

**BUSITEMA
UNIVERSITY**
Pursuing Excellence

FACULTY OF ENGINEERING

DEPARTMENT OF WATER RESOURCES AND MINING ENGINEERING.

FINAL YEAR PROJECT REPORT

**DESIGN AND SIMULATION OF ROADSIDE RAINWATER HARVESTING
SYSTEM**

CASE STUDY: GULU MUNICIPALITY, GULU DISTRICT

OCEN INNOCENT

BU/UP/2014/612

+256785809759/752616169

oceninnocent509@gmail.com



SUPERVISORS

MAIN SUPERVISOR: Mr. LWANYAGA JOSEPH DUMBA

CO-SUPERVISOR: Ms. NAKABUYE HOPE NJUKI

A final year project proposal report submitted to the Department of water resources and mining engineering in partial fulfillment for the award of the Bachelor of Science in Water Resources Engineering degree of Busitema University

EXECUTIVE SUMMARY

The Uganda water supply strategy highlights rain water harvesting from various surface conditions as a main source water supply and for small scale irrigation development at farmer's level. While ponds, dams, and in-situ water harvesting systems have been implemented, roads have primarily been built for transportation purpose – the additional benefits: rain water harvesting for supplemental irrigation, groundwater recharge have not yet been explored. As is the case in the study area of this BSc. research, lack of proper integration of road construction into the broader municipal livelihoods has resulted in various negative impacts: soil erosion and gully formation in cultivated land, flooding of agricultural and inhabited areas, and reduced recharge of groundwater.

Piloting on the Logere - Adere – Gulu town to Aswa 15 Km road in the Northern Region, Uganda. This research aimed at minimizing the negative impacts of road development and maximizing the benefits. It employed both quantitative methods - modelling (HEC-HMS and Hydraulic toolbox in combination with field observation and interviews as well as discussions with diverse stakeholders. The runoff generated was estimated from the roads using HEC-HMS model. The contributions of water supplemental rainfall to enhancing productivity were investigated with crop grown around the reservoir. Field observation and interviews resulted in a better insight on how significant the negative impact of roads could be when they are not properly integrated into water supply and the overall agricultural and rural development programs.

From the model simulation in every catchment, the calibration results of Calculated or simulated discharge for 32.16m³/s and 426 MCM/year from 1996 - 2016 respectively. Simulated result for Validation period for catchment was done and from the discharge different components of the roadside rainwater harvesting were designed accordingly.

The SPSS analyses of the interviews have revealed that 70% of farmers living on the study area were affected by the road side runoff as follows: 45 % of their farm land was exposed to temporary water logging and around 65% of the cultivable land was affected by erosion,

This research has demonstrated that the road in the study area is having significant negative impact to the human water demand livelihoods, but that also it has a huge potential to be a key contributor to the enhancement of the livelihoods. The three major recommendations are :(1) for the betterment of the impacts, it is suggested that Roads for water harvesting and multiple uses be mainstreamed in educational systems (Marcy et al.) There should be integration between relevant institutions and authorities (Marcy et al., 2000) in making future road development plans. And (Chen et al.) Awareness generation should be done to encourage farmers utilize the runoff from roads for productive purposes. Moreover, technical assistance and training's needs to be delivered at grass-root level.

DECLARATION

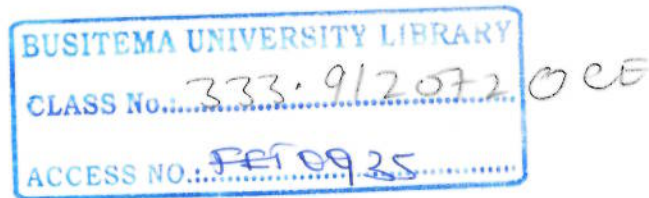
I OCEN INNOCENT, declare that all the material portrayed in this project proposal report is original and has never been submitted in for award of any Degree, certificate, or diploma to any university or institution of higher learning.

Signature



Date

06/05/2018



APPROVAL

This project report has been submitted with the approval of the following supervisors

MAIN SUPERVISOR: Mr. LWANYAGA JOSEPH DUMBA

SIGNATURE:.....

Date.....
27-05-2018

CO-SUPERVISOR: Ms. NAKABUYE HOPE NJUKI

SIGNATURE:.....

Date.....

ACKNOWLEDGEMENTS

I have taken efforts in this project. However, it would not have been possible without the kind support and help of many individuals and organizations. I would like to extend sincere thanks to all of them.

