PREFEASIBILITY STUDY FOR THE DEVELOPMENT OF THE KOKUMA FALLS FOR SMALL HYDROPOWER GENERATION

BY

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DECLARATION

I hereby declare that this submission is my own work towards the MSc. in Renewable Energy Technologies 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.

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ABSTRACT

Electricity production from hydropower has been, and still is today, the first renewable source used to generate electricity. In 2011, the global share of electricity was 20% and in the EU, the share was 21%.

The prospects of harnessing the hydro-electric potential of small rivers in Ghana have been investigated for over 20 years, leading to the identification of many potential mini hydro sites.

The purpose of this research work is to conduct a prefeasibility study of the Kokuma Falls, on the Dum River, to identify a preliminary assessment of its technical and financial viability for hydro power generation.

The head of the fall was established by the use of a total station and a staff with the assistance of a surveyor. Hydrological analysis was conducted using rainfall and temperature data obtained for Kintampo from the Meteorological Services Department of Ghana. This data was analysed using the water balance method.

The results indicate that the project is technically viable with a head of 23 m and a discharge of 0.30 m^3/s. The Run of the River Scheme with a Cross-Flow Turbine was determined to be ideal for this project. The potential firm capacity was 57 kW with an annual energy generation of 399,456 kWh/yr.

The financial viability of the project was assessed using the RET Screen software. The project is financially viable with an initial cost of the project was $253,000.00, a positive Internal Rate of Return (IRR) before tax for equity and assets of 21.9% and 6.8% respectively. The equity and simple payback period is 5.1 years and 8.8 years respectively. However for a discount rate of 10% and above, the NPV is negative in which case the project becomes not viable.

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ABBREVIATIONS

CO_2	Carbon Dioxide
ECOWAS	Economic Communities of West African States
ECREE	Centre for Renewable Energy & Energy Efficiency
EIA	Environmental Impact Assessment
EMR	Energy, Mines and Resources
EU	European Union
GDP	Gross Domestic Product
GPS	Global Positioning System
KITE	Kumasi Institute of Technology and Environment
kW	kilo Watt
MW	Mega Watt
NED	Northern Electrification Department
O&M	Operation and Maintenance
PHS	Pumped Hydroelectric Storage
REN21	Renewable Energy for the 21^{st} century
SHEP	Self Help Electrification Programme
SHP	Small Hydropower Plants
UNEP	United Nations Environmental Programme

UNESCO	United Nations Educational, Scientific and Cultural Organization
UNIDO	United Nations Industrial Development Organization
US	United States
VRA	Volta River Authority
WBCSD	World Business Council for Sustainable Development

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

The demand for energy is increasing day by day with the growing industry and living standards of people (Aydin, 2010). A number of countries already produce very high shares of electricity from renewables, mainly from hydropower in most countries. REN21 in 2013 reported that developing countries will face a number of development pressures in the future that renewable energy can address. Electricity production from hydropower has been, and still is today, the first renewable source used to generate electricity. In 2011, the global share of electricity was 20% and in the EU, the share was 21% (REN21, 2013). Nowadays hydropower electricity in the European Union - both large and small scale – represents, according to the White Paper, 13% of the total electricity generated, so reducing the CO_2 emissions by more than 67 million tons a year. But whereas the conventional hydro requires the flooding of large areas of land, with its consequential environmental and social issues, the properly designed small hydro schemes are easily integrated into local ecosystems. (Tafazoli and Budsweit, 2011).

The prospects of harnessing the hydro-electric potential of small rivers in Ghana have been investigated in Ghana for over 20 years, leading to the identification of many potential mini hydro sites in the country (Dernedde and Ofori-Ahenkorah, 2002). Since the 1970's new surveys have been carried out systematically whilst information of existing reports have been updated. In spite of the existence of the numerous reports and an apparent interest in the development of the mini-hydro technology in the country, not a single small hydro plant has been constructed so far. The Likpe Kukurantumi mini-hydro project which was initiated in the 1980's was abandoned midway for unexplained reasons. (Dernedde and Ofori-Ahenkorah, 2002). There has also been some basic level of studies at other potential sites such as the Kintampo Falls, Fuller Falls, Kokuma Falls and even the Barekese Water Treatment Dam.

The country has only resorted to the use of thermal generation to supplement the existing installed capacities from the two main hydropower plants, the Akosombo and the Kpong Plants.

1.2 Problem Statement

The expansion of the Ghanaian economy has led to an increasing demand for energy for manufacturing, mining and communication sectors of the economy. There is an increase in domestic energy requirements due to urbanisation and also the connection of rural communities to the National Grid under the Self Help Electrification Programme (SHEP).

The annual increase in demand is 200MW (Ministry of Energy, 2010) with a current installed capacity of 2,169 MW (46% thermal). The country has resorted to the development of thermal plants to meet the increase in the demand for energy. This however, comes with an increased cost of production as a result of the high cost of crude oil and irregular supply of gas. There is also the issue of increased Green House Gas emissions.

It has become necessary for Ghana to research into and direct its attention from the thermal plants to more economically sustainable and environmentally friendly sources of electricity generation.

1.3 Objectives

1.3.1 Main Objectives

The main objective of this thesis is to conduct a prefeasibility study for the development of Kokuma Falls for hydropower generation.

1.3.2 Specific Objectives

1. Determination of head and collection of flow data to establish available discharge

2. Determination of scheme type based on topographical and geological investigations

3. Determination of turbine option, potential firm capacity, power and annual energy generation.

4. Establish the financial viability of the scheme

1.4 Justification

Small hydropower development presents a very reliable and sustainable source of energy due to its low operating and maintenance cost. It also has a relatively better advantage over the large hydro plants due to:

1. Minimum or no resettlement of communities within the project area

2. Minimum disturbance to the environment

3. Minimum change in the land use of the area

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Ghana and the Energy Sector

2.1.1 Electricity and National Economy

Electricity consumption in a nation is one of the main indicators showing the level of overall development (Kaygusuz, 1999). Electricity accounted for 8.4% of total national energy consumption in 2008. It is largely used in the residential sector, accounting for about 47% of total electricity consumed in the country. Electricity is also the dominant modern energy form used in the industrial and service sectors accounting for 65.6% of modern energy used in the two sectors of the national economy (Ministry of Energy, 2010). In addition, the generation and supply of electricity provides employment for a significant number of Ghanaian professionals. Electricity exports have provided an important source of foreign exchange earnings for the country as Ghana exports power to the neighbouring countries including Togo, Benin, and Burkina Faso. On the other hand Ghana imports power from La Cote D'Ivoire when necessary. Becoming a major exporter of electricity is a key objective of the energy sector vision and the opportunity exists for Ghana to expand its electricity exports under the West African Power Pool (WAPP) Project (Ministry of Energy, 2010).

2.1.2 Electricity Load Growth Rate in Ghana

Electrical load growth rate in Ghana has constantly exceeded expectations and, with current 2.6% population growth rate (Nkrumah, 2002). The demand for electricity services will increase significantly leading to enormous challenges in the energy sector. For instance, the loss to the economy because of energy crisis in 1998 has been estimated to be over US$ 300 million (Nkrumah, 2002), which is attributed to over-dependence on hydroelectric power station at Akosombo on the Volta River. This adversely affected industrial productivity. With predicted 50% rise in the global demand for primary energy for the period 1990-2020, energy consumption in Ghana could be 5 times the current levels by 2100. More so, for Ghana to reach middle-income status, energy output must increase at a rate of 16% annually in order to guarantee that Ghana has the necessary power infrastructure to support the 8% GDP growth rate requirement. Thus, hydroelectric power plant at Akosombo and Kpong and the Thermal Power Plant at Aboadze alone can no longer provide the amount of energy the country needs to meet its growth requirements (Nkrumah, 2002).

2.2 Water as a Source of Energy

More than 70% of our planet is covered by water, but less than 3% of that is fresh. Of this, 2.5% is frozen in glaciers and not available and only 0.5% is available in aquifers, lakes, rivers or wetland (UNESCO, 2003). Water is used in energy production such as electricity generation; energy is used for pumping, moving, and treating water. Humans have been tapping the power of flowing water for centuries as shown in figure 2.1. However, freshwater is required for each step energy extraction and production, refining and processing, transportation and storage, and electric-power generation itself.

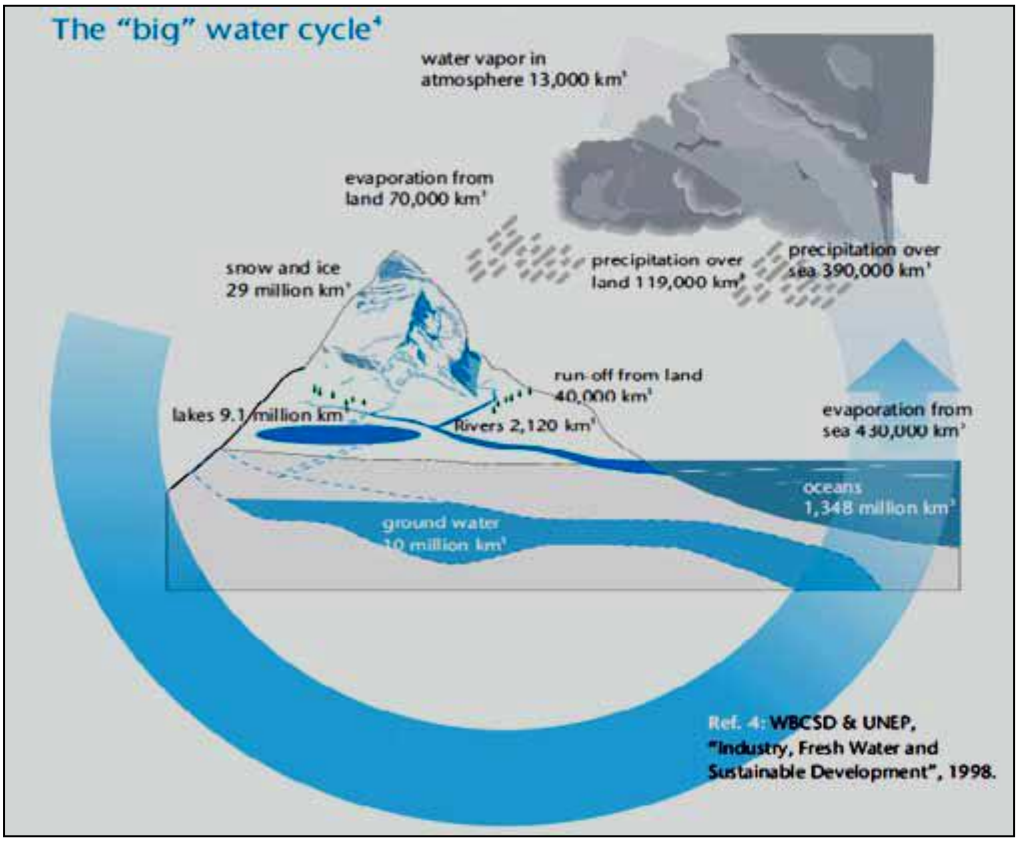

Figure 2. 1 A flow chart showing hydrologic system

(Source: WBCSD & UNEP, 1998)

2.3 The Concept of Hydropower

2.3.1 Hydro Power

Hydropower refers to the power captured from the water as it moves from potential to kinetic energy, the process of which is driven by gravity (Department of Energy, 2008; Hiserodt, 2007). Hydropower is not only a significant source of energy; it also has the distinction of ranking number one among all renewable energy resources (Chiras, 2006).

Hydropower from large dams is estimated to contribute to 19% of the world's total electricity supply (as opposed to total energy supply). Approximately one-third of the world depends on hydropower for over half of their electricity, and 24% of those countries rely on hydropower to supply nearly 90% of their total electricity supply (www.dams.org). The percentage of electricity from hydroelectricity is expected to fall to 16% by 2030, however, as coal and natural gas consumption grows at a much faster rate than hydropower and renewables (U.S. Government, 2007).

2.3.2 Advantages of Power Generated from Hydropower

The principal advantages of electric power derived from river developments are:

1. the energy of falling water can be easily and economically concentrated into usable form through hydraulic turbines;
2. the flow of water in rivers is generally continuous, and, with the development of water storage in reservoirs, it can be easily and economically controlled as an assured and reliable source of energy;
3. water is a renewable and non- depletable resource;
4. the development of water power can be integrated with other water use programs which result in economical multi-purpose developments;
5. the technology of water power is fully developed, and the mechanical equipment is highly reliable to produce uninterrupted and carefree service;
6. the conversion of potential energy to usable energy is a highly efficient process, whereby 80 to 85% of the theoretical energy is developed into usable electrical energy;
7. Hydropower is easily controlled on a short time basis (i.e., seconds, minutes, or hours), so that its output can respond quickly to load fluctuations.

2.3.3 How Hydropower Works

In nature, energy cannot be created or destroyed, but its form can change. In generating electricity, no new energy is created. Actually one form of energy is converted to another form. Hydroelectric power comes from water at work, water in motion.

To generate electricity, water must be in motion. This is kinetic (moving) energy. When flowing water turns blades in a turbine, the form is changed to mechanical (machine) energy. The turbine turns the generator rotor which then converts this mechanical energy into another energy form – electricity (U.S Department of the Interior, 2005). Since water is the initial source of energy, we call this hydroelectric power or hydropower for short.

Some power plants are located on rivers, streams, and canals, but for a reliable water supply, dams are needed. Dams store water for later release for such purposes as irrigation, domestic and industrial use, and power generation. The reservoir acts much like a battery, storing water to be released as needed to generate power (U.S Department of the Interior, 2005). Fig. 2.2 shows a schematic diagram of how hydro power plants work.

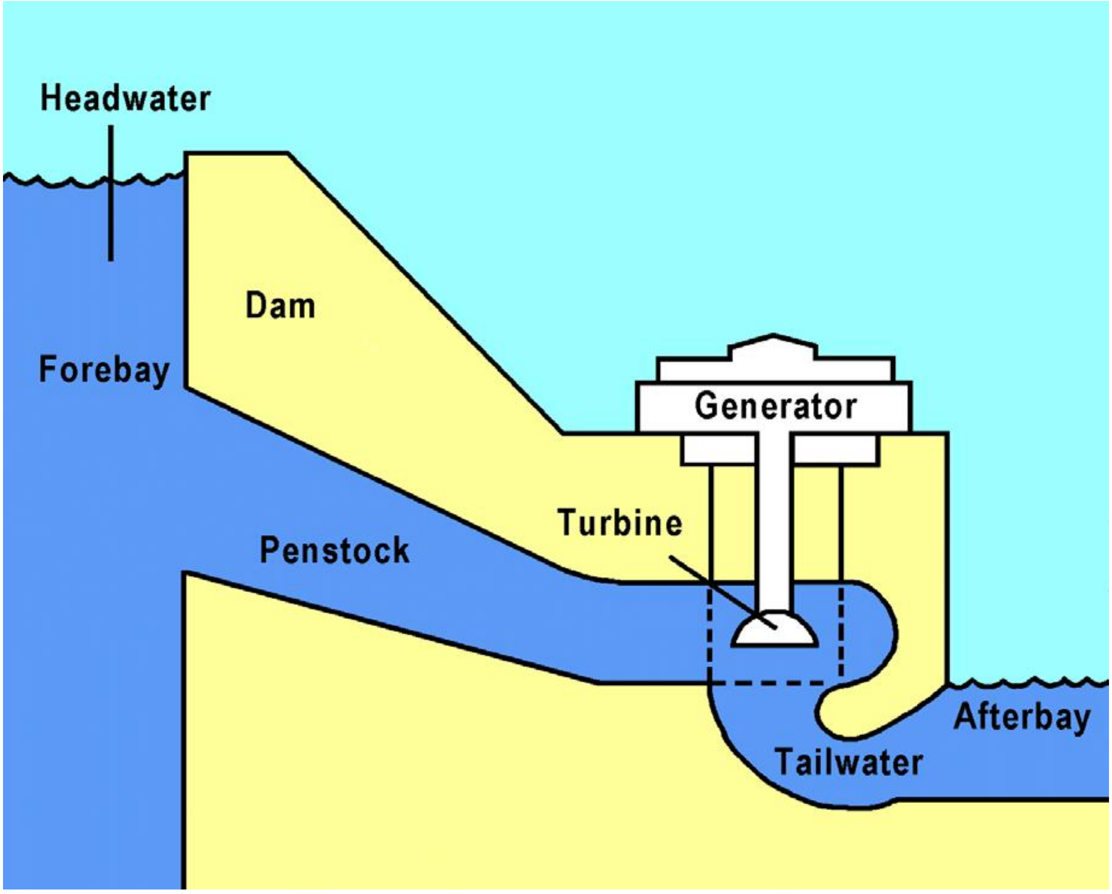

Figure 2. 2 Illustration of the schematic arrangement for hydropower plant

(Source: U.S Department of the Interior, 2005)

The dam creates a “head” or height from which water flows. A pipe (penstock) carries the water from the reservoir to the turbine. The fast-moving water pushes the turbine blades, something like a pinwheel in the wind. The water force on the turbine blades turns the rotor, the moving part of the electric generator. When coils of wire on the rotor sweep past the generators stationary coil (stator), electricity is produced.

2.3.4 Technical Aspects of Small Hydro Systems

Hydropower can be classified into large, small, mini, mirco, and pico, depending on capacity of energy that can potentially be generated. There is no universally accepted definition of the term "small hydro" which depending on local definition can range in size from a few kilowatts to 50 megawatts or more of rated power out (Wilson, 2000). Installed capacity, however, is not always a good indicator of the size of a project. For example, a 20 MW, low-head "small" hydro plants is anything but small as low-head projects generally use much larger volumes of water, and require larger turbines as compared with high-head projects. From the classification in table 2.1, it can be said that mini, micro and pico hydro are all subdivisions of small hydro since they fall within <10 kW upper limit.

Table 2- 1 Classification of Hydro Systems

Hydro Classification	Capacity
Large	>500 MW
Medium	< 500 MW and >10 MW
Small	<10 MW
Mini	<500 kW
Micro	< 500 kW and 10 kW
Pico	<10 kW

(Source: KITE, 2002)

2.3.5 Types of Hydroelectric Schemes

Hydro-electricity is produced by using the power of water under pressure to turn the turbines of generating sets in power stations (Cumarsaide and Nadurtha, 2007). Hydro power schemes usually determine load balancing in hydroelectric power plants. Load balancing refers to the use of various techniques by electrical power stations to store excess electrical power during low demand periods for release as demand rises (Energy Strategies Technologies, 2007). According to Currie et al

2002, hydroelectric schemes can be divided into three parts; (1) Run of the River, (2) Impoundment and (3) Pumped Hydroelectric Storage.

2.3.5.1 Run of the river

According to Currie et al, 2002, "In the Run of the River type of scheme, the turbine and generator are located either in the dam or found alongside it. The dam uses the flow of the river to create the hydrostatic head; this method can also be applied to tidal barrage systems". Most at times run of river schemes have little or no storage and exploit the natural flow of the river which is then piped to a power house sometimes distanced kilometers downstream. According to Cumarsaide and Nadurtha, 2007, "the schemes usually incorporate a pool area above a natural or man-made weir across the river; a fully submerged intake arrangement which feeds the pipe is positioned along the bank of the pool and these schemes are generally designed to operate at all times, even under low flow.

2.3.5.2 Impoundment

The most common type of hydroelectric power plant is an impoundment facility. An impoundment facility, typically a large hydropower system, uses a dam to store river water in a reservoir. Water released from the reservoir flows through a turbine, spinning it, which in turn activates a generator to produce electricity. The water may be released either to meet changing electricity needs or to maintain a constant reservoir level (http://energy.gov/eere/water/types-hydropower-plants).

2.3.5.3 Pumped Hydroelectric Storage (PHS)

Pumped Hydroelectric Storage (PHS) is a scheme that incorporates two reservoirs (Currie et al, 2002). According to Webinar, 2013, Pumped Hydroelectric Storage (PHS) scheme is an efficient means to store energy when the demand for power is low and to generate power with the stored energy when the demand is high. Pumped storage is the largest-capacity form of grid energy storage available, and, as of March 2012, the Electric Power Research Institute (EPRI) reports that PSH accounts for more than 99% of bulk storage capacity worldwide, representing around 127,000 MW (EST, 2012). Ingram stated that “As of 2009, there are hundreds of PHS stations operating with total capacity of 127 GW worldwide”. There are two main types of PHS facilities: (1) pure or off-stream PHS, which rely entirely on water that were previously pumped into an upper reservoir as the source of energy; (2) combined or pump-back PHS, which use both pumped water and natural stream flow water to generate power (Army Corps. Engineering and Design, 1985).

