MODELLING THE OCCURRENCE OF FLOODS ON MUYEMBE RIVER AND TEST AN APPROPRIATE STRUCTURE TO MITIGATE.

(Case study: Bulambuli District)

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RESEARCH INFOMARTION

Research Article. **Modelling the occurrence of floods on Muyembe river and test an appropriate structure to mitigate.**

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Abstract

This project research is about Modeling the occurrence of floods on river Muyembe and testing an appropriate structure to mitigate for River Muyembe in Bulambuli district.

This work is presented in chapter form. Chapter one is composed of the introduction to the research problem. Chapter two contains a review of literature which has been produced by other scholars and researchers about flood modelling. The third chapter presents the various methods which were employed to achieve the objectives amongst them were; to develop the hydraulic model of river Muyembe which was done by HEC-RAS software. The fourth chapter presents the findings from the research.

The communities living along Muyembe River found in Bulambuli district experience frequent floods threatening their lives and property. Climate change and anthropogenic perturbations to the natural environment increase flooding frequency.

Recently, the development of models for flood calculation and hazard assessments has made full use of the advancement in computer-aided technology. This study focuses on applying a hydraulic model (HEC-RAS) in a GIS context for the flooded areas of Muyembe subcounty in Bulambuli

district, and produces inundation maps, flood depth, and water surface elevation of 15, 25, 50,100, 500, 1000-year Return Period.

The research included reading a variety of literary works and gathering supplemental information in the form of journals and reports. This aided in developing the project's technique as a whole. The stage of modeling came next. The initial data collection process used a number of sources, including DEM, discharge flow, rainfall, and soil data were all collected. These datasets were prepared and processed in the GIS environment using the ArcGIS application. The HEC-RAS program was used to compute for unsteady flow simulation and create geometry data. The area's flood extent was viewed using the RAS Mapper.

Two major hydraulic structures were considered in this research i.e. a weir and a dam to determine the most appropriate for flood mitigation of floods along river Muyembe. Various return periods were run in absence of any structure and then also ran with the presence of a weir and a dam while observing a significant drop in the depth downstream.

1 Background

Flood is the most frequent type of natural disaster and occurs when an overflow of water submerges land. Floods are often caused by many factors including heavy rainfall, overflowing rivers due to debris in the river that reduces the storage capacity of the river, among others (Pérez Ciria et al., 2019).

Globally, floods are increasingly among the devasting natural hazards affecting human life. Floods have caused nearly US 386 billion dollars economic loss in the last three decades of the twentieth century in the United Nations states that approximately 2.3 billion people were affected and 157,000 died by floods 1995-2015 worldwide (Nolan, 2006).

Over the years, Uganda has been experiencing climate change and environmental related problems with the mountainous sub regions of Rwenzori and Elgon being the most hit. Flood risk is distributed and variable across Uganda but it is expected that on average up to each year, 50,000 people could be affected by flooding, 40 education and health facilities and 40km of transport infrastructure could be exposed to floods. Future changes in Uganda’s population and economy, coupled with changes in climate-related hazard, are expected to increase the impacts of droughts and floods.

Bulambuli district being located on the slopes of mount Elgon experiences significant flooding during rainy seasons. Subsistence agriculture and animal husbandry are the two main economic activities in the district. Crops grown include: Matooke, Cassava, Rice, Groundnuts, Sorghum, Millet (UBOS, 2017).

The primary natural factors causing flood on river Muyembe are high intensity and long duration of rainfall and meandering courses of the river. These floods cause massive damage to life and property. People living in flood-prone areas get homeless as a result of devastating floods. Agricultural lands are washed away and often disrupt transport and communication.

In 20th May 2018, Floods ravaged five sub-counties in Bulambuli district, leaving over 680 households and pit latrines submerged by water hence forcing families to resort to open defecation raising a cholera outbreak. Several families fled their homes and took shelter in the nearby schools, churches and trading centres.

In 2019, Flash floods triggered by heavy rainfall rendered several people in Bulambuli district homeless. The floods submerged homes in Bunangaka, Bufuhula, Nabbongo, Bufumbula, Buwakoli and Bumasoho parishes in Nabbongo sub counties. At least 950 houses were flooded, leaving more than 4,500 people in need of shelter. Critical infrastructure, including roads, bridges and schools has been damaged and/or destroyed. Some schools were temporarily closed.

