



# Integrated Flood Risk Management and Drainage Masterplan for Ibadan City

*Flood Risk Management and  
Drainage Masterplan Report  
Volume 1/3: Main Report*



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dar.com

★ Ibadan



## Volume 1 - Main Report

### Terminology

Terminology	Description
ARF	Areal Reduction Factor
ARK	Urban Africa Risk Knowledge
BMC	Budget Monitoring Committee
BPPDC	Bureau of Physical Planning and Development Control
CN	Curve Number
DEEB	Department of Environmental Engineering and Beautification
DEM	Digital Elevation Model
DMCU	Drainage Maintenance and Coordination Unit
DTM	Digital Terrain Model
FRMDMP	Flood Risk Management and Drainage Master Plan
GIS	Geographic Information System
HEC 22	Hydraulic Engineering Circular No. 22
HEC-HMS	Hydrologic Engineering Center - Hydrologic Modelling System
IITA	The International Institute of Tropical Agriculture
IMP	Ibadan Master Plan
IUFMP	Ibadan Urban Flood Management Project
LCDA	Local Council Development Areas
LGA	Local Governmental Area
LiDAR	Light Detection and Ranging
MP	Masterplan
NIHORT	National Horticultural Research Institute
NIMET	Nigerian Metrological Agency
NRCS	Natural Resource Conservation Service
OSEMA	Oyo State Emergency Management Agency
OSME&WR	Oyo State Ministry of Environment and Water Resources
OSMF&B	Oyo State Ministry of Finance and Budget
OSMLGCM	Oyo State Ministry of Local Government and Chieftaincy Matters
PIU	Project Implementation Unit
RFP	Request For Proposal
ROW	Right Of Way
SSA	Storm Analysis by Autodesk
SCS	Soil Conservation Service, of United States Department of Agriculture

Terminology	Description
SRTM	Shuttle Radar Topography Mission
SWM	Solid Waste Management
TEF	Tractebel Engineering France
TOR	Terms of Reference
TRMM	Tropical Rainfall Measuring Mission
UH	Unit Hydrograph
USD	United States Dollars
USGS	United States Geological Survey
WB	World Bank

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## 1. Introduction

### 1.1. Purpose of Flood Risk Management and Drainage Masterplan

On 26<sup>th</sup> August 2011, a rainfall downpour of 187.5 mm (NWRI<sup>1</sup>, 2011) occurred in around 6 hours resulting in the overflow of the Eleyele reservoir, causing the death of more than 120 people and inflicting serious damage to infrastructure (many bridges collapsed, roads washed away, and substantial property loss)<sup>2</sup>. Following the floods, The Executive Governor of Oyo State, his Excellency, Senator Ishaq Abiola Ajimobi, set up a task force on flood prevention and management.

The outcome was a report containing short, medium and long-term recommendations to the state government, which included the proposal to prepare three masterplans for the city:

- Ibadan City Masterplan
- Solid Waste Masterplan
- Flood Risk Management and Drainage Masterplan (this project)

Recognizing the need for an integrated and long-term solution to flooding in the City of Ibadan, the Oyo State Government has set up “The Ibadan Flood Management Project” (IUFMP) to improve the capacity of Oyo State to effectively manage flood risk in the city of Ibadan. This project is funded by the World Bank (WB) and is being executed with WB’s assistance through the Project Implementation Unit (PIU).

The Project Implementation Unit (PIU), acting as the Client, commissioned Dar (the Consultant) to prepare an Integrated Flood Risk Management and Drainage Masterplan for Ibadan City (the Project), covering the 11 local government areas which include the Ibadan Metropolis and the surrounding outlying areas.

This Masterplan therefore sets a process to mitigate the flood risks in the city today and over the next 20 years to 2040. The strategies and proposals put forward are intended to benefit all residents and visitors in Ibadan.

### 1.2. Project Context

Ibadan is the capital city of Oyo state, Nigeria, located on seven hills (average elevation 200 meters) 160 km from the coast of the Atlantic Ocean. Established in the 1830s as a war camp, Ibadan has grown ever since to become one of Nigeria’s largest cities with a population of over 6 million as reported by the Ibadan City Masterplan<sup>3</sup>. Over recent times, the rate of growth has accelerated. The

result is a populated city, but under increasing strain from an inadequate drainage system. A perspective view of the city is shown in Figure 1.2.

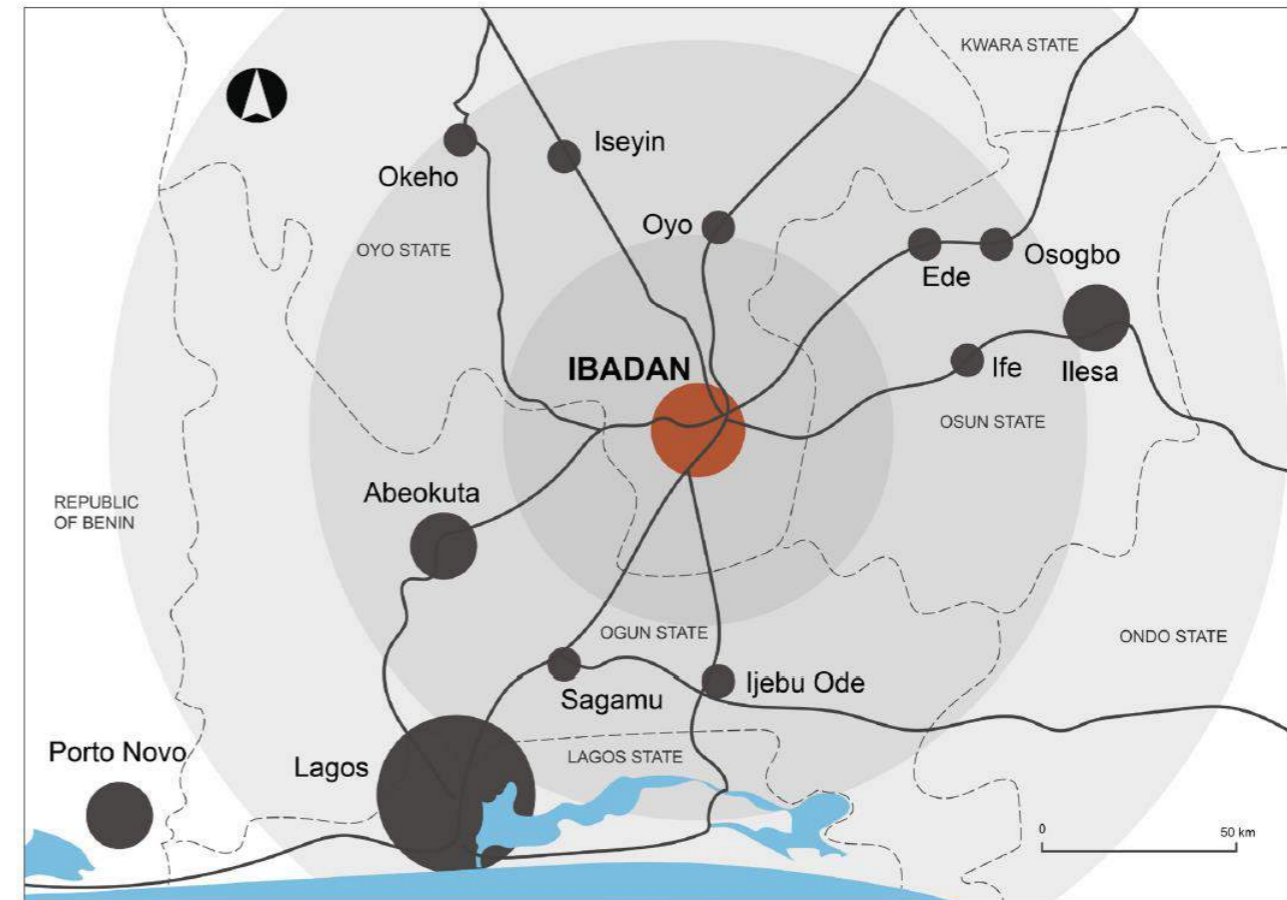


Figure 1.1: Ibadan Regional Context

### 1.3. Project Background

The incentive to prepare the Flood Risk Management and Drainage Masterplan came following the flood event of 2011. This event aroused awareness of the importance of a suitable flood risk plan to mitigate the severe flooding impacts across the city. It was recognized that flooding and the associated risks are in large part caused by land use factors. The persistent construction of buildings on flood plains substantially increases the flood risks in the city. Deforestation of natural forests has been identified as another factor. Dumping of solid waste in streams and rivers is a common practice in Ibadan which blocks the free flow of water downstream. Laws and regulations for development in Ibadan are generally inadequate to protect from the associated risks of flooding in developed areas in the city.

<sup>1</sup> Report of Assessment of the 26th August 2011 Ibadan Flood Disaster, Oyo State, Nigeria, National Water Resources Institute, September, 2011

<sup>2</sup> Ibadan Urban Flood Management Project: Environmental and Social Management Framework Final Report, January 2014.

<sup>3</sup> Ibadan City Masterplan, Dar Consultant, December 2017

#### 1.4. Current Status

This report is considered as the eighth milestone to the project. The report confirms the particulars as indicated in the Request for Proposal (RFP) for the project and the Consultant's proposal submission dated March 2017.

#### 1.5. Vision

The flood risk management aims at decreasing/minimizing the risk of flooding on people, and all people activities and natural resources. Flood risk management is not an on-off activity, such as constructing a building or dam. It is a continuous process characterized by activities that not only protect people and the urban and physical environment from flooding but also prevent them from experiencing devastating events and help them pass the flood event safely. Not only that, the flood risk management is also a learning process where the post event measures are an important part of the management plan. Through this post event measure, the existing implemented measures can be evaluated, and the upgrade plans can be better prioritized to address the actual needs based on the evaluation of the system. An important part of the plan is the implementation and adaptation of the watershed conservation activities to control flooding in the city.

#### 1.6. Objectives of the Project

The objectives of this project as stipulated in the Terms of Reference are as follows:

1. Develop a robust understanding of present and future flood risk for the entire city, considering social, environmental and economic factors.
2. Develop an overarching flood risk management strategy and drainage master plan that sets out the policies, regulations and institutional arrangements needed to manage flood risks.
3. Develop a city-wide flood risk management plan that sets out the approach to managing flood risks across the city that protects life as well as promoting the city economy and ecosystems. The flood risk management plan adopts a mix of structural and non-structural measures and seek to make space for water and work with natural processes rather than against them.
4. Prepare new institutional arrangements that help implementing and following up the activities of the flood risk management. This should also include capacity building within the government and communities of Ibadan.
5. Actively engage stakeholders, communities and ownership in the decision-making process to encourage buy-in.

#### 1.7. Study Area

The study area as defined in the TOR is presented in Figure 1.3. The city includes four North-South flowing river systems, namely, Ona River (Western), Ogunpa River (Western Central), Ogbere River (Eastern Central) and Omi River (Eastern) as shown in Figure 1.3. Eleyele reservoir is located in the north-western part of the city. These rivers are the main drainage channels that can cause flooding

when not properly maintained. There is an extensive network of rivers and streams throughout the city leading to an extensive number of crossing structures with the existing road network.

#### 1.8. Scope of Work

The scope of work as defined in the TOR is the preparation of a comprehensive Ibadan City Flood Risk management and Drainage Masterplan. This comprises suitable upstream integrated catchment management plans, city flood risk management and urban drainage master plans including proposed institutional arrangements.

#### 1.9. Contents of this Report

The contents of this report include the following sections:

- Section 1 introduces the report and provides the purpose of the Flood Risk Management and Drainage Masterplan
- Section 2 provides the context of the masterplan
- Section 3 presents the flood risk management framework
- Section 4 describes the characteristics of the watershed
- Section 5 describes the components of flood risk
- Section 6 describes the flood risk management measures including protective measures
- Section 7 presents the drainage masterplan
- Section 8 describes the preventive measures
- Section 9 describes the post event measures
- Section 10 describes the watershed conservation.
- Section 11 presents the institutional framework
- Section 12 presents the methodology of managing flood risks including managing flood hazards, flood exposure and vulnerability to flooding.



Figure 1.2: The City of Ibadan

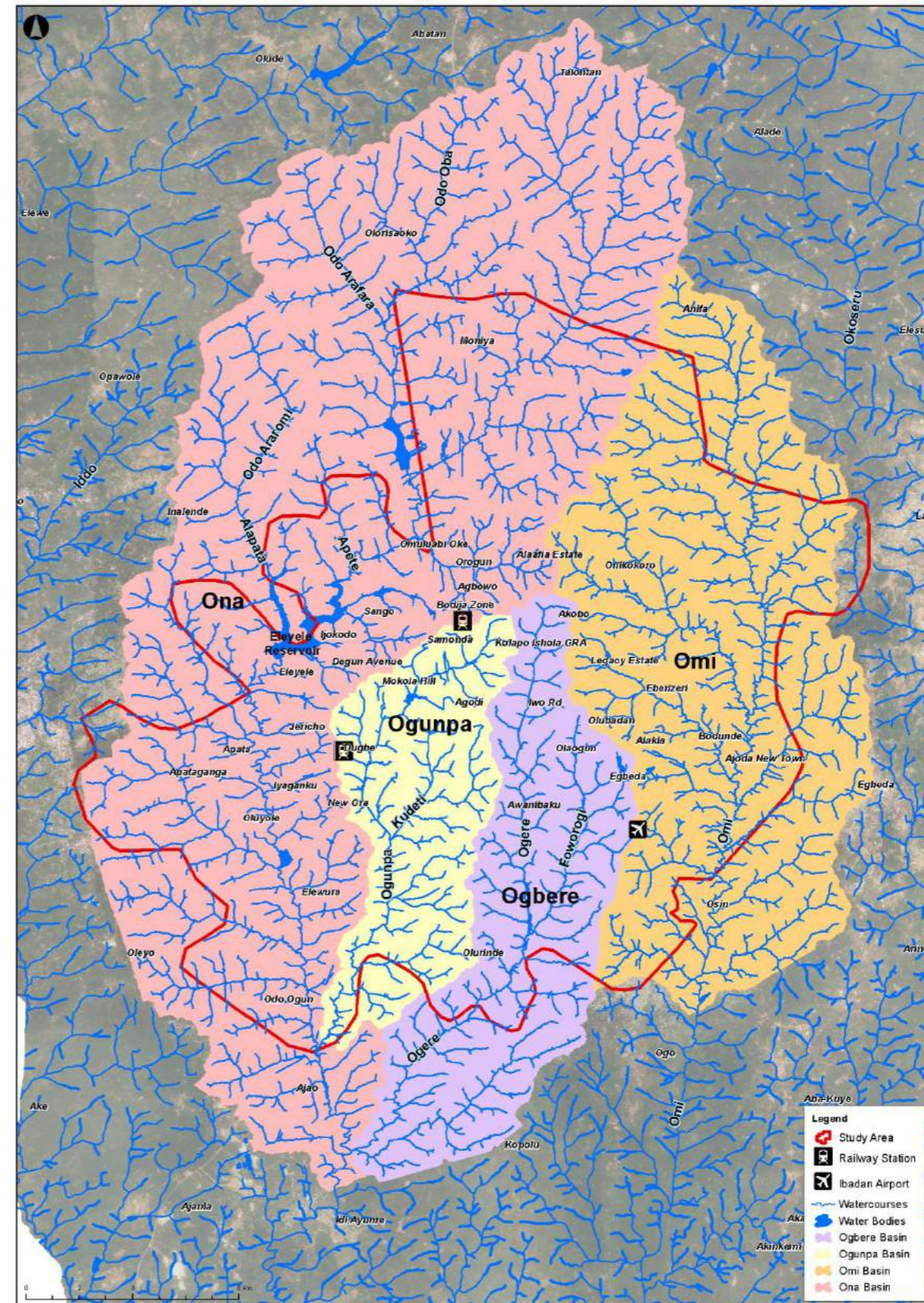


Figure 1.3: Study Area, Major Rivers, Basins and Extensive Network of Streams

## 2. Context of the Masterplan

### 2.1. Regional Settings

As the capital of Oyo State, Ibadan occupies a strategic regional position within Nigeria. With a population of over 6 million, it is the most populous city in the state, and the third most populous city in Nigeria, after Lagos and Kano. The city is well connected to the national road and rail networks. Located in the south-eastern part of Oyo State, it is approximately 119 kilometers north-east of Lagos and 120 kilometers east of the border with the Republic of Benin.

Ibadan lies within the tropical forest zone but close to the boundary between the forest and the savanna. It is characterized by rugged terrain with steep slopes creating a dense network of streams with wide valley plains. The city ranges in elevation from 150 meters in the valley area, to 275 meters above mean sea level on the major north-south ridge which crosses the central part of the city.

#### 2.1.1. Extent of the Project Area

The project area lies within latitudes 7°33'N and 7°17'N and longitudes 3°47'E and 4°3'E. The total landmass of the study area is 492 km<sup>2</sup>, refer to Figure 2.1.

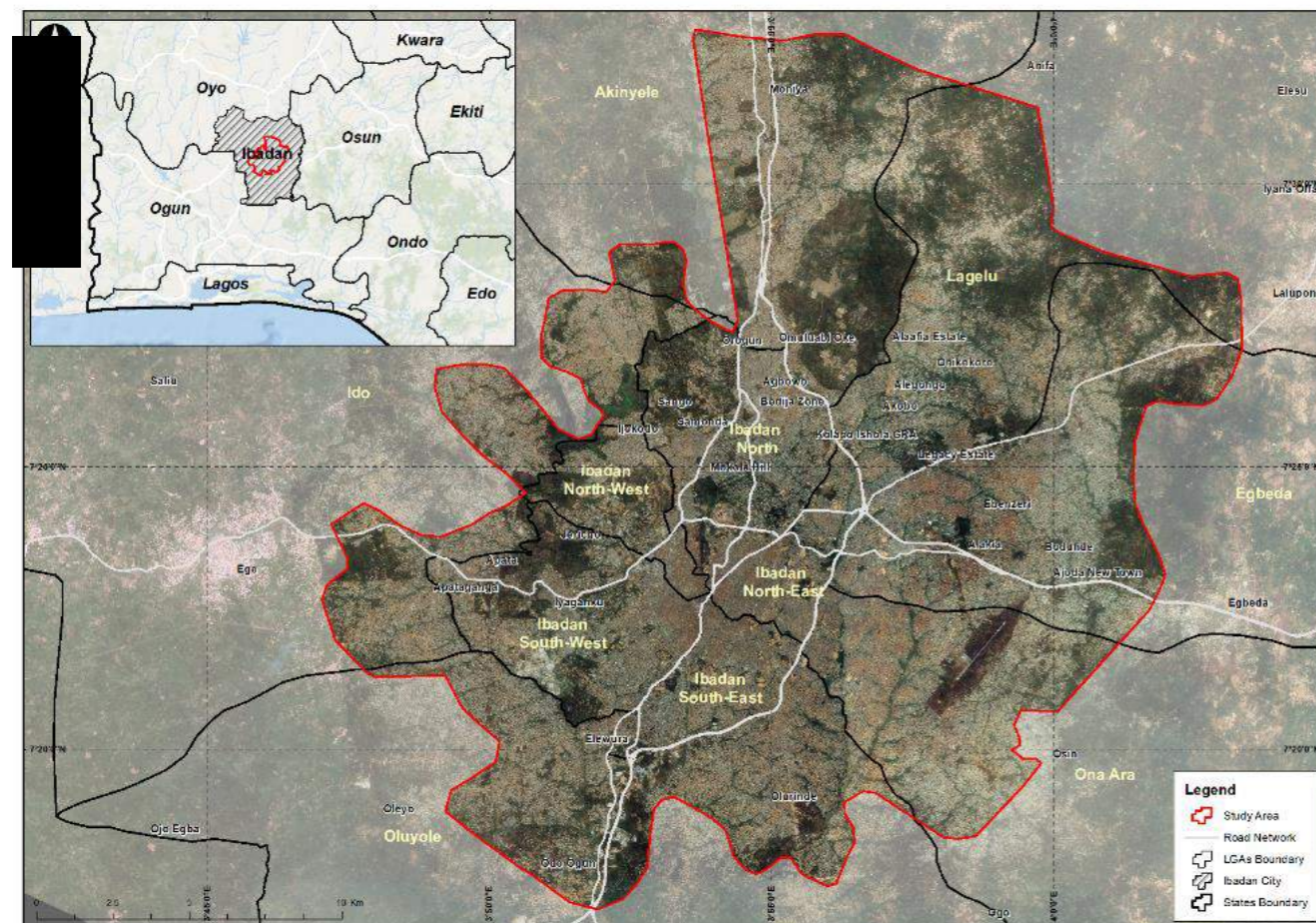


Figure 2.1: Extent of the Project Area

### 2.1.2. Administrative Boundaries

Ibadan comprises of eleven (11) Local Government Areas (LGAs) in Ibadan Metropolitan area consisting of five urban local governments in the city and six semi-urban local governments in the less city. Figure 2.2 presents the 11 LGAs with respect to the Study Area and the Major River Basins.

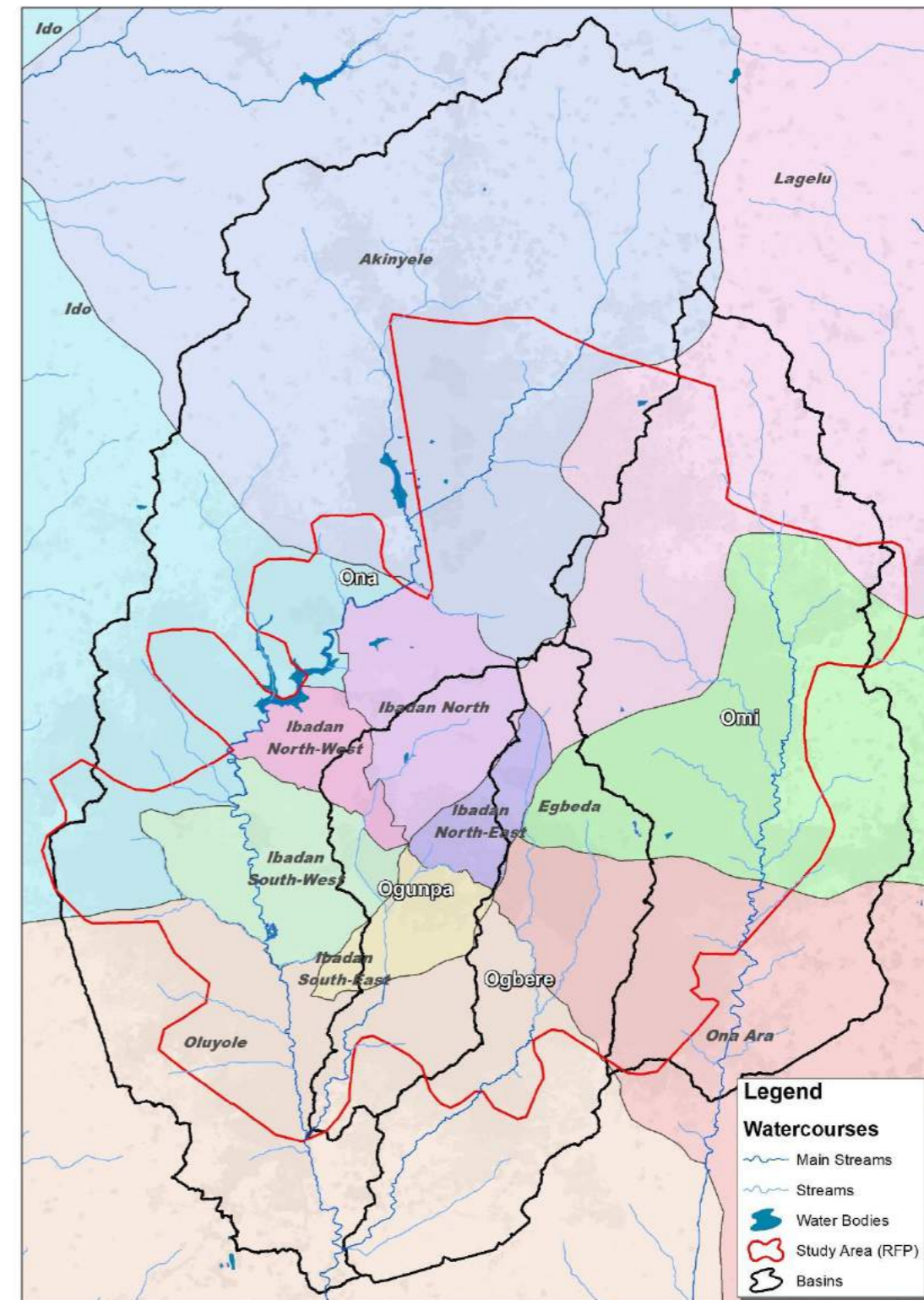


Figure 2.2: The 11 LGAs of Ibadan with respect to the Study Area and the Major River Basins

## 2.2. Summary of Existing Conditions

### 2.2.1. Built-up area and Land Use Distribution

- The built-up area has expanded rapidly in the past 18 years. Physical urban growth has been along the main highways with infill development taking place as communities become established.
- Population growth and built up areas have been occurring in an unplanned way, with more and more construction in flood plains.
- The core area of the city suffers from the pressures of an inadequate provision of infrastructure to support the high population density. The houses are in poor condition and the provision of community facilities and utilities is low. There are numerous older buildings that have historical importance, but many are in a poor state of repair.
- Many of the residential areas have been developed in an informal manner and the supporting infrastructure to meet their needs is insufficient.
- Outside the built-up area there are large areas of forest and agricultural land, although high grade agricultural soil is limited to the southern parts of Ibadan.
- Uncontrolled growth to the periphery of Ibadan is affecting the dense vegetation and forestry – this related deforestation is limiting the ability of water to be absorbed into the ground and is one of the causes of flooding.

Figure 2.3 shows the land use distribution in 2016 for Ibadan. The land use classification is sourced from the "Space Standards for Physical Development in Oyo State" prepared by the Ministry of Physical Planning and Urban Development in December 2014.

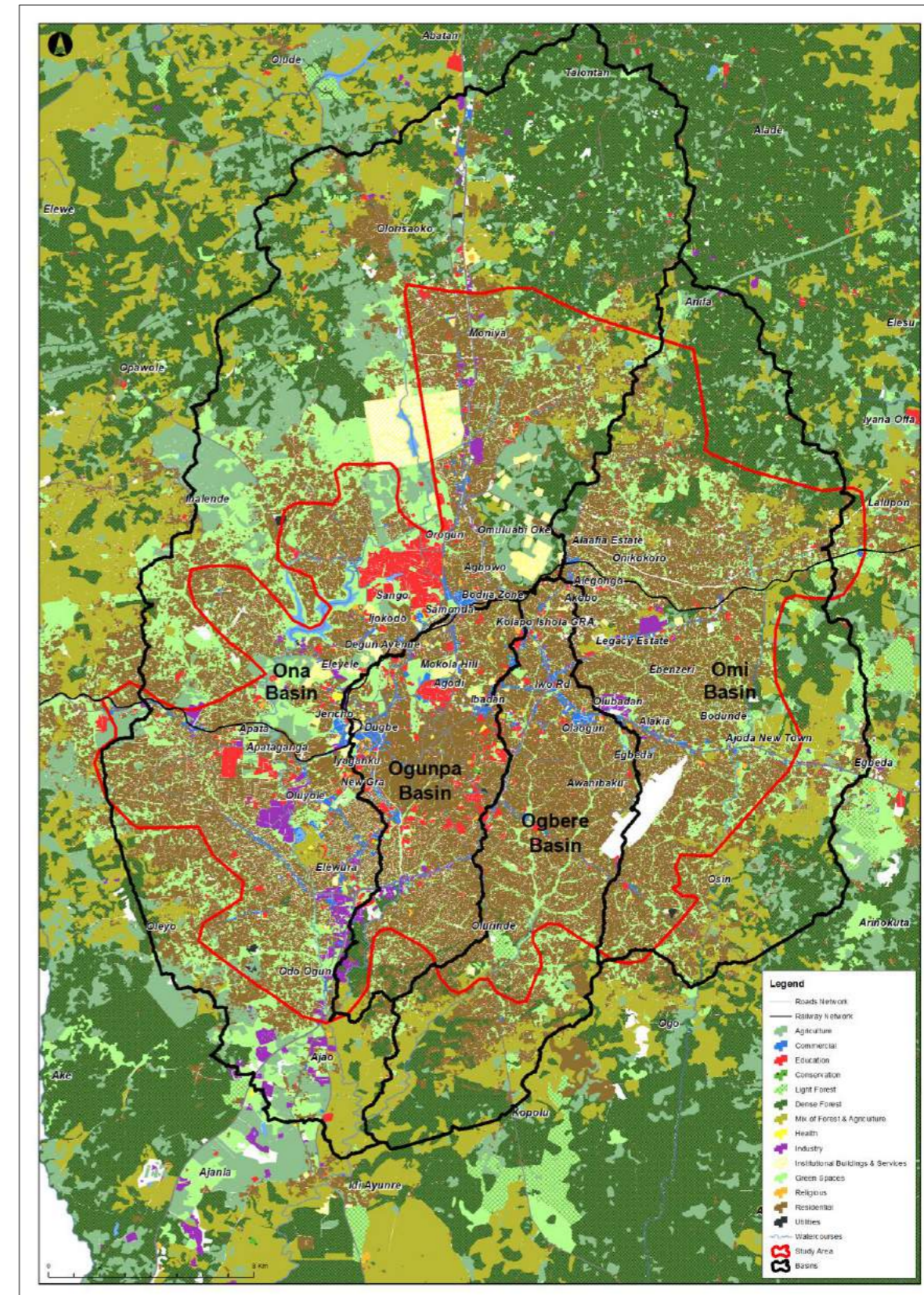


Figure 2.3: Existing Landuse Distribution (2016)<sup>4</sup>

<sup>4</sup> Ibadan City Masterplan, December 2016

### 2.2.2. Population

The population estimates for Ibadan were sourced from the approved Ibadan City Master Plan. It should be noted that the client and relevant government agencies were involved in the population estimate process.

Through the Ibadan City Master plan and in order to obtain an accurate estimate of Ibadan’s current population, a series of house counts, and household occupancy surveys were undertaken by the City Masterplan in October 2016. In total, 936 hectares of residential areas were covered containing over 14,000 houses and over 2,400 households housing more than 10,000 people; these represent large samples for city-wide surveys. Based on the results of these surveys, the population in 2016 was estimated to be just over 6 million. Table 2.1 compares this estimate to population data from the 1991 and 2006 Censuses and the latest available official estimate from the National Bureau of Statistics.

**Table 2.1: Ibadan Population Estimates**

LOCATION	POPULATION (000S)				ANNUAL GROWTH RATES		
	1991 <sup>1</sup>	2006 <sup>1</sup>	2011 <sup>2</sup>	2016 <sup>3</sup>	1991-2006	2006-2016	1991-2016
Inner LGAs	1,229	1,343	-	1,507	0.60%	1.20%	0.80%
Outer LGAs	607	1,217	-	4,511	4.70%	14.00%	8.40%
Ibadan	1,835	2,560	-	6,018	2.20%	8.90%	4.90%
	1,835	2,560	3,034 <sup>2</sup>	3,596 <sup>4</sup>	2.20%	3.50%	2.70%

Source: Ibadan City Masterplan, December 2016

A preferred projection of Ibadan’s population to 2036 has been made by assuming an annual growth rate of 3.32% which is slightly lower than the current growth rate. This is based on the assumption that there will be a decrease in the annual rate of natural increase of 0.1% in each 5 year period and a constant migration rate of 1.3% annually.

Table 2.2 presents the population projections based on the above assumptions and result in a 2036 population of 11.6 million which is used in the masterplan. This represents an increase of over 90% over the next 20 years at an annual rate of 3.32%. This rate of growth entails an average annual increase of 277,000 people compared with 210,000 at present.

### 2.2.3. Transportation Networks

Ibadan is a major Nigerian transport hub with freeways linking it with Lagos in the South, Abeokuta in the West, Oyo in the North, Ife and other cities towards the East. The city of Ibadan has a large road network, refer to Figure 2.4.

**Table 2.2: Ibadan Population Estimate Projections**

Projection Scenario	Assumed Annual Net Migration Rate	2016-2036 Growth Rate <sup>1</sup>	Population (000'S)					ANNUAL INCREASE (000'S)
			2016	2021	2026	2031	2036	
LOW	0.6% - reduced by 50%	2.60%	6,018	6,899	7,871	8,936	10,095	204
PREFERRED	1.3% pa - same as now	3.30%	6,018	7,137	8,424	9,894	11,565	277
HIGH	1.9% pa – increased by 50%	3.90%	6,018	7,346	8,925	10,791	12,985	348

1. Incorporates decrease in rate of natural increase

Source: Ibadan City Masterplan, December 2016

- Ibadan benefits from its location with respect to the national road and rail networks. The Lagos-Ojo Expressway, part of the Trans-African Highway network, passes through the city as does the Lagos-Nguru railway line.
- The Expressway provides a bypass route for traffic, and in particular heavy goods vehicle traffic, to avoid Ibadan’s central areas.
- The primary road network serving Ibadan is formed of radial routes converging at the center of the city, together with a number of lower-order (collector) orbital links between these radials.
- The main road network is of a good standard, generally dual-carriageway roads with two or three lanes in each direction. Flyovers have been introduced at major junctions to increase junction capacities. The roads are largely in good condition, although with some evidence of localized surface deterioration.
- High levels of pedestrian activity are observed across the city. Dedicated pedestrian facilities are provided in the form of footways and footbridges.
- The Ministry of Transport and Works has an on-going program of road construction and rehabilitation which includes some 182 individual projects involving approximately 940 km of carriageway, State-wide. The proposal for an outer Circular Road encircling the whole urban area involves the construction of some 110 km of expressway-standard road.

### 2.2.4. Drainage Network

The city of Ibadan is naturally drained by highly interconnected network of rivers and streams; most are seasonal such that the volume of water is reduced during the dry season and increased when the rain sets in, these include: Ona, Ogunpa, Ogbere and Omi Rivers.

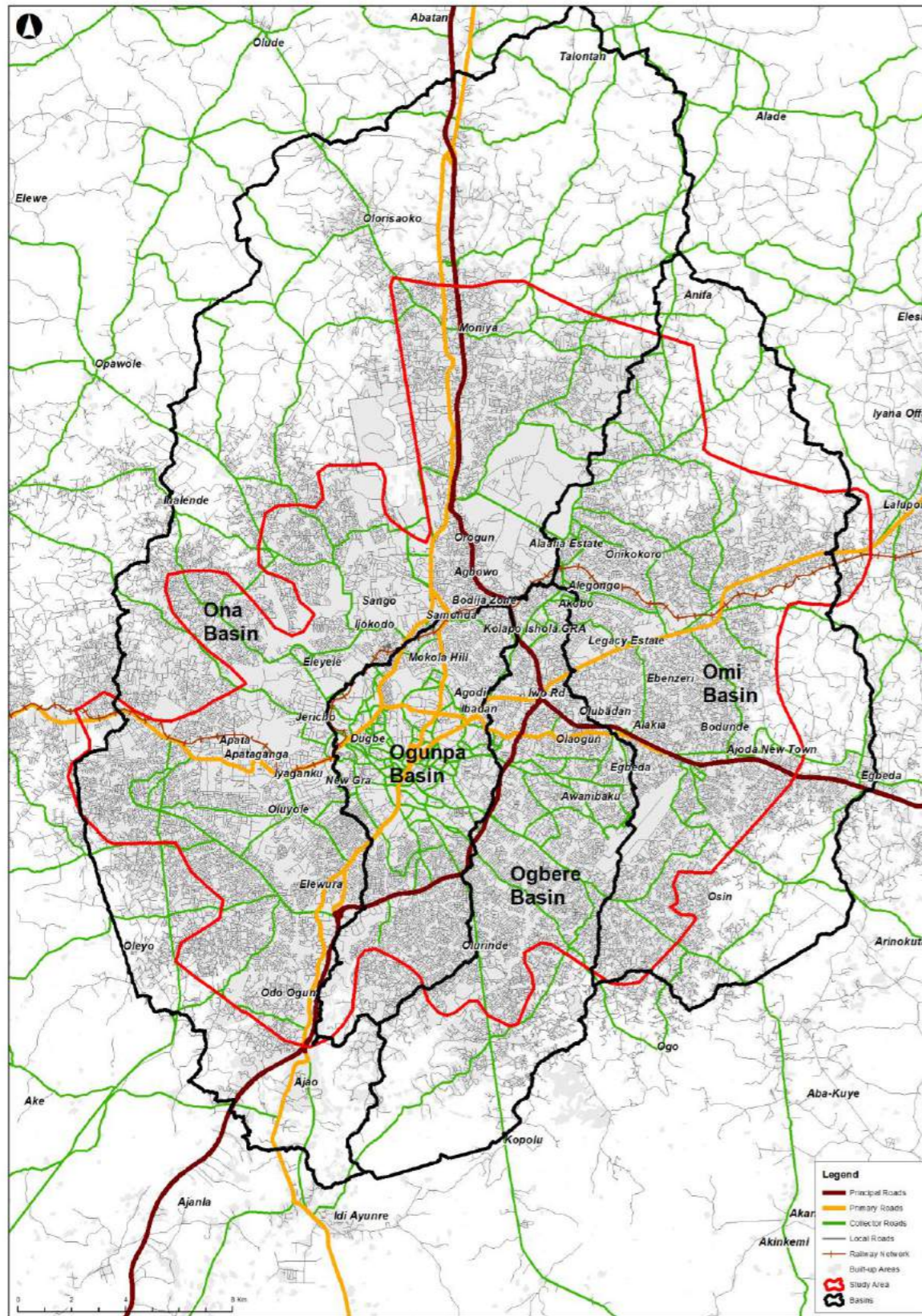


Figure 2.4: Existing Transportation Network (2016)

2.2.4.1. Current Setbacks

Oyo state has issued regulation in regard to defining the river setback based on past flood analysis. Oyo state identified the setbacks for several rivers across the city of Ibadan as shown Table 2.3. The setbacks are the distances from the river edge to the start of building construction. The intention was to protect the people and to define a river corridor that people should respect. The problem with these setbacks is that it did not consider the flood plain topography and as such cannot ensure the safety of the people and the buildings.

Even with the limited functioning of these setbacks the general status in Ibadan is that these setbacks are not followed and many violations do occur along all the rivers and streams and even the reservoirs. This violations affect the people and the buildings and create disasters with any minor flood event.

Table 2.3: Current Setbacks for Rivers in the Ibadan Metropolitan Area<sup>5</sup>

No	River Name	Approved Setback by Oyo State (m)
1	Odo- Ona Elewe	15.0
2	Adamo	15.0
3	Alalubosa	15.0
4	Sango	15.0
5	Oluyole	15.5
6	Kudeti	30.5
7	Orogun	30.5
8	Onire	30.5
9	Gbaremu	30.5
10	Alaro	30.5
11	Ogbere	30.5
12	Gege	30.5
13	Ogunpa	45.0
14	Odo-Ona	45.0
15	Ona-Ara	45.7
16	Others	15.0

Setback values given in the table above are measured from the River Bank

<sup>5</sup> Towards an Environmental Action Plan for Oyo State, Oyo State of Nigeria, 2005

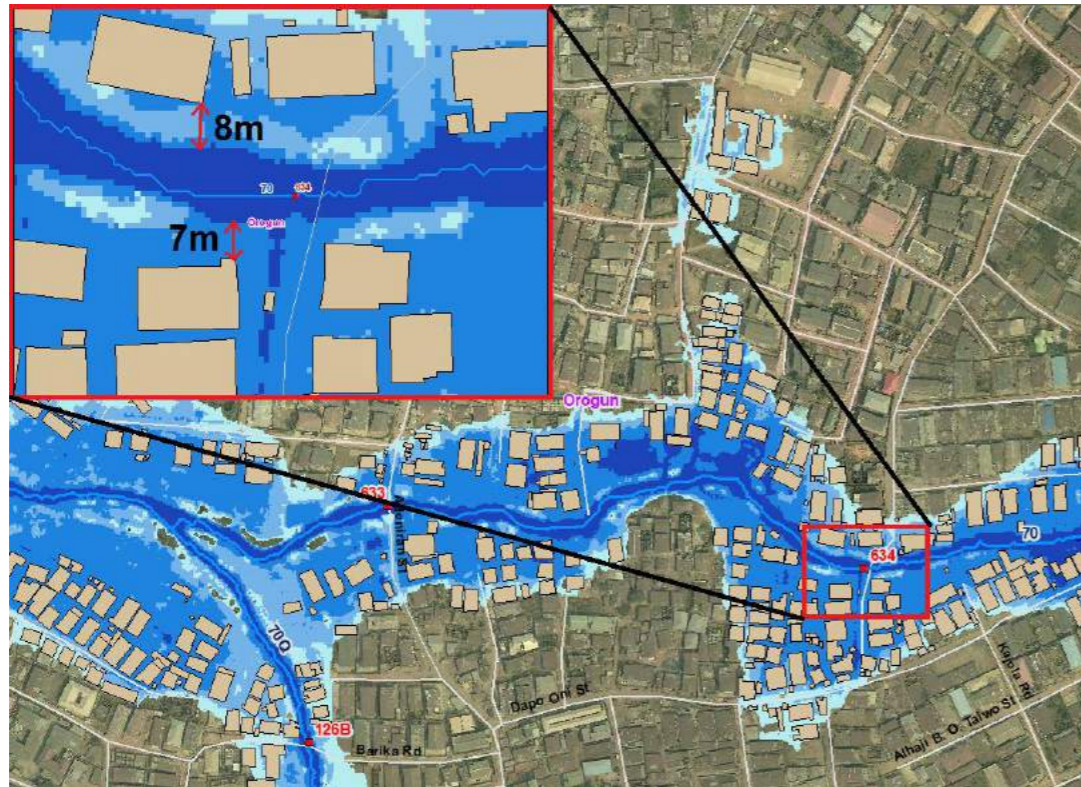


Figure 2.5: Orogun River and Encroachment of Buildings on Current Setbacks

Whenever there is heavy rainfall, most of the city get flooded and water overflows into houses and across roads at many parts of the city.

Historically, flooding is not a new phenomenon to Ibadan. From 1902 to 2011, there has been many recorded cases of flooding in Ibadan. These are as follows:

- i- 1902 – First flood-flooding of Oranyan swamp;
- ii- 1924 – Ogunpa overflowed its banks;
- iii- 1956 – Ogunpa flood which rendered many homeless
- iv- 1960 – Ogunpa flood disaster-destroyed 400 houses;
- v- 1963 – Ogunpa river overflowed its bank again causing disaster to many homes
- vi- 1978 – Ogunpa river destroyed properties worth several millions Of Naira at Old Gbagi market, Ogunpa Oyo, Omitowoju and Molete (Tomori, 1979);
- vii- 31 August 1980- Ogunpa flood disaster; the most devastating ever in the history of Ibadan.
- viii- 26<sup>th</sup> August 2011 - A most severe and catastrophic flood occurrence when, this time it was not really Ogunpa that overflowed its banks, because sections of it has recently been channelized, but Ona and Ogbere Rivers, which claimed many lives and destroyed many properties, rendering thousands homeless.

Three major flood events occurred in Ibadan in 1963, 1980 and 2011, with maximum daily rainfall depths of 258mm, 274mm, and 187.5mm, respectively. Available historical records of floods in Ibadan are shown in the Table 2.4 along with the amounts of rainfall causing them in Ibadan between 1951 and 2011.

Table 2.4: Rainfall induced floods in the city of Ibadan, Nigeria, between 1951 and 2011<sup>6</sup>

Dates	Rainfall (mm)	Estimated damage to Properties (Naira)	Estimated Loss of Lives
9–10 July 1951	161	Unknown	Unknown
16–17 June 1955	173	Unknown	Unknown
16–17 August 1960	178	Tens of thousands of naira	At Least 2 persons
27–28 August 1963	258	Tens of thousands of naira	At Least 2 persons
14-May-1969	137	Tens of thousands of naira	3
20-Apr-1978	126	Over 2,000,000	At least 2 persons
31-Aug-1980	274	More than 300 million	More than 500 with over 50,000 displaced
26-Aug-2011	187.5	Over 30 billion	Over 100

### 2.2.5. Institutional Framework

The enforcement of planning laws and regulations in Oyo State is weak and largely ineffective. This is in part due to:

- The sectoral way in which the administration works, with little interaction between ministries and even within departments.
- Lack of commitment by the authorities, in terms of providing resources needed for the departments to be more effective. This refers not only to plan enforcement but having in place a structure of plans for the State that can guide planning and planning decisions.
- Lack of the institutional arrangements for stakeholder involvement and approval at the local level, which weakens the effectiveness of the role of flood risk management.

However, many working in the State administration are aware of the need for better cross working and the need for more inclusive involvement of stakeholders.

### 2.3. Historical Flood Events

Ibadan has been afflicted by devastating floods from long time ago, when Gege Rivers submerged houses of those living on its banks. The area suffered from varying degrees of recurrent flooding.

<sup>6</sup> The August 2011 Flood in Ibadan, Nigeria: Anthropogenic Causes and Consequences; Int. J. Disaster Risk Sci. 2012, 3 (4): 207–217, and Nigeria Environmental Study Action / Team (NEST 1991, 107), and National Water Resources Institute (2011, 10). \* Akintola and Ikwuyatum 2012, 19

### 2.3.1. 1963 Flood Event

All available information indicates that the 1963 flood of August caused a great damage in Ibadan. Several houses were destroyed and least two people lost their lives during the flood. In the northern portion of the Ogunpa, the Egerton Road culvert and many of the culverts in that area were damaged. Further south, damage was greatest at the Ogunpa Motor Park area, Dugbe area, Dugbe Market, the Salvation Army Road, and portions of Araromi, Oniyanrin, Oke Ado and the Molete. Several retaining walls were destroyed at the lower ends of Lebanon Street and New Court Road. At Osoba Road south of Oke Bola Street, the flood waters rose to a depth of eight feet above the street causing damage to many houses and shops, and the collapse of some.

Flooding on the Kudeti by overtopping of banks was not as serious as on Ogunpa since the Kudeti channel is generally deeper and wider and people had not yet encroached on the flood plain to the same extent. In 1963, the bridge at Kudeti Street was destroyed and the bridges at Alafara Street and those to the north caused serious flooding on roadways.

### 2.3.2. 1980 Flood Event

The event of August 31<sup>st</sup>, 1980 is considered as the worst disaster that ever occurred in Ibadan history. Oguntala and Oduntoyinboz 1982<sup>7</sup> and many references mentioned that a flood occurred in Ibadan in 31<sup>st</sup> August 1980 with a value of 274 mm as recorded at Ibadan Old Airport (middle Ona basin). Konsadem Associates 1988 reported<sup>8</sup> that before the 1980 flood, the stage was set for a disaster. The river channels were clogged with solid wastes. The Ogunpa channel was flattened with sediments and the passages beneath the bridges were partially blocked.

The August 31, 1980 flood occurred as a result of heavy downpour which started around mid-day on a Sunday. Some worshippers were still in their churches for the normal services. By 1:00pm, flood waters had reached the knee level in buildings adjacent to the Ogunpa stream between Mokola and Gbagi. The rains continued heavily and by 4:00pm that Sunday, the Ogunpa channel, between Elizabeth Road and Molete had become a massive body of water extending 150 meters on both banks.

This great expanse of water was caused by the bridges which now suddenly became temporary dams. Solid wastes had completely blocked the spaces beneath the bridges. Those bridges affected along the Ogunpa are the bridges on Elizabeth Road, Omitowoju Street and Ogunpa Oyo. Serious damages were done through the expanse of water to buildings with weak structures. Some collapsed killing all occupants who by then had moved upstairs awaiting reduction in flood water level.

<sup>7</sup> Oguntala, A. B., & Oguntoyinbo, J. S. (1982). Urban flooding in Ibadan: A diagnosis of the problem. *Urban Ecology*, 7(1), 39-46.

<sup>8</sup> Konsadem Associates, "Preliminary Engineering Report for Flood and Erosion Control Works on Kudeti Stream", Ogun Oshun River Basin Development Authority, November 1988.

Some bridges downstream i.e. from Ogunpa Oyo to Molete were still being used by people and vehicles. By 6:00pm, the bridges upstream had collapsed and massive flood waves were sent downstream. This was the most devastating part of the flooding. The flood came with such massive force that it swept away huge buildings, stationary vehicles and buses full of passengers.

The disaster caused by this 1980 flood was of such a magnitude that Ibadan was declared a national disaster zone. In terms of monetary costs, an estimate of ₦300 million is far below the truth. Official records gave loss of life at about 500 people.

### 2.3.3. 2011 Flood Event

Like many previous floods but more serious, the catastrophic 2011 flood tragically resulted in 120 deaths along with extreme destruction to the city's infrastructure. After six hours of torrential rain, River Ona flooded everything in its path causing the death of more than 120 people and serious damage to infrastructure (many bridges collapsed, roads were washed away, and substantial property lost). In addition to the livestock and fish in ponds which were carried away by the flood.

Some damages caused by the flood in 2011 were stationed in the embankments of the bridges on the River Ona at Apete and Ogbere in Olomi which were swept away, causing drowning of all the surrounding communities for over four days. Many culverts were completely blocked due to the sweeping of solid wastes with the flood. The flooding also created serious congestion to traffic flow on highways that were not affected by the flooding. According to the Terms of Reference, the damages caused a substantial property loss valued at 2 Billion Naira (12.5 Million US Dollars).

The automatic rain gauge at the IITA recorded an all-time high of 187.5mm<sup>9</sup> rainfall on August 26, 2011. The rain started at 16:40 in Friday afternoon, continuing in intense torrents until 20:00 in the evening, with intermittent drizzling until 23:00 late at night. The rainfall was most intense in a 70-minute period between 18:10 and 19:20 when 140.63mm of the rain fell. On the same day, the rain gauge at the new airport at Alakia recorded 86.20mm; while the old Airport recorded 153.50mm during the period<sup>10</sup>

The Eleyele spillway is routinely spilling water over its crest during the rainy season, and there is no way of actively controlling the discharge. There are no records of water levels prior to or during the flood. Neither are there any data of the discharge into the reservoir.

From eyewitness accounts the water level in the reservoir rose rapidly, resulting in inundation of the water works around 21:30 (9:30 pm). Thirty minutes later the water works were evacuated as the rising water became deeper<sup>11</sup>.

<sup>9</sup> Report on the 26th of August 2011 flood in Ibadan, World Bank Report no. 70608, 2012

<sup>10</sup> Assessment of Urban Flood Disaster: A Case Study of 2011 Ibadan Floods, Hydrology for Disaster Management, Special Publication of the Nigerian Association of Hydrological Sciences, 2012

<sup>11</sup> Report on the 26th of August 2011 flood in Ibadan, World Bank Report no. 70608, 2012

According to eyewitnesses the water levels in the dam rose to above the dam crest but were held back by the parapet which has been erected on the dam (World Bank Report no. 70608, 2012).

No evidence is available that records the maximum height attained within Eleyele reservoir at the instant moment of the peak event.

However, other information reveals that continuous rainfall resulted in the overflow of Eleyele reservoir causing "flash flood like tsunami<sup>12</sup>" by midnight into the downstream urban areas (mostly illegal settlements).

The flood caused some damage to the spillway and washed over the sidewalls of the channel downstream of the dam which caused considerable damages. Downstream the water quickly inundated the water works, which promptly were evacuated.

It was noted from several references that the water did not overtop the dam.

The areas flooded include Onipepeye, Oda-Ona Elewe, Oda Ona Apata, Nihort, Ijokodo, Sango, Apete, Ajibode, Orogun, Agbowo, old Bodija, Ikolaba, Ibadan Polytechnic, Fatusi Ogbere, Olodo Kumapayi, University of Ibadan, Eleyele Waterworks and Oluyole Estate.

## 2.4. Constraints and Opportunities

### 2.4.1. Constraints

There are number of constraints that the study tackled while preparing the Ibadan flood risk management. These include:

- Limited rainfall data and incorrect rainfall records.
- No flow measurements that limit the model calibration. In this regard, during the course of the study the Consultant make use of the existing defined cross-section of Ogunpa stream and marked two location with level marks. During 2017 two rainfall events occurred and the levels were recorded and were used to calibrate the models developed for the catchment.
- No images showing the flooding of the previous flood events even for the latest 2011 event and very limited documented information of the flooding extent and levels. The limited records were used in calibrating the models developed.
- No design records of some of the existing drainage structures, as such this study surveyed and documented most of the drainage structures within the city limits.
- Limited documentation/records of the existing buildings, this was limiting the asset valuation, it is important to note that this study documented most of the building affected by flooding and located in flood plains through the asset survey done during the study.

- The available survey at the start of the project was 1991 for a limited area of the city was available. However, at the start of the project Lidar survey was performed that assisted in developing the flood risk maps for the city of Ibadan.

As for the challenges that the flood risk management plan seeks to address. These include:

- Flooding is the most serious threat and encroachment on flood plains, poor maintenance of the drainage system and blockages in the watercourses has increased flood risk. There is a need to mitigate the flooding impact and identify the flood prone areas where no development should be permitted. Providing a proper drainage system is critical.
- Complex drainage network intersecting with the transportation network has led to a numerous number of crossing structures. Most crossing structures are undersized which has resulted in bottle necked structures, constriction of the flow and inadequate conveyance leading to inundation and increased flood hazards. Rehabilitation of crossing structures is necessary.
- People's accessibility to drainage systems through numerous crossing structures is causing a high impact of littering in these systems. Street trading continue to dump their wastes in drainage systems that pollutes the environment resulting in health problems which blocks the waterways leading to flooding.
- Unplanned urbanization causes problems such as encroachment on streams rights of way. Encroachment of people on approved setbacks has exposed people and buildings to flood hazards. The provision of sufficient adequate flood protection and identification of illegal settlements is therefore one of the key considerations of the Masterplan.
- Rapid urban growth and high dense urban area has left no space for attenuation within Ibadan metropolis.
- There are vast areas of forest or dense vegetation at risk of deforestation and encroachment which must be retained to allow the soil to absorb storm water.
- One of the main reasons for the absence of planning controls and the lack of proper land management is due to an ineffective institutional framework, one in which ministries in Oyo State do not share resources, resulting in overlap in their remit. This also results in an inefficient funding stream, whereby resources could be allocated more efficiently.
- No early warning, and very limited capability within the emergency services to respond, the citizens of Ibadan are left in a vulnerable position.
- The unavailability of hazard or risk maps to define the hazardous zones during floods and no demarcations are available within the floodplain area.
- The lack of public campaigns and awareness about the precautions and procedures to be followed before, during and after the flood event and especially in the curriculums in schools.

<sup>12</sup> The Project for Review and Update of Nigeria National Water Resources Master Plan, Supporting Report 5, Water Resources Sub-Sector Development Plan

- Lack of proper drainage regulations and polices in new developed areas results in increased run-off and peak discharges downstream. This should be controlled so as not to generate drainage flows more than what is generated before the development is constructed. These can be done by applying all possible sustainable drainage systems to control the flow within the new development before passing the flood flow downstream.
- Lack of respect of planning polices and regulations in the floodplain zone which lead to the presence of people and vulnerable assets within the floodplain area and increase the probability of exposure and damage during floods.
- There are no watershed conservation policies to be followed by the farmers in the cultivated lands which lead to high erosion and loss of soil during floods.