2.4 Turbines

A number of different types of turbines have been designed to cover the broad range of hydropower site conditions found around the world (Acres International, 1984). Turbines used for small hydro applications are scaled-down versions of turbines used in conventional large hydro developments.

Small hydro turbines can attain efficiencies of about 90% (Wilson, 2000). Care must be given to selecting the preferred turbine design for each application as some turbines only operate efficiently over a limited flow range (e.g. propeller turbines with fixed blades and Francis turbines). For most run-of-river small hydro sites where flows vary considerably, turbines that operate efficiently over a wide flow range are usually preferred (e.g. Kaplan, Pelton, Turgo and cross flow designs).

2.4.1 Types of Turbines Used in Small Hydro Power

As water passes through a hydropower plant, its energy is converted into electrical energy by a prime mover known as a hydraulic turbine or water wheel. The turbine has vanes, blades, or buckets that rotate about an axis by the action of the water. The rotating part of the turbine or water wheel is often referred to as the runner. Rotary action of the turbine in turn drives an electrical generator that produces electrical energy or could drive other rotating machinery. Hydraulic turbines are machines that develop torque from the dynamic and pressure action of water. The hydraulic head under which hydropower plants operate ranges from about 2 m to as much as 700 m. The hydraulic turbines for low-head (up to 30 m) plants are generally of the propeller type (either fixed or movable blades) (Rockwood, 1979).

They can be grouped into two types. The specific type of turbine to be used in a power plant is not selected until all operational studies and cost estimates are complete. The turbine selected depends largely on the site conditions.

2.4.1.1 Impulse Turbines

Turbines used for high-head applications are generally referred to as impulse turbines (Paish, 2002).There are 3 main types of impulse turbine in use: the Pelton, the Turgo, and the Cross-flow. The runner of an impulse turbine spins in the air and is driven by a high-speed jet of water (Leopold, 1974). It utilizes the kinetic energy of a high-velocity jet of water to transform the water energy into mechanical energy. The potential energy of water flowing from a forebay through a penstock is transformed into kinetic energy in a jet or jets of water striking the single or double bowl-shaped buckets of the impulse runner. The jet of water strikes the runner tangentially to a circular line of the pitch diameter of the buckets and acts at atmospheric pressure (Harvey, 1993). Impulse runners have multiple jets and the mounting can be with another a horizontal or a vertical shaft. Fig. 2.3 illustrates a schematic arrangement of an impulse turbine.

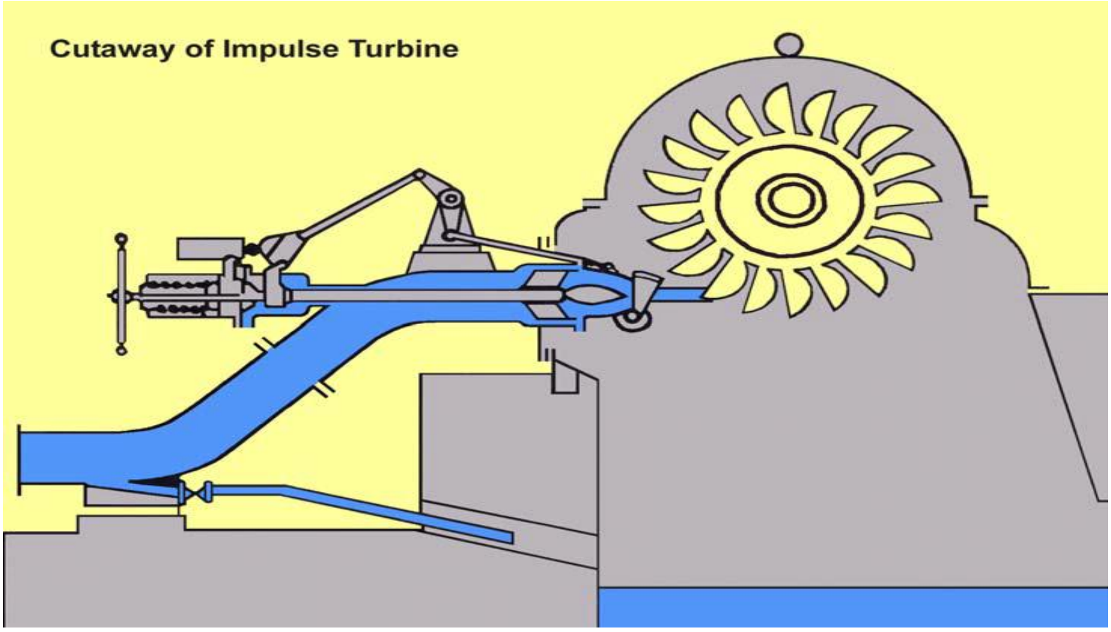

Figure 2. 3 Schematic arrangement of an impulse-type unit.

(Source: U.S Department of the Interior, 2005)

The main advantages of these turbines are:

- They can be easily adapted to power variation with almost constant efficiency.
- The penstock overpressure and the runner over-speed control are easier.
- The turbine enables an easier maintenance.
- Due to the jet, manufacturers of these turbines impose a better solid particles' control inducing, consequently, a lower abrasion effect (Source: Ramos et al., 2000).

2.4.1.2 Reaction Turbine

The second type is a reaction turbine, which develops power from the combined action of pressure energy and kinetic energy of the water.The runner or turbine "wheel" of a reaction turbine is completely submersed in water. Reaction turbines can be further divided into several types, of which the principal two are the Francis and the propeller (Warnick, 1984).

In the operation of reaction turbines, the runner chamber is completely filed with water and a draft tube is used to recover as much of the hydraulic head as possible. This is illustrated by Fig. 2.4. Three conditions of flow determine the designs of reaction wheels. If the flow is perpendicular to the axis of rotation, the runner is called a radial-flow turbine. If the water flow is partially radial and partially axial, it is called a mixed-flow turbine. If the flow is parallel to the axis it is called axial flow turbines. The most common mixed-flow turbine was developed by James B Francis and bears his name. Francis turbines have a crown and band enclosing the upper and lower portions of the buckets, while a propeller-type runner merely has blades projecting from the hub.

The main advantages of this type of turbine are:

- It needs lesser installation space (e.g. the runners are smaller than Pelton runners).
- It provides a greater net head and a better protection against downstream high flood levels (can run submerged).
- It can have greater runner speed.
- It can attain higher efficiencies for higher power values (Source: Ramos et al., 2000).

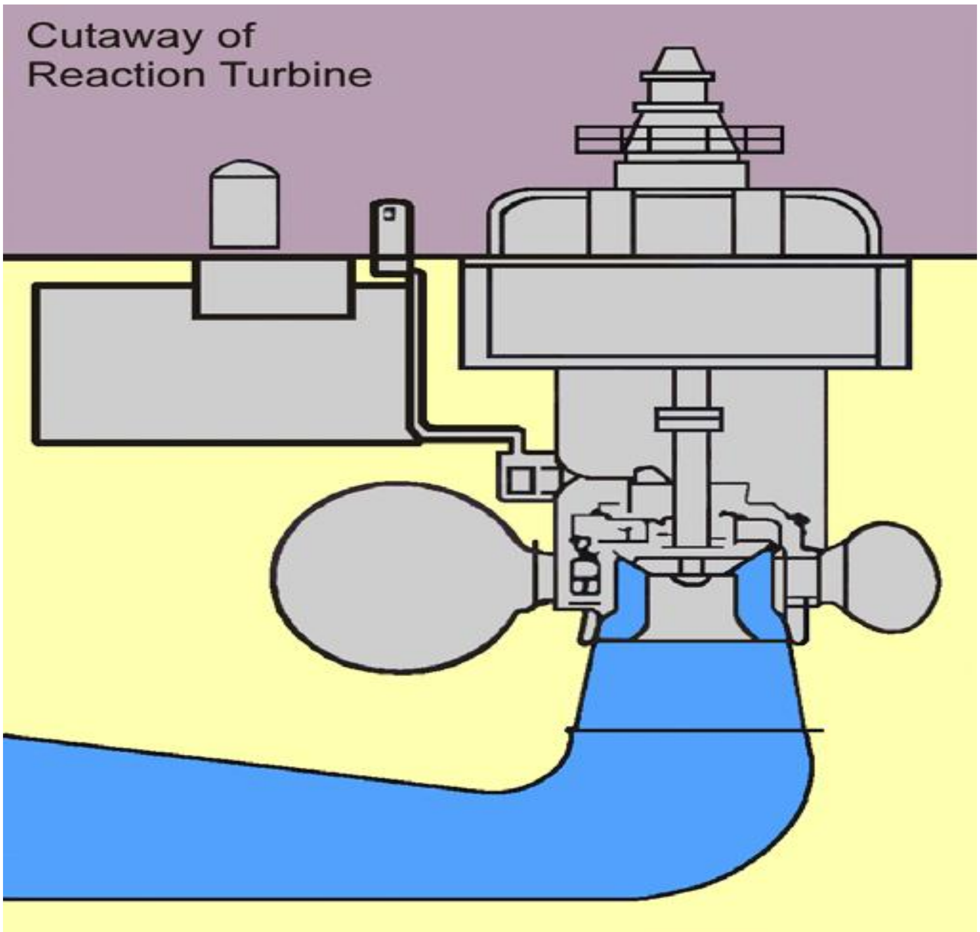

Figure 2. 4 Schematic diagram of the arrangement of Reaction Turbine.

(Source: U.S Department of the Interior, 2005)

2.5 Speed Control Devises

Many small hydro stations in developing countries are not connected to a national grid, but supply a local town or village. In this case there is no strong grid to hold the generator to the correct frequency (50 or 60 Hz) and an effective speed regulation system is important to ensure that the voltage and frequency remain constant as the electrical load changes through the day (Parish, 2002). In some cases a valve is automatically driven by a governing mechanism which adjusts the flow to the turbine to meet variations in power demand. In other cases the turbine always runs at full power and speed control is achieved by adjusting the electrical power output rather than the water power input. In this situation excess electrical power is switched in and out of a ballast load by an Electronic Load Controller or ELC. The advent of reliable ELC's in the 1980s radically improved the reliability of small hydro projects remote from the grid.

2.6 Small Hydro Project Development

The development of small hydro projects typically takes from 2 to 5 years to complete, from conception to final commissioning. This time is required to undertake studies and design work, to receive the necessary approvals and to construct the project. Once small hydro plants constructed, small hydro plants require little maintenance over their useful life, which can be well over 50 years (EMR, 1988). Normally, one part-time operator can easily handle operation and routine maintenance of a small hydro plant, with periodic maintenance of the larger components of a plant usually requiring help from outside contractors.

The technical and financial viability of each potential small hydro project are very site specific (Wilson, 2000). Power output depends on the available water (flow) and head (drop in elevation). The amount of energy that can be generated depends on the quantity of water available and the variability of flow throughout the year. The economics of a site depends on the power (capacity) and the energy that a project can produce, whether or not the energy can be sold, and the price paid for the energy (Gullivers, 1991). In an isolated area (off-grid and isolated-grid applications) the value of energy generated for consumption is generally significantly more than for systems that are connected to a central-grid (Acres International, 1984). However, isolated areas may not be able to use all the available energy from the small hydro plant and, may be unable to use the energy when it is available because of seasonal variations in water flow and energy consumption.

2.6.1 Small Hydro Power Development in Ghana

Until 1997 and 1998, virtually all Ghana's electricity was produced from two hydro dams at Akosombo and Kpong, which have a combined installed capacity of 1,122MW (Energy Foundation, 2002). It is estimated that Ghana may have the potential for additional 2,000 MW of hydropower of which 1205 MW will be from large hydro sources and the rest from medium to small hydro plants (Odai, 1999). The overall hydroelectric potential (small, medium and large scale) located in the fifteen ECOWAS countries are estimated at around 25,000 MW. It is estimated that only around 16% has been exploited. In Ghana a total of 85 potential sites were estimated for small-scale hydropower with an overall hydropower potential of 110MW (UNIDO, 2012). Small hydro powerhouses are generally kept to the minimum, and safety (Guilliver & Arndt, 1991). Simplicity in design, with an emphasis on practical, easily constructed civil structures is of prime concern for a small hydro project to keep costs at a minimum (Ackom, 2005).

2.6.2 Kokuma Falls

The Energy Foundation in year 2002 investigated the potential of the Kokuma Falls for the development of a small hydro scheme. They identified the site to be feasible with a potential power output of 75 kW and an annual generation of 375, 000 kWh.

Figure 2. 5 A view of the Kokuma Falls

(Source: Ofosu-Ahenkorah, 2002)

2.7 Barriers Hindering SHP Development in Ghana

The challenges that SHP developers are facing are manifold and most of them are part of the larger picture of general barriers for the uptake of renewable energy. The main constraints for SHP development in Ghana can be summarized as follows:

2.8 Small Hydropower Resources

The ACRES report concluded among other things that 'the development of SHP resources can only have marginal effect on the overall fuel and energy balance of Ghana' (ACRES International, 1991). They submitted however, that there is a niche market for the technology in the context of rural electrification programmes. The modest assessment for the country's SHP resources possibly accounts for the reason why not a single SHP has been implemented in Ghana. Year round resource inadequacy is an important barrier to the development of SHP in Ghana.

Again gaining permission to occupy land and abstract water from a river has always been necessary (Parish, 2002). Developers now have to invest in detailed analyses and expensive hardware to prevent adverse effects on fishing; they have to counter a range of perceived conflicts with river-based leisure interests, and prove that there will be no impacts to the river bed, river banks, flora and fauna, land drainage, or the ability to remove flood waters (Parish, 2002).

2.9 Technical Aspects of Small Hydropower Development

There is no known technological barrier presently that could have impeded the development of SHP sites in Ghana. There is a worldwide consensus that SHP technology is now mature. It has been greatly improved by electronic load controllers, lower turbine cost, the use of 124electric motors, and the use of plastics in pipe work and penstocks (Khennas and Barnet, 2000).

Continuous improvement in R&D can still bring the cost of generating equipment down. This however does not lie within the purview of the Ghanaian engineer, nor is there any economic justification for embarking on such a venture since other countries such as India and China have a comparative cost advantage so far as the manufacturing of equipment is concerned. The latter point is based on a conclusion drawn by ACRES International (1991) that ‘the size of the SHP potential in Ghana does not give sufficient scope for considering domestic manufacturing of the main equipment components (turbines, valves, generators). Project engineering, construction and installation, O&M of SHP plants can be carried out entirely by Ghanaian institutions and expertise (ACRES, 1991).

2.10 Financial Analysis

The high initial installation cost for SHP is a potential barrier. There is lack of long-term financial mechanisms tailored for SHP projects which usually have high investment costs and low operation and maintenance costs (ECREEE &UNIDO, 2012). An Attempt to carry out an independent financial analysis by a local research instruction, KITE was unsuccessful (KITE, 2002). The failure was primarily due to lack of cost estimates and more recent hydrological studies of the rivers (Ackom, 2005). Another constraint form SHP investments is the low willingness and ability to pay of the population in rural areas (ECREEE & UNIDO, 2012).

2.11 Environmental Impact Assessment

The purpose of an environment impact assessment (EIA) applied to small hydro power plant consists in the evaluation of the favourable and unfavourable impacts, in what concerns the two categories of impacts, in natural and social environmental context.

Natural impacts include hydrology and sediment effects, as well as the water temperature and quality, ecology, engineering construction, biology, landscape and effects on archaeology and cultural assets, soils and geology, air, noise and, eventually, climate local change (Ramos et al., 2000).

Social impacts involve social, cultural and economic development inducing local industrialisation and changes in citizens' life quality as well as potential people displacement due to submersion by the reservoir.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Tools and Materials

The following materials were used in this project;

1. GPS
2. Total Station
3. Light object
4. Clothed tape
5. Poles
6. Topographical map of Ghana (1/50,000)
7. Rainfall and temperature records

3.2 Method of Data Collection and Analysis

3.2.1 Determination of Head

There are a number of methods for head measurements. Some methods are more suitable on low head sites, but are inaccurate on high heads; some are only suitable on high head sites. Always choose the most accurate method given the equipment available. The methods described are;

- Water-filled tube (with rods or person)
- Water-filled tube and pressure gauge
- Spirit level and plank (or string)
- Altimeter
- Total Station

- Sighting meters
- Sighting meters with spirit level
- Builder’s level
- Topographical Maps

For the purpose of this study a total station was used. A local coordinate system was established and height readings obtained for both the proposed intake location and that of the powerhouse. The head was determined as the height difference between the proposed intake location and that of the powerhouse.

3.2.2 Determination of Discharge of the River

The appropriate method employed for the determination of the discharge of a river is dependent on the site conditions, available data and instruments. Where there are gauging stations data from these sites can be easily analyzed to determine the discharge. Other rivers without gauging stations make use of flow data from a nearby gauged river and by correlation compute the discharge of the river in question. In the absence of these two the float method could be used. However in case where accessibility to the stream is difficult the water balance method could be used. For the purpose of this study the water balance method would be used due to time and resource constraints. The float method would however be used as a control measure.

3.2.2.1 The Float Method

The float method is the easiest way to measure the flow of a stream because it requires the least equipment and less time. The cross sectional area of the stream is multiplied by the average velocity of the water to calculate the flow. This is represented by the equation

$$Q = A \times v \text{...1}$$

Where Q is stream discharge (volume/time), A is cross-sectional area, and V is flow velocity.

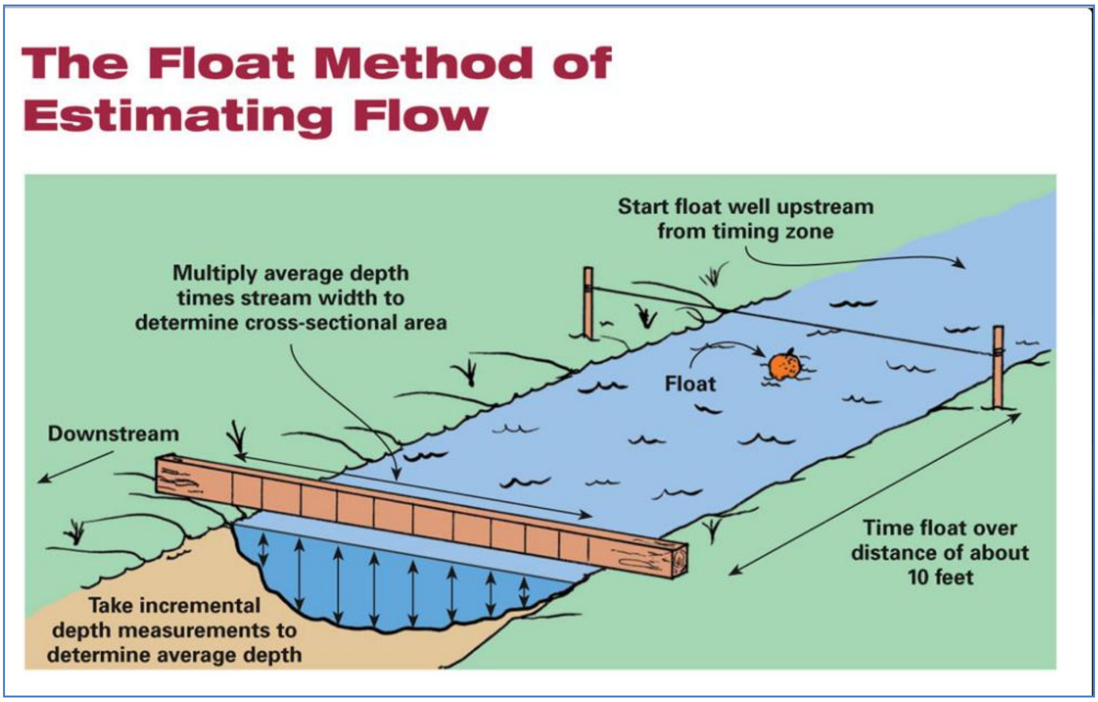

Figure 3. 1 Determination of flow using the Float Method

(Source:http://www.homepower.com/articles/microhydro-power/design-installation/intro-hydropower-part-2)

The float method requires the use of the following;

- tape measure
- stop-watch
- rod, yard or meter stick to measure depth
- at least three highly visible buoyant objects such as a drifting branches or logs, pine cone, coffee stir sticks, half filled bottles, or oranges (objects buoyant enough not to be effected by the wind)

- stakes for anchoring tape measure to stream banks

The essential idea is to measure the time that it takes for an object to float through particular distance downstream of the stream.

