ASSESSING THE MICRO-HYDRO POWER POTENTIAL FOR LOWER RIVER NZOIA BASIN IN KENYA

BY

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A Research Project submitted in partial fulfillment of the requirements for award in Postgraduate Diploma in Meteorology.

November, 2018.

DECLARATION

I declare that this research project is my original work and has not been presented anywhere by any one in any other university for an academic award**;**

Signature…………………   Date…………………

Chrispine Ouma Andare
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This Research Project has been submitted for examination with our approval as University Supervisors

Supervisors:

Signature……………………………...   Date…………………….

Dr. C. Oludhe

Signature……………………………..   Date…………………….

Prof. F. M. Mutua

DEDICATION

I dedicate this research project to my family members and friends for their words of encouragement and prayers.

ACKNOWLEDGEMENTS

The author is very grateful to Dr. Christopher Oludhe and Prof. Mutua, all of the department Meteorology, University of Nairobi, for their supervision. Appreciation also goes to Kenya Meteorological Department and Kenya’s water management authority for the provision of rainfall and river discharge data respectively that were used in this research project.

Special thanks also goes to my family for their patience and understanding during the entire study period.

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SHP	Small Hydro Power
CF	Capacity Factor
KWH	Kilowatt hour
KW	Kilo watt
MHP	Micro hydropower
MW	Megawatt
IEA	International Energy Agency
KMD	Kenya Meteorological Department
WMA	Water Management Authority
WH	Water Head
RES	Renewable Energy Sources

ABSTRACT

Kenya generates 50% of her electricity demand from hydro power plants along Tana River. Micro-hydro generation is a key contributor to future energy supply. River Nzoia is one of the major rivers in the western region of the Country which can provide adequate hydropower generation if detailed assessment can be carried out. The real potential of this river is yet to be explored. This study is therefore an attempt to explore the potential for micro-hydroelectricity generation along River Nzoia which is partly influenced by precipitation within the river basin and gross head. Power computations that combines flow discharge and water head was used to determine the hydropower potential of this river

CHAPTER ONE

1.0 INTRODUCTION

River Nzoia is one of the major permanent rivers in western Kenya. The river starts from Cherangani Hills and drains into Lake Victoria near town of Port Victoria in Budalangi constituency, after covering a distance of approximately 257Km. River Nzoia basin experiences recurrent floods around its sections closer to Lake Victoria spreads particularly, Budalang'i region of the border county of Busia. Wet seasons are experienced through all year round in Nzoia River Sub basin, with major wet seasons being in March-April-May season another one in October-november-December season. Highest rainfalls are experienced in the northwestern parts of the basin which covers counties such as Bungoma, Kakamega, Trans Nzoia and Uasin Gishu. Generally, the basin receives high rainfalls compared to other parts of the country, with annual averages varying from 1,000 to 1,500 mm.

The major soil types in the Nzoia river basin is mainly heavy black cotton soil along the sugar belts of Mumias among others and light soil in areas such as Nandi hills. The lowland areas of Budalangi have clay soil at around 77 percent.

The economy in this basin is still mainly rural with Agriculture (smallholder subsistence farming and large scale farming) and livestock keeping being the main source of income to the inhabitants. Other economic activities include fishing around Sio port, a town centre around Lake Victoria shore in Busia County, Tourism centered mainly on Kakamega forest, financial services and domestic trade in major towns such as Kitale, Kakamega, Webuye, Busia, Bungoma Mumias, Eldoret, Ugunja among others.

The Nzoia river basin has immense natural capitals like forests, streams as well as rivers with good discharges throughout the year, 83.0 m^3/s per annum, as recorded at 1EE01, which when harnessed can provide reliable and affordable hydropower to support industrial agro-processing and manufacturing to reduce high level of poverty in this region. Despite, high rainfalls hence good river discharges, there are no major hydropower developments along this river.

The major hydroelectricity plants in Kenya are located along Tana River basin which according to Baker *et al*. (2015), provides about 50% of the Country's entire electricity demand over a sequence of five dams constructed alongside the river (Muthuwatta *et al*., 2018).

First hydro-power schemes became operational in the late nineteen century. Global agency for energy, (IEA) indicates that extensive hydro-power systems presently provide about 16% of electrical power used globally. Nevertheless, these schemes needs great masses of acreage to be impounded for dams plus flood control (Nasir, 2014) resulting to massive loss of arable land hence a threat to food security. More so, huge dams are also associated with environmental impacts like inundation of habitats which are a cause of concern.

Though, large hydro-electric systems have huge scope and a producing capability of numerous hundreds or even thousands of Megawatts as well as high return on investments, their implementation may be delayed due to huge financial requirements and socio-political issues.

Micro-hydro-electricity system is unique arrangement for generating electrical power from flowing rivers and streams. Their power generation lies between five and a hundred Kw once fully installed. Numerous Micro hydropower schemes are operated through route of a stream, which implies no enormous barrier is built in the form of a dam even land inundation is avoided (Medveď and Hvizdoš, 2006). A mere portion from the existing river discharge during the year is used to produce electricity with insignificant environmental effect. Since well-designed micro-hydroelectricity system has least ecological interruption towards the waterway or tributary, its coexistence together with the natural ecosystem is usually possible.

Sites for micro-hydropower are usually numerous and therefore can be harnessed to provide affordable, reliable, sustainable and modern energy as per agenda 2030, number seven of sustainable development goals, SDGs, to the rural population that still heavily rely on fossil fuel as a source of energy which is a major contributor to greenhouse gases responsible for climate change. The cheap power from micro-hydropower schemes can also support local agro-processing industries resulting to massive job creation hence rapid development to the local communities.

1.1 Problem statement

The expansion of economy is accompanied with demand for more energy and this involves burning of more fossil fuel to power the mechanical engines which usually emit greenhouse gases which are responsible for global warming and finally climate change and associated impacts. The price of electrical power in Kenya is on the rise due to over dependence on expensive thermal powered production and large hydropower schemes which are weather dependent. There is therefore need for alternative affordable, reliable and sustainable source of energy that has little social and environmental impacts.

