BUSITEMA UNIVERSITY
Pursuing Excellence

P.O. Box 236, Tororo, Uganda
Gen: +256 - 45 444 8838
Fax: +256 - 45 4436517
Email: info@adm.busitema.ac.ug
www.busitema.ac.ug

FACULTY OF ENGINEERING

DEPARTMENT OF AGRICULTURAL MECHANISATION AND IRRIGATION ENGINEERING

(AMI)

RESERVOIR SEDIMENTATION MODELING USING COMPUTATIONAL FLUID DYNAMICS MODEL: CASE STUDY OF KIBIMBA RESERVOIR

By:

BULANGA RONALD

(BU/GS18/MID/2)

SUPERVISORS:

1. **DR. NIBIKORA ILDEPHONSE**
2. **MR. OKIRYA MARTIN**

Final year thesis submitted to the Directorate of Graduate Studies, Research and Innovation in Partial fulfilment of the requirements Leading to the award of Master of Science in Irrigation and Drainage Engineering of Busitema University

December, 2020

ABSTRACT

This work comprises modelling reservoir sedimentation using Computational Fluid Dynamics software for Kibimba reservoir. However the knowledge about the rate and the pattern of sediment deposition is one of the important requirements for understanding sedimentation and morphological processes in the reservoir.

The overall objective is to come up with a reservoir sedimentation model which will predict sediment variation as a guide to reservoir management and this will be achieved through simulation of different sedimentation processes within the reservoir during operation and flushing process in the reservoir. In order to achieve this, the following specific objectives have to be accomplished. Estimating the sediment loading from the contributing sub-catchment and the current reservoir volume is one of the specific objectives. Quantifying different kinds of sedimentation that occur in the reservoir and its distribution pattern within the reservoir is another. Finally all the above will aid in the development of a sediment model for Kibimba reservoir and this model will be used to simulate different sedimentation processes.

The project was able to come up with a model which was developed using SSIIM tool in CFD to determine various reservoir parameters using Navier Stokes equations.

The analysis looks at estimating sediment loading in the reservoir from the contributing sub-catchment and estimating current reservoir volume, quantifying different kind of sedimentation that occurs in the reservoir and its distribution pattern within the reservoir and the numerical modeling. This also covers the Graphical User Interfaces (GUI) of various reservoir parameters as far as sedimentation and water level is concerned. The interfaces include both SSIIM and Paraview 5.9.0 RC3. The input values that were used in the model were from both River Malaba and River Kibimba.

The annual rate of increase is 56.4% hence increase in sediment transportation in Kibimba reservoir.There was reduction of the area occupied by the reservoir from 450Ha to 442.656Ha and the volume of the reservoir was reduced from 31.4 million m^3 to 25.7 million m^3.

This model can be re-adjusted and simplified to fit various reservoir conditions in order to carry out simulations of various reservoirs hence an application for this model.

DECLARATION

I BULANGA RONALD, declare that this thesis report is as a result of my original work and has never been presented to any university for the award of a Master of Science degree in Irrigation and Drainage Engineering (MID).

APPROVAL

This report thesis by BULANGA RONALD has been prepared under my supervision and is now ready for presentation to the Department of Agricultural Mechanization and Irrigation Engineering of Busitema University with my due approval.

Signature:……..

Supervisors

DR. NIBIKORA ILDEPHONSE

Signature:……..

MR. OKIRYA MARTIN

Signature:……..

DEDICATION

I owe much thanks to the Almighty God who guided me to achieve my dreams. To my dear wife Ozunga Rose, my beloved sons Bulanga Raymond Mark, Bulanga Jeremiah Exodus and my daughter Bulanga Precioushoney Faith, for their patience and encouragement during this research.

Finally, to my beloved mother Mrs. Annet Babi- my first mentor who shaped my destiny.

ACKNOWLEDGEMENT

I express my gratitude to my advisors Mr. Okirya Martin and Dr. NibikoraIldephonse for their guidance, supervision and support throughout this entire work. Their kindness and patience enabled me to enjoy the process and conclusion of this work.

I thank Eng. Badaza Mohammed for his advice and time he gave me on my research. The knowledge I learned from the courses taught by Eng: Badaza Mohammed and Dr. Rwahwire Samson will benefit me for the rest of my life.

I am also very grateful to Dr.Nibikora Ildephonse for his valuable suggestions and providing me necessary computer resources as far as CFD is concerned.

All of you kindly provided me help whenever I asked for it.

I acknowledge the help of my officemates, Dr. Kasadha Matthias Legson and Mr. Kasadha Peter for their friendship and support.

I also thank the Agricultural Mechanization and Irrigation Engineering department for providing support in my research thesis, Mr. Eriau Emmanuel and Mr. ObetiGrism Lawrence.

