elevation: 3.6m), Hon. Attah Close, Peter Odili Road (4.793833, 7.05075; elevation: 3.9m), Akwaka Street, Rumuodomaya (4.880281, 6.994285; elevation: 14.1m), and Uyo Street, Rumumasi (4.838444, 7.017583; elevation: 5.7m). These locations experienced minimal flooding due to higher elevations or better drainage.

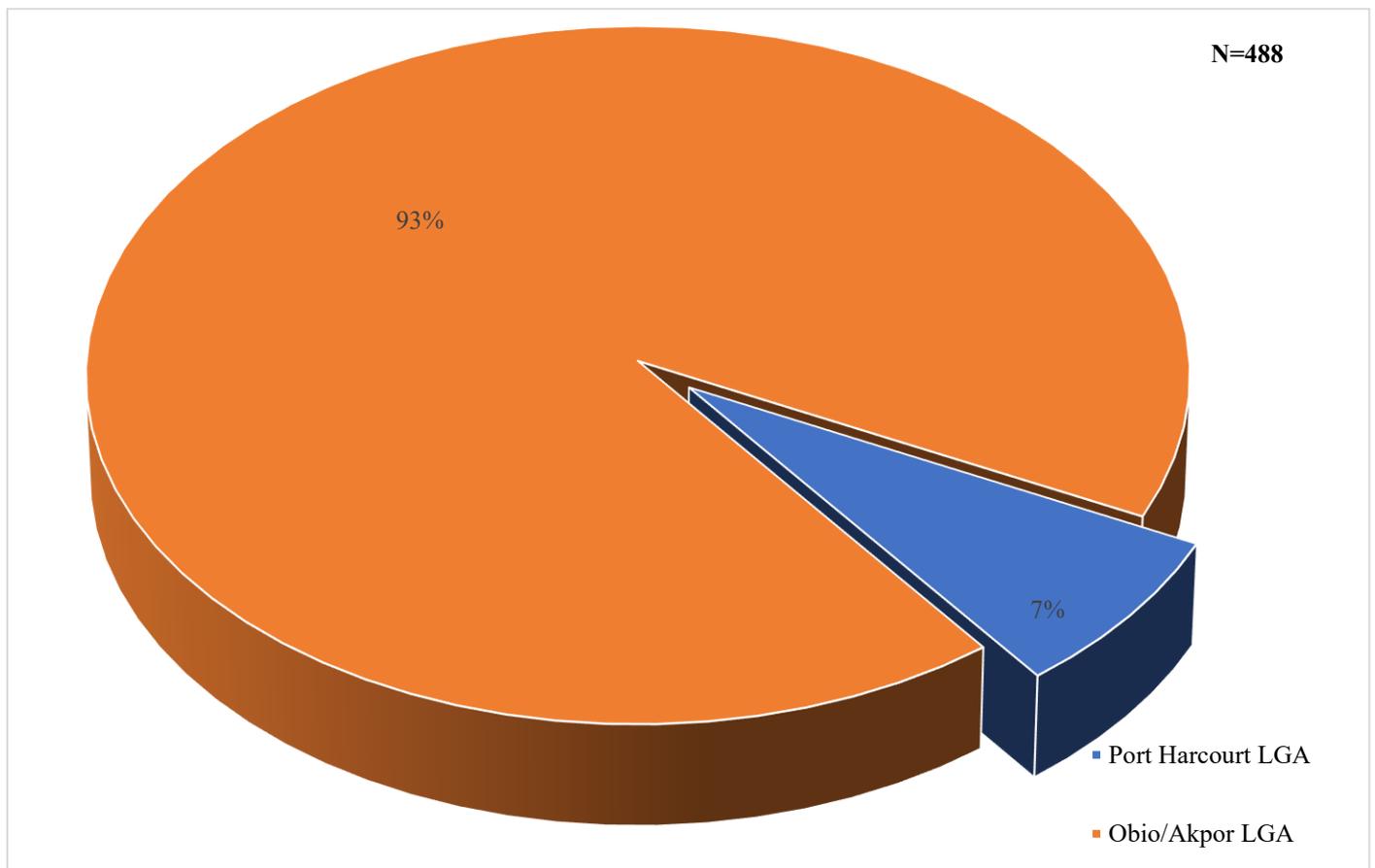
Flood management in these areas remains largely community-driven, with residents implementing strategies such as concrete wall flood barriers, sandbags, raised driveways, rainwater collection systems, and raised DPC levels. The absence of government-provided flood adaptation measures underscores the need for structured flood management initiatives in the metropolis.



**Plate 4.3: Flood Water Level Along Rumuewhara New Layout.**  
(Source: Fieldwork, 2024)



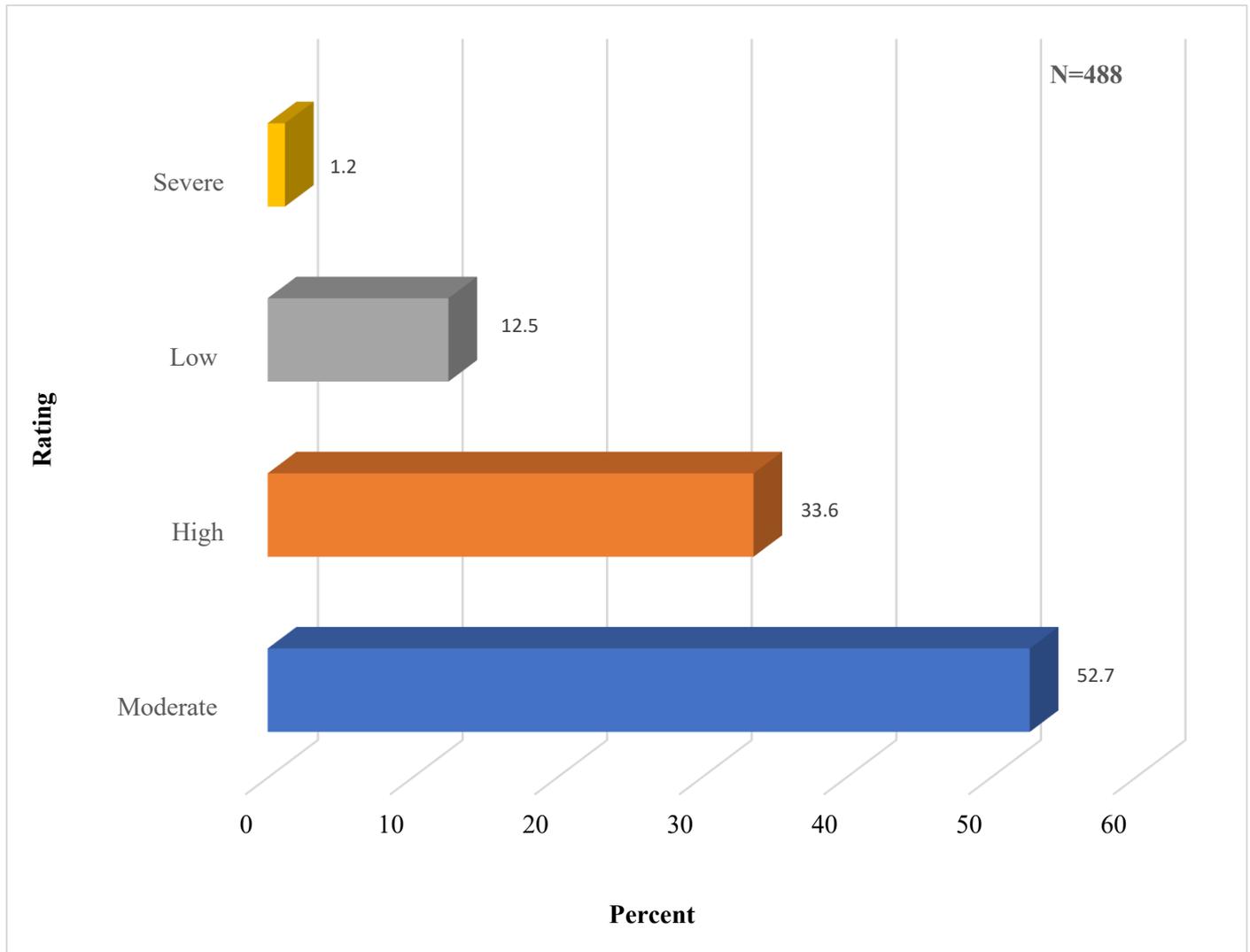
**Plate 4.4:** Flood Water Level in a Compound on Emmanuel Close.  
(Source: Fieldwork, 2024)



**Figure. 4.13:** Percentage Distribution of Mostly Flooded Parts of Port Harcourt Metropolis  
(Source: Researcher, 2024)

Figure 4.10 illustrate the overwhelming perception of respondents regarding flood-prone areas within Port Harcourt Metropolis. Over 90% of respondents identified Obio/Akpor Local Government Area as the most flooded part of the metropolis, highlighting its vulnerability to frequent and severe flooding. Contributing factors may include inadequate drainage infrastructure, rapid

urbanization, low elevation levels, and the presence of impermeable surfaces that hinder water absorption. Meanwhile, 10% of respondents indicated Port Harcourt City Local Government Area as the most flooded, suggesting localized challenges in certain parts of the city. These findings underscore the need for targeted flood management strategies in both areas.

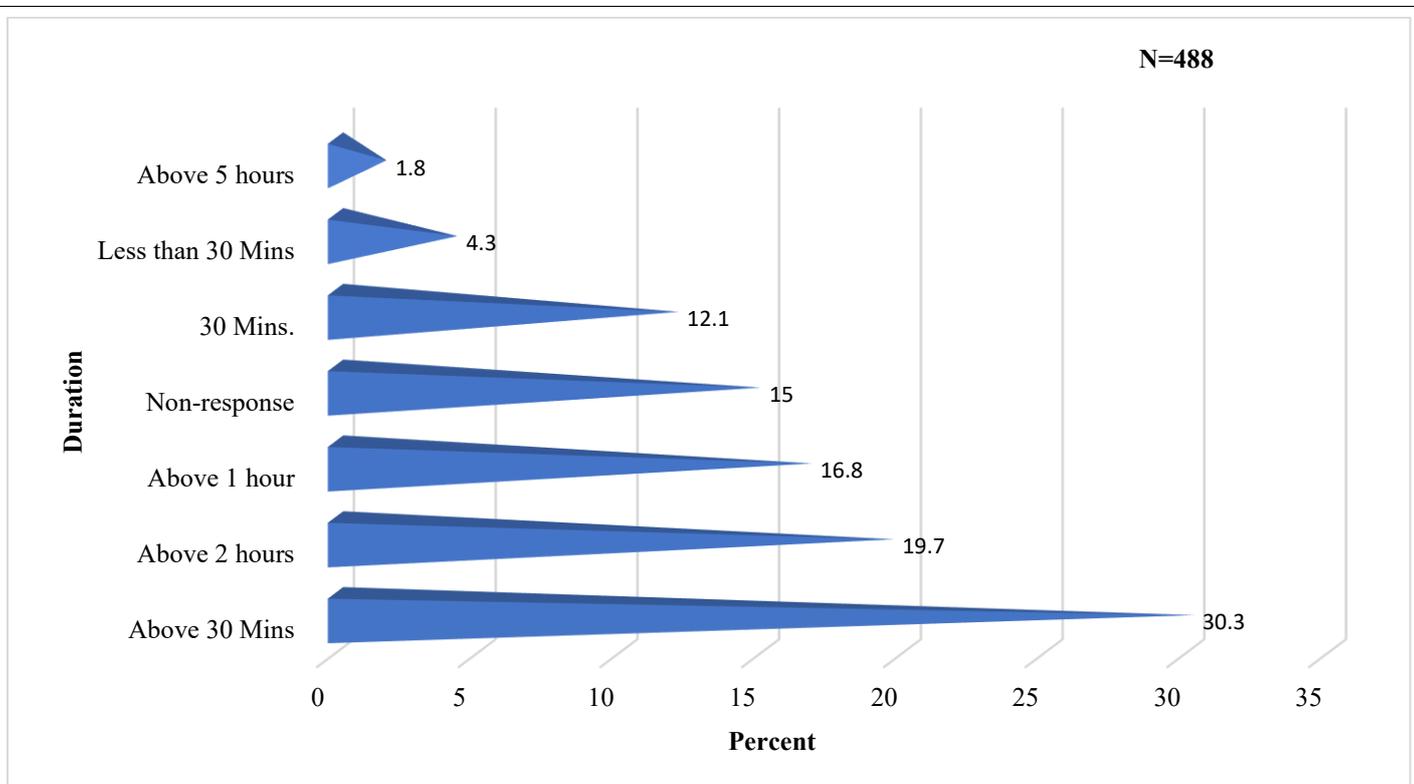


**Fig. 4.14: Percentage Distribution of Magnitude and Level of Flooding**  
(Source: Researcher, 2024)

Figure 4.11 illustrate the respondents' perceptions of the magnitude and severity of pluvial flooding in their neighborhoods. A significant portion of respondents, 52.7%, rated the magnitude of flooding as “Moderate - Above Ankle (101mm to 200mm),” suggesting that while flooding is disruptive, it is not excessively severe in most cases. This moderate level of flooding may result from insufficient drainage systems and partially blocked water channels.