#### **2.4.2. Opportunities**

Based on several meetings with the Client, the World Bank and stakeholders, a number of opportunities is available to mitigate the flooding problems in Ibadan such as:

- Topography and large reserves of forests at the periphery of the city are the most important physical features of Ibadan. They could provide opportunities for construction of dikes and dams for flood risk reduction, attenuation purposes and water resources.
- There are many green areas adjacent to existing streams. These areas provide an opportunity to allocate them potentially for landscape and attenuation purposes.
- There is enough land available in Ibadan for channelizing drainage systems to protect people from flood hazards. There is an opportunity to make these systems hydraulically efficient with supporting policies to restrict encroachments on their Right of Way.
- The initiative led by the adoption of the Ibadan Flood Risk Management and Drainage Masterplan will enhance the awareness of citizens, identify locations of flood hazards and manage flood risk effectively.

### 3. Flood Risk Management and Drainage Masterplan Framework

Flood risk management deals with a wide array of issues and tasks ranging from the prediction of flood hazards, through their societal consequences to measures and instruments for risk reduction. Due to this variety of aspects, management of flood risks needs systematization and integration. This section provides an overview of central terms, the systematization of tasks and components and a basic framework for flood risk management. The term management is used in at least two different ways in the literature on floods, either excluding or including risk analysis. The first understanding is based on the hydrological reliability of existing flood defense structures. Management is interpreted, therefore, as decisions and actions undertaken to mitigate the remaining risk above flood protection design standards.

The purpose of this framework is to provide clear guidance on how river flood risks within Ibadan City will be managed into the future. This approach will encourage better integration between the various stakeholders involved in flood risk management, and between the various strands of work that are currently occurring or need to occur in the future.

The aim of this strategy is therefore to strengthen the current approach to managing flood risks, by embedding a risk management approach and recognition of the nature and behaviour of river systems into all river flood work activities. It builds on the existing work that local authorities and other agencies currently undertake to address flood risks, and is closely aligned with and complementary to emerging national directions.

The flood risk management follows the Sendia Framework for disaster risk reduction, where four priorities are actioned. These priorities are:

- Understanding risk
- Strengthening disaster risk governance to manage disaster risk
- Investing in disaster risk reduction for resilience
- Enhancing disaster preparedness for effective response, and to «Build Back Better» in recovery, rehabilitation and reconstruction

These four priorities are addressed in the flood risk framework as follows:

- Understanding watershed characteristics;
- Assessing flood risk;
- Analyzing flood risk;
- Adapting flood risk measures.
- Institutional arrangements

#### 3.1. Understanding Watershed Characteristics

Before starting the process of managing risk due to floodwaters, understanding the characteristics of watershed is a vital step. Watershed characteristics include the following:

- Getting information about the climate pattern within Ibadan City;
- Collecting and analyzing rainfall data;
- Studying the topographic characteristics of the watershed and developing digital elevation model with high accuracy to simulate the real topography.
- Delineating the main basins within the watershed and defining the main rivers;
- Allocating the main dams and water bodies
- Conducting full survey for the existing structures along the main rivers and tributaries to identify their sizes and conditions;
- Getting information about the existing and projected land use for Ibadan City along with identifying the available soil types;
- Conducting geotechnical investigations at different structures to assess the physical, mechanical and chemical properties of the subsurface materials;
- Identifying the current levels of ground water all over the drainage basins

#### 3.2. Assessing Flood Risk

Generally, assessing the risk due to floods requires preparing a hydrological and hydrodynamic model to study the effect of floodwater depths and velocities on people, structures and objects. The procedure for the assessment of flood risk is developed by allocating the workload into three steps which could be summarized as follow:

- 1- Preparing hydrological model: The main objective of the hydrological model is to simulate the rainfall and runoff and to determine the output flood hydrograph, the HEC-HMS model version 4.1 was used. Most of the data collected while studying the characteristics of watershed will be used as input data for the hydrological model.
- 2- Preparing Hydrodynamic model: Simulating the flood flows and developing the inundation maps can be achieved through developing two-dimensional unsteady hydrodynamic model. HEC-RAS software is one of the key programs for the two-dimensional hydrodynamic modelling. The output from the hydrological model along with topographic data are the main input data for the hydrodynamic model. The output from the hydrodynamic model could be concluded in flood extent, depth and velocity maps.

#### 3.3. Analyzing Flood Risk

Analyzing flood risk depends mainly on the depth and velocity maps obtained from the hydrodynamic model along with the results from the conducted survey for the assets within the floodplain. These data could be used to develop and study the three main components of flood risk which are:

- 1- Flood hazard: which depends mainly on the depth and velocity of floodwaters;
- 2- Exposure: which defines the assets exposed to risk within the floodplain are due to flood waters.
- 3- Vulnerability: which defines how valuable the assets allocated within the floodplain or people against floods.

### 3.4. Adapting flood risk measures

If risks have been assessed as not tolerable, measures and instruments are applied for risk reduction. Measures could be categorized as follow:

- 1- Protection measures: These measures include the concrete, earthen or other engineering structures. These structures could be used to reduce the amount of discharge running down a river such as reservoirs and they could be used as of flood defenses, such as channels, embankments, crossing structures, attenuation ponds and adopting sustainable protective measures such as swales and rain gardens.
- 2- Preventive measures: Preventive measures are measures not involving physical construction which use knowledge, practice or agreement to reduce disaster risks and impacts, through producing flood risk maps, policies and laws, public awareness raising, training and education and flood warning systems including disaster contingency and evacuation plans, and emergency response coordination systems at community and government levels.
- 3- Post event measures: These include the measures which have to be done immediately following a flood event. They include the documentation of the event and damaged assets and structures along with developing remediation plan for the damaged assets.
- 4- Watershed conservation: The main aim of these measures is to decrease surface runoff and soil erosion and therefore to reduce flood peak. These interventions should consider a number of basic principles related to the main factors influencing runoff and erosion, namely soil, topography, land cover and use and farming practices.

### 3.5. Institutional arrangements

The development of the Flood risk management requires providing institutional arrangements to define the way of managing the dynamic process. This will require to address

- Needed institutions to manage the plan
- Responsibilities of the institutions
- Staff arrangements and capacity building
- Funding arrangements

Figure 3.1 summarizes the flood risk management framework proposed by the Consultant to control flood risk within Ibadan City. The institutional arrangements are addressed separately in section 11 where it addresses the institutional requirements based on the risk management plan requirements.

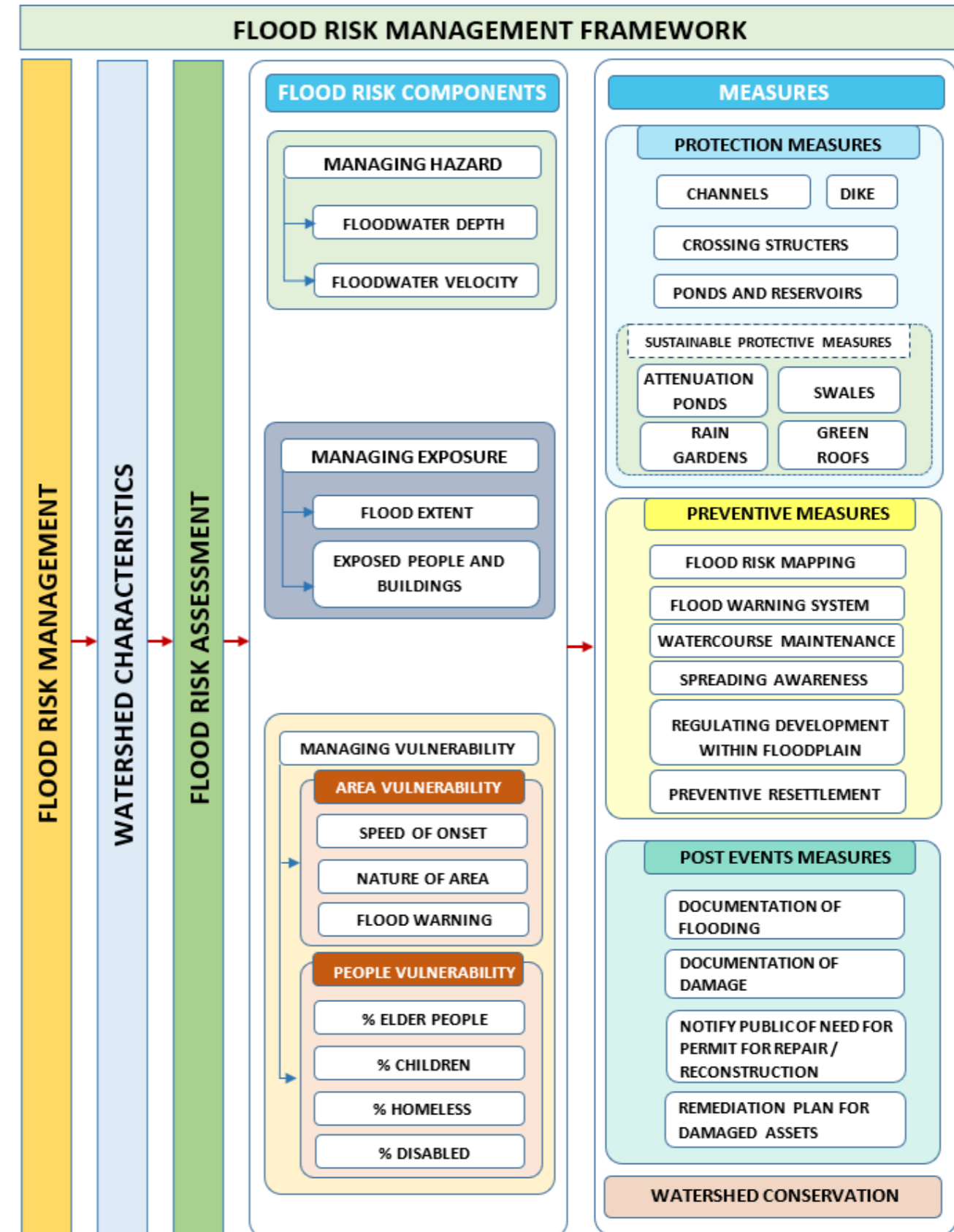


Figure 3.1: Flood Risk Management Framework

## 4. Watershed Characteristics

This section includes the characteristics of Ibadan watershed such as climate, rainfall, topography, river basins, existing dams, crossing structures, landuse and land cover, topsoil, geology and groundwater conditions.

### 4.1. Climate

Ibadan has a tropical wet and dry climate with a lengthy wet season and relatively constant temperatures throughout the course of the year. Ibadan's wet season runs from March through October, though August sees somewhat of low precipitation. This low precipitation nearly divides the wet season into two different wet seasons; i.e. from March to July and from September to October, flooding usually occurs in these two periods. November to February forms the city's dry season, during which Ibadan experiences the typical West African climate. The mean total rainfall for Ibadan is around 1420 mm, falling in approximately 109 days. There are two peaks for rainfall, June and September. The mean maximum temperature is 26.46°C, minimum 21.42°C and the relative humidity is 74.55%. Relative humidity is considered high within Ibadan especially during the rainy season.

Climate change is another factor that may increase frequency and magnitude of natural disasters such as flooding. Climate Change projections in Nigeria is illustrated in the Hydrological Analysis Annex, refer to annex 1.

### 4.2. Rainfall and Hydrometric Data

Ibadan has two distinctive wet and dry seasons. Rains start around the third week of March and ends approximately in mid-October after which it is the dry season. The wettest month is June. Parts of Ibadan receive an annual average of over 1400mm rainfall depth.

Rainfall data is extracted from 7 meteorological stations in Ibadan along with the historical data collected from available literature. Data from four stations within the city of Ibadan (Ibadan New Airport, IITA, NIHORT, and Ibadan Old Airport) have been collected. In addition, data from three stations outside Ibadan (Abekouta, Ijebo Ode, and Iseyin) have also been collected for comparison and evaluation of the regional distribution of rainfall in the area. Rainfall data is illustrated in Hydrologic Analysis Annex, refer to annex 1. Figure 4.1 shows the maximum daily rainfall series for the NIMET station at Ibadan new airport. The maximum recorded daily rainfall depth is 183.4 mm and was recorded on July 3<sup>rd</sup>, 2001.

### 4.3. Topographic Characteristics

Ibadan city setting is characterized by rugged terrain with steep slopes creating a very dense network of streams with wide valley plains. Three major landforms which are hills, plains and river valleys dominate the whole landscape of Ibadan region. The general elevation within the built up area is between 350m and 100m above mean sea level. Topographic elevations are extracted from the acquired LiDAR survey in both UTM WGS 1984 and Minna coordinate systems.

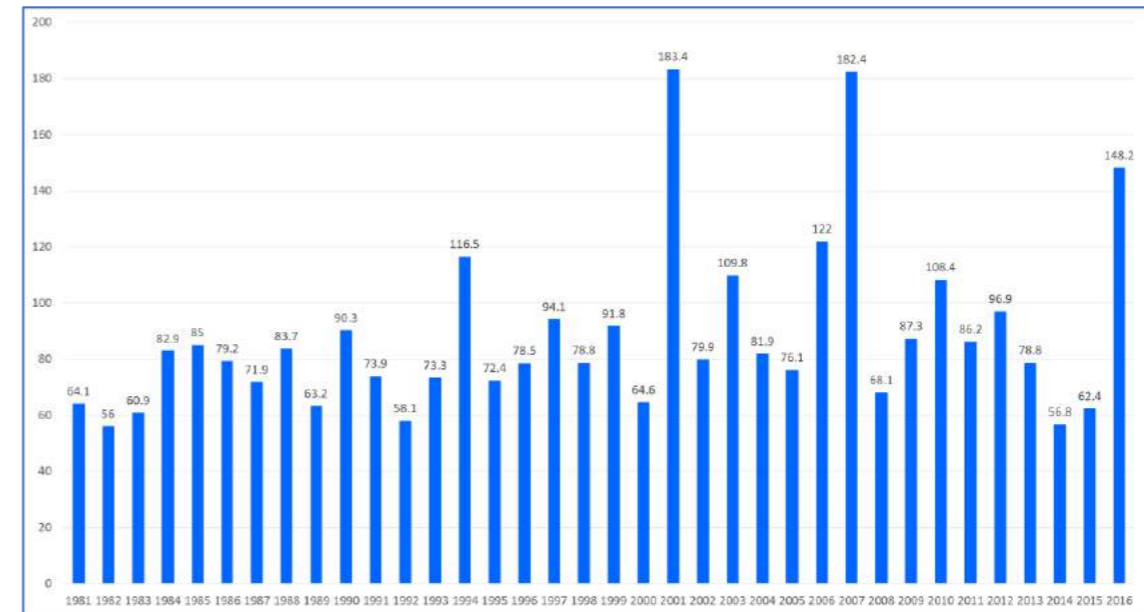


Figure 4.1: Ibadan New Airport Station - Maximum Daily Rainfall in Ibadan 1981 to 2016  
[Data Source: NIMET]

### 4.4. LiDAR Survey

A detailed aerial survey was conducted in January 2018 covering the core area of Ibadan with a total surface area of approximately 1,030 km<sup>2</sup>. The survey was performed using a fixed-wing aircraft platform consisting of three-dimensional laser scanning (LiDAR) and high-resolution aerial photography. More information on the LiDAR data acquisition is illustrated in the GIS Database Annex, refer to Annex 5.

#### 4.4.1. LiDAR Data Collection

The LiDAR data was collected with an average density of around 2 points/sq. meter for the project area. The LiDAR covers the study area (in black) and the 4 major basins, in addition to the proposed ring road, refer to Figure 4.3. A sample of the LiDAR for a close view is presented in Figure 4.2.

The LiDAR was processed and filtered to produce Digital Elevation Models (DEM) and Digital Terrain Model (DTM) in both ASCII XYZ grid format and GeoTIFF format (1m and 5m intervals respectively). DTM represents the elevation of the bare earth or the natural terrain. DEM represents the natural terrain including the elevation of the objects. Vertical data of the LiDAR data is available in two coordinate systems:

- The World Geodetic System 1984 (WGS1984)
  - The vertical datum is the ellipsoidal WGS1984 datum.
  - Their elevations represent the ellipsoidal height above WGS1984 datum.
  - It is regarded as a global system.
- Minna System
  - The vertical datum is the Mean Sea Level (MSL)
  - Their elevations represent the orthometric heights above the MSL
  - It is regarded as a local system in Nigeria.

The Consultant used the WGS1984 UTM 31 North Coordinate system as the basis of all analysis

#### 4.4.2. Aerial Photos

A 100-megapixel camera was used for capturing the high-resolution aerial photos simultaneously with the LiDAR scanning. Image frames were developed from the captured format to TIFF format. The imagery has a resolution of 0.2 m which is acquired for the project area, refer to Figure 4.4. The imagery covers the study area (in black) and the 4 major basins, in addition to the proposed ring road. A sample for a close view is presented in Figure 4.5.

The imagery was orthorectified using available base maps, survey 1991 and online databases (Streets, landmarks) as well as a set of ground control points acquired during a field survey in both UTM WGS 1984 and Minna coordinate systems.

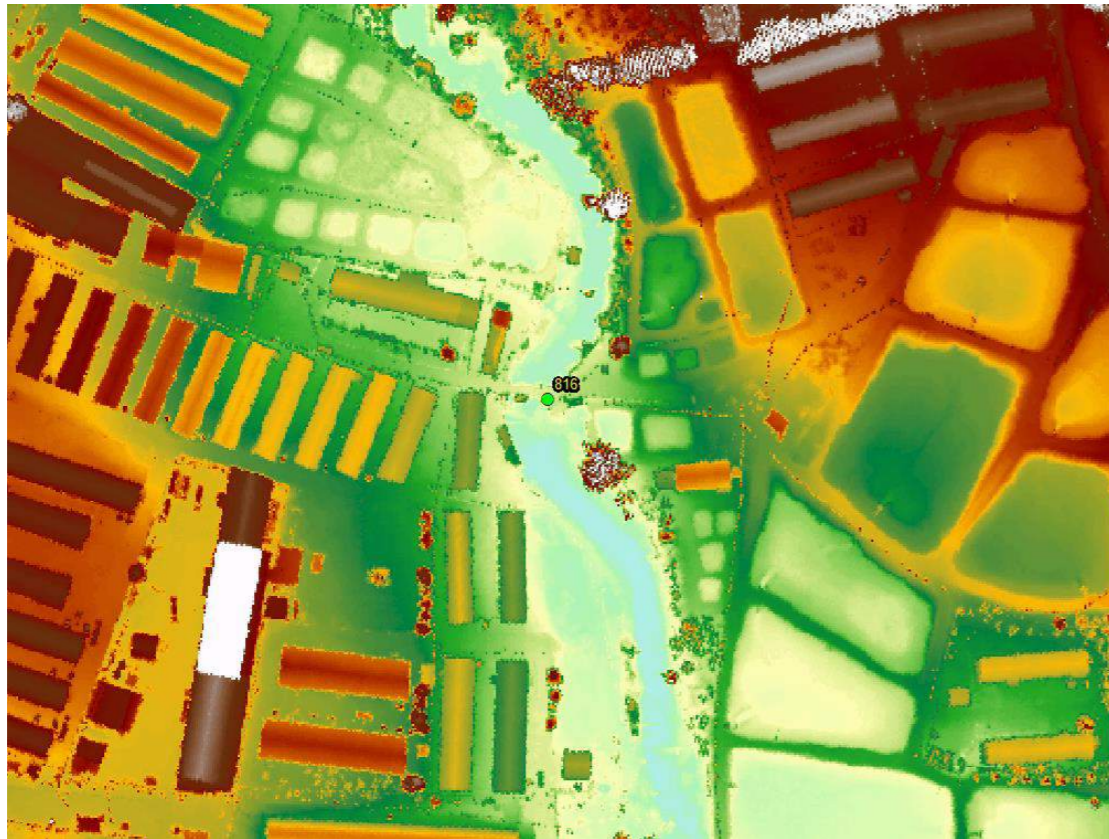


Figure 4.2: A sample of LiDAR DEM over Oluyole Industrial Estate, Zartech and Ona River, Bridge no. 816 (N1), (594,045mE, 813,649mN WGS1984, Z31N)

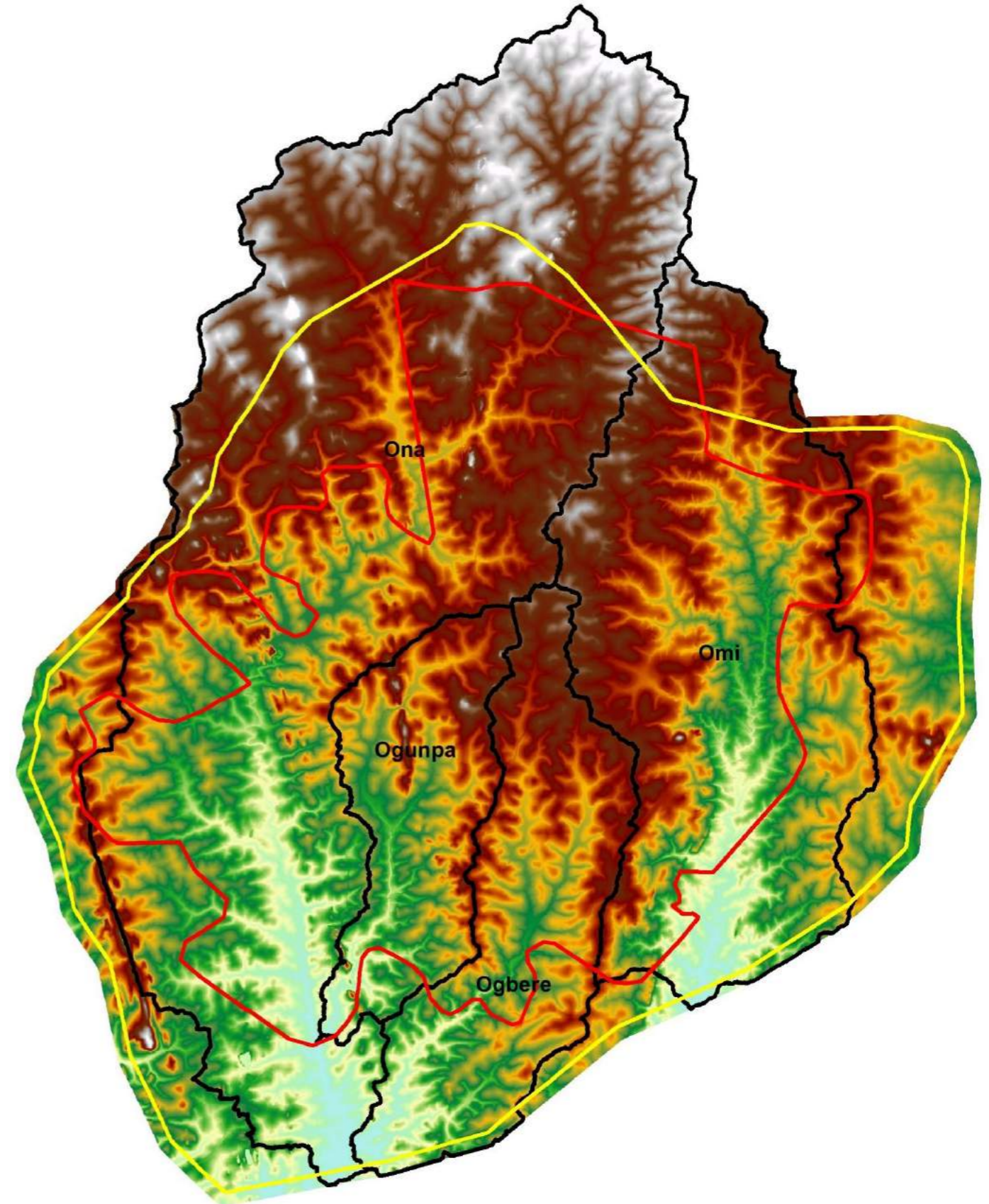


Figure 4.3: LiDAR DTM for the Project Area, January 2018

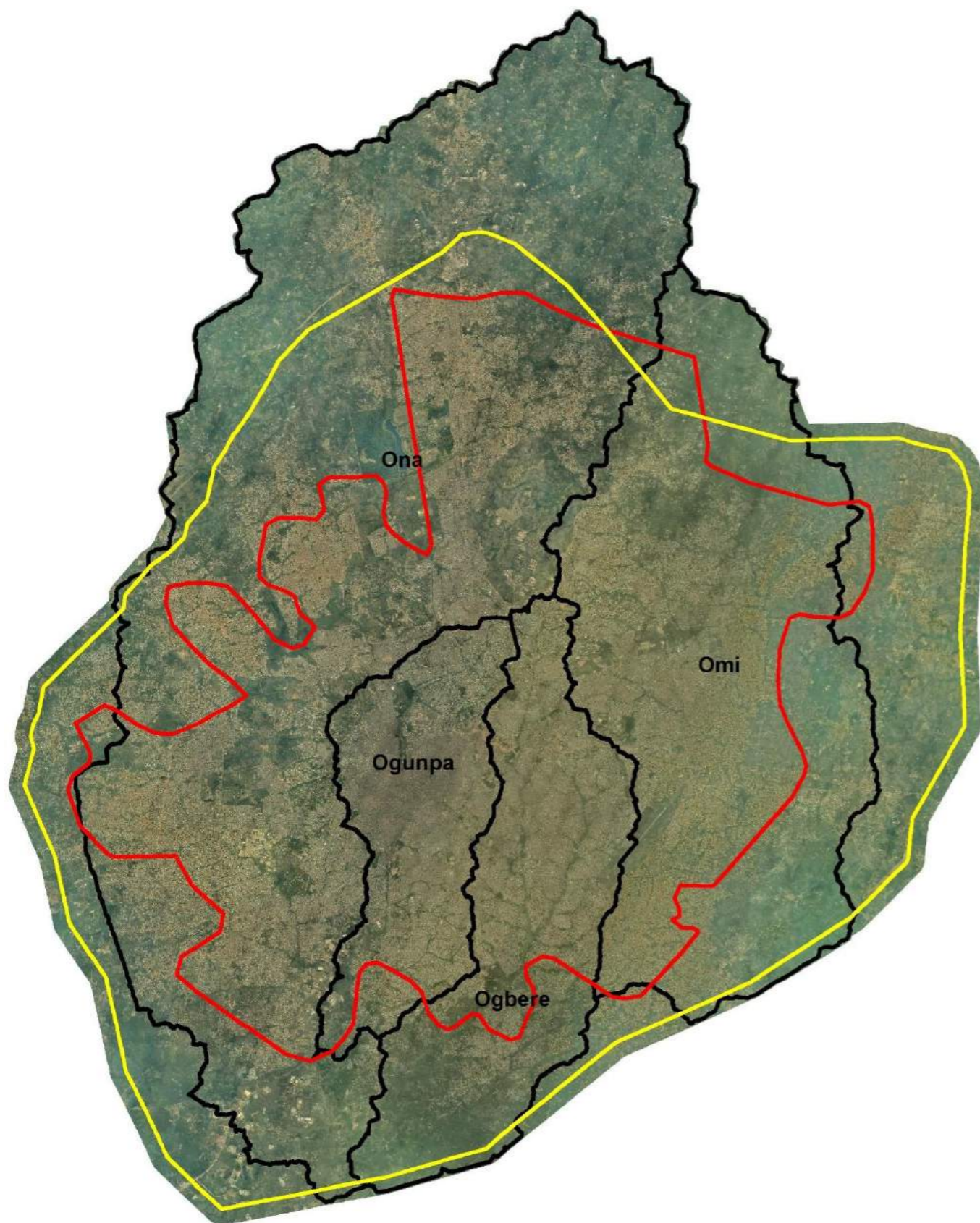


Figure 4.4: High Resolution Aerial Imagery over the Project Area, January 2018

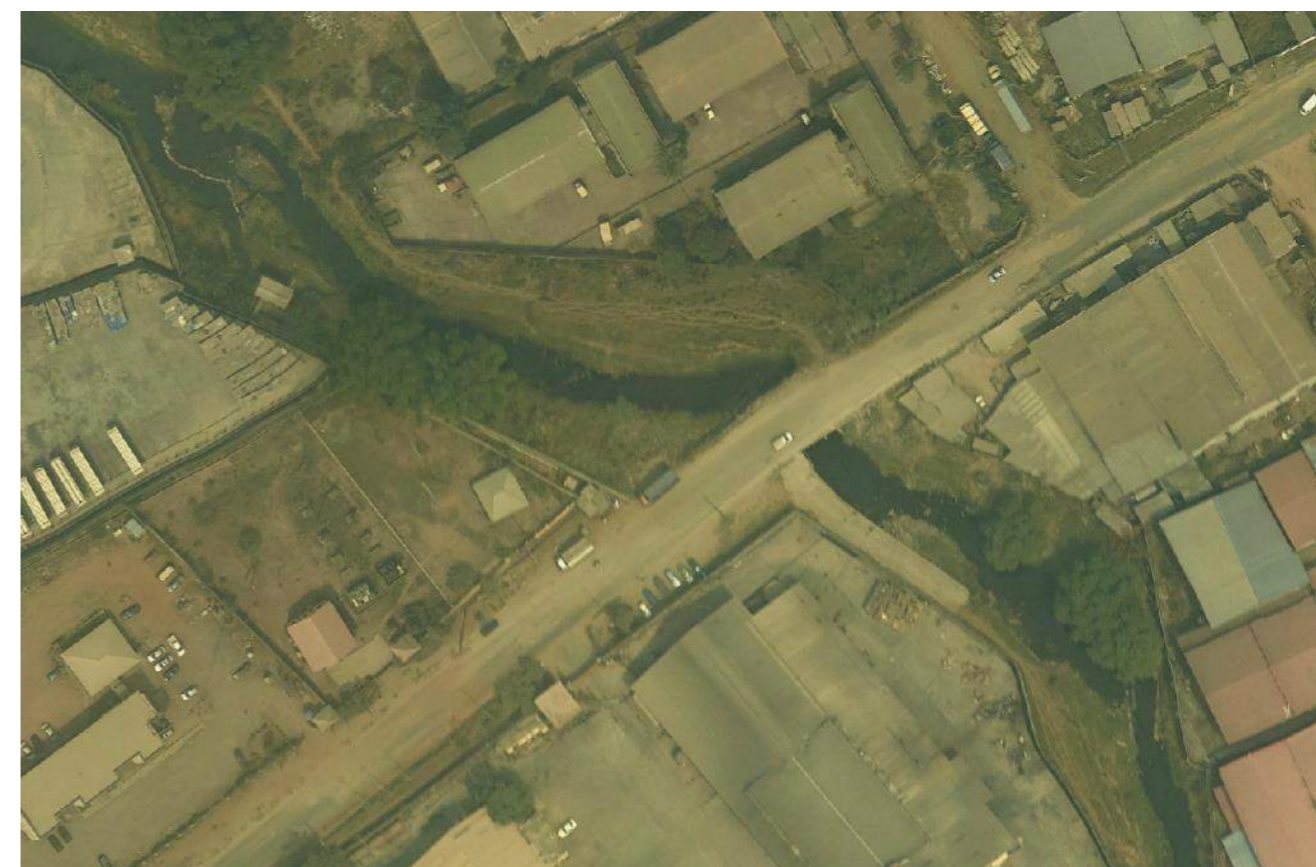


Figure 4.5: A sample of the high resolution aerial imagery over Oluyole Industrial Estate, Zartech and Ona River, Bridge no. 816 (N1), (594,045mE, 813,649mN WGS1984, Z31N)

#### 4.5. River Basins

The city of Ibadan is naturally drained by a dense network of rivers and streams, most of them are seasonal such that the volume of water in them is reduced during the dry season and increased when the rain sets.

##### 4.5.1. Major Basins

The major basins in Ibadan includes the following basins: Ona (Western), Ogunpa (Western Central), Ogbere (Eastern Central) and Omi (Eastern). Figure 2.2 shows the 4 major basins and their relationship with the 11 LGAs and the urban area of Ibadan. The extents of the 4 major basins are available in the GIS Geodatabase.

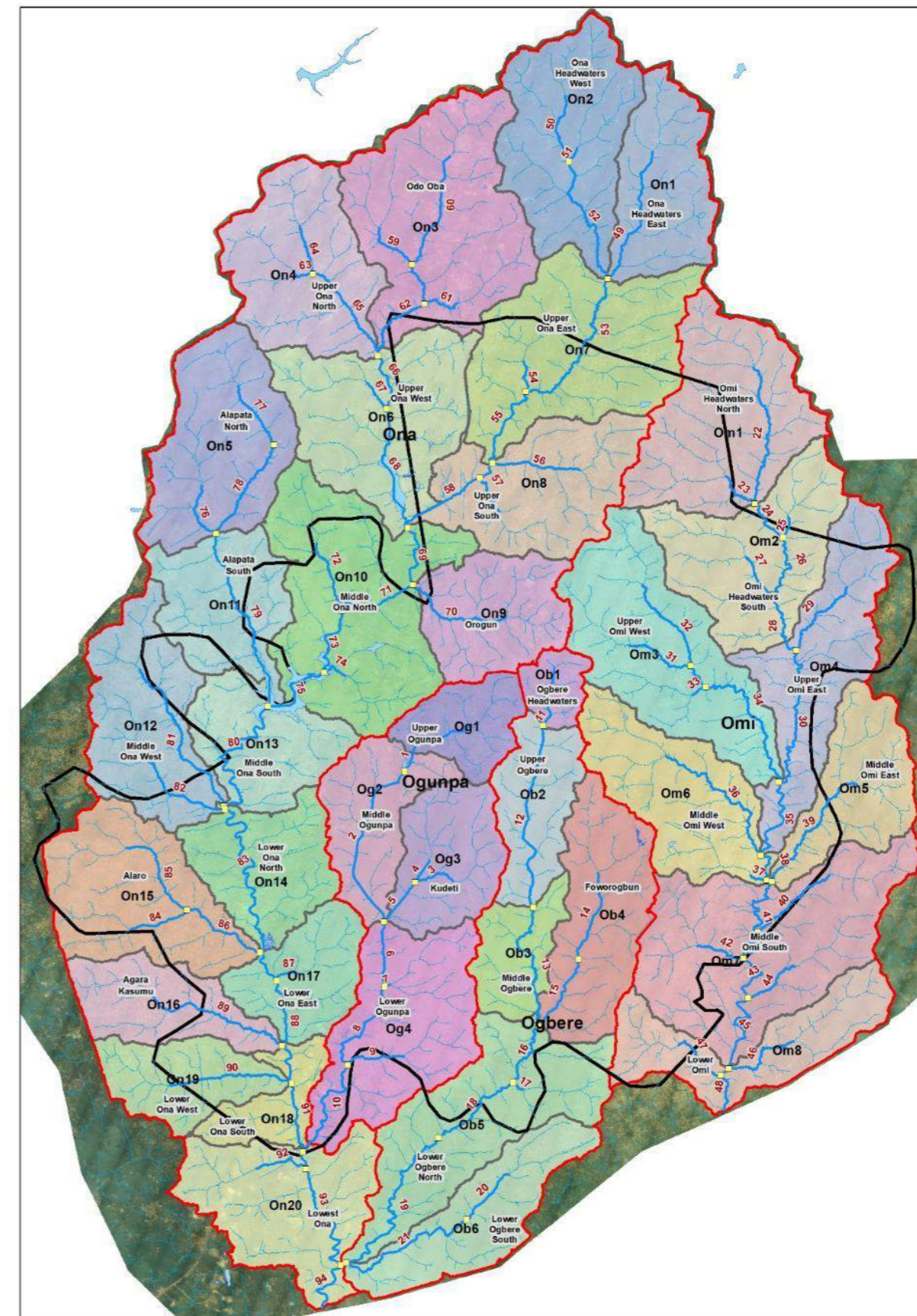
##### 4.5.2. Sub-Basins

The major basins in Ibadan are divided into 38 subbasins. Figure 4.6 shows the 38 subbasins in Ibadan along with a code name identity for each subbasin. e.g. subbasin of Upper Ogunpa is coded with an identity of Og1, while the headwaters of Ogbere is coded as Ob1. Moreover, Figure 4.6 shows the main streams of Ibadan with a stream threshold of 5km<sup>2</sup>. The main streams are identified with system code names from 1 to 94. The names of each subbasin are identified in

Table 4.1. The extents and the attributes of the 38 subbasins and 94 systems are available in the GIS Geodatabase.

**Table 4.1: Identification of Ibadan 38 Sub-basins and Catchment Area**

Code	Subbasin Name	Catchment Area (km <sup>2</sup> )	Code	Subbasin Name	Catchment Area (km <sup>2</sup> )
	<b>Ona Basin</b>	<b>479.3</b>		<b>Ogunpa Basin</b>	<b>71.8</b>
<b>On1</b>	Ona Headwaters East	19.5	<b>Og1</b>	Upper Ogunpa	10.7
<b>On2</b>	Ona Headwaters West	28.9	<b>Og2</b>	Middle Ogunpa	16.2
<b>On3</b>	Odo Oba	39.2	<b>Og3</b>	Kudeti	16.2
<b>On4</b>	Upper Ona North	26.7	<b>Og4</b>	Lower Ogunpa	28.7
<b>On5</b>	Alapata North	27.5		<b>Ogbere Basin</b>	<b>104.8</b>
<b>On6</b>	Upper Ona West	30.8	<b>Ob1</b>	Ogbere Headwaters	5.0
<b>On7</b>	Upper Ona East	36.2	<b>Ob2</b>	Upper Ogbere	14.4
<b>On8</b>	Upper Ona South	25.5	<b>Ob3</b>	Middle Ogbere	10.4
<b>On9</b>	Orogun	18.2	<b>Ob4</b>	Foworogbun	23.9
<b>On10</b>	Middle Ona North	40.3	<b>Ob5</b>	Lower Ogbere North	31.8
<b>On11</b>	Alapata South	19.1	<b>Ob6</b>	Lower Ogbere South	19.3
<b>On12</b>	Middle Ona West	24.9		<b>Omi Basin</b>	<b>223.0</b>
<b>On13</b>	Middle Ona South	17.6	<b>Om1</b>	Omi Headwaters North	31.7
<b>On14</b>	Lower Ona North	18.4	<b>Om2</b>	Omi Headwaters South	26.8
<b>On15</b>	Alaro	27.7	<b>Om3</b>	Upper Omi West	33.9
<b>On16</b>	Agara Kasumu	15.3	<b>Om4</b>	Upper Omi East	26.9
<b>On17</b>	Lower Ona East	14.6	<b>Om5</b>	Middle Omi East	17.9
<b>On18</b>	Lower Ona South	8.5	<b>Om6</b>	Middle Omi West	24.2
<b>On19</b>	Lower Ona West	13.9	<b>Om7</b>	Middle Omi South	41.9
<b>On20</b>	Lowest Ona	26.5	<b>Om8</b>	Lower Omi	19.7



**Figure 4.6: The 38 Subbasins in Ibadan and the 94 Systems**

## 4.6. Main Rivers

The city of Ibadan is naturally drained by a dense network of rivers and streams; most are seasonal such that the volume of water is reduced during the dry season and increased when the rain sets in, these include: Ona, Ogunpa, Ogbere and Omi Rivers, refer to Figure 4.7.

The following section describes the main rivers within Ibadan.

### 4.6.1. River Ona

River Ona rises in Talontan in Akinyele Local Government and is considered as the largest river passing through Ibadan built up area, having a length of around 81km and a drainage area of around 479 km<sup>2</sup> excluding River Ogunpa and River Ogbere basins.

River Ona flows through the low density western part of the Ibadan built up area. The river flows in a north-south direction where it is dammed at Eleyele creating a reservoir which continues to be one of the most important sources of water supply in Ibadan. Awba Dam and a further dam at the IITA are located on Ona's tributaries. Meanderings are common and the overall channel slope varies from 0.15 to 0.25 percent. A picture is taken for Ona River where it leaves the urban area of Ibadan at Ibadan-Lagos Expressway is presented in Plate 4.1. The crossing structure at this location is Bridge no. 151B.



**Plate 4.1: River Ona, Location Id no. 151B**  
(Location: 595,570m E, 805,844m N)

### 4.6.2. River Ogunpa

River Ogunpa rises from about 220 meters above mean sea level in the center of the Ibadan built up area near Agodi and Bodija, and eventually flows southwards past the secretariat to Agodi lake. This lake was created by building a dam across the Ogunpa (referred to as Dandarua Dam) to store water for

water supply but it is now used only for fishery operations. Downstream of the lake, River Ogunpa flows southwards to the south-east of a business district called Gbagi and then to Oke Fodo, Oke Ado and Isale-Ijebu until it is joined by the River Kudeti.

River Ogunpa's drainage basin has a catchment area of around 71.8km<sup>2</sup> including Kudeti basin. The length of River Ogunpa is around 19km where it then discharges into the Ona River.

A picture is taken for Ogunpa River near the core area of Ibadan from Ogunmola Street (A1), refer to Plate 4.2. The plate presents the artificial section of Ogunpa channel. The crossing structure at this location is Bridge no. 155B.



**Plate 4.2: River Ogunpa, Location Id no. 155B**  
(Location: 598,332m E, 813,745m N)

### 4.6.3. River Ogbere

River Ogbere rises in Egbeda to the north of Ibadan International Airport and flows southwards into River Ona. River Ogbere is around 24km long and has a catchment area of around 105km<sup>2</sup>.

A picture is taken for Ogbere River where it intersects with Olomi Road, refer to Plate 4.3. The plate presents the rehabilitation works for the bridge no. 65B during construction during the site visit conducted in August 2017. In addition, the plate presents the rocky nature of the bed.



**Plate 4.3: River Ogbere, Location Id no. 65B**  
(Location: 602,045m E, 807,453m N)

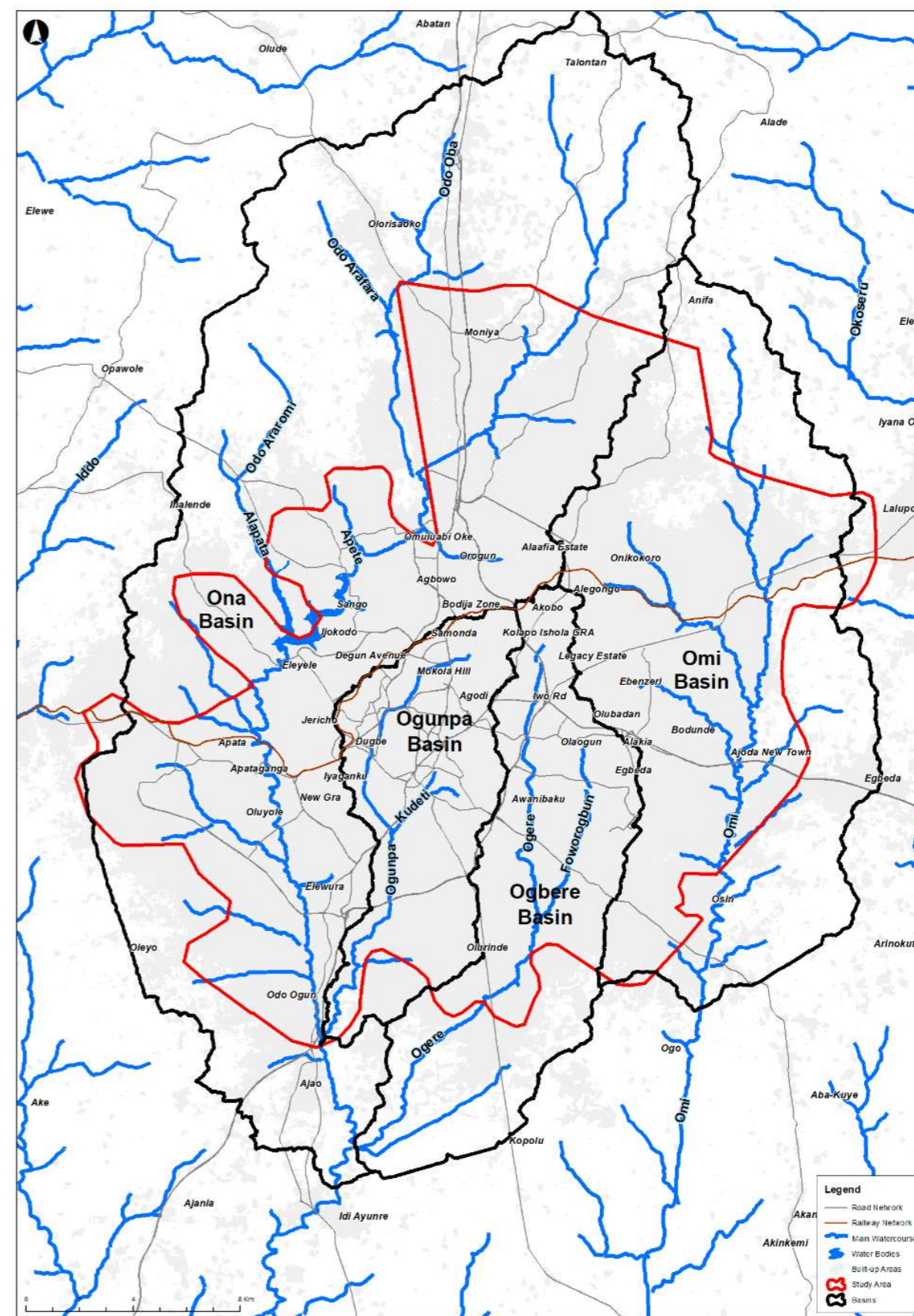
#### 4.6.4. River Omi

River Omi rises in Lagelu Local Government Area, and flows south where it then joins River Ona at the Gambari forest reserve. The catchment area of the River Omi within Ibadan is around 223 sq.km. The watershed hydrology of the river over the years, has changed considerably due to ever increasing anthropogenic activities. The resultant effect is the inundation of farmlands and flooding of residential areas in Omi-Adio Township, whenever the river overflowed after heavy rain.

A picture is taken for Omi River where it intersects with Ajia Road near Orisunmbare community market at location no. 1141, refer to Plate 4.4.



**Plate 4.4: River Omi, Location Id no. 1141**  
(Location: 611,036m E, 813,009m N)



**Figure 4.7: Main Rivers**

### 4.7. Dams and Water Bodies

There are 4 four main dams located on the main streams within the built-up area of Ibadan, and 2 small dams at the outer skirts of the Ibadan metropolis. The 4 main dams are: Eleyele dam, Awba, Dandaru and the IITA dam, while the 2 outer dams are Eno-Oosa and Akufo, refer to Figure 4.8. It has been observed that fishing ponds are located in many areas along streams.

**Table 4.2: Characteristics of the Dams in Ibadan Built-up Area**

Dam Location	River	Easting (m)	Northing (m)	Dam Type	Height	Capacity (MCM)	Dead Storage (MCM)	Length (m)	Year
Eleyele-Ibadan	Ona	594,270	820,328	Earth Fill	14.5	6.89	0.89	243	1942
IITA	Ona	599,002	827,447	Earth Fill				280	
Awba	Ona	597,840	822,703	Earth Fill	5.5	0.227		110	1964
Danduru	Ogunpa	599,110	818,574	Concrete	5	0.1		90	
Akufo	Alapata	589,800	827,490	Earth Fill	8.5	0.11	0.011	185	2007
Eni-oosa	Ona	607,181	831,039	Earth Fill	8	0.12		240	1988
Asejire				Earth Fill	26.2	32.2	3.22	853.4	1972
Pade				Earth Fill	9.5	0.74	0.074		1992
Sanusi				Earth Fill	9.5	0.624	0.0624		2006
Ijaye/Alabata				Earth Fill	11	2.02	0.202		2010
Onidundu				Earth Fill	5	0.097			2013

Easting and Northing values are according to the UTM – WGS 84 – Zone 31 N coordinate system.

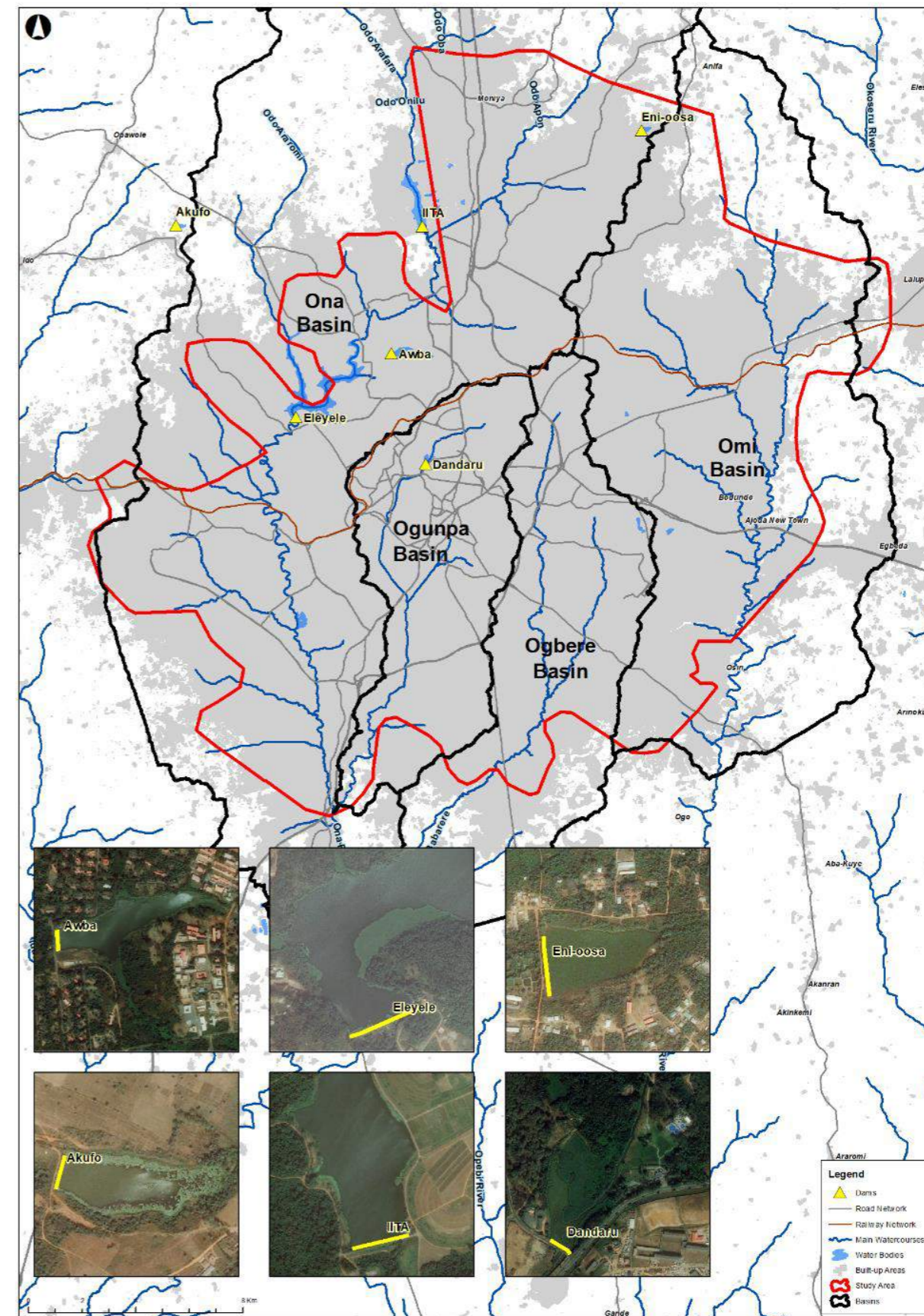
Source: Data received from PIU

#### 4.7.1. Eleyele Dam

The Eleyele Waterworks (dam, reservoir and treatment works), started operations in 1942. The dam is located on River Ona just downstream the confluence of River Ona with the River Alapata.

The reservoir is located to the north-west of Ibadan’s city centre. The catchment area of the reservoir is about 319 km<sup>2</sup>, while the surface area of the lake is around 160ha. The reservoir’s capacity is around 6.9 MCM. Figure 4.9 shows a satellite image of Eleyele Lake.

The area surrounding the reservoir comprises a variable width of light forest and a margin of wetland around the perimeter of the lake as shown in Plate 4.5. The reservoir contains areas of floating vegetation in the vicinity of the spillway (Plate 4.6) a short distance upstream of the embankment. Satellite images indicate that the floating vegetation can become extensive and mobile.



**Figure 4.8: Dams and Waterbodies**

#### 4.7.1.1. Dam Details

- The reservoir is contained by an earth fill embankment and side channel ogee spillway with the line of the spillway crest an extension of the centre line of the embankment.
- The embankment section is 138m long with a maximum crest height of 14.5m.
- The downstream slope was constructed to an angle of 2 horizontal to 1 vertical slope (Plate 4.7).
- The crest width is approximately 2.85 m with 1.1 to 1.2m high solid concrete block work wall (parapet) founded on a concrete strip which divides the crest width into a 1.8m wide strip on the downstream side and a 0.8m wide strip on the upstream side (Plate 4.8).
- The exposed area of upstream slope above reservoir water level is constructed to an angle of 1 horizontal to 1 vertical.
- Dam Crest level to ogee spillway crest level is about 1.50 m.
- The intake tower is equipped with: one metallic access bridge, three metallic floors, three level of intake pipes, one raw water pipe to supply the water treatment plant and one bottom outlet pipe.
- The dam has been under operation for more than 70 years since 1942.



**Figure 4.9: Eleyele Lake Satellite Image**  
(Location: 594,252mE, 820,317mN, WGS1984, Z31N)

#### 4.7.1.2. Spillway

- Comprises a free overflow side channel spillway with ogee shaped crest with length of about 106m.
- Maximum ogee wall height is 5.2m from crest to level of trough base slab.
- Design flood is quoted as 367.9 m<sup>3</sup>/s. (This value is the design flood capacity of the spillway as quoted from the Environmental and Social Management Plan developed by Ibadan Urban Flood Management Project (IUFMP) for the Eleyele Dam Ogee Scour Palliative Works and published in April 2016.). It is worth to note that this spillway is to be rehabilitated to convey a flow of 1269 m<sup>3</sup>/s. This is based on the hydrological design report issued by the Consultant responsible for the Design of Eleyele Dam Rehabilitation.
- The overflow is directed downstream to a concrete-lined tailrace canal which also acts as flow energy dissipater by means of a series of concrete steps.

#### 4.7.1.3. Eleyele Dam Rehabilitation Project Scope of Works

Moreover, it is noted through the brief handing over of site to the contractor (dated 6<sup>th</sup> April, 2018) that the scope of works for Eleyele Dam Rehabilitation Project includes the following:

- Rehabilitation of the spillway weir
- Rehabilitation of spillway channel to Ologuneru Bridge (Id. No. 138B)
- Rehabilitation and raising of the existing embankment from its existing height of 183.6m to 185.4m (**1.8m heightening**).
- Rehabilitation of the intakes tower, scour channel, scour tunnel and reservoir.
- Design flood with a return period of 10,000 years.



**Plate 4.5: Eleyele Reservoir and Intake Tower**



**Plate 4.6: Spillway of Eleyele Dam**



Plate 4.7: Parapet and Dam downstream embankment



Plate 4.8: Dam's Parapet upstream and Spillway in the background

#### 4.7.1.4. Information from PIU

More information from the PIU confirmed the heightening of the dam by 1.8m and revealed the following information:

- A concrete parapet wall will be built on the dam with 1m height.
- Elevation drawdown by lowering the existing water level to 180m MSL (a drop 2.3m from the existing crest level).
- New spillway with a modified profile with the same crest level 182.3m
- Spillway crest length is 101.5m
- Maximum Water Level is 185.4 (3.1m above spillway crest level)

It is worth to note that the above elevation values do not match any of the well-known coordinate systems (Minna or WGS84). It is presumed that these elevations are local survey ones.