Protecting property and community from being flooded is a very sensible option. This research work is aimed at modelling the occurrence of floods on river Muyembe and test an appropriate structure to mitigate. Structural flood mitigation structures can be constructed or modified to reduce the impact of flooding on individual properties or whole catchments and these structures include Infrastructure such as dams, levees, bridges and culverts. This was achieved by the use of HEC RAS software and google earth.

2 Methodology

2.1 Specific objective 01: To develop a physically based hydraulic model of River Muyembe.

2.1.1 Terrain/ Geometric model building.

Software used was HEC RAS and google earth.

The terrain data (DEM) of 12.5m resolution for the catchment to be modelled was imported into the RAS mapper by creating a new terrain layer under “terrains”. The units were changed from imperial to metric and the WGS UTM 36N projection was utilized. Manning's n values were read from land use dataset.

The cross-sections used in creating channel bathymetry were generated using the geometric data editor in GIS. Under “geometries” in the RAS mapper the imported cross-sections are exported to create a GeoTiff DEM for the bathymetry.

In order to modify the catchment DEM(Terrain.rivermuyembe.tif) to include channel bathymetry, the new DEM (modified.modifiedchanel.tif) generated from cross-sections is superimposed as shown in **Error! Reference source not found.** and a new terrain created.

There were two main types of data entered: Geometric Data, describing the river channel setting and the structure, and Unsteady Flow Data describing the water and flow characteristics.

The geometric editor is then opened and a 2-D flow area mesh was drawn over the terrain as shown in **Error! Reference source not found.**. The mesh size is then set in accordance to the degree of detail of result required. The “SA/2D BC Lines” tool is then used to draw the boundary condition lines (i.e., upstream, and downstream which allow flows to be introduced into and taken out of the model.

2.2 Specific objective 02: To simulate potential floods on river Muyembe.

Model simulations were run using 2D Unsteady flow simulation option given the unevenness of the river terrain in most cases. Various plans were created in the absence of an inline structure to run different cases which included but not limited to plans containing different flood parameters, plans containing different flow conditions, plans with and without extreme flood peaks. e.g., cases for mean flows, 5yr, 75yr and 10,000yr return periods.

Boundary conditions

I input boundary conditions, that is, flow hydrograph, normal depth.

- The boundary condition line at the flow inlet was set to a flow hydrograph boundary condition with the flow hydrograph depending on the case being considered considering mean flow, 5yr, 75yr and 10,000year return period where the respective flow hydrograph obtained from Gumbel method were used.

TABLE 2-1: SHOWS FLOWS

MEAN	9.038497788		
SD	2.447156118		
REDUCED MEAN	0.5481		
REDUCED SD	1.159		
RETURN PERIOD (years)	**REDUCED VARIETE Y_T**	**FREQ FACTOR K_T**	**ACTUAL DISCHARGE X_T**
5	1.499939987	1.294167374	12.2055274
75	4.310784111	3.719399578	18.14044922
10000	9.21029037	7.946756143	28.48545071

- The Energy Grade slope for the flow hydrograph was set to 0.006.
- The boundary conditions line at the flood outlet was set to a normal depth boundary condition with a friction slope of 0.0006.

2.2.1 Running the unsteady flow simulation

Using the unsteady flow analysis editor, the model was run using a one-minute computation interval for 30 minutes duration using the shallow water equation for all scenarios after choosing all the necessary data for a successful run. The choice of data output was also made here, that is, flood plain mapping among others.

2.3 Specific objective 03: To test and validate the performance of the structure.

HEC-RAS has the ability to model inline dams, weirs, and gated structures with radial gates (often called tainter gates), vertical lift gates (sluice gates), overflow gates (open to the air or with a closed top), gates modelled with user defined curves, culverts, culverts with flap gates, user defined outlet rating curves, and user specified outlet time series. The spillway crest of the gates can be modelled as an ogee shape, broad crested weir, or a sharp crested weir shape.

Inline Structures in consideration were a weir and a dam:

Considering a weir

To insert a weir, Inline structure button from the geometric data window was selected. “Weir/Embankment” option was used to set Weir width, Weir coefficient Cd, Weir crest shape.

Considering a dam

To insert a dam, “SA/2D Area Conn” tool was then used to sketch the axis of the dam (connection line) and then given a unique name. To model the dam, the “connection data editor” tool shown in figure below was accessed. The “Weir/Embankment” option was used to set Weir width, Weir coefficient Cd, Weir crest shape.

The “Gate” option was selected to access the “Connection Gate Editor” shown in the figure below. Various gates groups are created for which will be controlled by the same operating rules set in the “Unsteady flow data” input panel.