Additionally, 33.6% of respondents categorized flooding as “High - Above Knee (201mm to 600mm),” indicating

a more severe disruption in these areas. A smaller proportion, 12.5%, rated flooding as “Low – Ankle (51mm to 100mm),” reflecting relatively minor impacts, likely in areas with better drainage infrastructure or higher elevation. Notably, only 1.2% reported “Severe - Waist Level (601mm to 900mm)” flooding, suggesting that extreme flooding events are less frequent but highly impactful when they occur. These results underscore the variability in flood magnitude across neighborhoods and highlight the need for tailored interventions to address both moderate and severe flood risks effectively.



**Fig. 4.15: Percentage Distribution of Flood Duration**  
(Source: Researcher, 2024)

Figure 4.12 illustrates the distribution of flood durations across the study areas. The majority of respondents, 30.3%, indicated that flood durations typically exceed 30 minutes, marking it as the most common flood duration in the area. A significant portion of respondents reported flood durations ranging from one hour (16.8%) to two hours (19.7%), while a smaller group (1.8%) mentioned floods

lasting up to five hours. In total, about 38.3% of respondents experienced flooding that lasted between one and five hours after a heavy downpour. These Result highlight the prolonged nature of flooding in the area, emphasizing the need for improved drainage systems and flood control measures to address this persistent issue.

**Table 4.10 Consequences of Flood on Infrastructure**

S/N	Consequence	Response		
		Yes	No	Total
1.	Unightly looking buildings (water stains on walls, watermarks mold growth due to leakages, etc.).	73.6	26.4	100
2.	Property damage (rising damp, soil erosion, peeling paint, etc.).	79.3	20.7	100
3.	Infrastructure damage (broken gutters/drains, damage to roads/driveways, damaged inspection chambers, damaged septic tanks/soak-away pits, etc.)	34.6	65.4	100
4.	Health and safety issues (Contact with contaminated water, slippery surfaces, water-borne diseases, etc.)	95.7	4.3	100

**Source: Researcher, 2024**

Table 4.10 illustrates the consequences of flooding on infrastructure in the study area. A significant 73.6% of respondents reported that flooding caused unsightly buildings with issues such as water stains, mold growth, and watermarks due to leaks. These impacts negatively affect the aesthetic and structural integrity of properties. Furthermore, 79.3% of respondents identified property damage resulting from rising damp, soil erosion, and peeling paint, emphasizing the destructive effects of floodwater on residential and commercial buildings.

Regarding infrastructure, 34.6% of respondents highlighted damage to essential structures such as broken gutters, damaged roads, and septic tanks, revealing that flooding also disrupts crucial public utilities and services. The most alarming consequence, however, was related to health and safety concerns, with 95.7% of respondents acknowledging the risks posed by contact with contaminated floodwater, slippery surfaces, and the increased likelihood of waterborne diseases. This demonstrates that the public

health impact of flooding is the most pressing concern in the area.

In addition, the result reveal that while property and infrastructure suffer from flooding, the greatest concern lies in the health risks associated with contaminated floodwaters and the potential spread of diseases. These results emphasize the urgent need for effective flood

control measures to safeguard both public health and property.

**Research Question (2): What is the impact of perennial pluvial flooding on the architectural quality and performance of buildings in Port Harcourt, considering safety, functionality, aesthetics, comfort, and durability?**

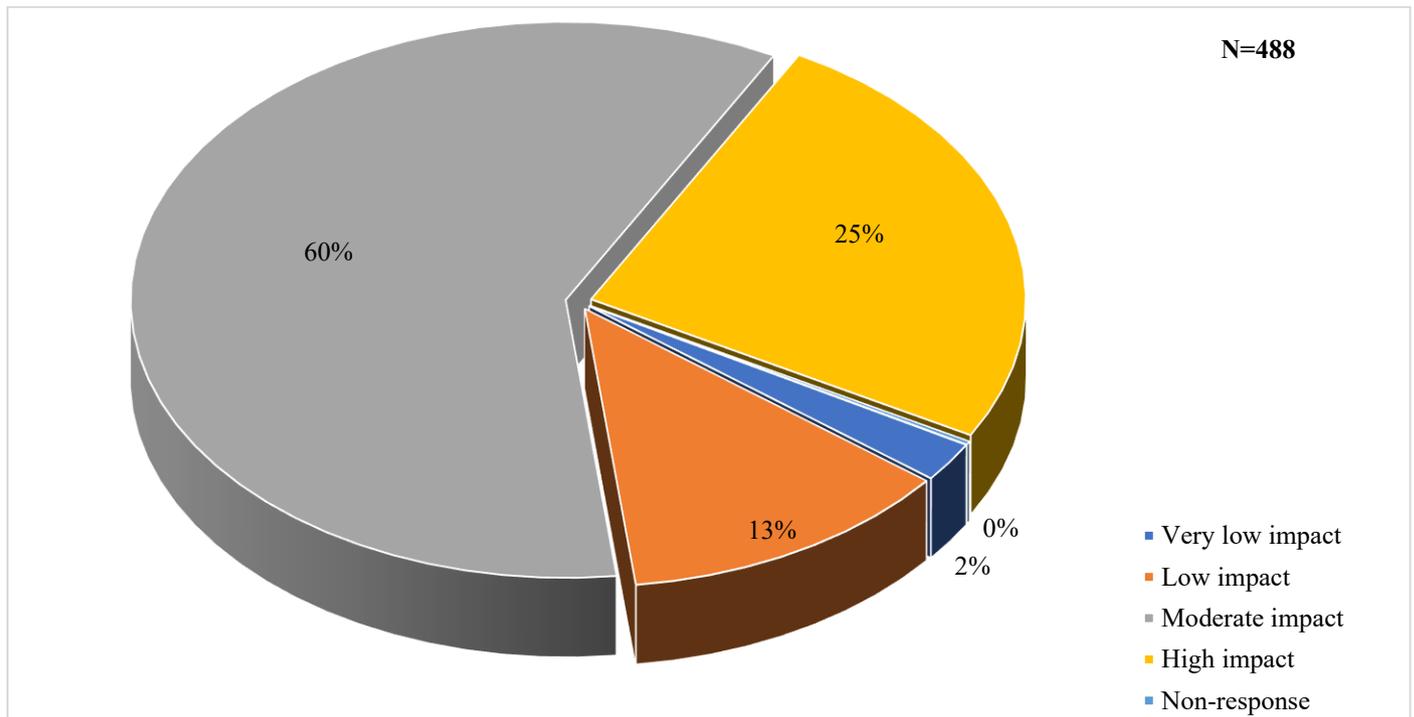
**Table 4.11 Main Reason Some Areas Experience Severe Flooding**

S/N	Reason	Response		
		Yes	No	Total
1.	Overwhelmed drainage systems	99.8	0.2	<b>100</b>
2.	Impermeable ground surfaces (that don't allow water to pass through)	91.4	8.6	<b>100</b>
3.	Intense rainfall	98.0	0.2	<b>100</b>
4.	Climate change	95.5	4.5	<b>100</b>

*Source: Researcher, 2024*

Table 4.11 presents the main reasons or reveals key factors contributing to severe flooding in certain areas. Overwhelmed drainage systems were identified by 99.8% of respondents as the primary cause, indicating that insufficient or inadequate drainage infrastructure is a major contributor to flooding. A significant 91.4% highlighted impermeable ground surfaces, such as concrete and asphalt, that prevent water absorption. Intense rainfall was also

recognized by 98.0% as a leading factor, emphasizing the role of heavy downpours in exacerbating flooding. Additionally, 95.5% of respondents attributed flooding to climate change, suggesting that changing weather patterns are influencing flood severity. These findings point to a combination of infrastructure challenges and environmental changes as the main drivers of severe flooding.



**Fig 4.16: Rating of Impact of Perennial Pluvial Flooding on the Safety of Buildings in the Affected Area.**

*(Source: Researcher, 2024)*

Figure 4.13 presents respondents' rating of the impact of Perennial pluvial flooding on the safety of buildings in the affected area. However, the survey results on the impact of perennial pluvial flooding on the safety of buildings in the

affected area present an interesting distribution of opinions. The largest portion of respondents (60%) categorized the impact as moderate. This suggests that, while the flooding is an issue, it is not universally viewed as a major threat.

Respondents who selected this option likely feel that flooding has noticeable consequences on the structural integrity of buildings, such as water damage or foundation issues, but may not pose an immediate or severe risk to safety.

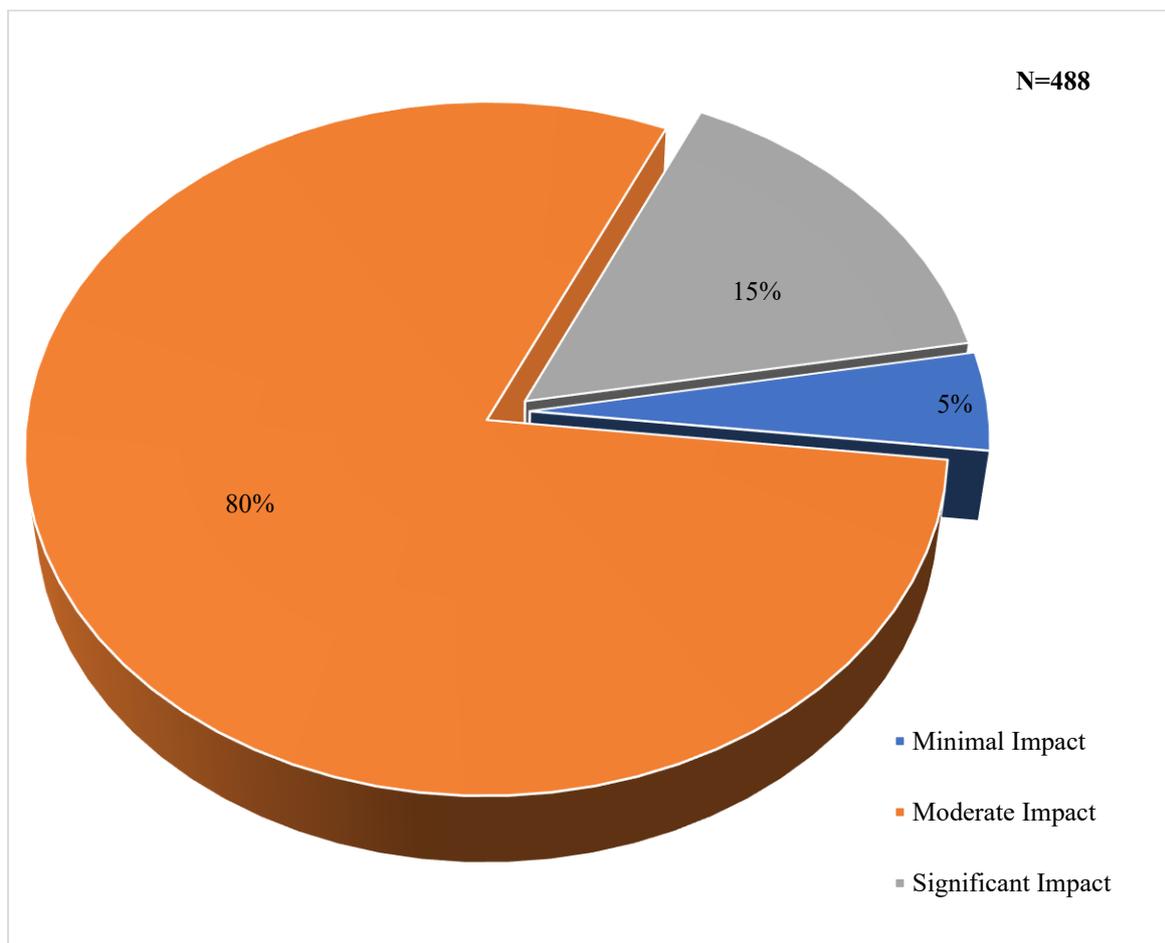
Meanwhile, 25% of participants assessed the impact as high, indicating that a significant portion of the population views the flooding as a serious concern for building safety. This group likely believes the effects of flooding, such as erosion or water seepage, are substantial enough to threaten the safety of structures in the area. This perception of a high impact could be tied to more frequent or intense flooding events that are undermining the stability of buildings, making this a critical issue for many.

On the opposite end of the spectrum, 13% of respondents considered the flooding's impact to be low, and just 2% rated it as very low. These individuals might live in areas less frequently affected by flooding, or they may believe

that the buildings in their area are sufficiently resilient to handle such conditions. As a result, they may not see flooding as a significant threat to safety.

Interestingly, there were no non-responses, suggesting that every participant in the survey felt strongly enough about the issue to offer an opinion. This level of engagement reflects the community's awareness of the risks associated with flooding and the perceived need to address its effects on building safety.

