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IMPACTS OF URBAN LAND USE CHANGE ON SOURCES OF DRINKING WATER IN KUMASI, GHANA

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ABSTRACT

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Land use has a major influence on water quality, and the issue is of great concern in developing world urban areas where there are competing land uses. Kumasi, Ghana like most cities in the developing world, struggles to control and prevent urban water supply pollution through appropriate water resource protection measures that minimize or eradicate adverse impacts of land uses. Presently all rivers in the city are highly polluted, including the one where raw-water is obtained for treatment and supply of potable water. This study investigates how sources of drinking water are impacted by land use in Kumasi, the implications associated with the impacts, community perceptions of urban land use impacts on sources of drinking water, and community adaptations to water supply problems. It relies on field data collected through semi-structured interviews, a transect walk conducted upstream from the source of public water supply, and a transect walk bisecting the river in each of two communities characterized by differing levels of economic affluence. The study also draws on other secondary data sources. Using these methods, the study finds that urban land use is increasing the nutrient content of the source of public water supply, threating water quality, reducing a water reservoir's storage capacity, increasing the cost of water treatment, and contributing to water supply restrictions causing water scarcity at the household level, especially in the poor urban community. As a result residents use various coping mechanisms to manage with water scarcity. To ensure sustainable water supply, there is the need to address land use challenges and the threats they pose for sources of public water supply, and this calls for collaboration among all departments, institutions, agencies, and interest groups involved in land use and water resource protection issues.

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I am more than grateful to my family for their support (physically and spiritually) and encouragement. I say may God richly bless us and continue to support us all. To my wife, Mrs. Hannah Eduful, I say thank you very much for being there for me and your motherly love and support for the children in my absence. And to everybody that contributed in one way or the other to making this research a reality, I say thank you and thank you again.

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CHAPTER ONE: INTRODUCTION

Problem Statement

Access to improved, clean, and plentiful water is infinitely precious (Stauffer 1998) and water and life are intricately linked (Smol 2002; Mwanza 2005). Mwanza (2005), in contributing to the discussion on access to water from improved sources after the World Summit for Sustainable Development (WSSD) held in Johannesburg, South Africa in 2002, emphasized that access to improved water sources is central to poverty eradication and sustainable development. The World Health Organization (WHO 2005) also stressed the importance of adequate water supply and water resource management in propelling a country's economic development which contributes immensely to poverty reduction.

Though there has been improvement in access to water supply from improved sources in urban areas in the developing world (UNICEF/WHO 2012), access to water supply in urban areas continues to threaten the socioeconomic wellbeing of the majority of urban populations, especially those living in disadvantaged or poor urban communities. The problem is exacerbated by rapidly increasing urban populations and urban development which adversely impact sources of water supply. Global statistics indicate that cities are currently home to nearly half of the world's population and over the next 30 years most of the two billion plus person increase in global population is expected to occur in urban areas in the developing world (Cohen 2006). The rapid rate at which urban areas in developing countries are being transformed by increasing populations and continued urbanization presents formidable challenges to addressing the

water supply needs of their populations. One such challenge is rapidly urban development and the intensification of urban land use (e.g., higher densities of residents and structures, conversion of sensitive lands to urban uses, and new industrial activities).

Studies have shown the adverse impacts of urban land uses on sources of water supply (Solbe 1986; Stauffer 1998; Smol 2002; Randolph 2012); urban land use increases non-permeable areas resulting in high volumes of urban storm-water contaminated with traffic related pollutants such as heavy metals and organic micro pollutants which end up polluting sources of water supply. Moreover, urban land use reduces riparian vegetation cover which has negative impacts on water quality. Though one of the major problems of urban water pollution in the developing world is poor sanitation (Simon et al. 2001; Adarkwah and Post 2001), urban areas in the developing world are increasingly becoming more impermeable as a result of increasing urban populations and urbanization. According to Kurian and McCarney (2010), the fast growing urban populations in developing countries are having negative impacts on freshwater resources. This is seen in both the demand for water supply and increase in land uses that adversely impact freshwater resources.

Kumasi has seen much development recently, and the city has grown in size and population. According to Population Census 2010, the population of the city stands at 2,035,064; this is slightly more than a 73% increase over the 2000 population census, which measured the population at 1,170,270. The increase in population is a result of high natural growth rate, at 5.2% per annum, and rural – urban migration, making Kumasi one of the fastest growing cities in the country. The challenges posed by the rapid population growth are enormous. More people are living in poor communities with

limited access to basic infrastructure and services, especially access to potable water (Devas and Korboe 2000; Nyarko et. al. 2006). Some parts of the city do not have access to public water supply, and in places that do, supply is rationed and moreover, erratic and unreliable (Ghana National Water Policy 2007; Akple et al. 2011).

With the increase in the city's population comes an increase in land use related challenges. Many cities in Sub-Saharan Africa are confronted with increasing pollution and waste disposal problems as a result of rapidly increasing urban population, widespread poverty, inadequate and weak local governance, and limited financial resources (Adarkwah and Post 2001; Simon et al. 2001). Kumasi exhibits such characteristics as land uses in the city have grown in type, size, and in number; the most worrisome land uses are indiscriminate dumping of solid waste, which gets carried by surface runoff and ends up polluting water resources, real estate (housing) development, sand winning/mining, and wood collection within catchment areas of water bodies (McGregor et al 2006).

Currently, water resources in Kumasi are highly polluted with high nutrient content carried from land uses as a result of limited land use regulations and poor sanitation. Land uses adversely impact sources of drinking water such as hand dug wells, bore holes without protective covers, and most importantly the source of public water supply in the city. The Waste Management Department, the Town and Country Planning Department, the Public Health Department, the Ghana Water Company, and the Environmental Protection Agency are trying to control land uses that adversely impact water quality in the city, but because enforcement and coordination have been very poor, not much success has been achieved. Land use continues to pollute sources of water, and

many poor communities without access to public water supply or with erratic and unreliable water supply are forced to cope with daily water supply challenges; and alternative sources of water supply come with their own set of problems.

Kumasi is no different than other cities in the developing world in terms of increasing population, increasing land uses, and water supply challenges. This study therefore seeks to investigate how sources of water supply are impacted by land uses in Kumasi, especially sources of public water supply, and how the community perceives impacts of land uses on waterways. It also examines land use impacts on water treatment, water supply, and access to water supply at the household level in one affluent community and one poor community. This will improve our understanding of urban water supply challenges, access to water supply at the household level, and community perceptions of impacts of land uses on waterways, and will be useful to all cities in the developing world.

Research Questions

Research questions posed for this study are:

1. How are sources of drinking water impacted by urban land uses in Kumasi?
2. What are the implications for water treatment and supply and access to safe water supply at the household level?
3. What differences in perceptions of land use and waterways, access to water supply, water supply challenges, and coping mechanisms exist between poor and more affluent residents?

Effectively answering these questions calls for a critical look at urban land uses because they can release organic and toxic pollution into runoff with adverse implications for water bodies. Randolph (2012) argues that activities on the land will affect the fate of water because precipitation falling on the land will either run off to join surface water or infiltrate to join groundwater. Answering these overarching questions demands exploring how land uses are impacting sources of public water supply in Kumasi, examining how the operations of the Ghana Water Company Limited (GWCL) are affected, and embarking on a transect walk to document land uses at the upstream of the Owabi River impounded by the company for treatment and supply of potable water to Kumasi communities. Also, this study will seek to explore community residents' water supply challenges and adaptation, and how the two different urban communities (i.e., neighborhoods) perceive land uses impacting waterways. And lastly, this study explores how community perceptions compare to land uses observed through transect walks on rivers in the communities.

Objectives

The primary objective of this study is to provide information to policy makers, urban planners, municipalities, and interest groups about the implications of urban land uses on sources of drinking water and the challenges they pose to communities, especially those with erratic and unreliable water supply. This study provides this information by analyzing data collected from one poor urban community (low class area),

one more wealthy (high class) community[1], and key informants (government officials) on land use, sources of water supply, access to water supply, and water supply challenges and implications.

This study could be used by the Ghana Water Company Limited (GWCL) to improve its services. It accomplishes this objective by providing information on water supply challenges at the community level. This study could also influence municipal policy direction about urban land use planning and waste management. The research provides information on the consequences of the Waste Management Department's (under the Kumasi Metropolitan Assembly) inability to collect all waste generated in the city, the lack of effective land use management regulations, the lack of strong enforcement measures, and the ineffective collaboration amongst departments and other stakeholders involved in land use and water protection issues.

Moreover, the research contributes to the literature of geography and urban planning by broadening our understanding of access to water supply, urban land use and water pollution, and the implications of water supply challenges in the urban areas.

[1] The classification is based on Kumasi Metropolitan Assembly classification system. KMA uses Tipple and Hellen's (1984) study to classify areas into High Cost Sector, Tenement Sector, Indigenous sector, and Government built Sector. High Cost Sectors which are also referred to as High Class areas, are characterized by low density with 1 to 3 houses/2.4 acres and 50 persons/2.4 acres. On the other hand, the Indigenous Sector, also referred to as Low Class areas or poor communities, are characterized by high density with more than 7 houses/2.4 acres and more than 200 persons/2.4 acres.

Significance of the Study and Contribution to Literature

Water supply in urban areas is a very important issue around the world, especially in the developing world where rapidly increasing urban population is stressing available water resources and supply services. Available statistics indicate that over 344 million people in Africa are without access to clean drinking water from an improved source (AMCOW 2012). Further aggravating the problem is poor sanitation resulting from a combination of factors such as inappropriate, uncontrolled, and unregulated land uses, widespread poverty, and inadequate sanitation facilities (Simon et al. 2001). As a result significant pollutants are carried by urban runoff into sources of water supply. Since access to water from improved sources is essential to good health and improvement in socioeconomic status, and critical for the attainment of Millennium Development Goals in education and gender (Maoulidi 2010), the need for improved access to potable water has never been so important. The importance of urban water supply and the link that exist between land use and sources of water supply make research into land use change and sources of drinking water very significant.

Elsewhere in the developed world, many studies have examined the effect of land use on water quality (Solbe 1986; USGS 1996; Randolph 2012). Other studies have focused on controlling nonpoint source water pollution with the principal idea that contaminants carried by runoff from the land into waterways are a major problem and come with a huge financial cost (Novotny and Chesters 1981; Hansen, Babcock & Clark II 1988). Pitt et al. (1996) in "*Groundwater Contamination from Storm Water Infiltration*" note that with urbanization, impermeable surfaces reduce infiltration and

increase surface runoff resulting in less ground water recharge and increased quantities of pollutants in waterways.

Other studies have investigated urban water supply challenges in the developing world. In a study examining *Water usage pattern in low urban communities in Uganda*, Howard et al. (2002) conclude that low-income urban dwellers rely on multiple sources of water supply. Zerah (2000) examines the household strategies employed by low-income community dwellers in Delhi, India, for coping with unreliable and poor quality water supplies and found that storage, pumping, adaptation, collection, and quality were important strategies. She concluded that lack of reliability characterizes the water supply situation in Delhi (quality and quantity aspects). In Kumasi, a number of studies have investigated land and water related issues by emphasizing that streams in the city contain high levels of human waste and chemicals far above WHO 1989 and 2000 standards (Cornish et al. 1999; McGregor et al. 2001, 2011). McGregor et al. (2002) concluded that the presence of fecal coliform concentration in rivers in Kumasi presents a potential risk. Other researchers have investigated the challenges and implications the urban poor face daily in accessing water supplies. In their paper *Microbiological quality of water from hand-dug wells used for domestic purposes in urban communities in Kumasi*, Akple et al. (2011) note that hand-dug wells can suffer from fecal coliform contamination as a result of their close proximity to communal facilities such as public toilets and waste disposal sites. According to Bour (2003), water quality in Kumasi has both direct and indirect effects on the health of women and is a causative factor of poverty. Erni et al. (2011) studied *Urban water and nutrient flow in Kumasi* and argue that waterways contain high amounts of nutrients that render the water unsafe for any domestic activity.

The city of Kumasi illustrates the typical problems of urban land use change, water pollution, and water scarcity of poor urban communities in developing countries. The city's authorities are faced with challenges posed by urban land use change on the environment, especially on water resources, in the sense that changes in urban land use significantly impact sources of drinking water (Randolph 2012). However, little, if any, published research has specifically examined the impacts of land use change on sources of drinking water, especially sources of public water supply and the implications on water treatment, water supply challenges at the household level, and community perceptions of land uses on waterways. The research described in this thesis is therefore significant in broadening knowledge and understanding of land use impacts on sources of water supply, water scarcity, and challenges at the household level in cities of the developing world.

Thesis Organization

This study is organized into six chapters. This chapter has considered the problem that places the research in the wider context. It has also presented research questions, objectives, and significance of the study and contribution to literature. In Chapter Two, various literatures on urbanization, land use, urban water, and urban water scarcity are reviewed to provide a framework for evaluating and analyzing the results of the study. Chapter Three follows with background information of the study area to provide understanding of the physical, social, and economic characteristics of the area. Chapter Four covers the methodology employed in the study. In that chapter, the procedure for data collection and analysis are discussed. Chapter Five presents the results and discussion of the study. Finally, Chapter Six examines the findings and synthesizes the

major findings. The chapter concludes by offering some policy recommendations, and then suggests areas that need additional study or research.

CHAPTER TWO: LITERATURE REVIEW

Introduction

This chapter briefly presents urbanization in Africa to demonstrate how rapid population growth in African cities is presenting formidable urban development challenges. The chapter also explores how land use has been related to water bodies and urban water supply and use in sub-Saharan Africa and Kumasi. This study is based on land use change concepts and issues surrounding urban water supply in the developing world; these provided the overall organizing idea and the working principle within which the research was carried out.

Urbanization in Africa

Urbanization continues to affect most cities across the world, in both developed and developing countries. The proportion of the world's urban population is expected to increase to about 57% by 2050 from 47% in 2000. More than 90% of future population growth will be accounted for by the large cities in developing countries (AfDB 2012). In the developing world today, especially in Africa, the rate of urbanization far exceeds what is happening in most cities in the developed world. Global statistics indicate that Africa has experienced the highest rates of urban growth during the last two decades (at 3.5% per year) and this rate of growth is expected to hold into 2050 (AfDB 2012). The urban populations of sub-Saharan African cities like Lagos in Nigeria, Abidjan in Cote D'Ivoire, Yaoundé in Cameron, Addis Ababa in Ethiopia, Nairobi in Kenya, and Accra in Ghana are growing at rapid rates. For example, the 2010 population census in Ghana puts Accra's population at 4,010,054, which represents a 38% increase from the 2000 population of 2,905,726 (GSS 2012). Today more than 325 million people live in urban

settlements in sub-Saharan Africa (LSE 2012) and according to UN projections the number will triple in the next few decades, reaching over 1 billion by 2050. The rapid rate of population grow in the sub-Saharan African cities is not only changing the demographic landscape, but also physical landscape. Since sub-Saharan African cities have failed to properly accommodate all the rural-urban migrants, many find themselves living in very deplorable conditions in slums, squatter settlements, and shanty towns exacerbating the problems of access to services, including potable water (Berger 2006).

According to Cohen (2006) the speed of urban transformation in the developing world presents formidable challenges. Most notably are the risks to the immediate and surrounding environment, to natural resources, to health conditions, to social cohesion, and individual rights. Since some slums, shanty towns, and squatter settlements are found along river banks and nature reserves without proper sanitation, they pose significant threat to natural resources and the environment, especially water resources. It is estimated that 72% of urban population of Africa now live in slums (UN-HABITAT 2003). Moreover, expansion of cities is generally at the expense of destruction of forests and other natural environments or ecosystems which increases both air and water pollution (AfDB 2012). In most sub-Saharan African cities a large portion of urban vegetation has been removed and riparian vegetation has been encroached upon, both of which have negative consequences on water quality (McGregor 2006).

The rapidly increasing urban population in African countries is contributing to the depletion of biodiversity resources in the urban areas, triggering the release of tons of carbon dioxide from direct land use change. The increasing population leads to congestion in the cities, thereby driving it toward increased demand for land resources

(Sharma et al. 2012). According to Mengistu et al. (2012) rapid population growth is considered as a push factor for resource degradation, and in Ethiopia the higher proportion of younger urban population implies that huge pressure will be exerted on the land resources. As urban population continues to grow rapidly, urban poverty becomes increasingly widespread and economic incentives become the driving force, often encouraging land degradation and discouraging conservation (Mengistu et al. 2012) which has repercussions on both surface water and groundwater, because what happens on the land eventually ends in water bodies (Randolph 2012).

Rapid urban population growth in African countries is also presenting formidable sanitation challenges. Though there have been improvements in sanitation in most African cities over the years, a high percentage of the urban population still does not have access to improved sanitation. According to WHO and UNICEF (2008), in 2006 the African population without access to sanitation increased by 153 million, from 430 million in 1990 to 583 million in 2006. Though open defecation in Africa has dropped from 33% in 1990 to 24% in 2006, almost a quarter of the population in Africa (228 million) engages in open defecation. This is the riskiest sanitation practice as most often it is carried out along river banks contributing to water pollution. Waste disposal also constitutes another sanitation problem in most African cities. In many sub-Saharan African cities there is increasing evidence of pollution and waste disposal problems, and this is the result of rapid growth and urbanization, widespread poverty, inadequate and weak local governance, logistical problems, and limited financial resources (Adarkwa and Post; Simon et al. 2001). This means city authorities are not able to collect and properly dispose all waste that are generated in the city, and adding to the problem is

indiscriminate dumping of waste by urban residents, especially residents of poor urban communities. Indiscriminate dumping of waste has negative impacts on urban water resources because waste gets carried by urban runoff into water bodies.

Land Use Change and Water Bodies

Impacts of land use and land use change on water bodies are complex, diverse, and wide ranging. On its transit through the landscape, water is exposed to the properties of the terrestrial surface which is an important determinant for both water quantity (sufficient supply of freshwater to support human and natural systems) and water quality (suitability of supply for an intended use). While humans use land in diverse ways to improve their quality of life, most uses have caused negative effects on the environment. In examining environmental problems associated with land use change, Solbe (1986, 22) noted that "many of the environmental problems which countries are experiencing are resulting from the increasing rapidity of land use change and one of the critical facts about changes in land use is that the effects may be long-term and sometimes irreversible." Smol (2002) agrees with Solbe, arguing that some changes are due to natural processes, but that we now know that anthropogenic activities are responsible for many of the environmental problems we are currently facing.