#### 4.7.2. John Craig Dam (IITA Lake)

IITA was established in April 1967. The catchment area of IITA is 95.88 km<sup>2</sup>, while the approximate capacity of the lake behind the dam is 0.98 MCM. The lake is an impounding reservoir with a total surface area of 175 Acres (0.7082 km<sup>2</sup>) and a maximum length of 2.6Km. Figure 4.10 shows a satellite image of IITA Lake.

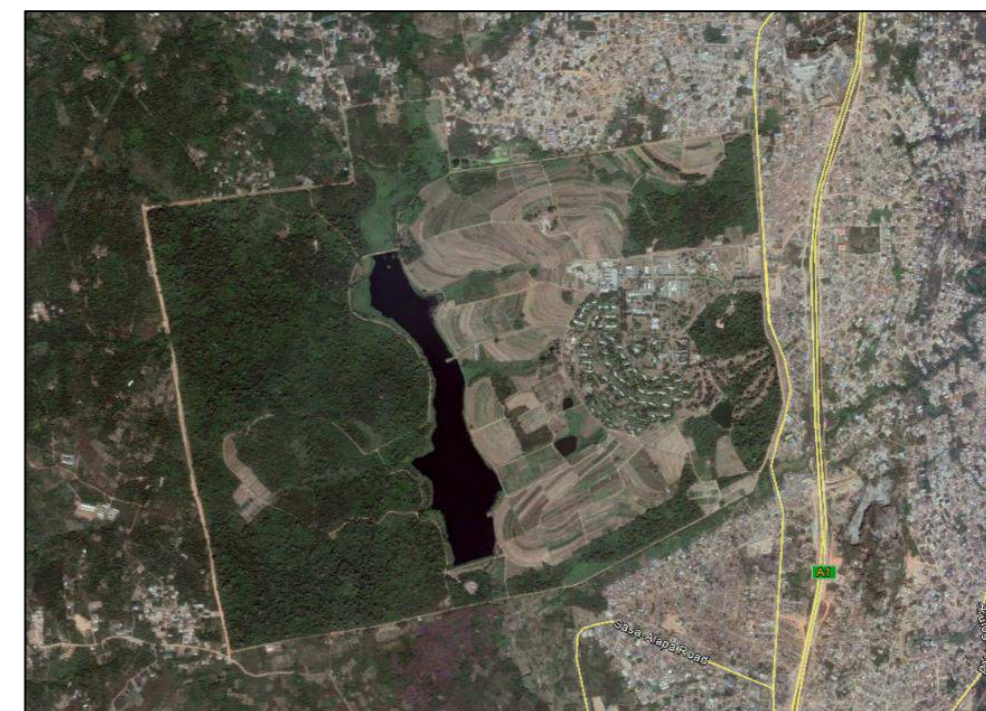


Figure 4.10: John Craig Dam - IITA Lake (598,947mE, 827407mN, WGS1984, Z31N)

For construction of the dam, approximately 1,000 ha of land were acquired in October 1965, lying between Ojo in Ibadan town and Moniya villages. The land was covered mainly with oil palms, cassava, maize, cocoyam, and a variety of indigenous trees and climbers.

The dam is an earth fill embankment constructed in 1970 with an upstream slope of 2.5H:1V and downstream slope of 2H:1V. The dam is 12.2m high provided with an Ogee Spillway of 6.1m wide and 360m long crest. Currently, the dam is in good condition and considered functional. It is indicated that the water overtopped the dam twice in 2009 and 2011. The dam is provided with a screen upstream of the spillway to retain vegetation (Plate 4.9), and channel downstream of the spillway to convey excess water to Ona River.

The spillway crest is divided into 5 bays (Plate 4.10). The crest is about 12 m long. The middle bay has a different crest elevation, while one of the bays is provided with a sluice gate. A bridge above the spillway connects the road across the dam's crest.



Plate 4.9: IITA Reservoir and Upstream Screen



Plate 4.10: IITA Spillway and Downstream Channel

#### 4.7.3. Awba Dam

The Awba Dam is located in the southwestern part of the University of Ibadan, and 1.5km North-East of Eleyele reservoir. The dam was constructed in 1964 primarily for domestic water supply, fish production and research purposes for the University of Ibadan community. The dam creates a small lake with a surface area of around 6 hectares, a maximum depth of 5.5m and a storage capacity of 0.227 MCM. Figure 4.11 shows a satellite image of Awba Lake. The water level in the Reservoir (Plate 4.11) is regulated at a spillway through which excess water flows out so the level remains almost constant throughout the rainy season. However, during the dry season, the water level reduces.

The impoundment reservoir of Awba dam dredged in 1971 to increase the water supply to the University community. Later in 2014, more dredging works were performed to increase fishing activities and for recreational purposes.

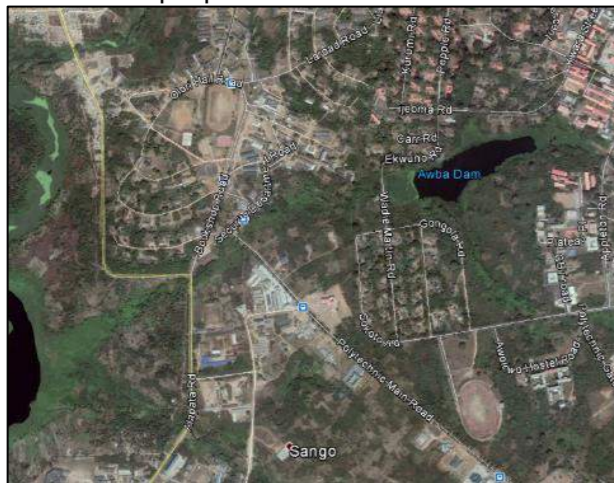


Figure 4.11: Awba Dam Satellite Image  
(Location: 597,839mE, 822,701mN)



Plate 4.11: Awba Dam Reservoir

#### 4.7.4. Dandaru Reservoir

Dandaru reservoir (Agodi lake) lies on Ogunpa River. The Ogunpa stream originates in the north-east of the city near Asi; from which it flows through New Bodija and Agodi Gardens to the Ogunpa Lake (Dandaru Reservoir) site. The catchment area of the Upper Ogunpa flowing to the Agodi Lake (Dandaru Reservoir) is 12.59 km<sup>2</sup> and the volume of the reservoir is 62,300 m<sup>3</sup>.

The dam was constructed in 1970. The purpose of this dam was to create a reservoir for fishing and detention of flood waters. The dam was further rehabilitated under a project titled "The dredging and improvement works of Ogunpa Lake". The project consisted of the construction of an outlet culvert, retaining walls and dredging of the reservoir. The construction works were scheduled to be completed in 1988. Moreover, the reservoir was completely dredged in 1999 and partially dredged in 2011.

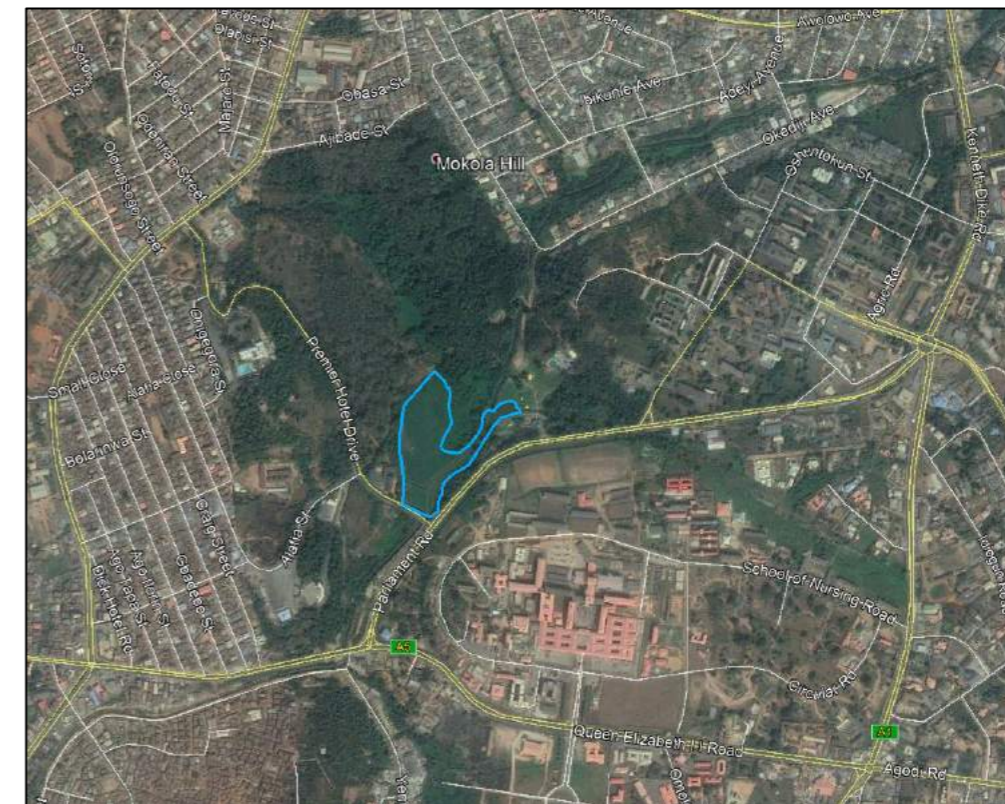


Figure 4.12: Layout of Agodi Lake

Based on the site visit to the Ogunpa Lake (Dandaru Reservoir), it was obvious that the reservoir is completely full of sediments, solid waste and vegetation, refer to Figure 4.13. Dredging of the reservoir is essential to provide sufficient capacity to attenuate the flood flow. The main reason for the frequent siltation of this dam, in addition to the sediments and solid waste, is that the bottom outlet flow is controlled through gates, and since the gates are closed, sediments accumulates in the pond. For the proper operation of the dam, the bottom outlet of the dam should be open to release the flood water following the flood event. Provision of an operable bottom outlet is necessary for the following reasons:

- Decrease siltation
- Drawdown of accumulated water in the reservoir to provide sufficient capacities to attenuate the flood flows.



Plate 4.12: Solid Wastes and Siltation of Ogunpa Lake (Dandaru Reservoir)



Plate 4.13: High Vegetation and Siltation of Ogunpa Lake (Dandaru Reservoir)

Figure 4.13: Ogunpa Lake (Dandaru Reservoir)

The dams are mainly constructed for water storage and fishing activities. The dams are facing couple of issues as:

- Some of these dams have siltation problems in their reservoirs.
- The dams are always full especially in the wet season, spillways are observed with continuous spillage.
- The bottom outlet of some of these dams are not working due to clogging.
- The dams do not provide any flood management capacity except Dandaru dam (no attenuation in the dam reservoirs)

The dams should be rehabilitated to provide the following:

- Solutions to de-silt impoundment reservoirs of these dams.
- Maintenance of bottom outlets or provision of larger bottom outlets.

Drawdown of the reservoir level beneath the spillway crest level by an adequate depth to provide sufficient capacities. Such capacities should contain flood volumes and play a role in the attenuation of peak flows.

#### 4.8. Crossing Structures

Due to the extensive network of rivers and streams throughout the city and the high dense network of main roads and local roads, there are hundreds of crossing structures that exist in Ibadan. These crossing structures are either bridges, culverts or footstep bridges, while some are just primitive wooden bridges. Some of these structures have good conditions while others are badly damaged.

Several site visits to the crossing structures of Ibadan were conducted in the period from February 2016 to December 2018 starting from the preparation of the Drainage Master Plan Proposal and till the preparation of this report, refer to Annex 5. A detailed field survey was carried out for over 1600 crossings of roads with watercourses, refer to Figure 4.14, where 321 location with no structures constructed.

The aim of the survey was to validate the geographic positions of the structures using handheld GPS devices, collect detailed information showing the characteristics, dimensions, conditions and to analyze the existing and potential flood hazard to affected locations. The assessment of these crossing structures is presented in Annex 8 and Annex 11.

The inventory includes all necessary information to crossing structures such as locations in Easting and Northing with respect to a WGS1984 UTM Zone 31N coordinate system, the types of structure such as culverts, bridges or footsteps, the cross-section dimensions of these structures such as bridge spans, height under the bridge, number of culverts cells, width, height, diameter of circular culverts and depth of culvert's invert level below the road level.

Each structure is coded with a unique number to identify its location with numbers ranging from 1 to 1585. Damaged structures reported by the PIU were coded with a suffix "D" for Damaged structures and added to the serial number in the PIU list of damaged structures. For example, number 47 of the PIU 1<sup>st</sup> List is coded as 47D. The assessment of damaged structures is presented in Annex 7.

A GPS camera was used to capture inlet and outlet pictures of each crossing structure, while a free software application "Geosetter" was used to place these pictures in their respective coordinates. The coordinate system used is a WGS 1984 UTM 31N coordinate system. The information of all surveyed structures are included in the GIS Geodatabase. . (Handheld GPS was used to determine the position of the each structure onsite, while LiDAR survey was used to determine the accurate x and y information of each structure (Culvert/Bridge).

The survey captured different kinds of damages including scouring, erosion, potential instability, partial and complete damaged structures. Some structures were found relocated from their position or completely destroyed with no sign of the structure itself. Other locations included cut-off roads, water accumulation, overtopped culverts, bypassed culverts, eroded roads, buildings blocking the drainage main route and gullies.

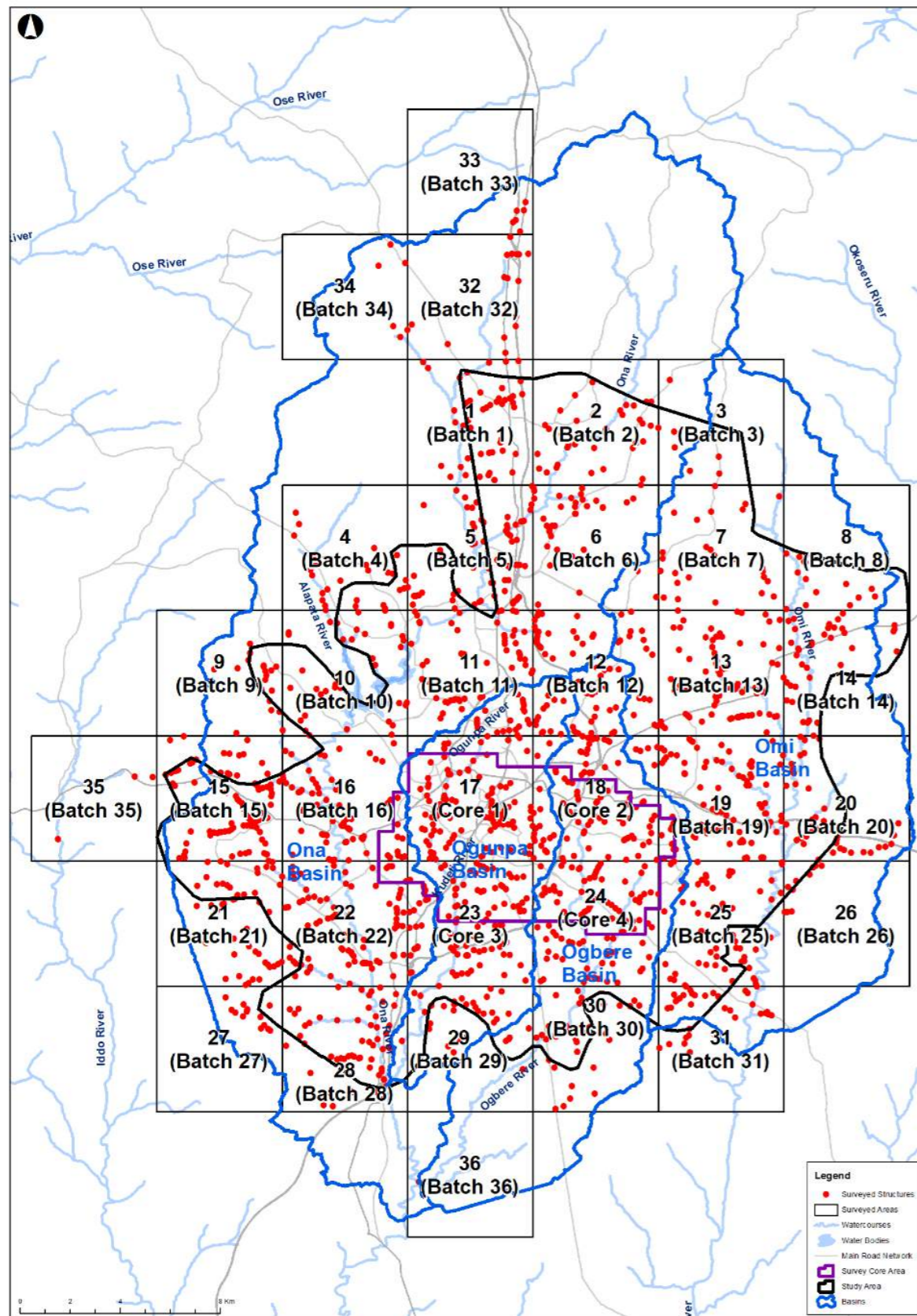


Figure 4.14: Surveyed Crossing Structures

#### 4.9. Land Use and Land Management

The Consultants reviewed the existing landuse (2016) and the proposed future landuse (2036) from the “Ibadan City Master plan”. These plans are used as the basis for hydrological analysis in the existing and future scenarios.

Figure 2.3 and Figure 4.15 show the existing and projected land use for Ibadan City respectively. (Landuse classification was sourced from the Ibadan City Masterplan).

The land use classification is as follows:

- **Residential** includes bungalows, duplexes, flats, terrace housing/apartments, condominiums/service flats, tenement houses and cottages.
- **Commercial** includes markets, shopping centers/malls, office complexes, showrooms/garages/warehouses, banks, petrol/gas filling stations, hotels, motels/guest houses, bars/restaurants and event center/multipurpose hall.
- **Recreational** includes amusement parks, children’s park, sports complexes, gymnasia, fitness centers, club houses, concert halls, resorts, cinemas, theatres, discotheques and mobile/temporary homes (caravan).
- **Conservation** includes zoos/wildlife/nature areas/urban forests, cemeteries, museums, arboretum, heritage sites, games reserves, old/listed buildings and wet land.
- **Health institutions** includes teaching hospitals, general hospitals, specialist hospitals, clinics, laboratories, maternity centers and primary health centers.
- **Agriculture** includes farm houses, ranches, orchards, bee farms, rabbitry, hatcheries, poultry, fish ponds, piggery, horticultural gardens, plantations, and cultivated lands (arable farms).
- **Institutional buildings and services** includes Secretariat complex, libraries, river ports, motor parks, lorry depot, truck depot, water pumping stations, sewage treatment plants, electricity substations, fire stations, telephone exchanges, postal agencies/offices, radio stations, satellite earth stations, TV stations, prisons, remand homes, juvenile center, archives, police station and barracks.
- **Religious** includes churches, mosques, other worship centers, and crusade ground.
- **Educational** includes daycare/playgroup, nursery/primary schools, secondary schools/colleges, tertiary institutions, special schools, research institutes, training centers, vocational centers.
- **Industry** includes light industries, medium industries and heavy industries.
- **Light Industries** includes wood work, shoe factory, garment industry, motor repair workshop, dry cleaning, watch repairs/cobblers/electronic, workshops, bakeries, agro-based and allied industries.
- **Medium Industries** includes printing press/publishing houses, soap manufacturing and mills.
- **Heavy industries** includes petro-chemical, steel industries, surface mineral works, electric power station, gas works, water works and metal fabrication.

- **Circulation** includes roads, streets, parking spaces, alleys, footpaths, walkways, railway stations, airports, tri/motorcycle parks, bus terminals and motor parks.

The land use and land cover data is used as one of the inputs for the development of the Curve Number Map. The usage of this data is further presented in the Hydrological Analysis (Annex 1).

It is worth to note that the land use and land cover data are necessary to define open space areas that can be further developed as attenuation ponds or demarcated as flood hazard areas.

Moreover, the land use and land cover data are used as one of the inputs for the development of the Curve Number Map. The usage of land use and land cover is further presented in the Hydrological Analysis (Annex 1).

#### 4.10. Geology and Soils of Ibadan

The soils of Ibadan region are related to the underlying geology and other environmental factors. These soils were formed from the underlying rocks especially granite gneiss, quartz-schist, biotite gneiss and schist. They were formed under moist semi-deciduous forest cover and belong to the major soil group called ferruginous soils. With reference to the Dominant Soils of Nigeria map, the Ibadan area comprises three main soil groups; Lixisols (LX), Leptosols (LP), and Fluvisols (FL), refer to Figure 4.16.

More information on these types of soils is presented in the Geological Considerations and Geotechnical Annex, refer to Annex 2

The soil information mentioned above is used as one of the inputs for hydrological analysis and specifically the development of the Curve Number Map. The usage of soil information is further presented in the Hydrological Analysis (Annex 1).

#### 4.11. Subsurface Investigations

Geotechnical investigations were carried out to the structures in the 3 pools of priority investments (Lot1, Lot2 and Lot3) to assess the physical, mechanical and chemical properties of the subsurface materials at the location of the proposed structures. After the completion of the geotechnical site investigation work, the findings were collected in a detailed report (Geotechnical Investigations). The report aimed in documenting the findings and necessary recommendations. Annex 2 presents the findings of the geotechnical investigations of these structures including the following data:

- All geotechnical and geological data.
- Soil stratifications and subsurface conditions.
- Groundwater condition based on the carried out boreholes.

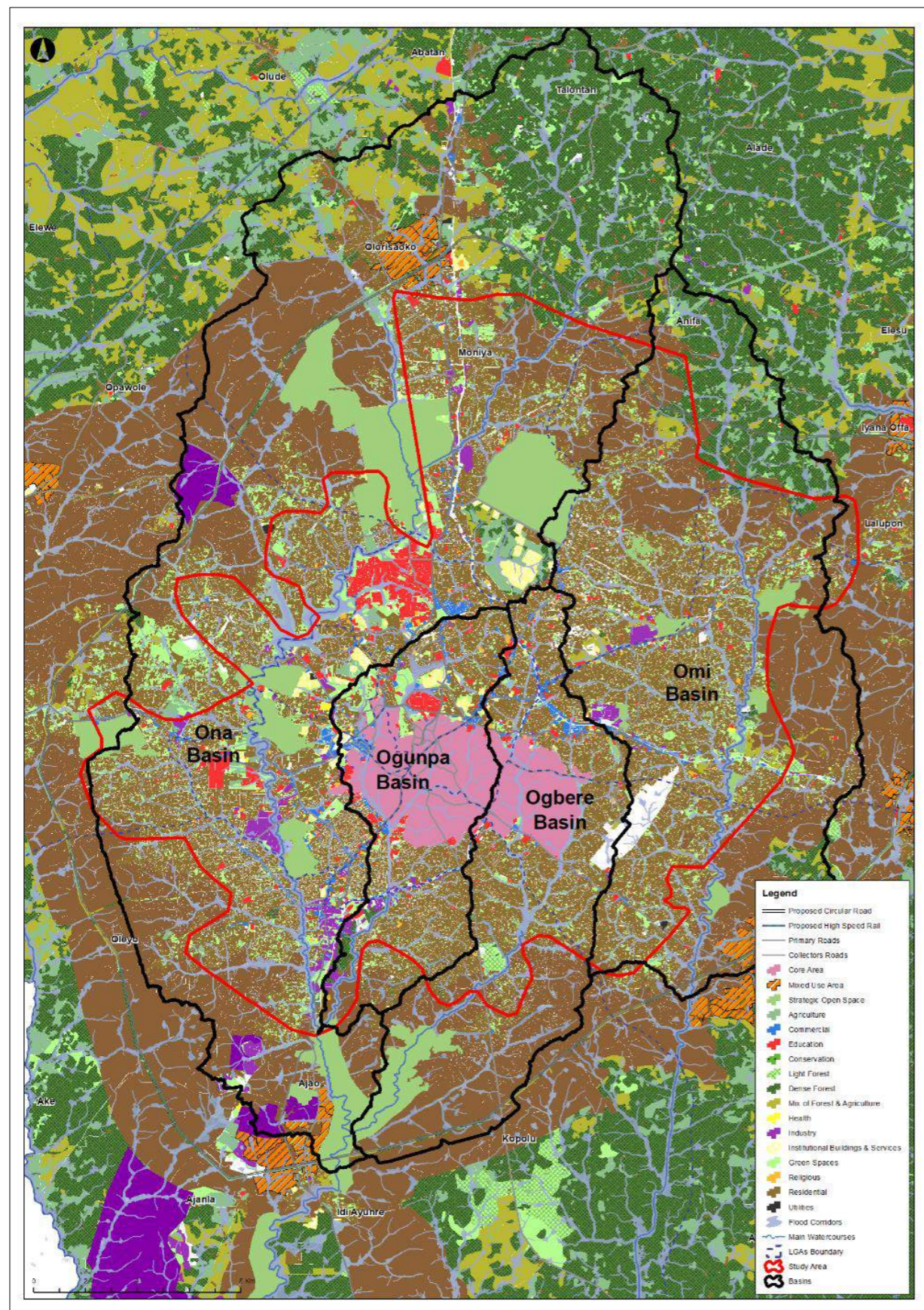
#### 4.12. Groundwater Conditions

The groundwater depth was measured inside drilled boreholes during the site investigation campaign.

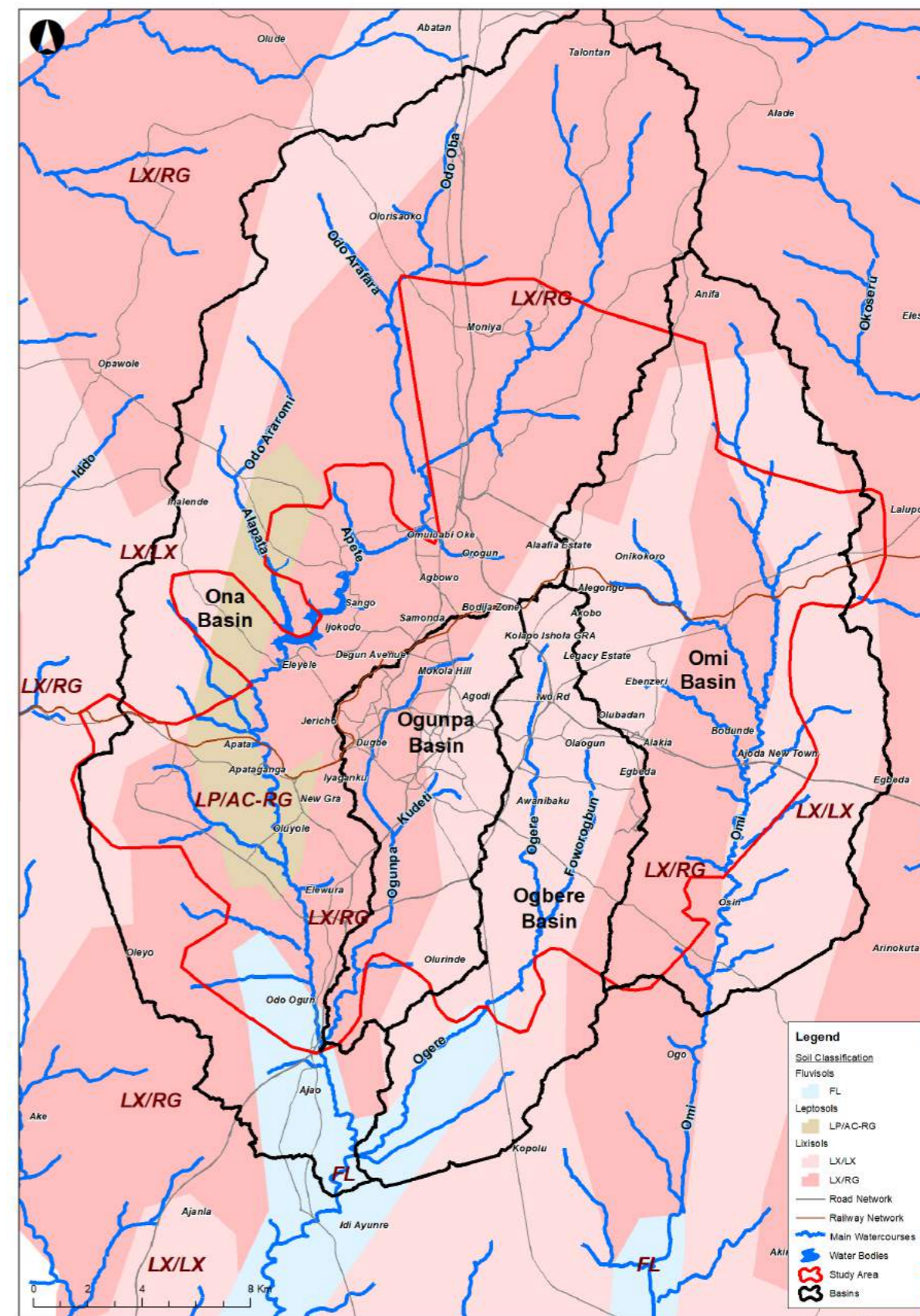
- a) Orogun River  
Groundwater table varies between 1.13 m and 2.65 m below the natural ground level.
- b) Upper Ogunpa (Agodi River)

- c) Kudeti River  
Groundwater table varies between 1.40 m and 2.85 m below the natural ground level.
- d) Ogbere River  
Groundwater table varies between 1.95 and 2.00 m below the natural ground level.
- e) Ona River  
Groundwater table varies between 1.02 m and 6.79 m below the natural ground level.
- f) Separate Structures  
Groundwater table varies between 1.5 m and 4.3 m below the natural ground level.

More information on groundwater depths for the specific sites of the priority works is presented in the Geological Considerations and Geotechnical Annex, refer to annex 2.



**Figure 4.15: Projected Landuse Distribution (2036)**  
 Source: Final Masterplan Report, Ibadan City Masterplan, December 2017



**Figure 4.16: Ibadan Soil Classification**

### 5. Flood Risk Framework

This section provides an overview of the flood risk assessment process which starts from defining the required base data of the study area till developing the flood risk maps. In general, assessing the risk for any study area due to floods requires performing hydrologic analysis then preparing a hydrodynamic model to develop the water spread and to define the water depths and velocities. Following that all expected scenarios shall be developed to define the possible extent and duration of flooding. Based on the flood water spread/inundation and the defined exposure the assets valuation process should be performed. Finally, and based of the outcomes of the above processes (hydrodynamic model results and assets valuation results) the risk can be assessed and defined.

The procedure for the flood risk framework is presented in Figure 5.1 where the methodology is divided into three different categories. Each one of these categories is shown with different colors. The categories are as follows:

- 1- Simulation Modeling: The first stage is the development of the city wise simulation model to define the expected water depths and velocities and the spread and inundation maps for the existing drainage and natural streams within the city.
- 2- Development of Scenarios: The second stage is using of the developed simulation model to assess the different scenarios including the no action scenario.
- 3- Risk Maps development: The third stage is the development of the risk maps for the different basins within the city limits.

These three stages were developed throughout project development, where each stage were developed, calibrated and documented in different reports and was approved throughout the project development. Stage 3 was not presented previously and shall be developed here after.

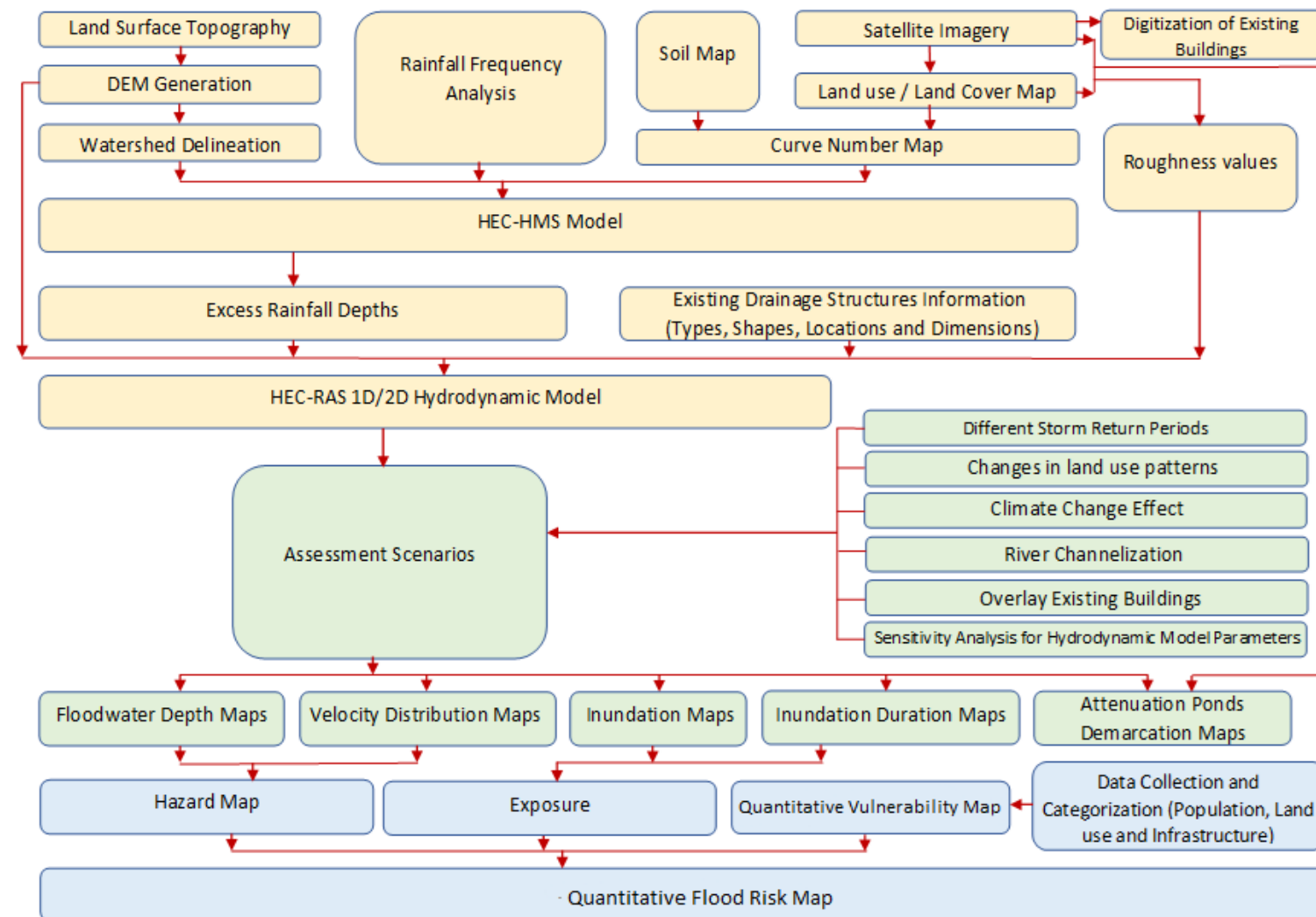


Figure 5.1: Methodological framework for qualitative flood risk assessment

## 5.1. Simulation Model

The development of the simulation model passes through several steps and uses different tools. These steps start from data collection to defining the analysis methodology and developing the simulation model using a preselected modeling tool followed by calibrating developed model and finally presenting the model results.

All the steps for the development of the simulation model were documented in several reports developed during the project stages. Some of these reports, among others, are as follows:

- Flood hazard assessment framework (N17036-0100D-RPT-ENV-06-Rev0)
- Technical Report of Data, Methodology and Damage Function (N17036-0100D-RPT-ENV-10-Rev0)

The data collected to develop the simulation model were listed as follows:

- Climatological data, including rainfall data
- Land Surface topography data, including digital elevation model generation
- Satellite imagery and aerial photos data
- Land use and land cover data
- Soil maps
- Historical data of previous floods
- Existing drainage structure information

The analysis methodology was based on the following:

- Defining hydrological analysis basis as presented in Annex 1
- Use of the developed hydrological analysis to define the excess rainfall hyetograph (Depth versus Time) to be used as presented in the Flood Hazard Assessment Report.
- Using of a 1D/2D simulation model using the dynamic wave equation as presented in the Flood Hazard Assessment Report. The software used in this analysis was the Hec Ras software.
- While developing the 1D/2D model the existing conditions within the stream is analyzed this include the channel cross-section, the crossing sizes and all other features that could be affecting the stream cross-sections.
- The main output of this analysis is the water depth and water velocity in all the river streams.
- The other main output of these analysis is defining the adequacy of all the existing crossing structures. It is to be noted that the existing structures were part of the developed model.

## 5.2. Development of Scenarios

Through this stage the developed simulation model was used to study the different scenarios which addresses the following:

- Storm Events with different Return Periods
- Changes in land use patterns

- Sensitivity Analysis
  - o Hydrological input such as:
    - Climate Change
  - o Model parameters and Computational Methods such as:
    - Different surface roughness coefficient
    - Different computation equations
  - o Assumptions made such as:
    - Modelling Existing Buildings
    - Stream Morphology

The methodology adopted in the Flood Risk Assessment Report (N17036-0100D-RPT-ENV-06-Rev0) was used to study the different scenarios.

The main outcomes of this stage were the following:

- Inundation maps where it defines the exposed areas, buildings, roads utilities.
- Flood water depth maps
- Velocity distribution maps
- Inundation duration maps
- Attenuation ponds maps and demarcation requirements.

These outputs are the basis for the development of the next stage which is the risk analysis and risk maps generation.

## 5.3. Risk Assessment

The risk assessment is developed using all the detailed analysis performed in the first two stages in addition to another round of data collection and assets studies. Through this stage the risk is calculated which depends on the following three main parameters:

- Hazard calculations and analysis
- Exposure definition
- Vulnerability to assets and people.

Each of these parameters require special analysis which is presented in the Technical Report of Data, Methodology and Damage Function (N17036-0100D-RPT-ENV-10-Rev0).

In summary the parameters were calculated as follows:

- Hazard maps is calculated from the generated depth maps and hazard maps.
- Exposure is defined using the inundation maps and the inundation duration maps.
- Vulnerability is calculated based on the asset's valuation analysis performed and the hazard analysis developed. It is worth noting that the assets valuation requires extensive surveys and data collection and analysis, where the buildings, and infrastructure surveys should be performed.

The Technical Report defining the Damage Function (N17036-0100D-RPT-ENV-10-Rev0) explains clearly this risk assessment procedure.

#### 5.4. Development of Risk Maps

The main outcome of the flood risk analysis is the development of the Flood Risk Maps. These maps are the starting point for the developing of the flood risk management and the drainage master plan and the defining of the priorities and institutional requirements. The risk maps developed are two different risk maps as follows:

- Risk maps for buildings and assets
- Risk maps for people.

These risk maps developed for the full city of Ibadan is shown in Volume three where we have two sets of maps for all the city one set for the assets/building risk and one for the people risk. It is important to note that ignorance of the flood risk among the people and authorities is one of the major reasons of flood damages and as such these maps are very helpful in preventing percentage of these damages.

Flood risk maps are the starting point for the development of the different interventions and measures. In this respect the flood risk maps are:

- The defining tool for the initiation of any protection measures.
- It defines the priorities for the interventions
- One of the most effective preventive tools as it can be used to warn and move the people in risk areas during any flood event or expected flood event.
- It is used as the base of comparing the previous flood events conditions with these developed risk maps. It can even be used as a base to compare to any new flood event.

The following subsections present the methodology that can be followed to develop these maps also present the main elements within each map.

##### 5.4.1. Risk to People Maps

Flood risk to people combines three concepts which are 'Flood Hazard', 'Area Vulnerability' and 'People Vulnerability'. These are combined for each zone of the floodplain in order to estimate the annual average individual or societal risk of serious harm or fatalities due to flooding. Some key concepts and definitions are listed below.

- **Flood Hazard:** describes the flood conditions in which people are likely to be swept over or drown in a flood, and is a combination of flood depth, velocity and the presence of debris. The results are classified in hazard classes.
- **Area Vulnerability:** describes the characteristics of an area of the floodplain that affect the chance of being exposed to the flood hazard. People are more vulnerable in areas of low rise, single-storey buildings, campsites and open floodplain areas than in areas of two-storey or high-rise buildings that can provide "safe refuge" above the maximum flood level.

- **People Vulnerability:** describes the characteristics of the people affected by flooding and their ability to respond to ensure their own safety and that of their dependents during a flood.

The following methodology may be applied to develop risk to people maps through ArcGIS software:

1. Preparation of Inundation Maps (shapefiles) presenting the floodwater extent for defined return periods (5, 25, 50 and 100-years) for each basin.
2. Preparation of Water Depth Maps (raster files) which present the water depth within the flood plains for the defined return periods.
3. Preparation of Velocity Maps (raster files) which presents the velocity distribution of the floodwater within the floodplain.
4. Preparation of Flood Hazard Maps (shapefiles) presenting 5 hazard classes (very low hazard, low hazard, moderate hazard, significant hazard and extreme hazard), and as illustrated in the Flood Hazard Assessment Report. The shapefile should include the 5 classes of flood hazards in its attribute table.
5. Preparation of a shapefile showing the boundaries of the Local Government Areas (LGAs) in Ibadan, this shapefile should include the following attribute data:
  - a. The areas of each LGA in hectares
  - b. The existing population records extracted from the 2006 Census
  - c. The projected population in year 2035 developed by the study done by Dar in the City Master Plan
  - d. Categorized Urban Areas developed by the City Master Plan for each LGA (High Dense, Medium Dense, Low Density, etc.)
  - e. The existing and projected population intensities (Capita/hectare) for each categorized urban area and each LGA.
6. Calculation of the Number of People within each hazard class. This is calculated by multiplying the projected population intensity by the area of each hazard class (from Step 1). The calculated numbers can be stored in a new shapefile as two attributes; one for the hazard class and the other one for the number of people within each hazard class.
7. Calculating Area Vulnerability Scores per each hazard class while justifying the score of each factor which contributes in the calculations of area vulnerability (Flood warning, speed of onset and Nature of area). Table 5.1 shows an example of area vulnerability scores.

**Table 5.1: Area vulnerability scores**

Hazard class	Flood warning	Speed of onset	Nature of area	Sum = Area vulnerability
<b>Extreme hazard</b>	3	2	3	8
<b>Significant hazard</b>	3	2	3	8
<b>Moderate hazard</b>	3	2	3	8
<b>Low hazard</b>	2	2	3	7
<b>Very low hazard</b>	2	2	3	7

8. Calculating (X) Percentage of people at risk per each hazard class per LGA and this is could be simply calculated by multiplying the area vulnerability score obtained (from step 7) by the average hazard rating of each hazard class, refer to Table 5.2.

**Table 5.2: Example of calculating X (Percentage of people at risk)**

Hazard class	N(Z)	Hazard Rating (HR)	Area Vulnerability (AV)	X = HR x AV	N(ZE)
<b>Extreme hazard</b>	500	4.5	8	36%	180
<b>Significant hazard</b>	700	2.8	8	22.4%	157
<b>Moderate hazard</b>	800	1.95	8	15.4%	123
<b>Low hazard</b>	1000	1.5	7	10.5%	105
<b>Very low hazard</b>	1500	0.13	7	0.91%	14

Note: N(Z) is the population in each hazard class in each LGA

N(ZE) is the number of people exposed to the risk in each hazard class in each LGA

9. Calculating (Y) **People Vulnerability** based on the summation of percentage of very old residents, Percentage of inform/disabled/long term sick; Percentage of children, and percentage of roofless and homeless. All these percentages are calculated as per each LGA.

$$Y (\%) = \%elder\ residents + \%residents\ suffering\ from\ long\ term\ illness + \%children + \%roofless\ and\ homeless. \quad (Eq\ 2)$$

10. According to Department of Environment Food and Rural Affairs, **Number of Injuries** could be calculated using the following equations:

$$No.\ of\ injuries = 2 \times Y \times N(ZE) \quad (Eq\ 3)$$

Where;

Y is the people vulnerability

N(ZE) is the number of people exposed to the risk in each hazard class in each LGA

11. The obtained numbers can be classified into categories and Figure 5.3 and Figure 5.4 below presents sample of the produced risk map to people due to flood within Ibadan City.

A full set of flood risk maps on people for the four basins of Ibadan City is presented in Volume 3b. The prepared flood risk maps are prepared for the existing situation and after interventions and applying the protective measures to address the importance of applying them.

### 5.4.2. Risk to Buildings Maps

Risk of flooding waters on buildings can be presented by developing risk matrix, sometimes known as operational risk management (ORM), which is regarded to be a qualitative technique based on the risk = hazard x vulnerability definition. The hazard dimension of a risk forms one dimension of the matrix and is broken into qualitative segments or categories and the same for the vulnerability. Categories like low, medium, high and very high are used, and they are usually defined in a subjective manner.

As previously discussed in the flood risk assessment report hazard is classified into classes which are very low, low, moderate, extreme and significant. This classification depends on the three main parameters of any flood event which are the depth and velocity of floodwaters in addition to the presence of debris in the water.

The categorization of vulnerability is developed based on a qualitative approach. This categorization is represented in vulnerability index where each item in the different attributes was evaluated according to a scale ranges from (1 – 8) where the value 1 indicates low vulnerability and the 8 indicates high vulnerability. In other words, buildings with poor physical conditions are more vulnerable than buildings with good physical conditions and buildings with low income inhabitants are more vulnerable than buildings with high income inhabitants. Table 5.3 below presents the vulnerability index for the different attributes.

**Table 5.3: Vulnerability index for different attributes**

Land use	
Type	Vulnerability
Public facility (1)	8
Religious	7
Residential	6
Commercial	5
Industrial	4
Educational	3
Public facility (2)	2
Others	1
Property condition	
Type	Vulnerability
Low	8
Medium	5
High	2
Number of floors	
Type	Vulnerability
One floor	8
Two floors	5
Three floors	3

To develop a weighted vulnerability map which comprises the above attributes with their different scale of vulnerability, different subjective weights to be assigned to the attributes based on their importance to reflect their contribution in describing how vulnerable the property is Table 5.4 shows the assigned weights for the attributes discussed above.

**Table 5.4: Weighting factors assigned to the attributes based on their importance**

Attribute	Weighting factors
Building type	0.50
Building condition	0.30
Number of floors	0.20

In this respect, the total value of vulnerability per each building was developed using GIS interface by processing the above attributes and using the following equation:

$$\text{Total vulnerability} = (0.50 \times \text{Vulnerability of Building type}) + (0.30 \times \text{Vulnerability of Building condition}) + (0.20 \times \text{Vulnerability of number of floors}).$$

Subjective categorization for the total vulnerability values has been done based on multi criteria analysis to study all the possible combinations between the four attributes. And the final categorization has five classes which are very low, low, medium, high and very high.

The Consultant adopted flood risk matrix to present the levels of flood risk the exposed buildings. This risk matrix is a product of the multiplication of hazard and vulnerability classes. Figure 5.2 below presents the adopted risk matrix to represent the risk to buildings. Figure 5.5 and Figure 5.6 below present sample of the risk on buildings maps for the existing situation and after interventions. The Consultant developed a full set of risk maps on buildings and presented in Volume 3c.

<b>Hazard</b>	Significant	Very high	High	High	Medium	Medium
	Extreme	High	High	High	Medium	Medium
	Moderate	High	Medium	Medium	Medium	Low
	Low	Medium	Medium	Medium	Low	Low
	Very low	Low	Low	Low	Low	Low
		Very high	High	Medium	Low	Very low
		<b>Vulnerability</b>				

**Figure 5.2: The Adopted flood risk matrix**

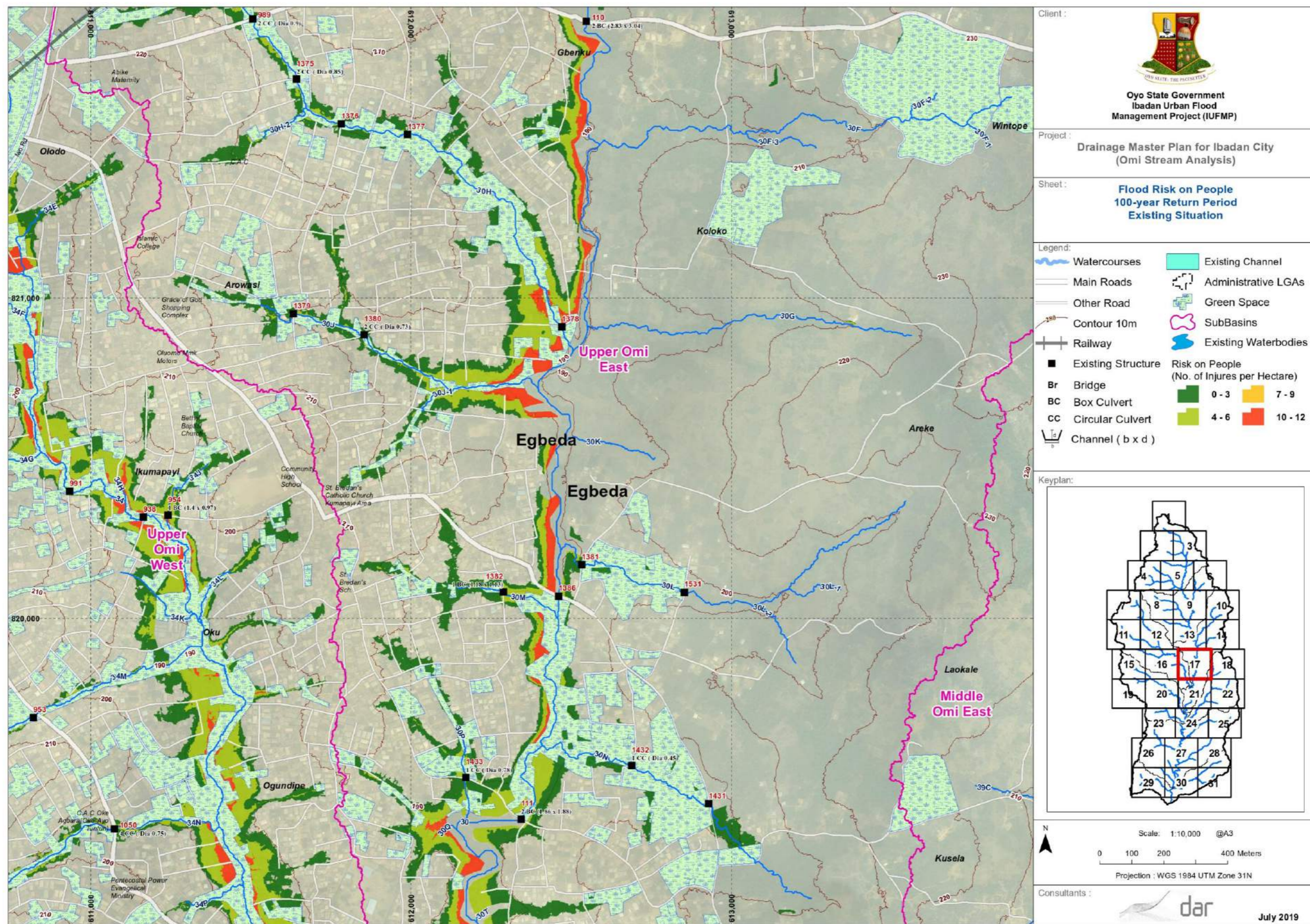


Figure 5.3: Flood Risk on People Map for the Existing Situation

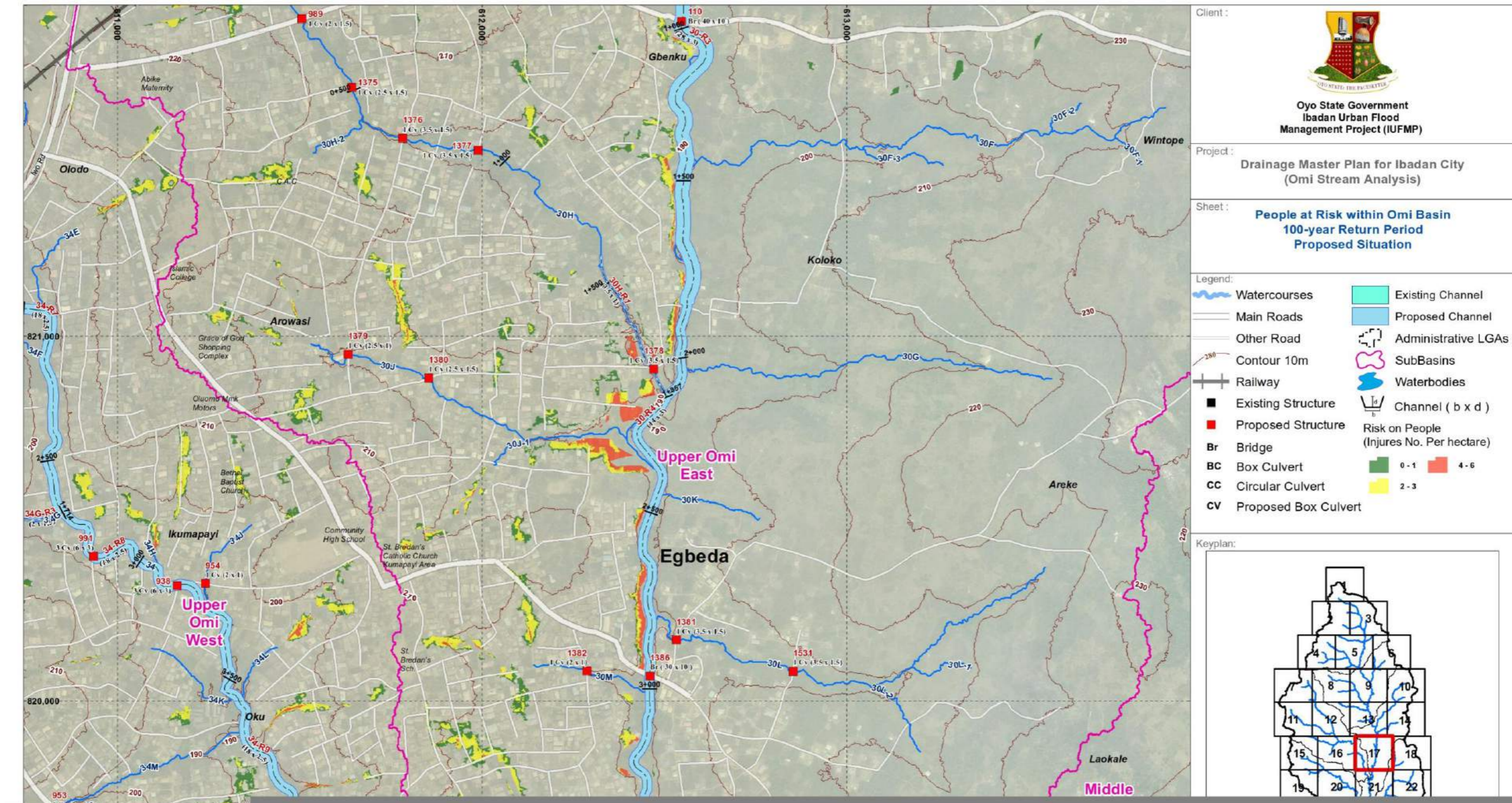


Figure 5.4: Flood Risk on People Map After Interventions

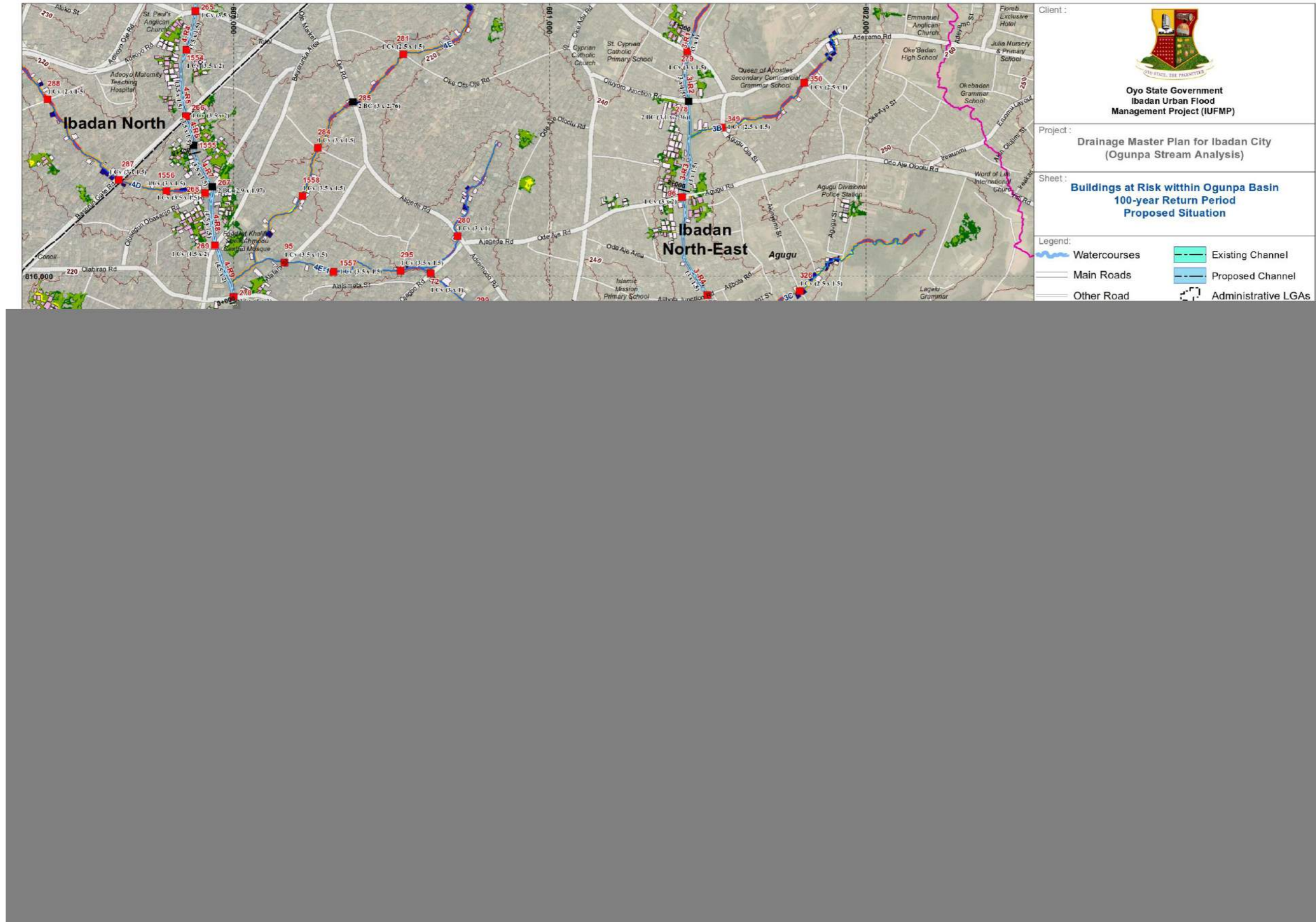


Figure 5.6: Flood Risk on Buildings Map After Interventions

## 6. Protective Measures

This section covers the protective measures to be applied in the city of Ibadan considering the special characteristics of the city. These measures include different types of works and interventions aimed at either controlling flood or reducing flood peak. These measures may include flood defenses constructed locally along watercourses and their corridors to contain the surplus of water, whilst the latter include catchment-wide interventions to reduce or delay runoff from rainstorms.