Furthermore, while the majority of respondents (60%) perceive the impact of flooding as moderate, a significant portion (25%) view it as a high risk to building safety. This indicates that while some see the flooding as manageable, many consider it a pressing concern that may require intervention. The low percentages of those who downplay the issue further emphasize the widespread acknowledgment of flooding's potential to compromise the safety of buildings in the affected area.



**Fig. 4.17: Rating of Impact of Perennial pluvial floods on aesthetics of Buildings.**

*(Source: Researcher, 2024)*

Figure 4.17 shows the Impact of Perennial Pluvial Flooding on the aesthetic Quality of Buildings. The result indicates that a small portion (5%) of buildings experiences minimal impact, indicating that some structures are better equipped

to withstand flood effects, possibly due to their design, materials, or location in less vulnerable areas. However, the majority of respondents (80%) reported moderate damage, reflecting widespread yet less severe aesthetic issues, such

as water stains, discoloration and minor erosion, which collectively degrade the visual appeal of buildings over time. Meanwhile, 15% of respondents reported significant damage, such as structural cracks, peeling paint, and severe corrosion, highlighting the more extreme consequences of

persistent flooding. This distribution underscores the pervasive yet variable impact of pluvial floods, emphasizing the need for proactive measures to prevent long-term deterioration and maintain the aesthetic value of buildings in flood-prone areas.

*Table 4.12: Comfort level within buildings is unbearable during or after flooding events*

<b>comfort level within buildings is unbearable during or after flooding events</b>		
<b>Responses</b>	<b>Frequency (F)</b>	<b>Percentages (%)</b>
Strongly Agree	42	9%
Agree	74	15%
Neutral	23	5%
Disagree	192	39%
Strongly Disagree	157	32%
<b>Total</b>	<b>488</b>	<b>100%</b>

*(Source: Researcher, 2024)*

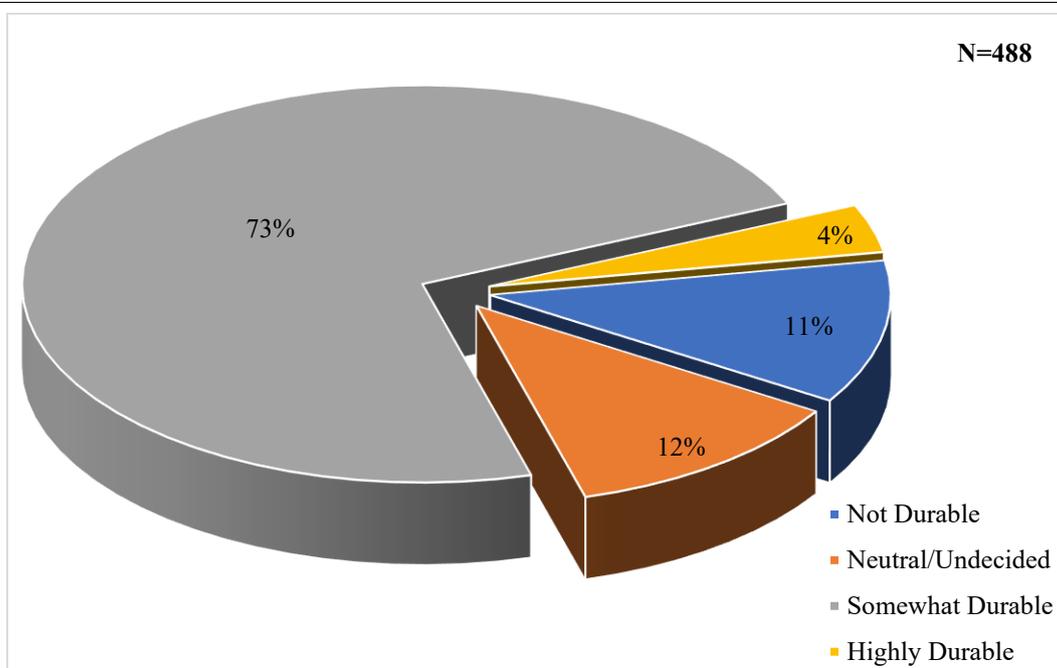
Table 4.12, provides insight into respondents' perceptions of comfort levels within buildings during or after flooding events. A significant majority of respondents, comprising 39% who disagreed and 32% who strongly disagreed, collectively accounting for 71%, do not consider the comfort level within buildings unbearable during or after flooding. This suggests that for most individuals, buildings might provide adequate protection or comfort during such events, or they may have adapted to the conditions to an extent that discomfort is not perceived as severe.

On the other hand, a smaller portion of respondents, totaling 24%, either agreed (15%) or strongly agreed (9%) that the comfort level within buildings becomes unbearable. This minority may represent individuals whose living conditions or building structures are more severely affected by flooding, leading to greater discomfort. Such experiences

could stem from factors like inadequate drainage, poor building materials, or prolonged exposure to flooding effects.

Furthermore, a minimal 5% of respondents remained neutral, indicating that they neither agreed nor disagreed with the statement. This neutrality could reflect indifference, lack of direct experience, or uncertainty about the extent of discomfort caused by flooding events.

In summary, the results highlight that while a significant majority of respondents do not find comfort levels unbearable during or after flooding, a smaller but notable proportion experiences discomfort. This disparity underscores the need for targeted interventions to address the specific challenges faced by those significantly affected by flooding in their buildings.



**Fig. 4.18: Durability of Building**  
(Source: Researcher, 2024)

Figure 4.18 shows the Durability of Buildings. However, the survey results show a generally favorable yet cautious view among respondents. A large majority (73%) consider the buildings to be somewhat durable, suggesting that most people believe the structures are fairly stable and resilient. This indicates that the buildings are generally viewed as solid, likely due to adequate construction or maintenance, although there may be a recognition that some level of upkeep is required to ensure their long-term durability.

In contrast, 11% of respondents feel that the buildings are not durable. These individuals may be concerned about factors such as poor quality of construction, aging materials, or insufficient care that could lead to the deterioration of the buildings over time.

Additionally, 12% of respondents were neutral or undecided, possibly due to a lack of concrete information or direct experience with the buildings' performance. This suggests that for some, the issue of durability may not have

been a significant concern or they might not have sufficient data to form an opinion.

Only 4% of respondents believe the buildings are highly durable, which reflects a perception that some of the structures are built with superior quality materials or construction methods, leading to greater long-term reliability.

In addition, while most respondents regard the buildings as somewhat durable, the results indicate that concerns about durability remain, especially regarding the need for ongoing maintenance. This suggests a general satisfaction with the buildings' durability but also points to areas where improvements could be made to enhance their long-term resilience.

**Research Question (3): What architectural strategies have been adopted in Port Harcourt to address the challenges posed by pluvial flooding?**

**Table 4.13: Awareness of Flood Mitigation strategies implemented in the neighborhood**

**Are you aware of any flood mitigation strategies implemented in your area?**

Awareness	Frequency (F)	Percentages (%)
Yes	296	61%
No	192	39%
<b>Total</b>	<b>488</b>	<b>100%</b>

(Source: Researcher, 2024)

Table 4.13 Awareness of Flood Mitigation strategies implemented in the neighborhood. However, results reveal a mixed level of awareness regarding flood mitigation strategies in the neighborhood. A majority of respondents, 61%, reported being aware of the flood mitigation measures implemented in their area, indicating that these strategies are relatively well-known among the residents. This could be attributed to effective communication or public awareness campaigns conducted by local authorities or community organizations. However, the remaining 39% of respondents expressed a lack of awareness about the flood mitigation strategies in place. This gap in awareness

suggests that there may be a need for improved communication channels or targeted outreach efforts to ensure that all community members are informed about these crucial strategies. The discrepancy between the two groups may also point to the effectiveness of current awareness campaigns, which might not have reached all residents or may not have been compelling enough to garner widespread attention. Therefore, further efforts to educate and engage the community are essential to ensure that everyone is informed and prepared for potential flood risks.

**Table 4.14 Attempts to Mitigate Flooding**

S/N	Reason	Response		
		Yes	No	Total
1.	Improved drainage systems	3.9	96.1	100
2.	Flood Barrier	69.5	30.5	100
3.	Land –use planning	1.4	98.6	100
4.	Early warning Systems	3.3	96.7	100
5.	Public awareness campaigns	26.6	71.5	100

*Source: Researcher, 2024*

Table 4.14 shows attempt to Mitigate Flooding. However, the data on flood mitigation efforts in Port Harcourt metropolis highlights significant challenges in addressing flooding effectively. Flood barriers appear to be the most implemented strategy, with 69.5% of respondents acknowledging their presence. Other essential measures show considerable deficiencies. Improved drainage systems were reported as inadequate by 96.1% of respondents, revealing a critical gap in infrastructure. Land-

use planning and early warning systems were also perceived as ineffective by 98.6% and 96.7%, respectively, indicating weaknesses in urban development and flood preparedness. Additionally, only 26.6% of respondents were aware of public awareness campaigns, pointing to limited community engagement. These result stress the urgent need for flood management strategies, including better drainage, strategic urban planning, robust warning systems, and effective public education.



**Plate 4.5: Architectural adaptation strategy (permeable road pavement, green verge by the road, and covered drainages to prevent indiscriminate refuse disposal).**

*Source: (Researcher, 2024)*

**Research Question (4): How effective are the existing architectural strategies in mitigating the risks of perennial pluvial flooding in Port Harcourt Metropolis?**

*Table 4.15: Architectural Adaptations to Mitigate Flooding*

S/N	Reason	Response		
		Yes	No	Total
1.	Elevate building DPC above the flood level	99.2	0.8	<b>100</b>
2.	Apply waterproof coatings, sealants	98.6	1.4	<b>100</b>
3.	Raise or floodproof HVAC equipment and mechanical, Plumbing, and electrical system components	93.6	6.4	<b>100</b>
4.	Use of water pumping machine	100	0	<b>100</b>
5.	Construct permanent barriers (floodwalls)	99.8	0.2	<b>100</b>
6.	Collection and storage of rainwater to reduce runoff when it's raining	90.0	10.0	<b>100</b>
7.	Permeable ground surfaces to promote water infiltration	96.5	3.5	<b>100</b>
8.	Retention ponds	90.0	10.0	<b>100</b>

*Source: Researcher, 2024*

Table 4.15, presents the list of architectural adaptations that have been effective in mitigating flood-related issues. However, the results show that significant architectural adaptations have been made in Port Harcourt metropolis to reduce flooding risks. Nearly all respondents (99.2%) reported that buildings are designed with elevated damp proof courses (DPC) to prevent water intrusion. Additionally, 98.6% of respondents use waterproof coatings and sealants for enhanced protection, and 93.6% raise or floodproof critical systems like HVAC, plumbing,

and electrical equipment. Water pumping machines are universally used (100%), underscoring their importance in flood management. Permanent flood barriers are also common (99.8%), while 90% of respondents collect rainwater to minimize runoff. Furthermore, permeable ground surfaces (96.5%) and retention ponds (90%) are commonly used to manage rainwater effectively. These findings highlight proactive steps taken to address flooding, though better integration with urban planning could further enhance their effectiveness.

*Table 4.16: Challenges Hindering Successful Implementation of Flood Mitigation Measures*

S/N	Reason	Response		
		Yes	No	Total
1.	Insufficient funding	99.8	0.2	<b>100</b>
2.	Infrastructure limitations	99.4	0.6	<b>100</b>
3.	Community resistance	28.9	71.1	<b>100</b>
4.	Regulatory issues	84.8	15.2	<b>100</b>

*Source: Researcher, 2024*

Table 4.16 presents the challenges hindering successful implementation of flood mitigation measures in the study area. The successful implementation of flood mitigation measures in Port Harcourt metropolis faces significant challenges, primarily due to insufficient funding and inadequate infrastructure. Nearly all respondents (99.8%) cited a lack of financial resources as a key hindrance, stressing the importance of adequate funding to support flood management projects. Similarly, 99.4% identified

limitations in existing infrastructure, suggesting it is not equipped to handle the growing flood risks. Regulatory issues also emerged as a notable challenge, with 84.8% of respondents highlighting difficulties in enforcing effective policies. However, community resistance was less of a concern, as 71.1% felt there was little opposition. These findings underscore the need for better funding, infrastructure improvements, and more effective regulatory measures to address the city's flood challenges.

**Table 4.17: Primary Goals of Flood Mitigation Strategies in Alignment with Architectural Objectives**

S/N	Option	Response		
		Yes	No	Total
1.	Protecting infrastructure	100	0	<b>100</b>
2.	Enhancing community safety	100	0	<b>100</b>
3.	Preserving architectural heritage	100	0	<b>100</b>
4.	Sustainable urban development	100	0	<b>100</b>
5.	Human comfort & building sustainability	100	0	<b>100</b>

*Source: Researcher, 2024*

Table 4.17 presents the Primary Goals of Flood Mitigation Strategies in Alignment with Architectural Objectives. However, the result reveal that flood mitigation strategies in Port Harcourt are fully aligned with key architectural objectives. Every respondent (100%) emphasized the importance of protecting infrastructure, enhancing community safety, preserving architectural heritage, supporting sustainable urban development, and ensuring human comfort

and building sustainability. This shows a shared consensus on the necessity of integrating these goals into flood mitigation efforts. The alignment indicates a holistic approach that addresses immediate flooding risks while also focusing on long-term urban sustainability, public safety, and the preservation of both cultural and architectural heritage within the metropolis.

