Planning and provision of Public Infrastructure: A case study of drainage canals in Tema, Ghana

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Planning and provision of Public Infrastructure: 
A case study of drainage canals in Tema, Ghana

A professional report submitted to the graduate faculty in partial fulfillment of the requirements for the degree of Master of Community and Regional Planning and Master of Urban Design

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By

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Executive summary

Rapid urbanization is a threat to the efficient and proactive provision of basic urban infrastructure. This is usually the case when this growth outstrips the capacity of local governments to plan and provide infrastructure as expected and needed. Nonetheless, existing formal regulations and design standards are often outmoded, too expensive, cumbersome to implement and inconsistent with the incremental urban development practices that are prevalent. In response to this, many urban residents resort to self-financing and provision of their basic infrastructure based on their resource capacities—time, money, and labor. Focusing on drainage systems in Tema, a Ghanaian city with both planned and unplanned neighborhoods, the report explores cases where this situation has led to different varieties of construction materials, types and sizes/capacities of drains that are not in conformity with the formal design standards.

As the city of Tema keeps growing, increasing pressure is put on the existing drainage infrastructure to efficiently serve existing and incoming residents. The effective functioning of the drainage systems as flood control mechanisms is affected as a result of planning approaches which have not been able to capture the context of place, time and culture of citizens, as related to their everyday low-cost, organic and incremental practices, to develop a coherent system of providing infrastructure. In view of this, this research sought to address the broader question: How are drainage systems planned and provided in the rapidly urbanizing city of Tema?

Using a comparative analytical and multi-scalar approach, the study examines the quality, connectivity and availability of drains and its relationship with formal regulations, standards and approaches adopted in three neighborhoods in Tema, Ghana: a planned neighborhood - estate area in Sakumono and unplanned neighborhoods (non-estate areas)- Obonkor-Zinginshor-Ashaman in Tema Manhean (Newtown) and Asoprochona in Sakumono. Following a thorough analysis, it was
found that there is a general lack of connectivity and poor quality in the drainage system in both planned and unplanned areas.

The local government is expected to finance and provide drainage canals -both major and minor drains. However, currently, the financing and provision of drainage canals (especially minor drains) by local residents have become the norm due to delays or the lack of proactive provisioning of drains by the local government. Residents who are able to afford estate areas have the opportunity of having drainage canals provided as part of their purchased/mortgaged housing. Yet, this opportunity is not accessible to most residents who purchase non-estate housing, representing 90 percent of Ghana’s housing stock. As a result, in planned areas, which are normally provided with ‘sites and services’ on plots as part of housing developments, it was found that there is a high level of connectivity and quality in the drainage system. Meanwhile, in non-estate areas (unplanned areas), where majority of minor drains are self-provided and therefore subject to individual resident’s access to resources, there were rather low levels of connectivity and quality in their drainage system since their provisions depend on when they have access to resources. It was also found that easement regulation- that ensures an ‘orderly’ spacing between houses, roads and drains- were not adequately followed in non-estate areas. This situation creates uneven access to adequate and quality drainage canals which leads to different levels of vulnerability to flooding hazards depending on how close residents are to low elevation areas, even though all residents in Tema are likely to bear the impact of flooding.

The challenge, as revealed in this research, has been the inability of the local government to capture the context of local residents. There is the need for the local government to leverage the low-cost and incremental practices of local dwellers to provide them with drains that are of
appropriate sizes, materials and type. There is also the need for the creation of an interrelated system between drainage, housing and transportation in the quest to controlling urban flooding. This implies that institutions that are involved in these aspects must collaborate and cooperate. While another challenge has been related to separating the use of drains as sewage lines and waste disposal points from its original use as runoff channeling systems, incorporating green infrastructure and green space developments would not only serve as a resilient and adaptable method, but could also transform the landscape of Tema into a safer, environmentally friendly and aesthetically pleasing environment.

Key words: Public infrastructure, drainage systems, flooding, Ghana.
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# Contents

Executive summary ........................................................................................................................................... i
Acknowledgement ............................................................................................................................................... iv

Chapter One ...................................................................................................................................................... 1

Introduction ...................................................................................................................................................... 1

1.2 Problem identified .................................................................................................................................. 5
1.3 Research question .................................................................................................................................. 7
1.4 Need for research .................................................................................................................................. 8
1.5 Organization of paper ............................................................................................................................ 9

Chapter Two .................................................................................................................................................... 10

Planning of Drainage Infrastructure ............................................................................................................... 10

2.1 Drainage canals as infrastructure ......................................................................................................... 10
2.2 What is an effective drainage system? .................................................................................................... 11
2.3 Formal planning and insurgency ........................................................................................................... 15
2.4 Planning for Incremental development .................................................................................................. 17

Chapter Three .................................................................................................................................................. 20

Methods ......................................................................................................................................................... 20

3.1 Brief profile of study area ....................................................................................................................... 20
3.1.1 Selection of Study areas .................................................................................................................... 22
3.2 Sources of Data ...................................................................................................................................... 23
3.2.1 Secondary Data ................................................................................................................................ 25
3.2.2 Primary Data .................................................................................................................................... 25
3.3 Spatial analysis ....................................................................................................................................... 31
3.3.1 District level analysis ......................................................................................................................... 32
3.3.2 Transect Analysis ............................................................................................................................. 32
3.3.3 Elevation, proximity and rainfall analysis ......................................................................................... 33

Chapter Four .................................................................................................................................................... 37

Results ............................................................................................................................................................. 37

4.1 Profile of Study area ................................................................................................................................. 37
4.1.1 History of Tema ............................................................................................................................... 38
4.1.2 Land management in Tema Manhean and Sakumono .................................................................... 39
4.2 Natural Characteristics ............................................................................................................................ 39
4.2.1 Hydrogeology setting ....................................................................................................................... 39
4.2.4 Climate ......................................................................................................................... 40
4.2.5 Topography .................................................................................................................. 41
4.3 Demographic, Housing and Waste management characteristics .................................. 42
4.3.1 Population of Tema Metropolis .................................................................................. 42
4.3.3 Occupation .................................................................................................................. 45
4.3.4 Housing stock .............................................................................................................. 46
4.3.6 Methods of waste disposal (liquid) ............................................................................. 47
4.4 Flood Prone Areas in Tema Metropolis ......................................................................... 48
4.5 Flooding events at the Regional level ............................................................................ 48
4.6 Flooding in Sakumono and Tema Manhean .................................................................. 50
4.7 Current Drainage system in Sakumono and Tema Newtown ........................................ 52
  4.7.1 Elevation and proximity to water bodies .................................................................... 52
  4.7.2 Case of Sakumono ...................................................................................................... 54
  4.7.3 Case of Tema Manhean ............................................................................................. 67
  4.7.4 Road easement compliance, Layout of blocks and influences on availability of drains 79
  4.7.5 Summary of findings and implications ...................................................................... 81
Chapter Five ......................................................................................................................... 86
Conclusion ............................................................................................................................. 86
  5.2 Recommendation .......................................................................................................... 86
    5.2.1 Planned (Estate areas) .............................................................................................. 87
    5.2.2 Unplanned (non-estate areas) ................................................................................ 88
    5.2.3 Both planned and unplanned areas ......................................................................... 90
Appendix ............................................................................................................................... 94
  6.1 Abbreviations ................................................................................................................ 94
  6.2 Definitions ...................................................................................................................... 94
  6.3 Institutions ..................................................................................................................... 95
    6.3.1 Tema Metropolitan Assembly .................................................................................. 95
    6.3.2 Tema Development Corporation ............................................................................ 95
  6.4 Criteria for measurements ............................................................................................ 96
  6.5 Snapshot and scroll-down of Fulcrum app ................................................................... 96
  6.6 Media Search ................................................................................................................ 97
  6.7 Choking and Cracks in Drains Maps (Right drain only) ................................................ 98
Bibliography ......................................................................................................................... 101
Chapter One

Introduction

Local governments in developing countries are faced with the challenge of providing basic infrastructure efficiently and proactively in cities experiencing rapid increase in population (Roy 2009; Talen 2015). Currently, 55% of the world’s population lives in urban areas and that number is expected to increase to 68% by 2050 (World Urbanization Prospects 2018). In Ghana, the number of people living in urban areas represents 51.5% of the total population (UN-DESA 2011). Urbanization presents prospects for bringing economic development and it can do so effectively if residents are served with quality and adequate infrastructure. As cities keep increasing in population, there is a corresponding increase in demand for infrastructure provisions (Asoka et al 2013). Local governments in low resource contexts find it challenging to meet the needs of the rapidly growing population as this growth often overwhelms their capacity to provide infrastructure. This often compels them to be selective in the provision of infrastructure. Hence, rapid urbanization presents challenges in the provision of adequate basic infrastructure to ensure health and safety, secure a healthy urban environment and even satisfy transportation needs (Owuama et al 2014; Yira et al 2013) as expected through formal planning intervention.

The relevance of planning

Formal planning and regulation provide important tools to ensure that cities are served with adequate infrastructure that meet the needs of residents. According to Conyers and Hill (1984, 3) planning is “a continuous process which involves decisions or choices about alternative ways of using available resources, with the aim of achieving particular goals at some time in the future.”
Campbell (2016), on the other hand, describes the objective of planning as “outcomes that are better than would have been in the absence of planned intervention.” Hence, these definitions imply that planning interventions through regulations, policies and programmes are expected to lead to positive outcomes or the achievement of goals in future. Planning with the aid of city development plans, development controls, planning principles and regulative instruments, just to mention a few, are needed to ensure cost-effectiveness in the use of resources, equitable distribution of infrastructure, promotion of health and safety and maximization of environmental friendliness. However, formal planning approaches, regulations and design standards are often too outmoded, expensive and cumbersome to implement, and inconsistent with the organic low-cost incremental urban development practices in many African cities. This leads to a situation where expectations from formal planning do not meet the realities on the ground.

Residents thus take it upon themselves to provide public infrastructure based on their resource capacities. Since their provisions are subject to their availability of resources, different types and quality levels of infrastructure are provided in the city’s landscape, hence, leading to the inability or insufficiency of the infrastructure in serving its purposes. This circumstance is applicable to the provision of infrastructures such as drainage canals, roads, sidewalks, water and electricity. For the sake of this research, specific focus would be placed on the planning and provision of drainage canals in Tema, Ghana.

**Drainage systems as part of housing**

Drains co-evolve with housing development and the construction access roads. It is expected that the local government provides drainage canals that connects to other chains of drainage canals of
nearby land parcels. Currently, however, estate areas (planned areas) in Ghana often have a
different phasing between drainage provision and housing development as compared to non-estate
areas (unplanned areas). Drains in estate areas are normally acquired as part of housing through
purchase by buying or mortgaging and they are typically common in subdivisions. Abusah (2004)
stresses that “real estate development is a highly regulated process.” A physical site appraisal
which includes aspect of drainage is usually done by the real estate developers and inspected by
local planning authority before completion of housing. However, not all residents can afford this
housing finance structure (mortgaging) and housing development process. Drains in non-estate
areas are often provided after housing developments. According to Acquaah-Harrison (2004, 22),
landowners “survey the land and sell plots, and people proceed to build houses without roads,
water, electricity, waste management services, sullage drains and other community services and
facilities.” This is the common practice of phasing between housing and drainage provision in
Ghana.

According to Moss (2003), in Ghana, “the payment income ratio is too high” and “small
loans are unprofitable and riskier for a commercial lender” (Moss 2003, 6). In view of this, it
“offers very limited support to the rental and incremental housing development” (Moss 2003, 6).
Hence, “private real estate developers provide just about 3 to 5 percent of the number of houses
churned out every year” (Kissiedu 2017) while “90 percent of the housing stock has been
incrementally constructed by homeowners and small-scale contractors, with construction taking
between 5 to 15 years” (Kavaarpuo and Sarfoh 2016). Hence, in Ghana, non-estate housing which
follows an incremental self-provision process seems to be the norm. The long construction period
(5 to 15 years) in housing leads to various levels of delays in the provision of drainage canals since
it is provided based on individual residents’ resource capacities. Hence, the existence, condition
and quality of drains available in many Ghanaian cities depend on what residents can afford. A distinction in the relationship between drains and housing is that drains are provided based on a collective basis while housing is purchased based on an individual or household basis. This creates challenges for local governments in meeting the needs of self-help housing residents since it becomes dependent on residents timeline in housing. Another challenge in housing as related to drainage provision, is experienced when certain regulative instruments in housing such as the National Building Regulations 1996 (LI 1630)\(^1\) which provides site and setback requirements are hardly complied to in unplanned (non-estate) areas because of the organic layout in their building orientations and plot alignments. These affect the consistency in quality, condition and connectivity of the drainage system.

**Response from residents**

Conforming to certain standards and planning structures or consulting trained engineers requires residents to use appropriate but expensive materials, sizes and capacity/level of infrastructure. It often disregards the organic and incremental practices of residents. Hence, residents who cannot afford it tend to circumvent formal planning procedures, standards or regulations since it does not meet their needs. Inconsistencies therefore occur between intended formal plans and residents’ low-cost incremental phasing in housing development as a result of not only the overwhelming growth of city but also the approach to planning. Hence, even when the government has good planning intentions expressed in the existence of formal planning codes and regulations to improve the quality of life of residents, *the approach* to planning serve as a constraint to meeting the

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realities of residents. As a result, residents are left with no choice but to circumvent the formal standards. “Most households use their own savings, sweat, equity, barter arrangements and remittances to build their houses” (Ferguson and Navarrete 2003). Hence, under self-provisioning, these developments are provided according to their resource capacities- time, money and labor.

Under these circumstances, the use of different varieties of materials and sizes of drains are adopted in the construction of the drains which affects the quality of the infrastructure. Also, drains are not well constructed to connect water into water courses, rivers and the sea to ensure a neat drainage discharge (Agyei-Boahene 2018). This could lead to choking and certain obstructions in the flow of the run-off. Hence, attributed to the condition of the drains. Moreover, these self-provisions are made when resources are available. Hence, influencing the existence of drains at certain points in time and leaving gaps in areas that have not been provided with drains. This could lead to issues of connectivity. These attributes constitute the determinants of an effective drainage system. However, it should also be noted that, even under these circumstances, the city keeps on urbanizing. Hence, the greater the increase in a city’s population, the more pressure is put on existing drains in that city. This has led to setbacks in the mitigation of flooding in Tema, Ghana.

1.2 Problem identified

In Ghana, as at July 2010, floods had affected about 33, 602 people with up to 15, 000 people displaced- living in temporary shelters and 36 dead (GRCS 2010; Yira et al 2013). According to Yira et al (2013), the effects of flooding include spread of sewage, fatalities, injuries, loss of crops and livestock, river bank erosion and damages to housing infrastructure. In economic terms, estimated cost of damage due to flooding in July and August were more than 1 million US dollars
and it is expected to increase to about US 4 million dollars in future. From 1900-2012, cost of damages due to flooding stood at 74,700,000 US dollars. (Yira et al 2013; CRED 2012). Loss of lives and properties are often witnessed in areas such as Odawna, Kwame Nkrumah Circle, Obetsebi roundabout, Kaneshie, Abossey Okai, Nima and Tema.

