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Investigating the potential of using simple SuDS in informal settlements in Lagos, Nigeria to transition to a sustainable surface water management system

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Investigating the potential of using simple SuDS in informal settlements in Lagos, Nigeria to transition to a sustainable surface water management system

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Declaration

I declare that this project is the result of my own work and all the written work and survey are my own, except where stated and referenced otherwise. This thesis has not been accepted or submitted for any comparable award elsewhere.
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ABSTRACT

Rapid urbanisation, coupled with climate change, highlights the underperformance and failure of current conventional water management systems. Flooding during the rainy season has become a yearly phenomenon for most countries across Africa, with the poor, living in slums or informal settlements being impacted the most. In order to better manage this problem, this research investigated the potential of adopting a sustainable alternative: sustainable surface water management (SSWM) systems. A transition framework was developed to deliver SSWM focused on informal settlements using sustainable drainage systems (SuDS) as the major driver. SSWM systems reduce runoff by treating stormwater as close as possible to its source, preferably on site. Presently, there appears to be a paradigm shift towards more SSWM practice in developed countries with the growing adoption of SuDS to replace or work in conjunction with, existing conventional drainage methods. However, less-developed countries (LDCs) such as those in West Africa still rely solely on conventional drainage methods.

Lagos, Nigeria was chosen as the study site, as it suffers regular flooding, is surrounded by informal settlements, and the existing drainage infrastructure is generally not fit for purpose. A mixed research method was adopted to collect data for this study. This entailed the administration of questionnaires, interviews and focus group meetings with relevant stakeholders, including residents, community leaders and government officials. Data was collected in 2 visits between April and August 2015 across 9 settlements in Lagos. The first visit comprised the administration of 150 questionnaires across the visited sites, and 76 of these were retrieved. Focus group meetings were also conducted to familiarise the respondents with SuDS. During the second visit, 154 questionnaires were retrieved of the 200 distributed, and interviews were carried out with 15 participants, including residents (formal and informal alike), community leaders and government officials.

The result from this study indicated that the informal settlers experienced more flooding episodes and also more severe incidences than those living in formal areas. Compared to the formal settlers, negative impacts were much worse and flood waters remained for longer periods in the informal settlements. Further findings showed that the government placed little or no emphasis on addressing these flooding issues in the informal areas. Additionally, the realisation that conventional systems are failing was highlighted in the results, as respondents indicated that blocked gutters were a major cause of flooding. It was also found that the informal residents were interested in the concept of SSWM and its implementation using SuDS in order to address the ongoing flooding issues. These findings clearly demonstrate a need to address these issues, hence, for the first time a framework has been developed focused on informal settlements to set out a process whereby SSWM could be achieved. This framework aims to guide stakeholders in the water management sector to achieve SSWM through the adoption of SuDS. The transition framework has been designed by adapting and building upon 4 existing water

management frameworks, but tailored to suit developing countries. It has been evaluated by field experts across four countries: Nigeria, Gambia, Uganda and the UK. The evaluation process indicates that the framework is fit for purpose and can deliver SSWM. The design consisted of 4 iterative phases: Phase 1, knowledge/change; Phase 2, strategy; Phase 3, tactics; and Phase 4, implementation and maintenance. It identifies the implementation of SuDS as an essential tool to ensure SSWM.

This study has collected data on flooding issues and events amongst selected informal settlements that have not been previously investigated or recorded. This data was a pre-requisite for the development of a novel framework to guide the transitioning to SSWM by all stakeholders. The use of simple yet effective methods have been investigated and evaluated to sustainably manage runoff in this study. Furthermore, the framework delivers a sense of responsibility to residents as well as officials to effect positive and sustainable change to their water management systems, not just in Nigeria but in other LDCs.

Keywords: Conventional drainage, Flooding, Informal settlements, Transition framework, Sustainable Drainage Systems (SuDS), Sustainable Surface Water Management (SSWM), Stakeholders, Urbanisation.

Dedication

This work is dedicated to God Almighty in whom I live, move and have my being, without whose grace this would be impossible. I also dedicate this work to my parents. Dad, Late Lambert Levi Brown Ogolo, many years ago you planted a seed, and God willing it has come to fruition. I hope I have been able to live up to your expectations and have made you proud. Mum, Mrs. Valentina Veronica Anne Ogolo, words are not enough to say thank you for all your sacrifices and support, moral and otherwise. Finally, my kids Kamsiyochukwu Mezue and Munachiso Mezue, this is dedicated to both of you, who have been the reason for it all. You have both been my greatest motivators to see this to a finish.

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CHAPTER 1: INTRODUCTION

1.0 Introduction

Until recently, stormwater was seen as a nuisance that needed to be disposed of as quickly as possible. As a result, conventional drainage is designed as surface water management systems, put in place to convey stormwater away from its point of generation to receiving bodies downstream, as quickly as possible (POST 2007). However, currently, various developed countries have accepted stormwater as an asset that can enhance the urban environment and increase water security (Armitage *et al.* 2013). Therefore, a more sustainable surface water management system has been sought. In hindsight, the use of traditional/conventional methods of managing stormwater via pipes and drains causes more problems than it solves. It is now clear that the problems caused by conventional drainage relatively outweigh its benefits.

It has been established in the literature that conventional drainage leads to flooding and other underlying issues such as pollution of the receiving natural water bodies by the channelling and depositing of pollutants carried by runoff, erosion problems, etc. It is therefore not sustainable (Berry 2000; Monk 2006; CIRIA 2007; Ghani *et al.* 2008; Armitage 2011; Poletti and Tassi 2012; Shuttleworth *et al.* 2017). Sustainability of water resources, especially taking account of climate change, is essential. Water, an essential universal commodity, is lacking in various areas of the world, hence the realisation that there is a need to sustain it in all its forms. Stormwater is an asset that should be fully utilised now and for posterity, therefore a stormwater management system that is sustainable is extremely important. A sustainable drainage system that acknowledges equally water quantity, quality, amenity and biodiversity in the management of drainage is now the popular approach to ensuring and delivering a sustainable surface water management system (SSWMs) in Europe, Australia, the USA and other countries. This system is known by many names: Sustainable Drainage System (SuDS) in the UK (formerly Sustainable Urban Drainage Systems); Best Management Practices (BMP) in Europe; Low Impact Development (LID) in the USA and Water Sensitive Urban Design (WSUD) in Australia. However, they all cover the same approach to sustainable drainage (Shuttleworth *et al.* 2017). For the purpose of clarity throughout the study, SuDS (as it is called in the UK) will be the adopted name

for these techniques. The idea behind SuDS is to replicate or mimic the natural or original drainage process at each site, using cost-effective systems that are sustainable or that have a low environmental impact. There are a plethora of definitions of SuDS by various scholars and researchers. According to CIRIA (2005), SuDS is a concept that includes long-term environmental and social factors in decisions made about drainage. The concept is represented in Woods Ballard et al., 2015 as the SuDS square, which is further discussed in section 2.10, Figure 2.4. It takes into account the quantity and quality of runoff, as well as the amenity and biodiversity value of surface water in the urban environment and comprises a sequence of management practices and control structures designed to drain surface water in a more sustainable fashion than some conventional techniques (Charlesworth 2010).

SuDS as a tool to manage runoff can be designed as a single technique or a train of techniques designed in one system, depending on various factors such as flood occurrence and frequency, existing planning and regulation policies, land mass, existing drainage pattern, cost etc. Some of these techniques include pervious pavements, porous asphalt and concrete, swales, detention ponds, rain gardens, green roofs, etc. Recent studies have shown that these techniques could provide multiple benefits, in addition to the SuDS square (Woods Ballard *et al*. 2015; Armitage *et al.* 2013). Some of these multi-benefits include reduction of urban heat island effect (Graham *et al.* 2012), irrigation and water supply for landscaped areas (Nnadi 2009), and the provision of renewable energy using ground source heat systems (Charlesworth, Faraj-Lloyd and Coupe 2016).

However, the implementation of simpler, cost-effective SuDS as a tool to manage stormwater in informal settlements in Lagos, Nigeria is the focus of this research. The rationale behind choosing cost-effective SuDS as a sustainable alternative is mainly due to the precarious situation that informal settlers find themselves in financially, especially with no assistance from the government. This is primarily because they are informal settlements and should not be there in the first place. It is worth noting that one of the barriers to SuDS implementation is cost, i.e., the cost of implementing and maintaining these devices. Therefore, the implementation of a cost-effective SuDS will

be better accepted by the informal settlements, as they possess minimal finances to cater for their livelihoods, without spending on drainage devices.

Eight informal settlements and one formal settlement in Lagos, Nigeria have been selected as study sites. The rationale behind selecting Lagos as a prime location is discussed in detail in Section 2.16.

SuDS the concept and all its techniques to manage runoff are discussed in depth in the following chapters. This concept has been widely adopted by various developed countries and has recently been successfully implemented in some developing countries. The implementation of SuDS in these developing countries will be discussed in the subsequent chapters, in order to draw on the experiences of countries that seemingly share similar characteristics to Lagos, Nigeria. For example, SuDS have been successfully implemented to combat flooding in certain areas of Malaysia, Brazil, Chile and India, which are all developing countries (Ghani *et al.* 2008). While the implementation of SuDS in Africa is almost non-existent, recently countries such as South Africa and Algeria have also implemented SuDS to manage runoff. It is, however, safe to say that these countries are arguably more developed than the poorer less-developed countries in West Africa.

The government plays a vital role in ensuring a sustainable environment for its citizens; the problems of drainage in most developing African countries are not considered a priority, mainly because of a lack of knowledge. Current information on urban drainage is very limited for developing countries. According to Armitage (2011), most information focuses on conventional methods. He stated that the existing literature fails to view urban water management in a holistic manner: “the failure to comprehend that every drop of water brought into an informal settlement has to be safely removed otherwise it becomes a drainage problem and possible health threat, borders on criminal” (Armitage, 2011). This research focuses on filling that void by holistically addressing flooding and drainage problems in the selected informal settlements in Lagos.

This lack of knowledge has led to the government in Nigeria failing to prioritise flooding as an issue that needs resolving; it constantly turns a blind eye to the imminent

problems created by flooding and poor conventional drainage methods (Nkwunonwo, Whitworth and Baily 2016). It focuses more on issues that are perceived as more pressing, whilst continued flooding and its underlying factors brought about by urbanisation continue to negatively impact society. It is therefore, time the poorer communities who seem to be affected the most, effect a change that would improve their quality of life by attempting to sustainably manage stormwater using simple or soft SuDS. Hence, this study sought to explore the implementation of SuDS at a community-based level in informal settlements in Lagos, Nigeria as a tool to deliver sustainable surface water management.

1.1 Statement of Research Problem

Although the recognition of stormwater as an asset has led to the implementation and documentation of SuDS as a tool to sustainably manage runoff by various developed countries and a few developing countries, there still exists a knowledge and technological gap about this ideology in most of the developing world. Very little research on the issue exists with an emphasis on its application in West Africa, hence the desire to bridge this knowledge gap as well as to proffer sustainable techniques to cost-effectively combat flooding issues in poorer countries. It is worth noting that although the term SuDS is not widely recognised in most developing countries, some of its simpler techniques have already been applied as erosion/flood control measures as well as for irrigation and water-saving purposes.

1.2 Research Questions

With the above problem in mind, the research seeks to answer certain questions such as:

- What is the potential value of SuDS and SSWM in informal settlements?
- Can SSWM be achieved by implementing SuDS in informal settlements?

1.3 Aims and Objectives

Aim 1

To investigate the suitability of SuDS in informal settlements in Lagos, Nigeria with a view to exploring potential challenges, advantages and enabling factors that would affect the implementation of SuDS.

Objectives:

1.1 To determine whether SuDS devices can be implemented as a SSWM tool in informal settlements in Lagos, by investigating the applicability of SuDS as a SSWM tool, and by exploring where and what SuDS have been implemented to attain SSWM.

1.2 To determine the potential for its use while establishing suitable SuDS for selected study sites.

1.3 To investigate potential factors affecting the implementation of SuDS with an emphasis on informal settlements in Lagos, Nigeria.

Aim 2

To design and evaluate a potential framework for the implementation of SSWM in informal settlements in Nigeria.

Objectives

2.1 To design a transition framework for implementing SuDS as a SSWM tool in Lagos, Nigeria.

2.2 To evaluate the framework for suitability in informal settlements in Lagos and its wider application.

1.4 Methodology Overview

To achieve the aims and objectives of this project a methodology has to be adopted. The research adopted a mixed method, consisting of a combination of quantitative and qualitative methods, as an appropriate strategy for this research. This involved a bench study comprising a critical analysis of the existing literature on SuDS, the existing literature on tropical SuDS, and the existing literature on key indices in Lagos such as

geography, climate, population, urban migration, flooding and drainage patterns. Field-based studies were carried out, as well as the administration of questionnaires, semi-structured interviews and focus group meetings for data collection and analysis purposes. The use of Google Earth to identify clustered settlements (informal settlements) has been explored in this study to allow for ease of selection of tools for the selected study sites. Further to this, the potential of using Google Maps as a decision-making tool for SuDS selection in informal areas was also investigated.

1.5 Field Trials

The research also involved exploratory/observatory field trials. Field trips to Lagos were carried out to explore the study area and to discuss the selected techniques based on field observations. The research also undertook an observation study to investigate the attitudinal approach to the selected techniques. The study sought to observe how the communities adapted to the suggested SuDS designs. This was necessary to evaluate the feasibility of implementing SuDS in the area. Survey visits were made to the selected study sites to provide the researcher with a clear picture of the flooding issues faced by the community.

Face-to-face interviews, questionnaires and meetings with the community were conducted for data collection purposes. This enabled a better understanding and clearer view of the flooding problems being faced. Focus group meetings were held to create awareness for the success of the project as well as to educate the community on SuDS, its benefits, requirements and maintenance.

A desktop study using the results from the field experiments provided an indication of the applicability of SuDS within the community.

1.6 Significance of the Study

While this project aimed to introduce SuDS as method/driver to deliver sustainable stormwater management in informal settlements in Lagos, it also possesses more potential. Currently, in Nigeria and the whole of West Africa, there exists no implementation or documented literature on SuDS. This research introduces SuDS in informal settlements in Lagos, making it one of the pioneering African cities to implement and produce documented literature on SuDS. In this way, it will create a

platform for future research on West Africa and other tropical regions. This will be vital because coupled with the experience drawn from other tropical regions, a study covering a West African country and a local community is likely to be embraced by other African countries, as they share similar characteristics, cutting across various factors like climate, and social and cultural way of life. Furthermore, lessons can be learned as this study involves a low-cost implementation approach and sustainable resource use that are not presently employed in the implementation of some SuDS techniques.

One of the major barriers to the implementation of SuDS worldwide is the lack of design information (Reed 2004). However, this research critically examined relevant frameworks while considering existing conditions such as climate, drainage methods, terrain, land use type, legislation etc. This was considered necessary because the issue has to be addressed from a slightly different perspective. While design information does exist, it was created to fit more temperate countries, which have a very different environment to tropical and developing regions (Reed 2004).

Furthermore, the outputs from this thesis are expected to lead to increased non-potable water uses, hence promoting the ideology that stormwater is indeed a resource. According to Ashley *et al.* (2011), stormwater runoff in urban areas is recognised as one of the largest untapped potential sources of water**.** In addition to this, the wide range of SuDS techniques may also provide additional multi-benefit impacts on SuDS techniques in Africa, i.e. reducing pollution of water bodies, urban heat reduction, reducing temperatures of receiving water bodies etc. In summary, the rationale behind this research is to bridge an existing knowledge gap, and to design a SuDS technique or chain of techniques with the use of indigenous materials that will sustainably manage runoff and combat flooding. This will ensure that SSWM practices are adopted. Further to this, it will also focus on creating community awareness and encouraging the maintenance of these techniques. Ultimately, this research seeks to occasion a change in attitude and a paradigm shift, leading to the acceptance of SuDS as a technique to manage flooding.

1.7 Scope of the Study

This research focuses on exploring the potential of implementing SuDS as a SSWM tool to manage runoff in informal communities impacted by flooding. A transition framework has been designed for Lagos and other less developed countries (LDCs) in Africa to ensure the delivery of SSWM through the implementation of SuDS. This design and implementation will greatly depend on the receptiveness of the local community as the project aims to become a community-based system for implementation in informal settlements. The incentive behind involving the community is to allow for the maintenance of the adopted design by the community. This can be achieved by engaging all stakeholders in the selection, design and maintenance process. The study explores and investigates various SuDS methods and their implementation as this will help to achieve the aims and objectives of the research. Furthermore, it will also focus on investigating the community's receptiveness to SuDS, as this is a determining factor in the success of its implementation.

This thesis is structured as follows. The first chapter introduces the overall subject, and discusses the various aspects of the introductory chapter. The subsequent chapter is the literature review, where SuDS as a tool to manage stormwater is discussed in detail. The relationships between the various factors that prompt flooding are highlighted, along with a review of Lagos, Nigeria. This chapter also presents the rationale for site choice. Chapter 3 details the methodology, including the various methods and approaches the research undertook to carry out the study. Chapter 4 presents the data analysis and a discussion of the results obtained from the data analysis. Following the analysis of the results, a proposed technique is proffered to manage stormwater in the study area. Chapter 5 presents the development and design of a framework to transition Lagos to SSWM using SuDS. Chapter 6 presents the evaluation process undertaken for the framework. Chapter 7 is the recommendation and conclusion chapter, where recommendations are presented as well as a conclusion of the thesis. It also details the research limitations, and future research as an outcome of the study.

CHAPTER 2: LITERATURE REVIEW

2.0 Introduction

In order to define the scope and significance of this research, chapter two critically reviews relevant literature on sustainable drainage systems as a tool to manage stormwater. However, due to the nature of this research, some of the subsequent chapters will also comprise a review of literature.

This chapter is divided into two sections. Section 1 draws a relationship between the key factors that relate to urban flooding by discussing flooding, urbanisation and climate change. It also examines the impact that climate change has had on stormwater management, as well as challenges inherent in informal settlements in Lagos that tend to aggravate the existing issues of stormwater management and drainage. It also reviews various SuDS techniques, while highlighting countries where it has successfully been implemented. However, little emphasis is placed on the more complex SuDS techniques, due to their cost and technicality which is outside the scope of this research, which is the implementation of indigenous (simple) SuDS in informal areas. Much emphasis is however placed on simpler techniques that are cost effective and can be easily adopted by poorer less-developed communities. Section 2, on the other hand, introduces the study area and aims to familiarise the reader with Lagos. This chapter comprises the backdrop of the research; the insightful understanding of the issues presented in this chapter which are pertinent to achieving the aims and objectives as given in Chapter 1.3**.**

2.1 Climate change and flooding

Climate change is the greatest environmental challenge the world faces today, with predicted increases in global temperatures, leading to various changes in weather patterns (DEFRA 2007). According to the Intergovernmental Panel on Climate Change (IPPC) fourth assessment report (AR4), the earth has warmed 0.74°C over the last century. Around 0.4°C of this warming has only occurred since 1970, primarily as an effect of human activities that release greenhouse gases into the atmosphere (DEFRA 2007). IPPC AR4 predicts a global rise in mean annual temperature of between 1.1°C and 6.4°C above 1990 levels, should emissions continue. This will result in a further

rise in global sea levels of between 20cm and 60cm, the continued melting of ice caps and glaciers, changes in rainfall, and the intensification of tropical cyclones (DEFRA 2007).

According to DEFRA (2007), the IPPC further warns that flood risks will be most felt by less-developed countries. Global warming has already caused chronic flooding in cities around the globe. According to Douglas *et al.* (2008), flash floods in tropical regions occur when conventional drainage methods are incapable of handling substantial amounts of rainfall because much of the tropics are characterised by localised rainfall covering less than $10m^2$. This rain is described as intense and lasting for short periods. The most intense storms, which occur on average once every two years, can deposit large amounts (around 90ml) of rainfall in just under thirty minutes (Douglas *et al.* 2008). This large volume of water runs across impervious surfaces, and can surpasses the volumes and speeds that conventional drainage methods were designed to handle, invariably leading to localised flash floods (Douglas *et al.* 2008).

With the weather becoming increasingly volatile in most African countries, climate change will most definitely increase the vulnerability of urban dwellers as most houses are built on flood plains and steep, unstable hills (ActionAid 2006a). Climate change is making the weather more unpredictable; rain is uncertain and floods are more likely. Flooding events have increased in frequency and this has been attributed to urban growth. Urban growth necessitates the building of increased hard surfaces that have replaced vegetation, resulting in higher temperatures compared to the surrounding rural areas. These high temperatures generate local air circulations that trap dust particles, which act as condensation nuclei, and then condense as rain, leading to storms (Action Aid 2006b). In summary, climate change is altering rainfall patterns and increasing the likelihood of storms, thus increasing the potential of flooding, and future predictions show an increased rise in temperature, which has been projected to cause frequent and more intense weather events (Dore 2005; Douglas *et al.* 2008). However, although climate change plays a role in flooding, it is clear that paved surfaces and artificial drainage outlets aggravate the situation. Therefore, a system that is sustainable, as well as one close to the natural dynamics of drainage, is required to be put in place.

2.2 Flooding in Lagos

In developing countries to a great extent, a significantly large proportion of runoff emanates from low-income areas, e.g. informal settlements and slums. These areas are poorly served, if at all, by unreliable drainage systems (Armitage *et al.* 2013; Adelekan 2010).

Lagos is characterised by two seasons: rainy and dry. It experiences heavy rainfall during the rainy season, which occurs from April to September with an average rainfall of about 2,032mm. This amount, although not significantly large compared to other coastal areas in Nigeria, puts the city at risk of flooding due to certain factors as described by Osodi (2013). These include:

- Its population, which is a result of urbanisation.
- Topography: Lagos is a low-lying coastal city. Around 22 percent of its landscape has been classified as wetland, while creeks, lagoons and rivers are a dominant feature in the city. These wetlands are being lost due to urbanisation and the erecting of illegal structures by migrants, giving rise to informal settlements scattered over the area.
- Development guide plans have been comprehensively compromised, as evidenced by the proliferation of informal settlements scattered across the city, which continue to spread.
- Provision of drainage infrastructure is not on par with the rate of urbanisation and population growth in Lagos.
- Lack of regulatory frameworks to manage the development of existing drainage systems.
- Large and incessant land reclamation and dredging projects across water bodies with little or no regard for the environmental impacts of such projects.

During the peak of the rainy season, water rises up and floods homes. The existing drains are flooded yearly with gutters and pipes carrying a capacity load almost ten times the size they were designed to transport. Figure 2.1 and 2.2 present a clear scenario of what residents in Lagos go through during the rainy season; hazards such as this have become the norm. People living in informal settlements have learned to adapt

to the constant invasion of water, for example by having their beds built on stilts, which means sleeping just above stagnated water, which compromises their health (IRIN 2008).

Notably, the residents of informal settlements such as these suffer a wide range of environmental problems associated with a lack of adequate drainage infrastructure; these inhabitants are usually the most vulnerable to flooding because of their location (Parkinson 2003). As is the case with most informal settlements in Lagos, they are mostly located in the most flood-prone areas, primarily because these areas have been left uninhabited – for obvious reasons. The inhabitants of these settlements constantly suffer health issues, which are entwined with the poor drainage facilities that the occupants suffer daily (Adelekan 2010). To compound issues, the inhabitants of these informal settlements are usually the poor, who have migrated from the rural areas in search of work in the city. As can be imagined, the poor in society have the least resources to assist with the recovery from flooding occurrences and their negative impacts (Douglas *et al.* 2008; Parkinson, Tyler and Mark 2007).

While Lagos has had its fair share of internal and external influences from both local and international non-governmental organisations (NGOs), giving assistance and aid to manage the impact of the flooding situation, before any real change can be effected the root cause of the problem will have to be dealt with. Emphasis should be placed on effectively managing this stormwater to prevent flooding in the first instance.

2.3 Impacts of urbanisation on flooding

"Urban conditions exacerbate drainage problems; runoff is increased by impermeable urban surfaces and, due to inadequate development control mechanisms and their incompetent enforcement, settlements are constructed with little consideration for stormwater drainage" (Parkinson 2003). The need to build on natural drainage systems, to accommodate settlers who move to these areas in search of a better life, has led to increase flooding occurrences in these urbanised areas. Natural drainage channels are experiencing a significant increased pressure due to the concretisation of the earth's surfaces from urbanisation and increasing population; this has resulted in increased flooding (Shuttleworth *et al.* 2017).

Figure 2. 1: Showing Occupants of Flooded Area in Lagos

(Source: Vanguard 2012)

Figure 2. 2: Showing Flooded Area in Lagos

(Source: LIB 2015)

Most cities, particularly in developing countries, lack adequate and effective storm drainage systems. In addition to this, ill-planned construction blocks natural watercourses. New buildings occupying floodplains and natural drainage paths arise from unregulated developments and cause downstream flow constraints, which are the main problem associated with stormwater drainage. In some urban areas, wetlands are an important feature for providing essential hydrological functions for flood alleviation. Sadly, these benefits are usually ignored as cities develop and natural waterways are either destroyed or paved over with concrete, and wetlands are drained to give way for development (Parkinson and Mark 2005). Urbanisation and urban growth are the key contributors to the loss of the natural permeability characteristics of land (Armitage *et al.* 2013). Cities everywhere are becoming increasingly vulnerable to flooding because of the rapid rate of urbanisation (Lade *et al.* 2014). With a dense population there is a need to build infrastructure, which results in a loss of vegetation, and the creation of impermeable surfaces due to the paving of roads and the erecting of buildings and roofs (Elliot and Trowsdale 2006; Ogba and Utang 2008), which are then drained by hard infrastructure (Armitage *et al.* 2013).

These permanent physical changes to existing areas result in changes to runoff patterns, which invariably affect the magnitude and frequency of flooding, and the discharge rate and volume of stormwater. The overall effect of urbanisation is that higher amounts of water reach river channels more rapidly due to the alteration of natural drainage patterns; runoff travels quicker over hard surfaces than over natural ones. Therefore, a decrease in infiltration increases the peak flow in urban areas, creating flood peaks, as illustrated in Figure 2.3. This leads to channel instability, triggering the occurrence of a flood (Butler and Davis 2004; Okoko 2008; Nnadi, Coupe and Oyelola 2012). In addition, as areas continue to urbanise, a reduction in groundwater is observed as less surface water reaches the ground naturally.

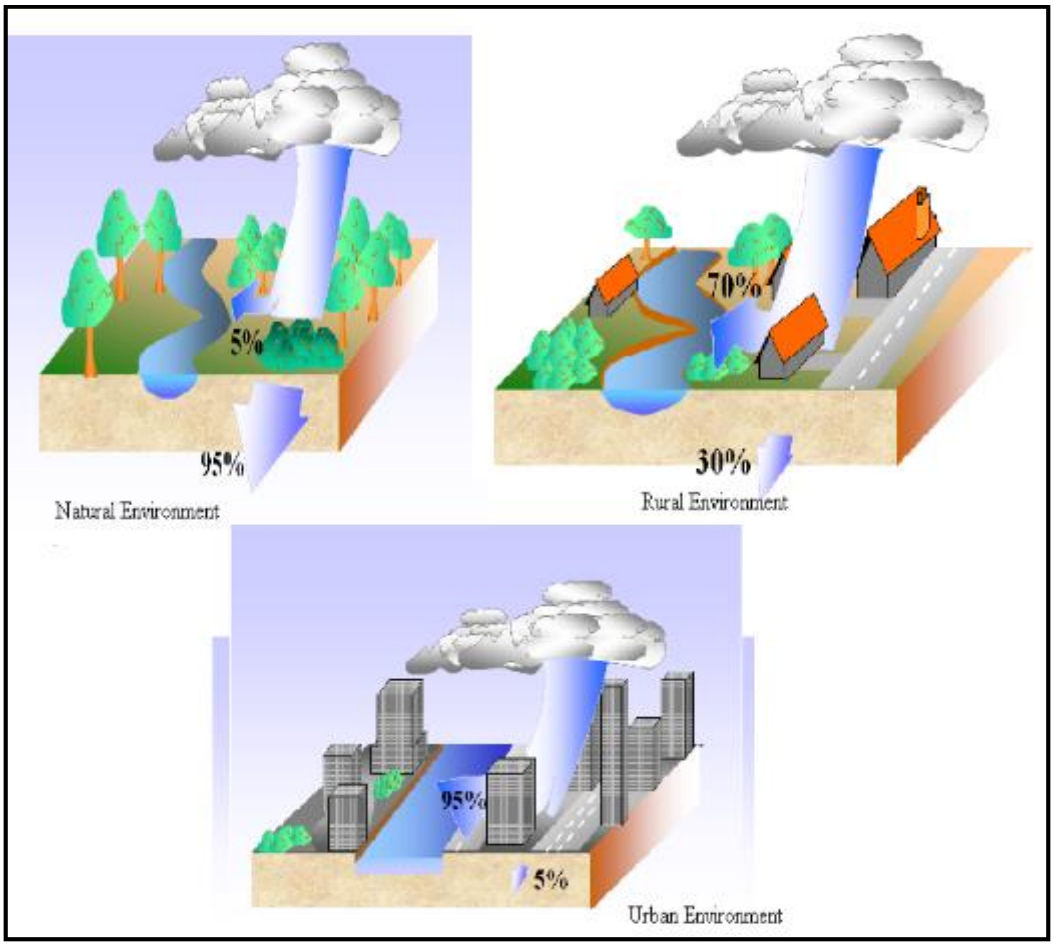

Figure 2.3 Impacts of urbanisation on infiltration and peak runoff

(Source: adapted from Nnadi, Coupe and Oyelola 2012)

2.4 Impacts of Flooding Informal Settlement Residents

According to Mark and Parkinson (2005), Okoko (2008) and Douglas *et al.* (2008), the poor in the community are the worst hit by flooding. They are especially vulnerable to flooding because of their settlement location, which is usually located downstream or on ecologically vulnerable areas, hence the negative impacts of flooding are compounded in these communities.

The consequences of flood events are usually quite devastating as such communities have fewer resources available for rebuilding and they generally receive little external support to recover from flooding from their government, leaving them vulnerable to associated flooding risks and problems (Parkinson 2003). The livelihoods of residents in these areas are also more vulnerable to flooding and associated disruption, compared to formal residents (Parkinson 2003).

2.5 Urbanisation and its implications in Lagos

Rapid urban growth is a major contributor to slum formation (Space Syntax 2010). According to Parkinson, Tyler and Mark (2007), most developing countries are characterised by large areas of informal settlements stemming from urban spread. The authors state that usually these settlements are not built in line with official planning guidelines, hence they are not organised officially by the government. This invariably translates to the absence of adequate infrastructure in these areas. In the case of certain areas in Lagos, this is exactly what is found. One of the most intricate problems facing cities in developing countries is the provision of adequate, sustainable, basic amenities such as potable water, electricity, drainage, roads, sanitation, education, healthcare, recreation and waste disposal facilities (DFID 2004; World Bank 2006).

It is evident that as urban areas in developing countries continue their rapid population growth, these problems and challenges are only going to escalate. DFID (2000) estimated that LDCs will face an average urban growth rate of 2.6% per annum. Lagos faces one of the fastest growing rates of urbanisation in LDCs – an average increase of 3.2% (Oshodi 2013). Like many cities in the developing world, Lagos has experienced major population increases in recent years, and presently more than twenty-one million inhabitants populate the city. A combination of factors such as poor land-use, planning and enforcement has led to Lagos witnessing a series of collateral problems. These include the degradation of natural resources for building materials, urban sprawl and major deficiencies in public infrastructure – water supplies, drainage, flooding and waste disposal (Oshodi 2013). The influx of migrants to the city can be attributed to the fact that it is the economic and financial capital of Nigeria (Aderogba 2012).

Owning little or nothing, these migrants are unable to pay for accommodation, instead, they set up shacks on unwanted land. These informal settlements have further exacerbated the problems of urban flooding in the region, causing countless problems associated with floods for the urban poor.

In most developing countries, the main cause of various developmental and infrastructural issues is not necessarily bad governance but the lack of knowledge about certain issues. In this case, there is a lack of knowledge of how to manage stormwater to prevent floods from plaguing its citizens. This lack of knowledge, coupled with

increased rates of urbanisation in the city of Lagos have surpassed developmental plans set up by the government, and led to informal settlements and slums being visible all over the city. These areas are currently worst hit by flooding and problems with hygiene.

It is not uncommon to find slums with illegal structures littering the suburban areas of Lagos. Whether or not there are plans for the efficient drainage of stormwater, it is clear that these informal settlements with their illegal structures will not adhere to policies and regulations, primarily because all the residents require somewhere to live close to where they can find work. As a result, these areas become flooded, due to the lack of drainage infrastructure. The Government of Lagos places more emphasis on the development of formal settlements and infrastructure, such as the building of roads and the development of its financial and economic industry. It does not deem the management of flooding in informal areas to be a priority, rather they are perceived to be a nuisance to be demolished, with the land being reclaimed for other governmental uses (as is the case of Makoko and various other slum settlements across Lagos), hence the continued neglect and suffering of residents of such areas.

2.6 A precarious unhealthy relationship – climate change: flooding, urbanisation and conventional drainage patterns

Flooding has a devastating effect on the environment (Adedeji and Salami 2009). Although it is a natural phenomenon/hazard, the problem can be intensified by artificial modifications and alterations to natural flow patterns. A relationship can been drawn between the environment, sustainable development, and flooding: excessive rainfall is the major cause of flooding, which occurs when rainfall intensity surpasses the infiltration capacity of the soil and urbanisation is the major factor influencing soil infiltration capacity (Ogba and Utang 2008).

In recent times, flooding in urban areas has no longer been attributed to heavy rainfall and extreme climatic conditions alone; it is also now characterised by changes brought about by the building up of areas and the command and control (conventional) methods deployed to drain these areas. Conventional drainage methods are the most common flood management systems in most countries; their role is to rapidly carrying this runoff downstream (Douglas *et al.* 2008). According to POST (2007), the risk of flooding is a

function of the probability and impact of the flood itself. Urban areas have a much higher impact and as such face greater consequences because they are densely populated and built up. As mentioned above, as urban areas develop, the natural drainage processes are altered because soil loses its ability to infiltrate and store rainwater. This gives rise to a substantial increase in the volume of runoff being carried to lower topographic areas, causing flooding (Poleto and Tassi 2012). Douglas *et al.* (2008) explain that as urbanisation in African cities increases, human impacts on urban land surfaces and drainage are intensified. Therefore, rivers experience high flows, even from moderate storms, because of the surface runoff generated from hard surfaces and drains. The authors further explain that water flowing through artificial channels, including culverts and concrete conduits, cannot adjust to changes in the frequency of heavy rain, as natural channels would do. They also become obstructed by silt and urban debris, leading to blockages (Douglas *et al.* 2008).

For there to be positive change and for development to occur, action has to be taken. The changing role of government in infrastructure provision and the need for a community-based approach is not a new concept. This has informed the concept of introducing sustainable drainage systems (SuDS) to informal settlements in Lagos, potentially a cost-effective and efficient means of managing surface runoff. This project therefore seeks to design a tool or set of tools that will empower the community to manage stormwater at a community-based level with materials indigenous to that community. This way, the design is effective but remains low cost and sustainable. However, for this to be achieved, the concept of SuDS has to be fully understood.

2.7 Sustainability + Stormwater Management = Sustainable Surface Water Management

In years past, conventional drainage methods were assumed to be the best ways to deal with stormwater, carrying runoff as quickly as possible from the source and depositing it downstream via underground pipes and sewers (Post 2007; Reed 2004). This alters the natural hydrological cycle and also initiates its own problems. In the context of climate change, resource limitation, increased water quality degradation, flooding, etc. there is a growing international acceptance of the fact that these conventional approaches of command and control applied to manage stormwater are inadequate to

deliver the services that society presently requires (Fergusona, Frantzeskaki and Brown 2013.) In light of these problems, a more sustainable means of handling runoff to imitate the process of the natural hydrological cycle has been sought (Reed 2004; Poleto and Tassi 2012; Armitage *et al.* 2014).

Surface water management is the management of this runoff, mainly by dealing with potential flooding that occurs via drainage systems that transport these waters quickly to receiving water bodies, i.e. the use of conventional command and control methods (Ashley and Nowell 2010).

Sustainable surface water management: the use of alternative sustainable methods to manage runoff to prevent flooding and its associated problems (Charlesworth and Booth 2016).

Sustainable surface water management system (SSWM): a system that adopts and incorporates sustainable methods (e.g. SuDS) to manage runoff.

2.8 Simple SuDS – a driver to achieving SSWM

The aim of sustainable stormwater management is to reduce stormwater runoff by dealing with it as close as possible to the source, ideally on site (CIRIA 2007; Hoyer *et al.* 2011; Woods Ballard *et al.* 2015). Unlike conventional drainage methods, SSWM does not collect excess water and quickly deposit it downstream, but reduces runoff flow and volume by the use of technologies to increase infiltration and evaporation, thus mimicking the natural water cycle (Hoyer *et al.* 2011).

Sustainable drainage systems are devices that can be applied within a SSWM approach to achieve the management and treatment of this excess runoff. Simple SuDS is a derivation of SuDS, which is mainly applied to the urban water cycle, taking into account the quality and quantity of the water, as well as biodiversity and amenity of the area where the water is managed. As such, therefore, it is quite urban-settlement oriented. In this research, simple SuDS is a contextualised term for the implementation of the approach in informal areas. Simple SuDS are less complex in design, cheaper, easy to maintain and effective in the management of stormwater, thus the best approach to consider for informal settlements. Simple SuDS includes devices that are mainly

designed with raw materials indigenous to the areas in which they would be deployed, adding more value to the term 'sustainable' in SuDS.

As Lagos is rapidly changing due to urbanisation and development, coupled with changes in climate, the existing conventional drainage systems are failing. According to Hoyer *et al.* (2011), conventional systems are not designed to be adaptable, and therefore cannot adapt to uncertain or changing conditions from increased city development and climate change, leading to unmanageable stormwater runoff. This has led to seasonal flooding in the area with informal settlements becoming the worse hit by the impacts of flooding.

Where informal settlements are located downstream it is likely that most runoff from the upstream area ends up in their environs. This substantially increases the problems, in association with either total lack of drainage, or the non-maintenance of any inadequately deployed devices. For the purposes of this research, therefore, simple SuDS have been identified and recommended to suit the settlements. This recommendation stems from the evaluation of the characteristics of the visited sites, field observations, feedback from residents via meetings and the results from the questionnaire analysis (see Sections 3.6 and 3.6.2).

Further to this, good housekeeping has also been suggested (as it pertains to keeping the existing drainage devices free flowing) which is particularly relevant to stormwater management in these areas.

2.9 What are sustainable drainage systems?

Urbanisation is synonymous with the building up of areas and they need to be drained to remove surface runoff to prevent flooding (CIRIA 2000, 2005; Butler and Davies 2004). Previously, as highlighted in Section 2.6 above, the acceptable and most common means for the removal of stormwater has been the traditional or conventional method of drainage. This involves the use of gutters, culverts or underground pipe systems designed to manage surface runoff quantity thereby preventing flooding locally by transporting the water away as quickly as possible from the perceived threatened area (CIRIA 2000, 2005; DTI 2006; Gunasekara and Bray 2005).

In recent times, these conventional methods of drainage have been perceived as unsustainable because they fall short in certain respects. Primarily they alter a natural flow pattern which leads to problems such as flooding, pollution of surface and ground waters, watercourse erosion and ecological impacts on the downstream catchment (CIRIA 2000, 2005; DTI 2006). The perception that conventional drainage methods are not sustainable has led to the idea of SuDS. Sustainable drainage systems are a chain of techniques that try as closely as possible to mimic the natural flow, and the physical, chemical and biological processes of detention, evaporation, filtration, and dispersion of surface runoff (DTI 2006; SEPA 2000a). This is achieved by replicating as closely as possible the natural hydrological cycle concept through a treatment train (Woods Ballard *et al.* 2015; Armitage *et al.* 2012) using ponds, open spaces, rooftops, streetscapes, parking areas and pedestrian areas (DTI 2006; Environment Agency 2008). Ahammed (2017) suggests that the application of SuDS technologies in practice could be the panacea to the everyday problems of small-scale stormwater management, flood and pollution control as well as stormwater harvesting.

2.10 SuDS objectives

The SuDS square, as mentioned in Chapter 1, is made up of the unique objectives of SuDS in relation to its effective management of stormwater:

- Quantity: SuDS seeks to encourage infiltration and to attenuate peak flows where appropriate, with emphasis being placed on management at source where possible.
- Quality: offering water quality treatment through natural processes throughout the system.
- Amenity: adding aesthetic and recreational value to the area, thus creating and sustaining better places for people.
- Biodiversity: providing habitat and function for all organisms in the system (Armitage *et al.* 2012; CIRIA 2005, 2007, Woods Ballard *et al.* 2015, SuDSWales 2014; Shuttleworth *et al.* 2017).

These objectives capture the true picture of sustainability in terms of surface water management which Figure 2.4 illustrates, making it an alternative to conventional command and control methods of managing runoff.

Figure 2.4: SuDS Balance between Quantity, Quality, Amenity and Biodiversity
(Source: Adapted from Woods Ballard *et al.* 2015)

The inclusion and balance of these objectives in a storm management system allows for the balance between social, economic and environmental requirements, thus reducing the conflict between economic development and protection of the environment (Ghani *et al.* 2008).

2.11 SuDS management train

The SuDS management train is designed to allow runoff to flow through a sequence of devices, rather than having standalone techniques for treatment purposes before reaching receiving water bodies (SuDSWales 2014; Lashford *et al.* 2013; see Figure 2.5). This means that the fundamental rationale behind the train is the achievement of the SuDS square and the successful design of a SuDS scheme (Woods Ballard *et al.* 2015).

Figure2.5: SuDS Management Train

(Source: adapted from CIRIA, 2000).

The management train emphasises the importance of managing runoff at the source; only if it cannot be managed at source should it be transported down the train to other SuDS devices. The train begins by placing priority on prevention of runoff by reducing impermeable surfaces and encouraging water to infiltrate. Good housekeeping is encouraged in order to reduce pollution and it progresses from local source control through to regional controls. Good housekeeping is the first step in ensuring the quality of water. It involves minimal use of hazardous chemicals that could cause pollution incidents (CIRIA 2005, EA 2008a; SEPA 2000a, Woods Ballard *et al*. 2015).

The next phase in the train is local source control, where permeable or porous surfaces such as permeable paving, filter trenches or swales can be implemented to manage and control runoff at or adjacent to the source. This is followed by the site control phase, which can involve the use of detention basins and small ponds. Site controlled runoff is received by local facilities from upstream locations and is managed downstream; often channelling runoff downstream is routed with several inlets and just one controlled outlet (Berry 2000; CIRIA 2005, SEPA 2000a, woods Ballard *et al.* 2015).

The final phase in the train is the regional control stage (end of pipe systems). This involves the use of larger features, which collect runoff from upstream control including ponds and wetlands (SEPA 2000b). Regional controls should only be the last option after all other techniques along the train have been exploited, as it is best to deal with runoff locally (Berry 2000; CIRIA 2005, Woods Ballard *et al.* 2015). However, for SuDS to successfully manage stormwater, runoff does not need to pass through all the stages in the management train (CIRIA 2005).

2.12 Overview of SuDS techniques and devices

In order to establish SuDS as the preferred alternative to conventional drainage methods, an overview of the various devices and techniques is given in the following section, split into three main groups. SuDS comprises a variety of structures to manage surface water runoff. These devices vary from simple to complex and strive to render positive solutions to flooding and pollution when used alongside good management of the site.

1 Source control: These devices are designed to manage runoff as closely as possible to the source through infiltration, attenuation and general reduction of runoff to the receiving water body. They reduce flood risks and improve water quality. They consist of devices such as green roofs and walls, rainwater harvesting, infiltration basins, trenches, permeable pavements and soakaways (SuDSWales 2016; Mezue 2009).

2 Permeable conveyance systems: Involve the movement of runoff slowly towards the receiving water body, allowing for storage, filtering and some loss of runoff water through evaporation and infiltration before it reaches the discharge point.

The main types of permeable conveyance systems are underground systems such as filter drains and surface water swales (SuDSWales 2016).

3 Passive treatment: This involves the use of natural processes to break down and remove contaminants and pollutants from surface runoff. It places emphasis on natural purification processes, including devices such as filter strips, detention basins, retention ponds and wetlands.

Source control devices

Green roofs

These are deployed on the roofs of buildings, and usually involve the partial or complete covering of the roof with vegetation and a growing medium. In designs that are more complex, root barriers, drainage, and irrigation systems may be included (SuDSWales, 2016). Green roofs are of two types:

1 Intensive green roofs – which are thicker and heavier because of the deep growing medium deployed. They support a wider variety of plants, therefore require more maintenance.
2 Extensive green roofs – consist of a thinner growing membrane and therefore support less vegetation.

Green roofs have several functions:

- Absorption and storage of rainfall, hence attenuation of peak flow
- Filtration of pollutants from rain
- Provides insulation for buildings
- Promotes the aesthetic value of the area it is being deployed in
- Helps to lower urban air temperatures and combat urban temperature rises

Green roofs are beneficial, especially in densely urbanised areas where there is less space for SuDS (Armitage *et al.* 2012). Green roofs as a SuDS device have been widely implemented in developed countries and have proven to be effective in managing stormwater at source.

Green walls

These are vegetative walls that may be adopted as elements of a building or as free-standing barricades (Armitage *et al.* 2012). They have been proven to significantly attenuate first flush floods from buildings. This is achieved by detaining rainwater on the surface of the leaves and other parts of the plant (Armitage *et al.* 2012). Vegetation is usually grown on a number of inorganic layers therefore they require high maintenance, especially if they are located in dense urban areas.

Rainwater harvesting (RWH)

This involves the capture and storage of rainwater from rooftops, land surfaces or rock catchments (Lade and Oloke 2015). It has been described as probably the oldest stormwater management technique used to collect rainfall and runoff (Reed and Thomas 1999). It is said to be one of the main available options to improve water supply, especially in rural and peri-urban areas of low-income countries, by mitigating the temporal and spatial variability of rainfall and providing water for basic human needs and other small-scale productive activities (Opare 2012; Cruddas *et al.* 2013; Lade and Oloke 2015). It has been found that RWH can achieve water savings of between 30% and 87.6% (Amado and Barroso 2013; Bocanegra-Martinez *et al.* 2014; Campisano *et al.* 2013).

It can be very simple in design and consist mainly of a collecting medium such as pots, buckets, tanks, big basins and/or a pipe network to divert rainwater from the rooftop into the container below. A more complex design would in addition comprise an overflow bypass and a pump distribution network to deliver water for non-potable water uses (Hunt and Szpir 2006; Lade and Oloke 2015; SuDSWales 2016). Harvested rainwater is a renewable source of relatively high-quality water (although short of potable water standards in most jurisdictions) thus making it ideal to be used at the household level as well as for irrigation purposes. It has been characterised as a sustainable cost-effective intervention (Lade and Oloke 2015; Shuttleworth *et al.* 2017.) The quantity of rainwater harvested depends on monthly precipitation, roof catchment area and roof run-off coefficient, whilst the quality of rainwater harvested depends on roof type, level of atmospheric pollution, geographical location, container size,

catchment characteristics, land use practices and local climate of the region (Woltersdorf *et al.* 2015).

Infiltration devices

They include basins and trenches and are designed to infiltrate runoff directly into the ground. Infiltration trenches are a smaller version of an infiltration basin, and are designed to service smaller catchments. They are shallow, excavated trenches that are lined with geotextile material and backfilled with stone to create an underground reservoir (EA 2008c; SuDS Wales 2016). Infiltration basins are shallow in design and store runoff until it is infiltrated through the soil to the basin floor (SuDSWales 2016; NWRM 2015). In events of extreme rainfall an overflow may be required when the capacity of the basin is exceeded. The performance and effectiveness of the basins depend on the permeability characteristics of the soil and the depth to the water table (CIRIA 2005, 2007; EA 2008; SuDSWales 2016). To improve the effectiveness and lifespan of the basin, a management train type pre-treatment needs to be used e.g. through the use of a filter strip to remove excess solids. Studies show that properly constructed and maintained infiltration basins can remove large proportions of solids and a lower proportion of soluble pollutants (Elliot and Trowsdale 2007; Graham *et al.* 2012; SuDSWales 2016). Their other function includes increasing soil moisture content and helping to recharge groundwater, which can mitigate problems of low river flows (CIRIA, 2005).

Permeable pavements

This is an alternative to conventional paving; its design allows for water to filter through the paved device rather than running off it (Charlesworth, Harker and Rickard 2003, Graham *et al.* 2012; SuDS Wales 2016). These devices possess permeable characteristics with a capacity to store surface water below ground (CIRIA 2005, Kirby 2007). The surface of these devices could be gravel, concrete or plastic webbing, concrete blocks designed for the purpose or porous asphalt (CIRIA 2005, SuDSWales 2016). They are then underlain with a structure that temporarily stores the runoff before infiltration or draining; a geotextile material may be added, although water may infiltrate directly into the subsoil in situations that involve favourable conditions. The

water can also be held in a reservoir structure under the paving for reuse, infiltration or delayed discharge (Graham *et al.* 2012, SuDS Wales 2016). Permeable pavements have been proven to be effective in removing pollutants with high removal rates for sediments, trace metals, and organic matter having been reported, as well as a reduction in nutrients (CIRIA 2005, 2007).

Permeable conveyance systems

Filter drain: This is a trench lined with geotextiles and then filled with gravel. Runoff is diverted to these devices either from drained surfaces or through a piped system (Charlesworth, Harker and Rickard 2003, CIRIA 2007, SuDS Wales 2016). Sediments and organic matter are trapped by the gravel, filtering the runoff to an extent. It reduces runoff rates and also provides runoff storage. These systems have been widely applied in road drainage designs across the developed world.

Swales: are shallow and relatively wide vegetated surface depressions that are designed to allow surface water to flow slowly overland from the drained surface to a storage or discharge system (Charlesworth, Harker and Rickard 2003, EA 2008b; *Ghani et al.* 2008, Woods Ballard *et al.* 2015; SuDSWales 2016). They are usually sited close to the source of runoff and are designed to form a network within a development, linking storage ponds and wetlands (Graham *et al.* 2012; SuDS Wales 2016). A swale is usually dry in the dry season but wet when it rains, the water contained within it then moves slowly through the grass which slows it down and provides some filtration (SuDSWales 2016). Sediment is deposited, while oily residues and organic matter are retained to be broken down in the top layer soil and vegetation (CIRIA 2005, SuDSWales 2016).

Passive treatment

Filter strips are designed for conveyance and infiltration (where appropriate). They consist of gently sloping areas in the ground that treat runoff from adjacent impermeable areas by vegetative filtering and particulate settlement, slightly reducing the peak flow and improving water quality. Filter strips are best employed at the upstream end of the drainage system, accepting runoff from small areas. They prove effective in removing excess solids and pollutants before discharging to an infiltration

system (EA 2008b, 2009, Charlesworth, Harker and Rickard 2003, Susdrain 2012; Woods Ballard *et al.* 2015; SuDS Wales 2016).

Detention Basins are designed to hold storm runoff for a few hours to allow solids to settle. Detention basins are often used in attenuating the peak flow from a rainfall event; they also allow filtering and sedimentation processes to take place, which contribute to water quality improvement (Charlesworth, Harker and Rickard 2003; Woods Ballard *et al.* 2015, Graham *et al.* 2012; Susdrain 2012; SuDSWales 2016). Basins are usually flat areas of grass, not normally containing water in dry weather – they remain dry except after a major storm. They are designed to hold storm runoff for a few hours to provide flood control through attenuation of surface runoff (EA 2008d; Lampe *et al.* 2004; Susdrain 2012). They include floodplains, detention basins and extended detention basins. Effective operation requires that any sediment and debris are removed upstream (Charlesworth, Harker and Rickard 2003; Susdrain 2012). Therefore, they are usually located towards the end of the management train (Kirby 2005).