The study took one step further to use these measures to develop a comprehensive drainage master plan for the city of Ibadan. In this respect, protective measures are presented in two sections as follows:

- Section 6 Protective Measures; which defines the types of works to control flood
- Section 7 The Drainage Masterplan; which sets the plan to implement a comprehensive drainage master plan.

The following subsections present the measures in detail.

### 6.1. Channels

Channelization is a method of river engineering that widens or deepens rivers to increase the capacity for flow volume at specific sections of the river. As a result, during flood times watercourses can move more efficiently and facilitate more water, which results in less damage to banks. Furthermore, channelization can provide erosion control and the rehabilitation of watercourses. River channelization occurs by dredging the river to facilitate more water. During a flood, this would mitigate damage to riverbanks and facilitate increased speed of the river flows.

Re-channeling a river requires actions such as river widening, deepening, dredging or re-aligning the natural flow and ecology of a river. Removing or changing sediment deposition at the bottom of a river changes the velocity and flow of the water body. While this measure can alleviate flooding in one section of the river, it also enhances the speed of the river which can cause downstream flooding that can further impact the surrounding watershed. In this respect, all works which will be applied on the channels within Ibadan City have to be done based on well-studied criteria and approaches. Annex 14 comprises the adopted criteria by the Consultant for the design of channels while Annex 3 presents the prepared multi-criteria analysis of channel lining to explain the optimum selection for lining through the existing and proposed channels within Ibadan City.

### 6.2. Crossing Structures

Due to the extensive network of rivers and streams throughout the city and the high dense network of main roads and local roads, there are hundreds of crossing structures that exist in Ibadan. These crossing structures are either bridges, culverts or footstep bridges, while some are just primitive wooden bridges or boardwalks. Some of these structures have good conditions while others are badly damaged.

Several site visits to the crossing structures of Ibadan were conducted in the period from February 2016 to December 2018 starting from the preparation of the Drainage Master Plan Proposal and till the

preparation of Masterplan report. A detailed field survey was carried out for over 1600 crossing structures located at the crossings of roads with watercourses. The assessment of these crossing structures is available in Annex 8 and Annex 11.

The aim of the survey was to validate the geographic positions of the structures using handheld GPS devices, collect detailed information showing the characteristics, dimensions, conditions and to analyze the existing and potential flood hazard to affected locations.

The inventory includes all necessary information to crossing structures such as locations in Easting and Northing with respect to a WGS1984 UTM Zone 31N coordinate system, the types of structure such as culverts, bridges or footsteps, the cross-section dimensions of these structures such as bridge spans, height under the bridge, number of culverts cells, width, height, diameter of circular culverts and depth of culvert's invert level below the road level.

Each structure is coded with a unique number to identify its location with numbers ranging from 1 to 1585. Damaged structures reported by the PIU were coded with a suffix "D" for Damaged structures and added to the serial number in the PIU list of damaged structures. For example, number 47 of the PIU 1<sup>st</sup> List is coded as 47D.

The survey captured different kinds of damages including scouring, erosion, potential instability, partial and complete damaged structures. Some structures were found relocated from their position or completely destroyed with no sign of the structure itself. Other locations included cut-off roads, water accumulation, overtopped culverts, bypassed culverts, eroded roads, buildings blocking the drainage main route and gullies. Assessment of drainage problems are presented in Annex 15.

Rehabilitating the damaged structures and expanding the undersized ones is a vital measure to be considered while controlling the flood to reduce the hazard and risk on people and buildings within the floodplain. Annex 14 comprise the adopted criteria by the Consultant for the design of culverts and bridges.

### 6.3. Attenuation Reservoirs (Dikes and Dams)

Attenuation reservoirs are proposed to reduce and control storm run-off water as close as possible to its origin, and before it enters a watercourse. These reservoirs are designed to detain the water for a certain amount of time and keep the runoff to a desired rate. When the rain ends, the water detention reservoirs will empty shortly afterwards. The role of these reservoirs is to attenuate the flow and decrease the proposed sizes of drainage elements. These reservoirs are selected in undeveloped land locations where expropriation for land is at the low side. These reservoirs are considered as one of the applications of Best Management Practices (BMP), such systems are often termed Sustainable Drainage Systems

Based on historical flood events in Ibadan, the urban areas in Ibadan are prone to significant flood hazards due to extreme floods and absence of a good drainage systems. Potential interventions by introducing attenuation reservoirs to reduce the flow running through the main systems.

Attenuation Reservoirs are created by introducing dikes or dams. A dike or a dam is an embankment that acts as a barrier to control or restrict the flow of water in a River. The dikes shall detain the water for a certain amount of time and only allow a limited volume of water to flow downstream. For further information, refer to Annex 6.

The following identification criteria is set for selection of dike or dam locations:

### 6.3.1. Attenuation Structure/Dikes

- Attenuation structures/dikes are selected in narrow stream sections to allow a short structure length and reduce its corresponding cost
- The expected impounding reservoir should have no effect on existing urban areas and road networks
- Attenuation structure having short heights (4 to 8m) are placed in Tributaries having a contributing catchment area of less than 25km<sup>2</sup> at the attenuation structure location.
- Catchment areas obstructed by the attenuation structure should have a considerable area that is large enough to have a significant contribution to flood flows; this area should be greater than 2km<sup>2</sup>.
- Higher capacities are favored over lower capacities for the same attenuation structure location.
- Attenuation structures with small filling volume and high attenuation are favored over other ones in order to reach an economic dike; this is examined by dividing the dike's volume by the magnitude of the flow reduction (attenuation).

### 6.3.2. Dams

In addition to the identification parameters of dikes, the following parameters will be applied for dams;

- Dams have heights greater than 10m are placed along Rivers having a contributing catchment area of more than 25km<sup>2</sup>
- Dams are used for multi-purposes such as storage for water supply and attenuation.
- Attenuation structures/dikes or dams are preferred to have a flat storage area to allow for a wide impounding reservoir area and a large storage volume in its upstream.
- Distance between dikes or dams should assure no overlapping of consecutive impounding reservoirs induced by other dikes.

## 6.4. Sustainable Protective Measures

The concept of Sustainable Drainage Systems (SUDS) is to divert surface water runoff from paved areas to attenuate on-site the stormwater. Attenuation slows down storm events through storage. It does not, eliminate runoff volume. It only reduces the peak runoff rate. Drainage systems are designed to convey a pre-controlled storm runoff. In this case, built-up areas should be limited according to certain polices. Such laws can be set by institutional regulations or governmental decrees to ensure non-encroachment on green areas.

It is worth to note that the runoff generated from urbanized catchments in Ibadan should not increase flows to downstream reaches, the catchment should maintain either the same flows or the flows that the downstream sections can accommodate. In order to limit the flood flows generated to values that are reasonable to be handled, sustainable drainage systems are implemented. These sustainable methods consider decreasing the storm flows entering the main courses using different control methods as follows:

- a) Retardation/Capture at the source  
This includes green roofs, household storm water collection system, infiltration trenches...etc. Retardation/capture at the source should be introduced as policies and regulations to enforce developers use sustainable urban drainage systems and best management practices in order to ensure that storm water runoff remains with their same values prior to urbanization.
- b) Attenuation of peak flow.  
The following subsections elaborates on different methods considered in the masterplan to attenuate the peak flow.

More details on Sustainable Urban Drainage Systems are available in Annex 19.

### 6.4.1. Development of Floodplain Areas

Acquisition of flood prone areas and its development to landscape areas such as sports and community parks is a successful practice in many countries to limit extensive floodplain encroachment. Sports can be developed within flood prone areas such as football fields, basketball, athletic courts and picnic facilities. Community parks and rain gardens can be created such as Cuyahoga Falls, Ohio, USA refer to Plate 6.1. This system is applied in some locations within Ibadan and could be further developed and maintained in the new developments.



Plate 6.1: Community park and rain garden in Cuyahoga Falls, Ohio

### 6.4.2. Attenuation Ponds

Attenuation ponds contribute to flood mitigation while controlling the drainage as close as possible to its source and avoiding the on-flow of flooding downstream. The system is to limit the discharges to the exiting channels and to relocate volumes of water from flooding that does occur by directing it to ponds

established in the surrounding floodplains; thus, preserving their natural conditions for the mitigation of flooding. This system is applicable and implemented within Ibadan.

Attenuation ponds are allocated in the natural low-lying areas. The above has the following advantages:

- 1- Reduced flow downstream the pond.
- 2- Reduced sediments downstream the pond.
- 3- Reduced sizes of the drainage system dimensions downstream the pond
- 4- Can be used as an attractive integrated landscape feature for recreational activities.

### 6.4.3. Vegetated swales

These are shallow landscaped areas designed to capture, convey, and potentially infiltrate stormwater runoff as it moves downstream. Vegetated swales are widely accepted stormwater strategy, simple to construct and have a relatively low-cost to implement. Vegetated swales can be implemented in places such as residential and commercial streets, within street medians, within the interior and along the edges of parking lots, and within building perimeter landscaping. This system is applicable at some locations within Ibadan.

### 6.4.4. Rain Gardens

Shallow landscape areas that can collect, slow, filter and absorb large volumes of water, delaying discharge into the watershed system. Rain gardens can provide the greatest stormwater flow and volume benefit if large in size. Rain gardens can be placed adjacent to parking lots, streets and at large landscaped areas next to buildings. This is applicable in Ibadan.



Plate 6.2: Swales Adjacent To Roads



Plate 6.3: Rain Gardens

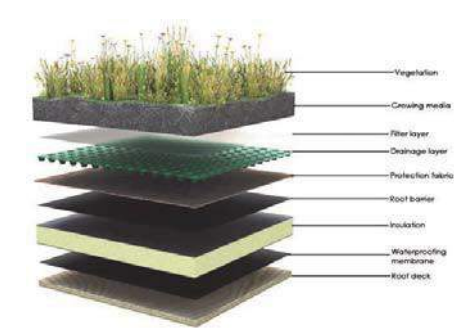
### 6.4.5. Green Roofs

Rainfall in green roofs is stored by the substrate and then taken up by the plants from where it is returned to the atmosphere through transpiration and evaporation. In summer, depending on the plants and depth of growing medium, green roofs retain 70-90% of the precipitation that falls on them; in winter they retain between 25-40%. Green roofs not only retain rainwater, but also moderate the temperature of the water and act as natural filters for any of the water that happens to run off. Green roofs reduce the amount of stormwater runoff and also delay the time at which runoff occurs, resulting

in decreased stress on sewer systems at peak flow periods. The applicability of this system is limited in the existing structures however future buildings can consider this system in the design.



Plate 6.4: Green Roof and Cross-Section



### 6.5. Landscape Design

Landscape designs are intended to establish consistency and continuity within the river's sides, unity within designated areas, and to allow for variation where appropriate. The strategy is intended to ensure that the landscape design is functional and respond to location, climate, local conditions and user needs. The design accommodates with the functions and activities of the project, including the pedestrian circulation, maintenance procedures, and safety & accessibility regulations.

For design purposes, pathways are proposed at 3m from each side of the channel/trained stream while other landscape areas are proposed outside the channel/trained stream.

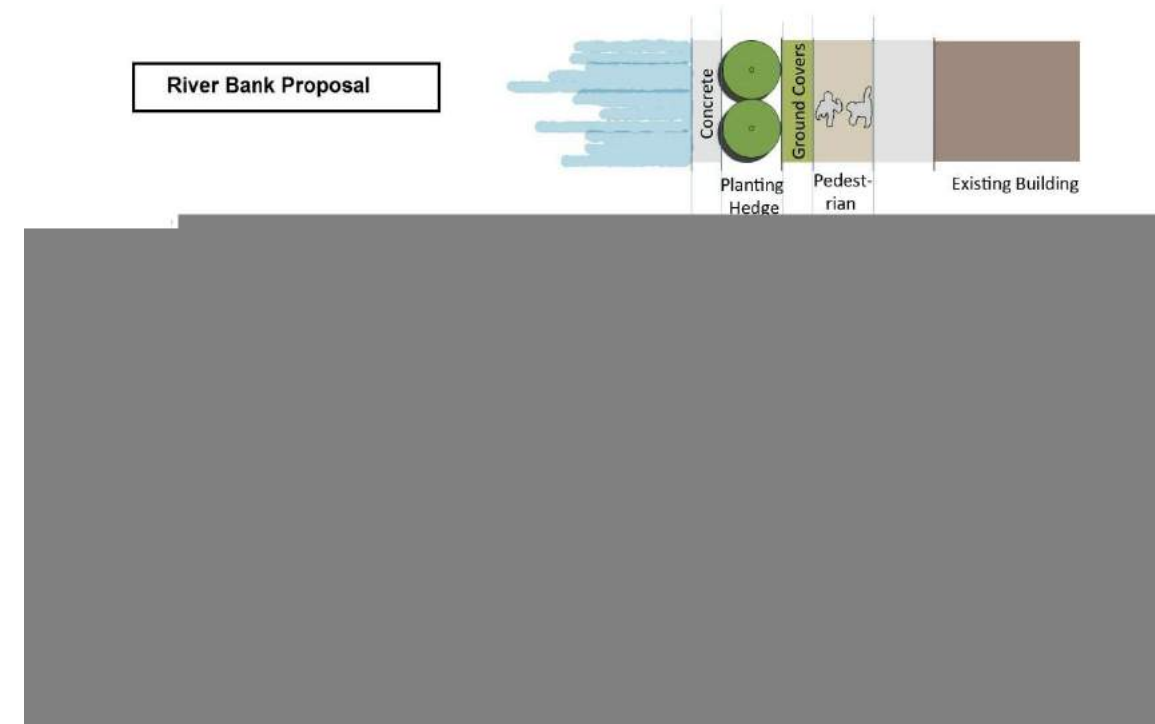


Figure 6.1: River Banks and Pathways

The following sections presents the criteria for the design of the landscape works within the river channel's right of way:

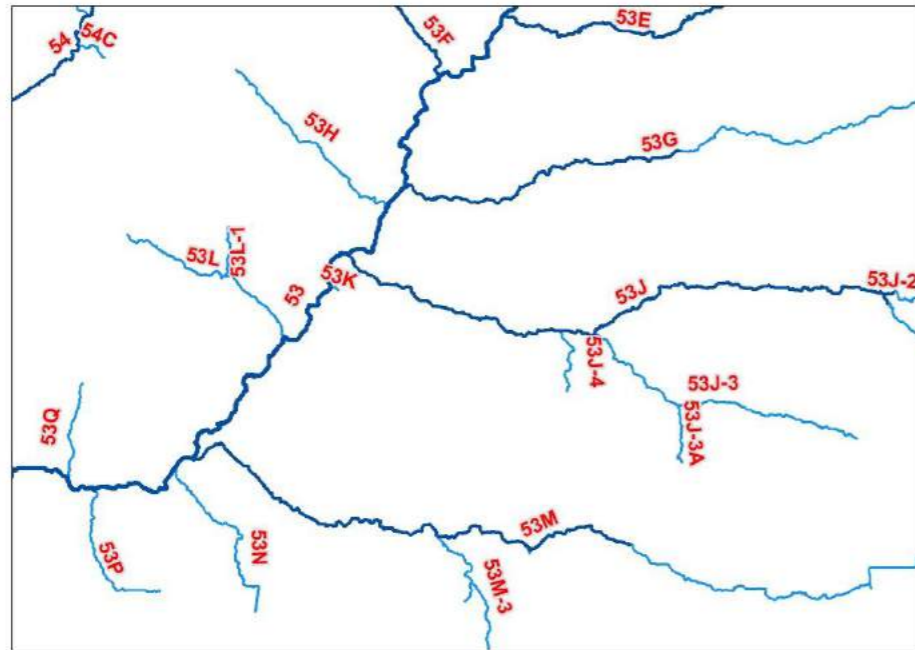


Figure 7.3: Drainage Numbering System

**7.1.3.2. Identification of Crossing Structure Numbers**

Similarly to systems, crossing structures are identified with unique numbers. The crossing structure numbers are based on the same numbering sequence used in the survey works. The masterplan includes 1615 identified locations for crossing structures comprising culverts and bridges. All identified locations are further assessed in the following sub-sections. Information on the survey methodology of these structures is illustrated in Annex 5.

**7.1.3.3. Inundation Maps**

Volume 3 presents the maps of the 4 main basins of the Master Plan in both existing and future conditions. Figure 7.4 presents a sample for the flood depth maps in the existing situation, while Figure 7.5 presents a sample for the flood depth maps in the future situation. Both samples are taken for the same drainage system (System 7) to clarify the impact of channelization on flood extents. System 7 is one of the tributaries of Ogunpa River. Both figures present the following:

- The expected inundation for a 100-year storm event.
- The buildings exposed to the 100-year flood extent.
- System numbers and identification numbers for crossing structures.
- The number of cells and dimensions of structures (culverts or bridges).

For the existing situation, structures are indicated with a black square and labelled with their existing dimensions. On the other hand, for the future situation, new structures (that require rehabilitation) are indicated with a red square and labelled with their proposed dimensions. It is worth to note that structures that do not require rehabilitation are left indicated with a black square with the same dimensions of the existing situation. In addition, for the future situation, proposed channels are outlined and labelled with proposed dimensions.

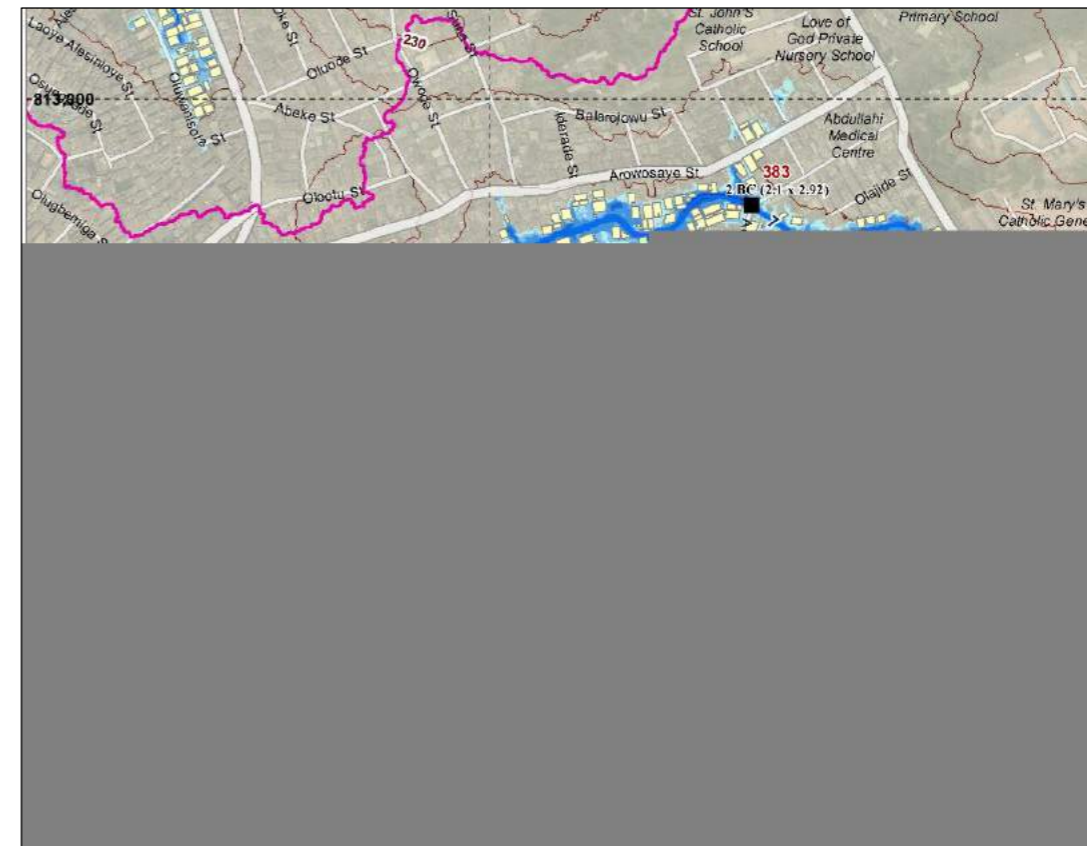


Figure 7.4: Flood Depth Map 100yrs - Existing Situation - System 7 - Ogunpa Basin

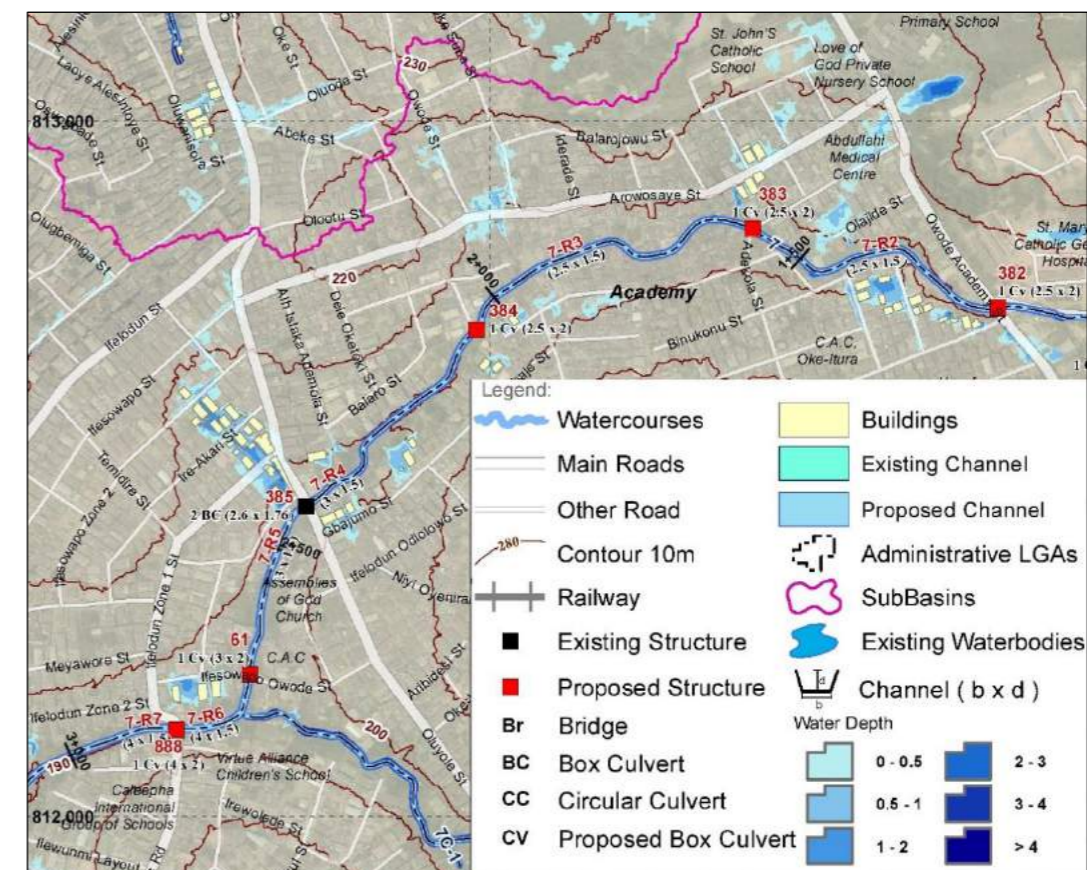


Figure 7.5: Flood Depth Map 100yrs - Future Situation - System 7 - Ogunpa Basin

#### 7.1.4. Assessment of the Existing Drainage System

The first step prior to the design of any structure is to assess the performance of the existing drainage system. This includes the dense drainage network in Ibadan, all existing crossing structures, dams and reservoirs. The existing crossing structures includes culverts and bridges that are lying on Rivers, Tributaries and Streams, refer to Figure 7.6.

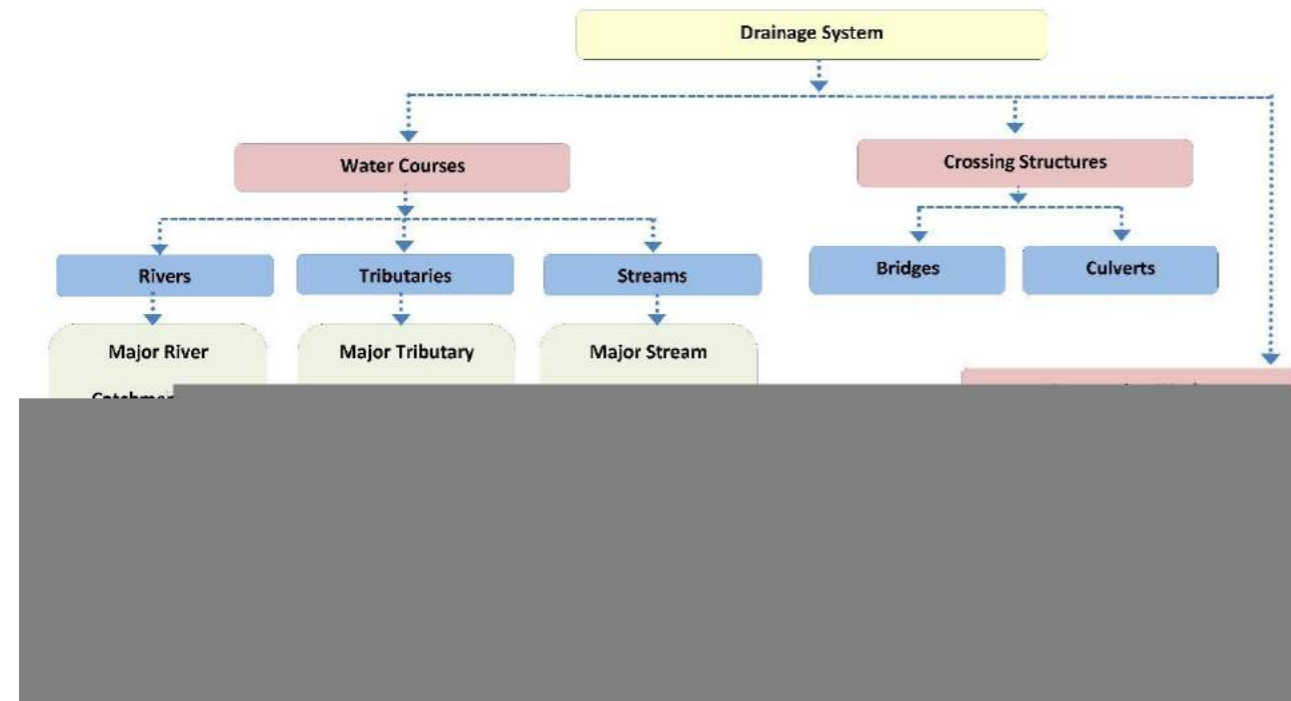


Figure 7.6: Drainage System Classification Diagram

Most of the crossing structures lie within the urban area, however, some are located in rural areas at the outer skirts of the city. Most of the crossing structures lie within the 4 main basins (Ona, Ogunpa, Ogbere and Omi) while a few lies in Iddo and Osun Basins.

In the Masterplan, the drainage systems ranging from 1 to 94 are divided according to the 38 subbasins in Ibadan, refer to Figure 7.2 and Table 7.2. The following sub-sections presents the existing drainage system and the assessment of all crossing structures. The methodology of the assessment is illustrated through the analysis of a selected pilot system, refer to Annex 8 and Annex 11.

##### 7.1.4.1. Subbasins

There are 38 identified subbasins in Ibadan, where 29 subbasins lie within the urban area and 9 remaining subbasins lie in the rural areas. The 29 subbasins in the urban areas are shaded in light blue in Table 7.2.

In the Masterplan, all Rivers and Tributaries lying within the 29 subbasins are studied. On the other hand, all crossing locations identified in Ibadan (1615 locations) are assessed.

To achieve a well-understanding of the drainage system, it is important to organize the drainage network and their crossing structures altogether. Each subbasin includes a group of system watersheds, each

system watershed includes a set of crossing structures. Figure 7.7 shows a sample of a subbasin in Upper Omi West (Om3), system watersheds (31, 32, 33 and 34) and their associative structures.

Figure 7.7 represents the drainage system of all the streams and their associative structures having a catchment area > 0.1km<sup>2</sup>.

It is important to appreciate that there is a very dense network of Rivers, tributaries and streams in Ibadan. This dense network needs to be divided such that it can be easily assessed. In the Masterplan, the assessment of the drainage system is divided into 2 divisions:

- 1- Assessment of Rivers, Tributaries and their associative drainage structures having a catchment area > 1km<sup>2</sup>.
- 2- Assessment of Streams and their associative drainage structures having a catchment area < 1km<sup>2</sup>

Figure 7.7 represents the above two divisions in different colors such that they may be easily distinguished.

##### 7.1.4.2. Drainage Network

Rivers and Tributaries are regarded as the backbone of the drainage system. A well drainage system is a key factor to mitigate flooding in Ibadan. There are no signs for channelization in the Ibadan drainage network except Ogunpa channel. It is worth to mention that no flooding has occurred in Ogunpa since its channelization in 1990. For a well-drainage system, it is necessary that the Masterplan investigates the channelization of Rivers and Tributaries specially the ones having a catchment area of more than 1km<sup>2</sup>.

##### 7.1.4.3. Crossing Structures

There are around 1615 crossing locations in Ibadan comprising of 46 Bridges, 1067 Culverts and 181 boardwalks and footpaths. The rest of these crossing locations (321) have yet still no structures. It important that the sizes of these structures are sufficient to convey the flow through them without causing any constrictions or bottle necks.

Annex 8 presents the assessment of all identified crossing locations of the 1<sup>st</sup> Division (catchment area > 1km<sup>2</sup>), while Annex 11 presents that of the 2<sup>nd</sup> Division (catchment area < 1km<sup>2</sup>). This data is also copied to the GIS geodatabase.

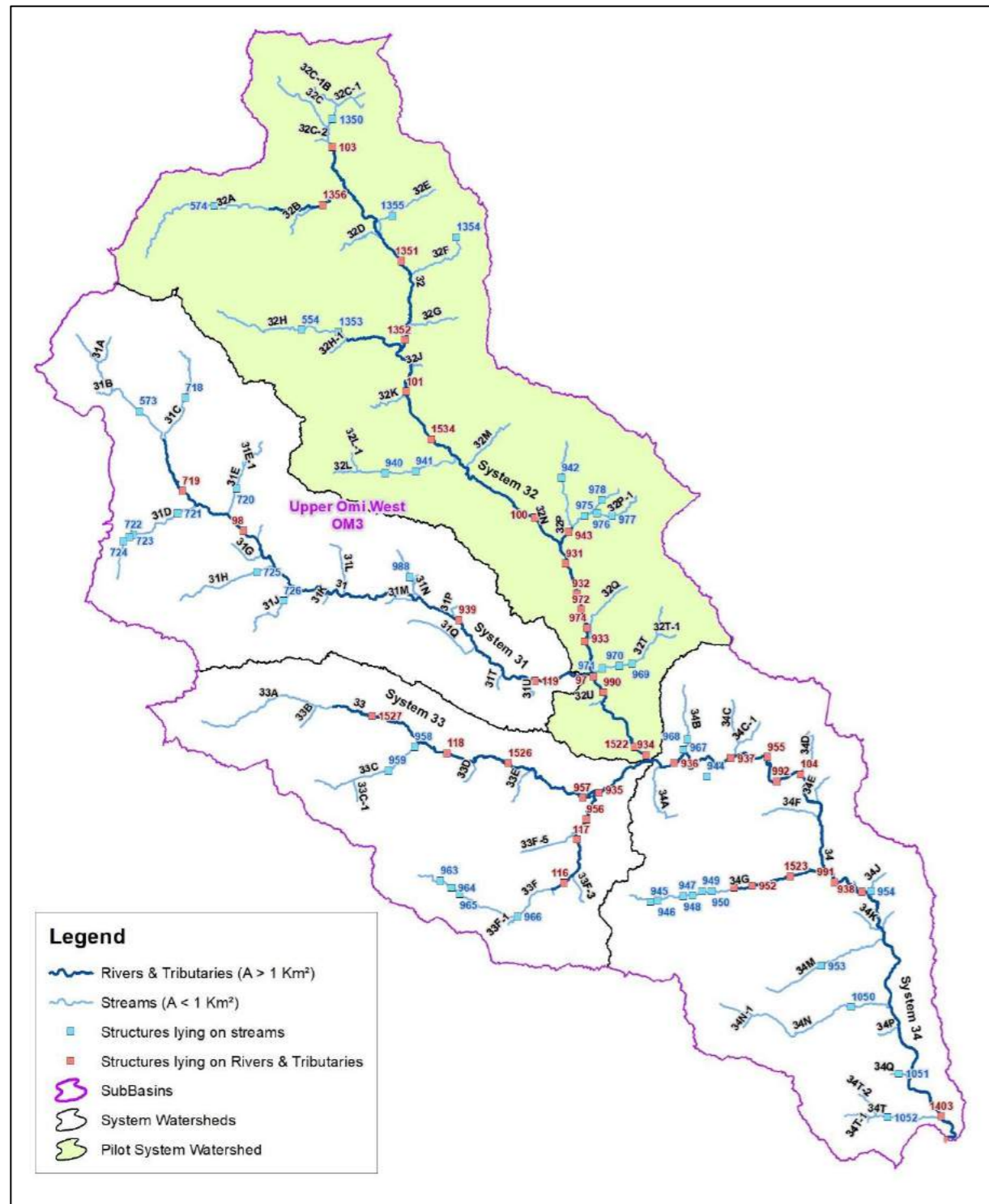


Figure 7.7: Main Rivers, Tributaries and Associative Structures for Upper Omi West (OM3)

## 7.2. Development of the Drainage Masterplan

This section presents the design development of the proposed channels with their associative crossing structures. In addition, this section presents the design of the crossing structures that are lying on natural streams. The methodology of the design is illustrated through the design of a pilot system, refer to Annex 9.

### 7.2.1. General

As mentioned previously, there are 94 main systems, each have a maximum length of 8km. However, not all of these systems lie within the urban area, only 69 main systems (including Middle Ogunpa existing system) lie within the study area and within 29 subbasins.

Based on the assessment of the existing drainage system, all Rivers and Tributaries (69 main Systems) passing through the densely populated area and which have a watershed coverage area of more than 1km<sup>2</sup> are proposed to be channelized to mitigate flooding and ensure sufficient drainage.

The drainage masterplan includes the proposed structural measures such as channels, dikes, dams and crossing structures (roads with waterways). Figure 7.9 presents the Drainage Masterplan with 69 proposed main systems and their associative sub-systems making a total of 188 systems, the figure also includes the existing system dimensions of Middle Ogunpa (System 2). The figure also presents the proposed dikes and dams for attenuation and multi-purpose respectively.

The proposed channel sizes are presented on a larger map divided into 2 part plans (a northern part and a southern part), refer to Figure 7.10 and Figure 7.11. In addition, Table 7.3 presents the 188 systems with their proposed section sizes, length, the contributing watershed catchment area at their end reaches and their corresponding design flows.

The design of the above systems (proposed channels and crossing structures) and the basis for their design are illustrated in the following sections. In addition, the proposed dikes and dams are illustrated in a separate section, refer to Annex 6.

### 7.2.2. Proposed Channels

This section presents the proposed channels in Ibadan. Annex 9 presents the tabularized form for the design for each channel. This data is also copied to the GIS geodatabase. All channelized river and tributaries are presented in part plans in Volume 3 with a scale of 1:10,000.

#### 7.2.2.1. General

As mentioned above, there are 188 systems comprising of Rivers and Tributaries that are proposed for channelization. These channels lie in different areas in Ibadan. In order to organize the design in coherent way; each group of channels are gathered in a specified subbasin. In addition, each channel is divided into a set of reaches. New reaches are identified when there is either a change in the size dimensions, a crossing structure dividing the channel or a change in the system numbering. In other

words, only one structure is located on a single reach. However, it is not necessarily that a reach includes a crossing structure.

Figure 7.8 presents an example for the channelization of Yemetu Stream or Upper Kudeti (System 3), the systems is divided into reaches 3-R1, 3-R2, 3-R3...etc. A crossing structure lies on their reaches such as structures no: 279, 278 and 96. The existing and proposed dimensions of crossing structures are also presented.

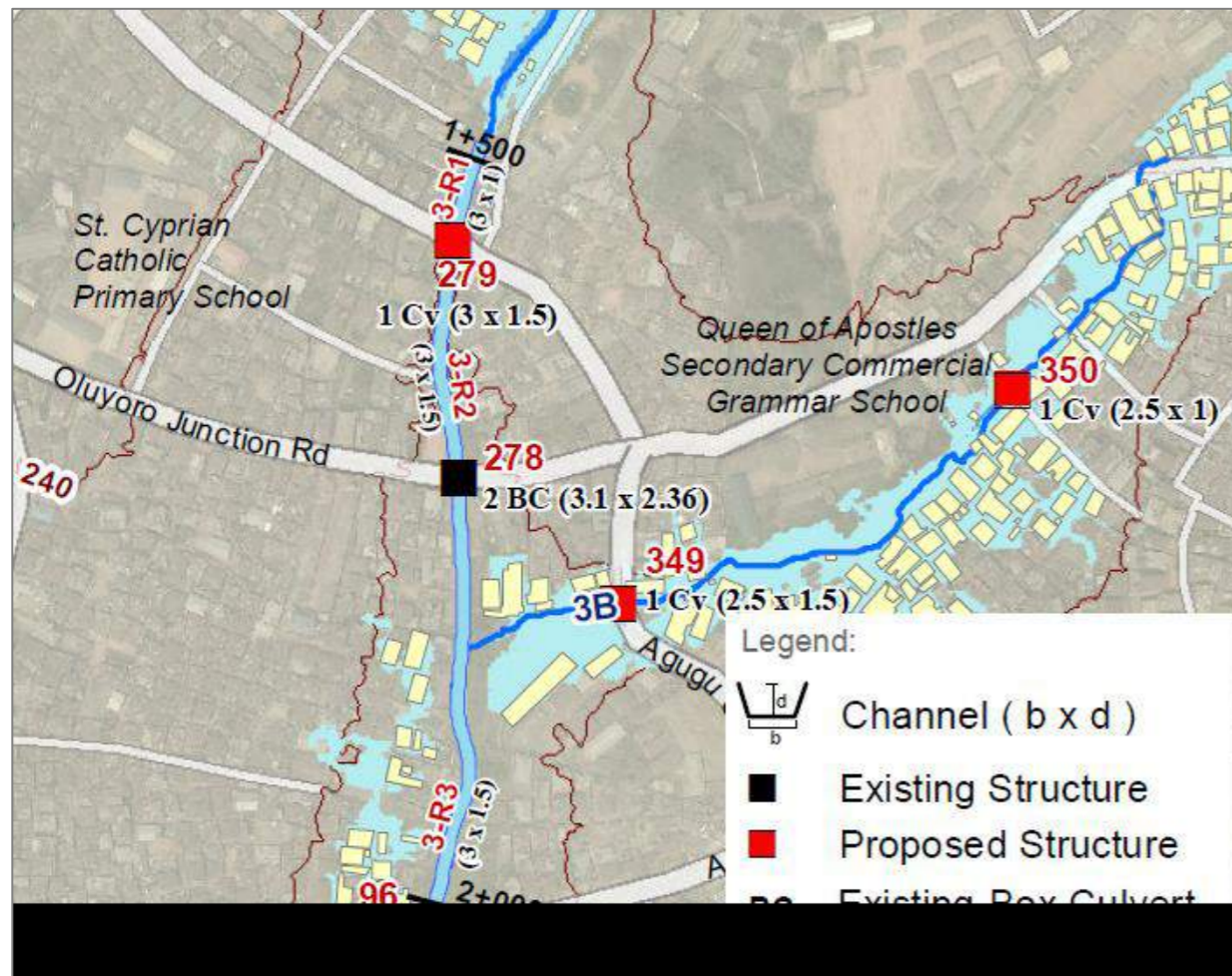


Figure 7.8: Reaches and Crossing Structures

### 7.2.2.2. Design Basis

Based on the design criteria illustrated in Annex 14, channels are designed based on the following:

- Channels are sized according to the application of Manning's formula for open channels. The design is prepared using a hydraulic model (FlowMaster) and checked by another hydraulic model (SSA).
- Channels and their associative crossing structures are designed altogether. The design basis of crossing structures is illustrated in Section 7.2.3.
- Channels are designed with trapezoidal shaped sections having side slopes of 2H:1V.
- The design longitudinal slopes are proposed to match the natural ground slope as much as possible to minimize earthworks.
- The channel is proposed to be excavated/dredged by an average of 0.5m to ensure that the size of the channel is fitted, and the channel may convey the flow within the proposed cross-section.
- The design flow is extracted from the rainfall-runoff model (HEC-HMS)
- The design flow is based on a specified design return period, the design return period depends on the catchment area of the channel
  - Channels having a catchment area < 50 km<sup>2</sup> are designed to accommodate a flow of 50-years return period and checked for the 100-year return period.
  - Channels having a catchment area > 50 km<sup>2</sup> are designed in their structural section to accommodate a flow of 25-years return period. On the other hand, the system is designed to accommodate the 100-year return period within both the channel (structural section) and the flood fringe (the non-structural section).
- Concrete lining protection is proposed for channels such that:
  - Channels having a catchment area < 25 km<sup>2</sup> are proposed to be completely lined (bed and side slopes protection), manning roughness coefficient is taken as 0.017.

Channels having a catchment area > 25 km<sup>2</sup> are proposed to be partially lined (side slopes protection only), manning roughness coefficient is taken as 0.027.

### 7.2.3. Crossing Structures lying on Proposed Channels (1st Division)

As mentioned previously, all inadequate crossing structures lying on the proposed channels needs to be rehabilitated. There are around 657 crossing locations in Ibadan that are located on proposed channels. Based on the structure's assessment in Section 7.1.4, there are around 544 crossing locations that needs to be rehabilitated. All these crossing locations are designed under the Masterplan such that they comprise of 53 Bridges and 491 Culverts. Annex 9 presents the design of all identified crossing locations located on proposed channels (Crossing structures of the 1<sup>st</sup> Division - Catchment area > 1km<sup>2</sup>).

This section presents a summary of the design basis of the crossing structures lying on the proposed channels.

Channel ID	Subbasin	Channel Length (m)	Catchment Area (km <sup>2</sup> )	Design Flow (m <sup>3</sup> /s)	Proposed Channel Dimensions (Bed Width x Depth)
14V	Ob4 Foworogbun	1658	2.5	29.5	6 x 1
14X	Ob4 Foworogbun	409	1.1	15.9	2.5 x 1
15	Ob4 Foworogbun	2955	20.7	256.5	27 x 2
15H	Ob4 Foworogbun	1966	2.5	30.2	6 x 1
16	Ob5 Lower Ogbere North	2714	60.3	463.0	45 x 3
16D	Ob5 Lower Ogbere North	1895	2.4	28.5	6 x 1
16F	Ob5 Lower Ogbere North	1331	1.2	17.3	3 x 1
17	Ob5 Lower Ogbere North	2447	5.3	61.7	6 x 1.5
17H	Ob5 Lower Ogbere North	424	1.2	16.6	2.5 x 1
18	Ob5 Lower Ogbere North	3552	66.9	463.0	45 x 3
18H	Ob5 Lower Ogbere North	861	1.1	15.6	2.5 x 1
18K	Ob5 Lower Ogbere North	375	1.5	20.0	3 x 1
19	Ob5 Lower Ogbere North	1040	66.9	463.0	45 x 3
19A	Ob5 Lower Ogbere North	959	1.5	20.0	3.5 x 1
19B	Ob5 Lower Ogbere North	1373	3.0	35.0	4 x 1.5
24	OM2 Omi Headwaters South	1748	32.9	237.4	20 x 2
25	OM2 Omi Headwaters South	2353	5.7	60.0	6 x 1.5
26	OM2 Omi Headwaters South	2313	40.1	290.3	22 x 2.5
27	OM2 Omi Headwaters South	3275	8.2	61.8	10 x 1.5
27K	OM2 Omi Headwaters South	1597	3.0	35.0	4 x 1.5
28	OM2 Omi Headwaters South	2460	58.5	372.6	28 x 2.5
28A	OM2 Omi Headwaters South	3034	3.5	39.9	4.5 x 1.5
28D	OM2 Omi Headwaters South	1197	2.1	25.5	3 x 1.5
29	OM4 Upper Omi East	5428	9.3	88.5	10 x 1.5
29B	OM4 Upper Omi East	138	1.5	20.0	4 x 1
29E	OM4 Upper Omi East	886	1.5	20.3	3.5 x 1
30	OM4 Upper Omi East	5628	99.0	393.0	31 x 3
30D	OM4 Upper Omi East	2336	1.5	19.6	3 x 1
30H	OM4 Upper Omi East	439	1.2	16.6	3.5 x 1
31	OM3 Upper Omi West	4744	7.4	72.3	10 x 1.5
32	OM3 Upper Omi West	6823	19.9	226.4	16 x 2
32C	OM3 Upper Omi West	436	1.1	15.6	2.5 x 1.5
32H	OM3 Upper Omi West	524	2.0	25.0	4 x 1
32P	OM3 Upper Omi West	183	1.1	16.0	2.5 x 1
33	OM3 Upper Omi West	3253	5.7	60.1	9 x 1.5
33F	OM3 Upper Omi West	1020	2.0	25.2	3 x 1.5
34	OM3 Upper Omi West	5964	33.9	235.4	20 x 2.5
34G	OM3 Upper Omi West	786	1.3	18.0	2 x 1.5
35	OM4 Upper Omi East	3511	119.0	393.0	35 x 3

Channel ID	Subbasin	Channel Length (m)	Catchment Area (km <sup>2</sup> )	Design Flow (m <sup>3</sup> /s)	Proposed Channel Dimensions (Bed Width x Depth)
36	OM6 Middle Omi West	8032	17.8	150.8	12 x 2
36A	OM6 Middle Omi West	680	1.7	21.9	3 x 1.5
36D	OM6 Middle Omi West	1834	2.6	31.1	4 x 1.5
36D-5	OM6 Middle Omi West	240	1.0	15.4	2.5 x 1
36D-7	OM6 Middle Omi West	1054	1.6	21.4	3 x 1.5
36M	OM6 Middle Omi West	1327	1.9	23.6	3 x 1
37	OM6 Middle Omi West	3042	4.6	51.6	6 x 1.5
37D	OM6 Middle Omi West	1217	2.0	24.9	2.5 x 1.5
38	OM6 Middle Omi West	1461	82.0	430.0	45 x 3
39	OM5 Middle Omi East	7356	17.3	143.8	12 x 2
39D	OM5 Middle Omi East	1060	2.0	25.0	4 x 1
39H	OM5 Middle Omi East	2583	5.0	55.0	5.5 x 1.5
39H-6	OM5 Middle Omi East	1126	1.5	20.0	4 x 1
39M	OM5 Middle Omi East	1507	2.5	30.0	4.5 x 1
40	OM7 Middle Omi South	6302	9.8	95.7	12 x 1.5
40Q	OM7 Middle Omi South	303	1.0	15.0	2.5 x 1
41	OM7 Middle Omi South	4230	174.4	444.8	45 x 3
41B	OM7 Middle Omi South	681	1.5	20.0	3 x 1
42	OM7 Middle Omi South	3948	10.0	91.9	12 x 1.5
42H	OM7 Middle Omi South	113	1.5	20.0	2.5 x 1
42J	OM7 Middle Omi South	1360	3.5	40.3	4 x 1.5
43	OM7 Middle Omi South	2050	186.0	455.6	45 x 3
44	OM7 Middle Omi South	4672	9.0	83.7	10 x 1.5
44J	OM7 Middle Omi South	850	1.5	20.0	3.5 x 1
45	OM7 Middle Omi South	3687	203.1	471.7	45 x 3.5
45E	OM7 Middle Omi South	2128	2.2	26.6	3 x 1.5
45H	OM7 Middle Omi South	2871	3.6	40.6	4 x 1.5
53G	ON7 Upper Ona East	1307	1.6	20.5	5.5 x 1
53J	ON7 Upper Ona East	2587	4.5	49.8	6 x 1
53M	ON7 Upper Ona East	2229	1.4	18.7	6 x 1
54	ON7 Upper Ona East	2640	5.7	78.6	10 x 1.5
54D	ON7 Upper Ona East	1035	2.2	27.4	3 x 1
55	ON7 Upper Ona East	3222	82.6	335.4	32 x 3
55B	ON7 Upper Ona East	1752	2.3	27.7	6 x 1.5
55F	ON7 Upper Ona East	202	1.0	15.1	3 x 1
56	ON8 Upper Ona South	4900	13.3	134.9	12 x 2
56B	ON8 Upper Ona South	213	1.0	15.0	3 x 1
56E	ON8 Upper Ona South	698	2.0	25.0	3 x 1
56H	ON8 Upper Ona South	2056	2.8	32.5	3 x 1.5

Channel ID	Subbasin	Channel Length (m)	Catchment Area (km <sup>2</sup> )	Design Flow (m <sup>3</sup> /s)	Proposed Channel Dimensions (Bed Width x Depth)
56K	ON8 Upper Ona South	1316	2.0	24.6	6 x 1
58	ON8 Upper Ona South	3900	107.8	391.1	40 x 3
57	ON8 Upper Ona South	4021	6.3	69.4	8 x 1.5
66	ON6 Upper Ona West	2110	67.2	376.3	40 x 3
66C	ON6 Upper Ona West	2605	3.5	39.9	4.5 x 1.5
67	ON6 Upper Ona West	3838	4.5	74.2	7 x 1.5
68	ON6 Upper Ona West	661	81.5	402.9	60 x 2
68A	ON6 Upper Ona West	1852	2.7	31.6	4.5 x 1
68C	ON6 Upper Ona West	2075	3.1	35.7	4 x 1.5
69	ON10 Middle Ona North	2576	210.8	435.2	43 x 3
69C	ON10 Middle Ona North	439	1.6	20.7	3 x 1.5
70	ON9 Orogun	5466	15.9	164.0	32 x 2
70J	ON9 Orogun	1840	1.2	16.5	3 x 1
70P	ON9 Orogun	1429	2.5	30.1	4 x 1.5
70Q	ON9 Orogun	1826	2.8	33.0	4 x 1.5
71	ON10 Middle Ona North	2906	242.0	508.6	66 x 3
71C	ON10 Middle Ona North	2997	4.2	46.9	5.5 x 1.5
72	ON10 Middle Ona North	4923	9.5	113.4	12 x 2
72F	ON10 Middle Ona North	312	1.5	20.0	3 x 1
72H	ON10 Middle Ona North	718	1.3	18.4	3 x 1
73	ON10 Middle Ona North	1166	248.0	508.6	80 x 3
73D	ON10 Middle Ona North	1235	2.0	24.7	3.5 x 1.5
74	ON10 Middle Ona North	2400	4.5	50.0	6 x 1.5
74N	ON10 Middle Ona North	3069	4.2	47.1	5.5 x 1.5
75E	ON10 Middle Ona North	400	1.2	17.1	3.5 x 1
79	ON11 Alapata South	4461	53.0	313.5	45 x 2.5
79B	ON11 Alapata South	1535	2.0	25.0	3.5 x 1
79D	ON11 Alapata South	734	1.3	18.3	3 x 1
79G	ON11 Alapata South	2399	1.7	22.1	4 x 1
79L	ON11 Alapata South	2379	3.0	34.8	4 x 1.5
79M	ON11 Alapata South	1206	2.0	25.0	4 x 1
80	ON13 Middle Ona South	5488	327.7	551.6	40 x 3.5
80A	ON13 Middle Ona South	290	1.3	18.4	3.5 x 1
80B	ON13 Middle Ona South	1108	2.6	30.5	4 x 1.5
80B-3	ON13 Middle Ona South	383	1.0	15.1	3 x 1
80K	ON13 Middle Ona South	1461	1.9	24.2	4.5 x 1
80L	ON13 Middle Ona South	2440	2.3	28.2	4 x 1.5
80U	ON13 Middle Ona South	805	1.5	19.9	2.5 x 1.5
81	ON12 Middle Ona West	8080	12.7	199.9	12 x 2