Apart from the natural drainage systems that are in the form of waterbodies, there are also engineered drainage infrastructure which are intended as hard infrastructure to mitigate the occurrence of flooding. However, engineered drains meet a small fraction of the city’s requirement. In countries like Nigeria, many have been observed to be undersized, unconnected or improperly channeled (Owuama et al 2014). Meanwhile, in Ghana, floods have been traced to faulty drains (Ngnenbe 2018; Sam 2009). Logah et al (2013a, 67) attributes the frequent flooding in Greater Accra Region to poor design of drainage systems which have most of them undersized and cannot hold runoff volumes. According to them, “most of the drainage systems were designed without considering the appropriate rainfall intensity values of the metropolis” (Logah et al 2013a). They are unsuitable for the environment they are located in. A study on flooding in Accra in Greater Accra Region, by Amoako and Boamah (2014), also identified the “three-dimensional” causes of flooding to include three interrelated factors: namely, rainfall and storm surges, impervious urban landscape and management of surface water resources and anthropogenic activities such as urbanization and land use changes.

In view of the challenges identified, it is obvious that the planning and provision of drainage infrastructure in Ghana has not been able to collectively and effectively achieve its function of mitigating flooding. Major constraints include rapid growth, mismatch between standards and needs, and the disconnect between scale of housing and scale of drainage infrastructure provision. Formal planning has not been able to capture the cultural context of
citizens, their everyday low cost, organic and incremental practices to come up with a coherent system that synchronizes all the infrastructures which are representations of people and institutions of the city. The planner’s intention has not been compatible with the local dwellers’ actual needs. It is apparent that informalities are reflections of the failure of formal planning. The insurgent practices of local residents are meant to address the problems they face in their everyday lived experiences. Hence, a robust and applicable approach to formal planning of drains is needed in order to enable infrastructures to serve their purpose effectively as intended. It must also be reiterated that drains serve as public infrastructure. Hence, they must also be planned, financed and provided in such a manner that it works for all. In doing so, lives could be saved, livelihood enhanced and the general quality of life improved. This research asks the broader question: How are public infrastructure systems planned for and provided in the rapidly urbanizing city?

1.3 Research question

The specific questions this research seeks to answer include:

- What are the differences in the quality, condition and connectivity of drains between planned and unplanned areas in Tema?

- How does the quality, condition and connectivity of drains affect its effectiveness in mitigating flooding in the planned and unplanned areas in Tema?

- How do residents adapt to planning regulations in drainage infrastructure provision?

- What should be the appropriate planning response by the local government?
1.4 Need for research

There have been extant studies about Government’s delay or inability to provide site and services adequately because of unbearable increase in population in urban areas (Roy 2009; Talen 2015). However, there is a gap in research about the paradoxical relationship between the low-cost, organic and incremental self-provision of public infrastructure and the imposition of order that is supposed to ensure consistency in type and quality of infrastructure, environmental friendliness and acceptable attitudes of residents. This research will serve as benchmark on which to advance knowledge about the need to consider the context of place, time and people in formal planning. It also reveals and proposes a robust approach in dealing with the challenge of keeping track of the various individual developments of a city and synchronizing them into a coherent system. This may appear contemporary to most cities that fund, provide and manage infrastructure in a conventionally large-scale and short-term remedial approaches which usually compromises on considering the need for ‘people’ as part of infrastructure.

This research demonstrates the need for a systemic, incremental and collaborative approach to city building where every individual’s practices and spaces become as part of a system to remedy urban challenges. Infrastructure planning and provisioning is expected to work for all. This is in support of Sustainable Development Goal 11 which seeks to make “cities and human settlements inclusive, safe, resilient and sustainable” (UN 2018). This research is not only relevant to planners, but also Architects, Urban designers and Public Institutions in Ghana and beyond who have the political authority in making decisions as part of public policy and planning. Thus, this research looks beyond the context of Tema by considering the provision of drainage systems the provision of not only drainage systems but other infrastructure such as water, sidewalks, roads and electricity. Target institutions in Ghana include National Disaster Management Organization
(NADMO), Tema Metropolitan Assembly, Tema Development Corporation and Tema Tradition Council.

1.5 Organization of paper

This paper is organized in five chapters. Chapter One (1) provides a background of the need for drainage system under the rapid urbanization and the political, social and economic aspects that influence its quality and condition. Chapter Two (2) provides a review of literature about the different approaches to planning. It looks at establishing relationships between what is expected from formal planning and what seems to be the reality. Chapter Three (3) the method that was used to assess the effectiveness of the existing drainage system of the two study areas. Chapter Four (4) examines the characteristics of the existing drainage system according to the characteristics of the natural environment. It tries to make inferences by looking at it through the lenses of resident’s adoption of certain materials and sizes of drain and institutional approaches in terms of housing finance structures and regulations. Finally, Chapter Five (5) summarizes the findings and provides recommendations for the planning, financing and provision of drainage.
Chapter Two

Planning of Drainage Infrastructure

This chapter provides an overview of literature explaining the effectiveness of drainage infrastructure and revealing the gap in planning and provision of drainage canals in Ghana. Simply, it looks at the provision of drainage canals as public infrastructure and how ineffective drainage system could cause problems such as flooding.

2.1 Drainage canals as infrastructure

Drains are infrastructure. According to Jochimsen (1966, 100), infrastructure is defined as “the sum of material, institutional and personal facilities and data which are available to the economic agents and which contribute to realizing the equalization of the remuneration of comparable inputs in the case of a suitable allocation of resources, that is complete integration and maximum level of economic activities.” Simone (2018, 407) also views infrastructure as positioning “its residents, territories and resources in specific ensembles where the energies of individuals can be most efficiently deployed and accounted for.” Hence, these definitions view infrastructure as supportive systems that promotes development. Drainage system in Western and European countries typically consist of street gutters and storm drains that are covered. The street gutters carry untreated water downstream by gravity to storm drains and are finally channeled to rivers or streams. Meanwhile, in Ghana, the drainage system consists street gutters and storm drains whereby “the conventional drainage type include open drains.” There are also pipes and small gutters in and around houses that connect to street gutters. These structures are commonly referred to as ‘gutters’ by Ghanaians. However, in this research, they are referred to as drainage canals or drains.
2.2 What is an effective drainage system?

Since the effectiveness of drains is dependent on the ability of the drain to perform its functions properly, the functions and outcome of a drain is used to determine whether a drain is effective. In order to know how the variables of connectivity, condition and quality influence the effectiveness of drainage system, there is the need to know what an effective drainage system is. Some researchers have defined effectiveness of drainage infrastructure in different ways. Magdi’s (2014) work in Khartoum in Sudan was centered on the linkage between poor drainage and road performance (life span) in Khartoum, a city in Sudan. Inadequate drainage system were observed to result in damages of pavements leading to unhealthy environment and poor drainage conditions.

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especially during rainy seasons. The most common causes of road drainage problem were found to be related to improper road geometry, insufficient capacity of drainage structures, poor construction, and lack of proper maintenance. Yira et al (2013), on the other hand, investigated the reasons for the inadequate drainage systems on roads and surrounding environments in Narok-Mai Mahiu road. Results were that the drainage system was inadequate to drain the runoffs, hence, resulting in the washing away of parts of the road, gully erosion on people’s land, blockage of road, loss of human lives and property. Meanwhile, according to Owuama et al (2014), “an effective drainage system has the capacity to remove overland flow soon after rainfall.” However, in contemporary times, projects such as Living with Water by Waggonner and Ball Architects (2013) have introduced modern practices which views storm drains as not only draining/channeling runoff water downstream areas but also retaining/slowing, storing and circulating water. Holding the water decrease the time of concentration by increasing storage and slowly releasing water after an event. Hence, bringing a new perspective of drains as multi-functional. These researchers seem to assume that the issues they identified would not have occurred if there were proper drainage systems. Hence, in cases where expectations did not meet reality, the drainage system is said to be ineffective. This implies that where the downpour of rain has led to flooding, the drainage system has not been effective.

Based on the previous studies as mentioned above, it could be established that the quality, condition and existence of drains influences the occurrence of flooding, especially lower elevation areas that are by nature prone to flooding. Hence, implying that an effective drainage system of a particular area is one that could prevent these different issues. Hence, seeking to meet the required functions of drains, in this study, is the ability of drains to mitigate flooding. Asumadu-Sarkodie et al (2015) define flooding as a natural hazard which displaces people by destroying their land,
houses and other tangible goods and assets. According to Zakaria et al (2017), on the other hand, flooding occurs when water overflows a river bank and / or inundates land that is normally dry. Flooding does not only lead to structural damages but also has impacts on the socio-economic lives of residents. Yira et al (2013), links flooding to poverty. He insists that flooding events have impacts on the economy as a lot of resources are needed to recover damages. According to Yira et al (2013), the effects of flooding also include spread of sewage, fatalities, injuries, loss of crops and livestock, river bank erosion and damages to housing infrastructure. Hence, there is the need for effective drainage systems that are engineered to prevent flooding.

According to the National Hydro-Meteorological Technical Committee and the National Platform on Disaster Risk Reduction and Climate Change Adaptation, a research conducted to evaluate all flood-prone areas in Ghana found that the cause of flooding include: defective engineering works; building on waterways; changes in land use due to urbanization; poor land administration and planning; poor sanitation and lack of drain maintenance; obstructive activities by utility agencies; tidal influence of the sea and the inadequate funding for flood mitigation measures (Yira et al 2013). It was emphasized that “there is no evidence that unusual rainfall has been occurring recently that could explain the increased occurrences of flooding being experienced. Rather, the problem was lack of drainage facilities to collect the storm water for safe disposal” (Karley 2009; Yira et al 2013). Karley (2009) asserts that this was as a result of ineffective planning regulation “which either ignore the illegal erection of buildings and other structure on floodplains and unhealthy habit of dumping refuse and other solid wastes in open drainage systems.” According to Yira et al (2013), the flaws in the drainage network are as a result of being “undersized, unconnected or improperly channeled drains.” In addition, humans contribute to flooding by developing in areas that are otherwise supposed to serve as natural flood
buffers. Parameters of the rainfall influence the spatial and temporal characteristics of the catchment (Yira et al 2013) and if drainage canals do not have the necessary capacity to drain away the amounts of rain, a flooding event is likely to occur. Hence, it could be argued that “location of the urban areas in the catchment is a key element in its exposure to floods” (Yira et al 2013). This implies that the appropriate condition, quality and connectivity of the drainage system that is needed to support the built environment as it meets the natural environment. This permits us to focus on assessing the effectiveness of the drains as a contributing factor that could lead to the occurrence of flooding. Hence, there is the need to focus more on the human-induced flooding.

Most floods take hours or even days to develop, giving residents ample time to prepare or evacuate (Zakaria et al 2017). Though this may be true, these short-term interventions may not be relevant in areas where flooding is perennial. Resilience is defined by Amoako (2015) as the capacity of individuals, communities, institutions, businesses, and systems to survive, adapt, and grow regardless of the changes and challenges they experience. “Where sustainability aims to put the world back into balance, resilience looks for ways to manage in an imbalanced world” (Zolli 2012). There is the need to incorporate resilience and sustainability in social, political, environmental structures that support the physical infrastructure. This would help to minimize local residents vulnerability to natural hazards for present and future generations. Vulnerability is defined as the “characteristics of a person, a group or place in terms of their capacity to anticipate, cope with, resist and recover from the impact of a natural disaster” (Wisner et al 2004; Amoako 2015). According to Wisner et al. (2004), vulnerability is measured by the actual outcome of the hazard such as lives lost and properties damaged. These outcomes could have inter-generational impacts on affected people. Amoako (2015) also views vulnerability of an individual or community in three levels: the exposure of the community or individual to the perceived or actual
hazard. This is based on social, economic, physical, or environmental. Second, the sensitivity to the perceived or actual hazard, which is based on social, economic, and political conditions. The third is the ability to plan for, respond or adapt to the hazard. Hence, vulnerability to hazards is dependent on the exposure, sensitivity and ability to plan, respond or adapt to the hazards. Amoako’s (2015) work reveals that growth processes, land ownership structure, security of tenure, and state government institutions have played important roles in the exposure and vulnerability to perennial flood events in Accra. Hence, the social, economic and environmental aspects of planning all have implications on the physical which in turn influences vulnerability of people. This research considers exploring the physical aspects which could lead to vulnerability of residents to flooding hazards and the interrelationships between other aspects of planning. It seeks to find gaps in these interrelationships and recommend possible solutions to strengthen them.

2.3 Formal planning and insurgence

In developing cities, it is dominated by self-help, progressive and incremental delivery process with varied levels of informality, management and state support (Yiftachel 2009, 5). In most developing countries such as India and Ghana, informality is a norm. There are also worst cases of informality that exists in the form of slum developments and squatter settlements. Informal communities are often located on flood plains; steep slopes prone to subsidence, landslides, and mudslides; wetlands; and unused state lands close to major transport terminals or networks (Amoako 2015; Gencer 2013). Informal communities may therefore be more vulnerable to natural hazards. Roy (2009) explained that “urban informality is not the ecology of the megaslum, rather, it is a mode of the production of space and a practice of planning.” Hence, informality has been attributed to poor planning. “Citizens and other stakeholders have knowledge to contribute and
values to assert” (Healey 2010, 15) and Miraftab (2016) suggests that people’s agencies are so strong that they are able to counter hegemonic interests. However, at what point would people no longer be able to adapt to formal planning?

Earlier conventional approach to planning had limited its scope to the scientific goal setting approach. As a result, planning intentions have not been able to meet realities since social aspects are equally important. Realizing the complexity of interests in cities have led to the several discussions about the need for planning to be more people oriented, incremental and collaborative. Hence, a departure from highly technical and managerial approaches in planning. Jane Jacobs’ (1961) writing has made a paradigm shift in how cities should be viewed - from the ground level and as a whole. As stressed by Lynch (1960, 110), “the city is not built for one person, but for great number of people of widely varying background, temperaments, occupations and class.” They suggest that the interests of all people should be factored in addressing the needs of today. By assembling our observations, we should arrive at a view of the whole which will help us to understand the urban organism in all its functions (Sert 1947, 10). Hence, the interventions of a city planner should be geared towards attaining a consolidation or consensus of the views of all people – the public image.

Governments usually tries to “codify this multiplicity of views into classifications and definition to legitimize them” (Simone 2018). According to Simone (2018), “once this is done, the different elements of society assume their own places and trajectories and become vectors through which social power is enunciated.” This report that they assume their own places and trajectories based on the choices/options they have. The standardization of infrastructure provisions/needs results in a situation whereby it becomes a typical notion that “there are to be few surprises, few chances of unregulated encounters as the city is turned into an object” (Simone 2018, 408). This
undermines the organic production of spaces by local residents through innovative practices and actions undertaken in their everyday life as they seek to satisfy their basic needs in order to survive. Under this notion, citizens who cannot afford to follow this rigid system are unable to conform to the formal planning regulations. This leads to an insurgence on one part and an imposition on the other part. Under this condition, participation, consolidation and communication becomes challenging.