From the “Connection Gate Editor”, the gate groups are created and named, the gate type, sluice discharge coefficient, orifice coefficient, weir shape and gate geometric properties are set.

3 RESULTS, ANALYSIS AND DISCUSSIONS

3.1 Specific objective 01: To develop a physically based hydraulic model of River Muyembe.

Here, the hydraulic model for Muyembe river was generated as described in the methodology to objective one.

For model building: Reaches of the river valley were created. 2-D flow area mesh was created having SA/2D BC Lines indicating boundary condition lines of upstream and downstream which allow flows to be introduced into and taken out of the model.

3.2 Specific objective 02: To simulate potential floods on river Muyembe

For Flow model: Inundation zones were displayed. Flooded area were observed to keep increasing with increasing return period as shown in table below. Flood plain maps were generated for the catchment for the mean flows, 75- and 10,000-year floods as shown in the figures below.

Return period	Mean flows	75	10000
Inundated area(m^2)	234415.037708	276288.393521	299481.307345

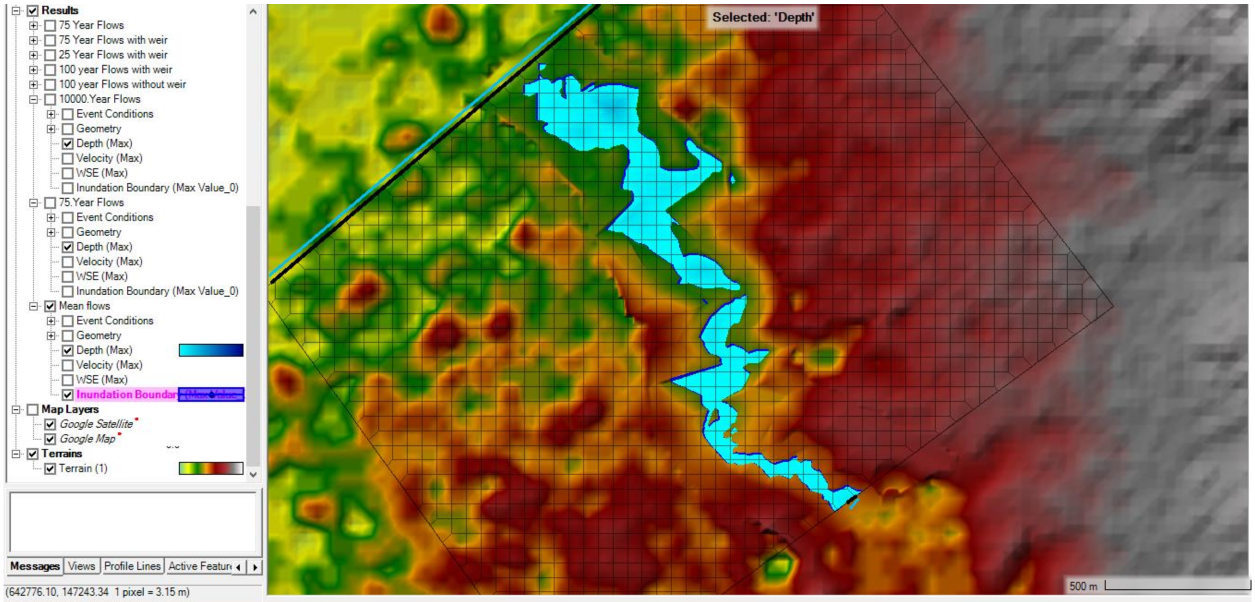


FIGURE 3-1 SHOWS THE MEAN FLOW FLOOD HAZARD MAP

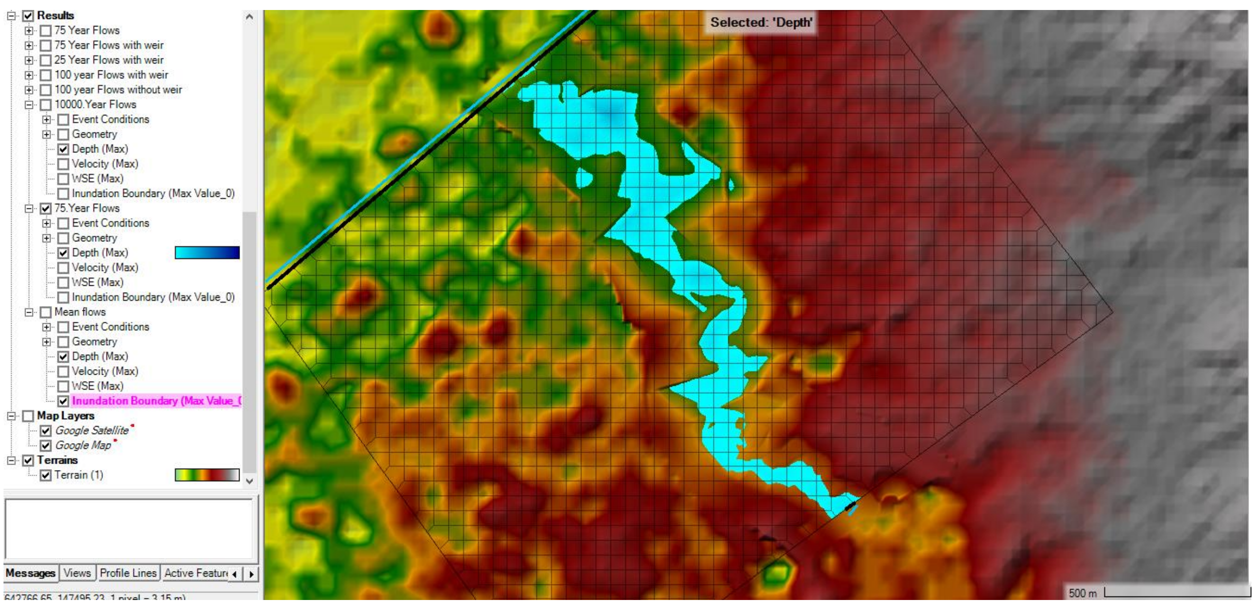


FIGURE 3-2 SHOWS THE 75-YEAR RETURN PERIOD FLOOD HAZARD MAP

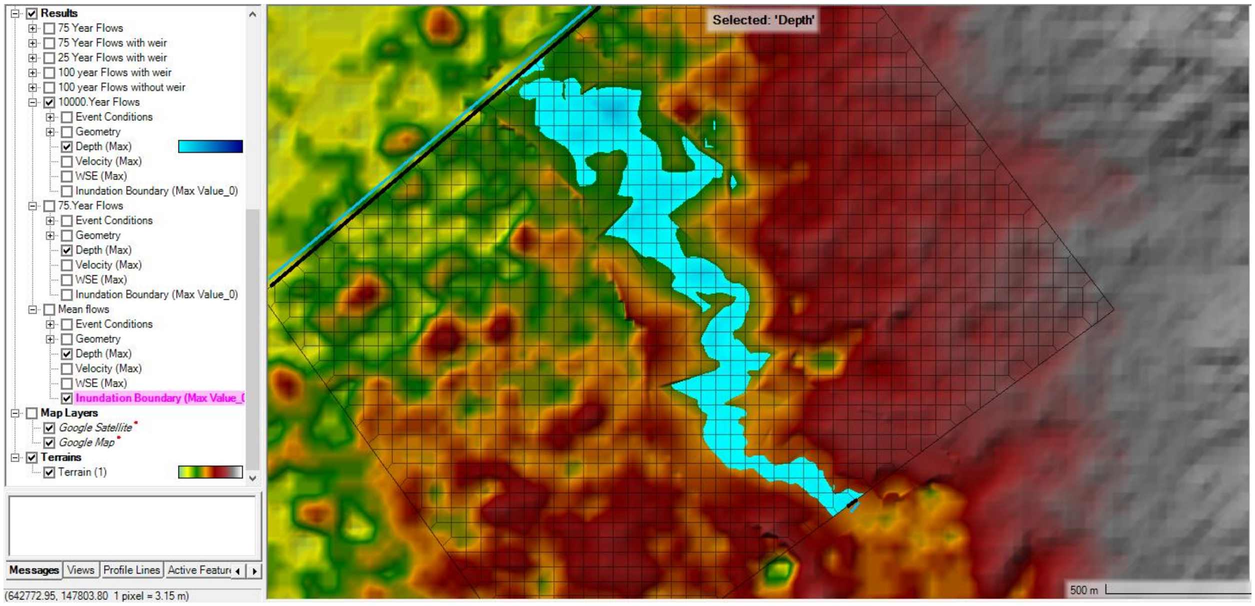


FIGURE 3-3 SHOWS THE 10,000-YEAR RETURN PERIOD FLOOD HAZARD MAP

3.3 Specific objective 03: To design, and validate the performance of an appropriate hydraulic structure in mitigating the floods.

Testing a weir

- As per weir's operation, it allows water to pool behind them, while allowing water to flow steadily over top of the weir, essentially a small-scale dam.

