FLOOD INVESTIGATION ON LOWLANDS OF ALA RIVER UPSTREAM WATERSHED

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ABSTRACT

The residential areas in the lowlands of Ala river upstream watershed are seasonally inundated with flood waters. Estimating the magnitude of peak discharge and the geometry of flood flow is important for safety of life and property. The peak discharges were simulated for the outlet of the upstream watershed using 25 and 100 years return period storm. Hydrologic Engineering Center-Hydrologic Modeling System was used in simulating 25 and 100-years return period storms. The flood geometry would be simulated with Hydrological Engineer Center – River Analysis System. The runoff curve number parameter was extracted using land use description obtained from land use and land cover classification of the watershed. The classification was performed with supervised classification method. Peak discharge for 25 and 100-years return period storm were 142.3 m^3/s and 229.8 m^3/s respectively Maximum flood height for 25 and 100 years return period flood was simulated as 4.46 m and 5.02 m respectively. The maximum offset from stream bank for 25 and 100 years return period flood was simulated as 31.07 m and 37.25 m respectively.

Keywords: Watershed, flood, peak discharge, return period, and land use and land cover.

INTRODUCTION

Rainfall-runoff simulation is important in generating peak discharges required for design of hydraulic structures and flood investigation Lengthong *et al*, 2016 carried out a flood mapping on Mekong River Cambodia using the HEC-RAS and HEC-HMS models. The result shows that the total affected areas in both side of this 50 km long of the river was ranged from 1,400 to 7,400 ha (made of various land use such as residential, rice field and industrial area) while flood depth was from zero to about 10 m for both sides of river. Saghafian *et al*. (2008) used the HEC-HMS hydrological model to show that land use change from forest and rangelands to cultivated areas over hill slopes caused substantial land degradation and increased the outflow peak and total runoff volume observed. The residential areas in Alaba estate located in the lowlands of the upstream watershed have seasonal flooding challenges. The side drains, culverts and roads are overtopped with flood waters during the peak of rainy seasons in the months of July and September. It is therefore imperative to estimate the peak discharge and flood sections for the lowlands.

METHODOLOGY

Description of the study area

The upstream watershed lies between longitude 5° 7' E to 5° 10' East and latitude 7° 17' N to 7° 20' North. The watershed covers an area of 12.63 km^2 with the vegetative area occupying 4.39 km^2 and built-up area occupying 5.87 km^2. The watershed drains Ipinsha areas, the Federal University of Technology Akure north gate and south gates areas, and part of the road to Ijare town. The location map in figure 1is the watershed in Akure and in Nigeria. The watershed area experiences regular rainfall between April and July with a short break in August which continues between September and November with the heaviest rainfall occurring in July. Annual rainfall depth varies from 1,500 mm to 3500mm. The average daily temperature ranges from 22˚ during the harmattan period (December-Febuary) to 32˚C in March. The upstream watershed has an average annual relative humidity of 75 percent which is highest during the day during the rainy season when it rises to about 90 percent.

The area around the Akure metropolics is underlain by the basement complex rocks of southwestern Nigeria. The petrological unit include Migmatite-Gneiss-Quartzite complex, Charnockitic and Diorite rocks, older Granites and nnmetamorphosed dolerite dykes (Rahaman, 1998).