2.4 Planning for Incremental development

Lynch (1960, 2) identifies the city to be one with “no final result, only a continuous succession of phase.” How can this idea be carried unto infrastructure planning and provision? According to Ferguson and Navarrete (2003), “in developing countries, 70% of housing investment occurs progressively—that is households acquire land through purchase or invasion, and gradually improve the structure and legal tenure, and lobby for basic services.” This is the case for non-estate (unplanned) areas. The improvised activities of people are to be seen as part of the solution rather than problems as perceived by city officials.

Talen (2015) and Simone (2018) made emphasis about incremental planning. According to Talen (2015), Camillo Sitte appreciated “complexity, diverse urban forms as opposed to the geometric regularizing.” This served as influences of others such as John Ruskin and William Morris who advocated for dense urban fabric and the way cities developed slowly over time, through many individual, human scaled adjustments. According to Jacobs (1961, 205), “high densities of dwellings and overcrowding of dwellings are often confused.” She made a strong argument that “the dense concentration of people are one of the necessary conditions for flourishing city diversity” (Jacobs 1961, 205). Contrary to those who oppose high densities and
view the noisy interactions of people in the streets to be chaotic, Jacobs (1961) insists that social relationships between people in cities needs to be strengthened. However, at what point does densification (usually in unplanned areas) become unbearable? In recent times, densification are being advocated for because of its benefits to human health, social interaction and environment. It also saves resources since it minimizes the cost of the utility lines. Hence, reducing plot sizes have become a popular intervention recently.

Jacobs (1961) encouraged planners to translate real life experiences into policies and make the citizens, the center of dominance. That being said, how can ‘orderly’ densification be planned for as part of an effort to incorporate the low-cost incremental provision of drainage infrastructure? Jacobs (1961) also argued writing that “emphasis on bits and pieces is of the essence: this is what a city is, bits and pieces that supplement each other and support each other.” However, how can large-scale infrastructure funds be channeled towards these expectations especially when local governments try to use available scarce resources to provide infrastructure which seems to be cost-effective and favors large-scale producers of materials when provided in a standardized fashion?

Simone (2018) also spoke about the complex intersections as against the rigid formal institutional frameworks. According to him, “the accelerated, extended, and intensified intersections of bodies, landscapes, objects and technologies defer calcification of institutional ensembles or fixed territories of belonging.” Cities, by nature, are built on this very notion. How can the flexibility that is inherent in the development practices of residents be incorporated into formality or standardization? Decision makers are under limits of time, money and expertise and allocating these resources in an incremental phasing for large-scale drainage infrastructure provision is a challenge. Hence, implementing drainage infrastructure projects could be challenging. This is because the incremental housing development of residents are usually based
on individual or family investment while drainage infrastructure, on the other hand, are provided on a collective scale. Simone (2018, 409) was of the view that “the disposition of irregularities and the outcomes of collaborative in the city can be open ended, unpredictable and made singular.” This hints the possibility of incorporating flexibility in planning and provision of drainage systems. Open collaboration and engagement with residents who are beneficiaries to any planning intervention made by local governments could lead to a low-cost incremental and flexible approach to providing drainage canals in rapidly urbanizing cities.

There is a gap in research with regards to the paradoxical relationship between the low-cost, organic and incremental self-provision of public infrastructure and the imposition of order that is equally needed for equity, environmental, health and safety purposes. Based on the gaps identified here, this research hence seeks to assess how drains as public infrastructure systems, are planned and provided. This research seeks to describe, understand and address challenges regarding the relationship between drainage systems and the approach to planning and provision of drains in rapidly growing cities.
Chapter Three

Methods

This chapter explains the research methodology that was adopted in assessing the effectiveness of the drainage system in the study areas. It begins with a profile of the study areas, describing how they were selected. This study uses three indicators – quality, condition and connectivity- to measure the effectiveness of drainage infrastructure.

3.1 Brief profile of study area

Based on the research questions and objectives put forth in this research, this study relied mainly on observation method and spatial analysis through mapping to assess the quality, connectivity and availability of drains of three neighborhoods and its influence on the effectiveness of the drains.

The three neighborhoods studied here include: the planned neighborhood- the estate area in Sakumono and the unplanned (the non-estate) neighborhoods- Asoprochona in Sakumono and Abonkor, Ziginshor & Ashaman area in Tema Manhean (also known as Tema Newtown). All study areas are found in the industrial metropolis of Tema. According to the International New Town Institute (2009), planned settlements “were built according to a blueprint designed by an architect or planner” while unplanned settlements are ‘self-organized’. Since there’s no justification that the unplanned areas mentioned here have had no formal planning, this research defines planned and unplanned areas based on certain characteristics in layout and housing development processes as shown in Table 3.1. While the estate neighborhoods have been provided drainage infrastructure through the formal real estate development processes in housing, the non-
estate neighborhoods have most of its drainage infrastructure provided by residents themselves and usually do not comply to formal planning regulations and principles. It is also worth noting that these areas do not strictly represent income levels of residents but rather housing development processes that works for them based on their context of time, place and culture.

Table 3.1: Description of planned (estate) and unplanned (non-estate) areas

<table>
<thead>
<tr>
<th>Types of spaces</th>
<th>Example</th>
<th>Characteristics of space</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Planned areas</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Estate areas)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Sakumono</em></td>
<td></td>
<td>These are estate areas that usually have site and services provided as part of housing for purchase. They have an orderly arrangement of buildings, streets and lots.</td>
</tr>
<tr>
<td><strong>Unplanned area</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Non-estate areas)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Asoprochona</em> neighborhood*</td>
<td></td>
<td>These areas grow organically and have organic layout and street pattern. Housing and drainages are usually provided by residents themselves. This is similar to Acquaah-Harrison’s (2004) description of “unplanned development.”</td>
</tr>
<tr>
<td><strong>Unplanned area</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Non-estate areas)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Tema Manhean neighborhoods -Abonkor, Ziginshor &amp; Ashaman</em></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Google Earth 2019
3.1.1 Selection of Study areas

The study areas were selected based on the following criteria (see Figure 3.1.1): First, selection was based on areas are prone to flood; Second selection constitute areas which meet what the research demands- which area areas that are planned and unplanned. Finally, third selection was based on areas that qualify for the first and second selection (areas that are planned, unplanned and partially planned that are prone to flooding) and fall within the same geographical characteristics- (topography, ground level, soil type, raining season (mm rain). The final selected areas became Tema Manhean, Sakumono Estate area and Sakumono Village.

Figure 3.1.1: Method for selection of study areas

These study areas were selected using purposively with the help of the Municipal Authority using background secondary data lists flood prone areas and geographical characteristic based on the criteria aforementioned above. Also, a preliminary survey was made to ensure that all criteria are met. In order to successfully make comparisons of effectiveness of drainage system between these three neighborhoods, the study areas were selected based on their differences in terms of
population densities and their similarities in terms of hydrology, rainfall patterns and waste management (similar methods of waste disposal and amount of waste generated). To make the natural characteristics of the areas inclusive in this study, areas prone to flooding or waterlogging were selected. Hence, all the study areas have similar hydrological characteristics such as topography, soil type and watershed characteristics. It ensures that the all major independent variables that could influence the effectiveness of drainages, as identified from literature, were included. Also, since the method of disposal of waste could also influence the effectiveness of drains, this study measured whether a drain is choked or not. This could help to identify the magnitude of influence of waste on the effectiveness of drainage at a particular study area. Even though all these factors/variables influence flooding, it is also true that every city has different causes (manmade and natural causes) of flooding because of differences in geographical contexts, culture and governance. Hence, selecting study areas in which certain variables had less influence on flooding in the two study areas was imperative. Hence, the study areas were selected in such a manner that poor drainage systems was the outstanding cause of flooding in the area.

3.2 Sources of Data

Methods used in this study were borrowed from previous studies related to drains and flooding. Yira et al (2013) undertook a research about the perennial occurrences of floods in Accra. His research set out to ascertain the hydrological, economic and political contexts and its relationship with urbanization processes and the annual occurrences of flooding. He used case study of recent types and causes of floods in Accra and Ghana. He also used secondary data obtained from internet, journal publications, reports and newspaper publications. Personal accounts and observation of incidence of floods in Ghana were also obtained from secondary data which included statistics of
flooding events and time series data. It was concluded that flooding in Ghana is multidimensional and that the rainfalls in Ghana are not unusual hence attributing flooding mainly to human and hydrological factors. He recommended that the hydrological, economic and political perspective be integrated. Victor’s (2010) study, on the other hand, concerned itself with examining the adequacy of the drainage system in Narok-Mai Mahiu road. A research survey was designed to obtain the information that would describe the state of drainage infrastructure. Data collection methods included the use of questionnaires, photographs, observation and interviews. To measure the adequacy of drainage system, Jitendra et al (2013) also used the ordinal measurement criteria for classifying drainage system. This criteria assumes that removal of runoff water within 2 hours from the layer of a drain implied that the drain’s ability to undertake this function has been excellent while within 1 day, 7 days and 1 month meant that it has been good, fair and poor respectively. However, if runoff water does not drain then it meant it has been very poor.

Inspired by these researchers, this research followed a similar methodology. However, these research methods which are used to measure the effectiveness of drainage infrastructure were adopted to fit the context of Ghana. While some of these studies were done at block-scaled, others were done at neighborhood scale and even regional. This study would however be undertaken at multi-scalar level. The assessment of the drainage system in this study would be focused at a neighborhood scale while the natural characteristics are studied at a regional scale. In pursuance of the objectives, this study adopted both quantitative and qualitative methods. Sources of data included both secondary data- from news and research articles, reports and historical documents- and primary data which were collected by relying mainly on observation and pictures to record the quality, condition and availability of drains in the study areas. Even though data on
records of flooding events that was taken immediately after flooding were insufficient and this research was constrained by time and money to conduct Owuama-like survey, a low-budget but quality method was adopted. The method used to answer the research questions is described below.

3.2.1 Secondary Data

Relevant secondary data in this study included population densities, waste disposal methods, rainfall patterns, natural drainage and hydrological characteristics. It also used DEM maps as similarly used by Nyarko (2000) to analyze the topography of the study areas. This was relevant in selecting the study areas. Secondary data included building codes, ordinances and zoning regulations. It gave a brief description of certain programs and regulations adopted for the study areas. These are data which were used to find what the planner intended for the study areas and compare it to the existing situation in order to answer the research questions. Also, time series data of flooding from 2010 - 2015 records of the study areas were also collected.

These data were gathered from the internet and institutions including Tema Development Corporation, Ghana Meteorological Agency and Tema Town and Country Planning Department. Hence, this study utilized secondary data which were analyzed alongside primary data to measure the quality, connectivity and availability of the drains and their effectiveness in mitigating flooding in the planned areas and unplanned areas.

3.2.2 Primary Data

Qualitative primary data of drains were collected using the observational method to record the variables of quality, condition and connectivity as seen in Figure 3.2.2 and Table 3.2.2. These would be recorded in the form of a YES or NO response. Meanwhile, quantitative primary data for this study included size of drains which were measured by height and width, all within the same units of measurement (inches) using tape measure. Photos were also taken as part of the
observational study. Only photos of the physical infrastructure were taken while ignoring human figures. These images are only to give evidence of the existence of all qualities of the drain which cannot be measured accurately by only observing from Fulcrum but through field observation. Hence, the images were to enable observations that are less likely to be effectively observed in Google map view. The following lists the measurements used in this study:

**Figure 3.2.2: Variables used in measurement**

- **Quality**
  - materials
  - cracks

- **Condition**
  - dense vegetation
  - type of drain
  - choked

- **Connectivity**
  - gaps
  - size

Source: Field work, 2019
<table>
<thead>
<tr>
<th>Measurements</th>
<th>Examples</th>
<th>Brief Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Materials</td>
<td>• concrete</td>
<td>The type of material used in the construction of drains is an indicator of its quality. With regards to materials used for construction, another indicator of quality of drains is the existence of cracks in the drainage structure. For the purpose of this research, only materials that could be observed clearly with the researchers eyes were considered.</td>
</tr>
<tr>
<td></td>
<td>• cement blocks</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• block and concrete</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• pipe sand/soil</td>
<td></td>
</tr>
<tr>
<td>Existence of cracks</td>
<td></td>
<td>Cracks in drains is an indicator of its quality. Note that the availability of cracks do not imply that it was as the result of the materials. It could be as a result of the continuous usage or damage from vehicles or it could also depend on the age of the drain/year it was built. Hence, since cracks alone as a measure cannot be used to determine quality of drains, materials used in the construction of the drains was also assessed. Due to the lack of data on the age of drains, the type of materials adopted became a primary measure while the existence of cracks became the alternative measure. Another reason is the challenge of identifying how many cracks would count as evidence enough to be attributed to the low quality of the drain. In response to this, a</td>
</tr>
</tbody>
</table>
The severity of the cracks measure\(^5\) was adopted measuring from low to high levels.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of drains:</td>
<td>This is to assess the design of the drains which affect its quality and its relationship with controlling runoff. The types of drains include covered, open, pipe and un-engineered drains. ‘Covered’ means that the drain is constructed or casted with concrete as part of the covering. It does not include wooden covering or culverts for crossing the drain by pedestrians or vehicles.</td>
</tr>
<tr>
<td>Dense vegetation around drain</td>
<td>Dense vegetation could prevent easy draining of runoff water. Hence, observations were made considering areas that are affected.</td>
</tr>
<tr>
<td>Choked with waste</td>
<td>The waste measurement is to measure whether it is choked to the brim of the gutter. If a drain is filled more than 50% of the height of the drain, it is described as a highly choked drain. The selection of date to check waste in drains was done at random since waste disposal is done on a daily basis.</td>
</tr>
<tr>
<td>Siltation</td>
<td>Siltation occurs when sand or other particles from surrounding areas accumulates in drains, when it is carried by run-off water, wind or human actions, resulting in the reduction of the size of the drain. The severity of the siltation is also measured to assess the level of siltation.</td>
</tr>
</tbody>
</table>

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\(^5\) See Appendix 6.4
### Connectivity

| Gaps | The link between one drainage line of a lot and the other of a different lot are considered as nodes connectivity in this study. The differences of sizes of drainage lines as well as the existence of gaps aligning particular lots could result in a lack of connectivity of the whole drainage system. In order to focus on the drains, studying the culverts are also replaced with *connectivity in the nodes of one drain to another*. Since culverts exists for connectivity purposes, the study of connectivity here automatically incorporate the function of culverts in the analysis. |
| Size (in feet) | This measures the height and width of the drain (in inches) to find its appropriateness in specific areas. For map making sake, the height x width (ft²) was also used in order to clearly see the differences in sizes from area to area. It is expected that areas in close proximity to water bodies which have lower elevations have larger sizes of drains. Knowing the sizes of the drains would help to ascertain whether or not there are indeed variations of sizes since it is assumed that the bigger the size of drains, the better. |

Source: Author’s construct, 2019

### 3.2.2.1 Data collection using Fulcrum

These data were collected on-site using Fulcrum. Fulcrum is an application on mobile phones, iPads and even laptops that is used by researchers for designing surveys and recording data based on the survey design. It could be used through its website or downloaded as a mobile phone app.
Pictures could also be taken in addition to recording data based on where the researcher was standing. This helps to enable easy mobility during data collection and also assures credibility of information. Data was recorded via Fulcrum for left drain and right drain, cleaned and input into ArcGIS.

