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Recurrent Expenditure of Urban Water Supply Systems – Case Study of ATMA and Kumasi Water Supply Systems

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Recurrent Expenditure of Urban Water Supply Systems – Case Study of ATMA and Kumasi Water Supply Systems

By

Sharon Amanda Quaye (B.Sc. Hons)

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CERTIFICATION

I hereby declare that this submission is my own thesis towards the M.Sc. and that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text.

Sharon Amanda Quaye	....	....
(PG 5853511)	Signature	Date
Certified by:		
Dr. Kwabena B. Nyarko	……................................	....
(Principal Supervisor)	Signature	Date
Mr. B. Dwumfour-Asare	……...................................	....
(Second Supervisor)	Signature	Date
Prof. M. Salifu	....	....
(Head of Department)	Signature	Date

DEDICATION

This thesis is dedicated to God Almighty and my family.

ABSTRACT

Over the past decade, the urban population of Ghana has been increasing and provision of potable water to urban dwellers has become a huge burden on the urban water utility provider because water demand exceeds the supply. In order to bridge the gap, there is the need to invest within the sector to sustain service delivery and expand service coverage. Meanwhile, it is not clear how much is needed to ensure continuous service delivery. This research established the recurrent costs of large water systems using the two largest urban water systems in Ghana; the Kumasi Water Supply System (WSS) and Accra-Tema Metropolitan Area (ATMA) WSS. The recurrent expenditure used for study included expenditure on operation and minor maintenance (OpEx), capital maintenance (CapManEx) and capital enhancement (CapEx Enhancement).The study was based on a 5 year analysis period (2007-2011) using cost data from reports and documents of Ghana Water Company Limited (GWCL). Key personnel of GWCL such as Managers and Technical Operators of the water supply systems were interviewed to establish the maintenance practices and financing mechanisms within the urban water sector. The total annual recurrent cost obtained for ATMA WSS was GH¢77,261,008 (i.e. GH¢0.55 per m^3) and GH¢28,412,007 for Kumasi WSS (i.e. GH¢1.03 per m^3). OpEx ranged from 43%-57% (GH¢0.31-0.45 per m^3), CapEx Enhancement ranged from 38%-50% (GH¢0.21-GH¢0.51 per m^3) and CapManEx ranged from 5%-7% (GH¢0.03-GH¢0.07 per m^3) of the total recurrent cost for the systems. The highest contribution to the recurrent costs along the supply chain was from production and the least contribution was expenditure on transmission. The development of asset management within the urban water utility will help GWCL manage its assets and enable better planning for recurrent expenditure.

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LIST OF ABBREVIATIONS

AfDB	African Development Bank
AsDB	Asian Development Bank
ATMA	Accra-Tema Metropolitan Area
AVRL	Aqua Vitens Rand Limited
AWWA	American Water Works Association
CapEx	Capital Expenditure
CapManEx	Capital Maintenance Expenditure
CoC	Cost of Capital
CWSA	Community Water and Sanitation Agency
DC	Decommissioning cost
DWA	Department of Water Affairs
DWAF	Department of Water and Forestry
EFCOG	Energy Facilities Contractors Group
ExpDS	Expenditure on Direct Support
ExpIDS	Expenditure on Indirect Support
GoG	Government of Ghana
GPRS	Growth and Poverty Reduction Strategy
GSGDA	Ghana Shared Growth Development Agenda
GSS	Ghana Statistical Service
GWCL	Ghana Water Company Limited
GWSC	Ghana Water and Sewage Corporation
GWP	Global Water Partnership
HLPS	High Lift Pumping Station
IAM	Infrastructure Asset Management
IWA	International Water Association
LCC	Life-Cycle Cost

LCCA	Life-Cycle Costs Approach
LLPS	Low Lift Pumping Station
MWRWH	Ministry of Water Resources, Works and Housing
NMEFC	New Mexico Environment Finance Centre
OFWAT	Office of Water Services
O&M	Operation and Maintenance
OpEx	Operation and minor maintenance Expenditure
PURC	Public Utilities Regulatory Commission
RWS	Raw Water Source
RBM	Risk-Based Maintenance
RC	Renewal and adaptation cost
RCM	Reliability Centred Maintenance
RVAAL	R.V. Anderson Associates Limited
TAC	Total acquisition cost
TAM	Typical annual maintenance
UK	United Kingdom
UNEP	United Nations Environment Programme
USEPA	United States Environmental Protection Agency
WASH	Water Sanitation and Hygiene
WASHCost	Water Sanitation and Hygiene Cost
WHO	World Health Organisation
WRC	Ware Resources Commission
WSS	Water Supply System
WSP	Water Supply Project
WTP	Water Treatment Plant

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Water service is the most important of all public services and any hindrance to its delivery is a threat to the survival of humanity (Doe, 2007). A growing concern to urban water supply is the high rate of population growth and urbanisation in developing countries. Again, the number of Africa's urban population without access to safe drinking water is increasing tremendously (UNEP, 2011). For example over half of Ghana's population live in urban areas and almost half of urban residents live in the country's two largest cities -Accra and Kumasi (GSS, 2012 & MWRWH, 2007). The rapid rate of urbanisation has increased the demand for water in urban areas and has placed a lot of pressure on the government and urban water utility provider to supply water to urban dwellers. In Ghana, the Ghana Water Company Limited (GWCL) is responsible for urban water supply service and Community Water and Sanitation Agency is responsible for rural water supply service. GWCL's coverage as at 2009 was 59% with a deficit of 41% (MWRWH, 2009).

Moreover, to reduce the urban coverage deficit, it is necessary to invest in the expansion of service coverage and sustain the maintenance of existing supply systems to ensure optimum performance. The cost normally identified with expansion of service coverage and sustaining facilities maintenance includes acquisition cost of new infrastructure or assets and recurrent cost needed to maintain the existing infrastructure and expand service coverage. A good balance must be made between the two in order to ensure continuity of service.

GWCL uses assets to manage and operate its eighty-six (86) systems. Many of their systems were built decades ago and are ageing and the company faces a challenge in maintaining its assets (MWRWH, 2007). In most cities worldwide, there has been years of neglected maintenance of water infrastructure assets due to inadequate financial resources and poor management (Khatri and Vairavamoorthy, 2007). The situation may be same with Ghana's urban water sector as very little or no data exists on the magnitude and levels of maintenance within the water utility. Assets deteriorate due to neglected maintenance and when this occurs, the reliability and quality of service delivery declines and the health and well-being of consumers is negatively impacted.

It is necessary to maintain assets in order to keep them in good working condition to ensure continuous and quality service delivery. Maintenance can be preventive or reactive and planned or unplanned. Maintenance, when carried out, should be well planned for (Jabar, 2003).

This study focuses on recurrent cost within the urban water utility. The recurrent cost in this study comprises capital maintenance expenditure (CapManEx), operation and minor maintenance expenditure (OpEx) and expenditure on capital enhancement (CapEx Enhancement). CapManEx refers to the occasional costs of renewing (replacing, rehabilitating, refurbishing, restoring) assets in order to ensure that services continue at the same level of performance that was first delivered whereas CapEx Enhancement refers to expenditure needed to expand service coverage and OpEx refers to the activities performed on regular basis to keep the system running (Franceys and Pezon, 2010). Also, the cost associated with the entire supply chain is considered focusing on the production, transmission, distribution and commercial phases of supply.

1.2 Problem statement

The pressure to provide water service to people, particularly in Ghana's urban centres is intense as there is inadequate water supply for urban dwellers. There is the need to maintain and expand existing systems in order to meet the ever increasing demand. A balance must be established between capital maintenance and expansion of the systems in an attempt to bridge the demand gap. Lack of understanding of the magnitude and levels of recurrent costs as well as financing mechanisms available makes it difficult to effectively plan and manage the water supply systems. Meanwhile, existing data on recurrent costs is usually aggregated and forms part of the total expenditure generally reported. This does not give a clear representation of major cost components including OpEx, CapManEx and CapEx Enhancement and their constituent.

1.3 Objective of study

The main objective of this research is to determine the existing recurrent expenditure of the two largest urban water supply systems.

The specific objectives are:

- To determine the unit costs of the urban water supply chain;
- To determine the magnitude of recurrent cost components of the urban water systems;
- To identify the possible factors influencing capital maintenance expenditure within the urban water supply systems.

1.4 Justification

An understanding of recurrent costs within the urban water service delivery will assist in budgetary allocation and planning towards water assets management. This will ensure continuous and quality water service delivery as well as sustainability of the service. This will further contribute to better policy design and decision making within the urban water sector. Knowledge from this study will also serve as a foundation for future research in this area.

1.5 Research questions

- What is the OpEx of the urban water systems?
- What is the CapManEx of the urban water systems?
- What is the cost of expansion of the urban water systems?
- What are the financing mechanisms available in carrying out rehabilitation and expansion works?
- What factors influence the magnitude of capital maintenance expenditure?

1.6 Scope of study

The study was conducted within the urban water utility. With focus on production, transmission and distribution, the two largest urban water systems in Ghana were selected for the study. These are:

- Accra-Tema Metropolitan Area (ATMA)Water Supply System which consists of Kpong and Weija water treatment plants, their transmission and distribution network
- Kumasi Water Supply System which consists of the Barekese and Owabi water treatment plants, their transmission and distribution network.

Also, cost data covering a period of 5 years (2007 to 2011) was used for analysis.

1.7 Structure of the report

The report is presented in five chapters. Chapter one provides background information, problem statement, the objectives, justification and scope of the study. Chapter two is a review of available literature on the subject of study. Chapter three describes the study area and gives the methodology and approach used in carrying out this study. Chapter four provides the data collected, the results drawn from the analysis of collected data and the discussions deduced from the results. Chapter five draws conclusions from the results and discussions of the study and further provides some recommendations.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Urbanisation and water supply

Khatri and Vairavamoorthy (2007) suggest that one of the world's most important challenges in the next few decades will be population growth and urbanization. As at 2010, more than half of the world's population live in an urban area and it is estimated that by 2030, 6 out of every 10 people will live in a city, and by 2050, this proportion will increase to 7 out of 10 people (WHO, 2013). Africa's urban centers are growing at a faster rate than anywhere else in the world. It is estimated that 40% of Africa's population live in urban areas and water supply in these areas is inadequate (UNEP, 2011).Ghana's census figures records the urban population as 43.8% in 2000 and 50.9% in 2010 (GSS, 2012). These figures clearly demonstrate that Ghana's rate of urbanisation is not too different from the general trend in Africa. Ghana's National Water Policy recognises that the country is rapidly growing with almost half of urban residents living in the country's largest cities – Accra and Kumasi. MWRWH (2007) forecasted that by 2015 half of Ghana's population will be living in towns and cities, but by 2010 this was already a reality.

Urbanisation is not much of an issue if the rate of development of public infrastructure progresses accordingly. Meanwhile, technological and financial challenges are faced in maintaining and upgrading existing ageing and deteriorating infrastructure due to increasing population and urbanisation (Khatri and Vairavamoorthy, 2007).Increase in population in urban areas has also increased the demand for water. The reality in Ghana is that the rate of urbanisation exceeds existing levels of urban water supply and it is difficult for planning and infrastructural development to keep pace (Water Aid 2005& MWRWH, 2007).It is estimated that 61% of the urban population have access to improved water supplies with 40% of the total urban population covered by GWCL's networks (WaterAid, 2005). However, supply to most areas is intermittent. WaterAid further reports that only 25% of residents in Accra enjoy a 24-hour water supply. This means that 75% of residents in Accra lack 24 hour supply. Averagely, 30% of Accra's residents have 12 hours service every day for five days a week (WaterAid, 2005). GWCL's coverage increased to 59% by the end of 2009 (MWRWH, 2009).

2.2 Urban water supply systems

An urban water supply system aims to provide water of acceptable quality, adequate quantity and sufficient pressure for domestic use, fire protection and industrial purposes (Misiunas, 2005 & Copeland and Tiemann, 2010). It can therefore be said that the key element of urban water supply is that water supplied should be of good quality and adequate quantity.

Municipal water systems generally comprise of collection works, purification works, transmission works and distribution works (Shammas and Wang, 2011). This composition is similar to the description of the four components that make up the water delivery systems identified by Noll et al. (1999). These are abstraction from the resource, treatment to improve quality, transporting and delivery of water to users. This composition is typical of urban water supply systems in Ghana.

2.3 Supply chain of water delivery

According to Beamon (1998), a supply chain is an integrated manufacturing process which converts raw material into final products and delivers the product to customers. "Water delivery results from a process which can be viewed as a chain of events and this chain is only as strong as its weakest link." These events constitute the supply chain of water delivery (DWA, 2011). This implies that the various portions of the chain are interrelated and what happens at one phase affects the other phases.

The supply chain for this study includes the production, transmission, distribution and commercial phases of water supply. Production of water involves its abstraction and treatment. Water abstraction is an engineering process of obtaining water from its source and treatment of water seeks to make it wholesome for use (Shammas and Wang, 2011) in accordance with set guidelines such as that of the WHO. Water transportation comprises water transmission and distribution. The transmission system has been described by Misiunas (2005) as the components that have been designed to carry large amounts of water over great distances and usually connect major facilities within the system and distribution systems distribute water transported within transmission pipelines to the consumer. The point at which the service is brought directly to the household or consumer begins the commercial phase of the supply chain. The distribution and commercial phase of the supply system are closely linked to each other. Formerly, they were considered as one unit within the supply chain by GWCL. According to sources from GWCL, the company has found it necessary to separate the two. The distinction lies primarily in the roles they play within the supply chain. The commercial process identifies itself as the last end of the supply chain and may be viewed as the "business center" as its primary focus is supplying water service to the customer, billing the customer for the service, collecting tariffs and addressing issues that the customer may have with the service (customer care).

2.4 Overview of Ghana's urban water sector

Ghana's water supply sector is divided into 2 main subsectors namely the urban water sub sector and the rural water subsector. GWCL is solely responsible for urban water supply and Community Water and Sanitation Agency (CWSA) facilitates water supply to rural areas. Rural water supply systems are managed by the District Assemblies. The lead government institution responsible for the water sector is the Ministry of Water Resources, Works and Housing (MWRWH, 2007).

2.4.1 History of GWCL

In 1965, the Water Supply Division of the Ministry of Works and Housing was transformed to Ghana Water and Sewerage Corporation (GWSC). GWSC handled both rural and urban supply. GWSC was converted to GWCL in 1999 as a state owned limited liability company to focus on urban water supply (MWRWH, 2009). With the conversion of GWSC to GWCL, the company was required to set up and maintain a depreciation fund for the replacement of fixed assets and a Sinking Fund for the expansion and development for the efficient management of its assets but GWCL's operations have not been self-sustaining and it has relied on the Government of Ghana (GoG) to subsidise its operation and maintenance costs and to bear full responsibility for capital investments (MWRWH, 2007).

In 2007, a merged company from South Africa and Netherlands named Aqua Vitens Rand Limited (AVRL) began a 5 year management contract to manage the operations of GWCL. GWCL continued to act as managers of the systems. AVRL brought about some transformation in the company. However, at the end of the 5years, the contract was not renewed. Following the expiration of the management contract and the exit of AVRL, a new company, Ghana Urban Water Limited

(GUWL), has been formed by government to take over the management of urban water systems in the country temporarily (MWRWH, 2007). Currently the company is still undergoing transition to determine the most efficient way of handling its operations.

2.4.2 Stakeholders of GWCL

MWRWH (2007) identifies the mandate of GWCL's stakeholders as follows:

- **The Ministry of Water Resources Works and Housing(MWRWH)–** MWRWH is the principal water sector ministry responsible for overall policy formulation, planning, coordination, collaboration, monitoring and evaluation of programmes for water supply and sanitation.
- **Water Resources Commission (WRC)** -The WRC was established by the Water Resources Commission Act, 1996 (Act 522) to harmonize water resources management and related issues concerning all consumptive and non-consumptive uses of water in Ghana.
- **The Public Utilities Regulatory Commission (PURC)**–PURC is an independent body that regulates the standard of services including the quality of drinking water provided by GWCL and also the tariff set by the company for urban water supply.

MWRWH (2009) outlines some responsibilities of the company

- Planning and development of water supply systems in urban communities in the country.
- Provision and maintenance of acceptable levels of service to consumers in respect of quantity and quality of water supplied.

- Contracting of design, construction, rehabilitation and expansion of existing as well as new works.
- The conduct of research and engineering surveys relative to water and related subjects.
- Submission of tariff proposals to Public Utility Regulatory Commission for review and final approval.

2.5 Asset management

An asset is something owned or a physical component of a facility that provides services with an economic life greater than one year (Hopper et al., 2009). Assets are used to produce, store and deliver water at various stages within the supply chain. According to Franceys and Pezon (2010), water and sanitation delivery depends largely on the use of fixed assets. A water supply asset is any components of a water supply facility with an independent physical and functional identity and age (e.g. pump, sedimentation tank, etc.) (USEPA, 2008).