Retention ponds are designed to provide storage, through the retention of surface water runoff, or attenuation of the storm peak by detaining a certain volume of storm water. Pond are generally deployed towards the end of the management train (Kirby 2005; Ghani *et al.* 2008). Retention is provided on the surface through ponds, but can also be made available underground commonly as geocellular tanks, which are designed to contain a particular volume of water at all times. The ponds can be fed by either a swale system, a filter drain network or a conventional surface water system (EA 2008d; SuDS Wales 2016). They can provide both stormwater attenuation and treatment, and are also surface storage devices containing water in the dry season. They are engineered to contain more when it rains, and include attenuation ponds, flood storage reservoirs, lagoons, retention ponds and wetlands (EA 2008d; Susdrain 2012; Woods Ballard *et al.* 2015). Retention ponds are designed to collect runoff from each rain event, which is then retained and treated (EA 2008d; Susdrain 2012; Woods Ballard *et al.* 2015). Retention time promotes pollutant removal through sedimentation and the opportunity for biological uptake mechanisms to reduce nutrient concentrations, improving water quality (Susdrain 2012). They are designed to support emergent and submerged aquatic

vegetation along their shoreline, hence enhancing biodiversity (Susdrain 2012; see Figures 2.6 and 2.7).

Figure 2. 6: Pond Managing Runoff

(Source: SuDS Wales 2016)

Figure2. 7: Detention Pond

(Source: SuDSWales 2016)

Wetlands: Susdrain (2012), describes wetlands as a SuDS technique that provides both stormwater attenuation and treatment via the use of sedimentation and filtration processes. Wetlands are designed to detain flows for an extended period to allow for sedimentation to occur, and also for the removal of contaminants by facilitating adhesion to vegetation and aerobic decomposition (Charlesworth, Harker and Rickard 2003; Ellis, Shutes and Revitt 2003; Susdrain 2012,).

A wetland comprises three basic features, namely an inlet zone (sediment basin); a macrophyte zone, which is usually a shallow, densely vegetated area; and a high-flow bypass channel, which is mainly a wide vegetated swale from the inlet pond around the side of the wetland.

Like the detention and retention techniques, wetland treatment is not usually the first option for the management of stormwater. Wherever possible, wetlands should be the last treatment stage of the SuDS management train to avoid the risk of extensive siltation. However, siltation may be avoided if there is upstream treatment (Charlesworth, Harker and Rickard 2003; Susdrain 2012).

Wetlands are included in the SuDS square as they treat polluted runoff, provide attenuation and deliver biodiversity and amenity. They can fit into already existing urbanised areas by designing a hard edge or by being part of the streetscape or other hard landscaping features and furniture. However, these must be appropriately sized for the catchment to ensure hydraulic support for water treatment (Susdrain 2012; Woods Ballard *et al.* 2015).

All of the devices discussed above can be used individually or combined in series to provide services at different temporal and spatial scales (CIRIA 2000; 2007; Booth and Charlesworth 2016; Zhou 2014).

2.13 Implementation of SuDS in various countries

Countries like the USA, Canada, the United Kingdom, Germany, Australia etc. have successfully adopted SuDS. Its implementation and application are widespread across these countries. The successful employment of SuDS to manage surface runoff in these countries has been documented in various case studies and literature (e.g.

Environmental Agency 1999; Angelis and Shaw 2004; Melbourne Water 2004; USEPA 2007; Woods-Ballard *et al.* 2007; Susdrain 2012; Woods Ballard *et al.* 2015; SuDS Wales 2016; Shuttleworth *et al.* 2017). However, of more relevance and importance to this research are accounts of the implementation and success of SuDS in developing countries. It would seem that accounts from these countries offer better comparable examples as they share various characteristics, thus presenting a more attainable picture than could be achieved with accounts from developed countries.

Malaysia is a LDC that has been at the forefront of the implementation of SuDS with the successful implementation of Bio Ecological Drainage System (BIOECODS). This consists of infiltration devices and soakaways, which are a SuDS approach implemented to manage flooding and its associated problems. It was pioneered by the River Engineering and Urban Drainage Research Centre (REDAC) and Universiti Sains Malaysia (Ghani *et al.* 2008.) Its successful implementation and recorded success in managing runoff shows that it is a sustainable method for addressing stormwater runoff, and one that is also applicable in LDCs (Sidek *et al.* 2002). The implementation of BIOECODS in Malaysia offers an exemplary model for SuDS in developing countries (Parkinson and Mark 2005). India has also successfully implemented the concepts of SuDS to help manage excess runoff in Bangalore, associated flooding and also the increased demand for water supply; the authorities amended existing building bye-laws to incorporate the use of rainwater harvesting systems. This allowed the collection of rooftop rainwater from new houses and developments, hence reducing the impacts of flooding by attenuating peak flow and providing a supplementary source of water for residents (Parkinson and Mark 2005). The implementation of rainwater harvesting in Bangalore has been successful and as such is an integrated approach aimed at source control and reuse of stormwater, which has subsequently been adopted and implemented in various parts of India (Parkinson and Mark 2005). Brazil has implemented several green roof gardens as a means of managing runoff (Kholer *et al.* 2001; Kholer *et al.* 2004) and Chile has also used SuDS to manage excess stormwater (Parkinson and Mark 2005). Dhaka, the capital city of Bangladesh, undertook a recent study to investigate the feasibility of stormwater quantity control using rainwater harvesting (RWH) systems, which is also a SuDS approach (Ahammed 2014). Results obtained using a monthly water balance model confirm that RWH systems are capable

of diverting a significant percentage of roof runoff away from the drainage systems, hence resulting in a significant reduction in the flooding problems of Dhaka City. In addition to flood peak attenuation, RWH systems could cater for 100% of the water demand for non-potable uses during the period from May to September each year (Ahammed 2014). However, the most significant element of this study is the implementation of SuDS in South Africa where it is called WSUDS, an amalgamation of WSUDS in Australia and SuDS in the UK.

2.14 Implementation of SuDS in South Africa

Stormwater management in the urban areas of South Africa predominantly focuses on collecting runoff and channelling it to the nearest watercourse. This has resulted in a significant impact on the environment through the resulting erosion, siltation and pollution (Armitage *et al.* 2014). Therefore, an alternative approach is to consider stormwater as part of the urban water cycle, a strategy that is being increasingly known as Water Sensitive Urban Design (WSUD). The stormwater management component (SuDS) has been investigated and is currently being implemented widely in South Africa.

Armitage et al. (2013) undertook a study aimed at providing strategic guidance to urban water management decision makers (primarily city managers and other local authority officials) on the use of WSUD in South Africa. It introduced the philosophy of WSUD – a new paradigm in urban water management. A policy review (including institutional and legal issues) was also carried out in order to identify obstacles to WSUD and to provide recommendations on how they may be overcome. At the end of this exercise, a SuDS guideline was designed. The widespread implementation of SuDS has been undertaken in various parts of South Africa (Button *et al.* 2010; Armitage *et al.* 2013; Armitage *et al.* 2014; Fitchett 2017).

2.15 South Africa: SuDS implementation case study: An informal settlement in Diepsloot

Diepsloot is an informal settlement situated on the northern periphery of Johannesburg which is located to the north east of the country. The lack of urban drainage infrastructure and limited waste removal in this area impacted negatively on water

quality, with pollutants frequently washed into the Jukskei River which flos to the south of the settlement (Fitchett 2017). Diepsloot has been characterised by budgetary constraints because it was perceived as an illegal slum settlement. As such, municipal officials were not willing to commit capital expenditure to large-scale interventions. An intervention that comprised the implementation of a SuDS approach in an attempt to mitigate and alleviate some of the problems of standing surface water in two sites within the informal settled parts of Diepsloot was undertaken by Fitchett 2017. The SuDS devices adopted included simplified standard SuDS, such as pervious channels, semi-vegetated channels, soakaways and a miniature bio-retention area.

The primary objectives of these interventions were to reduce the occurrence of stagnant water and minimise the risk of flooding. The efficacy of the implemented SuDS intervention was measured through the use of a mixed-method approach, which included water quality testing, the recording of aesthetic conditions before and after the intervention, and also discussions with community members (Fitchett 2017). Two sites were monitored, and results showed that the interventions were successful at managing surface water. Reports from residents at the first site after SuDS implementation suggested that, in the absence of rain, domestic wastewater percolated below the surface almost immediately. Also after moderate rain, water permeated below the newly constructed surfaces of the channels within a few hours. At site 2, water in the more vegetated channel remained for much longer than in the predominantly paved channel. Water quality test results also showed improved water quality at both sites. According to Fitchett (2017), the results of the study show promise for similar interventions in other informal settlements in southern Africa, if not globally.

The next section discusses why Lagos was selected as the case study for this research.

2.16 Rationale for selecting Lagos as a case study and the potential for implementing SuDS in Lagos, Nigeria

This section presents the rationale for selecting the location as a case study area. It also highlights the potential of implementing SuDS to attain SSWM at the selected study site.

Nigeria is one of the largest countries in Africa with a population of around one hundred and ninety-eight million people (NPC 2018). As highlighted in Section 2.5, it is a prime location for this study because of its high population density, with around 70% of the population living in informal settlements (Adelekan 2010).

Lagos is rapidly developing and is currently considered the most urbanised state in Nigeria (DURP 2012); the city is also the most urbanised in Nigeria. Furthermore, it possesses characteristics representative of the distribution of informal settlements in general. Rapid urbanisation in a generally low-lying area has led to unplanned and excessive reclamation of wetlands, and encroachment on natural drainage channels (Obiefuna *et al.* 2017). Its recorded annual rainfall and flooding history add to its suitability as a prime location. Furthermore, Lagos is also characterised by an insufficient and ineffective drainage system, which is continually being stressed through the spread of unplanned buildings, due to continued slum sprawl. These buildings block existing drainage and can be a major contributor to annual urban flooding, thus, the city presents a worse-case scenario of locations that suffer yearly urban flooding. Finally, according to Adelekan (2010), Lagos currently ranks thirtieth for a population exposed to flooding within the current climate scenario and fifteenth in a future climate scenario (scenario for the 2070s). Hence, the succesful implementation of SuDS in Lagos has great potential to exemplify SSWMs to other West-African countries. The proceeding sub- section presents the background on Lagos.

2.16.1 General background of Lagos

This section describes the study area, Lagos, Nigeria in terms of its geography, people, land use, etc.

Lagos is one of the 36 states that make up the Federal Republic of Nigeria, and is located in the South-West of the country (Figure 2.8). It is a low-lying littoral (coastal) region, lying between latitude 6° 23'N and 6° 41', longitude 2° 42' and 3° (Google Maps 2015). It is around 100m above sea level with an average gradient of less than 1:100,000 (Aderogba 2012; MOE 2009).

It is bordered to the south by the Atlantic Ocean and to the west by the Bright of Benin; its northern and eastern boundaries are formed by Ogun State (Aderogba 2012). It

occupies 180km of Nigeria's coastline, while covering an area of approximately 3577km^2, which represents 0.45% of the Nigerian territorial land mass (Ministry of Environment Lagos 2009; LSG 2011). The city spreads over large islands separated by many creeks on a vast lagoon. Lagos Island is located in the south-west mouth of the Lagos lagoon, while being protected from the Atlantic Ocean by the Bar Beach, which stretches as far as 100km east and west of the mouth (LSDM 2015).

The city receives stormwater runoff from its neighbouring states as it drains two-thirds of South-West Nigeria and southwards into the Atlantic (MOE 2009; LASEMA 2012). Property developments on the floodplains and the indiscriminate dumping of refuse in artificial and natural channels are amongst the most common features of urban development in Nigeria. Such malpractices reduce the carrying capacity of the storm water channels and thus increase the risk of urban flooding (Aderogba 2012; MPL 2015).

Figure 2.8 Map of Lagos showing location in Nigeria. (Source: IJSER 2013)

Lagos is made up of both urban and rural areas; however, the rural areas are being urbanised because of population growth. A defined development plan to manage the

migration of settlers from inside and outside Nigeria is lacking (MOE 2009; MPL 2015). Most parts of Lagos are flood prone and the informal settlements are always the worst hit. Figure 2.9 presents a map of Lagos and pinpoints the settlements selected as study areas.

Figure 2.9 Map of Lagos with location of settlements visited

(Source: adapted from Aderogba *et al*. 2012)

Flooding in Lagos is characterised by two main factors:

- Natural factors that are attributed to its location, flat topography, increased and persistent rainfall, poor infiltration properties and the inundation of the coast by salt water from the rise in sea and ocean levels (Oyinloye *et al.* 2013).
- Artificial features, created by rapid urbanisation and excessive land reclamation. This has led to an increase in accumulated runoff. This is noticed across all parts of Lagos, from the covering up of natural channels and building on flood plains to the obstruction/blockage of conventional drainage via improper and indiscriminate waste disposal into drainage courses. These all contribute to the flooding which has occurred in the region (Oyinloye *et al.* 2013).

2.17 Current Status

2.17.1 Topography:

Lagos is naturally made from depositional landforms, including wetlands, beaches, barrier islands, basins, low-lying tidal flats and estuaries (MOE 2009). Water is very much influenced by topographical features in the area. The low-lying areas and wetlands occupy 78% of the entire landmass of the region, with an additional 12% covered by seasonal flooding (MOE 2009). The land surface gently slopes from north to south and is particularly low lying and flat in the metropolis, especially around Victoria Island, Lagos Island/Ikoyi, and Apapa (Elias and Gbadegesin 2011).

2.17.2 Demographic figures

Lagos is the world's sixth largest city by population, the most populous city in Africa and the most populous city in Nigeria (Nkwunonwo, Whitworth and Baily 2016). Although it is a metropolis, it is also the smallest state in Nigeria, with an estimated population of 21 million people. According to the MOE (2009), about 85% of the state population resides in just 37% of the state territorial land mass. The majority of the population is made up of both local indigenes and migrants from other Nigerian states and overseas (Nkwunonwo, Whitworth and Baily 2016).

MOE (2009) records show that an estimated 3,000 people from other states migrate to Lagos every day in search of a better standard of living. Lagos and its ever-increasing urban population growth, coupled with the scarcity of dry lands, is now characterised by muddled human settlements, encroachments, overcrowding, illegal structures and slum developments sprawled all over the city (Nkwunonwo, Whitworth and Baily 2016). For want of space many people tend to inhabit unsuitable locations, and put up houses with no adherence to local building regulations and town planning guidelines (MOE 2009). In particular, the wetlands and foreshores in Lagos have become havens for disordered human settlements which are prone to severe flooding.

2.17.3 Administrative boundaries

According to the Office of the Surveyor General, Lagos has 22 local government areas, as indicated in Table 2.1.

Table 2.1 Local Government areas in Lagos

Local Government	Area (Km^2)
Badagary Region	723.7
Badagary	444.6
Ojo	172.7
Amuwo-Odofin	106.4
Lagos Metropolis Region	729.4
Ifako-Ijaiye	32.2
Oshodi-Isolo	27.4
Ajeromi-Ajeromi – Ifelodun	12.5
Surelere	19.9
Mushin	17.0
Apapa	48.5
Alimosho	201.5
Shomolu	10.3
Agege	12.2
Kosofe	60.3
Lagos Island	5.0
Ikeja	52
Lagos Mainland	20.2
Lekki Region	643.7
Ibeju-Lekki	469.6
Eti-Osa	174.1
Epe-Ikorodu Region	1616.0
Epe	1205.0
Ikorodu	411.0

(Source MPL 2015)

2.17.4 Climate

Lagos is located in the tropical climate zone and possesses a wet equatorial climate influenced by its close proximity to the equator and the Gulf of Guinea (MPL 2015). It is characterised by an average daily temperature that varies between 33ºC in February, which is the hottest time of the year, and 24ºC in August, which is the coldest month. There are two seasons, the rainy season and the dry season. The rainy season occurs from April to October (MPL 2015) and it is characterised by two peak periods, with the rain reaching its peak in the months of May through to July, and September and

October. The mean annual rainfall varies from location to location around the Lagos mainland, which has recorded up to 1,750mm of rainfall – Badagry at the extreme western end of the state has recorded 1,636mm, Epe at the extreme north-east recorded 1,676mm and Agege in the north-west recorded 1,567mm (Elias and Gbadegesin 2011). Table 2.2 presents the monthly average maximum, minimum and total mean rainfall and also the mean number of rainy days throughout the year.

The dry seasons lasts from the end of October to March, and it is characterised by constant high temperatures with mean monthly temperatures of 30ºC the highest temperatures occur around November/December. The relative humidity is generally high and very rarely falls below 70% throughout the year; vegetation type is predominantly mangrove swamp forest (Aderogba 2012). Figure 2.10 presents a climate graph of Lagos, indicating that the peak periods in the rainy season are between May and July, with the month of June experiencing the highest precipitation.

Table 2. 2 Lagos Monthly Average Temperature and Rainfall

	Mean Temperature ^{o}C		**Mean Total Rainfall (mm)**
	Daily Minimum	Daily Maximum	
Jan	22.3	32.2	14.3
Feb	23.5	31.2	42
March	23.8	32.7	77.1
April	23.6	32.1	142.4
May	23.1	30.9	204.8
June	22.6	29.2	312.2
July	22.1	28.1	256.9
August	21.7	28.1	112.4
Sept	21.9	28.9	167.1
Oct	22.3	30.4	135.8
Nov	22.6	31	54
Dec	22.4	31.9	19
Mean/Month	22.6	30.7	110
Sum (Annual)			1538

(Source: WOE 2013)

Figure 2.10 Climate Graph Lagos

(Source: http://www.lagos.climatemps.com)

2.17.5 Principal water bodies in the area

Lagos has a number of creeks and lagoons where runoff eventually drains, see (Table 2.3).

2.17.6 Drainage channels and systems

Lagos employs a conventional drainage system, leading to a considerably high proportion of the rainfall being discharged rapidly into the sea. This is due to key factors such as the nature of its topography, with low-lying, low-permeability soils and the high proportion of paved surfaces in the urban area (Okoko 2008; Aderogba *et al.* 2012). Channels and streams are the principal elements in the drainage of stormwater to lagoons, creeks or major rivers. Secondary drainage channels include mostly gutters along the roadsides within settlements, and drainage channels, commonly known as

canals amongst the residents. These conventional drainage systems discharge into natural stream channels and finally into the Atlantic Ocean (Okoko 2008; Aderogba *et al.* 2012). These drainage channels in Lagos were first constructed around 35 years ago; they are the principal feature of the first drainage master plan (Master Plan area 1974).

Table 2.3 Lagoons and Creek in Lagos

Water Body	Water Salinity		Area (km^2)	Max. Length (km)
	Fresh	Brackish		
Badagry Creek		√		75
Porto Novo Creek		√	16	5.4
Lagos Lagoon		√	388	59
Lekki Lagoon	√		223	40
Epe Creek	√		30	21
Ologe Lagoon	√		10	9.6
Omu Creek		√	4.7	25

(Source: MPL 2015)

In present-day Lagos, it is common to see drainage pipes and gutters transferring runoff to downstream catchment areas; these traditional methods are visible all over the city. Most of the drainage networks are reported to have been built in the 1970s during the FESTAC festival. Although the government has set up projects to further develop the city, there have been no significant improvements to drainage facilities.

Visits to the area depict a clear picture of the existing nature of these drains. The road gutters are constructed of precast concrete sections with curved inverts whereas the main street drain is made of standard precast concrete open channel sections of concrete or brick-lined channels of various sections constructed in situ; these designs are typical of most less-developed countries.

Flooding occurs in various parts of Lagos, and with the changes in climate, rainfall has become more intense (Figure 2.12). Flooding in this region tends to be associated with short duration storms that rarely persist for more than a few hours. Mostly the inability of the drains to cater for the volume of water result in overtopping of the drainage network. This breakdown in the system can be attributed to inadequate channel capacity to accommodate frequent flood flows, as this drainage infrastructure was not designed

to carry such quantities of water (World Bank 1994). Other factors which exacerbate flooding include the lack of regular maintenance operations, particularly the clearance of silt and debris, garbage disposed of in the channels, and the lack of repair of collapsed or damaged sections (World Bank 1994).

Figure 2.11. Flooded informal settlement. (Source: The World Bank)

The rainy season reaches its peak in July and with it, associated loss of life and property which appears to have intensified year on year. Unfortunately, there are no quantitative data on flood depths or durations during the major flood events and no flow measurements have been undertaken on either the natural or artificial channels in the Lagos area. Furthermore, information on flood damage is also only based on anecdotal evidence, but undoubtedly flooding in the city has resulted in the loss of several lives, with the risk of loss higher in the poorer areas. The occupants of these areas have blamed floods on the poor drainage system in the city, calling on the government to improve drainage infrastructure to prevent it overflowing during heavy rain (Aderogba *et al.* 2012).

2.17.6.1 Secondary drainage channels

Gutters: These are visible across most of Lagos, more dominant in the formal areas and rarely available in informal settlements. They are shallow depressions, mostly concrete, designed to collect stormwater flowing along the street. Sometimes these gutters are linked to the receiving drainage canal or directly to the waterway, depending on its proximity to the water body. A composite gutter section consists of a section

immediately adjacent to the kerb, preferably 2.0 feet (0.61m) at a cross slope of 0.06ft/ft (0.02m/m) or a pavement with a much smaller cross slope, around 0.02ft/ft (0.02m/m), however, a uniform gutter has a uniform cross slope (American Drainage Manual 2000). While the above dimensions are a guide, the length, depth, slope and width of the gutters deployed in Lagos are dependent on their owners (Oshodi 2011). While a gutter deployed by the government would most likely fit the above description, one deployed by a community would have its design tailored to cost and the availability of space. A gutter constructed by an individual would most likely be shallow, focused on transporting water away from the immediate vicinity, rather than the wider area.

Drainage canals: These are much deeper, broader concrete drainage devices in comparison to the gutters installed by the Lagos government to collect stormwater. They feed directly to the receiving waterway and are designed to have a far greater runoff carrying capacity, hence their size. Drainage canals are mostly used to service a larger area and are fed by surrounding gutters and surface runoff. These devices are often seen full of floating garbage because they are also used as dumping sites by the residents, causing blockages and spillage of runoff into surrounding areas. They therefore fail in their aim to manage stormwater and runoff. Figure 2.12 shows the construction of a large canal and one blocked by solid waste.

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Construction of canal in Lagos A blocked canal in Lagos

Figure 2.12: Canals in Lagos (Source: Newsroom Nigeria 2017)

2.18 Natural Causes of flooding

2.18.1 Intense rainfall

Meteorological records show that during the past 35 years, the annual rainfall depth has been greater than 1500mm (Nigerian Meteorological Agency 2012) with on average, 80% of the total rainfall events occurring in the rainy season months (Aderogba 2012). Further detail on rainfall is given in section 2.17.4.

2.18.2 Flat topography

As discussed in Section 2.17.1, the topography of Lagos is largely flat, which slows the flow of surface runoff and prevents its discharge into the receiving watercourse or sea (MPL 2015). This water consequently accumulates over land surfaces, creating large pools of water, raising the groundwater table and creating temporary flooding of the area.

2.18.3 Poor infiltration

Lagos has little or no arable land. Although four soil groups exist in the region, the western half of the coastal margin is characterised by juvenile soils on recent windborne sands (Ogundele and Fatai 2012). The rest of the coastal area towards the east is covered by juvenile soils on fluviomarine alluvium (mangrove swamp). The third soil group is a narrow and discontinuous band of mineral and/or organic hydromorphic soil that occurs in the middle and northern-eastern sections of the state. The fourth group occurs in two small and discontinuous patches along the northern limits, consisting predominantly of red ferrallitic soils on loose sandy sediments (Ogundele and Fatai 2012). According to Fagbami and Shogunle (1995), Lagos soil is characterised by a high base saturation greater than 50% throughout, and within 125cm of the soil's surface. This characteristic translates into poor infiltration into the soil, resulting in most of the rain being rapidly discharged as runoff to surrounding water bodies. The retained runoff is captured as surface floodwater.

2.18.4 Low land elevations and wetland areas

A recently conducted vegetation index study revealed that Lagos possesses many green areas; however, most of these green areas are wetlands and swampy areas (MPL 2015)

as shown in Figure 2.13. These areas are characterised by low elevation relative to the sea, and hence it is difficult to support them with a good drainage system. Results generated from remote sensing classification used to extract green area layers from Terra MODIS vegetation indices show that 52% of Lagos is covered with green vegetation, 22% is water bodies, hence leaving only 26% land cover. These figures also indicate various low-lying areas and these also contribute to flooding within the region (MPL 2015).

Figure2.13: Swamp vegetation in Lagos (Source: Author 2015)

2.19 Artificial Causes

2.19.1 Rapid urbanisation

Land reclamation is very common in various parts of Lagos; this is due to the large influx of people into the state. Lagos has both rural and urban areas, although the rural areas are being sporadically urbanised. Building on floodplains and covering up natural drainage with construction has changed land levels and natural drainage patterns. This activity prevents natural sheet and channel flow being able to escape (Aderogba 2012; MPL 2015).

2.19.2 Under design, lack of maintenance and ageing of conventional drainage systems

Drainage systems require maintenance to sustain the rate of rapid urban development in

the region. Currently stormwater far supersedes the designed carrying capacity of these drainage systems, hence they overflow, causing flooding in the area.

The operational efficiency and effectiveness of the designed drainage systems are determined by the way the system is managed. Their efficiency can be compromised due to a variety of issues e.g. blockage of the channel, dumping of waste into the drainage infrastructure and, as often seen, direct construction across the drainage system or encroachment on the right of way (MPL 2015). In many Lagosian slums, therefore, it is not uncommon to find houses built over drainage channels, which will significantly reduce the effectiveness and efficiency of the system. Figure 2.14 presents an example of the state of a drainage system in Lagos.

Figure 2.14: Lack of maintenance, incorrect construction and dumping of rubbish in a drainage channel in Lagos

(Source: MPL, 2015)

The existing drainage systems in Lagos are therefore generally in an unacceptable state. This can mainly be attributed to the poor attitude of some of the residents. Complete or partial blockages are encountered in most of the existing drainage systems; examples of such blockages are shown in Figure 2.15. These activities negatively influence the hydraulic efficiency and capacity of the drainage system and cause flooding in the area, both upstream and downstream.

Figure 2.15 Solid waste contributing to the blockage of a drainage system in Ijora Lagos

(Source Author 2015)

2.20 Summary

This chapter introduced the concept of SuDS in terms of current and historical use of it as a SSWM tool, and by identifying how SuDS has already been used successfully and how its implementation can manage runoff. It also drew a relationship between the factors that allow urban flooding to occur. As discussed in this chapter, Lagos is a highly urbanised coastal area characterised with a predominantly flat topography, poor infiltration capacity due to soil type and urbanisation, a high populace of informal settlements, as well as being made up of islands and wetlands, all of which mean that residents are continuously impacted by flooding. Residents in informal settlements suffer most, as the government does nothing to address flooding or its associated problems. This chapter has shown the factors implicated in why flooding occurs in the informal settlements, its impacts and factors influencing its severity in terms of climate, geography, population etc. It has thus discussed the various factors affecting the feasibility of SuDS and its implementation. The subsequent chapter discusses the approaches and methods adopted to study the application of SuDS in informal settlements in Lagos.

CHAPTER 3: METHODOLOGY

3.1 Introduction

This chapter begins by discussing the research design, to explain the methodology adopted in order to address the aims and objectives defined in Section 1.3. It highlights the set objectives and a suitable methodology to achieve them. In addition, the appropriateness of the chosen methods, design and approaches are justified. A mixed-methods research paradigm using both quantitative and qualitative methods was adopted, in order to achieve triangulation and validity. The methods and processes of data collection are presented with details of both field study visits undertaken. The chapter discusses the design of a transition framework and also the process undertaken to evaluate it. It also discusses ethical issues and the validity of this research. The final section explains how the data was analysed. In summary, a systematic approach to the methodology was adopted in order to gather information and analyse the data.

3.2 Research Design

A research design is simply a plan for selecting subjects, study sites and data collection procedures in order to answer the research questions. Further to this, the aim of a sound research design is to produce results that are credible and valid (McMillan and Schumacher 2001). The purpose of the research design, as stated by Burns and Grove (2001), is to achieve greater control of the study and to improve its validity by examining the research problem. Parahoo (1997) describes research design as "a plan that describes how, when and where data are to be collected and analysed". The research design here comprises a mixed approach, which allows the researcher to choose from different alternatives and options to ensure that the research purpose and perspective are clarified and achieved. According to Zikmund *et al.* (2010), the research problem will determine the methods and procedures: the types of measurement, the sampling, data collection and data analysis to be employed for the proposed research.

The research design was planned so that suitable research methods were used to ensure the aims and objectives set out in Chapter 1 were achieved. This section thus begins by discussing the criteria for selecting Lagos as a study site. It then discusses the research

methods that informed and determined the best research design, data-collection method and selection of subjects. This section further discusses the research methodology adopted and finally it details the research strategy for this study.

The rationale for selecting Lagos has been discussed in Section 2.16. In addition, the criteria for selecting Lagos include:

- This research is novel as no previous research on SSWM and SuDS have been carried out in West Africa. SSWM and SuDS have been investigated and implemented to manage runoff in various countries in the developed world and in a few developing countries (Section 2.13). However, this has not been the case in West Africa, there is therefore limited knowledge on this in this region.
- Residents of the study area suffer yearly flooding with little or no help from the government, primarily because urban flooding is not a prioritised problem. It is usually ignored with residents expected to manage it by themselves.
- The specific location of the site is such that there is potential to accommodate the implementation of recommended SuDS. With failing conventional drainage systems visible across the city, it is clear that a more sustainable method to manage surface runoff is required, particularly when taking the frequent yearly flooding into consideration. The terrain is characterised by features suitable for various SuDS devices, which can successfully manage the flooding problems currently being experienced.
- This study focuses on informal settlements in Lagos, which constantly suffer yearly urban flooding and are therefore suitable for this study.

Due to the nature of this study, a mix of three research methods was adopted: explanatory, exploratory and descriptive designs.

1. Explanatory research has been defined by Kumar (2012) as an attempt to clarify why and how a relationship exists between two or more aspects of a situation or phenomenon. In the case of this study, the relationship being investigated is drawn from existing literature, which has shown that there is a relationship between urbanisation, drainage patterns and climate change, leading to flooding, and thus issues associated with stormwater management.

2. Exploratory research is usually undertaken to investigate an area where little is known or to consider the possibilities of undertaking particular research, e.g. a feasibility or pilot study (Kumar 2012). Regarding the present study, little is known about the applicability of SuDS in Lagos and whether or not it is an appropriate tool to manage runoff. This is because SuDS have not been explored in developing countries, including Nigeria.
3. The descriptive research method was appropriate to this study because of the need to describe SuDS, its roles, benefits etc., which are essential to its ultimate acceptance and implementation. This description was obtained from existing literature on SuDS and addresses Aim 1 and Objective 1.1.

Thus, the three research methods were appropriate for the study as they provided insights into the required data, which have helped determine the best research design and data-collection method.

All research must be guided by a defined methodology which guides the way in which data are collected and analysed (Babbie and Mouton 2010; Leedy and Ormrod 2010). Babbie and Mouton (2001) viewed research methodology as focusing on the research process and the kind of tools and procedures to be used. O'Connor and Frew (2004) suggest that in order for research to achieve its aims, it is essential to identify and use suitable tools and techniques, which may be qualitative or quantitative in nature, or a combination of both approaches.

The research methodology was conducted by a combination of a literature study, which comprised the review of literature to achieve aim 1 objectives 1.1-1.3, and empirical research, which enabled the achievement of aim 2 objective 2.1 and 2.2 the development of the framework and its evaluation.

Figure 3.1 presents a flowchart of the research methodology discussed below. The literature review comprised 2 aspects, firstly the background literature review and secondly a review of existing SSWM frameworks to be adapted within the transition framework. The empirical aspect comprised a mixed-method approach using both quantitative and qualitative methods essential to the achievement of triangulation and

evaluation (Clarke 2005). Qualitative research bases its findings on discussions, thinking and knowledge in order to help to improve understanding of an area of research (Silverman 2013). Quantitative research, on the other hand, relies heavily on statistical analysis to draw conclusions or to test a hypothesis (Huff 2008). According to Gill and Johnson (1997), a mixed-method approach leads to the justification of research outcomes through internal cross-checking. Hulme (2007) also suggests that integrating both approaches produces findings that can be evaluated, and hence trusted. Therefore, this research adopted an explorative mixed-method approach in order to determine the perception of SuDS as a SSWM tool and hence its potential to be successfully implemented. For this purpose, questionnaires were administered (quantitative method) and used to collect data in 2 field visits. The 1st visit, was a pilot study to give first-hand knowledge of the situation through direct observation, and was also used as an opportunity to inform the community about SuDS through focus group meetings. Data collected from a questionnaire exercise was analysed quantitatively, with the results informing the design of the questionnaires administered during the second visit. Semi-structured interviews (qualitative method) were conducted during the 2nd field visit, with data collected analysed using thematic analysis and Nvivo. Both quantitative and qualitative results from direct field visits, in addition to the literature review, produced the transition framework, which was then evaluated by field experts and a revised framework proposed.

The framework focussed on transitioning Lagos to sustainable surface water management using SuDS as a driver, to ensure its implementation. This would require changes in the way that surface water was managed in order to address issues with flooding. It also investigated the readiness of the investigated settlements to adopt and maintain SuDS. Figure 3.2 presents the design of the framework using the results of mixed methods and the existing literature.

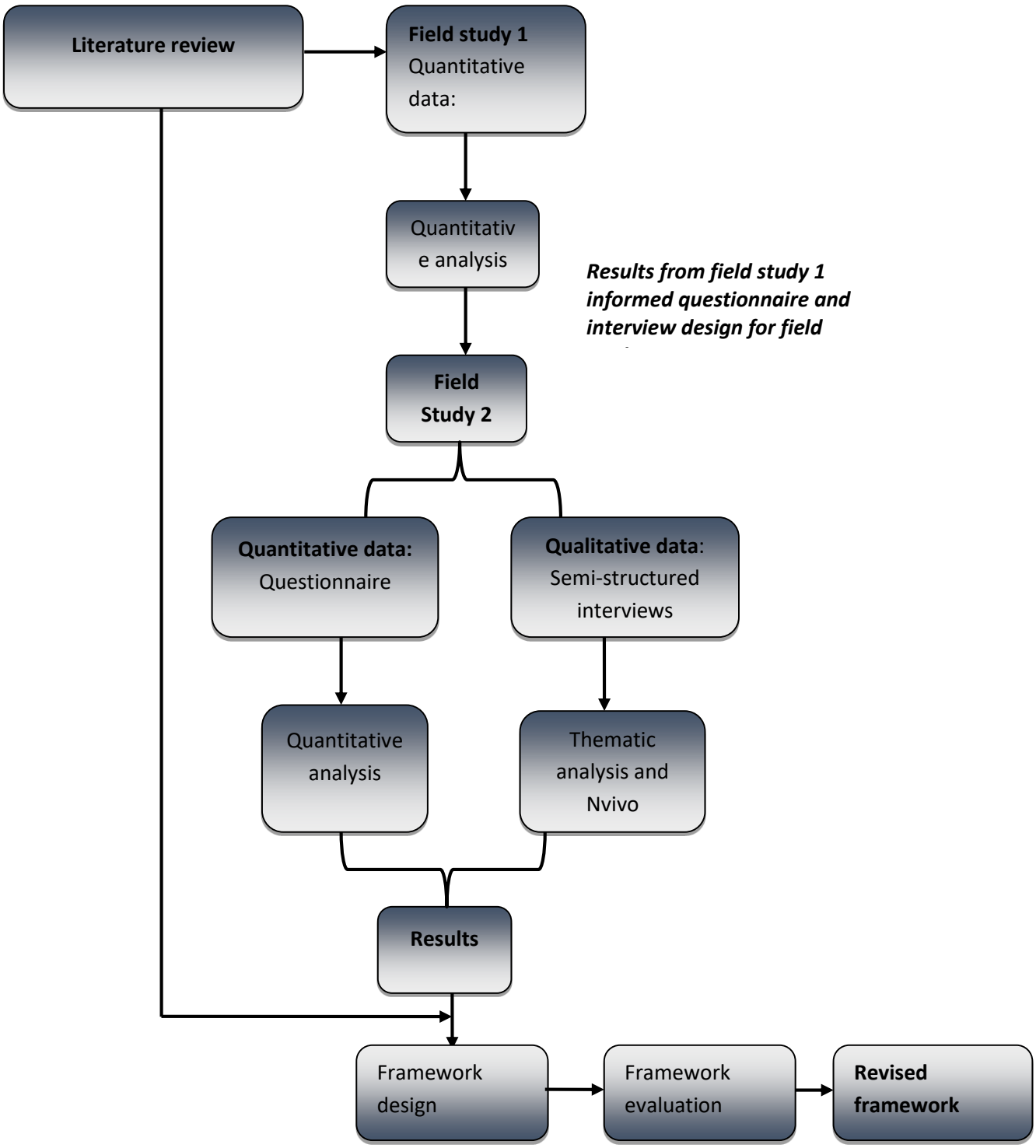

Figure 3.1: Flowchart summarising the research methodology

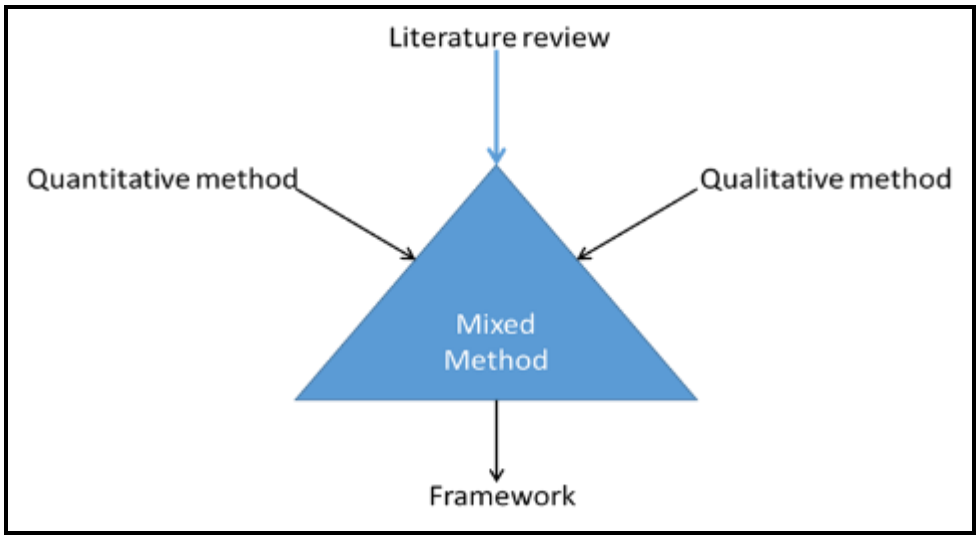

Figure 3.2: Framework Design Approach

3.3 Data Collection Methods, Analysis and Reasons for the Selected Approach

The methods employed to collect and analyse data are presented in this section, along with the rationale behind their selection. Research is required to have trusted data collection methods that can be evaluated to prove a hypothesis. Therefore, in order to minimise error in data collection and analysis it has to be robust. This study therefore comprised two field visits, direct observation and mixed survey research, as outlined in section 3.2. This approach was employed to collect appropriate data, with multiple sources of data used in order to aid the interpretations of the results. Survey research methods are the most commonly used methods for data collection of a descriptive nature (Kumar 2012). They involve the collection of information from a sample of individuals through their responses to questions being asked by a researcher, to measure views as well as take account of events. Researchers have found it to be an efficient method for systematically collecting data from a broad spectrum of individuals (Clarke 2005; Cooper and Schindler 2011; Kumar 2012).

Research has shown that response rates are high with face-to-face interviewing which are able to explore respondents' perspectives due to the qualitative nature of the information (Kvale 1996). The whole purpose of using interviews was therefore to gain a descriptive, in-depth and clear understanding of the pivotal issues around the specific area of flooding, its associated impacts and the potential to implement SuDS.

As indicated in Chapter One, the research involved field visits. In the first phase, data was collected through questionnaire administration and field survey, which involved direct observation. The rationale behind this was to identify the true nature of the research problems, revisit the overall methodology and accurately answer the research questions.

The questionnaire administration, direct observation, semi-structured interviews and focus group meetings undertaken during the field visits enabled the collection of information currently lacking from these sites. These included historical floods, the frequency and extent of flooding, residents' opinions on the causes of flooding, current infrastructure put in place to manage flooding, the effectiveness of the existing flood management devices, and community readiness to adopt and maintain SuDS. The use of the questionnaire also enabled the collection of robust responses from a large target population. Focus groups provided a broader range of information, allowing the participants to become more comfortable while talking in a group; these interactions can also generate more discussion and, therefore, more information (Palomba and Banta 1999). The semi-structured interview format is flexible, allowing the interviewee and interviewer to discuss matters pivotal to the research and issues that might not have been captured before, but can aid in solving the research problem. Semi-structured interviews allow for better communication between the researcher and the respondent (Kvale 1996; Gill *et al.* 2004; Edwards and Holland 2013). They allow both parties to be at ease, and they give the informants the freedom to express their views on their own terms; this translates into a richer, more reliable and comparable form of qualitative data. The interviews were structured into 5 sections;

Part 1 was designed to capture the respondents' views on flooding events, historical floods as well as their occurrence and frequency.

Part 2 involved the respondents sharing their views on the impacts of floods, first on them personally, and then on the community.

Part 3 investigated existing stormwater management in the community and the rationale behind the chosen methods.

Part 4 gauged the respondents' receptiveness to the implementation of SuDS as an appropriate tool to manage runoff, and their readiness to become involved in initiatives to address the flooding issues.

Section 3.4 discusses the rationale behind investigating the use of Google Earth as a potential tool for SSWM to identify the distribution of informal settlements and the potential to be able to design a SuDS system around the shelters.

3.4 Use of Google Earth as a tool to potentially identify informal settlements

Various studies have been able to apply GIS to Google Earth imagery to identify areas of interest and this has proven to be an effective time management tool in the field (Pickle 2003; Viavattene *et al.* 2008). It enables the familiarisation of the study area via satellite imagery before actually visiting the study site. Potentially, therefore, flood-prone areas could be identified, as well as characteristics of the terrain which would drive the selection of different SuDS techniques.

Thus, the potential of Google Earth to identify informal settlements as well as its ability to recognise cluster and flood-prone areas was explored, from which to produce base maps before going into the field. If it proved suitable, Google Earth could potentially save cost and time in the pilot studies.

Before the field visits, aerial images captured on 26/11/2013 and 3/1/2015 were able to identify slums in Ijora and Makoko respectively, and were selected because of their clarity. Google Earth images enabled key geospatial references to be identified and analysed including informal settlements, land cover type, land use type, building clusters and open spaces. Polygons were traced around visible open spaces and transferred onto the base maps taken into the field to be evaluated by ground truthing. However, the ground truth process discussed in the following chapter revealed shortcomings in the appropriateness of Google Earth. The final map outputs are given in detail in Section 4.2.1 and 4.2.2.

3.5 Pilot Study

The implementation of SuDS in informal settlements requires consideration and preparation (Button *et al.* 2010). Technical, institutional, economic, geographical and social factors were identified and considered, e.g. the settlement pattern, terrain, cultural

and social practices, current land constraints and potential restrictions due to pre-existing conditions such as land ownership, right to erect structures etc. Informal settlements are usually characterised as having a low-income environment, an important consideration when working in these environments (Douglas *et al.* 2008). The failure to correctly identify and define these factors can lead to high running costs and the sustainability of the proposed system could be negatively affected.

Two field visits were made to Lagos between April and August 2015, the former being the pilot study, the latter occurring in the peak of the rainy season. The first visit involved an observation of the area, the identification of the most flood-prone areas within the settlements, and the administration of questionnaires and focus group meetings to familiarise respondents with the concept of SuDS. The pilot study was intended to give first-hand knowledge of the area while analysing the suitability of SuDS in the settlement communities. It entailed visiting the settlements to view flooded areas, to ascertain the source and extent of the floods and to identify the factors influencing the implementation of SuDS techniques. This all contributed to the development of the framework focused on sustainably managing stormwater in a cost-effective manner in the area and also to successful transitioning towards SSWM.

Seven settlements in Lagos served as local case studies for this pilot, six of which were informal settlements and one formal settlement (Ikeja) for comparative purposes. The informal settlements were Ifako-Ilaje, Ijora, Iwaya, Ijaye, Makoko, Oshodi-Isolo and Ikeja (see Figure 2.9), which were chosen because they were typical of informal settlements across Lagos, were in various stages of development and suffered major flooding incidences yearly. Ikeja was included to identify differences between both types of settlement regarding the perception of flooding, and the management of surface runoff. It was also used to gain a perspective of the formal residents' willingness to adopt strategies that could have an influence on flooding. The sustainable management of surface water cannot be dealt with in isolation in just one settlement type, i.e. informal settlements, because one will affect the other in terms of management. Therefore, in order to obtain a holistic picture of the situation, it was necessary to include a formal area.

3.5.1 Questionnaire distribution

A total of 150 questionnaires were administered randomly to residents across the seven different study sites to elicit information. The number of questionnaires subsequently retrieved after the questionnaire excercise are presented in Tables 3.1 and 3.2 respectively. The questionnaires asked residents about their perceptions of flood occurrence/incidence, their frequency, effect on the residents, and measures put in place to combat flooding, etc. 76 responses were retrieved from across all seven settlements, giving a response rate of 50.6%. Forty-two males and thirty-four females returned the questionnaire.

Table 3.1 questionnaire distribution for pilot study

Target Group	Questionnaires Distributed	Questionnaires Retrieved	Response Rate
Visited Settlements	150	76	50.6%

3.5.2 Questionnaire outline

The questionnaire was designed to provide data on areas where no formal records exist, for example, respondents' perceptions and perspectives on the issue of flooding, to collate data on historical flood events in the area, with their occurrence and frequency, as well as ascertaining the local community's readiness for SuDS. It went further to question the respondents' views on the impacts of floods, both on them personally and on the whole community. The questionnaire also queried what the residents thought caused the flooding, any formal protective and preventive measures already in place and any the existing stormwater management practices in the informal communities. Views on the effectiveness of these devices and also the ownership of the devices were gathered. The rationale behind asking about the ownership of these systems was that some of the devices were owned by the government while others were owned by the community or individuals. For example, while most gutters and canals would be government owned, other flood defence systems such as smaller sized gutters, sandbags and tyres, etc. were owned by the community and individuals. The study asked about the ownership of these devices in order to identify the changes that had been put in place to manage flooding without government influence. This would indicate a potential

interest in seeking alternative flood control measures, and by inference the implementation of SuDS. The final part of the questionnaire involved investigating the respondents' receptiveness to the implementation of SuDS as an appropriate tool to manage runoff. Finally, respondents were asked to provide feedback on how existing measures could be improved to sustainably manage flooding problems faced by the communities involved. Suitable quotes from the responses were presented, and also to capture a total picture of responses from the questionnaire, statistical relationships between variables were identified, explored and presented.

3.5.3 Questionnaire analysis

The quantitative data was presented via the use of frequency and cross-tabulation. The rationale for using these functions was firstly their simplicity, as they are easy to compute and understand. Furthermore, the crosstab function provides comparative data on two or more variables across multiple features at one glance (Cooper and Schindler 2011). Additionally, crosstabs can be used with any type of data whether it is ordinal, nominal, ratio or interval (Cooper and Schindler 2011). Comparisons and relationships between various factors can be drawn, such as existing flood defences and flood management, which ensured clear and easy understanding of the data collected.

The results obtained from the pilot study enabled the questionnaire to be adapted in order to capture further questions on the second visit. Information was used to identify potentially suitable SuDS techniques, which was then reflected in the questionnaire for the second field visit to gauge respondents' receptiveness to the recommended SuDS; all of this was integral to the design of the transition framework.

3.5.4 Focus group sessions

Focus group sessions were held in order to introduce the respondents to the concept of SuDS and included presentations and illustrations of example devices. The various simple/soft SuDS, their benefits and examples of where they had been successfully implemented were discussed. In addition, their implementation, as well as their private maintenance, without the help of the government, was discussed. These discussions were carried out both in English and a translation into the local Yoruba dialect. This meeting also allowed the researcher to gauge the level of receptiveness to the idea of

SuDS to manage flooding, as attitudinal research through direct observation was being undertaken.

3.6 Second field visit to Lagos in August 2015

The second visit to Lagos took place in August 2015 just after the peak of the rainfall season. Having obtained information from direct observation and the results gathered from the pilot study, suitable techniques were suggested and included in the questionnaires, focus groups and interviews with stakeholders (residents of the settlements as well as regulatory bodies in charge of water management in Lagos). These activities comprised visiting four locations: two slum developments new to the study and two locations that were visited previously in the pilot study. These were visited for two purposes, namely:

1. For evaluation of previous responses.
2. To redefine questions based on findings from the pilot questions previously administered.

The four sites visited were Ajeromi-Ifelodun, Apapa, Igumu, Makoko, and a formal settlement Ikeja. The Ajeromi-Ifelodun, Apapa and Igumu settlements were selected because they were highly populated slum sites. Makoko was revisited to evaluate the data collected from the pilot study. The visit was carried out between August and September 2015; this period was chosen because the peak of the rainy season occurs in July.

3.6.1 Questionnaire outline

The main questionnaire followed the same outline as those in the pilot (see Section 3.5.2), modified based on the pilot study results. Previous observations identified the need for a positive change in the management of surface water by most of the residents in the informal areas, therefore more direct questions regarding their receptiveness to change explored. This was necessary to achieve more grounded data and information, rather than just basing the communities' willingness to adopt sustainable and effective strategies on observation alone. Therefore, a section that presented questions about the different settlements willingness to adopt and maintain SuDS devices privately was

included. This was necessary because one of the barriers to the implementation of SuDS is its management thereafter.

Based on observation and the previous results obtained from the pilot study, simple SuDS that could be implemented as a first step to transitioning to sustainable water management were identified. This was based on the characteristics of the slum settlements, such as inadequate space, the intensity and frequency of rainfall, as well as the absence of vegetation, leading to filter strips and swales not being considered. However, the use of rainwater harvesting (RWH) was identified and recommended as an additional method to those already being employed to manage flooding. The use of containers to collect rainwater for non-potable uses was observed during field visits, but rather infrequently. Therefore, questions pertaining to RWH as an adaptable strategy to manage flooding were included in the last section of the questionnaire to gauge its acceptability and to find out whether the community was indeed willing to adopt change, as was inferred from the pilot. The questionnaire ensured clarity and strategic questioning to identify key issues such as readiness to implement and maintain the suggested SuDS.

As presented in Table 3.2, a total of 200 questionnaires were handed out, and 154 were retrieved, giving a response rate of 77%. The male: female numbers were 86:68 respectively. Data was collected and then coded with Excel and crosstabs. Frequency functions were used to present the questionnaire responses.

Table 3.2 Questionnaire distribution for the second visit

Target Group	Questionnaires Distributed	Questionnaires Retrieved	Response Rate
Visited Settlements	200	154	77%

3.6.2 Justification for rainwater harvesting (RWH) as a suitable management strategy to manage flooding

According to the literature (CIRIA 2007; Susdrain 2012; Charlesworth and Booth 2016), SuDS are selected in accordance with the surface water management train (see Chapter 2 Section 2.11). The preferred technique is to manage surface runoff as closely

as possible to the source and to manage it locally while using a variety of suitable techniques to deal with the issue (CIRIA 2007; Woods Ballard *et al.* 2015; Charlesworth and Booth 2016). Therefore, site characteristics determine the appropriate SuDs technique to be used, for example location, size, soil type for infiltration purposes, vegetation, topography, and urban density.

Bearing the above in mind, in order to accomplish objective 1.2, RWH was identified as one of the most appropriate SuDS techniques due to its simplicity, cost-effectiveness and efficiency in managing runoff, coupled with the existing site characteristics: flat topography, little or no vegetation and clustered settlements lacking sufficient space for larger devices.

Although there are other simple SuDS that do not require space, such as green roofs and walls, they are not applicable in the study area, primarily because they are dependent on vegetation and are not simple or cheap to install. Other devices such as swales, filter strips, filter drains, infiltration trenches and sand filters (see section 2.12 for further details) would not be suitable for sites characterised by fine clay or silty soil, as is the case in the study sites, as they have high clogging potential. They also require space and as the study sites are densely populated, there is insufficient space to deploy these devices. Finally, Lagos is characterised by a high-water table, which also reduces their efficiency and effectiveness; and for these reasons they were were not selected. Maintenance of devices with standing water would also prove difficult and the breeding of mosquitoes might occur, hence creating more problems.

In summary, the inadequacies of the some of the simpler SuDS to manage runoff on the study sites make them inapplicable. This decision was based on the following site criteria/characteristics.

- High water table
- Soil has low permeability
- No space in highly dense areas
- High clogging potential of devices
- Potential lack of maintenance

A more detailed SuDS selection criteria for the site conditions under study is given in Appendix 5 Section 9.5 Figure 1.