V = travel distance/ travel time = L/t....................................2

The following steps below describe the procedure;

- Choose an approximately straight section on the stream with minimum turbulence (ideally at least 3 channel widths long).
- Mark the start and end point of your reach.
- Drop your object into the upstream section of your chosen area.
- Start the watch when the object crosses the upstream set point and stop the watch when it crosses the downstream set point.
- You should repeat the measurement at least 3 times and use the average time obtained and the distance between the two set points to calculate your velocity.
- Measure stream's width and depth across at least one cross section where it is safe to walk across. If possible, measure depth across the stream's width at the start and stop set points and find the average of the two. However, if measuring one cross section then the downstream section should be chosen. Use a marked rod, a yard or meter stick to measure the depth at regular intervals across the stream. Average your cross-sectional areas (A): Using the average area and corrected velocity, you can now compute discharge, Q.

3.2.2.2 Water Balance of the Drainage Area

The water balance method of determining discharge makes use of rainfall and temperature data within a specific catchment area to estimate the discharge of a stream. The method is described in detail below;

The relation of rainfall, runoff (direct runoff, base runoff), and evaporation is indicated by the viewpoint of annual water balance as shown in the formula below. In this case, pooling of drainage area and inflow and runoff to/from other drainage area are not necessary.

$$P = R + Et \qquad (3)$$

$$= Rd + Rb + Et$$

where,

P: Annual rainfall (mm)

R: Annual runoff (mm)

Rd: Annual direct runoff (mm)

Rb: Annual base runoff (mm)

Et: Annual evaporation (mm)

Runoff (R) is obtained from calculated evaporation (Et) by the presumption formula and observed rainfall (P).

A pattern figure of the relation of rainfall (R), possible evaporation (Etp), and real evaporation (Et) is shown in fig. 3.2. Indicated as diagonal line is real evaporation and area above line b-c is river runoff including sub-surface water. Possible evaporation (a-b-c-d) is obtained by presumption formula.

3.2.2.2.1 Direct Runoff and Base Runoff

A pattern of annual runoff is shown in Fig. 3.3. The runoff is provided from sub-surface water, and it contained base runoff with less seasonal fluctuation and direct runoff wherein the rainfall immediately becomes the runoff. The ratio of sub-surface water to annual runoff (R) is shown in Table 3-1. Where, Rg = Rb,

Rb / R = constant, Ratio of Base (sub-surface) Runoff to Annual Runoff

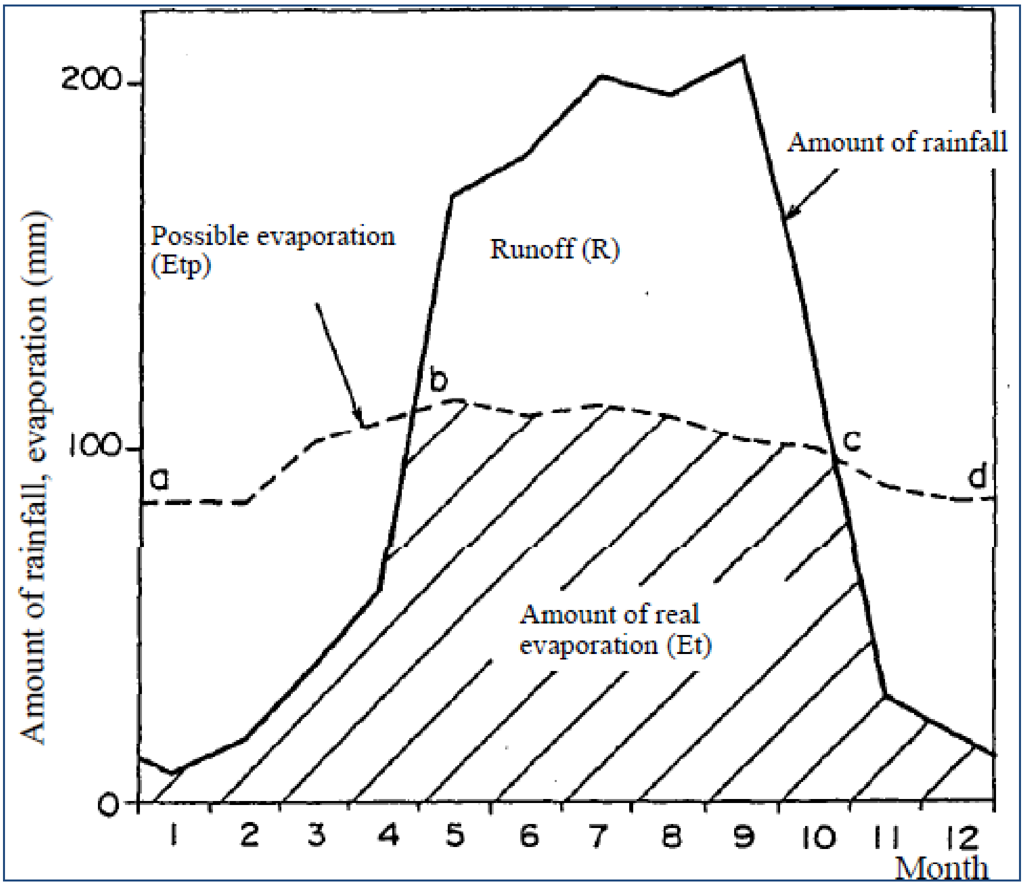

Figure 3. 2 Pattern of Amount of Rainfall and Evaporation

(JICA 2000)

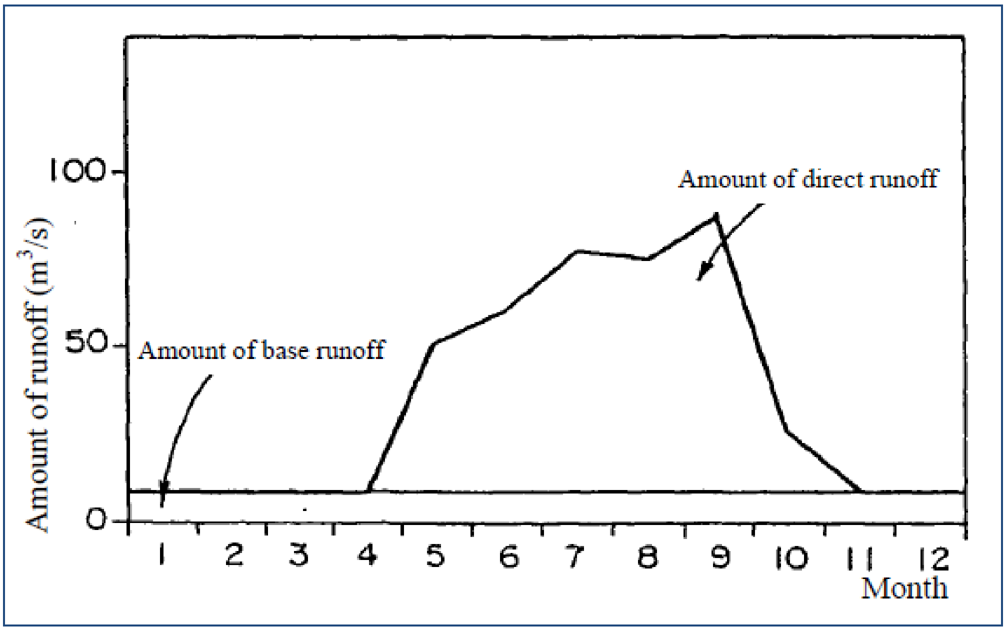

Figure 3. 3 Pattern of Annual Runoff

(JICA 2000)

Table 3- 1 Ratio of Sub-surface Water to Annual Runoff

Area	**Asia**	**Africa**	**North America**	**South America**	**Europe**	**Australia**	**Japan**
Rainfall (P)	726	686	670	1648	734	736	1788
Runoff (R)	293	139	287	583	319	226	1197
Direct runoff (Rd)	217	91	203	373	210	172	-
Subsoil water	76	48	84	210	109	54	-
Evaporation (Et)	433	547	383	1065	415	510	597
Rg / R	26	35	32	36	34	24	-

(Source: Lvovich 1973)

3.2.2.2.2 Calculation of Possible Evaporation

For the purposes of determining the possible evaporation, the Blaney-Criddle formula was used.

3.2.2.2.3 Blaney-Criddle Formula;

$$u = K.P.\frac{(45.7T + 813)}{100} \qquad \ldots\ldots\ldots\ldots\ldots\ldots 4$$

where,

u = Monthly evaporation (mm)

K = Monthly coefficient of vegetation

P =Monthly rate of annual sunshine (%)

T = Monthly average temperature (°C) (Kintampo Meteorological Station)

3.2.2.2.4 Monthly Average Temperature and Monthly Rate of Annual Sunshine

- Monthly average temperature; using temperature records at the drainage area of the selected site
- Monthly rate of annual sunshine; this is obtained by the latitude at the drainage area of selected site

In the northern hemisphere, Table I-1 in Appendix I will be used, and in the southern hemisphere Table I-2 in Appendix I will be used.

(3)K value depends on the vegetation condition.

3.2.2.2.5 Calculation of Evaporation

The monthly evaporations are attained by selecting the lower of the rainfall or possible evaporation value. This is demonstrated in Table 3-2.

Table 3- 2 monthly Evaporation Values

Month	(1) Temperature, t (°C)	(2) Monthly Rate of Annual Sunshine, p (%)	(3) Possible Evaporation from Blaney-Criddle formula (mm)	(4)Rainfall (mm)	(5)Real Evaporation, smaller value of (3) and (4) (mm)
Jan.	A	B	C	D	X< C, D
Feb.	A	B	C	D	X< C, D
Mar.	A	B	C	D	X< C, D

(Note): (1) data obtained (2): from Table 1-2 (3): from Blaney-Criddle Formula

3.2.2.2.6 Computation of Monthly Runoff Data

a) Table 3-3 illustrates the computation of the monthly runoff.

b) Derivation of the monthly mean discharge data at the selected site by the formula.

$$Q(i) = \frac{\text{MonthlyRunoff } ((4) \text{ of table } 3\text{-}5)}{1000} \times CA \times 10^6 \times \frac{1}{86{,}400 \times n} \text{.................5}$$

Where,

Q (i): Monthly mean discharge at the selected site in ‘i (month)’ (m^3/s)

CA: Catchment area (km^2)

n: Number of days in the month

The discharge for the catchment area of P km^2 is shown in Table 3-3.

In addition, the ratio of the base runoff to the total runoff and the monthly distribution of base runoff (constant) can be analyzed with regards to the characteristic of runoff at the area.

Table 3- 3 Estimation of base runoff, monthly runoff and the monthly discharge

Table 3-3 Month	(1) Runoff (4)-(5) of Table 3-2 (mm)	(2) Direct runoff (1)× (100% - Rg / R)(mm)	(3) Base runoff (Note) (mm)	(4) Monthly runoff (2)+(3) (mm)	(5) Monthly mean discharge (m^3/s)
Jan.	E=D-X	F=E x (100% - Rg / R)	H=G x I	J=F + H	Q
Feb.	E= D-X	F=E x (100% - Rg / R)	H=G x I	J=F + H	Q
Mar.	E=D-X	F=E x (100% - Rg / R)	H=G x I	J=F + H	Q
Total	Et	Ft	Ht	Jt	

(Note) (3)Surface runoff: distribute uniformity Et × (Rg / R) = G mm to each month, I = number of days in the month divided by the number of months in the year.

3.2.3 Determination of Power Output

The potential power will be calculated with the formula;

$$Power\ (kW) = \eta QHg \qquad \text{.........6}$$

Where;

Q = flow in m^3/s and

H = head in meters.

Ŋ = combined efficiency

g = acceleration due to gravity

An efficiency factor of 85% the formula above will be used to estimate the power output of the site.

3.2.4 Determination of the Annual Energy Generation

With an estimated working time, the annual energy generation could be estimated. The power output (P) of a turbine in a particular site could be multiplied by capacity factor (cf) to the total time, t (hours run, hr) in a year to estimate the annual energy generation (E) in kWh.

$$E = cf \times t \times P \qquad \text{...7}$$

3.2.5 Determination of the Turbine Option

Turbine selection depends mostly on the available water head, and the available flow rate. Impulse turbines are mostly used for high head sites, and reaction turbines are normally used for low head sites. Kaplan turbines with adjustable blade pitch are well-adapted to wide ranges of flow or head conditions, since their peak efficiency can be achieved over a wide range of flow conditions. The selection of the turbine type will be done with the aid of the Turbine Application Chat in fig. 3.4.

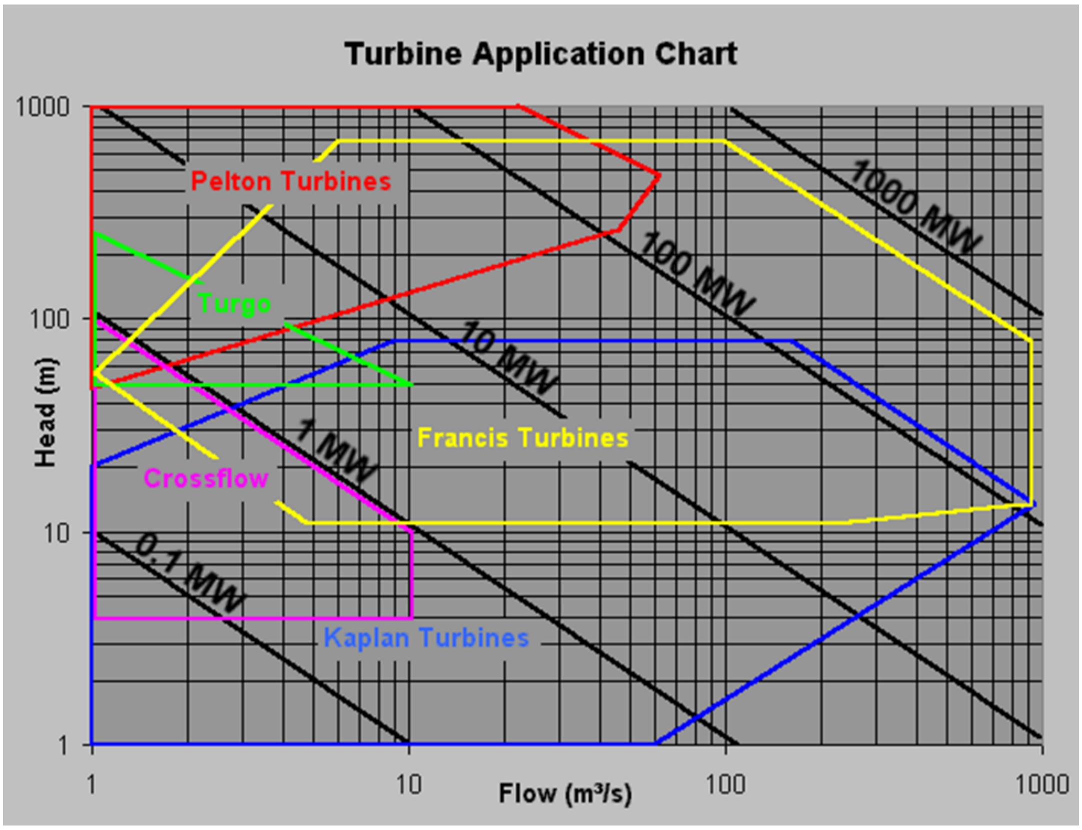

Figure 3. 4 Application chart for type of turbine

They are different types of turbines which could be used depending on the type of head available. These are, Hydraulic wheel turbines which requires heads within the range 0.2< H< 4; Archimedes screw turbines with their heads within the range 1< H< 10; Kaplan turbines within the range 2< H< 40; Francis which falls within the range 10< H< 350; Pelton which falls within the range 50< H< 1300; Turgo falling within the range 50< H< 250.

The suitable turbine which will be selected for the site will depend on the head of the fall.

3.2.6 Establishing the Financial Viability of the Scheme

A thorough financial analysis will be done on the project using RETSreen Software to calculate the financial viability of the project. It will involve the inputs and the outputs of the project to see if it would be financial feasible.

3.2.6.1 RETScreen Overview

The RETScreen Clean Energy Project Analysis Software is the world's leading clean energy decision-making software. It is provided completely free-of-charge by the Government of Canada as part of Canada's recognition of the need to take an integrated approach in addressing climate change and reducing pollution. RETScreen is a proven enabler of clean energy projects worldwide.

RETScreen significantly reduces the costs (both financial and time) associated with identifying and assessing potential energy projects. These costs, which arise at the pre-feasibility, feasibility, development, and engineering stages, can be substantial barriers to the deployment of Renewable-energy and Energy-efficient Technologies (RETs). By helping to break down these barriers, RETScreen reduces the cost of getting projects on the ground and doing business in clean energy.

RETScreen allows decision-makers and professionals to determine whether or not a proposed renewable energy, energy efficiency, or cogeneration project makes financial sense. If a project is viable—or if it is not—RETScreen will help the decision-maker understand this: quickly, unequivocally, in a user-friendly format, and at relatively minimal cost (http://www.retscreen.net/ang/what_is_retscreen.php).

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

This chapter gives a brief description of the results obtained from the prefeasibility study in the Kokuma falls. It tends to address the objectives of the project as presented in the introduction

4.1 Study Area

The site of the study is the Kokuma falls, on the River Dum, which is located in the town of Kokuma in the Kintampo South District. The district lies within longitudes 10 20' West and 20 10' East and latitude 80 15' North and 70 45' South. Jema is the District Capital of the Kintampo South District with an estimated population of about 7,868 while the total District population stands at 93,600 (Ministry of Food and Agriculture, Ghana). The district is strategically located at the centre of Ghana and serves as a transit point between the northern and southern sectors of the country.

The Kintampo South District which falls within the Voltain Basin and the Southern Plateau physiographic regions is a plain with rolling and undulating land surface with a general elevation between 60-150m above sea level. The district which falls within the Voltain basin is endowed with a lot of water resources. The major rivers are River Pumpum, River Oyoko, River Odum, River Nante and River Tanti. These rivers flow to join the Black Volta. Most of The Kintampo South District experiences a modified Tropical Continental climate or modified Wet Semi-equatorial climate. This is because the district lies in the transitional zone between the Wet Semi-equatorial and Tropical Continental climates. Like other parts of the country, the district experiences two seasons namely wet and dry.

The Wet season shows double maxima (peaks) rainfall pattern (i.e. major and minor). The major raining season starts in early March and reaches its peak in June, and tapers off gradually through July. The minor season starts in late August and reaches its peak in September/November.

However, because of the transitional nature of the district, the distinction between the peaks is often not so much; the first peak is often obscured. The mean annual figures range from 115cm to 125 cm.The mean monthly temperature in the district is between 24 ^{o}C in August and 30 ^{o}C in March. These conditions create sunny conditions for most part of the year. The relative humidity is also high varying from 90% - 95% in the rainy season. The climate of the district has the tendency to change and be inclined more to the Dry Tropical continental conditions or to the Wet Semi-Equatorial conditions. The vegetation of the district falls under the Woodland Savannah Zone. However, due to its transitional nature the area does not exhibit typical savannah conditions. The savannah is heavily wooded with relatively taller trees in contrast to trees in the typical savannah grassland areas of the north but not as tall as trees in the deciduous forest areas of the south. Typical in the district exist the formation of a "fringe forest" found along the banks of major rivers and streams. The type of tree species prevalent in the district includes the Mahogany, Odum, Senya, Apupuo, Shea, Wawa, Dawadawa etc. These trees have adapted to the environment but are dispersed (Ghana Districts, 2006). Fig. 4.1 shows the location of Kokuma on the Map of Ghana.