"Asset management is maintaining a desired level of service for what you want your assets to provide at the lowest life cycle cost" (USEPA, 2008). USEPA further explains the lowest life cycle costs as the best appropriate cost to repair, rehabilitate or replace an asset. New Mexico Environment Finance Centre (NMEFC) recognises the fact that assets lose their value with time and views asset management in utilities as an approach to manage these deteriorating assets within the utility system (NMEFC, 2006). The Department of Water Affairs (DWA) of South Africa describes asset management as an integrated decision making and planning process of acquiring, utilising, safeguarding and disposing of assets to maximise their service delivery potential and to minimise their related risks and costs over their entire life benefits DWA (2011). Thus, it can be explained that asset management in a water utility is a way of ensuring continuous service delivery by acquiring, utilising and disposing water supply assets in such a way that maximum benefit is obtained in the most cost efficient manner.

Bhagwan (2009), states that asset management in water supply was started in the United Kingdom (UK) in 1989. This as claimed, was as a result of privatisation of the water industry. He further stated that it was necessary to provide investors with information about the condition of the assets and investment requirement associated with the takeover process (ibid).

Utility companies must have a good knowledge on the assets they own, their location, condition, remaining useful life and value (USEPA, 2008). This information can be used to create a good inventory of the assets so that they can be managed effectively. In developing countries, the deteriorating processes of assets are more severe. This is due to little utilisation of knowledge about the specific classes of assets deterioration, the technical service life and value of assets (Misiunas, 2005). Asset management aims at preventing failure of assets so that service is not interrupted. Eerens (2008) considers failure not only as a total breakdown and stoppage of an asset, but also as quantitative or qualitative deterioration of its output. Functional failure is when an asset performs below its required performance (Weber and Thomas 2005).

- **Benefits of asset management**

USEPA (2008) outlines the following benefits of asset management:

- Prolonging asset life and aiding in rehabilitation, repair and replacement decisions through efficient and focused operations and maintenance

- Meeting consumer demands with a focus on system sustainability
- Setting rates based on sound operational and financial planning
- Budgeting focused on activities critical to sustained performance
- Meeting service expectations and regulatory requirements
- Improving the security and safety of asset.

2.5.1 Useful life of assets

Every asset has a lifespan and this is the useful life of the asset. The useful life is defined as the period during which a depreciable asset is expected to be used (Hooper et al., 2009). The potential service life of an asset before it physically becomes unable to produce goods or services is the physical life (Scott, 2003). Hooper et al., (2009) suggest that the economic life of an asset is the period from acquisition to the time when the asset ceases to be the lowest cost alternative to provide a particular level of service. The economic life is at maximum when it is equal to the physical life (ibid).

Many factors influence the useful life of an asset. According to the New Mexico Environment Finance Centre, NMEFC (2006), poor installation, defective materials, poor maintenance, and corrosive environment will shorten an asset's life, while factors such as good installation practices, high quality materials, proper routine and preventive maintenance, and non – corrosive environment will tend to lengthen an asset's life. Table 2.1 gives the typical useful life of some assets.

Table 2.1Typical useful life of some assets

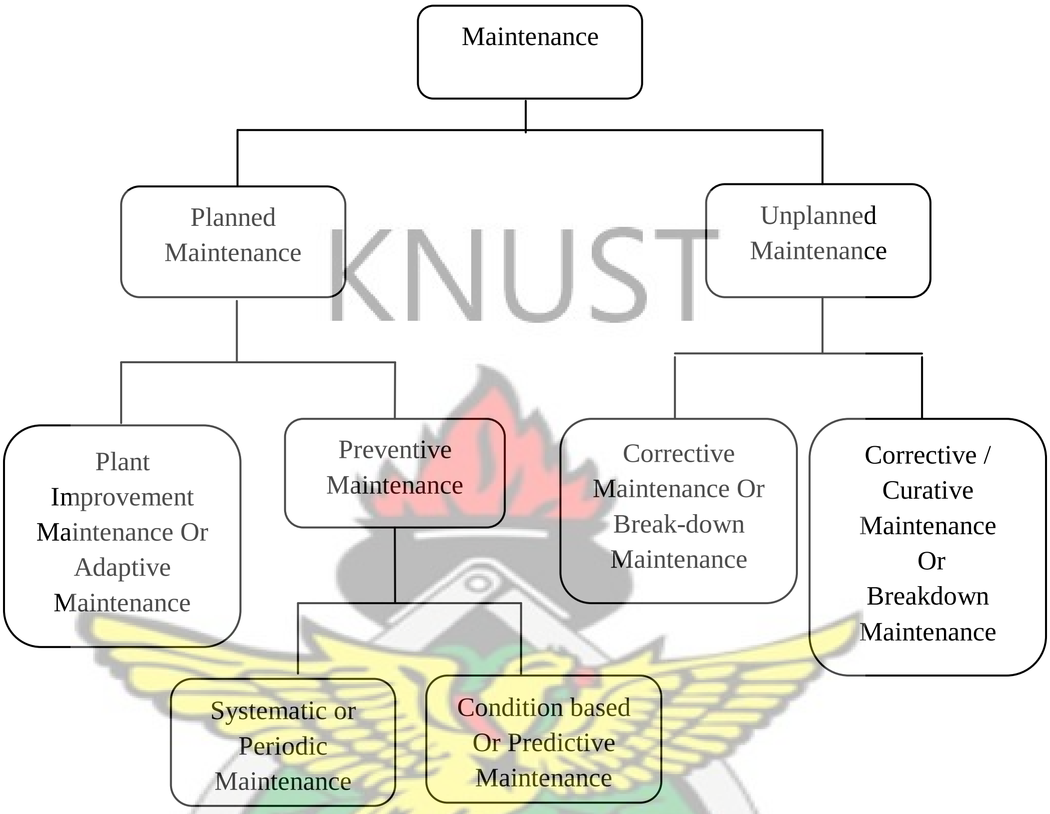
Asset	Typical Useful Life (years)
Dams, weirs and intakes	60
Concrete reservoirs and tanks	50
Steel reservoirs	40
Chemical equipment	10
Other mechanical equipment, new	15
Mechanical equipment, overhauled	5
Buildings	50
Electrical equipment	15
Pumping Structures	40
Pipe lines	50
Access Roads	30

Source: GWSC Design Criteria Report (1992)

2.5.2 Maintenance of assets

Water delivery needs to be understood as embracing not just the construction of infrastructure but the operation, maintenance and augmentation of that infrastructure throughout its design life (DWA, 2011). The primary function of maintenance is to reduce or eliminate the consequences of physical asset failures (Weber and Thomas, 2005). Maintenance is any activity carried out on an asset in order to ensure that the asset continues to perform its intended functions (Jabar, 2003). Figure 2.1 shows the various classifications of maintenance.

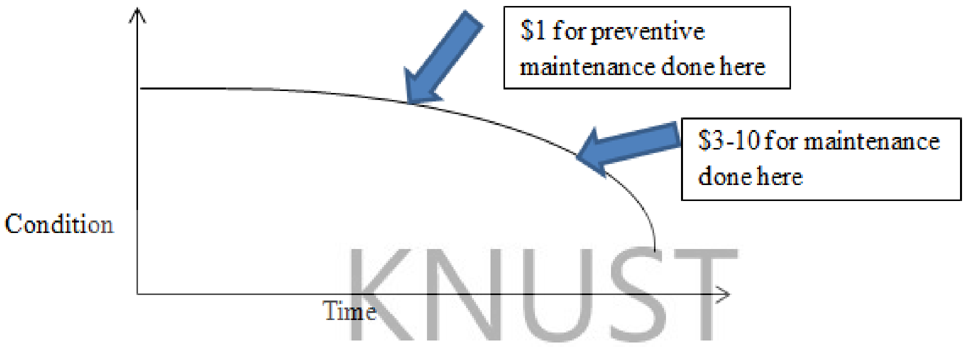
Maintenance can be either planned or unplanned. It is planned when it is organised and carried out with fore thought and unplanned when there is no predetermined plan and is necessitated by breakdowns (BS 3811, 1984).



Source: UNIDO /ILO (1994:41), Adapted by Cobbinah (2010).

Figure 2.1 Classifications of maintenance

Many strategies are employed in maintenance. Common strategies used include breakdown maintenance, preventive maintenance, predictive maintenance and proactive maintenance.These strategies are summarized in Table 2.2. Breakdown Maintenance is a reactive maintenance technique that waits for an equipment to fail before any maintenance action is taken (Mobley, 2002).Preventive maintenance is a time-based maintenance strategy where maintenance is done on a predetermined periodic basis (Jabar, 2003). Fig 2.2 shows that when preventive maintenance is delayed, it becomes more expensive at a later time. Thus in order to reduce cost, maintenance must be done in a timely manner.



Source: Jabar (2003)

Figure 2.1 Time cost of maintenance

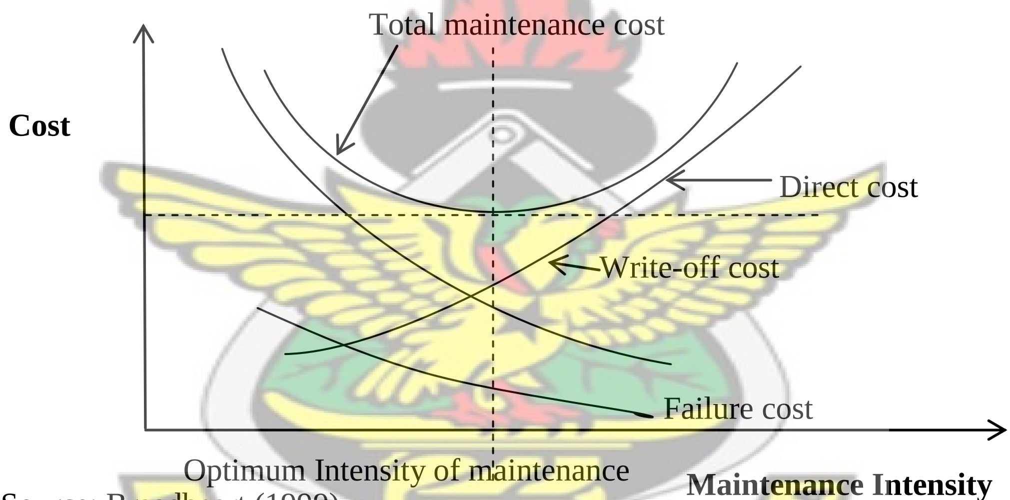
Table 2.2Maintenance strategies and approaches

Maintenance Strategy	**Maintenance Approach**	**Signification**
Breakdown Maintenance	Fix-it when broke/ Run-to-failure	Large maintenance budget
Preventive Maintenance	Scheduled Maintenance	Periodic component replacement
Predictive Maintenance	Condition-based Monitoring	Maintenance decision based on equipment condition
Proactive Maintenance	Detection of Sources of Failures	Monitoring and correcting failing root causes

Source: Jabar (2003)

Predictive maintenance strategy uses the actual operating condition of plant equipment and systems to optimize total plant operation and schedules all maintenance activities according to the needs of the plant or equipment (Mobley, 2002). Proactive maintenance strategy concentrates on the monitoring and correction of root causes to equipment failures and is designed to extend the useful age of the equipment to reach the wear-out stage by adapting a high mastery level of operating precision (Jabar, 2003).

Fig 2.3 has been adopted from Braadbaart (2009) and it depicts maintenance expenditures as an optimisation problem. Total maintenance cost is presented as the sum of the direct costs of maintenance activities, the cost of breakdowns, failures and stoppages of production equipment, and the cost of writing-off production equipment. Makar and Kleiner (2000) mentions that losses associated with failure include direct costs, indirect cost and social costs.



Source: Braadbaart (1999)

Figure 2.2 Optimisation of maintenance cost

This depicts that as your maintenance effort is increased (do more preventive maintenance), failure costs and write-off costs will decrease. According to Albonico et al. (2011), the "rate at which capital depreciates depends positively on its utilisation and negatively on maintenance expenditures." Braadbaart (2009) considers the view that more maintenance will produce less failures and longer lasting equipment as a narrow perspective of maintenance. A recent form of maintenance that is becoming popular is Reliability Centred Maintenance (RCM) also known as Risk Based Maintenance (RBM). The aim of RCM is not to preserve the assets in themselves, but to preserve the asset's functions (whatever the user wants it to do, as defined by performance standards). Thus it does not aim at preventing failures but rather preventing the consequences of failure (Energy Facilities Contractors Group, EFCOG, 2005). Risk-Centred Maintenance originated from the realisation that more maintenance does not automatically translate to less stoppage or failure. More maintenance especially preventive maintenance may even cause failure rather than prevent it (Braadbaart 1999).

Maintenance options for assets

There are four basic options for dealing with the actual assets over time:

- Operate and maintain the existing asset
- Repair the assets as they fail-this aims to revive an asset to bring it back to its original state (Cobbinah, 2010).
- Rehabilitate the assets- rehabilitation brings the assets back to a functional condition and may extend the assets' life span considerably. It refers to that one time event when a major activity is performed on the asset to extend its life so that the asset continues providing service for some additional period of time (RVAAL, 2002).
- Replace the assets- At a point in time, an asset can no longer be kept in service through maintenance or repair or and will need to be replaced. Replacement costs are 100%of the assets value (RVAAL, 2002).

NMEFC (2006) states that these options are closely linked to each other. The frequency with which one option is used impacts the frequency of the other, whether or not the other is done at all, or the time frame in it is done. Some infrastructure assets can remain in the 'operation and maintenance phase' of their life cycle with little probability of closure or decommissioning. However, many infrastructure assets undergo some form of improvement or upgrade to maintain the level of service they deliver or their performance (NMEFC, 2006).

2.6 Cost of water delivery

2.6.1 Cost concepts

Cost is a measurement, in monetary terms, of the amount of resources used for the purpose of production of goods or rendering services (McNeill and Tate, 1991).

- **Direct costs** are costs that can be traced exclusively to an output and relate to provision of the service (Kelley, 2002).
- **Indirect costs** are not exclusive to a particular output and are often relatively insensitive to changes in quantity of output (Kelley, 2002).
- **Fixed costs** do not vary in the short term with respect to the amount of water produced. Fixed costs for a water supply system include administrative costs, scheduled maintenance and equipment replacement (Kelley, 2002).
- **Variable costs** are directly dependent on the volume of output or service but not necessarily in the same proportion as the increase in output. It includes energy cost, chemical cost and cost of raw material (Kelley, 2002).

Sometimes it is difficult to categorise some cost components because they can be variable or fixed depending on the situation, e.g. labour and some forms of maintenance (McNeill and Tate, 1991). Fixed costs tend not to change with changes in service levels and thus are more difficult to reduce in the short term than variable costs (Kelley, 2002). The fixed costs of a water system usually are very high compared to the variable costs for instance in

UK, fixed costs account for over 80% of the costs of supplying water (Armstrong et al., 1994).

- **Recurrent cost** are the operations and maintenance expenditures that are needed to run the project or supply system at a level consistent with its expected use and to maintain its capacity during its expected lifetime (Hood et al., 2002).
- **Unit cost**

A unit cost is the cost of producing one unit of a given service. Since unit costs relate input to output, they are good management tools (Kelley 2002). It gives a relationship between the resources consumed and the resulting product.

- **Cost drivers**

A cost driver is any factor that significantly affects cost. Any change in the cost driver will change the total cost (Roy et al., 2001). Cost drivers can be quantitative or qualitative. Quantitative cost drivers are those that can be given a precise value whereas qualitative cost drivers are difficult to assign a precise value and they are determined through the judgement of the estimator (Roy et al., 2001).

2.6.2 Life cycle costing

The lifecycle of an asset starts with planning and continues to procurement or construction, operations and maintenance, renewal and then disposal (Australian Standards, 1999 & Department of Water Affairs and Forestry (DWA, 2010). Meanwhile, the life-cycle costs (LCC) as defined by Fonseca et al. (2010) represent the aggregate costs of ensuring delivery of adequate, equitable and sustainable water, sanitation and hygiene (WASH) services to a population in a specified area. In the WASH sector, sustainable services are qualified using a methodology developed by the WASHCost known as the Life Cycle Costs Approach (LCCA). LCCA seeks to raise awareness of the importance of life-cycle costs in achieving adequate, equitable and sustainable WASH services, to make reliable cost information readily available and to mainstream the use of LCC in WASH governance processes at every level. Table 2.3 gives the life cycle cost classification by Australian Standards (1999) and Fonseca et al. (2010).