3.6.3 Focus group

The focus group sessions were carried out similar to those described in Section 3.5.4 and were organised for the two additional study sites. SuDS were introduced and discussed, as well as its implementation and maintenance. These discussions were undertaken with the aid of two interpreters from the Ministry of Environment (MOE), appointed as guides to the visited areas.

3.6.4 Stakeholder interviews

A total of 15 interviews were held with stakeholders of SuDS in Lagos. There were two separate sets of interviews, tailored to capture the perspectives of two different groups interviewed: formal and informal residents, and government officials. This interview exercise was necessary to achieve Aim 1 and to evaluate the quantitative data collected and to obtain a richer context and in-depth description of the subject matter by sharing in the participants' experience. Responses from all the stakeholders have been used to evaluate the claims made by the different groups.

- **Group 1**

The first group of interviewees comprised 10 residents of the formal and informal settlements, 2 of whom were community leaders, 8 from the informal areas of Apapa-Igamu and Ajeromi-Ifelodun and 2 formal participants from Ikeja. This was to enable a balanced perception of how flooding and its management were perceived by the residents of Lagos.

The interview questions were designed around a set of research questions:

Research questions for residents

This second field visit built on interviews conducted during the pilot (see section 3.5.2), and included more in-depth enquiry of:

- What the community was already doing to combat the problems of flooding.

- How efficient such measures have been in handling flooding episodes, and whether there was opportunity for improvement and their potential to be incorporated into a proposed SSWM design.
- How the community perceived the implementation of new strategies to manage runoff.

The interviews were designed to be semi-structured in nature, therefore they allowed the participants to be liberal with their responses without digression from the subject matter. The interview questions were based on seven major themes:

Interview theme outline:

Theme 1- Settlement type, residence and length of residency: These first sets of questions were designed to capture the background details of the interviewees. They identified settlement type and length of stay at the location. This was necessary to gauge the extent of the interviewees' flooding experiences, as this could significantly substantiate and evaluate the findings from the field study

Theme 2- History of flooding in the area: The study sought to gather data on the flooding history of the settlement from these interviews to use as primary data to collaborate and evaluate what was already known. It was believed that the informal settlements experienced more severe flooding than the formal settlements, therefore additional data from people who have experienced this first hand makes the data richer and more valid.

Theme 3- Causes of flooding: This interview question was necessary to enquire about the participants' knowledge of the causes of flooding, in this case from excess runoff.

Theme 4- Impacts of flooding: If the impacts of flooding were able to be easily managed it might be easier to carry on living with the issue without looking for alternatives, as it would just be considered a way of life. Hence this is a barrier to the adoption of SuDS. However, the more severe the impacts, the more there is a drive to look for solutions, and the greater the willingness to accept strategies that would improve the situation. Thus, it was pertinent to gauge how the respondents viewed the impacts of flooding on their day-to-day activities. This would also influence the

framework design as it would identify exactly what to focus on. The more pressing issues could be prioritised in the creation of the framework.

Theme 5- Existence of flood defence systems: The study investigated whether the areas visited were serviced with flood defence systems to manage excess runoff, and if so, what these were. This was for evaluation reasons as well as for creating a clearer picture of how the systems worked in the various settlements. When creating or designing a framework to be used certain people, it is important to understand the existing structure for which an alternative is being offered.

Theme 6- Effectiveness/ownership of flood defence systems: The respondents' perceptions of the effectiveness of the drainage devices available to them were sought, while also seeking understanding of the ownership of these devices. This was necessary to establish maintenance responsibilities of the suggested SuDS.

Theme 7- Implementation of SSWM and willingness to maintain them: The responses to this question enabled respondents' willingness and preparedness to search for alternative methods to manage their excess runoff to be gauged. A question relating to the private maintenance of SuDS without government influence was also included. A commitment to maintain SuDS privately would translate to the participants being ready to address the situation themselves without waiting for the government. See Section 4.6 for results.

- **Group 2**

The second group were 5 government officials with the ability to influence surface water management in Lagos. They were staff from the MOE and Lagos State Emergency Management Agency (LASEMA). The key responsibility of the visited departments is highlighted below.

The drainage, construction and water resource department is responsible for:

- Flood control and management
- Identification and management of flood-prone/flood-affected areas
- Attending to drainage matters/complaints

- Monitoring and provision of technical assistance for all drainage projects handled by other MDAs and Non-Governmental Organisations (NGOs)
- Assisting in formulation of policies on stormwater drainage channels

The emergency flood abatement department is accountable for mostly statutory responsibilities. These include:

- Flood abatement and provision of flood relief at times of distress
- All year-round cleaning and maintenance of secondary collectors drains and tertiary drains where necessary
- Respond to correspondence/complaints from the public on flood matters
- Reconstruction and rehabilitation of collapsed drains and other hydraulic structures that are encountered in the course of their activities
- Construction of drain and related hydraulic structures

LASEMA: The Lagos State Emergency Management Agency's responsibilities include:

- Overall coordination of emergency management in Lagos
- Provision of adequate and prompt response as well as sustaining interventions in all forms of emergency/disaster situations, e.g. in a state of emergency

The participants represented a mix of staff across the bodies in charge of managing stormwater runoff in Lagos. They were selected because of their individual roles and responsibilities (see Table 4.28). These government officials were approached and briefed on the reason for the interview; they were interested and gave their consent to participate.

Research question for government stakeholders

What has been the government's influence on managing runoff in both formal and informal settlements and are they willing to transition to SSWM in order to better manage flooding?

Further questions and responses helped formulate the framework design. Specific responses reinforced these findings and were presented in narrative form. This format enabled the articulation of their opinion of the government's engagement in the management of storm runoff and their perceptions of the implementation of SuDS.

The interview questions were designed to capture the interviewees' perceptions of the existing drainage systems, whilst gauging the government's openness to implementing SuDS as a means of achieving SSWM. The 5 themes that formed the interview outline are highlighted below.

Theme 1: Background details of respondents

This section of the interview sought to establish the background details of the respondents and to identify their roles as stakeholders as they pertained to the management of surface water in Lagos State.

Theme 2: History of flooding

This theme discussed the history of flooding in Lagos, pinpointing when these events occurred and their severity. The participants were asked to briefly describe the history of flooding in the state. This was required in order to gauge and at the same time collaborate/evaluate the study's finding on flooding and its occurrence.

Theme 3: Lagos Government management of excess storm runoff

Interviewees' responses of how the Lagos State government managed excess stormwater runoff to indicate their perceptions of the effectiveness or ineffectiveness of the current system. This was integral to ascertaining the government's willingness to implement alternative methods for managing runoff. It also indicated whether or not the government had identified the causes of flooding and what preventative measures were being implemented.

Theme 4: Perceptions of implementing SSWM

This enabled the identification of whether a knowledge gap relating to SuDS existed. The interviewees were therefore asked if they knew what SuDS were. This is because before a shift in paradigm or a change from the norm can occur, an understanding of the new/alternative option is essential.

Theme 5: Willingness to implement SuDS by the Lagos Government

The last question in the interview was one that would enable an understanding of the government's preparedness to shift to a more SSWM. The interview question was:

Do you think the government will be willing to adopt SuDS to cater for flooding, rather than the existing drainage methods?

The responses to this question would determine the necessary steps in the framework design to achieve a successful transition to SSWM in Lagos. This is because these respondents represent the bodies that create legislation, regulation and planning on surface water management matters in Lagos. Therefore, their perceptions of the implementation of SuDS are the most valid gauge of whether SSWM is something the government would even contemplate addressing.

The interviewees' responses have been analysed, interpreted and are presented in Section 4.7.

The participants were assigned numbers and labelled accordingly to maintain anonymity. Some of the comments have been paraphrased to suit the context and are not the participants' direct quotes and commentaries. However, direct quotes and commentaries have been used where necessary or pertinent.

The rationale behind these interviews was to achieve Aim 1: to explore the potential of using sustainable water management methods to manage runoff in Nigeria. In addition, the interviews were necessary to evaluate the results from the quantitative data obtained from the questionnaire exercise. The interviews also ensured a richer context and an in-depth understanding of the situation by investigating participants' experiences, which only an interview session can achieve (Gill *et al.* 2008; Bolderston 2012).

There are various methods of analysing qualitative data; these methods can be combined to ensure a more robust result (Green and Thorogood 2004). For this study, thematic analysis and Nvivo were adopted to analyse the interview data. The rationale behind the implementation of thematic analysis was that it provides a clear series of steps used to manage large and complex sets of qualitative data. It is easier to manage compared to other methods of analysis. According to Braun and Clark (2006), it is simple and

flexible and is widely used to analyse qualitative data, focusing on investigating themes within the data (Daly, Kellehear and Gliksman 1997). According to Guest, MacQueen and Namey (2012), thematic analysis goes beyond counting explicit words or phrases, as it also explores and describes both implicit and explicit ideas within the data.

Data analysis began by transcribing the questions and responses from the interviews and saving them securely in Microsoft Word. The data was then imported into the Nvivo analysis software, which supports qualitative and mixed-method research (Bazeley and Jackson 2013) where it was auto-coded for major themes/nodes. It is designed to help researchers organise, analyse and find insights in unstructured or qualitative data such as interviews, articles, open-ended survey responses, social media and web content (QSR International n.d.). Zamawe (2015) states that Nvivo is a useful tool that saves researchers from 'time-consuming' transcription and boosts the accuracy and speed of the analysis process.

A review of the entire dataset was conducted to explore emerging patterns and similarities, which was followed by the identification of significant statements by grouping and coding the responses using thematic content analysis. Thematic coding is a qualitative analysis method that entails recording or identifying passages of text or images that are connected by a common theme or idea, enabling the indexing of the text into categories and thus establishing a framework of thematic ideas (Gibbs 2007). After coding, the next step involved extracting potential themes and significant statements. This led to an interpretation of the meanings in the statements, developing patterns and trends, while searching for similarities and repetitions (Green and Thorogood 2009). The process led to the further development of code themes/nodes and sub-themes/child nodes from the participants' responses, which allowed for a richer and more grounded analysis. Nvivo enabled the tracking of text frequencies (coded significant statements), and their location and occurrence in the entire dataset. Azham and Hamidah (2011) suggest that research is valid when it has successfully measured the intended variables and then produces a conclusion, and/or leads to findings that can be generalised. The study involved engaging a real-life setting (residents who were prone to flooding by virtue of their residency location and government officials who influence the management of surface water management), utilising qualitative research methods

utilising a representative data sample.

3.7 Tools of Research Evaluation and Credibility

The evaluation of the findings, ensures the accuracy, credibility, reliability and trustworthiness of the findings collected in the field through various processes (in this case semi-structured interviews). It is common knowledge that not all questions asked in an interview are answered truthfully or correctly; certain factors such as mood, bias, etc. might actually influence a respondent's answer to a particular question. Hence, the validity of the data collected further reflects the accuracy with which the findings represent what was stated (McGuiggan and Lee 2008).

The main means of evaluation for the data and findings of this study were achieved via:

1. A participant information check.

2. The use of mixed methods for data collection, to achieve triangulation and evaluation.

3.7.1 Participant information check

Research shows that the triangulation and evaluation of data can be achieved via mixed methods for data collection (Saunders *et al.* 2003; Cooper and Schindler 2011). Therefore, it is often suggested that researchers use different methods of data collection in order to achieve triangulation and evaluate results.

Kumar (2012) suggested a different method of triangulation by transcribing interviews or field notes and then sharing them with the interviewees for confirmation and approval. Therefore, the 5 government interviewees were told that a transcript would be forwarded to them via email to check the accuracy of the recording. The interviews were then transcribed as soon as possible after the interview and a summary of each transcript forwarded to the interviewees. This process was designed to eliminate any bias or error as far as possible. The participation information and consent form is attached in Appendix 1, and Sections 9.1.1 and 9.1.2 respectively.

3.8 Sustainable Surface Water Management Transition Framework

A four-phase iterative SSWM transition framework was developed and adapted from four relevant existing water management frameworks. The framework was designed to establish the implementation, maintenance and sustainability of the proposed SuDS techniques to transition the informal settlements in Lagos to SSWM i.e. with the view that SuDS is a transitioning tool. The framework was also designed with information obtained from the field visits, including:

- Background information on site location, general site conditions, land use, vegetation and relevant history of the site.
- Technical information such as types of intervention currently practised to manage runoff, challenges faced and outcomes, operation and maintenance procedures.
- Environmental information: such as vegetation, soil type, topography and weather events.
- Social and legal information**:** such as land ownership, attitudes towards flooding etc.
- Relevant governance in place to support SSWM.

3.8.1 Framework evaluation

The evaluation process aimed to gauge the viability of the developed framework by establishing its ability to be implemented, its reliability, usefulness and adaptability. It thus addressed the current state of water management practices and activities in order to provide guidance in a successful transition to SSWM. The evaluation process included perspectives from key water management stakeholders across six African countries, selected based on their experience in the water management sector. A total of 26 were identified, and an introductory email, in addition to the framework and relevant literature, was sent out. However, only 12 evaluators across three countries (Nigeria, Gambia and Uganda) replied. Table 3.3 presents the profiles of all 26 evaluators.

Table 3.3 Evaluators' Profile

Respondent No.	Country	Received Feedback	Name of Establishment

1	Gambia	Yes	National Disaster Management Agency
2	Nigeria	Yes	Rivers State Ministry of Environment
3	Nigeria	Yes	National Environmental Standards and Regulation Enforcement Agency
4	Nigeria	Yes	National Environmental Standards and Regulation Enforcement Agency
5	Nigeria	Yes	Ministry of Land and Town Planning Anambra
6	Nigeria	Yes	Ministry of Land and Town Planning Anambra
7	Nigeria/UK	Yes	Independent researcher
8	Nigeria	Yes	Lagos State Ministry of Environment
9	Nigeria	Yes	Lagos State Ministry of Environment
10	Nigeria	Yes	Imo state Ministry of Environment and Health
11	Uganda	Yes	African Union of Conservationist
12	Uganda	Yes	African Union of Conservationist
13	Sierra Leone	No	Ministry of Water Resources
14	Sierra Leone	No	Njala University Sierra Leon
15	Sierra Leone	No	University of Sierra Leone
16	Ghana	No	Ministry of Environment, Science, Technology and Innovation Ghana
17	Ghana	No	Ministry of Environment, Science, Technology and Innovation Ghana
18	Ghana	No	University of Accra, Ghana
19	Ghana	No	University of Accra, Ghana
20	Cameroon	No	Ministry of Environment and Nature Protection
21	Cameroon	No	Ministry of Environment and Nature Protection
22	Gambia	No	National Disaster Management Agency
23	Nigeria	No	Lagos State Emergency Management Agency
24	Nigeria	No	University of Lagos
25	Nigeria	No	University of Port Harcourt
26	Nigeria	No	University of Port Harcourt

Brockoff (1975), suggests that an acceptable number of candidates can be as little as four to perform such an exercise; hence 12 was judged to be acceptable.

The objective of the evaluation was to test the usefulness of the framework by requesting these 26 key stakeholders critique it and give recommendations for its improvement and applicability. The administered questionnaire was designed to reflect three main categories for evaluation:

1 The framework design

(i) Functionality of framework

(ii) Transition framework process flow

2 Viability of framework

3 Implementation of the framework

The evaluators' responses were recorded and a summary of their responses to the scaled questions and open-ended questions created. The tables were then used to analyse the responses, which are discussed in detail in the following chapter.

3.8.2 Justification of selected countries for evaluation exercise and rationale behind selected stakeholders

Nigeria was selected as one of the countries to evaluate the framework, primarily because Lagos was the study site. Objective 2.2 was to evaluate the application of the framework for informal settlements in Lagos, thus stakeholders from there were selected. Objective 2.2 integrates the purpose of the evaluation process, which was to check the flexibility and appropriateness of the framework to suit developing countries in Africa, not just Nigeria, hence the selection of the other countries. Further to this, the response time of the evaluators was considered, as countries where personal contacts acted as a go-between were selected; this was to overcome the limitation of the feedback turnaround time. In the introductory email sent out to the evaluators, the reason for the exercise was detailed, and key personnel introduced to the evaluators. This was necessary because some of the evaluators hold prestigious positions and a contact was necessary to prioritise the evaluation exercise because of time limitations. Some evaluators who did not give feedback were going through political/social changes in their countries such as coups, change of government etc., hence their inability to respond.

It was very important that the participants in the process were indeed "experts" in the field under investigation (Singh and Kasavana, 2005). The justification behind the selection of the stakeholders was their expertise in the water management field as well as their ability to influence the acceptance and possible implementation of the framework. Feedback and recommendations relevant to the framework obtained from the evaluation process were all reflected in the revised framework and have been discussed in Chapter 7.

3.9 Ethical Considerations

All research raises ethical issues, hence all work carried out or submitted to any university body should be morally acceptable. It is therefore a requirement of Coventry University that ethics approval is sought for research work carried out involving human participation and living organisms. All ethical requirements and procedures were carried out and ethical approval was granted (see Appendix 4 Section. 9.4.1 Table 1).

3.10 Summary

This chapter outlined the various methodologies proposed for the study, identifying the sites selected and the rationale behind the choice of location. It further explained the choice of methods, the approaches adopted and the rationale behind these choices. A combination of qualitative and quantitative methods, or mixed methods, was adopted in order to achieve triangulation. The chapter outlined the design criteria for the study. It further indicated the various sources of data collection and the tools used for analysing the obtained data. In addition, methods for the evaluation of the designed framework were discussed and finally ethical concerns and the approval procedures for the study were also confirmed in this chapter. The following chapter discusses in detail the results achieved from the field visits.

CHAPTER 4: RESULTS

4.0 Introduction

This chapter presents results of the quantitative and qualitative investigations carried out and discusses findings from the two field visits undertaken. Results are based on methods discussed in the preceding methodology Chapter 3, (Sections 3.5 to 3.7). This chapter is divided into 3 with the pilot study results presented first followed by results of the investigation of using Google Earth as a means of establishing the distribution of buildings, and finally a discussion of the results of the second field study.

4.1 Quantitative analysis from the questionnaire administered to formal and informal residents undertaken during the first (pilot) study.

This section presents the results and analysis collated from questionnaires administered to the residents of the seven communities in Lagos given in Section 3.5.

4.1.1 Resident's background

In order to establish background details of the respondents where data was collected, the first set of questions related to their age, gender, residency and length of residency as well as flooding experiences witnessed.

- **Age Group:** The aim of collating respondents' age was to investigate the relationship between age and length of residency in their settlement, as well as the relationship between age and historical flooding events. Ages ranged from (18-60+). However, there was no significant difference between age and length of residence, which was mostly short regardless of age. This can be attributed to settlement characteristics; in a slum development people constantly arrive and leave. In addition, the government in Lagos regularly destroys these developments only for the residents to relocate and rebuild. Again, because most of the residents did not live in a particular area long they had little first-hand knowledge or experience of historical floods in the area
- **Gender:** Results showed an even spread of 55.3% male to 44.7% female, (Table 4.1) thus addressing gender bias.

Table 4.1 Gender distribution

Gender	Frequency	Percent
Male	44	55.3
Female	34	44.7
Total	**76**	**100.0**

4.1.2 Knowledge of flooding in their environment

Results from individual awareness of flooding incidences in the various communities revealed that of the 76 respondents, 62 expressed knowledge of flooding in the area. 14 people claimed they had not experienced flooding but only because they had just recently relocated to the area and were yet to experience the rainy season.

Table 4.2 presents the frequency analysis of responses collated regarding residents' awareness of flooding in their community. The respondents were asked to rate their knowledge of flooding history in their location, options available ranged from none, basic to expert. Results reveal the highest number of participants, sixty-three, perceived themselves to have basic knowledge, while four expressed expert competence in their knowledge of flooding history in the area, and 9 claimed to have no knowledge at all.

Table 4.2 Flooding awareness of participants

Knowledge	**Frequency**	**Percent**
None	9	11.8
Basic	63	82.9
Expert	4	5.3
Total	**76**	**100.0**

4.1.3 Respondents perceptions on causes of flooding

Amongst the major causes identified were rainfall 59.2% and a combination of rain and blocked drains (13.2%)

Figure 4.1: Blocked drain an informal settlement in Ijora Lagos

(Source: Authors Photograph 2015)

Other leading causes included obstructed drainage systems and the inadequacies of these systems. Although some communities have gutters designed to carry the rainfall, they are regularly used for waste disposal as Figure 4.1 shows. It is common to see these drainage systems filled with refuse, hence their blockage/obstruction. Table 4.3 presents results from participants' responses on the causes of flooding in their community, which identified rainfall as the leading cause. These results show a slight disparity with similar investigations carried out in Lagos, by Aderogba (2012), which showed that 97% of the sampled population were of the opinion that blocked canals were the major cause of flooding, 94.3 % believed it was from inadequate drainage facilities and 94.1% believed it was from torrential rain. However, it is likely the reason for this disparity was because the sampled population in the study by Aderogba (2012) was spread across the whole Lagos metropolis which would have more canals and gutters compared to the study sites for this investigation which mainly focused on informal settlements, which have few canals. However, both results show a consensus that flooding is caused mainly by obstruction of drainage facilities and persistent

rainfall.

Table 4.3: Causes of flooding

Cause	Frequency	Percent
Rain	45	59.2
Burst drain	5	6.6
Overflowing riverbanks	4	5.3
Other	1	1.3
Rain and blocked drain	10	13.2
Rain, burst drain	6	7.9
Rain, overflowing riverbanks	2	2.6
No Answer	3	3.9
Total	**76**	**100.0**

4.1.4 Perceptions of flood severity in the various settlements

Figure 4.2 represents a cross-tabulation comparing residence of respondent and how flooding severity was perceived from barely to moderate to extreme. The results show that Ikeja (formal) had the highest number of respondents that were of the opinion it barely flooded, while the informal settlements ranked severity mostly from moderate to extreme, with a minority of respondents in the informal settlements ranking flooding as barely occurring. It is likely that these respondents only just took up residence in these areas and were yet to experience the flood. Results obtained are in line with various studies, which suggest that informal settlers are the worst hit by flooding and would indeed perceive flooding as extreme compared to those in formal areas (Parkinson and Mark 2005; Douglas et al 2008; Adelekan 2010). Results also showed that most of the informal settlements experienced over 7 flooding episodes yearly, whereas the formal residents revealed that they experienced between 1 and 2 flooding episodes annually. Ikeja is a planned settlement and the government has put certain storm management infrastructure in place to service the area. Also, it is located upstream of the slum areas which are usually located downstream (Parkinson 2003), causing the runoff to flow to these much lower areas causing flooding. According to Adelekan (2010), about seventy percent of Lagos comprises informal settlements characterised by regular flooding of homes that lasts for a long time because of the increased frequency of storms, combined with heavy rainfall of long duration or high intensity and the increasing inadequacy of drainage systems. Ilaye recorded the highest number of respondents who felt they

experienced extreme rainfall which is similar to studies such as those of Adeloye and Rustum (2011), Aderogba (2012) who also relate flooding directly to poor drainage and the continued expansion of the slums.

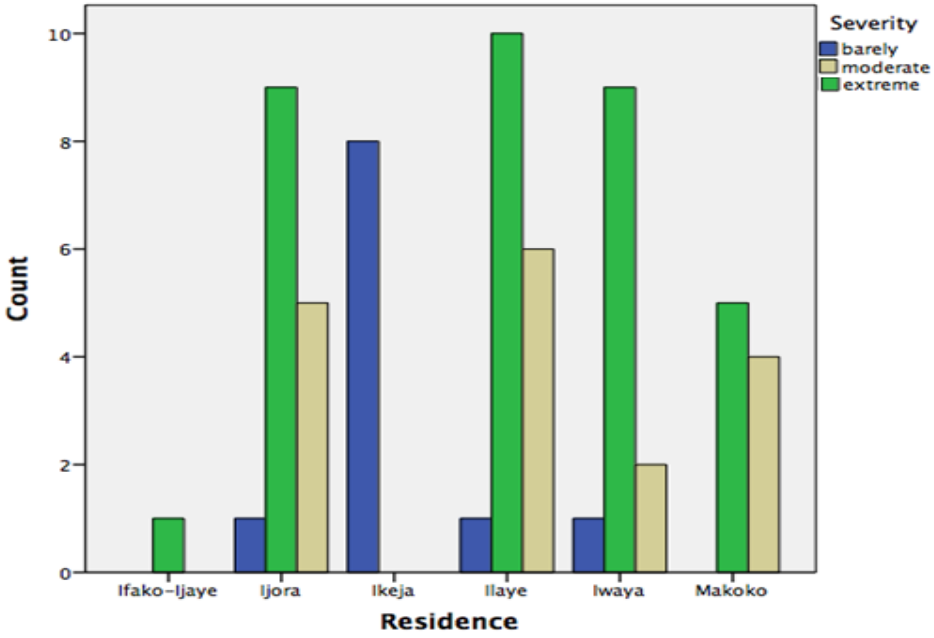

Figure 4.2: Flood severity at study sites

4.1.5 Existing drainage systems in the various settlements

The devices put in place to manage floods were predominantly canals and gutters, which are generally the most used storm management infrastructure in LDCs (Armitage 2011; Parkinson and Mark 2005). Field observation as well as results showed that some informal settlements possessed more of this drainage infrastructure compared to the others. For example, Makoko, where the very poorest of the settlers lived had little or no such government infrastructure, whereas some informal areas in Ijora, Illaye and Iwaya possessed more drainage facilities. This finding is in line with results from an assessment of conditions and facilities in communities conducted by the Lagos Metropolitan Development and Governance Project in 2006. It showed that the majority of slum communities that included Makoko ranked the provision of drainage facilities foremost in their prioritisation of facilities needed (LMDGP 2006). It is likely that those areas with infrastructure have put pressure on the government to provide basic amenities, possibly because they have existed for a long time and occurred as a result of the slums spreading, the government recognised the residents have nowhere to relocate,

hence installing minimal drainage. According to Armitage (2011), it is not uncommon for local authorities to accept the existence of an informal settlement, but the fact that they are usually illegal means that they are reluctant to provide much apart from some basic services. These basic services typically comprise insufficient infrastructure.

The lack of conventional drainage in Makoko area can be attributed to the fact that it had been earmarked by the government for demolition due to its illegal location on a floodplain (Amnesty International 2006; BBC 2012). The government has tried unsuccessfully many times to relocate residents, and have therefore left them to manage any flooding issues themselves. Residents in these areas have created makeshift devices to help manage excess runoff, which is quite a common practice among informal settlements in LDCs. Studies carried out at Monwabisi Park (Button *et al.* 2010) and other settlements in South Africa show similar practices and structures in place. It is common to see sand bags and tyres surrounding the informal shacks to attempt some protection against floodwaters. The residents of Makoko for example are of the opinion that these devices manage the excess water to a certain extent, keeping it at bay for a while. Table 4.4 and Figure 4.3 both show a variety of drainage infrastructure in use at the study sites, but that canals and gutters are the dominant drainage system.

Table 4.4: Existing Flood Management Devices

Residence	**Description**				**Total**
	Canals	Gutters	Use of sand, drums and tyres	Use of sandbags	
Ifako-Ijaye	0	1	0	0	1
Ijora	0	6	1	1	8
Ikeja	0	1	0	0	1
Ilaye	6	5	0	0	11
Iwaya	4	4	0	0	8
Makoko	0	0	0	3	3
No Answer	0	1	0	0	1
Oshodi-Isolo	0	0	0	1	1
Total	**10**	**18**	**1**	**5**	**34**

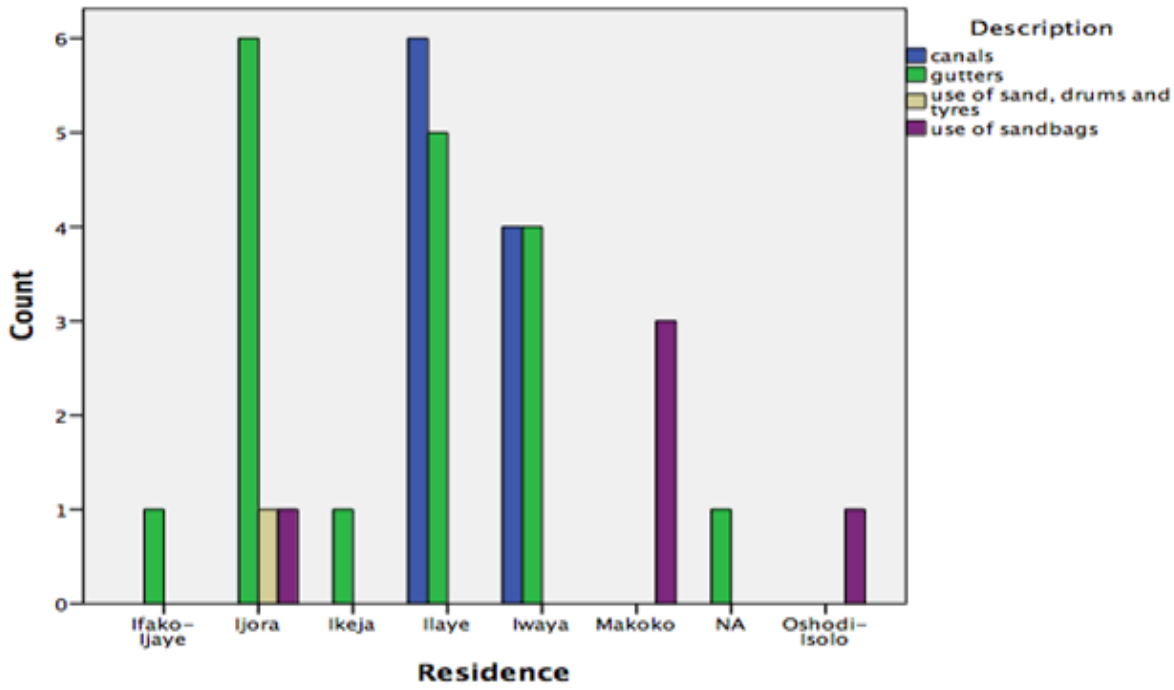

Figure 4.3: Existing Flood Management Devices.

4.1.6 Results from residents' expertise and knowledge of flood management

In order to identify exactly where to begin a dicussion on flood management, the extent of respondents expertise on flood management strategies, and how this knowledge was accquired was sought. Options available on expertise ranged from: basic, intermediate to expert. Out of 76 responses, 59 had a basic understanding/ knowledge of how to manage flooding issues. When asked about how this was acquired, 60 out of the 76 respondents stated that it was personal, however a few had also learned flood management via media and government intervention. Individual flood management techniques in the informal areas ranged from sand bags, tyres filled with sand, the use of corrugated roofing materials for barricading their property and diversion of flood waters. Responses also included moving of property to higher ground, as well as cleaning the gutters regularly to ensure free-flowing systems.

Almost every individual, even if they had lived in their present settlement for only a short time had experienced a flooding incident and had gained some competence on how to avert extreme flooding issues. Table 4.5 shows a cross-tabulation analysis of the levels of expertise in flood management and Table 4.6 shows how they acquired this knowledge.

Table 4.5: Level of expertise on flood management techniques

Residence	Expertise					Total
	Basic	Intermediate	Expert	No Answer	None	
Ifako-Ijaye	1	0	0	0	0	1
Ijora	10	2	1	3	1	17
Ikeja	9	0	0	0	0	9
Ilaye	13	2	1	1	0	17
Iwaya	11	1	1	0	0	13
Makoko	8	1	0	0	0	9
No Answer	6	1	0	1	0	8
Oshodi-Isolo	1	1	0	0	0	2
Total	**59**	**8**	**3**	**5**	**1**	**76**

Table 4.6: Acquisition of knowledge of flood management techniques

Residence	Acquisition				Total
	Personal experience	Government Intervention	Media	No Answer	
Ifako-Ijaye	0	1	0	0	1
Ijora	14	1	0	2	17
Ikeja	8	0	0	1	9
Ilaye	13	1	1	2	17
Iwaya	11	1	0	1	13
Makoko	8	0	0	1	9
No Answer	4	0	2	2	8
Oshodi-Isolo	2	0	0	0	2
Total	**60**	**4**	**3**	**9**	**76**

4.1.7 Perceptions of the effectiveness of existing drainage systems

Respondents were given options that ranged from not effective, effective, very effective to I don't know. The use of canals and gutters appeared to be the most popular choice although canals were chosen over gutters when it came to effectiveness in managing excess runoff.

Figure 4.4 shows that the use of sand bags and tyres ranked as effective, while gutters ranked the least favourite as the great majority stated that they were mostly ineffective. This again can be attributed to the fact that most gutters can only carry a certain

capacity, urbanisation and the covering over of drainage structures results in them being regularly overwhelmed. Drainage structures in LDCs generally cannot cope with stormwater, and since governments tend not to revisit such old projects, residents are left to cater for themselves (Parkinson 2003). A greater number of gutters in Lagos if not all, experience storm water carrying capacity being exceeded as well obstructions and blockages due to dumped refuse.

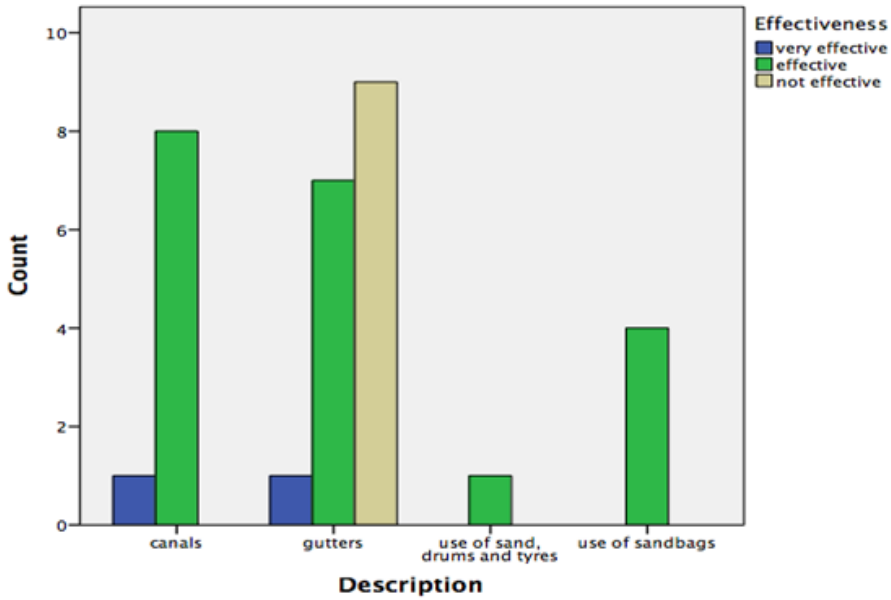

Figure 4.4: Effectiveness of existing flood management devices

4.1.8 Receptiveness to change.

Respondents were asked if they were willing to embrace SuDS as a means of managing excess runoff in their communities, and if they could suggest better ways to manage flooding. Table 4.7 shows that a greater number of the responses obtained were open to the idea of SuDS which is in line with feedback received during the focus group meetings where SuDS were discussed. Additionally, during the meeting a receptive attitude to SuDS was observed as the residents expressed interest when the multi-benefits of SuDS were reviewed.

Various suggestions were made by the respondents on better ways to manage flooding. Many were around government assistance such as covering up of existing gutters with slabs to the dredging of canals, a significant number identified that measures such as good housekeeping to keeping gutters and canals free flowing, keeping the surrounding

environs clean etc, would help manage flooding. Unclogging blocked drains and deterring the dumping of refuse were also mentioned. Some respondents suggested education and awareness of the causes of flooding and how it can be avoided would also help. These suggestions/feedback indicated that the communities recognised flooding as a problem and have not simply accepted it as a way of life, but were willing and open to suggestions to make living in these areas less flood prone.

Table 4.7: Receptiveness to SuDS

Receptiveness to SuDS	Frequency	Percent
I am willing and receptive to change	48	63.2
I am indifferent to the situation	4	5.3
I am not interested	2	2.6
Other	1	1.3
NA	21	27.6
Total	**76**	**100.0**

Furthermore, to check the readiness of the community to embrace and adopt the idea of SuDS their views on privately maintaining the devices were also sought. Figure 4.5 shows a greater percentage answered that they were willing to undertake this, which could be recommended at the end of the study. Out of the 76 respondents, only 14 answered negatively. The communities were therefore open minded, willing and receptive to new ideas. This result gives credibility to the observation of a positive attitude to implement SuDS perceived during the focus group meeting.

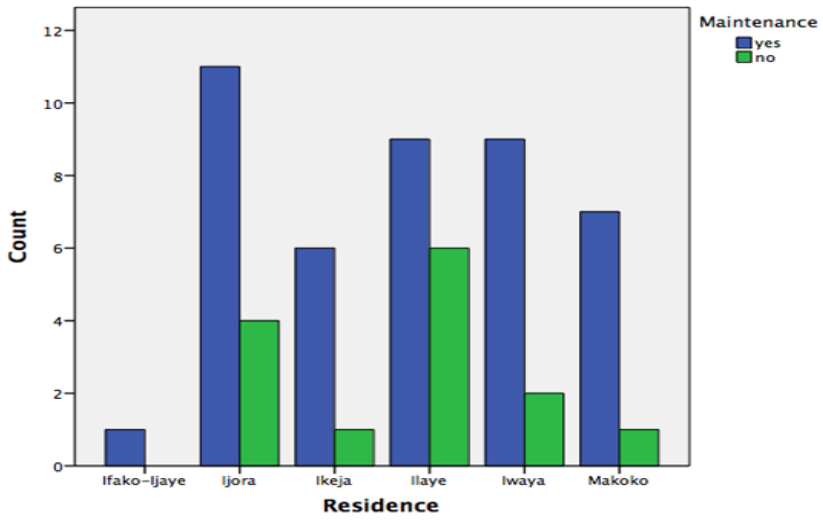

Figure 4.5: Willingness to maintain SuDS

4.2. Google Earth investigation of 2 settlements

The potential of utilising Google Earth as a decision-making tool to identify the distribution of informal settlements in Lagos and investigate whether it could aid to determine SuDS feasibility was explored by generating maps from Google Earth as discussed in section 3.4.1. To ascertain the usefulness of the maps produced, an accuracy assessment was undertaken by validating the images from Google Earth to what was truly on the ground after field observation. The findings for both sites are discussed below.

4.2.1 Study site 1: Ijora slum settlement

A Google Earth image collected for Ijora at coordinates latitude 6°28'2.00"N and longitude 3°21'58.68"E is illustrated in Figure 4.6. The open spaces on the imagery were plotted using polygons available on the Google Earth toolbar, which yielded 80 polygons in total. The images and their coordinates were then exported to ArcGIS, which generated the maps presented in Figure 4.7; these were taken into the field and used for ground truthing, i.e. the maps were compared to open spaces actually present on the ground.

Field observation revealed that individual buildings and open spaces were not accurately represented on the Google Earth maps, with an additional 56 open spaces identified, which were not present on the satellite imagery.

Figure 4.6: Google Earth aerial image of Ijora

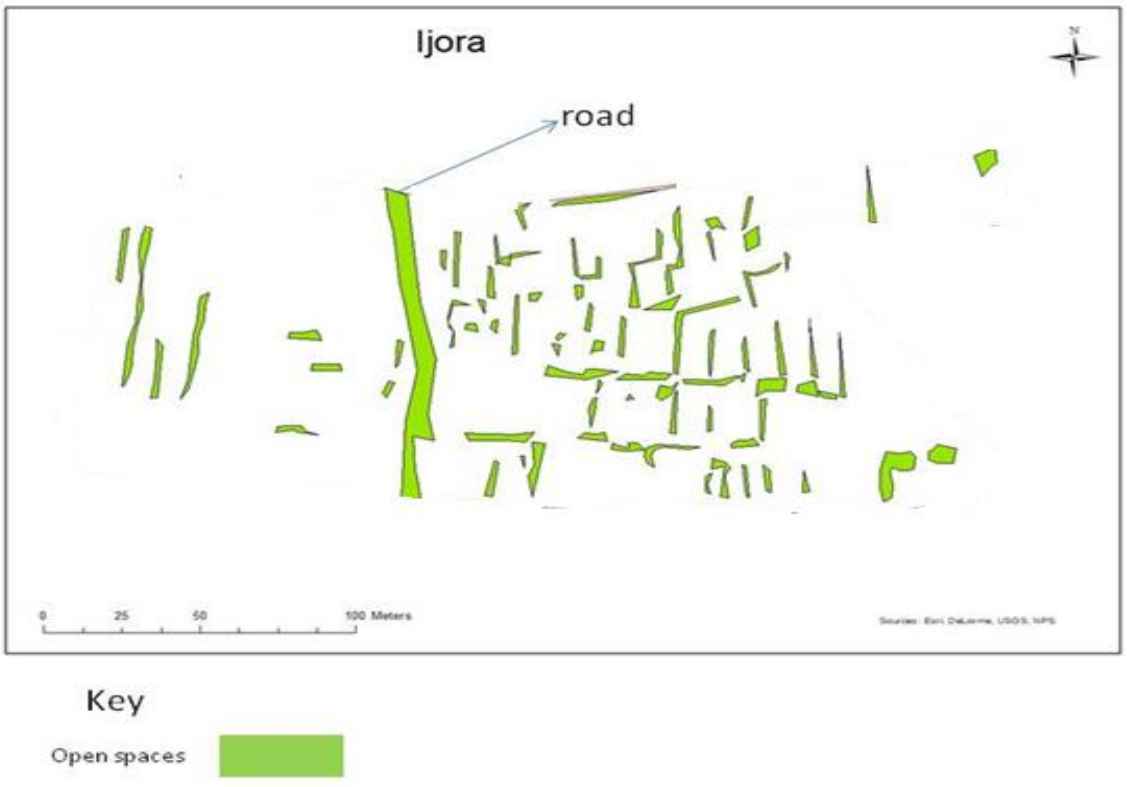

Figure 4.7: Ijora base map showing open spaces mapped during the field visit

4.2.2 Study site 2 Makoko slum settlement

A Google Earth image collected for Makoko at latitude 6°31'54.75"N and longitude 3°24'0.78"E is presented in Figure 4.8. Ground truthing the image yielded a total of 56 open spaces and polygons were traced around them. An ArcGIS generated map is shown in Figure 4.9.

4.2.3 Google Earth results

Individual buildings and open spaces were not accurately represented on Google Earth maps and the images were quite unclear. Hence, its accuracy for detail is highly debatable. It is arguable that since it is a slum area and frequently evolves, land use has changed over time. Therefore, the open spaces available upon ground inspection may have been covered up by buildings/ shacks at the time of satellite by-pass and image capture. However, the time difference between aerial capture, map creation and field visit for this study were quite close; especially with the Makoko map see Section 3.4.1. The time difference from image capture to ground truthing is probably too short for land use to change or fluctuate substantially, showing the shortcomings in aerial capture of these areas. Google Earth Images may have been unclear because of various factors such as:

- Abundance of cloud cover over Lagos
- Time of satellite by pass; this could influence picture quality as the time of day when the satellite imagery was taken would determine the clarity of photo i.e. day time photos would be a lot clearer than those taken during the night.
- Angle and elevation at which the images were captured as well as poor picture resolution can make it almost impossible to view images from the application.

Using images from Google Earth to identify key geospatial references in the informal settlements (Section 3.4.1) could not be achieved due to the inaccuracies. For example, certain SuDS like swales or filter strips require space and vegetation to manage runoff, if Google Earth cannot produce an accurate map with these geospatial references, a decision cannot be made of what device to recommend using. Although it was possible to identify the informal settlement with the aid of Google Earth maps, other key geospatial references were inaccurate or of very poor picture resolution. Therefore, Google Earth did not provide valuable results and was not investigated any further.

Figure 4.8: Google Earth aerial image of Makoko

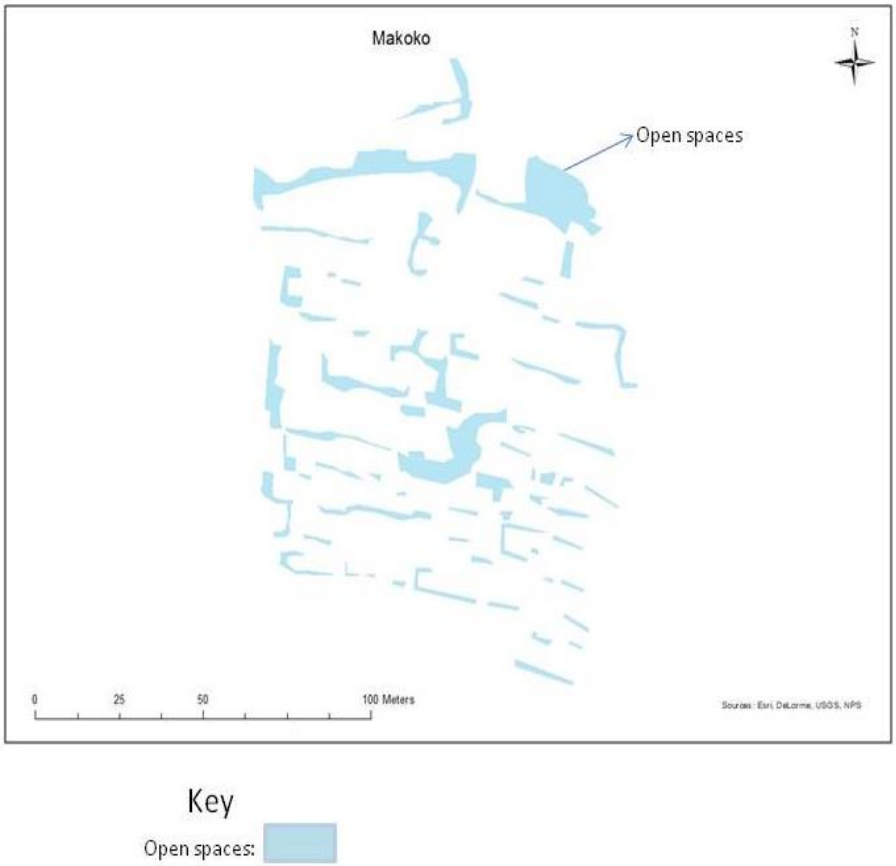

Figure 4.9: Makoko base map

4.3 Second field study

In order to provide a comparison, two new informal locations (Apapa-Igamu and Ajeromi-Ifelodun) were investigated to determine if they were similar to those from the pilot study; this was essential for the wider application of the proposed framework. Makoko and Ikeja were revisited for evaluation purposes; these sites drove the focus for the second field study.

4.3.1 Response rate

154 questionnaires yielded a response rate of 77% with a male: female ratio of 86: 68. 126 were from the informal settlement and 28 from the formal as presented in Table 4.8, Table 4.9 shows the percentage retrieved from each settlement individually.

Table 4.8: Questionnaire Distribution amongst Settlement Type

Settlement type	Frequency	Percent
Formal	28	18.2
Informal	126	81.8
Total	154	100.0

Table 4.9: Questionnaire Distribution in the Different Locations

Settlement location	Frequency
Apapa-Igamu	39
Ajeromi-Ifelodun	48
Ikeja (Formal)	28
Makoko	39
Total	**154**

4.3.2 Respondents knowledge of flooding in their environment

The second field visit revealed similar results to the first, confirming belief that they have at least basic knowledge of flood history as illustrated in Table 4.10 whereby 89% have at least a basic knowledge.

Table 4.10: Flooding history knowledge of respondents

Knowledge	Frequency	Percent
Basic	137	89
Expert	8	5.2
None	9	5.8
Total	**154**	**100.0**

4.3.3 Respondents perceptions on the causes of flooding

Results showed that a total of 84 respondents from both settlement types believed the flooding was caused by a combination of rain and blocked drain. 76 of were informal settlers and eight were from Ikeja, the formal area. Rainfall was ranked second with 31 responses; other responses are shown in Table 4.11. Further analysis on the perceived causes by individual settlements is included in Appendix 6, Section 9.6.1 Table 2. This is different from responses from the pilot study, as residents in Apapa-Igamu and Ajeromi- Ifelodun had more gutters in their communities compared to worse off slum settlement like Makoko. Apapa-Igamu and Ajeromi-Ifelodun have experienced first-hand major accidents such as loss of life and property due to blockage of drains with solid waste material, hence recognising its role in flooding. In the pilot study, it was likely that the blockages had not been identified as the primary cause of flooding hence its reduced importance. These results showed a common consensus with similar investigations carried out on the causes of flooding, which also suggest that flooding was linked to poor drainage (Parkinson and Mark 2005; Adeloyeand Rustum 2011; Aderogba 2012; Aderogba et al 2012). Results from Aderogba (2012) and Aderogba et al, (2012), further confirmed findings from this study, showing blocked drainage ranked highest as the major cause of flooding in Lagos.

Table 4.11: Perceived causes of flooding in settlement types

Settlement type	Causes of Flooding								
	Rain	Burst drain	Over flowing of river banks	Other	Rain and blocked drain	Rain, burst drain	Rain, over flowing of river banks	No Answer	Total
Formal	11	3	0	0	8	3	0	3	28
Informal	20	4	7	2	76	9	4	4	126
Total	**31**	**7**	**7**	**2**	**84**	**12**	**4**	**7**	**154**

4.3.4 Flooding severity

The majority of respondents from the formal settlements and 12 from the informal (Table 4.12) said that the area barely flooded; the latter findings could be attributed to the respondents only just having moved into the area and yet to experience a flood. The highest responses (82) were for moderate flooding, 74 of whom were informal settlement dwellers and 8 from the formal settlement. 34 respondents felt flooding was extreme, all of whom came from the informal settlements, supported by findings by Parkinson and Mark (2005) who also suggested that downstream experience the worse impacts of flooding.

When asked about how long the floodwaters lasted before dissipating, 31 respondents from the informal settlement indicated that it lasted for about one week, with 16 indicating that the ground was covered with water for over a week after the rain had stopped. This is in comparison with the formal area where the ground remained covered for a maximum of 1 day, see Appendix 6 Section 9.6.2 Table 3 for results. These results support findings by Aderogba (2012) and Aderogba *et al.* (2012) who also found that flood waters tended to last for longer in the informal settlements. Regarding frequency of flooding, the informal areas exhibited a much a higher count of between 4-9 floods annually compared to the formal area of 1-2. These findings further confirm that informal settlements are worst hit by flooding as suggested by similar investigations.

Table 4.12: Perception of flood severity.

Settlement Type	**Severity**				Total
	Barely	Moderate	Extreme	No Answer	
Formal	18	8	0	2	28
Informal	12	74	34	6	126
Total	**30**	**82**	**34**	**8**	**154**

4.3.5 Effectiveness of Government implemented flood defence systems.

The majority of the informal settlement residents (86 out of 126) indicated that gutters and canals were ineffective in managing surface runoff as shown in Table 4.13. The formal settlers were mostly of the opinion that the systems were effective with 5 of them indicating that they were very effective; however, 4 indicated that the devices had not been effective in managing runoff.

Table 4.13: Perception of effectiveness on the flood defence systems by settlement type

Settlement Type	Effectiveness of Existing Flood defence system					
	Very effective	Effective	Not effective	I don't know	No Answer	Total
Formal	5	13	4	2	4	28
Informal	0	7	86	14	19	126
Total	**5**	**20**	**90**	**16**	**23**	**154**

These results show that informal residents recognise that conventional methods of drainage which are rarely available to them have failed in their design to curb flooding; instead it has been described as one of the main causes of flooding. Figure 4.10 shows a gutter blocked by rubbish and filled with rainwater, it is inevitable that this gutter will overflow during the next storm.

Figure 4.10: Ineffective drainage system in Ajeromi-Ifelodun

(Source: Author, 2015)

Table 4.14 presents further analysis on respondents' perception of the effectiveness of existing drainage systems by the different locations. The majority of the 36 respondents from Ajeromi –Ifelodun were of the opinion that these systems were ineffective, 28 from Apapa- Igamu also felt that they had failed to manage runoff, as did 22 from Makoko and 4 from Ikeja. However, 5 residents from Ikeja indicated that the devices had been very effective and 13 thought they had been effective in managing runoff but no-one from the informal settlements agreed with the systems being very effective. It is likely that the informal settlers who indicated the effectiveness of the gutters and canals had not experienced flooding as they may have been new residents.

Table 4.14: Effectiveness of flood defence system by location.

Residence	Very effective	Effective	Not effective	I don't know	No Answer	Total
Apapa, Igamu	0	4	28	4	3	39
Ajeromi – Ifelodun	0	2	36	4	6	48
Ikeja	5	13	4	2	4	28
Makoko	0	1	22	6	10	39
Total	**5**	**20**	**90**	**16**	**23**	**154**

Regarding ownership of flood defence systems available to both settlement types, results are shown in Table 4.15 and Figure 4.11. In terms of the presence of flood defence devices, a large number of the informal settlement residents had used makeshift defences to protect their homes. These included the use of sand bags, sand alone, corrugated roofing sheets to raise the ground level, use of tyres etc.