Urban land use produces impermeable surfaces as a result of increased development in the form of residential and commercial buildings (rooftops), highways and driveways, car parks etc.; these give rise to greater runoff, increasing the risk of channel degradation and other environmental consequences. Solbe (1986) argued that runoff from impervious surfaces such as heavily trafficked motorways, car parks etc., has

implications for the water cycle, both in terms of quantity and quality. A wide range of organic, inorganic, and metallic pollutants may be removed from the land and road surfaces and occur at high concentrations in the runoff water, which is then carried into water bodies.

Urban livelihoods in most cities in the developing world have compelled many households to supplement household income with urban agriculture. This system of urban farming has introduced the use of pesticides and fertilizers, which have negative effects on water bodies. The use of commercial fertilizers, containing primarily nitrogen (N), phosphorus (P) and potassium (K), negatively affect water quality, extending into stream chemistry across both watershed zones and coastal systems (Merz et al. 2004; Mustard and Fisher 2004), and agrochemicals, in particular, may have a larger impact over a long period of time. Tillage, application of fertilizers and pesticides, and other activities associated with agricultural land use potentially affect surface water and ground-water quality. According to Smol (2002), many important sources of potable water have been severely affected by urban farm wastes.

Urban Water and Poor Communities

In general there have been major improvements in access to water supply over the years, especially in the past three decades. However, in practice improved access to water supply varies, especially in poor urban communities in the developing world. To ensure adequate water supply and to help achieve sustainable development (Itama et al. 2007), the General Assembly of the United Nations declared the period between 1981 and 1990 as the International Drinking Water Supply and Sanitation Decade (IDWSSD). The

World Summit on Sustainable Development (WSSD) conference in Johannesburg in 2003 and the Third World Water Forum, (in Japan) also added voice to the need for improved access to drinking water and sanitation.

In 2006, estimates from the WHO/UNICEF Joint Monitoring Programme for Water and Sanitation put the global urban population with access to drinking water from improved sources at 95%. This high rate of urban drinking water coverage has been as a result of deliberate efforts by international organizations (e.g., the United Nations), governments, and non-governmental organizations to improve access to drinking water in urban areas. The WHO/UNICEF Joint Monitoring Programme for Water and Sanitation (2006) stated that the world is on track to achieving the Millennium Development Goal (MDG) drinking water target of halving by 2015 the proportion of the population without sustainable access to safe drinking water, and that this will occur in urban areas; in March 2012, the WHO/UNICEF announced that the world has achieved the target.. This good news, which is likely to be over-estimated (Kirkwood 1998), masks the unacceptable access to drinking water supply in most urban areas in developing countries, and especially in the poor urban communities. In these poor urban communities, residents are confronted with no access to piped water, dilapidated water infrastructure, erratic or unreliable water supply and contaminated water bodies.

The United Nations Environment Programme (1999) estimates that the present shortage of clean water will only get worse, to the point that in 25 years, two-thirds of the world's population will have no access to adequate clean drinking water. In 2004, a study estimated that 2.6 billion people in the developing world lack access to safe drinking water and sanitation services (Rijsberman 2004). This is not surprising considering the

rapid rate of population growth in cities in developing world without a corresponding increase in water supply infrastructure. Erni et al. (2011), attribute the problem of access to safe drinking water in poor urban communities to population growth and human pollution resulting from urban land use change. One out of three people in the developing world does not have access to safe drinking water.

Urban Water and the Urban Poor in Sub-Saharan Africa

Access to safe drinking water from an improved source is a huge challenge in poor urban areas in most developing countries, especially in sub-Saharan Africa. In 2003, the United Nations estimated that sub-Saharan Africa lags behind the rest of the world and has the worst supply of water and sanitation. Currently, 331 million people in sub-Saharan Africa are without access to improved drinking water (AMCOW 2012)[2]. In 1997, a study conducted in Abidjan, Cote d'Ivoire, on access to piped water found that less than half of urban population of 3 million people received water from the official distribution system (Champetier et al. 2000). In most poor urban communities access to piped water remains a dream, and residents depend on multiple sources with uncertain water quality and unreliable supply, accessibility, and cost (Howard et al. 2002). Even high-to-middle-income urban communities with piped water are confronted every day with unreliable or erratic water supply and bad water quality. In Conakry (Guinea), in 1997, only about 45% of the urban population was connected to the city's water system. A significant number of the 45% that were connected to the formal water supply system

[2] Regional differences exist in the number of people without access to drinking water from improved source. In Eastern Africa people without access to improved drinking water source in 2010 stands at 126 million, 107 million in Western Africa, 50 million in Central Africa and 49 million in Southern Africa (AMCOW 2012).

also experienced unreliable flows due to old and dilapidated infrastructure (Champetier et al. 2000). The situation is no different in Mombasa (Kenya), where a study by Devas et al. (2004) revealed that a large section of the population with water pipes has seen no water in their pipes for several years because the water supply as a whole is insufficient to meet demand. The official statistics will always show overstated figures because official statistics classify those with "access to piped supplies" as adequately served, even if the water supply in the pipes is unreliable and of poor quality (Devas et al. 2004). Coverage rates of the urban population enjoying water supply at home or within the home remains low and is usually concentrated in high-income areas (UNDP 1999).

In sub-Saharan Africa, a majority of the urban population without access to piped water are the people who live in poor urban communities with a polluted environment and associated health risks (Andreasen 1996; Akple et al. 2011). Therefore, the urban poor depend on multiple sources (e.g., boreholes, wells, streams, and other natural sources) of water supply offering varying quality, reliability, accessibility, and cost. The water supply challenges that the urban poor face thus require them to adopt a variety of social and economic coping mechanisms. Access to reliable water supply means the urban poor will have more time for other economic activities, thereby improving their socio-economic status. In 2009, a study by the World Bank found that the urban poor can spend between 9% and 20% of their income on water. de Waal (2008) argues that in Tanzania a three day water shortage would send an additional 10% of the population below the poverty line. In Kenya, the poor prefer to spend more time fetching "free" water than to incur costs at water kiosks (Gulyani et al. 2005). However, collecting free water requires queuing and hence lost economic activity, which also comes with health

risks. A study by Kobel and Mistro (2012) found that in Kampala (Uganda), the majority of the urban poor who are not served by the formal water supply system use water bought from vendors or free water from springs. However, according to the Kampala City Council, over 65% of the springs in the city are contaminated by coliform bacteria (Chemiphar and Health Service Commission 2006).

Considering household economic activity in relation to access to reliable water supply also reveals a gender dimension. Shortages of water or poor quality water heavily impact women in poor communities not only because of their domestic responsibilities, but also because their livelihoods tend to be neighborhood-based and often involve the use of water for activities such as food processing (Devas et al. 2004).

As noted above, in the face of water supply challenges, the poor adopt a variety of strategies to cope with the situation. Howard et al. (2002) studied water usage patterns in low-income urban communities in Uganda and found that the poor collect water from a variety of different sources for different uses. Coping mechanisms adopted by the urban poor range from strategies of storage, pumping, adaptation, and collection to quality strategies (Zerah 2000). A particular household could combine two or three strategies, provided they are socially acceptable and economically feasible. The socio-economic characteristics of a particular household may determine which coping strategies it adopts, since strategies come with their own economic, social and health risks. Devas et al. (2004) note that in the face of unreliable water supply in Colombo (Sri Lanka), the people are obliged to collect water at night for use during the day. Storage brings problems of hygiene and increased risk of disease.

Urban Water Supply in Kumasi, Ghana

The problem of access to reliable drinking water from improved sources in Sub-Saharan African cities is no different in Kumasi. Most of the city's water bodies are polluted, mostly as a result of land use. According to estimates by the Waste Management Department, the markets produce about 100 t/d of waste (mostly organic), and since the department lacks the capacity to collect all waste generated, some is carried by surface runoff into rivers in the city. A study by CEDAR (2002) confirms the extent of water pollution in the city. The study shows that the Oda River at the city's boundaries suffers from high nutrient levels (20.7mg/l nitrogen, 7.1mg/1phosphorus), high fecal coliform numbers (16,360/100ml), and relatively low levels of dissolved oxygen (2.5mg/1 DO). These high nutrient contents have resulted in increased algal and plant growth in streams (Erni et al. 2011), rendering the water undrinkable and even polluting groundwater to some extent. Devas et al. (2004) noted that many of the boreholes and wells in Kumasi are highly contaminated, and many of the streams used for water collection are also used for defecation.

According to the Ghana Statistical Service (2005), over 90% of Kumasi's population has access to improved drinking water, and 75% accesses its drinking water through the piped distribution system, which is provided by the Ghana Water Company Limited (GWCL). However, water supply is unreliable and rationed. Water is rationed to many customers, and in the peri-urban and the densely populated poor urban areas, customers receive water once a week or not at all (Ghana National Water Policy 2007). A 2006 survey conducted by the Ghana Demographic and Housing Survey found that only four out of ten respondents living in urban areas had piped water in their homes and that

42.6% purchased water from water vendors. The majority of the population in Kumasi without access to piped water is the urban poor, who extensively use hand-dug wells (McGregor et al. 2000). Akple et al. (2011) concluded that well water in Kumasi, which for most years was perceived as safe for drinking and is increasingly being used for such due to erratic supplies of piped water, is turning out to be a health threat. Under these circumstances, what are the socio-economic implications for the poor urban household, and what coping mechanisms are available to them in the face of water scarcity and water pollution challenges?

CHAPTER THREE: BACKGROUND OF THE STUDY AREA

Introduction

This chapter presents the study area in its physical, economic, and social characteristics. This will enable the reader to appreciate the context within which data were collected and organized.

Location, Climate, and Physical Characteristics

Kumasi is located in the moist-semi deciduous section of the South East Ecological Zone (Arhin and Gyan 1992; KMA 2006) of south-central Ghana, an average elevation of approximately 853 feet above sea level. It is about 170 miles north of the national capital, Accra. The city is about 157.8 sq. miles in extent. The relative central location of the city with respect to more densely populated portions of Ghana makes it an important hub in this part of the country. Kumasi (Figure 1) shares boundaries with other local authorities, including Kwabre East District to the north, Atwima District to the west, Ejisu-Juaben Municipal to the east, and Bosomtwe District to the south.

The climate of the area is wet, semi-equatorial, with mean annual rainfall of 53.15 inches (MDS 2006). Minimum and maximum monthly average temperatures are around 69.8^0F and 80^0F, respectively, with little variability throughout the year. Although several major rivers and small streams such as Subin, Wiwi, Owabi, Aboabo, Nsuben, Daban among others pass through the city (drainage is generally from north to south). Many small streams such as Ada, Mnono, Kamafo, and Aynasu serve as tributaries to the Owabi River which flows southward to the reservoir (in the northwestern portion of Kumasi) created by the Ghana Water Company Limited (GWCL - the company is the

lead organization responsible for urban water supply and is a statutory corporation created by Parliament under the Ghana Water and Sanitation Corporation Act, Act No. 310, 1965). The Subin and the Daban Rivers are both tributaries of the Sisa River flowing south into the Oda River. Approximately 75% of the urban area is located in one watershed that drains into the Oda River at the southern boundary of Kumasi.

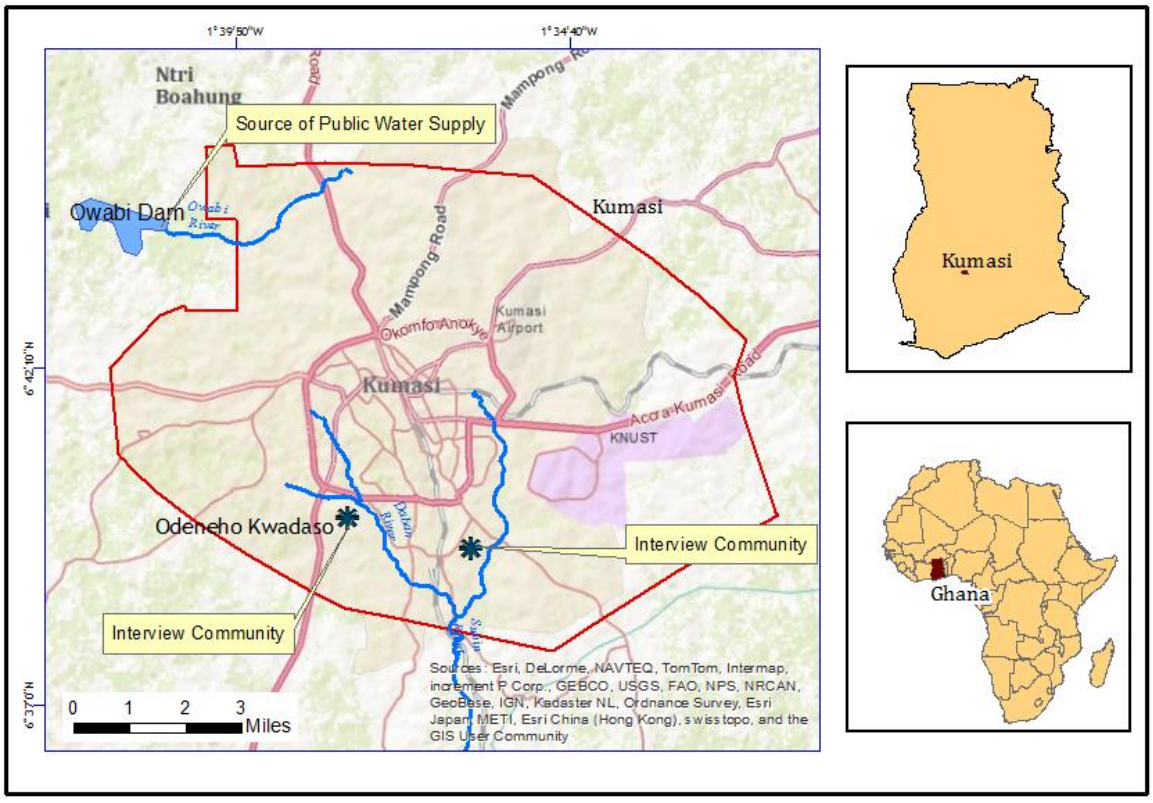


Figure 1: Map of Kumasi showing the study locations

In general, the city shows compact mixed use development, even within the Central Business District (CBD). The old communities such as Bantama, Ash-Town, Fante New Town, Asokwa, Asafo, Asawase, and Aboabo, which are adjacent or closer to the CBD, are more compact than other communities that were developed when the city started outward physical expansion. Because the old communities are more compact, they have high populations. The CDB area is comprised of Adum, Central Market (the largest

market in West Africa), Kejetia, and Roman Hill; the area is the main shopping center offering both wholesale and retail goods, financial services, and other services. The CBD has become a commercial hub for much of Ghana as it attracts people from all over the country. Though commercial activities could be seen all over the city, commercial activities reduce in intensity as one moves away from the CDB and enters into a more residential areas. As a result of the socioeconomic structure of the city, there is no community that is exclusively residential.

Since 2000, the city has seen major improvements in infrastructure development, economic development, and physical expansion. The city experiences road congestion especially in the CBD area. However, the construction of the missing 2 miles South-eastern part of the existing by-pass as a dual carriageway to link Asokwa to Oforikrom has improved road traffic in the city. Construction of the Sofoline interchange which is part of 7 miles road to like Kejatia to Abuakwa on the Kumasi-Sunyani Highway still continues; when this is completed it will facilitate traffic flow from Kumasi to the Northern part of the country, and the interchange will be the largest in West Africa. Urban growth propelled by economic activities has enabled urban renewal, which has made it possible for brownfields and dilapidated buildings to give way to modern commercial buildings, especially in the CBD. Adum, in the CBD, shows some interesting edifices such as the Dufie Towers, Aseda house, KAMA Plaza, Ecobank Plaza, Asantehene Plaza, and many others.

Over the years the city has grown to incorporate other settlements and villages at the periphery and still continues to grow, taking up agricultural lands at the periphery as a result of urban sprawl and the need to settle new migrants. In 1992 the total area of the

city was 91.7 sq. miles (Arhin and Gyan 1992) and currently the total area of the city is about 157.8 sq. miles (KMA 2006). Though the city has expanded in all directions, it has expanded significantly to Kodee in the north and to Sokoban in the south. The old communities and the CBD are experiencing more infill development as a result of economic viability of these areas. The new communities at the periphery and the affluent communities are low density areas compared to the old communities and communities in close proximity to the CBD.

The low density development at the periphery of the city means that the city is consuming land at a faster rate than it is able to accommodate the growing population. This is putting pressure on nature reserves and on riparian areas in the city. Though there are no city-wide statistics about which nature reserves and riparian areas have been encroached upon evidence on the ground shows that these areas have suffered encroachment. According to KMA (2006), human activity in terms of estate development, encroachment, and indiscriminate waste disposal practices have negatively impacted the drainage system and have consequently brought water bodies to the brink of extinction in the city.

Demography

The population of the city continues to grow rapidly from both natural increase and in-migration (primarily rural-to-urban). According to the 2010 Population Census (GSS 2012), the city's population was 2,035,064 in 2010, with an annual growth rate of 5.4 percent. The population is made up of 680,365 people between the ages of 0 and 14 (33.43 percent), 1,280,712 people between the ages of 15 and 64 (62.93 percent), and

73,987 people 65 years and above (3.64 percent of the total population). The city's age structure is indicative of a young and growing population. The high proportion of the population in the 0-14 age cohort gives an indication that a large number of dependent young people place a heavy economic burden on the working-age cohort. Comparing the 2010 population to that of 2000, which was 1,170,270, the population of the city grew by 73.9 percent. There were also significant increases in the city's population in the past; the percentage change in population between 1984 and 2000 was 139 percent, with an annual population growth of 5.2 percent during that period (GSS 2002). Bour (2004) attributes the high population growth of the city to high fertility, a decreasing mortality rate, and cultural, administrative, industrial, commercial, and migratory factors. Industrial job opportunities and brisk commercial activities attract people from the neighboring districts, and even across the country to the city. The Fertility Rate is high, especially in poor communities and slums (GSS 2010).