Special thanks goes to my wife Rose, my daughter Precioushoney and my two sons Raymond and Mark, as well as my parents and my brother and sister for their love, patience, encouragement and everlasting support.

TABLE OF CONTENTS

Contents

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS AND ACRONYMS

ADCP: Acoustic Doppler current profiler

CFD: Computational Fluid Dynamics

CN: Curve Number

SSIIM: Simulation of Sediment movements In Water Intake with Multiblock Option

SIMPLE: Semi-Implicit Method for Pressure Linked Equations.

SCS: Soil Conservation Service

TIN: Triangulated Irregular Network

TSS: Total Suspended Solids

UTM: Universal Transverse Mercator

CHAPTER ONE: INTRODUCTION

This work comprises of modelling Reservoir Sedimentation using Computational Fluid Dynamics software for Kibimba reservoir.
Numerical sediment transport models are available in one, two, and three dimensions. However, more modelling is performed with one-dimensional (1D) models which tend to be more robust than their two- and three-dimensional counterparts and require less input data and computation time. Two-dimensional (2D) sediment transport models are much more common than three-dimensional (3D) models. Recent advances in computing power and model code have resulted in the increased use of multi-dimensional models.

Guidance pertaining to the selection of the appropriate model is gained from professional experience and from the literature. Model complexity and capability varies with the ability to handle unsteady flows, bed load and suspended load, sediment exchange processes, type of sediment (cohesive versus non-cohesive), and multifractional sediment transport.

Therefore, basing on the previous experiences for sedimentation and the capabilities of the SSIIM tool, this tool in CFD is suitable to perform reservoir sedimentation modelling.

1.1 Background

Reservoirs are built for many purposes, including flood control, water supply (for agriculture, industry, and urban usage), power generation, navigation and recreation, etc. As rivers carry sediment load, whether in large or small amounts, reservoir sedimentation occurs simultaneously with the impounding of water. Meanwhile, the river channel downstream of the reservoir experiences modifications induced by the changes in flow and sediment regimes. Those changes upstream and downstream of dams lead to intensive changes in environment, ecology and river morphology, affecting engineering projects along the river, etc. It is necessary to predict such changes(Xiaoqing, n.d.).

Reservoir sedimentation happens in most reservoirs in the world, and the sensitivity of such phenomena is determined by the normal reservoir size, hydrological size as well as the morphological behaviour of the river system. From the water resources point of view, due to limitation of the natural resources and the global changes that happen in the latest century, the problem of reservoir sedimentation has become a serious problem especially when it affects the availability of water resources in such area and maximizing the risks coming from the excessive floods due to weather changes.

Mahanadi Catchment , India) APPLICATION OF UNIVERSAL SOIL LOSS (Case study : Upper Mahanadi Catchment , India).

Semmahasak, S., & Philosophy, D. O. F. (2014). *A thesis submitted to the University of Birmingham for the degree University of Birmingham Research Archive*. *August*.

Society, U. S. (2015). *Modeling Sediment Movement in Reservoirs United States Society on Dams Modeling Sediment Movement in Reservoirs* (Issue June).

Xiaoqing, B. Y. (n.d.). *WORLD METEOROLOGICAL ORGANIZATION OPERATIONAL HYDROLOGY REPORT No . 47 MANUAL ON SEDIMENT MANAGEMENT AND* (Issue 47).

Handbook for Assessing and Managing Reservoir Sedimentation

Doc. No. CDSO_GUD_DS_04_v1.0, February**2019**

http://www.birdlife.orgon 27/09/2019.

Sedimentation and sustainable use of reservoirs and river systems

Draft ICOLD bulletin

World Environmental and Water Resources Congress 2019

Assessment of Reservoir Sedimentation Level and Storage Capacity Using Remotely Sensed Data for Namadope Reservoir in Luuka District, Uganda

Wilberforce Mbatya, Lawal Abdul Tunji Qayoom, PhD and Jotham Ivan Sempewo, Ph.D.

Projects Dept., Uganda Electricity Generation Company, PO Box 75831, Plot 6-9, Okot Close, Kampala, Uganda. Email: jotham.sempewo@uegcl.go.ug

WATER RESOURCES RESEARCH, VOL. 49, 1017–1029, doi:10.1002/wrcr.20117, 2013

www.dhisoftware.com/mike21c

JOURNAL OF HYDRAULIC ENGINEERING © ASCE / FEBRUARY 2008

River Flow 2010 - Dittrich, Koll, Aberle&Geisenhainer

McMullin, Nicholas (2015)

UN-Water's *Sustainable Development Goal 6 Synthesis Report 2018 on Water and Sanitation*