A total of 6 formal settlement respondents also indicated that they had personally put up structures in addition to the existing gutters and canals to protect their homes. 15 of them solely depended on the conventional drainage systems put in by the government. A total of 52 respondents from the informal dwellings indicated that they had set up flood defence systems, and 26 respondents stated they had designed structures collectively as a community. The findings that informal settlements are inadequately served by the government, if at all, are similar to those from the pilot study given in Section 4.1.5 where Armitage (2011), also contextualises the findings. Observations during the field visits of these structures and responses indicate a level of interest in making positive changes, instead of waiting for the government.

Table 4.15: Ownership of flood defence systems

	Ownership						
Settlement Type	Home owner/ Tenant	Govt infra-structure	Community engagement	Home Owner/ Tenant and Community engagement	Home Owner/ Tenant Govt infra-structure	No Ans.	Total
Formal	6	15	4	0	0	3	28
Informal	52	8	26	15	4	21	126
Total	**58**	**23**	**30**	**15**	**4**	**24**	**154**

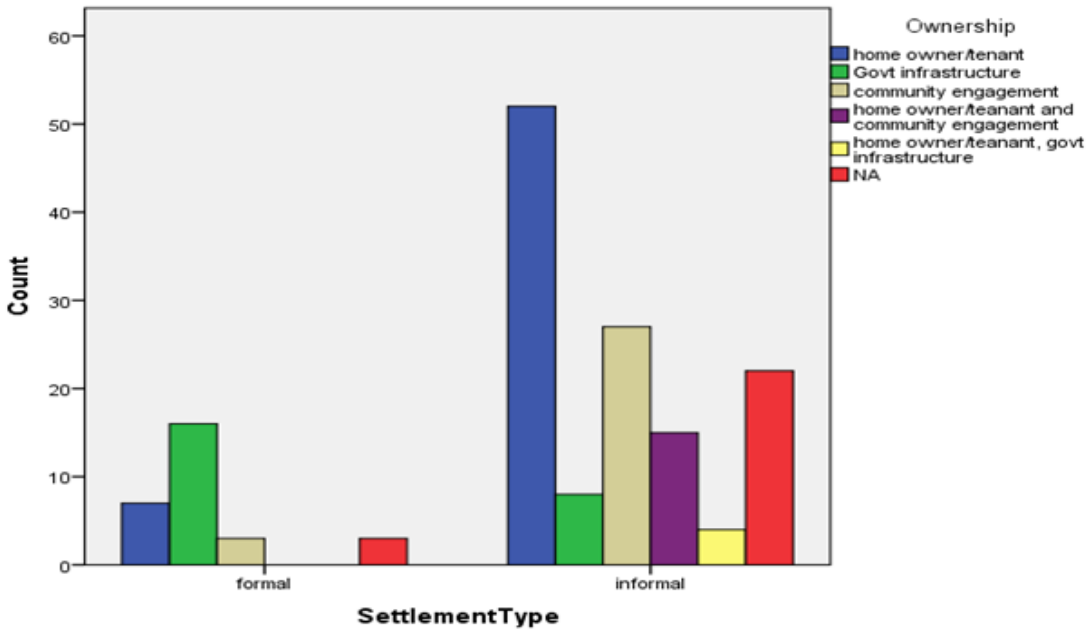

Figure 4.11: Ownership

4.4 Receptiveness to Change

Table 4.16 shows that 56% or 87 respondents in total from both settlement types indicated they were receptive to change, and of those 18 were from the formal settlement and 69 from the informal settlement. In spite of those living in formal areas indicating they rarely experienced flooding, and that they felt the conventional drainage devices put in place by government were to reasonably effective in managing flooding, nonetheless they were open to there being substantial changes in the way surface water was managed. Informal settlers also showed interest although 49 of the informal and 7 formal residents gave no response.

Table 4.16: Residents receptiveness to change

Settlement type	Receptiveness to change				Total
	I am willing	I am not interested	I am indifferent to the situation	No Answer	
Formal	18	3	0	7	28
Informal	69	5	3	49	126
Total	**87**	**8**	**3**	**56**	**154**

As discussed in Section 3.5.4, a focus group introducing SuDS was undertaken, and their views on its implementation as well as its maintenance privately without the help of the government was something the respondents and by extension the community was willing to undertake. Some of the simple SuDS devices were already being put to use eg RWH, however residents were unaware of the technicalities/ diverse functions of the devices. For instance, the use of sand bags or used tyres filled with sand was quite common in the informal settlements to create a barrier to prevent water entering their homes. They were unaware that sand bags have other functions, such as filtering runoff with the potential to improve water quality (Woods Ballard *et al.* 2015, Susdrain 2012), attenuation of peak flow and the reduction and slowing down of excess surface water being quickly transported to receiving water bodies. As presented in Table 4.17, results showed that a total of 103 respondents indicated they were willing to adopt SuDS, of which 14 were formal respondents and 89 informal respondents, 4 of the formal respondents indicated they were indifferent to the situation and 6 similar responses were indicated by the informal settlement dwellers. Both settlements had 4 respondents indicating they were not interested in implementing SuDS. The formal and informal settlements had counts of 6 and 25 respectively who did not answer the question. Both the pilot study and the second field visit showed that there was a willingness from the communities to adopt SuDS to manage flooding problems.

Table 4:17: Implementation of SuDS by residents

Settlement Type	Implementation of SuDS				
	I am willing and receptive to change	I am indifferent to the situation	I am not interested	Other	No Answer
Formal	14	4	4	0	6
Informal	89	6	4	2	25
Total	**103**	**10**	**8**	**2**	**31**

Regarding maintenance of implemented SuDS, Table 4.18 shows that there were 95 positive responses, 89 of these were from the informal settlers. 45 negative responses were recorded with 19 from the formal, 25 from informal residents and 16 respondents

did not answer the question. This result showed mixed reaction to the personal maintenance of SuDS. Whilst the informal residents seemed more willing to privately manage their devices the formal residents were reluctant to do so, this is understandable given the those in the informal settlements are poor and are used to making their own arrangements. They also cannot afford to pay for maintenance and are thus willing to adopt and maintain systems that would lead to a better standard of living. The formal residents on the other hand have had their flooding issues mostly maintained by the government, hence the hesitation to privately maintain these devices.

Table 4:18: Responses to privately maintain SuDS devices

Settlement Type	Maintenance			Total
	Yes	No	No Answer	
Formal	6	19	3	28
Informal	89	25	12	126
Total	**95**	**45**	**16**	**154**

4.5 Rainwater Harvesting as a Suitable Management Strategy to Manage Flooding

It was observed that some of the residents already practised RWH on a small scale (see Figure 4.12) mostly this practice was in religious centres such as mosques which collected the rainwater for non-potable use such as washing. RWH was practised by 65 residents, 15 of whom were formal residents and 50 from the informal residents, (see Appendix 6 Section 9.6.3 Table 4). These results support similar findings showing RWH is common in LDCs (Opare, 2012, Lade and Oloke, 2015); however, it is used as an alternative source of water saving, rather than as a flood management tool, however studies have shown (Leggett *et al.* 2001, Gerolin *et al.* 2009, Memon *et al.* 2009, Campisano *et al.* 2013, Debusk and Hunt 2014) that it can attenuate stormwater by storing rainwater and releasing it slowly. As stated above RWH has a significant influence on reducing runoff and the more residents adopt this technique the more excess runoff will be reduced with less the pressure on the already failing conventional drainage system.

Figure 4.12 Barrels used for collecting and storing rainwater in Apapa Igamu
(Source: Author's photograph 2015)

Small devices such as buckets and basins were the most popular to harvest rainwater; this was likely due to cost and lack of space to accommodate larger devices. 56 respondents capture rainwater in buckets and basins, 48 from informal settlers and 8 from Ikeja. 9 indicated they harvested rain water using tanks (Table 4.19 and Figure 4.13).

Table 4.19: Rain water harvesting collection methods

Settlement Type		Harvesting collectors			Total
		Buckets, Basins	No Answer	Storage tanks	
	Formal	8	17	3	28
	Informal	48	72	6	126
Total		**56**	**89**	**9**	**154**

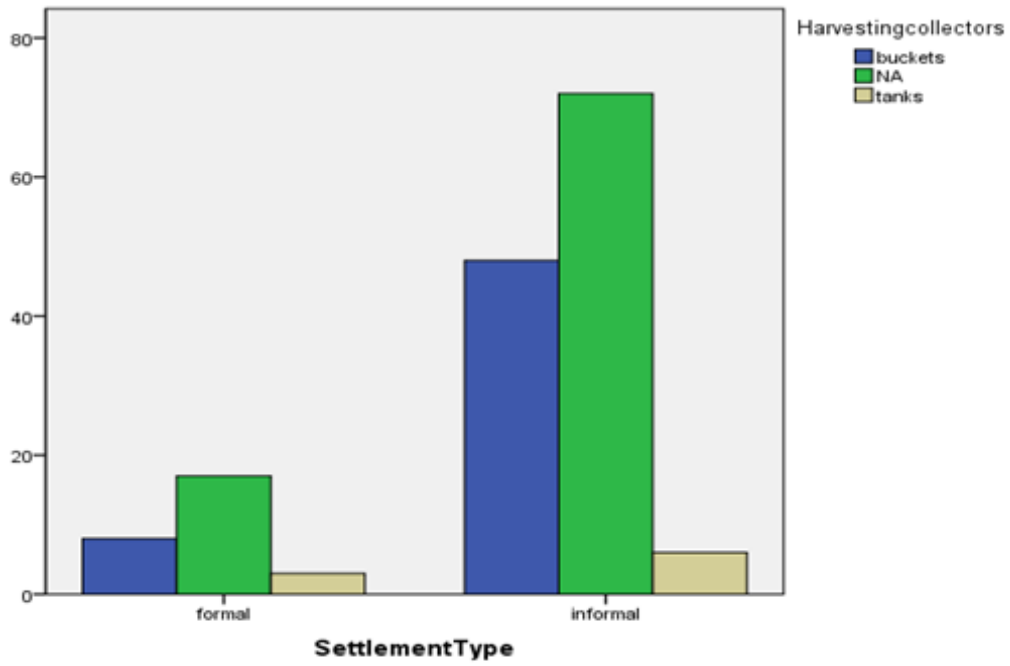

Figure 4.13: Responses to rain harvesting collection methods

4.5.1 Uses of harvested rainwater

Non-potable uses of the captured water include washing and bathing, 49 out of the 126 respondents in the informal areas indicated water was used this way with 15 from the formal settlements indicating likewise (Table 4.20). Rain water was used frequently amongst households.

Table 4.20: Uses of harvested rainwater

Settlement Type	Harvest Uses		Total
	No Answer	Washing, Bathing	
Formal	13	15	28
Informal	77	49	126
Total	**90**	**64**	**154**

4.5.2 Distance to potable water

Potable water was quite close for the majority of respondents with 80 in total travelling a maximum of five minutes and 25 respondents 1 minute away as shown in Table 4.21.

Table 4.21: Time taken to gain access to drinking water

Settlement type	Time (mins)							Total
	1	2	3	4	5	6	20	
Formal	4	3	2	1	18	0	0	28
Informal	21	10	29	2	62	1	1	126
Total	**25**	**13**	**31**	**3**	**80**	**1**	**1**	**154**

However, it was found that all 154 paid for their drinking water supplies; this is standard practice in most areas of Nigeria as selling water is a business for some people. Accessibility to water is therefore not an issue; however, it is expensive and particularly impacts the poor living in slum settlements, so saving this expense maybe an incentive to promote the implementation of rain harvesting techniques, which can also reduce runoff.

4.5.3 Implementing rainwater harvesting

All 154 respondents answered positively to implementing RWH as a method to sustainably manage runoff Table 4.22.

Table 4.22: Interest in implementing rain water harvesting

Settlement Type	**Rain Water Harvesting Interest Yes**	**Total**
Formal	28	28
Informal	126	126
Total	**154**	**154**

Both the formal and informal settlements were interested in managing excess runoff using RWH; the fact that formal settlements were willing is important as they are usually located on less vulnerable areas upstream of the informal ones (Parkinson and

Mark 2005, Douglas *et al.* 2008 and Armitage 2011). They can therefore influence the quantity and quality of runoff being carried to the informal settlements downstream. This implies that the sustainable management of surface water is a joint commitment of both formal and informal dwellers and should not be the responsibility of just the one settlement. Small changes such as good housekeeping, such as disposing of litter appropriately, implementation of simple yet effective sustainable surface water strategies can positively influence the quality of life of both resident types. Legislation is weak in LDCs, thus flooding prevention is not prioritised, and informal settlements are particularly at risk due to their informal status. The results presented so far have shown that there is some traction in a bottom-up approach, community-led to address issues of flooding.

4.6 Interviews with Individual Stakeholders to Determine Attitudes to SSWM

4.6.1 Qualitative analysis

The first set of interviews were with residents of both formal and informal settlements comprising 10 respondents. The second group were 5 government officials with the potential to influence the management of surface water in Lagos. This interview exercise was necessary to achieve Aim 1 of the thesis which was to explore the potential of using SSWM methods to manage runoff in Nigeria. It was also pertinent to evaluate the quantitative data by giving questionnaire results a richer context and in-depth description of the subject matter by sharing in the participants' experience.

4.6.2 Resident analysis and results

Interview questions were designed to answer the research questions discussed in Section 3.7.1.

4.6.2.1 Theme 1: Demography/ settlement type / background details

These first set of questions captured the background details of the interviewees such as settlement type and length of stay at the location.

Table 4.23 shows a total of 8 informal settlers were interviewed two of whom were community heads in Ajeromi-Ifelogudun and Apapa-Igamu. Participants 8 and 9 were from formal settlements and were randomly selected for interview.

Table 4.23: Respondents location, settlement type and length at the settlement

Participant	Residence	Settlement type	Length of stay at residence
Participant 1	Apapa-Igamu	Informal	18yrs
Participant 2	Apapa-Igamu	Informal	10yrs
Participant 3	Apapa-Igamu	Informal	1yr
Participant 4	Ajeromi-Ifelodun	Informal	5yrs
Participant 5	Ajeromi – Ifelodun	Informal	2yrs
Participant 6	Ajeromi – Ifelodun	Informal	5yrs
Participant 7	Ajeromi – Ifelodun	Informal	4yrs
Participant 8	Ikeja	Formal	6yrs
Participant 9	Ikeja	Formal	11yrs
Participant 10	Apapa-Igamu	Informal	8 yrs

4.6.2.2 Theme 2: Flooding history

Flooding experience, frequency and occurrence.

Results showed all respondents from both settlements had experienced flooding but severity was higher in the informal settlements. Some comments regarding flooding gathered during the interviews are given below.

"Last raining season I had a fall because it was late and the gutter was filled with water I didn't remember it was there because it has been covered with water." (Participant 10)

"I have lost some property to the floods when I newly moved in, I didn't know how bad the flooding was, this particular raining season it was so bad it was almost impossible to move around. Everywhere was full of water and garbage floated around making the environment very dirty". (Participant 7)

"Recently Ikeja has begun to experience seasonal floods." (Participant 9)

"It rarely floods in my area, but when it does it is not usually very bad. The roads are covered with water and there is some traffic because drivers slow down". (Participant 8)

These quotes illustrate that the worst flooding is experienced by informal residents i.e. (Participants 7 and 10) compared to the formal settlers (Participants 8 and 9). These quotes further contextualised the findings from this study as well as those of Parkinson

and Mark (2005), Douglas *et al.* (2007) that the informal areas are those impacted badly by flooding.

Flooding occurrence for both settlements fell in the 3rd quarter of the year, during the rainy season in Nigeria. However, whilst in the formal areas flooding occurred at the peak of the rainy season, in informal settlements flooding happened whenever it rained, and regardless of the amount. This confirms results in Sections 4.1.4 and 4.3.4, i.e. that flooding in the formal settlements occurred twice per year and an average of 4 times a year in the informal settlements.

4.6.2.3 Theme 3: Perceived causes of flooding.

Results showed that 9 out of the 10 participants indicated the cause of flooding was from the gutters and canals being blocked. Responses to perception of the causes of flooding are presented in Table 4.24 below.

Table 4.24: Cause of flooding in the area

Participant	Settlement type	Perception on causes of flooding
Participant 1	Informal	The gutters are filled with garbage and can no longer carry much water
Participant 2	Informal	Gutters are too small, and filled with dirt. Canal all blocked with rubbish
Participant 3	Informal	The gutters and canal are blocked with rubbish
Participant 4	Informal	Illegal dumping of rubbish in the gutter
Participant 5	Informal	The gutters are blocked with rubbish and are too small
Participant 6	Informal	The gutters and canals blocked
Participant 7	Informal	The gutters and canals blocked
Participant 8	Formal	Rain is usually quite heavy
Participant 9	Formal	Rain and gutters are few considering the number of people living here
Participant 10	Informal	The rain is too much and gutters are blocked

These responses corroborate results from the questionnaire exercise undertaken and detailed in Sections 4.1.3 and 4.3.3, that participants recognise that these causes are due to the activities of society and thus a change in attitude can bring about a positive change. The failure of these drainage systems to manage flooding was due to their design and size, command and control approach coupled with the system being blocked

with rubbish. These responses also corroborate responses from the interviews carried out with the government officials who insist that the ineffectiveness of the drainage system is related to illegal dumping of garbage, thereby turning these drainage devices into waste disposal sites as presented in Figure 4.14.

Figure 4.14: Indiscriminate dumping of refuse causing blocked gutters in Makoko
(Source: Author photograph 2015)

4.6.2.4 Theme 4: Impacts of flooding

Results showed all participants interviewed indicated the flooding had a negative impact on their day-to-day activities. Quotes by respondents given below give an insight into what the respondents said concerning the impacts of the flooding.

"Whenever it floods homes and roads are covered with dirty water from the rain and overflowing gutter. A lot of accidents occur in the rainy season and people who are strangers get injured because they do not know where the gutters are because of the flood, and sometimes people fall into them. The gutters have no covers. We have called on the government to come to our aid, but no help has come. We as a community have had to put up danger signs during the flooding to warn strangers. We have recorded loss of lives from these incidents in the past that is why we decided to put up signs. Also, people's homes get flooded and garbage float all over the area for days till the water recedes." (Participant 1).

"Whenever it floods we have to move everything from the ground." "Everywhere is covered with dirt and water. It is dangerous to move about and it made my son sick". (Participant 3).

"It slows down movement, and causes traffic jams." (Participant 8).

Results from responses indicate that the participants from the informal settlements are more negatively impacted by the flooding incidences as compared to the formal settlers. These impacts, while life threatening to the informal settlers are simply an inconvenience to the formal resident. The interview responses corroborated results of the quantitative analysis as well as that in the literature thereby ensuring triangulation. They also enabled a better understanding of the situation in comparison to the use of questionnaires.

4.6.2.5 Theme 5: Existence of flood defence system

All 10 respondents had access to some kind of flood defence system, this is illustrated in Table 4.24. Gutters and canals are the main devices used although they are far more abundant in formal settlements. These responses further corroborate findings from Armitage (2011), Parkinson and Mark (2005) which suggest the use of gutters and canals are the predominant devices deployed in LCDs to manage runoff, while also agreeing with results from both field studies undertaken and discussed in Section 4.1.5 and 4.3.5.

4.6.2.6 Theme 6: Effectiveness and ownership of the devices

Table 4.25 shows that the informal settlements indicated that the devices identified in Table 4.24 were ineffective with the 2 formal residents indicating they were effective. Participant 9 thought they had been effective until recently since his area, which hadn't flooded in the past, had started to do so, attributing this change to increased rainfall and the dumping of rubbish into drainage systems. This response reiterates the causes of flooding as perceived by the residents during the focus group meetings as well as results from questionnaire exercises undertaken previously (see Section 4.1.3 and 4.3.3). All 10 participants indicated that they felt the devices belonged to the government; however, participants 1 and 5 thought some had been installed by the community and individuals.

Table 4.25: Existence of flood defence systems and their types

Participant	Settlement	Settlement type	Existence of flood defence systems	Description of flood defence systems
1	Apapa-Igamu	Informal	Yes	gutters and canals
2	Apapa-Igamu	Informal	Yes	Gutters
3	Apapa-Igamu	Informal	Yes	Gutters
4	Ajeromi – Ifelodun	Informal	Yes	Gutters and canals
5	Ajeromi – Ifelodun	Informal	Yes	Gutters and canals
6	Ajeromi – Ifelodun	Informal	Yes	Gutters and canals
7	Ajeromi – Ifelodun	Informal	Yes	Gutters and canals
8	Ikeja	Formal	Yes	Gutters
9	Ikeja	Formal	Yes	Gutters
10	Apapa-Igamu	Informal	Yes	Gutters

The ownership of some devices by the community members as stated by Participants 1 and 5 who are informal residents supported results from Section 4.1.7 and 4.3.5 which showed that members of the community had installed makeshift flood defence systems such as sandbags and partitioning to divert water to protect their homes. The ownership of these makeshift devices is indicative of the willingness to adopt methods to better manage flooding (Table 4.26).

It would appear therefore, that conventional drainage is failing, the lack of an effective drainage network, the high incidence of flooding in informal areas as well as potential for flooding in formal areas can be used as a driver to the implementation of SuDS to better manage the flooding situation. The responses regarding the ineffectiveness of these devices is clear, and has greatly informed the subsequent framework design.

Table 4. 26: Effectiveness of drainage system

Participant	Settlement type	Effectiveness of drainage system	Ownership of drainage device
1	Informal	It is not effective	The government and the community/individuals
2	Informal	It is not effective	The government
3	Informal	It is not effective	The government
4	Informal	It is not effective	The government
5	Informal	It is not very effective	The government and the community/individuals
6	Informal	It is not effective	The government
7	Informal	It is not effective	The government
8	Formal	It is quite effective	The government
9	Formal	It is quite effective until recently	The government
10	Informal	It is not effective	The government

4.6.2.7. Theme 7: Implementation of SuDS and willingness to privately maintain them

The willingness of residents to implement SuDS would signify a shift in paradigm, from always waiting for the government to act, to being proactive in improving their environment. It would also potentially signify the acceptance of SuDS as solutions to the problems of flooding. Finally, receptiveness to change will indicate more strongly the resident's readiness to transition to SSWMs.

Nine out of 10 participants indicated a willingness to adopt the simple SuDS suggested, particularly as the government rendered little or no help to address existing conditions. Matrix coding results graphs generated by Nvivo for SuDS implementation are attached in Appendix 6 Section 9.6.4. Figure 2. Results from the graphs indicated 4 respondents were not prepared to privately maintain the SuDS devices without government influence. Participants 8 and 9 from Ikeja, the formal settlement, indicated they were not interested mainly because;

1. Participant 8 said they did not see the need for it as they barely experienced flooding in their area.

2. Participant 9 stated that government should have responsibility for SSWM devices deployed as did participants 4 and 10. Even though they were ready to implement these devices, they felt that their management should be undertaken by the government.

Participants 1, 2, 5 and 6 said they were prepared to privately maintain SuDS. The 2 remaining participants, 3 and 7, indicated they were willing to privately maintain SuDS however required government assistance as well. The results of the interviews reinforced findings from the 2nd field visit which also showed a readiness to implement SuDS, whereas there was a mixed response regarding maintenance as shown in Table 4.8 and Section 4.4. The pilot study results, on the other hand, did not show this mix, as it showed a more positive and unified response to private maintenance of SuDS devices (Figure 4.5). It is likely that this was influenced by the spread of drainage infrastructure amongst the communities, with some informal areas possessing more drainage infrastructure than others (Section 4.1.5). Those areas with less drainage may have wished to improve their quality of life independent of the government, hence their readiness to privately maintain SuDS, since they knew they would not get help either way. This mix of responses seems to indicate that better informed communities can be involved to solve such issues independent of government intervention. Also, results reflect the fact that the government has no interest in the informal settlements, unlike their support for formal areas, hence the reason why some residents were willing to assist and some were not.

A comparative analysis (see attached in the Appendix 6 see Section 9.5.6. Figure 3) was undertaken between two selected participants from each represented settlement. Both participants were selected based on their length of residency in their communities; as they had both resided the longest, it was assumed they would have more experience of flooding history, occurrence and impacts. This comparative analysis was necessary to summarise the existing situation; of how it is perceived and handled and the willingness to adopt alternative sustainable strategies by both parties. Results showed they had both experienced negative impacts from flooding which happened at the same time of the year i.e. in the 3rd quarter (June – September). Both participants acknowledged that rain and blocked drains were the cause of flooding in their location and both experienced negative impacts from the flooding. However, the impacts experienced by the

participant from the informal settlement was of a more life-threatening nature. Both respondents had flood defence systems in place such as gutters, owned by the government. Both participants were willing to adopt new strategies to combat flooding. However, they differed when it came to issues such as flood frequency, for example the informal participant experienced flooding about 5 times a year, whilst the formal settler rarely experienced flooding, and if it did happen it occurred about twice a year. When queried on perception of the effectiveness of flood defence systems the informal settler indicated that the devices were ineffective, and were a nuisance rather than a solution. The formal participant indicated the gutters were effective in combating flooding to some extent. The informal settler indicated he was willing to privately, and with the help of his community, manage SuDS. The formal settlement participant had no interest in the maintenance of any device and insisted it was solely the responsibility of the government. This result shows the willingness of informal residents to implement SuDS, confirming the findings that the informal residents were more willing to privately maintain SuDS as suggested from the pilot study results.

4.7 Government Official Stakeholder Interviews

4.7.1 Theme 1: Background detail of respondents

Table 4.27 presents the roles and responsibilities of the interviewees in order to contextualise their roles in terms of the aims and objectives of the project.

Table 4.27: Ministry of Environment (MOE)

Participant	Organisation	Role	Role Description
1	Lagos State Emergency Management Agency	Director	Ensure provision of adequate and prompt responses. Ensure intervention in all emergency situations in Lagos
2	Department of drainage construction and water resources (MOE)	Engineer	Monitor, supervise, and inspect all drainage construction. Maintenance of drainage in the state Attend to drainage complaints
3	Department of Emergency Flood Abatement (MOE)	Emergency flood supervisor	Prevention of flooding Rehabilitation of flooded areas
4	Department of drainage construction and water resources (MOE)	Enforcement officer	Identify and inventory flood-prone areas. Research on strategies to reduce and minimise the impact of flooding. Carry out inspection visits. Provide remediation and assessment of the impact of flooding.
5	Department of Emergency Flood Abatement (MOE)	Flood abatement officer	Ensure flood prevention, Rehabilitation of flood-prone areas Provision of relief material in the case of flood among other duties

4.7.2 Theme 2: History of flooding

All interviewees stated that flooding occured frequently especially in the rainy season, see Figure 4.15. Participant 4 in particular, was able to give the greatest detail of flooding history as presented in Figure 4.16. All five participants indicated that although flooding had occurred frequently in the past, it was their perception that it had worsened recently.

"Flooding is a perennial event in Lagos and has been occurring since time immemorial, though it has increased in the frequency of occurrence and volume in recent times as some areas in Lagos are usually submerged during the rainy season." (Participant 4)

All interviewees attributed this to be from the spread of slums and building of illegal structures over natural drainage, as well as the disposal of garbage blocking the artificial drainage constructed by the government.

"Well in the past (20 years ago) the state could boast of very minimal flooding as there are free-flowing drainages all over the state, unfortunately, most of these drainages (both secondary and tertiary) have been blocked either by trash or illegal structures and erosion. For this reason, the intensity of flooding has increase above 50%" (Participant 5)

Thus, this is indicative that the government recognises that flooding has become worse over time and they realise the cause. This information is vital to the tactical phase of the proposed framework that discusses institutional considerations to support SSWMs (see Section 5.8.6) i.e. with the government knowing exactly what the problem is legislation can be put in place to prevent its occurrence where possible.

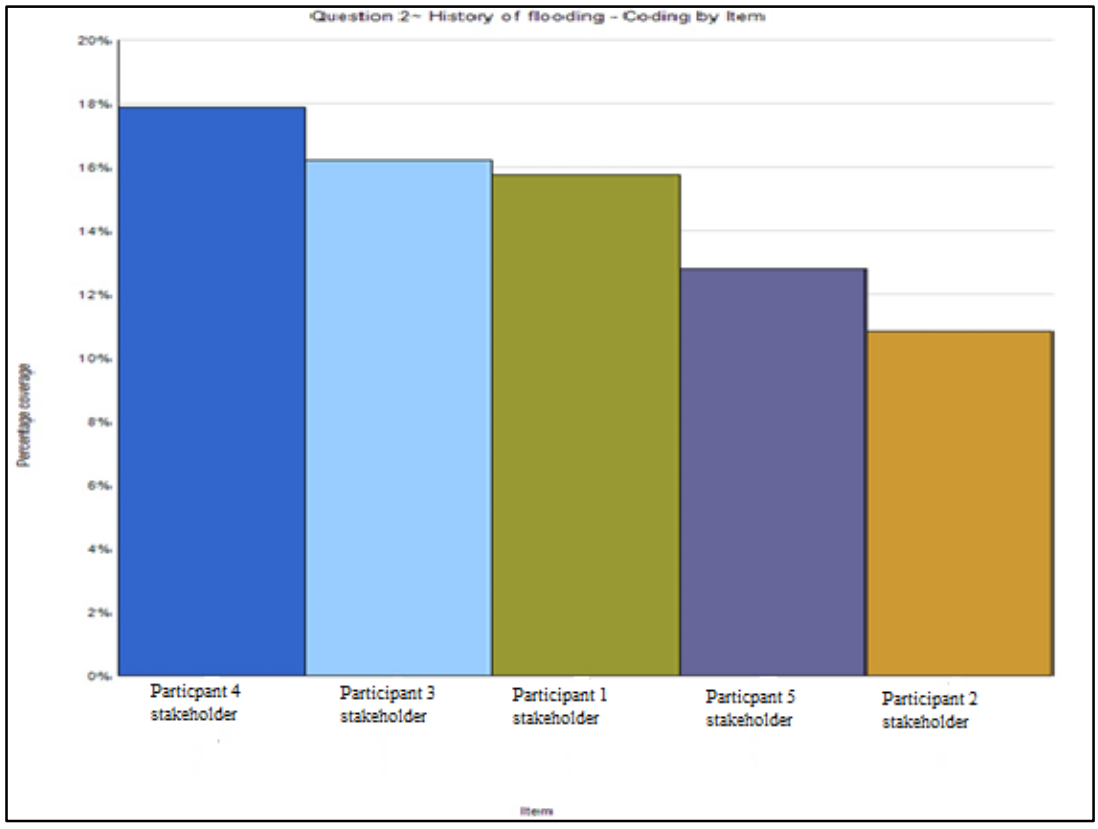

Figure 4.15: History of flooding (drawn in NVIVO)

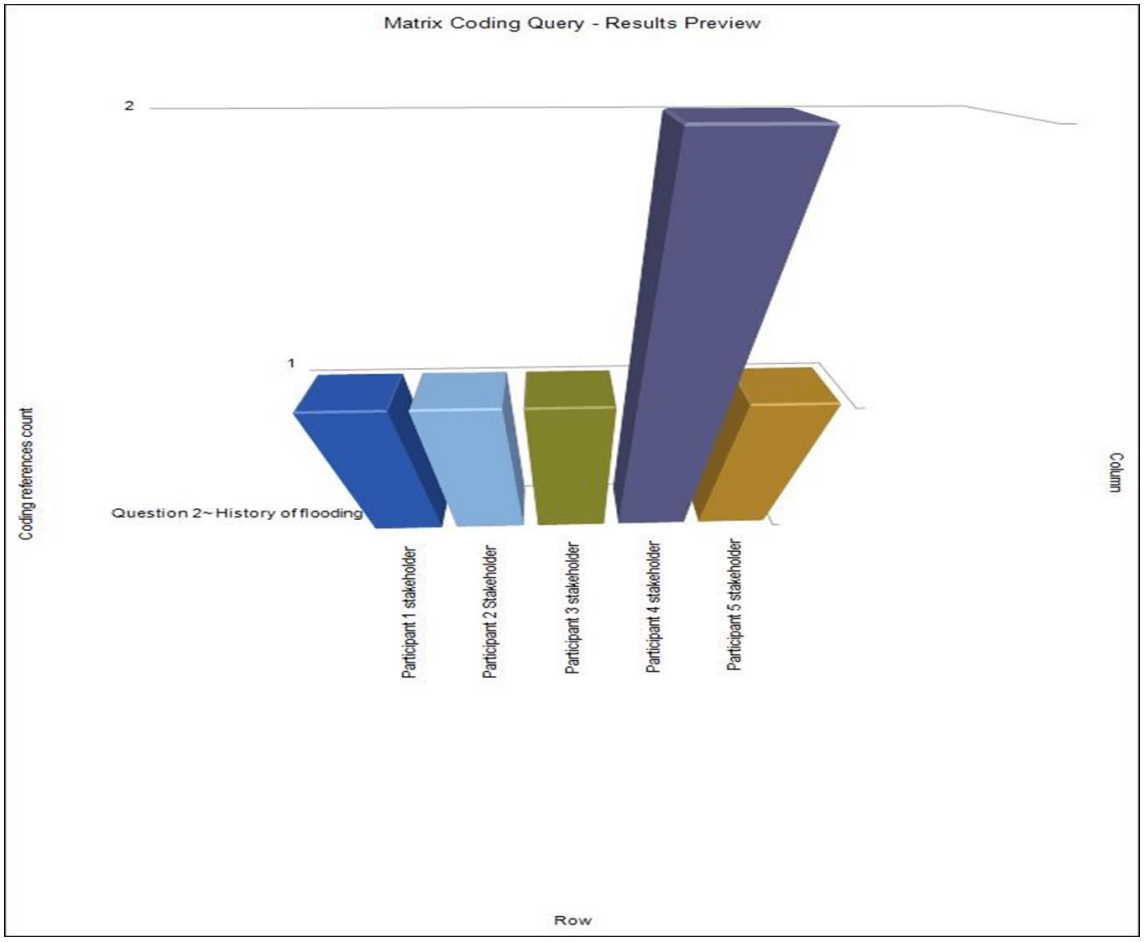

Figure 4.16: Feedback on flooding history (drawn in NVIVO)

4.7.3 Theme 3: Lagos Government's management of excess storm runoff

Interviewees' responses on how the Lagos government managed excess runoff from stormwater were similar amongst all 5 participants. Responses indicated that the government did this by implementing a drainage plan created for Lagos consisting of providing and maintaining conventional drainage devices which transport runoff to receiving water bodies.

4.7.3.1 Sub-Theme 1: Government Strategies to manage runoff

4 of the interviewees stated that the government had created bodies within and outside the MOE including: Regulatory, Supervisory and Enforcement roles to address flooding issues. Participant 3 indicated that there were plans to overhaul the existing drainage

plan as it was deemed outdated. Participant 1 stated that the drainage plan directed the design and continued management of drainage facilities across Lagos.

"The education of residents about flood management and control is on-going" (Participant 4).

Participant 5 provided further details of the difference between strategies for formal and informal settlement at government level: *"The strategies for the formal settlements which is easier than the latter is high level of effective drainage, unlike the informal settlements is harder to manage due to the fact that they are illegal structures and the people in this area are hardly sanitary conscious; moreover, making them comfortable in delicate areas are not the government's goal"*

The quote by Participant 5 indicated that the government had no intention of making life easier for informal settlements. All they want is for them to be relocated, thus there was no strategic plan in place to manage flooding in these areas. This supports responses pertaining to the issue of flood defence system ownership in the formal areas; even where there were some in the informal settlements, it was not being serviced or inspected, with residents left to address issues around flooding themselves.

4.7.3.2 Sub-Theme 2: Influence of government to reduce flooding incidences

The most common responses were the removal of informal residents from floodplains and natural drainage; all 5 participants indicated that this contributed to the reduction of flooding in Lagos. 4 participants stated that the government builds and maintains additional conventional systems where the need arose and constantly monitored their effectiveness (Participant 5).

Participant 4 indicated that the government had schemes to educate the public on flood warning and prevention mainly through the media and engaging with young people in schools; it also provided information via local community leaders and heads. Participants 2 and 3 mentioned a monthly clean up routine to unclog drains and tidy the environs. The creation of flood management enforcement bodies in the MOE was also mentioned as one of the ways government influences flood reduction (Participant 3).

As identified from the results of the questionnaires and interviews, the infrastructure in place to manage stormwater was confirmed by Participant 5 as the use of gutters, culverts and canals.

4.7.3.4 Sub-theme 3: Effectiveness of existing devices as perceived by interviewees

Responses varied regarding the effectiveness of existing drainage systems but none of the respondents admitted that these devices had failed in their design.

Participant 1 stated that although the drainage systems had been effective in some areas, Lagos still flooded and he believed the deployment of more conventional infrastructure would better manage the problem.

"I would say that in some areas they have been quite successful, however, Lagos is plagued with yearly flooding, so the deployment of more infrastructure is required."

Participant 2 suggested that the drainage devices have been effective in some areas, e.g. in expensive neighbourhoods where drainage was serviced, cleaned and maintained barely experienced flooding, whereas complaints were received regularly due to flooding in other areas that were more populated and not as well maintained.

"I think it depends on the areas: in the Victoria Garden City, for instance, flooding barely occurs but in areas such as Apapa and the likes which are densely populated the systems cannot sufficiently cater for the residents."

Participant 3 felt that conventional methods did the job in the past because previously Lagos did not have flooding problems and any issues with flooding mainly occurred in densely populated areas.

"Some formal settlements do not interfere with their drainage so they are free flowing and prove to be effective."

"*Honestly the government has been more reactive than proactive in handling the issue of flooding. It hasn't been totally effective as some areas in Lagos still experience flooding.*" (Participant 4).

"Of course yes, I would boldly say they are very effective. Although we still find ways to figure out more perfect ways to abate the flooding problems." (Participant 5).

These responses indicate that the existing drainage systems have been reasonably effective but blame any failures on their mismanagement. None of the interviewees categorically denied the effectiveness of the system for political reasons, however, an undertone to the ineffectiveness of these devices can be perceived. Statements such as "some formal settlements" do not experience flooding are indicative that other formal settlements do experience flooding. It confirms the questionnaire results as well as interviews where formal residents in Ikeja indicated that although it barely floods, flooding does occur from time to time as shown in Sections 4.1.4, 4.3.4 and 4.6.2.2. Irrespective of their location, if the role of these devices was to manage flooding and they fail, this will translate into ineffectiveness or a flaw in the design. This is because clearly, the volumes of runoff produced during storms have surpassed their designed carrying capacity. This increased runoff can be related to increased populations as was found by Adeloye and Rustum (2011). Also, the illegal dumping of rubbish and blocking of these drains have been identified as reasons for such failures. Statements made during the interviews support results from the questionnaires regarding the effectiveness of drainage devices as perceived by both settlements. The following section investigates the government's interest in alternative methods to manage flooding.

4.7.4 Theme 4: Perceptions of implementing SSWM

4.7.4.1 MOE and LASEMA perceptions of the term "sustainable drainage systems"

Participant 1 indicated that SuDS as a term they had heard before and its implementation to work alongside existing drainage had been previously discussed within the ministry. Participants 2, 3, 5 stated that they understood SuDS to be systems that are sustainable and would last for generations to come. Although these responses are correct in the sense of sustainability and drainage, Participant 4 indicated a better understanding of the term, by stating that SuDS were drainage systems that mimic natural drainage processes and aim to reduce surface water flooding while improving water quality and enhancing the amenity and biodiversity value of the environment.

They went further to say it is a more sustainable way of managing surface water run-off to prevent sewer flooding.

Whilst SuDS is not an unfamiliar term for those governing bodies in charge of surface water management, a knowledge gap on SuDS and its benefits exists. Participant 4 was the only interviewee with in-depth understanding of SuDS, however they indicated that this knowledge was personally acquired, this finding is not unique and agrees with the literature which suggests gaps in knowledge of SuDS are one of the barriers to its implementation worldwide (Todorovic, Jones and Roberts 2008; CIRIA 2007; Mezue, 2009).

4.7.5 Theme 5: Willingness to implement SuDS by the Lagos Government: Responses varied across the different bodies; the results have been split into 3 different groups corresponding with participants' specific department.

4.7.5.1 Department of Water Resources and Drainage Construction

Participant 2 (an engineer) stated that SuDS was being contemplated by the ministry, and its implementation had been discussed; it is a work in progress. Further to this: "*I personally do not believe devices such as these can perform better than our hard engineered devices, however, I am of the opinion that these devices working together alongside the existing devices will make the difference".* According to Todorovic, Jones and Roberts (2008), engineers have been identified as a barrier to the implementation of SuDS mostly due to lack of knowledge, experience, and skills, hence contextualising Participant 2's remark. It did not, therefore, come as a surprise when this objection to SuDS replacing conventional drainage methods was raised. However, Participant 2 did admit when asked, that both systems could be integrated successfully.

Participant 4 (an enforcement officer) had the broadest knowledge of SuDS, and whilst they were personally receptive to the implementation of SuDS, unfortunately, they did not think the government would be willing despite the many benefits. The reasoning was because SuDS was not fully understood at the national level. Again, the lack of knowledge, experience, and skill of SuDS continued to create a barrier to its implementation, as found by Grant *et al.* (2016), Todorovic, Jones and Roberts. (2008), CIRIA (2007), Woods Ballard (2015).

Further, Participant 4 went on to say that environmental issues are not usually a priority at the national level "*The regular drainages haven't even been constructed in some flood-prone areas, suggesting a new and innovative drainage system to overtake the old will make no sense as the government feels it has more important matters to handle than drainage issues.*"

4.7.5.2 Department of Emergency Flood Abatement (MOE)

The two participants from this department, Participants 3 and 5, were receptive to the implementation of SuDS. In fact Participant 3 indicated that the Lagos government already planned its use: "*Yes, of course, I think so, in fact, I know so. The government keeps searching for improvements to make life better for its citizens, any drainage systems that can beat the present drainage systems that would cater for the increasing need for draining runoffs and how to clean up this waste to serve the populations environmental needs, I am sure will be welcomed*."

Participant 5 also shared a similar view to the government implementing SuDS and is quoted as saying "*Yes I do think so, that's why these researches are going on, as long as there is one out there we would assess it if it suits us."*

4.7.5.3 Lagos State Emergency Management Agency

Participant 1 (director of the LASEMA) suggested that governments' willingness to implement SuDS was best directed to the MOE: "*The Government of Lagos is dedicated to protecting its citizens and has put in place the Ministry of Environment to cater for all associated flooding problems in the state. We are continually searching for more efficient and reliable ways manage the flooding issue and will explore alternative methods*." They were of the opinion that the MOE would be willing to investigate the implementation of SuDS if it wasn't already planned. They reiterated the continued promise by their office of searching for efficient and reliable ways to manage flooding issues and the continued exploration of alternative methods of which SuDS was one.

There would appear to be a knowledge gap due to lack of experience and technical know-how of SuDS in Lagos which is a barrier to its implementation (see Section 4.7.2.1). For this barrier to be overcome education or re-education is required. A

participant clearly stated that at the national level, environmental issues such as flooding is not prioritised. For there to be a transition towards sustainable methods of drainage a change in the perception of flooding as a non-priority also needs to be addressed. Also, the awareness that conventional approaches are failing in their design to manage excess runoff needs to be addressed before looking for alternative methods.

4.8 Summary

This chapter presented the results obtained from collected data, which applied a mixed-method approach to evaluate findings. It presented questionnaire results from both field studies undertaken, Google Earth imagery, as well as interviews in its aim to achieve triangulation whilst also creating a clearer picture of the situation and hence drawing a more versatile and data rich conclusion. The shortcoming of using satellite imagery from Google Earth to analyse factors that can determine SuDS feasibility in the informal settlements in Lagos was identified and discussed. Results from this study revealed that existing drainage facilities are inadequate and have proven to be ineffective in managing runoff; findings similar to those of Adeloye and Rustum 2011, suggesting that the provision of drainage infrastructure is not commensurate with the rate of urbanisation and population growth in the State, thus flooding is widespread.

This study revealed through observation of study sites that the situation in all informal settlements studied are similar, which is also found in studies of informal settlements across Africa (Burton *et al.* 2010, UN-HABITAT, 2006, LSC, 2016, Magigi and Majani, 2006, Asumadu-Sarkodie *et al.* 2016). Therefore this study can be applied as a representation of the wider environment in West Africa/ Africa making it more widely applicable across various African countries.

These results obtained were pertinent to the development of the transition framework. This chapter revealed the readiness and willingness of the Lagos community as a whole to begin transitioning to achieving SSWM. Therefore, Chapter 5 uses these results in order to formulate a framework that would transition settlements in Lagos to SSWM with SuDS as a transition deliverable tool. To achieve this framework, a review of existing frameworks relevant to SSWM in Lagos has been undertaken. A comparison with existing countries which have or are in the process of transitioning to SSWM has

been made. Chapter 5 further discusses some existing government regulations as it pertains to SSWM in various developed countries that have adopted SuDS. It also investigates existing laws relevant to SSWM in Lagos, Nigeria; this is necessary because government regulations are a prerequisite to the successful implementation and maintenance of SuDS and as such a driver to the attainment of SSWM (Hoyer *et al.* 2011).

CHAPTER 5: FRAMEWORK DESIGN

5.1 Introduction

This chapter develops the proposed framework, which is designed to transition informal settlements in Lagos to a SSWM system, which addresses Aim 2 in Section 1.3.

This chapter is presented in three sections. In order to design and create the proposed framework, four relevant existing water management frameworks were investigated, in order to critically assess existing concepts and theories and investigate what would be applicable to the situation in Lagos. It also enabled the research to build on what already existed and to identify gaps in terms of their applicability in informal settlements in developing countries. Therefore, these frameworks are discussed in the first section. These insights lead into the next section of this chapter which reviews the governance in place in Lagos to support SSWM. This is important because institutionalisation has been identified as a driver or barrier to the implementation of concepts that would promote water management system sustainability. Section 3 comprises the proposed framework itself, its applicability to Lagos and potential indicators of its success.

5.2 Review and evaluation of existing water management frameworks

To address research objective 2.1, four water management frameworks were evaluated. To help in the evaluation of these frameworks, in addition to assessing their relevance to informing the development of the proposed framework, set criteria were adopted which these frameworks should meet. These criteria also added to the applicability of the proposed transition framework. These criteria are as follows:

- **Visual appeal**: The framework should be visually appealing to the target audience to maximise the potential to communicate concepts, whether technical or non-technical, Jefferies and Duffy (2011).
- **Simple, realistic and flexible**: the framework should meet these criteria as it should be readily understandable, with straightforward diagrams. At the same time, it should be realistic and achievable. It should also be flexible enough to incorporate feedback loops to encourage continued improvement.
- **Cost-effective and sustainable**: because this framework is targeted at an audience that is a mix of stakeholders including the government which does not

prioritise issues with flooding and is not willing to assist informal settlers, it should apply cost-effective, sustainable measures to attain its goal. A cost-effective, yet sustainable framework has the potential to engage with these stakeholders, encouraging genuine interest.

- **Communication/interaction between stakeholders**: the importance of a framework that encourages interaction between stakeholders cannot be overemphasised. The engagement and inclusion of stakeholder participants is one way of ensuring the sustainability of the implemented system.
- **Institutions, geography and cultural norms:** A provision for the consideration of these should be taken into account when creating the framework, although, to some extent, it may compromise the flexibility and adaptability of the framework. However, it promotes the target audience's willingness to accept it, when it conforms with their existing institution, geography and cultural norms.
- **Adaptive/wide applicability:** the framework should possess adaptive potential. It should be able to fit in and be applied or adopted at different scales and scenarios. According to Loorbach (2007), innovations are not usually born, they are required to be adapted before being perceived as a solution that addresses future local and global risks.
- **Reflective:** the framework should not be rigid in nature but make provision to be reflective and iterative. Change processes should not be fixed but rather reflective, in order to reflect changing circumstances and the evaluation of new inventions (Dirven *et al.* 2002).
- **Visionary:** According to Brown *et al.* (2008), when planning for a sustainable future, stakeholders need to know their place in the process, and the planned outcome, to enable them to envision the way in which the ultimate goal can be carried out. Therefore, a framework that is able to demonstrate this transition is of immense value.
- **Adaptive management/ leapfrogging**: a framework that advocates this enhances development and sustainability at a much faster rate than one which does not. This concept is currently being applied to developing countries, allowing them to transition to more sustainable futures while not making

mistakes but learning from the experiences of countries that have progressed to the desired stage (Jefferies and Duffy 2011).

Based on the above criteria, four frameworks for sustainable water management were selected, reviewed and evaluated to shape and enhance the design of the proposed Lagos framework. The frameworks are presented chronologically from age of design.

5.2.1 An adaptive management framework for connected groundwater-surface water resources in Australia

Brodie *et al.* (2007) suggest that both groundwater and surface water bodies are connected and interchangeable and if managed properly when one is deficient the other can be used to sustain and complement it. For example, wetlands and perennial plants can rely on groundwater during times of natural low stream flow in the course of drought (Brodie *et al.* 2007). Figure 5.1 below presents Brodie *et al.*'s 2007 Conjunctive Water Management Framework designed to aid the management of surface water and groundwater together.

Figure 5.1: An adaptive management framework for surface and groundwater in Australia (Source: Brodie *et al.* 2007)

Historically, surface water and groundwater in Australia were managed separately, however, as a result of increasing demand for water, it was recognised that water available for consumptive use was being accounted for twice, i.e. once as groundwater and then again as surface water sources (Brodie *et al.* 2007). An increase in drought and irrigation activities increased the likelihood of groundwater sources being utilised. Whilst there was an understanding that the connection between groundwater and surface water resources had increased significantly, there remained a concern that many water management plans still did not fully account for stream-aquifer connectivity. This concern was particularly the case for the impact on surface water availability due to increased groundwater use. Therefore, a framework to manage connected surface and groundwater was developed to provide stakeholders with a checklist of the main factors to be considered when planning water resource management. The framework could be applied at any scale, from a single project, to a catchment, to the national-level i.e. it was designed to be applicable/adaptable at all levels (Brodie *et al.* 2007).

Brodie *et al.* (2007) suggested that for effective management to occur, each stakeholder must have a clear understanding of who does what, where and how. They also suggested that one participant can have more than one role, i.e. they can play a different role at different levels in the management process. The framework clearly identified the role of all stakeholders, giving room for inclusion and engagement as well as a clear understanding of specific roles so that there was no replication of responsibility. The framework called for further study and future work, giving room for continued learning and therefore an improved system.

5.2.1.1 Aims of the framework

• Provision of a consistent national approach to conjunctive water management in Australia in line with the principles of the National Water Initiative.

• To encourage decision-making based on an understanding of both the hydrological and hydrogeological characteristics of a catchment.

• The provision of a common understanding of groundwater-surface water connectivity.

• Cataloguing available tools for assessing connectivity.

• To raise awareness of the value of numerical models and other predictive tools in setting management targets and options.

• To promote the coordinated monitoring of groundwater and surface water resources.
• Identification of sources for the key datasets required for management decisions (Brodie *et al.* 2007).

To develop this framework, the use of terms had to be redefined and contextualised because Brodie *et al.* (2007) suggested that there was no common or agreed definitions for many of the key concepts surrounding the connectivity of steam aquifers (ground and surface water). This lack of common terms impeded the development of an effective management system, therefore there was a need to clearly define the key terms so that they can be understood by all. A scheme based on the position of the water table, the direction of dominant seepage, the ability of the geological material to transmit water and the impact of connectivity on management targets was proposed.

5.2.1.2 Components of the framework

The framework was made up of six phases. It was continual in nature, allowing room for a feedback loop because of uncertain imminent changes in the future, e.g. changes in community priorities and expectations. Water management would need to evolve in response to these changes, hence the framework had to be flexible and achieved this via an adaptive management process. It recognised the need for a simple checklist of activities set out to provide an opportunity for stakeholders to access and review their position. The philosophy of adaptive management is followed where policies and practices are continually improved by learning from the outcomes of previous work (Brodie *et al.* 2007). The process is iterative and aspects of the management process are revisited and reviewed. It is flexible and it evolves.

5.2.1.3 The framework: steps/ phases

1. *Identifying the management source phase*

This involved identifying key features defined in the management structure, i.e. land and the water catchment, and the identification of problems in the management structure:

- **Planning and policy** to determine existing legislation, policies and rules that impact or influence water management. As it relates to the transition framework, it indicates the importance of reviewing existing policy in order to

support SSWM in Nigeria and identify policies that have promoted or acted as barriers to SSWM.