1.2 Study Objectives

The main objective of the study was to assess hydropower potential for river Nzoia with special focus on micro-hydro power potential in the lower Nzoia basin.

The specific objectives of the study were to:

i) Characterize rainfall and river discharge within the River Nzoia Basin.
ii) Determine the relationship between rainfall and discharge over this river basin.
iii) Estimate the hydropower potential for the Nzoia River Basin using standard hydropower equation.

1.3 Justification

Affordability, sustainability and reliability of micro hydroelectric system makes it a viable option for electrical power production. Generation lies between five and a hundred Kilowatt of power once installed across a river or stream. The power generated is enough to support local light industries off grid. This can bring rapid development for the rural communities. In fact numerous small hydroelectric schemes are operated through the course of the waterway without construction of huge dam and land inundation. A mere portion from the existing river discharge year can be utilized for electricity production, therefore a well-designed micro-hydroelectricity system can coexist with local ecology without much environmental disturbance to the river or stream. Despite the benefits, no hydropower potential along this river is being harnessed.

1.4 Area of Study

Nzoia River watershed and also the largest catchment area within the larger Lake Victoria watershed is located amid 1.5^0 N and 0.08^0 S and amid 34^0 E and 35.8^0 E in western Kenya. The Nzoia River system which has its major source in the Cherangani hills and tributaries from Mount Elgon, flowing into Lake Victoria just north of Yala Swamp was chosen as the study area since its real hydropower potential is yet to be explored. The Nzoia catchment has an area of 12 700 km^2 with varying catchment elevations in the range of 1150 m above sea level at the outlet into Lake Victoria to over 3500 m above mean sea level in the Mt. Elgon ranges (Kizza *et.al.* 2013), (Figure 1.1).

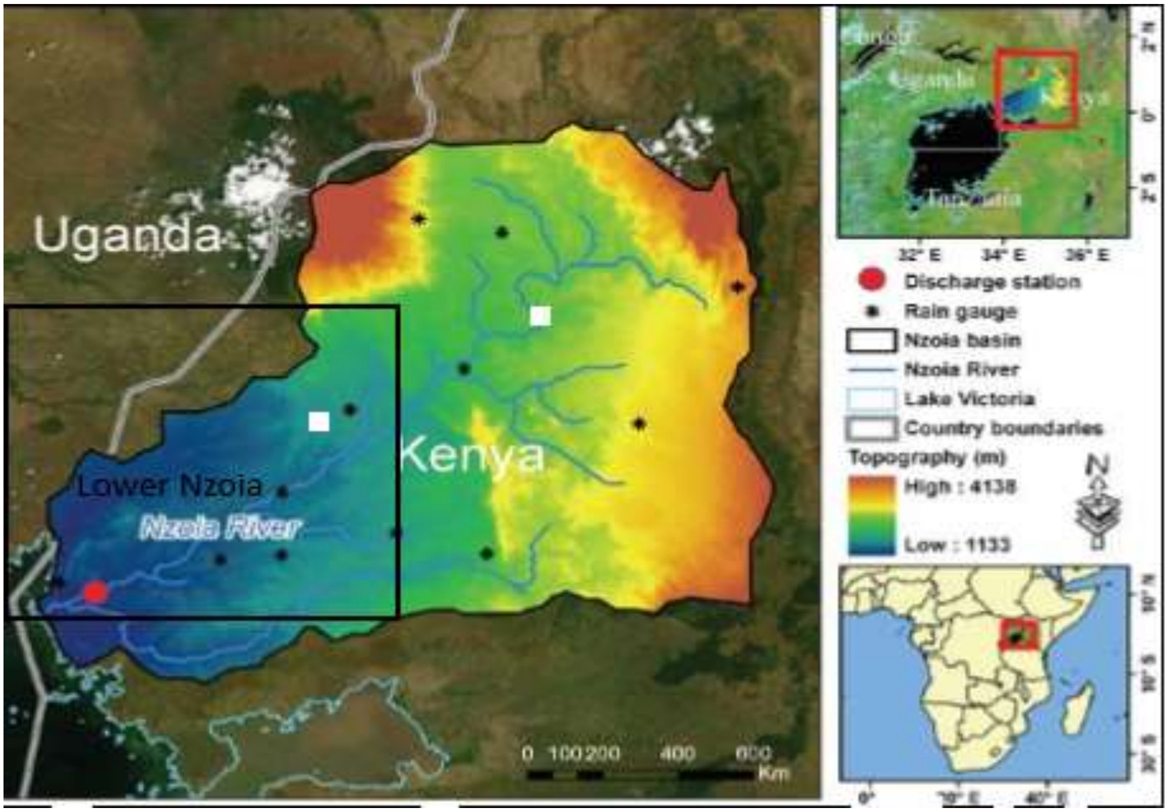


Figure 1.1: Mapping for River Nzoia sub-watershed within Lake Victoria basin indicating position of Lower Nzoia river sub-basin, source (Ngaina, 2014).

CHAPTER TWO

This chapter reviews relevant previous work that had been done globally, regionally and within the country.