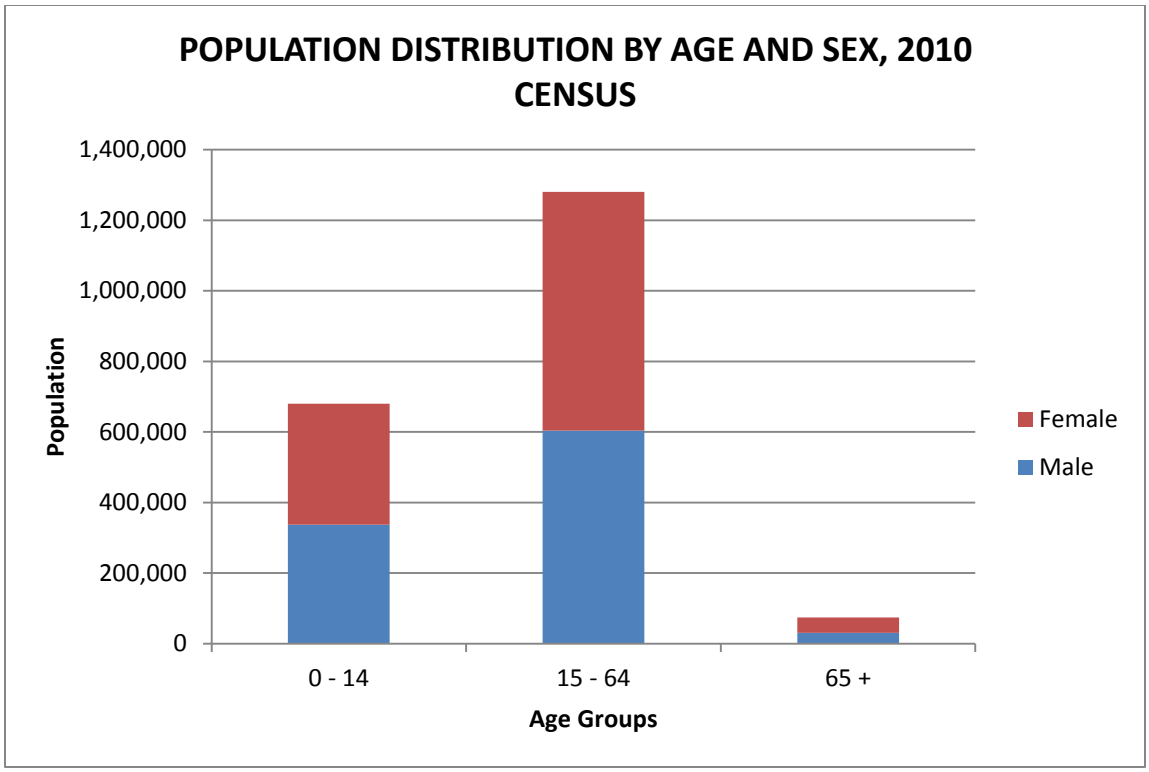


Figure 2: Population Distribution by Age and Sex in Kumasi (Source: 2010 Population Census, Ghana Statistical Service)

The city's population is diverse in many respects; as a result of its unique location, the city has historically been a focal point of migrants in the country. It was estimated in 1960 that one-sixth of all the immigrants who arrived in Ghana from other African countries settled in Kumasi (Arhin and Gyan 1992). A special study in 1990 by the Ghana Statistical Service revealed that persons from all the ten regions of Ghana are fully represented in Kumasi. Migrants of the same ethnic origin generally tend to concentrate in one locality (demonstrating chain migration), and such localities are usually named after the ethnic group. Examples include the Anloga community, which identifies people from the Volta Region and Fante New Town, named by people who have migrated from the Central Region.

The Economy

Kumasi is economically vibrant. The unique location as a regional capital and even national commercial hub (secondary to Accra) is an ideal place for the development of all forms of economic activities. The economy of the city is dominated by commerce, manufacturing, extractive industries, and services. The commercial hub of the city keeps on expanding; in the early 1990s, commercial activities were mostly concentrated in the Central Market, Asafo Market, and Adum, but currently, economic activities have spread far and wide. Central Market is the largest market and is located at the heart of the city. Goods offered for sale here include local and foreign luxury goods, local food items, and imported goods. The volume of trade is several thousands of cedis (US$ 1 = GHc 2.07) per day. There have been a number of fire events in the market recently, which have led to loss of several million cedis in properties. Adum, on the other hand, is the main shopping center, where wholesale, retail, and boutique shops are lined up on each side of streets, especially Prempeh II street, which bisects the Adum suburb and leads to the offices of the Ministries and Central Post Office. Since the latter part of 1990, many financial institutions have established offices in Adum, which is gradually becoming the financial center of the city (Figure 3).

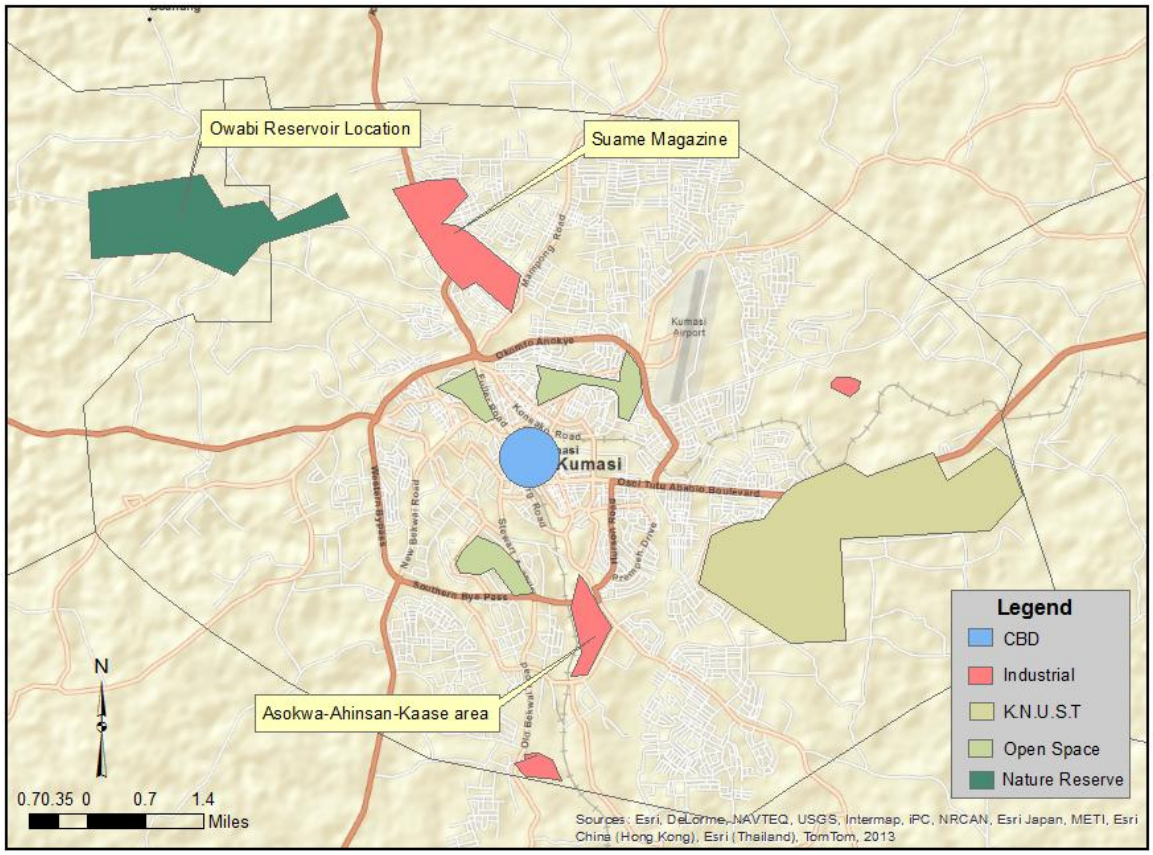


Figure 3: Map of Kumasi showing major land use districts

Asokwa-Ahinsan-Kaase area (see Figure 3) is the center of industrial activity in the city, and all manufacturing and extraction industries are located in this area. These industries offer thousands of jobs to residents of the city. The major manufacturing industries in the city include Kumasi Brewery, brewers of Star and Gulder beer; Guinness Ghana Limited, brewers of Guinness Stout beer and malt; and one soft drink manufacturing plant, the Coca-Cola bottling plant. Apart from these major industries, wood related industries like furniture making are prominent in the city. These are scattered in various parts of the city, especially at the edges of rivers, with the most important center being Sokoban wood village located at the edge of the city. Moreover, the industrial areas host a number of lumber processing and construction companies, such as Logs and Lumber Limited (LLL), Consar Ltd, etc., offering employment to over 4000

people (Arhin and Gyan 1992). Some of these industries discharge liquid waste directly into rivers, contributing to river pollution. The Environmental Health Department regulates the discharge of industrial effluent into rivers, but whether regulations are strictly enforced and adhered to is a different matter. The only institution shown on Figure 3 is Kwame Nkrumah University of Science and Technology (KNUST), which is the largest science and technology university in West Africa.

Governance

The Kumasi Metropolitan Assembly (KMA) is the legislative authority in the city and it administers and manages the affairs of the city by guiding, directing, and supervising all other administrative authorities in the city. The Local Government Act 462 of 1993, the Town and Country Planning Ordinance of 1945 (CAP 84), and the Local Government Legislative Instrument (LI) 1614, of 1989, established the KMA to manage the city and empowered it with legislative responsibilities to make policies, including the rules and by-laws, which give legal effect to its decisions. These laws gave authority to KMA to become a Planning Authority as well to mobilize financial resources through taxation from the metropolis to undertake development projects.

The Assembly has 10 Sub-Metropolitan District Councils that work to maintain and fulfill the vision of the Assembly. However, as a result of logistics and financial challenges since 2000, only four are currently operational. This is hampering the efforts of the city to control land uses that can have negative impacts on the environment, including water resources. Moreover, the Town and Country Planning Department operates with the Town and Country Planning Ordinance of 1945 (CAP 84) and other

local by-laws which are all outdated and therefore ineffective in controlling current land uses and new development.

CHAPTER FOUR: METHODOLOGY

Introduction

The methodology addresses how this study was organized in general - what and how materials were collected, what research tools or instruments were used in data collection, how respondents and study areas were selected, how data were analyzed, and what tools were used in the analysis. Any of these could have influenced the final outcome and therefore limitations of the means of data collection are also discussed.

Data Collection Methods

This research utilizes qualitative research methods in the form of semi-structured interviews and incorporates transect walks, a Participatory Rural Appraisal (PRA) technique to investigate how sources of drinking water are impacted by urban land use. The Participatory Rural Appraisal techniques are useful and effective tools for exploring local issues in a rapid and cost-effective manner (Mukherjee 2002). Though either method could be used as a stand-alone for data collection, the use of both methods was necessary because research that combines methods enhances the researcher's ability to address the research questions than using either approach exclusively (Creswell and Clark 2006). Moreover, transect walks complemented the semi-structured interviews, gave detailed information, and made the final results a true representation of conditions on the ground. In addition, the mixed method approach (i.e., interviews and transect walk) was used because of the benefit of corroboration. Conclusions reached at the end of this research will be more accurate if data gathered through transect walks about the impact of urban land use on sources of drinking water converges with qualitative data gathered through interviews about community perceptions. Berg (1998, 5) argues that by

combining several lines of sight, researchers obtain a better and more substantive picture of reality, a richer, more complete array of symbols and theoretical concepts, and a means of verifying many of these elements.

Research Subjects

The subjects for this research included city government officials, key staff of the Ghana Water Company Limited, and selected residents in a poor urban community (or neighborhood) and a more affluent community. All subjects selected were above 18 years of age, and none of the subjects were in the vulnerable population group as defined under Institutional Review Board's (IRB) criteria for research involving human subjects.

Study Areas

The researcher selected Kumasi because it exhibits many of the characteristics of a growing city in the developing world. The city is confronted with a rapidly growing urban population, uncontrolled land uses, increased urban water pollution, increasing squatter settlements, an inadequate public water supply system, poor sanitation, inadequate infrastructure, and many other problems. Urban land use poses challenges for the source of public water supply in the city and other sources of water supply at the community level. This affects both the quality and quantity of water supply in urban communities. Getting the right and detailed information to influence policy decisions requires detailed information on public water treatment challenges resulting from land uses, household data, data on water scarcity, data on land use in the catchment areas of rivers, and land use impacts on water supply as perceived by community residents. The best way to get reliable information that could influence policy is from the source: in this

case the public water supply company and at the household level. For information at the household level, the researcher selected two areas as a case study because it was appropriate for this study to compare the impacts. Yin (1984) argues that the use of case studies is an appropriate research methodology when the focus of the research involves "how" or "why" questions. Using two communities in Kumasi as case study areas (Figure 1), this research investigates how sources of drinking water are impacted by urban land use and explores the implications of the impact. It is important to select two communities, a poor community and an affluent community (high class), because this will help establish differences and similarities, if any, in community perceptions on land use and waterways, water supply, and implications of water scarcity. This could subsequently encourage the formulation of urban development policies that will benefit both poor communities and affluent communities.

In choosing the case study areas, the researcher used Kumasi Metropolitan Assembly's community classification system (list) mentioned above. The list classifies communities as high class (affluent areas), medium class, and low class (poor areas) in terms of their location, density, and population. Low class communities are characterized by high population, high density, high concentration of "compound houses" (multi-family houses) and squatter houses, multi-ethnic, and erratic and unreliable or lacking public water supply. In addition, the Ghana Water Company Limited's list of pro-poor (a term used to stimulate economic growth for the benefit of the poor) communities was also used to complement KMA's list. The researcher's objective was to identify one poor community and one affluent community with access to a public water supply system and at the same time closer to a river. A community's location, its accessibility, and its

openness were also considered in selecting a particular community. Due to time and financial constraints, the idea was to select communities that met these criteria but which were not far apart from one another. After using Google maps and embarking on reconnaissance walks in a number of communities to gather information on community location, accessibility, access to public water supply, and closeness to a river, the researcher selected Kaase as the poor urban community and Odeneho Kwadaso as the affluent community (see Figure 1). Kaase is a suburb of Kumasi and is about 2.49 miles south of the center of the city. It has a high population and a high concentration of "compound houses" with an average household size of 22, and it is closer to the industrial area in Kumasi. Moreover, the Subin River flows within the eastern part of the community. Odeneho Kwadaso an affluent community, is also a suburb of Kumasi and is about 1.55 miles south-west of the center of the city. Its population is low and it has a high concentration of single family houses with an average household size of nine and Daban River is at the north-eastern part of the community. Here, fence walls are not too high, and not all houses have fence walls as compared to other high income communities. Therefore, houses were more open and approachable than in other communities where houses have tall fence walls as a barrier.

Semi-Structured Interviews

Interviews were the main method employed in soliciting information about community perceptions of how sources of drinking water and waterways are impacted by urban land use, what the implications of these impacts are, and how public water supply is impacted by urban land use. Interviews have been described by Berg (2007) as a conversation with a purpose; the purpose for conducting interviews in this study was to

gather information to answer the research questions. The researcher employed a semi-structured approach in which interviewees were asked a set of predetermined questions (see Appendix A) and the researcher probed beyond the responses to the predetermined questions in order to get further clarification and additional information. The researcher is of the belief that people have different experiences with issues and that experiences vary from place to place; it is through probing that these differences come to bear. Berg (2007, 62) argues that, "Questions used in a semistandardized (semi-structured) interview can reflect an awareness that individuals understand the world in varying ways. Researchers can accomplish this through unscheduled probes that arise from the interview process itself".

All interviews for this study followed the same structure, but predetermined questions did not follow any systematic or particular order; in many instances, questions were reordered to suit the context.

The Interview Questions

Different questions were structured for the household level and government officials. For government officials, the departments included in the study have different objectives and influences within the metropolis; therefore, the questions were diverse. However, in general, the questions for the interviews were designed to elicit relevant information pertaining to land uses affecting water resources in the city. The questions therefore explored land use regulations and measures in place to control nonconforming land uses. They also explored waste management, the capacity to manage waste, and water contamination and its controls. In addition, they focused on the impacts of land use

on the Ghana Water Company's reservoir in Kumasi and any implications this has for water treatment and supply.

At the household level, questions explored residents' perception about how land use impacts waterways. Additionally, questions explored water supply challenges, water scarcity, and coping mechanisms adopted by residents to overcome water supply challenges.

The areas explored through interview questions were:

- Municipal Assembly
    - The role of departments in urban land uses
    - Collaboration among departments in urban land use issues
    - Land use regulations and by-laws
    - Conservation/preservation/nature reserve areas and floodplain management
- Ghana Water Company
    - Water supply in the city
    - Water treatment and urban land use
- Community - Household level
    - Perception of land use and waterways
    - Access to water supply
    - Coping mechanisms

(Appendix A contains the complete interview guide).

Sampling Procedure at the Community Level

A stratified systematic sampling method was employed in selecting the community respondents for interviews. Many writers have written in favor of the method; for example Babbie (1999) states that stratified systematic sampling is a method for achieving a higher degree of representativeness and decreasing the probable sampling error. According to Patten (2001), when systematic sampling is used properly, it produces a population sample that is basically as valid as a sample obtained using simple random sampling.

To ensure that respondents constituted a fair representative sample of the community, the researcher visited each community to assess how roads and streets networks could be used to partition these into four subsections. After two visits to each community, good information was obtained about the systems of roads and streets, and each community was partitioned into four using these as well as by taking the social structure of the community into consideration. Babbie (1999) reinforces the importance of collecting data from different geographical locations by stating that within a city, stratification by geographical location usually increases representativeness in social class, ethnic group, and so forth. Next, respondents were identified in every third house in each of the four subsections. After one or two interviews within one subsection the researcher moved to the next subsection until all had been visited, and then started the process again until reaching data saturation.

As it turns out, more women were selected than men, because culturally in Ghana, women are the primary water collectors, and they better understand water scarcity at the

household level. The UNICEF and WHO (2008) findings establish that when drinking water is not available at home, women shoulder the bulk of the water collection responsibility, and that it often takes a considerable amount of time to collect. Women in Africa are more than five times as likely as men to usually go to a source and collect drinking water for the household. Shiva (2002) also argues that in developing countries, women play a very important role in ensuring that their families have sufficient water.