4.2 Power Connection

The village of Kokuma has been connected to the National Grid by the Northern Electricity Network (NED) of the Volta River Authority (VRA).

Figure 4. 1 Location of Kokuma on the Map of Ghana

4.3 Determination of Head

With the help of a total Station, the vertical height difference between the proposed intake and powerhouse was determined. A local coordinate system was established by the Surveyor and height readings obtained for both the proposed intake location and that of the powerhouse. The difference in height was obtained as 23.1 m.

With the established coordinate system, the position of the intake and that of the diversion weir were obtained. From the coordinates obtained for the diversion weir and the intake, the distance between them was calculated to be 30.1 m. This is shown in fig. 4.2. Also, the distance of the powerhouse from the intake was calculated to be 39.0m. Thus from equation 8, the slope for the penstock is 1.7.

$$s = \Delta l / \Delta z \rightarrow 39/23.1 = 1.7 \qquad \ldots\ldots 8$$

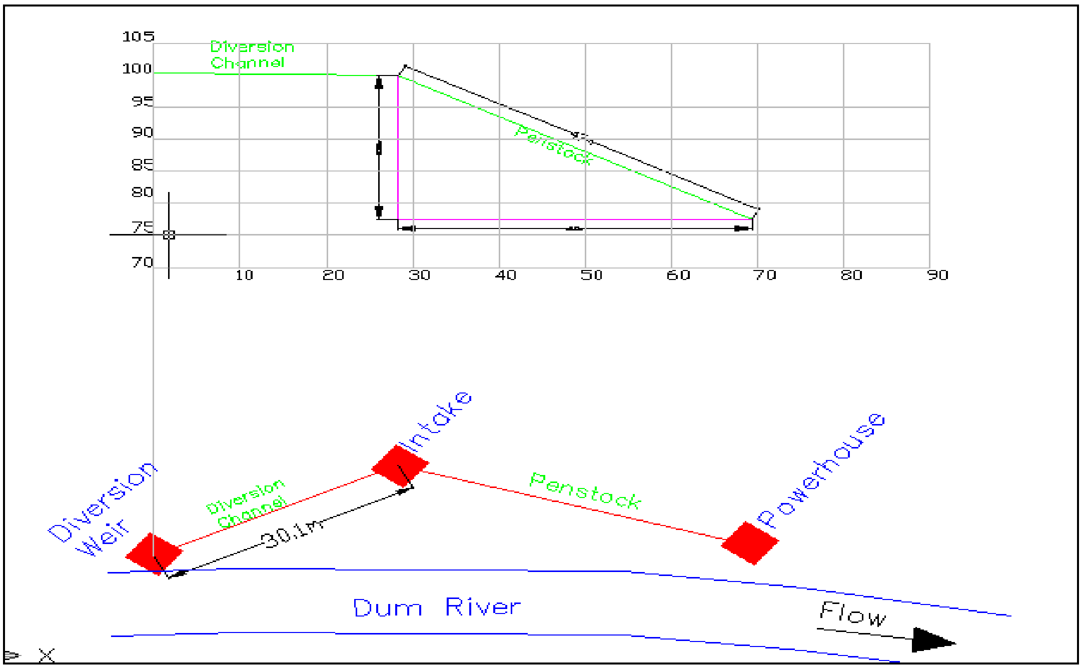

Figure 4. 2 A profile of the proposed location of scheme components

Figure 4. 3 Surveyor Picking Points for the Head Determination (in the background is the Dum River)

Figure 4. 4 Surveyor Picking Points for Head Determination

4.4 Determination of Catchment Area

The catchment area was traced on the Topographical Map of Ghana in AutoCAD environment. In the AutoCAD environment, an area calculation command was used to obtain the area within the traced boundary to be 77.9 sq. km as indicated in fig. 4.5. Specifically, the catchment area is 26km North-East of Wenchi on the western side, about 85km North-West of Atebubu on the eastern end, 25km South-West of Kintampo on the northern side and 29km North-East of Techiman on its southern end. Fig. 4.5 illustrates the catchment area for the Dum River.

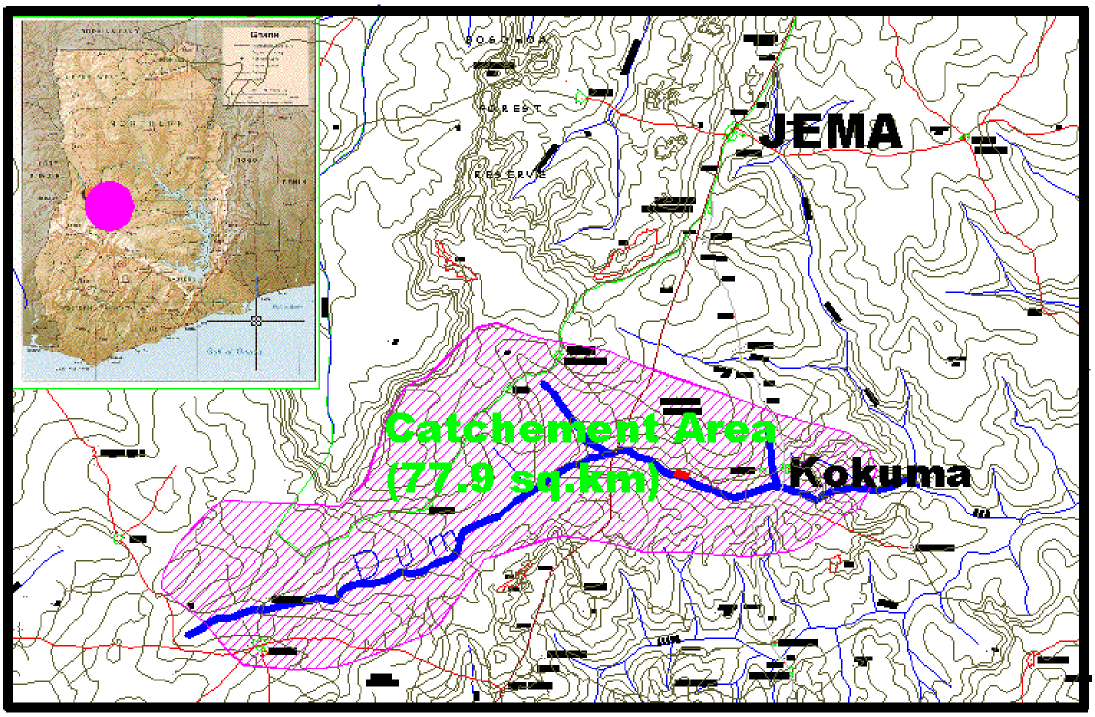

Figure 4. 5 Catchment Area for the River Dum

4.5 Meteorological Data

Monthly mean rainfall and temperature records (Table II-1 and Table II-2 of Appendix I) for the period January 1992 to December 2007 for Kintampo was obtained from the Brong Ahafo Meteorological Services Department for analysis and analysed together with the monthly rate of annual sunshine (Appendix I) to obtain the hydrological data. The highest mean monthly rainfall was between November and March with the minimum being in January with 9.23 mm of rainfall. The hottest month was April with a mean temperature of 32.58 °C whiles the July had the lowest mean temperature of 25.16 °C. Fig. 4.6 and Fig. 4.7 illustrate the mean rainfall and mean temperature records respectively for the above period. The rainfall and temperature data was used in section 4.6.2 for the determination of the discharge of the river.

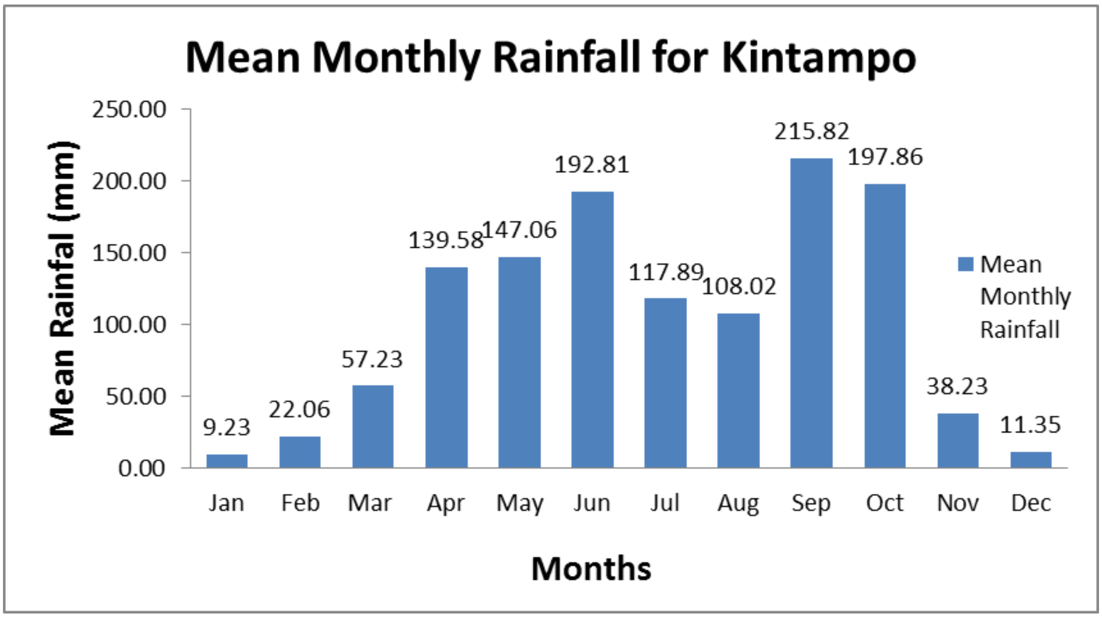

Figure 4. 6 Mean Monthly Rainfall for Kintampo

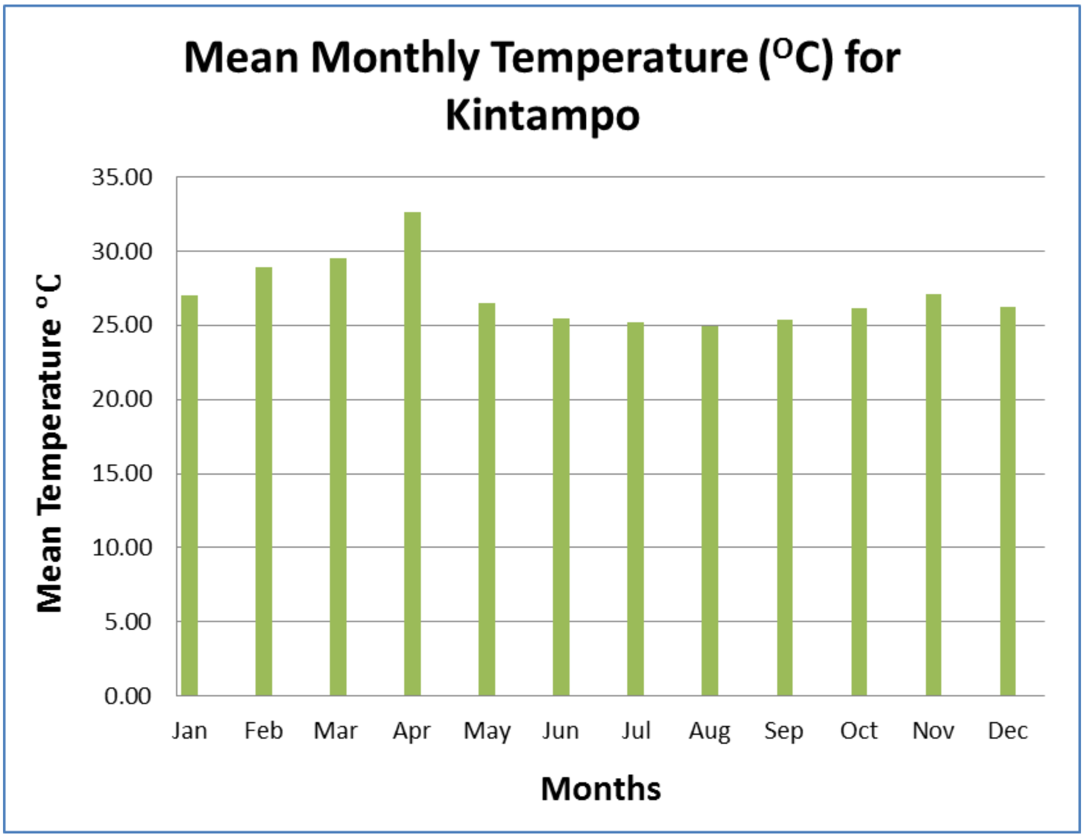

Figure 4. 7 Average Monthly Temperatures for Kintampo

4.6 Discharge Measurement

The Water Balance Method of discharge determination was used in this study. This was because there was no gauging station on the Dum River. Also there was not enough time to take monthly discharge measurements with the float method for all the 12 months in the year. The Float Measurement Method was however used as a control.

4.6.1 Float Method

The Float method was used to determine the discharge of the Dum River in June, 2013. Two locations were selected along the Dum River and the depths across the river at these two sections were measured at intervals of 0.5 m. The distance between the two sections were recorded as well as the time taken for a floating object to float from one end to the other. Tables 4-1 and 4-2 give the depths as well as the cross-sectional area obtained for Location 1 and 2 respectively. The distance between the two sections was recorded as 2.585 m and the average time taken for a floating object to float from one end to the other was also 2.59 s. The time was obtained as a result of 4 trials to obtain the average as in scientific experiments.

Table 4- 1 Data recorded for Location 1 and Cross-Sectional Area Obtained

	Location 1		
Points	Depth (m)	Position (m)	Area (m2)
L 1	0.140	0.000	0.000
L 2	0.220	0.500	0.090
L 3	0.227	1.000	0.112
L 4	0.272	1.500	0.125
L 5	0.309	2.000	0.145
L 6	0.354	2.500	0.166
L 7	0.390	3.000	0.186
L 8	0.400	3.500	0.198
L 9	0.467	4.000	0.217
L 10	0.474	4.500	0.235
L 11	0.490	5.000	0.241
L 12	0.389	5.500	0.220
	0.145	5.500	0.134
Total		Area 1 =	**2.067**

Table 4- 2 Data recorded for Location 2 and Cross-Sectional Area Obtained

Location 2			
Points	Depth (m)	Position (m)	Area (m2)
L 1	0.060	0.000	0.000
L 2	0.215	0.500	0.069
L 3	0.225	1.000	0.110
L 4	0.250	1.500	0.119
L 5	0.200	2.000	0.113
L 6	0.190	2.500	0.098
L 7	0.270	3.000	0.115
L 8	0.250	3.500	0.130
L 9	0.190	4.000	0.110
L 10	0.000	4.500	0.048
Total		Area 2 =	0.910

The average cross-sectional area obtained $A_t = (A_{L1} + A_{L2})/2$

= **1.4885 m^2**

The mean velocity calculated was **0.999 m/s** as a result of the values obtained for the distance and the time from the experiment. The mean discharge for the River Dum for June 2013 can be estimated as **1.958 m^3/s**. This value was used as a control to the values provided by the Brong Ahafo Meteorological service for Kintampo.

Figure 4. 8 Measurement of Discharge Upstream of the Kokuma Falls

4.6.2 Water Balance Method

Table 4-3 shows the monthly mean results of possible and real evaporation of the site using the water balance method. Detailed calculations of the possible as well as the real evaporation values are captured in Table III-1 of Appendix III.

Table 4- 3 Possible Evaporation and Real Evaporation Values

Month	Temperature t (°C)	Monthly Rate Of Annual Sunshine p (%)	Possible Evaporation (Blaney-Criddle)	Rainfall (mm)	Real Evaporation
Jan	26.97	8.21	100.75	9.23	9.23
Feb	28.87	7.51	96.09	22.06	22.06
Mar	29.48	8.45	109.53	57.23	57.23
Apr	32.58	8.34	115.18	139.58	115.18
May	26.49	8.74	106.12	147.06	106.12
Jun	25.46	8.53	101.17	192.81	101.17
Jul	25.16	8.78	103.39	117.89	103.39
Aug	24.90	8.66	101.36	108.02	101.36
Sep	25.35	8.25	97.58	215.82	97.58
Oct	26.16	8.37	100.87	197.86	100.87
Nov	27.09	7.98	98.20	38.23	38.23
Dec	26.23	8.18	98.74	11.35	11.35

Table 4-4 contains the runoff and monthly mean discharge values as calculated using the water balance method with the meteorological data obtained from the Ghana Meteorological Service.

Table 4- 4 Runoff and Monthly Mean Discharge Values

Month	Runoff (mm)	Direct Runoff (mm)	Base Runoff (mm)	Monthly Runoff (mm)	Monthly mean discharge (Q)
Jan	0.00	0.00	11.69	11.69	0.34
Feb	0.00	0.00	10.56	10.56	0.31
Mar	0.00	0.00	11.69	11.69	0.34
Apr	24.40	15.86	11.32	27.17	0.79
May	40.94	26.61	11.69	38.31	1.12
Jun	91.64	59.57	11.32	70.88	2.06
Jul	14.50	9.43	11.69	21.12	0.62
Aug	6.66	4.33	11.69	16.02	0.47
Sep	118.24	76.86	11.32	88.17	2.57
Oct	96.99	63.05	11.69	74.74	2.18
Nov	0.00	0.00	11.32	11.32	0.33
Dec	0.00	0.00	11.69	11.69	0.34
	393.37	255.69	137.68	393.37	11.46

The detailed calculation of monthly discharge values for the period between January 1992 and December 2007 are presented in detail in Table III-2 of Appendix III. The discharge values obtained were used for the hydrological analysis in section 4.7.

4.7 Hydrological Analysis

The mean rainfall and mean temperature data obtained was analysed using the Water Balance Method to determine discharge for the purposes of this study. The mean rainfall and temperature are presented in section 4.5. This was because there was no gauged station along the Dum River. The discharge obtained for June 2013 using the Float Method is used as a control for the discharge values obtained using the Water

Balance Method. The discharge obtained using the float method for June 2013 was 1.958 m^3/s whiles the mean for June obtained using the water balance was 2.06 m^3/s. This indicates that the discharges obtained using the water balance method was close to the actual discharges measured on the river using the float method.

4.7.1 River Discharge Analysis

The quantitative availability of water for hydro generation at the selected site is illustrated by the hydrograph (Fig. 4.9). The maximum mean discharge obtained was 4.09 m^3/s whiles the minimum was 0.34 m^3/s.