- Various return periods were run with the weir and there was significant drop in the depth downstream as compared to when there is no structure present. Considering a worse flood of 10,000yr return period, a weir reduced the flood downstream from a depth of about 1.65 to 1.10metres as displayed in the depth plot at a particular known over flooded point.

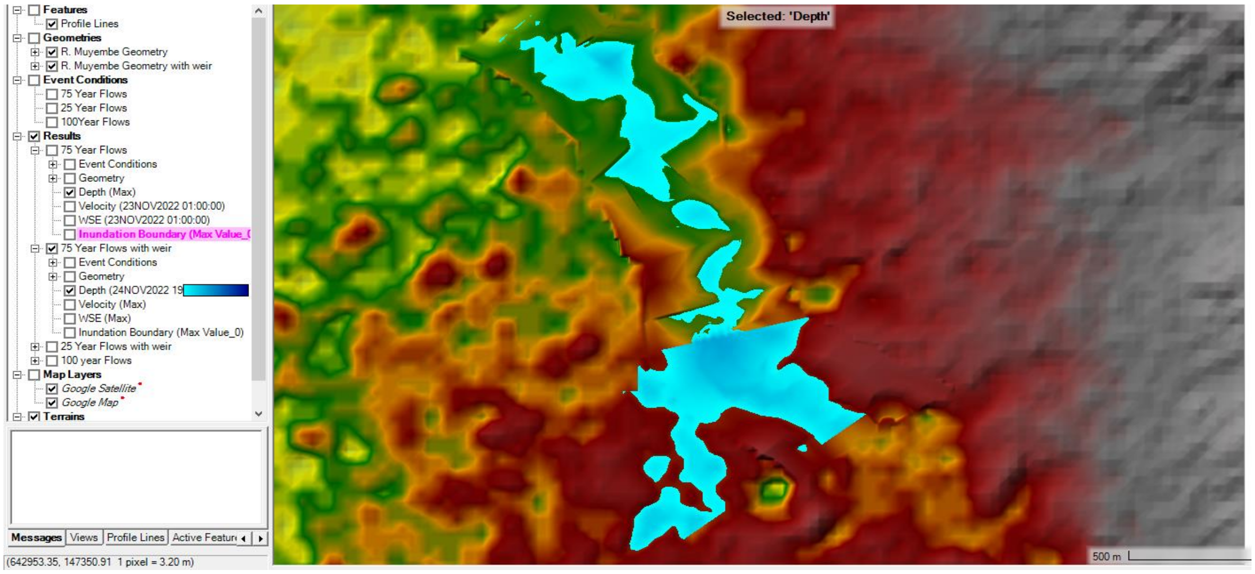


FIGURE 3-4 SHOWS THE 75 YR RETURN PERIOD FLOWS WITH A WEIR

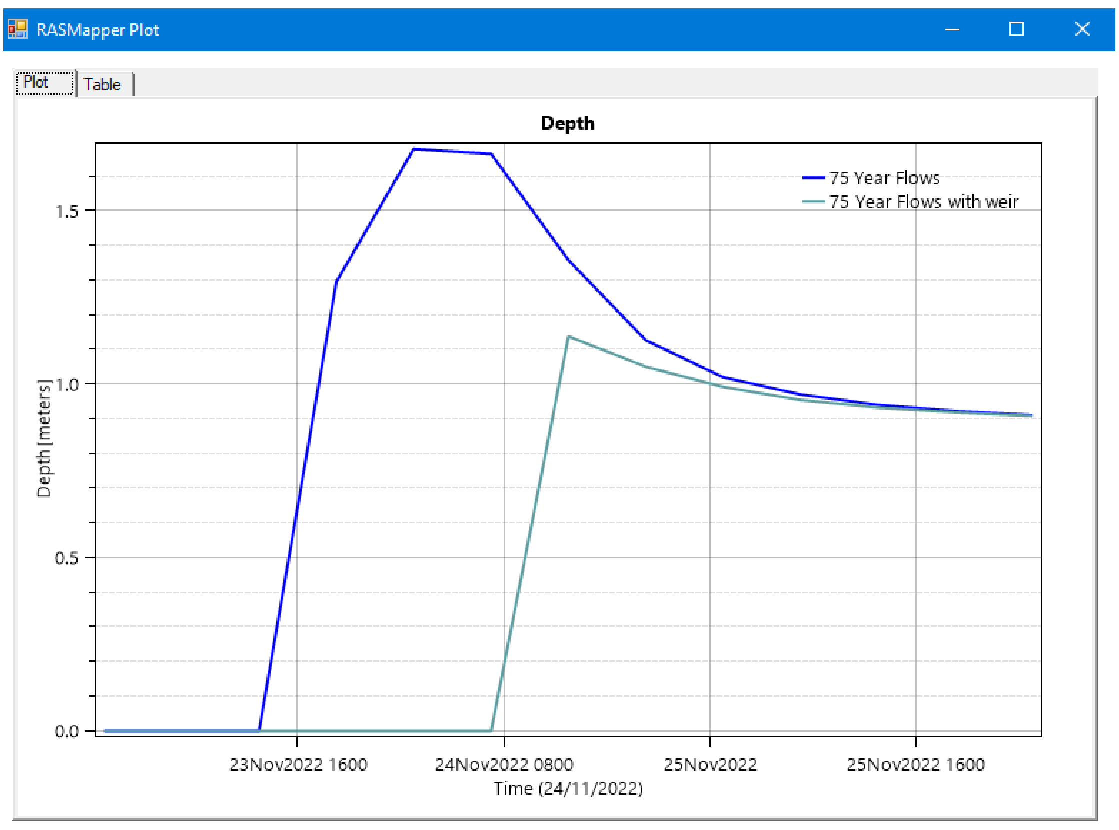
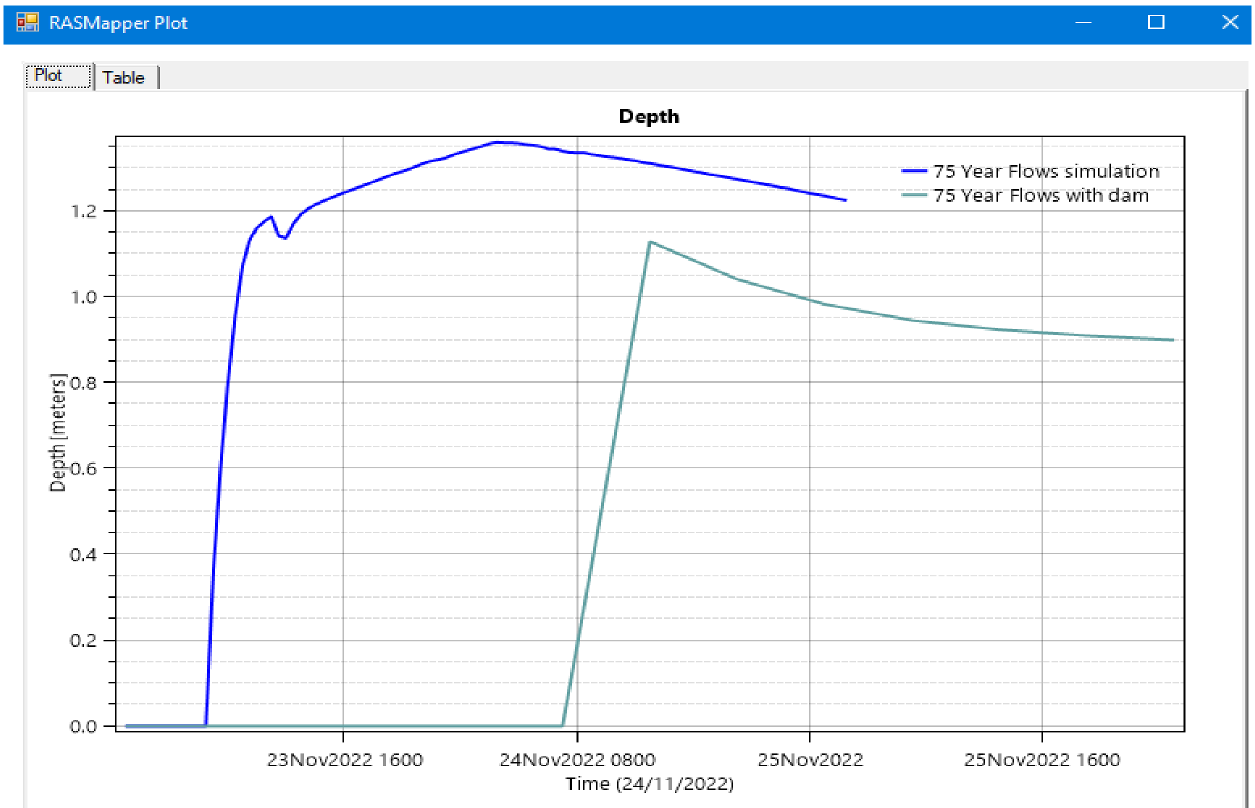


FIGURE 3-5:THE GRAPH ABOVE, PRESENCE OF A WEIR REDUCES FLOOD IN TERMS OF DEPTH.

