ASSESSMENT AND ANALYSIS OF FLOOD VULNERABILITY IN ABIA STATE USING TUFLOW AND HEC-RAS

Abstract- *This study aimed at Assessing and analyzing flood vulnerable areas in Abia State using HecRAS and Tuflow***.** *The methodology involved acquisition of Sentinel-2 imagery covering Abia State, Rainfall data and ALOS PALSAR. Image subsetting was done to extract the area of study from the acquired dataset; this was followed by analysis of DEM accuracy using root mean square error, image classification to extract the landuse/landcover of the study area, surface runoff modelling to determine surface runoff potential in the study area and flood modelling. The flood frequency return as modeled by HecRAS revealed a 25.43km^2 inundation extent in a 2-year return period, 28.09km^2 inundation extent for a 5-year period and 26.67km^2 inundation extent for a 10-year return period, increasing to its peak extent by 3.15% by the 5-year return period, then decreasing by 1.8% by the 10-year return period. The flood frequency return as modeled by TUFLOW also revealed a 24.97km^2 inundation extent for 2-year return period, 27.87km^2 inundation extent for a 5-year period and 26.10km^2 inundation extent for a 10-year return period, increasing to its peak extent by 3.67% by the 5-year return period, then decreased by 2.24% by the 10-year return period. The surface runoff potential revealed that 35.99% with an area of 1630.19 km^2 had low infiltration potential, 32.51% with an area of 1472.56 km^2 had moderate infiltration while 31.50% with an area of 1426.82 km^2 had high infiltration. This indicated that a large portion of the study area has a high potential of low surface infiltration which will lead to flooding during rainfalls. The modelled zones points were compared to flood points obtained from ground using correlation analysis and the results revealed that HecRAS modelled result obtained a coefficient of 0.8411 and standard error of 0.44 against the ground flood points, TUFLOW modelled result obtained a coefficient of 0.8296 and standard error of 0.46 against the ground flood points while flood modeler modelled result obtained a coefficient of 0.8296 and standard error of 0.46 against the ground flood points. These results indicated that HecRAS came out on top as having the best fit to the ground flood points*.

Keywords-Flood Vulnerability, HecRAS, Tuflow, Sentinel-2, Surface Runoff

1.0 Introduction.

Flood Management is currently a key focus of many national and international research programmes with flooding from rivers, estuaries and the sea posing a serious threat to millions of people around the world during a period of extreme climate variability (Drogue et al, 2004, Wadsworth, 1999, Wang 1999 and Dilley et al 2005). Floods are among the most devastating natural disasters (Förster *et al*., 2020), and Abia State of Nigeria is no exception to city and county that experienced flooding in recent time. This state has suffered losses due to flood problem arising from the dramatic river flow (Moses, O.and Ikechukwu, E.O (2016), topography (Chidi E. O, Felix I, and Virginia U. O. (2015), and sediment which is prone to spread (Nwilo, 2012). In 2021, worst experience of this intermittent and frequent flood occurred with great impact on the people and submerged a two storey building and still spreading (Abia News November 16, 2021). However, it is important to note that, to effectively manage any disaster, a good knowledge of the root cause(s) and impact of the disaster are necessary. The studies of Bariweni et *al*, (2012) and Dupe et *al*, (2013),) have modelled flooding in Abia State but the situation remains the same, reduction of the risk of flooding will depend largely on the amount of information on the flood models that is available and the knowledge of the areas that are likely to be affected during a flood event (Hoey and Ferguson 1994). Therefore, it is necessary to use modern day technique in developing measures that will help relevant authorities and relief agencies in the identification of flood prone areas and in planning against flooding events in the future. Determining the flood prone area is important for effective flood mitigations and to this effect, this study aimed at assessing and analyzing flood vulnerability in Abia State using

HecRAS and Tuflow, so that planners can have an accurate data necessary for planning and managing flooding in Abia State Nigeria.