Channel ID	Subbasin	Channel Length (m)	Catchment Area (km <sup>2</sup> )	Design Flow (m <sup>3</sup> /s)	Proposed Channel Dimensions (Bed Width x Depth)
81F	ON12 Middle Ona West	760	2.3	27.9	3 x 1
81J	ON12 Middle Ona West	740	1.1	16.3	4 x 1
82	ON12 Middle Ona West	6075	12.2	120.0	12 x 2
82E	ON12 Middle Ona West	425	1.1	15.9	3 x 1
82J	ON12 Middle Ona West	515	1.0	15.3	3 x 1
82M	ON12 Middle Ona West	2027	2.8	33.3	5.5 x 1.5
83	ON14 Lower Ona North	7415	372.3	563.6	40 x 3.5
83F	ON14 Lower Ona North	2523	3.3	37.7	4.5 x 1.5
83G	ON14 Lower Ona North	925	1.6	21.4	2.5 x 1.5
83H	ON14 Lower Ona North	1031	1.2	16.9	3 x 1
83M	ON14 Lower Ona North	2619	4.1	46.4	4 x 2
84	ON15 Alaro	4013	6.9	69.1	8 x 1.5
84D	ON15 Alaro	1271	2.3	28.3	4.5 x 1
85	ON15 Alaro	6090	14.0	154.0	13 x 2
85F	ON15 Alaro	541	1.2	17.4	3 x 1
85G	ON15 Alaro	1079	2.1	26.2	3 x 1.5
85L	ON15 Alaro	1520	2.0	25.2	3 x 1.5
86	ON15 Alaro	3247	30.0	255.7	48 x 2.25
86C	ON15 Alaro	1070	2.0	24.5	2.5 x 1.5
86G	ON15 Alaro	699	1.3	18.3	2.5 x 1
87	ON17 Lower Ona East	3107	7.5	54.2	6 x 1.5
87E	ON17 Lower Ona East	482	1.6	20.6	2.5 x 1.5
88	ON17 Lower Ona East	3893	415.2	574.3	50 x 3.5
88D	ON17 Lower Ona East	1679	2.5	30.2	3.5 x 1.5
88E	ON17 Lower Ona East	615	1.5	19.6	4 x 1
88G	ON17 Lower Ona East	529	1.1	15.9	2.5 x 1
89	ON16 Agara Kasumu	7867	15.0	144.5	12 x 2
89L	ON16 Agara Kasumu	1974	2.7	32.2	5.5 x 1
89M	ON16 Agara Kasumu	231	1.1	15.7	3 x 1
90	ON19 Lower Ona West	6544	13.5	169.7	17 x 2
90M	ON19 Lower Ona West	624	2.0	25.0	3.5 x 1
90N	ON19 Lower Ona West	419	2.0	25.0	3.5 x 1
91	ON18 Lower Ona South	4118	452.7	603.4	67 x 3.5
91H	ON18 Lower Ona South	2612	3.4	38.5	4.5 x 1.5

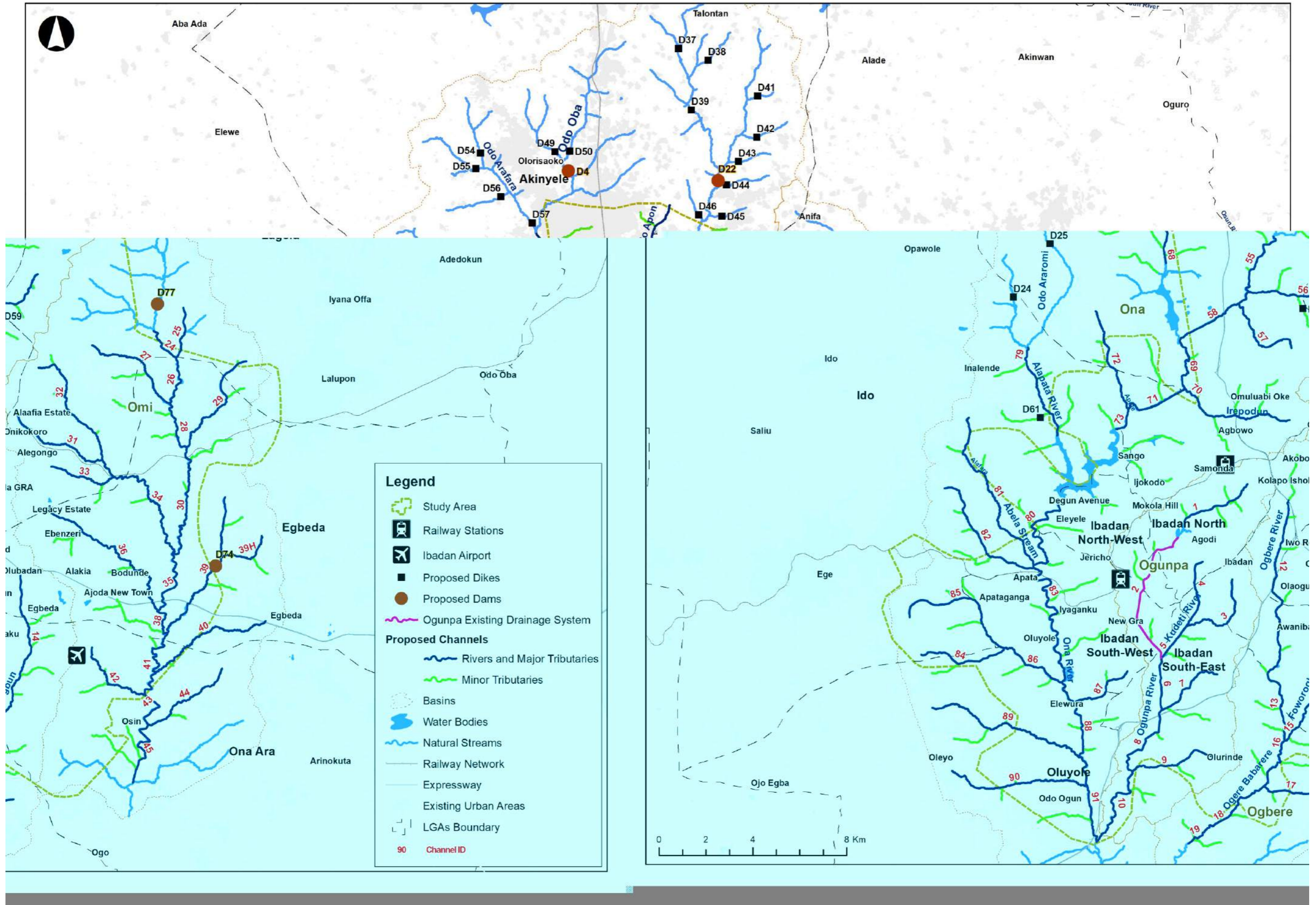


Figure 7.9: Drainage Masterplan (General Figure)

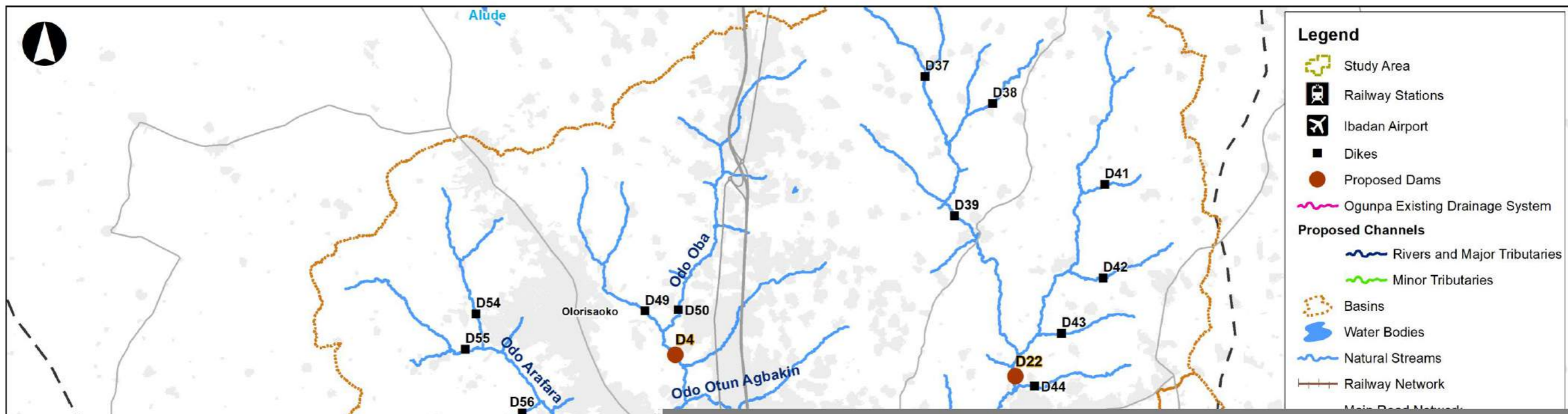


Figure 7.10: Drainage Masterplan – Northern Part Plan

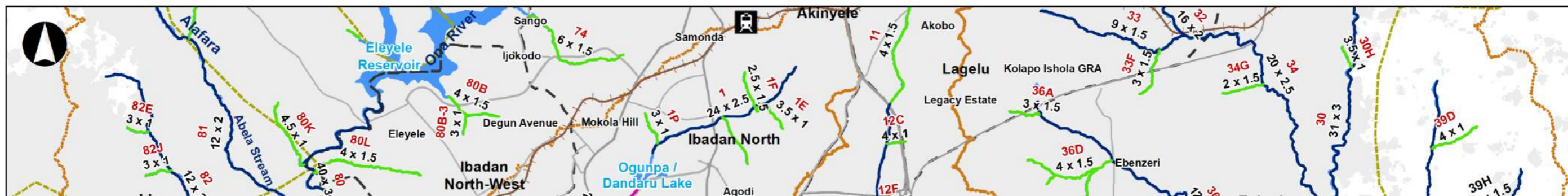


Figure 7.11: Drainage Masterplan - Southern Part Plan

### 7.3. Cost Estimates

This section presents the cost estimate of the Masterplan works excluding any other works related to the pool of priority investments or works by other Consultants. The description of each drainage infrastructure item is first presented, followed by the unit rates for each drainage item. Finally, the cost estimate is presented for the proposed channels, bridges, culverts and dams along with their final cost.

#### 7.3.1. Basic Items

The drainage infrastructure items include the following works:

- Excavation/Earthworks
- Concrete and Steelwork
- Crossing Structures (Culverts/Bridges/Dams)
- Channels (Lined/Earth)

##### 7.3.1.1. Excavation/Earthworks

This item covers earthworks for channels. Earth work is expected to be mechanized, and although various types of machinery and differing costs may be applied for earth work operations in different sections of the project area, unified average prices are used. All lands are expected to be loose and compactible and no rock is expected to be encountered. The unit cost includes the excavation, trimming, and transporting of excess material after backfilling.

##### 7.3.1.2. Concrete and Steelwork

The concrete and steel works to be encountered in the proposed systems is divided into the following categories:

- Concrete Lining (250/20), 15cm thickness
- Concrete for Culverts (300/20), 50cm thickness
- Reinforcement: High tensile steel reinforcement of all diameters

##### 7.3.1.3. Crossing Structures (Culverts/Bridges)

The cost estimate of bridges is based on a two-way carriage road; each carriage road consists of 1 to 3 lanes. The cost estimate of culverts is based on different culvert sizes and number of barrels. Culvert's barrel length varies from 12 to 60m according to the type of crossing with different kinds of roads, while bridge widths varies from 12m to 30m.

The design return period for Culverts and Bridges are based on a 25-year and 100-year respectively as indicated in Section 4 in Annex 14 Drainage Design Criteria. Steps of calculations are covered in Annex 10 and Annex 12.

For both structures, the price includes all necessary accessories such as culvert inlets, outlets, fences and guardrails.

To cover expenses related to any necessary potential works for the roads, the cost estimated for the rehabilitation of culverts shall be multiplied by a factor ranging from 1.4 to 1.6 (taken as 1.6 in this report).

The cost estimate of culverts or bridges are based on replacing undersized culverts by new ones. However, maintaining the new ones and adding other cells is necessary to be investigated in detailed design projects in order to reduce the final cost of these structures.

##### 7.3.1.4. Channels

The cost estimate of lined channels is based on both excavation and lining. Regarding excavation, the cost estimate is based on the assumption that 80% of the existing stream's section needs to be excavated to accommodate the required channel's capacity. The proposed section is presented in Figure 7.12.

Regarding the lining of the channel, the cost estimate is based on the concrete lining of channel's section (bed and side slopes) or the side slopes only with a thickness of 15cm and providing a key to the lining section with an initial dimension of 30cm x 2m. The proposed section is presented in Figure 7.13 and Figure 7.14 respectively.

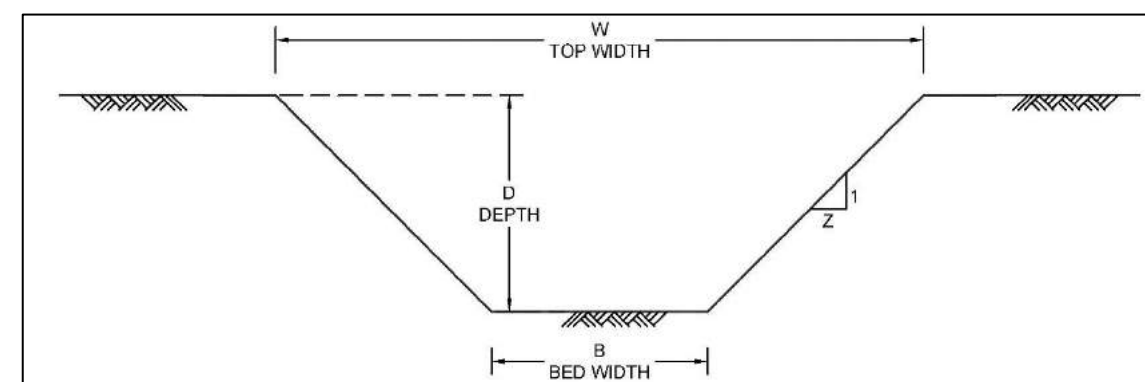


Figure 7.12: Typical Cross-Section for an Earth Channel

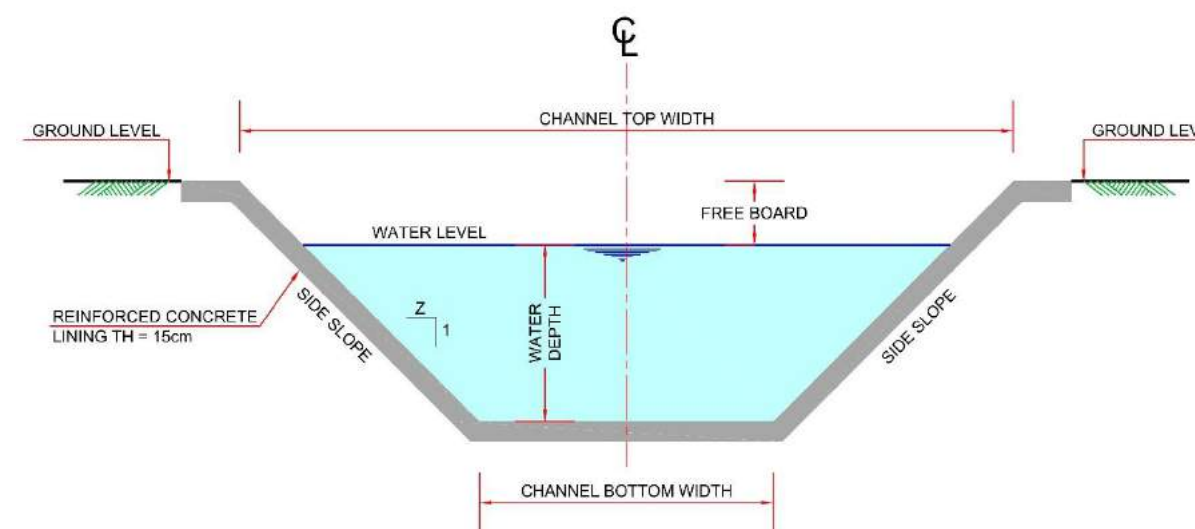


Figure 7.13: Typical Cross-Section for a Concrete Lined Channel (Bed and Sides)

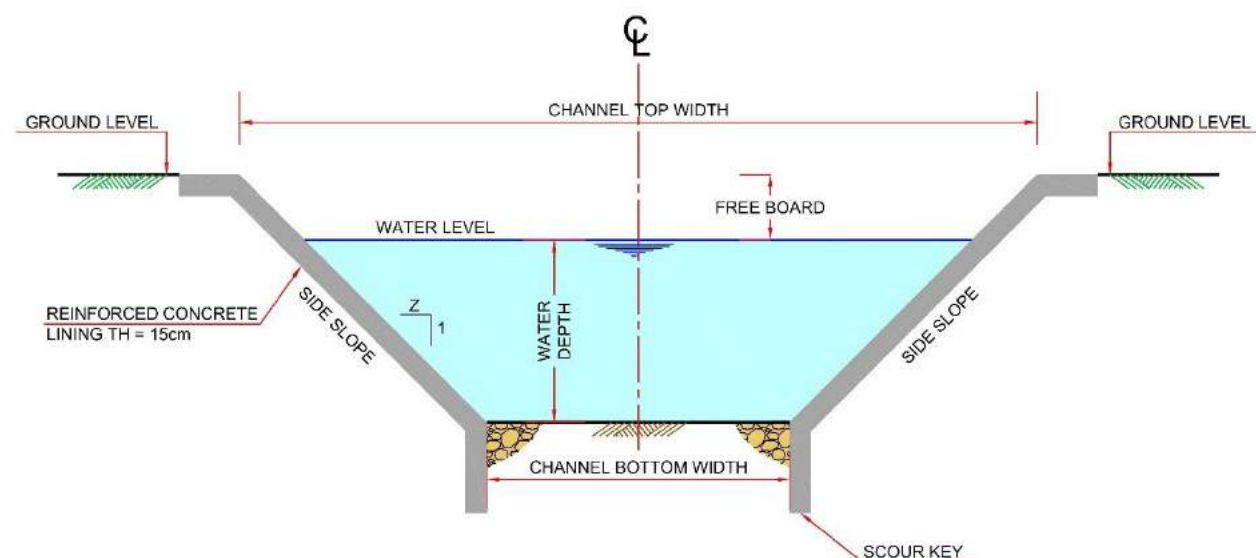


Figure 7.14: Typical Cross-Section for a Concrete Lined Channel Sides and Natural Bed

**7.3.1.5. Dams**

The cost estimate of dams is based on filling works for the dam’s embankment and covering the dam’s surface with an economic protection layer such as grouted riprap. The dam is proposed to have side slopes of 3.5:1 H:V and a top width of 6m to accommodate a one-way carriage road. The dam is associated with a bottom outlet (culvert) and a spillway. The quantities of each item are multiplied by appropriated unit prices covering the expenses linked to each of them (equipment, mobilization...). The details of construction costs for earthfill dam, other ancillary structures, and the proposed access roads are considered.

**7.3.2. Unit Rates**

The cost estimate unit rates are based on true figures extracted from awarded contracts in similar projects in West Africa and rates received from the PIU. Unit Rates of the main items in USD and Naira are summarized in Table 7.4.

Table 7.4: Basic Unit Rates of Drainage Infra-Structure Elements

	General Rates	Unit Rate	Unit	Unit Rate	Unit
		in USD		in Naira	
<b>1</b>	<b>Concrete</b>				
1.1	High yield steel	1,556	USD/Ton	474,580	Naira/Ton
1.2	In situ concrete class 300/20 for Box culverts, Wing Walls & Apron Slabs	260	USD/m <sup>3</sup>	79,300	Naira/m <sup>3</sup>
1.3	In situ concrete class 250/20 for Concrete Lining for Channels, Service Ramps and Pavement Screed Layer	240	USD/m <sup>3</sup>	73,200	Naira/m <sup>3</sup>
<b>2</b>	<b>Earthworks</b>				
2.1	Excavation	10	USD/m <sup>3</sup>	3,050	Naira/m <sup>3</sup>
2.2	Backfilling	11	USD/m <sup>3</sup>	3,355	Naira/m <sup>3</sup>
<b>3</b>	<b>Bridges</b>				
3.1	Vehicle Bridge	1500	USD/m <sup>2</sup>	457,500	Naira/m <sup>2</sup>

	General Rates	Unit Rate	Unit	Unit Rate	Unit
		in USD		in Naira	
3.2	Vehicle Bridge and Road Rehabilitation	2500	USD/m <sup>2</sup>	762,500	Naira/m <sup>2</sup>
<b>4</b>	<b>Riprap</b>				
4.1	Riprap per m <sup>3</sup>	65	USD/m <sup>3</sup>	19,825	Naira/m <sup>3</sup>

\*Exchange Rate USD to Naira = 305

**7.3.3. Masterplan Cost Estimate**

This section presents the cost estimate for all the proposed drainage elements comprising the channelization works, structures (Culverts/Bridges) and dams. The summary of all proposed Masterplan works is presented in Table 7.5.

Table 7.5: Cost Estimates of all Proposed Drainage Elements

		Total		
		Length (Km)/ No.	Cost (MUSD)	Cost (B Naira)
<b>Channels</b>		418.1	381.1	116.2
<b>Structures on Proposed Channels</b>	Culverts	491	44.4	13.5
	Bridges	53	73.5	22.4
<b>Structures on Natural Streams</b>	Culverts	845	43.9	13.4
	Bridges	8	17	5.2
<b>Dams</b>		4	997.9	304.4
<b>Total</b>			<b>1557.8</b>	<b>475.1</b>

**7.3.3.1. Channels with Associative Crossing Structures**

Annex 10 presents the cost estimate of channels and crossing structures (Bridges/Culverts) lying on these channels. In the Masterplan, there are 188 proposed channels with a total length of 418 km and a total cost of 381 MUSD (116 B Naira). In addition, there are 53 proposed bridges lying on proposed channels with a total cost of 73.5 MUSD (22.4 B Naira). Moreover, there are 491 proposed culverts lying on proposed channels with a total cost of 44.3 MUSD (13.5 B Naira).

Table 7.6 summarizes the cost estimate of channels and crossing structures (Bridges/Culverts) lying on these channels. The break down for channel cost is presented in Table 7.7.

Table 7.6: Cost of Channels and associative structures (Culverts and Bridges) in USD and Naira

	Structures on Proposed Channels		
	Length(Km)/ No.	Cost (MUSD)	Cost (BNaira)
<b>Channels</b>	418.1	381.1	116.2
<b>Culverts</b>	491	44.4	13.5
<b>Bridges</b>	53	73.5	22.4
<b>Total</b>		<b>499.0</b>	<b>152.2</b>

**Table 7.7: Breakdown of Channel Costs in USD and Naira**

Channel ID	Subbasin	Channel Length (m)	Total Cost of Channel (USD)	Total Cost of Channel (Naira)
11	Ob1 Ogbere Headwaters	2221	1,171,000	357,155,000
12	Ob2 Upper Ogbere	6877	1 <sup>st</sup> Pool (Lot 1)	1 <sup>st</sup> Pool (Lot 1)
12C	Ob2 Upper Ogbere	351	159,000	48,495,000
12F	Ob2 Upper Ogbere	810	370,000	112,850,000
12P	Ob2 Upper Ogbere	930	425,000	129,625,000
13	Ob3 Middle Ogbere	4500	1 <sup>st</sup> Pool (Lot 2)	1 <sup>st</sup> Pool (Lot 2)
13A	Ob3 Middle Ogbere	476	239,000	72,895,000
13E	Ob3 Middle Ogbere	487	198,000	60,390,000
13K	Ob3 Middle Ogbere	1176	614,000	187,270,000
13M	Ob3 Middle Ogbere	982	399,000	121,695,000
14	Ob4 Foworogbun	5618	5,751,000	1,754,055,000
14L	Ob4 Foworogbun	1265	626,000	190,930,000
14Q	Ob4 Foworogbun	1157	531,000	161,955,000
14V	Ob4 Foworogbun	1658	796,000	242,780,000
14X	Ob4 Foworogbun	409	145,000	44,225,000
15	Ob4 Foworogbun	2955	5,169,000	1,576,545,000
15H	Ob4 Foworogbun	1966	974,000	297,070,000
16	Ob5 Lower Ogbere North	2714	5,305,000	1,618,025,000
16D	Ob5 Lower Ogbere North	1895	948,000	289,140,000
16F	Ob5 Lower Ogbere North	1331	536,000	163,480,000
17	Ob5 Lower Ogbere North	2447	1,616,000	492,880,000
17H	Ob5 Lower Ogbere North	424	150,000	45,750,000
18	Ob5 Lower Ogbere North	3552	7,891,000	2,406,755,000
18H	Ob5 Lower Ogbere North	861	304,000	92,720,000
18K	Ob5 Lower Ogbere North	375	151,000	46,055,000
19	Ob5 Lower Ogbere North	1040	2,310,000	704,550,000
19A	Ob5 Lower Ogbere North	959	390,000	118,950,000
19B	Ob5 Lower Ogbere North	1373	800,000	244,000,000
1	Og1 Upper Ogunpa	3388	649,000	197,945,000
1E	Og1 Upper Ogunpa	919	374,000	114,070,000
1F	Og1 Upper Ogunpa	679	353,000	107,665,000
1H	Og1 Upper Ogunpa	1046	423,000	129,015,000
1P	Og1 Upper Ogunpa	646	260,000	79,300,000
2	Og2 Middle Ogunpa	6390	Existing Ogunpa	Existing Ogunpa
2C	Og2 Middle Ogunpa	448	233,000	71,065,000
2F	Og2 Middle Ogunpa	1488	835,000	254,675,000
2Q	Og2 Middle Ogunpa	1038	546,000	166,530,000
3	Og3 Kudeti	4161	2,252,000	686,860,000
4	Og3 Kudeti	3190	1,874,000	571,570,000
5	Og3 Kudeti	1702	1 <sup>st</sup> Pool (Lot 1)	1 <sup>st</sup> Pool (Lot 1)
5B	Og3 Kudeti	1269	658,000	200,690,000
5C	Og3 Kudeti	1148	397,000	121,085,000
6	Og4 Lower Ogunpa	2301	4,501,000	1,372,805,000
7	Og4 Lower Ogunpa	3355	1,973,000	601,765,000
7E	Og4 Lower Ogunpa	2113	1,182,000	360,510,000
8	Og4 Lower Ogunpa	3758	7,937,000	2,420,785,000
8D	Og4 Lower Ogunpa	426	149,000	45,445,000
9	Og4 Lower Ogunpa	4129	2,975,000	907,375,000
9F	Og4 Lower Ogunpa	990	402,000	122,610,000
10	Og4 Lower Ogunpa	4279	10,078,000	3,073,790,000
10B	Og4 Lower Ogunpa	1238	565,000	172,325,000
10B-3	Og4 Lower Ogunpa	409	165,000	50,325,000

Channel ID	Subbasin	Channel Length (m)	Total Cost of Channel (USD)	Total Cost of Channel (Naira)
24	OM2 Omi Headwaters South	1748	2,970,000	905,850,000
25	OM2 Omi Headwaters South	2353	1,189,000	362,645,000
26	OM2 Omi Headwaters South	2313	4,815,000	1,468,575,000
27	OM2 Omi Headwaters South	3275	3,672,000	1,119,960,000
27K	OM2 Omi Headwaters South	1597	931,000	283,955,000
28	OM2 Omi Headwaters South	2460	5,770,000	1,759,850,000
28A	OM2 Omi Headwaters South	3034	1,768,000	539,240,000
28D	OM2 Omi Headwaters South	1197	629,000	191,845,000
31	OM3 Upper Omi West	4744	3,441,000	1,049,505,000
32	OM3 Upper Omi West	6823	5,848,000	1,783,640,000
32C	OM3 Upper Omi West	436	226,000	68,930,000
32H	OM3 Upper Omi West	524	239,000	72,895,000
32P	OM3 Upper Omi West	183	64,000	19,520,000
33	OM3 Upper Omi West	3253	2,110,000	643,550,000
33F	OM3 Upper Omi West	1020	534,000	162,870,000
34	OM3 Upper Omi West	5964	10,748,000	3,278,140,000
34G	OM3 Upper Omi West	786	368,000	112,240,000
29	OM4 Upper Omi East	5428	4,176,000	1,273,680,000
29B	OM4 Upper Omi East	138	63,000	19,215,000
29E	OM4 Upper Omi East	886	360,000	109,800,000
30	OM4 Upper Omi East	5628	10,067,000	3,070,435,000
30D	OM4 Upper Omi East	2336	941,000	287,005,000
30H	OM4 Upper Omi East	439	179,000	54,595,000
35	OM4 Upper Omi East	3511	6,665,000	2,032,825,000
39	OM5 Middle Omi East	7356	6,976,000	2,127,680,000
39D	OM5 Middle Omi East	1060	483,000	147,315,000
39H	OM5 Middle Omi East	2583	1,340,000	408,700,000
39H-6	OM5 Middle Omi East	1126	513,000	156,465,000
39M	OM5 Middle Omi East	1507	693,000	211,365,000
36	OM6 Middle Omi West	8032	7,694,000	2,346,670,000
36A	OM6 Middle Omi West	680	356,000	108,580,000
36D	OM6 Middle Omi West	1834	1,001,000	305,305,000
36D-5	OM6 Middle Omi West	240	84,000	25,620,000
36D-7	OM6 Middle Omi West	1054	554,000	168,970,000
36M	OM6 Middle Omi West	1327	534,000	162,870,000
37	OM6 Middle Omi West	3042	1,913,000	583,465,000
37D	OM6 Middle Omi West	1217	633,000	193,065,000
38	OM6 Middle Omi West	1461	3,168,000	966,240,000
40	OM7 Middle Omi South	6302	4,870,000	1,485,350,000
40Q	OM7 Middle Omi South	303	107,000	32,635,000
41	OM7 Middle Omi South	4230	9,397,000	2,866,085,000
41B	OM7 Middle Omi South	681	274,000	83,570,000
42	OM7 Middle Omi South	3948	2,546,000	776,530,000
42H	OM7 Middle Omi South	113	40,000	12,200,000
42J	OM7 Middle Omi South	1360	675,000	205,875,000
43	OM7 Middle Omi South	2050	4,554,000	1,388,970,000
44	OM7 Middle Omi South	4672	3,703,000	1,129,415,000
44J	OM7 Middle Omi South	850	346,000	105,530,000
45	OM7 Middle Omi South	3687	8,551,000	2,608,055,000
45E	OM7 Middle Omi South	2128	963,000	293,715,000
45H	OM7 Middle Omi South	2871	1,535,000	468,175,000
66	ON6 Upper Ona West	2110	4,434,000	1,352,370,000
66C	ON6 Upper Ona West	2605	1,557,000	474,885,000
67	ON6 Upper Ona West	3838	2,728,000	832,040,000

Channel ID	Subbasin	Channel Length (m)	Total Cost of Channel (USD)	Total Cost of Channel (Naira)
68	ON6 Upper Ona West	661	1,216,000	370,880,000
68A	ON6 Upper Ona West	1852	827,000	252,235,000
68C	ON6 Upper Ona West	2075	1,209,000	368,745,000
53G	ON7 Upper Ona East	1307	611,000	186,355,000
53J	ON7 Upper Ona East	2587	1,281,000	390,705,000
53M	ON7 Upper Ona East	2229	1,227,000	374,235,000
54	ON7 Upper Ona East	2640	1,503,000	458,415,000
54D	ON7 Upper Ona East	1035	416,000	126,880,000
55	ON7 Upper Ona East	3222	6,085,000	1,855,925,000
55B	ON7 Upper Ona East	1752	1,189,000	362,645,000
55F	ON7 Upper Ona East	202	81,000	24,705,000
56	ON8 Upper Ona South	4900	4,527,000	1,380,735,000
56B	ON8 Upper Ona South	213	86,000	26,230,000
56E	ON8 Upper Ona South	698	281,000	85,705,000
56H	ON8 Upper Ona South	2056	1,080,000	329,400,000
56K	ON8 Upper Ona South	1316	728,000	222,040,000
58	ON8 Upper Ona South	3900	8,309,000	2,534,245,000
57	ON8 Upper Ona South	4021	2,662,000	811,910,000
70	ON9 Orogun	5466	1 <sup>st</sup> Pool (Lot 1)	1 <sup>st</sup> Pool (Lot 1)
70J	ON9 Orogun	1840	741,000	226,005,000
70P	ON9 Orogun	1429	698,000	212,890,000
70Q	ON9 Orogun	1826	937,000	285,785,000
69	ON10 Middle Ona North	2576	5,599,000	1,707,695,000
69C	ON10 Middle Ona North	439	231,000	70,455,000
71	ON10 Middle Ona North	2906	7,394,000	2,255,170,000
71C	ON10 Middle Ona North	2997	1,898,000	578,890,000
72	ON10 Middle Ona North	4923	4,456,000	1,359,080,000
72F	ON10 Middle Ona North	312	126,000	38,430,000
72H	ON10 Middle Ona North	718	289,000	88,145,000
73	ON10 Middle Ona North	1166	3,570,000	1,088,850,000
73D	ON10 Middle Ona North	1235	589,000	179,645,000
74	ON10 Middle Ona North	2400	1,523,000	464,515,000
74N	ON10 Middle Ona North	3069	1,829,000	557,845,000
75E	ON10 Middle Ona North	400	162,000	49,410,000
79	ON11 Alapata South	4461	8,604,000	2,624,220,000
79B	ON11 Alapata South	1535	624,000	190,320,000
79D	ON11 Alapata South	734	295,000	89,975,000
79G	ON11 Alapata South	2399	1,094,000	333,670,000
79L	ON11 Alapata South	2379	1,272,000	387,960,000
79M	ON11 Alapata South	1206	550,000	167,750,000
81	ON12 Middle Ona West	8080	7,545,000	2,301,225,000
81F	ON12 Middle Ona West	760	306,000	93,330,000
81J	ON12 Middle Ona West	740	337,000	102,785,000
82	ON12 Middle Ona West	6075	4,843,000	1,477,115,000
82E	ON12 Middle Ona West	425	172,000	52,460,000
82J	ON12 Middle Ona West	515	207,000	63,135,000
82M	ON12 Middle Ona West	2027	1,274,000	388,570,000
80	ON13 Middle Ona South	5488	13,193,000	4,023,865,000
80A	ON13 Middle Ona South	290	117,000	35,685,000
80B	ON13 Middle Ona South	1108	646,000	197,030,000
80B-3	ON13 Middle Ona South	383	155,000	47,275,000
80K	ON13 Middle Ona South	1461	671,000	204,655,000
80L	ON13 Middle Ona South	2440	1,407,000	429,135,000
80U	ON13 Middle Ona South	805	418,000	127,490,000

Channel ID	Subbasin	Channel Length (m)	Total Cost of Channel (USD)	Total Cost of Channel (Naira)
83	ON14 Lower Ona North	7415	2,733,000	833,565,000
83F	ON14 Lower Ona North	2523	1,493,000	455,365,000
83G	ON14 Lower Ona North	925	454,000	138,470,000
83H	ON14 Lower Ona North	1031	415,000	126,575,000
83M	ON14 Lower Ona North	2619	1,704,000	519,720,000
84	ON15 Alaro	4013	2,510,000	765,550,000
84D	ON15 Alaro	1271	582,000	177,510,000
85	ON15 Alaro	6090	5,428,000	1,655,540,000
85F	ON15 Alaro	541	218,000	66,490,000
85G	ON15 Alaro	1079	562,000	171,410,000
85L	ON15 Alaro	1520	795,000	242,475,000
86	ON15 Alaro	3247	5,635,000	1,718,675,000
86C	ON15 Alaro	1070	527,000	160,735,000
86G	ON15 Alaro	699	247,000	75,335,000
89	ON16 Agara Kasumu	7867	7,867,000	2,399,435,000
89L	ON16 Agara Kasumu	1974	933,000	284,565,000
89M	ON16 Agara Kasumu	231	93,000	28,365,000
87	ON17 Lower Ona East	3107	1,946,000	593,530,000
87E	ON17 Lower Ona East	482	250,000	76,250,000
88	ON17 Lower Ona East	3893	2 <sup>nd</sup> Pool (Lot 3)	2 <sup>nd</sup> Pool (Lot 3)
88D	ON17 Lower Ona East	1679	858,000	261,690,000
88E	ON17 Lower Ona East	615	280,000	85,400,000
88G	ON17 Lower Ona East	529	187,000	57,035,000
91	ON18 Lower Ona South	4118	12,123,000	3,697,515,000
91H	ON18 Lower Ona South	2612	1,480,000	451,400,000
90	ON19 Lower Ona West	6544	6,728,000	2,052,040,000
90M	ON19 Lower Ona West	624	254,000	77,470,000
90N	ON19 Lower Ona West	419	170,000	51,850,000
	<b>Total</b>	<b>418,078</b>	<b>381,128,000</b>	<b>116,244,040,000</b>

**7.3.3.2. Separate Crossing Structures lying on Natural Streams**

Similarly to the previous section, Annex 12 presents the cost estimate of separate crossing structures lying on natural streams. There are 8 proposed bridges lying on natural streams with a total cost of 17 MUSD (5.2 B Naira). Moreover, there are 845 proposed culverts lying on natural streams with a total cost of 43.9 MUSD (13.4 B Naira). Table 7.8 summarizes the cost estimate of crossing structures (Bridges/Culverts) lying on natural streams.

**Table 7.8: Cost of Culverts and Bridges lying on Natural Streams in USD and Naira**

	Structures on Natural Streams		
	No.	Cost (MUSD)	Cost (B Naira)
<b>Culverts</b>	845	43.9	13.4
<b>Bridges</b>	8	17.0	5.2
<b>Total</b>		<b>60.9</b>	<b>18.6</b>

**7.3.3.3. Dams**

This section describes the tentative evaluation of construction cost related to the development of the earthfill dam with clay core and other appurtenant structures. Table 7.9 shows the main items in the roughly cost estimate of the proposed dams with its associated spillway and bottom outlets (culverts).

**Table 7.9: Cost Estimate for Proposed Dams in Ibadan**

Dam ID	4	22	74	77
Site Preparation - Installation, Clearing and Stripping	200,000	230,000	240,000	210,000
Excavation and Dewatering (Rock & Common Excavation)	40,072,000	46,082,800	48,086,400	42,075,600
Embankment Construction and Slope Protection Works	138,647,000	159,444,050	166,376,400	145,579,350
Concrete DAM and Abutments	28,953,000	33,295,950	34,743,600	30,400,650
Foundation Treatment	10,977,000	12,623,550	13,172,400	11,525,850
Monitoring System	935,000	1,075,250	1,122,000	981,750
HM equipment	6,000,000	6,900,000	7,200,000	6,300,000
External buildings	1,020,000	1,173,000	1,224,000	1,071,000
<b>Total cost USD</b>	<b>226,804,000</b>	<b>260,824,600</b>	<b>272,164,800</b>	<b>238,144,200</b>

**7.4. Prioritization of Drainage Masterplan**

Setting an implementation strategy for drainage masterplan interventions is important for the future development of Ibadan. The purpose of prioritization is to identify the areas where the greatest impact of drainage improvements in the systems will be felt in socio-economic terms and future urban planning, and hence arranging them in a coordinated manner based on a set of aspects such as damage losses, risk on human casualties, upstream-downstream inter-relationship, importance of Location, transportation and economic activities, etc..

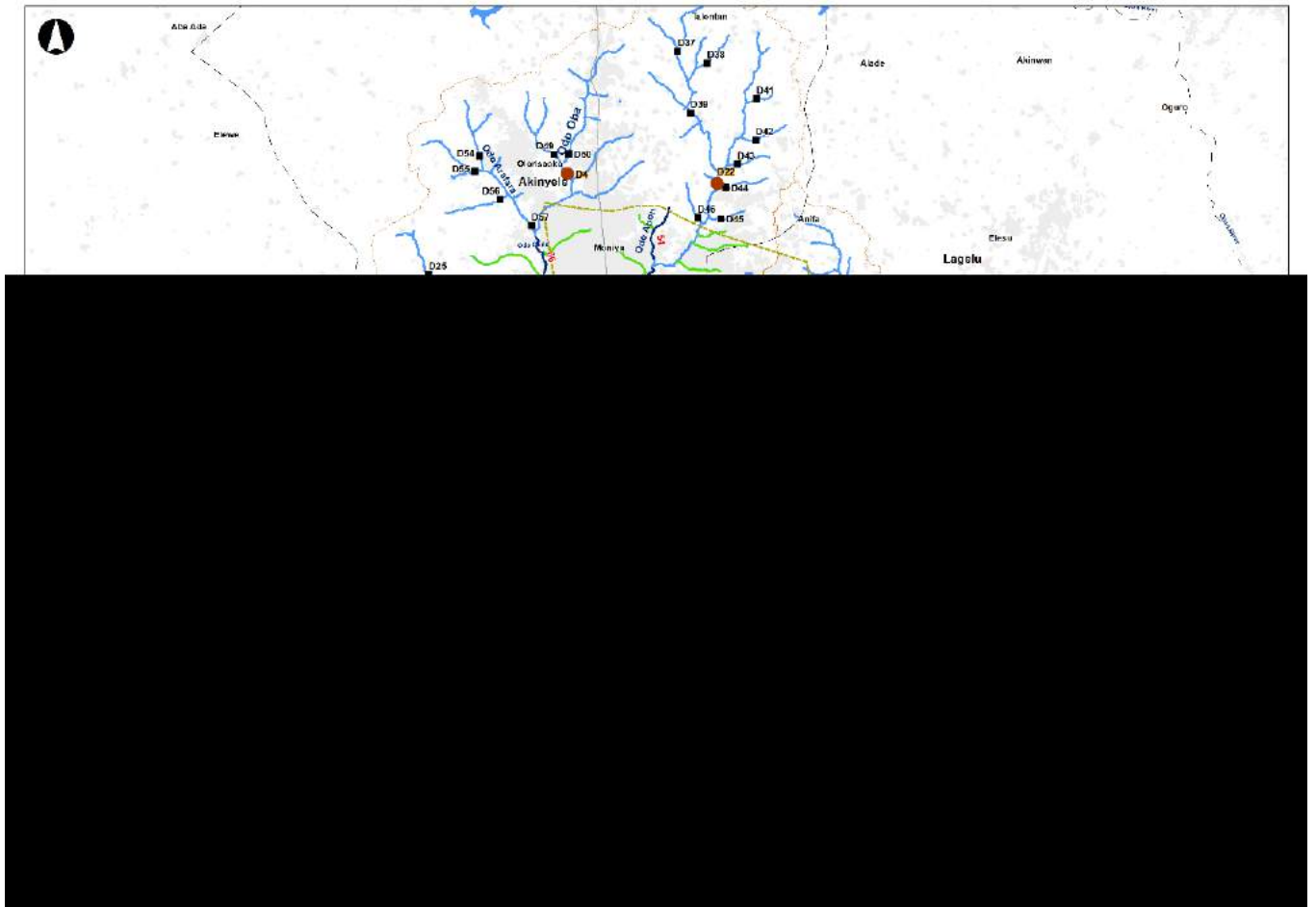
The drainage system for Ibadan comprises two main elements, systems; which are channels associated with structures and crossings needed for rehabilitation, and separate structures; which are separate crossings lying on natural streams. A twenty-year plan is proposed to implement all proposed drainage masterplan works starting from year 2021 to 2040, in addition to the works included in the three pools of priority works; where the detailed design and tender documents has been prepared and are ready for implementation.

The total cost of rehabilitation of the proposed drainage works is 683 MUSD. Excluding 155 MUSD for the three pools of priority works, then the total budget for the drainage masterplan is 528 MUSD. This budget is to be distributed among the 20-year action plan in four phases 5-years each. The implementation strategy as well as the adopted approach for prioritization for systems/channels and separate structures will be discussed in detail in the next sections.

**7.4.1. Approach for Prioritization**

**7.4.1.1. Selection of Prioritized Channels**

The Drainage Masterplan comprises 69 proposed main systems with their associative sub-systems, making a total of 188 systems as shown in Figure 7.15. These systems have a total length of 418 km and a total cost estimate of around 470 MUSD. All systems are associated with structures and crossings needed for rehabilitation.



**Figure 7.15: Proposed Systems in Ibadan**

To analyze the priority works, it is necessary to select the works that has the highest positive impact on citizens that could save them from potential flood damages, losses, casualties and risk analysis. The consultant studied two types of criteria:

- 1- Damage losses criterion, and
- 2- Risk zone criterion or Hotspots.

**a. Damage losses criterion**

- The 100-year return period is chosen as the significant return period to clarify the damage losses in each selected system.
- Areas that experience high damage losses are more important than those with less damages.
- Drainage systems with the most expected damage losses were selected in the 1st Phase in order to reduce expected damages and save the lives of people.



**7.4.2. Drainage Masterplan Implementation Strategy (Recommended Action Plan)**

As previously mentioned, a phasing strategy is important to ensure that the Drainage Masterplan in Ibadan is developed in a well-coordinated manner. This will ensure that priority areas are developed according to their importance and based on the areas subject to high risk of flooding.

In this respect, the recommended action plan for the Drainage Masterplan proposes the commencement of implementation of the three Pool of Priority Works at first, and hence the remainder masterplan drainage works are divided into 4 phases with a 5-five-year plan period for each phase as follows:

1. First Phase from year 2021 to 2025.
2. Second Phase from year 2026 to 2030.
3. Third Phase from year 2031 to 2035.
4. Fourth Phase from year 2036 to 2040.

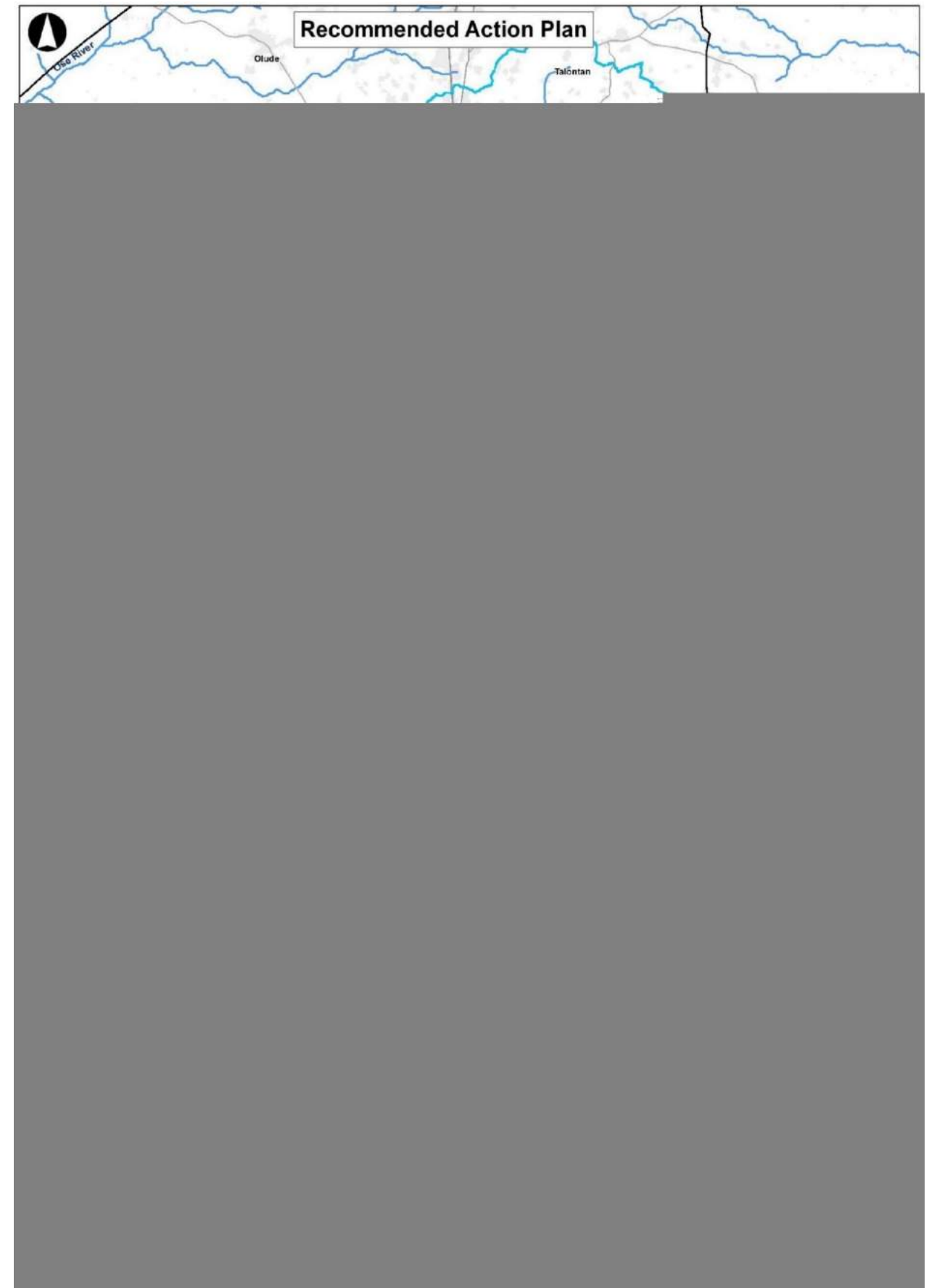
Figure 7.18 shows recommended action plan Ibadan drainage masterplan.

The total cost needed for rehabilitation works in Ibadan drainage master plan is 683 MUSD. Considering 155 MUSD as the rehabilitation cost for the three pools of priority works, the rest (528 MUSD) will be divided on the four phases (20 years plan). Figure 7.17 shows the required budgets for each of the drainage masterplan phases. It is to note that the budgets allocated for each phase may subject to changes (increase or decrease) depending on the government’s aspiration in allocating a certain budget that may be smaller or higher than the proposed budget.

The following sections describes the drainage works included in each of the drainage masterplan implementation phase.



**Figure 7.17: Action Plan Budget Classification**



**Figure 7.18: Recommended Action Plan for Ibadan Drainage Masterplan**

#### 7.4.2.1. First, Second and Third Pool of Priority Works

As per the Terms of Reference, the Flood Risk Management and Drainage Masterplan Project identified and prepared three pools of priority works (works volume between 30-40 million USD for each pool). Those no-regret infrastructure works are designed to mitigate flood risk on the short term. This is followed-up by the preparation of their detailed design, and tender documents to allow the kick-off of implementation of those infrastructure works.

Based on the above, Dar prepared three pools of works (Table 7.10 & Figure 7.19) which are sub-divided into four lots; these lots cover the channelization of major rivers such as Ona River and major tributaries such as Upper Ogunpa, Kudeti, Ogbere and Orogun. The channelization includes the rehabilitation of the crossing structures lying along these channels. The three pool of priority works include the rehabilitation of some separate crossing structures that required urgent upgrade to their infrastructure ability. In addition, the three pools include measures to reduce flood risk along lower Ona River.

The estimated rehabilitation cost for the three pools of priority works is 155 MUSD. These works are ready for tendering and should commence in implementation as soon as possible, before commencing in the 20-year drainage masterplan action plan.

**Table 7.10: Works Included in The First, Second & Third Pools of Priority Works**

Pools	Lots	Works	Total Cost
First Pool	Lot 1	Agodi River (2,295 m)	39 MUSD
		Kudeti & Olojuoro River (2,495 m)	
		Orogun River (2,330 m)	
		North Ogbere River (6,900 m)	
	Lot 2	South Ogbere River (4,500 m)	16.7 MUSD
		Separate Structures (7 Structures)	
Second Pool	Lot 3a	Ona1 River (6,250 m)	30 MUSD
	Lot 3b	17 Dikes in the upper catchment of Ona River	14.7 MUSD
Third Pool	Lot 4	Ona 2 & 3 Rivers (8700 m)	54.5 MUSD
		Alaro River (750 m)	

7.4.2.2. Phase 1 – From year 2021 to 2025

The first phase from 2021-2025 will focus on drainage systems with the most expected damage losses and more vulnerable to flood risks, in order to reduce expected damages and save the lives of people. The systems/channels were classified based on the criteria mentioned in section 7.4.1.1. Figure 7.21 shows the selected channels to be implemented in phase 1, from year 2021 to year 2025. Separate structures lying on natural streams- were prioritized based on the criteria mentioned in section 7.4.1.2, Annex 16 presents the selected structures, year of implementation and cost of rehabilitation.

An estimated total budget of 146 MUSD is proposed to serve the priority channels and structures in phase 1. This estimated budget (146 MUSD) consists of 121.7 MUSD for channels with structures lying along it, and 24.2 MUSD for separate structures lying on natural streams. This total budget (146 MUSD) will be divided among the 5-year plan of the phase, Figure 7.20 shows the different classifications of the total budget.

It worth mentioning that the implementation strategy considered the interrelationship between the downstream and the upstream works. However, in this phase particularly, downstream systems shall be vulnerable to flooding. In this respect, it is necessary to warn people in the downstream areas during the application of this phase by the preventive measures indicated in the Masterplan. It is to note also that phase 1 works should only commence in implementation after the execution of the three pools of priority works.