3.4 Testing a dam

Dams protect against flooding by collecting and holding waters when they reach a certain level. Water is then released back into the river at controlled speed or divert the water elsewhere for other uses.

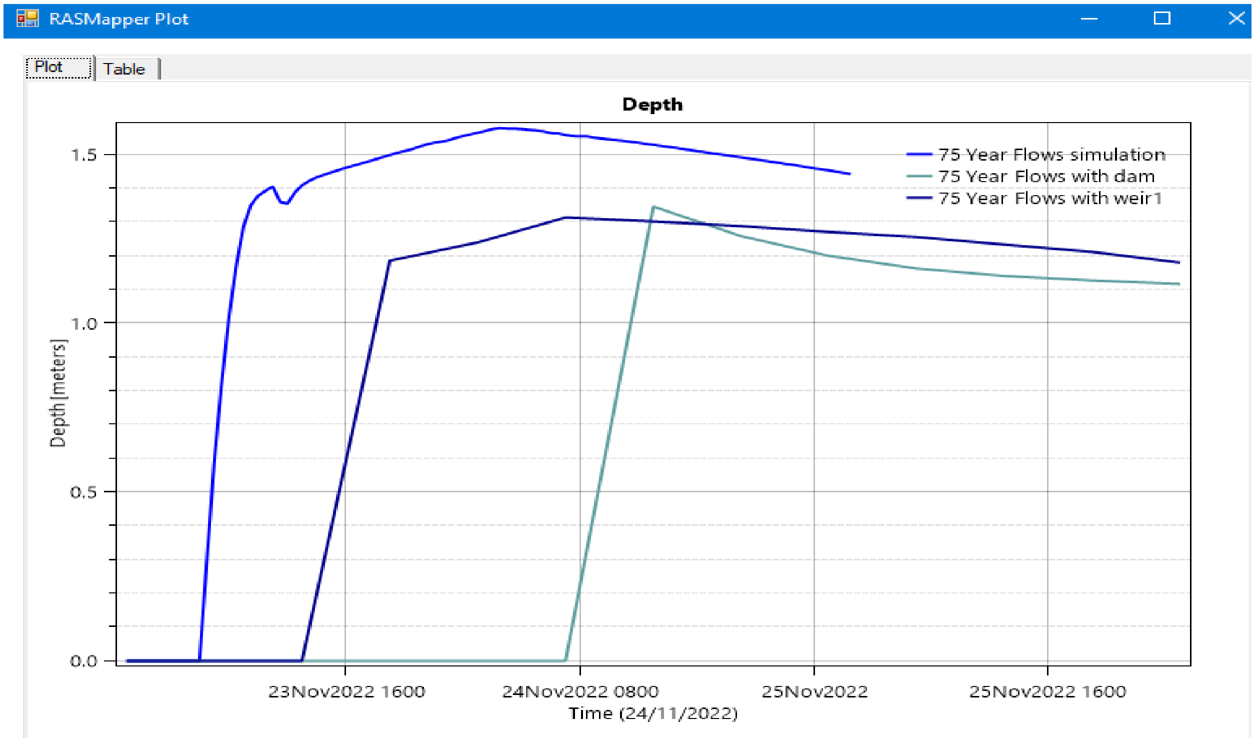
Various return periods were run with the weir and there was significant drop in the depth downstream as compared to when there is no structure present. Considering a worse flood of 75yr return period, a weir reduced the flood downstream from a depth of about 1.25 to 1.04metres as displayed in the depth plot at a particular known over flooded point.



3.5 Basic design of the hydraulic structure

From a combined graph showing the inundation depth without a structure, with a weir and with a dam, there was greater flood reduction downstream in the presence of a dam which was highly recommended for flood mitigation.

A basic design of a dam is calculated for flood mitigation to sustain spillway discharge.



Parameters looked at during the design are:

Effective length of spillway, Le

Number of piers, N

Design head including velocity head, Hd=4m

Net length of crest, b'

Pier contraction coefficient, Kp= 0.01

Abutment contraction coefficient, Ka= 0.1.