Data saturation was used as a determination of data sufficiency. Data saturation is reached "when no new categories or relevant themes are emerging" (Corbin and Strauss 2008). By using data saturation to determine sampling size, the researcher made sure that categories, dimensions, properties, variations, relationships, and concepts emerging out of the interviews were fully developed. In all, 30 interviews were conducted: 14 household-level interviews in Kaase, 11 household level interviews in Odeneho Kwadaso, and five (5) interviews with government officials as key informants.

Selecting Key Informants for Interview

Interviewing government officials as key informants was very important for understanding land use and water supply challenges in the city. The interviews provided insights into how the city is dealing with land use issues relating to water contamination and how land uses have expanded far and wide. The key informant interviews were also critical for understanding the impacts that land uses have on sources of public water supply in the city. The key informants were the Head of Department at Town and Country Planning, the Deputy Head of Department at Waste Management Department, the Head of Department at Public Health Department, the Water Quality Assurance

Manager at Ghana Water Company, and the Operations Manager at Ghana Water Company. These departments were selected because they are directly involved in land use control, water pollution and quality measures, and water supply in the city.

Interviews were arranged with key informants in these city departments by first contacting the Mayor of Kumasi in person with a letter describing the research and its purpose. The Mayor then called in the Co-ordinating Director to endorse the letter to send to the Department Heads. After meeting the Department Heads in their various offices, interviews were scheduled at their convenience. With Ghana Water Company, a letter was also sent to the Director of the Company in person and the letter was endorsed for the attention of the Operations Manager to help with any data needed. After the interview with the Operations Manager, the researcher was directed to also speak with the Quality Assurance Manager. The researcher visited with staff at the company's dam in Kumasi. Some of the interviews were conducted during lunch breaks and others were conducted very early in the mornings. In all a total of five key informants interviews were conducted.

In every interview, the respondent was made to understand the purpose of the interview. The researcher gave a brief description of the research and the nature of their participation, as required by the University of Montana IRB. The researcher also stated categorically that the interview was anonymous and that respondents were free to opt out of the interview at any time or skip answering any question if they felt uncomfortable. To protect the confidentiality of respondents, respondents are identified by codes in the results section; all personal identification has been removed.

Transect Walk

A transect walk is a Participatory Rural Appraisal technique. Chambers (1994, 1253) describes PRA as an emerging family of approaches and methods to enable local (rural or urban) people to express, enhance, share, and analyze their knowledge of life and conditions, to plan and to act. Mukherjee (2002) has described the PRA techniques as useful and effective tools for exploring local issues in a rapid and cost-effective manner.

As a technique to gather qualitative information, the transect walk is normally organized with local people to observe and document one or more phenomena (e.g., socio-economic, biophysical, etc.) along a predetermined transect and show spatial difference, as well as to ask questions about such phenomena. Many researchers have employed the technique in the process of data collection. In Mahiri's (1998) study "Comparing Transect Walks with Experts and Local people," he used the technique to both gather basic evaluations of the environment, and as a forum to elicit "expert" opinion on a range of issues. During the transect walk he documented features such as soil type, trees, landscape, and vegetation and questioned local people on policy and practice.

Transect walks conducted for this study observed and documented land uses and other phenomena adjacent to waterways. Three transect walks were conducted, one on the Owabi River upstream of the impoundment created by the Ghana Water Company for supply of potable water, one on Subin River in Kaase (the poor community), and the other on Daban River in Odeneho Kwadaso (the affluent community). The transect walk on the Owabi River upstream (Figure 4) was not part of the original plan, but after

interviewing key informants at the Ghana Water Company and learning about the level of land uses surrounding the river, the researcher decided to conduct a transect walk at the upstream of the river. It should be noted here that the Owabi Reservoir (Dam) and some portions of the Owabi River are protected by the Owabi Wildlife Sanctuary. The Sanctuary is about 8.07 sq. miles and has an inner Sanctuary of about 4.35 miles which surround the Owabi reservoir and portions of the river.

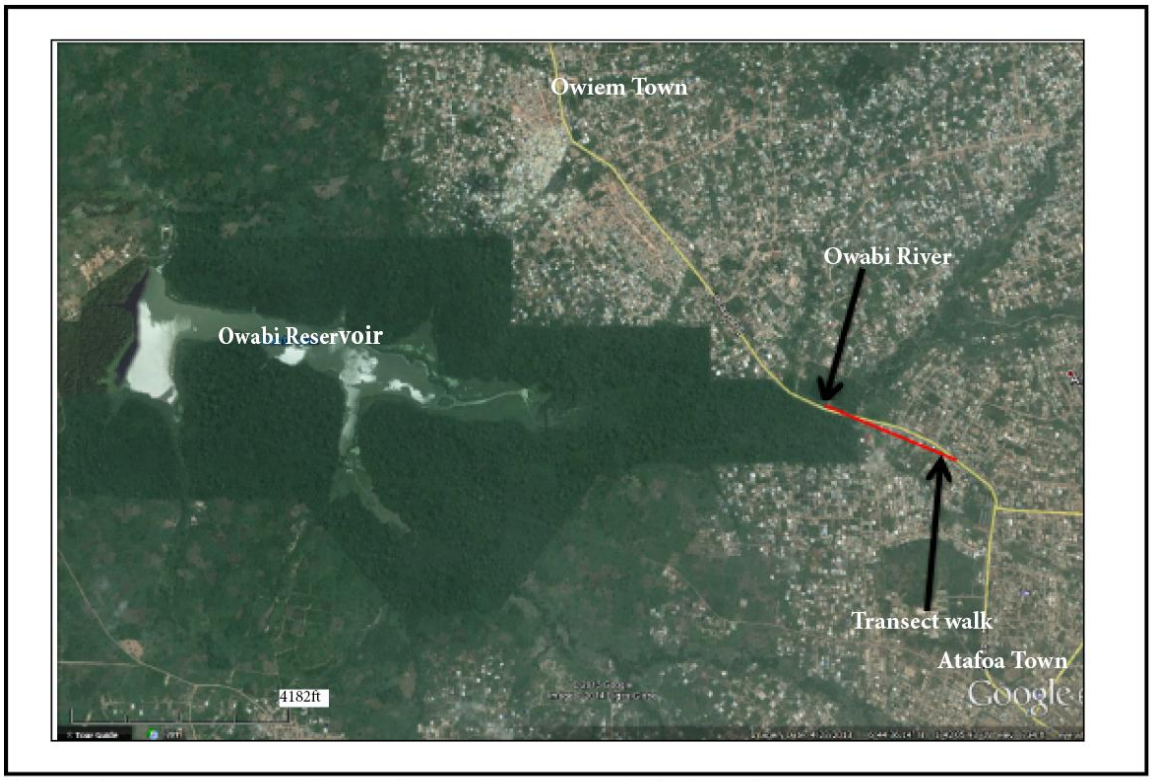


Figure 4: Owabi Reservoir and Transect location (Source: Google Earth 2014)

The rationale behind conducting transect walks is:

- To identify and document land uses, spatial differences in land uses, and changes in landscape;
- To compare one transect walk with the other, especially if the Owabi River (where Ghana Water Company gets its raw water) is treated differently in terms of land uses compared to the rivers at the community level;
- To find out if communities' perceptions about how land use impacts water bodies relates to what is actually on the ground.

The community transect walk was conducted after the household level interviews in that community. The idea was to use the interview period to identify potential participants and to agree with them on a set date. Those identified and who eventually participated in the activity were all above 40 years and with long term residence in the community. Moreover, they were those that had interest in the subject under study, particularly in water resources and sanitation management. Because land use tends to be more intensive along main roads, all the transect walks were along such roads. It took about 30 minutes to complete each. In Kaase community the researcher was accompanied by three residents (two women and one man). In Odeneho Kwadaso, he was accompanied by two men and one woman. Because no interviews were conducted in the Owabi River area, the researcher visited a nearby village called Atafoa for a group of three men who agreed to participate in the activity. Interest, age, and long term residence were also considered. Aside from observing, documenting, and taking photographs, the occasion was also used to gather more information from participants by questioning them about

land uses, land use change, and human – environment interactions and probing their answers for clarification.

Data Analysis Methods

Secondary data gathered were systematically organized and studied for relevant information to form the background of the research and to help understand context underpinning the research questions. Research articles were also studied and analyzed for differences and similarities on how they present or address issues relevant to the research topic.

The primary data analysis started with interview recordings; by playing back recordings to ensure that recordings proceeded smoothly, and then uploading the recorded data unto computer to be transcribed. After interview recordings were transcribed, the data were careful and thoroughly studied to establish familiarity with them. Warren and Karner (2010) argue that the first step in data analysis is to become intimately familiar with the data. The idea here is to generate analytic descriptions from the thickly descriptive interview data. Through the process of open coding, data were carefully read, reread, and contemplated to establish common themes that emerged from the data. In narrowing down the themes that emerged from the data, compelling themes with high frequencies that directly relate to addressing the research questions were selected. Some of these compelling themes with high frequencies were similar to some of the themes from the interview guide. After these compelling themes were selected, the interview data were revisited again, and using Nvivo software, coded around the compelling themes that emerged.

Qualitative data obtained from transect walks were also translated into visual representations of what is actually on the ground, with the help of locals. Lastly, quantitative data in the form of population figures obtained from Ghana Statistical Service were organized and presented in the form of a chart.

Problems encountered in the field

The researcher did not encounter any major problems with acceptance in the field. Respondents showed great enthusiasm in the research and made themselves available to be interviewed. However, on two occasions respondents refused to be interviewed based on the fact that the interview would be recorded. When a respondent refused to be interviewed, the researcher moved to the next house on the same line of houses to try to solicit an interview and continued the systematic sampling from that very house. One government official also refused the recording of the interview, but agreed that he would give any time needed to enable the researcher to write whatever he had to say. This affected the volume of information gathered with this particular official, but subsequent interviews with other officials complemented the data collected.

Identifying respondents, especially in the high income community, was not easy. Most of the residents are full time workers and were mostly not available at home during weekdays. The researcher therefore strategized and visited the community at certain times during weekends, when the researcher managed to get respondents for the interviews. In the affluent community, respondents requested to see an official student identification card before opening their doors to be interviewed. After the identification card was shown, the researcher was fully accepted into the household.

Interviews were conducted in the local dialect (Akan). The interview questions were in English, and there was a challenge of translation because certain words cannot be translated verbatim into the local language. Also, during transcribing, the same challenge was posed translating from local dialect to English. Nevertheless, every effort was made to help residents understand the actual meaning of the interview questions, and every effort has been made to maintain the original form of the data as presented by the respondents.

CHAPTER FIVE: RESULTS AND DISCUSSION

Introduction

This chapter presents the findings of the study. Information gathered through key informant interviews, household interviews, transect walks, and secondary data sources are organized under headings that emerged as interview themes. Community and Ghana Water Company's perspectives of impacts of land use on sources of water supply, water scarcity and challenges, and coping mechanisms are discussed. Effort has been made to link the findings to other studies in the field of land use and water-related issues.

Public Water Supply

Public water supply in the Kumasi Metropolis is managed by the Ghana Water Company Limited (GWCL). The Owabi River that drains the north-western part of the metropolis has been impounded by the GWCL for treatment and supply of potable water. The reservoir and the treatment plant are situated at the edge of the metropolis. The north-western portion of the city drained by the Owabi River is experiencing relatively rapid physical expansion (Figure 4). Physical development has occurred in close proximity to the river, and some structures have even encroached upon the catchment area. Also, the GWCL Barekese Dam and treatment plant on Offin River is located well outside of the city in a rural setting. The Owabi Dam has an installed capacity of 3 million gallons per day, complementing the Barekese Dam which has an installed capacity of 30 million gallons per day. Due to challenges such as finance, personnel, power supply, and infrastructure neither of the plants is operating at full capacity. Currently, the two plants can only produce 26 million gallons per day, which meets only about 70 percent of current demand. Most communities, especially poor communities, do

not have access to piped water. A GWCL official stated that "the two plants can support about 97 percent of the current demand, but because of challenges, we are not able to even meet the 97 percent" (Official #2). The challenges range from land use to finance, personnel, power supply, to infrastructure.

Land Uses and the Owabi River

According to Environmental Protection Agency (EPA) and GWCL rules, a person cannot do the following without the consent of the company: enter the catchment area, fish in the reservoir, farm within the catchment area, build within the catchment area, or tap water from the river or the dam. Yet these activities are going on within the catchment area, generally with impunity. Interviews with two officials coupled with a transect walk Upstream of the Owabi water supply project illustrate how land use is impacting raw water quality, water treatment, and water supply.

The raw water gets treated for heavy metals because GWCL has detected the presence of nickel, mercury, zinc, and copper in the raw water; however, they have not yet detected the sources of the heavy metals. Many land uses upstream are not regulated and end up polluting the Owabi River. One official discussing the source of heavy metal stated that "well as at now we are not sure where the source is; it could be that there is an activity upstream of the river, it could be some mining activities, but for now we are not sure because we have not seen any signs of mining activities …… [however], we have not detected heavy metal to the limit that it is not treatable" (Official #2). Suame Magazine, a heavy industrial area, is located within the catchment area of the Owabi River which supplies Owabi reservoir with raw water; wastes from this industrial site get

discharged or are carried by runoff into the river. The many attempts by GWCL to ensure proper discharge of wastes in the area have not yielded any positive results. "The wastes from Suame Magazine are leading to the pollution of the Owabi Reservoir because their waste is mainly made up of industrial waste including heavy metals like lead, and oil, and you realized that Owabi the extent of pollution these days is higher than that of Barekese" (Official #2). These two statements by Official #2 seem contradictory, and what must be noted here is that the company has not yet officially established by any study that Suame Magazine is the source of the heavy metal.

Several studies have emphasized the impact of farming activities on sources of water supply (Randolph 2012; Merz et al. 2004). During the transect walk, farming activities were identified within the catchment area of the reservoir, and these farmers apply agrochemicals, which may have a larger impact over a long period of time. Official#1 noted that:

> Farming activities are going on along the banks of the river; some farmers are farming vegetables and the like. They even use some chemicals, pesticides, weedicides in the course of their activities and some of them you will be surprised are banned pesticides. They are not allowed to be used by the Ministry of Agriculture, they are not to be used but they find themselves into the farmers and the farmers use them. Then, when rains set in then there is a major runoff on the farm, carrying all these chemicals into the river and this river carries it into the dam where we abstract our raw water.

Tillage, application of fertilizers and pesticides, and other activities associated with agricultural land use potentially affect surface water and ground-water quality. This lends support to Smol's (2002) assertion that many important sources of potable water have been severely affected by farm practices.

The transect walk also revealed that estate (housing) development has encroached on the catchment area. Some developments are less than 100 feet from the banks of the river. Interviews with GWCL officials confirmed this. These developments aside, removing riparian vegetation also channels liquid waste into the river and then into the reservoir. Official #2 made it clear that:

> What primarily is affecting the activities of our water treatment is encroachment on the catchment area by developers. Owabi catchment area is gradually being encroached upon by developers and real estate developers. So people are building their houses and companies are building estates and renting them to people, now their liquid waste, the disposal of liquid waste some individuals channel their liquid waste into the dam. Instead of channeling the liquid waste into septic tank and all that for treatment and discharge they don't do it, for easy way out they direct it into the dam, so we have a situation where we are having a lot of sewerage seepage, sewerage intrusion into the dam.

Another government official also alluded to this fact by stating that "some of them when it is full instead of calling septic tank operator with vehicle to dislodge the material will prefer discharging the effluent into a nearby stream or drain which ends up in the water bodies" (Official #3).

Another land use that was noted during the transect walk was church activities within the riparian zone. A church has erected a structure within the riparian vegetation zone and conducts church services within the area. Official #5 observed that "the nature reserve too people are taking lands there, especially churches have also been going to the nature reserves because the original land devoted for churches have finished". In responding to a question on the most challenging land use issues in the city, Official #5 stated that "the greatest problem we have with land use is chiefs giving out nature reserves for development, but for other land use problems it's for us to control." She was

not the only official to attribute some of the urban land use problems to the traditional authorities (chiefs) who are the custodians of lands in Ghana. Official #2 also stated that "now chiefs and the people of the community gradually resell lands in the catchment area and they gradually encroach on the land…our concern is that gradually our reservoir which we use to store raw water….is gradually being polluted." Though certain portions of the Owabi River and the Owabi reservoir are protected by Owabi Sanctuary, which serves as a conservation area creating a buffer zone to protect the river and the reservoir, protection measures are not strictly enforced and there is some apparent disrespect for the Owabi Sanctuary.

The field data gathered during transect walk showed evidence of "wrap and throw" in which people defecate into plastic bags and throw it into gutters or street corners (Devas et al. 2004), as well as open defecation within the riparian vegetation. Open defecation is a continuing phenomenon that is being practiced by certain groups of people despite improvements made in the provision of public toilets. "We still have some people, the "wee guys" (marijuana smokers) they prefer going to the bush, so we don't have zero open defecation, we don't have it, we still have some small percentage which actually constitute the open defecation that is the case" (Official #3). During one of his transect walks, the researcher came into contact with a group of "wee guys" on a bank of a river, smoking and defecating. As long as these "wee guys" prefer defecating along rivers banks, rivers will always carry fecal materials.

The riparian zone is also being used as a dumping ground. This was evident during the transect walk: lots of solid waste was scattered along the road, and some waste was bagged and intentionally dumped in the area. The river itself was full of solid waste

(Figure 5(A). Some people will not take their rubbish to the official rubbish collection point and will throw it into gutters and rivers, especially when they realize that rain is about to fall. An official at the GWCL stated that "people also physically dump their solid waste into the reservoir; they bag their solid waste and dump it into the dam, so periodically we find floating objects like solid waste in the river" (Official #2). The level of solid waste content in water courses is a problem in the metropolis; almost all the rivers in the metropolis carry loads of solid waste. Gutters and water channels are treated more or less as a dumping ground. This finding confirms a study on water pollution in Kumasi which showed that the Oda River at the city's boundaries suffers from high nutrient levels, high fecal coliform numbers, and relatively low levels of dissolved oxygen (CEDAR 2002). An interview with official #3 illustrated the blatant disregard for the need to conserve water bodies. This Official stated: "let me say that the inhabitants of Kumasi when they see that the clouds are darker and thunder, they know that rain is coming and instead of them sending their waste into the collection site to pay a token fee, because of poverty deliberately or not will decide to just dump the waste into the nearby gutter using the drain as a channel." One participant in the transect walk commented that "here people dump everything into the river because they don't directly drink from the river" (Dam transect participant #2). The fact that people do not directly drink from the rivers can influence their behavior towards river conservation; as will be shown below, interviews at the household level also confirmed that this attitude towards rivers seems to stem from the fact that communities do not directly fetch drinking water from the rivers.