- **Catchment issues**: for example, those facing the sustainability of the land and water resources in the area. Conjunctive management can be tailored to address these issues whether they are over-extraction of water, river salinity or ecosystem health. The scale of the issues and their overall importance in achieving catchment management objectives also need to be understood to allow for a prioritised approach. Catchment issues can be perceived differently by different groups of people and there may be different perceptions about their severity.

  This particular phase was built on and implemented within the Lagos framework design. It enabled the study to further recognise the importance of participation by all stakeholders and the importance of achieving common objectives to allow for prioritisation of issues. Therefore, a cross-table discussion for all stakeholders was included to agree on prioritisation of the problems in the area.

- **Water use and water resource development**: to define the degree of extraction of surface water and groundwater in the catchment and the nature and extent of existing infrastructure which dictates how conjunctive management can be applied. This also relates to the extent and nature of land use and development. Water availability is central to the economic and social sustainability of many regions, and potential impacts on water users need to be understood and all water users engaged in the planning process. These sections of Brodie *et al*. 2007 framework were not applicable to the Lagos/ Nigerian design because there is currently no legislation in place to guide conjunctive water management; it also went beyond the scope of the study. This framework is more developed-world oriented. However, it shaped the study's focus, enabling it to identify water uses in the study area and how SuDS implementation could be used to influence, support and complement the use of, and accessibility to, non-potable water. This allowed for knowledge of the

multiple benefits of SuDS, i.e. water re-use by stakeholders and thus a driver for its implementation; a key part of attaining SSWM.

2. *Access to water resources:* the next phase involved acquiring baseline information about the characteristics of both surface and groundwater systems and how they interacted. This involved:

- Assessing the relationship between catchment data such as climate parameters, surface drainage, land use, geology.
- Collation and interpretation of existing monitoring to describe the spatial and temporal variability of groundwater and surface water systems.
- Identification of key information gaps and the initiation of specific studies to clarify key processes.

This was relevant to the framework design because it further showed the importance of undertaking a field study to verify existing data with what was on ground. It enabled the research to have more valid background about the area and the impacts of flooding in those areas. Familiarisation with the study area through a field visit and direct observation, compared with only relying on secondary data, gives a more valid and richer data source. It is also important because it allows the justification of why certain strategies should be put in place, based on first hand observation and experienced of the existing situation. The baseline assessment makes it possible to develop a conceptual understanding of connected water resources (Brodie *et al.* 2007).

3. *Understand and predict:*

This phase in the design involved understanding the behaviour of surface water and groundwater in a catchment and the impacts of any existing development. It necessitated field investigations and developing predictive tools, the latter enabling an understanding of the impact of different conjunctive management options, and therefore their applicability to different sites. The Lagos framework required the use of simple, understandable, non-technical user terms, but this particular phase used some very technical terms and complex technical detail, such as the nature and geometry of groundwater flow systems, seepage prediction etc. which were complex in their relation to the target audience for the Lagos framework. However, it was necessary to

understand, and be able to predict, how surface water interacts with the environment, in order to be able to give recommendations on how to manage the excess runoff using SuDS devices to manage runoff.

4. *Set management targets:*

Brodie *et al.* 2007 suggest that an essential step in any planning process is the setting of targets, which can provide a basis for planning and management decisions and a benchmark against which subsequent performance can be assessed. The specific targets for any catchment will depend on the issues being addressed.

This stage is vital in any plan and has been integrated into the Lagos framework for SSWM. This shows continuity and allows for a wider applicability of the framework. Its ability to be flexible to allow different management issues to be addressed is essential.

5. *Develop and implement management actions:* This phase allows for the provision of a variety of options available for implementing conjunctive water management. The options are defined by:

- Problems identified in the catchment that require addressing;
- Current understanding of individual catchment water processes, as developed through baseline assessment, conceptualisation, field assessment and possible construction of predictive models;
- Management targets identified for the catchment;
- Availability of resources.

This framework suggested that it is possible to implement a balanced mix of both policy and investment options within the management process. The policy options that recognise the linkages between groundwater and surface water resources can include strategies such as licensing and allocation, risk management approaches, planning rules or buffer zones. Investment options involve on-the-ground works such as water banking infrastructure (such as aquifer storage and recovery schemes), groundwater interception schemes, or groundwater pumps to supplement stream flow (Brodie *et al.* 2007).

This phase, with its balance between policy and investment options and collaboration between stakeholders in the management system was important to integrate into the

Lagos framework. The engagement of all stakeholders cannot be overemphasised as it gives all involved a sense of responsibility and allegiance to the proposed goal, further ensuring the longevity of SSWM.

6. *Monitor and review performance*

A well-designed, cost-effective and robust monitoring programme was part of the conjunctive water management approach (Brodie *et al.* 2007). Monitoring involved collecting key indicators relating to priority management issues at appropriate spatial and temporal resolutions. The Lagos framework therefore included a strategy for monitoring and maintenance to ensure sustainability and continuity.

5.2.1.4 Summary of adaptive management framework

The review identified criteria that were incorporated in the Lagos framework, in order to create something that had a simple method which was easy to use, a realistic approach, as far as adaptability was concerned, and encouraged stakeholder participation. It is also important that such a framework could potentially be applied at multiple scales across a catchment, or nationally (Brodie *et al*. 2007). These were essential features to ensure flexibility and adaptability, thus allowing for wider application. Further to these benefits, it encouraged adaptive management approaches towards achieving its goals. The framework is iterative in nature and considers changes that could happen in the future such as changes in community priorities, by providing a feedback loop, hence making it an evolving tool to ensure continuity.

However, there is a drawback to this framework: the design was focused specifically on the developed world. In Nigeria, the concept of conjunctive management is not well established, and pursuing this concept would be difficult, particularly considering the current situation of water management in the country, which would be similar in most other LDCs. Before this framework could fit the Lagos system, SSWM would have had to have be achieved already. Since this would be highly unlikely, it would be impossible for it to be directly applied to the Lagos situation. However, elements of this framework were identified and discussed, as suitable to building a framework suited to transitioning Lagos to SSWM.

The second framework to be discussed is that of Water Sensitive Urban Design, also applied in the developed world, and also located in Australia.

5.3 Brown *et al.* (2008) Water Sensitive City framework (Australia)

Brown *et al.* (2008) suggested that sustainable urban water management (SUWM) in cities is slow. They claim that the reason for this is due to barriers such as the lack of a benchmarking tool for informing the development of a long-term policy for SSWM. Also, urban water strategists still lack a clear vision or goal to identify the attributes of a sustainable water city. To fill this gap, an urban transition framework designed as a tool to underpin the development of urban water transition policy and city scale benchmarking at the macro scale was proposed by Brown *et al.* (2008). The framework presents a typology of six city-states based in Australia to represent phases in paradigm shifts. They were: the 'Water Supply City', the 'Sewered City', the 'Drained City', the 'Waterways City', the 'Water Cycle City', and the 'Water Sensitive City'. The framework attempted to explain the linear transitioning of cities over time from one technological phase to another in achieving sustainability.

This framework considered the temporal, ideological and technological contexts that cities transition through when a shift in paradigm occurs when achieving sustainable urban water management. It also takes into consideration other influencing variables such as ecologies, geographies, histories of the six "cities", and socio-political dynamics, which have been shaped by how government, communities, and businesses interact to use their water, also known as hydro-social contracts. Brown *et al.* (2008) indicated that this contract was shaped by institutional frameworks and regulations, yet again highlighting the highly important role that governance plays in the pursuit of delivering SSWM. To design this framework, a historical review of the changing institutional and technological arrangements in place to support Australia's urban management spanning the last 200 years was undertaken.

5.3.1 Aims of the Water Sensitive City framework

- To assist managers in the urban water sector to understand the scope of the hydro-social contracts operating across cities. This would aid in the determination of capacity development and cultural reforms essential to the

effective transition to a more sustainable water management and ultimately to Water Sensitive Cities (Brown *et al.* 2008).

- The framework attempts to provide the phases of the hydro-social contracts in Australia as well as proposing future sustainable interactions between the stakeholders in SUWM (Brown *et al.* 2008).

An investigation into the institutionalisation of SUWM across Australian cities was carried out which involved identifying the times in history when well-defined changes in urban water technology and practice took place, while accounting for social and institutional factors that were likely to influence future change. The framework is thus iterative in nature, making room for future changes that are bound to happen, as it pertains to stakeholders' behaviour towards SUWM. At the same time, significant institutional barriers to SUWM were identified. Once this was completed, the six transitional developmental phases for each "City" described above were proposed.

5.3.2 Components of the research

To explain the transition from one technological phase to another, Brown *et al.* (2008) divided the research into the 3 phases in which institutions would be investigated, and subdivided them into hard and soft infrastructures.

- Hard infrastructures: formal organisational structure, bodies and institutionalised rules and instruments.
- Soft infrastructures: include social relations, informal networks, professional cultures and social world.

Further terms used in the institutions discussed included:

- Cognitive institution: dominant knowledge and thinking in the society
- Normative institution: values and leadership
- Regulative institution: designed to protect dominant values and thinking.

According to Brown *et al.* (2008), although Australia is well on its way to achieving a sustainable future, a barrier to its attainment is the lack of alignment between the

cognitive, normative and regulatory underpinnings of urban water management with the delivery of SUWM, which initiated the creation of the first two phases of the research.

- **Research phase 1**: What have been the major cognitive, normative and regulative developments in Australian urban water management history since the early 1800s? 'Water Supply City', 'Sewered City' and 'Drained City' all evolved from this historical research phase (Brown *et al.* 2008).
- **Research phase 2**: The second phase involved identifying current barriers to, and drivers of, SUWM. This was based on the issue that despite the development of technologies over the last 20 years in Australia to support SUWM, its implementation was not widespread. The literature indicated that while there may be best practices such as water sensitive urban design (WSUD) available, there was a lack of normative and regulative change to support the new practice. 'Waterways City' and part of the 'Water Cycle City' evolved from the second research phase.
- **Research phase 3**: The third phase consisted of projecting the future institutionalisation of SUWM to achieve a sustainable future. The remaining 'Water Cycle City' and 'Water Sensitive City' transition states evolved from this part of the research.

5.3.3 Components of the framework

The transition process in the six technological phases makes up the Water Sensitive City framework. Its components are discussed below.

The water supply city was the first phase and developmental step taken towards SUWM in Australia, the first modern urban water city-state. It was characterised by the use of pipes to supply water to city dwellers and its expansion.

Sewered city: Once access to a safe and secure water supply was provided, priority was diverted to addressing piped sewerage services.

Drained city: This was characterised by efforts to manage excess stormwater and ensure flood protection. Its main focus was on developing techniques that enabled the rapid transport of excess stormwater out of cities to receiving water bodies. At this

stage, stormwater was perceived to be a nuisance which had to be dealt with as quickly as possible, hence the development of rapid conveyance to receiving water bodies.

Waterways city: This aspect challenged service delivery functions adopted under the previous city-states with the aim of providing both social amenity and environmental protection in its management of water. At this stage, management of point and diffuse sources of pollution was addressed.

Water cycle city: The fifth phase, according to Brown *et al.* (2008), was a response to the recognition of the current 'limits' to traditional water sources, as suppliers to an ever-increasing population and associated urbanisation. This phase was characterised by resorting to diverse fit-for-purpose sources, conservation and the promotion of waterway protection. This is the city of the future; however, whilst it largely remains within levels of academic and policy delivery, it forms part of the cognitive attempt to address tensions that have arisen between the Waterways City and the preceding city-states.

Water Sensitive City: The final goal of this framework, this is a city that would manage its water in a significantly different way from the existing conventional urban water approaches. In this phase, the approach to water resource management would comprise a combination of adaptive, multifunctional infrastructure and urban design, reinforcing water-sensitive behaviours.

In the framework, transitioning from one phase to the next tends to be a natural evolution brought about by changing times. However, the transition from one developmental phase to the next is associated with different technical solutions and objectives (Lobina, 2010). From this framework it can be recognised that initial priority was given to the achievement of brown development, centred around health and social welfare. This ties in with the development of the first three city-states. Having achieved brown development, priorities in the proceeding phases shifted to green development, and the wider environment, and in turn to the futuristic Water Sensitive City (Lobina

2010). The six different technological phases proposed to achieve a sustainable urban water future as identified by Brown *et al.* (2008) are presented in Figure 5.2.

Figure 5.2: Framework for achieving a Water Sensitive City

(Source: Brown *et al.* 2008)

5.3.4 Summary of Water Sensitive City framework and its applicability to the development of the Lagos framework

With the design criteria developed for the transition framework for Lagos in mind, the Brown *et al.* (2008) framework is simplistic and easy to understand. It is reflective and iterative in nature, taking into account future changes in surface water management. These are all necessary for an effective framework and will be built upon with regard to their applicability to the design of the Lagos framework. This Water Sensitive City framework also emphasises the significance of stakeholder interaction and communication in achieving SSWM as well as the importance of regulation.

The importance and place of regulation in attaining a sustainable surface water management system cannot be overemphasised; its priority has been stressed in the various frameworks reviewed. Thus, changes in surface water development and regulation in Lagos have been investigated to locate barriers and drivers to SSWM. It has also informed consideration of where to locate where both informal and formal settlements in Lagos fall on the Water Sensitive City diagram; to enable phases to be identified, to allow for transition. Visioning is essential in encouraging the setting and

achieving of targets and goals as they relate to framework and to Lagos. However, in order to design a framework that can be applied to the situation in Nigeria, this is not suitable; gaps in its applicability have been identified since (like the one proposed by Brodie et al. 2007) this framework is designed for developed countries. Although as discussed above it has identified the current situation, and what the ambition is for Lagos, this model is linear, and leads from one technological stage to another. Some countries have undergone a nonlinear progression as it applies to this model, e.g. some countries in Europe have missed certain phases and some have witnessed the emergence of two or more phases at once. For example, the water supply city phase has emerged at the same time as the sewered city phase (Lobina, 2010).

Further to this, Green (2010) has identified a weakness in the linear transition proposed by Brown *et al.*'s (2008) framework by studying the emergence of the Water Supply City and the Sewered City in London's history. Green (2010) suggests that this linear transition of technological developments in terms of surface water management appears to apply exclusively to cities founded in the 19th century (Green 2010). It is also noteworthy that strict adherence to linear transition does not ensure the achievement of a Water Sensitive City, although it can succeed via adaptive management. However, this is not appropriate in a study of informal settlements. The contextualisation of terms is necessary to ensure the adaptability of Brown *et al.*'s (2008) framework into the design for Lagos.

5.4 Darwin Harbour framework (Australia)

This framework was initially designed to manage the impacts of urbanisation on the Darwin Harbour in Australia. Although the harbour was pristine, research determined there was potential for degradation in the future from urban stormwater and wastewater discharges. Prediction showed that the region could experience a high rate of population growth by 2050 and thus more urbanisation, which had the potential to greatly impact receiving water body quality in Darwin Harbour. For this reason implementation of WSUD, a holistic approach to the planning and design of urban development, was felt to be critical (McAuley *et al.* 2009). It aims to minimise the impacts of development on natural water cycles, as well as protecting the health of aquatic ecosystems. It promotes conjunctive water management at the development scale (McAuley *et al.* 2009). The

territory decided to implement WSUD for all new developments to buffer the impacts of urbanisation on the urban water cycle and integrate storm water management in the harbour (McAuley *et al.* 2009). To assist with implementation, a framework linking policy to locally relevant technical design guidelines, manuals, and industry tools was designed by the Department of Planning and Infrastructure in conjunction with NRETA (Department of Natural Resources and Environment).

The framework recognised and took into account the fact that policy, programmes, technical and decision-support systems work together to support the implementation of WSUD, and were thus considered in, and accounted for, within the framework. The framework also considered barriers to the implementation of WSUD and addressed how these could be overcome. The barriers were grouped into:

Policy and planning barriers:

Whilst the state government controlled planning regulations and instruments, there was

- A lack of policy leadership evidenced by no formal policy, limited guidelines, regulations and administrative procedures.
- A lack of consistency between local governments on the policy provisions and application of WSUD.
- Poor administrative integration between agencies and councils, as well as between departments in local councils, to implement WSUD.

Technical and knowledge barriers:

- Concerns over costs for building, maintaining and replacing WSUD-related infrastructure by private industry and government.
- A general lack of awareness by stakeholders and the community about the benefits and practicalities of WSUD, and lack of suitable training programmes and access to relevant information.
- Lack of consumer demand for WSUD developments, and lack of appropriate marketing about their costs, benefits, and rewards.
- Limited quantification of the benefits of WSUD in terms of initial costs and maintenance.

- Little regional and local data on water quality parameters and other modelling tools to design WSUD systems.

The framework built on existing identified barriers of policy and planning frameworks, technical guidelines, tools and decision-support tools that existed throughout Australia to enable policies to implement WSUD.

As summarised by McAuley *et al.* 2009:

> *"The implementation framework for WSUD in the Darwin Region needs to fit within the context of the existing administrative and legislative framework and needs to complement existing policies and programmes relating to stormwater management, catchment management and receiving waterways in the region. It should review the administrative and legislative framework for water management in the region and outline key policies and programmes relevant to WSUD.*"

Relating this to the framework to be designed for Lagos, for SSWM to take place, it needs to recognise that various systems should work together to support the implementation of SSWM. This framework reviewed the barriers to WSUD which could also relate to SSWM, identifying the main barriers as lack of policy, planning and technical knowledge. Overcoming these barriers was investigated and included within the Lagos framework, as was the identification of any relevant existing policy and governance.

In this context, this framework is not entirely suitable in the Lagos setting. It only takes into account areas/catchments that were approved by existing governance. The Darwin framework requires that it needs to fit in with existing legislative and administrative framework. This would be a hindrance in its application for the proposed Lagos framework since the priority is on implementing SuDS in the informal areas where there is little or no governance. However, there is no specific legislation for formal settlements relating to stormwater management either specifically in Lagos or across

Nigeria as a whole, so formal areas need to be included in order to attain SSWM. Polices are therefore required to be put in place, to ensure sustainability.

The stormwater management strategy for Darwin called for management plans to be drafted for individual sub-catchments in the region, thus the Lagos framework will include a platform that encourages the inclusion of all individual sub-catchments, in this case both the informal and formal areas.

The framework considers that WSUD needs to be supported by appropriate policy. The policy and planning framework should:

• Provide leadership from the territory government to support the implementation of WSUD.

• Include clearly stated WSUD design objectives.

• Inform and guide strategic land use planning (i.e. structured planning and master planning), infrastructure planning and development assessment decision making.

• Provide incentives for WSUD where appropriate.

The Darwin Harbour framework for implementing WSUD was built around frameworks developed for three states: South East Queensland, Victoria and New South Wales which established the following guiding questions:

1. Did state legislation (planning and environment) need to be amended to better support WSUD?
2. What state policies (planning and environment), if any, support the implementation of WSUD and did they need to be amended to provide/improve the level of support provided for it?
3. What amendments were required to Local Planning Schemes to improve implementation of WSUD in new developments (including greenfield and infill)?
4. What other supporting codes/guidelines/tools have been developed (or have been identified as being necessary) to improve the successful delivery of WSUD on the ground?

These questions shaped the framework for Darwin Harbour; they are also applicable to the Lagos framework because of the necessity for the development of policy and

regulation in order to achieve success and sustainability of any management process. These have therefore been included in the framework for Lagos and existing policy and governance have been investigated to capture the above questions.

5.4.1 Aims of the Darwin framework

The framework considers 5 goals and strategies relevant to WSUD:

- maintaining a healthy environment;
- supporting recreational use of the environment;
- encouraging an ecologically sustainable development;
- protecting cultural values and heritage to foster community ownership; and
- participation in management.

The Darwin framework itself is presented in Figure 5.3.

Figure 5.3: Darwin Harbour WSUD Framework

(Source: McAuley *et al.* 2009)

5.4.2 Summary of Darwin Harbour framework

The overall goal of the Darwin framework was the implementation of WSUD by developing a new framework, also taking account of those already in existence. The three key phases of implementing the WSUD strategy for new developments were:

• Setting and implementing WSUD objectives

• Developing an enabling framework

• Communicating with industry and government and including them in capacity building

The framework emphasised the importance of how policy, programme, technical and decision-support systems should work together to support the implementation of WSUD. It identified barriers to the implementation of WSUD and how these barriers could be overcome to make the implementation of WSUD successful.

In order to design a framework that would assist in the transition of Lagos to SSWM, the Darwin framework is therefore quite relevant. It identified essential stages for framework design and recognised WSUD as a means to address the impact of urbanisation on the harbour. Aspects of the Darwin framework have therefore been integrated into the Lagos framework. These include reviewing and identifying barriers and drivers to the implementation of SuDS, governance in place to support transition to SSWM, recognition of the importance of distinctive and definitive roles of government, responsibility sharing in relevant bodies as it pertains to stormwater management, and inclusion of community participation in the framework itself. Regarding the criteria for the design of the proposed Lagos framework, it addresses most of the requirements, however it is quite complex in its design representation. According to Duffy and Jefferies (2011), the most effective frameworks are simple to understand and have a communication potential for non-technical audiences. It is also quite rigid and fixed in its design as it does not make room for changes in the future which are a constant feature in every development, hence the importance of a reflective framework. As it pertains to the Lagos context, whilst much can be learnt and built upon, the main drawback in the suitability of this framework is that it does not consider informal settlements. The Darwin Harbour framework was designed to manage a catchment in a formal area in the developed world, hence it assumes the ideologies of that world. In

conclusion, whilst aspects of this framework are somewhat relevant, it does need contextualisation and building upon to suit the specific environment of Lagos.

5.5 South African framework by Armitage *et al.* (2014)

A framework adapted from Brown *et al.*'s (2008) work on achieving Water Sensitive Cities has been designed to address the water sector issues in South Africa (SA). The country is a water scarce nation and the inadequate provision of water is increasing in importance (Armitage *et al.* 2014). The rapid growth of urbanisation, coupled with the apartheid legacy in the country, means that the demand for water has increased.

With the realisation that the existing conventional water management in the country is failing, an alternative system with multiple-benefits of increasing water quality and quantity, and considering community values and aspirations, has been sought (Armitage *et al.* 2014). WSUD was therefore investigated as a water management strategy to deal with these problems in SA.

In order to adopt WSUD, Brown *et al.*'s (2008) framework was contextualised to address the issues particular to the situation in SA, for example, some of the terms used in the developed world literature on the management of water can be inappropriate. WSUD assumes that development and equality issues have been addressed and thus it does not take them into account when planning. This is not the case for SA and most developing countries. In countries such as SA where a large population does not have access to basic water supply, it would be unlikely for urban developments and redevelopments to address the sustainability of water. Some of the terms which were translated into the SA context are discussed below.

Water sensitive settlements in a developing country context – 'transforming our cities'

Water sensitivity is defined by Armitage *et al.* (2014) as the management of the nations' urban water resources through the integration of various disciplines such as engineering, social and environmental science. Its management methods should be based on a participatory approach.

Water Sensitive Settlement (WSS) is a settlement that manages water in a manner that reflects the principles of water sensitivity, i.e. the urban water cycle is undertaken in a 'water sensitive' manner. In a developing world context, selecting water-sensitive technologies would thus mean the best available technology fit for use that would optimally manage water in that context.

5.5.1 Aims of the framework

To assist in the transition of SA to WSS through the implementation of WSUD. This aims to provide strategic guidance to urban water management decision makers, mainly city managers and other local authority officials, on the use of WSUD in a SA context (Armitage *et al.* 2014).

5.5.2 Developing the WSUD framework for South Africa

The management of water sustainably requires the participation of all stakeholders. Therefore, for the development of the SA WSUD framework, a learning alliance (LA) approach was undertaken. The LA allowed researchers and multiple stakeholders (civil engineers, social anthropologists, environmental scientists, urban planners, political scientists, landscape architects, urban ecologists and hydro-geologists) to work together to create the shared vision, whilst also developing strategies to aid the transition to attain WSS.

5.5.3 Components of the framework

The framework had four major components:

- **Research component**: this was essential to build relevant guidelines for the realisation of WSS. A '4T' (tools, transfer, tactics, and trials) cyclical strategy was conceptualised to promote WSUD. It included the development of tools (guidelines and manuals), the transfer of knowledge to appropriate stakeholders, and the application of tactics (to revisit legislation) to encourage the implementation of WSUD and the trial stage, which involved testing/piloting the WSUD approach.
- **Vision component**: with the implementation of Brown *et al.*'s (2008) framework, 6 cities were identified to represent the transitioning through the technological phases of water management in the developed world. Most formal

areas in SA would fall under the drained city phase. However, in order for SA to transition to WSS in line with international best practice, issues such as the apartheid legacy translated into poorly serviced informal settlements, which needed to be addressed (Armitage *et al.* 2014). For this transition to take place, both formal and informal settlements needed to be recognised as stakeholders in the water management plan. WSUDS had to be applied to both settlements and participation of both was essential (Armitage *et al.* 2014).

- **Implementation component**: various drivers to WSUD implementation were identified, such as policy development; institutional structures; community participation; construction of infrastructure and operation and maintenance. It was a challenge to pursue this transition with limited resources, both human and financial, as was the case in SA. It would be impossible to expect a poor settlement to retrofit its urban water system, therefore poorer settlements needed to ensure that they at least met the physical water needs for their residents while attempting to provide services that would attain the WSS goal. Small steps such as revisiting local legislation was an initiative that could meet these basic needs and put the settlement well on the way to achieving WSS. While creating these short-term solutions it was important not to jeopardise the long-term goals of transitioning towards WSS (Armitage *et al.* 2014).
- **Narrative component**: comprised the education of stakeholders on three main items (*Why, How and Results*) i.e. why WSS was needed, how it could be implemented and what the end goal should be.

5.5.4 The framework explained

The framework from Brown et al. (2008) had to be modified and contextualised to include terms suited to SA; it is presented in Figure 5.4 showing that for WSS to be attained, formal and informal settlements have to transition simultaneously. Therefore, informal settlements, formal settlements and greenfield developments were all considered so that the framework provided a vision of how all communities could pull together to achieve water sensitivity.

Figure 5.4: Framework for achieving water-sensitive settlements in South Africa (Source: Armitage *et al.* 2014)

Formal (brownfield) areas: These areas fell within the "Drained City" of Brown *et al.*'s (2008) framework. To transition towards WSS, retrofitting and redevelopment of the brownfield areas in a water-sensitive manner was suggested by this framework.

Informal areas: Simultaneously, while transitioning is taking place in the formal settlements, the informal settlement identified in Brown *et al.*'s (2008) framework as the "Water Supply Cities" with limited sanitation, should also be redeveloped in a water-sensitive manner (Armitage *et al.* 2014). The framework suggested *leapfrogging* as a means of advancing the concept in the informal settlements without having to progress through all of the stages in between to avoid the need for a later retrofit, as in the formal settlements.

The use of water sensitive technologies could also result in a range of secondary benefits for these communities. Adequate maintenance of these systems was recommended by ensuring that an appropriate policy was in place.

Greenfield developments: Armitage *et al.*'s (2014) framework strongly suggests that several constraints on the redevelopment of informal areas exist within SA. For example, the national housing policy (NHP) advocated basic service provision only i.e. water supply and sanitation to these areas, and as such budgets were allocated accordingly. It was considered important that such provision by the NHP took place at the same time that the formal settlements were educated and encouraged to retrofit their systems. This meant that for WSS to be attainable in SA, each transition stage/phase towards achieving WSS would be carried out simultaneously by both settlements, albeit in a different context. Therefore, the benefits, burden, and responsibility of implementing WSUD should be borne by all residents of both settlements. Only then can it be truly possible to transition towards an equitable WSS. This transition diagram, therefore, suggests that in the pursuit of achieving WSS in the SA context, a potential solution to varied issues experienced in the country, which range from resource availability and environmental damage to social exclusion, equity and equality, could be achieved (Armitage *et al.* 2014).

5.5.5 Institutional considerations with particular reference to stormwater in South Africa

The implementation of WSUD in SA would require a holistic approach to understand the consequences of transitioning to such a system and to assist with overcoming the socio-economic issues, as well as promoting sustainable economic growth and protecting scarce natural resources (Armitage *et al.* 2014). Identifying the drivers and barriers to achieving WSUD in SA is essential because it is also a developing country in Africa with similar experiences which could be used to adopt WSUD for use in the proposed framework. It will enable adaptive management /leapfrogging by other countries. A major driver or barrier to the sustainable management of surface water was identified as regulation and policy, therefore existing institutional and legal policies were reviewed to identify obstacles to WSUD and provide recommendations on how they might be overcome. The review detailed existing regulations pertaining to

stormwater (The Constitution of the Republic of South Africa, Schedule 4 – Part B), determining that the provision of stormwater services in urban areas is the responsibility of the local municipality (RSA 1996). However, stormwater in most municipalities in SA have been separated from water and sanitation and assigned to the roads department. This has translated to stormwater being viewed as a hazard to be disposed of as quickly as possible, in order to prevent it damaging roads in the area. The fragmenting of urban water management has thus led to problems. According to Armitage *et al.* (2014), in order to optimise the benefits of the provision of water services, it is essential that the urban water cycle is managed as a whole and is not fragmented.

5.5.6 Summary of South African framework

One of the essential values of this framework is that it is the first of its kind regarding the development of frameworks to sustainably manage surface water in developing countries. It can be used by strategists and policymakers. Also, from a research perspective, it can be an underpinning framework for future work on transition policy research, hence the rationale behind selecting it as a framework to be evaluated. This SA framework shares similarities with the framework to be designed for Lagos; being designed for a developing country, similar peculiarities and complexities have been identified and addressed, such as the consideration of informal settlements. It is simple to understand, reflective and also visionary, the latter is an intricate part of transitioning (Jefferies and Duffy 2011). It identifies where the different settlements are on Brown *et al.*'s (2008) framework and makes suggestions that would transition both settlements to achieving the set goal, which is WWS. The contextualisation of terms in the framework is crucial to its success and has shaped the ideology around the framework design for Lagos. Another essential tool as identified in the SA framework is the LA approach; this was essential to gather all the possible knowledge in order to reach an equitable result. Further to this, the framework pinpoints the importance of the inclusion and participation of all stakeholders when planning to implement sustainable water systems. It also indicates the importance of reviewing existing regulations around stormwater management. The use of adaptive management/leapfrogging is also advocated in this framework; this is an advantage over Brown *et al.*'s (2008) framework, which suggests a linear progression to attaining a sustainable water future. The SA framework is

cyclical in nature with the conceptualisation of "4T": tool, transfer tactics, and trials. This accounts for its capability to create room for future change. The idea of piloting WSUDS before implementation is a vital phase that has been applied in the Lagos framework. This would enable a feedback loop to apply positive changes to the strategy where necessary to improve upon it and guarantee its success. Piloting also gives the person/body offering suggestion or recommendation some confidence as to the total success of actions to be implemented.

5.6 Inferences drawn from existing frameworks

Overall, these frameworks complement each other and cover the gaps where one fails in its applicability to the Lagos framework. The essential benefits, as identified by the 4 frameworks put together, includes encouragement of continued improvement through reflective, systemic and adaptive approaches with the emphasis on problem solving by implementing scientific interventions to ensure and deliver a sustainable water future. They also support knowledge flows between stakeholders at all levels and between the stages of a process, which are key factors to facilitate the uptake of sustainable practices and transition management concepts. The use of institutional regulation/policy to sustain water management systems is reiterated in all the frameworks and its importance taken into account. The visionary pictorial tool, as adopted by both Brown *et al.* (2008) and Armitage *et al.* (2014) is essential to planning a sustainable future, because stakeholders need to be able to see where they are and where they want to be in order to put strategies in place to achieve their ambitions. The leapfrogging concept, as adopted by both Brodie *et al.* (2007) and Armitage *et al.* (2014) is also a phase to be adopted, as it allows for learning from the mistakes made from the experience of others. Leapfrogging is basically the idea that developing countries could find new paths to grow their water infrastructure that are considerably more sustainable than those found in developed cities by studying existing infrastructure and avoid mistakes made in pursuit of a sustainable water future. This concept has been adopted and applied to developing countries and newly developing cities alike (Jefferies and Duffy, 2011).

In order to design a framework that would transition Lagos to SSWM, the combined implementation of relevant phases within the different frameworks is essential.

While these frameworks are relevant to a significant extent in the creation of the Lagos framework, they need to modified in order to address some of the challenges facing the country's water sector.

Further to this, existing guidelines and frameworks from developed countries are mainly what is currently available. Unfortunately, in their design, the complexities or peculiarities associated with developing countries have not been considered. The SA framework is therefore the most appropriate, rather than the other three, in that it is closest to the current situation of surface water management in Lagos. However, relevant material from all four frameworks have been considered, and used in the creation/designing of a framework to transition Lagos to SSWM.

Based on suggestions from the reviewed frameworks above, the importance of institutions to ensure the sustainability of sustainable surface water management has been reflected on throughout. Governance, legislature, and policy have been identified as drivers or barriers to achieve a sustainable water future globally. Therefore, the next section will review existing governance to support the management of stormwater in Lagos. This will enable the identification of particular drivers or barriers to SuDS implementation to attain SSWM in Lagos.

5.7 Surface water regulation in Lagos

This section reviews the existing regulation relevant to surface water management in Lagos Nigeria. However, before this is reviewed a brief perspective on the influence of regulation globally is discussed. The rationale behind this is to state more strongly the important role that governance has to play in attaining SSWM.

5.7.1 Institutionalisation and its influence on attaining sustainable surface water management: A global perspective

Drivers:

The literature indicates that legislation, policies and regulation strategies play a vital role in driving the implementation of SSWM the world over, especially in developed countries (CIRIA 2005; Hoyer *et al.* 2011; McAuley *et al.* 2009; Nkwunonwo *et al.* 2016). This section gives an overview of current and existing international and national regulations, guidelines, local regulations and incentives in some developed countries

with experience of successfully implementing SSWM (primarily Europe, particularly Germany and the UK, Australia and the USA). The rationale behind this overview is to enable a clear understanding of what needs to be done by the government to drive SSWM in Lagos, hence the use of adaptive management in the pursuit of success. It will also identify the lack of regulations in Nigeria relating to stormwater management and suggest strategies for the country to address this deficiency. The identification of this gap or lack in regulation is vital to the creation of a framework that is applicable and suited to the existing situation in Nigeria.

Hoyer *et al.* (2011), suggest that SSWM is ideally based on international and national regulations. Different countries, however, develop these regulations to suit their varying circumstances. In Europe, USA, and Australia, legislation is widely developed for the management of surface water and as such it can be used as a measure for adaptive management for other countries, and create regulatory support for stormwater management.

Legislation for stormwater management in Europe is quite advanced. Through the implementation of the Water Framework Directive (WFD) of the European Union (Water Framework Directive, 2000), all countries in Europe are directed to develop country-related legislation for all issues concerning water management 'including stormwater' (Hoyer *et al.* 2011).

The WFD initiates and drives communication and collaboration across Europe whilst developing goals for the protection and revitalisation of water systems. In the past, European water frameworks mainly focused on human health concerns; however, the WFD prioritises the environment without being hindered by political boundaries.

Germany

Germany seems to be at the forefront of SSWM regulation with the enactment of legislation such as the 2010 Germany Water Resources Act, which maintains clear directives for water resource management. It encompasses groundwater pollution and degradation, urban wastewater treatment, environmental protection and flood risks, and it establishes frameworks for community action networks. Recently, SSWM methods have been officially adopted as the preferred method for stormwater management.

These methods are therefore to be considered first and implemented when possible. The German Waste Water Levy Act strongly follows the "polluter pays" principle. It is the first nationwide environmental tax and places the financial responsibility of clean-up with polluters (Hoyer *et al.* 2011).

United Kingdom

The United Kingdom is also at the forefront of pioneering SSWM, typically placing emphasis on the implementation of SuDS, particularly in Scotland. Although not mandatory, SuDS are repeatedly listed as preferred solutions for stormwater management. Although there is no explicit national SuDS strategy in England, they are covered by a range of existing regulatory measures in place for flooding and water quality at both national and strategic levels (Warwick 2013). Examples include: legislation for improved surface water management using SuDS in England, which was enacted in the Flood and Water Management Act (FWMA) (Act of Parliament 2010), also in "Planning Policy Statement 25 for Development and Flood Risk" (*Planning Policy Statement 25* 2006) which requires that SuDS specifically be considered at every level of flood risk planning. The Town and Country Planning Assessment of Environmental Effects Regulations (*The Town and Country Planning Regulations* 1999) determine that SuDS may be used to mitigate negative impacts on the environment. In the building sector, "Document H" (*Approved Document H* 2006) established a hierarchy of building water management that favoured infiltration over piped systems. (Hoyer *et al.* 2011).

Australia

In Australia, although WSUD is not required by national regulations, WSUD strategies are however recommended for new developments (Hoyer *et al.* 2011). Further to this the collaboration between Commonwealth, State and Municipal governments has produced state environmental legislation and planning policy directed towards the specific development of WSUD strategies in the country. The Council of Australian Governments (COAG) has taken substantial steps to advance water reforms in urban environments (Hoyer *et al.* 2011). Currently there are at least nine water implementation plans (one of which is at the national scale). The aim is to implement the provision of

healthy, safe and reliable water supplies, increase water use efficiency, encourage re-use and recycling of wastewater, facilitate water trading and improve pricing (Australian Government, National Water Commission, 2010; Hoyer *et al.* 2011). In Australia, the state authorities provide strategic guidelines or technical parameters for stormwater management whereas local authorities determine project- (or water system) specific provisions for development, which is quite similar to the case of SuDS regulations in the UK.

USA

In the United States of America, it is at the federal level that water quality regulations for baseline quality and management criteria have been established, with overall water quality regulated by the Clean Water Act (*Clean Water Act* 1972). This act provides the statutory authority with the ability to regulate water pollution and aims to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters". State and regional levels regulate the specifics related to water management in the nation as a whole. The Environmental Protection Agency (EPA) represents the organising body for water quality regulation in the country, setting national standards for pollution (Water Quality Standards - WQS). Pollution is controlled through the National Pollutant Discharge Elimination System (NPDES) which has the responsibility of issuing permits to polluters contributing discharges directly to water bodies, which includes pollution via storm drains. NPDES permits are typically issued by authorised states or municipalities and are coordinated with local WQS (US EPA, 2009; Hoyer *et al.* 2011).

5.7.2 Local regulations and their influence on SSWM

Regulation at the local level tends to drive the implementation of SSWM more aggressively as is the case with the countries discussed below.

Australia

In Australia, it is the duty of the state to make policies and guidelines and also define technical parameters, whilst it lies in the jurisdiction of the local government to make specific developmental provisions. An example of this is Victoria's water legislation, which goes back to 1970 and has been consistently crucial in WSUD permissions. It

states that stormwater should not cause any damage to humans or animals, surface or underground water (Hoyer *et al.* 2011).

The 1989 Water Act in Southern Australia is also important. It stipulates rights with respect to the use of water and clears the path for rainwater harvesting and infiltration strategies, while the Planning Act in the Northern Territories created new indices for development and the Local Government Act widened the local authority platform to regulate stormwater (McManus 2009). The combination of these acts determined the basis for stormwater management at the local level with WSUD projects, permissions, and licences for local water schemes being issued locally. Melbourne and Sydney are at the forefront of WSUD support and make obtaining licences very easy. Melbourne not only provides clear guidelines but also gives a description of how to meet its water quality and pollution requirements. Projects are constantly being updated on the website (Hoyer *et al.* 2011; Melbourne Water, 2010).

USA

In the USA, it is the EPA that is responsible for water management, although regulation at the local level has increasingly been getting stronger with respect to SSWM practices. In Philadelphia for instance, stormwater regulations prescribe that projects manage the first one inch (2.54 cm) of rainfall from all directly connected impervious surfaces (Philadelphia Water Department 2006, S.600.5).

In Portland, regulations include a mandatory hierarchy stipulating on-site infiltration with surface vegetation as preferred (Portland Bureau of Environmental Services 2004). Quality standards for infiltration are stated at the local level. It is the opinion of Hoyer *et al.* 2011 that the likelihood is that with the backing of the EPA, local governments will become more active in the pursuit of stormwater management in the future.

In New York, some cities have started developing informal processes for stormwater management. Their planners have evaluated the relevance of using decentralised methods for stormwater and have outlined strategies for their implementation (Hoyer *et al.* 2011). This is a part of New York's PlaNYC 2030, which is the city's master plan for sustainable development. Hoyer *et al.* 2011 consider that stormwater management is more successful when handled locally, even though national and international standards

are used as a basis, and cities have a big say on whether decentralised methods like green roofs or infiltration areas for stormwater management are used or not. This is achieved by the control they have over price fixing for discharging rainwater into the sewer system and their power to waive these payments. Also, they can request compulsory usage of decentralised rainwater management methods for new developments and can introduce subsidies (Hoyer *et al.* 2011). The Emscher Region has been suggested by Hoyer *et al.* 2011 as an example of where water management may not be undertaken by individuals as the regional body handling it has made it decentralised.

United Kingdom

In the UK, numerous policies are in place to address different forms of flooding at local authority levels. Main river and coastal flooding are managed by the Environmental Agency (EA). The role of the Lead Local Flood Authority (LLFA) is to be responsible for the unitary and upper tier councils as ascribed by the FWMA and Flood Risk Regulations (Act of Parliament 2009). Their role is to create and apply a local flood risk management strategy (LFRMS) to be responsible for the flood response of water bodies outside the control of the EA, especially flooding from surface runoff, groundwater and ordinary watercourses (FWMA Section 9). It is the responsibility of the local authority to create a Surface Water Management Plan (SWMP) (DEFRA, 2010), which should assist in the cooperation between organisations managing surface water in local areas over a lengthy period (DEFRA, 2010). SWMPs foresee a role for SuDS to support a better strategy in the approach to drainage planning over a wider area (Hoyer *et al.* 2011).

Although there are different regulatory structures, roles and policy traditions in play in the various reviewed developed countries of the world (Germany, the UK, Australia, and the United States), it can be inferred that each country actively supports sustainable development in water management. Developing countries will need to place more emphasis on supporting sustainable water development as water becomes scarcer.

5.7.3 Influence of regulations on transition to SSWM in Lagos

In order to develop a framework that would assist in achieving transition to SSWM in Lagos, a review of governance or lack of it to support this transition is relevant. However, it should be noted that there is no specific drainage legislation which sets the responsibilities, duties, authority and powers towards the operation of drainage management in Nigeria or state level (MOE 2015). Therefore, existing policies and laws that potentially have an influence on sustainable development, and by inference SuDS in Lagos, have been evaluated to ascertain whether they are a driver or barrier to the attainment of SSWMs. There is a wide literature on policies that influence the attainment of sustainability in Lagos (MOE 2015; Oduwaye 2009; Aluko 2010 etc.). These policies are regulated and overseen by different agencies and parastatals within the government.

5.7.4 Existing relevant laws

It is the duty of the Nigerian Government to protect its citizens and in view of this, it responds by developing appropriate regulatory policies, which are adopted at the State Government level to oversee the smooth running of the country. Lagos has itself enacted additional policies to ensure development. The Lagos Government policy on the environment states that it is committed to the provision of a healthy environment that will promote the welfare of its citizens while maintaining biodiversity conservation and ensuring sustainable social and economic development (MOE 2015). Therefore, Lagos, in accordance with this policy, has passed several laws that are essential to the setting of a legal framework, within which the functionality and smooth running of systems within the state are suppported. Some of these laws are highlighted below; the policies with the most impact on drainage management will be discussed:

- Environmental Sanitation Law 2000
- Street Trading and Illegal Markets (prohibition) edict No. 1 1984
- Sand Laterite and Gravel Spillage (prohibition) edict No.4 1984
- Land use decree 1978
- Town and Country Planning Edict No.1 1986
- Environnemental Pollution Control edict N^{o}. 13 198
- The Land Use Act, LFN 2004; (iv)

- The Urban and Regional Planning Act, LFN 2004
- The Lagos State Waste Management Authority Law 2007 and
- The Lagos State Urban and Regional Planning and Development Law 2010.

Although these laws and edicts cover issues related to surface water management to some extent, and as a consequence have a bearing on drainage, the existing legislation which may have the greatest bearing on the operation of the drainage systems is the Environmental Sanitation Law 2000, which came into force on 21 November 2000. Although the law was not enacted to categorically regulate the drainage systems, it deals with many of the issues that currently impact upon their operation, such as the uncontrolled dumping of refuse, and the discharge of sewage. The decree also stipulates maintenance responsibilities for individuals with regard to drainage (MOE 2015).
The relevant extracts from the Law, with regard to drainage or issues that directly affect the drainage systems, are clauses 1, 2, 4, 5, 6, 9, 12, 14 and 16:

- ***Clause 1: duty of occupier***
- ***Clause 2 cleanliness of backyard***
- ***Clause 4. use of sanitary litter bins***
- ***Clause 5. every commercial vehicle to carry litter bins***

(1) ‘’As from the commencement of this law, every commercial vehicle in the state shall carry a litter bin for the use of the passengers’’

- ***Clause 6. obstruction and improper disposal or dumping of refuse***

(4) ‘’No person shall dump indiscriminately any domestic, industrial and commercial waste or discarded vehicle spare parts or tyres along highways, roads, channels, gorges, vacant land directly or through private operators, except at designated refuse disposal sites’’.

- ***Clause 9. structure on road set back and abuse of open spaces***

(1) No person shall:
(a) ‘’Defecate or urinate in the drainage of any open space’’.

- ***Clause 12. Maintenance of drainage, sewage, and septic tanks***

(1) Every person shall –

(a) ‘’Clean and maintain any drain in the frontage, sides or rear of his tenement or building, and’’

- **Clause 16. Silt removal**

‘’No person shall leave silt, earth, or other materials excavated during the construction or maintenance of drains on the roadside beyond 48 hours’’.

The main components of any stormwater drainage system already installed in developed areas consist of open channels designed around any natural streams (MOE 2015). The discharge point or the main receptor of the stormwater can either be the natural waterways or artificial channels which discharge into the ocean via creeks or lagoons. The channels are therefore susceptible to blockage by indiscriminate dumping of refuse. However, with the legislation, there is some curtailment or at least enforcement of the cleaning of already blocked drains by environmental sanitation officers who supervise this monthly exercise.

Although the Environmental Sanitation Act is the law that most closely influences the management of surface water, other laws and edicts highlighted above influence the management of surface drainage to some extent, providing a starting point to achieving SSWM. The participation and inclusion of the community in maintaining drainage devices is a step towards achieving sustainability in terms of surface water management, although the sanitation law was not specifically enacted for this purpose.

The Land Use Act, urban and regional planning laws, and the Waste Management Authority Law will be discussed in detail because it can be argued that they enabled the proliferation of informal settlements in Lagos and promoted the building of illegal structures.

The urban and regional planning act

Oduwaye (2009) suggests urban planning can play a vital role in achieving sustainability. It has been described as providing the lead system for “building” an environment, which is rudimentary for achieving sustained control and development. Urban and regional planning laws are designed to provide sustainable sites for human activities and these plans play a vital role in the promotion of sustainable development. According to Adesanya (1998), urban and regional planning is as essential in every

government as regulatory processes to protect the people, land, water and atmospheric resources. Lagos has been described as the most urbanised state in Nigeria (Ayeni 1979); only about 5% of the total population of the state live in rural areas, this has a serious impact on land use planning in the state. It also has implications for the provision of infrastructure such as housing, water supply, storm drainage, roads, electricity, telephone, waste management and other socio-economic, cultural and administrative issues (Oduwaye 2009). This increase in the urban population has resulted in the proliferation of slums and shantytowns throughout Lagos resulting in the unchecked expansion of the urban centres, which poses major planning problems as the provision and management of basic infrastructure such as roads, drainage, and sewage systems, among other infrastructure, proves very difficult. To this end, urban and regional planning law is essential, but unfortunately these in Nigeria have acted as legislative bottlenecks, creating barriers instead of drivers to sustainability and the potential implementation of SuDS. The following section critically evaluates the roles and impacts of the urban and regional planning laws in place.

Urban and regional planning laws

Oduwaye (2009) pinpoints the shortcomings of Urban and Regional Planning Decree 88, 1992. They state that there is selective implementation of this decree and that this has created problems instead of enabling the smooth running of planning in the state. Further to this, there are insufficient numbers of qualified officers in the field due to the inability of the government to remunerate workers adequately to carry out plans as stipulated and to implement enforcement orders. The lack of adequate working tools and the need for staff retraining, coupled with inter-departmental conflicts and top-down revenue-sharing formulae, have been identified by Oduwaye 2009 as the main reasons for the ineffectiveness of this decree. These flaws in the law and its enactment have led to the indiscriminate and unchecked construction over natural drainage structures.

Further to the shortcomings mentioned above, Oduwaye (2009) also identified the lack of community participation in the decree which resulted in the disinterest of the community, because the decree basically demands that planning is still basically "for the people", rather than being "with the people". Therefore, planning ends up being unsustainable as the people do not feel a sense of responsibility for their environment.

This is clearly evident in the attitudes towards the management of the drainage facilities across Lagos; because community participation is not encouraged, drainage maintenance matters are left solely to the government.

Due to the rapid population expansion and subsequent increased urbanisation in Lagos, the Urban and Regional Planning Decree also covers the creation of schemes to build residential homes in the state. Land was subsequently acquired by the government and homes built. However, most Lagos residential schemes were not accessible to the urban poor, even though they constitute the majority of the population in Lagos. This made the acquisition of these homes impossible for the poor because they are not affordable and land which could have been acquired by these individuals and affordable structures erected were instead owned by the government for this scheme. This gave no choice to the poor in Lagos but to source cheaper accommodation in other areas such as Makoko and other informal settlements. By virtue of their location they are a lot cheaper than these residential home schemes. This failure of the Urban and Regional Planning Law to cater for the urban poor in society is a barrier to SuDS management because the poor who cannot afford to live in the formal areas create informal settlements. Currently in Lagos there is lack of standard or regulatory frameworks to manage the development and delivery of tertiary and many secondary drainage facilities at the community level, therefore many communities take it upon themselves to create them to manage excess surface water (Oshodi 2013). The decision made to construct and manage these devices depends on how compelling and affordable the drainage channel is to the respective plot owners. Equally, the construction and management of secondary drains are made possible through contributions obtained from community members. However, these contributions are often erratic and fragmentary in nature; this leads to poor quality drainage and mostly, abandonment. At the individual and community level, the construction and management of the drains are executed without any development guide, approved layout plan, regulations or any prescribed operational standard because of the failure of legislation in the system (Oshodi 2013).

In the schedule of responsibilities for the Lagos State Ministry of Environment, the construction and maintenance of secondary channels are integral parts of the Ministry's duties (MOE 2015). The provision of drainage infrastructure is not commensurate with

the rate of urbanisation and population growth in Lagos (Oshodi 2013). Mainly because the Urban and Regional Planning Laws failed to take into cognisance the poorer residents within the State, no provision was made for them at the planning stage. This has led to incessant land reclamation and dredging projects across the water bodies in the state, with little or no regard for the environmental impacts of such projects. In cases such as these, planning ends up being unsustainable as the people do not feel a sense of responsibility to their environment or the standards. This, therefore, has led to the creation and proliferation of slum settlements across the state (Aluko 2010).

In pursuit of sustainability, a revisit of this law is essential if SSWM is to be achieved. The exclusion of the community needs particular re-evaluation as excluding stakeholders from planning will only lead to the haphazard use of the amenities provided. A sense of responsibility by community members is essential for sustainable development to take place. Furthermore, a policy that takes into account both the rich and poor in a community cannot be overemphasised. The inclusion of both existing formal and informal settlements in the provision of amenities such as drainage facilities is required to ensure the effectiveness of the drainage system.

Land decree

Until recently, most of the development planning efforts in Nigeria concentrated on economics with little regard for the implications of the policies on the actual physical planning taking place. According to Oduwaye (2009), gaps in the Land Use Act of 1978 have yet to be revised. Prior to 1978, land administration in Nigeria had been predominantly guided by customary laws (Aluko 2010) which recognised the interests of individuals, families, and communities on land; it ensured that everyone had equal right of access to land. The chief or head of the family was made the trustee of the land and held the land for the people. However, since 1978, land tenure in Nigeria has been governed by the Land Use Act of 1978, under which all land in all the states of the federation have their Governor as their trustee. Therefore, access to land by way of a 'right of occupancy' is granted by the government (Aluko 2010). This change from family leader trustee to government ownership through the Land Use Act of 1978 led to many controversies over the acquisition, disposal, use and administration of land. These controversies are most prominent in areas of high rates of urbanisation.