**Table 4.18: How Community Involvement Can Be Enhanced to Ensure the Success of Flood Mitigation Initiatives**

S/N	Option	Response		
		Yes	No	Total
1.	Community engagement programmes	100	0	<b>100</b>
2.	Collaborative planning sessions	100	0	<b>100</b>
3.	Educational workshops	100	100	<b>100</b>
4.	Public awareness campaigns	100	0	<b>100</b>

*Source: Researcher, 2024*

Table 4.18 presents the best ways community involvement can be enhanced to ensure success of flood mitigation measures in Port Harcourt metropolis. However, the results highlight a strong agreement on the role of community involvement in the success of flood mitigation initiatives in Port Harcourt. Every respondent (100%) emphasized the importance of community engagement programs, collaborative planning sessions, and public awareness campaigns to ensure effective participation.

Additionally, educational workshops received full support (100%) as a means of enhancing public understanding and providing essential knowledge. This unanimous agreement underscores the need for an inclusive approach where the community is actively engaged in flood management efforts, ensuring that flood mitigation strategies are more widely accepted and effectively implemented.



**Plate 4.6: Raised Driveway, Golf course estate, off believers, road.**

*Source: (Researcher 2024)*



**Plate 4.7: Rumuewhara new layout after the flood December 2024 flood (remodeled shops with raised DPC)**

*Source: (Researcher 2024)*

**Research Question (5): What flood-resilient architectural design framework can be developed for Port Harcourt Metropolis to enhance flood mitigation and resilience?**

**Table 4.19: How to Make Buildings More Resilient to Perennial Pluvial Floods**

S/N	Options	Response		
		Yes	No	Total
1.	Effective architectural changes	100	0	<b>100</b>
2.	Assessment of current flood strategies	99.2	0.8	<b>100</b>
3.	Evaluation of how buildings perform during floods	100	0	<b>100</b>

*Source: Researcher, 2024*

Table 4.19 presents the best measures to make buildings more resilient to pluvial floods. However, the results indicate broad agreement on the need for measures to increase building resilience to recurring pluvial floods in Port Harcourt. Every respondent (100%) emphasized the importance of implementing effective architectural changes and evaluating how buildings perform during flood events. Furthermore, 99.2% of respondents supported the

assessment of existing flood strategies, with only a small portion (0.8%) opposing it. This highlights the need for ongoing improvements in building design and infrastructure, as well as the continuous evaluation of current flood mitigation efforts, to ensure that structures remain resilient to the frequent flooding challenges in the area.

**Table 4.20: How the Research Findings Could Impact the Way Buildings Can Be Designed to Withstand Floods**

S/N	Options	Response		
		Yes	No	Total
1.	Adoption of specific design ideas	100	0	<b>100</b>
2.	Use of new flood-resistant materials	100	0	<b>100</b>
3.	Changes to architectural codes and standards	99.6	0.4	<b>100</b>

*Source: Researcher, 2024*

Table 4.20 presents how the research findings could impact the way buildings can be designed to withstand floods. The results reflect a strong consensus on how the research findings could influence the design of buildings to better withstand floods. Every respondent (100%) agreed on the importance of adopting specific design strategies and using new flood-resistant materials. Additionally, 99.6% supported the idea of

updating architectural codes and standards to improve flood resilience, with a very small minority (0.4%) opposed. These findings highlight the necessity of incorporating innovative design approaches, advanced materials, and revised building regulations to enhance the ability of structures to resist flood impacts, emphasizing proactive changes in flood-prone areas.

**Table 4.21 How the Research Findings Could Impact the Way Buildings Can Be Designed to Withstand Floods**

S/N	Options	Response		
		Yes	No	Total
1.	Including flood-resilient designs in city planning	100	0	<b>100</b>
2.	Creating more green spaces for water absorption	100	0	<b>100</b>
3.	Changing zoning rules	99.6	0.4	<b>100</b>

*Source: Researcher, 2024*

Table 4.21 presents how City Planning can be Influenced by The Research to Better Protect Buildings from Flood. The results show a unanimous agreement on the impact of the research findings on building design in the study area to withstand floods. All respondents (100%) agreed on the importance of integrating flood-resilient designs into city planning and creating more green spaces for water absorption.

Furthermore, 99.6% supported the modification of zoning rules to better address flood risks, with only a small minority (0.4%) in disagreement. These findings underline the necessity of incorporating flood-resilient design strategies, promoting green spaces, and adjusting zoning regulations to enhance flood resilience and reduce the impact of flooding in vulnerable areas.

**Table 4.22: What Policies Do You Think Should Be Recommended Based on the Research to Improve How Cities Handle Floods, Considering Architectural Aspects**

S/N	Options	Response		
		Yes	No	Total
1.	Creating flood-resistant building codes	100	0	<b>100</b>
2.	Offering rewards for eco-friendly architecture	100	0	<b>100</b>
3.	Making land-use rules stricter	100	0	<b>100</b>

*Source: Researcher, 2024*

Table 4.22 presents policies that could be recommended based on the research to improve how cities handle floods, considering architectural aspects. The results indicate unanimous support for several policies aimed at improving how cities handle floods, with a focus on architectural aspects. Every respondent (100%) agreed on the importance of creating flood-resistant building codes, providing incentives for eco-friendly architecture, and enforcing

stricter land-use regulations. These findings emphasize the necessity for policies that foster resilience to flooding by promoting sustainable building practices and ensuring stricter control over land use. Such measures would not only reduce the risk of flood damage but also encourage environmentally responsible urban development, improving cities' overall flood management strategies.

**Table 4.23: How Research Findings Can Be Practically Applied in Architectural Projects to Make Buildings More Resilient to Floods**

S/N	Options	Response		
		Yes	No	Total
1.	Using research-based designs	100	0	<b>100</b>
2.	Training architects in flood-resilient practices	100	0	<b>100</b>
3.	Developing guidelines for flood-resilient architecture	100	0	<b>100</b>

*Source: Researcher, 2024*

Table 4.23 presents how the research findings can be practically applied in architectural projects to make buildings more resilient. The results show complete agreement on the practical applications of the research findings to make buildings more resilient to floods. All respondents (100%) supported the use of research-based designs, training architects in flood-resilient practices, and developing guidelines for flood-resilient

architecture. This suggests that incorporating these strategies into architectural practice is essential for enhancing the flood resilience of buildings. By adopting research-driven designs, equipping architects with specialized training, and establishing comprehensive guidelines, cities can ensure that buildings are better prepared to withstand the impacts of flooding, leading to improved overall resilience in urban areas.

### INTERPRETATION AND DISCUSSION OF FINDINGS

#### 5.0 Preamble

This chapter focused on interpreting the results of the findings and discusses how they apply to the aim and objectives of this study. The interpretation of this findings is guided by five (5) research objectives which help to understand Architectural Adaptation Strategies to Mitigate Perennial Pluvial Floods in Port Harcourt Metropolis.

#### 5.1 Interpretation of Findings

##### **Objective 1 identified the areas within Port Harcourt Metropolis that are most vulnerable to perennial pluvial flooding.**

However, 13 streets/roads were chosen from the 25 most flooded areas in Port Harcourt Metropolis; 4 lowly flooded, 5 moderately flooded, and 4 highly flooded. The 4 lowly flooded areas in Port Harcourt Metropolis, include Abanna Street (Old GRA), Hon. Attah Close, Uyo Street, and Akwaka Street. These areas, located within latitudes  $4.78^{\circ}$ – $4.88^{\circ}$  and longitudes  $6.99^{\circ}$ – $7.05^{\circ}$ , have altering elevations (ranging from 3.6m to 14.1m above sea level), better drainage infrastructure, and efficient urban planning. Even though they were classified as being lowly flooded by Wizer & Mpigi (2020), the flood vulnerability map grouped them as being highly vulnerable (Abanna street), and moderately vulnerable (Hon. Attah close, Akwaka street, and Uyo street). The findings reveal that these could be as a result of causal factors caused by human and climatic variables (See Table 4.9).

Findings on identified moderately flooded areas within Port Harcourt Metropolis, identified five moderately flooded areas in Port Harcourt Metropolis, including locations like Rumuodomaya, Ada George Road, Rumuigbo, Elelenwo, and GRA Phase II, within latitudes  $4.81^{\circ}$ – $4.87^{\circ}$  and longitudes  $6.97^{\circ}$ – $7.07^{\circ}$ . Flooding in these areas, such as Omachi Road in Rumuodomaya, Salem Close off Ada George road, Obi Wali Road in Rumuigbo, Odani road at Elelenwo, and Evelyn's close at GRA Phase II, is attributed to urban development and poor drainage. The findings stress the need for improved drainage, urban planning, and water retention systems. (Table 4.9).

Findings on highly flooded areas in Port Harcourt metropolis, identifies four highly flooded areas in Port Harcourt Metropolis, including Nkpolu Road 1 (Rumuigbo), Rumuewhara New Layout/Eneka Town, NTA/Apara Link Road, and Abacha road. These locations are prone to severe flooding due to rapid urbanization, inadequate drainage, and poor stormwater management. The areas, which span both developing and established neighborhoods, suffer from surface runoff caused by large

impermeable surfaces like asphalt roads, and “increte” stamped concrete pavers in residential compounds. The widespread nature of flooding in these areas emphasizes the need for improved drainage systems, sustainable urban planning, and better water management strategies (Table 4.7).

Findings on identifies flooded areas within Port Harcourt Metropolis using field observation by the researcher, highlights varying flood classifications and elevations across Port Harcourt Metropolis. Highly flooded areas include Rumuewhara New Layout/Eneka (17.1m elevation), NTA/Apara Link Road (13.5m), Abacha Road, GRA Phase II (4.2m), and Nkpolu Road 1, Rumuigbo (14.1m), with floodwaters reaching up to 200mm in some areas. Moderately flooded locations, such as Salem Close and Obiwali Road, showed lesser impacts, while low flooding was observed in areas like Abanna Street and Akwaka Street. Flood management relies on community-driven measures, including flood barriers and raised driveways, as no government adaptation strategies were physically evident, emphasizing the need for comprehensive intervention (Table 4.14).

Findings on Percentage Distribution of Mostly Flooded Parts of Port Harcourt Metropolis reveals that over 90% of respondents consider Obio/Akpor Local Government Area the most flooded part of Port Harcourt Metropolis, indicating its high vulnerability to severe flooding. Factors such as poor drainage, rapid urbanization, low elevation, and impermeable surfaces likely contribute to this issue. On the other hand, 10% of respondents identified Port Harcourt City Local Government Area as the most flooded, pointing to localized flooding challenges within specific parts of the city. These results highlight the importance of implementing focused flood management solutions in both areas to address their distinct needs (Figure 4.10).

Findings on perceptions of pluvial flood magnitudes in identified neighborhoods, shows that the majority (52.7%) rated flooding as “Moderate - Above Ankle (101mm to 200mm),” indicating frequent but manageable flooding. A significant portion (33.6%) experienced “High - Above Knee (201mm to 600mm)” flooding, suggesting more severe disruptions. Only 12.5% reported “Low – Ankle (51mm to 100mm)” flooding, reflecting areas with less impact, possibly due to better drainage or higher elevation. A minimal 1.2% described the flooding as “Severe - Waist Level (601mm to 900mm),” highlighting rare but extreme flooding events. These results emphasize the varying flood impacts across neighborhoods and the need for tailored flood management strategies (Figure 4.11).

Findings on flood durations across the study areas reveals that majority of respondents (30.3%) reported floods lasting over 30 minutes, making it the most common flood duration. A significant portion of respondents experienced flooding for one hour (16.8%) and two hours (19.7%). A smaller group (1.8%) reported floods lasting up to five hours. Cumulatively, 38.3% of respondents experienced flooding lasting between one and five hours after a downpour. These results underscore the prolonged nature of flooding in the area, highlighting the urgent need for improved flood management and drainage systems (Figure 4.12).

Findings on the consequences of flooding on infrastructure in the study area indicate that a large percentage of respondents (73.6%) reported that flooding causes unsightly buildings, with issues like mold growth and water stains. Property damage, such as rising damp and peeling paint, was noted by 79.3% of respondents. Infrastructure damage, including broken gutters and damaged roads, was observed by 34.6%, while health and safety concerns, such as contact with contaminated water and waterborne diseases, were identified by 95.7%. These findings underscore the need for improved flood management strategies to address both infrastructure damage and public health risks. (Table 4.10).