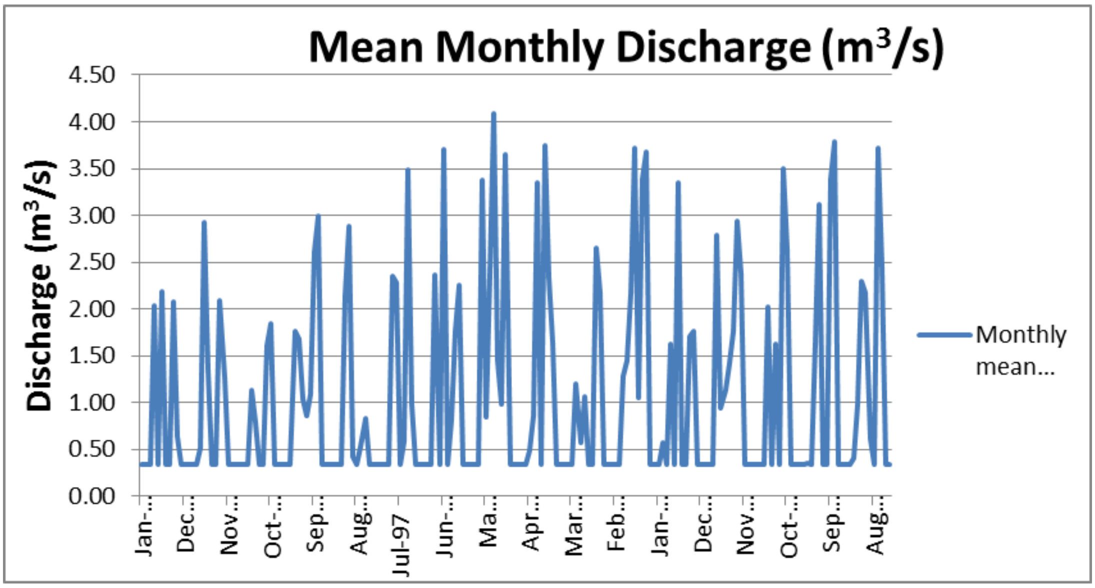

Figure 4. 9 Graph of Mean Monthly Discharge (m^3/s)

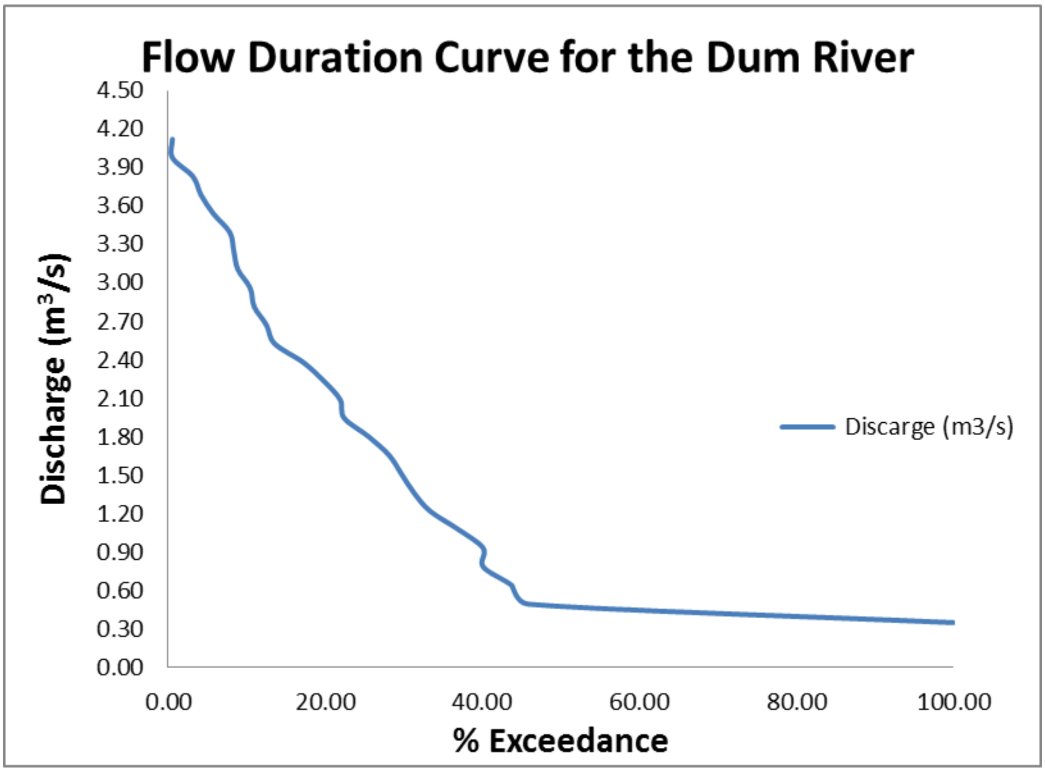

Figure 4. 10 Flow duration Curve for the Dum River

The calculated discharges in Fig. 4.9 were used to generate the flow duration curve of the Dum River (Fig. 4.10). Flow duration illustrates the percentage probability of equalling or exceeding the various discharge values within a year. The probability of equalling or exceeding the minimum flow of 0.34 m^3/s is 100% (Q_{100}) whiles the probability of equalling or exceeding the maximum flow of 4.09 m^3/s is 0.52% ($Q_{0.52}$).

4.7.2 Design Discharge

The discharge of 0.35 m^3/s (Q_{80}) for the Dum River was selected as the design discharge for the purposes of the study. The remaining 20% of the time would be used as maintenance periods. This value will be used as the firm flow for the purposes of power generation. The firm flow is as indicated in Fig. 4.11.

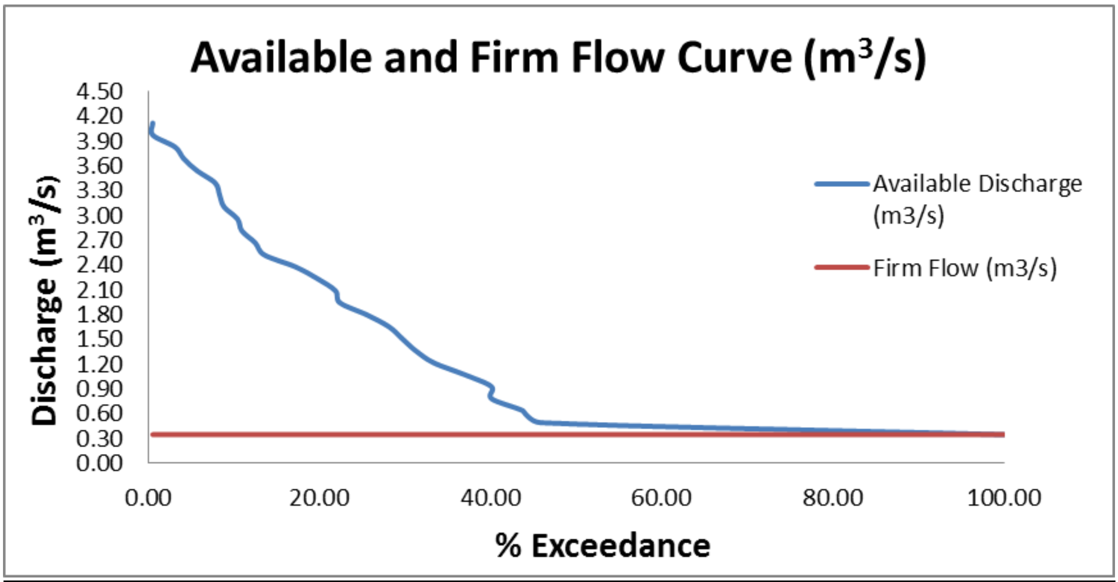

Figure 4. 11 Graph of Available and Firm Flow

4.7.3 Consideration for Ecological Flow

A flow of 0.05 m^3/s is allowed for ecological flow. This is to prevent the section of the river between the water diversion and the tailrace from totally drying up. The total design discharge is therefore 0.30 m^3/s.

4.8 Topography, Geology and Climate

The Kintampo South District which falls within the Voltain Basin (consists principally of sandstones, shale's, mudstones and limestone) and the Southern Plateau physiographic regions is a plain with rolling and undulating land surface with a general elevation between 60-150m above sea level. The district which falls within the Voltain basin is endowed with a lot of water resources. The major rivers are River Pumpum, River Oyoko, River Odum, River Nante and River Tanti. These rivers flow to join the Black Volta. Most of The Kintampo South District experiences a modified Tropical Continental climate or modified Wet Semi-equatorial climate. This is because the district lies in the transitional zone between the Wet Semi-equatorial and Tropical Continental climates. Like other parts of the country, the district experiences two seasons namely wet and dry (Ghana Districts, 2006).

4.9 Selection of Scheme Type

The Run of the River scheme will be adopted for the purpose of this study. This is because the topography of the study area is within the Voltain Basin (consists principally of sandstones, shale's, mudstones and limestone) and the Southern Plateau physiographic regions which is a plain with rolling and undulating land surface with a general elevation between 60-150 m above sea level.

There is therefore no natural basin formation to contain a reservoir for the dam type. Pursuing the dam type of scheme will mean the construction of an artificial reservoir and possible resettlement of community which will increase the investment cost. The damming of the river will also lead to the inundation of large area of land with its resultant environmental and socio-economic implications.

The Run of the River type of scheme will however cause little or no inundation of land area and has minimum civil works in the construction of a diversion weir, forebay and powerhouse building. The layout of the proposed Run of the River Scheme for this site is illustrated in Fig. 4.2.

4.10 Turbine Option, Potential Power Output and Annual Energy Generation

The analysis of the available data and the head determined for the selected site were used in the determination of the turbine option, potential power output and the annual energy generation as discussed in sections 4.10.1 to 4.10.3.

4.10.1 Turbine Option

The turbine for the hydro power plant was greatly determined by the head and the discharge of the stream. The head of the stream was 23 m and the discharge, 0.30 m^3/s. hence Fig. 3.4 clearly shows that the Cross-flow turbine should be used for this project.

4.10.2 Potential Power Output

The power output is calculated with equation 6 based on the following data;

$Q = 0.30\ m^3/s$

$H = 23\ m$

$g = 9.8\ m^2/s$

$\rho = 1000\ kg/m^3$

$\eta_{total} =$ 85% (combined turbine, generator and penstock efficiency) is assumed.

$$\mathbf{P_{max} = 0.30 \times 23 \times 9.8 \times 1000 \times 0.85} = \mathbf{57\ kW}$$

4.10.3 Annual Energy Generation

The annual power generation of the plant is based on the parameters;

Power, P= 57 kW

Time, t = 8760 h

The plant capacity factor is assumed to be 80%

Therefore using equation 7 yields,

E = **399,456 kWh/yr**

4.11 Financial Analysis

The financial viability of the project is assessed using the RETScreen Software.

4.11.1 RETScreen Tools and Determination of Initial Cost of Project

The assumptions in Table 4-5 were made for the resource assessments to arrive at the initial cost of the project.

Table 4- 5 Resource Assessment parameters and their Adjustment Factors

No.	Assessment Resource	Adjustment Factor	Remarks
1	Local vs. Canadian equipment cost ratio	1	
2	Local vs. Canadian fuel cost ratio	1	Average cost per litre: Canada=$0.1028, Ghana= $0.1055)
3	Local vs. Canadian labour cost ratio	0.032	Minimum wage; Canada=$10.25/hr ($82/day), Ghana = $ 2.62/day)
4	Equipment manufacture cost coefficient		The equipment is to be manufactured in Canada
5	$/CAD Exchange rate	0.95	$1.00 is equivalent to CAD 1.05
6	Length of Road	2km	
	Length of Penstock	47m	
7	Design Discharge	0.30m3/s	
8	Transmission Line	6km (33kV)	

Based on the assumptions in Table 4-5, $253,000.00 was determined to be the initial cost of the project. This includes the cost of feasibility, engineering, development, power system, balance of system and miscellaneous cost. The tools and initial cost model is illustrated in Table IIII-1 of Appendix IIII.

4.11.2 Energy Model

The project parameters were inputted into the RETScreen Software to generate the energy model. These parameters included measurements taken from the project site, analyzed hydrological data and assumptions made for the resource assessment. The parameters used are listed in Table 4-6;

Table 4- 6 Parameters Used for the Energy Model

Parameter	Value Used	Remarks
Design Head	23 m	Measured at the project site
Discharge exceedance obtained for the Dum River		From hydrological data obtained.
Percentage time firm flow availability	80%	Q_{80} selected from the flow duration curve (Fig. 4.9)
Design Discharge	0.30 m^3/s	Q_{80} – Ecological Flow(0.04m^3/s)
Efficiency Adjustment	6%	Assumed
Electricity Export Rate	$100/MWh	Assumed

The energy model yielded a firm power of 49kW as illustrated Table IIII-2 in the Appendix IIII. The energy model also generated the turbine efficiency and flow and power curves as shown by fig. 4.12 and fig. 4.13 respectively.

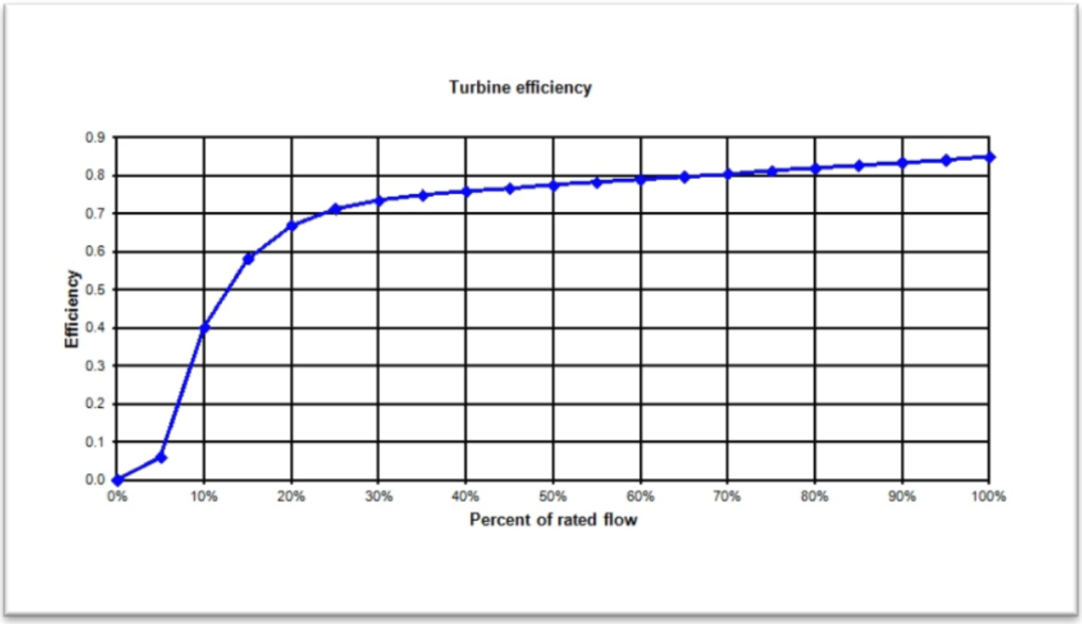

Figure 4. 12 Turbine Efficiency Curve

The turbine efficiency generated by the RETScreen Software and as indicated on Fig. 4.12 is 85%.

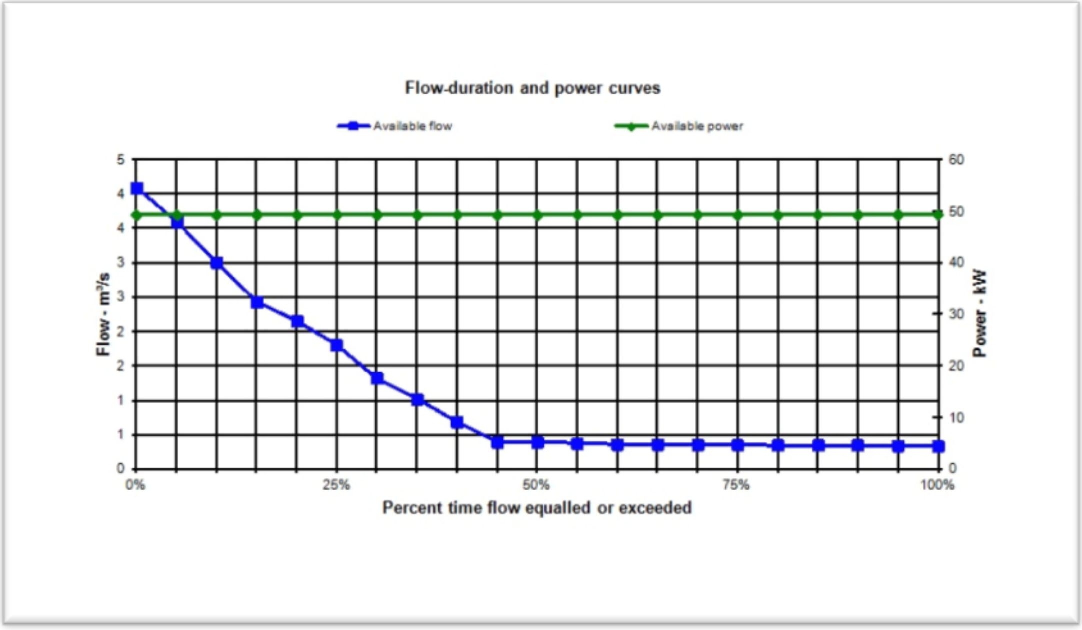

Figure 4. 13 Flow-Duration and Power Curves

The data inputs were analyzed by the RETScreen Software to generate a firm power of 49 kW as indicated in Fig. 4.13.

4.11.3 Financial Analysis

The debt financing for this project was assumed to be sourced from United States of America for the purposes of this study. The selected debt ratio was 70% and the prime lending rate (June, 2013) and inflation rates (May, 2013) was 3.25% (http://www.fedprimerate.com/) and 1.36% (http://inflationdata.com/Inflation/Inflation_Rate/CurrentInflation.asp) respectively. Operation and Maintenance Cost was assumed to be 5% of the initial cost. The project life was assumed to be 25 with a 15 year debt payment period. Table 4-7 and Fig. 4.14 illustrate the financial analysis as modeled by the RETScreen Software.

Table 4- 7 Financial Analysis

Financial Analysis			
Financial parameters			
Inflation rate	%	1.4%	
Project life	yr	25	
Debt ratio	%	70%	
Debt interest rate	%	3.25%	
Debt term	yr	15	
Initial costs			
Power system	$	253,000	100.0%
Other	$		0.0%
Total initial costs	$	253,000	100.0%
Incentives and grants	$		0.0%
Annual costs and debt payments			
O&M (savings) costs	$	12,150	
Fuel cost - proposed case	$	0	
Debt payments - 15 yrs	$	15,105	
	$		
Total annual costs	$	27,255	
Annual savings and income			
Fuel cost - base case	$	0	
Electricity export income	$	41,052	
	$		
Total annual savings and income	$	41,052	
Financial viability			
Pre-tax IRR - equity	%	21.9%	
Pre-tax IRR - assets	%	6.8%	
Simple payback	yr	8.8	
Equity payback	yr	5.1	

Cumulative cash flows ($)

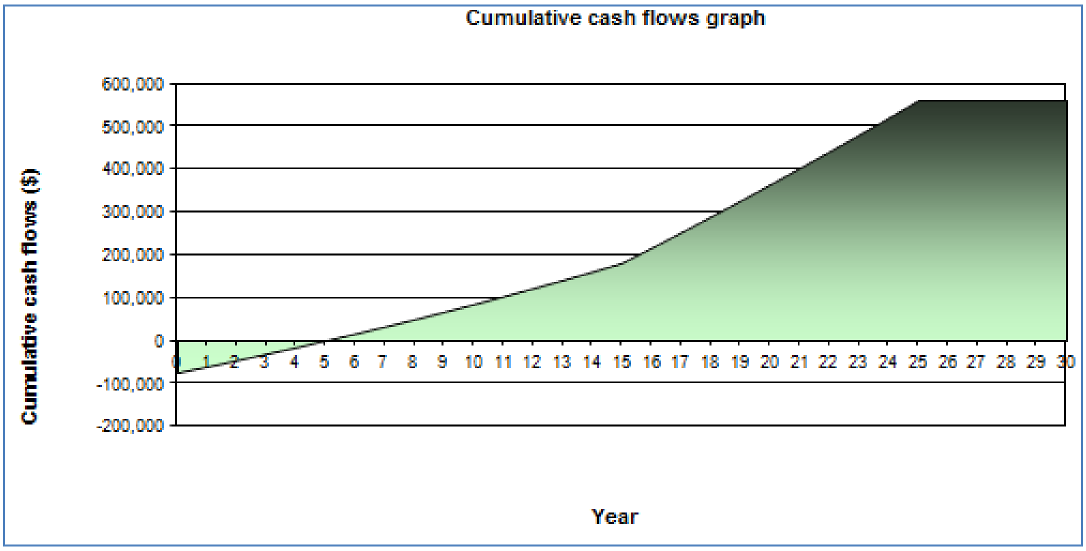

Figure 4. 14 Cumulative Cash Flow Graph

From the analysis in Table 4-7 and Fig. 4.14 the project has a positive internal rate of return (IRR) before tax for equity and assets of 21.9% and 6.8% respectively. The equity and simple payback periods are 5.1 and 8.8 years respectively.

Net Present Value (NPV)

The initial investment of $235,000.00, annual operation and maintenance cost of $12,650.00 (5% of initial investment cost), an annual cash inflow of $39,945.60 (annual generation of 399,456kWh multiplied by a feed in tariff of $0.10/kWh) and a discount rate of between 5%to 10% is used to generate the NPV scenarios for the 25 year period (projected lifespan) in Table 4-8.

Table 4- 8 Net Present Value Scenarios

Discount Rate (%)	Net Present Value ($)
5	**117,754.48**
6	**84,499.57**
7	**56,133.04**
8	**31,841.46**
9	**10,961.28**
10	**(7,050.93)**

From the scenarios in Table 4-8 the project yields a positive NPV for discount rate values 9% and below. The NPV is however negative for discount rate values 10% and above

CHAPTER FIVE

5.0 CONCLUSSIONS AND RECOMMENDATIONS

5.1 Conclusions

The Kokuma Falls on the Dum River provides an opportunity for the generation of hydro electric power.