2. Materials and Methods

2.1 Study area

Abia is a state in the south eastern part of Nigeria located between latitude 50 00'N and 60 00'N and longitude 70 00'E and 80 00'E of the equator see figure 1.0. It occupies about 6,320 square kilometers and bounded on the north by Enugu, west by Imo State, east by Akwa Ibom and to the south by Rivers State. The southern part of the State lies within the riverine part of Nigeria, which is a low-lying rainforest. The southern portion gets heavy rainfall of about 2,400 millimeters (94 in) per year especially intense between the months of April through October. The rest of the State is moderately high plain and wooded savanna and the most important rivers are the Imo and Aba Rivers which flow into the Atlantic Ocean through Akwa Ibom State.

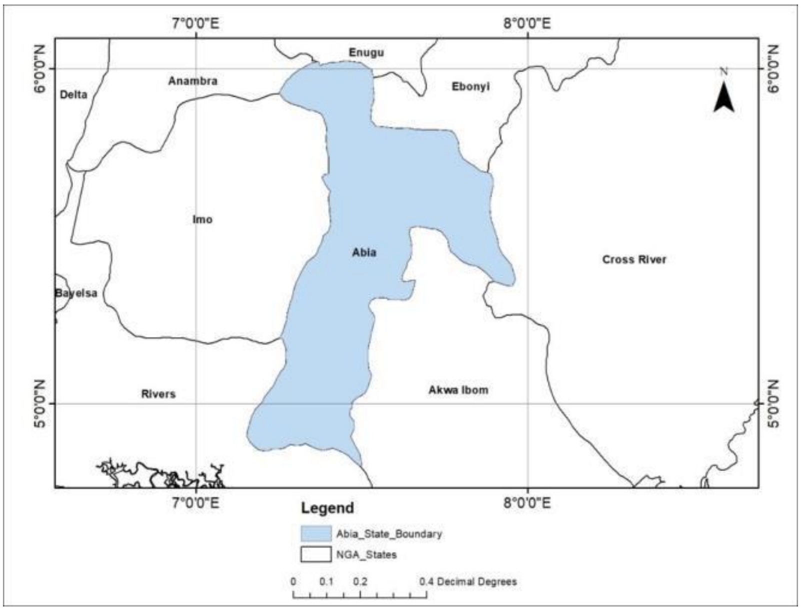


Figure 2.1: Location Map of the study area.

2.2 Methodology

This study utilized Sentinel-2 and ALOS PALSAR imageries of the study which were downloaded from the USGS website using the Earth explorer as the primary data. Digital administrative maps of Nigeria, Abia State which was sourced from the Department of Surveying and Geoinformatics, Nnamdi Azikiwe University Awka. Rainfall and soil data were gotten from NIMET Agency as the secondary data.