Due to its urbanisation rates, and the subsequent increase in the demand for use of land, Lagos is being negatively impacted by this law. According to Aluko (2010), from the onset, the Land Use Act has failed to make land readily available to Nigerians. This is primarily because the legislature put in place by this law makes the process of accessibility to land long, rigorous and expensive. The present public land administration, especially that of land acquisition, has the negative effect of contributing to land shortages rather than to land availability. Allocation of land by the Government is selective and there is speculation that officials are hoarding it, thus making it expensive (Aluko 2010). This has further encouraged the proliferation of informal settlers because the low-income earners cannot afford the high prices, or cannot go through the rigours of getting access to land through this policy; this law has basically acted as a barrier instead of a driver to sustainability.

As it relates to its influences on drainage systems, those settlers who have not been able to gain access to land because of this policy, build on floodplains or other vulnerable sites, building over natural drainage. The setting up of illegal structures on unplanned locations, in turn, affects natural drainage of water and also creates a population that was not accounted for when the existing drainage systems were designed. Therefore, the ineffectiveness of the existing devices provided by the government to manage stormwater is obvious. This ineffectiveness can be attributed to the drainage devices far exceeding the carrying capacity for which they were designed, causing flooding (Aluko 2010).

Oyesiku (1998) suggests that the structure and pattern of any settlement reflects the laws and policies that regulate land administration in the area. Further to this, he states that the structure and pattern of past and existing settlements in Nigeria are a function of land laws and administration, such as the Land Use Act of 1978 influencing the spread of informal settlements in the country. Although these regulations attempt to ensure citizens' health, safety and welfare by strictly controlling land and building standards, the regulations force the very group of citizens they seek to protect into completely unregulated informal sectors, thereby mounting pressure on natural and artificial drainage (Dowall and Clarke, 1996).

This legislation has been put into place to safeguard the country and its economy. Studies relate the failure of these policies to the failure of governing bodies to regulate the specific policies (Armitage *et al.* 2014). As stated earlier in this chapter, these policies are regulated by various bodies in the government; however, sharing of regulatory powers amongst bodies causes a breakdown in the functionality of that policy. An example of this is evident in the waste management authority law because it promotes fragmentation of regulation at various levels within the government and its agencies. With the creation of the Lagos State Waste Management Authority (LAWMA), which has responsibility for handling waste management, the Local Government has lost its direct powers to regulate or legislate on waste management, even in areas within its jurisdiction. However, the Local Government appears to have powers to regulate certain matters that are incidental and ancillary to waste management. For instance,

> *"item 1(e) and (f) of the Fourth Schedule to the Constitution empower the Local Government to establish, maintain and regulate markets, slaughterhouses, motor parks, roads, streets, drain etc. In ensuring cleanliness in these places, the Local Government may make a bye-law that provides for waste disposal and management. Also, item 1(h) allows the Local Government to maintain refuse disposal. In fulfilling this provision, the Local Government may also pass a bye-law that may bother on waste management. Such bye-laws, however, should not be seen to contract the Lagos State Waste Management Authority Law on the subject of waste management."* (Waste Management Authority Law, 2007).

This breakdown in regulatory powers can lead to the indiscriminate behaviour of residents because they know local government has little responsibility for waste management, so they can indiscriminately dump refuse without fear of penalty. It may also be the case that LAWMA officials are not located in close proximity to the settlement where this indiscriminate activity is occurring.

It is evident that while the government has created policies with the aim of ensuring sustainable development, some are drivers but some create barriers. These policies were set up with good intentions; however as discussed earlier, they were designed with an

economics focus, with little or no account taken of the physical development of the country and state, as is the case of Lagos. In addition, the inability of the policies to safeguard citizens occurs because Lagos lacks citywide administration (Oduwaye 2009). As indicated above, there is an overlap of functions and activities throughout the different levels of government leading to duties being replicated and, in the end, very little getting done (Aluko, 2010).

There are conflicts between parastatals and local governments, and because of this there is weak enforcement of the law. The general lack of dedication and competence of staff to enforce the law is quite evident among the governing bodies. An example of this is in corruption, which is widespread, whereby the planning authority will pass illegal structures in order to get money from the individual. This corrupt practice has led to conflicting land use such as the increasing construction of commercial structures on areas designated for housing, and the case in Festac Town, where illegal structures were built on land identified as floodplains or natural drainage pathways etc. (Aluko 2010). The regulatory authority ignores the numerous contraventions of town planning laws being committed by some developers in the state. The illegal siting of permanent structures on roads, and the shifting of building lines are carried out on a daily basis within Lagos, without compliance officers paying any attention. These are all contrary to what the law stipulates; this attitude is due to corruption and a lack of sense of responsibility brought about by the replication of duties in governing bodies (Aluko 2010).

According to Aluko (2010), the land use law is useless, and should be revisited to take into consideration informal land use, essentially for housing. The present inflexibility and inefficiencies of public land administration have promoted a situation where a high proportion of the city population with limited economic capacity to pay for public housing has engaged in the development of illegal and informal housing.

5.7.5 Flood risk management practices in Lagos

A review of Lagos Government flood risk practices is discussed below. This is essential because although there is no specific drainage legislation that sets the responsibilities, duties, authority and powers for the operation of drainage management in Nigeria, at the state-authority level in Lagos in the office of environmental services, a range of

strategies are in place to address different forms of flood management. These strategies are reviewed to investigate whether they support the frameworks identified from other countries which are applicable to Lagos for sustainable water management.

In mitigating the effects of flooding, the government of Lagos has adopted the following strategies:

1. Expansion of drainage facilities in the city: This strategy, put in place by the government, has seen the expansion and maintenance of primary drainage facilities. The central parts of Lagos, e.g. Bariga and Surulere, have all benefitted from this expansion in a bid to curtail flooding incidences. However, the shortcoming of this approach is that some of the drainage projects have not yet been completed and some suburban areas have not been included in the plans (Oshodi 2013).

2. Monthly environmental sanitation exercise by the community: This is enforced by the Ministry of Environment in Lagos. Every last Saturday of the month until 10 am, state residents are asked to clean up their environment; this involves cleaning clogged gutters and culverts. This activity is compulsory and regulated by the government; all movement is restricted and residents are asked to stay at home and take part in the cleaning exercise to enable the free flow of the drainage system after unclogging of these devices.

3. Annual clearing of debris from drainage facilities across the city: yearly, the government of Lagos through the Ministry of the Environment embarks on cleaning primary and secondary channels in the metropolitan areas. The deposition and collection of this debris from the drains is a consequence of both the indiscriminate disposal of garbage, and also siltation because the drains are left uncovered and has contributed to the failure of the existing drainage system. Again, this clean-up activity is only confined to the core urban areas of the state, excluding the majority of the peripheral urban areas.

4. Flood warning and advice to those living on the floodplains and in wetland areas to relocate: As the rainy season approaches, the government advises those living in flood-prone areas to relocate. This announcement is carried out through media jingles. Usually, evacuation or relocation plans that could guide such a relocation process, such

as where to relocate, and the nature of support for relocation etc., are not available. This leaves residents to decide on their best-considered approaches, most of the time therefore, the warnings are ignored because of a lack of alternative relocation areas. Instead, the residents stay to try and defend their homes and property from the flood.

5. Demolition of homes in informal settlements: In response to any major flood disaster in Lagos, homes in the flood-prone areas, especially in the informal settlement communities, are usually believed to be the major problem. Thus, it is judged necessary to demolish them, resulting in forced evictions and displacement of families, for example, the cases of the demolition of settlements in Agege and Ijeshatedo in August 2011, and Ijora-Badia in 2010, 2012 and 2013 (Oshodi 2013).

6. Proposed resettlement scheme for the residents of Ogun River catchment areas. The government, through the Ministry of the Environment in October 2011, informed the residents of Ajegunle community near Ikorodu to be prepared for relocation. The Commissioner for the Environment had assured the community that work would commence on the housing resettlement scheme before January 2012, citing land allocation problems for a delay in the project. Ajegunle is a peripheral urban settlement in the Northern part of the state under the Ikorodu division; a major community in the catchment areas of Ogun River. In the development plan of Lagos, the community and other adjoining locations were zoned as wetlands and for agricultural use. However, the lack of a clear implementation strategy for the plan, the huge housing deficit in the core urban areas, increased population and pace of urbanisation in Lagos finally led to the conversion of the area to residential use.

7: Proposed overhaul of existing drainage master plan: The government of Lagos, through the Ministry of the Environment, has developed a drainage master plan as part of proactive measures to tackle flooding in the entire state. The proposed master plan identifies major challenges and provides a framework to guide future development and investment. This should help unlock the sub-region's full potential while protecting and enhancing the natural environment. In its bid to achieve a sustainable drainage system, the government has prepared master plans to guide future development, which takes into consideration the implementation of SuDS. Of particular importance, is the

preservation of natural channels or floodplains where possible, taking into account all of Lagos, both formal and informal settlements (MOE 2015).

5.7.6 Summary

The role of governance in attaining SSWM cannot be overemphasised. Regulation, institutionalisation, policies and strategies put in place by the governing body act as a catalyst to ensure its consideration. The institutional impediments observed in Lagos are not uncommon and have been observed in various countries. Brown and Clark (2007) suggest that insufficient skills and knowledge, a lack of political will, organisational resistance, limited regulatory incentives, and unsuitable institutional capacity and arrangements, are significant impediments to this change.

Whilst the importance of governance/institutionalisation to attaining SSWM is recognised in the developed world, unfortunately from the review of governance in Lagos, it is evident that while some support the existing frameworks for SSWM for other countries, the application of this legislation in the government falls short due, in the main, to fragmentation of regulatory powers. It is therefore a priority in the proposed framework to include the creation or enactment of legislation and regulation that would promote and sustain the transitioning of Lagos to SSWM. The following section therefore describes the development of a framework in the Lagosian context to encourage the city to consider SSWM in its planning processes.

5.8 Framework design

5.8.1 Introduction

The framework provides a strategic phase-by-phase plan to change the current surface water management system into a sustainable one for the future. The framework aims to guide all stakeholders in the water management field on how to transition from what is currently available as regards surface water management to what can be achieved with SSWM. For this transitioning to take place, a shift in paradigm relating to the management of rainwater in this region needs to occur. In addition, the government needs to realise that flooding is a real problem that requires urgent attention and recognise and integrate the informal settlements into planning by the government when making decisions on surface water management.

For the transitioning of informal settlements to SSWMs to be successful, a bottom-up approach to managing stormwater is most appropriate and therefore needs to be undertaken. Communities need to be enabled to manage the runoff themselves, albeit it may be a short-term solution. This can be achieved by the implementation of simple SuDS.

In order to begin to build a framework, a visionary diagram has been adapted from Brown *et al.*'s (2008) Water Sensitive City framework which has been contextualised to suit the situation in Lagos. The aim of this was to give a pictorial description of where the informal, as well as formal settlements, fall within the framework. It also goes further to show where they should be to attain SSWM. The literature has shown the importance of the contextualisation of terminology to negate any form of confusion or misconception by the target audience (Brodie *et al.* 2007; Armitage *et al.* 2014). This framework is not exempt and terms have been contextualised to suit Lagos. For the ease of readers these contextualised terms have been defined below.

SuDS: for the purpose of this research because informal settlements are given priority the use of *urban* within the concept of sustainable *urban* drainage systems has been taken out. SuDS in this context are sustainable drainage systems.

Water Sensitive Cities: now referred to as Water Sensitive Settlements (WSS).

Simple SuDS: They include the use of indigenous raw materials to design SuDS devices that are effective in the management of excess stormwater yet are cost effective. They include the use of rainwater harvesting, swales, filter or gravel strips, sandbags etc.

IS: Informal settlement.

FS: Formal settlement.

For better understanding, the different settlement types within the visionary framework have been highlighted:

Water supply settlement: this can be described as one that is able to provide safe water to its residents.

Sewered settlement: this is a settlement that may have transitioned from being able to provide safe water for its residents to be able to treat wastewater i.e., sewage schemes. Lagos is a combined sewerage scheme. Most developing countries fall into this bracket.

Drained settlement: this can be described as one that is able to manage its surface runoff to an extent by transporting the water to receiving water bodies with the use of command and control methods which comprise conventional drainage devices such as gutters, canals etc. Some developing countries fall into this bracket.

Waterway settlement: a settlement that has realised that these command and control methods are not sustainable and has therefore adopted alternative sustainable methods to manage surface runoff. These settlements no longer perceive stormwater as a nuisance; instead, it is recognised as a resource that can be tapped into. Hence the implementation of devices designed around the SuDS concept.

Water cycle settlement: This is a futuristic settlement that plans for the continued provision of sustainable water management systems to cater for the ever-increasing population and as such urbanisation. Even developed countries are yet to attain this settlement type (Lobina 2010).

Water sensitive settlement: This is the aspiration of most developing and developed countries. In this phase, the prevalent approach to water resources management is composed of a combination of adaptive, multifunctional infrastructure and urban design reinforcing water-sensitive behaviours (Brown *et al.* 2008).

5.8.2 Where we are now

When planning for a sustainable future, stakeholders need to know where they are, where they want to arrive at and how to get there (Brown *et al.* 2008). With this in mind, it is essential to identify where the city of Lagos falls on the transitioning to WSS diagram. To achieve this, the field visit to the study area enabled decisions to be taken of where to place Lagos on that diagram. The field investigation, observations, questionnaire administration and interviews carried out in the field for data collection purposes are given in Chapter 3. The target population comprised all stakeholders, which included residents of the community, community heads, government officials from the Ministry of Environment, drainage engineers etc.

From the results obtained it was found that most if not all informal settlements in Lagos fall on the far-left of the WSS transition diagram, much before the first phase of being a water supply city. This is due to the fragmentary and in some cases non-existent basic infrastructure in the settlement. Upon investigation of the current water management practices in these locations, the problems and issues that have resulted in poorly performing and unsustainable water systems in the settlements became clear. The conventional command and control methods of managing surface runoff can be observed all over Lagos. In any case, even the use of these conventional methods is almost non-existent in some of the informal settlements but that some simple sustainable techniques to combat flooding were being utilised. Unlike the Water Sensitive City framework that advocates the transitioning of settlements from one phase to another in a linear progression, leapfrogging is highly encouraged to allow a bridging of the wide gap that exists between developed and developing countries with regard to surface water management. Figure 5.5 depicts how the formal settlements of Lagos fall just outside the sewered settlement and into the drained settlement, while the informal settlements fall further to the left outside the diagram.

Figure 5.5 Visionary Diagram adapted from Brown *et al.*'s 2008 framework to achieve a Water Sensitive City

5.8.3 Where we need to be

The transition to a WSS is beyond the scope of this research, but transitioning to a waterway settlement to attain SSWM, as indicated in Figure 5.5, is the aim of the framework and has been attained by most of the developed world.

As illustrated in Figure 5.5, informal settlements are not even on a par with the formal settlements with regard to managing water. To attain transition for the informal settlements, an adaptive system of management or leapfrogging should be included from the outset. According to Pahl-Wostl *et al.* (2007), an adaptive management procedure is a systematic process for improving already existing policies by considering and learning from the experience of those existing previously. Lessons can be learned from countries that have adopted this alternative system, and as such, studying them can lead to a smooth transition. It would be easier for these settlements to successfully reach a sustainable water goal than for the formal areas, which would require retrofitting to attain SSWM. The reason for this is that the informal settlements can be considered a blank slate, so they can begin with a clean start. Very little has been invested by the government to better the lives of the residents of these informal settlements, so it would be easier to implement SuDS here than in already existing, built-up settlements that would require a more complex and expensive retrofit if SuDS devices are to be employed to manage runoff. It cannot be overemphasised how important it is to show stakeholders when planning for a sustainable future where they are coming from and where they need to be, this puts into perspective what needs to be done to achieve the desired destination (Brown *et al.* 2008). Therefore, in order to capture the stakeholders' interest and get them on board with the plan, this visionary diagram has been adopted.

5.8.5 Framework to transition Lagos to sustainable surface water management

In order to create a framework, some questions have been formulated to ensure the identification of appropriate strategies to be applied within the framework. These include:

- How did we get here?

Recognition of the fact that the way water systems are managed is expensive, inefficient and unsustainable.

- Where are we going?

The realisation that there are newer and better ways to address water supply and sanitation problems, or to drain a city in more holistic and integrated ways.

- How are we going to get there?

Transition - a *'radical'* switch from one type of socio-technical system to another.
Transitioning – a new approach to influencing change towards more sustainable futures (Duffy and Jeffries 2011).

With this in mind, further specific questions that would ensure the framework is applicable to the study area were identified.

Who is this framework designed for and for what?

The framework is designed for all stakeholders in the stormwater management system. They include the residents of both formal and informal dwellings, government officials in charge of drainage in Lagos and community leaders. It is designed to ensure the transition from existing systems to an efficient sustainable alternative.

What is the problem?

The inability of the existing drainage system to manage surface runoff, leading to flooding, mostly of informal settlements, and environmental degradation.

What can be done to solve this problem?

Implementation of alternative sustainable surface water management system that will transition Lagos to SSWM and thus ensure the proper sustainable management of surface water.

What steps will be taken to solve the problem?

A framework designed for the implementation of relevant phases identified from existing frameworks.

What is the guarantee that this framework will deliver what it promises?

A phase-by-phase evaluation, with indices to indicate the success of each phase as it is delivered is required to ensure proper implementation, as well as an evaluation of the framework by field experts.

The overall aim of the framework is to create a tool that can be used by stakeholders to assist in the transitioning of Lagos to SSWM, with emphasis on the informal settlements. This is therefore clearly addressing Aim 2 of the research.

5.8.6 Components of the framework

The framework is made up of four phases, and like some of the reviewed frameworks above, is continual or cyclical in nature, allowing for a feedback loop. This is necessary because of uncertainties that might occur in the future, e.g. changes in community priorities and expectations, therefore water management will need to evolve in response to these changes.

1. **Knowledge/Change phase**: The purpose of this phase is to enlighten the stakeholders so that they realise and recognise that flooding is a problem that needs to be addressed. This phase locates the settlements on the existing WSS framework designed by Brown *et al.* (2008). The intent of this is to create a better understanding of the whole essence of the framework. It also draws the stakeholders' attention to the fact that the existing conventional drainage methods in place to manage runoff are not only failing but unsustainable. Hence the need to seek alternative methods to address the problem. This phase calls for a shift in paradigm from the use of command and control conventional drainage methods to manage excess runoff to the use of a system that considers water quantity, quality, biodiversity, as well as an amenity when managing surface runoff, i.e. the use of SuDS as detailed in, for example, Woods Ballard *et al.*, 2015.

   This shift in paradigm for handling and managing excess runoff sustainably has recorded great success in developed countries such as Germany, the UK, the USA and Australia as described in section 2.13.

2. **Strategic Phase**: At the strategic level, short- and long-term goals are deliberated and agreed upon. This level encourages communication between stakeholders as it requires them to collaborate in order to deliberate and decide on set goals. It also enables a cross-institutional platform to develop of stakeholders from different backgrounds bringing different expertise, knowledge and experience or inexperience to the debate. It would entail the occasional coming together of stakeholders in a learning enhanced forum to be educated on ways to sustainably manage runoff and also share information. This is a crucial phase in the framework as the encouragement of participation and interaction between stakeholders in a water management system ensures the continued sustainability of that system (Brodie *et al.* 2007).

3. **Tactical phase**: This is an essential phase as it is where activities such as institutional considerations, which consist of institutional networking, negotiations, planning and reviewing of existing governance to support the transition are carried out. It is recognised that the existing governance in Lagos does not support SSWM, therefore a revisit of the legislation is essential as it has been identified as a driver to achieving SSWM (Hoyer *et al.* 2011). This phase also comprises the implementation of leapfrogging or adaptive management concepts to enable informal settlements to transition at a quicker rate, drawing from the experiences of others. According to Armitage *et al.* (2014), leapfrogging is a concept being used by developing countries or in redeveloping settlements to increase the speed at which they transition to a set goal.

   This phase allows for deliberations and agreements to be made on what phases to leapfrog or transition through to attain SSWM. It also enables the deployment of suitable SuDS devices as benchmarks to assess their effectiveness, which may lead to a wider application should the pilot be successful. For wider applicability, the implementation of a pilot SuDS should be undertaken, but only after experts have deliberated and decided upon relevant techniques that are site specific as they relate to the SuDS selection criteria for each different location. See Figure 4 in Appendix 7 Section 9.5.1 for a site-specific SuDS guide. At this stage, the feedback loop is applied from the results obtained from the pilot. It

provides feedback on what changes are required to enhance the implementation and success of SuDS.

4. **Implementation and maintenance phase:** This phase involves the wider application of SuDS after the deployment and assessment of the effectiveness of the pilot, and if it has been successful. Implementation and maintenance are only possible with a balanced mix of policy and stakeholder investment in terms of financial resources and human capital. The inclusion of a monitoring and maintenance structure in any framework cannot be overemphasised (Brodie *et al.* 2007). In order for SSWM to be achieved in Lagos, the continued maintenance of deployed SuDS devices, either privately or collectively via community engagement, is essential to their sustainability and continuity. The setting up of a monitoring body is suggested to oversee the maintenance of devices across Lagos. In the informal settlement context, a coming together of sections of society, such as the youth to monitor the maintenance of the devices deployed may be possible. The local government, via regulation, can appoint regulatory bodies to monitor and oversee the smooth running of the devices. This phase also makes provision for a feedback loop back to the knowledge and change phase and as such the enhancement of a reflective framework.

These phases have to be passed through and not one is more essential than the other; equal priority has to be placed on all phases to achieve a successful transition. Based on the criteria identified earlier on in this chapter to the designing of a user-friendly framework, it has been designed to address all the criteria. The transition framework for Lagos developed by following these phases is presented in Figure 5.6.

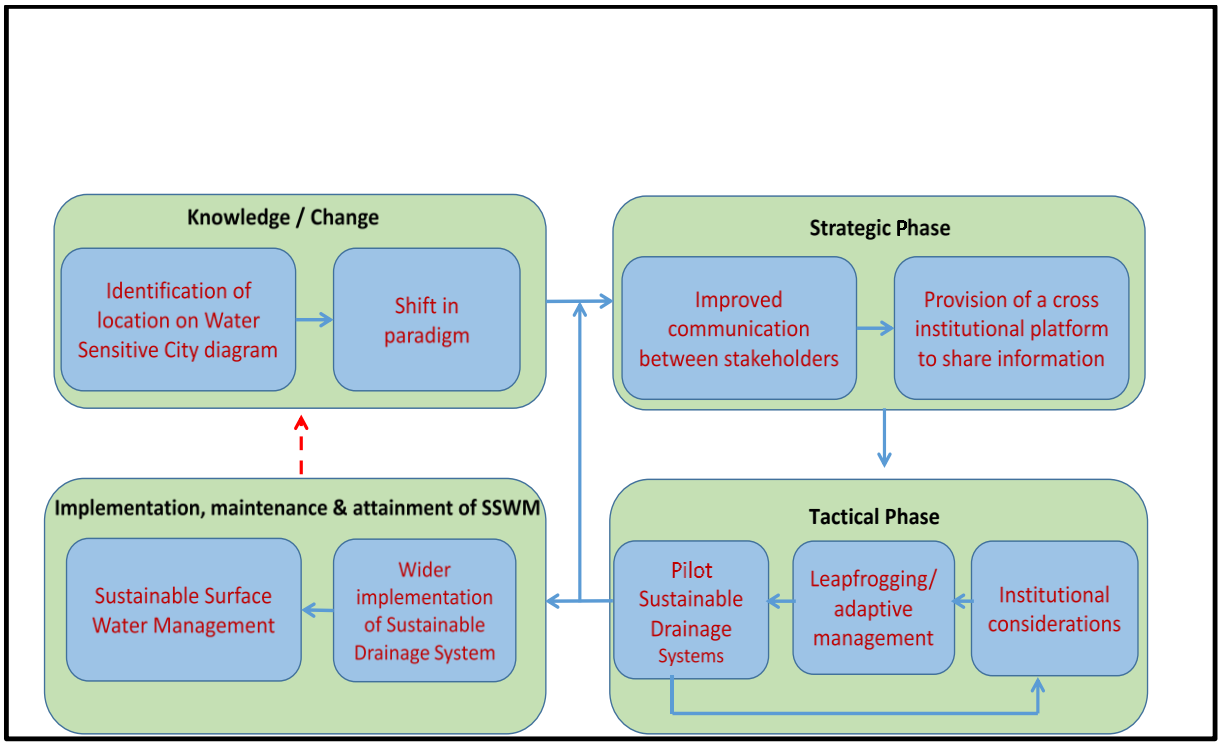

Figure 5.6 Lagos Sustainable Surface Water Management Transition Framework

5.9 Application of the framework to Lagos

The response to flooding incidences in Lagos tends to be extremely slow, exacerbated by informal settlements being perceived by the government as being illegal. If SSWMs is to be achieved in Lagos, the informal settlements' management of runoff has to be addressed because the management of runoff has knock-on effects. For SSWMs to take place, the government needs to realise that water management cannot be handled in isolation. It requires the inclusion of all of Lagos to attain SSWM.

Therefore, with this in mind, the application of the framework to Lagos has two routes to achieving SSWM, with different time scales. These routes comprise the informal and formal settlements and are a function of the attitude of the governments to both settlements. However, for SSWM to be achieved in Lagos, both settlements have to transition towards it with an acknowledgement that governance that will influence SSWM in a formal settlement is different from that required in an informal settlement. The developed framework does not differentiate between the settlements, as the same stages have to be undertaken by both. However, while in the case of the formal settlements mostly retrofit SuDS in addition to simple SuDS will be deployed, the

informal settlements will transition by implementing simple SuDS. Leapfrogging is an added advantage for the informal settlers in pursuit of SSWM. If applied properly it can place them on a par with the formal settlements. As indicated earlier, the informal settlements have been given priority in this research, which is why more emphasis has been placed on the implementation of simple SuDS.

In order for this to be achieved, an overhaul of existing policy is required. The government's behaviour towards informal settlements needs to change because it is arguable that these informal settlers have located their dwellings in environmentally vulnerable areas because the government has failed in its duty to protect its citizens. The influence of existing policy and legislation is implicated in the spread of slum developments. As indicated in Section 5.7.4, some policies, e.g. the Land Decree Law, has acted against the citizens by making land unattainable, a complex set of procedures and expensive. Also, the Urban and Regional Planning Decree, which enacted the creation of schemes to build residential homes within the state, has added to the proliferation of slum dwellings. These houses built by the government were not affordable so citizens needed to seek out cheaper affordable dwellings, which led to the development of slum areas. It is therefore not unreasonable to suggest that the government should try to right a wrong that they themselves caused. Taking account of the fact that these informal settlements need some buffer to assist them with coping in the raining season is not too much to ask of a government whose priority is to protect its citizens. The readdressing of legislation to support proper management of storm runoff in their favour, instead of simply requiring them to be evacuated without a plan to relocate this less- privileged section of society is long overdue. It is a step towards driving the implementation of SuDS and as such the attainment of SSWM. The engagement of all stakeholders is also key to achieving SSWM in Lagos. As indicated in Section 5.7.4, the institutionalisation relevant to stormwater noted that the law made no provision for community participation in planning, hence the reluctance to take responsibility. This framework encourages and places emphasis on all stakeholder inclusion and interaction in achieving a sustainable surface water management. It is hoped that the application of this framework, if carried out accordingly, will encourage the prospects of a sustainable and equitable future.

5.10 A method to ensure implementation and success of the framework

The proposed transition framework has identified the community focus for this framework as all the stakeholders of surface water management. As discussed, they include all the residents of the areas, as well as field experts, policy makers and enforcers. They make up the core components of this framework, and their views and observations have been reflected in it. It is necessary to evaluate phase by phase the components within the framework to ensure its success and implementation. For this purpose, indicators have been established to determine the success of each phase; this is presented in Table 5.1. It defines how all of the components work together to realise the framework's implementation goal.

5.11 Overview of frameworks adapted in proposed transition framework

Table 5.2 summarises the key components that have been adopted from all four frameworks to design the proposed transition framework for Lagos. Even though the framework for Lagos has been designed by adopting ideas from existing frameworks, its originality is based on the prioritisation of informal settlements to attain SSWM. Furthermore, it is adaptive and applicable for wider use, unlike most frameworks, which are mostly developed world oriented and do not consider limitations peculiar to developing countries such as poverty and the lack of government support via funding to deliver basic amenities (Armitage *et al.* 2014). The Lagos framework considers these issues and emphasises the use of cost-effective simple SuDS to drive SSWM. As such it can be adopted by both developed and developing countries alike.

Table 5.1 Implementation and Success indicator

Phases	Champions	Processes	Indicators
Knowledge Phase	All stakeholders	Field visit: Focus group meeting, interview sessions	1a, 1b, 2 *Phase is deemed successful if achieved
Strategic Phase	All stakeholders	Meeting sessions agreed on by all stakeholders e.g. quarterly, yearly meetings	1b, 2,3 *Phase is deemed successful if achieved
Tactical Phase	All stakeholders	Institutionalisation, deployment of pilot SuDS	1b, 3, 4, 5, 6a,6b and 6c *Phase is deemed successful if achieved
Implementation Phase	All stakeholders	Wider deployment of SuDS devices, Maintenance of SuDS devices	3, 6a, 7, 8a, 8b, and 9. *Phase is deemed successful if achieved

[1a]Stakeholders consent status. If consent is granted this implies willingness to learn and to realise that a change is required.

[1b]Observation: If attitude towards idea of effecting a change is positive, if not educate further and observe again.

[2]Questionnaire/interviews that establish respondents' wiliness to adopt SuDS.

[3]Continuous engagement of all stakeholders in decision making in SSWM, via meetings and deliberations.

[4]Revised legislation and policies to support SSWM: e.g. defragmenting of water management bodies, creating SSWM regulations for all settlements, not just those newly developed, revisiting the land use act, giving power to the local authority, inclusion of community participation within the law.

[5] Significant improvements in flood management strategies.

[6a] Evaluation and investigation of site and site conditions for SuDS selection.

[6b]Siting of pilot SuDS across the study area, evaluating deployed SuDS for their effectiveness and efficiency in managing runoff.

[6c]Significant effective management of runoff in pilot SuDS deployed areas.

[7]Increased siting and deployment of SuDS by government and community members.

[8a] Continued positive attitude to SuDS implementation. Good housekeeping: Free-flowing drainage devices, clean environments.

[8b] Creation of monitoring bodies to ensure maintenance.

[9] A significant improvement in runoff quantity, quality and improved quality of life.

Table 5.2 Overview of Key Components from Original Frameworks Adapted in the Proposed Lagos Transition Framework

Framework	Encourages implementation of SuDS	Emphasis on Governance to ensure SSWM	Emphasis on Adaptive management /leapfrogging to attain SSWM	Stakeholder Inclusion & participation as Driver of SSWM	Visioning	Reflective/ Iterative	Contextualization of terms	Developing country oriented	Informal settlements prioritized in framework	Emphasis on Pilot	Adaptive /wider applicability
Adaptive management framework for connected water resources (Brodie et al. 2007)	O	X	X	X	O	X	X	O	O	X	O
Transitioning to a water sensitive city (Brown et al. (2008	X	X	O	X	X	X	O	O	O	O	O
Darwin harbor framework. (McAuley et al. 2009)	X	X	O	X	O	X	O	O	O	X	O
Framework for water sensitive settlements in South Africa. (Armitage et al. 2014)	X	X	X	X	X	O	X	X	O	O	X
Transition Framework for Sustainable Surface water management	X	X	X	X	X	X	X	X	X	X	X

Key -X: Yes
O: No

5.12 Summary

This chapter detailed the development of a four-phased iterative framework which would ensure transition to SSWM in Lagos. It was designed for its wider applicability in similar LDCs hence it was designed based on an adopted 9-design criteria (see Section 5.1) to aid in its wider applicability and adaptability. The framework was adopted and built upon from four relevant frameworks, which accomplishes aim 2, objective 2.1. Legislation and governance have been recognised as drivers to the implementation of SuDS, therefore existing legislation in place in Lagos, as well as the lack of it to support, promote and maintain the designed framework was investigated. The findings reveal that while there exists certain legislation that can promote the implementation of SuDS, there are others that would act as a barrier, hence a revision of

legislation is required. However, before the review of existing legislation in Lagos was undertaken, an evaluation of supporting SuDS governance in developed countries that had successfully adopted SuDS was conducted. This was to enable the study to identify relevant governance that can promote the implementation of SuDS. Having designed the proposed framework, indicators to identify the success of the framework were identified. The following chapter discusses its evaluation and the processes undertaken to check its usefulness, as well as its wider applicability, while ensuring the credibility of the proposed framework.

CHAPTER 6: FRAMEWORK EVALUATION

6.0 Introduction

This chapter discusses the evaluation of the research framework designed for developing countries in Africa. It details the evaluation that has been undertaken to investigate the need for a framework and to assess whether it is fit for purpose. The final aim and associated objective 2.2 set out in Section 1.3 are achieved in this chapter.

6.1 Framework evaluation overview

The research presents a framework that has been developed to transition to SSWM in developing countries (mostly Africa). It uses informal settlements in Lagos, Nigeria as a case study for developing a SSWM system. It has been designed with the view of cost-effectiveness, efficiency, and adaptability.

The framework considered important factors that could affect implementation such as cost, flexibility, integration and users' requirements as described by Moody and Shanks (2003). The framework has been developed to overcome some of the main limitations brought about by urbanisation and existing water management practices as has been identified in the relevant literature. Having developed a framework, it is essential that it is evaluated and tested before it can be more widely disseminated; this serves as a measure to check the usefulness and appropriateness of the framework as a transitioning tool to SSWM. The evaluation process also serves as justification for the usefulness of a framework as it reveals the potential objectivity and reliability of the subject. Furthermore, it provides a solid background against which the research findings could be supported. In addition, evaluating the framework plays a vital role in its assessment as a useful tool.

Finally, the evaluation process helps to ensure that the research has actually identified key phases or stages that would ensure transition as well as implementation in other developing countries. In essence, this evaluation aims to establish the frameworks' ability to be implemented, its reliability, usefulness, and adaptability for stakeholders to address the current state of water management practices and activities and to guide to transition to SSWM successfully. The next section, therefore, describes the evaluation process as presented in Figure 6.1, and also the conclusions drawn from the findings.

The results of the evaluation and the way the framework was adopted due to these changes are also discussed.

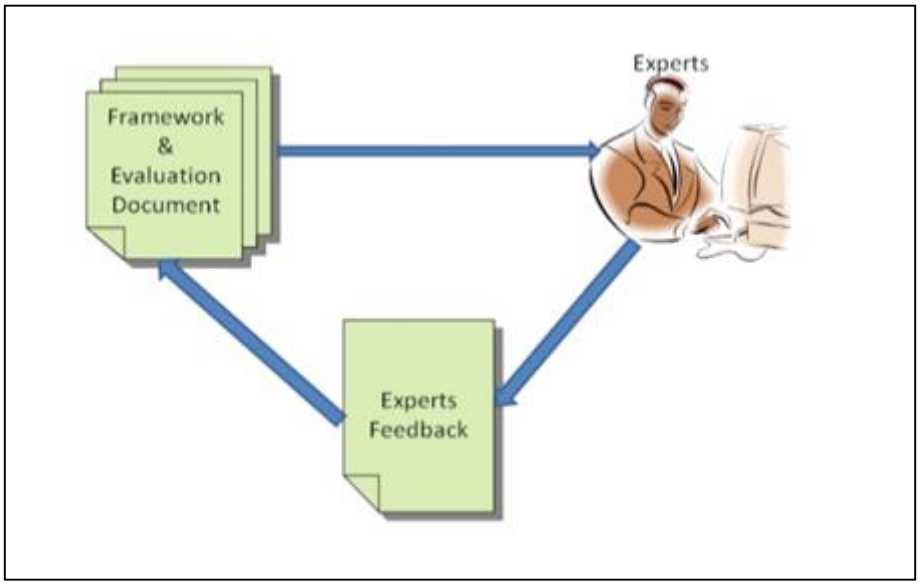

Figure 6.1: Framework Evaluation Process

6.2 Methods adopted

The evaluation process included the perspectives of some key water management stakeholders, presented in Table 6.1. The evaluation process was designed to test the use of the framework in three selected African countries, see Section 3.9.1. These stakeholders have critiqued and given recommendations on the designed framework as a means of evaluation. According to Moody and Shanks (2003) and Brodie *et al.* (2007), to ensure effective system implementation, stakeholders should be engaged in the evaluation process and in critical discussions of it. The following objectives were set out for the evaluation process:

1. Identify any improvements to the framework.

2. Identify changes that might be made in the application of the framework.

3. Serve as an evaluation method for the framework.

Table 6.1 Stakeholder Profile

Respondent No	Country	Organisation of respondent
1	Gambia	National Disaster Management Agency
2	Nigeria	Rivers State Ministry of Environment
3	Nigeria	National Environmental Standards and Regulation Enforcement Agency
4	Nigeria	National Environmental Standards and Regulation Enforcement Agency
5	Nigeria	Ministry of Land and Town Planning, Anambra State
6	Nigeria	Ministry of Land and Town Planning, Anambra State
7	Nigeria/UK	Independent researcher
8	Nigeria	Lagos State Ministry of the Environment
9	Nigeria	Lagos State Ministry of the Environment
10	Nigeria	Imo State Ministry of Environment and Health
11	Uganda	African Union of Conservationists
12	Uganda	African Union of Conservationists

6.2.1 Evaluation method and justification:

The method of evaluation consisted of the development of questionnaires tailored to capture views from stakeholders, and the applicability of the designed framework in their various countries; critical appraisals were also requested for the purposes of improvement. Evaluators were asked their opinion via a questionnaire, a copy of which can be found in Appendix 7 Sections 9.7.3., of what could be improved to ensure implementation. The evaluators' responses were then organised and analysed to produce a summary of their views. These views were then incorporated in the framework and the framework updated (Section 6.4, Figure 6.3a gives the revised framework).

The method adopted collated perspectives and critiques of the framework as a basis for revision and improvement. It also created an opportunity to obtain independent assessments with respect to comprehensiveness, clarity, conciseness, and correctness; which is a measure of its acceptability, applicability and final implementation.
Figure 6.2 illustrates the process undertaken to evaluate the framework

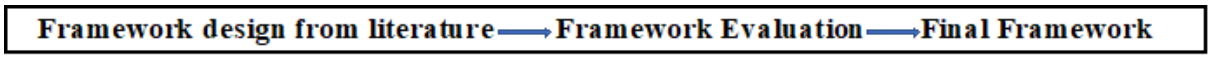

Figure 6.2 showing development of final framework.

6.2.2 Evaluator selection process: rational and justification

The rationale behind the selection process of evaluators was to identify stakeholders who were experts in the water management sector in each country (Singh and Kasavana, 2005; Sun, Li and Li 2013). During the selection process, an expert was defined as a professional who had acquired skills and knowledge through study and practices over time in a particular field or subject such that their opinion was helpful in problem-solving, finding facts, or understanding a situation (Liu and Zeng 2014; Business dictionary ND). A total of 26 experts were identified and evaluation documents sent out as shown in Table 3.3, Section 3.9.1; however only 12 were returned. According to Brockoff (1975), an acceptable number can be as little as four; also Kreber (2002) suggests that there is no generic benchmark for what constitutes the ideal number of experts to be included in an evaluation process hence 12 were deemed acceptable. The evaluators were all involved in influencing water management practices in their various countries.

The justification behind the selection of stakeholders was their expertise in the water management field as well as their ability to influence the acceptance and possible implementation of the framework. This ability was dependant on their positions in the water management hierarchy and was taken into consideration when assessing their responses, since the possibility of implementation had the potential be stronger should the framework have the support of experts in the field.

6.2.4 Summary of stakeholder comments and discussion

The questionnaire was designed to capture the evaluator's views on the appropriateness of the framework in terms of its comprehensiveness, clarity, conciseness, simplicity, adaptability and ability to transition the different countries to SSWM. In addition to written critiques, evaluators were asked to provide recommendations for an improved and more robust framework. In the event that an evaluator expressed dissatisfaction with certain aspects, the questionnaire was designed to seek further details, and also asked for suggestions of ways to make improvements.

Initial contact was made with potential evaluators by email inviting them to participate in the study; the questionnaire and a document describing the initial framework were

both attached. The evaluators were asked to return the document within two weeks; with a reminder email sent out before the due date.

The evaluators' responses were recorded, providing a summary to both scaled and open-ended questions; tables were then used to analyse responses. For each individual question, all comments and critiques were considered, reviewed, and evaluated in order to organise them. Responses for a question were first categorised into two groups:
(1) to be considered in framework revision or
(2) beyond the scope of the research.
Comments in the first group were then further classified into three categories:
(1) concerns that were repeated and/or seemed to be of major importance;
(2) concerns that were not so frequent and/or as major, and
(3) concerns that occurred infrequently and/or seemed less critical.

6.3 Evaluators' feedback

This section presents the changes made based on answers received from the questionnaires and how these changes evolved. This was an iterative process undertaken through internal critical reflection and exposure to external critique and feedback received from the evaluators. All changes identified below, have been incorporated into the revised framework shown in Figure 6.3a.

Q. 1: Are the explanations and rationale behind the transition framework concise and clear?

Responses: All respondents answers were positive

Discussion of the stakeholders' views: The stakeholders were all of the opinion that the rationale behind the development of the framework was presented concisely and clearly. This was important to ensure ease of adaptability, i.e. that the limitation of being difficult to understand because of the technical or ambiguous terms had been overcome.

Q. 2: Are the phases of the transition framework described adequately?

Response:	All respondents answers were positive

Discussion of the stakeholders' views: All 12 stakeholders agreed that the phases proposed had been adequately described in the information sent out. This was to ensure a clear understanding by stakeholders of the various processes or phases needed to be undertaken before transition to SSWM could be successfully achieved.

Q.3: Do you have any suggestions that you would like to make to revise the transition framework phases?

Stakeholder	Response
1	Communities and other partners to participate in the revision of the SSWM framework phases.
2	I think the first phase of the framework should be explained in more layman terms so that everyone who reads it can understand
3	No suggestion
4	No suggestion
5	Inclusion of a waste disposal system
6	No suggestion
7	Review/Evaluation stage
8	No suggestion
9	The maintenance of the current conventional methods of drainage should be discussed.
10	Inclusion of implementation of a functional wastewater management system to enable SSWM to work effectively.
11	Recommendation to create room for radical policy change in your design of the framework. Policies that can be able to drive change in the attitude of urban dwellers, planners, and implementers.
12	A need to consider existing ordinances, bye-laws in which the user groups comply with

6.3.1 Discussion of the stakeholders' views: This question yielded various recommendations from the stakeholders, some of which were considered to be beyond the scope of the research. However, there were issues raised that were felt to be integral to the development of a more robust, grounded and rounded framework.

Respondent 1 recommended that the communities and partners participate in the decision-making process within the framework. This was of utmost importance and was considered in phase 2 of the framework- the Strategic Phase -which involved decisions being made by the community as well as experts in the water management system, with

short and long-term goals deliberated and agreed upon. Also, within this phase cross institutional platform provision was advised, however, although this was reflected within the original framework, the term "cross-institutional platform" was re-worded in the revised version to reflect stakeholders' observation and make for easier comprehension. A call to further simplify the first phase of transition was recommended and this was taken into account. Stakeholders called for a waste disposal system to be put in place, which is beyond the scope of the purpose of this research, however, it is integral that for a SSWM to exist the need for a proper functioning waste disposal system exists, which is mentioned in the recommendation chapter, Section 7.1.2.

Respondents recommended the maintenance of existing current drainage to be reflected in the framework, and this has been included in the revised first stage as good housekeeping of existing methods, it has also been highlighted in Section 7.1.2. Respondent 7 suggested review be undertaken at the evaluation stage; when asked what this meant, they suggested that particular SuDS be suggested for the location where the framework was to be applied. In this case, again, it goes beyond the scope of the research, since Africa has varied terrain and site-specific characteristics and would require its own SuDS or SuDS management train to be designed. However, it is noteworthy to point out that a pilot SuDS is prescribed in the tactical phase to check the viability of selected devices before its wider application in the final phase. Respondents 11 and 12 recommended consideration of existing laws as well as the creation of policies that will serve as drivers to the implementation and longevity of SSWM. These were also considered in the framework design and were reflected in the tactical phase, which prescribes institutional considerations, however, these suggestions have been reiterated in Section 7.1.2

Functionality of Framework

Q.4: In your opinion are the concepts/processes in the framework flexible, adaptable, concise and easy to understand and implement?

Response: All respondents answers were positive

Discussion of the stakeholders' views: The ability of this framework to be adopted by various developing countries is an integral part of the success of the framework; each phase has to be to be flexible enough to be able to be applied to various situations. This gives an added advantage to drive implementation. All respondents were of the opinion that it was flexible enough to be adopted in their various countries, that the concepts and processes described were easy to understand and implementation would be relatively easy should the framework be approved by the government.

Q. 5: Do you agree with the processes described in the transition framework?

Response: All respondents answers were positive

Discussion of the stakeholders' views: All respondents agreed that the processes and stages described in the framework could transition to SSWM and also agreed with the order/ stages they followed.

Q.6: Owing to your experience and expertise are there any critical processes that you would like to incorporate in the transition framework?

Stakeholder	Response
1	To look into water harvesting projects for developing countries for sustainable development through resilience building and saving lives in drought committees/countries (e.g. aquaculture).
2	No response
3	The need to promote good sanitation and waste control practices. Avoidance of building construction in flood plains and waterways. awareness creation on causes, effects, and prevention of flooding.
4	Inclusion of creation of a sustainable waste management system within the framework
5	Inclusion of creation of a sustainable waste management system within the framework
6	No suggestion
7	Inclusion of evaluation process (of specific SuDS for the specific location)
9	Within the strategic phase, the continued maintenance of the existing drainage facilities and raise awareness on importance of keeping these drainage facilities free flowing
10	Incorporation of adequate urban waste management system in the cities of the developing nations in Africa. Any city with sub-standard waste management system cannot adapt to your framework
11	It will be important if your study could also focus on how SSWMs

	would deliver strong and resilient urban ecosystem for example wetlands which receive the amount of runoff and urban forests which controls stormwater through increasing its percolation rates in the soils.
12	Community component is missing

Discussion of the stakeholders' views: Responses about recommendations to be incorporated included the introduction of RWH which is already recommended within the framework. An evaluation process for specific SuDS for specific locations was also recommended, this has been reflected in the revised framework. Also, the promotion of good sanitation and practices, as well as inclusion of a functional sustainable waste disposal system and continued maintenance of it was recommended. While the latter is beyond the scope of the framework, it is further discussed in Section 7.1.2. Respondent 12 suggested the community component was missing; however, this is included at every phase of the framework, and without which it fails; participation by the community is what brings the framework alive and sustains it. The use of simple SuDS has been prescribed as a tool to attain SSWM; they are put in place on a personal and community level. Their maintenance and sustainability are ensured by community involvement alongside government legislation.

Transition framework flow process

Q.7: Is the process flow within the framework easy to understand and implement?

A: All respondents answers were positive apart from respondent 10

Respondent 10: It is not easy to understand because not all stakeholders are familiar with foreign existing frameworks adapted to design your current Adaptive Management Framework

Discussion of the stakeholders' views:

On reflection, the concerns of respondent 10 appeared less critical, since the framework had been adapted from "foreign existing frameworks" to suit the African context. Issues raised about unfamiliarity with adapted foreign frameworks have been critically evaluated in Sections 5.1-5.6. Also see Appendix 7 Section 9.7.2, where additional website links for literature were attached.

Q.8: Do you agree with the framework phase flow and concepts /processes described within each of the phases? If no, please critique as necessary?

A: All respondents answers were positive

Discussion of the stakeholders' views: All respondents were of the opinion that the phase flow and concept prescribed within the framework progressed in an agreeable order and worked well to deliver a successful transition to SSWM.

Q.9: What are your views on implementing a cross-institutional platform/learning alliance in the strategic phase of the framework? Do you think this will make a difference?

A: All respondents agreed it was a good plan

Discussion of the stakeholders' views:

All respondents were of the opinion that bringing together experts, researchers and multiple stakeholders to work together to create a set objective to attain transition to SSWM would create valid, robust results, whilst giving room for shared responsibility and accountability.

Q. 10: Within the tactical phase, what are your views on the implementation of SuDS devices as a SSWM tool and do you think the concept of SuDS will be accepted by stakeholders?

A: All respondents had similar opinions, in that SuDS were a viable tool to transition to SSWM. However, on the acceptability of SuDS by stakeholders, slight variations in responses occurred, however, most of them were positive.

Discussion of the stakeholders' views: SuDS was recognised as a viable tool for managing running runoff; all respondents were familiar with SuDS and were of the opinion that application of the approach could transition their countries to SSWM systems. However, when asked whether or not they thought it was an option that would be accepted by their various settlements, the responses, although mostly positive, were

less optimistic with regard to final implementation. When asked why this was so, responses mostly stemmed from political reasons i.e. it was not something the government would be willing to take on as a priority project.

Q.11: What are your views on revisiting existing regulations to prioritise and support the transition to SSWM as prescribed within the model?

A: All respondents shared similar views that the revisiting of existing regulation is integral to the transition to SSWM

Discussion of the stakeholders' views: All respondents were of the opinion that new laws and policies needed to be created in order to encourage the implementation and sustainability of transitioning tools such as the implementation of SuDS. Legislation was felt to be a driver to enable implementation of SuDS.

Q.12: Please provide your views on the concept of leapfrogging to attain SSWM.

A: The majority of the respondents thought that it was good concept, however Respondent 11 did not understand it and Respondent 7 thought it might be difficult to apply in some countries,

Discussion of the stakeholders' views: 10 of the 12 respondents thought leapfrogging would ensure a successful transition at a faster and possibly cheaper rate i.e. they agreed with Jefferies and Duffy (2011). Therefore, respondents mostly agreed that it should be an integral part of the framework. However, in response to respondent 7's view that it could be difficult for some countries to apply it, due to the lack of infrastructure in most African countries, leapfrogging would enable the avoidance of some of the problems encountered in developed countries when using conventional water management systems.

Viability of framework

Q. 13: Do you think the proposed framework can successfully transition your existing water management system to SSWM?

A: Respondents 1-11 were of the opinion that the framework could successfully transition existing water management to SSWM. However, respondent 12 was not sure.

Discussion of the stakeholders' views: This framework is designed to work in principle, in most developing countries in Africa the situation on ground includes political to cultural issues which require addressing to ensure the viability of the framework.

Q.14: Do you think there are any phases or processes that might not have been identified within the framework which would expedite its implementation?

Stakeholder	Response
1	The funding aspect is not mentioned anywhere and the implementing partners
2	No
3	No
4	Creation of a waste disposal system
5	No
6	No
7	Testing/trial and Evaluation stages
8	The importance of maintenance of the existing drainage facilities should be highlighted within the process. It cannot just be abandoned
9	Raised and continued awareness of the benefits of SuDS, responsibility, continuity and maintenance of SuDS should be discussed
10	No
11	Monitoring of indicators or measuring the success of the framework.
12	No

Discussion of the stakeholders' views: Respondent 1 mentioned funding, which obviously important, but is beyond the scope of this project, in particular since informal settlements are the main focus, and the lack of finances is a main characteristic of residents in such areas. The use of simple SuDS has been prescribed, which can be designed using basic indigenous materials which are affordable and sometimes cost next to nothing, e.g. rainwater harvesting consists of the use of containers owned by the household. The absence of implementing partners also goes beyond the scope of this research, as the framework has been designed to transition communities without any external aid or influence. Government influence is however fundamental to

implementation and sustainability since revision of existing legislation is an integral part of the transition process. Respondent 7 mentioned a testing/trial stage- this is reflected in the pilot phase as has been discussed above. Respondent 8 requests maintenance of the existing drainage system to be included in the process; this has been considered and is reflected in phase 1 under good housekeeping. Respondent 9 highlighted the need for the continued awareness of the various benefits of SuDS; this is a very important aspect, was reflected in the final phase of implementation and is discussed in more detail in Chapter 7. Respondent 11 mentioned the need for monitoring indicators to measure the success of the framework. This framework is yet to be tested, however success indicators have been established in Section 5.10, based on frameworks in other countries that were reviewed in Chapter 5 (Armitage et al 2014, Brodie et al 2007). Finally, several countries around the world have implemented SuDS successfully as discussed in Section 2.13. The implementation of SuDS as a tool to attaining SSWM is the major driver to achieving the set goal in this framework.

Q. 15: What are possible problems that can impede the implementation of the framework?

A: Respondents were similar in attributing politics, policy, collaboration among stakeholders, current waste disposal system, poverty, funding and climatic condition as issues which might potentially hinder framework implementation.