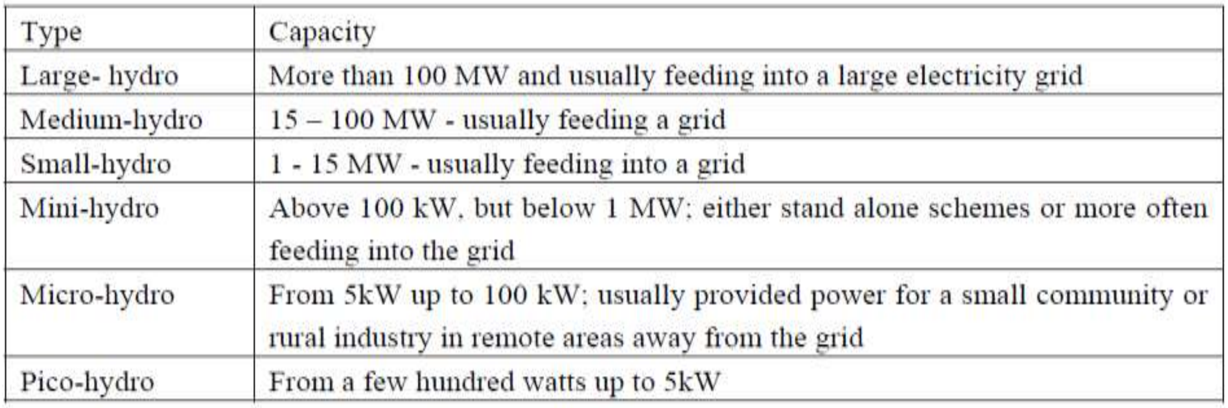
2.0 LITERATURE REVIEW

Electricity is a key promoter and driver of any viable economy as it is an unavoidable input essential for the industrial and socio-economic growth of a country in order to attain a reasonable standard of living among citizens (Odje, *et al*., 2018). Hydropower is a major source of renewable and clean electrical energy. Hydropower emanates after converting potential energy in flowing and falling water over a turbine to beneficial mechanized energy per unit time and finally transformed to electrical energy by an electric generator (Medveď, D. and Hvizdoš, M., 2006).

Theoretically, the potential of hydroelectricity, exists as sum of obtainable energy per annum that can come from rainfalls (possible superficial energy) or alongside a river (possible rectilinear energy) deprived of technical restrictions of construction enlargement, losses in river flow and water pressure or turbine efficiency (Nistoran *et.al*.,2017).

Classification of hydroelectric systems is based on their connected electricity generation capability. The large and medium hydroelectric systems are usually connected to national power networks to meet the national demand of the electricity. Small hydroelectric systems comprising of small, mini, micro as well as pico are mostly utilized in miniature grids or far-flung zones still off the national power grids. Micro-hydroelectric systems generate approximately five to one hundred kilowatts hence are suitable for provision of electricity in small communal as well as industries located in the countryside away from the state power network.

Table 2.1: Types of Hydro-Power Systems (Kougias, *et.al*. 2014**);**



Type	Capacity
Large- hydro	More than 100 MW and usually feeding into a large electricity grid
Medium-hydro	15 – 100 MW - usually feeding a grid
Small-hydro	1 - 15 MW - usually feeding into a grid
Mini-hydro	Above 100 kW, but below 1 MW; either stand alone schemes or more often feeding into the grid
Micro-hydro	From 5kW up to 100 kW; usually provided power for a small community or rural industry in remote areas away from the grid
Pico-hydro	From a few hundred watts up to 5kW

According to (Bavishi and Bhagat, 2017), pressure of water (water head) can be created through height variation at the turbine location with reference to point of water intake. Water head is mostly stated as perpendicular distance in meters or pressure in psi. The disposable water head, also force per unit area obtainable due to rolling water through the turbine is usually smaller than the static head water, (pressure produced during stationary flow) because of the fluid viscosity as water moves through penstock. The net head also depends on the diameter of pipeline.

2.1 Principles of Micro-hydropower (MHP):

Micro-hydroelectricity schemes are usually minor electrical power plants that generate slightly 100 kilowatts of electrical power to light up farmsteads, estates, homes as well as villages. Water head and river discharge are key parameters that must be accessible so as electricity can be produced. The first step involves diversion of water from a watercourse through a pipe. Focusing the diverted water downward via a penstock into turbine. The abrupt drip (water head) generates force at the tail end of the penstock. The turbine is then driven by force developed from emergent water at the end of the pipeline with a lot of pressure. The generator which is then driven by the turbine produces electricity for use. Usually, total electrical power which is harnessed is dependent on volume of falling water per unit time, (**discharge**) plus water head.

In (2005) the British Hydropower Association opined that micro hydropower have a number of benefits over other Renewable energy sources (RES); Great efficacy between seventy to ninety percent, greater capability factor (normally greater than forty five percent) in relation to some of the renewable energy sources like photovoltaic schemes which have just capability factor ranging between ten to thirty percent and wind system whose capability factor is between twenty to thirty percent. Micro hydroelectricity systems are also predictable, with longer lifespan that can strech beyond fifty years under little cost in maintaining them (Kougias *et.al*. 2014).

Studies that have been conducted on hydropower potential for different rivers and streams have found out that river discharge and gross water head are directly proportional to the potential hydropower that can be generated at any given site of the river. The flow rate / discharge and water head also have influence on the turbine type that can be installed for maximum hydropower generation. Hussain, (2018) in his study for Desang River in India found out that hydropower potential is all about rate of flow and head of a stream in a specific location. The greater the head in a particular location of discharge the greater the water pressure on that location. Hence the hydro turbine will have more impact in it resulting to generation of more power. In addition to generating more power, higher heads can also induce a higher flow rate through a smaller turbine, (Hussain, 2018).

Generally selection of appropriate power turbine is dependent on water head as well as the river discharge at various sections of the river or stream. Development of micro-hydropower systems in sections of the river with water head of five (5.0) meters and below and discharge of slightly one (1.0) cumecs will require cross flow turbine for optimization of power generation. However, feedback turbines that exploit rectilinear and angular momenta from water flow in running the blades are appropriate for areas of the stream or the river with average and small heads together with high discharge, (Nasir, 2014).

A study carried out for Kunhar River in Pakistan found out that the power potential of flowing water is not only a function of the discharge (Q) and the difference in head (H) between intake point and turbine but also a function of the specific weight of water (gρ), (Khan and Zaidi, 2015).

Another study by Odje, *et al*. (2018) for River Sombriero in Nigeria confirmed that the hydropower potential of a river fluctuates with river flow. Hydropower generation also have good financial viability, (Odje, *et al*. 2018) since the project economic, environmental and social values generally supersede the initial cost of investments.