The Owabi reservoir is suffering from micro-organic activities resulting from the presence of large amounts of organic matter, which is rendering the water unhealthy and also making treatment difficult. Official #2 affirmed that:

> We have a situation we called eutrophication happening in the dam. Eutrophication is where you have large amount of organic matter and large amount of micro-organisms feeding on the organic matter. When they feed on them they deplete the amount of oxygen in the water, rendering the river unhealthy, so when it comes to treatment, we tend to use large quantities of chemicals which we shouldn't have to. Use large quantities of chemicals before we can treat the water, so you realized that our chemical cost per cubic meter of water is very high compared to Barekese.

This finding is similar to what Nyenje et al. (2010) found in other urban areas of sub-Saharan Africa (Nairobi in Kenya, Kampala in Uganda, Dar-es salaam in Tanzania, and Lusaka in Zambia). They concluded that eutrophication is an increasing problem in sub-Saharan Africa, because it compromises the ecological integrity of surface water. When the ecological integrity is compromised not only does the water becomes hard to treat, but it also hampers aquatic life as oxygen levels become depleted.

Logging for both firewood and lumber is also another activity that was noted during the transect walk (discussed below). People illegally log timber within the riparian zone, depleting the vegetation cover which serves as a buffer, intercepting runoff speed by increasing infiltration and filtering runoff. Official #1 agrees that illegal felling of trees occurs along the banks of the river though not pronounced. He stated that "people are doing illegal felling of trees along the river and all this have impacts on the raw water quality". The depletion of the riparian vegetation is not only due to estate development, but also illegal felling of trees.

As a result of land use along the banks of the Owabi River and within the catchment area, the Owabi reservoir is suffering from the accumulation of sediments, which is gradually reducing the amount of water the reservoir can hold. River siltation occurs when land is disturbed through removal of forest cover, farming activities, and estate development within the watershed area of a particular stream. Propelled by runoff, sediments get carried from these activities to a receiving stream. Randolph (2012) notes that sediments reduce water quality, increasing turbidity and nutrients, and lowering flow capacity. Official #2 noted that "they are farming close to the dam and within the catchment area, when there is a major rain, a serious runoff, a lot of silt get carried into the reservoir so gradually there is a build-up of silt in the dam". Official #1 also noted that "in Owabi, because of encroachment, expansion will be difficult; we need to do serious dredging of the dam and protect the catchment area from further encroachment before any meaningful rehabilitation and expansion can be done." The gradual build-up of silt in the reservoir means that there will be less water for treatment and less water to supply.

Official #2, in explaining how land use affects water supply, noted that "it affects the quantity of water that is treated and the quality, so because of that we have to restrict production, so instead of producing say one million gallons of water a day we are restricted to producing 500,000 gallons of water a day". Currently, the company can only meet about 70 percent of demand, and with encroachment making expansion difficult coupled with the ever increasing city population, access to potable water will become increasingly difficult, especially in disadvantaged communities.

The extent of pollution in the Owabi River (Figure 5A shows suspended sediments and tires) resulting from land use is not only affecting the quantity and quality of raw water treatment, but also the cost of treatment. The cost of water treatment at Owabi treatment plant keeps on increasing, and it is far higher than the treatment cost at the Barekese Headwaters, which is in a rural setting. This means that rivers in the urbanized area suffer from land use more than rivers in the rural areas. In analyzing the trend of treatment cost at Owabi treatment plant, Official #2 stated that "three years ago, four years ago, you could see that the amount of chemicals we used was less compared to now, so gradually the trend is that the amount of chemicals we are using is increasing because gradually the quality of water in Owabi Dam is gradually deteriorating and gradually the pollution is increasing". Currently, the cost of treatment at Owabi treatment plant is GHc 825.00 per 1000 cubic meter (US$ 412.50 per 1000 cubic meter), and at Barekese the cost is GHc 605.00 per 1000 cubic meter (US$ 302.50 per 1000 cubic meter). The treatment costs described above suggest that it costs the company 36.36 percent more to treat the same amount of water at Owabi Dam.

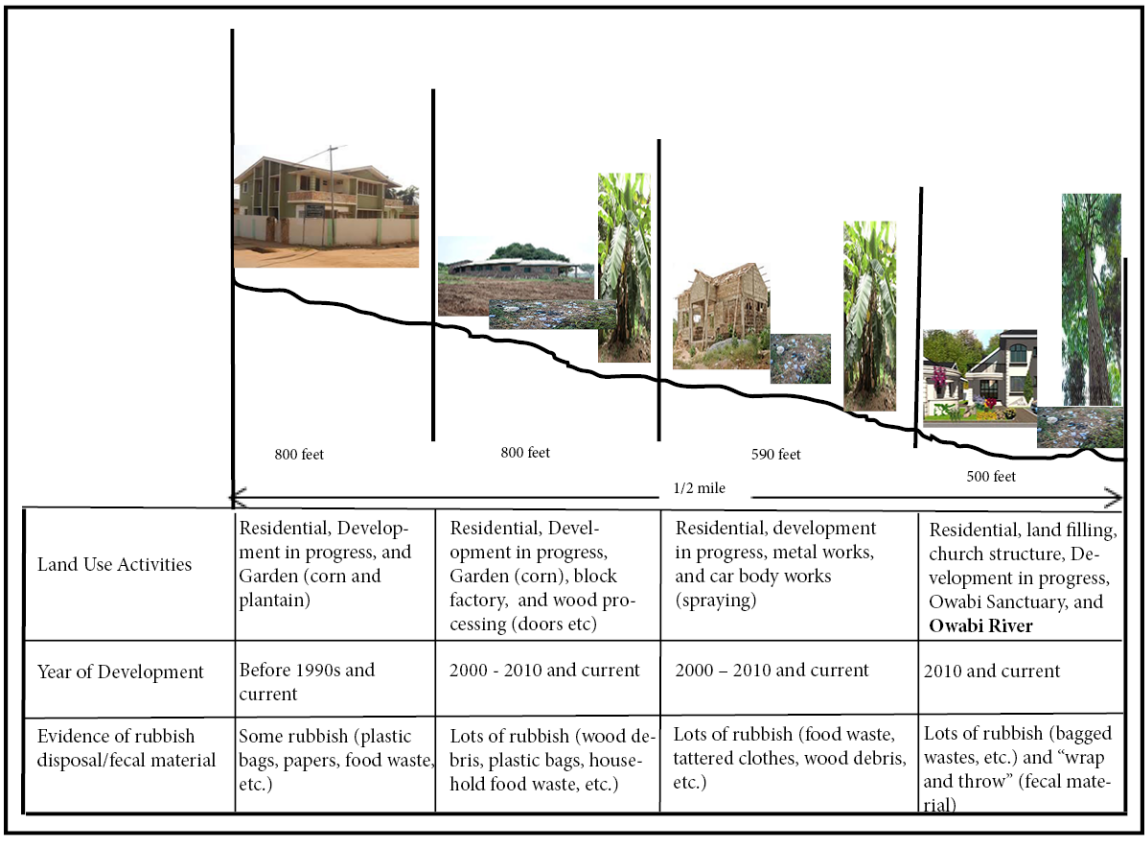
A: Upstream B: Downstream

Figure 5: Owabi River (Source: Fieldwork, July 2013)

Land uses documented during the transect walk that were not addressed by respondents in interviews are: filling of wetlands, cement blocks manufacturing, metal works, and wood processing. Though these activities all encroach on the catchment area, these specific land uses did not come up during the interviews. During heavy precipitation events, sediments from these activities (especially land filling and cement block manufacturing), can be carried by runoff into the river, gradually reducing the reservoir's capacity to hold water.

The transect walk on Owabi River took place on the road linking two towns, Atafoa and Owiem. The river separates these two towns north-west from Atafoa and south-east from Owiem (see Figure 4). The transect walk took about 30 minutes to complete with a group of three men documenting how land use, land cover change, and

landscape changes as one approaches the river. The transect diagram below (Figure 6) illustrates various land uses.



Land Use Activities	Residential, Development in progress, and Garden (corn and plantain)	Residential, Development in progress, Garden (corn), block factory, and wood processing (doors etc)	Residential, development in progress, metal works, and car body works (spraying)	Residential, land filling, church structure, Development in progress, Owabi Sanctuary, and **Owabi River**
Year of Development	Before 1990s and current	2000 - 2010 and current	2000 – 2010 and current	2010 and current
Evidence of rubbish disposal/fecal material	Some rubbish (plastic bags, papers, food waste, etc.)	Lots of rubbish (wood debris, plastic bags, household food waste, etc.)	Lots of rubbish (food waste, tattered clothes, wood debris, etc.)	Lots of rubbish (bagged wastes, etc.) and "wrap and throw" (fecal material)

Figure 6: Transect walk on Owabi River (Source: Fieldwork, July 2013)

Land adjacent to streams may be considered to be "cheap", "free", and sometimes "unprotected", and attracts squatters like furniture-making factories (carpentry workshops), food vendors, auto mechanic workshops, welding and metal work, vulcanizing workshops, car washing bays, garages, and other apprenticeship enterprises, and even people who cannot afford land in areas designated for development. The transect walk noted this phenomenon, and Official #4 observed that:

> Mechanical workshops are responsible for chemical contamination of water bodies in the metropolis, they are not allowed to be sited along water bodies – they discharge oil and other chemicals into the water bodies which are harmful to aquatic life. Carpenters most of the times are

> working along the streams and just at Anloga [community located along Sisa River at the eastern part of Kumasi] you see that at right hand side both left and right of the stream you find carpenters there and in fact it is a very big task to move them away from there.

Adding to this Officer #5 observed that, "you realized that the people who want to develop around the nature reserve are people who feel the land there is much cheaper than other areas and tend to go in for such places when they don't have enough money." This view illustrates that encroachment is also a factor of poverty.

Both the interviews and the transect walk suggest that the company has water supply challenges that need to be addressed. Given the current supply situation, the supply challenges discussed above, increasing population growth emphasized above, and other challenges that the company confronts, it will have difficulty in meeting the challenges of supplying the majority of the city's population with potable water.

Kaase – Poor Community

The Kaase community is located at the southern part of the city of Kumasi and is one of the suburbs within the Kumasi Metropolitan Assembly in the Ashanti Region. The area has a large concentration of "compound houses" (multi-family houses), has access to the public water supply system, and the Subin River drains the southeastern part of the community. As a result of affordable rent, proximity to the city center, and factory work, the community has attracted a large number of low-income people, especially people involved in informal economic activities. Houses here have an average of five families and an average of 22 household members sharing a common compound and sometimes a common kitchen and common bathroom. It is also a multi-ethnic community; people from all over Ghana can be found here.

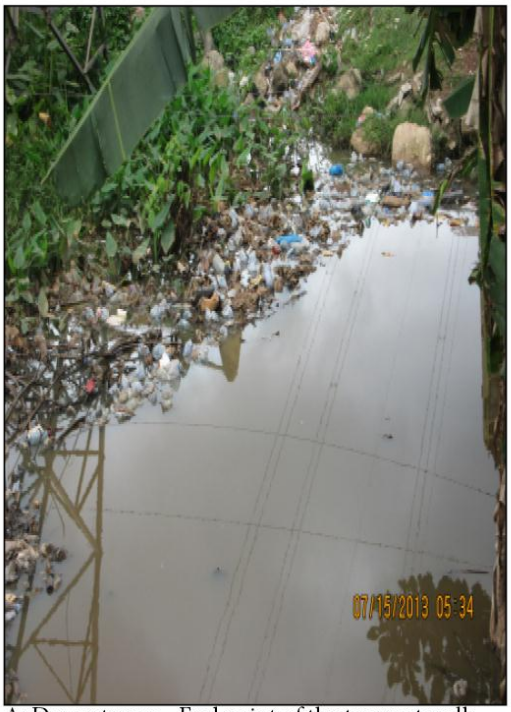
Perceptions and Knowledge of Land Uses and Impacts on Waterways

The most compelling themes that emerged from the interviews on the issue of land uses impacting waterways were rubbish disposal, open defecation, and animal rearing.

Rubbish disposal was identified as a contributory agent to water pollution. Indiscriminate disposal of rubbish into some gutters and street corners was evident in this community, and respondents noted this behavior is inappropriate because it contaminates sources of water. One respondent linked waste generation and health by stating that:

> So much waste is generated in the market which don't often gets cleaned up and some even throw their waste into gutters, when it starts raining the waste gets carried into the river. We don't clean our environment and this will have repercussions on the river, the river has been there for many years and if we don't take care of it and believe that the river is already contaminated and continuous to add to the contamination it will even breed mosquitoes which will make us sick (Kaase # 6).

Here, then, is a perspective that dumping of rubbish directly into the river harms its ecology. The community has been provided with a rubbish skip (land waste receptacle) by the Kumasi Metropolitan Assembly, located at the southeastern part of the community about 50 feet from the river, but from the interviews, some do not take their rubbish to the skip because they don't want to pay to dump and will dump it directly into the river. Kaase # 4 noted that "people don't care, they treat the river as gutter by throwing all sort of things into it". The banks and the channel of the Subin River (Figure 7) are full of solid waste.



A: Downstream - End point of the transect walk

B: Upstream

Figure 7: Subin River (Source: Fieldwork, July 2013)

Another land use that respondents identified as detrimental to water quality is open defecation. The community has three public toilets, but some people prefer open defecation along the railroad (about 50 feet from the river) and along the river banks. During an early community visit, the researcher walked along the railroad and the river banks and observed fecal materials all over. One respondent stated that "unfortunately, if you walk at the back of the houses near the railroad you will find out that people have defecated all over and when it rains the runoff washes all these mess into the river" (Kaase # 7). This finding is consistent with Devas et al. (2004) study of Kumasi, in which they noted that many of the streams used for water collection are also used for defecation. It should be noted, however, that members of this community do not generally collect water from the river; the use of surface water has declined significantly (UNICEF/WHO 2011). Some attributed open defecation to people's unwillingness to pay the fee charged

at the public toilet. It costs between GHc 0.20.00 and GHc 0.30.00 (US $0.10 and US $0.15), and some people cannot afford it. “There are toilets here, but some people don’t want to pay because they feel is expensive” (Kaase # 5) “and at times people defecate into the river” (Kaase # 4). The number one offenders in this case are the “Wee smokers” (Marijuana smokers), who find river banks the most convenient place to defecate. One respondent stated that “along the banks of the river is where “wee smokers” defecate, so that river (water) nobody fetches it for anything” (Kaase # 12). Using exploratory analysis of Department of Homeland Security (DHS) data from 2000 to 2012 to analyze trends in access to water supply and sanitation in 31 major sub-Saharan African cities, Hopewell and Graham (2014) concluded that nearly half of the cities did not make progress in reducing open defecation.

Livestock rearing was also identified as a land use that impacts the source of water. Sheep and goats were seen roaming all over in the community; animal pens were seen at the western part of the community. Animal droppings were scattered all over, especially at the western part of the community. Some of the sheep and goats were seen feeding at the banks of the river. The impact of these animals is not only on the river, but also on the hand dug wells in the community. Hand dug wells without protective walls (Figure 7) can become contaminated by animal droppings any time it rains. Kaase # 7, an unemployed 50 year old widow who lives with three other family members in a “compound house” made up of 41 household members, voiced her frustration with the incessant livestock disturbances and bemoaned the household’s lack of voice to influence what happens in its community. She stated that:

> The owners are near the railroad, they have many sheep and goats and some are even in the pens. We can't complain about those on free range destroying people's properties. They are everywhere in Kaase spreading droppings everywhere …… I just swept here this morning but now look around how droppings are all over here again. They bring so many negative impacts, even diseases. On one occasion we found a goat inside the hand dug well because someone forgot to cover it. When you drink such water you will surely get sick. This is our major problem regarding access to water in this part of the community and because we are poor without influence we cannot voice out our complaints but rather live with them.

In poor urban communities, the needs of the very poor are sometimes marginalized by the not-too-poor, and this often escapes policy makers because the poor lack the voice to influence policy decisions (Rakodi and Lloyd-Jones 2002). The sentiments expressed by this woman illustrate how the lack of voice can worsen the social and economic situation of the very poor in poor urban communities.

Expansion of existing buildings and development in the floodplain were also identified by respondents as some of the land uses going on in the community. However, their knowledge about how these land uses can impact sources of water is limited. Expansion of existing buildings was linked to rapid land consumption, which will deny future generations their share of land and affect access by emergency services. In response to the question "how development (expansion to existing buildings and new buildings) can impact sources of water", one respondent noted:

> You know, I am not sure how it will impact sources of water, but land use has grown over the years and even where we will live is increasingly becoming more and more difficult. If you take a closer look at the community even expansion to existing buildings are even bigger than the original buildings themselves. The land is being used in such a way that it will even be hard for our children to get a place to live" (Kaase # 11).