The Project was found to be technically feasible for electricity generation based on the following findings;

- A head of 23 m with a penstock length of 47 m and slope of 1.7
- A design discharge of 0.30 m^3/s which is available 80% of the year.
- A potential firm capacity of 57kW (about 0.002% of the current national installed capacity of 2,169 MW) with an annual generation of 399,456 kWh/yr can be realized from the Project.

The project is financially viable with an initial capital cost of $253,000.00, a positive Internal Rate of Return (IRR) for equity and assets of 21.9% and 6.8% respectively and an equity and simple payback period of 5.1 years and 8.8 years respectively. However for a discount rate of 10% and above the NPV is negative in which case the project becomes not viable.

The Project even though financially feasible is also expensive compared to the average cost per kilowatt for hydropower development. The cost per kilowatt for the development of the project is $4,438.00/kW whiles that for the most recent hydro power project in Ghana; the Bui Hydroelectric Project is about $2,000.00/kW.

The Kokuma Village is connected to the central grid therefore the option is to connect the Project to the central grid or feed the power generated to a local firm which is currently non-existent. Another possible option is to feed the power generated to nearby villages which are not connected to the grid as an off-grid system.

5.2 Recommendations

- The pre-feasibility conducted at this stage indicates that the project is viable. It is however recommended that a detailed feasibility study is undertaken on this Project to determine its viability in detail.

- A detailed load forecast of the nearby villages which are not connected to the central grid should be undertaken to identify the viability of the Project supplying electricity to these villages as an off-grid system.
- The Project should be subjected to various financial models to maximize its financial efficiency and thereby make it more attractive to private investors.

- The Government could also help by providing tax incentives and favorable tariffs to small and medium hydro power plant investors to boost their interest in developing this and other similar projects in the country.

REFERENCES

1. Pence, C. (2004). Guide on How to Develop a Small Hydropower Plant. Retrieved from http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Guide+on+How+to+Develop+a+Small+Hydropower+Plant#0. Accessed 23rd may 2013
2. World Gazetteer (2013).Ghana: largest cities and towns and statistics of their population.(Online)Available at: http://www.world-gazetteer.com/wg.php?x=1369660626&lng=de&des=wg&geo=-85&srt=npan&col=adhoq&msz=1500&men=gcis&lng=en. (Accessed 27th may, 2013)
3. Ghana Districts, (2006). Kintampo South (Online). Available at http://www.kintamposouth.ghanadistricts.gov.gh/?arrow=atd&_=37. (Accessed 27th may, 2013)
4. S. Yeoman, (2003). Pre-feasibility study for the proposed Emerson hydropower development project.
5. Aydin, B.E. (2010). Feasibility study of multiple hydropower projects: Case study of Baltaci stream, Trabzon, Turkey. Unpublished MSc thesis. Middle East Technical University, Turkey.
6. Nkrumah, F. (2002). Feasibility study of wind energy utilization along the coast of Ghana. Unpublished MSc thesis. Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.
7. Tafazzoli, A. and Bludszuweit, H., (2011). Methods for Performing a Prefeasibility Assessment of a Small Hydro Plant. Department of Energy, United State of America.
8. Energy Efficiency and Renewable Energy (2001). Small Hydropower System.

9. Dernedde, S. and Ofori-Ahenkorah, A.K. (Energy Foundation), (2002).Mini Hydro Power in Ghana, Prospects and Challenges, Energy Foundation.

10. Ministry of Energy, (2010). National Energy Policy Republic of Ghana.

11. Ministerial Conference on water for Agriculture and Energy in Africa: the challenges of climate change. Sirte, Libyian Arab Jamahiriya, (15-17 December 2008). Hydropower Resource Assessment of Africa.

12. The British Hydropower Association (2005). A Guide to UK mini-hydro Development. Version 1-2.

13. ACRES International, (1991). National Electrification Planning Study, Ministry of Energy

14. ACRES International, (1984). Hydrologuc Design Methodologies for Small-Scale Hydro at Ungauged Sites: Phase 1 Prepared for Environment Canada, Inland Waters Directorate, Executed for Energy, Mines and Resources Canada, 1984.

15. Ed Hiserodt (2007, November). The "Other" Renewables. The New American, 23(23), 25-27.

16. www.dams.org. Dams and Development: A New Framework For Decision-Making. 2008, Available at: http://www.dams.org//docs/overview/wcd_overview.pdf

17. Department of Energy. Hydropower. (2008). Available at: http://www.eren.doe.gov/RE/hydropower.html

18. EMR, (1985), Energy, Mines and Resources Canada. Heating and Cooling Equipment (Steam and Water), Energy Management Series 9.

19. Leopold, L.B. (1974). Water: A Primer. In e-textbook Small Hydro Power RETScreen. Available at: www.retscreen.net

20. Wilson, E.M. (2000). Assessment Methods for Small-hydro Projects, International Energy Agency-Implementing Agreement for Topographies and Programs, April 2000

21. U.S. Government. International Energy Outlook (2007). Energy Information Administration. Available at: http://www.eia.doe.gov/oiaf/ieo/highlights.html

22. KITE, (2002). Implementation of Renewable Energy Technologies-Opportunites and Barriers. Ghana Country Study.

23. Rockward, D.M., GeoJournal, (1979), Vol. 3, No. 5, Water — Availability, Demand, Use pp. 461-470

24. Harvey, A. (1993). Micro-Hydro Design Manual. Intermediate Technology Publications. Exeter

25. ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREE) and United Nations Industrial Development Organization (UNIDO), (2012): The ECOWAS Small Scale Hydropower Program, ECOWAS Workshop on SSHP

26. Chiras, D., (2006): The Homeowner's Guide to Renewable Energy. New Society Publishers

27. Kaygusuz, K.., (1999): Hydropower Potential in Turkey, Energy Sources, 21:7, 581-588 Available at: http://dx.doi.org/10.1080/00908319950014524

28. U.S Department of the Interior, (2005). Hydroelectric Power. Power Resources Office, Bureau of Reclamation.

29. Nkrumah, F. (2002). Feasibility Study of Wind Energy Utilization Along The Coast Of Ghana. Kwame Nkrumah University of Science & Technology, Unpublished Thesis

30. Paish, O., (2002). Small hydro power: technology and current status. Renewable and Sustainable Energy Reviews 6 (2002). Page 537–556

31. Warnick, C.C. (1984). Hydropower Engineering. Prentice Hall, Inc

32. Ramous, H. (2000). Guidelines for Design of Small Hydropower Plants. Western Regional Energy Agency & Network) and DED (Department of Economic Development), Belfast, North Ireland.

33. Harvey, A. et al., (1993) Micro-Hydro Design Manual. London: IT Publications Ltd.

34. Khennas S, Barnett A (2000). Best Practices for Sustainable Development of Micro-Hydro in Developing Countries, ESMAP Technical Paper 006, IBRD, World Bank,.

35. Ackom, E.K. (2005). Technical & Economic Viability Analysis of Renewable Energy Technologies in Ghana. Brandenburg University of Technology, BTU Cottbus, Germany

36. UNESCO, (2003), Water for People, Water for Life - United Nations World Water Development Report (WWDR).

37. Gulliver, J. S., Arndt, E.A. (1991). Hydropower Engineering Handbook, 1991.

38. Energy Foundation, (2002).Towards and Energy Efficient Economy-Five-Years of Leadership. Energy Foundation Annual Report & Financial Statements 2002.

39. Renewable Energy Network for the 21st Century, (2013). Renewable Global Report. Online.Availableathttp://www.ren21.net/REN21Activities/GlobalStatusReport.aspx. Accessed 03/07/2013

40. Department of Energy (DOE), Philippines (2009). Manuals and Guidelines for Micro-hydropower Development in Rural Electrification Volume I

41. http://energy.gov/eere/water/types-hydropower-plants.

42. http://www.homepower.com/articles/microhydro-power/design-installation/intro-hydropower-part-2

APPENDICES

APPENDIX I

Table I-1 Monthly rate of annual sunshine (Northern Hemisphere) (%) (JICA, 2000)

North Latitude	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
65	3.52	5.13	7.96	9.97	12.72	14.15	13.59	11.18	8.55	6.53	4.08	2.62
64	3.81	5.27	8.00	9.92	12.50	13.63	13.26	11.08	8.56	6.63	4.32	3.02
63	4.07	5.39	8.04	9.86	12.29	13.24	12.97	10.97	8.56	6.73	4.52	3.36
62	4.31	5.49	8.07	9.80	12.11	12.92	12.73	10.87	8.55	6.80	4.70	3.65
61	4.51	5.58	8.09	9.74	11.94	12.66	12.51	10.77	8.55	6.88	4.86	3.91
60	4.70	5.67	8.11	9.69	11.78	12.41	12.31	10.68	8.54	6.95	5.02	4.14
59	4.86	5.76	8.13	9.64	11.64	12.19	12.13	10.60	8.53	7.00	5.17	4.35
58	5.02	5.84	8.14	9.59	11.50	12.00	11.96	10.52	8.53	7.06	5.30	4.54
57	5.17	5.91	8.15	9.53	11.38	11.83	11.81	10.44	8.52	7.13	5.42	4.71
56	5.31	5.98	8.17	9.48	11.26	11.68	11.67	10.36	8.52	7.18	5.52	4.87
55	5.44	6.04	8.18	9.44	11.15	11.53	11.54	10.29	8.51	7.23	5.63	5.02
54	5.56	6.10	8.19	9.40	11.04	11.39	11.42	10.22	8.50	7.28	5.74	5.16
53	5.68	6.16	8.20	9.36	10.94	11.26	11.30	10.16	8.49	7.32	5.83	5.30
52	5.79	6.22	8.21	9.32	10.85	11.14	11.19	10.10	8.48	7.36	5.92	5.42
51	5.89	6.27	8.23	9.28	10.76	11.02	11.09	10.05	8.47	7.40	6.00	5.54
50	5.99	6.32	8.24	9.24	10.68	10.92	10.99	9.99	8.46	7.44	6.08	5.65
48	6.17	6.41	8.26	9.17	10.52	10.72	10.81	9.89	8.45	7.51	6.24	5.85
46	6.33	6.50	8.28	9.11	10.38	10.53	10.65	9.79	8.43	7.58	6.37	6.05
44	6.48	6.57	8.29	9.05	10.25	10.39	10.49	9.71	8.41	7.64	6.50	6.22
42	6.61	6.65	8.30	8.99	10.13	10.24	10.35	9.62	8.40	7.70	6.62	6.39
40	6.75	6.72	8.32	8.93	10.01	10.09	10.22	9.55	8.39	7.75	6.73	6.54
38	6.87	6.79	8.33	8.89	9.90	9.96	10.11	9.47	8.37	7.80	6.83	6.68
36	6.98	6.85	8.35	8.85	9.80	9.82	9.99	9.41	8.36	7.85	6.93	6.81
34	7.10	6.91	8.35	8.80	9.71	9.71	9.88	9.34	8.35	7.90	7.02	6.93
32	7.20	6.97	8.36	8.75	9.62	9.60	9.77	9.28	8.34	7.95	7.11	7.05
30	7.31	7.02	8.37	8.71	9.54	9.49	9.67	9.21	8.33	7.99	7.20	7.16
28	7.40	7.07	8.37	8.67	9.46	9.39	9.58	9.17	8.32	8.02	7.28	7.27
26	7.49	7.12	8.38	8.64	9.37	9.29	9.49	9.11	8.32	8.06	7.36	7.37

24	7.58	7.16	8.39	8.60	9.30	9.19	9.40	9.06	8.31	8.10	7.44	7.47
22	7.67	7.21	8.40	8.56	9.22	9.11	9.32	9.01	8.30	8.13	7.51	7.56
20	7.75	7.26	8.41	8.53	9.15	9.02	9.24	8.95	8.29	8.17	7.58	7.65
18	7.83	7.31	8.41	8.50	9.08	8.93	9.16	8.90	8.29	8.20	7.65	7.74
16	7.91	7.35	8.42	8.47	9.01	8.85	9.08	8.85	8.28	8.23	7.72	7.83
14	7.98	7.39	8.43	8.43	8.94	8.77	9.00	8.80	8.27	8.27	7.79	7.93
12	8.06	7.43	8.44	8.40	8.87	8.69	8.92	8.76	8.26	8.31	7.85	8.01
10	8.14	7.47	8.45	8.37	8.81	8.61	8.85	8.71	8.25	8.34	7.91	8.09
8	8.21	7.51	8.45	8.34	8.74	8.53	8.78	8.66	8.25	8.37	7.98	8.18
6	8.28	7.55	8.46	8.31	8.68	8.45	8.71	8.62	8.24	8.40	8.04	8.26
4	8.36	7.59	8.47	8.28	8.62	8.37	8.64	8.58	8.23	8.43	8.10	8.34
2	8.43	7.63	8.49	8.25	8.55	8.29	8.57	8.53	8.22	8.46	8.16	8.42
0	8.50	7.67	8.49	8.22	8.49	8.22	8.50	8.49	8.21	8.49	8.22	8.50

Table I-2 Monthly rate of annual sunshine (Southern Hemisphere) (%) (JICA, 2000)

South Latitude	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
0	8.50	7.67	8.49	8.22	8.49	8.22	8.50	8.49	8.21	8.49	8.22	8.50
2	8.55	7.71	8.49	8.19	8.44	8.17	8.43	8.44	8.20	8.52	8.27	8.55
4	8.64	7.76	8.50	8.17	8.39	8.08	8.20	8.41	8.19	8.56	8.33	8.65
6	8.71	7.81	8.50	8.12	8.30	8.00	8.19	8.37	8.18	8.59	8.38	8.74
8	8.79	7.84	8.51	8.11	8.24	7.91	8.13	8.12	8.18	8.62	8.47	8.84
10	8.85	7.86	8.52	8.09	8.18	7.84	8.11	8.28	8.18	8.65	8.52	8.90
12	8.91	7.91	8.53	8.06	8.15	7.79	8.08	8.23	8.17	8.67	8.58	8.95
14	8.97	7.97	8.54	8.03	8.07	7.70	7.08	8.19	8.16	8.69	8.65	9.01
16	9.09	8.02	8.56	7.98	7.96	7.57	7.94	8.14	8.14	8.78	8.72	9.17
18	9.18	8.06	8.57	7.93	7.89	7.50	7.88	8.10	8.14	8.80	8.80	9.24
20	9.25	8.09	8.58	7.92	7.83	7.41	7.73	8.05	8.13	8.83	8.85	9.32
22	9.36	8.12	8.58	7.89	7.74	7.30	7.76	8.00	8.13	8.86	8.90	9.38
24	9.44	8.17	8.59	7.87	7.65	7.24	7.68	7.95	8.12	8.89	8.96	9.47
26	9.52	8.28	8.60	7.81	7.56	7.07	7.49	7.90	8.11	8.94	9.10	9.61
28	9.61	8.31	8.61	7.79	7.49	6.99	7.40	7.85	8.10	8.97	9.19	9.74
30	9.69	8.33	8.63	7.75	7.43	6.94	7.30	7.80	8.09	9.00	9.24	9.80
32	9.76	8.36	8.64	7.70	7.34	6.85	7.20	7.73	8.08	9.04	9.31	9.87

34	9.88	8.41	8.65	7.68	7.25	6.73	7.10	7.69	8.06	9.07	9.38	9.99
36	10.06	8.53	8.67	7.61	7.16	6.59	6.99	7.59	8.06	9.15	9.51	10.21
38	10.14	8.61	8.68	7.59	7.07	6.46	6.87	7.51	8.05	9.19	9.60	10.34
40	10.24	8.65	8.70	7.54	6.96	6.33	6.73	7.46	8.04	9.23	9.69	10.42
42	10.39	8.72	8.71	7.49	6.85	6.20	6.60	7.39	8.01	9.27	9.79	10.57
44	10.52	8.81	8.72	7.44	6.73	6.04	6.45	7.30	8.00	9.34	9.91	10.72
46	10.68	8.88	8.73	7.39	6.61	5.87	6.30	7.21	7.98	9.41	10.03	10.90
48	10.85	8.98	8.76	7.32	6.45	5.69	6.13	7.12	7.96	9.47	10.17	11.09
50	11.03	9.06	8.77	7.25	6.31	5.48	5.98	7.03	7.95	9.53	10.32	11.30
48	6.17	6.41	8.26	9.17	10.52	10.72	10.81	9.89	8.45	7.51	6.24	5.85
46	6.33	6.50	8.28	9.11	10.38	10.53	10.65	9.79	8.43	7.58	6.37	6.05
44	6.48	6.57	8.29	9.05	10.25	10.39	10.49	9.71	8.41	7.64	6.50	6.22
42	6.61	6.65	8.30	8.99	10.13	10.24	10.35	9.62	8.40	7.70	6.62	6.39
40	6.75	6.72	8.32	8.93	10.01	10.09	10.22	9.55	8.39	7.75	6.73	6.54
38	6.87	6.79	8.33	8.89	9.90	9.96	10.11	9.47	8.37	7.80	6.83	6.68
36	6.98	6.85	8.35	8.85	9.80	9.82	9.99	9.41	8.36	7.85	6.93	6.81
34	7.10	6.91	8.35	8.80	9.71	9.71	9.88	9.34	8.35	7.90	7.02	6.93
32	7.20	6.97	8.36	8.75	9.62	9.60	9.77	9.28	8.34	7.95	7.11	7.05
30	7.31	7.02	8.37	8.71	9.54	9.49	9.67	9.21	8.33	7.99	7.20	7.16
28	7.40	7.07	8.37	8.67	9.46	9.39	9.58	9.17	8.32	8.02	7.28	7.27
26	7.49	7.12	8.38	8.64	9.37	9.29	9.49	9.11	8.32	8.06	7.36	7.37
24	7.58	7.16	8.39	8.60	9.30	9.19	9.40	9.06	8.31	8.10	7.44	7.47
22	7.67	7.21	8.40	8.56	9.22	9.11	9.32	9.01	8.30	8.13	7.51	7.56
20	7.75	7.26	8.41	8.53	9.15	9.02	9.24	8.95	8.29	8.17	7.58	7.65
18	7.83	7.31	8.41	8.50	9.08	8.93	9.16	8.90	8.29	8.20	7.65	7.74
16	7.91	7.35	8.42	8.47	9.01	8.85	9.08	8.85	8.28	8.23	7.72	7.83
14	7.98	7.39	8.43	8.43	8.94	8.77	9.00	8.80	8.27	8.27	7.79	7.93
12	8.06	7.43	8.44	8.40	8.87	8.69	8.92	8.76	8.26	8.31	7.85	8.01
10	8.14	7.47	8.45	8.37	8.81	8.61	8.85	8.71	8.25	8.34	7.91	8.09
8	8.21	7.51	8.45	8.34	8.74	8.53	8.78	8.66	8.25	8.37	7.98	8.18
6	8.28	7.55	8.46	8.31	8.68	8.45	8.71	8.62	8.24	8.40	8.04	8.26
4	8.36	7.59	8.47	8.28	8.62	8.37	8.64	8.58	8.23	8.43	8.10	8.34
2	8.43	7.63	8.49	8.25	8.55	8.29	8.57	8.53	8.22	8.46	8.16	8.42
0	8.50	7.67	8.49	8.22	8.49	8.22	8.50	8.49	8.21	8.49	8.22	8.50