Within East Africa, very little studies and documentation have been done on the hydropower potential of the numerous streams and rivers in the region. However, separate studies conducted for some streams and rivers suggested that huge untapped potential exist for most sections of the streams and rivers. For example, selected sites on Mushishito and Rukarara Rivers within the southern province of Rwanda have enormous hydropower potential that can supply reliable and affordable electricity to the local communities through Micro hydropower generation, (Wali 2013).

In Kenya the small, mini and micro hydropower potential is estimated at 3000MW countrywide with 45% of this potential located within the Lake Victoria drainage basin, (Oludhe, 2013).
However, the few operational micro hydropower generation systems are under private and community management especially in the tea plantations.

CHAPTER THREE

3.0 DATA AND METHODOLOGY

This chapter discusses the various datasets and the methodology used in this research project.

3.1 DATA

Monthly rainfall data were obtained from Kenyan Department of Meteorology, KMD, as shown in the table below whereas monthly discharge was obtained from Kenya Water Management Authority, Table 3.2.

Table 3.1: Rainfall Stations

S/No.	Name of Station	Number of Station	Geographic Co-ordinates	Period of Record
1.	BUNYALA IRRIGATION SCHEME	8934139	0 05N 34 03E	1987-2000
2.	CHORLIM A.D.C. FARM	8834013	1 02N 34 48E	1987-2000
3.	BUTULA CATHOLIC MISSION - BUNGOMA	8934039	0 02N 34 21E	1987-2000
4.	KIMILILI AGRICULTURAL DEPARTMENT	8934060	0 48N 34 43E	1987-2000
5.	KITALE METEOROLOGICAL STATION – NEW	8834098	1 00N 34 59E	1987-2000

Table 3.2: Discharge Stations

S/No.	Station ID	Co-ordinates	Location Name
1.	1EE01	0.18N 34.22E	Rwambwa, Nzoia
2.	1EF01	0.12N 34.09E	Siranga, Nzoia

3.2 DATA QUALITY CONTROL flowing

It consists of tests designed to ensure that data used meet certain standards. It involves looking for errors in their acquired data set ranging from storage media problems to data inhomogeneity or inconsistency. This was done through filling of missing data by simple arithmetic mean ratio method and homogeneity testing was by use of single mass curve method.

3.2.1 Simple arithmetic mean ratio method

It involves use of seasonal means of two datasets and their corresponding individual entries to find missing entry as indicated in the equation below;

$$X= (A/B)*Y \text{…………Equation 1,}$$

Where X is the value of missing entry to be determined, Y is the value of the related entry in the same basin, A is the long term mean of dataset with data gaps and B is the long term mean of the entry with complete dataset.

3.2.2 Single mass curve method

It involves the plotting of accumulated seasonal records at station against time. A straight line is an indicator of data homogeneity. If not a straight line then data is inconsistent.

3.3 DATA ANALYSIS

The rainfall and discharge characteristics of the basin were determined by statistical and graphical methods.

The statistical involved the use of excel to determine the mean, maximum and minimum values of each stations under study.

The graphical method involved of the plotting of the monthly means against time series for the stations under study.

3.4 Determination of Water head, H

Head is the vertical distance between in two points, intake and powerhouse (turbine and generator location). Therefore pressure is created by elevation difference between intake and turbine. A 500 meter distance downstream from intake (location of discharge stations) was considered reasonable for the first turbine for each case. Points were selected on Google imagery map at an interval of 500 meters up to 2500 meters from each discharge station (intake) with their elevations being noted. Elevation difference (head) between two consecutive locations was calculated with consideration of discharge station as the intake in both cases and the second point as the proposed turbine location.

Head (Meter) = Intake elevation –Proposed Turbine elevation

3.5 Calculation of generation capacity

The power potential was then computed from the standard power equation, Equation 2, below.

The water flow discharge (Q) and head (H) data, which have been directly measured and determined based on rainfall data, watershed and elevation are used in calculation of the capacity of micro-hydro power production.

The following formula is applied in calculating the generation capacity of the micro- hydropower system (Odje, *et al.*, 2018).

$P = Q \cdot H \cdot g \cdot \rho$ ……………………………Equation 2

Where: P is the Potential Output Power in kW and ρ is the density of the water in kg/ m^3.

H is the available head in metres, Q is the design discharge rate in m^3/s and g is the acceleration due to gravity given as 9.81 m/s

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

This chapter discusses the results obtained from the analyses of rainfall data, discharge of the river and computed hydropower potential for the different sections of the river.

4.1 Data quality control

The single mass curves for all rainfall and discharge stations under study were nearly straight lines which is an indication of consistency in the datasets, Figures 4.1 and 4.2.