I am highly indebted to Mr. Lwanyaga Joseph Ddumba and Ms. Nakabuye Hope Njuki for their guidance and constant supervision as well as for providing necessary information regarding the project and also for their support in completing the project.

~~I would like to express the gratitude towards my parents and my brother for their kind co-operation and encouragement, which helped me in completion of this project.~~

Great thanks and appreciations also go to my colleagues in developing the project and people who have willingly helped me out with their abilities.

I would like to give a warm and well-deserved thank you for their hard work, dedication, and soggy feet are greatly appreciated. On that token, a sincere thanks to the Godefrey Oyuki

Without these wonderful, inspiring, and charismatic people, I would not be who I am today, nor would I have accomplished as much as I have through the years.

LIST OF ACRONYMS/ABBREVIATIONS

GIS	Geographical Information System
HEC-RAS	Hydrological Engineering Centers River Analysis System
HEC-HMS	Hydrological Engineering Centers Hydrologic Modeling System
UNMA	Uganda National Metrological authority
<hr/>	
HRF	Horizontal roughing filtration
RWH	Rainwater Harvesting
MWE	Ministry of Water and environment
UNRA	Uganda national road authority

TABLE OF CONTENTS

EXECUTIVE SUMMARY	i
DECLARATION	iii
APPROVAL	iv
ACKNOWLEDGEMENTS	v
LIST OF ACRONYMS/ABBREVIATIONS	vi
TABLE OF CONTENTS	vii
<hr/>	
LIST OF FIGURES	xi
LIST OF TABLES	xii
CHAPTER ONE	1
1 INTRODUCTION	1
1.1 Background	1
1.2 Problem Statement	3
1.3 Purpose of the Study	3
1.4 Justification	4
1.5 OBJECTIVES OF THE STUDY	4
1.5.1 Main objective	4
1.5.2 Specific objectives	4
1.6 1.7 SCOPE AND LIMITATIONS	4
1.7 Project Area	4
1.7.1 Topography	5
1.7.2 Climate	6
1.8 Water Source	6
<hr/>	
1.9 Drainage	7
1.9.1 Drains	7
1.9.2 Road section of the study area	8
CHAPTER TWO: LITERATURE REVIEW	9
2 INTRODUCTION	9
2.1 Rain water harvesting	10

2.1.1	Rain water harvesting	10
2.2	History of rain water	10
2.2.1	Benefits of rainwater harvesting (Blue Drop Series book 2).....	14
2.3	Types of Water Harvesting Techniques.....	15
2.3.1	2.5.1 In situ rainwater harvesting (soil and water conservation).....	16
2.3.2	2.5.2 Micro-catchment water harvesting	16
2.3.3	Macro-catchment water harvesting.....	16
2.4	How Road Construction Links with Poverty Alleviation	17
<hr/>		
2.5	Water from roads	17
2.6	Water Harvest from Road Construction.....	17
2.7	Component of Roadside Water Harvesting System.....	18
2.7.1	Road Surface.....	18
2.7.2	Roadside drains.....	18
2.7.3	Design of Culverts	19
2.7.4	Horizontal flow roughing filters (HRF).....	21
2.8	HEC-HMS (Hydrological Engineering Centers Hydrologic Modeling System).....	23
2.8.1	Hydrological Model Building.....	24
2.8.2	Using runoff models	24
2.8.3	Intensity-Duration-Frequency Curves	27
2.8.4	Areal Reduction Factor.....	27
2.8.5	Geographic Information.....	27
2.8.6	Hydraulic Toolbox.....	28
CHAPTER THREE:		30
3	METHODOLOGY	30
<hr/>		
3.1	Introduction.....	30
	Project Area	30
3.2	System requirements and Architecture	30
3.2.1	System Architecture.....	30
3.2.2	System requirements.....	31
3.2.3	Data and Requirement Analysis	32