APPENDIX II

Table II-1 Mean Monthly Rainfall records for Kintampo (Jan. 1992 – Dec. 2007)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1992	0	9.3	80.3	191.4	91.6	195.4	46.1	9.2	184.6	115.5	52.7	0
1993	0	13	108.3	55.6	108	172	167.2	139.1	373.4	143.9	24.7	3.4
1994	0	0	32.9	74.8	148.1	124.7	32	88	162.7	179.9	11.3	0
1995	0	1.1	13.8	179.4	179	138.2	131.3	141	213.9	240.1	9.8	20.3
1996	8.1	32	72.2	99.2	203.1	232	107.4	76.4	106.7	126.2	0	0
1997	11.1	0	66	73.6	212.9	200.3	52.2	114.7	259.5	136.4	89.7	0
1998	0	29.6	0	210.7	71.3	275.4	42.5	127.3	170.5	202.1	73.4	32.8
1999	0	41.9	71.4	259.7	134.5	208.1	302.3	160.3	129.7	271.9	70.3	0
2000	41.90	0.00	7.30	114.60	136.30	255.90	31.30	280.90	199.40	170.80	10.40	0.00
2001	0.00	0.00	31.10	149.10	120.70	147.80	101.40	53.20	215.82	197.86	38.23	11.35
2002	0.00	0.00	64.80	152.30	166.60	195.80	281.80	138.20	253.20	277.10	34.80	15.90
2003	9.30	107.70	28.50	170.00	56.90	254.80	75.90	85.40	168.40	176.80	92.40	0.00
2004	70.80	44.10	48.80	229.70	139.20	142.90	161.00	176.90	230.30	209.50	47.40	24.40
2005	4.40	27.40	68.20	66.60	196.80	99.70	171.40	84.90	259.30	222.60	33.50	59.20
2006	2.10	18.60	108.40	69.00	176.20	245.00	64.60	22.00	254.90	283.30	0.00	0.00
2007	0	28.3	113.6	137.6	211.8	196.9	117.893	30.8	270.8	211.8	23	14.2

Table II-2 Mean Monthly Temperatures records for Kintampo (Jan. 92 to Dec. 07)

Temperature Data for January 1992 to December 2007

Year	Jan			Feb			Mar			Apr			May			Jun		
	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean
1992	32.9	19.4	**26.15**	35.8	22.6	**29.20**	34.6	24.1	**29.4**	32.7	23.1	**27.90**	31.4	22.7	**27.05**	29.2	21.4	**25.30**
1993	33.7	17.2	**25.45**	35.7	22.2	**28.95**	33.9	20.7	**27.3**	34.1	21.1	**27.60**	32.3	23	**27.65**	30.1	21.8	**25.95**
1994	34.2	20.1	**27.15**	36.5	22.9	**29.70**	36.5	23.7	**30.1**	33.8	23.8	**28.80**	30.1	23	**26.55**	29.6	21.9	**25.75**
1995	34.4	20.2	**27.30**	36.6	22	**29.30**	36.1	23.7	**29.9**	33.5	24	**28.75**	31.8	22.7	**27.25**	30.1	22	**26.05**
1996	34.4	21.2	**27.80**	35.4	21.4	**28.40**	35	23.4	**29.2**	33	23.2	**28.10**	31.7	22.9	**27.30**	29.6	21.9	**25.75**
1997	34.3	21.6	**27.95**	35.8	21.3	**28.55**	35.7	23.9	**29.8**	32.8	23.2	**28.00**	30.8	22.7	**26.75**	29.2	21.8	**25.50**
1998	34.3	19.3	**26.80**	36.2	22	**29.10**	37.8	26	**31.9**	34.3	24.1	**29.20**	33	23.7	**28.35**	30.4	22.2	**26.30**
1999	34.6	19.6	**27.10**	34.7	21.5	**28.10**	34.6	23.3	**29**	32.8	22.8	**27.80**	32.1	22.3	**27.20**	31.2	22.1	**26.65**
2000	33.5	20.7	**27.10**	35	20.8	**27.90**	36.5	23	**29.8**	34.6	23.2	**28.90**	32.6	22.6	**27.60**	29.9	21.7	**25.80**
2001	34.6	14.8	**24.70**	36.5	21.4	**28.95**	36.6	22.7	**29.7**	33.9	22.5	**28.20**	32.3	22.7	**27.50**	32.9	26.1	**29.50**
2002	33.7	21.9	**27.80**	36.1	23.4	**29.75**	35	24.1	**29.6**	32.8	22.8	**27.80**	31.5	23	**27.25**	30	21.8	**25.90**
2003	33.9	22.1	**28.00**	34.8	23.3	**29.05**	35.3	23.8	**29.6**	32.6	23.2	**27.90**	32.1	23.3	**27.70**	29.2	21.7	**25.45**
2004	33.3	21.9	**27.60**	34.5	23.2	**28.85**	34.5	23.7	**29.1**	32.9	23.1	**28.00**	31.1	23.1	**27.10**	29.9	21.9	**25.90**
2005	32	20.6	**26.30**	33.8	22.4	**28.10**	34.6	23.9	**29.3**	34.2	23.9	**29.05**	31.9	22.8	**27.35**	29.3	22.3	**25.80**
2006	33.7	21.6	**27.65**	35.1	23.1	**29.10**	34.2	23.2	**28.7**	33.7	23.8	**28.75**	31.5	22.7	**27.10**	30.4	22.3	**26.35**
2007	32.2	21	**26.60**	34.6	23.3	**28.95**	35.6	23.8	**29.7**	32.8	23	**27.90**	31.8	23.1	**27.45**	30.4	22.1	**26.25**
Mean	33.7	20.2		35.4	22.3		35.4	23.6		33.4	23.2		31.8	22.9		30.1	22.2	
Avg	**26.97**			**28.87**			**29.48**			**32.58**			**26.49**			**25.46**		

Temperature Data for January 1992 to December 2007

Year	Jul			Aug			Sep			Oct			Nov			Dec		
	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean
1992	27.5	21	**24.25**	28.1	20.6	**24.35**	29.2	20.1	**24.65**	30.6	20.9	**25.75**	31.7	20.1	**25.90**	32.5	17.4	**24.95**
1993	28.1	21.4	**24.75**	28.5	21	**24.75**	29.1	21.1	**25.10**	31.5	22	**26.75**	32.5	22.6	**27.55**	32.2	19.8	**26.00**
1994	29.3	21.8	**25.55**	29.6	21.3	**25.45**	29.2	21.4	**25.30**	30.1	21.8	**25.95**	33	20.5	**26.75**	33.5	18.9	**26.20**
1995	28.8	21.7	**25.25**	28	21.8	**24.90**	29.8	21.3	**25.55**	30.4	21.3	**25.85**	32.9	20.4	**26.65**	32.4	20.9	**26.65**
1996	28.7	21.4	**25.05**	28.5	21.6	**25.05**	28.6	21.7	**25.15**	30.6	21.2	**25.90**	33.4	20.5	**26.95**	32.8	21.9	**27.35**
1997	28.7	21.4	**25.05**	28.8	21.6	**25.20**	29.4	22.1	**25.75**	31.1	22.4	**26.75**	32.6	22	**27.30**	32.8	18.1	**25.45**
1998	28.9	22	**25.45**	28.8	21.6	**25.20**	29.6	21.5	**25.55**	31	21.5	**26.25**	33.6	22	**27.80**	33.1	20.3	**26.70**
1999	29.4	21.4	**25.40**	29.2	21	**25.10**	29	21	**25.00**	30.4	18.3	**24.35**	32.7	21.7	**27.20**	32.8	19	**25.90**
2000	28.6	21.3	**24.95**	28.4	20.8	**24.60**	28.7	21.6	**25.15**	32.3	21.2	**26.75**	32.7	21.6	**27.15**	32.7	17.3	**25.00**
2001	29.4	21.4	**25.40**	28.4	21.3	**24.85**	29.3	21.4	**25.35**	30.8	21.5	**26.15**	32.5	21.7	**27.10**	32.6	19.9	**26.25**
2002	28.3	21.8	**25.05**	27.7	21.6	**24.65**	28.8	21.5	**25.15**	30.2	21.9	**26.05**	31.4	22.5	**26.95**	32	21.4	**26.70**
2003	28.3	21.6	**24.95**	28.4	21.5	**24.95**	29.4	21.9	**25.65**	30.8	22.4	**26.60**	31.5	22.5	**27.00**	32.6	19.9	**26.25**
2004	29.1	21.6	**25.35**	28.5	21.6	**25.05**	29.4	21.4	**25.40**	31.2	21.8	**26.50**	32.2	22.8	**27.50**	32.4	22.5	**27.45**
2005	28.9	21.5	**25.20**	28	21.3	**24.65**	29.2	21.6	**25.40**	31.1	21.7	**26.40**	32.6	22.3	**27.45**	32.2	19.8	**26.00**
2006	29.1	22.3	**25.70**	28.8	21.9	**25.35**	29.8	21.8	**25.80**	30.6	22.2	**26.40**	32.2	21.8	**27.00**	32.4	20.8	**26.60**
2007	28.7	21.6	**25.15**	29.3	19.2	**24.25**	29.8	21.4	**25.60**	30.8	21.5	**26.15**	32.3	22	**27.15**	32	20.6	**26.30**
Mean	28.7	21.6		28.6	21.2		29.3	21.4		30.8	21.5		32.5	21.7		32.6	19.9	
Avg	**25.16**			**24.90**			**25.35**			**26.16**			**27.09**			**6.00**		

APPENDIX III

Table III-1 Determination of Possible Evaporation and Real Evaporation (Jan. 92-Dec.07)

Year	Rainfall (mm)	Temperature (°C)	Annual Sunshine	Possible Evaporation (Blaney-Criddle)	Real Evaporation
Jan-92	0.00	26.15	8.21	98.92	0.00
Feb-92	9.30	29.2	7.51	96.76	9.30
Mar-92	80.30	29.35	8.45	109.22	80.30
Apr-92	191.40	27.9	8.34	104.49	104.49
May-92	91.60	27.05	8.74	107.46	91.60
Jun-92	195.40	25.3	8.53	100.78	100.78
Jul-92	46.10	24.25	8.78	101.21	46.10
Aug-92	9.20	24.35	8.66	100.06	9.20
Sep-92	184.60	24.65	8.25	96.01	96.01
Oct-92	115.50	25.75	8.37	99.93	99.93
Nov-92	52.70	25.9	7.98	95.60	52.70
Dec-92	0.00	24.95	8.18	95.86	0.00
Jan-93	0.00	25.45	8.21	97.34	0.00
Feb-93	61.00	28.95	7.51	96.25	61.00
Mar-93	79.00	27.3	8.45	104.47	79.00
Apr-93	112.70	27.6	8.34	103.80	103.80
May-93	245.70	27.65	8.74	108.90	108.90
Jun-93	154.00	25.95	8.53	102.30	102.30
Jul-93	19.80	24.75	8.78	102.41	19.80
Aug-93	18.00	24.75	8.66	101.01	18.00

Sep-93	186.20	25.1	8.25	97.02	97.02
Oct-93	151.10	26.75	8.37	102.22	102.22
Nov-93	44.30	27.55	7.98	99.21	44.30
Dec-93	8.30	26	8.18	98.22	8.30
Jan-94	0.00	27.15	8.21	101.17	0.00
Feb-94	0.00	29.7	7.51	97.79	0.00
Mar-94	32.90	30.1	8.45	110.96	32.90
Apr-94	74.80	28.8	8.34	106.54	74.80
May-94	148.10	26.55	8.74	106.26	106.26
Jun-94	124.70	25.75	8.53	101.84	101.84
Jul-94	32.00	25.55	8.78	104.34	32.00
Aug-94	88.00	25.45	8.66	102.68	88.00
Sep-94	162.70	25.3	8.25	97.48	97.48
Oct-94	179.90	25.95	8.37	100.39	100.39
Nov-94	11.30	26.75	7.98	97.46	11.30
Dec-94	0.00	26.2	8.18	98.67	0.00
Jan-95	0.00	27.3	8.21	101.51	0.00
Feb-95	1.10	29.3	7.51	96.97	1.10
Mar-95	13.80	29.9	8.45	110.50	13.80
Apr-95	179.40	28.75	8.34	106.43	106.43
May-95	179.00	27.25	8.74	107.94	107.94
Jun-95	138.20	26.05	8.53	102.54	102.54
Jul-95	131.30	25.25	8.78	103.62	103.62
Aug-95	141.00	24.9	8.66	101.37	101.37
Sep-95	213.90	25.55	8.25	98.04	98.04
Oct-95	240.10	25.85	8.37	100.16	100.16
Nov-95	9.80	26.65	7.98	97.24	9.80

Dec-95	20.30	26.65	8.18	99.68	20.30
Jan-96	8.10	27.8	8.21	102.63	8.10
Feb-96	32.00	28.4	7.51	95.12	32.00
Mar-96	72.20	29.2	8.45	108.88	72.20
Apr-96	99.20	28.1	8.34	104.94	99.20
May-96	203.10	27.3	8.74	108.06	108.06
Jun-96	232.00	25.75	8.53	101.84	101.84
Jul-96	107.40	25.05	8.78	103.14	103.14
Aug-96	76.40	25.05	8.66	101.73	76.40
Sep-96	106.70	25.15	8.25	97.14	97.14
Oct-96	126.20	25.9	8.37	100.27	100.27
Nov-96	0.00	26.95	7.98	97.90	0.00
Dec-96	0.00	27.35	8.18	101.25	0.00
Jan-97	11.10	27.95	8.21	102.97	11.10
Feb-97	0.00	28.55	7.51	95.43	0.00
Mar-97	66.00	29.8	8.45	110.27	66.00
Apr-97	73.60	28	8.34	104.71	73.60
May-97	212.90	26.75	8.74	106.74	106.74
Jun-97	200.30	25.5	8.53	101.25	101.25
Jul-97	52.20	25.05	8.78	103.14	52.20
Aug-97	114.70	25.2	8.66	102.08	102.08
Sep-97	259.50	25.75	8.25	98.49	98.49
Oct-97	136.40	26.75	8.37	102.22	102.22
Nov-97	89.70	27.3	7.98	98.66	89.70
Dec-97	0.00	25.45	8.18	96.99	0.00
Jan-98	0.00	26.8	8.21	100.38	0.00
Feb-98	29.60	29.1	7.51	96.56	29.60

Mar-98	0.00	31.9	8.45	115.13	0.00
Apr-98	210.70	29.2	8.34	107.46	107.46
May-98	71.30	28.35	8.74	110.57	71.30
Jun-98	275.40	26.3	8.53	103.12	103.12
Jul-98	42.50	25.45	8.78	104.10	42.50
Aug-98	127.30	25.2	8.66	102.08	102.08
Sep-98	170.50	25.55	8.25	98.04	98.04
Oct-98	202.10	26.25	8.37	101.07	101.07
Nov-98	73.40	27.8	7.98	99.76	73.40
Dec-98	32.80	26.7	8.18	99.79	32.80
Jan-99	0.00	27.1	8.21	101.06	0.00
Feb-99	41.90	28.1	7.51	94.50	41.90
Mar-99	71.40	28.95	8.45	108.30	71.40
Apr-99	259.70	27.8	8.34	104.26	104.26
May-99	134.50	27.2	8.74	107.82	107.82
Jun-99	208.10	26.65	8.53	103.94	103.94
Jul-99	302.30	25.4	8.78	103.98	103.98
Aug-99	160.30	25.1	8.66	101.85	101.85
Sep-99	129.70	25	8.25	96.80	96.80
Oct-99	271.90	24.35	8.37	96.71	96.71
Nov-99	70.30	27.2	7.98	98.44	70.30
Dec-99	0.00	25.9	8.18	97.99	0.00
Jan-00	41.90	27.1	8.21	101.06	41.90
Feb-00	0.00	27.9	7.51	94.09	0.00
Mar-00	7.30	29.75	8.45	110.15	7.30
Apr-00	114.60	28.9	8.34	106.77	106.77
May-00	136.30	27.6	8.74	108.78	108.78

Jun-00	255.90	25.8	8.53	101.95	101.95
Jul-00	31.30	24.95	8.78	102.90	31.30
Aug-00	280.90	24.6	8.66	100.66	100.66
Sep-00	199.40	25.15	8.25	97.14	97.14
Oct-00	170.80	26.75	8.37	102.22	102.22
Nov-00	10.40	27.15	7.98	98.33	10.40
Dec-00	0.00	25	8.18	95.98	0.00
Jan-01	0.00	24.7	8.21	95.65	0.00
Feb-01	0.00	28.95	7.51	96.25	0.00
Mar-01	31.10	29.65	8.45	109.92	31.10
Apr-01	149.10	28.2	8.34	105.17	105.17
May-01	120.70	27.5	8.74	108.54	108.54
Jun-01	147.80	29.5	8.53	110.61	110.61
Jul-01	101.40	25.4	8.78	103.98	101.40
Aug-01	53.20	24.85	8.66	101.25	53.20
Sep-01	215.82	25.35	8.25	97.59	97.59
Oct-01	197.86	26.15	8.37	100.84	100.84
Nov-01	38.23	27.1	7.98	98.22	38.23
Dec-01	11.35	26.25	8.18	98.78	11.35
Jan-02	0.00	27.8	8.21	102.63	0.00
Feb-02	0.00	29.75	7.51	97.90	0.00
Mar-02	64.80	29.55	8.45	109.69	64.80
Apr-02	152.30	27.8	8.34	104.26	104.26
May-02	166.60	27.25	8.74	107.94	107.94
Jun-02	195.80	25.9	8.53	102.19	102.19
Jul-02	281.80	25.05	8.78	103.14	103.14
Aug-02	138.20	24.65	8.66	100.78	100.78

Sep-02	253.20	25.15	8.25	97.14	97.14
Oct-02	277.10	26.05	8.37	100.62	100.62
Nov-02	34.80	26.95	7.98	97.90	34.80
Dec-02	15.90	26.7	8.18	99.79	15.90
Jan-03	9.30	28	8.21	103.08	9.30
Feb-03	107.70	29.05	7.51	96.45	96.45
Mar-03	28.50	29.55	8.45	109.69	28.50
Apr-03	170.00	27.9	8.34	104.49	104.49
May-03	56.90	27.7	8.74	109.02	56.90
Jun-03	254.80	25.45	8.53	101.14	101.14
Jul-03	75.90	24.95	8.78	102.90	75.90
Aug-03	85.40	24.95	8.66	101.49	85.40
Sep-03	168.40	25.65	8.25	98.27	98.27
Oct-03	176.80	26.6	8.37	101.88	101.88
Nov-03	92.40	27	7.98	98.01	92.40
Dec-03	0.00	26.25	8.18	98.78	0.00
Jan-04	70.80	27.6	8.21	102.18	70.80
Feb-04	44.10	28.85	7.51	96.04	44.10
Mar-04	48.80	29.1	8.45	108.64	48.80
Apr-04	229.70	28	8.34	104.71	104.71
May-04	139.20	27.1	8.74	107.58	107.58
Jun-04	142.90	25.9	8.53	102.19	102.19
Jul-04	161.00	25.35	8.78	103.86	103.86
Aug-04	176.90	25.05	8.66	101.73	101.73
Sep-04	230.30	25.4	8.25	97.70	97.70
Oct-04	209.50	26.5	8.37	101.65	101.65
Nov-04	47.40	27.5	7.98	99.10	47.40

Dec-04	24.40	27.45	8.18	101.47	24.40
Jan-05	4.40	26.3	8.21	99.25	4.40
Feb-05	27.40	28.1	7.51	94.50	27.40
Mar-05	68.20	29.25	8.45	108.99	68.20
Apr-05	66.60	29.05	8.34	107.11	66.60
May-05	196.80	27.35	8.74	108.18	108.18
Jun-05	99.70	25.8	8.53	101.95	99.70
Jul-05	171.40	25.2	8.78	103.50	103.50
Aug-05	84.90	24.65	8.66	100.78	84.90
Sep-05	259.30	25.4	8.25	97.70	97.70
Oct-05	222.60	26.4	8.37	101.42	101.42
Nov-05	33.50	27.45	7.98	98.99	33.50
Dec-05	59.20	26	8.18	98.22	59.20
Jan-06	2.10	27.65	8.21	102.29	2.10
Feb-06	18.60	29.1	7.51	96.56	18.60
Mar-06	108.40	28.7	8.45	107.72	107.72
Apr-06	69.00	28.75	8.34	106.43	69.00
May-06	176.20	27.1	8.74	107.58	107.58
Jun-06	245.00	26.35	8.53	103.24	103.24
Jul-06	64.60	25.7	8.78	104.70	64.60
Aug-06	22.00	25.35	8.66	102.44	22.00
Sep-06	254.90	25.8	8.25	98.61	98.61
Oct-06	283.30	26.4	8.37	101.42	101.42
Nov-06	0.00	27	7.98	98.01	0.00
Dec-06	0.00	26.6	8.18	99.56	0.00
Jan-07	0.00	26.6	8.21	99.93	0.00
Feb-07	28.30	28.95	7.51	96.25	28.30