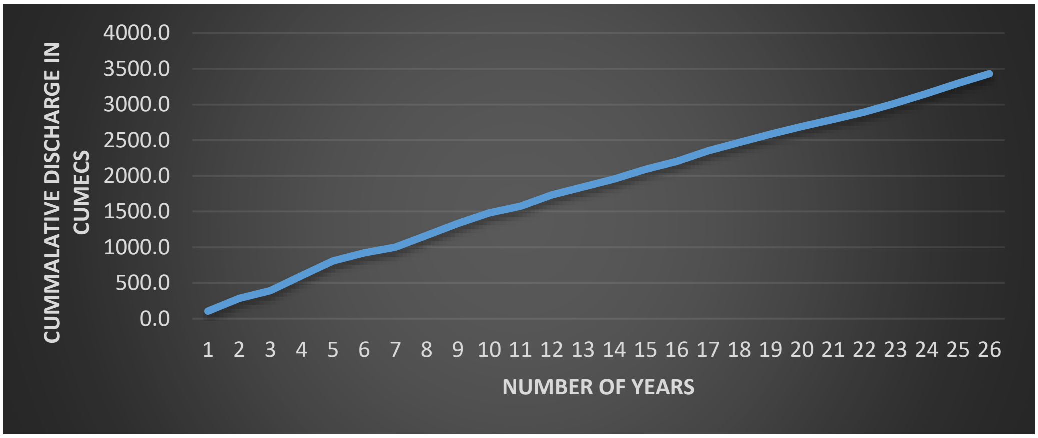


Figure 4.1: Single mass curve for Discharge Station

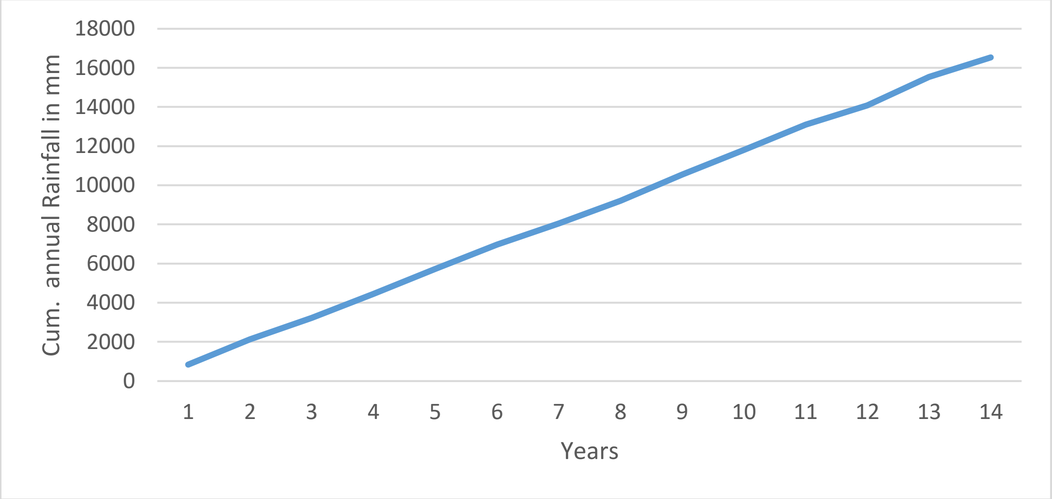


Figure 4.2: Single mass curve for Rainfall Station

4.2 Rainfall characteristics

The figure below, Figure4.3, shows the variation of monthly rainfall averages over the study period for all the stations considered in the basin.

The results show that the basin has bimodal kind of rainfall throughout the year with long rains (highest peak) being in March-April-May and short rains (higher peak) being in October-November-December.

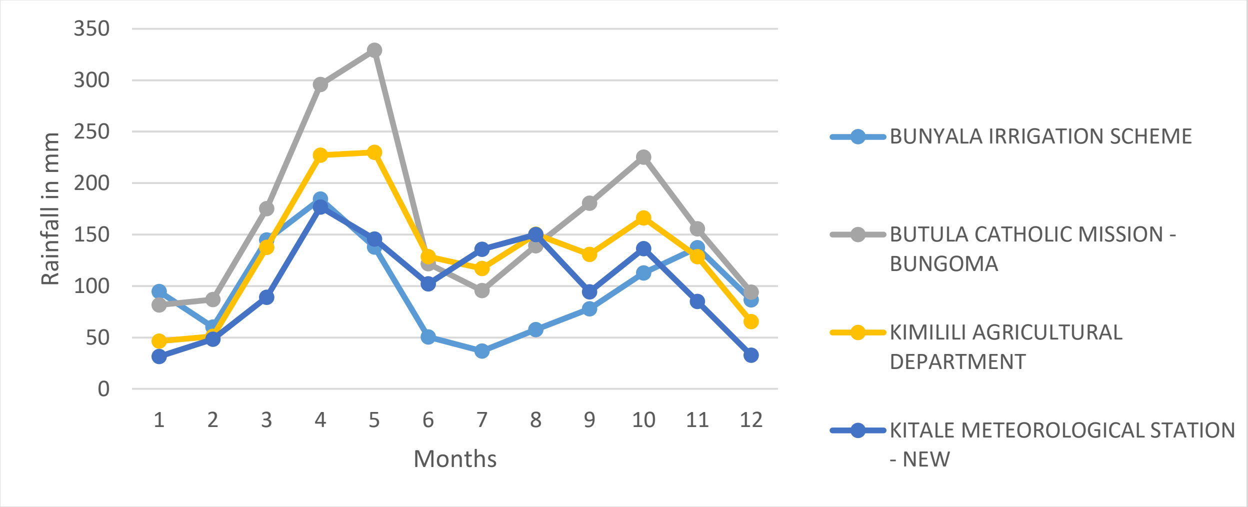


Figure 4.3: Average monthly rainfall for the rainfall stations

The monthly average rainfall major peak is in April for Kitale Meteorological Station-New and Bunyala irrigation scheme while the peaks for Butula catholic mission-Bungoma and Kimilili Agricultural Department are in May. This is then followed by decrease in all cases towards August-September until a minor peak in October for all the stations except Bunyala Irrigation Scheme with its minor peak in November. The months with lowest monthly rainfall are December and January in the basin for all the stations under study. Thereafter the cycle repeats itself.

The highest annual rainfall is recorded by Butula Catholic Mission-Bungoma, 1980mm and the lowest annual rainfall is reported by Chorlim A.D.C. farm, 1121mm as shown in Figure 4.4.