The exact point of location the researcher stands to take the pictures and direction of the camera could all recorded in Fulcrum. Hence, it provided an opportunity to obtain records for the left and right drain on a low budget. It was ensured that both study areas had the same unit of measurement. This was to enable easy comparisons. The researcher walked on the streets of the neighborhoods using the camera tool in the Fulcrum app to capture images of drains. During the map making process, the researcher ensured that the pictures which were taken using Fulcrum were referred to in order to know which drain was recorded as left or right using the direction that is shown in Fulcrum.

Figure 3.2.2.1: Use of Fulcrum app
Following the field data collection, left and right drainage lines were created by referring to the direction the picture was taken via Fulcrum app and data from record points were joined based on unique IDs. Data from record points were however cleaned before joining to drainage lines. This was done by exporting the record points data from ArcGIS in order to maintain the IDs created automatically by ArcGIS. Following this, it was cleaned in Excel and given unique IDs for both left and right drains of parallel road paths. This is to prevent loss of data and accuracy of data. After this, it was once again imported into ArcGIS for further detailing. When working in ArcGIS it must be ensured that drainage lines are split according to the lot size. Hence, representing the length of a drain aligning a particular lot/parcel. It assumes that people build their drains only to the full length of their lots. Parcel data for Tema Manhean and Sakumono were obtained from TMA and TDC, respectively. However, in areas that do not have well-defined lots/parcels, especially in some parts of the unplanned areas, data were recorded according to any changes in the measures-whether choked, size, type of drain, siltation, etc. This was done carefully by observing thoroughly. Human errors were easily controlled since the study areas are small in acreage.

3.3 Spatial analysis

These data were input, decoded and cleaned using Excel and ArcGIS software, and processed into useful information in the form of maps for further analysis. Available drainage systems would be shown through mapping. This was done by using existing historical satellite imagery. The existing drainage system was then compared to the corresponding flooding events that have occurred in the study areas to know how the quality, condition and connectivity of drainage systems could affect the likelihood of flooding occurrences.
3.3.1 District level analysis

The research made use of the 2012 boundaries of Tema Metro since districts were split in 2012. According to PHC Regional Analytical Report for Greater Accra Region, the 2010 Population and Housing Census was conducted in 170 administrative districts which are made up of 164 districts/municipals and 6 metropolitan areas. GSS also considered the 33 sub-metros under the 6 metropolitan areas. Hence, leading to 197 total number of statistical districts. Following this process, the 2010 census data were upgraded based on the new boundaries created. Currently in 2018, the certain district boundaries have been split again. When districts are split, it affects analyzing time series data. Hence, the year interval 2010-2018 was selected because the boundaries were not affected by any changes within this period.

Flooding records at the district level was obtained as well as flooding in the specific study areas. The district data was obtained from NADMO while the neighborhood level data was obtained through a media search. For neighborhood level data, a search was done online using key search words like “flooding in Sakumono,” “flooding in Tema Manhean” and “flooding in Tema Newtown.” News articles were reviewed and date reported, date occurred, areas, number killed, affected, displaced, houses affected and response from Authority were obtained. To know the date particular flood events occurred, the date reported and specific dates enlisted in the news articles were recorded. Following this, tables or graphs showing flood events were prepared.

3.3.2 Transect Analysis

A West-East transect line cutting across Tema Manhean and Sakumono was made. This presents a unbiased method of assessing the availability and qualities of the drains as it moves farther from the lagoons/waterbody and low elevation to higher elevations. A fixed interval was not selected. Rather, all specific points on the road which meets the transect line were analyzed. Also, the
direction of the lagoon was taken into consideration to position the transect line. Transect lines were in perpendicular to the lagoons in both study areas. Elevation sections were also created by measuring the distance of the points of contact from East to West.

**Figure 3.3.2 1: Showing transect lines and points**

3.3.3 Elevation, proximity and rainfall analysis

Since the effectiveness of drainage as a place at the regional level could affect the vulnerability of areas to flooding, it is rational to look at this research based on proximity to lagoons. Nyarko’s (2000) work used certain variables to know the discharge/runoff rate. It used \( Q = 0.28 \times Cs \times C \times I \times A \), where \( Q \) is runoff rate, \( Cs \) is storage coefficient, \( C \) is runoff coefficient, \( I \) as rainfall intensity and \( A \) as drainage area. Hence, at a certain rainfall intensity, giving a certain storage coefficient and runoff coefficient, the discharge could be obtained. According to a report from NADMO (2012), the proximity to water bodies and (altitude) elevation of the land are among the major indicators for knowing areas that could be vulnerable to flooding. Other indicators include the soil texture, rainfall, altitude, slope, flow accumulation areas and land use. As a result of the lack of sufficient data available and since this research studies the vulnerability of residents to flooding at a
neighborhood scale, it was reasonable to use the proximity to water bodies and elevation of specific area which are major alternative measures for vulnerability to flooding hazards. It could also be argued that the effectiveness of a drainage line elsewhere could affect the vulnerability of other areas at low elevations to flooding. Thus, requiring data that are not accessible for the researcher. Hence, a justification of the rationale behind using proximity to water bodies as basis for analysis.

Table 3.3.3.1: Criteria for proximity to waterbody

<table>
<thead>
<tr>
<th>Author’s criteria</th>
<th>NADMO’s criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Class</strong></td>
<td><strong>Description</strong></td>
</tr>
<tr>
<td>1</td>
<td>Very close</td>
</tr>
<tr>
<td>2</td>
<td>Near</td>
</tr>
<tr>
<td>3</td>
<td>Very far</td>
</tr>
<tr>
<td>4</td>
<td>Distant</td>
</tr>
</tbody>
</table>

Source: NADMO (2012) and author’s construct

The elevation of a place above sea level affects its susceptibility to flooding with low-lying areas at more risk as against highland areas, which are virtually safe from the hazard” (NADMO 2012, 21). Also, according to NADMO (2012, 23), “the proximity to water bodies within their environments is an indication of how vulnerable places will be to river flood, as places near rivers would experience the proximal effects of flooding than those farther away.”

Table 3.3.3.2: Criteria for Elevation

<table>
<thead>
<tr>
<th>Author’s criteria</th>
<th>NADMO’s criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Class</strong></td>
<td><strong>Description</strong></td>
</tr>
<tr>
<td>1</td>
<td>Very high</td>
</tr>
<tr>
<td>2</td>
<td>Gentle</td>
</tr>
<tr>
<td>3</td>
<td>Low lying</td>
</tr>
</tbody>
</table>

Source: NADMO (2012) and author’s construct
“The rainfall pattern influences the vulnerability of areas to flooding. Places with very high annual rainfall rates, given other underlying environmental factors, may be prone to either slow unset, rapid unset floods or river floods.” Since the scope of the study areas lie in one meteorological data collection station, comparison of the impacts of rainfall is based on the flooding events that have occurred over the years. Also, as a result of the purpose and context (scale) of this study, different criteria as seen in Table 3.3.3.1 and Table 3.3.3.2 are used to assess proximity of water bodies using miles as the unit of measure and the elevation (altitude) of the land in meters.

The outputs (maps) and transects were used to assess inhabitants’ conformity to plans and the effectiveness of the drains in curbing flooding. It was found that planned areas have effective drainage infrastructure as compared to unplanned areas. This is dependent on the quality, connectivity and availability of drains alongside the flooding events. Certain factors influence these challenges were found to be the lack of compliance to planning principles and codes by local residents in Tema Manhean. Based on the findings of the research, design strategies such as green infrastructure, modern practices in drainage design and progressive approaches to providing drainage infrastructure in a low-cost incremental financial phasing were proposed.

In summary, the following shows the data collected, type and source of the data:

Table 3.3.3.3 Summary of data collection and analysis

<table>
<thead>
<tr>
<th>Data collected</th>
<th>Specific data</th>
<th>Type</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demography and data on flooding</td>
<td>Demography and Natural</td>
<td>Secondary data</td>
<td>Reports and research materials</td>
</tr>
<tr>
<td></td>
<td>characteristics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standards and regulations, plans</td>
<td>Building codes, ordinances and zoning regulations</td>
<td>Secondary data</td>
<td>Online/Town and Country Planning (TCPD)</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>-----------------------------------------------</td>
<td>----------------</td>
<td>-----------------------------------------</td>
</tr>
<tr>
<td>Historical documents</td>
<td>History of morphology</td>
<td>Secondary data</td>
<td>Traditional authorities, reports and research articles</td>
</tr>
<tr>
<td>Physical characteristics of access roads and drains</td>
<td>Areas prone to flooding</td>
<td>Primary data: Recordings and aerial photos</td>
<td>On-site: Planned and unplanned areas, NADMO</td>
</tr>
<tr>
<td></td>
<td>Connectivity</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Quality</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Condition</td>
<td></td>
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</tr>
<tr>
<td>GIS shapefiles</td>
<td>Drains</td>
<td>Primary and Secondary data</td>
<td>Field data</td>
</tr>
<tr>
<td></td>
<td>Layout and parcels</td>
<td>TCPD, Tema Development Corporation (TDC)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Areas prone to flooding</td>
<td>Town and Country Planning (TCPD)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Elevation data</td>
<td>USGS</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Administrative boundaries</td>
<td>ESRI (online data)</td>
<td></td>
</tr>
</tbody>
</table>

Source: Author’s construct, 2019
Chapter Four

Results

4.1 Profile of Study area

Tema metropolis is a coastal district located 30 km East of Accra, the capital city of Ghana and found in the Southern part of Greater Accra Region- one of the 10 administrative regions of Ghana which covers approximately 786.59km2. The district is located within longitude 0° 00’ 5.40” E and latitude 5° 38’ 19.19” N. It covers a total land areas of approximately 87.8 km2 (constituting about 11 percent of the total land area of Greater Accra Region of Ghana) and shares boundaries with Dangme West District to the North East, Ledzokuku Krowor Municipal to the South west, Adentan Municipal and Ga East Municipal to the North-West, Akwapim South District to the North and Gulf of Guinea (sea) to the South while Ashaiman Municipality is appears to be an enclave located at the center of Tema Metropolis (see Figure 4.1).

Figure 4.1: Contextual map of study area

Source: Author’s construct using data satellite images from Google Earth, 2019
4.1.1 History of Tema

The metropolis has three main sub-metropolitan councils: Tema West, Tema East and Tema Central. However, in 2018, Tema West was carved out into its own district. Tema was created out of a cluster of small fishing villages. History has it that “Torman”, as it was originally called was founded by a migrating people called the ‘Kpeshie’s’ who were Gas. They brought along seeds of the gourd plant, which they planted at their new-found site. The seeds thrived very well producing lots of gourds. Hence, with time, the area became known as “Torman”, meaning a town of gourds. It was located at the current location of the old Meridian Hotel. The traditional people were later relocated to their present location at Tema Manhean in 1961 when the Tema Harbour was constructed.

The Tema Harbour was officially opened in February 1962 and since then, it has been the center of economic activities in the Metropolis and Ghana in general. Located on the Greenwich Meridian and 28.5 km East of Accra, it provides the appropriate facilities to handle efficiently the expected growth in trade and industry in the country. To ensure that this political ambition is met, the Tema Development Corporation (TDC) was established by the Tema Development Corporation Ordinance No. 35 of July 1952 and the government compulsorily acquired about 166 square kilometers for the construction of a harbour, industrial and commercial establishments and a township (Kasanga & Kotey 2001). Tema Manhean had to be resettled compulsorily to give way for these developments. Today the Metropolitan Area serves as the industrial hub of Ghana with over 500 industries engaging in mainly industrial, service and commercial activities. According to GSS (2014), the development of Tema Manhean was initially planned. However, with time, the area has experienced an organic growth pattern.
4.1.2 Land management in Tema Manhean and Sakumono

While Sakumono is part of the Acquisition area, Tema Manhean on the other hand make up the Non-Acquisition area in Tema. The metropolis has two district planning areas-namely, the Tema Acquisition Area 6 which is administered by Tema Development Corporation (TDC) and Non Acquisition Area 7 which is owned by various traditional authorities but managed by Town and Country Planning Department (TCPD) of Tema Metropolitan Assembly (TMA) 8. Before TMA was established by Act 462, the Tema Development Co-operation (TDC) which was established by L.I 1468 ensured appropriate developments at the Acquisition Area. Currently, this falls under the jurisdiction of TMA. This has resulted in an overlap and duplication of planning functions and responsibilities which leads to conflicts on issues between the two planning authorities. For instance, most residents report that development permits acquired from TDC are normally annulled by TMA and vice-versa (GSS 2014).

4.2 Natural Characteristics

4.2.1 Hydrogeology setting

The metropolis is in the coastal savannah vegetation zone, which consist of shrub land, grassland and a few areas of semi-deciduous forests. It is drained by Sakumono lagoon at the West (found in Sakumono) and Chemu lagoon (found in Tema Manhean) at the East. The sub-drainage basins of the Sakumo catchment area include Mamahuma-Onukpawhahe at the Western side) and Dzorwulu-Gbagbla-Ankonu at the Northern side of Greater Accra Region (Nonterah et al 2015). The Sakumono lagoon receives its lowest water level in the dry season. Meanwhile, during high

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6 Areas that were acquired through compulsory acquisition  
7 Areas that are still owned by Traditional authorities  
8 See Appendix 6.3
Tides, seawater flows into the lagoon. The lagoon covers an area of 1 km² in the dry season and about 10 km² during the rainy season. The Chemu Lagoon, on the other hand, exists to absorb industrial liquid waste and water from the eastern part of Manhean Township which is channeled through a major drain between the Tema harbour area and Tema Manhean (GSS 2014). Soils in Tema Metropolis include sand, clay, humus, gravel and stone (GSS 2014).