**Objective 2 examined the impact of perennial pluvial flooding on the architectural quality and performance of buildings, focusing on safety, functionality, aesthetics, comfort, and durability.**

Finding on the key factors contributing to severe flooding in the study areas identify overwhelmed drainage systems 99.8% as the main contributing factors by the respondents, highlighting inadequate drainage infrastructure as a major cause. Impermeable ground surfaces, such as concrete and asphalt, were noted by 91.4% of respondents, which hinder water absorption. Intense rainfall was recognized by 98.0% as a significant factor, emphasizing its role in flooding. Additionally, 95.5% attributed flooding to climate change, suggesting that altered weather patterns are exacerbating flood events. These findings underscore the need for improved drainage and urban planning, alongside addressing climate change impacts. (Table 4.11). Findings on the impact of Perennial pluvial flooding on the safety of buildings in the affected study area, reveal that the majority of respondents (60%) consider the impact of perennial pluvial flooding on building safety to be moderate, indicating noticeable but not severe effects. A significant portion (25%) view the impact as high, suggesting concerns over the serious threat flooding poses to structural integrity. Meanwhile, 13% perceive the impact as low, and just 2% see it as very low, likely due to less frequent flooding or resilient structures. No non-responses were recorded,

reflecting the community's strong awareness of the issue and the general recognition of flooding's potential risk to building safety (Figure 4.1).

Findings on the aesthetic impact of perennial pluvial floods on buildings, shows that 5% of the respondents reported minimal impact, likely due to flood-resilient designs and favorable locations, the majority (80%) experienced moderate effects, such as water stains and discoloration, which degrade building appearances over time. Additionally, 15% noted significant damage, including structural cracks and severe corrosion, highlighting the severe effects of persistent flooding in some areas. These findings emphasize the widespread but variable impacts of pluvial floods and underscore the importance of flood prevention and maintenance measures to preserve the aesthetic and structural integrity of buildings (Figure 4.14).

Findings on the perceptions of comfort levels in buildings during and after flooding shows that majority (71%) of respondents, including 39% who disagreed and 32% who strongly disagreed, believe buildings provide adequate comfort and have adapted to flooding conditions. Conversely, 24% (15% agreed, 9% strongly agreed) reported unbearable discomfort, likely due to inadequate drainage, poor building materials and prolonged flooding exposure. A small neutral group (5%) indicated indifference and uncertainty. Thus, while most respondents do not perceive significant discomfort, the experiences of those severely affected emphasize the need for targeted measures to improve building resilience and address flooding challenges (Table 4.12).

Finding on the Durability of Buildings show that 73% of respondents consider the buildings somewhat durable, indicating general satisfaction with their stability and resilience. However, 11% perceive the buildings as not durable, likely due to concerns about construction quality or aging materials. A small percentage (12%) were neutral or undecided, possibly due to lack of information or experience with the buildings' performance. Only 4% view the buildings as highly durable, suggesting that these structures may be seen as exceptionally resilient. Overall, the majority feel the buildings are relatively durable, but concerns about maintenance and longevity persist. (Figure 4.15).

**Objective 3 analyzed the architectural strategies currently employed to address perennial pluvial flooding in Port Harcourt Metropolis.**

Findings on the Awareness of Flood Mitigation strategies implemented in the neighborhood show that 61% of respondents are aware of the flood mitigation strategies implemented in their neighborhood, indicating that these measures are relatively well-known. However, 39% of

respondents are unaware of these strategies, suggesting a gap in communication or outreach efforts. This highlights the need for improved awareness campaigns or targeted community engagement to ensure that all residents are informed about the flood mitigation measures in place. Addressing this gap can help enhance preparedness and foster greater community involvement in mitigating flood risks. (Table 4.13). Findings on Flood mitigation efforts in Port Harcourt metropolis also show significant shortcomings. While 69.5% of respondents acknowledged the presence of flood barriers, other measures are lacking. Improved drainage systems were deemed inadequate by 96.1%, and land-use planning and early warning systems were ineffective for 98.6% and 96.7% of respondents, respectively. Furthermore, only 26.6% recognized public awareness campaigns, indicating limited community engagement. These findings highlight the urgent need for improved infrastructure, strategic urban planning, effective early warning systems, and enhanced public education to address the challenges of flooding and build resilience in the city (Table 4.13).

**Objective 4 evaluated the effectiveness of existing architectural and urban planning strategies in mitigating the risks associated with perennial pluvial floods.**

Findings on the list of architectural adaptations that have been effective in mitigating flood-related issues, indicate that in Port Harcourt metropolis, various architectural adaptations are widely employed to mitigate flooding. Nearly all respondents (99.2%) use elevated damp proof courses (DPC), and 98.6% apply waterproof coatings and sealants. Most buildings (93.6%) floodproof essential systems like HVAC, plumbing, and electrical equipment. Water pumping machines are universally used (100%), and permanent flood barriers (99.8%) are common. Additionally, 90% collect rainwater to reduce runoff, while 96.5% use permeable surfaces and 90% construct retention ponds. These measures show proactive flood mitigation, though their integration with broader urban planning could improve overall effectiveness in managing flood risks (Table 4.14).

Findings on the challenges hindering successful implementation of flood mitigation measures in the study area indicate that the implementation of flood mitigation measures in Port Harcourt faces challenges due to insufficient funding (99.8%) and inadequate infrastructure (99.4%). Regulatory issues also pose a significant obstacle, with 84.8% of respondents acknowledging difficulties in policy enforcement. However, community resistance is less of a concern, as 71.1% of respondents indicated minimal opposition to flood mitigation efforts. These results highlight the urgent need for increased financial resources,

enhanced infrastructure, and more effective regulatory frameworks to overcome barriers and improve flood management in the metropolis. Addressing these challenges is essential for implementing sustainable and effective flood mitigation strategies. (Table 4.15).

Findings on the Primary Goals of Flood Mitigation Strategies in Alignment with Architectural Objectives show unanimous alignment between flood mitigation strategies and architectural objectives in Port Harcourt, with 100% of respondents agreeing on key priorities. These include protecting infrastructure, enhancing community safety, preserving architectural heritage, supporting sustainable urban development, and ensuring human comfort and building sustainability. This consensus reflects a comprehensive approach to flood management that not only addresses the immediate risks of flooding but also emphasizes long-term sustainability, public safety, and the preservation of cultural and architectural values. The integration of these objectives indicates a well-rounded strategy for managing flood impacts in the metropolis (Table 4.16).

Finding on the best ways community involvement can be enhanced to ensure success of flood mitigation measures in Port Harcourt metropolis shows that all respondents (100%) agreed on the importance of community engagement programs, collaborative planning sessions, and public awareness campaigns to boost participation. Additionally, educational workshops were universally supported (100%) as an essential means to raise awareness and provide vital knowledge to the community. These findings highlight the need for an inclusive approach, ensuring that the community actively contributes to the planning and execution of flood mitigation strategies, thereby enhancing their effectiveness and acceptance (Table 4.17).

**Objective 5 proposed a Flood Resilient Design Framework (FRDF) tailored to Port Harcourt Metropolis, which integrates innovative architectural adaptation strategies, stakeholder involvement, and actionable policy recommendations to enhance urban resilience and minimize flood-related risks.**

Findings on the best measures to make buildings more resilient to pluvial floods, highlight a strong consensus on the importance of making buildings more resilient to perennial pluvial floods in Port Harcourt. All respondents (100%) emphasized the need for effective architectural changes and evaluations of how buildings perform during floods. Additionally, 99.2% supported the assessment of current flood strategies, with only a small percentage (0.8%) in disagreement. This indicates that both architectural interventions and the continuous evaluation of existing flood mitigation measures are essential to enhance building resilience against frequent flooding in the

metropolis, ensuring better protection for structures in flood-prone areas (Table 4.18).

Findings on how the research findings could impact the way buildings can be designed to withstand floods indicates that every respondent (100%) agreed on the importance of adopting specific design strategies and using new flood-resistant materials. Additionally, 99.6% supported the idea of updating architectural codes and standards to improve flood resilience, with a very small minority (0.4%) opposed. These findings highlight the necessity of incorporating innovative design approaches, advanced materials, and revised building regulations to enhance the ability of structures to resist flood impacts, emphasizing proactive changes in flood-prone areas. (Table 4.19).

Findings on how City Planning can be Influenced by The Research to Better Protect Buildings from Flood highlight strong agreement on how the research findings could improve building designs to withstand floods in the study area. All respondents (100%) emphasized the importance of incorporating flood-resilient designs into city planning and increasing green spaces for better water absorption. Additionally, 99.6% supported revising zoning rules to address flood risks, with only a small minority (0.4%) opposed. These findings suggest that integrating flood-resilient strategies, expanding green spaces, and adjusting zoning regulations are essential steps to enhance infrastructure resilience and reduce the impact of flooding in flood-prone areas, promoting sustainable urban development (Table 4.20).

Findings on policies that could be recommended based on the research to improve how cities handle floods,

considering architectural aspects indicate unanimous support for policies that aim to improve flood management in cities, particularly regarding architectural considerations. All respondents (100%) agreed on the importance of creating flood-resistant building codes, offering rewards for eco-friendly architecture, and implementing stricter land-use regulations. These findings suggest that such policies are crucial in fostering urban resilience to flooding. Thus, in promoting sustainable building practices, incentivizing eco-friendly designs, and regulating land use, cities can better manage flood risks and ensure long-term protection. These measures will enhance flood resilience while encouraging more sustainable urban development. (Table 4.21).

Findings on how the research findings can be practically applied in architectural projects to make buildings more resilient, indicate unanimous support for applying research findings in architectural projects to improve flood resilience. All respondents (100%) agreed on the importance of using research-based designs, training architects in flood-resilient practices, and developing guidelines for flood-resilient architecture. These findings highlight the need for integrating evidence-based strategies into architectural practices to ensure buildings are better equipped to withstand flooding. By implementing these approaches, cities can enhance building resilience and effectively address the challenges posed by floods. Thus, these measures are crucial for improving urban resilience and minimizing the impact of flooding on infrastructure (Table 4.22).

### CONCLUSION AND RECOMMENDATIONS

#### 6.1 Summary

The study identified key areas within Port Harcourt Metropolis most vulnerable to perennial pluvial flooding. Using field observations, the research highlighted flood-prone locations such as Rumuewhara New Layout/Eneka (17.1m elevation), NTA/Apara Link Road (13.5m), and Abacha Road, GRA Phase II (4.2m), where floodwaters reached up to 200mm. Moderately affected areas like Salem Close experienced lesser impacts, while minimal flooding was observed in Abanna Street. Findings indicate that over 90% of respondents identified Obio/Akpor Local Government Area as the most severely affected due to poor drainage, rapid urbanization, and low elevation. Perceptions of flood magnitudes revealed that most respondents (52.7%) experienced “Moderate” flooding, while 33.6% faced “High” flooding, with a minority reporting severe events. Flood durations commonly exceeded 30 minutes, with a cumulative 38.3% experiencing floods lasting one to five hours, underscoring the prolonged nature of flooding in the area.

The impact on infrastructure revealed widespread issues, with 95.7% identifying health risks from contaminated water and 79.3% noting property damage. Architectural quality was also affected, as 60% of respondents rated the safety impact of flooding as moderate, while aesthetics suffered due to water stains and structural corrosion reported by 80% of respondents. Regarding comfort, 71% felt buildings were moderately adapted, although a minority reported significant discomfort. Durability was deemed satisfactory by 73%, but concerns over aging materials and poor maintenance persisted.

The study also analyzed flood mitigation strategies, revealing gaps in awareness and implementation. While 61% of respondents were aware of flood measures like barriers and water pumps, inadequate drainage, poor urban planning, and ineffective early warning systems were significant challenges. Effective adaptations included elevated damp proof courses, floodproofing essential systems, and permeable surfaces, widely used across the metropolis. However, challenges such as insufficient funding, inadequate infrastructure, and policy enforcement hindered broader success. Stakeholder engagement and community-driven approaches, including public awareness campaigns and educational workshops, were identified as essential for enhancing resilience. Finally, a flood-resilient design framework integrating innovative architectural adaptations, stakeholder involvement, and policy recommendations was proposed to address the unique challenges of flooding in Port Harcourt.

#### 6.2 Conclusion

This study has explored the complexities of flood mitigation strategies in Port Harcourt Metropolis, focusing on the persistent challenges posed by pluvial flooding. The research utilized a mixed-methods approach, combining primary data collection through surveys, interviews, and field observations with an extensive review of existing literature. The findings underscore the necessity for an integrated flood mitigation approach that encompasses architectural adaptations, comprehensive urban planning, and robust governance frameworks.

Chapter 1 introduced the pressing issue of recurrent flooding in Port Harcourt, highlighting the inadequacies of existing mitigation strategies. Chapter 2 reviewed theoretical models such as the Blue-Green Infrastructure Theory and the Theory of Resilience, which advocate for sustainable and integrated flood management practices. Chapter 3 detailed the rigorous methodology employed, ensuring the reliability and validity of the findings. Chapter 4 presented the critical challenges and opportunities in flood mitigation, and aligned these findings with existing literature, reinforcing the need for a holistic approach.