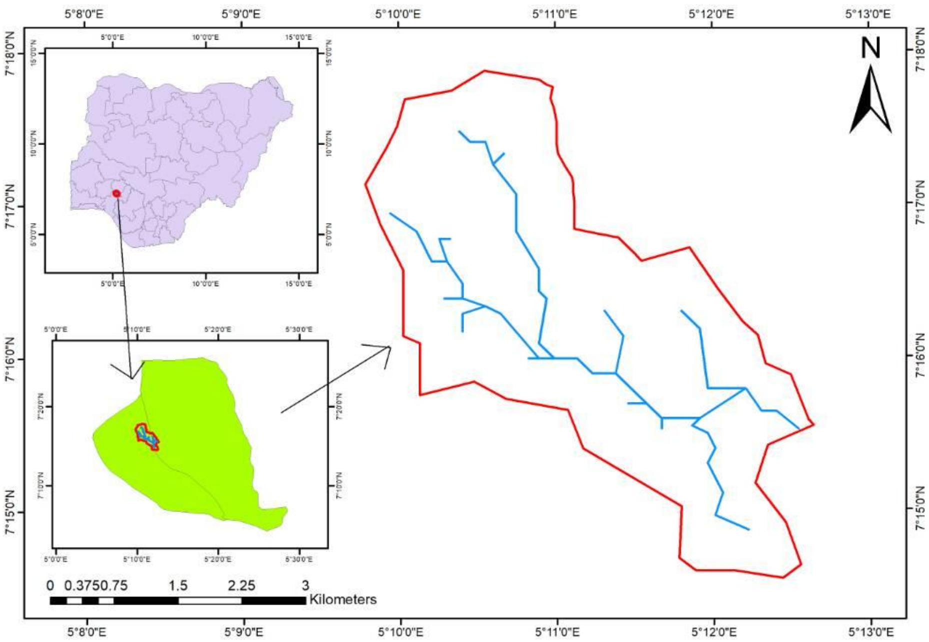

Figure 1: Location map for the Ala watershed

HEC-HMS Model

The Hydrologic Modeling System, developed by the Hydrologic Engineering Center of the United States Army Corps of Engineers, is a lumped or semi-distributed software package for modeling rainfall-runoff processes in watershed. It is public domain software developed by the US Army Corps of Engineers. It also has a wide range of methods to set up and control variables for simulating a rainfall-runoff (USACE, 2000).

Model application

In this model, interception, evaporation and infiltration processes in a catchment are determined from loss components while runoff processes are computed as pure surface routing using transform component. The selected methods used for parameterization were the SCS curve number (*CN*) method for loss component and Unit Hydrograph method for transformation routines. The SCS curve number corresponds to interception and depression storages with an initial abstraction. The *CN* for the study area catchment was estimated as a function of land use, soil types and antecedent moisture of the catchment. The *CN* is a function of three factors: the antecedent moisture condition (AMC) or soil wetness, the land use and land cover (LU and LC) description, and the soil group. The LU and LC description was obtained from the LU and LC classification. The information on soil group is derived from the available soil map of Akure metropolis. The soil is generally moderately fine and coarse textured soil.

HEC-RAS Model

HEC-RAS is a modeling program developed by the US Army Corps of Engineers and made available to the public. It models the hydraulics of flow through natural channels and other channels using two different approaches, i.e. (i) Steady flow simulation, and (ii) Unsteady flow simulation.

Model application

Geometric data in HEC-RAS model was generated from Arc-GIS. The flow path center line was established for stream. Selected points called river stations were established along these center lines and were given altitude from terrain model. Transverse lines were drawn perpendicularly across the river stations. The transversal lines were drawn to determine the banks of the stream bed and the flood plains. These lines were measured 200 m from both river banks. Cross-sections were extracted from the altitude values of these transverse lines spaced at distance 20-30 m. The cross-sectional profiles were extracted from altitude values extracted from terrain model for flood plains and bathymetric survey for the stream bed. Manning value were associated to land use and land cover classification the transverse lines intercepts (ranging from 0.30 – 0.60). Peak discharge values were generated for the river stations using HEC-HMS model. The peak discharges were generated from 25 and 100-year return period storm for Akure metropolis in Nigeria. The watershed areas for the river station were used in generating peak discharge for each of these stations. In order to run the flood simulation HEC-RAS, steady flow analysis was used for hydraulic analysis. The sub-critical flow regime was adopted. The resulting cross-section of flow generated for each cross-sections were verified with the rating curve.

GIS Model

The GIS model is used to create the basin model for HEC-HMS is based solely on topography. It drives watershed network from the topographic information and calculate their relevant characteristics. With this topographical map, other maps like soil type, land slope, land use/pattern, drainage network, curve number and watershed boundary map were extracted.
Remote-sensed images

Satellite Images

Landsat 8 Operational Land Imager (OLI) was used in determining land use and land cover types in upstream Ala watershed. These were images collected in the year 2017 respectively with path and row 189, 56. The images were downloaded from the United States Geological Survey (USGS) website. The Administrative map of Nigeria was the source from which the study area shape file was clipped out, this was done using ArcGIS. The 2017 images have resolution of 30 metres. All the images were enhanced, georeferenced and classified for the assessment of spatio-temporal pattern of land use and cover changes in the study area. In this study, the satellite images were classified using supervised classification method.

RESULTS

Land use and land cover

Values extracted from digitized land use map shown in Figure 2 indicate that the total watershed area is 12.63 km^2, while the vegetation area is 4.39 km^2, built-up is 5.87 km^2, and water body 2.37 km^2.