4.2.4 Climate

Two types of seasons exist in Ghana: the wet/rainy season and the dry season. Throughout the year, temperatures are normally high with few daily and seasonal variations. The hottest months are February and March, just before the rainy season, with mean monthly temperatures of 27 °C, whilst the coolest months are June-August. During this latter period, temperatures are around 21 °C. The rainy season is from April to July (as major rainy season) and September to November (as minor rainy season). Tema has mean annual rainfall of under 800 mm in 2001-2010, 800-1000 mm in 1991-2000 and under 800 mm in 1981-1990 (Logah et al 2013b, 5) and the month of June, which is the peak rainfall month, tend to have the most effect on people and their properties as can be seen in Table 4.6. Logah et al. (2013b, 6) lists Tema and Accra as having the driest areas. However, they also appear to be the two high flood risk areas in Ghana (NADMO data 2019). This implies that the flat topography of the land is a major contributing factor to the perennial flooding in Greater Accra Region amidst the increasing urban developments which increases the potency of more people being affected during the peak rainy season. According to NADMO (2012), “rainfall pattern influences the vulnerability of areas to flooding. Places with high annual rainfall rates, given other underlying environmental factors, may be prone to flooding.” Other environmental factors that could heavily influence the occurrence of flooding in specific areas/neighborhoods include the topography of the land and proximity to water bodies.
4.2.5 Topography

The coastal zone of Ghana is underlain by a gentle, mature topography that slopes toward the shore (Nonterah et al 2015). Tema’s land is relatively flat with occasional undulating elevations of 60m maximum and 35m minimum above sea level. Though it has a low rainfall precipitation as compared to other parts of the country, when it rains, some parts of the metropolis floods due to the fact that it is low lying and has a relatively flat terrain as seen in Figure 4.2.5. Within the lowest duration of rainfall, lower elevation areas in the metropolis are likely to flood. Resilience to these hazards is also constrained in areas where artificial drains are poorly connected due to its poor quality of materials, inadequate sizes and/or type of drain.

Figure 4.2.5: Regional scale Topography of parts of Greater Accra Region

Source: Author’s construct, 2019; DEM data obtained from USGSS, 2019
4.3 Demographic, Housing and Waste management characteristics

4.3.1 Population of Tema Metropolis

The population of the metropolis, according to the 2010 Population and Housing Census, is 292,773, which is about 7.3 percent of the total population in the Greater Accra Region.

Table 4.3.1: Population of Tema (1970-2010)

<table>
<thead>
<tr>
<th>Year</th>
<th>1970</th>
<th>1984</th>
<th>2000</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tema</td>
<td>60,767</td>
<td>100,052</td>
<td>141,479</td>
<td>292,773</td>
</tr>
</tbody>
</table>

Source: Ghana Statistical Service (2002); Ghana Statistical Service (2010); GSS (2005)

It has a migrant population constituting 166,506 migrants. Majority of the migrants (75.3%) were born outside Greater Accra Region with only a few 20.5% being born in the region. Migrants born outside the region have majority (23.1%) of them coming from Eastern region, 22.6% from Volta region and 22.4% from Central region. (GSS 2014) The city of Tema keeps on growing and hence it would have to deal with current and future pressure on the existing infrastructure as future inhabitants are likely to be underserved with these infrastructure as this growth overwhelms the capacity of the local governments to provide the needed infrastructure. Hence, there is the need to come out with long-term measures that could serve the incoming populations as this growth also has implications on increase in built up areas (see Table 4.3.2) which could be a challenge to addressing flooding. The conversion of land for residential and agricultural uses has significantly altered the hydrological characteristics of the land surface and modified pathways and flow of water into the wetland (Nonterah et al 2015).
Table 4.3.2: Land use changes in 1990, 2000 and 2007

<table>
<thead>
<tr>
<th>Years</th>
<th>1990</th>
<th>2000</th>
<th>2007</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Area (km²)</td>
<td>%</td>
<td>Area (km²)</td>
</tr>
<tr>
<td>Water</td>
<td>2.12</td>
<td>0.57</td>
<td>2.13</td>
</tr>
<tr>
<td>Wetland</td>
<td>27.96</td>
<td>7.65</td>
<td>21.83</td>
</tr>
<tr>
<td>Closed veg.</td>
<td>42.45</td>
<td>11.61</td>
<td>95.44</td>
</tr>
<tr>
<td>Open veg.</td>
<td>158.1</td>
<td>43.22</td>
<td>115.58</td>
</tr>
<tr>
<td>Cropped land</td>
<td>24.16</td>
<td>6.61</td>
<td>3.24</td>
</tr>
<tr>
<td>Built-up</td>
<td>110.98</td>
<td>30.34</td>
<td>127.56</td>
</tr>
<tr>
<td>Total</td>
<td>365.78</td>
<td>100</td>
<td>365.78</td>
</tr>
</tbody>
</table>

Source: Amenyo-Xa (2015, 15)

4.3.2.1 Direction of growth

Further, considering the impact of built up areas, Figure 4.3.2.1 and Figure 4.3.2.2 shows the expansion of Sakumono and Tema Manhean towards their peripheries. This growth could lead to encroaching of ecologically sensitive zones such as the Sakumo Lagoon and Chemu Lagoon which usually serve as boundaries of settlements and low elevation areas. Such areas usually require larger drains with the capacity and appropriate connectivity to effectively drain off water.

Figure 4.3.2.1: Sakumono’s direction and change in spatial growth

Dec 2003   Jan 2008   Oct 2013   April 2018

Source: Google Earth data, 2019 (Scale 1: 3000)
Table 4.3.2.1: Acreage change of Sakumono

<table>
<thead>
<tr>
<th>Year</th>
<th>Dec 2003</th>
<th>Jan 2008</th>
<th>Oct 2013</th>
<th>April 2018</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Built area</strong></td>
<td>888.03 (62.43)</td>
<td>915.78 (64.38)</td>
<td>1,003.95 (70.58)</td>
<td>1,199.96 (84.36)</td>
</tr>
<tr>
<td><strong>Undeveloped area</strong></td>
<td>534.42 (37.57)</td>
<td>506.67 (35.62)</td>
<td>418.50 (29.42)</td>
<td>222.49 (15.64)</td>
</tr>
<tr>
<td><strong>Total land area</strong></td>
<td>1,422.45(100.00)</td>
<td>1,422.45(100.00)</td>
<td>1,422.45(100.00)</td>
<td>1,422.45(100.00)</td>
</tr>
</tbody>
</table>

Source: Calculated using Google Earth, 2019

Figure 4.3.2.2: Tema Manhean’s direction and change in spatial growth

As observed above, the direction of growth for Sakumono is towards the Sakumo Lagoon which serves as the boundary and periphery. Developments have gradually moved towards the ecologically sensitive area. Tema Newtown on the other hand are gradually developing towards the Northern and North-Eastern part of the settlement. Since it is a fishing community and there is

Table 4.3.2.2: Acreage change of Tema Manhean

<table>
<thead>
<tr>
<th>Year</th>
<th>Dec 2003</th>
<th>Jan 2008</th>
<th>Oct 2013</th>
<th>April 2018</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Built area</strong></td>
<td>571.95 (41.91)</td>
<td>679.42 (49.78)</td>
<td>796.62 (58.37)</td>
<td>890.18 (65.22)</td>
</tr>
<tr>
<td><strong>Undeveloped area</strong></td>
<td>792.85 (58.09)</td>
<td>685.38 (50.22)</td>
<td>568.18 (41.63)</td>
<td>474.62 (34.78)</td>
</tr>
<tr>
<td><strong>Total land area</strong></td>
<td>1,364.8(100.00)</td>
<td>1,364.8(100.00)</td>
<td>1,364.8(100.00)</td>
<td>1,364.8(100.00)</td>
</tr>
</tbody>
</table>

Source: Calculated using Google Earth, 2019
a relatively high number of people working at home9, its growth has been centered towards the economic activity district where home and work is in close proximity to each other. Activities such as the smoking of fish and dumping of waste (fish guts) from such activities could likely choke the drainage system and contribute to an inadequate draining of the area during heavy rainstorms. This spatial growth has the propensity of significantly influencing flooding occurrences in the communities. This is because of the assertion that the more closer residents gets to flood prone areas or ecologically sensitive areas, there more vulnerable they are to flood risks.

4.3.3 Occupation

Aside the rapid urban growth, the activities of residents could influence the function of drainage infrastructure. At present, the predominant occupation in Tema Newtown residents is fishing making up 67.41% of the metropolis (see Figure 4.3.3). This is normally done within close proximity between work (near waterbodies) and home (fishing community). These business thrive mainly through family and friends groups which involves members into such occupations who support each other. It is therefore likely that when it floods, there is also a corresponding impact on their source of livelihood. Hence, it highly likely that when their properties and houses are destroyed, their sources of livelihood could also be destroyed. Meanwhile, Sakumono is mainly occupied by clerical support workers and professionals/managers. Hence, residents are predominantly blue collar workers.

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9 See Occupation
4.3.4 Housing stock

Tema district (4.0) has a relatively high household size as compared to the Region (3.8). Tema Manhean (2.3) has a relatively high household per house as compared to 2.2 in the Region and 1.7 in Sakumono and Tema Metropolis in general. This could be attributed to the high percentage of the traditional compound housing type (62.30) in Tema Manhean. This type of housing result in a layout which is able to contain a lot of households and number of people in a house. This is evident above as Tema Manhean has 8.8 persons per house as compared to other settlements listed below.

Table 4.3.4: Household and Housing stock

<table>
<thead>
<tr>
<th>Category</th>
<th>Region</th>
<th>District</th>
<th>Sakumono</th>
<th>Tema Manhean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
<td>4,010,054</td>
<td>402,637</td>
<td>22,713</td>
<td>76,848</td>
</tr>
<tr>
<td>Number of households</td>
<td>1,036,426</td>
<td>97,597</td>
<td>5,588</td>
<td>20,054</td>
</tr>
<tr>
<td>Houses</td>
<td>474,621</td>
<td>56,757</td>
<td>3,241</td>
<td>8,713</td>
</tr>
<tr>
<td>households per house</td>
<td>2.2</td>
<td>1.7</td>
<td>1.7*</td>
<td>2.3*</td>
</tr>
<tr>
<td>Average household size</td>
<td>3.8</td>
<td>4.0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Population per house</td>
<td>8.4</td>
<td>7.1</td>
<td>7.0*</td>
<td>8.8*</td>
</tr>
</tbody>
</table>

4.3.6 Methods of waste disposal (liquid)

As shown in the Figure 4.3.6, the use of gutters (drains) as a disposable site for liquid waste is relatively higher in Tema Newtown (61.34%) than Sakumono (14.84%), Tema Metropolis (20.15%) and Greater Accra Region (26.58%). Liquid waste disposal through drainage pipes into gutters is also a major method of liquid disposal. With regards to solid waste disposal in this fishing community, activities such as smoking fish could be a potentially contributor to drainage choking since fish guts are usually dumped at their work spaces and driven by runoff into drainage canals. This could contribute to the occurrence of flooding.

Figure 4.3.6: Liquid Waste Disposal Method

Source: GSS 2010, Urban Settlements
4.4 Flood Prone Areas in Tema Metropolis

According to Kwang and Osei’s (2017) regional-level study of flooding, Tema Newtown and Sakumono are part of areas with High possibility of flooding as these areas are found in the low elevation zone on flat terrains. Hence, implying that these areas are by nature liable to flooding.

Figure 4.4.1 (a): Flood prone map (b): Regional Topography

Source: Kwang and Osei, 2017
Source: Construct using DEM obtained from USGSS, 2019

4.5 Flooding events at the Regional level

Tema Metropolis has experienced flooding from 2010 to 2015 and beyond. However, in 2012-2013 the number of people affected per 1000 population decreased in 2011 (see Figure 4.5). It experienced its highest flood impact in 2015 which resulted in 6,593 people being affected. Hence, this period has the most impact on people. From the period 2014-2015, it has seen an increase in flood victims 884 to 6,593. It should however be noted that there has been fluctuations in the number of people affected which could be attributed to changes in rainfall patterns in Tema. Other districts which have had high number of flood victims within this period include Accra Metropolis which had 15,000 flood victims in 2015, Kpone Katamanso Municipality, Ga Central Municipality, La Nkwantanang-Madina Municipality and Ashaiman Municipality.
Figure 4.5: Map showing number of affected persons (per 1000 population)

Source: Author’s construct using NADMO Metropolitan-level data, 2019
4.6 Flooding in Sakumono and Tema Manhean

Flooding in Sakumono and Tema Manhean occurred within the period from 2010-2017 and majority of flooding in these study areas usually occurred within the peak rainfall month of June (see Table 4.6.1). The attention drawn to the public by the media shows an indication of a certain urgency to address the problem of flooding. This is targeted towards institutions such as National Disaster Management Organization and Tema Metropolitan Assembly. Evidence suggest that, in most cases, victims are only given donations after the floods have occurred (author’s media search 2019). Institutions have failed to address the problem in a comprehensive and sustainable manner.

Table 4.6.1: Flooding Events in Tema Manhean and Sakumono

<table>
<thead>
<tr>
<th>Type</th>
<th>Date occurred</th>
<th>Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Torrential</td>
<td>21-Jun-10</td>
<td>Tema Newtown</td>
</tr>
<tr>
<td>heavy storm</td>
<td>23-Jun-11</td>
<td>Tema Manhean</td>
</tr>
<tr>
<td>Torrential</td>
<td>9-Jun-15</td>
<td>Sakumono</td>
</tr>
<tr>
<td>Torrential</td>
<td>9-Jun-15</td>
<td>Tema Newtown</td>
</tr>
<tr>
<td>Torrential</td>
<td>3-Jun-15</td>
<td>Sakumono</td>
</tr>
<tr>
<td>Torrential</td>
<td>16-May-17</td>
<td>Tema Newtown</td>
</tr>
<tr>
<td>Torrential</td>
<td>5-May-17</td>
<td>Sakumono</td>
</tr>
<tr>
<td>Torrential</td>
<td>6-Jun-17</td>
<td>Sakumono</td>
</tr>
</tbody>
</table>

Source: Retrieved via Media search using Google search engine, 2019

It was found that within the period of 2010-2017, Tema Newtown has experienced flooding four times in four distinctive years while Sakumono has experienced flooding beginning from the period of 2015-2017. Since these records are from the media and it demonstrates the urgency of

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10 See Appendix 6.6 indicating sources of each post
these cases as news become worth publishing when it is worth the attention of the local government to take action and residents to take caution.