Kaase #7 also stated that, "currently people are adding more rooms to their buildings and people are building in places where they are not supposed to build. The problem is when

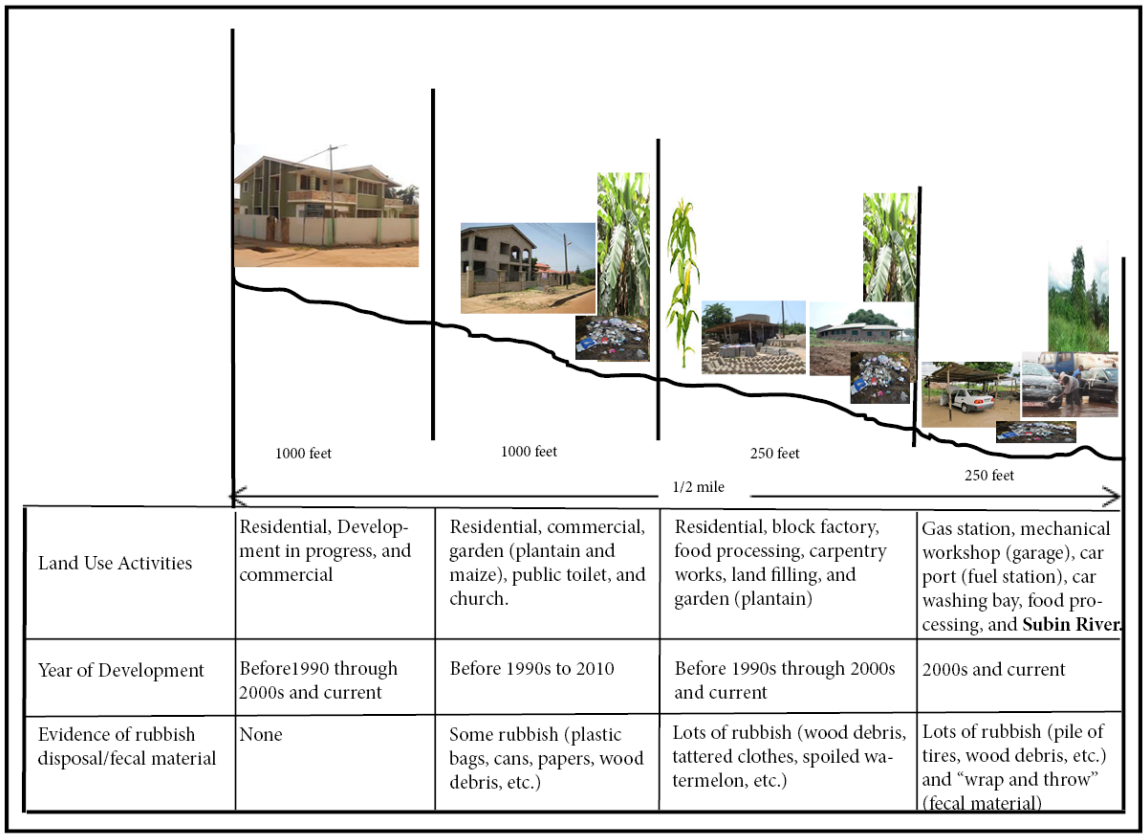
there is fire outbreak the fire service will not be able to get through because people have built on the roads and on the streets".

Community knowledge about how waste water contaminates the Subin River is also limited and has been influenced by many years of river pollution, which has rendered the river unsuitable for any household chores. Half of the community is within the floodplain area of the Subin River, and in some places the water table is so close to the surface that any small amount of rainfall leads to complete soil saturation and overland flow. Additionally, household waste waters have all been channeled directly into the river by gutters. Directing household waste both solid and liquid directly into the river is a common practice; a respondent stated that "we have directed waste water from our bathroom to the main gutter which leads to the river …… there is no impact on the river or the source of drinking water" (Kaase # 4). The idea shared by most of the residents is that the river is already contaminated and that household waste water will not make it any worse. Kaase # 6 said that "we have channeled used water into the gutter which leads into the river. What I know is waste water from many places goes into the river, I cannot fetch from the river because it is already contaminated by pollutants".

Land Uses near Subin River

As stated above under Methods, the goal of the transect walk on the river was to observe and document land uses and changes in these as one approaches the river, how observed land uses relate to the ideas and perceptions shared by the community, and how development in the area of the river has progressed over the years. It should be noted that development does not occur in any particular order. Some developments in the floodplain

are as early as 1980s and some are quite recent. The transect diagram (Figure 8) below shows patterns of land use as one approaches the river.



Land Use Activities	Residential, Development in progress, and commercial	Residential, commercial, garden (plantain and maize), public toilet, and church.	Residential, block factory, food processing, carpentry works, land filling, and garden (plantain)	Gas station, mechanical workshop (garage), car port (fuel station), car washing bay, food processing, and **Subin River**
Year of Development	Before1990 through 2000s and current	Before 1990s to 2010	Before 1990s through 2000s and current	2000s and current
Evidence of rubbish disposal/fecal material	None	Some rubbish (plastic bags, cans, papers, wood debris, etc.)	Lots of rubbish (wood debris, tattered clothes, spoiled watermelon, etc.)	Lots of rubbish (pile of tires, wood debris, etc.) and "wrap and throw" (fecal material)

Figure 8: Transect walk on Subin River (Source: Fieldwork, July 2013)

The transect walk showed a close relationship between observed land uses and community perceptions on impacts of land use on water bodies. Quantities of waste and litter seen along the transect route ranged from small amounts to loads of waste. The amount of waste increased near to the river and its banks contained the most rubbish. Some wastes identified were tattered clothes, household waste, plastic bags, spoiled watermelons, tires, "wrap and throw", and wood debris. Household effluent was evident in the main open gutter. The main gutter is used as a channel for household waste water into the river. The gutters in this community carry not only water but also solid waste.

This is reflected in the view expressed by Kaase # 8, she stated, "people sometimes wrap their rubbish and dump them at the road side and into the gutters and when it rains runoff carries these into the river." This observed land use corroborates the community view that land uses contaminate sources of water.

On the other hand, the transect walk identified some land uses which could impact the river but of which the community has limited knowledge. The wetland area and the buffer zone (riparian zone) are dominated by mechanical workshops (garages), a gas station, and a car washing bay. These activities discharge chemicals, oils, and debris directly into the river which are harmful to the stream's aquatic life, deteriorating water quality. A car washing bay sits directly adjacent to the river, taking water from the river and introducing dirt and detergents, which may contain phosphorous, directly into the river. In addition, land-filling was going on within the wetland area which was within 100 feet from the river. This activity introduces volumes of sediment into the river anytime there is a rainfall causing siltation in the river and reducing the river's ability to discharge effectively. The catchment area also contains a cement block factory and wood processing factory. Their activities lead to siltation in the river which is not healthy for its ecology.

Source of Water

The Kaase community is within the Ghana Water Company Limited water supply service area. The community is considered by GWCL as pro-poor community and has erected three standing pipes to supply the community with potable water. There is no individual household in this community that is directly connected to the GWCL supply

grid. The farthest distance from any part of the community to any standing pipe is an approximate ten minute walk. These standing pipes have caretakers who are responsible for selling the water (a bucket cost GHp 5.00 about US$ 0.025) and cleaning the surroundings, and when a caretaker is not available the tap is locked. So access to pipe borne water not only depends on water flowing through the taps, but also availability of the caretaker. Respondents noted, though, that when water is flowing through the taps, caretakers are usually available. One respondent noted, "we have standing pipe close by and it takes less than ten minutes to collect water, but sometimes you will go over and the caretaker will not be around" (Kaase # 2). Residents, however, did not emphasize the cost of water as a hindrance to accessing pipe borne water supply.

The community also depends on three hand-dug wells and one bore hole (Figure 9). These sources are managed by individual landlords or household members who offer the water free of charge. Kaase # 12 stated that "we pay for the pipe borne water but not the bore holes, the bore holes are kept clean and it is drinkable." Another respondent referring to the potability of the wells said, "that is what we drink because it has been approved by doctors as drinkable after they have inspected and tested the water" (Kaase # 1). However, she could not tell the specific date the bore holes were inspected and tested or whether all the four wells were inspected and tested.

Figure 9: Sources of water supply (Source: Fieldwork, July 2013)

Rain water is also used by some members of this community. Residents of Kaase use multiple sources of water supply and this is consistent with Howard et al. (2002) study on water usage patterns in low-income urban communities in Uganda. They found that the poor urban dwellers collect water from a variety of different sources for different uses.

Water Scarcity and Challenges

Ghana Water Company Limited (GWCL) is not able to supply water to the community all the time; therefore supply is erratic and unreliable. This is due to many factors including land use. As discussed above, land uses cause impacts on potable water production at the Owabi treatment plant. Official #2 stated, "land use affects the quantity

of water that is treated and the quality, so because of that we have to restrict production." Official #1 also added that "because of land uses Owabi dam and treatment plant expansions will be very difficult to implement." When the GWCL is not able to produce enough potable water as discussed above, poor communities like Kaase suffer because of their inability to pay for the service and communities like Odeneho Kwadaso that are able to pay are likely to be favored. Official #2 noted, "for high income communities they are able to afford the fees that they have to pay for the water and pipe lines to be laid for water to be connected to their premises, but for the low income people there is the challenge of payment of water connection fees, so accessibility to treated water is less in the poor communities than the high level income communities."

Because public water supply is erratic and unreliable, frequent closure is synonymous with public water supply in Kaase. Public taps can remain closed for more than a week, and when this happens water becomes very scarce in the community. A respondent indicated that "the public tap can remain closed for about five days or even a week and when this happens we buy sachet water[3] for drinking and if you cannot afford the sachet water then you have to rely on the contaminated bore hole for drinking" (Kaase #5). This statement shows that some residents are of the opinion that the bore holes are contaminated. However, closure of public taps puts pressure on the hand-dug wells and the bore hole in the community. Kaase #1 describes it by saying "when the taps get closed then water becomes scarce because all the people in this community come to collect water from the bore hole." Residents' reliance on wells conforms to an earlier study in Kumasi by McGregor et al. (2000), which found that because of unreliable and

[3] Sachet water is bagged water which is considered to be potable produced by drinking water companies.

insufficient water supply by the formal system, hand-dug wells are extensively used. This is mostly the case in poor urban communities.

The frequent closure of the public tap also introduces color dimension to the water. Respondents indicated that anytime the taps start flowing again the color of the water changes and in such circumstances they either don't collect water or collect it and allow time for dirt to settle at the bottom of a container. Officials agreed that sometimes the color changes, but this is due to repair works, system flushing, and dead ends in pipe lines rather than the quality of water they supply, because their standards also require that the color of the water should not be objectionable. Official #1 explained the color changes because "we have flushing points and occasionally we flush the lines and the dead ends contribute to some of the occasional water color change." Official #2 attributed the occasional change in color to aged pipe lines and repair works. He stated that:

> Pipe lines were laid as early as 1928 in the Kumasi Metropolis, as a result they have aged and are weak, so periodically we experience pipe line bust, …if the pipe bust is not immediately reported to us what happens is that a lot of dirt rather get into the pipe lines. When the dirt gets into the pipe lines after we have repaired the pipe those dirt are still inside the pipe lines, so when we reopen the pipe lines for water to flow the first quantity of water that will flow for the first one or two minutes will carry the dirt.

Whatever the causes of occasional change in the color of the water, the fact is, the community gets stressed and their access to potable water is reduced. One respondent stated that "when the public tap gets reopened there is no way that one can use the water for the first couple of minutes because the water turns red in color and sometimes takes a long time to clear. When this happens, you cannot drink such water or use it to cook; you just have to set the water down for dirt to settle down, and use it for bathing" (Kaase #1).

The frequent closure of the public tap is the source of water scarcity at the community level. Pressure mounts on the few hand dug wells and bore hole in the community any time that GWCL cuts water supply to the community. The longer the public taps remain closed the more pressure builds on the few wells and the more water becomes scarce. When pressure mounts on the wells, the demand for water exceeds the rate of supply of the wells and this stresses the water, resulting in water becoming full of sediments. Kaase #6 explains how access to water becomes difficult when the public taps get closed. She explains that:

> When the public tap gets closed for two days and you don't get to the bore hole at dawn you will not get water because people continue to collect water as late as 3am. When demand for water becomes great and the water level in the bore hole goes down the water becomes full of sand particles. When we see the sand particles we cover the bore hole and allow it ten (10) to twenty (20) minute to accumulate more water. In times like this we waste so much time at the bore hole, but because we need the water we just have to wait.

When pressure mounts on the few wells, long queues form and the time residents spend waiting before collecting water can exceed one hour, which deprives them of useful economic time. A study in East Africa analyzing changes in urban water also concluded that protected wells (hand-dug wells and bore holes) are an alternative source of water supply in terms of quality, accessibility, and reliability; however, they are used by a large number of households, which means users frequently encounter lengthy waiting time at the point of collection (Thompson et al. 2000).

In Kumasi 8.2% of households spend 30 minutes or more collecting water (Hopewell and Graham 2014). This figure varies from community to community and depends on availability of a variety sources (Howard et al 2002) of water supply;

however, the figure could be far higher during periods of water supply disruptions. According to Kaase #5 “when the public tap is closed we queue to collect water from the bore hole” and Kaase #11 stated that “if you want clean water you can spend as much as one hour.” Residents waste time not only on collecting water from the wells, but also when they have to rest the well water to allow sediments to settle before using it. This keeps residents in suspense and delays their activities. Kaase #2, in describing challenges of well water supply, stated that “as a result the water you collect contains small particles of sand and other particles. These make the water unhealthy for drinking and cooking, you have to set the water down for the particles to settle down before pouring the top part for washing.”

Queuing at the wells sometimes produces conflict. The need for water and the desire of some individuals to jump the queue leads to quarrels, and in such cases school pupils suffer a great deal. Kaase #7 stated that “sometimes great quarrel takes place on the bore hole as people struggle to get water and I usually pity school pupils. Sometimes school pupils even don’t shower before going to school, because they could not get water from the bore hole.” Quarrels usually occur in the morning when there is greater demand placed on the wells. Some try to avoid confrontations in the morning associated with collecting water from wells when the public taps are closed. Kaase #3 made this clear by stating that “I don’t want to quarrel with anyone over collecting water so I don’t collect water in the morning.”

As a result of queuing, water collection can extend deep into the night, depriving people of valuable sleeping time. Kaase #12 describes her experience by saying “when the public tap is closed water becomes scarce and because all the community go down to

the wells, I sometimes get up as early as 2am to collect water and even at 2am there will be queue on the bore hole and I will be lucky if I manage to get three buckets of water." Kaase #8 added: "Sometimes when the public tap is closed you can queue from morning to afternoon and not get water." The interviews showed that access to water can be very stressful and time consuming as residents have to forego all other things and queue for over an hour, and sometimes even forego sleeping in order to collect water. In the face of this, residents adopt strategies to cope with water supply challenges.

Coping Mechanisms

Due to the erratic and unreliable nature of public water supply and pressure that mounts on the few wells in the community, residents have adopted strategies to cope with water supply challenges. Adoption of a particular strategy depends on individuals' water requirements, uses for the water, economic activity, and distance to the source. It should be noted that residents combine different strategies in order to cope with water supply challenges and some have been able to build coping strategies around their socioeconomic life. Storing water is the most common strategy among residents. Everybody in this community stores water and in response to the question "why do you store water" one respondent stated that "the pipe borne water is unreliable, I store so that when the public tap is closed I will not be in need of water" (Kaase #5) and Kaase #9 also stated that "I store so that when I become thirsty at night I will have some to drink." Residents store water in anticipation of hardship and for particular needs; this also determines how much an individual is prepared to store. This finding supports that of an earlier study in East Africa, which showed that in East Africa residents collect water from various sources and store it at home to ensure an adequate supply because piped systems

are so unreliable (Thompson et al. 2000). Respondents indicated that they use all sorts of containers to store water, ranging from small to large; these include buckets, bowls, and barrels (Figure 10). Respondent Kaase #2 indicated that:

> I have bought a big container to store water during dry season when public water supply becomes highly unreliable because of frequent closure. I normally go out to sell goods (wares) and come back in the afternoon when I know that there are virtually nobody at the bore hole and the water is clean. This is the time I collect water and store in my big container which I cover and lock.

A: Water storage container (250 liters)

B: Drinking water storage container

Figure 10: Water storage containers (Source: Fieldwork, July 2013)

Timing, as indicated by Kaase #2, is also another strategy adopted by residents. The time one collects water during periods of water scarcity determines the quality of water. When pressure builds on the wells in the morning the water level goes down and might contain more sediment. Kaase #1 also confirmed this by stating that:

> I make sure I have clean water to store, to get clean water depends on the time you go over to collect water. In the morning the water is stressed and in the afternoon the water is settled and there is no pressure on the bore hole and the water is drinkable.

This strategy works for those who do not have permanent employment that requires them to work during the daytime, or who do not have to travel outside the community for the whole day for economic activities. Kaase #4, a 25-year-old apprentice who is learning how to fix heavy duty machines like tractors, goes to work six (6) days a week. He stated that "though I don't use so much water, but sometimes it becomes hard for me to get clean water. If I need clean water I have to depend on sachet water"."

Rainwater harvesting, another source of water supply for this community, is another strategy residents use to overcome water supply challenges. Residents normally only harvest rainwater for washing when the public water supply is cut because they believe that rain water is not hygienic. One respondent stated that "because of the roof I think rain water is not hygienic; cats and birds are always on the roof" (Kaase #9). Rainwater is used solely in this community for washing. Kaase #8 made it clear that rainwater is only for washing. She noted that "yes we harvest rainwater and use it for washing dishes and washing of clothes. We don't add it to water we store because cats defecate on the roof and makes rainwater unhygienic for drinking or cooking." UNICEF/WHO (2008) considers rainwater as an improved drinking water source;[4] however, the medium within which the water is harvested can make it non-potable. There is another dimension to rainwater that makes rainwater the preferred choice for washing.

[4] An improved drinking-water source is defined by UNICEF/WHO as one that, by nature of its construction or through active intervention, is protected from outside contamination, in particular from contamination with fecal matter (UNICEF/WHO 2008).

It lathers easily with soap and reduces the amount of soap needed to wash. Kaase #5, therefore, states why rainwater is her preferred choice for washing: "Whenever it rains I collect some for washing because it lathers easily with soap that is the reason why I love rainwater. It helps me to save money on soap and pipe borne water, with rainwater I can use small amount of soap to wash."

Another strategy identified was the uses for different sources of water. As a result of the erratic and unreliable nature of public water supply, residents distinguish between drinking water and water for other uses. The pipe borne water is considered potable but scarce, and for this reason, the majority of the residents do not mix it with other sources of water. As discussed above, pipe borne water is often stored and kept clean for drinking and other consumption and the majority of the people will only drink water from the wells when there is no pipe borne water and when they cannot afford buying sachet water. One respondent described her strategy for storing pipe borne water. She states that "I have two containers one for pipe borne water which I drink from and the other for bore hole water which I use for washing, bathing, and cleaning. However, when public tap is closed we even drink the bore hole because it is kept clean" (Kaase #7). Others have made it a habit to collect water every day to top up their stored water as long as there is water flowing through the taps. Kaase #12 does not let her stored water run dry before collecting water. She stated that "I always make sure I have water and I normally fetch in the evening when there are fewer people at the public tap".