Table 2.3 Life-cycle cost components

Australian Standards (1999)	Fonseca et al. (2010)
• Total acquisition cost (TAC) / capital • Typical annual maintenance (TAM) cost / routine maintenance, • Renewal and adaptation cost (RC) / corrective maintenance, • Decommissioning cost (DC) / disposal cost	• Cost of capital (CoC) • Capital expenditure (CapEx) • Capital maintenance expenditure (CapManEx) • Operating and minor maintenance expenditure (OpEx) • Expenditure on direct support (ExpDS) • Expenditure on indirect support (ExpIDS)

TAM cost and OpEx are related in that they both involve day-to-day operational and routine maintenance activities. Renewal also relates to CapManEx and it is the occasional cost of maintenance done to rehabilitate, repair and renew assets. The Australian Standards, however, does not mention expenditure on direct and indirect support costs which is evident in the LCC classification by Fonseca et al. (2010).The LCC classification by Fonseca et al. (2010) has been adopted for this study because it gives a more detailed breakdown on LCC.

Life cycle asset management seeks to ensure that an asset achieves at least its estimated useful life and works according to its original design and also to extend the life and/or capacity of the asset through selective refurbishments or upgrading rather than to total reconstruction of the asset at greater cost (DWA, 2010).

2.6.3 Maintenance Expenditure

Maintenance costs are scheduled costs associated with the upkeep of a system and repair costs are unanticipated expenditures that are required to prolong the life of a system without replacing the entire system (DEED, 1999). According to Albonico et al.(2011), a survey in Canada indicates that total expenditure on maintenance and repair amounted on average to around 6.3% of GDP for the period 1956-1993 (roughly a third of amount spent on new investments). The expenditure incurred in maintaining assets is termed as maintenance expenditure. This expenditure has been classified into two components namely operation and minor maintenance expenditure (OpEx) and capital maintenance expenditure (CapManEx).

2.6.3.1 Operation and minor maintenance expenditure

Operation and maintenance (O&M) refers to all activities needed to run a water supply which excludes construction of new facilities (Castro et al., 2009). Operation involves activities which have no effect on asset condition but are necessary to keep the asset utilised appropriately and minor maintenance include the ongoing day-to-day work required to keep assets operating at required service levels (Ruffell and Light, 2012).

The cost components for OpEx at GWCL's systems include personnel (labour), water treatment chemicals, electricity, fuel and lubricants, material cost, hiring of equipment, overheads and repair and minor maintenance.

2.6.3.2 Capital maintenance expenditure

"Capital maintenance is planned work carried out by companies to replace and refurbish water and sewerage assets to provide continuing services to customers" (Binnie, 2000). Since water supply systems consists of different assets with different lifespans which wear out at different times, there is the need have an approach that ensures funding for the system in order to ensure continuing service. Without capital maintenance, many systems are abandoned and the full benefit that should be derived from the infrastructure is not obtained. Loss of serviceability is a serious failure of public health and convenience (Franceys and Pezon, 2010). Franceys and Pezon (2010), state that the true cost of water delivery cannot be obtained without considering the cost of capital maintenance expenditures. This is because as the assets are used in producing water, they depreciate and will have to be maintained in order to restore them to acceptable levels of performance. The cost of maintaining the assets must be known and provision must be made for it so that assets will not fail and water service delivery will be sustained.

There are many ways to estimate the CapManEx for water assets. Some people use depreciation of assets over their useful lives and thus determine the amount needed to restore the assets. Office of Water Services (OFWAT), a regulatory body for water companies in the UK determines the CapManEx for water utility companies based on historic levels of capital maintenance, the trends of service to customers and the scope for further capital efficiency both catch-up and minimum annual improvement (Binnie, 2000). Some of the water companies argue that this is not an accurate basis for the estimation of capital maintenance as times and conditions have changed (ibid). In using historical prices, necessary price adjustments must be made to reflect changing condition of the local environment.

A challenge in determining the CapManEx of systems is the unavailability of data. This is common for new systems, systems where major maintenance has been neglected or where there is no proper record keeping. The investigation of CapManEx becomes more uncertain where necessary capital maintenance is appropriately combined with improvements in quality or extensions to give greater accessibility or increased quantity and will require a more complex approach to the apportionment of costs between CapEx and CapManEx (Franceys and Pezon, 2010).

2.6.4 Differentiating between CapEx, CapManEx and OpEx

Sometimes, CapManEx is viewed as CapEx and other times as OpEx due to the way they are interrelated. There is therefore the need to establish parameters to differentiate CapManEx from Operational Expenditure and Capital Expenditure.

Franceys and Pezon (2010) suggest that when an existing system undergoes minor maintenance, the related cost is part of on-going operating expenditure (OpEx). The point where minor maintenance becomes capital maintenance is a matter of frequency (if it occurs more than a year) and of amount (the significance of the cost as compared to OpEx).

Ruffell and Light (2012) differentiates between the expenditures by the same principle but from a different perspective. Service potential and thresholds are used to differentiate between CapEx, CapManEx and OpEx. CapManEx restores capacity whereas CapEx (in this case CapEx Enhancement) increases original capacity of the system (Fonseca et al., 2010). OpEx does not usually constitute replacement of parts and when it does, the cost of doing so is not very significant as compared to CapManEx.

2.7 Financing in water supply

A pressing issue for maintenance and expansion in most developing countries is adequate cost recovery and though most countries in Africa have national water policies and programmes, none of the cost recovery strategies consider the replacement or rehabilitation cost of fixed assets (AfDB, 2010). An objective of Ghana's National Water Policy for urban supply is to ensure a financially viable utility and adequate funding level to rehabilitate, improve and expand infrastructure, and also to undertake operation and maintenance (MWRWH, 2007). Though some measures have been put in place for achieving this target, the country still has a long way to go in enforcing these measures in order to derive their full benefit.

Financing water infrastructure means spending money to finance long-term physical assets and sustainable financing implies that expenditures are balanced with revenues (EUWI FWG, 2007). This further mentions that five countries in Africa (Kenya, Mozambique, Zambia, Egypt and Ethiopia) have developed or are in the process of developing financing strategies in water supply and sanitation. A challenge in long term infrastructure development is the overriding political nature of decisions on infrastructure investments considering the short term nature of the political cycle (GWP, 2011). To ensure proper asset management, one needs to secure adequate long term investment funding for maintenance and renewal (Hooper et al., 2009).

2.7.1 Funding sources and challenges

According to a report by the Johnson Foundation (2012), there are two primary approaches to financing water system improvements and maintenance: cash financing or debt financing. Cash financing is limited to the revenue at hand, which is usually from water rates, service fees, connection fees from new accounts, or taxes. Debt financing is the typical way that utilities raise upfront capital to invest in their systems and it includes collecting loans to finance the infrastructure (ibid).

MWRWH (2009) also identifies three main sources of funds for developmental projects in Ghana's urban water sector, namely external support agencies, government's annual budget and other development votes and from internally generated funds mainly through water sales (MWRWH, 2009).

American Water Works Association (AWWA) is committed to the principle that utilities should be self-sustaining through their rates AWWA (2001). AWWA (2001) recognises that huge investment is needed by the water utilities to maintain and replace existing infrastructure and wonders if this can be done by the utilities financing themselves at tariffs customers can afford. GWP (2011) considers tariff revenue as the most important source for cash flows and charges should contribute to investment costs as well as finance maintenance and operation (GWP, 2011). According to Fuest and Haffner (2007), a self-sustainable tariff should cover the operation and maintenance of the system, investment for the rehabilitation and renewal of the distribution, investment in infrastructural development and return on capital employed. A mandate for water and sanitation utilities in Africa is cost recovery and about 60% of the utilities are meeting their full operation and maintenance cost (Banerjee et al., 2010). Cost recovery through tariffs is also a challenge in Ghana. The Public Utilities Regulatory Commission (PURC) is the regulating body for utilities in Ghana. PURC is responsible for approving water tariffs. Though PURC's establishment has brought about some improvement, however, GWCL is still unable to recover its costs and this situation is aggravated by government's failure to pay water bills of its departments and agencies (WaterAid, 2005).

Another source of funding within the sector is grants from donors and commercial funding. In 1990-2003, donor investments made in the country in the water sector were worth $196million and the highest single amount of $120million was received by urban water from the World Bank under the Water Sector Rehabilitation Project (WaterAid, 2005). International aid for water and sanitation fell from $3.5 billion in 1996–98 to $3.1 billion a year in 1999–2001. The general lending trend in the WASH sector varies. The annual loan approval of World Bank in 1990–98 was $1.25 billion and it dropped slightly to $1.1 billion in 1999–2001, that of Asian Development Bank (AsDB) has been rising, though with year to year fluctuations ($275 million a year in 1996–2000, compared with $200 million a year in 1990–95) and lending from the African Development Bank (AfDB) has also been rising. Reports from Ghana's water sector indicate that from 2006 to 2009, GWCL was able to attract substantial grant and loan funding of about $500 million to improve its systems. Loans and grants obtained in 2006 amounted to $59 million, it increased to $66 million in 2007 and shot up to $286milion in 2008 but decreased to $36 million in 2009. Netherlands has been a principal source of these loans most of which have been under concessionary terms. The World Bank has also been a significant contributor (MWRWH, 2009). Recently, China has also become a major source of concessionary funding within the urban water sector in Ghana.

CHAPTERTHREE

3.0 STUDY AREA AND RESEARCH METHODOLOGY

3.1 Study area

The study was conducted in the two largest water supply systems of Ghana. They are ATMA WSS located in the Greater Accra region and Kumasi WSS located in the Ashanti region. Fig 3.1 shows the location of the systems and their coverage areas.

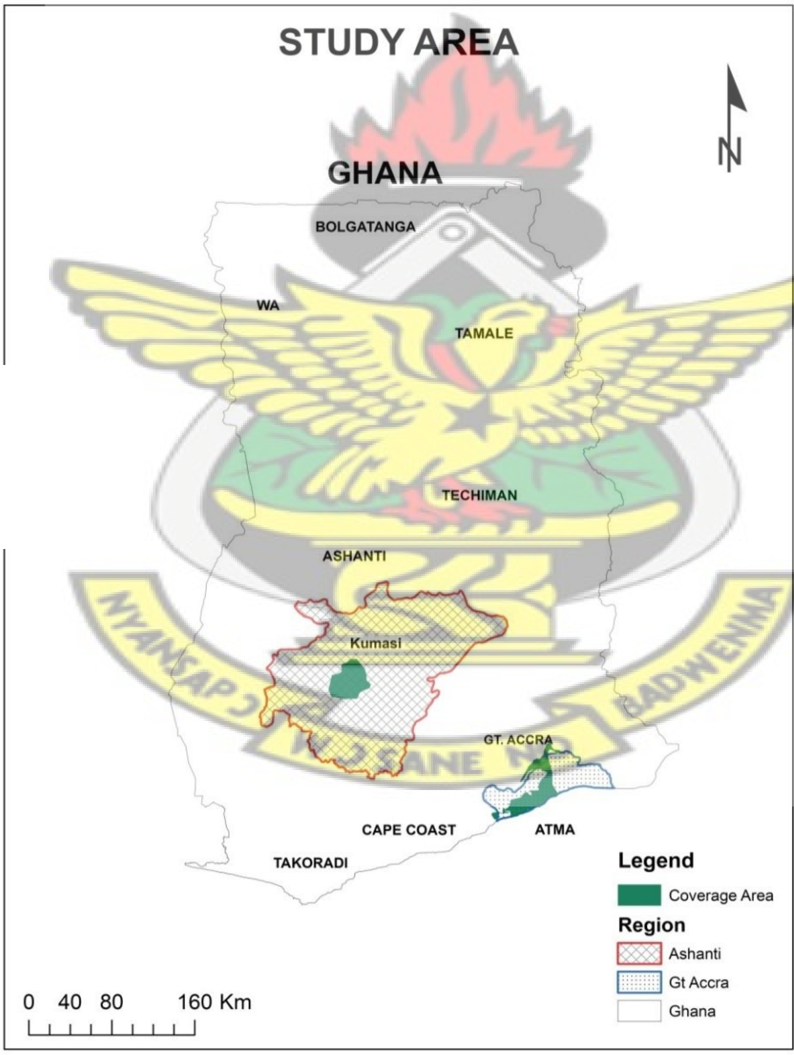


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Figure 3.1 Study area

3.1.1 Kumasi water supply system

The Kumasi Water Supply System is located in the Ashanti Region of Ghana. The Ashanti Region is the third largest region in Ghana and is centrally located in the middle belt of Ghana. In terms of population, however, it is the most populated region in Ghana with a population density of 19.74/km^2. Water to Kumasi is supplied by the Kumasi Water Supply System. The Kumasi Water Supply System is made up of two plants, the Barekese and Owabi treatment plants and a combined distribution network.

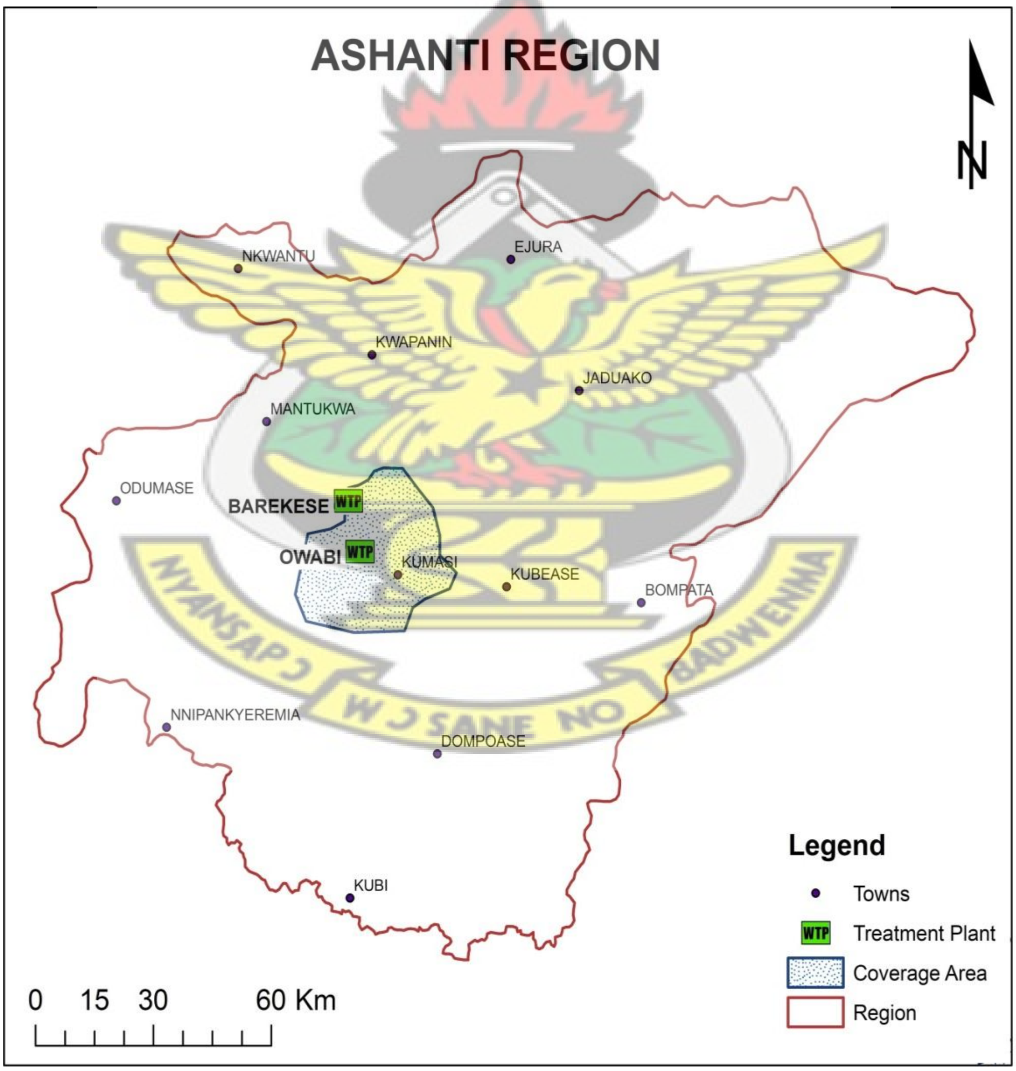


Figure 3.2 Kumasi Water Supply System

The Barekese Treatment Plant receives water from River Offin and the Owabi Treatment Plant obtains water from the Owabi River. The Owabi River receives runoff from the city of Kumasi. This causes pollution of the river and negatively impacts its raw water quality. There is an on-going expansion of the Barekese plant which will add an additional module of 6million gallons per day. Table 3.1 gives a description of the Barekese and Owabi treatment plants.