**Table 4.6.2: Flooding Impact in Tema Manhean**

<table>
<thead>
<tr>
<th>Neighborhoods</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>Average number of people affected</th>
</tr>
</thead>
<tbody>
<tr>
<td>U compound</td>
<td>19</td>
<td>11</td>
<td>33</td>
<td>16</td>
<td>25</td>
<td>21</td>
</tr>
<tr>
<td>Zighenshour</td>
<td>95</td>
<td>146</td>
<td>234</td>
<td>163</td>
<td>482</td>
<td>224</td>
</tr>
<tr>
<td>Waterland</td>
<td>367</td>
<td>288</td>
<td>217</td>
<td>326</td>
<td>458</td>
<td>331</td>
</tr>
<tr>
<td>Valco down</td>
<td>190</td>
<td>237</td>
<td>85</td>
<td>145</td>
<td>377</td>
<td>207</td>
</tr>
<tr>
<td>Bankuman</td>
<td>67</td>
<td>182</td>
<td>127</td>
<td>58</td>
<td>92</td>
<td>105</td>
</tr>
<tr>
<td><strong>Tema Newtown</strong></td>
<td><strong>738</strong></td>
<td><strong>864</strong></td>
<td><strong>696</strong></td>
<td><strong>708</strong></td>
<td><strong>1,434</strong></td>
<td><strong>888</strong></td>
</tr>
</tbody>
</table>

Source: Data collected from NADMO, Tema (2019), Tema Metropolitan Area, 2019

Within the period from 2010-2014, Tema Newtown has had an average of 888 people affected. In 2020, 738 people were affected by flooding. This increased to 864 people in 2011. In the year 2014, however, the number of people affected significantly increased to 1,434 people. As observed from Table 4.6.2, it is also be clearly seen that Zighenshour neighborhood, which is closer to the lagoon area and on a lower elevation of 45m above sea level, have more people affected than Bankuman neighborhood which is farther from the lagoon and on a higher elevation of 50-65m above sea level. Hence, justifying that residents closer to lower elevation areas are more likely to be affected by flooding. These flooding events affects lives and properties and hence there’s the need to describe the existing drainage system with respect to its connectivity, condition and quality, gain understanding from these cases and recommend a more robust approach to planning and provision of drainage systems.
4.7 Current Drainage system in Sakumono and Tema Newtown

Generally, it is expected that drains are provided by the Government. Meanwhile, the current norm indicates that drains, especially minor drains, are provided by residents, using their own resources, particularly in non-estate areas. However, few cases found few portions of estate areas to be deprived of drainage canals as few houses/plots are either uncompleted and hence, unoccupied by potential estate clients. However typically, estate areas which serve as part of the planned areas, have drains provided by estate developers before habitation. Tema Manhean, which according to this research, is referred to as an unplanned area, has a total drainage length of 109,630.50 ft while Sakumono accommodates 159,215.79 ft length of drainage line.

4.7.1 Elevation and proximity to water bodies

The elevation of Sakumono is relatively flat with a minimum elevation of 45m asl located near the Sakumo Lagoon while the maximum elevation 60m asl appears to be predominant at the Northern part of Sakumono (see Figure 4.7.1.1). Similar to Sakumono, Tema Manhean has a low elevation of 40-45m asl in areas close the lagoon. It however has a maximum elevation of 70m asl and a minimum elevation of 40m asl as seen in Figure 4.7.1.2:

**Figure 4.7.1.1: Elevation of Sakumono (Asoprochona and Estate area)**
Figure 4.7.1.2: Elevation of Tema Manhean (Abonkor, Ziginshor & Ashaman neighborhoods)

Source: Author’s construct using DEM data from USGS, 2019

It could be clearly observed that as the distance from the lagoon increases, the elevation also increases to a certain point until only few instances of occasional lower elevations are seen. This makes areas which are in proximity to the lagoon more likely to flood during heavy downpour of rain. Moreover, due to the fact that Tema finds itself as part of the relatively flat terrain of Greater Accra Regional, it also becomes subject to flood hazards. Depending on the soil-which in this case, both neighborhoods under study have the same soil type being mainly sandy- and the topography, some areas are bound to be free from the inundation of water while others areas are more likely to be vulnerable to flooding. The latter is the case for areas closer to waterbodies.
4.7.2 Case of Sakumono

4.7.2.1 Connectivity of drainage system

The link between one drainage line of a lot and the other of a different lot are considered as nodes. Connectivity of the drainage system could be determined in terms of the gaps in the drainage line aligning plot/s of land. Connectivity is also influenced by the size of the drains. Hence, connectivity in this study is based on the fact that the differences of sizes of drainage lines as well as the existence of gaps aligning particular lots could result in a lack of connectivity of the whole drainage system. This could lead to ponding and flooding on roads and surrounding areas. This case is especially relatable to low elevation areas.

Figure 4.7.2.1: Existing drainage system (feet length)
In Sakumono-Asoprochona (non-estate neighborhood), there is a huge infrastructure gap of 67.10% of the total drainage system. This reveals the lack of provision of drains aligning parcels in the neighborhood. Meanwhile, Sakumono (estate area) has only 37.89% of infrastructure gap. As observed in Figure 4.7.2.1 above, low elevation areas on the East of the neighborhood towards Sakumo Lagoon, which are expected to have drains available, are rather lacking. Since the connectivity of drainage system could enable the effective channeling of runoff water into the lagoon, the current drainage system in Sakumono is therefore viewed as inadequate for effectively enabling that function.

4.7.2.2 Size of drains in Sakumono

Another contributing factor in the connectivity of the drainage systems is the adoption of appropriate sizes of drains in a specific area. Normally, areas in close proximity to water bodies such as Sakumo lagoon are expected to have larger sizes of drains (ft$^2$).

As observed in Figure 4.7.2.2 and Figure 4.7.2.7, the Estate neighborhood at the North and Western part of this part of Sakumono (at elevations of 50-60 asl) appear to have drains that
are larger (2.9 x 1.8 ft maximum for major drains and 2.3 x 1.5 ft for minor drains) than the non-estate neighborhood (2.5 x 1.7 ft maximum for major drains and 1.8 x 1.3 ft for minor drains) at the Eastern and Southern part (which is rather in close proximity to the Lagoon and hence, are automatically in the low elevation areas reaching 30m-50m asl\(^{11}\)). This situation could result in the likeliness of low elevation areas being liable to flooding when it rains during the months of June and July.

Figure 4.7.2.2: Map showing the various sizes of drains

Source: Author’s construct using field data, 2019

\(^{11}\) See Figure 4.7.2.2
4.7.2.3 Quality of drains

4.7.2.3.1 Materials

The type of material used in the construction of drains is an indicator of its quality. In the estate area, a substantial part (93.84%) of the total drainage length of Sakumono is constructed with concrete. This is followed by Sand/soil and Cement blocks representing 4.52% and 1.12% of the total drainage length, respectively. This is similar to non-estate areas, where a huge part of the total drainage length is made with concrete while 2.91% (higher than estate) is made with cement blocks. Drains constructed entirely with blocks become less appropriate as a component of the drainage structure. In the likely event of high intensity rainfall during the rainfall season, there is a high possibility of a collapse of the drainage structure as seen in Figure 4.7.2.3.2.

Figure 4.7.2.3.1: (a) Estate area (b) Non-estate (Asoprochona)

Source: Author’s construct using field data, 2019
4.7.2.3.2 Cracks in Drainage structure

Apart from the materials used for construction, another indicator of quality of drains is the existence of cracks in the drainage structure. Moreover, these two indicators go hand-in-hand since the materials used in the construction drains could lead to cracks within the drainage structure within a short-term. Hence, appropriate use of materials in the construction of drains could result in good quality drains that are devoid of excessive cracks. [send to methodology]
Figure 4.7.2.3.2: Proportion of drains cracked

<table>
<thead>
<tr>
<th>Type of Drains</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drains with cracks</td>
<td>1.75%</td>
</tr>
<tr>
<td>Drains without cracks</td>
<td>3.88%</td>
</tr>
<tr>
<td>Other drains (Pipe, Unengineered)</td>
<td>94.37%</td>
</tr>
</tbody>
</table>

Source: Field data, 2019

4.7.2.3.3 Type of Materials and Percentage of Drains cracked

In both estate and non-estate areas, majority (94.37%) of the overall drainage length has no cracks in the structure while 3.88% of the drainage length has major and minor cracks. The rest are made-shift use of sand/soil for un-engineered drains. Correlating the Type of Materials with the Percentage of drains cracked, it was found that cement blocks have proven to be ineffective in serving as a strong and durable material for channeling run-off water. Apparently, 28.18% of drains constructed with Cement blocks have cracks in them. This is higher than 3.62% representing the percentage of concrete drains which has been liable to cracks. Poor quality drains have the tendency to erode within short-term periods. However, some residents (a representation of 5.63% of the total drainage system) choose to either use this material since it is cheaper to construct or constructed un-engineered drains themselves through hand-digging. Using concrete would lead to incurring an additional cost in stones/gravels.
### Table 4.7.2.3.3: Type of Materials and Percentage of Drains cracked

<table>
<thead>
<tr>
<th>Materials</th>
<th>Length of cracked drains</th>
<th>Total length</th>
<th>Proportion of cracked drains/Total Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete</td>
<td>2,610.97</td>
<td>72,056.96</td>
<td>3.62</td>
</tr>
<tr>
<td>Blocks on concrete</td>
<td>0.00</td>
<td>290.50</td>
<td>0.00</td>
</tr>
<tr>
<td>Cement blocks</td>
<td>345.24</td>
<td>1,225.28</td>
<td>28.18</td>
</tr>
<tr>
<td>Sand/soil</td>
<td>-</td>
<td>3,096.20</td>
<td>-</td>
</tr>
<tr>
<td>Total length of cracked drains</td>
<td>2,956.21</td>
<td>76,668.93</td>
<td>3.86</td>
</tr>
</tbody>
</table>

Source: Field data, 2019

### Figure 4.7.2.3.3: (a) High severity and (b) Low severity

Source: Field data, 2019

Cracks with low, medium and high severity levels were found in the drainage system from one end at the Western part of the road to the Eastern part of the main road. It is observed that high severity of cracks in drains are rather found in areas which are in proximity to the Lagoon (miles from Lagoon) while low severity of cracks are seen in areas farther from the lagoon and low elevation areas. It is expected that drains in general, whether or not they are in proximity to

---

12 See Severity of cracks map in Appendix 6.7: Figure 6.7.1
the lagoon, must be devoid of cracks in order to enable the proper functioning of the drain when it rains. This is because cracks could result in the disintegration of the drainage system. In the worst case scenario (as in the case of Figure 4.7.2.3.3(a)), it could be completely destroyed which could in turn change the orientation and position of the drainage line. This has the tendency of resulting in ponding on the road and flooding in that particular area, depending on the intensity of rain.

4.7.2.5 Siltation and Choking of drains

Siltation occurs when sand or other particles from surrounding areas accumulates in drains, when it is carried by run-off water, wind or human actions, resulting in the reduction of the size of the drain. Choked drains, on the other hand, have parts of the drainage canals blocked by solid waste materials such as plastic bottles, polythene bags and fish guts. These limit the easy flow of run-off water in drains. In estate areas, 19.66% of the overall existing drainage line is affected by siltation while, in non-estate areas, 24.09% are affected. This is attributed to the type of drains adopted as design of drainage canals. Currently, open drains make up the majority of the total length of the existing drainage system for both estate and non-estate areas. This is followed by Covered drains, Un-engineered drains and Pipe drains as seen in Figure 4.7.2.5.4.

Figure 4.7.2.5.1 : (a) Estate area           (b) Non-estate (Asoprochona)

Source: Field work data, 2019
Figure 4.7.2.5.2: Map showing drains affected by siltation

Source: Author’s construct using field data, 2019

Figure 4.7.2.5.3: (a) Estate area

(b) Non-estate (Asoprochona)

Source: Author’s construct using field work data, 2019
4.7.2.6 Type of Drain and relationship with Siltation in drainage system

The type of drains could be a contributing factor to siltation. This is because Open drains are more likely to attract sand and particles of the soil than Covered drains, Pipe drains and Un-engineered drains. Even though pipe drains are also enclosed and therefore it is less likely that sand particles would enter, the connectivity of their nodes and exposure of their outlets as they lay on the ground could also contribute to siltation and choking in the pipe system. Hence, the study correlated the drains’ vulnerable to siltation and the type of drain.
In both estate and non-estate areas, covered drains rather appeared to have the highest proportion (0.28%) of its drainage line subject to siltation while Open drains had 0.21% of its drainage line affected by siltation. This is possible since sand particles or solid waste materials could be carried by rain and/or wind from one drainage line to another. This suggests that the use of open drains in one area could affect the entire drainage system. This brings to mind the need for a well-integrated drainage infrastructure system.

**Table 4.7.2.6: Length of drains affected by siltation and its type**

<table>
<thead>
<tr>
<th>Type of drain</th>
<th>Length of drain liable to siltation</th>
<th>Total length</th>
<th>Proportion of drains with siltation /Total Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Covered drain</td>
<td>1,799.15</td>
<td>6,348.89</td>
<td>0.28</td>
</tr>
<tr>
<td>Open drain</td>
<td>14,171.68</td>
<td>66,525.61</td>
<td>0.21</td>
</tr>
<tr>
<td>Pipe drain</td>
<td>-</td>
<td>148.90</td>
<td>0.00</td>
</tr>
<tr>
<td>Un-engineered drain</td>
<td>-</td>
<td>3,645.52</td>
<td>-</td>
</tr>
<tr>
<td><strong>Total length of drains liable to siltation</strong></td>
<td><strong>15,970.82</strong></td>
<td><strong>76,668.93</strong></td>
<td><strong>0.21</strong></td>
</tr>
</tbody>
</table>

Source: Author’s construct using field data, 2019

**4.7.2.7 Transects for Sakumono**

A West-East transect in Sakumono shows the current situation at different elevations as observed during field survey. As could be observed in *Figure 4.7.2.7*, Transects 1, 2 and 3 appears to lack adequate drains and adequate drain size in the case of Transect 2. These are in the closest proximities to the lagoon in distances of 0.79, 1.04 and 1.05 miles and in elevations of 51-52m asl, respectively. Transect 4 which is at a distance of 1.11miles and an elevation of 50m asl, on the other hand, has both sides of the road having drains with appropriate sizes. However, it was observed that it was choked on one side and completely covered with weeds and cracked on the
other side. This could result in a likely occurrence of flooding at that spot and also hinder the ease of flow of the runoff water. Meanwhile, Transect 5 to 9 have no drains available while Transect 10 only has dug-out un-engineered drains at both sides of that particular road. It could however be seen that Transect 8 has drainage line on one side but the width and length of the drain is only 0.9ft which can barely hold and channel enough runoff water when it rains. Transect 11 also has drains on both sides of its road. However, the drainage line one side appears to be affected by heavy siltation.
Figure 4.7.2.7: Transect showing availability, size and condition of drains in Sakumono

Source: Author’s construct, 2019
4.7.3 Case of Tema Manhean

4.7.3.1 Availability and Connectivity of drainage system

The existing drainage line make up 40.63% (44,544.16 ft) of the total drainage system (109,630.50 ft) that is expected to cover the neighborhood. This leaves a drainage infrastructure gap of 59.37% (65,086.34 ft). These gaps in addition to the differences in sizes of drain (as seen in Figure 4.7.3.2) and the disintegration of the nodes (outlets of the drains) contributes the lack of connectivity of the drainage system as a whole. As observed in Figure 4.7.3.1 and Figure 4.30, areas within the elevation of 40-50m asl appears to be rather deprived of the existence of drains. This could contribute to the ineffectiveness of the drainage system in performing its function as flood mitigation structures during high intensity rainfalls.
**Figure 4.7.3.1: Map showing Availability and Connectivity of drains**

![Map showing Availability and Connectivity of drains](image)

Source: Author’s construct using field data, 2019

### 4.7.3.2 Size of drains

As observed in *Figure 4.7.3.2* and *Figure 4.7.3.8*, the Northern and Southern part of the neighborhood with elevations of 40-60 asl appear to have drains that are of suitable sizes (2.5x1.7 ft maximum). However, the Western parts close to the lagoon (with 2.1x1.7 ft maximum) rather lack suitable drainage sizes that can effectively drive runoff water away. This could result in the likeliness of flooding when it rains in the peak rainfall seasons.
Also, certain fishing activities such as smoking fishes results in the chuff (fish scales) being left on site and later driven by rain into the already undersized drains in low elevation areas close to the lagoon where it is expected to have larger drains. This additionally serves as a constraint to the easy channeling of runoff water into the lagoon. When this happens, water keeps accumulating until such areas are inundated with flood.