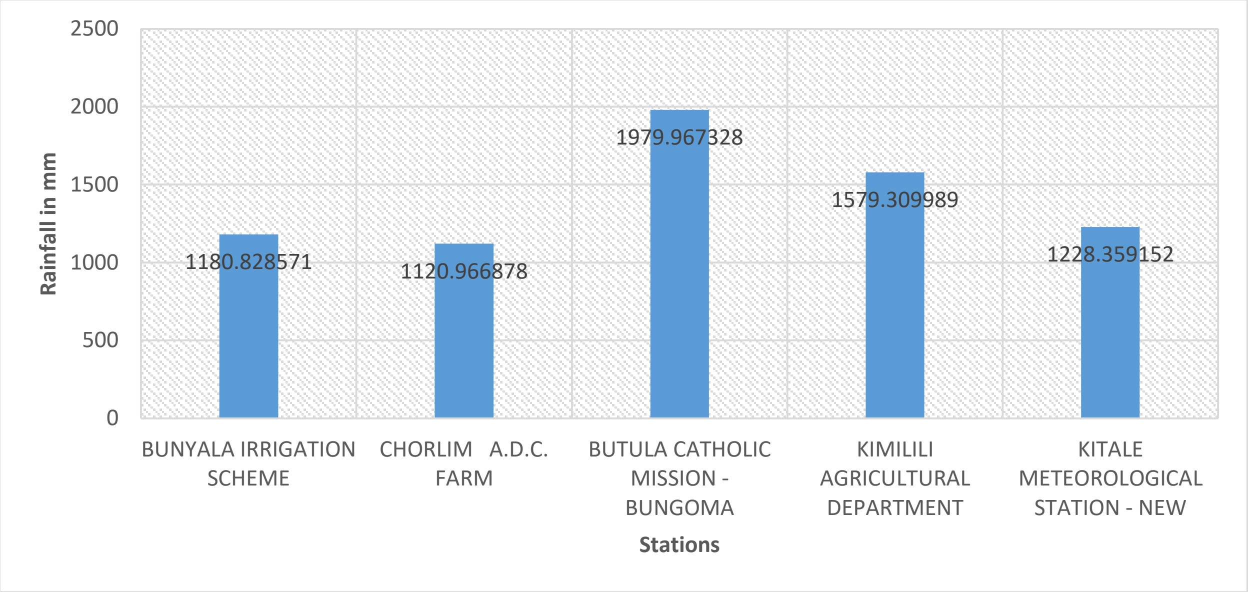


Figure 4.4: Annual rainfall for the rainfall stations

4.3 Discharge characteristics

The annual variation of discharge at the two discharge stations 1EE01 and 1EF01 is shown in Figure 4.5.

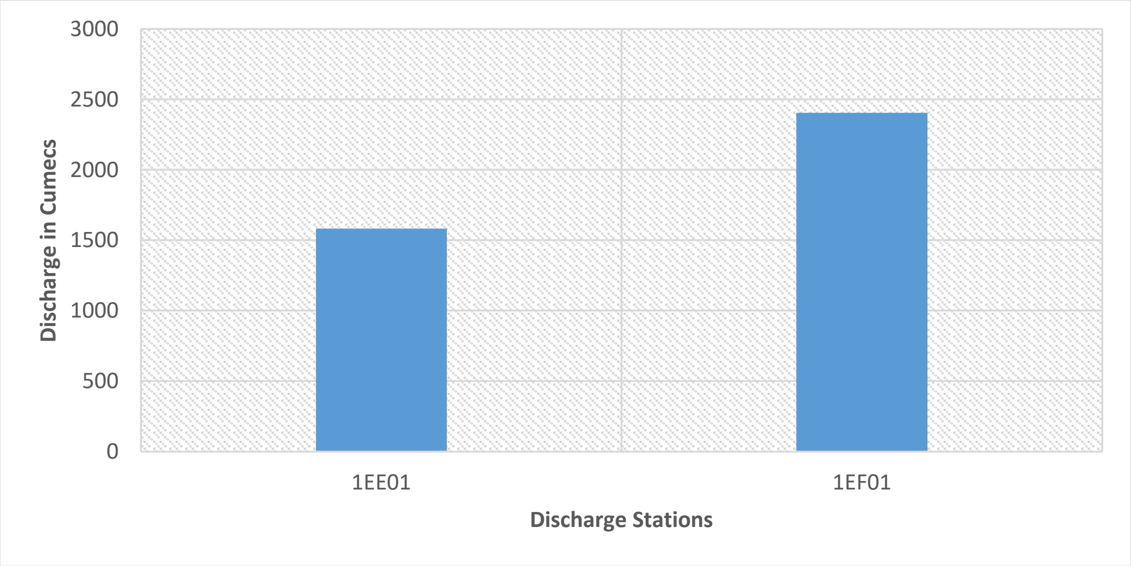


Figure 4.5: Annual discharge variation

The discharge station 1EE01 has the lowest annual discharge of 1583 Cumecs while 1EF01 has the highest discharge of 2405 Cumecs.

The peak discharges are realized during April-June and August-October, with the highest peaks of discharge coinciding with the long rains period in the basin for the 1EF01 while 1EE01 reports the highest peak in August –October period which is matching with the short rains period.

Both discharge stations show decrease in discharge in the period of December to January which is also associated with low rainfalls.

The time series of stream flows for the stations showed an increasing trend for 1EF01 (Siranga) and decreasing trend for 1EE01 (Rwambwa), downstream of the study area for the study period, as shown in Figure 4.6.