The research identified key flood-prone areas that are highly susceptible to flooding. Rumuewhara New Layout/Eneka (17.1m above sea level), and NTA/Apara Link Road (13.5m above sea level) with their high elevations still experience flooding due to causational climatic and human factors. Moderately affected areas such as Salem Close and minimally affected zones like Abanna Street still experience pluvial flooding.

The findings revealed that most residents experience moderate to high flood magnitudes, with events lasting several hours, emphasizing the recurrent and disruptive nature of flooding in the area. Impacts on infrastructure were substantial, with severe health risks from contaminated water, extensive property damage, and a decline in architectural quality. Water stains, structural corrosion, and diminished aesthetic appeal were commonly reported, alongside moderate discomfort in affected buildings. Despite satisfactory ratings for building durability, concerns over aging materials and poor maintenance highlight the need for more resilient architectural designs.

Existing flood mitigation strategies, while present, revealed shortcomings in awareness, implementation, and funding. The research emphasized the value of practical measures such as elevated damp-proof courses, floodproofing essential systems, and incorporating permeable surfaces.

However, systemic challenges like poor urban planning, ineffective drainage systems, and weak enforcement of policies remain significant obstacles.

To address these issues, the study proposed a flood-resilient design framework that incorporates architectural innovations, effective stakeholder involvement, and strong policy measures. Thus in enhancing public awareness, fostering community participation, and prioritizing sustainable urban planning practices, Port Harcourt Metropolis can better manage and mitigate the impacts of perennial pluvial floods while building a more resilient urban environment.

### 6.3 Implementing Blue-Green Infrastructure (BGI) for Flood Resilience in Residential Buildings

As the frequency and severity of flooding events continue to rise, it has become increasingly important to develop effective strategies for mitigating flood risk in residential areas. One promising approach is the implementation of Blue-Green Infrastructure (BGI) in residential buildings. BGI combines natural systems with urban planning to reduce stormwater runoff, improve water quality, and enhance urban livability. This guide provides practical guidance on implementing BGI in residential buildings, with the aim of promoting flood resilience and creating more sustainable and resilient communities. It applies to new and existing residential buildings in Port Harcourt Metropolis.

#### 6.3.1 Benefits of BGI

1. Reduced stormwater runoff and flood risk
2. Improved water quality
3. Enhanced biodiversity
4. Increased property value
5. Reduced stormwater management costs
6. Improved public health and well-being
7. Enhanced aesthetic appeal

#### 6.3.2 BGI Strategies for Existing Building Developments

**Blue Roofs:** Constructing blue roofs over concrete carports within the compounds of existing buildings to capture and slowly release rainwater and provide insulation.

**Rain Gardens and Bioswales:** Creating shallow depressions and vegetated channels to capture and filter stormwater runoff in estates and communities.

**Permeable Pavements:** Replacing impervious surfaces with porous materials to allow stormwater infiltration.

**Rainwater Harvesting:** Installing rainwater collection systems for non-potable uses.

**Green Walls and Vertical Gardens:** Integrating green walls and vertical gardens to absorb stormwater and improve aesthetics.

**Underground Rain Tanks:** Collecting and storing rainwater in underground storage, and slowly releasing it to the surrounding soil.

#### 6.3.3 BGI Strategies for New Building Developments

**Perimeter Blue Roofs:** Create blue roofs around the proposed building to collect rainwater and slowly release.

**Rain Gardens and Bioswales:** Shallow depressions and vegetated channels capture, and filter stormwater.

**Permeable Pavements:** Porous materials allow stormwater infiltration, reducing runoff.

**Rainwater Harvesting:** Collecting and storing rainwater for non-potable uses.

#### 6.3.4 Key Considerations for Implementing Blue-Green Infrastructure (BGI) Strategies

Implementing BGI strategies requires careful consideration of several key factors. The following are essential considerations for successful BGI implementation:

##### **Incorporate BGI features into building design from the outset**

This includes:

- Considering the site's topography, drainage patterns, and environmental conditions
- Incorporating green roofs, walls, and other BGI features into the building design
- Ensuring that BGI features are integrated with other building systems, such as plumbing and electrical systems

##### **Conduct Site Assessments**

Evaluate site conditions, drainage patterns, and environmental factors to determine the most effective BGI strategies. This includes:

- Assessing site topography and slope
- Evaluating soil type and permeability
- Analyzing existing drainage patterns and infrastructure
- Considering environmental conditions, such as wind and sunlight

##### **Collaborate with Stakeholders**

Engage architects, engineers, landscape architects, and other stakeholders in the BGI design and implementation process. This ensures that:

- All aspects of the project are considered
- BGI strategies are effective and sustainable

- Stakeholders are informed and supportive of BGI implementation

### **Ensure Maintenance and Upkeep**

Develop maintenance plans to ensure that BGI systems continue to function effectively over time. This includes:

- Regular inspections and maintenance
- Repair and replacement of components as needed
- Upgrades and improvements to the system
- Training for maintenance personnel

### **Monitor Performance**

Track the effectiveness of BGI systems and make adjustments as needed. This includes:

- Monitoring stormwater runoff and management
- Evaluating water quality and pollution reduction
- Assessing biodiversity and habitat creation
- Tracking community engagement and education

### **6.3.5 Policy Frameworks for Supporting BGI Implementation**

Effective policy frameworks are crucial for supporting the implementation of BGI strategies.

The following policy frameworks can encourage BGI adoption and support the creation of more sustainable and resilient communities:

#### **Zoning Regulations**

Update zoning regulations to encourage BGI implementation. This can include:

- Requiring BGI features in new developments
- Providing density bonuses or other incentives for BGI adoption
- Designating specific areas for BGI implementation

#### **Building Codes**

Update building codes to incorporate BGI requirements. This can include:

- Mandating green roofs or walls in new buildings
- Establishing standards for rainwater harvesting systems
- Providing guidelines for BGI maintenance and inspection

#### **Incentives and Tax Credits**

Offer incentives and tax credits to encourage BGI adoption. This can include:

- Tax credits for BGI installation
- Grants for BGI design and implementation
- Low-interest loans for BGI projects

#### **Education and Training**

Provide education and training on BGI design, implementation, and maintenance. This can include:

- Workshops and training sessions for developers, architects, and engineers
- Online resources and guidance documents
- Certification programs for BGI professionals

### **6.3.6 Recommendations**

1. Incorporate BGI into building design: Incorporate BGI features into building design from the outset.
2. Conduct thorough site assessments: Evaluate site conditions, drainage patterns, and environmental factors.
3. Collaborate with stakeholders: Engage architects, engineers, landscape architects, and other stakeholders.
4. Ensure maintenance and upkeep: Develop maintenance plans to ensure BGI systems continue to function effectively.
5. Monitor performance: Track the effectiveness of BGI systems and make adjustments as needed.

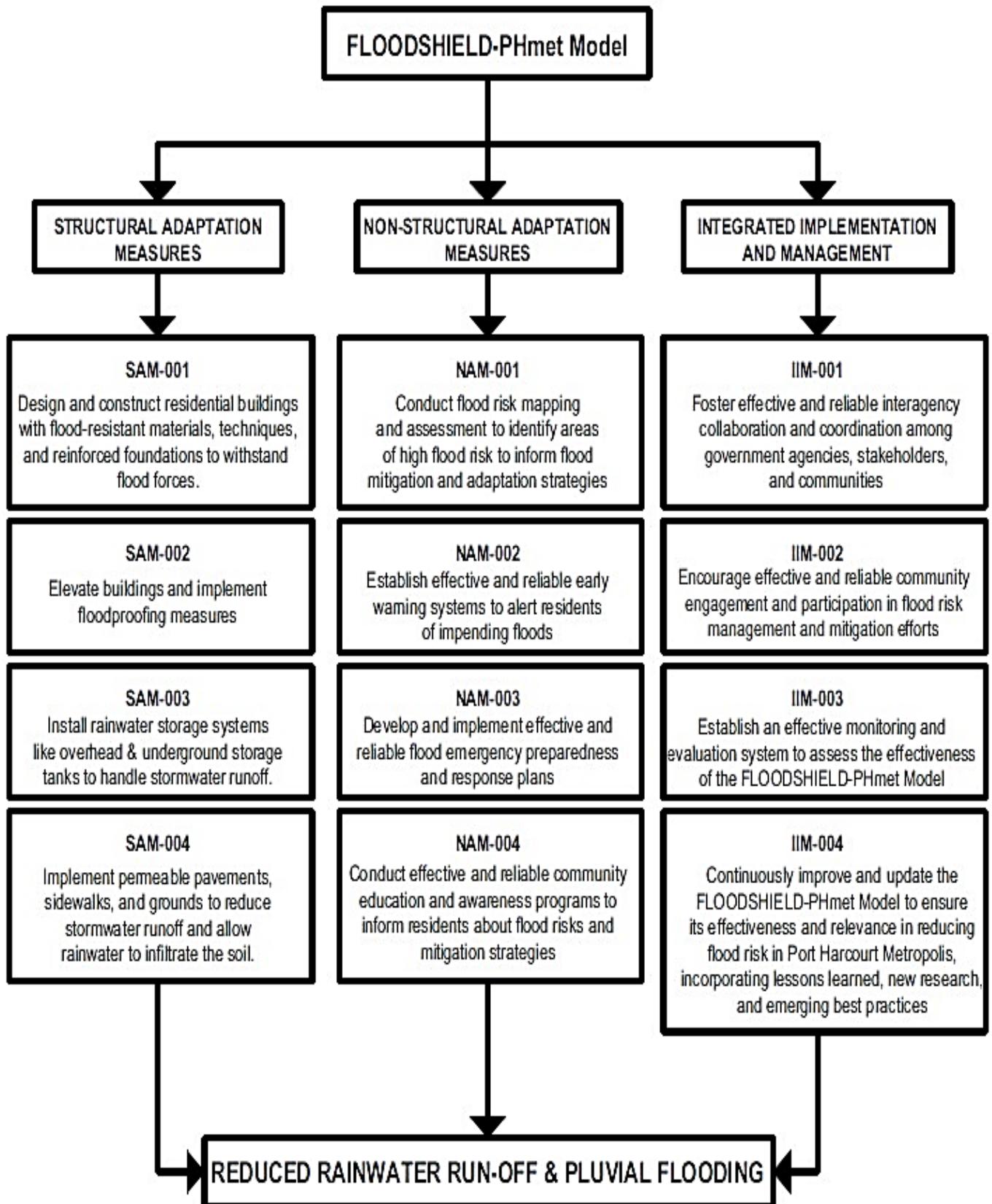
### **6.4 Recommended Architectural Adaptation Strategies to Mitigate Perennial Pluvial Floods in Port Harcourt Metropolis**

To mitigate recurrent pluvial flooding in Port Harcourt Metropolis, a multi-faceted approach involving a combination of architectural adaptation strategies, urban planning, and community engagement is essential. This integrated approach will enable the city to effectively address the complex factors contributing to flooding, while also promoting sustainable urban development. Hence, the development of a comprehensive Flood Resilient Design Framework (FRDF) is crucial, integrating architectural adaptation strategies, stakeholder engagement, and policy recommendations. This framework will enhance the city's resilience against future flood events, improving the quality of life for its residents. The FRDF will provide a structured methodology for assessing flood risks, identifying adaptation strategies, and implementing effective flood mitigation measures. By adopting this framework, Port Harcourt Metropolis can reduce the economic, social, and environmental impacts of flooding, while also promoting sustainable urban growth. The dubbed name for this framework is FLOODSHIELD-PHmet Model (Flood Resilient Adaptation Strategy for Port Harcourt Metropolis), reflecting its focus on providing a protective shield against flooding for the city. The FLOODSHIELD-PHmet Model will serve as a valuable tool for urban planners, policymakers, and stakeholders, guiding the development of flood-resilient infrastructure and communities. By implementing this framework, Port

Harcourt Metropolis can emerge as a model for flood-resilient urban planning in Nigeria, showcasing effective strategies for mitigating the impacts of pluvial flooding. Ultimately, the FLOODSHIELD-PHmet Model will

contribute to creating a safer, more sustainable, and resilient urban environment for the residents of Port Harcourt Metropolis.

**6.4.1 FLOODSHIELD-PHmet Model (Flood Resilient Adaptation Strategy for Port Harcourt Metropolis)**



**Fig. 6.1: Flood Resilient Design Framework (FLOODSHIELD-PHmet)**  
(Source: Researcher, 2024)

The purpose of this framework is to provide guidance on the implementation of the FLOODSHIELD-PHmet Model, a comprehensive framework designed to enhance the resilience of residential buildings in Port Harcourt Metropolis against flooding. The scope of this framework applies to all residential building development projects in Port Harcourt Metropolis (new and existing).