Discussion of the stakeholders' views: As expected, most of the respondents attributed the impediment of the implementation of the framework to politics. Most governing bodies in Africa do not perceive flood as a priority especially for areas/ settlements that are informal. Funding and the lack of it was also an important factor that would act as a barrier to the implementation of the framework. These were however considered in its design, with the prescription of a learning or deliberation platform in the framework, and experts being given the opportunity to put the case for SuDS before governing bodies. With its control on policy, and once it understands SSWM, government can encourage the use of SuDS in the implementation of the framework. As mentioned above, locally sourced materials are advised to be used to ensure cost-effectiveness, so funding issues have been considered and initially should not pose a major barrier.

The collaboration among stakeholders was also mentioned as a barrier; studies have shown that stakeholders need designated responsibilities to engender a sense of obligation so that they work together to ensure success of the project. This is where the tactical phase plays a vital role in the success of the framework as a transition tool. Differences, as well as ideas to promote SSWM, need to be discussed by stakeholders who can then come to an agreement favourable to all parties.

The current conventional methods of command and control were also mentioned as a barrier; this cannot be overlooked as it is an integral part of the communities. However, it is important to highlight that the communities visited in the field study had the opinion that these current systems have failed in their design and that the settlers were open to try new techniques. It would be unrealistic to abandon the existing drainage system, but both systems can be integrated in the short term whilst SuDS can continue to be installed in the long term.

Implementation

Q.16: Do you have any suggestions for how the framework might be introduced in a more coherent and simple manner

Stakeholder	Responses
1	No suggestion
2	Making it available in the local dialect will make a difference
3	Provision of introductory letters to sensitize stakeholders about their respective duties
4	Making it available in the local dialect will make it simpler
5	Making it available in the local dialect will make more acceptable to the community
6	Making it available in the local dialect will make it simpler
7	A pilot study and formal discussions with stakeholders
8	No suggestion
9	No suggestion
10	Making it available in the local dialect will make a difference
11	Making it available in the local dialect
12	Making it available in the local dialect

Discussion of the stakeholders' views:

Of the 12 respondents, 7 advised that the framework is translated to the local dialect of the areas where it is to be adopted for better understanding and acceptance of the

framework. This has been left to the discretion of the various countries that choose to adopt the framework. There are several languages spoken across Africa, the opportunity for misinterpretation, errors or terms being lost in translation are high. However, since Lagos was the study area selected for this study, a translation of the framework into Yoruba has been carried out and attached in Appendix 7. See Section 9.7.4. Figure 5.

Respondent 3 recommended an introductory letter be formulated informing those involved in implementation of their roles; this goes beyond the scope of the study but has been mentioned in the recommendation section. Respondent 7 mentioned carrying out a pilot study to determine the selected SuDS to be applied, this is site-specific and goes beyond the scope of this study, the piloting and selecting of appropriate SuDS should be carried out in the various countries the framework is adopted. Respondent 7 also advised on a formal discussion with stakeholders to ensure understanding. In this instance a formal discussion was carried out with stakeholders in Lagos concerning the implementation of SuDS, its benefits, and maintenance.

Q.17: Given the completed concise framework, would you be willing to implement the proposed transition framework?

A: All respondents answers were positive

Discussion of the stakeholders' views:

All 12 respondents responded positively, stating they were interested in putting the completed framework forward to the responsible bodies in their countries.

Q.18: Do you perceive any dispute that may arise from stakeholders with regards to the possible implementation/acceptance of the framework?

A: All respondents were of the opinion that disputes/barriers may arise

Discussion of stakeholders' views:

Respondents advised that disputes may arise from resource sharing brought about by budgetary allocation in the informal settlements; they also stated that the framework may conflict with other political mandates. The latter may include for example, conflict over existing conventional drainage as well as a lack of political interest, since flooding

issues are not perceived as priority in most developing African countries. Furthermore, respondents also stated that a possible review of policies may affect some units of government, as they would no longer be needed as the framework will effectively manage their duties, i.e. the perception that the implementation of the framework will identify and remove replicated duties among staff in the existing water management units. Stakeholders in these units may therefore be against the framework, and as such pose a barrier to its implementation. While the proposal of this framework is not political in approach i.e. job creation or the loss of it by the government implementation of SuDS, its purpose is to deliver SSWM and the defragmenting of monitoring bodies to eliminate replication of duties is necessary to ensure accountability and responsibility.

Q.19: If yes, how can the barriers to the possible implementation/acceptance of the framework be overcome?

A: All respondents gave responses on how to overcome the barriers: See also Section 7.3.2 where some of these views have been reflected as recommendations.

Discussion of stakeholders' views:

Stakeholders advised that the barriers to the framework discussed in question 18 were likely to occur owing mainly to a gap in knowledge of SuDS. However, to overcome barriers to the implementation of the framework, there has to be education and re-education of all stakeholder on the importance of why this framework is necessary, the importance of SSWM, why SuDS is a better alternative and also the understanding of SuDS devices and their maintenance. Stakeholders advised this can be achieved by having regular meetings with representatives of the stakeholders who can then disseminate the information throughout the community. This however has been accounted for within phase 2 of the framework, where a learning platform is incorporated to share and pass down SuDS knowledge and technological know-how. This continuous re-education of stakeholders would ensure SuDS benefits are reiterated in these meetings. Key personnel within the community need to be trained to chair and where necessary educate stakeholders during the meetings. Evaluators also recommended that these meetings will also give stakeholders a sense of responsibility and inclusion, as gate keepers can be appointed at this meeting to ensure the

implementation and maintenance of the SuDS. It was recommended that these regular meetings to educate stakeholders are carried out in forms understandable by the target audience as much a possible describing terms and concepts relatable to their day to day activities, this is to ensure clarity and understanding. The use of the media, flyers and poster in local dialects were also recommended to introduce the community to the concept of SuDS. Evaluators also recommended the introduction of incentives to further encourage implementation of the framework, such as the provision of tanks for communities who wanted to start rain water harvesting, the provision of plastic pipes, basins and containers to store rainwater would encourage the acceptance of SuDS.

On overcoming the barriers of resource sharing, evaluators advised that this can be overcome by implementing cost-effective SuDS which do not require government intervention to execute. However, with all the stakeholders being educated on the importance of SSWM, stakeholders including the government will come to realise that SSWM cannot be achieved if only formal settlements are catered for, hence the inclusion of informal settlements in budgetary allocations to cater for SuDS and SSWM.

On overcoming barriers of conflicts with political mandate i.e. conflict over existing conventional drainage, this can be deliberated upon during these recommended meetings where the application of the framework will be presented as a complementary tool to work alongside existing drainage systems to manage flooding, and not being perceived as a competitor. The presentation of the framework to work alongside existing drainage, as against calling for an overhaul of the conventional drainage system will make it more acceptable thus overcoming that barrier.

The barrier of fear of the framework identifying and removing duties being replicated can be overcome by informing these stakeholders that implementation of the framework can create more job opportunities. While it will enable the removal of replicated duties, job creation is possible since implementing the framework would require a work force to ensure its installation and maintenance. Existing staff within the water sector can be trained to be SuDS experts giving advice and carrying out maintenance and inspections where necessary, they can be enforcement officers etc. It would also create job opportunity for the residents, e.g. appointment of gate keepers amongst the community members to ensure SuDS continuity.

Q. 20: Are any cultural changes required before the implementation of the framework?

A: All respondents gave varying responses

The responses varied from the request for the framework to be translated into various dialects (which was already addressed in Question 16) to the manner by which information was disseminated amongst stakeholders. The cultural changes highlighted by the evaluators were relative to their various countries, and as such goes beyond the scope of this study. Therefore, any cultural changes required for implementation of the framework will be left to the discretion of implementers to revise the framework in accordance with existing cultural diversity in the community. The next section presents the final framework.

6.4 The final framework

The framework was adapted and developed from reviewing existing relevant frameworks and results from analysis of qualitative and quantitative research. This has enabled the developed framework to encapsulate and build upon the ideas and concepts gained from the literature review of existing frameworks in the developed world; it was then tailored to suit the current situation in developing countries, particularly Africa, and thus presents a coherent framework to guide in successful transition to SSWM.

Evaluation of the framework has resulted in changes to certain components. It is clear from the feedback, however, that SuDS is perceived as a tool to attaining SSWM and that implementing the framework has the potential to successfully transition developing countries to SSWM. This will be achieved by adapting the framework to suit the needs of the various countries. The framework is flexible enough to be applied across African countries without altering the structure. The revised framework has been further contextualised to suit the target audience, including rewording of seemingly complex terms to be further simplified in order to ensure clarity.

This newly revised framework is supported by theory and exposure to critique, offering improvements over existing frameworks adapted to successfully transition developing countries in Africa to SSWM. Figure 6.3a illustrates the revised framework, where the changes/rewording recommended from the evaluation process have been reflected. This

is further compared against the original framework shown in Figure 6.3b, to highlight the changes made.

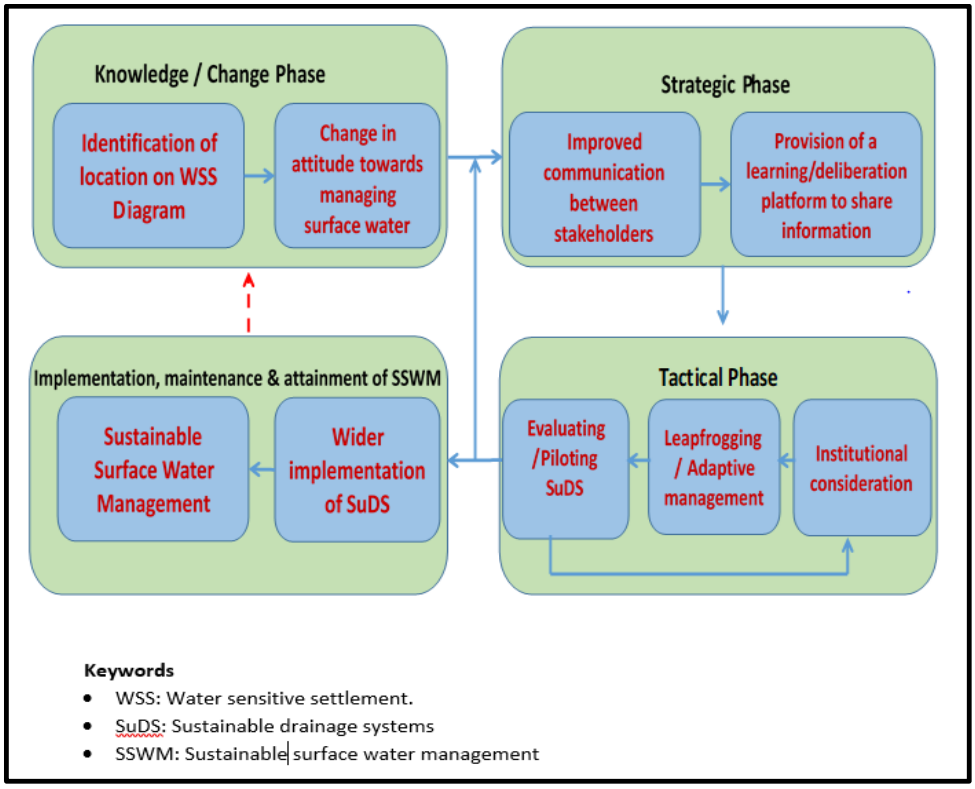

Figure 6. 3a Revised Transition framework.

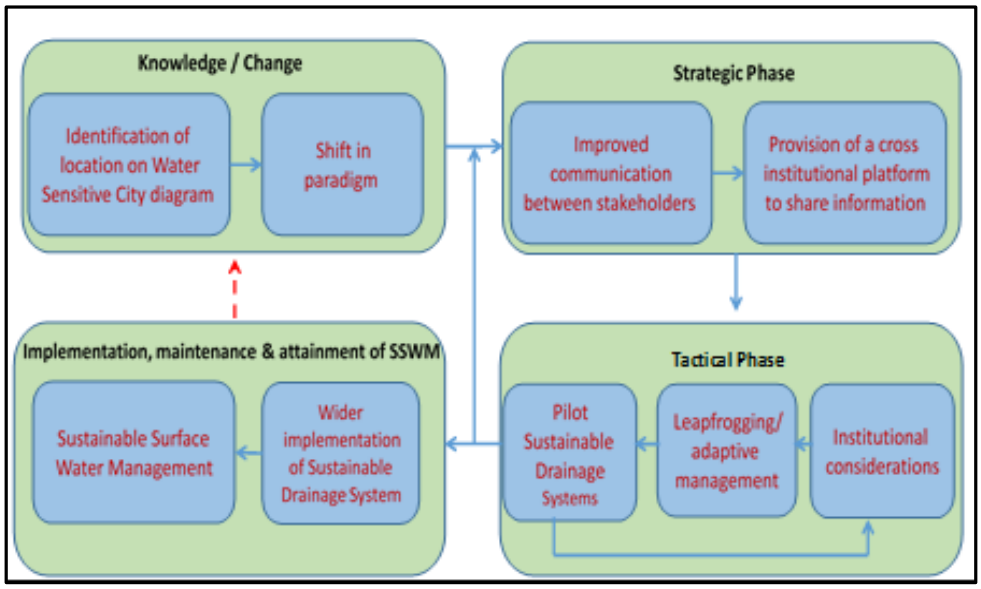

Figure 6. 3b Original Transition framework.

Figure 6.4 demonstrates the flows necessary in the process of implementing the individual phases of the framework, in order to attain SSWM. The 4 phases are introduced in Section 5.8.5, and the flowchart details how stakeholders are engaged, legislation is created, and the SuDS concept is integrated into the SSWM design.

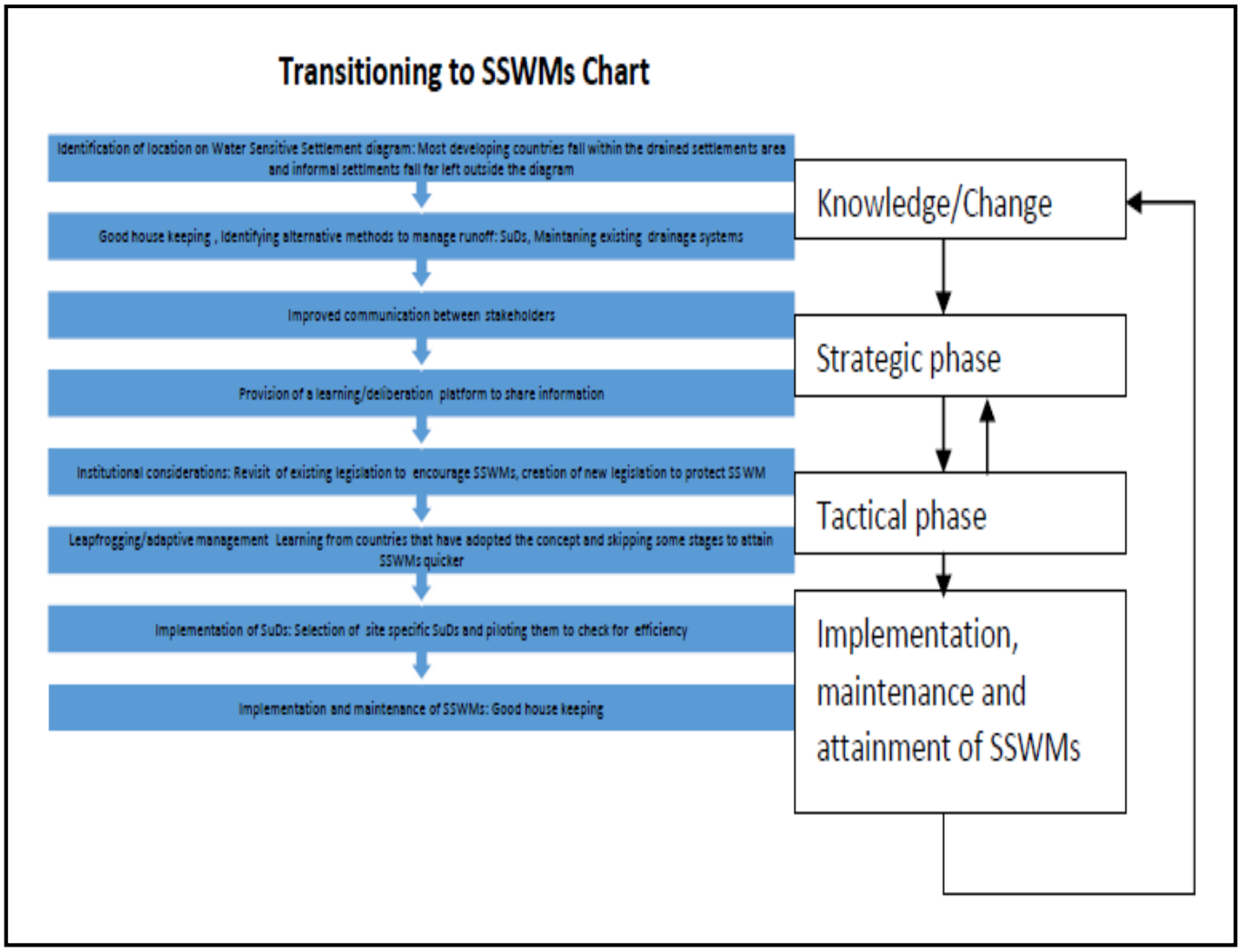

Figure 6.4 SSWMs Transition flowchart

Figure 6.5 shows where most informal settlements and formal settlements are located on the water sensitive settlement diagram (See Section 5.8.2) and also where they need to be, (see Section 5.8.2). As discussed previously in Sections 5.2 and 5.8.2 the importance of visioning in the setting and achieving of targets cannot be over emphasised, hence Figure 6.5 shows the position of both settlements currently, and where they should be

(or the setting of the goal) to achieve SSWM. These have all been translated into Yoruba and are given in Appendix 7 see Section 9.7.4, Figure 7.

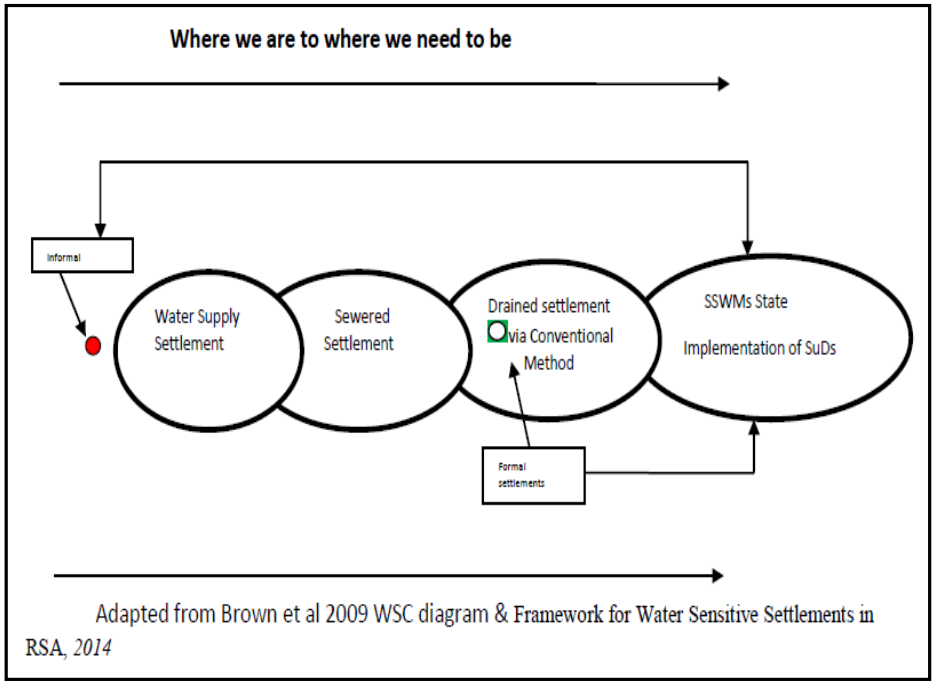

Figure 6.5 Diagram locating informal and formal settlements, showing desired goal.

6.5 Summary

This chapter detailed the evaluation and revision of the developed SSWM transition framework. This offered a simple, holistic, critical, bottom–top, high-level strategic approach to ensure a successful transition.

While adapted from existing frameworks, it is unique, since previously existing frameworks were designed for developed countries. The Lagos framework has been specifically tailored to suit developing countries in Africa with the focus being placed on informal settlements or slums attaining SSWM alongside the formal settlements. The inclusion of informal settlements in frameworks developed for the West are non-existent, but the transition framework developed by Armitage *et al.* (2014) for South Africa does consider informal settlements. However, while the South African framework includes the informal in its framework, informal settlements were not

prioritised. A further distinguishing component that adds originality to this framework is that it encourages and emphasises the use of simple SuDS by all stakeholders to achieve SSWM. It is intended to help cater for the yearly flooding impacts on developing countries and in particular informal settlements in these regions.

The phases/ stages in the framework have been adapted from empirical research and literature review and refined through critical reflection and reasoning. In combination with feedback from external experts, a revised version of the framework was produced. It is recognised that the contributions towards this revision are not exhaustive, further adding to the value of this framework as it is iterative, giving space for a continuous feedback loop to account for change.

The proceeding chapter presents recommendations for both now and future research and also addresses comments from the evaluation process which have been suggested by the experts to be included as recommendations in the implementation of the framework.

CHAPTER 7 CONCLUSIONS AND RECOMMENDATIONS

7.0 Introduction

The purpose of this research was to investigate the potential of implementing simple SuDS to aid in the transitioning of informal settlements in Lagos to SSWM. A framework was designed to guide stakeholders through this transition.

The attainment of SSWM by both informal and formal settlements in Lagos and by extension other LDCs in Africa is achievable. However, before this is possible certain structural, as well as non-structural water management practices need to come into effect. These practices have been identified and reflected in a proposed framework that has been designed to enable this transition. All results from primary and secondary data collected in this study informed the contextulisation and development of the proposed framework which was evaluated by experts. These have all been reflected in the proposed framework and in its delivery; thus, this study has answered the research questions set out in Section 1.2.

This chapter presents conclusions as well as recommendations, and is divided into 4 sections; the first section summarises the findings of this study. The second section presents the accomplishment of the research aims and objectives. The third section presents recommendations, in which relevant feedback from the framework evaluation has been taken account of as it reinforces the study recommendations. The fourth section presents the main contribution of this study to existing knowledge and suggestions for future research.

7.1 Summary of findings from this study

This section summarises the overall findings and their significance in relation to the objectives of this study. A critical literature review and direct observation identified a failure in the existing surface water management system to successfully manage stormwater in informal settlements in Lagos. Hence there was a need to seek alternative cost-effective and efficient methods to sustainably manage runoff. This section therefore summarises the findings which contribute to, and justify, the necessity of this research specifically in Lagos, and thus the research aims and objectives:

1. Existing conventional drainage devices have failed in their design to manage runoff.
2. Flooding and environmental degradation impact more on the quality of life of those residing in informal settlements in comparison with those in formal areas. However, residents in these areas are keen to adopt effective ways to add to their quality of life.
3. There is a need to find a cost effective and efficient alternative to existing water management systems.
4. SuDS (simple SuDS) is a sustainable alternative to conventional drainage, which can work alongside it to deliver SSWM.
5. A change in attitude is required by all stakeholders, including the government, to critically examine more sustainable and efficient ways to manage runoff, i.e. the need to implement SuDS as an alternative method.
6. However, currently, the government is not prepared to take further responsibility for illegal settlements i.e. provide drainage infrastructure.
7. Informal residents' own self-deployed infrastructure, which may provide some protection from the impacts of flooding, is very short term and incapable of managing the frequent flooding being experienced across the settlements.
8. Governance and institutionalisation are drivers to SuDS implementation.
9. There is a lack of legislation to support and maintain SSWM.
10. There is a knowledge and technological gap in the concept of SuDS.

The following sections discuss the achievement of the research aims and objectives and where they have been accomplished in the study.

7.2 Accomplishment of the research aims and objectives

The literature revealed SuDS as a driver for the implementation of SSWM, with numerous studies showing it to be a suitable alternative to the failing conventional drainage systems across developed countries, such as the United Kingdom, US, Australia, Germany (Armitage *et al*. 2013; Angelis and Shaw 2004; Booth & Charlesworth 2016; Darwin 2009; Environmental Agency 1999; Ghani *et al.* 2008; Melbourne Water 2004; Shuttlewood *et al.* 2017; SuDSWales 2016; Susdrain 2012; USEPA 2007; Woods Ballard *et al.* 2007; 2015).

However, there is a lack of empirical studies on the successful implementation of SuDS and SSWM practices in Africa. It was further revealed in the literature that although SuDS and SSWM have been investigated in South Africa, further research was needed to prioritise the transition of informal settlements to SSWM using SuDS. This study is necessary because, as discussed in Section 5.9, before SSWM can be achieved, the management of surface water from both formal and informal settlements needs to be sustainably managed. Hence the importance of including informal settlements in transitioning to SSWM. Therefore, aim 1 of this research was:

> To investigate the suitability of SuDS in informal settlements in Lagos with a view to exploring potential challenges, advantages and enabling factors that would affect the implementation of SuDS.

It was necessary to prioritise informal settlements because as discussed throughout this study and also evidenced by literature, they are usually not included in developmental reform planning because of the nature of their location (Parkinson 2003). Also, research was required to establish suitable SuDS for selected sites while also investigating how best to harness and exploit the potential factors affecting its implementation and as such, the delivery of SSWM.

The following sections therefore address achievement of the Objectives associated with the first Aim:

7.2.1 Objective 1.1: To determine whether SuDS devices can be implemented as a SSWM tool in informal settlements in Lagos, by investigating the applicability of SuDS as a SSWM tool.

The basis of this objective was to review SuDS to manage surface water sustainably and effectively as an alternative to the failing conventional drainage system. Its use as a tool to deliver SSWM was investigated by reviewing its application in different countries which have successfully adopted SuDS. This was intended to determine whether or not the SuDS approach were appropriate strategies or approaches to attain SSWM. This research identified a significant number of studies which demonstrated SuDS as being successful in the management of surface runoff in various countries. It was found that where SuDS devices had been implemented to work independently or alongside conventional drainage, significant attenuation in peak flow was recorded. Additionally, in the informal settlements, some respondents recounted their use of makeshift devices designed to assist in manage surface runoff i.e. sand bags and tyres were used to prevent flood waters from getting into their homes, therefore attenuating peak flow. This therefore suggests SuDS is a suitable alternative to conventional drainage and thus its implementation can deliver SSWM to informal settlements.

7.2.2 Objective 1.2: To determine the potential for its use while establishing suitable SuDS for selected study sites.

In this objective, individual devices were investigated for their suitability for selected sites, hence the review of the different SuDS devices, the components that made them up and how they function. This was necessary to inform what type of SuDS is suitable for implementation at particular sites, e.g. retention ponds will not be suitable for a densely populated area because of the lack of space (see Appendix 9.5).

7.2.3 Objective 1.3: To investigate potential factors affecting the implementation of SuDS with an emphasis on informal settlements in Lagos, Nigeria.

The literature showed that for SuDS to be successful, certain factors must be in place to encourage their implementation and maintenance thereafter, for continuity. With this in mind the study sought to investigate potential factors that may have affected the use of SuDS in countries where implementation had been successful. The literature review

identified government regulation and legislation as a major factor encouraging the implementation of SuDS. A review of existing legislation revealed their absence in Nigeria as a whole, and Lagos in particular, and hence the lack of formal government policies to drive the implementation of SuDS. Furthermore, both structural (fixed, physical and permanent facilities) and non-structural (intangible facilities that work by changing behaviour through government regulation e.g. planning and environmental laws, persuasion and/or economic instruments) components were lacking in the existing water management systems in Lagos, leading to their failure to manage runoff successfully. A pilot study and follow-up field work generated data on experiences and expertise of the informal and formal communities in terms of their flood memory, its impacts and their perceptions of how flooding should be managed. The results revealed the willingness of both communities to be involved in SSWM, that they acknowledge that flooding is a problem, but that informal residents are impacted far more than those living in formal areas. Blocking of what drainage infrastructure had been installed (mostly canals and gutters) by solid waste was identified as the main problem along with intense rainfall and continuing urbanisation covering drains over.

Finally, this investigation also enabled the study offer recommendations for the adoption of regulations /polices that would encourage the use of SuDS in both formal and informal areas of the city.

The literature revealed that developed countries have designed frameworks to guide stakeholders to achieve SSWM. Therefore, to deliver this in informal settlements, a framework which contextualised informal settlements specifically (i.e. poverty, building clusters etc) was necessary to guide stakeholders to achieve SSWM, hence aim 2 of this research which was:

> To design and evaluate a potential framework for the implementation of SSWM in informal settlements in Nigeria.

The following sections therefore address the achievement of the Objectives associated with Aim 2.

7.2.4 Objective 2.1 To design a transition framework for implementing SuDS as a SSWM tool in Lagos, Nigeria.

A review of existing SSWM frameworks designed by countries that had implemented SuDS, was carried out in order to devise a framework suitable for Lagos. Components of these frameworks have therefore been extrapolated, built upon and contextualised within the Lagos framework to inform which stages, phases and processes are essential to achieving SSWM. Only one of the frameworks reviewed (Armitage et al., 2014) was found to be directly applicable to the situation in Lagos, i.e. the juxtaposition of both formal and informal settlements.

7.2.5 Objective 2.2 To evaluate the framework for suitability in informal settlements in Lagos and its wider application.

It was necessary to investigate the usefulness of this framework to deliver SSWM. Therefore, it was evaluated by key stakeholders who were experts in the water management sector, and who were based in 3 African countries, allowing for wider application of the framework in these countries and similar developing countries. Table 7.1 below presents sections where the aims and objectives defined in chapter 1 were met. Section 7.3 discusses recommendations developed from this research.

7.3 Recommendations from the study

In order to attain SSWM, those structural and nonstructural components found to be lacking needed to be addressed. It has been proven that conventional methods are a cause of flood, instead of being the answer to the problem. However, these systems already have a strong presence in most surface water management systems. The overhaul of these systems to alternative methods would be almost impossible in the short term mainly because of cost, a significant technological and knowledge gap, as well as the absence of policies to support their removal. The inclusion of conventional drainage systems and SuDS to work alongside each other to manage surface runoff in the short term has the potential to significantly reduce flooding. The deployment of simple SuDS devices such as rainwater harvesting, swales, vegetated filter strips and sand filters do not require any complex construction and are cost-effective for informal as well as formal settlements, and they can also work alongside the existing systems to

better manage surface runoff. However, before these devices are deployed a site inspection to determine suitable SuDS is recommended. See SuDS site selection guide in Section 9.5 Appendix 5.

Table 7.1 Sections where the aims and objectives defined in chapter 1 were met.

Aim 1: To investigate the suitability of SuDS in informal settlements in Lagos, Nigeria with a view to exploring potential challenges, advantages and enabling factors that would affect the implementation of SuDS.	
Objectives	**Chapters/Section addressed**
1.1 To determine whether SuDS devices can be implemented as a SSWM tool in informal settlements in Lagos, by investigating the applicability of SuDS as a SSWM tool.	Chapter 2 Section 2.13-2.15, Chapter 3 Section 3.2-3. Chapter 4
1.2 To determine the potential for its use while establishing suitable SuDS for selected study sites.	Chapter 2, Section 2.12, Chapter 3 Section 3.5- 3.8
1.3 To investigate potential factors affecting the implementation of SuDS with an emphasis on informal settlements in Lagos, Nigeria.	Chapter 5 Section 5.7.3-5.7.4
Aim 2: Design and evaluate a potential framework for the implementation of SSWM in informal settlements in Nigeria.	
2.1 To design a transition framework for implementing SuDS as a SSWM tool in Lagos, Nigeria.	Chapter 5. section 5.2-5.10, 6.4
2.2 To evaluate the framework for suitability in informal settlements in Lagos and its wider application.	Chapter 3: Section 3.9-3.9.2 Chapter 6. section 6.1-6.4

7.3.1 Structural components: While SuDS devices make up part of the structural components that deliver SSWMs, before they can be implemented, certain other structural components need to be present for them to be successful. The existence of a functional solid waste disposal system is essential to the maintenance and effectiveness of drainage devices especially in LDCs. The indiscriminate dumping of refuse in drainage devices which causes blockages and leads to flooding is as a result of the

absence of waste disposal or collection. In the course of the framework evaluation, the reviewers clearly stated and reiterated that a functional waste disposal system was essential. While solid waste management is a problem faced by both developed and developing countries, its provision is readily available in the developed world, however this is lacking in most LDCs (Guerrero, Maas and Hogland 2013, Diaz 2011, Garfì and Bonoli ND). The government needs to provide suitable waste disposals sites and systems that can cater for the growing population. Continued maintenance of the existing system is essential, as was highlighted by the experts during the evaluation process. Good housekeeping, which includes the clearing of gutters, canals and environs to ensure free-flowing drainage devices, is recommended and was also suggested by experts also during the evaluation exercise to ensure SSWM.

7.3.2 Non-structural components: These are intangible facilities that work by changing behaviour through government regulation e.g. planning and environmental laws, persuasion by education and enlightenment of the public (PPRC 2014). Government regulation through institutionalisation, legislation and policy-making, plays a major role in implementing SuDS, and by extension attaining SSWM see Section 5.7.1 (Hoyer *et al.* 2011; CIRIA 2005). The enactment or revision of laws, policies and regulation to support SSWM in LDCs is required for its implementation and continuity, e.g. town planning controls, to ensure a decrease in the area of impervious surfaces, regulatory controls: e.g. enforcement of local laws to improve erosion and sediment control on building sites. Regulatory instruments such as environmental licences can aid in the management of premises likely to contaminate stormwater. Also, programmes to minimise illicit discharges to stormwater (PPRC 2014) is recommended. Some developing countries e.g. India have already had to revise some of its laws to accommodate the implementation of certain SuDS devices to manage runoff, these devices with the help of government regulation have recorded significant success in attenuation of peak flow, see Section 2.13. A review of the influence of legislation on the ability of Lagos to transition to SSWM (see Section 5.7.3), showed that whilst there are certain laws that may influence drainage management positively there is nothing that specifically caters for it; see Section 5.7.4. It further showed there are certain policies that can be a barrier to SSWM. Also, the defragmentation of monitoring bodies in the water management system is necessary; according to Armitage *et al.* (2014), the urban

water cycle should be managed as a whole and not fragmented. This is because a duplication of responsibilities within these bodies can result in a lack of overall responsibility. While Armitage *et al.* (2014), call for a defragmentation of water management, Oshodi (2013), suggests that structural decentralisation of flood management institutions in Lagos State and strengthening of the Ministry of the Environment will enable these organisations to play more proactive roles in overall supervision, policy and strategic direction for environmental management. In addition, the field experts from the evaluation exercise also highlighted its importance and called for its inclusion in any framework. While relevant legislation will drive the implementation of SuDS it also needs to cater for its maintenance and continuity. Other non-structural practices include the engagement and collaboration of all stakeholders in the community to ensure implementation, maintenance and continuity of SuDS. This inclusion gives a sense of responsibility and hands-on attitude to all members of the community. A change in attitudes towards how flooding is managed by the government in formal and informal areas is required, while currently priority is given to the formal areas and informal areas are usually not given any consideration. It is time the government managed surface water as a whole without isolating management of runoff to formal areas alone. In fact, the recent flooding of prominent formal areas may provide the driver needed to initiate attitude change in government circles to investigate more sustainable and efficient ways to manage runoff. Finally, filling the knowledge gap as regards SuDS is essential for both the regulatory bodies as well as members of the public, (see evaluators recommendation in Section 6.3, Question 19). Knowledge of SuDS techniques, maintenance, etc, is essential to the continuity of SuDS in any environment. Countries like the UK, US, Australia and SA have SuDS guidance manuals to educate, familiarise and guide stakeholders towards implementation and maintenance (CIRIA 2007; Armitage *et al.* 2014; Woods and Ballard *et al*. 2015). Documents and literature such as these should be made available to the general public, also pamphlets, posters etc. preferably in the local dialect which present SuDS in less technical terms for the less educated target population. The use of the media to educate on these sustainable flood management systems is also recommended, interaction that necessitates transfer of knowledge between governing bodies and community members can also bridge this knowledge gap. Although there is a very long way to go before any

area of Lagos could be considered to be managing their flooding crisis in a sustainable manner, a better future awaits and SSWM is attainable in the not so distant future if SuDS, the structural and non-structural components discussed are implemented and sustained.

7.4 Contributions to knowledge

1. **Novel investigation**: Prior to this research there is a paucity of empirical studies investigating the implementation of SuDS in West Africa, although there is a plethora of studies in the developed world. Furthermore, there is no empirical study exploring the use of simple SuDS by informal settlements to transition to SSWM**.** This study, therefore, adds to the existing body of literature on SuDS in LDCs and in Africa specifically.
2. **Established readiness to implement SuDS in Lagos:** No previous study has investigated the use of simple SuDS to manage runoff in informal settlements in Lagos; this study is a first of its kind. It has been able to investigate readiness to implement SuDS by residents of both formal and informal settlements as well as by the government of Lagos State. Overall evidence presented has identified and filled a gap as it pertains to the readiness of Lagos to seek alternative methods (SuDS) to manage runoff.
3. **An evaluated transition framework:** This research designed and evaluated a transition framework that would deliver SSWM to both formal and informal settlements alike, in addition, this framework has been translated into Yoruba, the language local to the case study area. Emphasis has been placed on cost effective SuDS devices to achieve SSWMS. The framework provides a phase by phase iterative model that would ensure synergy of all stakeholders in the community in the pursuit of SSWM. Additionally, the developed framework can also be used by other researchers conducting similar work. The framework will not only assist informal settlements in Lagos but is applicable to similar African countries and LDCs as well.

7.4.1 Recommendation for future research

It is intended that this framework benefits all relevant stakeholders by providing guidance and support while encouraging further investigations into the potential of implementing SuDS as an alternative to conventional drainage methods in West Africa. While this research placed emphasis on informal areas and the use of simple SuDS to manage flooding, more research into the multi-benefits of both hard and soft SuDS is required for its further implementation in LDCs. Further exploration of the benefits of the individual components of the SuDS "square" of improved water quality, reduced water quantity, provision of both amenity and biodiversity in its implementation in Africa and other LDCs is required to enable its wider application, hence the widespread attainment of SSWM. The framework designed in this research has not been trialed, although potential success indicators have been established, thus, further research could trial it and, as it is iterative in nature, improve its ability. This framework will be of immense benefit to LDCs but still requires evidence-based investigation to be realised. In addition the investigation on the potential of using Google Maps to identify and map informal settlements needs further exploration by investigating the use of other available GIS tools. GIS tools are capable of identifying and delineating runoff flow direction, they can also accurately identify and define small scale urban catchment areas using geospatial data. Therefore the further investigation of these GIS tools as a decision making tool for SSWM is recommended. Finally, there is still a localised knowledge gap as it relates to SuDS implementation particularly in Nigeria and various LDCs, this gap can be filled through further research.

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Online Resources:

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http://www.Lindaikejiblogshot.com
http:/www.moelagos.gov.ng
http://news.bbc.co.uk/1/hi/world/africa/935617.stm
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Lagos State Government Publications

- Environmental Sanitation Law 2000
- Street Trading and Illegal Markets (prohibition) edict No. 1 1984
- Sand Laterite and Gravel Spillage (prohibition) edict No.4 1984
- Land use decree 1978
- Town and Country Planning edict No.1 1986
- Environnemental Pollution Control edict N0. 13 198
- The Land Use Act , LFN 2004; (iv)
- The Urban and Regional Planning Act, LFN 2004;
- The Lagos State Waste Management Authority Law 2007; and
- The Lagos State Urban and Regional Planning and Development Law 2010.

APPENDICES

9.1 Appendix 1: Participant information and consent sheet

9.1.1 Participant Information Sheet

Study Title: Investigating the potentials of using simpler SuDS in informal settlements in Lagos Nigeria to attain sustainable surface water management.

What is the purpose of the study?

The aim of this study is to investigate the use of indigenous raw materials and vegetation in a Sustainable drainage method designed to cater for flooding in the community, while involving the community members in the whole process.

Why have I been approached?

For the purposes of the study I need to recruit a large number of adult participants who can read and write in English. This is the only criteria that I have for recruiting people to the study.

Do I have to take part?

No. Participation is entirely voluntary. If you change your mind about taking part in the study you can withdraw at any point during the sessions and at any time in the two weeks following that session. You can withdraw by contacting me on email and providing me with your participant information number. If you decide to withdraw all your data will be destroyed and will not be used in the study. There are no consequences to deciding that you no longer wish to participate in the study.

What will happen to me if I take part?

You will be approached by the researcher and asked few questions regarding the weather conditions of your area and the prevalent problems caused by flooding if any in the area.

You will also be asked to come for a meeting / briefing session lasting no longer than 45 minutes with the researcher and other participants, the meetings will involve briefing on

the importance of these designs and the pros and cons associated with its implementation. Questions and answer session will be application in these sessions; feedback between researcher and participants/respondents will be exchanged on a collective or a one-to-one basis as required with the researcher during the session.

What are the possible disadvantages and risks of taking part?

Some of the questions asked by the researcher may seem repetitive. This is deliberate, as I am interested in totally capturing the precise picture of the situation on ground. However, you may feel uncomfortable if you tend to become self-conscious if you make a mistake or are unsure of an answer. You can refuse to answer any questions you might find uncomfortable. Another disadvantage is that you will need to attend a series of meetings on separate occasions, which may be difficult if you have to make special childcare or travel arrangements.

What are the possible benefits of taking part? As community member, by taking part in this study you will gain an insight into how these techniques are designed and also be more enlightened and empowered as it pertains to mitigating flooding issues in your community, these sustainable drainage method(s) is a multi-beneficial project; the possibilities of gaining deeper insight and information on innovations taking place around the world as it pertains to drainage and flooding issues can be achieved.

What if something goes wrong?

If we have to cancel a meeting/ briefing session, I will attempt to contact you as soon as possible using the method indicated by you on the consent form. If you change your mind about taking part in the study you can withdraw at any point during the sessions and at any time in the two weeks following that session by contacting me using the email address stated below.

If you decide to withdraw all your data will be destroyed and will not be used in the study.

Will my taking part in this study be kept confidential?

Yes. Only I will have access to the raw data. All the consent forms will be stored in a secure location. Your participant code number will only identify you. I will only retain the raw data from the project until my final mark for my dissertation has been given. They will then be destroyed. When the data has been entered into a computer file, your

responses will only be associated with your code number and access to the file will be password protected.

What will happen to the results of the research study?

The results will be written up and presented as part of my thesis. If the results and responses from our briefings are novel, it may also be presented at academic conferences and / or written up for publication in peer reviewed academic journals.

Who is organising and funding the research?

The research is organised by [MARGARET MEZUE], who is a research student at the Coventry University in Geography, Environment and Disaster Management Department.

This project is not externally funded.

Who has reviewed the study?

This study has been through the University Peer Review process and been approved.

Contact for Further Information

NAME: MARGARET MEZUE

UNIVERSITY EMAIL ADDRESS:OGOLOMEM@UNI.COVENTRY.AC.UK

Independent Contact

NAME: Dr Sussanne Charlesworth

ADDRESS: apx119@coventry.ac.uk

1. Informed Consent Sheet

Participant Statement of Understanding / Consent.

Participant Reference Code: ……

I confirm that I have read and understand the participant information leaflet for this study involving the designing of sustainable drainage method(s) to manage storm runoff in my settlement. I have had the opportunity to ask questions if necessary and have had these answered satisfactorily.

I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason. If I withdraw my data will be removed from the study and will be destroyed.

I understand that my personal data will be processed for the purposes detailed above, in accordance with the Data Protection Act 1998.

Based upon the above, I agree to take part in this study.

Name of participant…… Date…… Signature…….

Name of researcher: MARGARET MEZUE. Date 2nd April 2015. Signature: MARGARET MEZUE

9.2 Appendix 2: Questionnaire for flood victims in Lagos, Nigeria.

9.2.1 Questionnaire for Pilot Study

This questionnaire has been designed to capture the individuals view on flooding in the designated location as a requirement for my research on effective flood defence measures.

Participation in this study is entirely voluntary and for ages 18 and over. It is your entitlement to withdraw from the survey at any point you so desire without any restrictions from the researcher. Please consider that all information provided by yourselves will be strictly confidential and you remain anonymous. By responding to this questionnaire, you consent to take part in this survey is assumed. Thank you.

1. Your details

Age group: 18-24 [ ] 25-30 [ ] 31-40 [ ] 41-50 [ ] 51-60 [ ] 60+ [ ]

Gender: Male [ ] Female [ ]

2. Flood History and occurrence:

2.1 What LGA in Lagos do you reside in?

2.2 How long have you lived at your current address?

0-1year [ ] 1-10 [ ] 11-20 [ ] 21-30[ ] 31-40[ ] 41+ [ ]

2.3 Are you aware of any history of flooding in your area?

Yes [ ] No [ ]

2.4 How would you rate your knowledge of flooding history in your location?

None [ ] Basic [ ] Expert [ ]

2.5 At what times in the year does the area flood?

2.6 How many flood occurrences occur yearly in your estimation?

1-2 [ ] 3-4 [ ] 5-6 [ ] 7+[ ]

2.7 From your experience how would you describe flood severity?

Barely [ ], Moderate [ ], Extreme [ ]

2.8 What do you feel is the cause of the flooding?

(a) Rains

(b) Burst drains

(c) Overflowing of riverbanks

(d) Other: (please specify)

2.9 How long do the flooded areas remain flooded?

3. Impact of flood:

3.1 Do you feel the flooding impacts greatly on your day-to-day activities? Yes [ ] No [ ]

3. 2 Does it impact positively [ ] or negatively [ ] on your livelihood? Maybe if so, how?

3.3 Have there been any loss of lives or property with relation to floods?

Yes [ ] No [ ]

3.4 Have there been any health issues or disease outbreaks due to the flooding occurrences? Yes [ ] No [ ] I don't know [ ]

3.5 If yes what health issues or out breaks are you aware of, what?

4. Protective / Preventive measures:

4.1 Do you have any existing flood defences in place?

Yes [ ] No [ ] I don't know [ ]

4.2 What flood defence /protective system do you have in place?

4.3 How knowledgeable are you about the flood defence systems in your area?

Basic [ ] Intermediate [ ] Expert [ ]

4.4 How was this knowledge acquired?

Personal Experience [ ] , Government interventions [ ], Media [ ].

4.5 If you answered yes to the question 4.1 above can you describe the flood defences, which exist, in your area? If you answered no please go to section 5

4.6 How effective have these defence systems being in curbing floods?

Not Effective [ ] Effective [ ] Very Effective [ ]

4.7 Who put the defences in place?

1. Private [ ]
2. Community engagement [ ]
3. Government infrastructure [ ]
4. Other (please specify) [ ]

5. If you answered NO to question 4 above how receptive are you to change?

1. I am willing to have an infrastructure put in place to curb flooding in my area
2. I am not interested in having any infrastructure put in
3. I am indifferent to the situation
4. Other (please specify)

6. If you answered YES to 4 above, how willing are you to adopt new strategies to combat flooding?

1. I am willing and receptive to change

2. I am not interested in implementing new strategies to the issue
3. I am indifferent to the situation
4. Others

6.1 If you answered [a] in question 6 above can you suggest improvements or initiatives on flood defence systems you would like to see put in place in your area?

6.2 Are you willing to maintain privately/personally, without the intervention of the government or external bodies the new infrastructures that will be put in place to combat flooding in your area? Yes [ ] No [ ]

Thank you for your time.

9.2.2 Questionnaire for second field visit

Questionnaire for flood victims in Lagos, Nigeria.

This questionnaire has been designed to capture the individuals view on flooding in the designated location as a requirement for my research on effective flood defence measures.

Participation in this study is entirely voluntary and for ages 18 and over. It is your entitlement to withdraw from the survey at any point you so desire without any restrictions from the researcher. Please consider that all information provided by yourselves will be strictly confidential and you remain anonymous. By responding to this questionnaire, your consent to take part in this survey is assumed. Thank you

1. Your details

1.1 How old are you?

1.2 Gender: Male [ ] Female [ ]

2. Flood History and occurrence:

2.1 What LGA in Lagos do you reside in?

2.2 How long have you lived at your current address?

2.3 Are you aware of any history of flooding in your area?

Yes [ ] No [ ]

2.4 How would you rate your knowledge of flooding history in your location?

None [ ] Basic [ ] Expert [ ]

2.5 At what times in the year does the area flood?

2.6 How many flood occurrences occur yearly in your estimation?

1-2 [ ] 3-4 [ ] 5-6 [ ] 7+[ ]

2.7 From your experience how would you describe flood severity?

Barely [ ] Moderate [ ] Extreme [ ]

2.8 What do you feel is the cause of the flooding?

(a) Rains

(b) Burst drains

(c) Overflowing of riverbanks

(d) Other: (please specify)

2.9 How long do the flooded areas remain flooded?

3. Impact of flood:

3.1 Do you feel the flooding impacts greatly on your day-to-day activities? Yes [ ] No [ ]

3. 2 Does it impact positively [ ] or negatively [ ]on your livelihood? Maybe if so, how?

3.3 Have there been any loss of lives or property with relation to floods?

Yes [ ] No [ ]

4. Protective / Preventive measures:

4.1 Do you have any existing flood defences in place?

Yes [ ] No [ ] I don't know [ ]

4.2 What flood defence /protective system do you have in place?

4.3 How knowledgeable are you about the flood defence systems in your area?

Basic [ ] intermediate [ ] Expert [ ]

4.4 How was this knowledge acquired?

Personal experience [ ], Government interventions [ ], Media [ ].

4.5 If you answered yes to the question 4.1 above can you describe the flood defences, which exist, in your area? If you answered no please go to section 5

4.6 If you answered Gutters in question 4.5 above, do the gutters have covers?

4.6.1 If No, do you dispose of refuse in the gutters?

4.6.2 How often are these gutters cleaned?

4.7 How effective have these defence systems being in curbing floods?

Not Effective [ ] Effective [ ] Very Effective [ ]

4.8 Who put the defences in place?

1. Private [ ]
2. Community engagement [ ]
3. Government infrastructure [ ]
4. Other (please specify) [ ]

5. If you answered NO to question 4.1 above how receptive are you to change?

1. I am willing to have an infrastructure put in place to curb flooding in my area
2. I am not interested in having any infrastructure put in
3. I am indifferent to the situation
4. Other (please specify)

6. If you answered YES to 4.1 above, how willing are you to adopt new strategies to combat flooding?

1. I am willing and receptive to change
2. I am not interested in implementing new strategies to the issue
3. I am indifferent to the situation
4. Others

7. Design /Maintenance of Sustainable Drainage Systems

If you answered [a] in question 6 above can you suggest improvements or initiatives on flood defence systems, you would like to see put in place in your area?

7.1 Are you willing to maintain privately/personally, without the intervention of the government or external bodies the new infrastructures that will be put in place to combat flooding in your area? Yes [ ] No [ ]

7.2 Can you give suggestions on how these devices will be privately/personally maintained?

Reuse of rainwater

8. Do you have access to potable water?

Yes [ ] No [ ]

8.2 If you answered no in question 8.1 how far do you have to travel to purchase/gain access to water?

8.3 Do you buy this water or is it available free of charge

Yes [ ] No [ ]

8.4 What do you use the water for asides drinking and cooking?

8.5 Do you collect rainwater?

Yes [ ] No [ ]

8.6 How do you harvest this water?

8.7 Do you treat the harvested rainwater before use?

Yes [ ] No [ ]

8.8 If you answered YES in 8.7 above, what treatment is used?

8.9What do you use harvested water for?

8.10 If you answered No in question 8.5 will you be willing to interested in collecting rainwater for your use?

Yes [ ] No [ ]

Thank you for your time.

9.3 Appendix 3: Interview Briefs

9.3.1 Interview Brief for flood Victims in Study sites

Researcher: can you tell me the name of your community and how long you have lived in this area?

Respondent:

Researcher: Can you please briefly describe a flooding incident that has happened in the past or currently in this area?

Respondent:

Researcher: Can you tell me what times of the year the flooding occurs and how many times in the year you experience the flooding:

Respondent:

Researcher: what do you feel is the cause of the flood?

Respondent:

Researcher: What do you think you can do to change the situation?

Respondent:

Researcher: Can you briefly describe what strategies has been put in place by the government to manage runoff

Respondent:

Researcher: Will you say they have been effective in managing the runoff?

Respondent:

Researcher: Can you briefly describe how the community protects themselves from flooding?

Respondent:

Researcher: Have these techniques been successful?