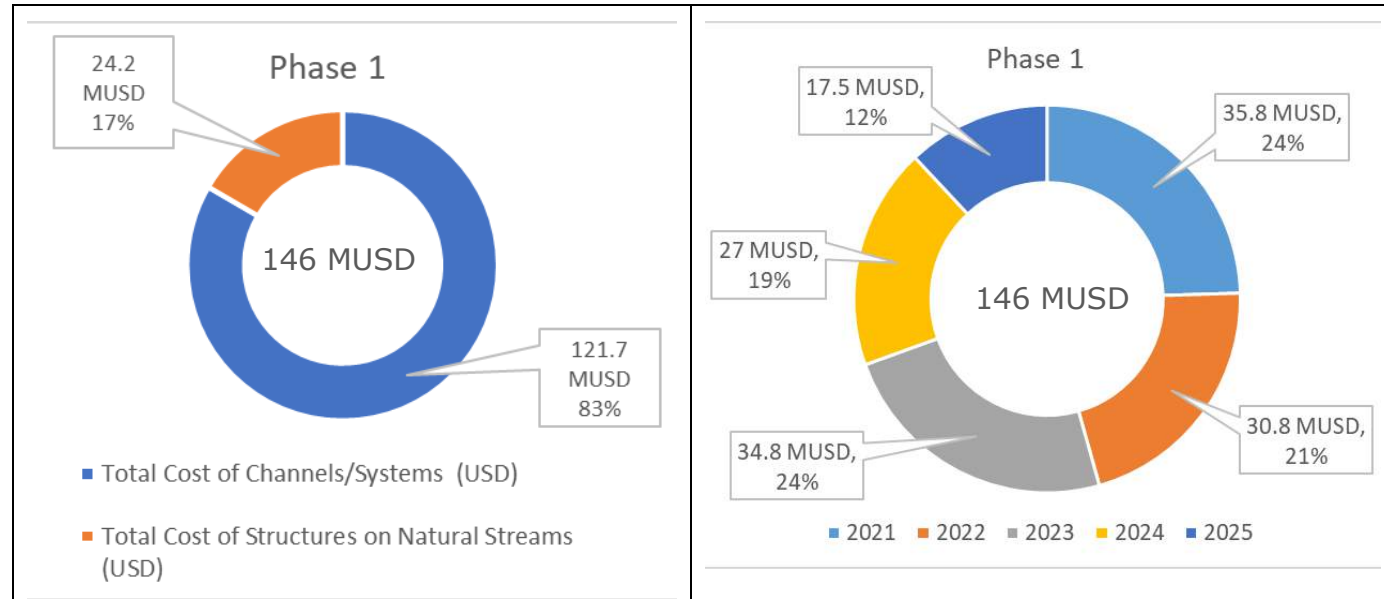


Figure 7.20: Classifications of Phase 1 Total Budget

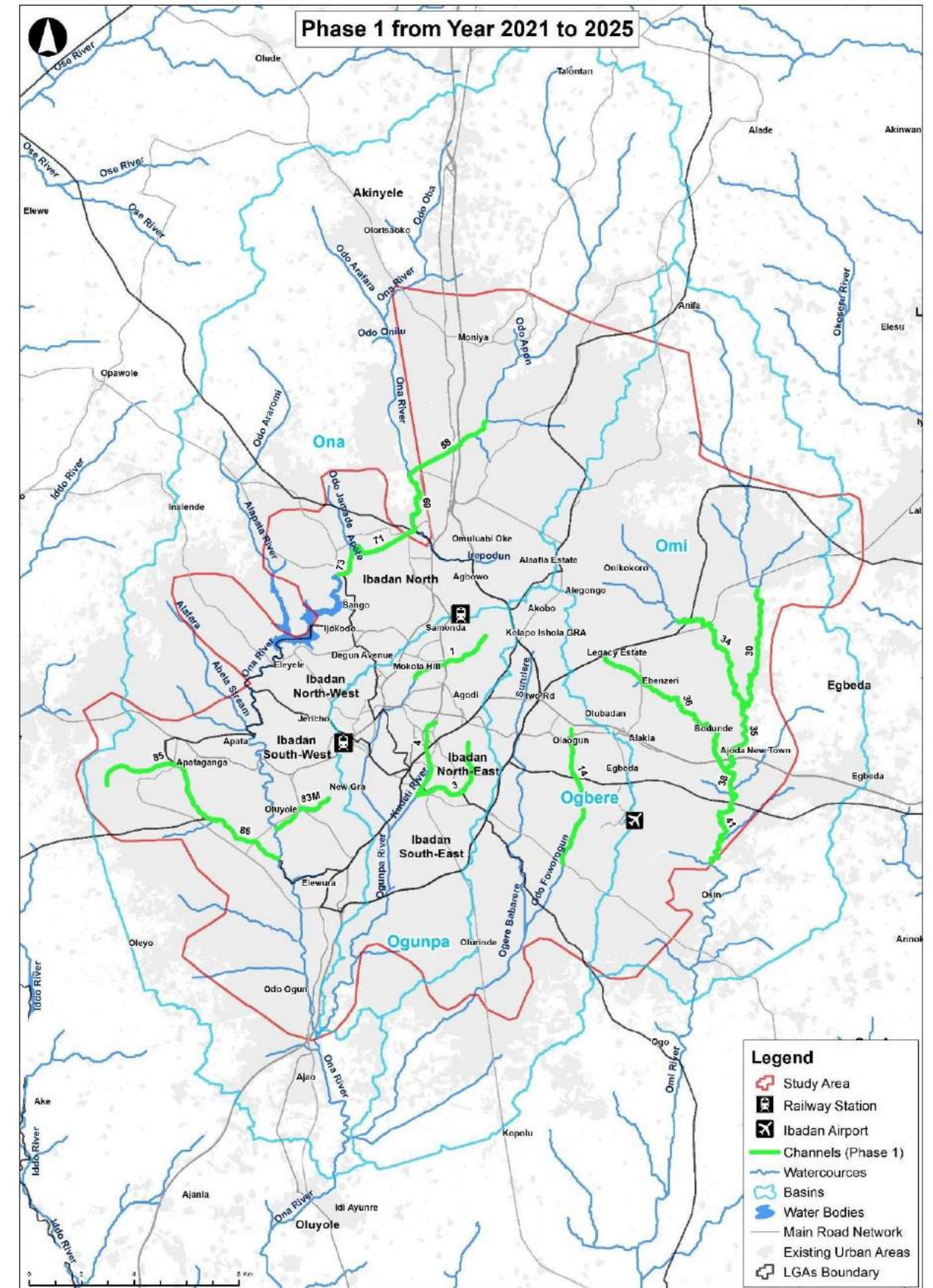


Figure 7.21: Systems to be Implemented in The First Phase (2021-2025)

The selected channels in the first phase from year 2021 to 2025 with their length, rehabilitation cost estimate for each system, year of implementation, and the total cost of rehabilitation works per year are presented in Table 7.11, while Figure 7.22 shows total cost of rehabilitation of channels per year in phase 1.

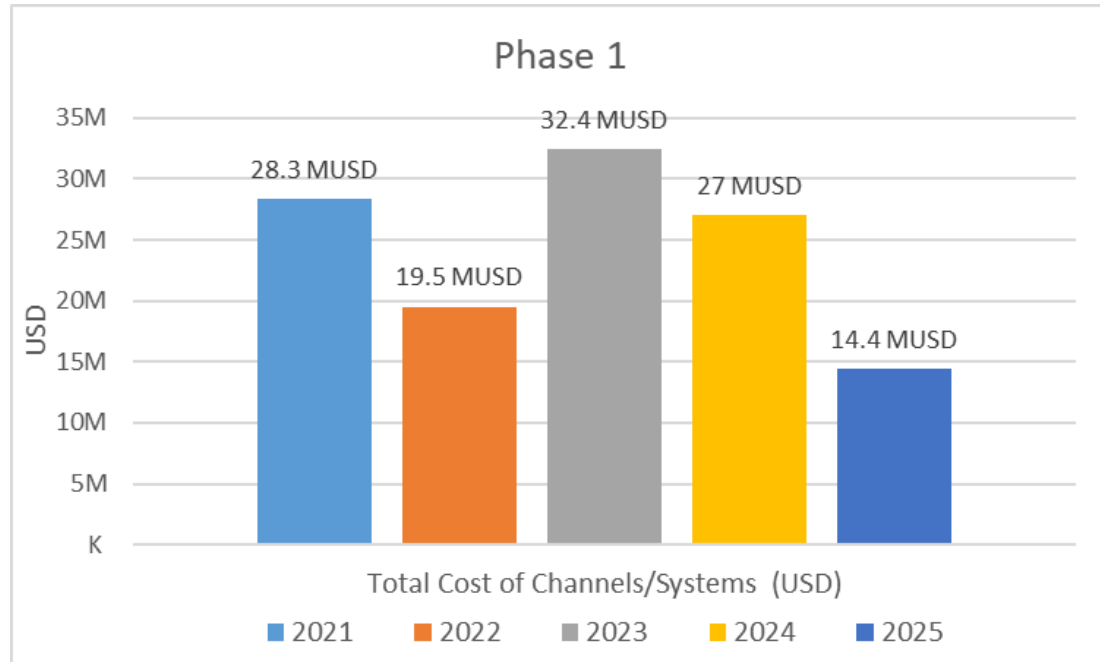


Figure 7.22: Total Cost of Rehabilitation for Channels per Year in phase 1

Table 7.11: Selected channels in Phase 1 from year 2021 to year 2025

Channel ID	Subbasin	Channel Length (m)	Cost of Rehabilitation of Channel/system (USD)	Year	Total Cost of Rehabilitation Works/year (USD)
1	Og1 Upper Ogunpa	3,388	705,000	2021	28,312,400
4	Og3 Kudeti	3,190	2,323,600		
86	ON15 Alaro	3,247	6,366,200		
14	Ob4 Foworogbun	5,618	6,520,600		
41	OM7 Middle Omi South	4,230	12,397,000		
3	Og3 Kudeti	4,161	2,746,400	2022	19,524,400
38	OM6 Middle Omi West	1,461	3,168,000		
35	OM4 Upper Omi East	3,511	10,040,000		
73	ON10 Middle Ona North	1,166	3,570,000		
71	ON10 Middle Ona North	2,906	8,769,000	2023	32,447,200
36	OM6 Middle Omi West	8,032	9,361,200		
30	OM4 Upper Omi East	5,628	14,317,000		
85	ON15 Alaro	6,090	7,685,600	2024	27,045,000
69	ON10 Middle Ona North	2,576	5,599,000		
34	OM3 Upper Omi West	5,964	13,760,400		
83M	ON14 Lower Ona North	2,619	1,993,600	2025	14,427,600
58	ON8 Upper Ona South	3,900	12,434,000		

The total cost estimates for channels and separate structures for each year, as well as the total per phase 1, are presented in Table 7.12 and Figure 7.23.

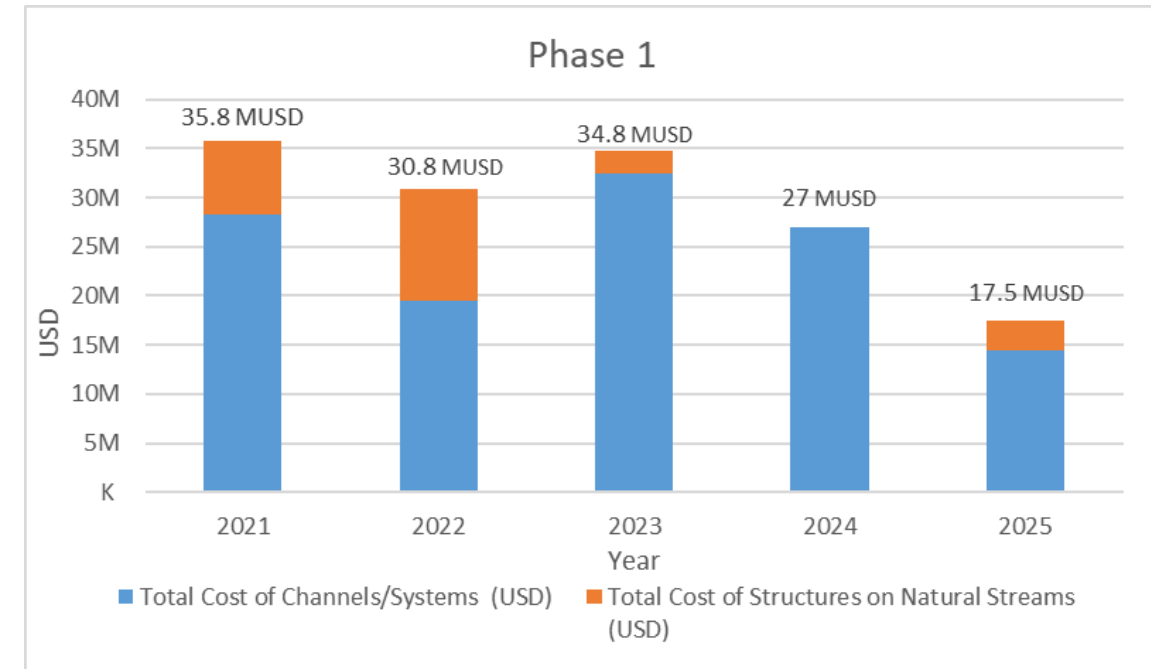


Figure 7.23: Total Cost Estimates for Channels and Separate Structures Rehabilitation for Each Year in Phase 1

Table 7.12: Total Cost Estimates for Channels and Separate Structures Each Year in Phase 1

Phase	YEAR	Total Cost of Systems/Channels (USD)	Total Cost of Separate Structures on Natural Streams (USD)	Total (USD)
Phase 1	2021	28,312,400	7,480,000	35,792,400
	2022	19,524,400	11,296,400	30,820,800
	2023	32,447,200	2,377,600	34,824,800
	2024	27,045,000		27,045,000
	2025	14,427,600	3,060,800	17,488,400
<b>Total</b>		<b>121,756,600</b>	<b>24,214,800</b>	<b>145,971,400</b>

7.4.2.3. Phase 2 - From year 2026 to 2030

In the 2nd phase, from year 2026 to 2030, the consultant selected the downstream channels of Omi, Ogbere and Ogunpa basins to be implemented in order to protect these downstream areas from the interventions that undergoes in the upstream areas. And hence, selecting other upstream systems that are exposed to high damage losses and are vulnerable to flood risks, in order to reduce expected damages and protect more people.

Based on the above, and the criteria mentioned in section 7.4.1.1, the channels selected to be implemented in phase 2, from year 2026 to year 2030, are shown in Figure 7.25. while, the separate structures were prioritized based on the criteria mentioned in section 7.4.1.2, the selected structures are presented in Annex 16 with its year of implementation and cost of rehabilitation.

An estimated budget of 133.5 MUSD is proposed to serve the priority channels and structures in phase 2. The estimated total budget of 133.5 MUSD consists of 116.4 MUSD for channels with structures lying along it, and 17.1 MUSD for separate structures lying on natural streams. This total budget (133.5 MUSD) will be divided among the 5-year plan of the phase, Figure 7.24 shows the different classifications of the total budget.

It worth mentioning that the implementation strategy in phase 2 considered the interrelationship between the downstream and the upstream areas, so it is crucial to commence implementation of works in a coordinated manner as presented in Table 7.13. It is to note also that phase 2 works should commence in implementation after the execution of the phase 1 interventions.

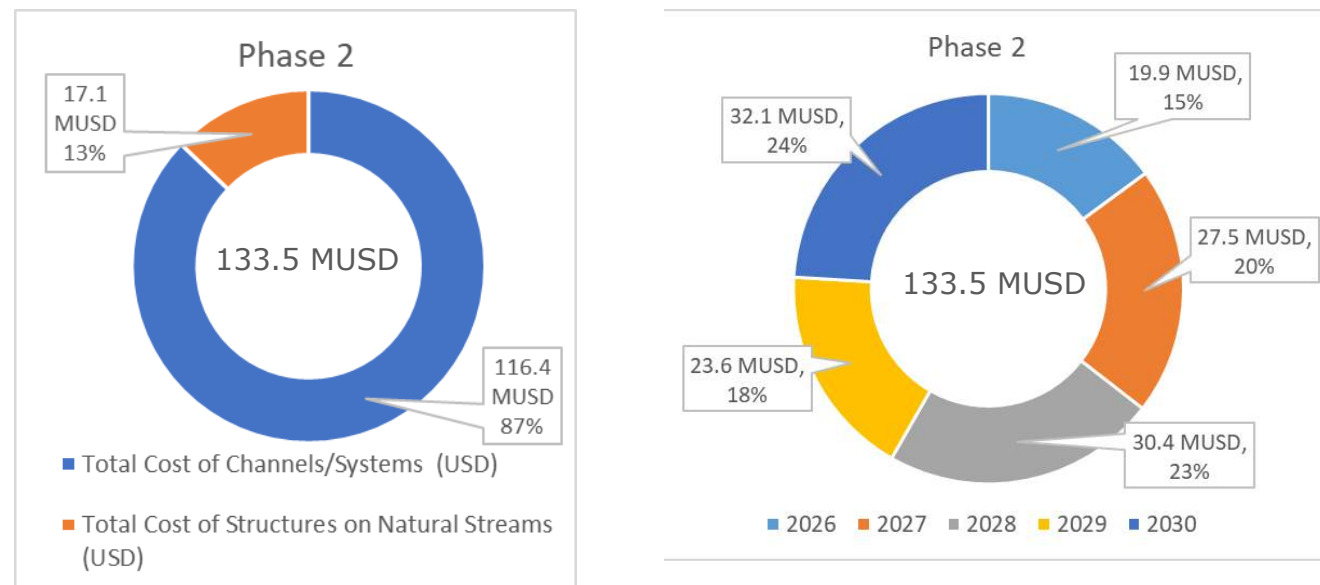


Figure 7.24: Classifications of Phase 2 Total Budget

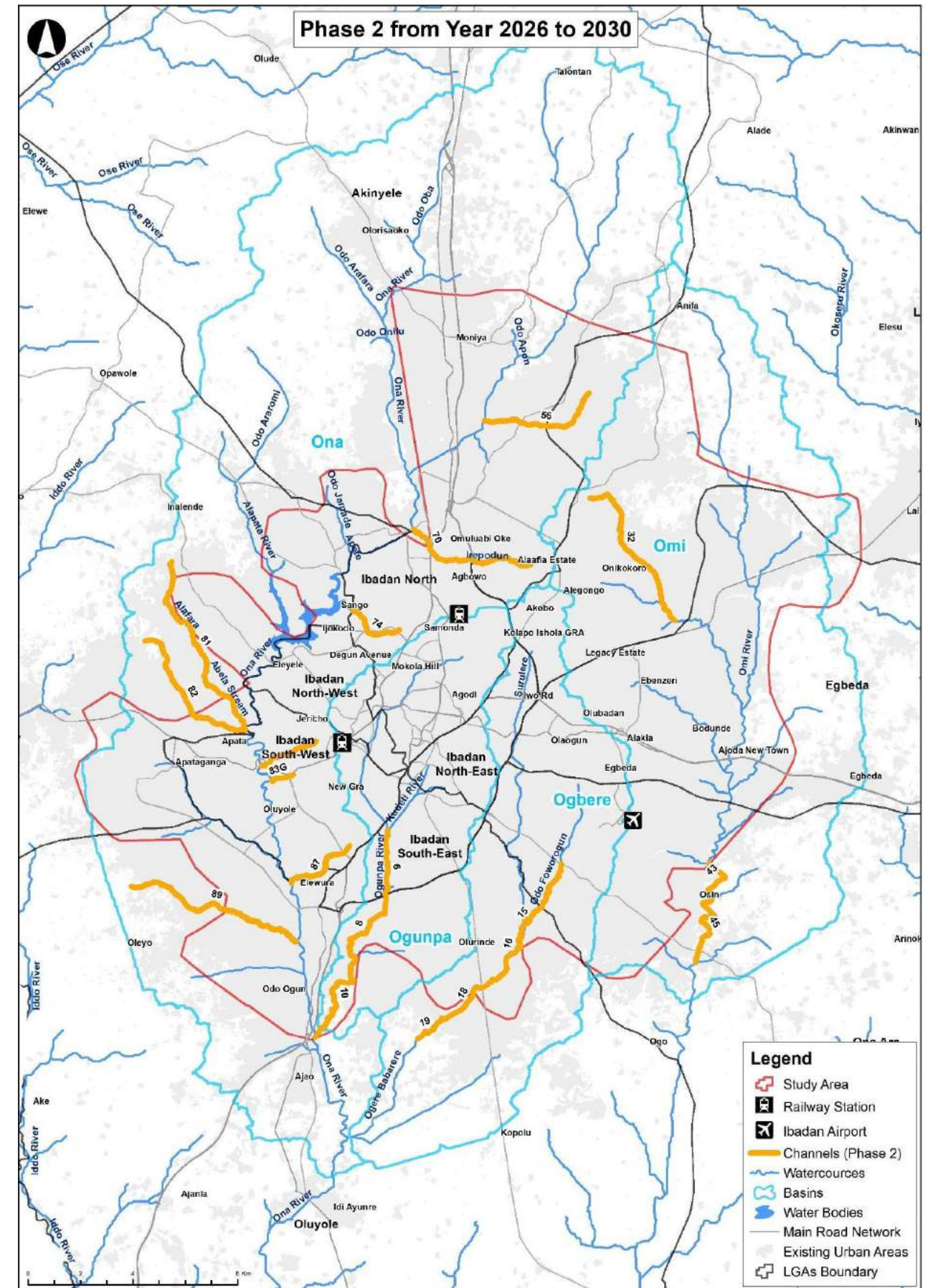
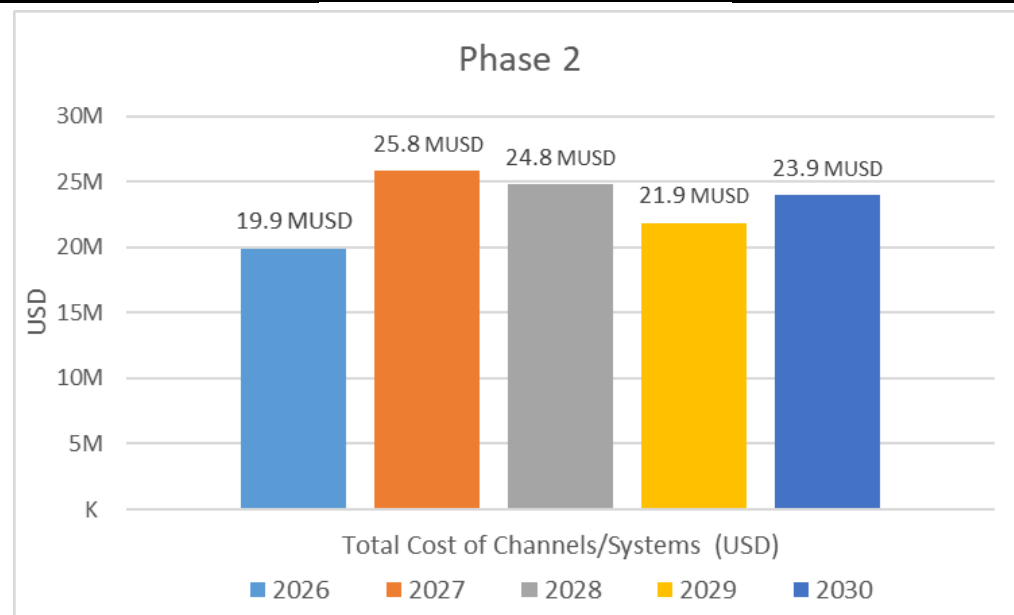


Figure 7.25: Systems to be Implemented in The Second Phase (2026 - 2030)

The channels selected in the second phase from year 2026 to 2030 with their lengths, rehabilitation cost estimate for each system, year of implementation, and the total cost of rehabilitation works per year are presented in Table 7.13, while Figure 7.26 shows total cost of rehabilitation of channels per year in phase 2.

**Table 7.13: Selected Systems in Phase 2 from year 2026 to year 2030**

Channel ID	Subbasin	Channel Length (m)	Cost of Channel/system (USD)	Total Cost of Rehabilitation Works/year (USD)	YEAR
45	OM7 Middle Omi South	3,687	11,551,000	19,915,000	2026
43	OM7 Middle Omi South	2,050	6,054,000		
19	Ob5 Lower Ogbere North	1,040	2,310,000		
18	Ob5 Lower Ogbere North	3,552	7,891,000	25,867,400	2027
16	Ob5 Lower Ogbere North	2,714	12,305,000		
15	Ob4 Foworogbun	2,955	5,671,400		
10	Og4 Lower Ogunpa	4,279	11,203,000	24,766,000	2028
8	Og4 Lower Ogunpa	3,758	9,062,000		
6	Og4 Lower Ogunpa	2,301	4,501,000		
82	ON12 Middle Ona West	6,075	6,003,000	21,856,600	2029
74	ON10 Middle Ona North	2,400	1,758,200		
32	OM3 Upper Omi West	6,823	7,877,600		
56	ON8 Upper Ona South	4,900	5,395,800		
70	ON9 Orogun	5,466	822,000		
83F	ON14 Lower Ona North	2,523	1,747,400	23,945,000	2030
89	ON16 Agara Kasumu	7,867	10,041,400		
87	ON17 Lower Ona East	3,107	2,306,000		
83G	ON14 Lower Ona North	925	594,800		
81	ON12 Middle Ona West	8,080	9,255,400		

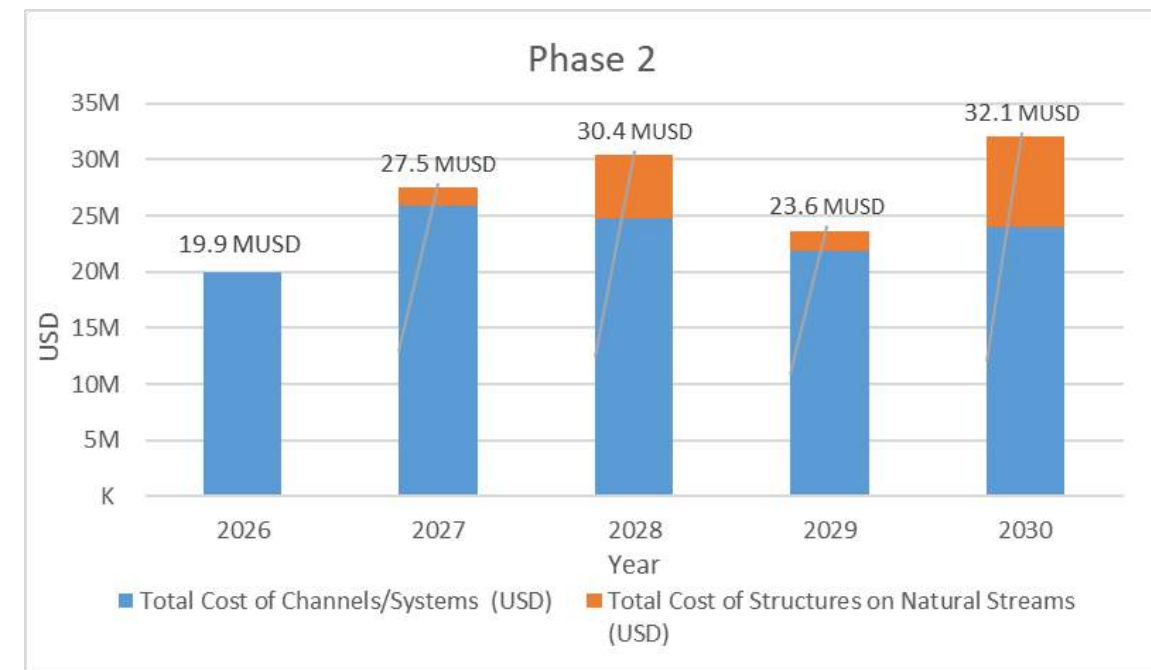


**Figure 7.26: Total Cost of Rehabilitation of Channels per Year in phase 2**

Also, the total cost estimates for channels and separate structures for each year, as well as the total budget for phase 2 are presented in Table 7.14 and Figure 7.27.

**Table 7.14: Total cost estimates for channels and separate structures each year in phase 2**

Phase	YEAR	Total Cost of Channel/System with Associative Structures (USD)	Total Cost of Structures on Natural Streams (USD)	Total (USD)
Phase 2	2026	19,915,000		19,915,000
	2027	25,867,400	1,625,000	27,492,400
	2028	24,766,000	5,620,000	30,386,000
	2029	21,856,600	1,747,200	23,603,800
	2030	23,945,000	8,156,800	32,101,800
<b>Total</b>		<b>116,350,000</b>	<b>17,149,000</b>	<b>133,499,000</b>



**Figure 7.27: Total Cost Estimates for Channels and Separate Structures Rehabilitation for Each Year in Phase 2**

7.4.2.4. Phase 3 – From year 2031 to 2035

The third phase, from year 2031-2035, focuses on third degree projects that are less vulnerable to flood risks and damage losses. The implementation strategy follows the criteria mentioned in section 7.4.1.1 in a coordinated manner such that downstream drainage systems to be implemented prior to upstream drainage systems. The channels selected to be implemented in phase 3, from year 2031 to year 2036, are shown in Figure 7.29. While, the separate structures were prioritized based on the criteria mentioned in section 7.4.1.2 and the selected structures are presented in Annex 16 with its year of implementation and cost of rehabilitation.

A total estimated budget of 121.5 MUSD is proposed to serve the priority channels and structures in phase 3. The estimated budget (121.5 MUSD) consists of 117.6 MUSD for channels with structures lying along it, and 3.9 MUSD for the separate structures lying on natural streams. This total budget (121.5 MUSD) will be divided among the 5-year plan of the phase, Figure 7.28 shows the different classifications of the total budget.

It is to mention that the implementation strategy in phase 3 considered the interrelationship between the downstream and the upstream areas, so it is crucial to commence the implementation of works in a coordinated manner as presented in Table 7.15. It is to note also that phase 3 works should commence in implementation after the execution of the phase 2 interventions.

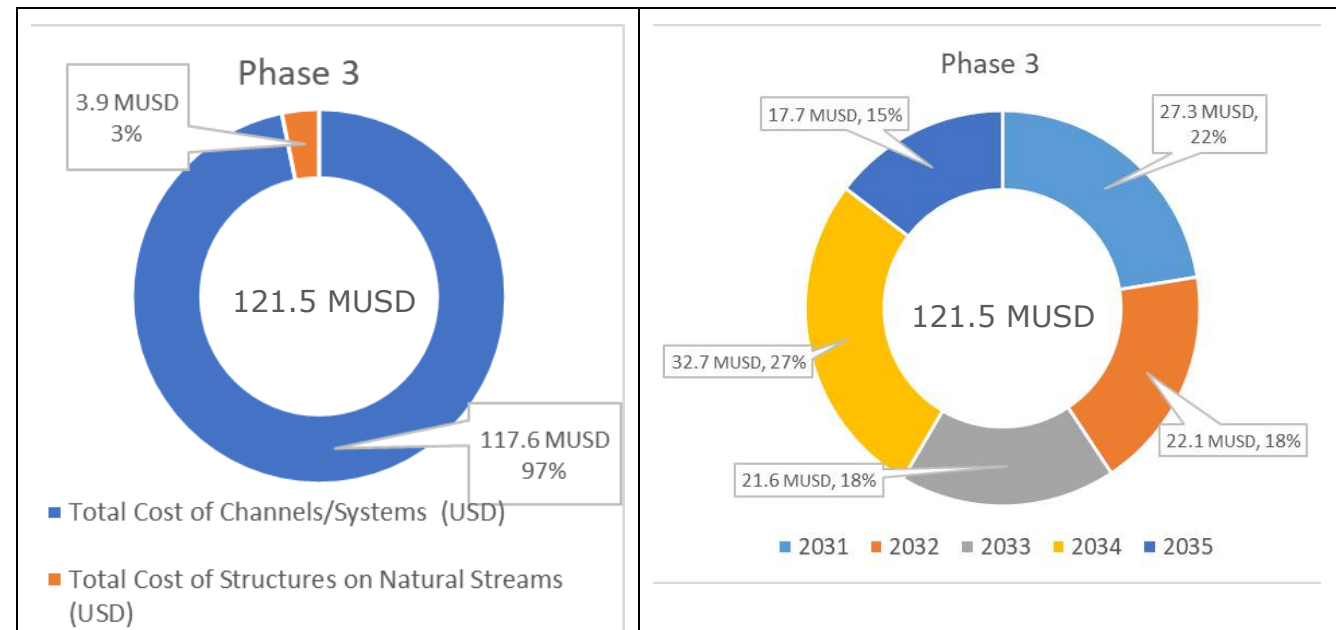


Figure 7.28: Classifications of Phase 3 Total Budget

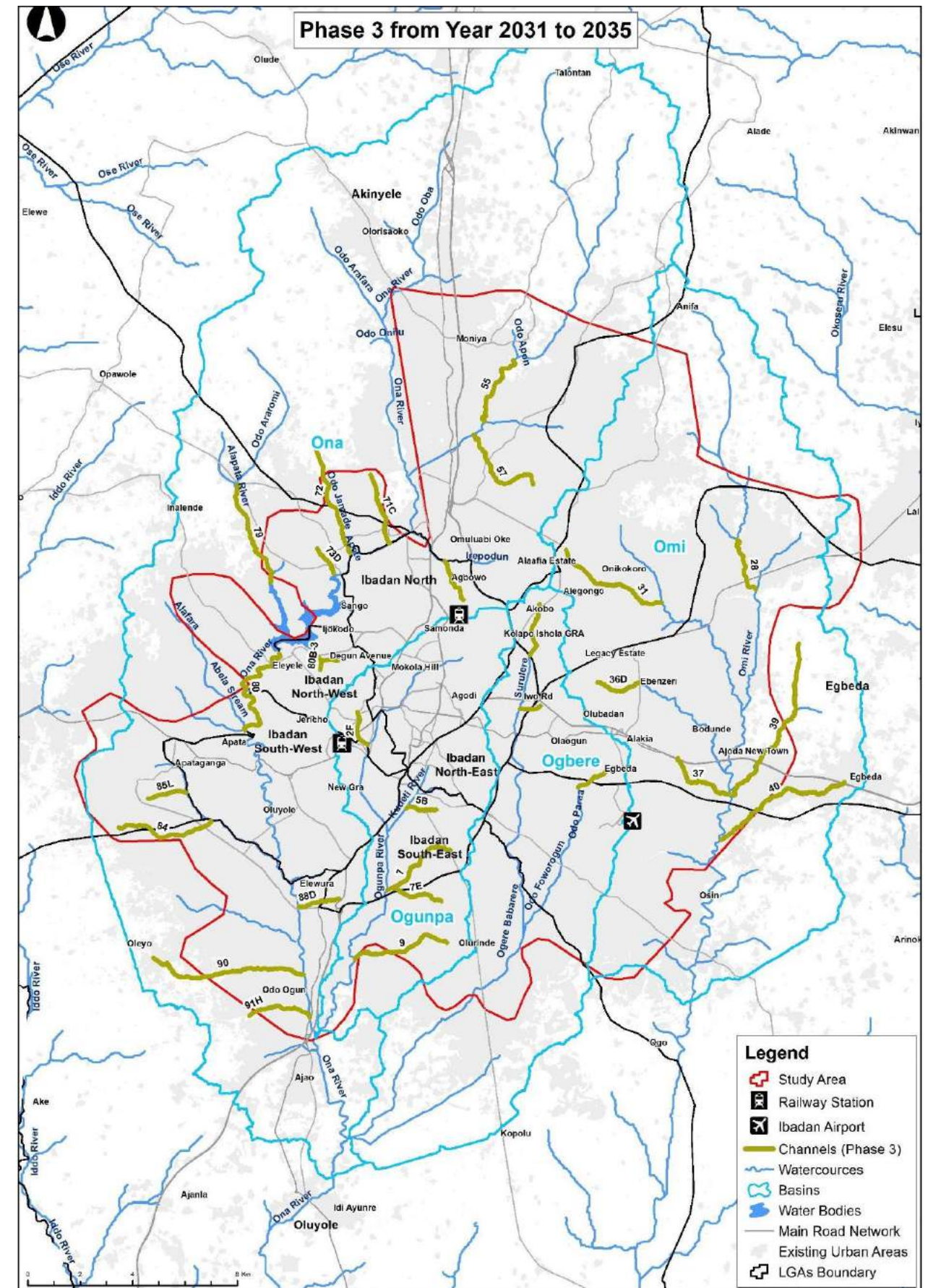
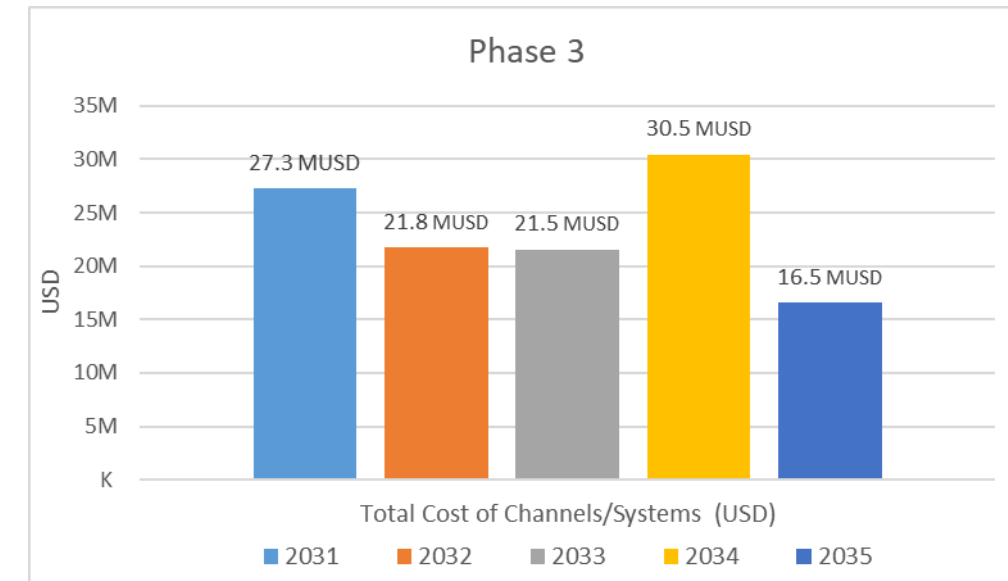


Figure 7.29: Systems to be Implemented in The Third Phase (2031 - 2035)

The channels selected in the 3rd phase from year 2031 to 2035 with their lengths, rehabilitation cost estimate for each system, year of implementation, and the total cost of rehabilitation works per year are presented in Table 7.15, while Figure 7.30 shows Total Cost of Rehabilitation of Channels per Year in phase 3.

**Table 7.15: Selected channels in Phase 3 from year 2031 to year 2035**

Channel ID	Subbasin	Channel Length (m)	Cost of Channel/system (USD)	Total Cost of Rehabilitation Works/year (USD)	YEAR
70Q	ON9 Orogun	1,826	1,215,400	16,901	2031
7	Og4 Lower Ogunpa	3,355	2,384,200		
31	OM3 Upper Omi West	4,744	3,810,600		
2F	Og2 Middle Ogunpa	1,488	1,206,200		
80	ON13 Middle Ona South	5,488	18,693,000		
28	OM2 Omi Headwaters South	2,460	8,645,000	7,903	2032
55	ON7 Upper Ona East	3,222	11,710,000		
11	Ob1 Ogbere Headwaters	2,221	1,407,800		
72	ON10 Middle Ona North	4,923	5,564,800	20,838	2033
40	OM7 Middle Omi South	6,302	6,298,800		
90	ON19 Lower Ona West	6,544	7,736,000		
73D	ON10 Middle Ona North	1,235	693,000		
36D	OM6 Middle Omi West	1,834	1,269,800		
84	ON15 Alaro	4,013	3,194,800	20,320	2034
80B	ON13 Middle Ona South	1,108	814,000		
7E	Og4 Lower Ogunpa	2,113	1,639,600		
39	OM5 Middle Omi East	7,356	8,460,800		
5B	Og3 Kudeti	1,269	877,200		
79	ON11 Alapata South	4,461	15,479,000	22,458	2035
80B-3	ON13 Middle Ona South	383	198,200		
37	OM6 Middle Omi West	3,042	2,164,200		
9	Og4 Lower Ogunpa	4,129	3,371,800		
57	ON8 Upper Ona South	4,021	3,295,600		
71C	ON10 Middle Ona North	2,997	2,274,000		
88D	ON17 Lower Ona East	1,679	962,000		
14L	Ob4 Foworogbun	1,265	851,600		
85L	ON15 Alaro	1,520	939,000		
12F	Ob2 Upper Ogbere	810	514,000		
91H	ON18 Lower Ona South	2,612	1,969,600		

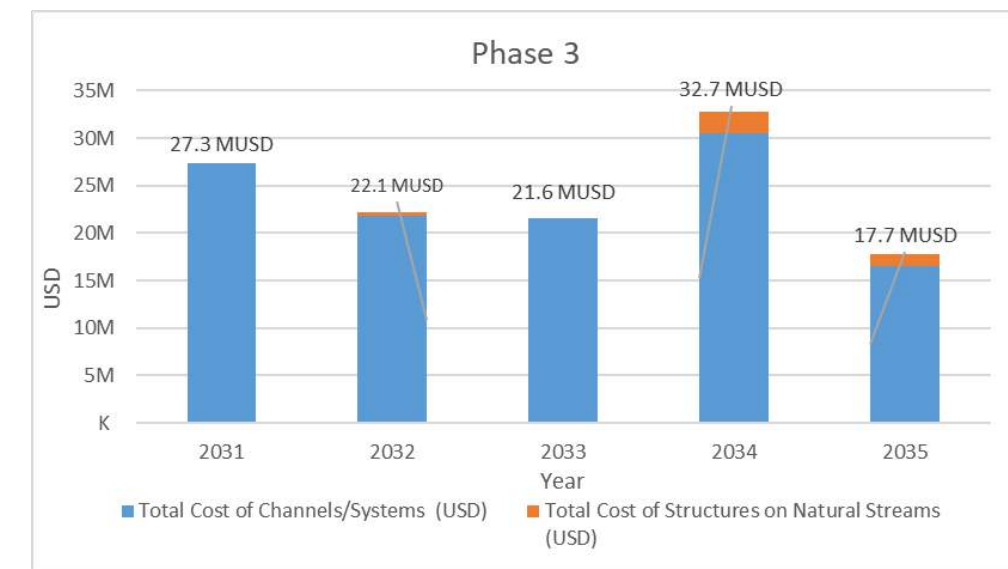


**Figure 7.30: Total Cost of Rehabilitation of Channels per Year in phase 3**

Also, the total cost estimates for channels and separate structures for each year, as well as the total budget for phase 3 are presented in Table 7.16 and Figure 7.31.

**Table 7.16: Total cost estimates for channels and separate structures each year in phase 3**

Phase	YEAR	Total Cost of Channel/System with Associative Structures (USD)	Total Cost of Structures on Natural Streams (USD)	Total (USD)
Phase 3	2031	27,309,400		27,309,400
	2032	21,762,800	385,600	22,148,400
	2033	21,562,400		21,562,400
	2034	30,465,400	2,278,400	32,743,800
	2035	16,540,000	1,224,000	17,764,000
<b>Total</b>		<b>117,640,000</b>	<b>3,888,000</b>	<b>121,528,000</b>



**Figure 7.31: Total Cost Estimates for Channels and Separate Structures Rehabilitation for Each Year in Phase 3**



The channels selected in the 4th phase from year 2036 to 2040 with their lengths, rehabilitation cost estimate for each system, year of implementation, and the total cost of rehabilitation works per year are presented in Table 7.17, while Figure 7.34 shows Total Cost of Rehabilitation of Channels per Year in phase 4.

**Table 7.17: Selected priority channels in Phase 4 from year 2036 to year 2040**

Channel ID	Subbasin	Channel Length (m)	Cost of Channel/system (USD)	Total Cost of Rehabilitation Works/year (USD)	YEAR
1P	Og1 Upper Ogunpa	646	303,200	23,747,600	2036
45H	OM7 Middle Omi South	2,871	1,811,800		
45E	OM7 Middle Omi South	2,128	1,303,800		
1E	Og1 Upper Ogunpa	919	470,000		
70P	ON9 Orogun	1,429	1,101,200		
88E	ON17 Lower Ona East	615	385,600		
66C	ON6 Upper Ona West	2,605	2,011,400		
14V	Ob4 Foworogbun	1,658	1,084,000		
2Q	Og2 Middle Ogunpa	1,038	643,600		
5C	Og3 Kudeti	1,148	445,000		
28D	OM2 Omi Headwaters South	1,197	680,200		
86C	ON15 Alaro	1,070	736,600		
27	OM2 Omi Headwaters South	3,275	4,540,800		
79L	ON11 Alapata South	2,379	1,564,800		
86G	ON15 Alaro	699	429,400		
37D	OM6 Middle Omi West	1,217	865,000		
8D	Og4 Lower Ogunpa	426	182,600		
42	OM7 Middle Omi South	3,948	2,781,200		
1F	Og1 Upper Ogunpa	679	445,800		
17	Ob5 Lower Ogbere North	2,447	1,961,600		
28A	OM2 Omi Headwaters South	3,034	2,065,600		
87E	ON17 Lower Ona East	482	389,200		
15H	Ob4 Foworogbun	1,966	1,185,200		
29	OM4 Upper Omi East	5,428	5,072,000		
66	ON6 Upper Ona West	2,110	7,184,000		
68A	ON6 Upper Ona West	1,852	1,038,200		
82M	ON12 Middle Ona West	2,027	1,662,800		
33F	OM3 Upper Omi West	1,020	719,600		
36M	OM6 Middle Omi West	1,327	620,400		
2C	Og2 Middle Ogunpa	448	313,000		
30H	OM4 Upper Omi East	439	227,000		
56K	ON8 Upper Ona South	1,316	881,600		
80K	ON13 Middle Ona South	1,461	786,200		
33	OM3 Upper Omi West	3,253	2,422,000		
68	ON6 Upper Ona West	661	2,966,000		
				22,144,800	2037
				22,957,000	2038

Channel ID	Subbasin	Channel Length (m)	Cost of Channel/system (USD)	Total Cost of Rehabilitation Works/year (USD)	YEAR
16D	Ob5 Lower Ogbere North	1,895	1,130,400		
36A	OM6 Middle Omi West	680	458,400		
1H	Og1 Upper Ogunpa	1,046	557,400		
12P	Ob2 Upper Ogbere	930	559,400		
36D-7	OM6 Middle Omi West	1,054	605,200		
12C	Ob2 Upper Ogbere	351	285,400		
53J	ON7 Upper Ona East	2,587	1,557,800		
75E	ON10 Middle Ona North	400	210,000		
85F	ON15 Alaro	541	261,200		
55B	ON7 Upper Ona East	1,752	1,333,000		
84D	ON15 Alaro	1,271	846,000		
85G	ON15 Alaro	1,079	752,400		
83H	ON14 Lower Ona North	1,031	544,600		
14Q	Ob4 Foworogbun	1,157	694,200		
36D-5	OM6 Middle Omi West	240	122,400		
74N	ON10 Middle Ona North	3,069	2,062,600		
9F	Og4 Lower Ogunpa	990	546,000		
53G	ON7 Upper Ona East	1,307	803,000		
54	ON7 Upper Ona East	2,640	1,709,400		
41B	OM7 Middle Omi South	681	274,000		
14X	Ob4 Foworogbun	409	183,400		
55F	ON7 Upper Ona East	202	119,400		
13K	Ob3 Middle Ogbere	1,176	804,400		
89L	ON16 Agara Kasumu	1,974	1,149,000		
13A	Ob3 Middle Ogbere	476	285,400		
53M	ON7 Upper Ona East	2,229	1,355,000		
34G	OM3 Upper Omi West	786	451,200		
13M	Ob3 Middle Ogbere	982	399,000		
26	OM2 Omi Headwaters South	2,313	5,690,000		
82J	ON12 Middle Ona West	515	250,200		
10B-3	Og4 Lower Ogunpa	409	165,000		
10B	Og4 Lower Ogunpa	1,238	617,800		
81J	ON12 Middle Ona West	740	423,400		
88G	ON17 Lower Ona East	529	225,400		
72H	ON10 Middle Ona North	718	375,400		
42J	OM7 Middle Omi South	1,360	780,600		
82E	ON12 Middle Ona West	425	215,200		
68C	ON6 Upper Ona West	2,075	1,271,400		
18H	Ob5 Lower Ogbere North	861	371,200		
79D	ON11 Alapata South	734	371,800		
32H	OM3 Upper Omi West	524	239,000		
				22,640,400	2039

Channel ID	Subbasin	Channel Length (m)	Cost of Channel/system (USD)	Total Cost of Rehabilitation Works/year (USD)	YEAR
13E	Ob3 Middle Ogbere	487	198,000	18,988,200	2040
16F	Ob5 Lower Ogbere North	1,331	579,200		
80A	ON13 Middle Ona South	290	165,000		
79G	ON11 Alapata South	2,399	1,146,800		
81F	ON12 Middle Ona West	760	362,000		
32P	OM3 Upper Omi West	183	102,400		
27K	OM2 Omi Headwaters South	1,597	931,000		
56H	ON8 Upper Ona South	2,056	1,142,400		
79M	ON11 Alapata South	1,206	550,000		
89M	ON16 Agara Kasumu	231	136,200		
32C	OM3 Upper Omi West	436	306,000		
24	OM2 Omi Headwaters South	1,748	3,229,200		
17H	Ob5 Lower Ogbere North	424	265,200		
42H	OM7 Middle Omi South	113	40,000		
67	ON6 Upper Ona West	3,838	2,728,000		
72F	ON10 Middle Ona North	312	126,000		
70J	ON9 Orogun	1,840	817,800		
40Q	OM7 Middle Omi South	303	145,400		
44	OM7 Middle Omi South	4,672	3,703,000		
90N	ON19 Lower Ona West	419	170,000		
56E	ON8 Upper Ona South	698	281,000		
39M	OM5 Middle Omi East	1,507	693,000		
19A	Ob5 Lower Ogbere North	959	390,000		
19B	Ob5 Lower Ogbere North	1,373	800,000		
18K	Ob5 Lower Ogbere North	375	151,000		
80L	ON13 Middle Ona South	2,440	1,517,400		
30D	OM4 Upper Omi East	2,336	984,200		
29E	OM4 Upper Omi East	886	408,000		
54D	ON7 Upper Ona East	1,035	416,000		
25	OM2 Omi Headwaters South	2,353	1,299,400		
44J	OM7 Middle Omi South	850	346,000		
90M	ON19 Lower Ona West	624	254,000		
56B	ON8 Upper Ona South	213	86,000		
29B	OM4 Upper Omi East	138	63,000		
39H-6	OM5 Middle Omi East	1,126	513,000		
79B	ON11 Alapata South	1,535	624,000		
80U	ON13 Middle Ona South	805	418,000		
69C	ON10 Middle Ona North	439	231,000		
39H	OM5 Middle Omi East	2,583	1,340,000		
39D	OM5 Middle Omi East	1,060	483,000		

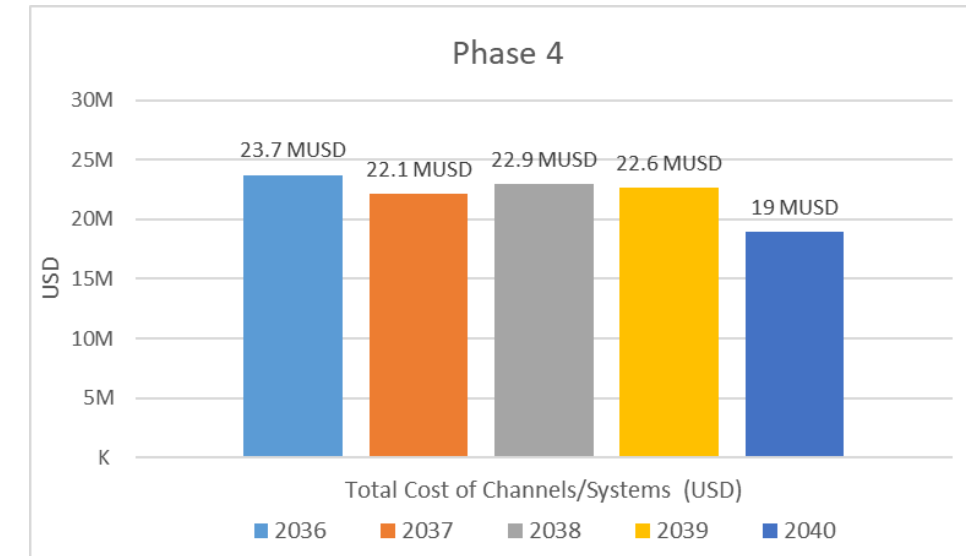


Figure 7.34: Total Cost of Rehabilitation of Channels per Year in phase 4

Also, the total cost estimates for channels and separate structures for each year, as well as the total budget for phase 4 are presented in Table 7.18 and Figure 7.35.

Table 7.18: Total cost estimates for channels and separate structures each year in phase 4

Phase	YEAR	Total Cost of Channel/ System with Associative Structures (USD)	Total Cost of Structures on Natural Streams (USD)	Total (USD)
Phase 4	2036	23,747,600	5,939,200	29,686,800
	2037	22,144,800		22,144,800
	2038	22,957,000	1,664,000	24,621,000
	2039	22,640,400	6,138,400	28,778,800
	2040	18,988,200	2,125,000	21,113,200
<b>Total</b>		<b>110,478,000</b>	<b>15,866,600</b>	<b>126,344,600</b>

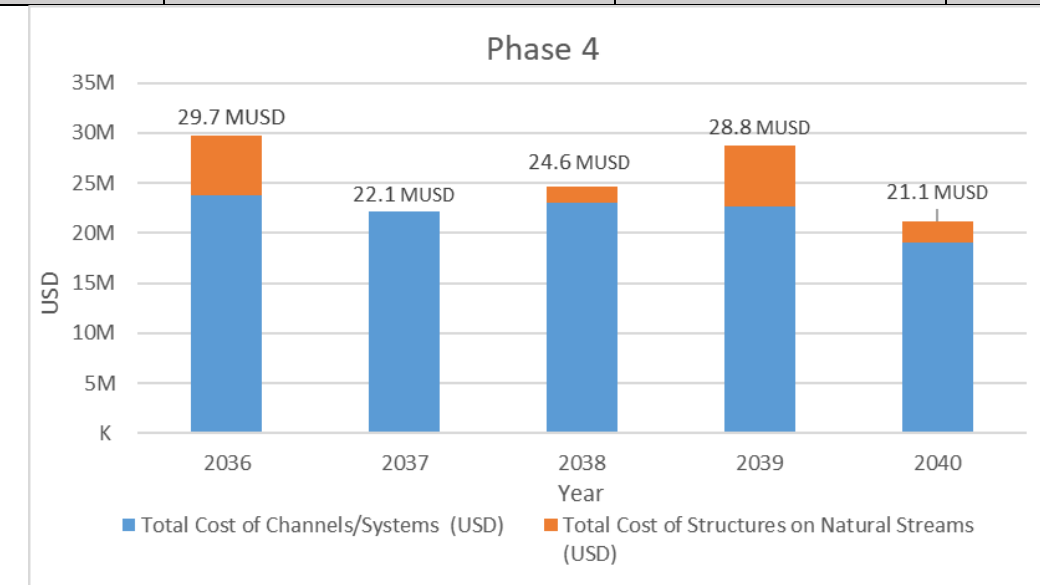


Figure 7.35: Total Cost Estimates for Channels and Separate Structures Rehabilitation for Each Year in Phase 4

## 8. Preventive Measures

Preventive measures are measures not involving physical construction which use knowledge, practice or agreement to reduce disaster risks and impacts, through producing flood risk maps, policies and laws, public awareness raising, training, maintenance programs and education.

Preventive measures are investigated thoroughly in this section to address many sorts of measures that can be used to reduce flooding impacts and to allow the city to be resilient to the flood emergency conditions without using hard concrete and heavy civil works.

### 8.1. Flood Risk Mapping

A risk map is a special topographic map where the hypothetical flood characteristics are represented graphically. It is convenient for singling out a special test flood risk mapping, because a flood map synthesizes past flood events. If such flood events are recorded sufficiently and accurately to enable the drawing of flooding contours, the empirical value of the results is highly important. However, flood risk maps mean more than just a map for one specific flood event. Risk mapping is the basic tool and starting point of any regional intervention policy for flood control. Flood risk maps are the starting point for the development of the different interventions and measures. In this respect the flood risk maps can be used for several purposes:

Defining tool for the initiation of any protection measures.

- Material that helps in defining the priorities for the interventions
- One of the most effective preventive tools as it can be used to warn and move the people in risk areas during any flood event or expected flood event.
- It is used as the base of comparing the previous flood events conditions with these developed risk maps. It can even be used as a base to compare to any new flood event.
- Flood risk ignorance is perhaps responsible for almost 40% of flood damage. As such availability of the flood risk maps is an aid to reducing the risk.
- They provide the basic initial information for land use planning;
- They allow correct development for new urban areas;
- The cost of flooding and risk reduction benefits can be adequately evaluated by using these maps;
- The feasibility of preventive flood control measures such as flood proofing can be correctly assessed;
- They can form the basis for any type of insurance plan;
- Flood risk maps serve as a logical base for investment planning and priority setting, mainly for preventive measures; and
- Last but not least, flood risk maps increase the public awareness of risk.