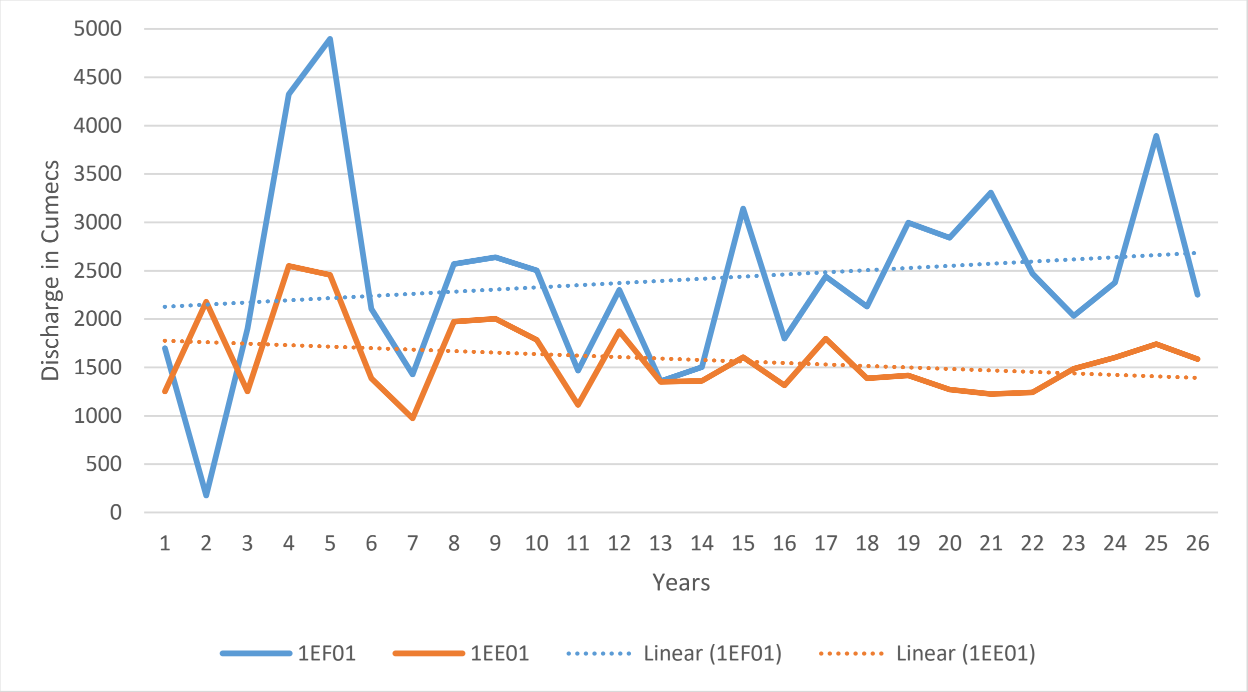


Figure 4.6: Annual discharge variation and trend

The discharges were also noted to closely follow the pattern of the peak rainfall during the year in the basin. Therefore it can be noted that the discharge is directly proportional to the rainfall within the basin.

4.4 Water heads

The water heads were computed and obtained as shown in Table 4.1 below;

Table 4.1: Heads of various sections of the river;

		Elevations of Intakes and Interval Points Downstream and Heads				
Station/Points	0Km	0.5Km	1.0Km	1.5Km	2.0Km	2.5Km
1EF01	1180	1176	1174	1173	1170	1167
Head(M)		4	6	7	10	13
1EE01	1147	1147	1148	1144	1146	1147
Head(M)		0	-1	3	1	0

A head of -1m at 1.0 km downstream of 1EE01 will result to negative power which is not possible hence a clear indication of unviable point for power generation.

4.5 Computed Hydropower Potential

The potential hydropower for various heads of the two stations were obtained as indicated in Table 4.2 below. The hydropower potential for the turbine location with negative 1M (-1M) as head is posted as (-) since negative power is not viable.

Table 4.2: Computed Hydropower Potential of various sections of River Nzoia

	Potential Power computation			(P=1000*9.81*Q*H) /1000KW									
Station/Months	Jan.	Feb.	Mar	Apr	May	Jun.	Jul.	Aug	Sept	Oct	Nov	Dec	TOTAL
1EE01	59.57188	77.48484	72.11494	140.4809	172.7593	154.7198	147.2461	206.2326	187.7221	133.2482	136.1758	95.28722	1583.044
1EF01	99.24066	87.50301	110.3898	236.5899	300.6782	230.3113	232.4418	272.3589	261.1167	201.7521	223.7803	148.365	2404.527
1EE010.5km	0	0	0	0	0	0	0	0	0	0	0	0	0
1EF010.5km	3894.203	3433.618	4331.694	9283.788	11798.61	9037.416	9121.015	10687.36	10246.22	7916.752	8781.14	5821.841	94353.66
1EE01,1km	-584.4	-760.126	-707.448	-1378.12	-1694.77	-1517.8	-1444.48	-2023.14	-1841.55	-1307.17	-1335.88	-934.768	-15529.7
1EF01,1km	5841.305	5150.427	6497.541	13925.68	17697.92	13556.12	13681.52	16031.04	15369.33	11875.13	13171.71	8732.761	141530.5
1EE01,1.5km	1753.201	2280.379	2122.343	4134.353	5084.306	4553.404	4333.453	6069.425	5524.662	3921.495	4007.653	2804.303	46588.98
1EF01,1.5km	6814.856	6008.832	7580.465	16246.63	20647.57	15815.48	15961.78	18702.88	17930.88	13854.32	15366.99	10188.22	165118.9
1EE01,2.0km	584.4002	760.1262	707.4476	1378.118	1694.769	1517.801	1444.484	2023.142	1841.554	1307.165	1335.884	934.7676	15529.66
1EF01,2.0km	9735.508	8584.046	10829.24	23209.47	29496.53	22593.54	22802.54	26718.4	25615.54	19791.88	21952.85	14554.6	235884.1
1EE01,2.5km	0	0	0	0	0	0	0	0	0	0	0	0	0
1EF01,2.5km	12656.16	11159.26	14078.01	30172.31	38345.49	29371.6	29643.3	34733.93	33300.21	25729.44	28538.7	18920.98	306649.4

The hydropower potential is found to be directly proportional to the river discharge and the water head, therefore areas with good heads and good discharge have indicated huge potential for hydropower generations.

The sections just downstream of the 1EF01 discharge stations have indicated viable hydropower potentials of varying magnitudes that can be harnessed to provide the local communities with modern, affordable, clean, reliable and clean energy for lighting and agro-processing throughout the year unlike few sections, 1.5Km (46589KW of power annually) and 2.0Km (15529KW of power annually) just downstream of the 1EE01 discharge station as shown in figure 4.7. The other sections (0.5 Km, 1.0 Km, and 2.5 Km) downstream of the 1EE01 discharge station have no potential since 0KW is recorded in each case.