### **Structural Adaptation Measures (SAM)**

#### **SAM-001 Flood-Resistant Construction**

- Design residential buildings with flood-resistant materials and construction techniques, such as waterproofing, flood-resistant doors and windows, and elevated electrical and mechanical systems.
- Ensure that buildings are constructed with reinforced foundations and walls to withstand flood forces.

#### **SAM-002 Elevation and Floodproofing**

- Elevate residential buildings above flood levels.
- Implement floodproofing measures, such as levees, floodwalls, and flood gates.

#### **SAM-003 Water Storage and Detention**

- Design and construct water storage and detention systems, such as ponds, tanks, and green roofs.
- Ensure that water storage and detention systems are designed to handle the expected stormwater runoff volume.

#### **SAM-004 Permeable Pavements and Grounds**

- Implement permeable pavements, sidewalks, and grounds to reduce stormwater runoff and allow rainwater to infiltrate the soil.

### **Non-Structural Adaptation Measures (NAM)**

#### **NAM-001 Flood Risk Mapping and Assessment**

- Conduct flood risk mapping and assessment to identify areas of high flood risk.
- Use flood risk maps to inform flood mitigation and adaptation strategies.

#### **NAM-002 Early Warning Systems**

- Establish early warning systems to alert residents of impending floods.
- Ensure that early warning systems are effective and reliable.

#### **NAM-003 Flood Emergency Preparedness and Response**

- Develop and implement flood emergency preparedness and response plans.
- Ensure that flood emergency preparedness and response plans are effective and reliable.

### **NAM-004 Community Education and Awareness**

- Conduct community education and awareness programs to inform residents about flood risks and mitigation strategies.
- Ensure that community education and awareness programs are effective and reliable.

### **Integrated Implementation and Management (IIM)**

#### **IIM-001 Interagency Collaboration**

- Foster interagency collaboration and coordination among government agencies, stakeholders, and communities.
- Ensure that interagency collaboration and coordination are effective and reliable.

#### **IIM-002 Community Engagement and Participation**

- Encourage community engagement and participation in flood risk management and mitigation efforts.
- Ensure that community engagement and participation are effective and reliable.

#### **IIM-003 Monitoring and Evaluation**

- Establish a monitoring and evaluation system to assess the effectiveness of the FLOODSHIELD-PHmet Model.
- Ensure that the monitoring and evaluation system is effective and reliable.

#### **IIM-004 Continuous Improvement and Update**

- Continuously improve and update the FLOODSHIELD-PHmet Model based on lessons learned, new research, and emerging best practices.
- Ensure that the FLOODSHIELD-PHmet Model remains effective and relevant in reducing flood risk in Port Harcourt Metropolis.

### **Responsibilities**

1. Developers: Ensure that all residential building development projects comply with the FLOODSHIELD-PHmet Model.
2. Government Agencies: Provide guidance and oversight on the implementation of the FLOODSHIELD-PHmet Model.
3. Communities: Participate in flood risk management and mitigation efforts and provide feedback on the effectiveness of the FLOODSHIELD-PHmet Model.

### **Timeline**

1. Immediate: Begin implementing the FLOODSHIELD-PHmet Model in all residential building development projects.

2. Short-term (6-12 months): Establish interagency collaboration and coordination, community engagement and participation, and monitoring and evaluation systems.

3. Medium-term (1-2 years): Review and update the FLOODSHIELD-PHmet Model based on lessons learned and new research.

4. Long-term (2-5 years): Continuously monitor and evaluate the effectiveness of the FLOODSHIELD-PHmet Model and make updates as necessary.



***Plate 6.1: Rumuewhara New Layout (4°52'35"N 7°02'21"E 20m)***

*(Source: Landsat, 2021)*

### Area Tabulation

Area of Plot = 1,358.973m<sup>2</sup>  
Total Built-up Area = 572.14m<sup>2</sup>  
Total Unbuilt Area = 786.833m<sup>2</sup>



Plate 6.2: Site Plan (Rumuewhara New Layout)

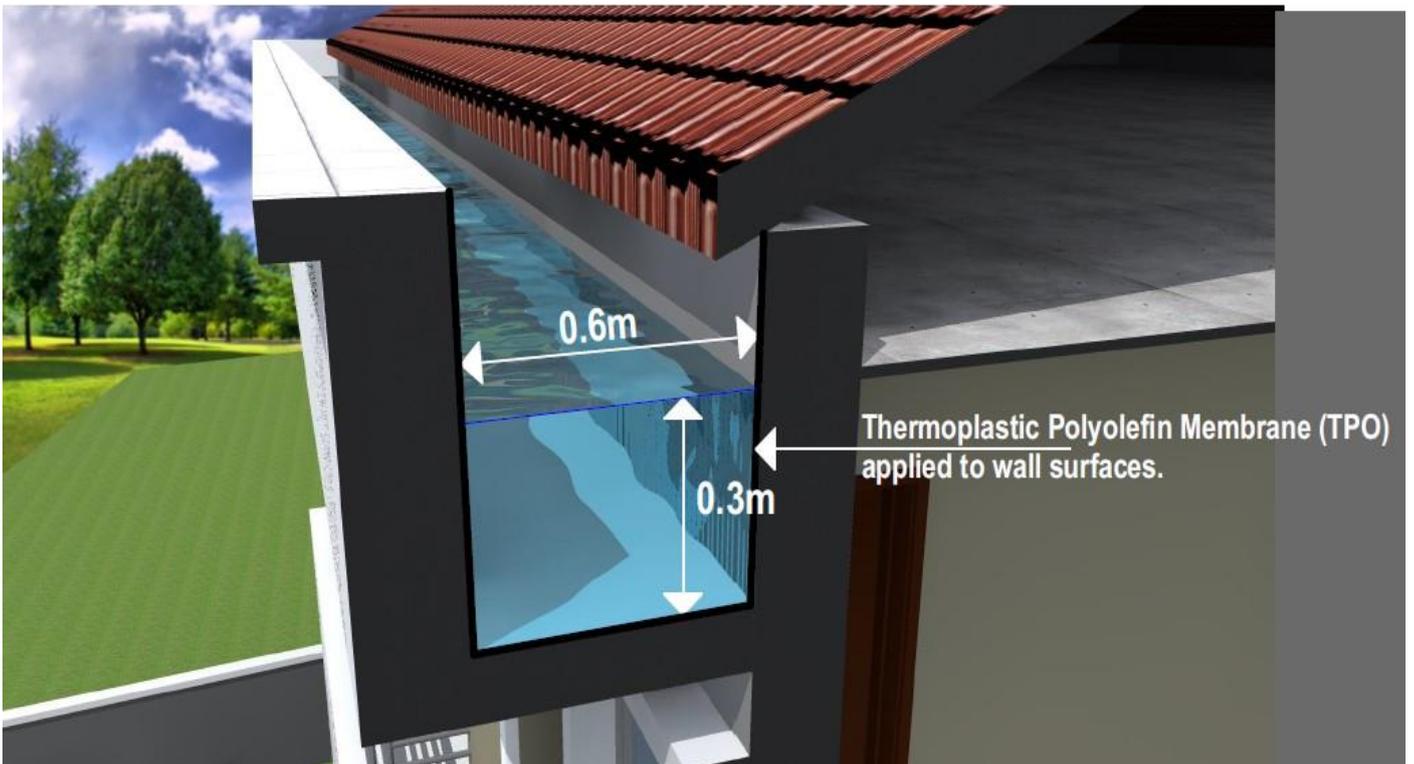
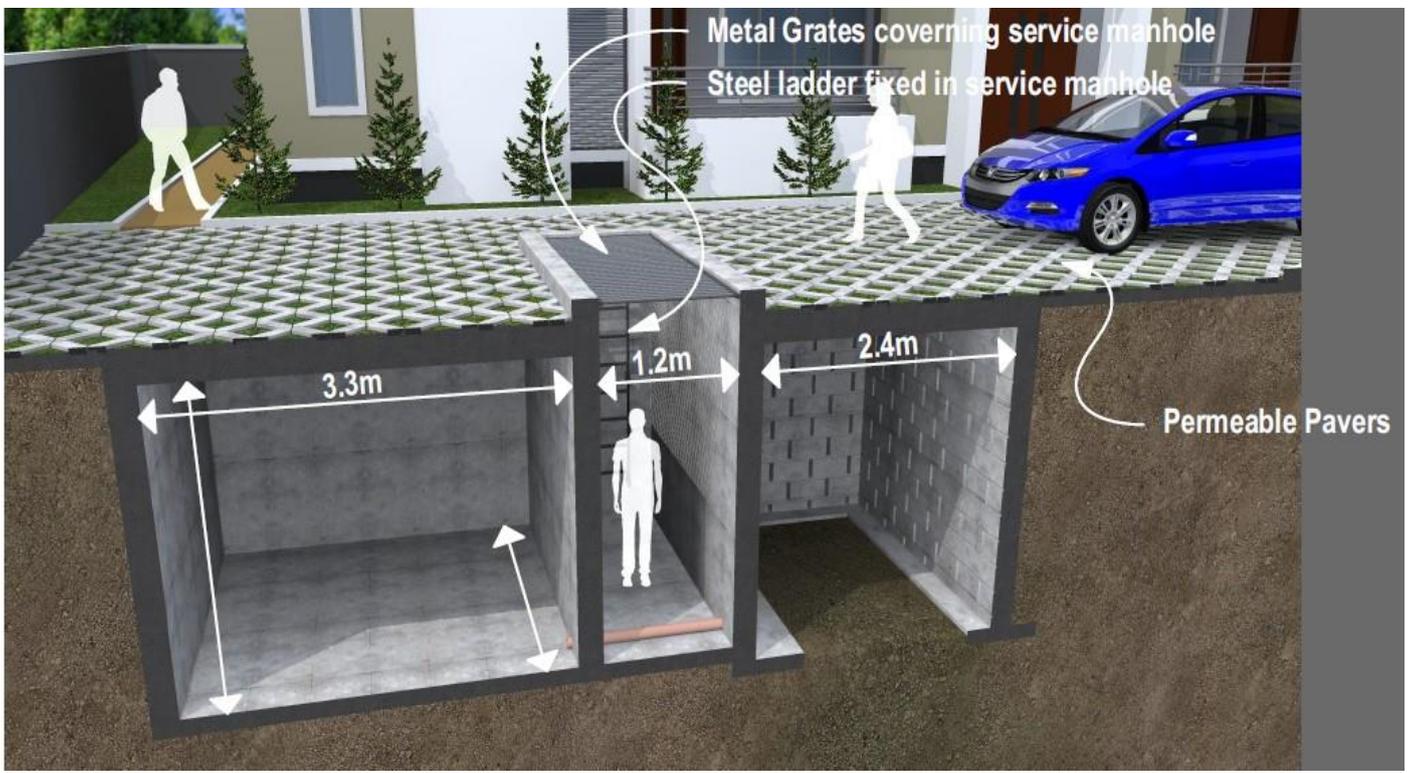
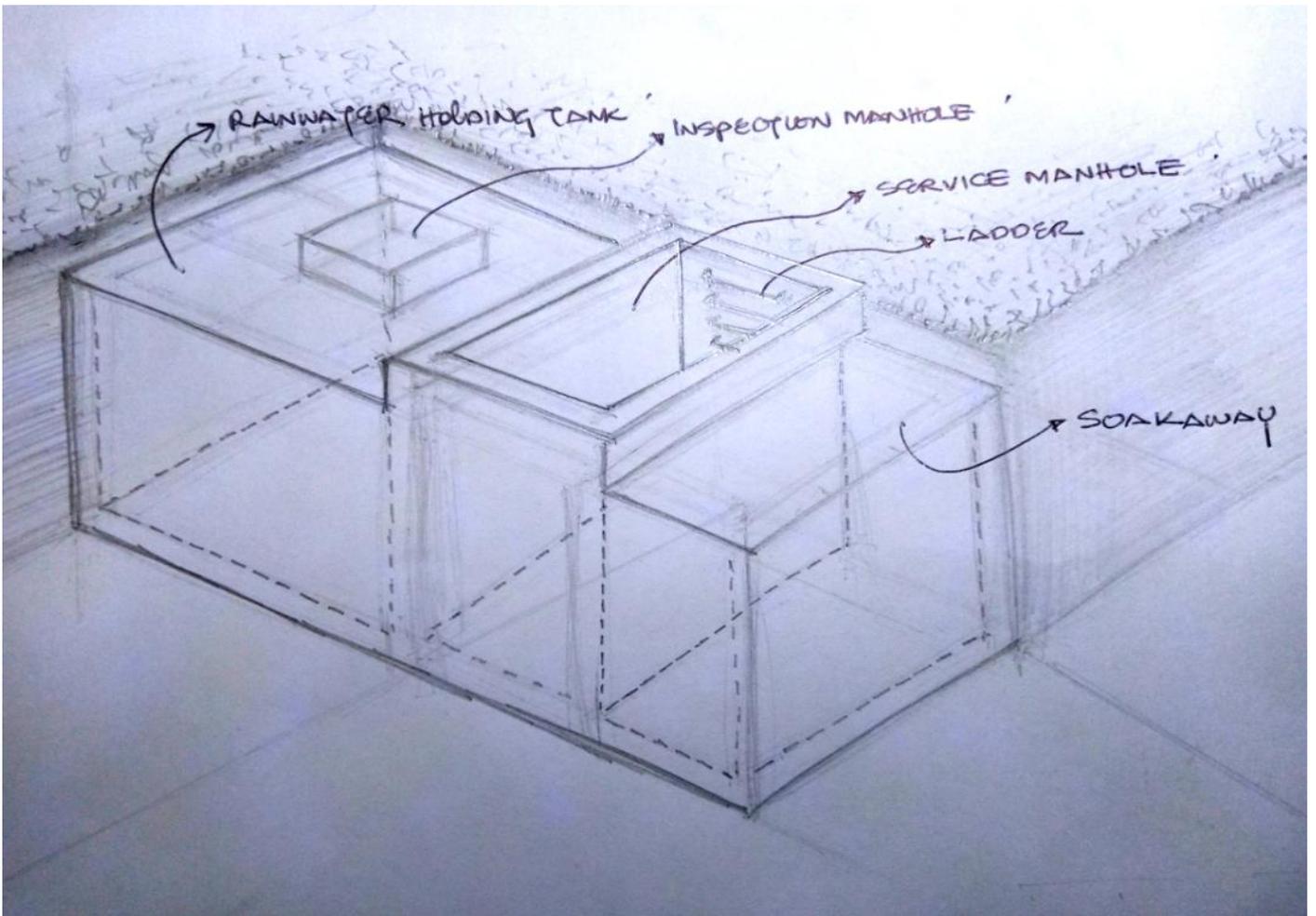