**Figure 4.7.3.2: Map showing Sizes of drains**

Source: Author’s construct using field data, 2019
4.7.3.3 Quality of Drains

4.7.3.3.1 Materials

Appropriate use of materials could affect the quality of drains. As observed from the field survey, common materials for construction used for drains in Tema Manhean include concrete, Cement blocks rendered with Sandcrete, pipe (PVC) and sand/soil (mainly for un-engineered drains).

Figure 4.7.3.3.1: Map showing (a) Pipe drain  (b) Concrete

Source: Field data, 2019

Majority (96.77% of total drainage system) of drains with a length of 43,104.69 ft in Tema Manhean are constructed with concrete. Meanwhile, 794.95 ft (1.78% of total drainage system) is constructed with sand/soil for un-engineered drains. There also Pipe drains which make up only 0.37% (165.34 ft) of the existing drainage system. The sand/soil and pipe drains are predominant at the North-Western part of the community which is rather in close proximity to the Lagoon. Hence, this area which is expected to have a better material that can withstand water and has material strength, is rather subject to inadequate use of unsuitable materials. This has the propensity of reducing the quality of the drain which could be carried which could, in turn, lead to potential flooding in such areas.
4.7.3.3.2 Type of materials and cracks

In addition to the use of certain materials which indicate the quality levels of the drain, cracks are also seen as detrimental to the proper functioning of the drainage system. In most cases, the former leads to the latter. It was found that 38.33% of the length of drains made with cement blocks have cracks in them while 5.15% of concrete drains constitute drains with cracks. This implies that, similar to the case of Sakumono, cement blocks as used by some residents for constructing drains appears to be unsuitable for draining runoff in the long-term.

Table 4.7.3.3.2: Showing correlation between Type of materials and cracks

<table>
<thead>
<tr>
<th>Material</th>
<th>Length of drain with cracks</th>
<th>Total length</th>
<th>Proportion of cracked drains/Total Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe</td>
<td>-</td>
<td>165.34</td>
<td>0.00</td>
</tr>
<tr>
<td>Concrete</td>
<td>2,218.17</td>
<td>43,104.69</td>
<td>5.15</td>
</tr>
<tr>
<td>Cement blocks</td>
<td>183.67</td>
<td>479.17</td>
<td>38.33</td>
</tr>
<tr>
<td>Sand/soil</td>
<td>-</td>
<td>794.95</td>
<td>0.00</td>
</tr>
<tr>
<td>Total length of cracked drains</td>
<td>2,401.84</td>
<td>44,544.16</td>
<td>5.39</td>
</tr>
</tbody>
</table>

Source: Author’s construct using field data, 2019

4.7.3.3.3 Cracks in drainage structure

At present, a substantial component (92.82%) of the existing drainage system in Tema Manhean are devoid of cracks. However, there a some drains having major cracks in them. In some cases, cracks in the drains have resulted in the disintegration of certain drainage lines. This could result in inundation of flood in such areas during heavy downpour of rain.
Figure 4.7.3.3.3: (a) Proportion of drainage system with cracks  (b) Severity of cracks

Source: Author’s construct using field data, 2019

Source: Field data, 2019

Figure 4.28: Map showing Type of materials used for constructing drain

Source: Author’s construct using field data, 2019
As observed in the current drainage system, cracks are predominantly found in the Western part of Tema Manhean which is in the low elevation areas which are usually prone to flooding. Even though Concrete was used as a material for constructing this drain, it could be clearly seen that this drain has undergone some wear and tear. This could be attributed to the fact that Tema Manhean is an industrial area whose roads are usually subject to frequent damages from trucks. Also, this area an older part of the community and hence, are part of few drains that were provided were provided at the time. It is argued that there has been technological advancements in materials since the 1960s and hence, periodic maintenance is expected to ensure the longevity of the drainage structure. Since the Government’s supervisory role towards infrastructure maintenance has been limited as a result of the unavailability of drainage maps and the lack of institutional coordination between Tema Metropolitan Authority (TMA), Tema Traditional Authority and Tema Development Corporation (TDC).

4.7.3.6 Siltation and choking of drains

The map below indicate that 34.01% out of the existing drains in Tema Manhean is affected by siltation. This could be attributed to the predominant use of Open drains as type of drain. Open drains were found to be the predominant type of drain in Tema Manhean making up 88.56% of the existing drainage system. This is followed by covered drains, un-engineered and Pipe drains which constitute 9.29%, 1.78% and 0.37% of the total drainage system.

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13 See Figure 4.7.3.6
4.7.3.7 Length of drains affected by siltation and its type

The design of open drains exposes it to the attraction of sand particles that is driven into them by wind, runoff water or human activities. Hence, there is the need to consider the appropriateness of type of drains and drainage design in construction. It was found that 38.00% of total length of open drains are affected with siltation while covered drains have only 3.86% of its length affected with siltation. Their distinct layout of buildings and sizes of blocks\(^\text{14}\) have also been found to be a

\(^{14}\) Refer to Section 4.7.4
contributing factor with regards to the use of inappropriate sizes in drain construction and a total lack of existence of drains in worst case scenarios as seen in Transect 7 and 8 in Figure 4.7.3.8. This could result in the reduction of the drainage space for runoff channeling.

Table 4.7.3.7: Length of drains affected by siltation and its type

<table>
<thead>
<tr>
<th>Type of Drain</th>
<th>Length of drain liable to siltation</th>
<th>Total length</th>
<th>Proportion of drains with siltation /Total Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Covered drain</td>
<td>159.61</td>
<td>4,136.53</td>
<td>3.86</td>
</tr>
<tr>
<td>Open drain</td>
<td>14,988.36</td>
<td>39,447.33</td>
<td>38.00</td>
</tr>
<tr>
<td>Pipe drain</td>
<td>-</td>
<td>165.34</td>
<td>0.00</td>
</tr>
<tr>
<td>Un-engineered drain</td>
<td>-</td>
<td>794.95</td>
<td>-</td>
</tr>
<tr>
<td><strong>Total length of drains liable to siltation</strong></td>
<td><strong>15,147.97</strong></td>
<td><strong>44,544.16</strong></td>
<td><strong>34.01</strong></td>
</tr>
</tbody>
</table>

Source: Author’s construct using field data, 2019

It was also found that their major local economic activities include fishing. Activities such as fish smoking which results in the disposal of fish scales and chuff in drains has the propensity to facilitate choking of drains in addition to the siltation in the drains. These activities usually happen in close proximity to the water bodies where they live as fishermen. Such activities could choke not only the artificial drainages but also the natural drainages (specifically Chemu Lagoon) which are supposed to store runoff water. This could lead to a likely occurrence of flooding in such areas.
4.7.3.8 Transect for Tema Manhean

The various transects below shows the drainage situation on the ground in terms of quality, availability and condition. It was observed that Transect 1 to 4 lack drains. Meanwhile, they are located in close proximity to the lagoon in an elevation of 50m asl. These are areas which can easily be inundated with flood when rainfall results in runoff extended from the 45m elevation asl unto 50m elevation asl. Moreover, in Transect 5, a relatively better drainage condition, quality and size could be seen where drains on both sides of the road has height of 2.3 ft and width of 2 ft. Transect 6, 7 and 8, on the other hand, has only one side of the rain having a drain whereby it is
either choked as in the case of Transect 6 and 8, and un-engineered in the case of Transect 7. There also multiple of Transect 10’s situation in Tema Manhean, where there are flat bottomed open drains that only has width and height of 0.6 and 1.1 ft. This is the case as lack of space for creating bigger drains lead to the creation of rather smaller drains.\textsuperscript{15} It could be observed from Transect 9 and 10 in \textit{Figure 4.7.3.8} that the closeness of building to the streets leaves no space for drains to be provided. Hence, leading to the inadequate sizes or lack of drains in some cases.

\textsuperscript{15} Refer to Section 4.7.4
Figure 4.7.3.8: Transect of Tema Manhean

Source: Author’s construct, 2019
4.7.4 Road easement compliance, Layout of blocks and influences on availability of drains

It was found that the layout of buildings and blocks could have influences on the existence or the use of appropriate sizes in drain construction. Orderly arrangement of buildings comply with setback rules (in this case, National Building Regulations 1996, LI 1630) and leave enough space for utility lines as it aligns itself compatibly with road dimensioning principles. Easements “set aside land to carry water collected from neighborhood streets and land parcels through a complex drainage network, thereby protecting homes and businesses from water damage” (Grayson n.d.).

Customarily, street line setbacks are required in order to allow enough space for sewage lines, utility lines and road drains. Thus, in cases where the arrangement of houses does not comply with these principles, the spaces that are supposed to contain road drains may be limited as seen in Tema Manhean’s Transect 7-9 in Figure 4.7.3.8 and Sakumono’s Transect 6 and 8 in Figure 4.7.2.7. These circumstances could result in the use of drain sizes that are only minimal to what is expected. Also, the sizes of blocks have huge implications on the availability of drains aligning the blocks. In areas especially unplanned areas where layout plans of blocks containing lots do not exist, houses tend to be built organically, however, without consideration for layout planning principles. Hence, spaces that are expected to have roads with drains on each sides according to the street/drain hierarchy (main drain or minor drain) is less likely since. For instance, if a main drain with its required size is required, it is likely that minor drains might be rather built since it falls under the category of a lesser hierarchy of the road drainage system. This could lead to the adoption of inappropriate drain size or a total lack of existence of drains.
Figure 4.7.4.1: Showing layout of planned and unplanned neighborhood

(a) Asoprochona (non-estate)  (b) Sakumono (estate area)  (c) Tema Manhean (non-estate)

Source: Obtained from Google Earth Pro, 2019

Figure 4.7.4.2: Illustration of regulation guiding site coverage of buildings

Source: Author’s construct with reference to National Building Regulations 1996, (LI 1630)

Table 4.7.4.3: Requirements under LI 1630

<table>
<thead>
<tr>
<th>Regulation under LI 1630</th>
<th>Regulation 13: Site requirements</th>
<th>Regulation 14: Site coverage of buildings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Requirements</td>
<td>(2) “No site liable to flooding shall be built upon”</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(3) “No building shall be erected over a drain”</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Setback to frontage= 15m minimum</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Area of site= 450 sqm minimum</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Floor area= less than 80%</td>
<td></td>
</tr>
</tbody>
</table>

Source: National Building Regulations 1996 (LI 1630)
4.7.5 Summary of findings and implications

Generally, there is a lack of connectivity in the drainage system simply as a result of either unavailable drains in certain areas, differences in sizes and materials as well as type of drains. It seems to be the case that residents nearer to lagoons are more vulnerable to flooding hazards. This could imply the use of more resources in the use of bigger drains with better materials for residents that are rather closer to lagoons and water bodies. From the analysis made above, it is apparent that the trend reveals circumstances whereby residents who are closer to the lagoon have more responsibility and investments needed to contribute to the overall mitigation against flooding. The state and condition of drainage infrastructure in the planned areas have also been observed to be a little different from unplanned areas.

**Figure 4.7.5: Summary of findings**

<table>
<thead>
<tr>
<th>Planned areas</th>
<th>Unplanned areas</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Sakumono (Estate area)</em></td>
<td><em>Sakumono (Asoprochona)</em></td>
</tr>
<tr>
<td><strong>Existing drains</strong></td>
<td></td>
</tr>
<tr>
<td>Existing drain</td>
<td>62.11</td>
</tr>
<tr>
<td>Gap</td>
<td>37.89</td>
</tr>
<tr>
<td><strong>Total expected</strong></td>
<td></td>
</tr>
<tr>
<td><strong>drainage length</strong></td>
<td><strong>100.00</strong></td>
</tr>
<tr>
<td><strong>Size</strong></td>
<td>inadequate within close proximities to lagoons</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Materials</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement blocks</td>
<td>1.12</td>
<td>2.91</td>
<td>1.08</td>
</tr>
<tr>
<td>Blocks and concrete</td>
<td>0.52</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Concrete</td>
<td>93.84</td>
<td>94.38</td>
<td>96.77</td>
</tr>
<tr>
<td>Pipe</td>
<td>0.00</td>
<td>0.00</td>
<td>0.37</td>
</tr>
<tr>
<td>Sand/soil</td>
<td>4.52</td>
<td>2.71</td>
<td>1.78</td>
</tr>
</tbody>
</table>
Major gaps could be seen in the unplanned areas (Sakumono-Asoprochona and Tema Manhean) than the planned area (Sakumono-Estate area). This contributes to the poor connectivity of the drainage system. With respect to sizes of drains, drains are expected to be bigger as it gets closer to low elevation areas. However, this was contrary to the case in both estate and non-estate areas. It was found that all study areas had inadequate drains within close proximities to lagoons: specifically, Chemu lagoon as in the case of Tema Manhean and Sakumo Lagoon as in the case of Sakumono. The sizes also contribute to poor connectivity since it leads to disconnected nodes of the drainage canals.

In the aspect of construction materials as influences of quality of drains, concrete was the major material for constructing drains in both estate and non-estate areas. However, in non-estate
areas inappropriate materials such as cement blocks and pipes were relatively predominant than in estate areas. Sand/soil as material which were highly used in the form of un-engineered (improvised) type of drains in planned areas were mostly captured in areas with uncompleted houses. This is evident that time factor or readiness of residents to construct housing also influences drainage effectiveness. It was also found that areas which had relatively greater length of drains constructed with inappropriate drainage canals, had cracks as compared to areas with appropriate drainage canals (see Table 4.7.2.3.3 and Table 4.7.3.3.2). Hence, cracks were observed to be predominant in non-estate areas as compared to estate areas.

Meanwhile, in the aspect of condition of drains, the type of drains influences the condition (state) of drains. Hence, covered drains and pipe drains are expected to have low levels of siltation and choking than open drains and un-engineered drains. However, it is also rational to say that pipe drains and covered drains which have outlets exposed to sand particles and solid waste materials at certain points of the drainage canal would likely be affected by choking and siltation since runoff carries these particles/ materials to other points (especially downstream) of the drainage canal. In view of this, siltation and choking were predominant in both non-estate and estate areas. However, Tema Manhean whose residents partake in fishing activities such as dumping of fish guts in the western part (part of their place of work) of the community, had the highest levels of siltation.