The point with the greatest hydropower potential is 2.5 Km downstream (head of 13M) of 1EF01 discharge station with an estimate of 306649.4KW of power annually. Just 0.5Km (head of 4M) downstream of 1EF01 gives 94353.6KW of power annually, though the least in this section from the 1EF01 intake point but still can be useful if well harnessed.

The hydropower potentials in all cases of the Stations are found to follow the same peak patterns as that of those of the rainfall peaks and discharge peaks within the basin, as shown in Figures 4.8 and 4.9.

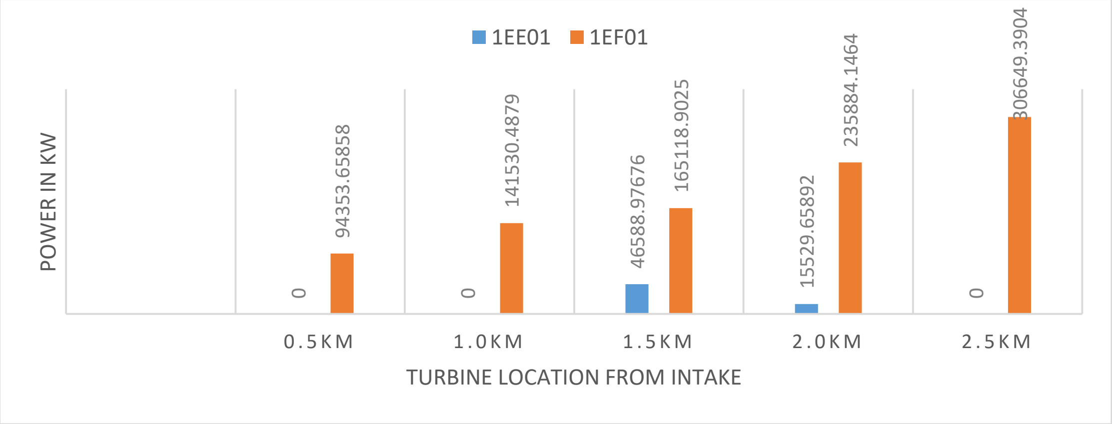


Figure 4.7: Annual potential power variation

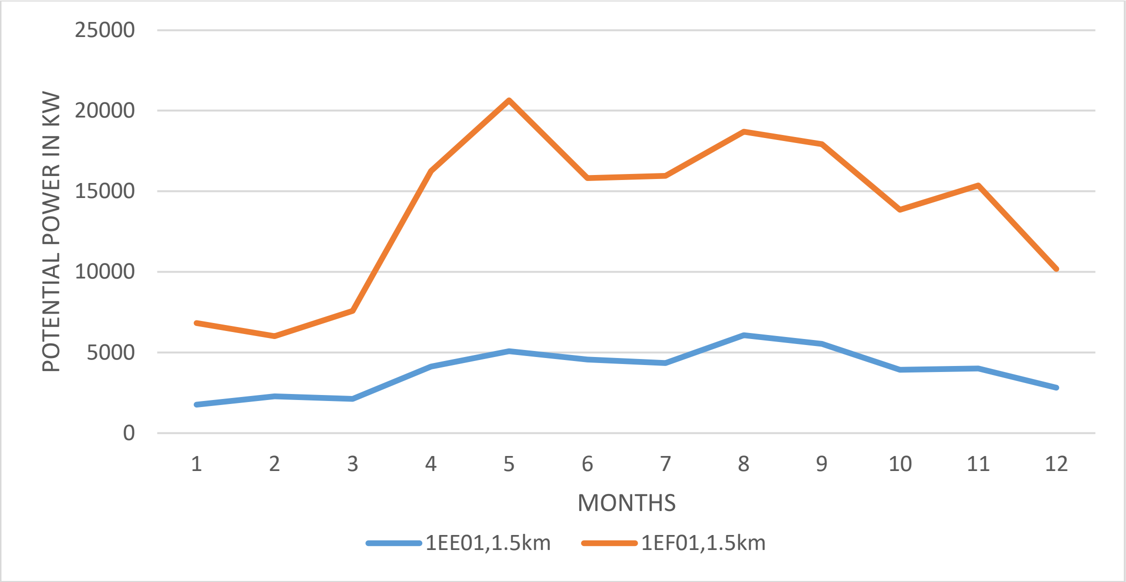


Figure 4.8: Monthly variation of Potential power 1.5km downstream from intake

The major peak of hydropower potential is in April to June period with minor peaks in August-October period which are also the periods with highest discharge peaks. The power potential decreases with decrease in discharge as is the case with December to January period.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

This chapter summarises the key findings of the research project.

5.1 Conclusion

River Nzoia basin has bimodal type of rainfall throughout the year with major peaks in April and May and minor peaks in October and November.

The annual rainfall within the basin ranges between 1120mm to 1980mm.

The discharge of the basin varies between 1583 Cumecs to 2405 Cumecs with major peaks being in April to June period and minor Peaks in August to October period, indicating that the discharge of the river is directly proportional to the rainfall patterns within the basin.

Therefore, there is sufficient rainfall and river discharge that can support satisfactory generation of hydropower within the basin.

There is huge hydropower potential in the upper sections of the River basin as opposed to the lower section of the basin towards the Lake due to decrease in both discharge and water heads.

The theoretical hydropower potential is large due to inconsideration of other factors such as electrical losses associated with friction and turbine inefficiencies.

5.2 Recommendations

Further research with consideration of more parameters such temperatures, humidity, soil type, land use, increased discharge stations and socio-economic activities within the basin is recommended.

The study also recommends collaboration among energy stakeholders such as Kenyan rural electrification authority, Kenya electricity generating company (KenGen) and the county governments within River Nzoia basin.

There is need for major reforms within the energy sector to overcome institutional, policy and technical barriers to hydropower development within the country.

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