3.2.4	Functional Requirements	32
3.2.5	Non-Functional Requirements	32
3.2.6	System Design	33
3.3	Methodology for objective one	33
3.3.1	Hydrology of the catchment area.....	33
3.3.2	Delineating the catchment area and land use in the catchment area.....	33
3.3.3	Filling missing rainfall data	34
3.3.4	Determining the value of surface runoff/quantifying the runoff	37
3.3.5	Generation of the Intensity Duration Frequency Curves	39
3.3.6	Establishing the road network	41
3.3.7	Determination of flow in the channel	41
3.4	Methodology for objective two.....	42
3.4.1	Design of Various Component Parts of Roadside Water Harvesting System	42
3.4.2	Design of the roadside gutter/drain.....	42
3.4.3	Design of screens	43
3.4.4	Design of horizontal roughing filtration	44
3.4.5	Design of the storage tanks.....	46
3.5	Methodology for objective three.....	46
3.5.1	Simulation.....	46
CHAPTER FOUR:.....		47
4	PRESENTATION AND DISCUSSIONS OF RESULTS.....	47
4.1	Analysis of hydrological and geological data.....	47
4.1.1	Hydrological analysis of the rainfall data.....	47
	Rainfall data was obtained from Gulu Meteorological station.....	47
4.1.2	4.1.1 Consistency.....	47
4.2	Characterizing the Catchment Area	48
4.3	To determine the hydrology of the catchment area and the hydraulics analysis	49
4.3.1	Average monthly rainfall variation for the 20 years.....	49
4.3.2	Rainfall intensity.....	52
4.4	Design of various component of roadside rainwater harvesting.....	63

4.4.1	Design of Trapezoidal Channel	63
4.4.2	Adequacy of Existing culverts	68
4.4.3	Design of the screen	69
4.4.4	Roughing filter design consideration	71
4.4.5	Sizing of the recharge pond reservoir	74
4.4.6	Simulation of the System	79
CHAPTER FIVE		82
5	Conclusions and Recommendations	82
5.1	Conclusions	82
5.2	Recommendations	83
APPENDICES		70

LIST OF FIGURES

<i>Figure 1.1: Location of the study area</i>	5
<i>Figure 2.1: showing slope and drainage map of the study area</i>	6
<i>Figure 3.1: showing major rivers in Gulu</i>	7
<i>Figure 4.1: Showing the road section of the study area</i>	8
Figure 5.2: Hydrological cycle (U.S depart department of interior geological survey, 2014).....	9
Figure 6.2: Categories of rain water harvesting according to type of catchment.....	13
<i>Figure 7.2: showing Classification of the aforementioned water harvesting systems. OWB:</i> Open water basins; FWH: Flood water harvesting.....	16
Figure 8.2: Showing roughing filtration system.....	22
Figure 9.3: showing system architectural.....	31
<i>Figure 10.3: Showing schematic flow of GIS</i>	
<i>Figure 11.3: showing hydrological flow steps</i>	38
<i>Figure 12.4: consistency test for Gulu Rainfall</i>	47
<i>Figure 13.4: showing land cover in catchment area</i>	48
<i>Figure 14.4: Showing digital elevation mode</i>	49
<i>Figure 15.4: showing HEC HMS file with different basin</i>	51
<i>Figure 16.4: showing precipitation and global summary table</i>	52
<i>Figure 17.4: Graph of maximum daily rainfall (Temmink) against return period</i>	55
<i>Figure 18.4: IDF curve for Gulu</i>	57
<i>Figure 19.4: Hydraulic toolbox channel section details</i>	67
<i>Figure 20.4: channel section</i>	68
<i>Figure 21.4: layout of 2D for roughing filter</i>	74
<i>Figure 22.4: longitudinal section of the pond</i>	77
<i>Figure 23.4: Showing sectional view of the recharge pond</i>	78
<i>Figure 24.4: showing three dimensional drawing of the composite component</i>	79
<i>Figure 25: Showing convergence of naviers stoke equation</i>	80
<i>Figure 26: showing velocity profile in the simulation</i>	80
<i>Figure 27: showing neural network for filter simulation</i>	81

LIST OF TABLES

<i>Table 1: showing table of datasets</i>	34
<i>Table 2: showing variables in constant suspended loads</i>	45
<i>Table 3.4: Showing monthly rainfall variation</i>	49
<i>Table 4.4: Maximum daily rainfall in a year and their relative ranks</i>	52
<i>Table 5.4: Maximum daily rainfall data and corresponding Return period (T)</i>	53
<i>Table 6.4: Return period, maximum 24-hour rainfall, maximum 24-hour intensity and coefficient aT</i>	55
<i>Table 7.4: Return period, maximum 24-hour rainfall, maximum 24-hour intensity and coefficient aT</i>	56
<i>Table 8.4: Time of concentration and intensity at various return period</i>	56
<i>Table 9.4 Typical values of Runoff Coefficient for Urban Areas</i>	61
<i>Table 10.4: Land use areas in watershed</i>	62
Table 11: The results for stream flow measurement	62
Table 12: The results for time of float measurement	63
<i>Table 13.4: Suitable side slope for channel built in various types of materials (chow,1959)</i>	64

CHAPTER ONE

1 INTRODUCTION

This chapter presents the general information relevant to the research as it clearly shows the problem of interest for the intended research. It as well shows how this study will help reduce the problem through the fulfillment of a number of objectives listed.