Table 3.1 Description of Barekese and Owabi treatment plants

Item	Barekese	Owabi
Year of Construction	1967	1928
Year(s) of Expansion	2009,2012	
Design Capacity	24million gallons per day	3million gallons per day
Raw Water Source	River Offin	River Owabi
Low Lift Pumping Station(LLPS)	Pumps (4 No.)	Flow is by gravity
Aeration	Cascade Aerator	Cascade Aerator
Coagulation Flocculation Sedimentation	Flash Mixer Tank Circular Flocculator (2No.)	3 rectangular units with 14 chambers
Filtration	Rapid Gravity Filter (5 No.)	Rapid Gravity Filter (3 No.)
Chemical Dosing	• Alum • Chlorine	• Poly Aluminium Chloride (PAC) • Chlorine
Clear Water Storage Capacity	1MG	2MG
High Lift Pumping Station (HLPS)	Pumps (4 No.)	Pumps (3 No.)
Transmission Pipe	36 inches	18 inches and 14 inches

Source: Compiled by Author

3.1.2 The Accra Tema Metropolitan Area (ATMA) Water Supply System

The ATMA water supply system is located in the Greater Accra region of Ghana. The Greater Accra region, though it is the smallest region, it is however the second most populated region of Ghana. It has a population density of 1204.86/km^2 (GSS, 2010). The Greater Accra region also harbours the seat of government in the capital city of Accra. The ATMA WSS supplies water to the Accra Tema Metropolitan Area located in the Greater Accra region. The New Kpong was connected to Weija Treatment Plant under the East-West Interconnection Project in 2008, thus the ATMA water supply system is made up of the Kpong and Weija Treatment Plants using an interconnected distribution network.

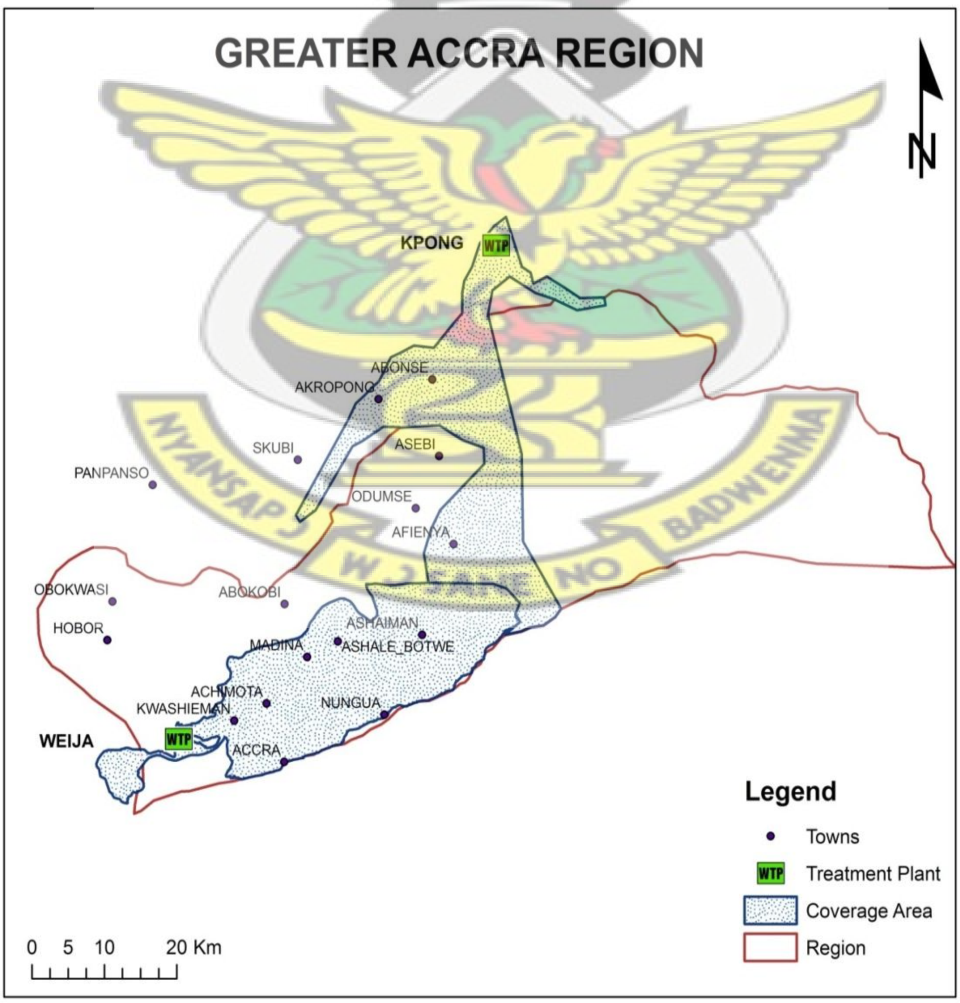


Figure 3.3 ATMA Water Supply System

- **The Kpong Water Treatment Plant (WTP)**

The Kpong water supply system is divided in two sub-systems: Kpong Old and Kpong New. The common raw water source of the two sub-systems is the Lake Volta. The Old Kpong plant was constructed in three phases, resulting in three sections namely Candy (1), Candy (2) and Pintsch Bamag sections. The three treatment units are not independent and are served by common facilities (GWCL, 2008).The ATMA Rurals Water Supply Project also expanded Old Kpong by 9million gallons per day (42,000m^3/d). Currently, there is an on-going expansion work at New Kpong by China Gezhouba Group Company Limited on a turnkey basis that will add 40million gallons of treated water per day (182,000m^3/day).

- **The Weija Water Treatment Plant**

The Weija water supply system is divided into three sub-systems: Weija-Adam Clark (Canadian-New Works), Weija- Candy and Weija-Bamag. The raw water source for the treatment plant is the Densu River which has its source in the Akwapim Hills in the Eastern Region. An earth-filled dual-purpose dam (water supply and irrigation) was constructed in 1978 to replace an older one washed away during the rainy season of July 1968. Part of the impounded water is used for irrigation in the dry season (GWCL, 2008).

Table 3.2 Description of Kpong treatment plant

Item	**Candy 1**	**Candy 2**	**Pintsch Bamag**	**New Kpong**
Year of Construction	1954	1954-1964	1960	1967
Year(s) of Rehabilitation/ Expansion	Ceased Operation in 1967. Was Reintegrated into system in 1974. Expansion by 9mgd completed in 2012.			1997 On-going Expansion
Design Capacity	1.25million gallons/ day	3million gallons/ day	3.75million gallons/ day	36million gallons/ day
RWS	Volta Lake			
Intake Pipeline	20 inches			57 inches
LLPS	4 No. Pumps			
Aeration	-	-	-	-
Coagulation Flocculation Sedimentation	Clarifiers (2No.)	Clarifiers (3No.)		Mixing Basin (1No.) Clarifiers (5No.)
Filtration	Rapid Gravity Filter (4No.)	Rapid Gravity Filter (4No.)	Rapid Gravity Filter (5No.)	Rapid Gravity Filter (10No.)
Chemical Dosing	– Alum – Lime – Chlorine			
Clear Water Storage Capacity	0.5 Million Gallons (MG)			
	1.0 MG			
HLPS				4 Pumps
Transmission Pipe	15 inches AC Pipeline			42 inches Steel Pipeline

Source: Compiled by Author

Table 3.3 Description of Weija treatment plant

	Adam Clarke	**Bamag**	**Candy**
Year of Construction	1980s	1960s	1950s
Year(s) of Expansion	2002, Expansion by 14.5mgd completed in 2008.		
Design Capacity	34.5million gallons per day	5.5million gallons per day	8.75million gallons per day
Raw Water Source	River Densu		
Intake Pipeline	42" diameter		
Low Lift Pumping Station	Deep Well Turbine (4No.)		
Aeration	Cascade Aerator		
Coagulation Flocculation Sedimentation	Mixing Chamber Clarifier (6No)	Flash Mixer Tank Circular Flocculator (2No.)	1MG Raw Water Coagulation Tank Hopper Bottom Clarifier (16 No.)
Filtration	Rapid Gravity Filter (12 No.)	Rapid Gravity Filter (5 No.)	Rapid Gravity Filter (8 No.)
Chemical Dosing	Alum, Lime, Chlorine gas/ Calcium Hypochlorite		
Clear Water Storage	Reservoir Capacity 1MG (2No.)	Reservoir Capacity 1MG	Reservoir Capacity 1MG
HLPS	-		
Transmission Pipe	(2 No.) 36 inches Pipeline to Accra Distribution (1 No.) 21 inches Pipeline to Accra Distribution		

Source: Compiled by Author

3.2 Research methodology

The method used included desk study, data collection and analysis for the selected systems.

3.2.1 Desk studies

Desk studies involved reviewing existing documents, reports, papers and journals to obtain relevant information on the subject matter.

3.2.2 Data collection

The study captured data on the systems in ATMA and Kumasi. The data collection procedure comprised review of documents, field visits and interviews. Cost data and other relevant data were obtained by reviewing documents such as annual reports, financial statements, progress reports, contract documents, Bill of Quantities (BOQs), payment certificates and GWCL's Strategic Investment Plan (SIP). Field visits were made to selected systems to identify their assets and the processes employed in producing water at the systems. In-depth interviews were conducted with relevant personnel of GWCL to obtain information on the maintenance culture of the company, financing mechanisms, common failure of assets and cost drivers of maintenance. Key personnel interviewed included the operations and asset manager, head of projects, project manager, finance managers, production managers, station managers, maintenance supervisors and technical operators. The data collected and means of collection is attached as Appendix 1.

3.2.3 Conceptual framework

Fig 3.4 illustrates the conceptual framework adapted for this study. The conceptual framework provides an understanding on recurrent cost of urban water supply.

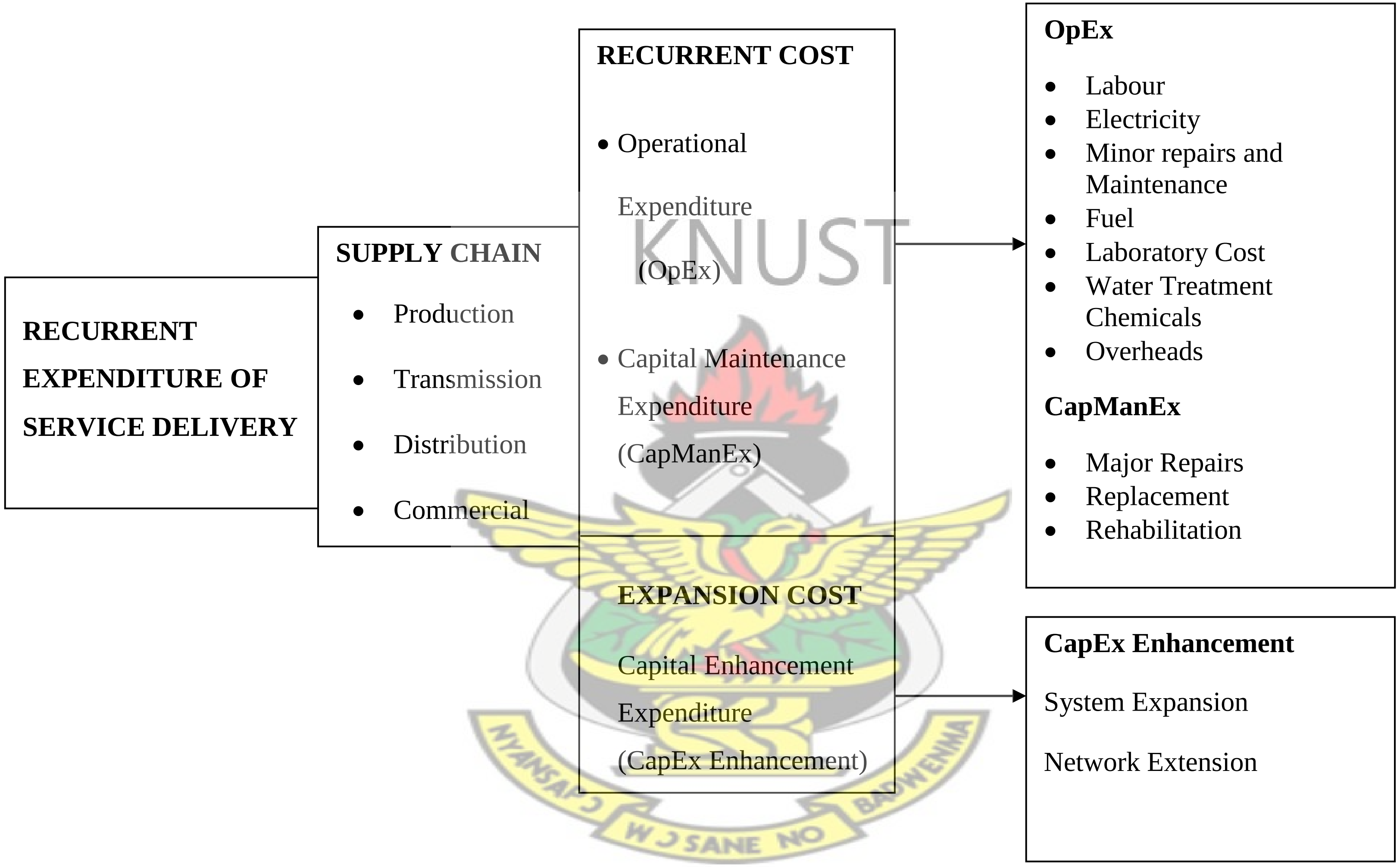


Figure 3.4 Conceptual Framework

The recurrent expenditure consists of OpEx, CapManEx and CapEx Enhancement and it occurs at all levels within the supply chain. The various components of recurrent expenditure can be disaggregated to identify their components.

3.2.4 Method of data analysis

Data covering a 5-year period (2007-2011) was used for analysis. Microsoft Excel was used to generate database on cost. All historic costs were adjusted to the current year (2011) figures using Gross Domestic Product (GDP) deflators from the World Bank. Cost in foreign currency was converted to Ghana Cedi using rates from the World Bank (World Bank, 2012).

A unit cost approach of cost per water produced (GH¢/m^3) and cost per capita (GH¢ per person) were adopted for analysis. Data was also analysed to show the relative magnitude of OpEx, CapManEx and CapEx Enhancement as a percentage of the total recurrent cost. The recurrent cost along the supply chain was determined. The components of OpEx were identified and disaggregated and their contribution to the total OpEx was determined. The recurrent cost obtained for both systems was used to determine the recurrent cost range for urban water supply. A cost comparison was also done between the two systems studied.

CHAPTER FOUR

4.0 RESULTS AND DATA ANALYSIS

4.1 Magnitude and relative magnitude of recurrent cost

The magnitude of the recurrent cost of water delivery obtained are summarised in Table 4.1. The data was collected during a period when rehabilitation and expansion projects were carried out and as such the results obtained are representative of the expenditure usually incurred on capital maintenance and enhancements at the systems. The magnitude of expenditure of capital maintenance and enhancements may vary depending on the period of data collection since they do not occur frequently at the systems. The OpEx is expenditure incurred on a daily basis and annual expenditure on OpEx is not expected to vary greatly irrespective of the data collection period.

Table 4.1Recurrent cost of water delivery (2007-2011)

	MAGNITUDE OF RECURRENT COST (GH¢/year)		UNIT MAGNITUDE OF RECURRENT COST(GH¢/m3)	
Cost	**ATMA WSS**	**Kumasi WSS**	**ATMA WSS**	**Kumasi WSS**
OpEx	43,973,375	12,359,216	0.31	0.45
CapManEx	3,720,141	1,918,401	0.03	0.07
CapEx Enhancement	29,567,492	14,134,391	0.21	0.51
Total	**77,261,008**	**28,412,007**	**0.55**	**1.03**
$1- GH¢1.51 (World Bank, 2012)				

Generally, the highest contribution to the total recurrent cost was from OpEx and the least expenditure incurred was on capital maintenance. The unit magnitude of recurrent cost has been summarised in Table 4.2. The total unit recurrent cost of Kumasi WSS was almost twice that of ATMA WSS. The difference is largely due to economies of scale.

The relative magnitude of each cost has been expressed as a percentage of the total recurrent cost and is summarised in Table 4.2.

Table 4.2 Relative magnitude of recurrent cost

RELATIVE MAGNITUDE OF RECURRENT COST			
	ATMA WSS	**Kumasi WSS**	**Average**
OpEx	57%	43%	50%
CapManEx	5%	7%	6%
CapEx Enhancement	38%	50%	44%

From Table 4.2, the average spending on OpEx is about 50% of the total recurrent cost. It is also evident that the current spending on capital maintenance is relatively low (5%-7%) as compared to spending on other recurrent cost components. Low CapManEx is typical of new systems where very few repairs and replacements have to be made. However, the systems studied were built over 50years ago and it was expected that more would have been spent on capital maintenance since they are old systems. Interviews with key personnel revealed that not much capital maintenance works have been carried out at the systems over the past decade. Low figures obtained for CapManEx is an indication of lower expenditure on capital maintenance than is required.

The total annual per capita recurrent cost for the systems are from GH¢18.19 (ATMA WSS) to GH¢21.73 (Kumasi WSS) per person. The breakdown of the per capita cost is given in Table 4.3.