Discharge coefficient, Cd= 2.0

Assume a high ogee spillway whose velocity head is very small. Thus, Hc=Hd=4m

From the expression, Q=CdLe

But Cd=2.0, ka=0.1, kp=0.01

Le=L-2(Nkp+ka)He………………(L) being net length of crest=9m

So, Le=9-2(2*0.01+0.1) *4 = 8.04m

Q=2.0*(8.04) * =128.64 Comics

Combined Model Calibrations and Validations

Together with on-site information acquired through physical visits, the model was calibrated using the daily flows and the daily water depth at a known point along Muyembe river by adjusting the manning's roughness coefficient of the 2D flow area until the flows on the particular day produced depth equal or very close to the actual recorded depths.

Manning's roughness coefficient was increased in order to increase the depth and decreased to decrease the depth. A graph of manning's roughness coefficients, n, against the observed flows was obtained.

Extrapolating to obtain the Manning's roughness coefficient at Probable Maximum Flood (PMF) gives a value of 0.057$m^{1/3}$/s. This is the value of Manning's roughness coefficient that was used for the analysis.

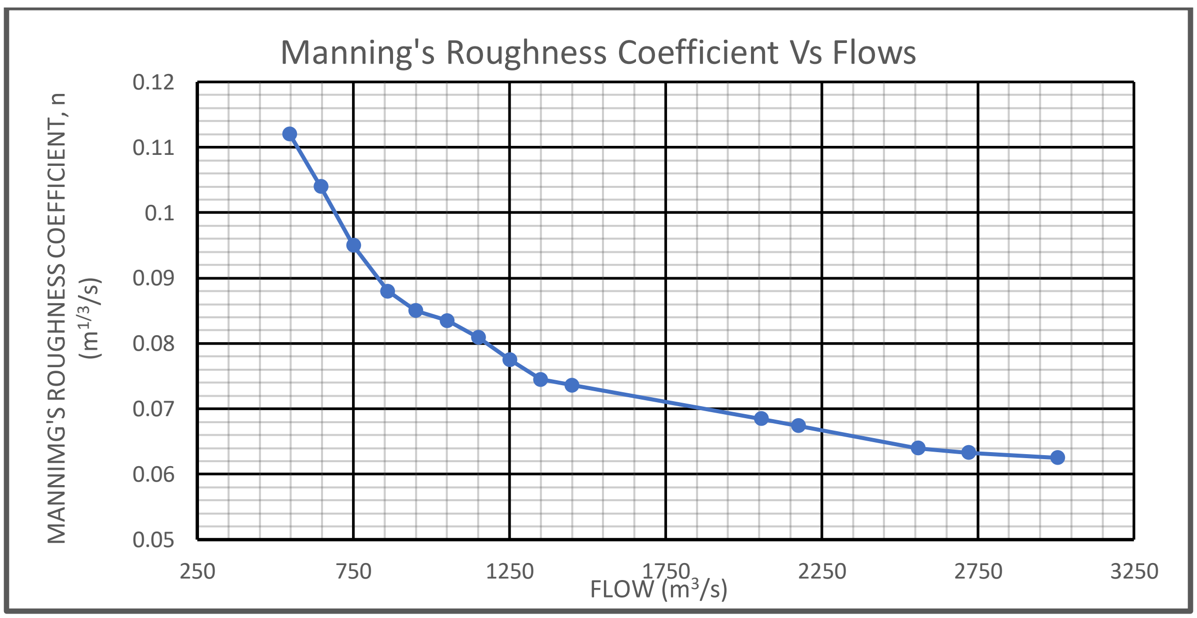


FIGURE 3-6: CALIBRATION USING MANNING'S COEFFICIENT

Conclusion

It is concluded from the research that by using running hydraulic model, it is very easy for decision support systems in preparation of flood management plans. It is also helpful in before, during and after floods, remote sensing and GIS are helped to decision makers for different analyses such as flood inundation mapping, flood risk and hazard analysis, flood damage analysis and also in flood mitigation management. Flood inundation depth, velocity and time maps can be derived and overlaid to obtain flood risk (hazard) map.

Though dams and weirs are similar structures that help in controlling the flow of water across a river, dams are considerably large and high while weirs are small. Weirs are characterized by specially designed opening to increase the flow of water. Water collected behind the walls of both dam and weir is used for agriculture and drinking water supply. Therefore, the dam is highly recommended preferably to a weir along river Muyembe for flood mitigation.

Recommendations

- During the design of the project, one of the most important factors is community consultation and participation. This is important for the long-term project maintenance, operation and overall acceptance.
- The operation of the project is very important. Some of the issues which should be looked at include: the site should be secured by fencing to avoid accidents by drowning and to avoid damage to the embankment by animals. To reduce evapotranspiration rates, trees with low evapotranspiration rates should be planted near the site.

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