3.0 Results

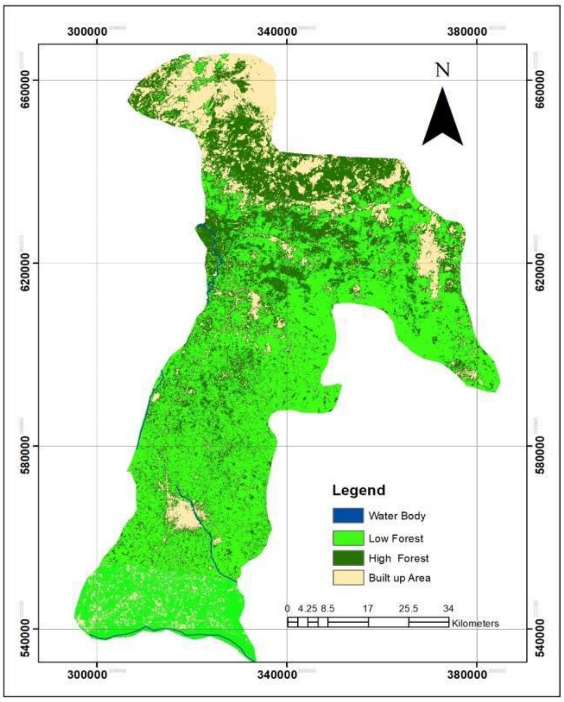
3.1 Analysis of DEM Accuracy

Before the ALOS PALSAR DEM could be used in flood modelling, it had to be validated first using ground control points. The elevation points obtained from the ALOS PALSAR DEM were compared with the elevation points picked from ground to obtain the horizontal and vertical accuracy of ALOS PALSAR using root mean square error. This returned vertical and horizontal accuracies of 5.64m and 14.39m respectively indicating that ALOS PALSAR was a good fit and represents the elevation values on ground.

3.2 Land Use Land Cover and Surface Runoff Modelling.

Abia State shape file was used to subset the area of study from Sentinel 2 imagery and the resulting image was classified using supervised classification in order to obtain its LULC. The landcover/landuse distribution (figure 3.1) indicated that grassland, accounted for the largest land cover/use of about 52.06% and an area of about 2459.28 km2. Urban area had 23.21% and a coverage area of 1096.41 km2, forest had 18.36% with an area of 867.44 km2 and water body had the lowest turnout with 6.35% with an area of 300.32 km2. The precision of the classified images was ascertained and accuracy assessment was carried out by comparing the classified Landsat image with known reference pixels. The overall classification accuracy gotten was 89.23% and the overall kappa was 0.8935.

The landcover/landuse map, rainfall data and soil map were used to model the surface runoff potential in Abia state. The landcover/landuse map, soil map and rainfall data were then used to derive the curve number map, the curve number being the one of the major governing factors that predominantly affect the runoff amount that flows over the land after satisfying all losses plays an important role in defining hydrological response of catchment. The surface runoff potential (figure 3.2) revealed that 35.99% of the study area with an area coverage of 1630.19 km2 had low infiltration potential, 32.51% with an area of 1472.56 km2 had moderate infiltration while 31.50% with an area of 1426.82 km2 had high infiltration. This indicated that the study area had a large extent of low surface infiltration which will lead to flooding during rainfalls.