Postponement of activity was also another strategy used by residents to overcome water supply challenges. Activities that are likely to be rescheduled when there is scarcity of water are washing and bathing. An individual is likely to postpone activity when

he/she did not anticipate a shortage of stored water and when pressure on wells makes it highly unlikely to obtain water. Kaase #3 explained that "one day when the public taps were closed and more people were on the bore hole I couldn't get water to wash and postponed washing." Kaase #5 also added that "my clothes got piled up for too long because there was no water. I go down to the bore hole and can't get water and the public taps were closed as well. Water became so scarce that we were buying sachet water for drinking." If there is water flowing through the taps rescheduling of an activity will probably not be due to water scarcity.

Odeneho Kwadaso – Affluent Community

The Odeneho Kwadaso community in this study includes the old Trade Union Corporation neighborhood, popularly known as TUC and is located southwest of the city of Kumasi (Figure 1), and is one of the suburbs within the Kumasi Metropolitan Assembly in the Ashanti Region. The community is about 1.55 miles from the center of the city and from the edge of the Kumasi-Bekwei Road it stretches to about 0.93 miles. The community is a planned community, but with an individual building (household) septic system that is normally pumped clean into trucks when it becomes full. The community has a large concentration of single family houses with a mixture of middle income and high income residents[5]. The average household size is nine; this is relatively low compared with Kaase with an average household size of 22. Almost all houses in this community are connected to the GWCL public water distribution system, and a large part of this community is served by Kumasi Metropolitan Assembly household solid waste

[5] It is assumed in Ghana that the majority of people living in areas classified as affluent community (High Class areas) are either middle income or high income residents.

collection service. The Daban River drains the northeastern part of the community. Because of this community's proximity to the city center and the availability of alternative routes into the city center, the community has attracted more formal and public sector workers than the Kaase community.

Perceptions and Knowledge of Land Uses and Impacts on Waterways

In this community, local knowledge and perceptions about land uses that can impact source of water are far richer than Kaase, the poor community. Themes that emerged from the interviews are rubbish disposal, open defecation, animal rearing, removal of vegetation cover, siltation, and floodplain development. Like Kaase community, residents here also agree that rubbish disposal, open defecation, and animal rearing can contaminate sources of water. Residents, however, added that farming and removal of vegetation cover, siltation, and building in the floodplain can have repercussions on both river and development, though opinions on how development impacts sources of water vary.

As noted above the removal of riparian vegetation for farming activities and development makes the land susceptible to erosion by runoff, which carries sediments and chemicals from farming and development activities to pollute the receiving water body (Randolph 2012). Residents believe that removal of vegetation cover and farming at the banks of Daban River (Figure 9) is having an impact on the river. One respondent noted that "I have seen vegetation cover removed with chemicals and maize planted along the river, when it rains this field gets washed by runoff into the river and this activity destroys the river" (Kwadaso #1). This comment is in reference to the urban

gardens that are commonly planted along river banks in Ghana, which are seen as an open space for such activity. Siltation was also identified that it impact the waterway by narrowing the river channel. Kwadaso #9 stated that "if surface is sealed there will be less siltation in the river, but as we have now runoff carry both solid waste and sand into the river, which then reduces the channel width." Another respondent linked siltation to land filling within the floodplain. She stated that "land filling in the areas closer to the river for building purposes will have an impact on the river because there will be gradual build-up of sediments in the river bed (shown in figure 11)" (Kwadaso #6).

Figure 11: Daban River (Source: Fieldwork, July 2013)

As stated above, development impacts streams in various ways, especially when household effluent is channeled to enter streams. These can have impacts on both the quality and quantity of water in the streams' channels. Respondents demonstrated that

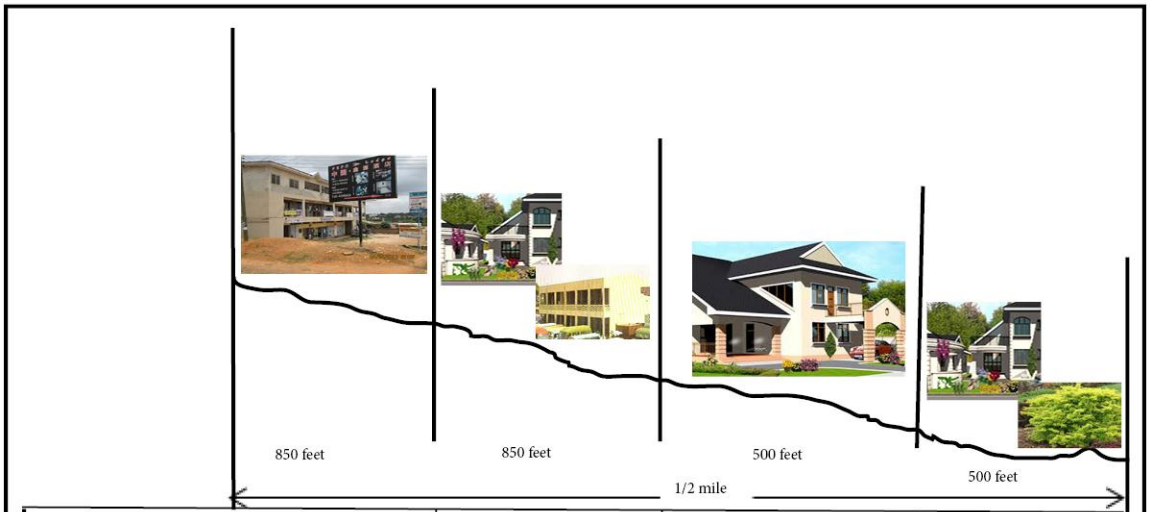
development can impact the streams, but their opinions vary as to how far from a river bank development will impact a river. Kwadso #3 noted that "people are building close to the river and when people build and it becomes close to the river it means that the river will not have a free passage. So during rainy season any small amount of rain means the river will overflow its banks and come close to the buildings or even enter buildings and therefore the river causes threat." He links building in the floodplain to dangers to human life and property. Kwadaso #2 believes people have built in the waterway and therefore prevent the stream from having a smooth and natural flow. She stated that "the river course has been blocked and some of its waters find their way into our houses. As you can see from the bottom of the fence wall, it has become black because water from the ground has penetrated it. When it rains we see more water coming from the ground".

The differences in opinions stated above are expressed by Kwadaso #1 and Kwadaso #4. Kwadaso #1, a 52 year old married woman lives with her husband and four children in a walled single family house. She completed Middle School and sells fish in Kumasi Central Market and her husband is a driver. She and her husband moved to Odeneho Kwadaso in the 1990s and their house is situated at about 147 feet from the Daban River. Any time it rains she finds overland flow within their walled compound and she is very frustrated. She stated that "well the river is far and it's quite surprising that all of us here are facing this problem. To me those closer to the river are those near the Church of Pentecost building (about 82 feet), but those of us here and those at the top are all facing this problem." Kwadaso #4 does not see anything wrong building in the catchment area (in the riparian); she stated that "building close to the river has nothing to do with the river." These views expressed here demonstrate that knowledge about how

development can impact sources of water is more limited than other types of impacts, which may explain why catchment areas (riparian) are seeing more and more development.

Land Uses near Daban River

The transect walk on Daban River documented land uses at varying distances from the river. The land uses that were observed seem to demonstrate that the community is more concerned about its environment than Kaase community. The transect diagram (Figure 12) below shows land uses on the river.



Land Use Activities	Residential and and commercial	Residential, food processing, and commercial.	Residential	Residential, shrubs/ flower garden, and **Daban River**
Year of Development	Before1990 through 2000s	Before 1990s to 2000s	Before 1990s through 2000s	2000s
Evidence of rubbish disposal/fecal material	Some rubbish (few scattered plastic bags)	None	None	None

Figure 12: Transect walk on Daban River (Source: Fieldwork, July 2013)

The community is primarily a low density residential area in the sense that not more than two structures occupy a1000 sq. ft. area. Since Tipple and Hellen's (1984)

study that classified affluent community as areas having 1-3 houses/2.4 acres, density has gone up in the affluent community. During the transect walk it was observed that where there is a second structure it normally forms part of a fence wall and owners use it for commercial purposes. The transect walk identified residential and commercial activities as land uses occurring in the community. These commercial activities observed along the transect are different from what was observed in Kaase; here commercial activities do not generate significant liquid and solid waste to be carried by runoff into the river. These commercial activities are a clothing shop, pharmaceutical shop, a hair dressing saloon, a beer bar and, at the edge of the river, a flower garden.

The gutters along the transect were clean without liquid waste and solid waste; in Kaase (as noted above) gutters were full of both liquid and solid wastes that easily get carried into the river. Though residential buildings extend to the edge of the river, this community was cleaner, including the banks of the river. Is this as a result of the house-to-house waste collection service the community receives? Whatever the reason, one can therefore, say that this community is more conscious about the environment.

Some differences and similarities can be drawn from the land uses observed during the transect walks. In Odeneho Kwadaso, there was no solid waste along the transect, no solid waste dumped at the banks of the river or in the waterway, and the river did not contain any floating materials. No household effluent flowing through the gutters was observed. This could be due to the fact that households here have their own individual septic systems. Along the transect walks in Kaase and at the upstream of Owabi River, land uses observed were quite similar and these observed land uses can have negative effects on both the waterways and water quality. Land uses observed along

these two transect walks were: dumping of solid waste, evidence of fecal matter and "wrap and throw", land filling, gutters as channels for household effluent, and enterprises (welding and metal works, carpentry, car washing and other) - these activities fill the catchment area with both solid and liquid wastes which get carried by runoff into the rivers. It was observed that the banks of Subin River and Owabi River are full of solid waste and the rivers were full of floating materials.

Source of Water

As noted above, the Odeneho Kwadaso community is supplied with water by Ghana Water Company Limited (GWCL) and almost all households in this community are connected to the GWCL water distribution system. The high number of households with piped water affirms the UNICEF/WHO (2011) findings that there has been an increase in the proportion of the population in developing regions using piped water on premises. However, this is mostly concentrated in the affluent communities; as noted above there is no household with piped water in Kaase. Some houses without a water connection are unapproved houses, some located close to the river. These houses without a water connection get water either from a neighbor's house or from the only public stand pipe in this community. Pipe borne water is the main source of water supply and one respondent confirmed it by stating that "oh I have piped water in the house" (Kwadaso #4). However, piped water comes with a financial cost that houses in poor communities cannot afford. Residents noted that they pay between GHc 25.00 (US$12.50) and GHc 40.00 (US$20) per month for water service (depending on amount used – each house is metered). Kwadaso #1, referring to financial cost associated with piped water, stated that "the cost ranges between GHc 25.00 and GHc 30.00, in this area water is expensive."

Because of the relatively reliable nature of pipe borne water supply in this community, the community has only two wells that some residents collect water from when water supply is cut and residents run out of stored water. These wells are managed and operated by individual landlords, and access to these wells is dependent upon the availability of the owners, since the wells are within a walled house. Kwadaso #2 made it clear how access to well water can be very difficult. She stated that "there is a well behind our building where we get water from when the tap is closed. The well is within a walled area, so when you are given the chance to collect water you have to make sure you have filled all your empty containers." When water is flowing through the taps well water is rarely used in this community.

Water Scarcity and Challenges

As a result of water supply constraints discussed above and the demand that exists for various uses, the Ghana Water Company Limited cannot supply water to the community 24 hours a day. However, because of the ability and willingness to pay, water supply is far more reliable in this community than Kaase community. This was confirmed by official #2 that "for high income communities, they are able to afford the fees that they have to pay for the water and pipe lines to be laid for water to be connected to their premises. But for the low income people there is the challenge of payment of water connection fees, so accessibility to treated water is less in the poor communities than the high level income communities." In their analysis of trends in access to water supply and sanitation in 31 major sub-Saharan Africa cities, Hopewell and Graham (2014) found that Kumasi has made significant progress in improving access to water supply. However, it should be mentioned that this improvement is not uniform across the board, it is mostly

visible in affluent communities like Odeneho Kwadaso, and even in affluent communities residents do experience water supply disruptions.

Pipe borne water supply do not get cut for too long in this community because GWCL is readily available to fix problems relating to access to water in affluent communities. Respondents confirmed that piped water does not get closed very often. Kwadaso #3 noted that "of course they don't close it for a long time so I cannot simply say may be a day or two, we may not even finish our stored water before the taps start flowing again and so that is it." However, sometimes the taps get closed for two to three days, especially when there is repair work going on. This supports the findings of Jaglin (2002) that in sub-Saharan Africa official services like public water supply are not in a position to meet urban demands in full. Also, Thompson et al. (2000) observed that in East Africa, affluent communities also do experience a decrease in water use levels. This creates greater hardship for those without overhead tanks for storing water. Because wells in the community are not solely for commercial purposes and are within a walled area, when taps get closed for too long some residents travel outside the community for water. Kwadaso #7 made this known by saying that "when there is road construction public taps get closed very often and water becomes scarce. In such circumstances we need to go somewhere else for water." The problem gets compounded because of the high level of use of water in the community. Residents use water for almost everything from cooking to flushing toilets. One respondent stated that "here the taps don't get closed for too long, but sometimes it takes two or three days. When it takes two or three days it creates problems for us; because we will flush the toilet and do many other things that use water (Kwadaso #9)."

Water does not flow through the taps all the time and as a result any time the taps start flowing again the color of the water changes. This poses challenges to residents' access to potable water since they normally don't use the water when the color changes; some allow the water to flow through the taps until the color is normalized, though because of the cost associated with doing this, some collect water in containers and allow time to clear. Kwadaso #2 noted that "currently we see dirt in the piped water. If you fetch the water and set it down for a few minutes you notice that dirt has settled under [in] the bucket. Moreover, when the piped water starts flowing again after it was closed the color becomes brownish. When it becomes brownish, I set it down for the dirt to settle down, and then pour the top clean water." Others will not collect the water at all but will allow other houses to collect till the color becomes clear. Kwadaso #4 believes that color change is also associated with taste. She stated that "sometimes the taste and the color changes especially when the system gets flushed. The color can become brownish; I don't collect such water, but will allow other households to collect until the color is normalized."

Coping Mechanisms

The nature of water supply determines whether an individual will adopt a coping mechanism. In this community, preferences and financial status determine what type of coping mechanisms an individual household will adopt. However, because of the relatively reliable nature of water supply in the community, some residents do not have strategy to cope with periods of water scarcity. For those who do cope, storing water is the most common strategy. Some residents have also erected structures for an overhead tank for storing water (Figure 13). One person, in responding to how they get water when

the taps are closed, stated that “oh we have reserve, we always reserve one that is why we have an overhead tank there” (Kwadaso #3). Others use medium to large containers that can hold between 100 and 250 liters of water for storing water. Kwadaso #4 noted that “I have overhead tank as well as barrels that I use to store water; moreover, they don’t close the taps for too long. The longest the tap can remain closed is two days and even that I usually have stored water. I have three big barrels each can contain 250 liters of water and two medium size barrels each can also contain about 150 liters of water.”

The reliable nature of water in this community also determines how much of water to store and for what purpose. Kwadaso #8 noted that “I don’t have a big container for storing water; I only have a medium size container that can hold about 100 liters of water.” Kwadaso #2 also stated that “I have a container that I store water for drinking and usually fill the container with fresh water every three days, but I don’t store water for other uses because the taps do not get closed very often. Unless there is a problem somewhere, our piped water always flows, so I collect water as and when needed except for drinking that I store.”

A: Metalic stand B: Concrete stand

Figure 13: Water storage facility - Overhead tank (Source: Fieldwork, July 2013)

Another strategy identified as a coping mechanism during water scarcity is postponement of an activity. It should be noted here that because of the relatively reliable nature of water supply in the affluent community, activities are more like to be postponed when water supply is disrupted than in Kaase, the poor community. Activities that are likely to be postponed are washing and bathing. Because water supply is relatively reliable in this community, some residents don't have any strategy in place to cope with a sudden shortage and are more likely to postpone activity any time the taps get closed for one or two days. Kwadaso #2 said that "one day I wanted to wash and the tap was closed so I postponed the washing" and Kwadaso #1 noted that "when the tap is closed I sometimes postponed bathing till I get water." During periods of water scarcity resulting from water supply shortages, residents are also likely to rely on sachet water for both drinking and cooking. This is illustrated in the opinion expressed by Kwadaso # 6, a 28

year old mother of two, who lives with 17 other family members; she stated that "when stored water gets finished and the tap is still closed, I have no other option than to buy sachet water for cooking and drinking." From the discussions above, Odeneho Kwadaso has a high demand for water for daily activities and only two wells as alternate sources of water when water supply is disrupted. So, with prolonged disruptions, water becomes more scarce in Odeneho Kwadaso than Kaase community where residents have five wells to depend on and are more adapted to water supply challenges.

CHAPTER SIX: SYNTHESIS OF FINDINGS, RECOMMENDATIONS, AND CONCLUSION

Introduction

This chapter synthesizes the findings of the study. Through the process of synthesizing the findings on land use, water supply, and access to water supply, policy recommendations are offered as to how land uses could be managed and regulated to ensure protection of sources of water that could lead to improvements in water supply. Finally, this chapter closes by addressing areas that need additional research and then draws the overall conclusions of the study.

Synthesis of Major Findings

The overarching questions this study sought to address are: how are sources of drinking water impacted by urban land uses in a developing world city, and what does this mean for water treatment, water supply, and access to safe water supply at the community level, especially in poor urban communities? Some of the findings are:

- the cost of water treatment is increasing and an important water treatment plant is working below capacity,
- there has been a significant reduction in the storage capacity of an important water supply impoundment,
- an important surface water source of public water supply is being impacted by land uses resulting in poor raw water quality,
- there are inadequate levels of water supply and service, and

- there are increased potable water accessibility problems at the community level, especially in the poor community.

The findings of the study are addressed in turn below.

The study found that land use is contributing to high cost of treatment of public water supply. In fact, it is costing GWCL about 36 percent more to treat a given quantity of water at the Owabi treatment plant location in an urban setting compared to the cost of treatment for the same amount of water at its treatment plant at Barekese Dam, which is in a rural setting. Household effluents are channeled into the Owabi River, solid wastes are dumped in or on the banks of the river, and open defecation and "wrap and throw" take place at the banks of the river. These wastes are carried by runoff into the river and end up in the Owabi impoundment and therefore increase the amount of chemicals needed to treat raw water to render it potable. On the issue of household effluent polluting sources of water, Kurian and McCarney (2010) argue that domestic wastewater constitutes the largest proportion of total wastewater generated and poses a serious threat to water supply sources, such as surface water and groundwater. The officials at the GWCL are concerned about the presence of heavy metals in the Owabi River and have yet to identify the source. Suame Magazine, a heavy industrial area, is located within the watershed of the Owabi River, solid waste and liquid waste disposal in this location are not regulated and could be the source of the heavy metals in the Owabi River.