There are two types of risk maps may be provided which are risk to people and risk to buildings maps. Risk to people maps show a distribution for the expected number of injures within the floodplain area while risk to buildings maps present three levels of risk for the buildings exposed to risk within the

floodplain. The development of the flood risk maps are presented in section 5 and the risk maps developed for the city of Ibadan are presented in Volume 3 before and after intervention.

### 8.2. Flood Warning

A simple prerequisite is to know about an impending flood so that appropriate action can be initiated. Flood warning therefore has a central role in flood management and the management of vulnerability in flood risk. All of the emergency plans prepared in advance must be activated by a flood warning. The simple idea of warning people of an impending flood is an appealing one since actions may then be taken to avoid, or at least reduce, harmful effects.

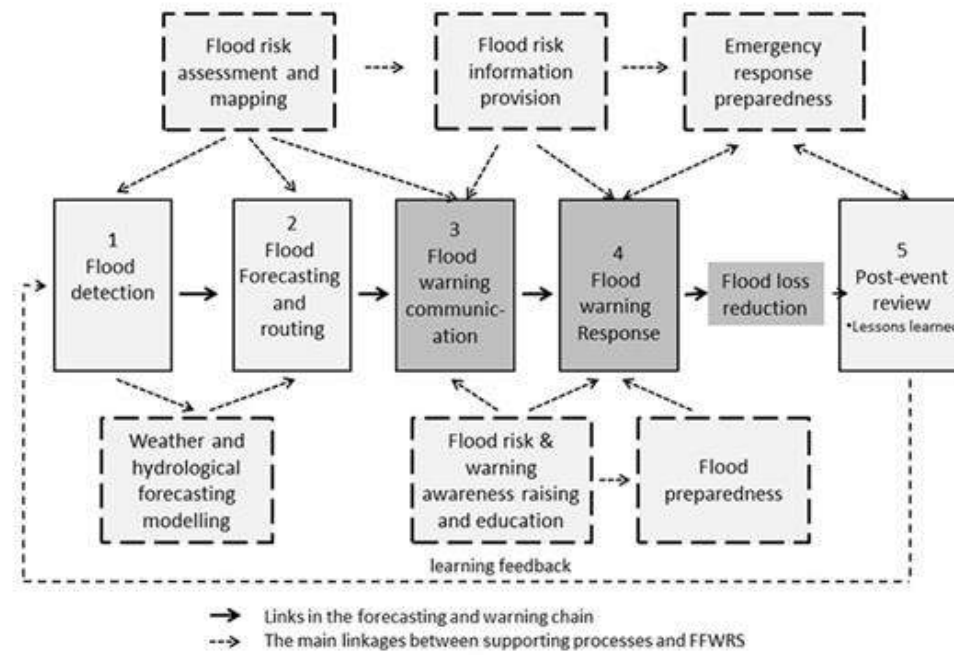
**A flood early warning system for the city of Ibadan is currently ongoing under the supervisions of the PIU and is implemented by another consultant.** This section is basic descriptions of the requirements of the Flood warning system and should be covered in the ongoing project.

A flood warning is information in the form of a prediction about a flood that is likely to happen. This information is usually targeted at and communicated to people who are in the path of the flood in advance of the flood occurring, with the intention of enabling them to avoid harm. Such information may also be communicated to infrastructure providers (e.g., electrical power companies) to enable them to take actions to avoid the disruptive effects of power outages and also to those operating flood barriers.

Flood warnings are the central component of a larger system of flood detection, forecasting, warning, and response systems which resemble a chain of components supported by a number of processes as illustrated in Figure 8.1.

The conditions that may lead to a flood are first detected by monitoring meteorological and river conditions. Indeed, the first sign of a flood developing may be a severe weather warning rather than a flood warning. Hydro-meteorological forecasting is a complex science that links numerical meteorological, hydrological, and hydraulic models (i.e., flood routing) in order to forecast the peak levels that a flood is expected to reach at particular locations and times. It is likely that flood risk will have already been assessed and flood risk zones mapped.

Once a flood forecast indicates that a flood warning should be issued, usually a predesigned flood warning message is communicated to a predetermined list of recipients. Typically, these recipients include flood defense officers who close flood barriers, professional emergency responders, infrastructure providers, the media, and the public, including householders and property owners who have registered to receive flood warnings from the flood warning agency. Designing effective flood warnings and communicating them in a timely manner in a compressed time frame so that they generate appropriate responses from recipients is complicated by a host of situational, cognitive, and behavioral variables.



**Figure 8.1: The flood forecasting, warning, and response system (FFWRS)**

Flood risk and flood warning awareness is a basic prerequisite for an effective warning response and so providing pre-flood information and education is very important. Similarly, flood preparedness by individuals and by the emergency services is also crucial. Warning response is the penultimate phase in the FFWRS chain and mainly involves individual property occupants and emergency responders taking timely, appropriate actions to avoid harm.

Although it is not always the case, the FFWRS process should be an iterative one with information flows in both directions as a flood develops and passes. Some of the more advanced FFWRS use community sourcing of observed meteorological and hydrological conditions to adjust forecasts and warnings during flood events. The final component of FFWRS is the post-event review: an important opportunity to learn about the performance of the system so that it may be enhanced through lessons learned. The flood warning component of FFWRS may be perfectly designed and operated, but because flood warning performance depends heavily on the effectiveness of flood detection and forecasting on the one hand, and on warning response on the other, it is crucial to identify those factors in the FFWRS chain that impact flood warning performance.

The FFWRS described above and shown in Figure 8.1 represents a formal, scientific approach to flood warning that is normally introduced by flood risk management agencies. However, as mentioned PIU is running a specific early warning system project for the city of Ibadan where an approach adopted to the specific of the city of Ibadan is under preparation. The Consultant sees that the outcomes of this early warning system should be included in the Flood Risk Management and Drainage Master Plan as an annex to be prepared by the Consultant performing the Early Warning system and under the PIU’s responsibility at a later stage following the completion of the flood warning study. This is input is important to ensure that the FRMDMP is comprehensive and includes all required works.

In the below sub-sections couple of the most important elements and parameters shall be presented.

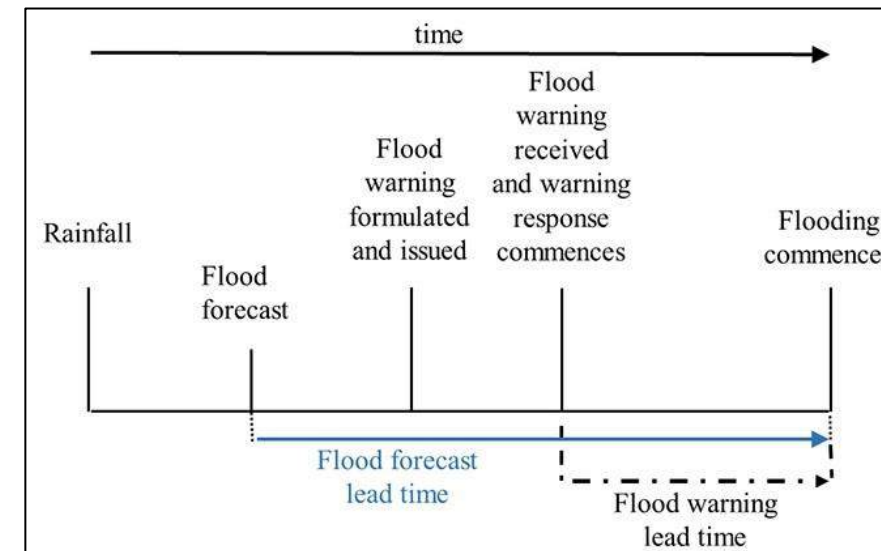
**8.2.1. Meteorological and River Monitoring Requirements**

The starting point for performing the flood warning system is to have appropriate data to first design the warning system and then to develop the flood forecast tools. In this respect the development of proper monitoring networks for the rainfall data and for the river measurement data are required.

This data shall serve the calibration of the hydrologic/hydraulic analysis of the system which is a very important step towards the proper design of the flood warning system. The data shall also be part of the information used to develop the meteorological forecast and the flood forecast.

**8.2.2. Flood Warning Lead Time**

Flood warning lead time is the amount of time between a warning being received and the onset of flooding or damage at any one location, and it differs from flood forecast lead time as illustrated in Figure 8.2 below.



**Figure 8.2: A simplified and idealized time sequence of flood forecasting, warning, and response illustrating lead times**

In densely urbanized, metropolitan areas with impermeable surfaces, slow-moving or stationary thunderstorms can generate intense rainfall that in a matter of minutes can produce severe surface-water flooding disruptive and hazardous to life. It may only be feasible to provide a very short flood warning lead time (i.e., minutes) which may be insufficient to avoid harm. Fortunately, in these circumstances, severe weather warnings may precede flood warnings, allowing early warning of the threat. Flood warning lead time is a critical factor in flood warning effectiveness, which explains why much of the effort in improving flood warnings has been directed at lengthening lead times.

**8.2.3. Measuring Performance**

Some of the most common ways of measuring flood warning performance are shown in Table 8.1. Some are technical measures, and others are social ones requiring social survey responses. To promote public confidence and response, flood forecasts and warnings must be sufficiently accurate to maintain their credibility. Enhancing forecast accuracy permits more accurate assessment of risk to life and property, leading to increased potential for flood damage avoidance. However, decreasing accuracy may lead to

in accurate flood warning messages. Less common performance measurement criteria include geographical coverage (i.e., flood warnings may not be available in some areas) and the degree to which warnings are accessible to vulnerable groups (e.g., minorities whose language may not be the principal one).

**Table 8.1: Common flood warning performance characteristics and measurement parameters**

Characteristic	Measurement parameter
Detection	Probability of detection
Accuracy	Forecast flood levels compared with actual flood levels; the proportion of those who received a warning who were subsequently flooded
Reliability	Flood hit, miss and false alarm rates; or false alarm ratio
Probability (i.e., uncertainty)	Amount or percentage of certainty/uncertainty associated with the forecast
Time range ahead of flood	How far ahead in time a forecast can be made
Timeliness	Forecast lead time; warning lead time; recipients' assessments of adequacy of lead times
Spatial resolution	The smallest area for which a forecast can be made
Warning information	Recipients' assessments of the degree to which the warning provided them with the flood information they needed
Satisfaction with flood warning service	Levels of satisfaction among those for whom flood warnings were/should have been provided
Damage reduction	The amount of flood damage saved by the warning
Protection of life and limb	The assessed number of lives and injuries avoided by the warning
Benefit-cost ratio	The ratio of the assessed benefits and costs of providing a flood warning

### 8.3. Watercourse Maintenance

Watercourses such as channels and culverts are designed to drain surface water away, before the water levels increase to an extent that puts property, roads, land and infrastructure at risk of flooding. If

channels and culverts are maintained to a good standard, any flooding is likely to only affect areas in the floodplain. Not all watercourses transport water, as some act purely for storage, but maintenance of the capacity of these storage features is important, as they prevent water flooding elsewhere.

The cost of maintaining a watercourse is minor compared to the costs that can arise from flood damage, not to mention the distress and inconvenience caused if your property is flooded.

#### 8.3.1. Main Steps for Maintaining Watercourses

##### 1. For open channels

##### a. Keep growth of vegetation (trees, weeds, reeds, grass etc) under control

- It is recommended to cut only up to just above the water level on one side of the watercourse, leaving the fringe of the bank uncut, thereby maintaining some habitat as well as enabling a free flow of water in the channel.
- Cuttings from any clearance work should be removed from the channel to avoid it causing blockages downstream. Putting removed material too close to the top of the bank can lead to it falling back in during times of flooding.

##### b. Keep watercourses free of debris (e.g. litter, grass cuttings, and fallen trees and branches)

- Remove any physical obstructions such as large rocks, rubble, fallen trees and branches and other waste materials (litter, grass cuttings etc) so that water can flow freely.
- All non-organic waste should be completely removed off site and disposed of in an appropriate manner.
- Any green waste resulting from the maintenance of channel can be left a safe distance from the bank for a few days to allow any organisms to move back into the watercourse, after which the green waste should be removed so it doesn't wash back into the watercourse.
- Ensure that any disturbed debris does not end up flowing downstream and causing problems for other landowners.
- Do not store anything alongside the watercourse which may interfere with maintenance, affect the stability of the bank or get washed into the channel.

##### c. Remove excess silt

Silt naturally builds up in watercourses as vegetation dies back each year. It can quickly reduce the capacity of a watercourse or block pipes into or out of the watercourse.

Silt should be removed along the length of the channel to ensure it flows properly in the right direction.

- If there are any pipes into or out of the channel you should remove silt to the same level or below the bottom of the pipe(s).

- Where possible, try to maintain the original slope and cross section of the channel when de-silting. If the slope of the channel is altered it can change the flow pattern, cause erosion or increase flood risk either upstream or downstream.
- As long as the silt is non-hazardous you can put it on the bank of the watercourse. Depositing silt on top of the banks of the watercourse allows for any organisms to move back into the channel. However;
  - It is essential that this material does not then block any other channels or nearby roads, or stop water draining into the channel if it would normally do so (e.g. from higher ground into the channel).
  - The silt must be deposited as close as possible to where it was dredged from either: on the bank of the waters from where it was taken or on land directly next to the watercourse.

## 2. **For pipes or culverts**

Piped or 'culverted' watercourses are prone to blockage or collapse and will degrade over time. Where they naturally silt up they can be difficult to access and clean. Cleaning the inside of a culvert is likely to cost more than carrying out maintenance of an open watercourse, due to the specialist equipment required to access it.

Blockages within the pipe or at the pipe entrance can cause flooding problems (refer to Figure 8.3). These blockages can be reduced by regular inspection and the removal of debris.



**Figure 8.3: Blocked pipe culvert that requires cleaning**

Culvert entrances at the proposed dikes often have protective grilles to prevent debris entering the culverts and causing blockages. These should be inspected and cleared regularly, especially during the periods of heavy rainfall when debris can accumulate very quickly.

### 8.3.2. **Timing and Frequency of Maintenance**

For all watercourses it is good practice to develop a program that sets out how often you will carry out maintenance works. Most watercourses require annual maintenance to some degree and the best time

to undertake works to be before the wet season (summer) which is normally from April to October. Annex 21 includes a maintenance program with the inspection sheets required.

- Maintenance works should be done when the water level is at its lowest i.e. when there has been little rainfall.
- Trash / weed screens and grilles should regularly be checked all year round, but, especially at times of anticipated high flow.
- Debris in channels should be removed as soon as it starts to build up.
- Culverts should be inspected for blockages or signs of collapse. If such problems are identified before a total obstruction to the watercourse occurs, it reduces the likelihood of flooding incidents.

## 8.4. **Spreading Awareness**

Raising public awareness of flood risk is important for those exposed to flood hazard. This is important in situations with a lower frequency of serious flooding (where awareness fades over time), new urban developments (where residents lack past flood experience), and in mountainous areas susceptible to flooding (where response must be swift). Preparedness can only follow from awareness.

### 8.4.1. **Public Awareness Campaigns**

Some important measures for a sustainable flood awareness campaign are given below.

- Include the following key points in flood awareness information:
  - Nature of the local hazard.
  - Unambiguous description of the flood warning system.
  - Responsibilities of the main agencies (and their limitations).
  - How/where to obtain further information at time of flooding.
- Use pictorial/iconic/colorful information as it is more readily remembered than text alone.
- Include clear behavioral information on what to do before, during and after a flood event, ideally with some prioritization of actions in educational messages.
- Ensure coverage on national news programs.
- Advertise in as many information systems as possible.
- Create interest by putting a week of public relations activities.
- Follow-up national mail shot to ensure that every household has basic information and has contact details to obtain further information.
- Clarify the key stages to follow by providing information on paper that is segmented into separate sheets.
- Created a flood telephone service, which could be a menu driven automatic information system, but should also retain the option to speak to flood "consultants".
- Made widely available regulations governing responsibilities and claims arising from a flood, as mechanisms for insurance vary greatly.
- Remind the public constantly of the risks of flooding and what actions to take as 'one-off' campaigns are not enough.

## 8.4.2. Public education schemes

### 8.4.2.1. Teaching at schools

The key message is to seek the advice of teachers at an early stage as teaching methods change in time and between schools

- It is essential that material be of immediate help to the teacher in applying the curricula.
- Concepts may have to be introduced within wider related subjects such as water resources management, water quality management, water ecosystems, human settlements etc.
- Introduction of information at school level must take careful consideration of different curricular requirements both by age and by country.
- Education at primary school level (7-11 year old) may be good starting point.
- For effective education, emphasis should be on visual messages, role-playing and fun.
- High quality products (text-based, video, internet, CD) should be widely accepted - these require realistic funding (e.g. video production, distribution to all schools).
- Starting point for schools could be production of basic 'Fact Pack' – a set of fact sheets, which photocopy easily and can be used as background information for a number of project areas

### 8.4.2.2. Drills

Flood warning occurs in real-time leaving little opportunity for those at risk to think through their actions. The best method of ensuring that actions are effective is through rehearsal. This can be done:

- Literally, as practiced by emergency services.
- Mentally, by working through prescribed check lists and charts designed specifically for public use.
- Virtually, through role-playing which can be aided by watching realistic video/tv/film reconstructions. In the future, more widespread availability of 'virtual reality' technology may help to bring further realism to this learning/rehearsal process.

### 8.4.3. Public participation: towards an integrated flood management approach

Flood management should be based on a participatory approach, involving planners and policy-makers at all levels and also the general public. Participatory approach involves raising awareness of flood risk amongst the general public who become involved in identifying needs, in identifying risks, in determining accepted risk levels and in developing solutions to better cope with floods. This can allow individuals and groups to exchange views and influence policies and decision-making. Although this process does not generally blend with the traditions of hierarchically organized emergency services, it can assist in the quality of policies and the efficiency of decision-making. This way, decisions are taken at the lowest appropriate level; with full public consultation and involvement in the planning and implementation of flood management plans. As a result, the acceptance of decisions made by government can be significantly enhanced.

Thus, there is an urgent need for participatory institutional mechanisms to be set up, in order to include a bottom-up approach in the dynamic and evolving process of flood management. An example of such

a mechanism could be the establishment of links with community groups, so as to retrieve grass roots feedback on how to raise awareness and generate action at the local level.

Feedback from the public is important for decision-making and also for research purposes. Inter-disciplinary experts can gain valuable input from the public and can consequently pass on interpreted information to decision-makers.

### 8.4.3.1. Self-help information against flash floods

A key challenge that still remains is the provision of policies to catalyze the metamorphosis of flood awareness into flash flood resilience, as this process implies changing public attitudes and responses to such events. The competent authorities are responsible for warning and informing the population in case of imminent danger and for the coordination of relief and rescue operations. However, all precautions taken by such Authorities would not be effective, if the public did not accept them and was not prepared to cooperate. Special attention must thus be given to thorough information dissemination and training of the public on self-protection. A checklist for the general public on how to cope with flash floods (before and during) is provided below.

### 8.4.3.2. Precautions to be taken in the event of an imminent flood

- Turn off gas and electricity.
- Pull out the plugs on electrical appliances.
- Put dangerous liquids, especially combustible ones, in a safe place and close containers securely.
- Tie down mobile containers containing inflammable or combustible liquids.
- Take important supplies, documents, and valuables to a higher place. Take furniture and mobile objects to upper floors; drive vehicles to places that will not be flooded.
- Have the following important supplies ready at a safe place:
  - food, drinking water
  - first-aid equipment, medicines
  - bucket, cloths, scrubbers
  - Spades, shovels, tools
  - Flashlights
  - Covers and blankets
  - Wooden planks, nails
  - Sandbags, if available
- Put sandbags by exposed openings (basement windows, doors); secure objects that are in the open.
- Anchor tanks in the house or cellar properly to prevent them from floating or being carried away; extend tank ventilation pipes until they are above the maximum water level expected.

### 8.4.3.3. Precautions to be taken during flood

- Turn on a (battery-driven) radio in order to be able to better assess the situation (information or warnings from civil defense can save lives).

- Avoid areas that can be flooded suddenly. Leave areas immediately that are exposed to flooding (i.e. dips, low-lying areas, eroded areas, etc.).
- Avoid areas that are already flooded and fast-flowing sections; do not try to cross water courses on foot if the water is more than knee-deep.
- Check the depth of water in depressions and underpasses before driving through them in your car (the road bed under the water may be eroded); if your car gets stuck, abandon it immediately.
- Take additional care at night as dangers are often more difficult to recognize.

### 8.5. Regulating Development within Floodplain

When examining the risk of a flood occurring it is also important to consider the consequence to the community as a direct result of the flood.

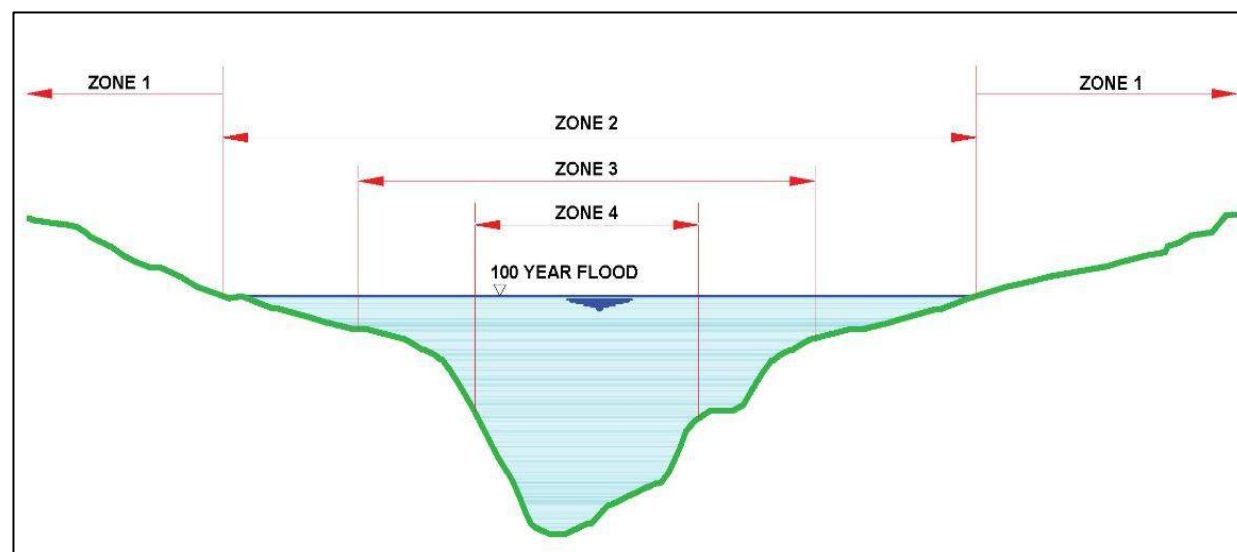


Figure 8.4: Flood Risk Zones

This zoning defines the main set back which is the setback associated with the flood extend for the 100 year event. This setback is defined in Volume 3 as the limits of the inundation due the 100 year flood event. Volume 3 includes the limits for the natural streams before interventions and the limits for the stream after interventions. This setback should be controlled by the Bureau of physical planning and development control through the physical development control department and the Urban renewal monitoring compliance and enforcement department. The following subsections presents the definition and the appropriate uses of these zones (refer to Figure 8.4).

- **Zone 1:**

**Definition:**

This zone comprises the lands outside the outer boundary of the 100-year event and the extent of the 100-year event as shown in Figure 8.4.

**Appropriate uses:**

All uses of land are appropriate in this zone.

**Flood risk assessment requirements:**

For development proposals on sites comprising one hectare or above the vulnerability to flooding from river, and the potential to increase flood risk elsewhere through the addition of hard surfaces and the effect of the new development on surface water run-off, should be incorporated in a flood risk assessment. This need only be brief unless the factors above or other local considerations require particular attention.

**Policy aims:**

In this zone, developers and local authorities should seek opportunities to reduce the overall level of flood risk in the area through the layout and form of the development, and the appropriate application of sustainable drainage systems.

- **Zone 2:**

**Definition:**

This zone comprises the lands between the outer boundary of the moderate hazard of the 100-year event and the extent of the 100-year event as shown in Figure 8.4.

**Appropriate uses:**

Essential infrastructure and the water-compatible, less vulnerable and more vulnerable uses, as set out in

Table 8.2, are appropriate in this zone.

**Flood risk assessment requirements:**

All development proposals in this zone should be accompanied by a flood risk assessment.

**Policy aims:**

In this zone, developers and local authorities should seek opportunities to reduce the overall level of flood risk in the area through the layout and form of the development, and the appropriate application of sustainable drainage systems.

• **Zone 3:**

**Definition:**

This zone comprises the lands between the extent of the moderate hazard of 5-year event and the inner boundary of moderate hazard of the 100-year event as shown in Figure 8.4.

**Appropriate uses:**

The water-compatible and less vulnerable uses of land (

Table 8.2) are appropriate in this zone. The highly vulnerable uses should not be permitted in this zone.

The more vulnerable uses and essential infrastructure should only be permitted in this zone. Essential infrastructure permitted in this zone should be designed and constructed to remain operational and safe for users in times of flood.

**Flood risk assessment requirements:**

All development proposals in this zone should be accompanied by a flood risk assessment.

**Policy aims:**

In this zone, developers and local authorities should seek opportunities to:

- Reduce the overall level of flood risk in the area through the layout and form of the development and the appropriate application of sustainable drainage systems;
- Relocate existing development to land in zones with a lower probability of flooding; and
- Create space for flooding to occur by restoring functional floodplain and flood flow pathways and by identifying, allocating and safeguarding open space for flood storage

• **Zone 4 - Functional Floodplain:**

**Definition:**

Zone 3 Functional Floodplain is defined as those areas in which “water has to flow or be stored in times of flood”. This zone could be defined as the moderate hazard zone of 5-year event, where the flow of flood water is not prevented by flood defences or by permanent buildings or other solid barriers from inundation during times of flood; also it could be defined as the land which provides a function of flood conveyance (i.e. free flow) or flood storage, either through natural processes, or by design (e.g. wash lands and flood storage areas).

**Appropriate uses:**

Only the water-compatible uses and the essential infrastructure listed in

Table 8.2 that has to be there should be permitted in this zone. It should be designed and constructed to:

- Remain operational and safe for users in times of flood;
- Result in no net loss of floodplain storage;
- Not impede water flows; and
- Not increase flood risk elsewhere.

**Flood risk assessment requirements:**

All development proposals in this zone should be accompanied by a flood risk assessment.

**Policy aims:**

In this zone, developers and local authorities should seek opportunities to:

- Reduce the overall level of flood risk in the area through the layout and form of the development and the appropriate application of sustainable drainage systems;
- Relocate existing development to land with a lower probability of flooding.

**Table 8.2: Flood risk vulnerability classification**

<b>Essential Infrastructure</b>	<ul style="list-style-type: none"> <li>• Essential transport infrastructure (including mass evacuation routes) which has to cross the area at risk.</li> <li>• Essential utility infrastructure which has to be located in a flood risk area for operational reasons, including electricity generating power stations and grid and primary substations; and water treatment works that need to remain operational in times of flood.</li> </ul>
<b>Highly Vulnerable</b>	<ul style="list-style-type: none"> <li>• Police, ambulance and fire stations, and Command Centers and telecommunications installations required to be operational during flooding.</li> <li>• Emergency dispersal points. Basement dwellings.</li> <li>• Caravans, mobile homes and park homes intended for permanent residential use.</li> <li>• Installations requiring hazardous substances consent. (Where there is demonstrable need to locate such installations for bulk storage of materials with port or other similar facilities, or such installations with energy infrastructure or carbon capture and storage installations, that require coastal or water-side locations, or need to be located in other high flood risk areas, in these instances the facilities should be classified as 'Essential Infrastructure' ).</li> </ul>
<b>More Vulnerable</b>	<ul style="list-style-type: none"> <li>• Hospitals</li> <li>• Residential institutions such as residential care homes, children’s homes, social services homes, prisons and hostels.</li> <li>• Buildings used for: dwelling houses; student halls of residence; drinking establishments; nightclubs; and hotels.</li> <li>• Non-residential uses for health services, nurseries and educational establishments.</li> <li>• Landfill and sites used for waste management facilities for hazardous waste.</li> <li>• Sites used for holiday or short-let caravans and camping, subject to a specific warning and evacuation plan.</li> </ul>
<b>Less Vulnerable</b>	<ul style="list-style-type: none"> <li>• Police, ambulance and fire stations which are not required to be operational during flooding.</li> <li>• Buildings used for: shops; financial, professional and other services; restaurants and cafes; hot food takeaways; offices; general industry; storage and distribution; non-residential institutions not included in 'more vulnerable'; and assembly and leisure.</li> <li>• Land and buildings used for agriculture and forestry.</li> <li>• Waste treatment (except landfill and hazardous waste facilities).</li> </ul>

	<ul style="list-style-type: none"> <li>Minerals working and processing (except for sand and gravel working).</li> <li>Water treatment works which do not need to remain operational during times of flood.</li> <li>Sewage treatment works (if adequate measures to control pollution and manage sewage during flooding events are in place).</li> </ul>
<b>Water compatible Development</b>	<ul style="list-style-type: none"> <li>Flood control infrastructure.</li> <li>Water transmission infrastructure and pumping stations.</li> <li>Sewage transmission infrastructure and pumping stations.</li> <li>Sand and gravel workings.</li> <li>Navigation facilities.</li> <li>Water-based recreation (excluding sleeping accommodation).</li> <li>Essential ancillary sleeping or residential accommodation for staff required by uses in this category, subject to a specific warning and evacuation plan.</li> </ul>

- People (including those with restricted mobility) should be able to remain safe inside the new development
- The treatment and control of surface water runoff should provide a level of betterment, incorporating the use of various SUDS techniques. As a minimum there should be no increase in the peak discharges/volumes from any existing Greenfield site and at minimum a 20% reduction of peak discharges/volumes from any existing Brownfield site where an existing positive drainage system has been identified
- The proposed development should be set-back from the watercourse with a minimum 8m wide undeveloped buffer zone from top of bank, to allow appropriate access for routine maintenance and emergency clearance.

**Future Development within Zone 3**

Land use with High Probability Flood Zone 3 should be restricted to the 'less vulnerable' uses to, and the following should be considered:

- Properties situated within close proximity to formal defenses or water retaining structures (reservoirs/canals) will require a detailed breach and overtopping assessment to ensure that the potential risk to life can be safely managed throughout the lifetime of the development. The nature of any breach failure analysis should be agreed with the Council, the Environment Agency and/or the operating authority, as appropriate.
- The development should not increase flood risk elsewhere, and opportunities should be taken to decrease overall flood risk (such as use of SUDS and de-culverting). This should be optimized by developing land sequentially, with areas at risk of flooding favored for green space. There should be a positive gain in the floodwater storage capacity provided and there should not be any detrimental impact on floodwater flow conveyance.
- Floor levels should be situated above the 100 year plus climate change predicted maximum level plus a minimum freeboard of 300mm. Within defended areas the maximum water level should be assessed from a breach analysis. Where there is sufficient depth between the undersides of the floor slab and the existing ground level, under-floor voids should be included with adequate void openings.
- The development should allow safe dry pedestrian access to and from the development above the 1% (1 in 100 year) flood level with an appropriate allowance for climate change emergency vehicular access should be possible during times of flood.
- Basements should not be used for habitable purposes. Where basements are permitted for commercial use, it is necessary to ensure that the basement access points are situated 600 mm above the 1 in 100 year flood level plus climate change.
- The treatment and control of surface water runoff should provide a level of betterment, incorporating the use of various SUDS techniques. As a minimum there should be no increase in the peak discharges/volumes from any existing Greenfield site and at minimum a 20% reduction of peak discharges/volumes from any existing Brownfield site where an existing positive drainage system has been identified. Space should be set aside for SUDS.

**8.5.1. Development Control within Ibadan City**

**Future Development within Zone 1**

There is no significant flood risk constraint placed upon future developments within the Low Probability Flood Zone 1, although the vulnerability from other sources of flooding should be considered as well as the effect of the new development on surface water runoff.

Typically, a Drainage Impact Assessment will be required to demonstrate that the treatment and control of surface water runoff can provide a level of betterment, incorporating the use of various SUDS techniques, which should take into account the local geological and groundwater conditions. As a minimum, there should be no increase in the peak discharges/volumes from any existing Greenfield site and at minimum a 20% reduction of peak discharges/volumes from any existing Brownfield site where an existing positive drainage system has been identified.

Consideration must be given to the effect of the new development in terms of off-site consequences from all sources of flooding.

**Future Development within Zone 2**

Land use within Medium Probability Flood Zone 2 should be restricted to the 'water compatible', 'less vulnerable' and 'more vulnerable' category. For development within this zone, the following is required.

- A detailed site-specific FRA should be prepared for any development area
- Floor levels should be situated above the 100 year plus climate change predicted maximum level plus a minimum freeboard of 600mm
- Safe dry pedestrian access to and from the development should be possible above the 1% AEP (1 in 100 year) flood level with an appropriate allowance for climate change and emergency vehicular access should be possible during times of flood
- Flood resistance and resilience should be incorporated into the design

- The proposed development should be set-back from the watercourse with a minimum 8m wide undeveloped buffer zone from top of bank, to allow appropriate access for routine maintenance and emergency clearance.
- For sites where the access and egress routes are within Flood Zone 3 or 2, the site should be considered as if being within that higher Flood Zone itself.

#### **Future Development within Zone 4 - Functional Floodplain**

This zone comprises land where water has to flow or be stored in times of flood (land which would flood with an annual probability of 50% (1 in 5 year) and the requirements for the development within this zone has to follow the following:

- Development in High Probability Flood Zone 4 should be restricted to 'water-compatible uses' only.
- Essential infrastructure can be located in Flood Zone 4. Essential infrastructure includes: essential transport infrastructure (including mass evacuation routes) which has to cross the area at risk; and strategic utility infrastructure, including electricity generating power stations and grid and primary substations. Essential transport infrastructure may be appropriate if designed in such a way that flood flow routes and flood storage areas are not affected (e.g. designing a bridge to cross the flood risk area). However, utility infrastructure may be less appropriate due to the potential consequences that may occur should the utility site become flooded.
- Essential infrastructure in this zone must be designed and constructed to remain operational in times of flood and not impede water flow.

#### **8.5.2. Preventive Settlement / Resettlement**

Settlement of people within the flood plains is an activity that should be controlled where the authority responsible of regulating the urban development is the department of physical planning. It requires the development of the regulatory framework to control the resettlement in flood plains.

Resettlement is a measure for intervention that seeks to address the exposure which is one of the components of vulnerability, and it results in nullification of the risk condition. Physically, it means changing the location of the exposed elements, in this case, the population, so that there is no time-space coincidence with a specific socio-natural phenomenon that may develop or intensify in the future. Therefore, resettlement is relevant, from a physical standpoint, only with regard to those phenomena where it is possible to reduce exposure effectively.

As discussed in the technical note which was submitted by the Consultant under the name of " A Technical Note on Flood Hazard Assessment and Relocation Criteria" with a number of N17036-0100D-NOTE-ENV-06-REV 0 that the resettlement of buildings and people depends mainly on the hazard due to floods. The following subsections presents the basis behind the resettlement process.

##### **8.5.2.1. Flood Hazard on Buildings**

Flood hazard on buildings can be represented as the percentage of damage corresponding to the flood water depths. Based on the damage functions adopted by the Joint Research Center (JRC) which describe the relationship between the floodwater depth and percentage damage for different types of buildings (residential, commercial and industrial), the Consultant adopted a depth of 1.50 m to be the governing depth for relocating any structure inundating within this depth. This depth of water is able to damage more than 50% of the total worth of any building.

##### **8.5.2.2. Flood Hazard on People**

As illustrated previously in section 5.1 that the floodplain could be classified into five hazard zones and the hazard starts to be noticeable from the moderate hazard zone which is danger for some inhabitant "Children". The moderate hazard zone includes the flood zone with deep standing water "attenuation areas" and fast flowing water.

In order to identify the critical water depth above which, all the inundated areas have to be evacuated and emptied from people, the hazard formula adopted by DEFRA has been applied on the attenuation areas where the velocity of water tends to be zero "standing water". The resulting water depth is found to be 1.5m which is corresponding to the lower limit of the moderate hazard class (1.75).

##### **8.5.2.3. Benefits of Preventive Settlement/Resettlement**

Resettlement of those living in high-risk areas can reduce the costs associated with emergency responses and reconstruction. The loss of life, infrastructure, assets, and other elements can be diminished in both monetary and non-monetary terms.

- **Human life:** By resettling those living in high-risk areas, it is possible to prevent the direct impact and costs of a disaster in terms of human lives and injuries. In so doing, indirect impacts and costs are also avoided, not only for those exposed to risk but also for society as a whole.
- **Infrastructure:** The direct costs associated with post disaster reconstruction of houses, institutional buildings, factories, and other public and private facilities cannot be avoided with resettlement, since all those structures should be built for resettled populations. Nevertheless, indirect monetary costs and non-monetary costs may be avoided. For example, shelters will not have to be built for the population affected by a disaster, and the provision of such services as health care and education will not be interrupted. Industrial and commercial activities will also be able to proceed without interruption.
- **Assets:** Resettlement means that all private, communal, and institutional assets can be relocated to a place where they will not be damaged or destroyed. The relocation of productive assets is particularly important so that economic activities can continue, and so that the income of the population or revenue for society as a whole will not be affected. The only asset that cannot be relocated is land, which will represent a cost in resettlement.

Table 8.3 provides details on possible savings from preventive settlements/resettlement, savings that arise from avoiding post disaster reconstruction costs. Items in green cells indicate the potential savings

from preventive resettlement; the only cost that remains, compared to the costs of post disaster reconstruction, is the direct monetary cost of building infrastructure and the land for new settlements.

#### ***8.5.2.4. Impacts of Population Displacement and Resettlement***

Resettlement of population is a complex process, and if it is not conducted properly can create serious problems for the people involved. A poorly planned and executed resettlement program can lead to social, economic, and cultural disasters even more serious than the natural disaster risks it is intended to prevent.

The ultimate objective of resettlement is to support people in rebuilding their livelihoods, which include not only housing but also their sources of income, economic activities, social relationships, access to public services, and social and cultural practices. The main achievement is the incorporation of the families or communities into the new habitat, which should ensure economic, social, and cultural conditions for the restoration of their standard of living and their normal development.

Given that one of the main objectives of resettlement for disaster prevention is safeguarding peoples' lives and assets, there is a risk of considering resettlement as a housing program. If resettlement is not conceived and planned as a multidimensional process that supports resettled people in restoring their livelihoods and helps them adapt to the new habitat, then several social and economic risks could be incurred. Another risk in planning the new settlement is to disregard the population's right to participation and its social and cultural characteristics.

**Table 8.3: Savings Achieved by Preventive Resettlement vs. Costs of Post disaster Reconstruction**

Impacts		Monetary		Non-monetary	
		Direct	Indirect	Direct	Indirect
Human Lives	<b>Death</b>	<ul style="list-style-type: none"> <li>Economic activity expected by society</li> <li>Funeral costs</li> <li>Areas for disposal of bodies</li> </ul>	<ul style="list-style-type: none"> <li>Loss of income</li> <li>Cost of attending to survivors (Widows, orphan children)</li> </ul>	<ul style="list-style-type: none"> <li>Trauma for survivors</li> <li>Disruption of family and social ties</li> </ul>	<ul style="list-style-type: none"> <li>Social impacts on survivors (Widows, orphan children)</li> </ul>
	<b>Injuries</b>	<ul style="list-style-type: none"> <li>Medical expenses</li> <li>Loss of work days</li> </ul>	<ul style="list-style-type: none"> <li>Loss of employment and income</li> </ul>	<ul style="list-style-type: none"> <li>Injuries, disabilities</li> </ul>	<ul style="list-style-type: none"> <li>Psychological consequences</li> </ul>
Infrastructure	<b>Home</b>	<ul style="list-style-type: none"> <li>Loss of investment</li> <li>Cost of repairs and reconstruction</li> <li>Rubble removal costs</li> </ul>	<ul style="list-style-type: none"> <li>Cost of temporary housing</li> <li>Loss of net worth</li> <li>Loss of access to credit</li> </ul>	<ul style="list-style-type: none"> <li>Loss of shelter</li> </ul>	<ul style="list-style-type: none"> <li>Psychological and social consequences</li> </ul>
	<b>Communal facilities (churches, parks, community centers)</b>	<ul style="list-style-type: none"> <li>Loss of investment</li> <li>Cost of repairs and reconstruction</li> <li>Rubble removal costs</li> </ul>	<ul style="list-style-type: none"> <li>Cost of temporary facilities</li> </ul>	<ul style="list-style-type: none"> <li>Loss of access to facilities and services</li> </ul>	<ul style="list-style-type: none"> <li>Disruption of social activates</li> </ul>
	<b>Public installations (medical care facilities, schools, sport and recreation centers, etc)</b>	<ul style="list-style-type: none"> <li>Loss of investment</li> <li>Cost of repairs and reconstruction</li> <li>Rubble removal costs</li> </ul>	<ul style="list-style-type: none"> <li>Cost of constructing or adapting temporary installations to deliver services</li> <li>Total or partial cost of loss services</li> </ul>	<ul style="list-style-type: none"> <li>Cost of constructing or adapting temporary installations to deliver services</li> <li>Total or partial cost of loss services</li> </ul>	<ul style="list-style-type: none"> <li>Reduction of human capital, increased morbidity rate</li> </ul>
	<b>Structures for productive activates (industry, trade, services)</b>	<ul style="list-style-type: none"> <li>Loss of investment</li> <li>Cost of repairs and reconstruction</li> <li>Rubble removal costs</li> </ul>	<ul style="list-style-type: none"> <li>Loss of net worth</li> <li>Loss of income</li> <li>Decline in productivity</li> <li>Unemployment</li> <li>Disruption of production chains</li> <li>Increased cost of transporting goods for external supply zones</li> </ul>	<ul style="list-style-type: none"> <li>Reduction in the supply of goods and services to the population</li> </ul>	<ul style="list-style-type: none"> <li>Potential social conflicts</li> </ul>
Assets	<b>Land (private, communal, public)</b>	<ul style="list-style-type: none"> <li>Loss of investment</li> </ul>	<ul style="list-style-type: none"> <li>Loss of economic activities related to the use of land</li> </ul>	<ul style="list-style-type: none"> <li>Loss of identity and belongings</li> </ul>	<ul style="list-style-type: none"> <li>Psychological and social consequences</li> </ul>
	<b>Other private assets</b>	<ul style="list-style-type: none"> <li>Loss of savings, IDs, and personal belongings (furniture, clothing, household, appliances, etc.)</li> <li>Replacement cost of goods</li> </ul>	<ul style="list-style-type: none"> <li>Replacement of IDs and personal belongings, costs of bringing relief items to victims</li> <li>Loss of investment</li> </ul>	<ul style="list-style-type: none"> <li>Loss of access to services</li> <li>Dependency on foreign aid</li> </ul>	<ul style="list-style-type: none"> <li>Psychological consequences</li> </ul>
	<b>Other public assets</b>	<ul style="list-style-type: none"> <li>Loss of public property</li> <li>Replacement costs</li> </ul>	<ul style="list-style-type: none"> <li>Reallocation of regular budget funds in order to replace assets</li> <li>Reduced investment in other areas</li> </ul>	<ul style="list-style-type: none"> <li>Reduced expansion of coverage or provision of services in different areas</li> </ul>	<ul style="list-style-type: none"> <li>Loss of human capital</li> </ul>

## 9. Post Events Measures

Immediately following a flood event, the community official can anticipate several possible scenarios. These include:

- Pressure to rebuild immediately with as little inconvenience as possible.
- A lack of coordination among community departments.
- Misinformation about both flood insurance and allowable repair within the floodplain.

The local Floodplain Administrator can curtail these problems by understanding the community's flood damage prevention ordinance and through the implementation of an effective floodplain development permit process.

In a post-disaster environment, the most important duty / procedure is focused on the assessment of damaged structures. The following three actions must be conducted:

- Determine whether damaged structures are located within the Special Flood Hazard Area.
- Conduct damage assessments for those damaged structures located within the SFHA.
- Make a reasonable attempt to notify owner(s) of damaged structures(s) of the requirement to obtain a building permit / floodplain development permit prior to repair, rehabilitation, or reconstruction.

### 9.1. Documentation of Flooding

Depending on the size of the community and the area impacted, the task of documenting the extent of flooding can be daunting. However, this historical data is vital. Photographs and video of the affected areas can be taken to assist in documenting the extent of damage to structures. Boundaries of inundation and high-water marks can be set to establish the area and height the water encompassed. The general public can also be utilized to provide information and data to community officials.

### 9.2. Documentation of Damage

The community should complete a preliminary 'windshield' survey of the damaged structures in the affected areas. These surveys should include site location (address), GPS coordinates, water level, (detected by mud lines, debris lines, etc.), construction type, and a preliminary damage assessment (i.e. affected habitable, minor, major, or destroyed). This task can be completed with the help of the local emergency manager, personnel involved with the permitting process, fire fighters, community officials, and / or volunteers. By pooling community resources, tasks that seem lengthy can be more easily accomplished.

A Preliminary Damage Assessment to be conducted after a disaster by two teams, which consist of a Public Assistance Team and an Individual Assistance Team. The teams generally consist of representatives from city public works, and fire or police department. Public Assistance PDA team is concerned with public infrastructure, how is it affected, how long repairs will take, what is the impact on budget and manpower, and can the community operate effectively with the damage. The Individual

Assistance PDA team is concerned with the severity of damages to privately owned property. This damage is categorized as: destroyed, major, minor and affected.

### 9.3. Notify Public of Need for Permit for Repair / Reconstruction

A natural reaction for flood victims is to try to restore life "back to normal" as soon as possible. This thought process usually does not immediately include the reality of obtaining the proper permits. For some victims, the reality may be that they will have to elevate their structure to or above the Base Flood Elevation, or that they may not be legally allowed to repair or reconstruct. It's important to emphasize the need to see the community's Floodplain Administrator and to know the expected flood elevation at the exposed areas.

Public notification can be given through the mass media (newspapers, radio, and television) and through the community website. Notices can also be posted at sites or community emergency shelters. In addition, individual damaged structures can be "red tagged," along with correspondence by mail to the property owner.

### 9.4. Remediation Plan for Damaged Assets

A damage and loss assessment following disasters can be used advantageously to determine post-disaster needs including economic recovery planning, and reconstruction program design. It may be used as well for monitoring progress of both economic recovery and reconstruction.

There are two distinct potential uses of the results of a damage and loss assessment: in the short term, to define government interventions in the immediate aftermath of the disaster that aim towards the lessening of people's suffering and to initiate economic recovery; in the medium to long term, to define the required financial needs to achieve overall recovery and reconstruction based on a preliminary strategy for post-disaster recovery and reconstruction.

The assessment of damage and losses – in addition to revealing the amount of effects caused by a disaster – provides information to define effects and impacts in most affected geographical areas and sectors of the economy, as well as on overall economic performance.

#### 9.4.1. Pre-Disaster Baseline for Assessment

This refers to the baseline of prevailing conditions before the disaster occurs, to be used as the basis for the estimation of damage and losses. Two sets of pre-disaster baseline are required:

- A baseline on physical assets, and
- A baseline on the performance

The baseline of physical assets refers to the existing physical facilities before the occurrence of the disaster within the affected areas and should include inter alia the number and type of housing units, the number and type of educational and health facilities, the extent of irrigated agricultural areas, the number and capacity of electricity, water supply and sanitation systems, the length and types of roads,

etcetera. In the case of some sectors, this baseline should also include the available facilities of nearby areas that may be used on a temporary basis to provide services in the affected area.

The second baseline refers to the manner in which all economic activities perform in the affected area under non-disaster conditions, referred to the volume and value of production, sales, etcetera, of goods and services. The calendar of agricultural production activities, the value of production and sales in other sectors, the volume and value of essential (electricity, water and sanitation, and transport) services, for the current and subsequent two years, are examples of the information required.

#### **9.4.2. Pre-Disaster Baseline for Assessment**

The second step to be undertaken in the damage and loss assessment is to develop a post-disaster scenario, based on the findings of both a field survey where the assessment specialists obtain a full grasp of disaster effects on each affected sector and interaction with local sector specialists (from the government and the private sectors) that can provide inputs for the assessment.

Two outputs are required in this step: a preliminary calendar or schedule for the reconstruction of physical assets, and a corresponding post-disaster, preliminary performance forecast of economic activities in each affected sector.

To develop the preliminary calendar of reconstruction, and based on the field survey and the consultations with local specialists on the subject, the following must be done:

- Define a typology of physical assets (by size, capacity, construction materials, et cetera)
- Obtain unit repair and reconstruction prices for above, not affected by scarcity or speculation
- Develop a preliminary calendar of repair and replacement of physical assets, giving due consideration to the existing construction sector (including availability of skilled labor and construction equipment and materials in the affected country or area) and to the expected availability of adequate financial resources.

To develop the preliminary forecast of economic activity performance after the disaster, it is essential that a conservative estimation be made of the time period required for the reconstruction and recovery of each sector, and to take into consideration all existing linkages between all sectors. The post-disaster performance of economic activities and services must be developed on the basis of the expected, staged repair and replacement of assets and the possibilities of adopting temporary solutions to other supply problems (such as tapping alternative water or energy sources from nearby areas), as well as the expected recovery of production. The expected calendar of economic recovery should include the resulting calendar of production recovery, income or revenues, and costs.

#### **9.4.3. Estimation of Damage and Losses**

The estimation of damage and losses for each and every sector is to be made through a comparison of the pre-disaster and post-disaster conditions, described under the two previous steps. Damage figures are to be presented in terms of the replacement value prevailing at the time of the disaster, and losses should be estimated in current values.

To determine the overall amount of disaster effects, damage and losses for all affected sectors must be added, giving due attention to avoid possible gaps and double accounting in the assessment. This requires that special care be exercised to ensure that the existing linkages between sectors are duly considered in the estimation of losses.

The overall amount of disaster effects will later on be compared to main macro-economic variables in order to define the relevance of each type of effect and its impacts on the economy and society, as well as to define economic recovery and reconstruction needs.

## 10. Watershed Conservation

Catchment-wide interventions can be effective to decrease surface runoff and soil erosion and therefore to reduce flood peak. These interventions should consider a number of basic principles related to the main factors influencing runoff and erosion, namely soil, topography, land cover and use and farming practices. Soil properties such as texture, structure, organic matter content and pH directly affect soil permeability, and therefore infiltration and runoff. Topography greatly influences the energy of the water particles and therefore runoff speed and timing and erosive potential. Protective effects of the vegetable covering against surface runoff and soil erosion vary according to the vegetable species, which form the covering. In fact, the protective function of forest species is greater than that of fruit trees, and similarly, pasture herbaceous species provide a better protection than arable herbaceous species such as, for instance, cereals, corn and soybean.

In cultivated lands, comprising herbaceous and woody crops as well as tree plantations, surface runoff and erosion are greatly affected by farming practices such as tilling, surface laying-out, type of crops, covering duration, management of residues coming from previous cultivation and preservation of soil fertility. Thus, runoff coefficient is higher when ploughing is performed along the maximum gradient, whilst deep ploughing allows greater water retention and reduction of total runoff. Surface laying out by means of drainage channels is one of the most effective systems for surface runoff regulation, as is the use of forage crops and their rotation, whilst ensuring a greater soil covering duration. Also, increase of organic matter released in the soil improves the structure, and thus the physical features of the soil with respect to erosion. In more natural systems, distinct behavior can be observed between natural turf forming plants, woods and abandoned lands. The former provides stability and resistance to the soil against erosion. In general, pastures provide higher protection against runoff and erosion than arable crops. However, inadequate exploitation of pastures such as an unsuitable livestock number with regard to grazing practices, as well as burning can have negative effects on vegetation retention capacity, thus increasing runoff and erosion. Woods contribute to regulate runoff and prevent soil erosion mainly because of interception from foliage and litter, greater speed of water infiltration and delayed concentration of water masses downhill. Rain interception is higher for evergreen species, while infiltration is higher in forests with no pastures and old plants. Finally, land abandonment generally results in a significant increase in permanent vegetable cover (mainly shrubs and turf), so insuring higher protection against erosion and runoff. Also, abandonment of forest land, especially in humid regions, can often cause a natural increase of forest cover therefore giving greater protection, although high precipitation can cause in some areas exceptional erosion and landslides. Based on the above principles, specific actions for agricultural and forest area management as well as for water control works in the catchment are presented in the following paragraphs.

### 10.1. Cultivated lands

- Conserve quick hedges and existing agricultural lay out: dry walls, water storage channels, terraces, etc.
- Avoid the shaping of slopes aimed at changing the size of agricultural holdings.

- Carry out periodical servicing of all water channels, especially of water mains, which impound water from the channels of agricultural holdings.
- Favour permanent vegetation on water mains and ensure a sufficient section for down flow.
- Promote farming practices aimed at increasing organic matter in the soil by manuring, rotation with improving crops and rational management of residues from previous crops.
- Build cross channels with appropriate spacing, based on soil texture (e.g. higher for sand than for clay), and slope angle.
- Carry out crosswise tillage where possible, and in case tillage along the maximum gradient proves to be necessary, build cross channels as well.
- Favour plurennial rotation of crops planted both using the plough and without it, contouring crops and contour strip-cropping.
- Select crops that ensure longer covering, especially in rainy periods.
- Stimulate the cultivation of species with a greater covering action (e.g. broadleaf species and fast-growing species).
- Favour grass growth on the entire surface, or at least on inter-rows, in case of tree plantations.

### 10.2. Turf forming plants

- Avoid conversion into arable lands where slope is high (e.g. greater than 25%).
- Keep quick hedges and existing cultural lay out: dry walls, water impounding channels, terraces, tracks;
- Favour all cultural practices, which aim at increasing organic matter in the soil (manuring).
- Avoid pasture renewal through fires, since this reduces soil organic matter.
- Regulate grazing through the correct assessment of optimum livestock number.
- Ensure a more homogenous distribution of livestock within the grazing area by a balanced spreading of livestock concentration spots (e.g. watering, feeding and standing spots).
- Use the rotation grazing method as much as possible.

### 10.3. Woods

- Promote and favour forest management plans.
- Favour more evolved and ecologically stable type of woods, e.g. by stimulating the formation of woods with a more complex structure (woods of different age), or with a different composition (by increasing the rate of mixture of the species), or by increasing the biomass (transformation of coppices into high forests).
- Favour the planning of access to woods, taking into account the different management of woods.
- Favour coppice cuttings with minimum development along the maximum gradient.
- Carry out coppice logging operations in non-rainy periods.
- Design adequate skidding tracks/roads for logging.
- Favour new roads useful to wide forest basins, thus servicing many users and agricultural properties.
- Increase the variability of coppice seedling bearers.
- Favour the conversion from coppice to stable, mixed seedling forest where possible.

- Favour mixed woods by thinning.
- Favour uneven aged woods by increasing their structural complexity.
- Favour forestry use in small areas (e.g. less than 5 hectares, and less than 5,000 m<sup>2</sup> in case of clear cutting).
- Favour the increase of autochthonous forest species (through selection thinning).
- Favour improvement and care of abandoned woods, possibly by conversion to coppices or seedling.