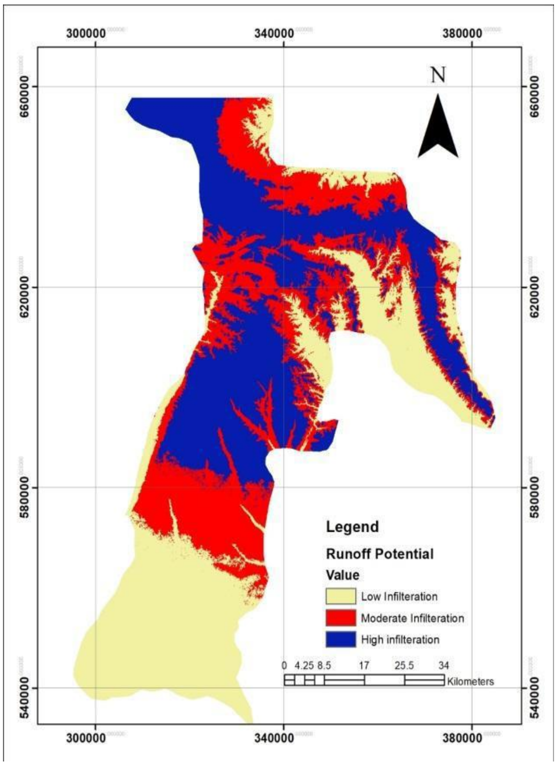


Figure 3.2: Landcover/landuse map

Figure 3.3: Surface runoff potential

3.3 Flood Frequency Analysis

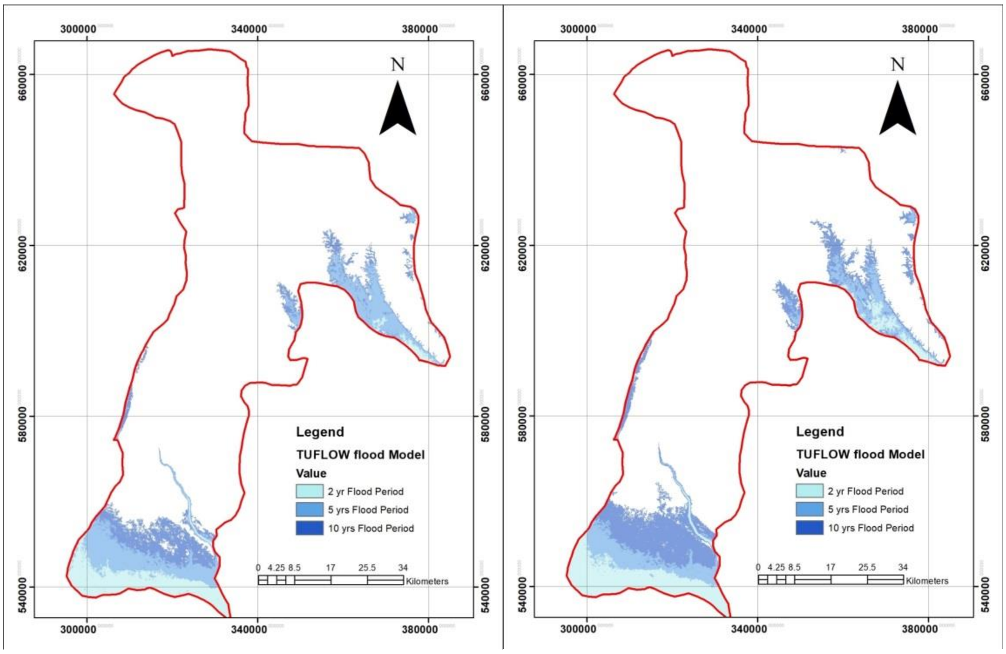
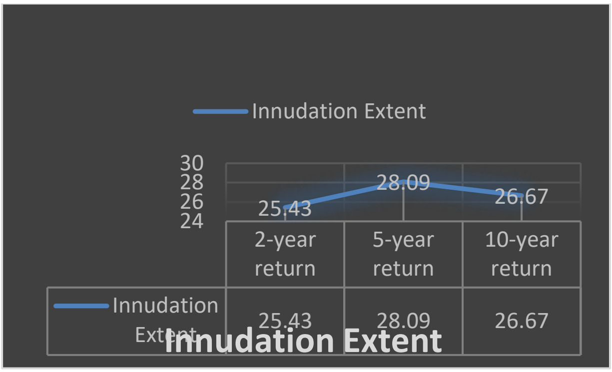


Figure 3.4: Flood frequency as modeled by HecRAS   Figure 3.5: Flood frequency as modeled by Tuflow

The results from the HecRAS model (fig 3.6), indicated that the inundation extents for a 10-year return period were given as 25.43km^2 inundation extent for 2-year return period, 28.09km^2 inundation extent for a 5-year period and 26.67km^2 inundation extent for a 10-year return period. The flood extent as modeled by HecRAS increased by the fifth-year return period by 3.15%, then decreased by 1.8% by the tenth-year return period, the peak inundation extent was reached at the 5-year return period. This is illustrated in table 3.1 while *t*he results from TUFLOW model (fig 3.7), indicated that the inundation extents for a 10-year return period were given as 24.97km^2 inundation extent for 2-year return period, 27.87km^2 inundation extent for a 5-year period and 26.10km^2 inundation extent for a 10-year return period. The flood extent as modeled by TUFLOW increased by the fifth-year return period by 3.67%, then decreased by 2.24% by the tenth-year return period and the peak inundation extent was also reached at the 5-year return period This is illustrated in table 4.7.