The interviews at the household level found that communities believe that household solid wastes and effluent and fecal material can contaminate sources of water supply. However, such knowledge is not translated into practice except in the affluent

community, which is clearly influenced by economic capacity. In Kaase community, in the quest to improve economic status and given the notion of "free land", enterprises have been set-up along the river, causing more damage to the river. As observed by Mengistu et al. (2012), economic incentives have always been a driving force, often encouraging environmental degradation and discouraging conservation. In this community, though, residents acknowledged that solid waste can pollute waterways. However, a large amount of solid waste was seen along the transect walk, especially at the banks of the river. It was observed that people's attitude toward a particular source of water is influenced by the uses of that particular source. When residents do not collect water from a particular source, they have little or no concern at all about the health of that particular source. In Kaase community residents feel that the Subin River is already contaminated and therefore any additional waste will not make it any worse. This, therefore, suggests why streams in the city are always full of solid waste.

Moreover, it was established that the impoundment created by Owabi Dam is suffering from continuous siltation from sediments introduced by land uses in the catchment area of the river, which has led to a reduction in its storage capacity. Farming activities and building development have encroached on the portion of the river's catchment area that is most proximate to the river leading to the removal of riparian vegetation that serves to filter sediment from overflow. The study found that encroachment appears to be a result of poverty and associated land tenure problems, the lack of knowledge about development impacts, and the idea of "free land." The interviews revealed that people tend to use such lands when they don't have enough money to purchase or lease others because they believe the lands along rivers are "cheap

land." In Ghana, lands belong to the traditional authorities and chiefs are the main custodians. The research found that chiefs normally give out lands in nature reserved areas without regards to environmental issues, because they feel they are the owners of the land. Again, it was found in Kaase community that there is limited knowledge about how development impacts sources of water. Many have erected structures close to the river, because they do not know how their structures exert impacts on the river. Others are confused about the distance that should exist between a development and the river to avoid negative impact. Another interesting finding was that river banks are likely to be encroached upon by enterprises and other businesses such as carpentry workshops, welding and metal works, vulcanizing workshops, garages, car washing bays, and others, because they regard those areas as either "free land" or "cheap land" (as observed by Official #5). This pattern could be attributed to the high cost of urban lands that are out of the financial capabilities of these enterprises.

Land uses (e.g., farming, discharge of household effluent, waste disposal, open defecation, "wrap and throw", and land filling), water distribution challenges, and inadequate power supply have culminated in restricted potable water treatment and supply at the Owabi treatment plant. With an installed capacity of 3 million gallons a day, the study found that the Owabi treatment plant can support about twelve (12) percent of current demand, but because of land use and other challenges the plant can only support less than seven (7) percent of current demand. The study further found that because of land use, expansion of Owabi water works will be very difficult and there is the need for dredging of the dam to get rid of sediment build-up at the bottom of the dam. When potable water supply is restricted, the effect is felt at the household level and most

especially the poor urban community household feels the full force of the restricted supply.

Urban water supply in Ghana is erratic, unreliable, and in some communities a public water supply system does not exist (Devas and Korboe 2000; Ghana National Water Policy 2007; Akple et al. 2012). This is not new; however, increasing evidence of land uses impacting sources of public water supply adds to the problems of urban water supply. Both communities studied are on the GWCL water supply system. The researcher observed that because of the erratic and unreliable nature of supply in Kaase community, residents depend on a variety of sources (as observed by Howard et al. 2002) for water supply and sometimes differentiating between uses of different sources for different purposes. In this community, the other sources of water supply apart from the public tap are four hand-dug wells and one bore hole and residents collect water for free, but pay a fee for collecting water from the stand pipe. When there is no water in the household, residents normally collect water from the closest source (either a stand pipe or well). Devas and Korboe's (2000) study in Kumasi found that in compound houses with piped water the system of pricing makes water expensive for the lower income people living in them. This study found, however, that because access to pipe borne water is from a public stand pipe the cost of a bucket of water (GHp 5 = USD 0.025) is not too expensive to burden the poor. In Odeneho Kwadaso, because of the relatively reliable nature of public water supply, residents are less likely to depend on other sources of water. The interviews established that water supply to Kaase experiences more frequent cuts than the supply to Odeneho Kwadaso, and that because stand pipes in Kaase are managed by caretakers, access to potable water does not depend only on water flowing through the taps but also

the availability of the caretaker. These findings support the findings of others who have found that while urban centers in Sub-Saharan Africa are working to ensure adequate water supply coverage, there are communities within these urban centers that are hardest hit by water supply challenges (Champetier et al. 2000; Hall et al. 2004).

During water supply disruptions, those Kaase residents that normally depend on the service also turn to the other sources of water supply. The study found that anytime public water stops flowing, pressure increases on the few wells in the community. Long queues are formed at the wells and residents spend several hours waiting for water; quarrels sometimes occur during such events and school pupils suffer the most. When pressure for water mounts on the wells, they can hardly support demand and therefore the water becomes full of sediments coming from the bottom of the wells causing consumers to further delay consumption so that these can settle out. In Odeneho Kwadaso, the researcher found that during disruptions in public water flows some residents turn to the two wells in the community and some turn to buying sachet water. In times of acute water shortage, residents of this more affluent community are more likely to travel outside their community for water supply, because wells in the community are not solely commercial and they are often within fenced walls. In both communities it was established that when water starts flowing again after supply was cut, the color of the water turns to brownish, and sometimes takes over an hour to clear. Officials at the GWCL attribute the color change to repair works on the lines, dead ends, and occasional flushing. The researcher found that the communities can hardly use the colored water and this reduces their access to potable water. What was clear throughout the household interviews is that when public water supply stops flowing for one to two days, the

communities suffer water scarcity. Therefore urban water scarcity is a product of GWCL inability to supply communities with adequate amount of water supply. Residents have therefore adopted strategies to cope with water supply challenges.

The study found that residents in both communities adopt coping mechanisms to manage water supply challenges. The coping mechanisms identified include storage, collection, and adaption strategies (also identified by Zerah 2000). Storage and collection were the most common strategies adopted by residents in Kaase community. Residents combine these strategies to cope with water supply challenges and the adoption of a particular strategy depends on individuals' water requirements, uses of the water, economic activity, and distance to the sources of water supply. In Odeneho Kwadaso residents combine storage and adaption strategies to cope with water supply challenges. Some residents use the expensive strategy of storing water in an overhead tank, and others use barrels to store water. However, as a result of the relatively more reliable nature of public water supply in this community, residents are more likely to use an adaptive strategy such as postponement of an activity (bathing and washing) in coping with water supply challenges. In both communities, it was found that in times of highly unreliable water supply, residents are forced to collect water at night because the public water tends to flow at night. The reason why public water tends to flow at night in periods of unreliable water supply is hard to tell, but some are of the opinion that it is a strategy that the company uses to cut down on demand. Devas et al. (2004) also found that in Colombo, Sri Lanka in the face of unreliable water supply the people are obliged to collect water at night for use during the day.

Policy Recommendations

Land use and zoning regulations are critical components of urban planning, not just in terms of ensuring harmonious land uses but also ensuring that land uses have minimal impacts on water resources. Though this is only one aspect of water resource management, it is very important for maintaining healthy water resources. Based on the findings of this study the recommendations offered here could help reduce impacts of land use on water bodies and can lead to improvements in water supply, especially to the disadvantaged or poor communities. First, updating the existing policies and associated zoning regulations and the development and adoption of a comprehensive land use zoning ordinance in the city would provide authority for land use planners and a framework with which to operate. The development of such an ordinance should involve the participation of all stakeholders such as Town and Country Planning, Waste Management Department, Public Health Department, Traditional Authorities, Environmental Protection Agency, Ghana Water Resource Commission, and other community-based interest groups. When all these stakeholders are involved in developing a comprehensive ordinance to manage land uses, there should be a reduction in the overlapping of responsibilities and conflicts of interest.

It is further recommended that there should be the development of a policy for the protection of streams and rivers by all interested parties such as mentioned above. This policy should require the delineation of all watersheds that intersect the city, necessary conservation areas, and other areas of riparian vegetation, floodways, and wetlands. Even though it was not reported in the results, it is apparent that there is a lack of coordination among departments and agencies involved in water resources management, such that one

department involved in land-use planning does not know what rules and procedures other agencies managing rivers/streams protection are using. Delineations and inventories will help responsible agencies to better protect Kumasi's watersheds, waterways, and water resources. These documents should be made available in both hard and soft format (i.e., posted on departments and agencies webpage) and should be accessible to all interested parties, including residents. In some instances during the fieldwork, the researcher found that some departments do not have immediate access to their own working documents. By making documents available and accessible, referencing will be easier and efficiency improved. Above all there should be strong collaboration amongst departments and between departments and agencies involved in land uses and stream protection or water resource management.

As concerns the development of a comprehensive land use zoning ordinance, the inclusion of an overlay zoning element to control existing development along the banks of Kumasi's rivers would be beneficial to their rehabilitation. Especially along the Owabi River, structures that are adversely impacting the river should be removed and farming activities halted. There should be development of strict regulations for existing structures to follow and regular monitoring should also be instituted. A proper mechanism should be instituted to allow GWCL to prevent and reduce negative effects of intransigent people encroaching on its catchment areas. As it stands, the Ghana Water Company Limited does not have powers to prevent any person encroaching on their catchment areas. It can only inform authorized agencies such as the Environmental Protection Agency and the Ghana Water Resource Commission. This existing lack of authority increases encroachment which leads to increases in water contamination. The GWCL

should therefore be given the powers to monitor its catchment areas to effectively prevent or reduce persons encroaching on the catchment areas.

During the interviews, GWCL officials revealed that Suame Magazine, a heavy industrial site, located within the watershed of the Owabi River could be the source of the presence of heavy metal contamination in the Owabi River. However, the discharge of both solid waste and liquid waste on this location is not regulated. The Environmental Protection Agency is supposed to regulate the Magazine's operations to reduce its impacts on the river. However, there are no regulations that dictate how its wastes are to be discharged. Though not discussed in the results section, it appears there are no regulations governing the Magazine operations. Therefore the Kumasi Metropolitan Assembly, the Environmental Protection Agency, Ghana Water Company Limited, and organizations in the area should develop rules and regulations to govern the disposal of waste from this area.

The documents reviewed in the course of this research and the findings coming from interviews with GWCL personnel confirmed that water bodies including Owabi River in the city are suffering from high levels of nutrients, and that the sources of these are human waste, animal waste, organic wastes from households, and market areas (these latter two are BOD waste). Officials at the Waste Management Department at the Kumasi Metropolitan Assembly confirmed that the city generates about 1,600 tons a day, but the capacity of the department can support collection and disposal of only about 1,400 tons a day because of personnel and equipment limitations. This means there is always a back log of 200 tons a day that keeps piling up. The majority of this left over waste ends up in gutters and is carried by runoff into water bodies. Therefore the need to adequately fund

the department in order to increase its capacity to be able to collect all waste generated in the city. This must be done through funding the department at a level that is adequate to expand service in waste collection.

There is also the need to intensify education on how land use can cause water contamination. The findings showed that the communities' knowledge on how land use impacts sources of water is limited. Therefore there is the need to educate communities on how they can mitigate land use impacts on rivers. And communities should also be educated about the importance of riparian vegetation. The Assembly can help encourage local voluntary organizations to help educate local residents on the importance of riparian vegetation and stream corridors. Local voluntary organizations can help in the management of stream corridors through creating awareness in communities. Moreover, traditional authorities (chiefs) should be encouraged to work with the Assembly on land use issues to ensure that river banks, areas demarcated as sensitive, and conservation areas are not offered for sale.

In 2013 the installed capacity of the Barekese water supply project was expanded from holding 24 million gallons a day to 30 million gallons. However, as a result of increasing population coupled with increasing demand for water supply in the city, water supply still remains unreliable and erratic. To reduce the stress that residents (especially those in poor communities) experience in periods of water scarcity, the GWCL should partner with other non-governmental organizations to educate communities on efficient water usage and rainwater harvesting techniques that reduce the risk of contamination. Rainwater usage is low in Kaase because residents perceive that rooftops from which

water can be harvested are not clean (i.e., they are frequented by birds and cats that defecate on them).

Finally, the GWCL can study water collection patterns in communities (especially poor ones) to plan work on the water distribution system in a more sensitive manner. The findings suggest that when public water supply is cut, pressure normally mounts on wells and bore holes, especially in the morning when people are preparing to go to work and in the evening when residents have returned from work. By scheduling repairs and related work according to community water collection patterns the company will help reduce the stress and frustrations associated with access to water supply at the community level.

Further Research

While this study serves to improve our understanding of the complex issues surrounding land use and water supply challenges in Kumasi, further studies in the areas suggested below will be important. These will also lead to the formulation of better policies, more engaged government agencies and departments, and collaborative planning in addressing the complex issues.

It is very important to investigate the effectiveness of policies and rules and regulations that are in place to ensure protection of water resources, especially urban streams. Some of these policies were developed in 1940s and are outdated. A classic example is the Town and Country Planning Ordinance (CAP 84) which was developed in 1945. Studies on their effectiveness will identify those that need to be repealed and those that need to be restructured to ensure that urban streams are protected from pollution from land uses. There is also the need to investigate the effectiveness of government

departments' responses to land use planning issues and how departments are collaborating with government agencies responsible for protecting water resources and public water supply. This can help strengthen linkages among departments and agencies, which will be very important in urban water quality policy reformulation.

The extent of removal of riparian vegetation or catchment area encroachment along Owabi River, a source of public water supply, needs to be studied. This could be done through mapping to delineate riparian resource areas to identify how much of the resource has been removed and where immediate remedial action is needed. This can lead to development of appropriate preservation measures to control depletion of the resources and will also lead to institutionalization of appropriate enforcement mechanisms to protect against encroachment. It is also suggested that a study be conducted to investigate the relationship between land use development and water supply infrastructure. This will help us to understand how land use can be planned alongside water infrastructure to make sure that it does not unnecessarily restrict water supply.

Finally, there is also the need for someone to investigate the impact of Suame Magazine, on the water quality of the Owabi River. If it is identified that the operations at the Suame Magazine contribute to poor water quality of the Owabi River, enforcement and/or improvement of water quality regulations to govern its operations should occur.

Conclusion

Some studies of urban water supply in developing world cities have sought to address the challenges posed by inadequate and dilapidated water infrastructure and access to piped water (Andreasen 1996; Champetier et al. 2000; Akple et al. 2011).This

study investigated the impacts of urban land use on sources of water supply in Kumasi, Ghana, to develop an improved understanding of the challenges posed by land use on water supply in urban areas in the developing world context. The Owabi River is suffering from pollution from land use and the pollution is carried into the Owabi Dam where Ghana Water Company abstracts raw water for treatment and supply of potable water. Land use is contributing to a high cost of water treatment at the Owabi treatment plant. The sources of pollutants in Owabi Dam are household effluent (including sewerage, solid waste, and fecal matter), farming activities, urban livestock and waste carried from the landscape as a result of poor sanitation and land use planning. This increases the amount of chemicals needed for treating the raw water which therefore translates into high cost of water treatment. Suame Magazine, a heavy industrial area, is also contributing to the poor quality of water coming from Owabi Dam. Communities have good knowledge that household effluent, solid waste, and fecal matter can contribute to poor quality of water supply, but this is not translated into practice as their behavior toward a particular source of water is influenced by the uses of that particular source.

Siltation from land use is also affecting the Owabi impoundment as a source of public water supply. This has reduced the storage capacity of the dam which means less raw water available for treatment. Land use coupled with water supply and distribution challenges and inadequate power supply has culminated in restricted potable water supply from the Owabi treatment plant. When the water supply is disrupted or restricted, the effects are felt at the household level and poor urban community households pay the

greatest price. Public water supply disruptions and restrictions are therefore the cause of water scarcity at the community level.

In the poor community, residents resort to other sources of water supply in order to cope with public water supply restrictions. Resorting to these few sources creates enormous pressure on them and access to water becomes very difficult. In the affluent community, because of the relatively reliable nature of supply and difficulty of access to other sources of water supply, residents sometimes resort to sachet water. And residents in both communities have adopted mechanisms to cope with water supply challenges. In the poor urban community residents are more likely to use storage and collection strategies and in the affluent community residents are more likely to use storage and adaptive strategies to cope with water supply challenges.

The findings suggest that land uses are increasing pollutants in the Owabi River, threating raw water quality, reducing the reservoir's storage capacity, increasing the cost of water treatment, and contributing to water supply restrictions. To ensure a sustainable water supply, there is the need for the development of a comprehensive land use planning, land use policies and zoning regulations, and effective enforcement measures. Moreover, there is also the need to address the challenges posed by existing land uses on or near the Owabi River. This, therefore, calls for all government departments, government agencies, institutions, NGOs, voluntary organizations, and citizens with an interest in land use planning and urban water protection to effectively collaborate with one another on issues of land use and urban water resources. And, given the continued growth of population and urbanization that Kumasi will experience in the coming decades, this is imperative.

APPENDIX A

INTERVIEW GUIDE:

HOUSEHOLD LEVEL INTERVIEW GUIDE

1. Land uses/land use change in the community over the years
2. Land development along the river and how land uses impact source of water
3. How are household solid and liquid wastes disposed
4. Sources of pollution in the community river
5. Fecal matter and solid waste and river contamination
6. Source of water supply in the community
7. Water supply challenges
8. Households water supply coping mechanisms
9. Why household adopt a particular coping mechanism

KEY INFORMANTS' INTERVIEW GUIDE

1. Waste management in the city
2. By-laws/Ordinance on solid liquid wastes disposal
3. Regulations on discharge of effluent into water streams and rivers
4. Land use regulations
5. Floodplain management and regulations
6. Conservation/preservation areas in the city
7. Rule governing streams protection
8. Restrictions on development within catchment areas
9. Enforcement mechanisms
10. Coordination between different departments involved in land use and water resource protection
11. Water supply in the city
12. Water supply challenges posed by land uses
13. Land uses within catchment areas and along water course
14. Owabi River and Owabi Dam

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