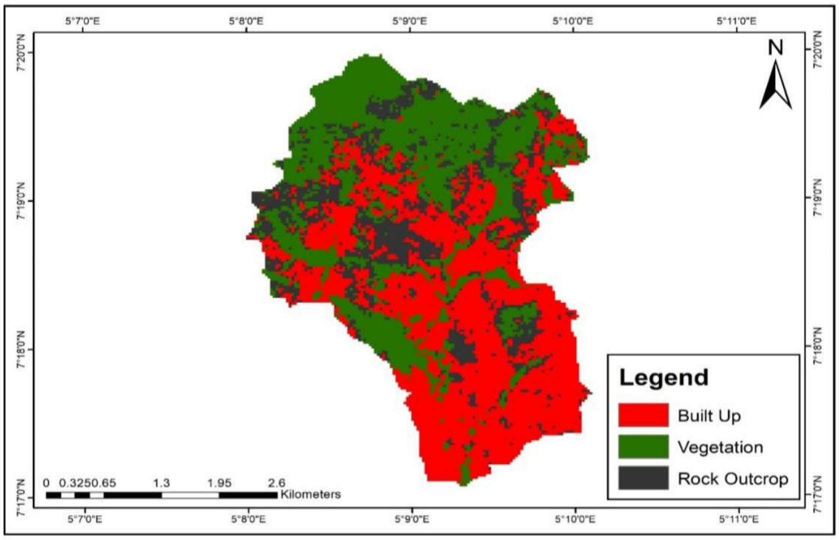

Figure 3: LU and LC map showing land use in 2017

Simulation of peak discharge

The runoff hydrograph for 25-year and 100-year return period storm is shown in figures 3 and 4. Peak discharges for both 25-year and 100-year return period are 142.3 m/s^3 and 229.8 m/s^3 respectively.