Respondent:

Researcher: Are you willing to adopt an efficient method, such as you are already utilising to will sustainably manage you stormwater?

Respondent:

THANK YOU FOR YOUR TIME

9.3.2 Interview Brief for Government Officials

Researcher: can you briefly describe your role in the ministry of environment?

Respondent:

Researcher: Can you please briefly describe how Lagos manages its storm water runoff

Respondent:

Researcher: Can you please give me a brief description of the flooding history of the areas in Lagos that floods?

Respondent:

Researcher: What has the government's contribution been in reducing these flooding incidences formal and informal settlements?

Respondent:

Researcher: Can you briefly describe what strategies have been put in place by the government to manage storm runoff?

Respondent:

Researcher: Can you please describe some of these infrastructure put in place in the existing water management system?

Respondent:

Researcher: What is your perception on these existing management systems? Can you say they have been effective in managing runoff?

Respondent:

Researcher: What does the term Sustainable drainage mean to you?

Respondent:

Researcher: Do you think the government will be willing to adopt SuDS to cater for flooding as against the existing drainage methods?

Respondent:

THANK YOU FOR YOUR TIME

9.4 Appendix 4: Ethical Approval Details

REGISTRY RESEARCH UNIT

ETHICS REVIEW FEEDBACK FORM

(Review feedback should be completed within 10 working days)

Name of applicant: Margaret Mezue P26775

Faculty/School/Department: CAWR : Centre for Agroecology, Water and Resilience

1. Evaluation of the ethics of the proposal: Confirmed	
2. Evaluation of the participant information sheet and consent form: Confirmed	
3. Recommendation: (Please indicate as appropriate and advise on any conditions. If there any conditions, the applicant will be required to resubmit his/her application and this will be sent to the same reviewer).	
X	Approved - no conditions attached
	Approved with minor conditions (no need to re-submit)

	Conditional upon the following – please use additional sheets if necessary (please re-submit application)
	Rejected for the following reason(s) – please use other side if necessary
	Not required

Research project title: Investigating the potentials of using simpler SuDS in informal settlements in Lagos Nigeria to attain sustainable surface water management.

Comments by the reviewer

Name of reviewer: Caroline Moraes

Date, 26 Feb 2015

9.5 Appendix 5: SuDS site selection criteria

9.5.1 Adapted SuDS site selection criteria diagram

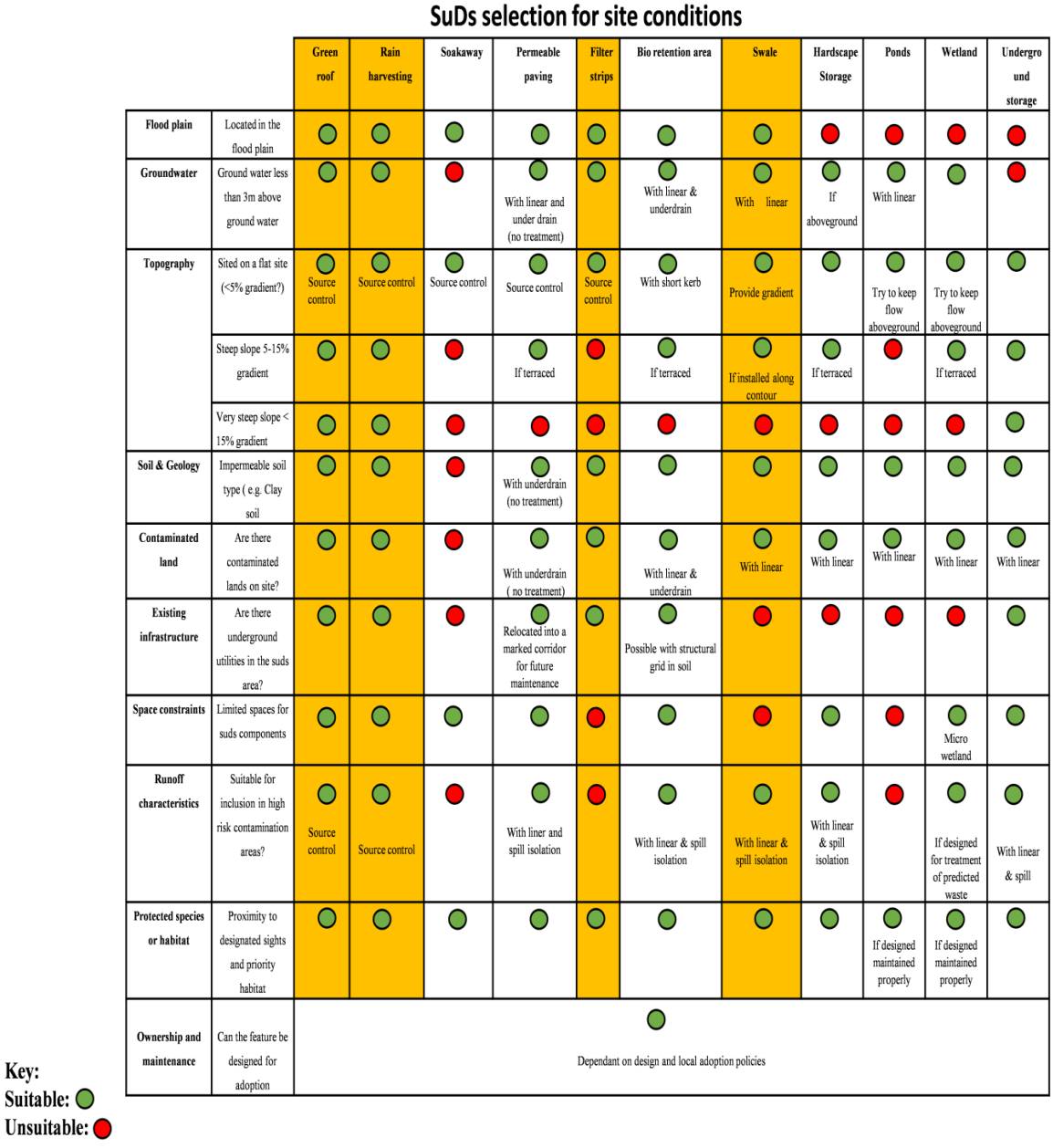


Figure 1: SuDS selection for site condition guide.

Source: adapted from: SuDS Design Guidance (2013)

9.6 Appendix 6: Results

9.6.1 Table 2: Causes of flooding by individual settlement

	Causes of Flooding								
Settlement type	Rains	Burst drains	Overflowing of riverbanks	Other	Rains and blocked drains	Rains, burst drains	Rains, overflowing of riverbanks	NA	**Total**
Apapa Igamu	3	1	3	0	27	3	2	0	42
Ifelogdun	5	3	1	2	36	4	0	0	47
Ikeja	11	3	0	0	8	3	0	3	29
Makoko	12	0	3	0	13	2	2	4	39
Total	31	7	7	2	84	12	4	7	154

9.6.2 Table 3: Duration of rainfall

	Duration									
Settlement Type	few hours	1 day	<1week	≤1week	1 week	≥1week	3 weeks	as long as rain lasts	NA	Total
Formal	2	6	3	1	1	3	0	1	11	29
Informal	3	12	21	31	2	16	1	14	26	128
Total	5	18	24	32	3	19	1	15	37	154

9.6.3 Table 4: Rain Harvesting

Responses	Frequency	Percent
No	89	57.8
Yes	65	42.2
Total	154	100

This table illustrates responses from both settlements regarding the harvest of rainwater, a lot of the respondents actually already harvest rain water, about 42% of the respondents practiced rainwater harvesting for non-potable uses.

9.6.4

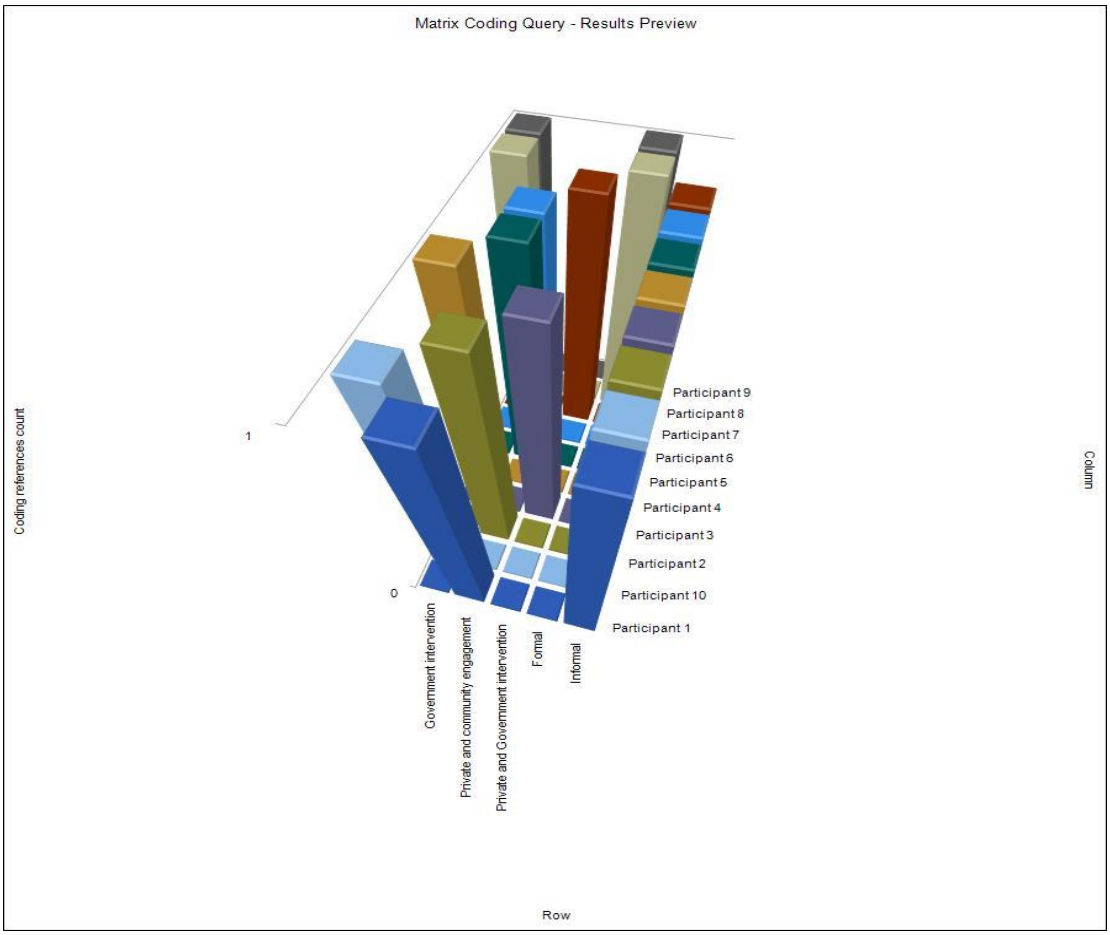


Figure 2: Matrix coding result for SuDS implementation

9.6.5

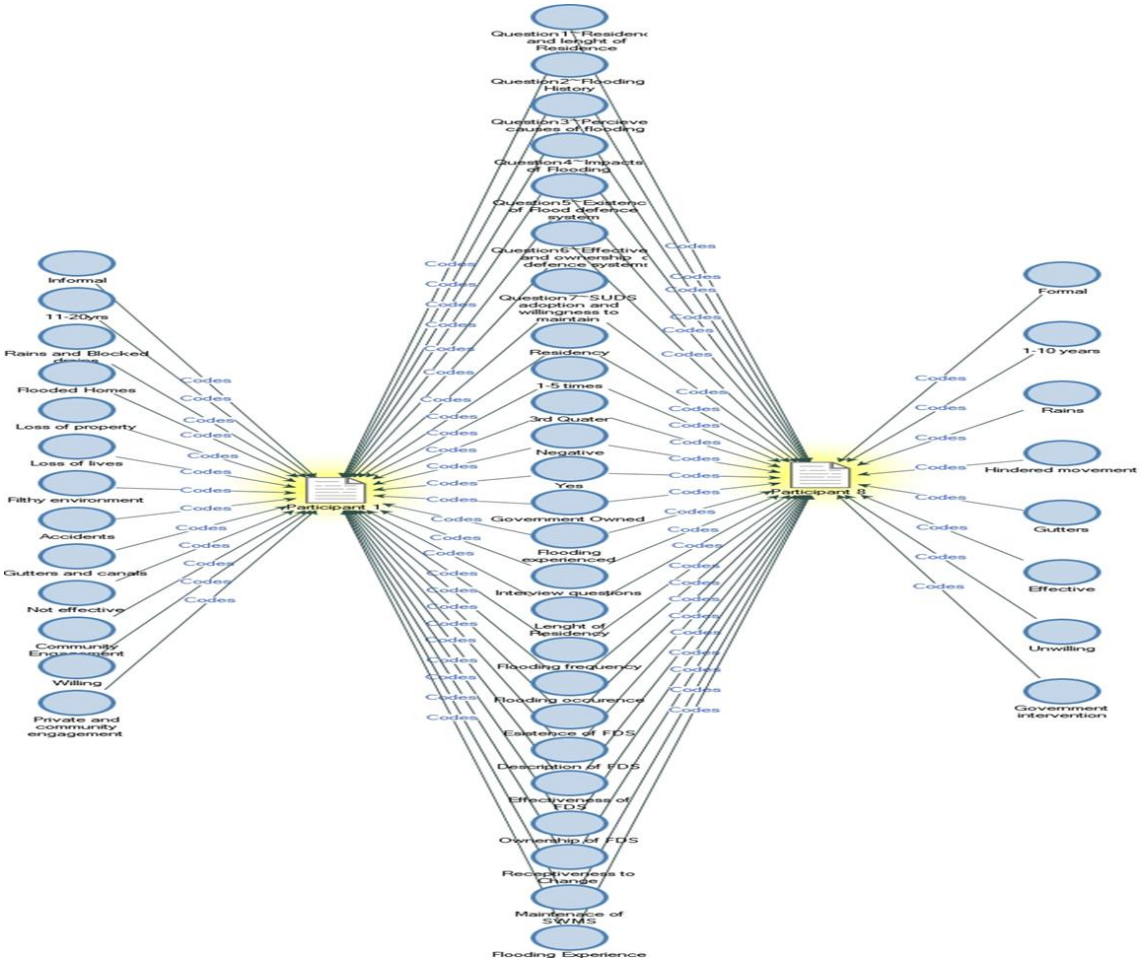


Figure 3: Diagram showing Comparative analysis between two respondents

9.7 Appendix 7: Framework evaluation

9.7.1 Email Invitation

Dear Evaluator,

I would appreciate your feedback on a transitioning to sustainable surface water management framework that I have developed as part of my doctoral research. This forms part of a study to explore the potentials of implementing sustainable surface water management systems to combat flooding in developing countries in Africa.

The exercise should take no longer than **30 minutes** to complete. By providing feedback and returning this form, you acknowledge your consent to participation in this study. Your responses as well as your personal identity will remain completely confidential. On completion of the thesis, a report outlining the overall findings will be sent to your organisation. The report will not identify any individual or their responses.

Once the thesis has been submitted (September 2017), the concise copy of the framework will be sent to you should you wish to adopt and use as a guide towards the transitioning process to attain sustainable surface water management systems in your country. It is my hope that this will be considered as a potential management structure to combat flooding in your country.

Attached you will find 2 documents:

1. *The Framework* – I would ask you to spend about 15 minutes familiarising yourself with the contents of this document as well as the acronyms within which will be used extensively for reader ease.
2. *Evaluation document* – This consists of questions relating to the framework. Feel free to write or type your responses.

Once completed, I would appreciate it if you could please return the feedback to my supervisory team who will also deliver to you hard copies and also electronically to ogolomem@coventry.uni.ac.uk .

For further information, please do not hesitate to contact:
Director of studies: Professor Sue Charlesworth: apx119@coventry.ac.uk
Thank you very much for your help and co-operation

Best wishes.
Margaret Mezue

9.7.2 Framework Literature/ Document

Why am I looking at this document and why is my contribution essential?

According to Moody and Shanks (2003), for effective system implementation, Key stakeholders should be engaged in the evaluation and evaluation process and critical discussion of it.

A framework has been designed to transition developing countries in Africa to a sustainable surface water management system (SSWMs), particularly as the use of existing conventional surface drainage systems (use of gutters, canals, culverts etc) have not effectively and efficiently managed runoff hence an increase in flooding occurrences. This framework is aimed at guiding stakeholders through the process of achieving a sustainable surface water management system. It is supported by theory and exposure to critique will further evaluate it, while offering relevant improvements on the framework hence the need for your input.

It is the aim of this researcher to investigate potentials of using sustainable surface water management systems to address the issue of flooding from storm water in developing countries in Africa.

Acronyms:

SSWMs: Sustainable surface water management systems

SuDS: sustainable drainage systems

WSC: water sensitive city

Introduction

Urbanisation coupled with the change in climate has led to an increase in flooding incidents. Flooding and its management is a universal problem and the dangers of this menace have been recognised and are being addressed by most developed countries. The conventional command and control methods of managing flooding have proved ineffective and as such more sustainable water management systems have been sought and implemented by most developed countries whom have since witnessed positive changes to the occurrence and management of flooding.

Sadly, this is not the case with the developing world, being saddled with seemingly more important issues. Urban flooding is usually not a prioritised problem especially in Africa and has been accepted as a way of life in most developing countries. Communities are more or less left to deal with the problem themselves. However Urban flooding is more dangerous than perceived; it can be likened to a cancer, silently taking its toll on the environment and its inhabitants. It is recognised that the conventional methods available to manage runoff are failing and the need for a new strategy is compulsory.

In a bid to somewhat improve quality of life in such areas the researcher proposes a framework that is intended to cost effectively and efficiently transition developing countries with priority on the informal settlements to a Sustainable Surface Water Management system which will manage runoff.

This proposed framework is developed as a guide to enable stakeholders understand the importance of implementing a sustainable surface water management system. Its design is aimed at demonstrating transition phases that would guide the existing water management systems in developing countries to more sustainable systems. It has been designed with a phase to phase iterative process to guide all stakeholder groups through the stages to successfully transition to SSWMs.

In summary the purpose of the transition framework is to enable stakeholders within these environments make effective, efficient and sustainable changes to the existing surface water management systems for now and posterity.

Sustainable surface water management Transition Framework

The framework provides a strategic phase by phase plan to enable developing countries change its water system from today's state into a better condition in the future. The framework aims to guide all stakeholders within the subject matter on how to transition from what is currently available as it regards surface water management to what can be achieved: SSWMs.

The framework has been designed to be simple and comprises of four iterative phases which allow for realisation of the problem, setting of visions/goals, flexibility to be employed to suit the different situations, similarities and peculiarities that may arise from country to country. It encourages a wider variety of options to be evaluated by the stakeholders using the vehicle of a cross institutional platform.

The framework was developed following an extensive review of four existing relevant SSWMs frameworks which have been contextualised and built upon to suit and make applicable to developing countries in Africa.

Reviewed frameworks

The transition framework was designed from adapting four relevant existing frameworks on sustainable water management. They are:

1. An Adaptive Management Framework for Connected Groundwater-Surface Water Resources in Australia (Brodie et. al, 2007) Available from : http:// http://www.southwestnrm.org.au/sites/default/files/uploads/ihub/brodie-r-et-al-2007-adaptive-management-framework-connected-groundwater.pdf
2. Towards a water sensitive city (Brown et. al, 2008) Available from: https://web.sbe.hw.ac.uk/staffprofiles/bdgsa/11th_International_Conference_on_Urban_Drainage_CD/ICUD08/pdfs/618.pdf

3. Darwin Harbour WSUD Framework (McAuley et. al, 2009) Available from: http://www.equatica.com.au/pdf/McAuley%20et%20al%202009.pdf

4. A transition framework for RSA (Armitage et, al, 2014) Available from: https://www.green-cape.co.za/assets/Water-Sector-Desk-Content/WRC-Water-sensitive-urban-design-WSUD-for-South-Africa-framework-and-guidelines-2014.pdf

These frameworks have been evaluated and contextualised. The concepts within them built upon to design the transition framework; their relevance and applicability in developing countries in Africa have been taken into cognisance. With the view of building on existing concepts and theories within the above reviewed frameworks, an evaluation process was undertaken and the most applicable processes within these reviewed frameworks were selected to suit the existing scenarios and peculiarities of developing countries. The existing frameworks have further been evaluated based on results from analysis and field observation as well as from literature of a developing country (Lagos, Nigeria). It has also enabled the researcher build-on from what is already in existence and bridge gaps related to issues that were lacking in the reviewed frameworks as it pertains to its applicability in different settlements of developing countries.

Criteria for transition framework

4. **Visual appeal**: The framework should be visually appealing to the target audience, according to (Jefferies & Duffy 2011) the most effective frameworks are visually appealing as they promote and encourage communication potential within a target audience, be they technical or non-technical

5. **Simple, Realistic and flexible**: the framework should meet these criteria as it should be readily understandable, with straight forward diagrams. At the same time realistic and not farfetched. It should also be flexible enough to allow for a feedback loop to encourage continued improvement.

6. **Cost effective and Sustainable**: because this framework is targeted at an audience of a mix of stakeholders: (A government that does not prioritise the issues of flooding, and not willing to assist informal settlers, and: Residents in informal settles: usually the less privilege and poor of the society) The framework should apply cost effective measures yet sustainable methods to attain its goal. A cost effective, yet sustainable framework will undoubtedly spark some interest in both parties and encourage its deliberation

7. **Communication / interaction amongst stakeholders Engagement and inclusion**: a framework that encourages the interaction amongst stakeholders cannot be over emphasised, the engagement and inclusion of stakeholder participants is a sure way of ensuring the sustainability of the any implemented system

8. **Institutions, Geography and Cultural Norms:** A provision for the consideration of these should be taken into cognisance when creating a framework, although to some extent, it takes away from the flexibility to adopt this framework anywhere, it however promotes target audiences' willingness to accept it, when is goes at par with their existing institution, geography and cultural norms

9. **Adaptive/ wide applicability:** the frameworks should possess adaptive potential, it should be able fit in and be applied or adopted in different scales and scenarios according to Loorbach (2007) innovations are not usually born, they are required to be adapted before been perceived as being good solution that address future local and global risks

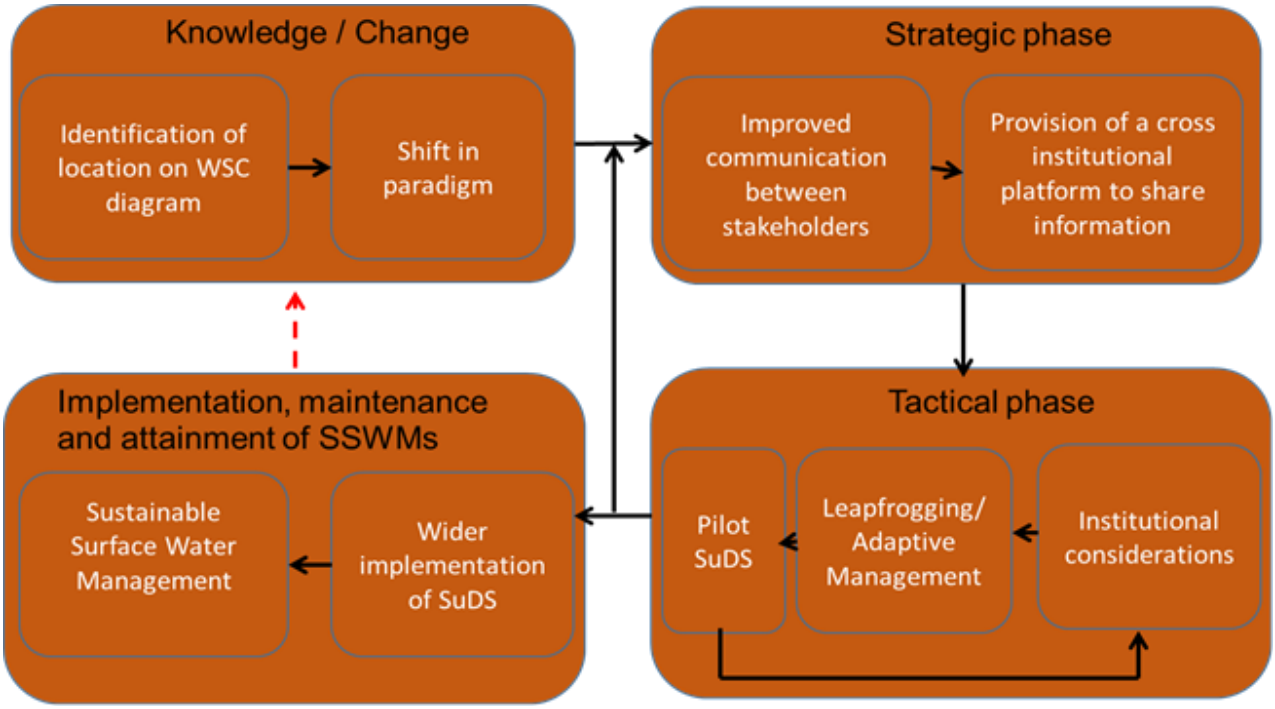
10. **Reflective:** the framework should not be rigid in nature but make provision to be reflective and iterative. Change processes should not be fixed rather reflective in order to reflect changing circumstances and the evaluation of new inventions (Dirven *et al*. 2002).

11. **Visionary:** According to Brown *et al*. (2008) When planning for a sustainable future, stakeholders need to know where they are from the planned destination to enable them plan on a way to get to the goal destination. Therefore, a framework that is able to demonstrate this transition is of great value.

12. **Adaptive management/leapfrogging**: a framework which advocates for this enhances development and sustainability at a much faster rate than one which does not. This concept is being currently applied to developing countries allowing them to transition to more sustainable futures while not making mistakes but learning from experiences of countries that have progressed to the desired stage they want to attain.

Based on the above criteria the Transition framework was developed and designed.

Sustainable Surface Water Management Transition Framework: Figure 4



Who is this framework designed for and for what: The framework is designed for all stakeholders within the stormwater management system. They include the residents of both formal and informal dwellings, government officials in charge of drainage, academia as well as community leaders

What is the problem: the inability of existing drainage to manage surface runoff thus the flooding of mostly informal settlements?

What can be done to solve this problem: The implementation of alternative sustainable surface water management systems that will transition African countries to SSWM and thus ensure the proper sustainable management of surface water. The implementation of an alternative sustainable method to manage excess runoff brought about by stormwater (SuDS) was suggested because it has proven to be effective.

What steps will be taken to solve the problem: A framework design from the implementation of relevant phases from existing frameworks.

What is the guarantee that this framework is full proof to deliver what it promises: Nothing ventured, nothing gained? Hence the evaluation process of the framework.

Aim: To create a tool that can be used by stakeholders to assist in the transitioning of existing failing water management system (command and control methods) to SSWMs.

Components of the Frame work

The framework is made up of four phases, and just like some of the reviewed frameworks above. It takes on a continual/ cyclic nature allowing for a feedback loop. This is necessary because of uncertainties which might occur in the future e.g. change in community priorities, and expectations, therefore water management will need to evolve in response to these changes.

1. **Knowledge/ Change phase**: It purpose is to enlighten the stakeholders to come to the realization and recognition that flooding is a problem that needs to be addressed. This phase locates the settlements on the existing WSS framework designed by Brown et al (2008). The intent of this is to create a better understanding on the whole essence of the framework. It also draws the stakeholders' attention to the fact that the existing conventional drainage methods in place to manage runoff are not only failing but unsustainable. Hence the need to sought for alternative methods to address the problem. This Phase calls for a shift in paradigm.

Shift in paradigm:

What is the existing paradigm: The use of command and control conventional drainage methods to manage excess runoff?

What is the new paradigm: The use of a system that takes into account water quantity, quality biodiversity, as well as amenity of a community when managing surface runoff. The use of SuDS to manage excess runoff. This shift in paradigm to handling and managing excess runoff sustainably, has recorded great success in the developed countries like German, UK, USA, Australia.

2. **Strategic Phase**: At the strategic level, long term goals are deliberated and agreed upon. The level encourages communication between stakeholders as it requires the coming together of stakeholders to deliberate and decide on set

goals. It also enables for a cross institutional platform. By this the researcher means the coming together of stakeholders from different backgrounds to bring their expertise, knowledge and experience or inexperience as the case may be. It would entail the occasional coming together of stakeholders in a learning enhanced forum to be educated on ways to sustainably manage runoff and also share information. This is a crucial phase in the framework as the encouragement of participation and interaction between stakeholders in a water management system ensures for continued sustainability of that system (Brodie et al 2007)

3. **Tactical Phase**: this is a very essential phases as it is where activities such as Institutional considerations which consist institutional networking, negotiations, planning and reviewing of existing governance to support the transition is carried out. It recognised that the existing governance in most African countries do not support SSWM, therefore the revisit of legislation is essential as Legislation has been identified as a driver to SSWMs (Hoyer et al 2011). This phase also comprises the implementation of leapfrogging/ adaptive management concepts to get the informal settlements to transition at a quicker rate, drawing from experiences of others. According to Armitage et al (2014), Leapfrogging is a concept being used by developing countries or redeveloping settlements to increase the speed at which the transition to set goal. This phase allows for deliberations and agreements to be made on what phases to leapfrog or transition through to attain SSWM. This stage also enables for the deployment of agreed SuDS devices as a bench mark to access its effectiveness which may need to wider application should pilot be successful. (For wider applicability the implementation of Pilot SuDS is undertaken only after experts have deliberated and decided upon relevant techniques which are site specific as it relates to SuDS selection criteria for each different location. As the characteristics site location is a determinant of SuDS device to be deployed in the area.) At this stage the feedback loop is applied from results obtained off the pilot. It would feedback on what changes are required to be made to enhance the implementation and success of SuDS.

4. **Implementation and Maintenance Phase:** This Phase involves the wider application of SuDS after the deployment and assessment of effectiveness of Pilot. This phase allows for the deliberation of varied options available for implementing SuDS. This Implementation and maintenance is only possible with a balanced mix of policy and stakeholder investment in terms to financial resources and human capital. The inclusion of a monitoring/ maintenance structure to be put in place in any framework cannot be over emphasised (Brodie et al 2007). In order for SSWM to be achieved, the continued maintenance of deployed SuDS devices either privately or collectively as community engagement is essential to sustainability and continuity of SWWMs. A monitory body is suggested to oversee this maintenance of devices.

   The local government via regulation can appoint regulatory bodies to monitor and oversee the smooth running of devices. This Phase also makes provision for a feedback loop to the knowledge / change phase and as such the enhancement of a reflective framework.

   These phases have to be passed through and no one is more essential than the other, equal priority has to be placed on all phases to achieve a successful transition.

9.7.3 Evaluation Document

Undertaking the evaluation

This process is necessary to generate evidence for the following two issues:

1. To evaluate the need for a sustainable surface water management system transition framework that will guide stakeholders in achieving the desired goal: to effectively and sustainably mange excess runoff.

2. To evaluate the proposed framework and its processes.

The framework will be evaluated by analysing the feedback and responses from the following questions.

1. Framework design

1. Are the explanations and rationale behind the *Transition Framework* concise and clear?

Answer	

2. Are the phases of the *SSWMs Transition Framework described* adequately?

Answer	

3. Do you have any suggestions that you would like to make to revise the *SSWMs Transition Framework Phases* (please provide particulars)?

Answer	

(i) Functionality of Framework

1. In your opinion are the concepts/processes within the framework flexible, adaptable, concise and easy to understand and implement?

Answer	

2. Do you agree with the processes described in the *SSWMs transition framework?*

Answer	

3. Owing to your experience and expertise are there any critical processes that you would like to incorporate in the *SSWM*s *transition framework?* (Please provide particulars)

Answer	

(ii)Transition framework flow process

1. Is the process flow within the framework easy to understand and implement?

Answer	

2. Do you agree with the framework phase flow and concepts /processes described within each of the phases? If No, please critique as necessary?

Answer	

3. What are your views on implementing a cross institutional platform/learning alliance in the strategic phase of the framework? Do you think this will make a difference?

Answer	

4. Within the tactical phase, what are your views on the implementation of SuDS devices as a SSWMs tool and do you think the concept of SuDS will be accepted by the stakeholders?

Answer	

5. What are your views on revisiting existing regulation to prioritise and support the transition to SSWMs as prescribed within the model?

Answer	

6. Please provide your views on the concept of leapfrogging to attain SSWMs.

Answer	

7. Do you have other relevant concepts/process that that should be identified within the framework model which would allow for wider applicability and implementation of the framework? (Please provide particulars)

Answer	

2. Viability of the framework

1. Do you think the proposed framework can successfully transition your existing water management system to the SSWMs?

Answer	

1.

2. Do you think there are any phases or processes that might not have been identified within the framework which would expedite the possible implementation of the framework?

Answer	

3. What are possible problems that can impede the implementation of the framework?

Answer	

3. Implementation process

1.

1. Was the introduction to the *Transition* framework adequate?

Answer	

2. Do you have any suggestions for how the framework might be introduced in a more coherent and simple manner (please provide particulars)?

Answer	

3. Given the completed concise framework, would you be willing to implement the proposed *transition* framework?

Answer	

4. Do you perceive any dispute that may arise from stakeholders with regards to the possible implementation/acceptance of the framework?

Answer	

5. If yes, how could the barriers to the possible implementation/acceptance of the framework be overcome (please provide particulars)?

Answer	

6. Are any cultural changes required before the implementation of the framework (system) (please provide particulars)?

Answer	

7. Are any standards required before the implementation of the framework? (Please provide particulars)?

Answer	

Your effort and time are truly appreciated.

Margaret Mezue

Researcher: Centre for Agro ecology and water Resilience

Coventry University

United Kingdom

Email: ogolomem@coventry.uni.ac.uk

9.7.4 Sustainable Surface Water Management Transition Framework Translated to Yoruba Language

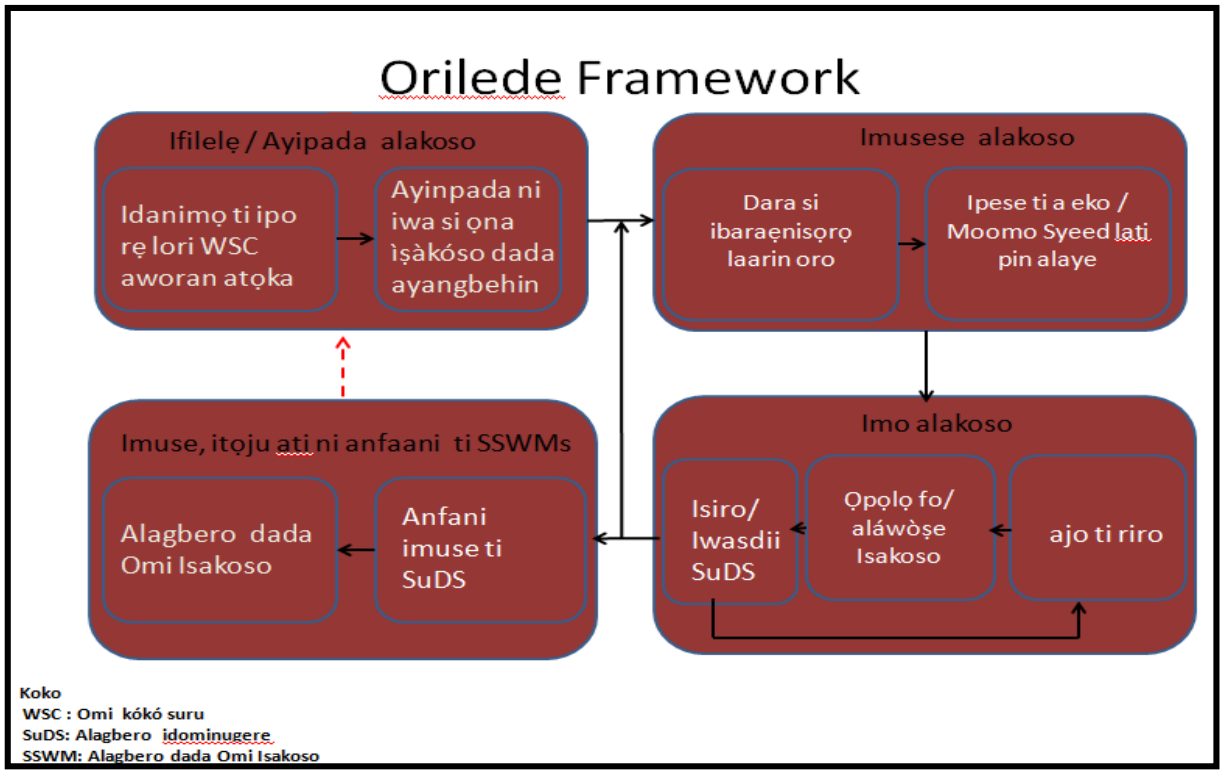


Figure 5: Transition Framework in Yoruba

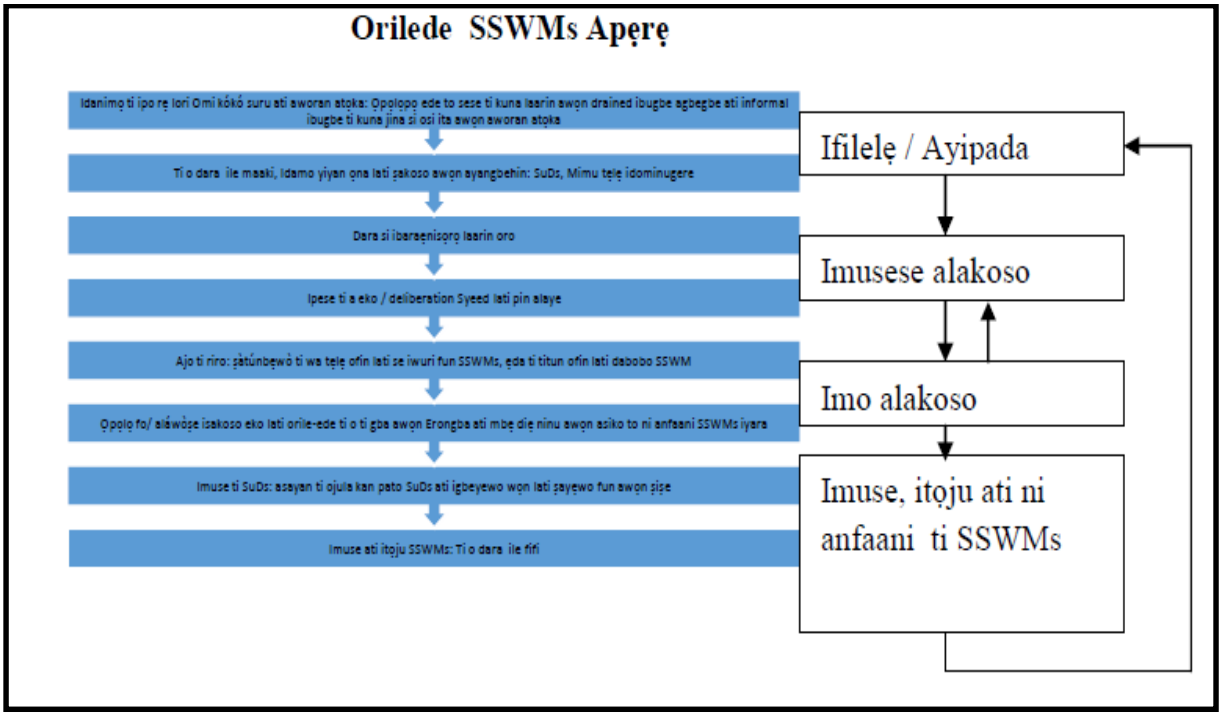


Figure 6: Transition Flow

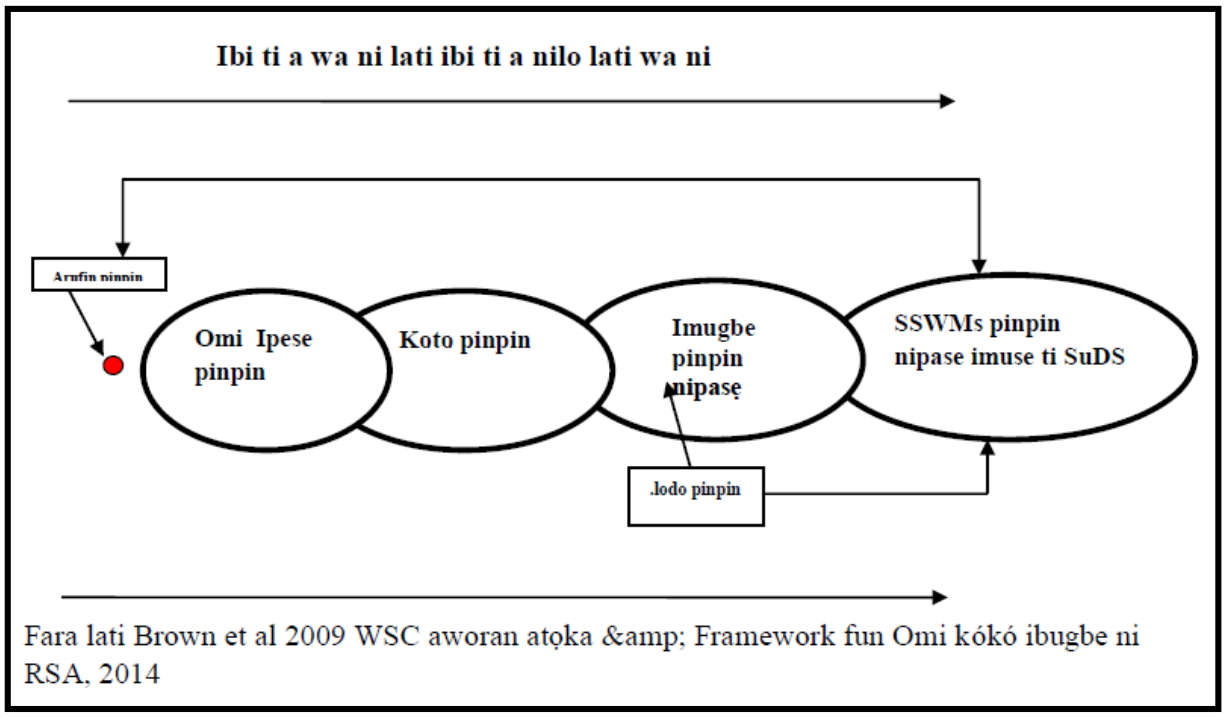


Figure 7: Location of settlements on Adapted framework in Yoruba Language

Ta ni ilana apẹrẹ fun ati fun ohun ti?

Awọn ilana ti a ṣe fun gbogbo awọn oro laarin awọn stormwater isakoso eto. Nwọn ni awọn olugbe ti awọn mejeeji lodo ati informal ibugbe, awon osise ijoba ni idiyele ti idominugere, academia bi daradara bi awujo olori.

Kini ni isoro?

O ti wa ni ailagbara ti wa tẹlẹ idominugere lati ṣakoso awọn dada ayangbehin bayi ni ikunomi ti okeene informal ibugbe.

Ohun ti le ṣee ṣe lati yanju isoro yi?

Awon gba ati olomo ti yiyan alagbero dada omi isakoso awọn ọna šiše ti yoo orilede-ede Afirika to Alagbero dada Omi Isakoso awọn ọna ṣiše (SSWMs) ati bayi rii daju awọn to dara alagbero isakoso ti dada omi. Awọn olomo ti yiyan alagbero ọna lati ṣakoso awọn excess ayangbehin mu nipa nipa stormwater Sustainable ilu idominugere Systems (SuDS) ti a daba nitori ti o ti fihan lati wa ni munadoko.

Ohun ti awọn igbesẹ yoo wa ni ya lati yanju isoro?

A ilana apẹrẹ lati awọn olomo ti o yẹ ifarahan lati wa tẹlẹ nílẹ.

Kini ni lopolopo ti yi ilana ti kun ẹri lati fi ohun ti o se ileri?

Ko si ohun ventured, ohunkohun ibe. Iwadi show iru paati nílẹ ti a ti apẹrẹ ati ki o ni ibi ninu awọn ti ni idagbasoke aye. Eleyi ilana ti a ti sile lati gba fun awọn ti ni idagbasoke aye kan pato aini bi ipo, asa, afefe, exiting ofin, ati be be Nibi ti afọwọsi ilana ti awọn ilana.

Ero: Lati ṣẹda kan ọpa ti o le ṣee lo nipa oro lati ran ni orilede ti wa tẹlẹ aise omi isakoso eto (pipaṣẹ ki o si iṣakoso awọn ọna) si SSWMs.

Irinše ti awọn Framework.

Ilana ni ṣe soke ti mẹrin awọn ifarahan, ati ki o kan bi diẹ ninu awọn ti àyẹwò nílẹ loke. O gba to lori kan titilai / salayipo iseda gbigba fun a esi lupu. Eleyi jẹ pataki nitori ti wipa eyi ti o le waye ni ojo iwaju fun apẹẹrẹ ayipada ninu awujo ayo, ati ireti, nitorina omi isakoso yoo nilo lati da ni esi si awon ayipada

1. **Imo / Ayipada alakoso:** oniwe-idi ni lati enlighten awọn oro lati wa si ni riri ati ti idanimọ ti o ikunomi ni isoro kan ti o nilo lati wa ni a koju. Yi alakoso locates awọn ibugbe lori awọn ti wa tẹlẹ WSS ilana apẹrẹ nipa Brown *et al.* (2008). Awọn Idi ti yi ni lati ṣẹda kan dara oye lori gbogbo lodi ti awọn ilana. Yi alakoso iwuri awọn ti o dara jùmọ ti wa tẹlẹ idominugere eto, awọn ti kii lilo ti àgbará bi idalẹnu ojula, bi daradara bi igbese ti yoo rii daju free ń ṣàn awọn ọna šiše ni gbogbo igba, O tun fa awọn oro ifojusi si ni otitọ wipe awọn ti wa tẹlẹ mora idominugere ọna ni gbe lati ṣakoso ayangbehin ko ba ti wa nikan aise sugbon ilo, sibẹsibẹ nibẹ ni o wa ni yiyan awọn ọna eyi ti o le ṣiṣẹ ẹgbẹ nipa ẹgbẹ pẹlu ohun ti wa ni on ilẹ. Nibi ti ye lati wá fun ayipada: yiyan awọn ọna lati koju awọn isoro. Yi alakoso ni ero lati dijo fun awọn ti tesiwaju itoju awọn mora idominugere titi ohun lori gbigbe ninu oro gun o ti waye ati alagbero ọna ti wa ni muse ati ki o gba lati ṣakoso awọn dada ayangbehin.

Yi ọna yiyan alagbero omi isakoso awọn ọna šiše: Kí ni awọn ti wa tẹlẹ omi isakoso eto? O ti wa ni awọn lilo ti pipaṣẹ ki o si dari mora idominugere ọna lati ṣakoso awọn excess ayangbehin. Kini ni yiyan eto: Awọn lilo ti a eto ti o gba sinu iroyin omi opoiye, didara ipinsiyeleyele, bi daradara bi amenity ti awujo nigba ti ìṣàkóso dada ayangbehin. Yi yiyan eto ni a npe ni SuDS ati awọn ti a lo lati ṣakoso awọn excess ayangbehin sustainably. O ti gba silẹ nla aseyori ninu awọn ti ni idagbasoke awọn orilẹ-ede bi German, UK, USA, Australia.

2. Imusese Alakoso: Ni ilana ipele, gun igba afojusun wa ni deliberated ati ki o gba lori nipa oran na kan, eyi ti o ni awujo omo egbe bi daradara bi amoye ninu omi isakoso eto. Awọn ipele iwuri ibaraẹnisọrọ laarin oro bi o ti nbeere bọ papo ti oro na to moomo ki o si pinnu lori ṣeto afojusun. O tun kí fun a eko / deliberation Syeed. Nipa eyi ni awadi tumo si ni bọ papo ti oro na lati yatọ si backgrounds lati mu wọn ĭrìrĭ, imo ati iriri tabi inexperience bi awọn irú le jẹ. O yoo fa awọn lẹẹkọọkan bọ papo ti oro na ni a eko ti mu dara si forum lati wa ni educated lori ona lati sustainably ṣakoso ṣiṣe awọn si pa ati ki o tun pin alaye. Eleyi jẹ a nko alakoso ninu awọn ilana bi awọn ìṣírí ti ikopa ati ibaraenisepo laarin oro na ni kan omi isakoso eto idaniloju fun tesiwaju sustainability ti ti eto (Brodie *et al.* 2007).

3. Imo Alakoso: Eleyi jẹ gidigidi kan ibaraẹnisọrọ ifarahan bi o ti jẹ ibi ti akitiyan bi ajo ti riro ti o ni ajo Nẹtiwọki, idunadura, gbimọ ati atunwo ti wa tẹlẹ isejoba lati se atileyin awọn orilede ni ti gbe jade. O mọ wipe awọn ti wa tẹlẹ isejoba ni julọ orile-ede Afirika ko ni atilẹyin SSWM, nitorina ni ṣàtúnbẹwò ti ofin ni awọn ibaraẹnisọrọ to bi Legislation ti a ti mọ bi a iwakọ to SSWMs (Hoyer *et al.* 2011). Yi alakoso tun marundinlogun awọn olomo ti leapfrogging / aláwòṣe isakoso agbekale lati gba awọn informal ibugbe to orilede ni a iyara oṣuwọn, loje lati iriri ti awọn miran. Ni ibamu si Armitage *et al*. (2014), Leapfrogging ni a Erongba ni lilo nipa ede to sese tabi ibugbe lati mu awọn iyara ni eyi ti awọn orilede lati ṣeto ìlépa. Yi alakoso gba fun deliberations ati adehun to wa ni ṣe lori ohun ti ifarahan to leapfrog tabi orilede nipaṣẹ lati ni anfaani SSWM. Yi ipele tun kí fun awọn imuṣiṣẹ ti gba SuDS ẹrọ bi a ibujoko ami lati wọle si

awọn oniwe-ndin eyi ti o le nilo lati anfani elo yẹ ki o awaoko wa ni aseyori. (Fun anfani fun lilo awọn imuse ti igbeyewo SuDS ti wa ni agbeyewo nikan lẹhin amoye ti deliberated ati ki o pinnu lori ti o yẹ imuposi eyi ti o wa ojula pato bi o ti tijoba si SuDS aṣayan àwárí mu fun kọọkan yatọ si ipo. Bi awọn abuda ojula ipo jẹ a determinant ti SuDS ẹrọ lati wa ni ransogun ni agbegbe.) ni ipele yi awọn esi lupu ti wa ni loo lati awọn esi gba si pa awọn awaoko. O fẹ esi lori ohun ti ayipada ti wa ni ti a beere lati wa ni ṣe lati mu awọn olomo ati aseyori ti SuDS.

4. Imuse ati Itọju Alakoso: Eleyi Alakoso je ni anfani elo ti SuDS lẹhin ti awọn imuṣiṣẹ ati iwadi ti ndin ti Pilot. Yi alakoso gba fun awọn deliberation ti orisirisi awọn aṣayan wa fun imulo awon SuDS. Eleyi imuse ati itoju ṣee ṣe nikan pẹlu kan iwontunwonsi illa ti eto imulo ati idoko stakeholder ni awọn ofin to owo ati eda eniyan olu. Ifisi ti a monitoring / itọju be lati wa ni fi ni ibi ni eyikeyi ilana le ko ni le lori tẹnumọ (Brodie *et al.* 2007). Ni ibere fun SSWM to wa ni waye, awọn tesiwaju itọju ransogun SuDS awọn ẹrọ boya ti aladani tabi collectively bi awujo igbeyawo ti wa ni awọn ibaraẹnisọrọ to sustainability ati ilosiwaju ti SWWMs. A monitory ara ti wa ni daba lati bojuto yi itọju awọn ẹrọ. Awọn agbegbe ijoba nipasẹ ilana le yan ilana ara lati se atẹle ki o si bojuto awọn dan yen ti awọn ẹrọ. Eleyi Alakoso tun mu ki ipese fun a esi lupu si imo / ayipada alakoso ati bi iru awọn ẹya ti a irisi ilana. Awọn wọnyi ni awọn ifarahan ni lati wa ni koja nipasẹ ko si si ọkan jẹ diẹ awọn ibaraẹnisọrọ ju awọn miiran, dogba ni ayo ni o ni lati wa ni gbe lori gbogbo awọn ifarahan ni lati wa ni koja nipasẹ ko si si ọkan jẹ diẹ awọn ibaraẹnisọrọ ju awọn miiran, dogba ni ayo ni o ni lati wa ni gbe lori gbogbo awọn ifarahan lati se aseyori kan aseyori orilede.