Plate 6.3: Perimeter Blue Roof



*Plate 6.4: Underground Rainwater Storage Tank*



*Plate 6.5: Underground Rainwater Storage Tank (Sketch)*



**Plate 6.6: Car Port Blue Roof**

## **6.5 Contribution to Knowledge**

This research contributed significantly to the understanding and mitigation of perennial pluvial flooding in Port Harcourt Metropolis by providing a comprehensive analysis of vulnerable areas, impacts on architecture, and effective adaptation strategies. The key contributions include:

1. **Spatial Vulnerability Mapping:** The study identified specific areas within Port Harcourt Metropolis that are most vulnerable to pluvial flooding, such as Rumuewhara New Layout/Eneka, NTA/Apara Link Road, and Abacha Road, highlighting varying flood classifications and elevations. This granular mapping of flood-prone areas provides a foundational framework for targeted urban planning and resource allocation to mitigate flooding risks.
2. **Insight into Community Flood Management Practices:** The findings reveal that flood management in the metropolis is primarily community-driven, with limited visible government interventions. Strategies such as flood barriers, raised driveways, and water pumping mechanisms underscore the ingenuity and resilience of local communities, while also emphasizing the urgent need for comprehensive, government-led interventions.
3. **Impact on Architectural Integrity:** The research provides detailed insights into how perennial pluvial flooding affects building safety, functionality, aesthetics, comfort, and durability. It establishes a strong correlation between inadequate drainage systems, impermeable surfaces, and compromised building integrity. The findings emphasize the need for durable, flood-resilient construction practices and improved urban drainage systems.
4. **Evaluation of Existing Flood Mitigation Strategies:** This study evaluated the effectiveness of architectural and urban planning strategies in mitigating flooding. However, the research identifies gaps, such as inadequate infrastructure, regulatory challenges, and insufficient community awareness, which hinder the success of flood mitigation measures.

5. Flood-Resilient Design Framework (FRDF): The research proposed the novel FLOODSHIELD-PHmet Model, a comprehensive Flood Resilient Design Framework that integrates architectural adaptation strategies, urban planning, community engagement, stakeholder engagement, and policy recommendations to mitigate pluvial flooding in Port Harcourt Metropolis. This framework integrated structural and non-structural adaptation measures to reduce rainwater run-off and mitigate pluvial floods in the study area.
6. Alignment of Flood Mitigation Strategies with Architectural Goals: The findings demonstrate a holistic alignment between flood mitigation objectives and architectural priorities, including infrastructure protection, community safety, and sustainable urban development. This alignment provides a blueprint for integrating architectural design with broader urban planning efforts to address flood risks effectively.

In addition, through its multi-dimensional approach, this research bridges the gap between architectural adaptation strategies and sustainable urban development, offering practical solutions to mitigate the challenges posed by pluvial flooding in Port Harcourt Metropolis. It serves as a valuable reference for policymakers, urban planners, architects, and researchers in similar flood-prone regions.

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APPENDIX A

SAMPLE QUESTIONNAIRE

PUBLIC PERCEPTION SURVEY OF THE FLOOD OCCURRENCE / ARCHITECTURAL ADAPTATION STRATEGIES, URBAN PLANNING / INFRASTRUCTURE, AND COMMUNITY ENGAGEMENT.

Date \_\_\_\_\_

Name of Respondent \_\_\_\_\_

*(Should be a landlord, tenant or a responsible occupant)*

Dear Sir/Madam,

I am currently enrolled as a Ph.D. student at the mentioned institution, and my research constitutes a necessary academic undertaking towards fulfilling the requirements for the Doctor of Philosophy (Ph.D.) Degree in Architecture. The focus of my inquiry revolves around architectural strategies for adapting to and mitigating recurrent surface water floods in the Port Harcourt Metropolis. Your cooperation and support in this matter are crucial. Please be assured that any information shared will be handled with the utmost confidentiality. Kindly indicate your responses by ticking the appropriate box and providing necessary details in the designated space.

Thank you,

**OKEY-EJIOWHOR, Caleb Happiness**

*Researcher*

*Please be precise by ticking the right box  when answering the questions*

**SECTION 1: BIODATA OF RESPONDENT**

1. Gender

Male	
Female	

2. What is your age bracket?

<i>Age</i>	<i>Tick</i>
20-24yrs	
25-29yrs	
30-34yrs	
35-39yrs	
40-44yrs	
45-49yrs	
50-54yrs	
55-59yrs	
60-64yrs	

65-69yrs	
70yrs above	

3. What is your Marital status?

Single	
Married	
Divorced	
Separated	
Widower	
Widow	

4. What is your Educational Level?

Primary	
Secondary	
Tertiary	
No Formal	

5. What is your Employment status?

Public Sector	
Private Sector	
Self Employed	
Pensioner	
Unemployed	

6. What is your Income level?

Below N30,000	
Exactly N 30,000	
Above N 30,000	
Above N 50,000	
Above N 100,000	
Above N 200,000	

## SECTION 2

### PART A: FLOOD HOTSPOT MAPPING

7. Can you choose from the following areas within Port Harcourt Metropolis that are consistently affected by frequent flooding? (Tick which LGA)

<i>Options</i>	<i>Tick</i>
Port Harcourt LGA	
Obio/Akpor LGA	
<i>(Write the town here)</i>	

8. On a scale of 1 to 5, where 1 represents minimal flooding and 5 represents severe flooding, how would you rate the magnitude and level of flooding in the area you identified?

<i>Options</i>	<i>Tick</i>
1 – Minimal (Below ankle)	
2 – Low (Ankle)	
3 – Moderate (Above ankle)	
4 – High (Above knee)	
5 – Severe (Waist level)	
6 – Very Severe (Above Waist level)	

9. How long did it take for the flood water to recede?

<i>Options</i>	<i>Tick</i>
Less than 30mins	
30mins	
Above 30mins	
Above 1 hour	
Above 2 hours	
Above 5 hours	

10. What do you observe to be the consequence of the flood?

<i>Options</i>	<i>Tick</i>
Unightly looking buildings (water stains on walls, watermarks, mold growth due to leakage, etc.)	
Property damage (rising damp, soil erosion, peeling paint, etc.)	
Infrastructure damage (broken gutters/drains, damage to roads/driveways, damaged inspection chambers, damaged septic tanks/soak-away pits, etc.)	
Health and safety issues (contact with contaminated water, slippery surfaces, water-borne diseases, etc.)	
All of the above	

**PART B: FLOOD RESILIENCE ANALYSIS**

11. In your opinion, what is the main reason some areas experience severe flooding?

<i>Options</i>	<i>Tick</i>
Overwhelmed drainage systems	
Impermeable ground surfaces (that don't allow water to pass through)	
Intense rainfall	
Climate change	
All of the above	

12. How would you rate the impact of perennial pluvial flooding on the safety of buildings in the affected areas?

<i>Options</i>	<i>Tick</i>
1 – Very low impact	
2 – Low impact	
3 – Moderate impact	
4 – High impact	
5 – Very high impact	

13. How would you describe the impact of perennial pluvial flooding on the aesthetic quality of buildings in the affected areas?

<i>Options</i>	<i>Tick</i>
Minimal impact	
Moderate impact	
Significant impact	

14. The comfort level within buildings is unbearable during or after flooding events. (*Tick where appropriate*)

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

15. On a scale of 1 to 5, with 1 being *not durable at all* and 5 being *highly durable*, how would you rate the durability of buildings (architectural elements) in the face of perennial flooding? (*Tick where appropriate*)

Not Durable at all	Not Durable	Neutral / Undecided	Somewhat Durable	Highly Durable

### PART C: EVALUATING FLOOD MITIGATION STRATEGIES

16. Are you aware of any flood mitigation strategies implemented in your area?

<i>Options</i>	<i>Tick</i>
Yes	
No	

17. What methods, if any, have been attempted to mitigate the flooding problem?

<i>Options</i>	<i>Tick</i>
Improved drainage systems	
Flood barriers	
Land-use planning	
Early warning systems	
Public awareness campaigns	
All of the above	

**PART D: FLOOD-RESILIENT ARCHITECTURAL STRATEGIES**

18. From the list below, identify architectural adaptations that have been effective in militating flood-related issues

<i>S/N0.</i>	<i>Options</i>	<i>Tick</i>
i	Elevate building DPC above the flood level	
ii	Apply waterproof coatings, sealants	
iii	Raise or floodproof HVAC equipment and mechanical, Plumbing, and electrical system components	
iv	Use of water pumping machine	
v	Construct permanent barriers (floodwalls)	
vi	Collection and storage of rainwater to reduce runoff when it's raining	
vii	Permeable ground surfaces to promote water infiltration	
viii	Retention ponds	
	Options i to v	
	Options vi to viii	

19. In your experience, what are the main challenges hindering the successful implementation of flood mitigation measures in Port Harcourt?

<i>Options</i>	<i>Tick</i>
Insufficient funding	
Infrastructure limitations	
Community resistance	
Regulatory issues	

20. Are there opportunities you see for improving the sustainability of flood mitigation efforts in Port Harcourt metropolis?

<i>Options</i>	<i>Tick</i>
Yes	
No	

21. What, in your view, should be the primary goals of flood mitigation strategies in alignment with architectural objectives?

<i>Options</i>	<i>Tick</i>
Protecting infrastructure	
Enhancing community safety	
Preserving architectural heritage	
Sustainable urban development	
Human comfort & building sustainability	
All of the above	

22. How do you suggest community involvement can be enhanced to ensure the success of flood mitigation initiatives?

<i>Options</i>	<i>Tick</i>
Community engagement programmes	
Collaborative planning sessions	
Educational workshops	
Public awareness campaigns	
All of the above	

**PART E: ARCHITECTURAL INSIGHTS ON ENHANCING URBAN FLOOD RESILIENCE**

23. What do you think could make buildings more resilient to perennial pluvial floods?

<i>Options</i>	<i>Tick</i>
Effective architectural changes	
Assessment of current flood strategies	
Evaluation of how buildings perform during floods	
All of the above	

24. How do you believe the research findings could impact the way buildings can be designed to withstand floods?

<i>Options</i>	<i>Tick</i>
Adoption of specific design ideas	
Use of new flood-resistant materials	
Changes to architectural codes and standards	
All of the above	

25. In your opinion, how should city planning be influenced by the research to better protect buildings from floods?

<i>Options</i>	<i>Tick</i>
Including flood-resilient designs in city planning	
Creating more green spaces for water absorption	
Changing zoning rules	
All of the above	

26. What policies do you think should be recommended based on the research to improve how cities handle floods, considering architectural aspects?

<i>Options</i>	<i>Tick</i>
Creating flood-resistant building codes	
Offering rewards for eco-friendly architecture	
Making land-use rules stricter	
All of the above	

27. How can the research findings be practically applied in architectural projects to make buildings more resilient to floods?

<i>Options</i>	<i>Tick</i>
Using research-based designs	

Training architects in flood-resilient practices	
Developing guidelines for flood-resilient architecture	
All of the above	

***APPENDIX B***

**TEMPLATE FOR PHYSICAL OBSERVATION**

	<p>VITAL OBSERVATIONS TO BE TAKEN:</p> <ul style="list-style-type: none"> <li>• Pictures of flood water level in streets</li> <li>• Picture of flood adaptation strategies</li> <li>• Pictures of unsightly buildings</li> </ul>
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