These factors contribute to the differences in quality, condition and connectivity of drains in estate and non-estate areas. These are as a result of certain setbacks in planning and provision of drains which have carved out certain differences between estate (planned) and non-estate (unplanned) areas as explained below.
4.7.5.1 Planned areas

Estates are found to have more connected drainage systems as seen in Figure 4.7.5. This is because estate areas are normally provided with ‘sites and services’ on plots as part of housing developments. Here, drainage provisions are concurrently provided together with housing. Non-estate areas, where people provide their own drains, on the other hand, lack connectivity in their drainage system. This is because drains in these areas are not provided concurrently with housing. People provide their own drains and therefore the timely provision of such drains are subject to people’s individual access to resources: time, money and labor. Their provisions depend on when they have access to labor (foremen) and financing. The element of individuality when it comes to financing of drainage provision results in inconsistency in the adaptation of certain needed types of drains. The price of a serviced plot at the time interviewed (November 2011) was pegged at US$22 000.00 (Twenty-two thousand United States dollars) per residential site. Residents’ drains are hence representations of what they can afford. The challenge therefore lies in how the element of ‘individuality’ in the provision of drains could be united coherently into a ‘system’.

4.7.5.2 Unplanned areas

The incremental housing-drainage construction approaches are not incorporated in the design of physical planning through layouts of buildings and drainage lines, and the design of financial systems. Financial plan must be based on an incremental phasing that is consistent with the infrastructures needed on an ad hoc basis for various plots that is expected to be developed. Hence, there is the need to create a coherent system which would rely on the coordination between the physical, natural, economic and human culture which are managed by various institutions such as Lands Commission, Town and Country Planning, Tema Development Corporation. In most cases, duplication of responsibilities could lead to duplication of the use of resources which does not
encourage an efficient use of resources. Hence, an institutional coordination is also very important to strengthen relationships that are needed to create a viable system.

It is apparent that for both planned and unplanned areas, there are setbacks in the provision of drainage infrastructure. In planned areas, it is seen that order was dominant in the aspect of compliance to easement regulations which is seen in leaving enough space for drainage lines. These are areas where most inhabitants had not been able to afford. While in unplanned areas, the organic development of residents was a helpful way for them to build at a low-cost incremental process in a long-term period. However, there were challenges in providing drains in that approach to housing development. It is therefore important that the approach is seen from the lenses of residents of unplanned areas since not doing so has led to an insurgence which has not been favorable to the existence of an effective drainage system. In view of this, it is strongly argued that it is not whether an area has been planned or not. The missing gap could be found in the approach to planning. It is evident that the context of place (geographical characteristics), time (technological advancement in drainage design and modern practices) and culture (people). In this case, the challenge is to provide a high quality and well-connected drainage system through a low-cost incremental process that is also in concurrence with the phasing of housing development.
Chapter Five

Conclusion

The increasing urbanization presents some challenges in terms of provision of basic infrastructure in times of floods and other natural disasters and hazards (Yira et al 2013). Rapid urban growth could outstrip the capacity of local governments leading to selective provision of public infrastructure which has been seen to favor only a few urban residents. Drainages systems as infrastructure are meant to supplement natural drainages and therefore if not properly suited to the characteristics of the natural environment, might fail to perform its functions effectively as flood mitigation structures. It must hence behave in a similar manner as natural drainages. Natural drainages are well connected and gets bigger as it gets to its source. What makes artificial drainage systems distinct from natural drainages is that it is provided by humans whose resources are scarce. This could lead to a gap between the expected outcomes from these infrastructure and the realities of place, time and people that formal planning is subject to. In cases where infrastructure provision by residents themselves is a norm, similar challenges as revealed in this research could prevail. This is not only relatable drainage systems but also water, roads, electricity and sidewalk infrastructure systems.

5.2 Recommendation

This research provides recommendations regarding the direction and approach to dealing with flooding in especially rapidly growing urban areas with local governments whose capacity to provide public infrastructure is limited. Future considerations in designing, financing, managing and maintaining drainage systems should consider the following in estate and non-estate areas:
5.2.1 Planned (Estate areas)

5.2.1.1 New Designs, New Technologies and New uses of space

Codes should be continuously revised for maximum safety according to the development of new technologies. The adaptive nature of the existing drainage system in both estate and non-estate areas presents opportunities for retrofitting. Improvements are needed in its design especially in the aspect of connectivity. Retrofitting could be an ideal intervention for places that has already been built. Mesh as a filtering system could be placed near drains as part of a green infrastructure design. Borrowing Owuama et al’s (2014) idea of trenchless drains could also be integrated as a low cost design strategy. Owuama et al (2014) suggested trenchless drain which consists of an absorption unit and grass cover for areas which could be prone to flood. According to him, “trenchless drain is a composite of absorption field and grass cover aligned on both sides of a road.” The concept seeks to provide trenches with relatively permeable material. “The grass cover provides the foliage for interception of rain drop, stems and leaves introduce greater roughness while the roots provide greater infiltration channels.” This could be considered as a form of green infrastructure.

Green infrastructure and green space developments not only make the area aesthetically pleasing, but also serve as a means to changing inhabitants’ perception about spaces. This could be a solution to the indiscriminate disposal of liquid and solid waste into drains. In contemporary times, projects such as Living with Water by Waggonner and Ball Architects (2013) have introduced modern practices which focuses on storm drains as not only draining/channeling runoff water downstream areas but also retaining/slowing, storing and circulating water. The idea has shifted from viewing drains as mechanisms only for channeling runoff water downstream to new practices of retaining or slowing water longer through infiltration strategies such as rain
gardens. This will work best for large drains (storm drains). Also, storing excess water through green roofs could be an ideal method of relieving the burden of lagoons downstream. Hence, these strategies are shifting from the single-purpose drainage systems to multi-functional drainage systems. Incorporating the idea of green infrastructure through the sourcing of expertise from landscape architects could be an alternative to bring to attention modern practices in drainage infrastructure designs.

5.2.2 Unplanned (non-estate areas)

5.2.2.1 Ensuring compliance to housing codes, design principles and regulations

Municipalities should be aware of the important role in the supervision of development for purposes of safety. Compliance to housing codes are also necessary to ensure that residents are protected from hazardous areas. Inclusion of architects should also go beyond design to construction. This would ensure consistency and order even as residents build in an incremental and organic basis. Training of draftsmen (informally trained planners) should also be done. This is to bridge the gap and finding the middle ground between orderly development and organic development since these groups are key influences in self-help housing. Also, providing building materials as incentives for construction during permit application processes could also not only ensure that infrastructure is incrementally provided but also encourage the adoption of the formal permit application processes and compliance to easement regulations.

5.2.2.2 Community engagement

Corburn advocated for the need to tap into local knowledge. It was found that the study areas have a great asset which is the existence of social groups which are utilized in their main economic activity-fishing. These community groups could be viewed as an asset to potentially utilize in engaging in communal housing project where they share resources to provide suitable
housing and drains that are not located in ecologically sensitive areas. Fishing, family and domestic jobs are normally done within close proximity to their houses. These businesses thrive mainly through family and friends groups which involves members into such occupations who support each other. Hence, in such cases, people are represented as networks which are assets for such communities. Such an asset can be utilized in designing a drainage framework that connects people together and enable shared visions and scenarios to be developed for sustainable reasons.

This research goes further to recommend a strong collaboration between Metropolitan Assembly, National Disaster Management Organization and chiefs who are the custodians of the land and strongholds in decision making. Land tenure systems have been recognized as part of the problem leading to haphazard development in cities. Collaborating with chiefs would therefore not only facilitate implementation of infrastructure projects but also ensure the building of trusts with other institutions. It will help to sustain neighborhood unions that could be potentially formed in the cities as self-management organizations. Such unions could be mobilized monthly for clean-up activities. This does not only create healthy environments but also encourage social sharing and interaction between groups. This intervention is highly dependent on the people than the local government.

5.2.2.3 Ensuring housing affordability

There is a challenge on how to have access to loans for housing developments on a low interest rate. Hence, the need for a flexible payment system. Housing loaning Institutions and Real estate firms are unwilling to promote loans on a long-term payment as it is not profitable. Since not all residents can afford the mortgages associated with purchasing Real estate housing, there is the need for an alternative way of financing housing for poor residents.
5.2.3 Both planned and unplanned areas

5.2.3.1 Towards the challenge of incremental financing of infrastructure

Creating drainage systems should consider an incremental approach to financing public infrastructure and maintaining them periodically. This should be accompanied by master plans which should not just include structural interventions but also clear financing plans. Drainage plans/maps are needed so as to ensure that this incremental process is followed. It needs to be updated consistently with new developments that would take place. Modern technology such as GIS and satellite imagery can be employed for this purpose.

5.2.3.2 Addressing sanitation challenges

There is the need for a more robust approach concerning waste management in Tema. It was found that most residents dispose their waste indiscriminately in gutters/drains which contributes to the problem of flooding in Tema. The case of filtration system in Kwinana city - Australia could be borrowed as it has proven to be successful in getting rid of trash in drainage systems.

In Kwinana, waste that are harmful for the environment are caught into nets which are fixed at the outlets of drainage pipes and sent by trucks to trash sorting centers at recycling sites. These biodegradable waste are used as fertilizers. More than 800 pounds of garbage were collected (Myworld 2019). “370kg of debris consisting of food wrappers, plastic bottles, sand and tree leaves was cleaned out of the nets” (Saseedaran 2018). The cost of net is $10,000 each. In 5 months (March - August), the nets have been cleaned 3 times. It is a safer and cost-effective system. The city used $20,000 as cost of installation which included the design, manufacture and associated civil works. This could be an intervention for both estate and non-estate areas.
This relatively low resource-intensive intervention could be adopted in Tema whereby it would be incorporated with the strategy of separating sewage pipes from drainage canals and channeling them separately to final disposal site which would accommodate a sewage/water treatment. Collaboration between local governments and manufacturing industries would ensure cheaper cost of manufacturing the nets. The treated water could be used for watering green spaces during the dry season. This could be a safer and healthier approach to disposing and separating liquid and solid wastes.

Figure 5.2.3.2: Case of Kwinana, Australia

Source: Myworld (2019); Saseedaran (2018).
It is apparent that planning could be used as a form of exclusion. In Ghana, we notice that the main challenges of drainage infrastructure provision are related to compliance and implementation. In real estate areas where we see an orderly layout of building, streets and lots, we observe that it is accompanied with appropriate type, sizes and materials of drains. This is planned but only a few people can afford (access to loans) to live within these planned enclaves. Hence, others are excluded of formal planning through this process. Excluded ones tend to be circumvent the process, hence, leading to unsuccessful implementation of programmes, policies and planning interventions. This compels us to question who determines the true urban form. In view of this, there is the need for planning to go beyond the idea that informalities must just be formalized. Being proactive would rather require formal planning to come to the level of local demand. It needs to be more incremental, less costly, participatory and organic. Formal planning is supposed to bring order in development and it is imperative since it ensures cost-effectiveness in the use of resources, equitable distribution of infrastructure, promotion of health and safety and maximization of environmental friendliness. Meanwhile, people’s organic growth, on the other hand, are expressed in their strong agency to assert rights in their spaces. Hence, if their activities and ways of life are not well incorporated in formal plans/codes/regulations, humans would begin to take action themselves as a way of adapting to these ‘rigid’ rules. In respect to this, there is the need for an orderly development that would ensure that drainage design and planning are compatible with incremental housing development and organic growth of the city. This calls for the need for an organic growth that is orderly- meaning complies with design principles but through the incremental and organic approaches of the people. This is necessary because while there’s the need to bring about order in development, there is also the need to
allow some kind of flexibility and organic development so that people are able to have their own experiences in their cities. However, the challenge is to do both concurrently.

Nevertheless, there is the need to consider context in terms of place, people and time. For place, it is in terms of the people’s incremental and organic practices. The research views these different use of materials, sizes and types of drains as a manifestation of the complexity of interests in the urban environment as it represents the affordability levels of residents. For place, it is in terms of their topography. For time, it is in terms of their era of technology in drainage system. An effective approach to planning would therefore be a flexible, collaborative and incremental planning practice. This research brings to attention the idea of ‘informalizing’ formal planning practices. The reversal.
Appendix

6.1 Abbreviations

GMET/GMA- Ghana Meteorological Agency
GSS- Ghana Statistical Services
MCE- Metropolitan Chief Executive
NADMO- National Disaster Management Organization
TDC- Tema Development Corporation
TMA- Tema Metropolitan Assembly
TTC- Tema Traditional Council
UN- United Nations

6.2 Definitions

I. **Planned areas (Estate areas):** These are estate areas that usually have site and services provided as part of housing for purchase. They also have an orderly grid system.

II. **Unplanned areas (Non-estate areas):** These are described as areas that grow organically. They usually have organic layout and street pattern. Housing and drainages (especially minor drains) are usually provided by residents themselves.

III. **A building permit** is “a permit to develop, construct, alter, extent a building given by TCPD to ensure that a development follows a particular layout, scheme and land use.” Before this, one must have legal title to a plot of land and intends to develop on it, site
must conform to approved layout, site must conform to approved zoning and 3 sets of drawings

IV. **Development application:** An application to change land use, alter, extend or build accompanied by scheme or layout

6.3 Institutions

6.3.1 Tema Metropolitan Assembly

The Local Government Act 462 1993 and Local Government Legislative Instrument LI 1929 are the legislative instruments used to establish the Tema Metropolitan Assembly in November 2007. Under this legislature, “the Assembly is mandated to initiate programmes for the development of basic infrastructure and provide municipal works and services as well as being responsible for the development, improvement and management of human settlements and the environment in the district” (ESMP 2017).

6.3.2 Tema Development Corporation

The TDC currently functions under Legislative Instrument (LI) I 469 as amended by LI1468 of 1989. The land was expropriated from Nungua, Tema and Kpone traditional authorities (Akrofi and Whittal 2013). The TDC was mandated to plan and develop the Tema Acquisition Area. Other functions that goes with this include constructing roads and public buildings, developing industrial and commercial sites and providing public utilities such as sewage and street lights. In achieving its objective, TDC is expected to work closely with the Tema Municipal Assembly
6.4 Criteria for measurements

**High severity** - Completely destroyed and/or disconnected (changed the orientation and position) the drainage line

**Medium severity** - Availability of cracks which has created a gap between two parts of the drainage line

**Low severity** - Availability of cracks but drainage line is still in order

6.5 Snapshot and scroll-down of Fulcrum app
### 6.6 Media Search

Figure 6.6: Showing source of Media search of Areas that has flooded from 2010 - 2018

<table>
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<th>Date reported</th>
<th>Date occurred</th>
<th>Areas</th>
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<th>Link</th>
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<td>Report</td>
<td>Link</td>
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</tbody>
</table>

6.7 Choking and Cracks in Drains Maps (Right drain only)

Figure 6.7.1 Showing Severity of Cracks in Sakumono (right drain only)
Figure 6.7.2 Showing spots in drains choked with solid waste materials in Tema Manhean
Figure 6.7.3 Showing spots in drains choked with solid waste materials in Sakumono
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