Mar-07	113.60	29.7	8.45	110.03	110.03
Apr-07	137.60	27.9	8.34	104.49	104.49
May-07	211.80	27.45	8.74	108.42	108.42
Jun-07	196.90	26.25	8.53	103.01	103.01
Jul-07	117.89	25.15	8.78	103.38	103.38
Aug-07	30.80	24.25	8.66	99.83	30.80
Sep-07	270.80	25.6	8.25	98.15	98.15
Oct-07	211.80	26.15	8.37	100.84	100.84
Nov-07	23.00	27.15	7.98	98.33	23.00
Dec-07	14.20	26.3	8.18	98.89	14.20

Table III-2 Determination of Runoff and Monthly Mean Discharge Values (Jan. 92 - Dec. 07)

Year	Runoff	Direct Runoff	Base Runoff	Monthly Runoff	No. Days in Month	Monthly mean discharge (m3/s)
Jan-92	0.00	0.00	11.69	11.69	31.00	0.34
Feb-92	0.00	0.00	10.56	10.56	28.00	0.34
Mar-92	0.00	0.00	11.69	11.69	31.00	0.34
Apr-92	86.91	56.49	11.31	67.81	30.00	2.04
May-92	0.00	0.00	11.69	11.69	31.00	0.34
Jun-92	94.62	61.50	11.31	72.81	30.00	2.19
Jul-92	0.00	0.00	11.69	11.69	31.00	0.34
Aug-92	0.00	0.00	11.69	11.69	31.00	0.34
Sep-92	88.59	57.59	11.31	68.90	30.00	2.07
Oct-92	15.57	10.12	11.69	21.81	31.00	0.64
Nov-92	0.00	0.00	11.31	11.31	30.00	0.34
Dec-92	0.00	0.00	11.69	11.69	31.00	0.34
Jan-93	0.00	0.00	11.69	11.69	31.00	0.34
Feb-93	0.00	0.00	10.56	10.56	28.00	0.34
Mar-93	0.00	0.00	11.69	11.69	31.00	0.34
Apr-93	8.90	5.79	11.31	17.10	30.00	0.51
May-93	136.80	88.92	11.69	100.61	31.00	2.93
Jun-93	51.70	33.60	11.31	44.92	30.00	1.35
Jul-93	0.00	0.00	11.69	11.69	31.00	0.34
Aug-93	0.00	0.00	11.69	11.69	31.00	0.34
Sep-93	89.18	57.96	11.31	69.28	30.00	2.08

Oct-93	48.88	31.77	11.69	43.46	31.00	1.27
Nov-93	0.00	0.00	11.31	11.31	30.00	0.34
Dec-93	0.00	0.00	11.69	11.69	31.00	0.34
Jan-94	0.00	0.00	11.69	11.69	31.00	0.34
Feb-94	0.00	0.00	10.56	10.56	28.00	0.34
Mar-94	0.00	0.00	11.69	11.69	31.00	0.34
Apr-94	0.00	0.00	11.31	11.31	30.00	0.34
May-94	41.84	27.20	11.69	38.89	31.00	1.13
Jun-94	22.86	14.86	11.31	26.17	30.00	0.79
Jul-94	0.00	0.00	11.69	11.69	31.00	0.34
Aug-94	0.00	0.00	11.69	11.69	31.00	0.34
Sep-94	65.22	42.40	11.31	53.71	30.00	1.62
Oct-94	79.51	51.68	11.69	63.37	31.00	1.85
Nov-94	0.00	0.00	11.31	11.31	30.00	0.34
Dec-94	0.00	0.00	11.69	11.69	31.00	0.34
Jan-95	0.00	0.00	11.69	11.69	31.00	0.34
Feb-95	0.00	0.00	10.56	10.56	28.00	0.34
Mar-95	0.00	0.00	11.69	11.69	31.00	0.34
Apr-95	72.97	47.43	11.31	58.74	30.00	1.77
May-95	71.06	46.19	11.69	57.88	31.00	1.69
Jun-95	35.66	23.18	11.31	34.49	30.00	1.04
Jul-95	27.68	17.99	11.69	29.68	31.00	0.86
Aug-95	39.63	25.76	11.69	37.45	31.00	1.09
Sep-95	115.86	75.31	11.31	86.62	30.00	2.61
Oct-95	139.94	90.96	11.69	102.65	31.00	2.99
Nov-95	0.00	0.00	11.31	11.31	30.00	0.34
Dec-95	0.00	0.00	11.69	11.69	31.00	0.34

Jan-96	0.00	0.00	11.69	11.69	31.00	0.34
Feb-96	0.00	0.00	10.56	10.56	28.00	0.34
Mar-96	0.00	0.00	11.69	11.69	31.00	0.34
Apr-96	0.00	0.00	11.31	11.31	30.00	0.34
May-96	95.04	61.78	11.69	73.47	31.00	2.14
Jun-96	130.16	84.61	11.31	95.92	30.00	2.89
Jul-96	4.26	2.77	11.69	14.46	31.00	0.42
Aug-96	0.00	0.00	11.69	11.69	31.00	0.34
Sep-96	9.56	6.22	11.31	17.53	30.00	0.53
Oct-96	25.93	16.85	11.69	28.54	31.00	0.83
Nov-96	0.00	0.00	11.31	11.31	30.00	0.34
Dec-96	0.00	0.00	11.69	11.69	31.00	0.34
Jan-97	0.00	0.00	11.69	11.69	31.00	0.34
Feb-97	0.00	0.00	10.56	10.56	28.00	0.34
Mar-97	0.00	0.00	11.69	11.69	31.00	0.34
Apr-97	0.00	0.00	11.31	11.31	30.00	0.34
May-97	106.16	69.00	11.69	80.69	31.00	2.35
Jun-97	99.05	64.38	11.31	75.69	30.00	2.28
Jul-97	0.00	0.00	11.69	11.69	31.00	0.34
Aug-97	12.62	8.20	11.69	19.89	31.00	0.58
Sep-97	161.01	104.65	11.31	115.97	30.00	3.49
Oct-97	34.18	22.22	11.69	33.91	31.00	0.99
Nov-97	0.00	0.00	11.31	11.31	30.00	0.34
Dec-97	0.00	0.00	11.69	11.69	31.00	0.34
Jan-98	0.00	0.00	11.69	11.69	31.00	0.34
Feb-98	0.00	0.00	10.56	10.56	28.00	0.34
Mar-98	0.00	0.00	11.69	11.69	31.00	0.34

Apr-98	103.24	67.11	11.31	78.42	30.00	2.36
May-98	0.00	0.00	11.69	11.69	31.00	0.34
Jun-98	172.28	111.98	11.31	123.29	30.00	3.71
Jul-98	0.00	0.00	11.69	11.69	31.00	0.34
Aug-98	25.22	16.39	11.69	28.08	31.00	0.82
Sep-98	72.46	47.10	11.31	58.41	30.00	1.76
Oct-98	101.03	65.67	11.69	77.36	31.00	2.25
Nov-98	0.00	0.00	11.31	11.31	30.00	0.34
Dec-98	0.00	0.00	11.69	11.69	31.00	0.34
Jan-99	0.00	0.00	11.69	11.69	31.00	0.34
Feb-99	0.00	0.00	10.56	10.56	28.00	0.34
Mar-99	0.00	0.00	11.69	11.69	31.00	0.34
Apr-99	155.44	101.04	11.31	112.35	30.00	3.38
May-99	26.68	17.34	11.69	29.03	31.00	0.85
Jun-99	104.16	67.70	11.31	79.02	30.00	2.38
Jul-99	198.32	128.91	11.69	140.60	31.00	4.09
Aug-99	58.45	38.00	11.69	49.69	31.00	1.45
Sep-99	32.90	21.39	11.31	32.70	30.00	0.98
Oct-99	175.19	113.87	11.69	125.56	31.00	3.66
Nov-99	0.00	0.00	11.31	11.31	30.00	0.34
Dec-99	0.00	0.00	11.69	11.69	31.00	0.34
Jan-00	0.00	0.00	11.69	11.69	31.00	0.34
Feb-00	0.00	0.00	10.56	10.56	28.00	0.34
Mar-00	0.00	0.00	11.69	11.69	31.00	0.34
Apr-00	7.83	5.09	11.31	16.40	30.00	0.49
May-00	27.52	17.89	11.69	29.58	31.00	0.86
Jun-00	153.95	100.07	11.31	111.38	30.00	3.35

Jul-00	0.00	0.00	11.69	11.69	31.00	0.34
Aug-00	180.24	117.16	11.69	128.85	31.00	3.75
Sep-00	102.26	66.47	11.31	77.78	30.00	2.34
Oct-00	68.58	44.58	11.69	56.27	31.00	1.64
Nov-00	0.00	0.00	11.31	11.31	30.00	0.34
Dec-00	0.00	0.00	11.69	11.69	31.00	0.34
Jan-01	0.00	0.00	11.69	11.69	31.00	0.34
Feb-01	0.00	0.00	10.56	10.56	28.00	0.34
Mar-01	0.00	0.00	11.69	11.69	31.00	0.34
Apr-01	43.93	28.55	11.31	39.87	30.00	1.20
May-01	12.16	7.91	11.69	19.60	31.00	0.57
Jun-01	37.19	24.18	11.31	35.49	30.00	1.07
Jul-01	0.00	0.00	11.69	11.69	31.00	0.34
Aug-01	0.00	0.00	11.69	11.69	31.00	0.34
Sep-01	118.23	76.85	11.31	88.16	30.00	2.65
Oct-01	97.02	63.06	11.69	74.75	31.00	2.18
Nov-01	0.00	0.00	11.31	11.31	30.00	0.34
Dec-01	0.00	0.00	11.69	11.69	31.00	0.34
Jan-02	0.00	0.00	11.69	11.69	31.00	0.34
Feb-02	0.00	0.00	10.56	10.56	28.00	0.34
Mar-02	0.00	0.00	11.69	11.69	31.00	0.34
Apr-02	48.04	31.23	11.31	42.54	30.00	1.28
May-02	58.66	38.13	11.69	49.82	31.00	1.45
Jun-02	93.61	60.85	11.31	72.16	30.00	2.17
Jul-02	178.66	116.13	11.69	127.82	31.00	3.72
Aug-02	37.42	24.33	11.69	36.02	31.00	1.05
Sep-02	156.06	101.44	11.31	112.75	30.00	3.39

Oct-02	176.48	114.72	11.69	126.41	31.00	3.68
Nov-02	0.00	0.00	11.31	11.31	30.00	0.34
Dec-02	0.00	0.00	11.69	11.69	31.00	0.34
Jan-03	0.00	0.00	11.69	11.69	31.00	0.34
Feb-03	11.25	7.31	10.56	17.87	28.00	0.58
Mar-03	0.00	0.00	11.69	11.69	31.00	0.34
Apr-03	65.51	42.58	11.31	53.90	30.00	1.62
May-03	0.00	0.00	11.69	11.69	31.00	0.34
Jun-03	153.66	99.88	11.31	111.20	30.00	3.35
Jul-03	0.00	0.00	11.69	11.69	31.00	0.34
Aug-03	0.00	0.00	11.69	11.69	31.00	0.34
Sep-03	70.13	45.59	11.31	56.90	30.00	1.71
Oct-03	74.92	48.70	11.69	60.39	31.00	1.76
Nov-03	0.00	0.00	11.31	11.31	30.00	0.34
Dec-03	0.00	0.00	11.69	11.69	31.00	0.34
Jan-04	0.00	0.00	11.69	11.69	31.00	0.34
Feb-04	0.00	0.00	10.56	10.56	28.00	0.34
Mar-04	0.00	0.00	11.69	11.69	31.00	0.34
Apr-04	124.99	81.24	11.31	92.55	30.00	2.79
May-04	31.62	20.55	11.69	32.24	31.00	0.94
Jun-04	40.71	26.46	11.31	37.78	30.00	1.14
Jul-04	57.14	37.14	11.69	48.83	31.00	1.42
Aug-04	75.17	48.86	11.69	60.55	31.00	1.76
Sep-04	132.60	86.19	11.31	97.50	30.00	2.93
Oct-04	107.85	70.10	11.69	81.79	31.00	2.38
Nov-04	0.00	0.00	11.31	11.31	30.00	0.34
Dec-04	0.00	0.00	11.69	11.69	31.00	0.34

Jan-05	0.00	0.00	11.69	11.69	31.00	0.34
Feb-05	0.00	0.00	10.56	10.56	28.00	0.34
Mar-05	0.00	0.00	11.69	11.69	31.00	0.34
Apr-05	0.00	0.00	11.31	11.31	30.00	0.34
May-05	88.62	57.60	11.69	69.29	31.00	2.02
Jun-05	0.00	0.00	11.31	11.31	30.00	0.34
Jul-05	67.90	44.14	11.69	55.83	31.00	1.63
Aug-05	0.00	0.00	11.69	11.69	31.00	0.34
Sep-05	161.60	105.04	11.31	116.35	30.00	3.50
Oct-05	121.18	78.77	11.69	90.46	31.00	2.63
Nov-05	0.00	0.00	11.31	11.31	30.00	0.34
Dec-05	0.00	0.00	11.69	11.69	31.00	0.34
Jan-06	0.00	0.00	11.69	11.69	31.00	0.34
Feb-06	0.00	0.00	10.56	10.56	28.00	0.34
Mar-06	0.68	0.44	11.69	12.13	31.00	0.35
Apr-06	0.00	0.00	11.31	11.31	30.00	0.34
May-06	68.62	44.60	11.69	56.29	31.00	1.64
Jun-06	141.76	92.14	11.31	103.46	30.00	3.11
Jul-06	0.00	0.00	11.69	11.69	31.00	0.34
Aug-06	0.00	0.00	11.69	11.69	31.00	0.34
Sep-06	156.29	101.59	11.31	112.90	30.00	3.40
Oct-06	181.88	118.22	11.69	129.91	31.00	3.78
Nov-06	0.00	0.00	11.31	11.31	30.00	0.34
Dec-06	0.00	0.00	11.69	11.69	31.00	0.34
Jan-07	0.00	0.00	11.69	11.69	31.00	0.34
Feb-07	0.00	0.00	10.56	10.56	28.00	0.34
Mar-07	3.57	2.32	11.69	14.01	31.00	0.41

Apr-07	33.11	21.52	11.31	32.84	30.00	0.99
May-07	103.38	67.20	11.69	78.89	31.00	2.30
Jun-07	93.89	61.03	11.31	72.34	30.00	2.18
Jul-07	14.52	9.44	11.69	21.13	31.00	0.62
Aug-07	0.00	0.00	11.69	11.69	31.00	0.34
Sep-07	172.65	112.22	11.31	123.53	30.00	3.72
Oct-07	110.96	72.12	11.69	83.81	31.00	2.44
Nov-07	0.00	0.00	11.31	11.31	30.00	0.34
Dec-07	0.00	0.00	11.69	11.69	31.00	0.34
	7300.79			6947.82		

APPENDIX IIII

Table IIII-1 RETScreen Tools

RETScreen Tools - Power project

Settings					
☐	As fired fuel	☐	Ground heat exchanger	☐	User-defined fuel - gas
☐	Biogas	☐	Heat rate	☐	User-defined fuel - solid
☐	Building envelope properties	☐	Heating value & fuel rate	☐	Water & steam
☐	Appliances & equipment	☐	Hydro formula costing method	☐	Water pumping
☐	Electricity rate - monthly	☐	Landfill gas	☐	Window properties
☐	Electricity rate - time of use	☐	Unit conversion	☐	Custom 1
☐	GHG equivalence	☐	User-defined fuel	☐	Custom 2

Hydro formula costing method			
Country	Ghana		
Local vs. Canadian equipment cost ratio		1.00	
Local vs. Canadian fuel cost ratio		1.00	
Local vs. Canadian labour cost ratio		1.00	
Equipment manufacture cost coefficient		1.00	
Exchange rate	$/CAD	1.00	
Cold climate	yes/no	No	
Design flow	m^3/s	0.3	0.3
Gross head	m	23	23
Number of turbines	turbine	1	1
Type		Cross-flow	Cross-flow

Flow per turbine	m^3/s	0.30		
Turbine runner diameter per unit	m	0.28		
Facility type		Micro	Micro	
Existing dam	yes/no	No		
New dam crest length	m	0		
Maximum hydraulic losses	%	2.0%	5.0%	See manual
Miscellaneous losses	%	2.0%		
☐ **Road construction**				
Length	km	2.0		
Tote road only	yes/no	Yes		
Difficulty of terrain		1.0		
☐ **Canal**				
Length in rock	m	3		
Terrain side slope in rock (average)	°			
Length in impervious soil	m	28		
Terrain side slope in soil (average)	°			
Total canal headloss	m	0.0		
☐ **Penstock**				
Length	m	47.0		
Number	penstock	1		
Allowable penstock headloss factor	%	2.0%		
Diameter	m	0.43		
Average pipe wall thickness	mm	6.34		
Transmission line				
Grid type		Central-grid	Central-grid	
Length	km	8.0		
Difficulty of terrain		1.0		
Voltage	kV	33.0		

Initial costs (credits)	**Amount $**	**Adjustment factor**	**Amount $**	**Relative costs**
Feasibility study	16,000	1.00	16,000	3.0%
Development	20,000	1.00	20,000	3.7%
Engineering	6,000	1.00	6,000	1.1%
Power system				
Hydro turbine	73,000	1.00	73,000	13.5%

Road construction	14,000	1.00	14,000	2.6%
Transmission line	267,000	1.00	267,000	49.3%
Substation	2,000	1.00	2,000	0.4%
Balance of system & miscellaneous				
Penstock	29,000	1.00	29,000	5.4%
Canal	0	1.00	0	0.0%
Tunnel	0	1.00	0	0.0%
Other	115,000	1.00	115,000	21.2%
Sub-total:	144,000		144,000	
Total initial costs	**542,000**		**542,000**	**100.0%**

TableIIII-2 RETScreen Energy Model

Proposed case power system				Incremental initial costs
Technology	Hydro turbine			
Analysis type		Method 1		
	□	Method		
	□	2	□	
Resource assessment				
Proposed project		Run-of-river		
Hydrology method		User-defined		
Gross head	m	23.0		
Maximum tailwater effect	m	0.00		
Residual flow	m³/s	0.000		
Percent time firm flow available	%	80.0%		

Firm flow	m³/s	0.35	
Hydro turbine			
Design flow	m³/s	0.300	$ 542,000
Type		Cross-flow	
Turbine efficiency		Standard	
Number of turbines		1	
Manufacturer	Ossberger		
Model	Cross-flow		
Efficiency adjustment	%	6.0%	
Turbine peak efficiency	%	6.0%	
Flow at peak efficiency	m³/s	0.0	
Turbine efficiency at design flow	%	85.0%	

%	Flow m³/s		Turbine efficiency	Number of turbines	Combined efficiency
0%	4.09		0.06	0	0.00
5%	3.60		0.06	1	0.06
10%	3.00		0.40	1	0.40
15%	2.43		0.58	1	0.58
20%	2.16		0.67	1	0.67
25%	1.80		0.71	1	0.71
30%	1.32		0.74	1	0.74
35%	1.02		0.75	1	0.75
40%	0.69		0.76	1	0.76
45%	0.39		0.77	1	0.77
50%	0.39		0.77	1	0.77
55%	0.38		0.78	1	0.78
60%	0.36		0.79	1	0.79
65%	0.36		0.80	1	0.80
70%	0.36		0.80	1	0.80
75%	0.35		0.81	1	0.81
80%	0.35		0.82	1	0.82
85%	0.35		0.83	1	0.83
90%	0.35		0.83	1	0.83
95%	0.34		0.84	1	0.84
100%	0.34		0.85	1	0.85

Maximum % 5.0%

hydraulic losses			
Miscellaneous losses	%	5.0%	
Generator efficiency	%	95.0%	
Availability	%	95.0%	
Summary			Firm
Power capacity	kW	49	49
Available flow adjustment factor		1.00	
Capacity factor	%	95.0%	
Electricity exported to grid	MWh	411	
Electricity export rate	$/MWh	100.00	