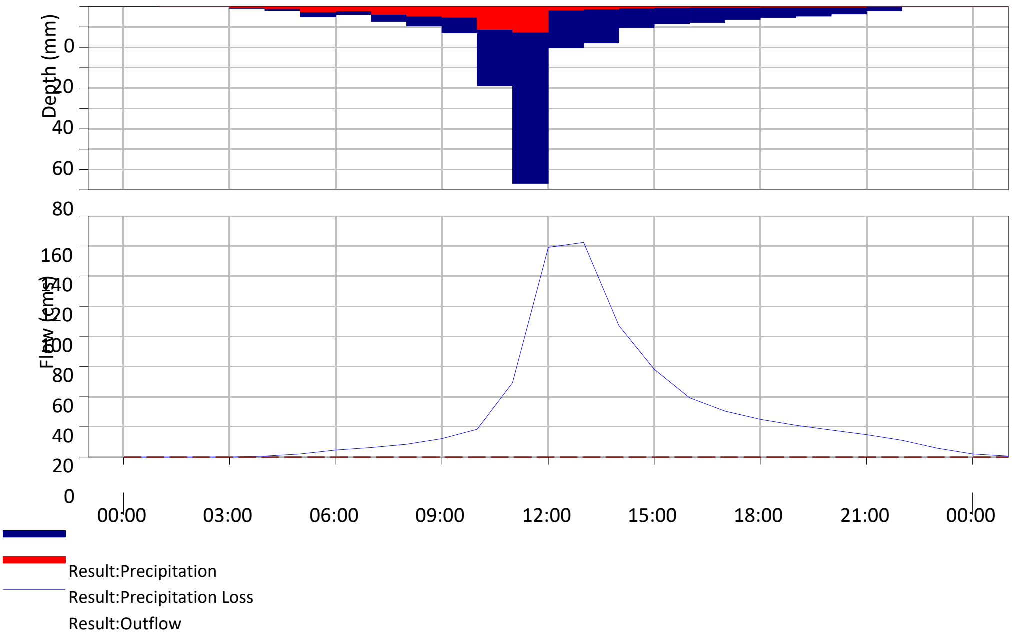

Figure 3: Hyetograph and simulated runoff for 25 - year return period rainfall

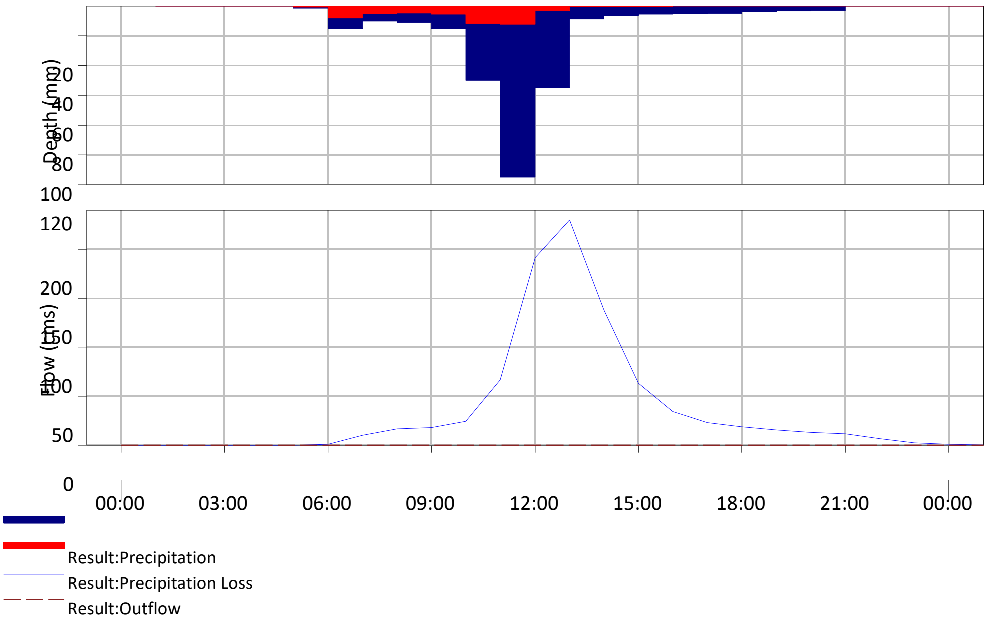

Figure 4: Hyetograph and simulated runoff for 100 - year return period rainfall

Rating curve

Figures 5 show the stage-discharge relationship (rating curve) estimated from the guage station installed at the outlet of the watershed.

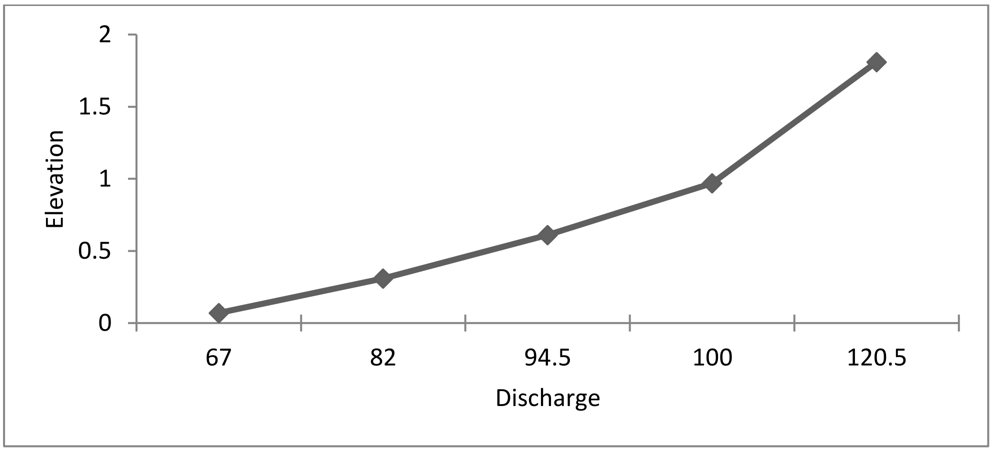

Figure 5: Rating curve for guage station at the watershed outlet

Simulation of flood water sections

The peaks discharges for five river stations were used for generation of the floods longitudinal section and cross-section. In figure 6 and 7 the longitudinal profile of flood for the five river stations is shown.