1.1 Background

Lack of water of adequate quality and quantity is a major constraint to development in many areas of the world. It affects every aspect of human life: health, agricultural yields, food security, technical development, and the economy of states. Water scarcity and water quality problems are of particular concern in the tropical regions of the world where many countries are less developed. In these regions, there is often a connection between poor water resources and poverty. Water balances (precipitation – evaporation) are often negative, and climatic oscillations, such as the monsoons and the El Niño Southern Oscillation, have far-reaching climatic, social and national effects.(Aroka, 2010)

A great number of people in the tropics rely on scarce and low-quality water sources, a problem that cascades from individual level to household and national scales, and which inhibits development and affects human welfare. Water stressed regions are further threatened by climate change. In Africa, there are predictions that climate change is a potential danger to future water and food scarcity (Solomon et al., 2007). However, it is imperative to recognize that the situations in many African countries are neither hopeless nor are they unmanageable. Africa is considered a water-scarce continent with most of the countries regularly experiencing extreme water shortage resulting from periodic dry spells. About 44% of people living in developing countries do not have access to clean water (UNEP). As of June 2014, Uganda's population with access to safe water in the urban area was 72.8% from 70% in the previous financial year while rural population with access to safe water remains at 64% which is similar to that of June 2013. The average functionality of rural water supplies was at 85% which is 5 percent points less than the sector target of 90% by 2015, SDG 7 target 10.(Terry et al., 2015)

and therefore bringing positive impacts on their livelihoods. Such positive impacts could include among others improved physical assets (road, irrigated land, new land under cultivation, ponds); livelihoods diversification (sale of water, commercial agriculture, raising fish, increased demand for labour); reduced vulnerability (seasonal water availability reduced, climate change resilience); and saved time in transport/travelling/irrigation/chores.

The case of Uganda, with its large rural agriculture based population, arid and semi-arid climate, and high inter-seasonal and inter-annual rain fluctuations suggests a high potential for multifunctional road infrastructure and rain harvesting, retention and re-use techniques.

Moreover, the perspective of a changing climate as well as the large scale road construction programme undertaken by the government, Netherlands organization called Metameta and the emphasis on poverty reduction provide the adequate timing for inclusion of multifunctional considerations into the infrastructure development agenda.

However, because the effects of roads are complex, can be positive as well as negative, and because road infrastructure planning and construction that integrate hydrological concerns are recent, the impacts of a multifunctional approach to road construction have to be empirically assessed.

Finally, while concerns for ground/surface water will decrease negative effects that occur because of insensitive road construction methods; these may also increase conflicts, since issues of unequal access to water resources will just add to existing distributional issues of costs and benefits of road construction. Such issues and the protracted negotiations that may result from this situation are also likely to complicate the task of engineers and surveyors in determining the shape and trajectory of the road and water infrastructure. Nevertheless, village politics and questions of access to water resources should first be addressed, so that vulnerable households can be positively discriminated and equal access to water resources can be safeguarded

REFERENCES

AROKA, N. 2010. Rainwater Harvesting in Rural Kenya: Reliability in a variable and changing climate.

BRYCESON, D. F., BRADBURY, A. & BRADBURY, T. 2008. Roads to poverty reduction?

Exploring rural roads' impact on mobility in Africa and Asia. *Development Policy Review*, 26, 459-482.

DEMENGE, J., ALBA, R., WELLE, K., ADDISUD, A. & MANJURD, K. Submitted to *Journal of Infrastructure Development* Multifunctional roads: the potential effects of combined roads and water harvesting infrastructure on livelihoods and poverty in Ethiopia.

IGLÓI, K., DOELLER, C. F., BERTHOZ, A., RONDIREIG, L. & BURGESS, N. 2010. Lateralized human hippocampal activity predicts navigation based on sequence or place memory. *Proceedings of the National Academy of Sciences*, 107, 14466-14471.

NISSEN-PETERSEN, E. 2006. *Water from dry riverbeds*, ASAL Consultants Limited for the Danish International Development Assistance.

SHIFERAW, A., SÖDERBOM, M., SIBA, E. & ALEMU, G. 2012. Road networks and enterprise performance in Ethiopia: Evidence from the road sector development program. *International Growth Centre, The College of William and Mary, Working Paper*, 12, 0696.

TEWELDEBRIHAN, M. D. 2014. *Optimizing intensified runoff from roads for supplemental irrigation: Tigray Region, Ethiopia*. UNESCO-IHE.