Table 4.3 Per capita cost of recurrent expenditure

Cost per Capita (GH¢/person/year)	**ATMA WSS**	**Kumasi WSS**
OpEx	10.35	9.45
CapManEx	0.88	1.47
CapEx Enhancement	6.96	10.81
Total	**18.19**	**21.73**

4.2 Recurrent cost along Supply Chain

Table 4.4 shows the recurrent cost along supply chain for the systems. The table does not include the CapManEx and CapEx Enhancement for ATMA WSS because data available was not disaggregated but reported as lump sum for the supply chain.

Table 4.4 Recurrent cost along supply chain

	ATMA WSS	**KUMASI WSS**		
Cost (million GH¢/year)	**OpEx**	**OpEx**	**CapManEx**	**CapEx Enhancement**
Production	27.89	2.73	6.85	1.40
Transmission	2.73	0.28	-	0.03
Distribution	6.85	1.68	-	1.02

Figure 4.1 shows the recurrent cost of Kumasi WSS along the supply chain. OpEx, CapManEx and CapEx Enhancement exhibit a similar trend with the highest cost incurred at production and the least expenditure was on transmission.

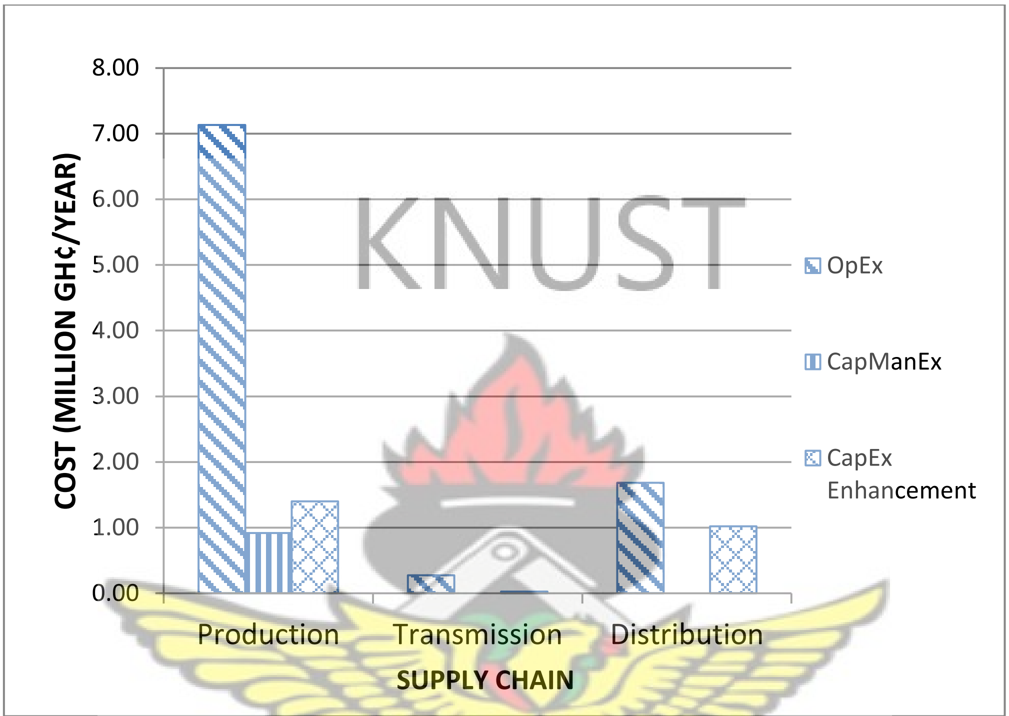


Figure 4.1 Recurrent cost along supply chain for Kumasi WSS

Rehabilitation was done only at the treatment plants hence there were no figures for transmission and distribution. Expansion work was however done for production, transmission and distribution.

4.3 Operation and Minor Maintenance Expenditure (OpEx)

The magnitude of OpEx along the supply chain was GH¢43,973,375 per year for ATMA WSS and GH¢12,359,216 per year for Kumasi WSS. The total unit cost for delivering water was GH¢0.31 per m^3 for ATMA WSS and GH¢0.45 per m^3 for Kumasi WSS. The results showed that the unit OpEx for supplying water along the supply chain was less in ATMA WSS than in Kumasi WSS. Though the unit cost obtained for the systems was affected by economies of scale, there is not much variation in the unit OpEx for the two systems. The average unit cost of water along the supply chain from 2007-2011 is summarised in the Table 4.5. Production cost gave the highest contribution to the total cost in both systems with ATMA WSS having a higher cost contribution of 63% as compared to that of Kumasi WSS (59%).

Table 4.5 Unit OpEx along supply chain

	ATMA		KUMASI	
SUPPLY CHAIN	**COST/VOL (GH¢/m^3)**	**% Contribution**	**COST/VOL (GH¢/m^3)**	**% Contribution**
Production	0.20	63%	0.26	59%
Transmission	0.02	6%	0.01	2%
Distribution	0.05	16%	0.06	14%
Commercial	0.05	15%	0.11	25%
TOTAL	**0.31**	**100%**	**0.45**	**100%**

4.3.1 Production Cost

The average cost obtained for producing one cubic meter of water was GH¢0.20 for ATMA WSS and GH¢0.26 for Kumasi WSS. Generally, production cost was lower in ATMA WSS than in Kumasi WSS due to lower chemical and electrical costs in ATMA WSS. Figure 4.2 shows the percentage contribution of the various components of production to the total production cost.

For both systems, 80% of the total cost was made up of variable cost components and 20% of the total cost was contributed by fixed cost components which for example is quite different from the experience in UK where fixed costs account for over 80% of the costs of supplying water (Armstrong et al., 1994). A high variable cost contribution implies that the total OpEx at the systems is influenced largely by the volume of water produced.

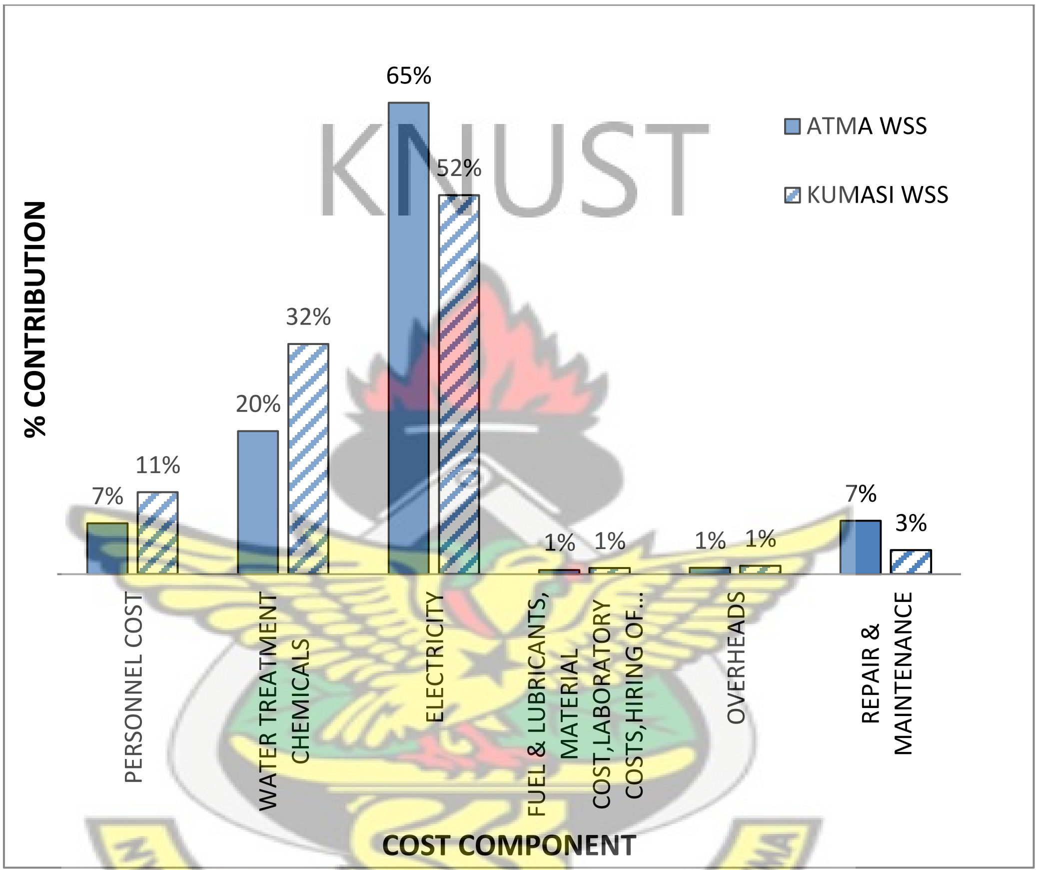
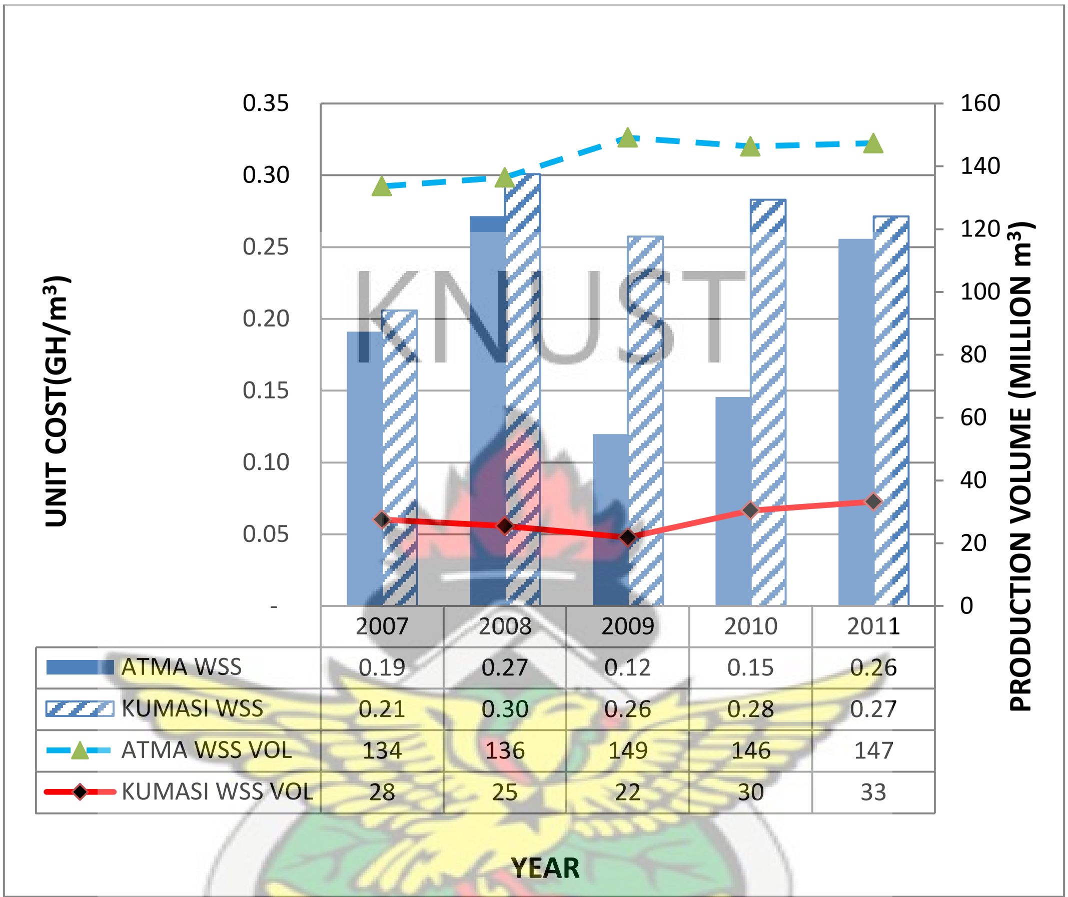


Figure 4.2 Cost components and their contribution to production

Fig 4.3 illustrates the cost pattern of production with the volume of water produced. Generally, cost of production increased with increase in production volume as expected and the unit cost decreased with increase in volume due to economies of scale. Though the volume of water produced per year in ATMA WSS was about four times that of Kumasi, the cost of production of the two systems did not differ greatly.

This suggests that ATMA is operating at a comparatively more optimum level than Kumasi WSS.



	2007	2008	2009	2010	2011
ATMA WSS	0.19	0.27	0.12	0.15	0.26
KUMASI WSS	0.21	0.30	0.26	0.28	0.27
ATMA WSS VOL	134	136	149	146	147
KUMASI WSS VOL	28	25	22	30	33

Figure 4.3 Unit production cost

The volume of water produced in ATMA WSS increased in 2009 after the completion of the East West Interconnection Project under which the capacity of Weija WTP was increased. Production was lowest at Kumasi WSS in 2009 because 2 out of 4 pumps at Barekese were working and only 1 pump was reliable. Also, due to malfunctioning of the pumps at Owabi, a number of downtime was experienced during troubleshooting to determine the cause of the problem and this contributed to the low volumes of production recorded in 2009. A number of minor maintenance works were done at both plants in that year. Motor rewinding was done at Barekese and some parts of the pumps at Owabi had to be replaced, hence it increased the cost of production. Production volume for Kumasi WSS increased in 2010 as a result of the completion of the rehabilitation and expansion work at Barekese and Owabi WTPs.

- **Cost of electricity**

The actual cost of electricity per volume of water was investigated since electricity cost was a significant component in the OpEx along the supply chain. The cost of electricity obtained ranged from GH¢0.05 to GH¢0.17 per m^3 for ATMA WSS and GH¢0.09 to GH¢0.18 per m^3 for Kumasi WSS.

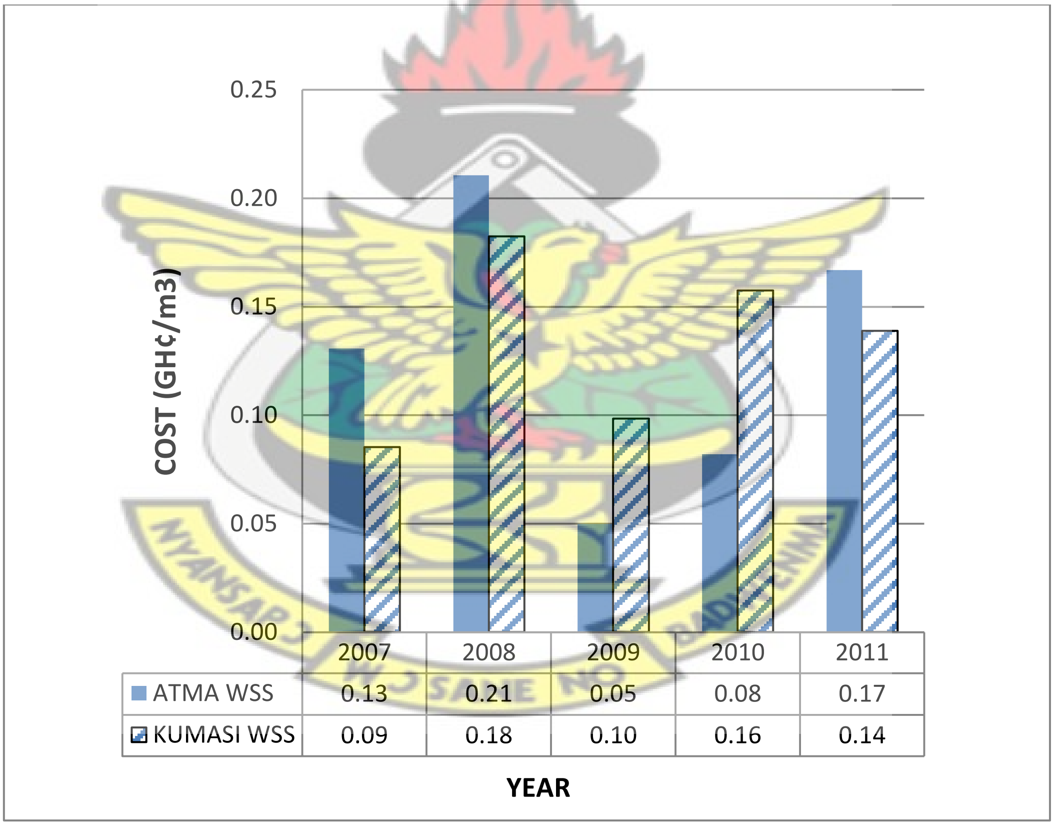


Figure 4.4 Cost of electricity in production

ATMA incurred a higher magnitude of electrical cost because the system employs the use of larger pumps. However, the average unit electrical cost for ATMA was lower than that of Kumasi WSS because more volume of water was produced at ATMA WSS. In 2008, there was an increase in unit charges per kW/h and peak load factors of electricity tariffs and this affected the electrical cost. Electricity accounted for 48% of the total production cost in ATMA WSS and 32% in Kumasi WSS and this is much lower than in US for example, where approximately 80% of municipal processing cost for water treatment and distribution are for electricity (CSS, 2012). This difference can be attributed mainly to the technology employed in treatment and distribution. Whereas the systems surveyed use conventional treatment method as is the general case in Ghana, US employs treatment methods such as reverse osmosis that are energy intensive. Water distribution for the systems studied engages less pumping and more of gravity flow as opposed to direct pumping common in the US.