#### **10.4. Revegetation**

This measure enhances vegetation development, thus preventing sudden moisture variations, helping also to prevent erosion and shallow landslides. Main methods include water seeding, revegetation through turf, broadcast sowing with chaff and laying of grass coverage. Amongst these, water seeding is the most diffused and the less expensive revegetation method. It consists of spreading a mixture of water, seeds, organic fertilizer, ligands and soil ameliorating substances over a previously prepared

seedbed by means of high-pressure sprinkling machines. This technique is used to completely revegetate bare areas including those due to erosion, landslides and excavation.

#### **10.5. Afforestation**

This measure reduces flooding as it improves the holding capacity of the natural soil. This method if implemented properly can reduce the excess rainfall and as such reduce the floodwater flow. In addition to reducing flooding, it improves the ecological conditions in the area. It also improves the soil conditions as it reduces soil erosion and as such also improves the river stream channels performance.

#### **10.6. Terracing**

This measure is also an important tool to reduce flooding and reduces soil erosion. The hillside of the basin is regraded in terraces and as such reduces the slope of the catchment and as such increase the travel time. Plants are cultivated in the terraces and as such help in increasing the holding capacity of the area resulting in reduced flood flows.

## 11. Institutional Arrangements for Implementation of FRMPMP

The development of a new FRMDMP requires providing institutional arrangements that is needed to define the way of managing the dynamic process whereby such a plan can be implemented. This section examines the current institutional context and proposes new institutional arrangements that seeks the most effective way of achieving a sustainable and cost-efficient way of managing the ongoing work and any future requirements. This section should be read in conjunction with Annex 18 where the details of the analysis is presented. This section is a summary of the key points towards developing a proper institutional arrangement to address the requirements of the FRMDMP. Currently the tasks of planning, implementing and maintaining the drainage facilities lies with Project Implementation Unit (PIU), headed by a Project Coordinator and assisted by a Technical Assistance Team of consultants, under the Project Steering Committee headed by the Governor.

This is a temporary arrangement but the OSMEWR has identified the DEEB as the responsible agency to take over the role of the PIU. However, as has been pointed out, Flood Risk Management goes beyond the statutory responsibilities of the DEEB or the Ministry alone as it also involves the work of many other ministries, departments and agencies.. It is also concerned with emergency management and preparation for emergencies to minimize their impacts and to aid recovery efforts, which is the responsibility of the Oyo State Emergency Management Agency (OSEMA) and Local Emergency Management authority (LEMA). Furthermore, the capacity of these agencies to fulfill their responsibilities or meet their targets depends on the budget assigned to them and hence the Budget Management Committee (BMC) under the Oyo State Ministry of Finance and Budget (OSMFB) will also play a vital role in the whole process.

A major concern, however, is the capacity of these agencies to fulfill their statutory responsibilities. This is because MDAs are very dependent on the government for recruiting and deploying staff including funding of their capital and operational expenditures. Thus, in addition to looking at the recruitment process, this report will also consider opportunities for improved revenue generation and how the use of such funds might be targeted more effectively.

The study commences with presenting the existing responsibilities and existing agencies capacities, then assesses the existing conditions considering the requirements of FRMDMP. Using the assessment and basic information the study proposes the possible arrangements to improve the institutional arrangements. Finally, the study presents the actions for the long-term sustainable flood risk management capacity of the State put into a timeline.

### 11.1. Existing Responsible Agencies

In considering responsibility for the planning, design, construction and management of the FRMDMP, we need to be mindful of all existing agencies involved in the various parts and stages of development of the system<sup>14</sup>. The works that the existing agencies are following are:

- Works related to the Design, construction and maintenance of the drainage systems
- Works related to the regulations enforced by the land use planning and development control requirements
- Works related to the drainage system cleaning.

The agencies involved in these three categories and the responsibilities are presented in Table 11.1.

**Table 11.1: Existing Drainage System Responsible Agencies**

Element	Planning & Design	Construction	Maintenance	Inspection	Cleaning
<b>Federal Roads</b>	Fed MOW	Fed MOW	Fed MoW or DEEB	DEEB & LG	DEEB
<b>State Roads</b>	OSMWT	OSMWT	OSPWD	DEEB & LG	DEEB
<b>Rural/Local Roads</b>	LGs/ OSMWT	LGs/ OSMW&T	LG/OSPWD/ DEEB	LG/DLGI/ DEEB	DEEB/LGs
<b>Canals</b>	DEEB/DWRM/OSMEWR	DEEB	DEEB	DEEB	DEEB
<b>Culverts/ Bridges</b>	OSMWT / DEEB/ LGs	OSMWT DEEB/LGs	DEEB/LGs	DEEB	DEEB
<b>Embankment/ Levees</b>	DEEB	DEEB	DEEB	DEEB	DEEB
<b>Drainage Channels</b>	DEEB with DWRM	DEEB	DEEB	DEEB	DEEB
<b>Riverbank Stabilization</b>	DEEB with DWRM	DEEB	DEEB	LG	DEEB/LGs
<b>Dredging</b>	DWRM, MDA	DWRM/LGs	DWRM/LGs	DWRM MDA	DEEB/LGs
<b>Dams</b>	DWRM/ OSADEP/ WCOS	DWRM/ OSADEP	DWRM/ OSADEP	DWRM/ OSADEP	DEEB/ OSADEP
<b>Emergency Activities</b>	OSEMA				
<b>Land Use Planning</b>	BPPDC, MPCIU, PDCD, URMCED				

<sup>14</sup> Based on information gathered from replies in December 2018 to a questionnaire developed by the Consultant and from a follow-up meeting with the PS of the OSME&WR and Directors of the DEEB, Environmental Health Services and Administration on 18<sup>th</sup> January 2019.

### 11.2. Institutional Analysis for Flood Risk Management and Drainage Master Plan Requirements

Flood risk management aims at preventing losses and damages to the physical environment (building, infrastructure, natural resources, etc..) and to the people by managing the main sources of Risk:

- 1- Managing Flood Hazard
- 2- Managing Exposure
- 3- Managing Vulnerability

In this regard Section 12 of the FRMDMP report discusses the management requirements clearly. The important thing here is to note that managing flood risk will require the involvement of many agencies and contributors to manage and control flood risk.

A major issue with the existing institutional arrangement is that we do not have an institute that look over reducing the flood risk. What we have is an ad-hoc system where different institutions are involved and most of them are following on one part of the problem and not looking at the full picture of the flood risk management problem.

This sub-section assesses the existing institutions with respect to accommodating the requirements of the FRMDMP. The assessment is performed through a simple gap analysis. Table 11.2 presents this simple gap analysis.

**Table 11.2: Agencies Gap Analysis**

Institution	Desired Future State	Current State	Identified Gap	Action Plan
OSMEWR	To be the main control agency managing flood risk management. Measured by: 80% in control of implementing the FRMDMP	Managing parts of the work and have no overall look at the FRMDMP Measured by: 20% in control	Gap 60%	Establishment of FRMDMP technical steering committee.
DEEB	To be the main implementing Agency and the main maintenance agency Measured by: 80% in control of implementing	Managing parts of the work and have no overall look at the FRMDMP Measured by:	Gap 40%	DEEB to ensure the responsibility of design, review design and construction and follow-up on proper construction of drainage works.

Institution	Desired Future State	Current State	Identified Gap	Action Plan
	drainage plan and maintaining the system	40% in control		DEEB to continue maintaining the drainage system and ensuring proper maintenance activities. This may require special arrangements.
BPPDC	To control urban development and issue approvals and if development is not approved to remove or demolish. Measured by: 60% in control	Managing parts of the work and have no overall look at the urban development laws and enforcement of law Measured by: 10% in control	Gap 50%	Implementing of the laws and enforcing it through active courts or some enforcing mechanism. Activation of the role of PDCD and URMCD Ensure the implementation of sustainable drainage systems within the new developments.
DH	Implementing the crossing structures to the appropriate sizes and based on specific design criteria and to follow the FRMDMP developed plan Measured by: At least 90% to follow the design criteria  At least 80% to implement the FRMDMP requirements	Design and construction of all the highway crossings, implementing the available design criteria, no vision of a full FRMDMP Measured by: Only 60% to follow design criteria	Gap 30%  Gap 70%	OSPWD to continue its responsibility to design and construct the proper crossing structures following the vision of the FRMDMP

Institution	Desired Future State	Current State	Identified Gap	Action Plan
		Only following 10% of drainage system		
PIU	Complete the different in progress activities developed under the IFMPIU and transfer the knowledge and information to the other implementing agencies.  Measured by:  80% transfer of knowledge  90% handing over of all the developed material under the project  100% completion of the construction works and development works under the project (complete all priority works, Eleyele dam construction, early warning system)	Partial completion of the construction works.  Ongoing transfer of knowledge, however it is in limited way.  Measured by:  30% transfer of knowledge  20% as PIU is handing the different stakeholders the material for review  15% very slow construction activities	60%  85%	Proper handing over of the works developed and prepared under the project to the implementing agencies.  Successfully completing the works under development by the PIU  Properly Transfer of knowledge and information gained during the PIU project period (capacity building, seconded staff to return to their original jobs to enrich the original agency with the knowledge gained.
OSEMA	Implement of the emergency plan  Measured by:	Ineffective operation  Measured by:	70%	Implementation of emergency Plan to be activated based on the early warning system

Institution	Desired Future State	Current State	Identified Gap	Action Plan
	90% improvement in applying the emergency plan	20% implementation of NEMA framework		
CBA/CBO	Take responsibility of improving:  Flood Risk public awareness  In understanding relation between solid and liquid waste and Flood Risk to control Solid and liquid waste dumping in rivers and natural streams.  Measured by:  70% increase in people awareness of the Flood Risk  70% increase in solid and liquid waste control in natural streams	Very limited public awareness as people is building in the flood plains and encroaching on the rivers and natural streams and even at storage lake of Eleyele dam. Dumping solid and liquid wastes in the rivers and streams  Measured by:  15% aware of the flood Risk  10% aware of solid and liquid waste impact on flood risk and water quality	55%  60%	Prepare a program to be implemented by the CBA and all other possible organizations such as churches/mosques schools, universities, communication agencies (television and radio)
OSSWMA	Development of solid waste management plan  Implementation of the plan  Measured by	No proper solid waste management activities within the city  Measured by:		Implementation of an efficient solid waste collection system

Institution	Desired Future State	Current State	Identified Gap	Action Plan
	100% development of a plan	No proper plan is available 20%	80%	
	70% implementation of the Plan	No proper implementation of the plan 20%	50%	
Department of Budget	To raise the required fund for implementing the FRMDMP  Measured by:  80% improvement in allocating funds to implement the FRMDMP	No adequate budget to run the system and to recruit staff  Measured by:  10% allocating funds	70%	Help in raising the fund and securing the required money and funds to implement the required works under the FRMDMP

The gap analysis was used to define the alternative institutional arrangements and the recommended new arrangements.

### 11.3. Recommended Institutional Arrangement

Based on the understanding of the different agencies capacities and the gap analysis to ensure that the existing institutional arrangements can properly manage the Flood risk Plan different alternative new arrangements were prepared where the recommended alternative and its action plan is presented in this section. The key agencies shall be as follows:

- OSMEWR as the key implementing agency which will be heading the Flood risk Management Technical Steering Committee. The Flood Risk Management Coordination Committee is the most important institution for the coordination of the flood risk management program. It is proposed that the Head of this unit be a civil engineer contracted by the OSMEWR and/or the Office of the Executive Secretary of EXCo. Membership of the Committee would include representatives from the following MDAs:
  - OSMEWR with DEEB as Secretariat
  - MLGCM
  - BPPDC
  - PMU
  - OSMFB
  - OSMWT
  - OSDPW
  - OSSWMA
  - OSMLHS
  - OSEMA
- OSMEWR through DEEB and DWRM with the help of DH and OSPWD to handle the design and Construction tasks of the protection measures.

- DEEB to handle the cleaning and maintenance. All problems would be reported to them as a one-stop shop, and DEEB would, with the authority of the Maintenance Coordination Committee, direct the responsible agencies to take necessary action.
- DEEB to develop a Drainage and Maintenance unit to handle the different drainage works and maintenance of these drainage works. It is proposed that staff positions in the Unit are recruited through competition. The performance of each employee should be evaluated annually and those not considered to be performing be returned to their old duties at the payment level they were on before joining the unit.
- Development regulation laws and rules to be arranged by the BPPDC through PDCD and URMCD.
- The Planning Tribunal which is incorporated in the current legislation establishing the BPPDC but has not even been instituted, although identified in all previous legislations on the State's physical planning institutions.
- CBA/CBO handling with the help of drainage and maintenance Committee the public awareness programs to be prepared.

Figure 11.1 presents the above arrangements in a diagram format.

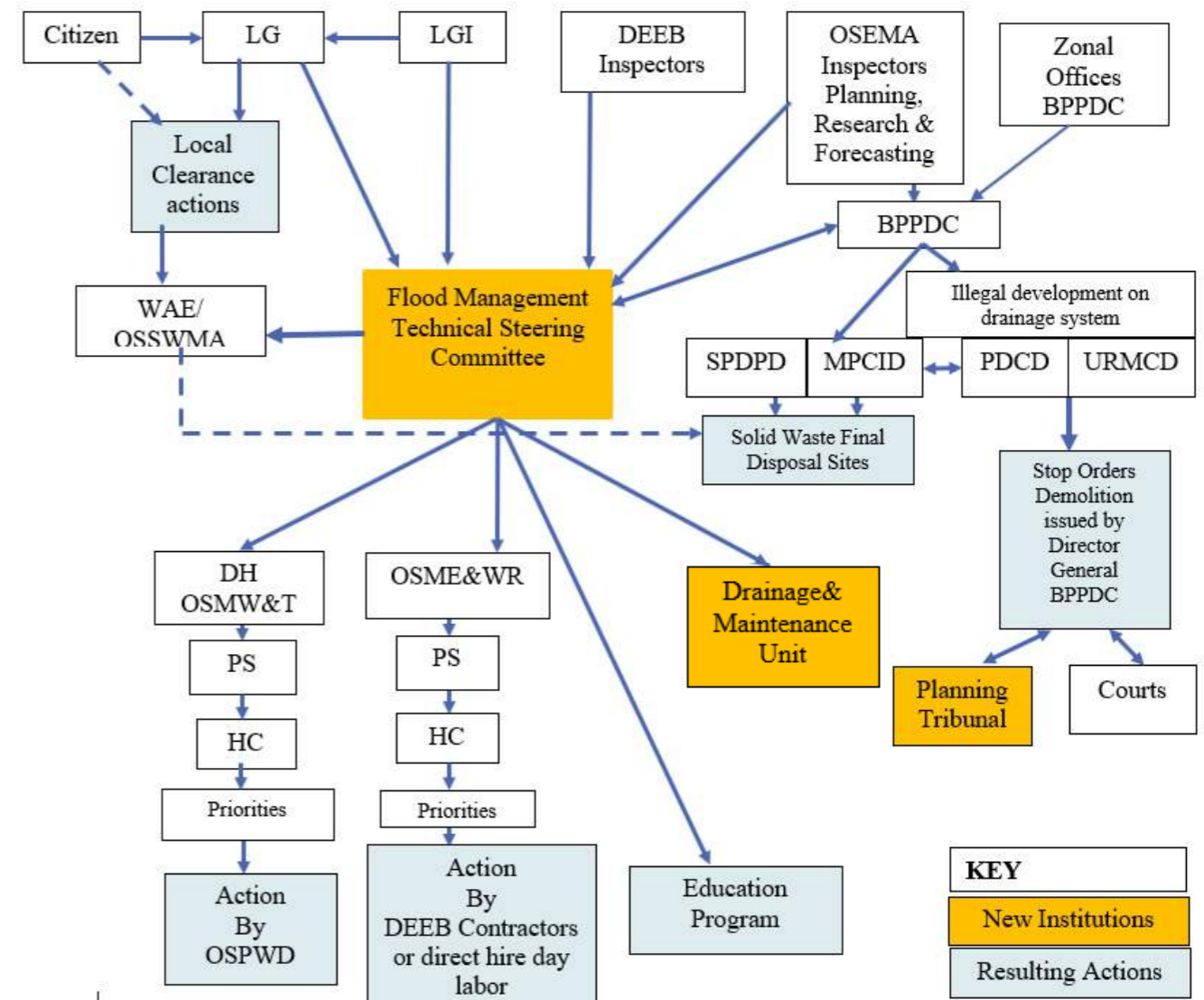


Figure 11.1: Proposed Flood Management Institutional Arrangement

The activity timeline is presented in Table 11.3.

Table 11.3: Activity Timeline

	Activity	Key Agencies	Short Term	Medium Term	Long Term
1	Establishment of Flood management Committee (i.e, permanent Technical Steering Committee)	<ul style="list-style-type: none"> <li>OSMEWR</li> <li>MLGCM</li> <li>BPPDC</li> <li>PMU</li> <li>OSMFB</li> <li>OSMWT</li> <li>OSDPW</li> <li>OSSWMA</li> <li>OSMLHS</li> <li>OSEMA</li> </ul>	Xxx		
2	Establishment of DMCU	DEEB	xxx		
3	Restructuring of OSMEWR	OSMEWR (ExCo)	xx	xxx	
4	DEEB to act as Client and contract out design and supervision of contracts	OSMEWR DEEB (OSMFB)	x	xxx	xxx
5	Contract out clearing of drainage system through retainership and performance-based contracts	OSMEWR DEEB DH (OSMWT) (OSMFB)	x	xxx	xxx
6	Signing of Law establishing BPDC by Governor	Governor	xxx		
7.	Ratification of IMP	ExCo and State Legislature Governor	xxx		
8	Establishment of Planning Tribunal	Exco OSMFB	xx	xxx	

	Activity	Key Agencies	Short Term	Medium Term	Long Term
9	Clarification in law of role of OSME&WR and BPPDC on responsibility for EIA approval	OSMEWR BPPC Office of Attorney General	xxx		
10	Decentralization of Planning and Development Control functions and capacity development	OSMLGCM BPPDC Head of Service		xxx	xxx
11	Stricter enforcement of fee collections to increase revenues	BPPDC (OSMFB)	xx	xxx	xxx
12	Identification and Planning of new sites and other means for Final Waste Disposal	BPPDC OSMLGCM (LG & LCDA) WAE OSMEWR PPP	xxx	xx	xxx
13	Reform of law on compensation for loss of land for state use	Dept. of Lands Office of the Attorney General ExCo Legislature Governor		xxx	xxx
14.	Development and approval of architecture for GIS, Data Base, including access and right of use	Office of Surveyor General BPPDC Dept. of Lands ExCo	xxx	xx	
15	Introduction of Ring Fencing Portion of fees	OSMFB ExCo	X	xxx	

	Activity	Key Agencies	Short Term	Medium Term	Long Term
	and Charges collected by an MDA for exclusive use	Auditor General BPPDC (OSMEWR)			
16	Introduction of Performance based stipends for employees in key Ministries	OSMFB Head of Service Other MDAs concerned	X	xxx	
17	Monitor impact of incentive payments	OSMFB Concerned MDAs		xx	xxx
18	Introduce increased penalties for unapproved developments and fly dumping	OSMEWR ExCo (Legislature and Governor)	X	xxx	xxx
19	Improving Capacity of OSEMA: increasing staff and providing needed equipment	OSEMA Head of Services OSMFB	X	xxx	
20	Providing adequate budget through ring fencing for exclusive use part of Ecological Fund	OSMFB		xx	xxx

**11.4. OSMEWR capacity Improvement**

As the OSMEWR is the main implementing agency with the help of other institutes and based on the required tasks to be handled by the OSMEWR and specifically DEEB, capacity improvements to DEEB is foreseen. As discussed, the DEEB shall not handle the performance of the tasks related to design, construction maintenance and post event activities by staff within the department, however these works shall be contracted to proper contractors to perform the. In this respect DEEB should have the staff capable of handling the preparation of the assignments and the management of all these tasks. This will result in limited capacity upgrade requirements which follow the vision of the Government to reduce the Government employees.

In this respect and based on Table 11.1 which lists the existing staff within the DEEB the below Table 11.4 lists the additional staff required based on the arrangements that DEEB staff shall contract the works to contractors to perform the works.

**Table 11.4: DEEB additional Staff requirements**

Position	Existing No.	Proposed No.	Balance
Civil Engineers	4	10	(6)
Hydrologists	4	4	(0)
Technologists (Civil)	2	10	(8)
Surveyors	1	3	(2)
Geologists	1	2	(1)
Technicians	3	10	(7)
draftsmen	1	5	(4)
Community Officers	2	5	(3)
Secretarial Assistants	2	5	(3)
Clerical Staff	2	5	(3)
Drivers	1	5	(4)
Forest/Agricultural Officers	1	6	(5)
Parks & Gardens Superintendents	1	5	(4)
Landscape Architects	1	2	(1)
Park Attendants	50	50	(0)
<b>TOTAL</b>	<b>76</b>	<b>127</b>	<b>(51)</b>

**11.5. Funding Arrangements**

- Budget provision must be made for the works required under the FRMDMP including the development of the different committees and units and the capacity building of the different institutions (as example DEEB). Furthermore, adequate budget provision must also be made for developing the geographic information base for the flood risk management of the city of Ibadan. Responsibility for this may lie with the Surveyor General’s Office but would involve DEEB and BPPDC and later, when more data is stored in digitized format, other MDAs, including the proposed DMCU. This system would require greater use of private contractors and increasing the capability of the responsible institutions to manage them. Furthermore, funding of a digitized land registry, including software, accommodation and hardware is an essential part of an

improved development-control system. The DEEB will also need to establish a computerized system for

- Handling the design and construction documents
  - Documenting the post events records
  - Handling of the Flood risk maps
  - recording of blockages and maintenance issues
  - improving efficiency of the prioritization program for repair and clearance work.
  - aid the monitoring of critical areas,
- The use of contractors will mean the role of the existing MDAs concerned will change to focusing on establishing strategies and standards, preparing TOR and selecting suitable and capable contractors, including monitoring implementation of the work. This is likely to change the form and size of the budget required, with more money being needed to cover payment for work done by the contractors. While less staff are required in the responsible MDA for design work, additional staff will be required for monitoring and measurement of water levels in the canals, behind the dams, and for identifying blockages and structural failures in the system. The establishment of DMCU in the DEEB will require staffing and equipment. In all probability, the overall budget in all the MDAs concerned, including the OYSMA, as mentioned earlier, will need to be increased. The question however is where such money will come from
  - One source such money would be from revenue generated through the issuance of licenses by BPPDC. It is proposed that about 20 percent of this be ring-fenced for increasing the capacity of the BPPDC, establishment of the Planning Tribunal, implementation of the GIS Data Base, establishment and equipping of the MCU and the provision of necessary and essential equipment for the OSEMA. The current estimated level of collections of revenue from this source is achieving approximately 50 percent of its potential. Improving the capacity of the BPPDC, including equipping the District Offices and the introduction of the GIS and the data base, will facilitate achievement of a higher level of collection. Currently, BPPDC receives less than 1.5% of the

revenue collected. Quadrupling the size of the departmental budget, including providing them with adequate and suitably equipped offices, would require the Bureau to achieve a ten or twenty percent increase in the revenue collected from this source. This would further increase the revenue available for other budget requirements of the State, including the proposed additional investment in the IUFMP as outlined in this report.

- Another source of money is the revenue generated from the fines exerted on the buildings illegally constructed and the illegal disposal of the solid and liquid wastes within the streams. Both BPPDC and OSSWMA can collect those fines wastes.
- A further proposal made in this report includes incentive payments for departmental staff when program targets are achieved. The success of the PIU is to a certain extent due to the special incentive payments made to the staff as well as the fact that the office is better than most government offices and is better equipped and has adequate access to transport. It raises the question of whether such incentives and employment conditions can be replicated for other departments (such as the BPPDC) and for those working in the MDAs responsible for the design, implementation and maintenance of the flood management program after the World Bank funding and for the 20% counterpart funding by the Oyo State Government for the costs has ended. Apart from the revenues raised through the licensing of contractors by BPPDC, OSME&WR also has powers to generate income through Environmental Development Charges on industrial and commercial premises. They also collect fees for approving the EIAs undertaken and various powers to impose fines on individuals and companies that dispose garbage in drains etc. While more probably needs to be done to enforce these powers, they exist and the OSME&WR receives back from the OSMF&B five percent of all the revenue they generate, which can be used in any way the Ministry sees fit to improve their services, be it the purchase of equipment, contracting of work or the payment of incentives. It is proposed that the Ministry of Finance and Budget increases the proportion of the amount that can be kept by OSMEWR and this be ring-fenced for the activities of a proposed DMCU in the DEEB.

## 12. Flood Risk Management

Flood risk management aims at preventing losses and damages by preventing flooding and/or by preventing the exposure of people and property to flooding. This includes lowering the probability of flooding as well as reducing the vulnerability of the society in flood-prone areas. Consequently, flood risk management may involve a large number of measures, for example flood defense measures, flood control measures, but also spatial planning and measures aimed at lowering the vulnerability of people and property. This is because single-measure management approaches do not take advantage of the way that various measures can reinforce each other. For example, better spatial planning to keep urban and other vulnerable development out of hazard zones may mean smaller scale engineering works to protect towns and villages. And adequate emergency response during floods can reduce flood damage and thereby lower insurance premiums.

Flood risk management is not an on-off activity, such as building an embankment or a dam. It is a continuous process, characterized by repeated activities: analysis of the flood risk, consideration of measures and policy instruments to reduce the risk, making policy decisions, implementing measures and instruments, monitoring their effects, etc. This permits constant adaptation to changing circumstances and changing societal requirements.

Flood risk management (FRM) is essentially preventive, as it focuses on all possible floods – both frequent and rare – in contrast to flood event (or incident) management, which is about dealing with floods that are happening or are about to happen. But flood risk management (FRM) does of course involve the development of flood warning systems or of insurance schemes that are essential for flood event management, as these should operate all the time and not just during flood events.

Measures and instruments are the actual 'tools' by which risk can be reduced. Measures are physical interventions in the environment, which exercise effect directly through their existence, for example embankments. They are usually implemented by the flood risk managing authorities. Instruments – or policy instruments –, in contrast, are no direct physical interventions in the environment but rather means to influence the behavior of other parties who co-determine the flood risk. For example: communication to warn inhabitants, insurance fees to make companies aware of the flood risk they run, or regulations to force local planners to better take into account flood risk.

Measures traditionally include all kinds of permanent structural measures, i.e. river engineering works, such as dams, flood walls, embankments, or river training works. Over the last few decades attention for preventive (non-structural) measures gained ground – beyond the field of river engineering – such as catchment management to enhance water retention, erosion control by reforestation, river rehabilitation, temporary defenses, etc..

Policy instruments are intended to influence the attitude and/or actions of others than the immediate responsible authorities themselves. Three main groups of instruments can be distinguished, namely communicative, financial and regulatory instruments. Communication may, for example, enhance the people's risk awareness and preparedness. Financial instruments may influence people's investments or

may encourage them to flood-proof their property. Regulatory instruments, such as land-use regulations, allow or prohibit certain activities.

In practice, measures and instruments are not so separate as represented here. It is virtually impossible to implement any structural measure without appropriate regulations, without communication about the reason for its implementation and without some financial compensation for those affected by it. And the other way around, policy instruments influence the behavior of others which may materialize in a physical form, for example, by moving to another area, by flood-proofing the houses, by raising the ground before development, etc.

The previous sections defined the risk components and listed and described the measures that could be performed to control and minimize risk. This section combines these information together where it defines which measures are important to manage the risk component. As previously defined, the flood risk components are:

- Flood Hazard
- Exposure
- Vulnerability

The measures are protective, preventive, post event and watershed conservation measures.

This section presents the link between the risk component to be managed and the possible measures to be performed to reduce, minimize and manage this risk component. Followed by the action plan to be implements

### 12.1. Managing Flood Hazard

As discussed previously flood hazard is affected by the depth, velocity and debris flows at certain location and as such to control or manage the hazard measures that affect this three factors are to be thought off and applied. Numerous mechanisms and measures are available for managing flood hazards. These can be conveniently organized in terms of three general strategies as presented below and illustrated in Figure 12.1.

- Modifying the hazard by using protection measures to alter the course or flow of the water or to attenuate the incoming flows.
- Adopting post event measures to document the extent of the occurred flood event and its impacts on structures and assets along with preparing remediation plan for the damaged assets.
- Controlling surface runoff within the catchment area through watershed conservation approaches.

The traditional approach to manage flood hazards is to adopt the protection (structural) measures i.e. concrete, earthen or other engineering structures. These structures could be used to reduce the amount of discharge running down a river such as reservoirs and they could be used as of flood defenses, such as embankments, flood walls. Examples of the protection measures could be presented below in details:

- River training is applied to increase the conveyance and hence the discharge capacity of rivers, which in turn means lower flood water levels. River training requires little space and can involve straightening, widening, deepening and lining of river channels.
- Embankments and flood walls are installed along rivers to protect parts of the natural floodplain from frequent flooding, thus allowing agriculture or more intense development. Embankments and floodwalls do allow intensive use of the floodplain.
- Checking the sizes of the existing crossing structures such as culverts and bridges to pass the flow of high events and rehabilitating the structures with bad conditions are very effective and crucial way to raise the capability of the drainage systems to accommodate high flows.
- Reservoirs may be used for the retention of water in the upper catchment. They are constructed mainly in the headwaters of rivers and tributaries in mountainous and hilly regions. Though usually primarily intended for power generation, they may also be used to delimit the discharge through the river by reserving capacity for the retention of water during heavy rainfall. Stored flood water can then be released after the rainfall peak to restore the capacity of the reservoir.

In addition to these protection (structural) measures, another more environmentally friendly measures could be adopted to focus on flood control while aiming to minimize environmental impacts. For example:

- Local, small-scale retention in small catchments or storage of water in urban areas can reduce runoff (often termed 'Sustainable Urban Drainage' or SUDS). This is particularly important for the management of urban flooding caused by the overflow of sewer systems. It is effective for small to medium scale floods.
- 'Room for rivers' measures aim to increase the available floodplain area or the channel dimensions in larger rivers, whilst allowing natural developments and enhancing the perceived 'spatial quality' of the environment. Measures include removing obstacles from the floodplain, setting back embankments (or 'managed realignment'), the lowering of floodplains, or the construction of bypass channels or 'green rivers'. The aim is to provide more room for discharge or storage along rivers while allowing more natural ecological development in the floodplain.

Once a flood occurs, post disaster recovery measures such as documenting the flood and damages, notifying public for repairing or reconstructing of damaged assets and applying remediation plan for damaged infrastructure are needed to moderate its impacts. A public policy dilemma associated with post recovery measures is the extent to which they encourage risk-taking. If a community knows that should a disaster strike it will receive assistance and relief in the form of low cost and subsidized insurance.

In addition to that, the important role of soil conservation in integrated flood management needs greater recognition, particularly during the development of master plans at the river basin scale. Management of land use in upper watersheds includes afforestation programs and programs to raise the awareness of the effects of inappropriate land use practices and to modify behavior in agricultural communities. Field programs and agricultural extension activities in rural areas should explain to land users how their land use practices are inappropriate for the conditions and how improved practices could enhance and sustain their incomes while conserving soil fertility and soil moisture

and reducing runoff and erosion. Education should also target school children so they mature with better understanding of the interdependence of society and nature, and appreciate the need to achieve harmony and sustainability in our use of natural resources.

Figure 12.1 presents the action plan proposed by the Consultant and summarizes the role of the above discussed measures in controlling and reducing the depth and velocity of flood waters to decrease the hazard of floods on inhabitants and assets.

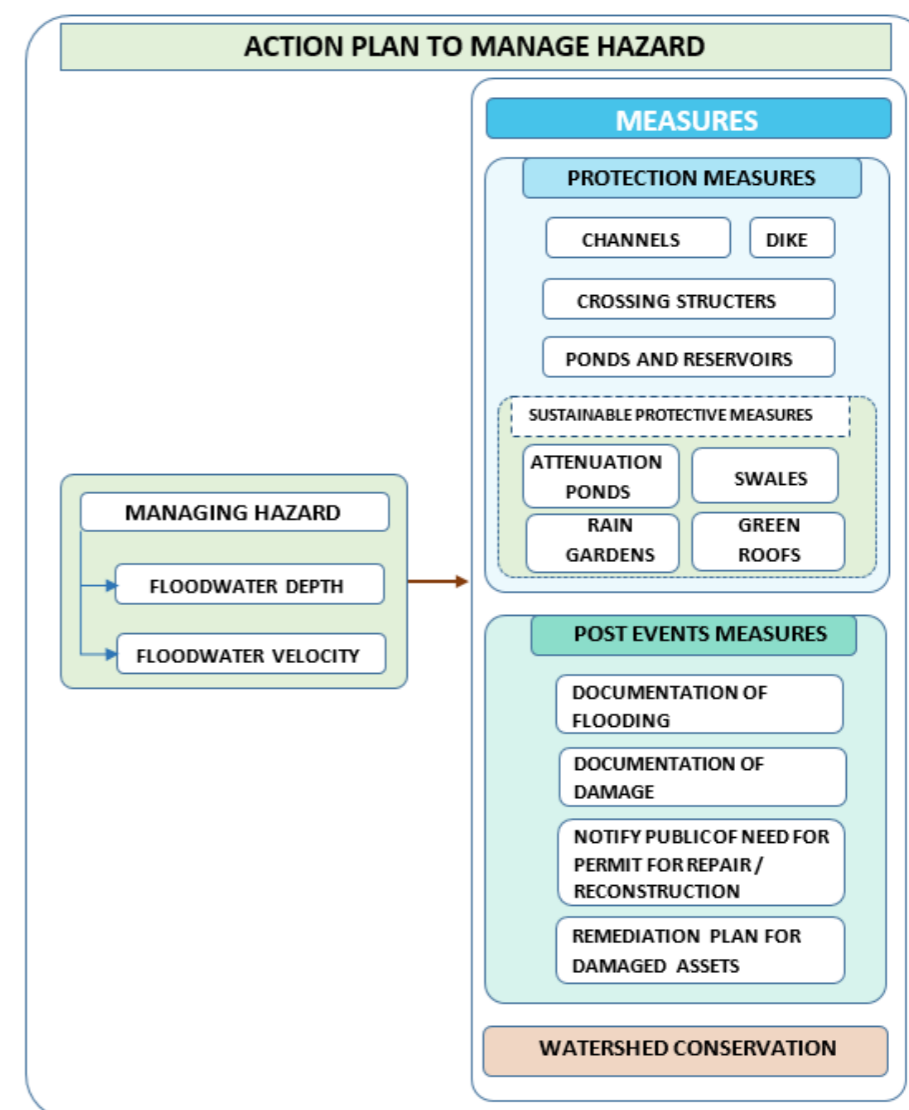


Figure 12.1: Proposed Approach to Manage Flood Hazard

### 12.2. Managing Exposure of People and Assets to Flood Hazards

Exposure to flood hazard can be contained and managed at a safe levels, levels with low hazard and as such low risk, by:

- Proposing interventions within the mainstreams, rehabilitating the damaged structures and adopting sustainable drainage measures which is covered under the protective measures.
- Using preventive measures to limit the people exposure to flooding through

- Preparing risk maps for the city and use these maps to inform the people to the status of the area they are living within.
- Regulating residential development to manage population increase in hazard areas,
- Managing the types of enterprise permitted in hazard areas, and
- Public Awareness to make the people aware of the actions to be taken in case of flood events and to make them aware if their lives are in danger if they are living in risk areas.
- Flood warning systems can reduce the number of people affected by floods.
- Performing post event measures which result in reduced exposure in the events to occur after.
- Controlling surface runoff within the catchment area through watershed conservation approaches.

As indicated in Figure 12.2, most all the protective and preventive measures along with the post events measures and watershed conservation could help in managing the exposure of people and assets to flood hazard. All these measures are able to limit the extent of the flood waters which in return decrease the exposure probability to floods.

This section will focus on the role of preventive measures in managing exposure to flood hazard since the remaining measures are discussed in the previous section and they could be summarized as follow:

1. Using the flood risk maps to demarcate the zones with high risk is an effective way to prevent the vulnerable groups of people from being there at the flood event and buildings with high vulnerability from being planned to be constructed in these zones.
2. Providing credible early warning and information systems at the community level. The guiding principle is to have easy-to-understand methods for people from all backgrounds. In addition to that, easily accessible alerts and announcements should be provided. Well-coordinated, clear and timely community alert systems should be in place. Facilities such as sirens and loudspeakers, installed in public places, can be effective in reaching the greater mass.
3. Practical training measures, enhance awareness, and support lifesaving actions. Designing and delivering appropriate capacity building measures for the communities living in high risk areas are pre-requisite to ensuring their safety. The activities should focus on raising the awareness of the communities, specifically on the nature of flood risk that they face, and how to respond individually, as well as collectively, in the community.
4. Awareness of escape routes and safety zones. All members of the community should be aware of all alternative escape routes to safe areas. It must be promoted prior to the occurrence of floods through use of accessible accessibly designed materials, incorporating features such as audio and visual information. For instance, descriptions of visual information such as maps. The presence of visual, tactical, and auditory cues in the physical environment must augment information contained in preparedness materials.
5. Land use regulations can then be attributed to the different zones or categories of flood hazard. This is best done in association with statutory spatial planning, a typical local government responsibility. The flood hazard should be considered in conjunction with other spatial planning objectives. However, in general, the regulations should determine the:

- Type of buildings that are appropriate;
- land use that is appropriate, which may exclude residential use or be limited to uses such as recreation and agriculture;
- Siting of public services such as schools, hospitals, emergency services, and flood refuges;
- Storage of hazardous chemicals and materials; and
- Routing and/or siting of key infrastructure such as electricity substations, water supply, water treatment, and sewerage facilities.

The land use controls should be linked to building regulations, which are also directed to reducing vulnerability to exposure that may be permitted under land use management, but are inextricably linked to land use controls and zoning. Building regulations may specify minimum floor levels. For example, they may require dual-story housing or place conditions on electrical supply, drainage, and sewerage provision. Certain types of construction may be proscribed as unsuitable for structural integrity during inundation or may be required to have ancillary measures to allow the sealing of openings and flood-proofing during flood alerts. This is not an exhaustive account, but indicates the type of regulations that may be introduced. They should be connected to the system of approvals for building applications. The system should include provision for inspections to ensure compliance and appropriate penalties for noncompliance.

Although methods of land use management are better suited to regulate future development, existing development exposed to flood hazard may also justify land use management intervention to redress past problems or planning omissions. For instance, this could entail voluntary or compulsory acquisition of properties. However, compulsory acquisition should be restricted to allotments where current land use or development exposes people to great danger or there is frequent inundation of the land (i.e., higher hazard land). After public acquisition, the land can be converted to alternative use more compatible with the flood hazard.

It may be possible to retain current land use and modify exposure to the flood hazard. For example, access to buildings may be modified, the lower levels of building levels may be converted to passive use such as car parks, and flood barriers and watertight seals may be added.

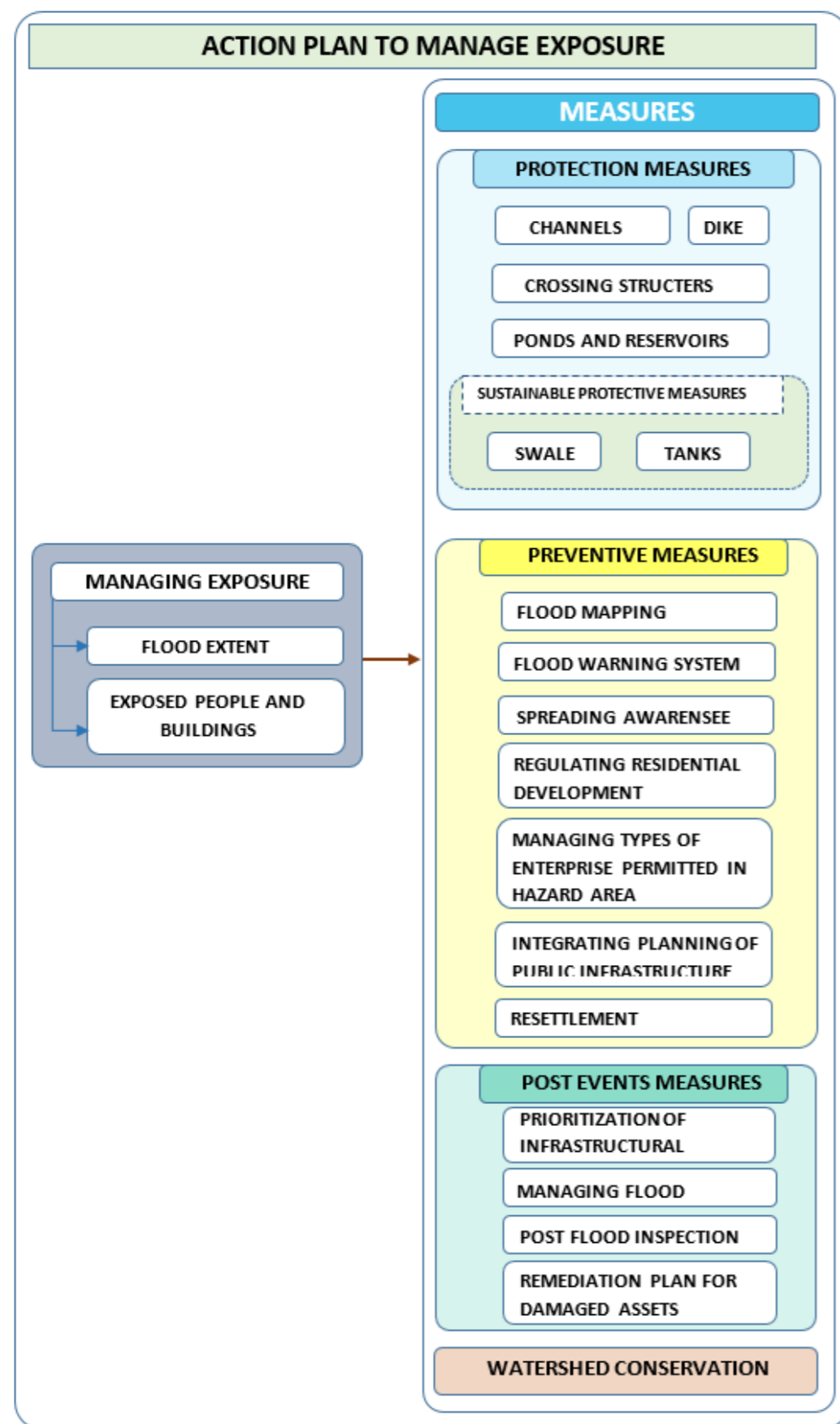


Figure 12.2: Proposed Approach to Manage Exposure of People and Buildings to Flood Hazard

### 12.3. Management of Vulnerability to Danger or Damage

Managing vulnerability is an essential component of preventing the risk of flooding. This section discusses the action plan to manage the area vulnerability to danger and damage due to floodwaters. As mentioned previously that managing area vulnerability depends mainly on managing its three main components which are speed of flood event, warning the inhabitants with the upcoming events and good planning of the floodplain area. This section also draws our attention to control the danger to the most vulnerable groups in a community - women, children, elderly, disabled, ethnic minorities and the poor. These are the members of the community who are generally likely to be the worst-hit in case of disasters because of their deprived access to resources such as social networks, influence, transportation, information, skills (including literacy) and employment, personal mobility, secure housing, control over decision-making, control over land and other economic resources and dependence upon others. Figure 12.3 presents the adopted action plan by the Consultant to manage vulnerability.

Managing area vulnerability could be implemented through the following:

1. Managing speed of onset through improving the management of upstream catchment areas. It can happen, for example, by limiting soil sealing or the adaptation of agricultural practices. Many scientific studies have shown that land use management on catchment areas is effective for very frequent rising rivers (return period up to about 25 years).
2. Providing flood warning to increase the number of people exposed to danger from being in the high risk zones.
3. Managing the development in the floodplain area through:
  - a. Restrict or prohibit new development in flood risk areas. These measures can have an impact on social and economic issues (issue of renewal of the population, economic weakening of the city, etc.)
  - b. Eliminate vulnerable properties. These measures are very difficult to implement: the people who settle in at-risk areas, do so, most of the time, because those areas are the only accessible ones from a land perspective. The answer sought must fit into the more general framework of housing assistance policy: the relocation of families in illegal housing should give them alternatives, and "squatting" should be immediately destroyed to not allow another family to settle. These actions are organized within dialogue with target populations, and with the involvement of associations or district representations to educate their communities on inherent risks and work to establish acceptable relocation.

Managing people vulnerability could be implemented through the following:

1. Identification of vulnerable groups and people at the community level. Segregated data of vulnerable group members should be collected and maintained prior to flood occurrence. Generally, such data is not available, but can be collected at community level, normally without difficulty.

2. Providing flood warning and information system and managing the development within the floodplain area have direct effect on managing the vulnerability of people in addition to managing area vulnerability.
3. Setting up of safe shelter far in advance of annual flood season.
4. Volunteer management plans. Youth volunteers can easily reach and help the vulnerable group members. They can provide support in evacuation, relief distribution, and caring for the sick or the needy.

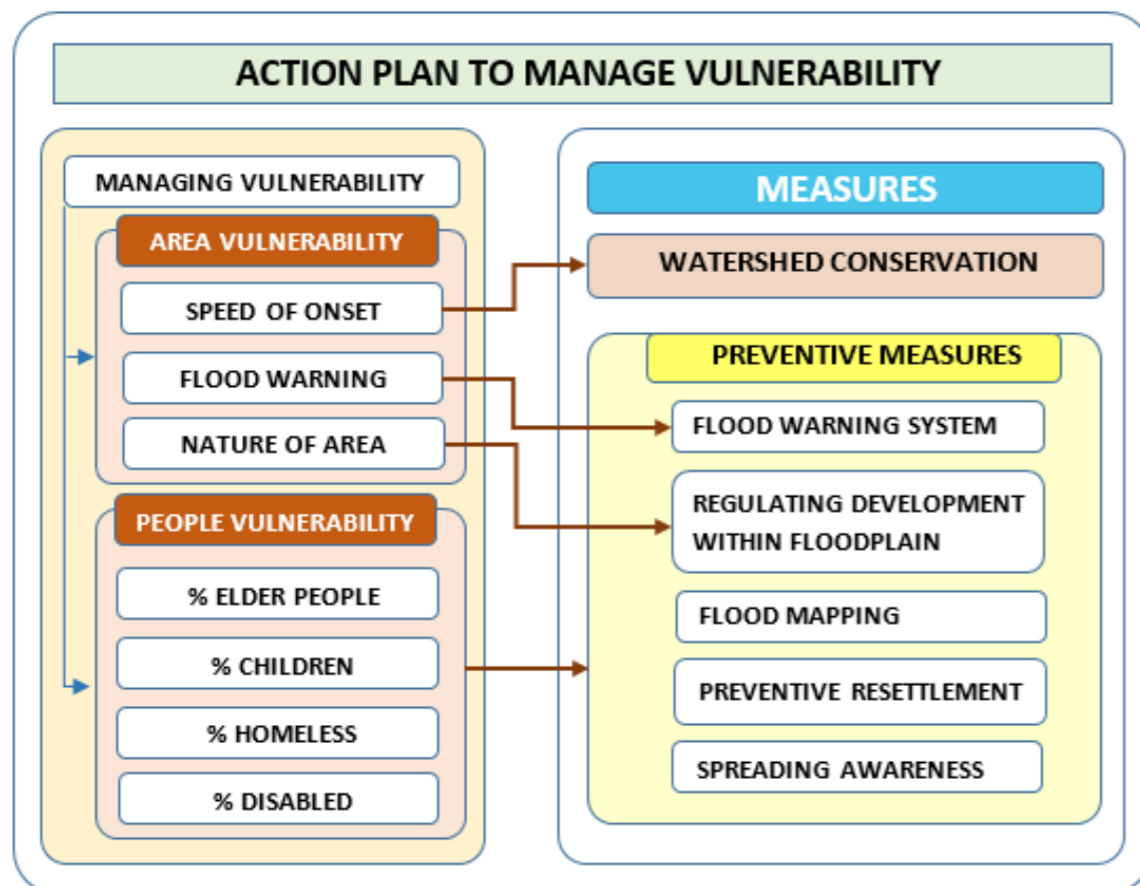


Figure 12.3: Proposed Approach to Manage Vulnerability to Danger or Damage

### 12.4. Flood Risk Management Action plan

The flood risk management action plan for the city of Ibadan is summarized in this section. The action plan is based on the management requirements for each of the flood risk components. In this respect the following actions are either defined and implemented or actions were proposed to be undertaken at a later stage and by others.

- Drainage master plan was designed to control the flooding. This drainage master plan used and applied different protection (structural) measures. This drainage master plan is presented in Section 7. In this drainage master plan the different protective measures were implemented in addition to different sustainable protective measures. The drainage master plan was prioritized based on risk and the cost of each priority was calculated and presented.

- As the master plan was targeting the medium and large scale basins and systems, sustainable drainage methods are proposed to be implemented at the local scale. This sustainable drainage measures are presented in Annex 19.
- Flood risk maps were developed for the full city of Ibadan for the existing conditions and for the case after implementing the different protective interventions. This flood risk maps can be used to warn people living in medium and high risk areas, control the developments in the risk areas and move people during flood events. Section 5 presents the methodology used in developing these risk maps. Section 8.1 presents the benefits of developing these risk maps and Volume 3b presents the building risk maps and volume 3C presents the People risk maps. Annex 18 present the institutions required to be involved in updating these risk mas and in using of the maps.
- Early warning system project is one of the projects undergoing by the IUFMP. For more information regarding this project it is advisable to refer to the main reports and implementation plan of this project. This is covered under Section 8.2.
- Maintenance program is proposed for the full city of Ibadan for the existing conditions and for the case after implementing the different protective interventions. This program is vital for the proper operation of the drainage system and as such for reduction of the flood risks. Section 8.3 covers the maintenance strategy while annex 21 covers the proposed maintenance program. Annex 18 present the institutional arrangements required for implementing this program. It is important to note that the PIU under the IUFMP is implementing maintenance tasks.
- Awareness is a vital measure in reducing exposure of people and safe vulnerable people. This includes awareness of the nature of flood risks that they face, awareness of risk locations, awareness of escape methods and routes. The awareness is handled by the PIU through a communication consultant and awareness programs are supported by the IUFMP. This measure is covered under section 8.3.
- Land use regulations within flood plains is handled by the BPPDC with the help of the respective departments. The regulations is usually linked with the building regulations where it limits the building within the risk areas. Section 8.5 present the guidelines and Annex 18 present the intuitional arrangements where PDCD, URMCD is the main implementing institution.
- Post event measures are also proposed as presented in Section 9 and the institutional arrangements for the implementation of these post event measures are proposed in Section 11 and Annex 18. Annex 5 presents the database developed within this project and as such can serve as the base case for the documented conditions within the city of Ibadan.
- Watershed conservation strategies and actions are proposed in Section 10. It is to be noted that the watershed conservations measures implementation requires the coordinated efforts between different institutions and stakeholders and as such actions in this regard are only proposed. The institutional arrangement proposed covers the means of coordinated works between the different institutions (refer to Annex 18).

The proposed action plan to manage Flood Risk is presented in Table 12.1.

**Table 12.1: Proposed Action Plan to Manage Flood Risk**

Action	Targeted risk component	Status	Cost estimate	Priorities	Implementation requirements	Comment
Drainage master plan	- Hazard - Exposure	Completed	Calculated	Defined	- Authorities approval of the Plan. - Funding requirements to perform detailed design and construction	Covered under Section 7 and associated Annexes
Sustainable measures	- Hazard - Exposure	Different methods are Proposed	Not calculated as this shall be implemented at the local scale and should be born by the developers	All new developments	- Enforcement laws and regulations to be devised. - Institutions authorized to control developments should be well equipped to perform this work.	Covered under Section 7 and Annex 19
Risk Maps	- Exposure - People Vulnerability	Completed	No cost is associated with using these maps. However the cost of updating these maps is to be born by the OSMEWR and DEEB as they are managing the design and construction of the drainage works	- Use of the maps from now to limit risk during the coming flood events. This can be done by starting informing people living in risk areas.	- Capacity building through transfer of knowledge from the PIU engineers and the OSMEWR and DEEB - Funding to establish the database system and the staff responsible for the update.	Covered under sections 5, 8 and Volume 3b and 3c and Annex 18
Early Warning System	- Exposure - Area Vulnerability	Project is in progress  And implementation of rainfall and flood flow monitoring stations are in progress	Refer to EWS project	- Central zone of the city of Ibadan including Ona river - It is important to note here that it is required to implement the EWS in the Omi basin.	- OSMEWR with the help of OSEMA	EWS project report and Section 8.2 of this report
Maintenance of drainage system	- Hazard - Exposure - People vulnerability	completed	Around 4,000,000\$ every year (which is around 1% of the total cost of the drainage master plan implementation)	- Central zone - At culverts and bridges - At locations where attenuation of flow exist. - It should be noted that PIU already defined some priority areas and they are implementing maintenance works at.	- DEEB, MDAs LGI, MPCID, and SPDPD	Covered under Section 8.3, Annex 21 and 18 (for institutional arrangements)

Action	Targeted risk component	Status	Cost estimate	Priorities	Implementation requirements	Comment
Public awareness	- Exposure - People vulnerability	Communication task is under the implementation of the IUFMP	Refer to IUFMP	- High risk areas - City center - Omi basin	- Refer to IUFMP	Section 8.4 and Annex 18
Land use regulations	- Exposure - Area vulnerability	Zoning is defined and setbacks are completed	- No cost is associated with defining the regulations and or the determination of the setback (as they are defined under this project) - Cost of implementing these guidelines is included in the scope of work of the BPPDC	- High risk area - Existing setbacks	- BPPDC with the help of PDCD and URMCD are required to start enforcing these setbacks - Funding can be generated from the cost of permits and from the fines associated with land regulations violators and illegal disposal of solid and liquid waste	Section 8.5 and Annex 18
Watershed conservation	- Hazard - Exposure - Area Vulnerability	Different methods are Proposed	Not calculated as realization of this will require the involvement of different stakeholders and institutions	- Rural areas within the northern parts of Ibadan (upstream catchment area). - Omi basin as many parts of this basin is still rural	- Proposed Steering Committee to manage flood Risk should coordinate these works - Other institutes to be involved	Covered under Section 10 and Annex 18.
Post event measures	- Hazard - Exposure	Different methods are Proposed	For establishing the platform around 200,000\$ to 300,000\$ are required. (covering, recruiting staff, database room computers and software. The GIS lab constructed within the BPPDC under the Ibadan urban master plan is an example to Post event requirements.	Establishing the platform to cover the implementation of proper database and perform the different measures, (the staff, computer facilities and database system)	- Oyo state ministry of environment and water resources through DEEB and the MDAs to arrange for the realization of this measure. - Funding required for implementation.	Sections 9 and 11 and Annexes 5 and 18
Institutional arrangement	All aspects of risk	New institutional arrangements are proposed	The proposed arrangement requires something in the order of 200,000 \$ per year for some 5 years to implement the new arrangements.	Establishment of the steering committee.  Proper handing over of the knowledge and information gained under the IUFMP to the respective institution	- Establishing the new institutional arrangement - Recruitment of staff - Implementing the funding proposals	Section 11 and Annex 18