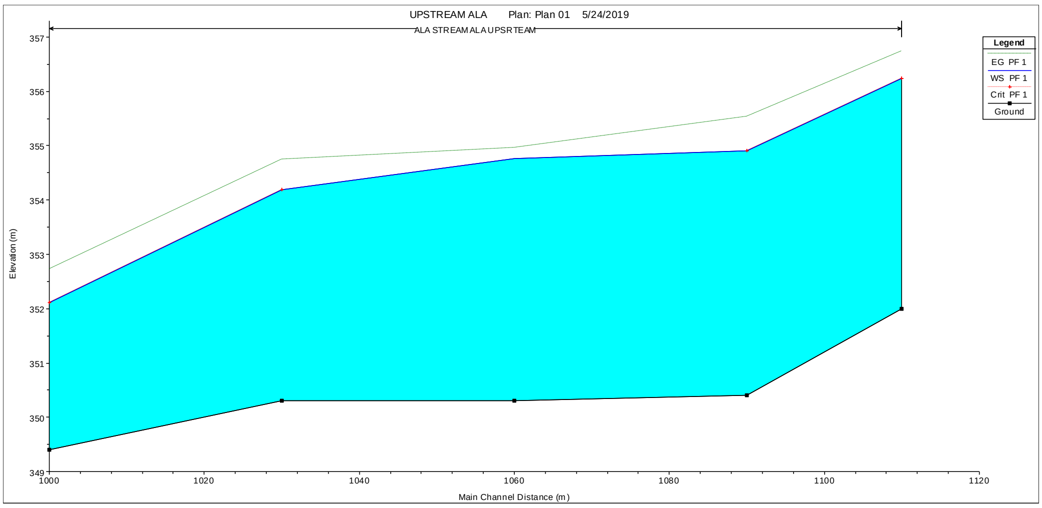

Figure 6: Longitudinal section of stream from 110 m from outlet (25-years return period flood)

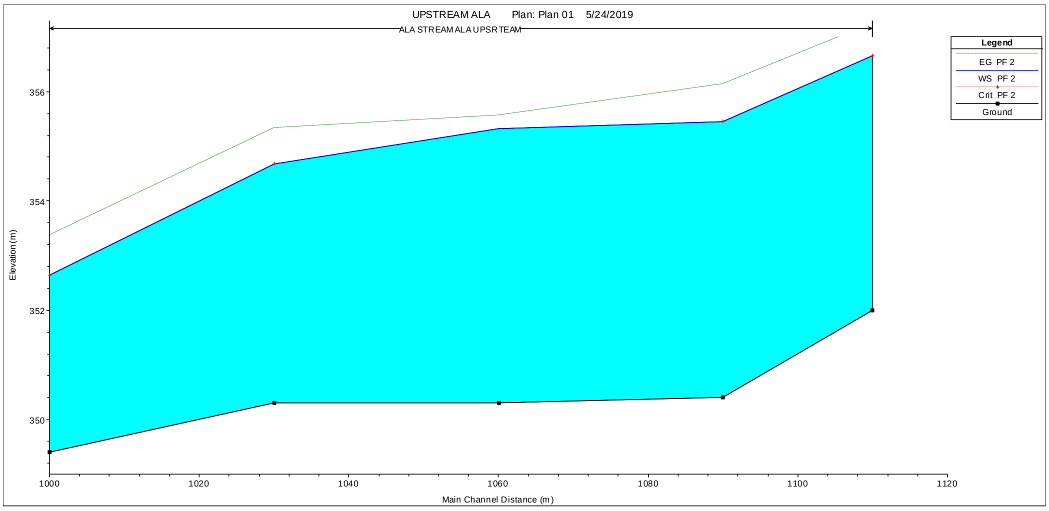

Figure 7: Longitudinal section of stream from 110 m from outlet (100-years return period flood)

DISCUSSION

The *CN* extracted from the SCS-runoff CN table and initial abstraction value is 70.27 and 21.49 respectively. This based on LC and LU classification. In flood mapping, extreme rainfall conditions are used to generate direct runoffs. The 25 and 100 years return period rainfall of 24 hours duration peak discharge was inputted into HEC-RAS model. In delineating floodplains,100 years return period rainfall for 24 hours duration is used. Hydraulic structures are designed with peak discharges of 25 years return period storm. Peak discharges for both 25-year and 100-year return period are 142.3 m/s^3 and 229.8 m/s^3 respectively

The rating curve elevation-discharge values are compared with simulated discharges and elevation values from both HEC-HMS and HEC-RAS to select optimal manning's value for channel flow and floodplain. The manning's value of 0.35 and 0.55 were chosen for channel and floodplains respectively.

The stream's reach of 110 m from the watershed's outlet was used in simulation of flood sections. Maximum flood height for 25 and 100 years return period flood was simulated as 4.46

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m and 5.02 m respectively. The maximum offset from stream bank for 25 and 100 years return period flood was simulated as 31.07 m and 37.25 m respectively.

CONCLUSION

HEC-HMS and HEC-RAS models were combined to generate peak discharges and flood water sections at the lowlands of an upstream watershed. CN and initial abstraction value for the HEC-HMS based soil type and LU and LC classification are was 70.27 and 21.49. The LU and LC were classified as for built up area, for vegetation area and for rock outcrop. Peak discharges for 25 and 100 years return period flood are and respectively. Maximum flood height for 25 and 100 years return period flood was simulated as 4.46 m and 5.02 m respectively. The maximum offset from stream bank for 25 and 100 years return period flood was simulated as 31.07 m and 37.25 m respectively.

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