- **Cost of water treatment chemicals**

Cost for water treatment in production was 20% of the total cost in ATMA WSS and 32% of the total cost in Kumasi WSS.

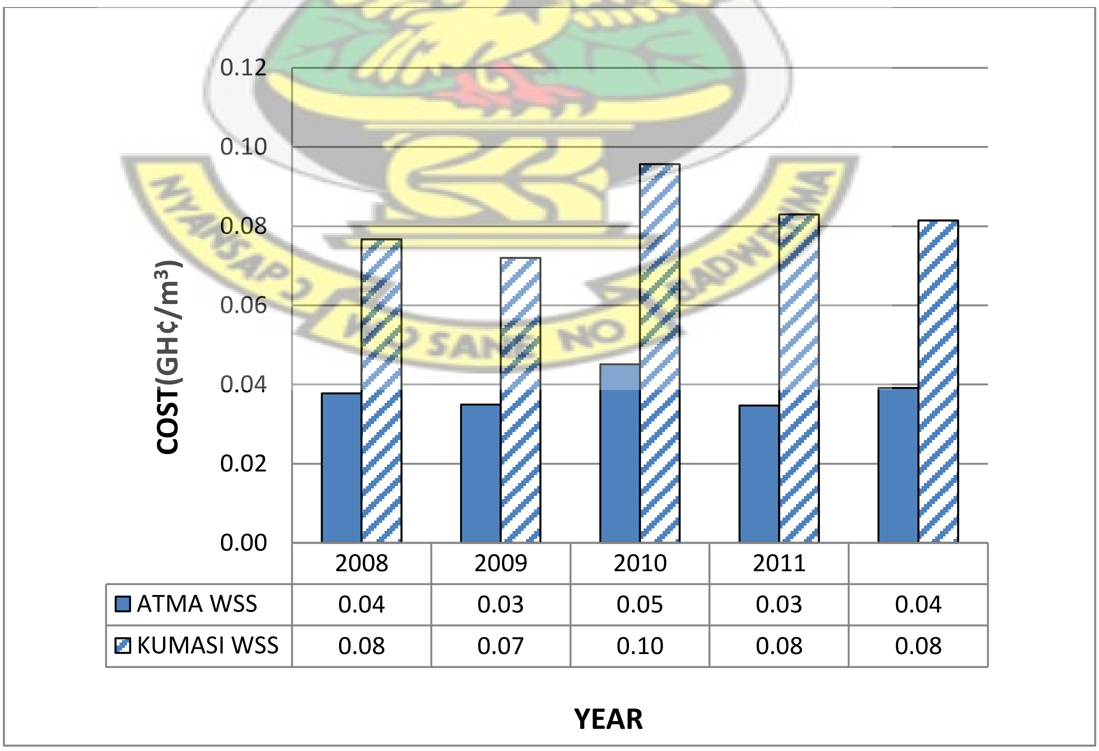


Figure 4.5 Cost of water treatment chemicals in production

The average cost of treatment chemicals for treating one cubic meter of water in Kumasi WSS was twice that of ATMA WSS (i.e. Kumasi- GH¢0.8 per m^3, ATMA- GH¢0.4 per m^3) due to relatively poorer raw water quality in Kumasi WSS than in ATMA WSS. Poor raw water quality is a challenge to Barekese, Owabi and Weija water treatment plants. Data from the survey revealed that anthropogenic activities such as farming affected the raw water quality at these systems. The quality of raw water of Owabi in particular is relatively poor and it may due to the fact that the Owabi River serves as a receptacle for runoff from Kumasi. Encroachment within the catchment of Weija treatment plant caused direct disposal of solid waste into the raw water source and may have adversely affected its raw water quality. The raw water quality at Kpong WTP is comparatively good and alum is seldom used for coagulation hence its contribution to the total cost treatment chemicals in ATMA WSS is negligible.

4.3.2 Transmission cost

The average transmission cost for ATMA WSS was GH¢0.019/m^3 as compared to GH¢0.011/m^3 obtained for Kumasi WSS. There was no transmission cost in Kumasi in 2011 because the cost was merged with that of production. Electrical cost for transmission in ATMA WSS was comparatively higher than Kumasi WSS contributing to a higher transmission cost. Electrical cost is higher in ATMA WSS because more pumping is done within the transmission network as compared to Kumasi WSS since ATMA WSS produces more water than Kumasi WSS. The topography of ATMA is generally flat and it employs the use of pumps to lift the water into overhead tanks and also to maintain adequate pressure. Thus, more energy is used in lifting the water accounting for higher transmission cost as compared to Kumasi WSS.

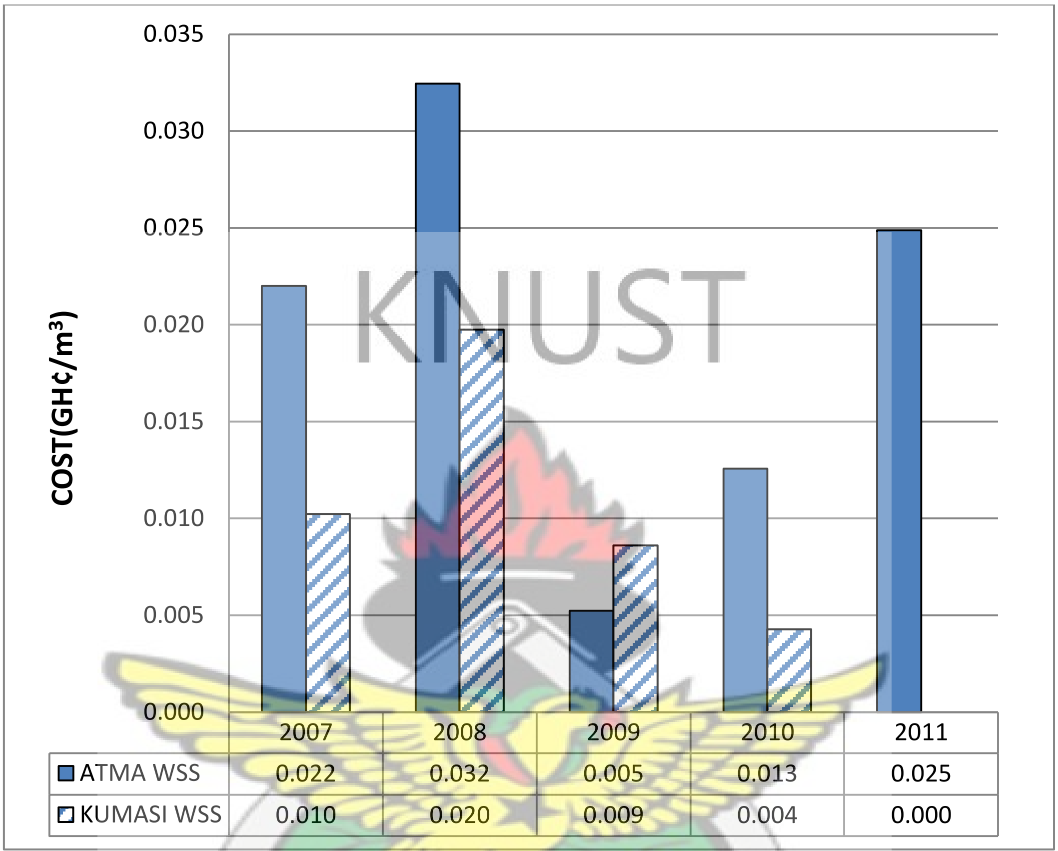


Figure 4.6 Transmission cost

4.3.3 Distribution cost

The average cost of distribution for Accra was GH¢0.048 per m^3 and GH¢0.061per m^3 for Kumasi WSS. Bulk of cost for distribution was contributed by cost of labour (47%-Accra, Kumasi-52%). Material and repair and maintenance costs were high in both Accra and Kumasi (40%- Accra, 35%-Kumasi).In Kumasi, after the completion of the rehabilitation and expansion project, more water was produced. The distribution network was extended and material cost increased. More pipe bursts were recorded because some of the pipes which had been out of service for a long time had water flowing and this increased the repair and maintenance cost.

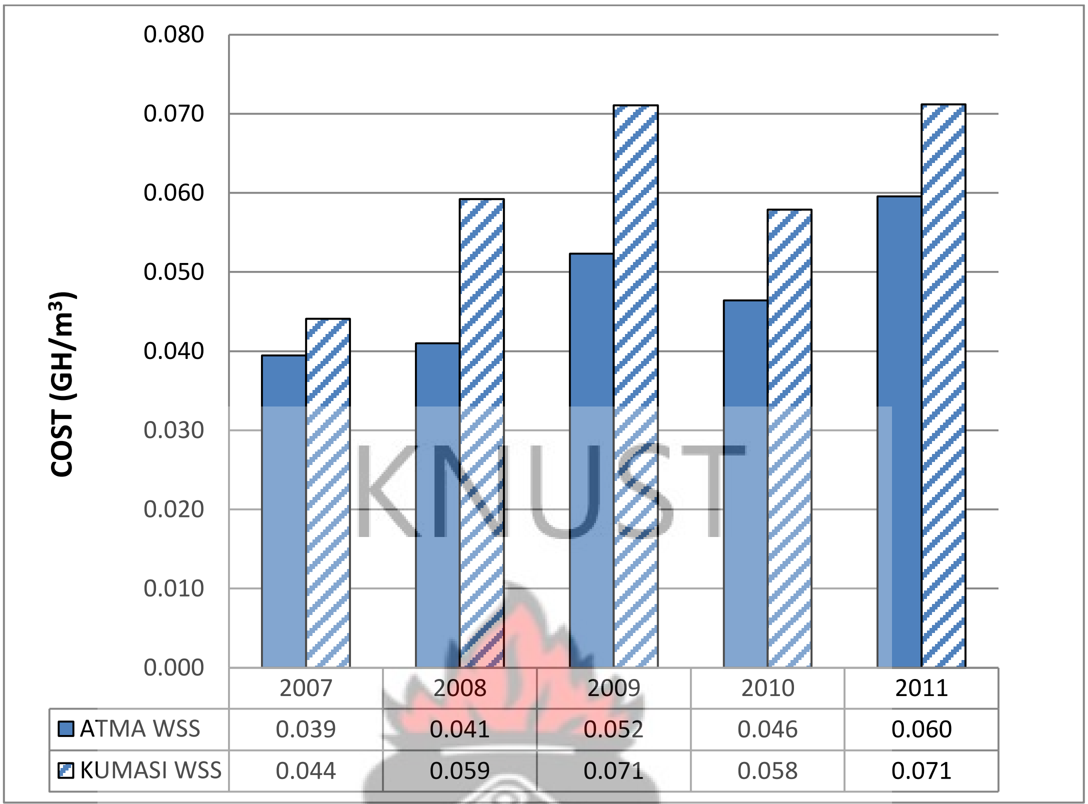
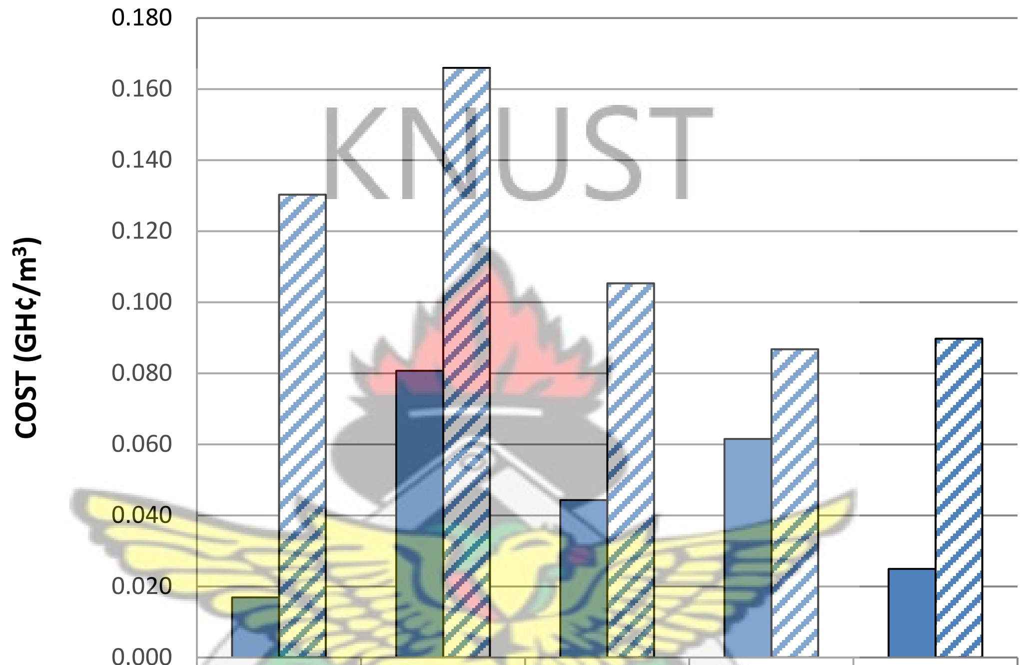


Figure 4.7 Distribution cost

The distribution network in ATMA WSS was expanded and this increased material costs. Electrical cost incurred in distribution is relatively insignificant since the flow of water in the distribution network is mainly by gravity.

4.3.4 Commercial cost

Commercial costs ranged from GH¢0.02 to 0.08 per m^3 for ATMA WSS with an average cost ofGH¢0.05/m^3. Kumasi WSS had a commercial cost range of GH¢ 0.09 to 0.17/m^3 and an average cost of GH¢0.12/m^3. The difference in commercial costs between ATMA and Kumasi was very high (0.14 higher for Kumasi).Cost of personnel accounted for almost half of the commercial cost for both areas (ATMA-46%, Kumasi-47%). Overheads also contributed immensely to the total cost in both areas. Kumasi however had a greater percentage contribution from overheads (45%) as compared to ATMA (38%). As part of overhead costs, bad debt that was incurred in both areas was huge. It accounted for 51% of the total overhead in Kumasi and 68% of the total overhead in ATMA.



	2007	2008	2009	2010	2011
ATMA WSS	0.017	0.081	0.044	0.061	0.025
KUMASI WSS	0.130	0.166	0.105	0.087	0.090

Figure 4.8 Commercial cost

4.4 Magnitude of capital maintenance and capital enhancement

Various rehabilitation and expansion works have been carried out at the systems and currently, there are some on-going works being carried out the systems under study. Table 4.6 gives a brief description of these works.

Table 4.6 Description of rehabilitation and expansion works (2007-date)

SYSTEM	PROJECT	DESCRIPTION OF WORKS
ATMA WATER SUPPLY SYSTEM	ATMA RURALS PROJECT	Expansion of WTP by 42,000m^3/d Transmission and Distribution improvements Construction of reservoirs
	EAST-WEST INTERCONNECTION PROJECT	Expansion Weija WTP by 66,000m^3/d Laying of interconnection pipelines Replacement of existing pumps at the Weija Intake and Accra Booster Station, Installation of Chlorination facilities at Accra Terminal Reservoir
	KPONG WATER SUPPLY EXPANSION PROJECT	Construction of a new 353,000m^3/d intake. Expansion of treatment plant to 250,000m^3/d Construction of new Transmission mains Distribution Improvement, Construction of Storage reservoirs Provision of dedicated electricity supply
KUMASI WATER SUPPLY SYSTEM	KUMASI WATER SUPPLY PROJECT (WSP)	Rehabilitation of Owabi & Barekese plants Expansion of WTP by 27,000m^3/d Transmission, Distribution Improvements Storage reservoirs and Booster Station
	KUMASI WSP ADDITIONAL WORK	Capacity Expansion (27,000m^3/d) Transmission, Distribution Improvements Construction of Storage reservoir Reforestation – Barekese Water Basin Supply &Install domestic/Zonal meters

The total amount used for rehabilitation works (CapManEx) in ATMA WSS was GH¢18,600,704and in Kumasi wasGH¢9,592,003. The unit magnitude of capital maintenance obtained during the period was GH¢0.13/m^3/year for ATMA WSS and GH¢0.07/m^3/year for Kumasi WSS. A total amount of GH¢147, 837,462 was used in ATMA WSS for expansion works (CapEx Enhancement) over the evaluation period and the amount used for expansion works in Kumasi WSS was GH¢70,671,952.67 (CapEx Enhancement). A unit magnitude for CapManEx obtained for ATMA WSS was GH¢1.04 per m^3/year and for Kumasi was 0.51 per m^3/year.

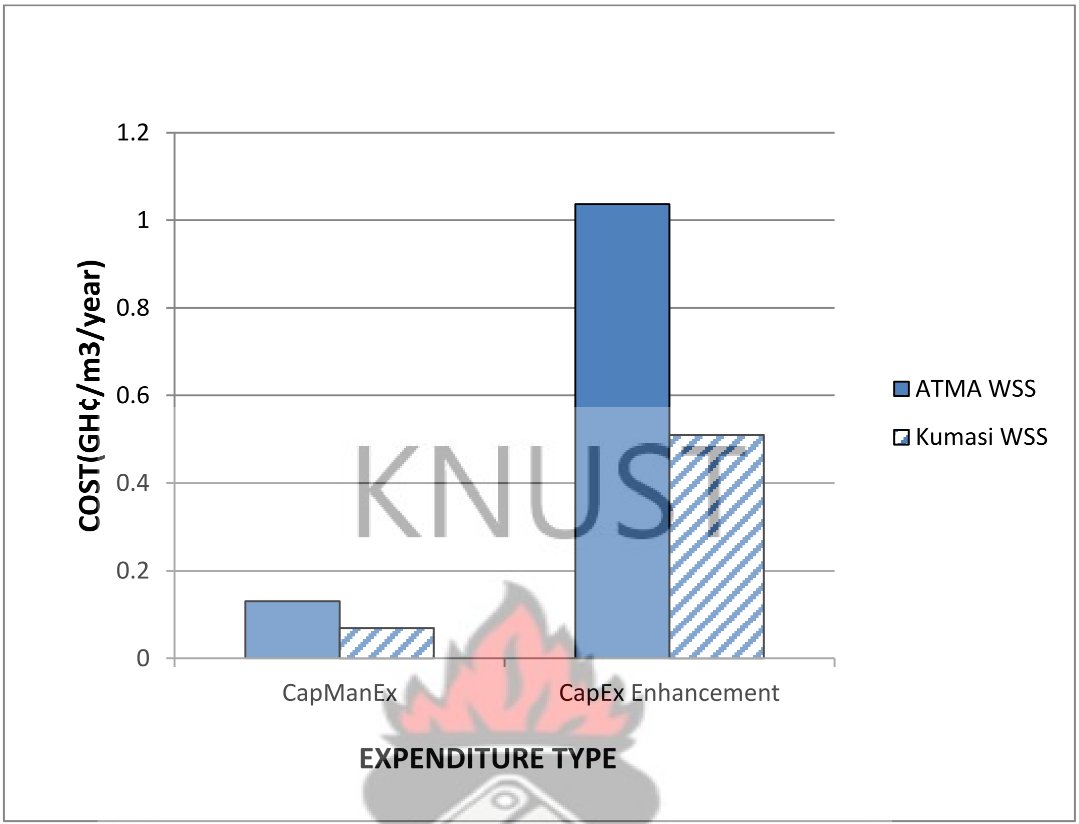


Figure 4.9 Expenditure on capital maintenance and capital enhancement

More was spent in carrying out rehabilitation and expansion works at ATMA WSS as compared to Kumasi WSS and this may be due to the larger size of that system than the Kumasi WSS.

4.5 Maintenance practice at GWCL

There was the need to consider the maintenance culture at GWCL's systems in order to have a better understanding of the factors that may influence the cost of maintenance. A qualitative assessment was done because there was not enough data available to quantify the factors that influence the cost of capital maintenance. Information was obtained mainly from interview with key personnel of the company.

GWCL has an asset register with standard components such as asset code, asset description, asset location, age. However, the last time the asset register was updated was in the 1990's. The company has a maintenance policy, which considers routine maintenance of plant and equipment and minor replacement of parts. The maintenance policy, however, does not consider capital maintenance of the systems. The survey revealed that maintenance at the systems is done in two main forms namely: 1. Preventive Maintenance 2. Breakdown maintenance

- **Preventive Maintenance:** These are regular maintenance carried out on components of the plant such as pipes, reservoirs, civil structures, pumps, and other electromechanical equipment to ensure that they function according to design. This form of maintenance falls under OpEx. Well-structured preventive maintenance programmes with accompanying schedules are adhered to rigidly. Operational manuals from manufacturers are normally re-written in a simplified form for use by the technical operators of the system. Maintenance schedules in the form of charts are displayed at the treatment plant for easy access by the maintenance team.
- **Breakdown Maintenance:** These are maintenance activities carried out as a result of a breakdown or failure of some part. If the breakdown requires a minor component repair it is considered under OpEx and if the breakdown requires a major component repair it is considered under CapManEx.

Spare parts are provided with the purchase of new equipment. These parts are kept at the Central Stores and requisition is made for them when there is the need for replacement of parts. GWCL has two workshops namely Central Stores for the southern sector and Base Workshop for the Northern Sector. At times, there is the need for fabrication of some parts and this is done at GWCL's Base Workshops.

- **Personnel for Executing Maintenance**

GWCL has personnel who perform maintenance and they include operators, maintenance officers. These personnel are well trained to carry out routine maintenance and minor repairs. There are maintenance supervisors who ensure that proper maintenance is carried out at the systems.

- **Planning and Budgeting for Maintenance**

Planning for maintenance is done at the district, regional and head office levels within GWCL on a yearly basis. The systems draw a maintenance program outlining daily, weekly and monthly activities that are to be done within the year. The maintenance requirements for the head works and districts are outlined and sent to the regional office. The regional office sends a budget to the head office for approval. The scheduled maintenance works are carried out according to the plans for the year. There is no policy for capital maintenance of the systems, only that the Strategic Investment Plan (SIP) of GWCL for 2007-2025 gives an idea of the needed investment required for rehabilitation and expansion of the GWCL's systems in order to meet water demand targets. However, it is inadequate to serve as a policy because it does not outline strategies and actions to be taken to achieve these targets.

- **Financing of Capital Maintenance Works**

Generally, financing Capital Maintenance Works is a huge challenge for the urban water utility. This is because there is no working reserve fund to carry out these works. GWCL is able to generate funds internally through revenue collected from customers. However, unaccounted for water is high, 58% in Greater Accra region and 36% in Ashanti region as at 2010. This means that less revenue is obtained than it is expected. Since revenue generated is low, it is unable to cater for all the operation and maintenance activities of the company and there is no reserve fund to finance all capital maintenance works. The Government of Ghana (GoG) gives some allocation for urban water and this is used for system extension and some maintenance works. Asset maintenance, therefore, is a huge burden on the urban water service provider. GWCL/GUWL has a challenge in performing the large capital maintenance works. This is due to inadequate funding from internally generated funds and donors. Huge capital maintenance works are financed by primarily through concessionary loans. The process involved in securing funding through concessionary loans is lengthy. Work requiring huge capital investment is funded by loans and grants obtained from foreign bodies secured by the GoG. GoG finances all Capital Investments of the systems.

4.6 Factors influencing capital maintenance expenditure

Ideally, it would have been appropriate to identify the factors influencing capital maintenance expenditure both qualitatively and quantitatively. However, due to inadequate available data, a qualitative approach was adopted. Factors influencing capital maintenance expenditure were identified from interviews with key personnel of GWCL/GUWL. These factors were identified from two perspectives namely:

1. Factors that influence the magnitude of expenditure
2. Factors that influence the magnitude and frequency of capital maintenance works

- **Choice of credit facility**

The interviews with experts revealed that two options are available for financing capital maintenance works in Ghana. They are cash and debt financing. Due to unavailability of reserve funds for capital intensive maintenance, GWCL resorts to debt financing for some capital maintenance work. Interest charged on the loan influence the magnitude of CapManEx. GoG pays more for the works carried out than it would have paid if it had financed the works through cash financing.

- **Use of foreign expertise**

Some capital maintenance works require a high level of technical expertise and the use of complex equipment and technologies. Where the technicality and magnitude of works is high, foreign companies are used in performing capital maintenance works in the Urban Water Sector because they are more experienced in carrying out huge maintenance works. These companies charge rates in their national currency and for their service. Since these personnel are expatriates, their charges include accommodation and feeding and this increases the total contract price. Table 4.7 shows contract prices of completed and on-going projects within the study area.

Table 4.7 Profile of capital intensive projects

CONTRACTOR	PROJECT	COUNTRY	AMOUNT
Tahal Consult	ATMA Rurals Water Supply Project	Israel	€71million
Ballast Nedam B.V	Barekese Rehabilitation and Expansion Project East West Interconnection Project	Netherlands	€37million €32million
China Gezhouba Group Company Ltd.	Kpong Expansion Project	China	US$287million

Source: GWCL

- **Size of system/ treatment plant**

Systems with higher design capacities had a higher magnitude of CapManEx. For instance, the CapManEx obtained at ATMA WSS was higher than Kumasi WSS.

The size of the treatment facility also influenced the magnitude of CapManEx. The CapManEx for Barekese WTP (24 million gallons) was higher than that of Owabi WTP.

Table 4.8 Comparison between CapManEx and size

Item	Size (Production Capacity)	CapManEx(GH¢/year)
ATMA WSS	103 million gallons	3,720,141
Kumasi WSS	27million gallons	1,918,401
Barekese WTP	24million gallons	1,517,189
Owabi WTP	3million gallons	39,881

- **Age of system**

As the components of the system ages, the asset and their components wear out and have to be repaired or replaced. Very old systems are less robust and usually need more repairs and replacements. Sometimes, their parts are obsolete and thus it is necessary to replace them with parts readily available on the market. This may require changing of certain components to accommodate for the new replacement.

- **Delay in carrying capital maintenance**

From the survey, it was realised that delaying repairs and replacements influences the cost in two ways;

1. Postponed repairs and maintenance accumulates in number and magnitude and contributes to a more complex problem.
2. Cost of maintenance changes due to the time value of money

Reasons given for delay in executing capital maintenance work at the systems include lengthy tendering procedure, unavailability of funds and unavailability of spare parts. For instance, GWCL's Strategic Investment Plan (SIP) outlines the investment requirements for rehabilitation and expansion work that need to be carried out at their systems as at 2008. Since funds for their execution are not readily available, most of the works are still pending and their cost keep on increasing with time.

- **Erratic power supply/ power surges and outages**

All the systems surveyed use power from the National Grid as their only source of energy. Ghana has been experiencing frequent power outages and power surges lately and this probably has increased the number of failure of some equipment and parts. Usually, when power supplied surges and is erratic, it causes the breakdown of certain equipment and thus the need for their repair and replacement increases. For instance, in 2009, two low lift pumps at Barekese developed faults as a result power outage. In 2010, the 3.3kV cables that supply the high lift pumps at Barekese WTP exploded and cables at Achiase booster station got burnt due to power fluctuation. Power fluctuation also caused a breakdown of the alum injection pump that same year. At the time of survey, one of the high lift pumps at Barekese had broken down due to power surges.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusions

The following conclusions are drawn from the study:

- OpEx is the highest recurrent expenditure and receives more priority than CapManEx and CapEx Enhancement in the company.
- GWCL is able to plan and make budgetary allocation for operations and minor maintenance activities yearly. Regular scheduled maintenance is performed at the systems satisfactorily.
- Operation and minor maintenance works and minor expansion of the system are funded by internally generated funds and budgetary allocations from GoG. Major works such as CapManEx and CapEx Enhancements are financed primarily through concessionary loans. However, usually there is delay in executing such works since the process of acquiring concessionary loans is lengthy.
- CapManEx for the systems was much lower than other recurrent expenditure and this may be an indication of less spending than is required. The systems were built about 5 decades ago and less spending on capital maintenance may result in rapid deterioration of the assets and service delivery.
- The company has no documented policy for carrying out capital maintenance and enhancements at the systems. GWCL’s SIP gives an idea of the needed investments within the utility but it does not give a clear picture of the current specific investment needs such as CapManEx of the company.

- Records for capital maintenance and enhancements were not properly organised and inadequate. Thus, there was not enough data available to quantify the factors that affect the cost of capital maintenance.
- It was realised from the Key Informant Interviews that the choice of credit facility, the use of foreign expertise, the size of treatment facility, deferred maintenance and erratic power supply affect the magnitude of CapManEx at the systems.
- The asset register of the company is out-dated and does not give a good account of GWCL's current assets. The practice of asset management is not well developed within the company.

5.2 Recommendations

- It is recommended that the company updates its asset register to reflect the current state of its assets. GWCL's SIP should also be updated regularly to reflect current investment needs of the water supply systems. A policy for capital maintenance if developed may also help in planning for capital maintenance of GWCL's assets. In order to improve asset management in GWCL, a proper asset management plan must be developed and adhered to by the company.
- Database on capital maintenance works should be improved so that a good historical cost data will be made available to be able to determine current levels of maintenance and make projections for future maintenance needs.
- It is imperative to increase spending on CapManEx. GWCL must explore other ways of financing CapManEx and other infrastructure investment requirements to ensure that repair works are carried out in a timely manner.

Other forms of obtaining funding for capital intensive works should be investigated.

- Since OpEx is high it is necessary that the company must put in place measures to increase its revenue base in order to make available financing for OpEx. GWCL should also identify possible measures to reduce OpEx especially chemical and energy cost.
- Further research should be carried out to identify and quantify the factors that influence CapManEx in urban water supply systems.

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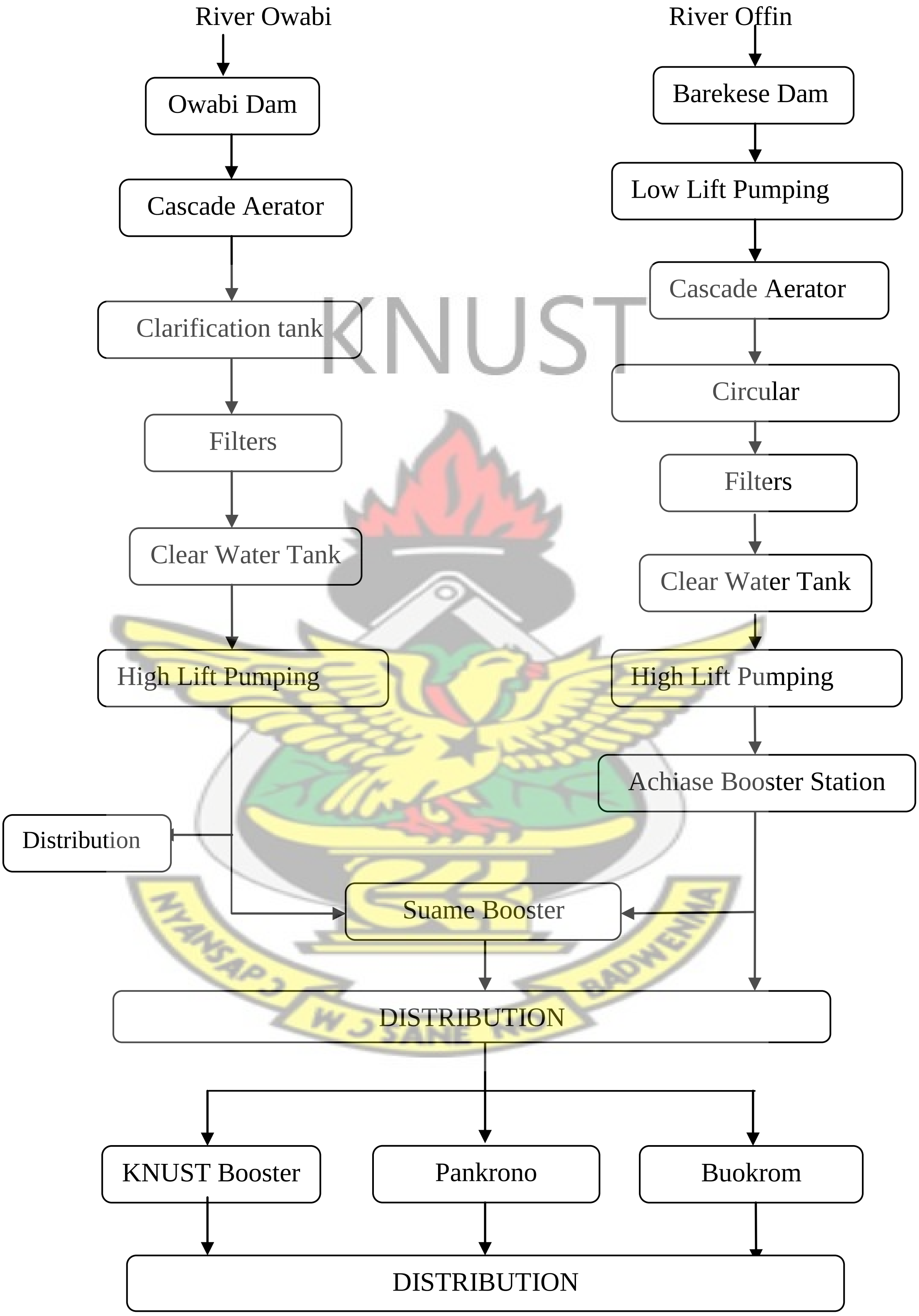
APPENDIX 1 DATA COLLECTED AND THEIR SOURCES

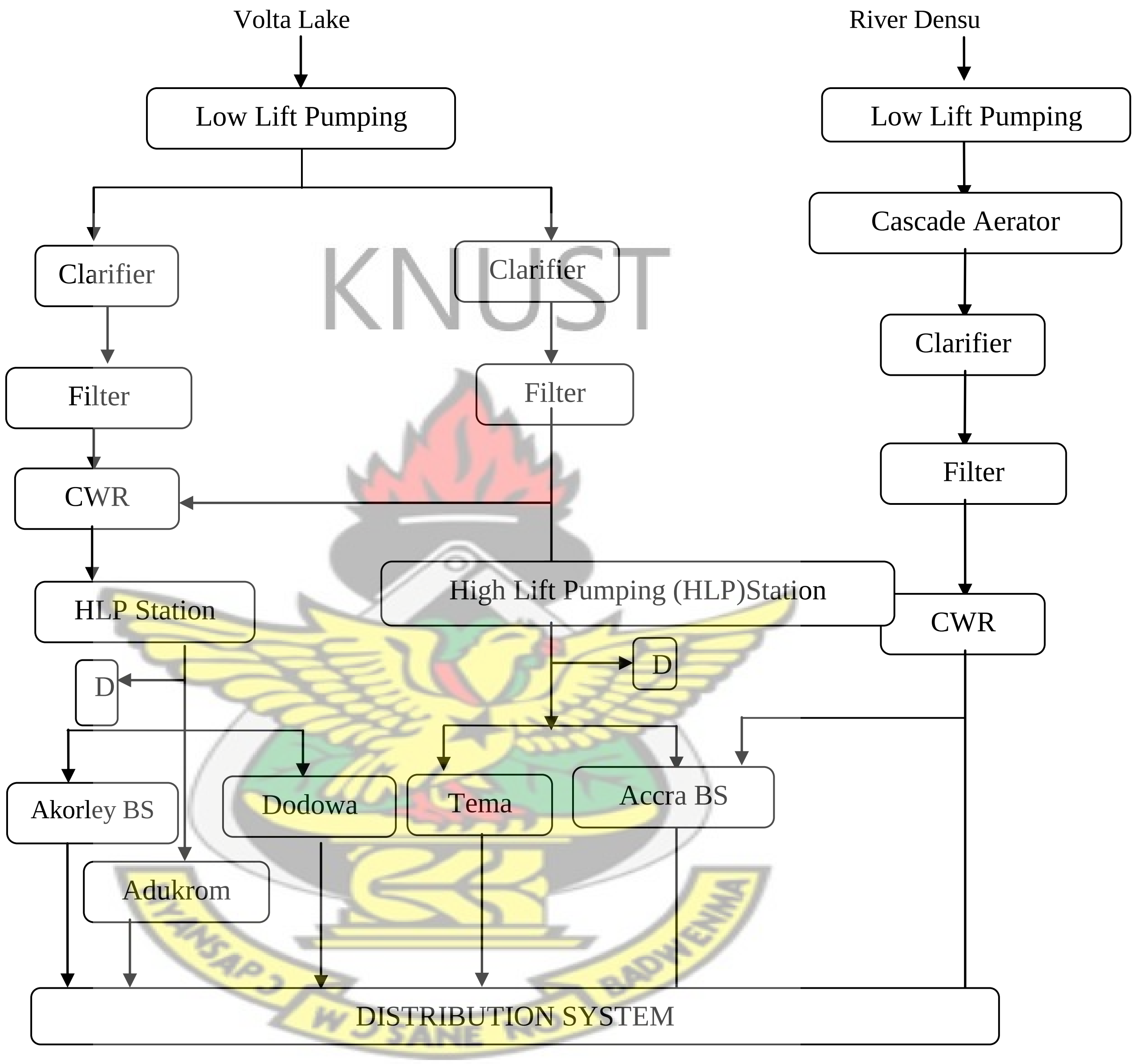
Data Type	Source of Data	Means of Data Collection
System components and characteristics (asset categorisation, age, technologies employed, source of energy,)	Existing documentation Managers System Operators	Review of existing documents Interviewing the managers and technical operators of the systems
System Performance (Installed Capacity, Production Capacity, Types of failure of system, Causes and consequences of failure, Frequency of failure)	Existing documentation Managers System Operators	Review of existing documents Interviewing the managers and technical operators of the systems
Disaggregated expenditure along the supply chain (personnel costs, material costs, laboratory costs, energy costs, other O&M costs)	Annual reports, quarterly reports, monitoring and evaluation sheets	Review of the annual, quarter and monitoring reports,
Rehabilitation and Expansion Works and Costs	Contract documents Progress Reports	Review of the documents
Asset Management Practices (Maintenance Culture, Record Keeping, Asset Management Planning, Existing policies, Resources available, Budgeting, CapManEx Constraints)	Managers System Operators	Interviewing the managers and technical operators of the systems

APPENDIX 2 TREATMENT AND SUPPLY SCHEME FOR KUMASI WATER SUPPLY SYSTEM



APPENDIX 3TREATMENT AND SUPPLY SCHEME FOR ATMA WATER SUPPLY SYSTEM

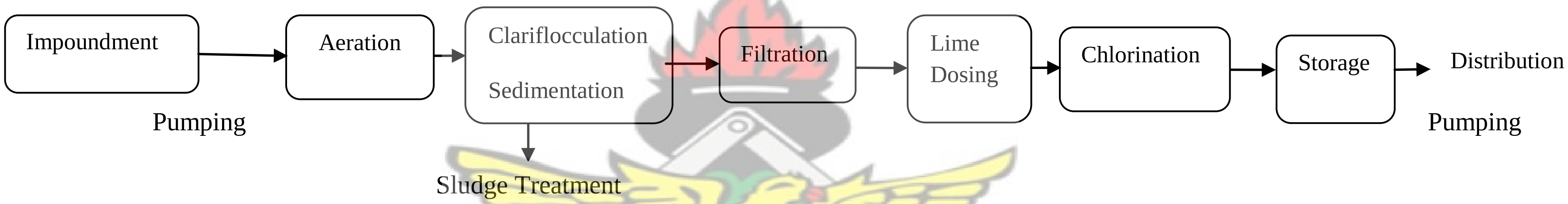
OLD KPONG NEW KPONG WEIJA



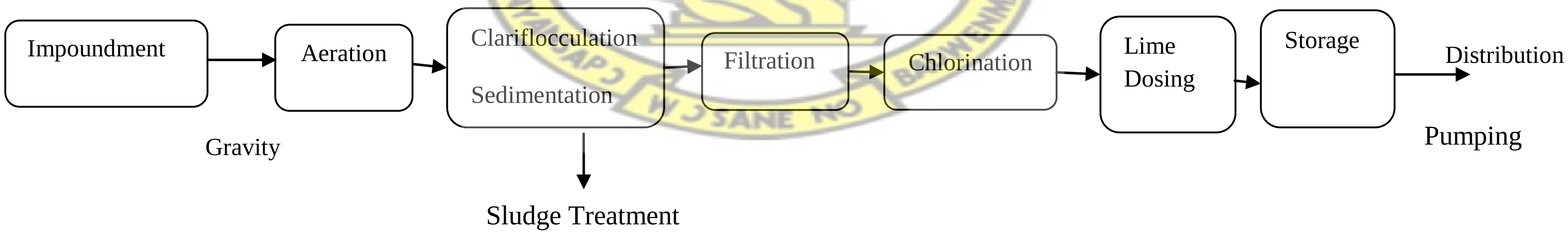
*D- Distribution

APPENDIX 4 PROCESS FLOW FOR KUMASI WSS

PROCESS FLOW FOR BAREKESE TREATMENT PLANT

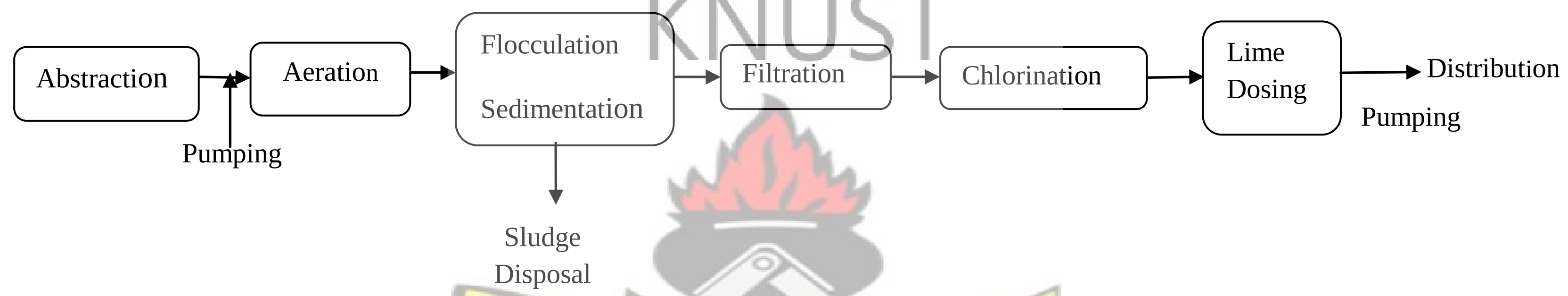


PROCESS FLOW FOR OWABI TREATMENT PLANT

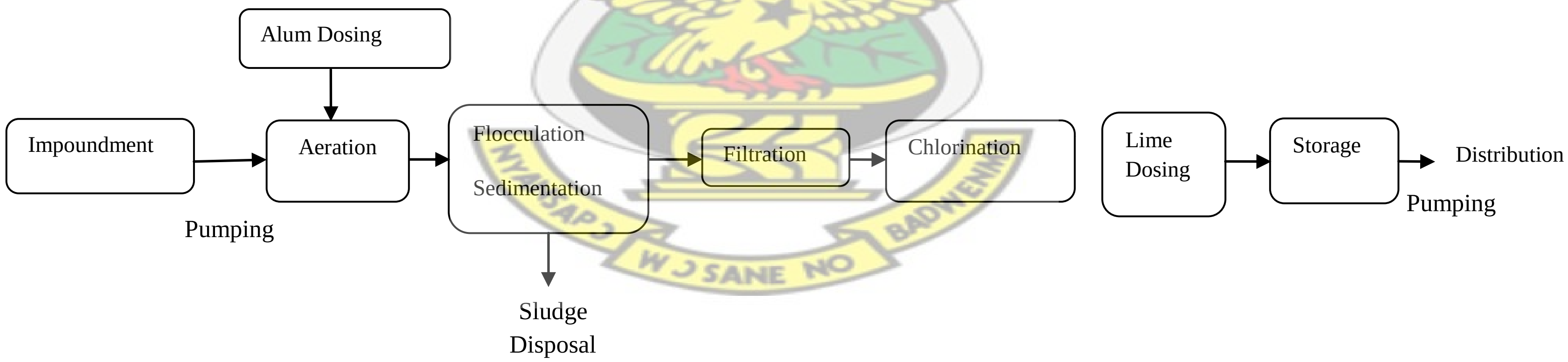


APPENDIX 5 PROCESS FLOW FOR ATMA WSS

KPONG TREATMENT PLANT



WEIJA TREATMENT PLANT



APPENDIX 6 QUESTIONNAIRE FOR KEY INFORMANTS

NAME:

POSITION:

1. Does GWCL have a way of classifying the water infrastructure/assets?

2. I would like to know how GWCL Asset Management Plan is managed.
    - History
    - Centralised or decentralised
    - How often is it updated
    - Is the plan followed

3. How are the following assets maintained at GWCL?

- pumps
- panels
- pipelines
- civil structures
- water reservoirs and tanks
- other electro-mechanical equipment

4. Do you have any specific policy when it comes to the maintenance of the following assets?
    - pumps
    - panels
    - pipelines
    - civil structures
    - water reservoirs and tanks
    - other electro-mechanical equipment

5. What would you consider as the common cause of failure of the following assets?

Asset	**Cause(s) of failure**
Pumps	
Panels	
Pipelines	
Civil structures	
Water reservoirs and tanks	
Other electro-mechanical equipment	

6. Is there any policy for the replacement of the following assets?

- pumps
- panels
- pipelines
- civil structures
- water reservoirs and tanks
- other electro-mechanical equipment

7. If yes, is it adhered to?

8. What are the challenges faced in the replacement of the under listed assets?

- pumps
- panels
- pipelines
- civil structures
- water reservoirs and tanks
- other electro-mechanical equipment

9. Is asset maintenance predictive or reactive?
10.

Assets	Useful life (yrs)	Number Of breakdown/yr.	Method of disposal	Planned rehabilitation	Planned replacement
Pipelines					
Boreholes					
Pumps					
Concrete structures					
water reservoirs and tanks					
electro-mechanical equipment					

11. What are the challenges faced in the replacement of the under listed assets?

- pumps
- panels
- pipelines
- civil structures
- water reservoirs and tanks
- other electro-mechanical equipment

12. What are the consequences of failure of the following assets?

- pumps

- panels
- pipelines
- civil structures
- water reservoirs and tanks
- other electro-mechanical equipment

13. What are the challenges faced in the replacement of the under listed assets?
    - pumps
    - panels
    - pipelines
    - civil structures
    - water reservoirs and tanks
    - other electro- electro-electro-mechanical equipment

14. What is the cost incurred in repairing the following assets?
    - pumps
    - panels
    - pipelines
    - civil structures
    - water reservoirs and tanks
    - other electro-mechanical equipment

15. Are there any other costs (social, environmental, etc.) that are associated with failure of these assets?

16. How is performance of the systems measured?

Capital maintenance expenditure (CapManEx) refers to the (occasional) costs of renewing (replacing, rehabilitating, refurbishing, restoring) assets in order to

ensure that services continue at the same level of performance that was first delivered.

17. What are the major issues confronting the urban water supply sector and its regulator with respect to Capital Maintenance needs?

18. What are the ways of by which information can be acquired in order to deliver adequate capital maintenance?

19. Is there enough information to inform decisions on CapManEx?

20. Is there an existing framework that establishes an appropriate way to carry out capital maintenance?

21. What are the cost implications in ensuring adequate CapManEx?

22. Who pays for the cost incurred in executing adequate CapManEx?

23. Whose is responsible for performing Capital Maintenance of the systems?

24. What are the challenges in addressing Capital maintenance?

25. In your view how can the challenges be addressed?

SYSTEM:
NAME:
POSITION:

ASSET CATEGORY	NO./ LENGTH	TYPE	STATUS	CAPACITY	NUMBER	YEAR OF CONSTRUCTION	YEAR(S) OF REHABILITATION	PLANNED REHABILITATION	CHALLENGES IN PERFORMING REHABILITATION	YEAR(S) OF EXPANSION
RAW WATER INTAKE										
• Low lift Pump										
• Pump 1										
• Pump 2										
• Pump 3										
• Pump 4										
• Raw Water Mains										
• Clear Water Reservoir										
• Control Panel										
TREATMENT PLANT										
• Aerator										
• Clarifier										

• Filter										
• Disinfection Chamber										
• Clear Water Tank										
Backwash Pumps										
TRANSMISSION										
• High Lift Pumps										
• Pump 1										
• Pump 2										
• Pump 3										
• Pump 4										
• Clear Water Transmission Mains										
• Clear Water Reservoir (CWR)										

SYSTEM: **NAME:** **POSITION:**							
ASSET CATEGORY	**CURRENT PERFORMANCE (SCALE 1-5) 1-POOR 5-EXCELLENT**	**OBSERVED USEFUL LIFE**	**COMMON TYPES OF FAILURE**	**CAUSES OF FAILURE**	**FREQUENCY OF FAILURE (/YEAR)**	**CONSEQUENCE(S) OF FAILURE**	**COST OF REPLACEMENT**
RAW WATER INTAKE							
• Low lift Pump							
• Pump 1							
• Pump 2							
• Pump 3							
• Pump 4							
• Raw Water Transmission Mains							
• Clear Water Reservoir							

• Control Panel								
TREATMENT PLANT								
• Aerator								
• Clarifier								
• Filter								
• Disinfection Chamber								
• Clear Water Tank								
TRANSMISSION								
• High Lift Pumps								
• Pump 1								
• Pump 2								
• Pump 3								
• Pump 4								
• Clear Water Transmission Mains								
• Clear Water Reservoir								

APPENDIX 7 ASSET CLASSIFICATION

Asset Category	Asset Example
Pipelines	Transmission pipes, distribution pipes
Water Storage Structures	Dam, Clear Water Tanks, Reservoirs
Civil Structures	Filter bed, Aerator
Pumps	Intake Pumps, High Lift Pumps, Inline Booster Pumps, Chemical Dosing Pumps.
Power	Panels, Cables, Transformer

Asset	Asset Location
Pipelines	Intake, Treatment Plant, Transmission, Distribution
Clarifiers	Treatment Plant
Reservoir	Treatment Plant, Distribution system
Pump	Intake, Treatment Plant, Distribution system
Panels	Treatment Plant, Distribution