Table 3.1: HecRas and Tuflow model flood frequency

	HecRas		Tuflow	
Period	Extent (Km^2)	Percentage	Extent (Km^2)	Percentage
2-year return period	25.43	32.18%	24.97	31.63%
5-year return period	28.09	35.55%	27.87	35.30%
10-year return period	26.67	33.75%	26.10	33.06%
Total	80.19	100	78.94	100%



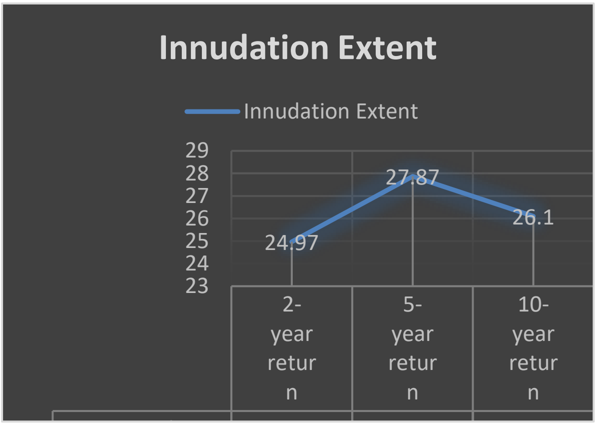


Figure 3.6: Graph showing Hec-RAS modeled flood extent for 2yr, 5yr, 10yr returns.

Figure 3.7: Graph showing Tuflow modeled flood extent for 2yr, 5yr, 10yr returns.

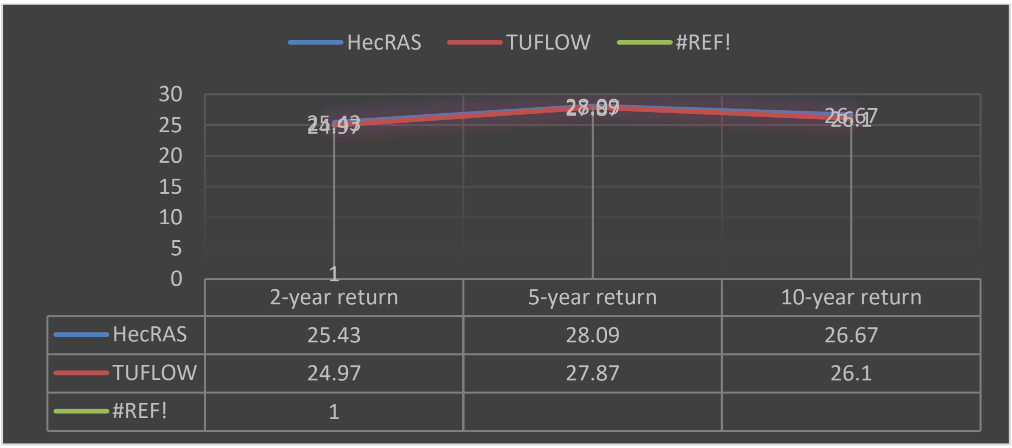


Figure 3.8: Summary of Flood Frequencies as modelled by HecRas and Flood Tuflow

4.5 Flood Vulnerability Mapping

The results of the vulnerability modelling with Hec-RAS and TUFLOW produced a layer showing four vulnerable very high risk flood zones in the study area. The results obtained from the Hec-RAS modelled vulnerability revealed very high-risk zone occupied 9.77% of the entire study area, covering an area of 442.59km^{2}and the TUFLOW modelled vulnerability revealed that very high-risk zone occupied 9.72% of the entire study area, covering an area of 440.59km$^{2.}$ This distribution is also represented in table 3.2

Table 3.2 Flood vulnerability distribution

S/N	HecRAS	Area (km^2)	%	TUFLOW	Area (km^2)	%
1	Very High Risk	442.59	9.77	Very High Risk	440.59	9.72
2	High Risk	1272.00	28.08	High Risk	1250.03	27.59
3	Moderate Risk	1491.58	32.92	Moderate Risk	1495.58	33.02
4	Low Risk	1323.42	29.21	Low Risk	1343.39	29.65
	Total	4529.59	100	Total	4529.59	100

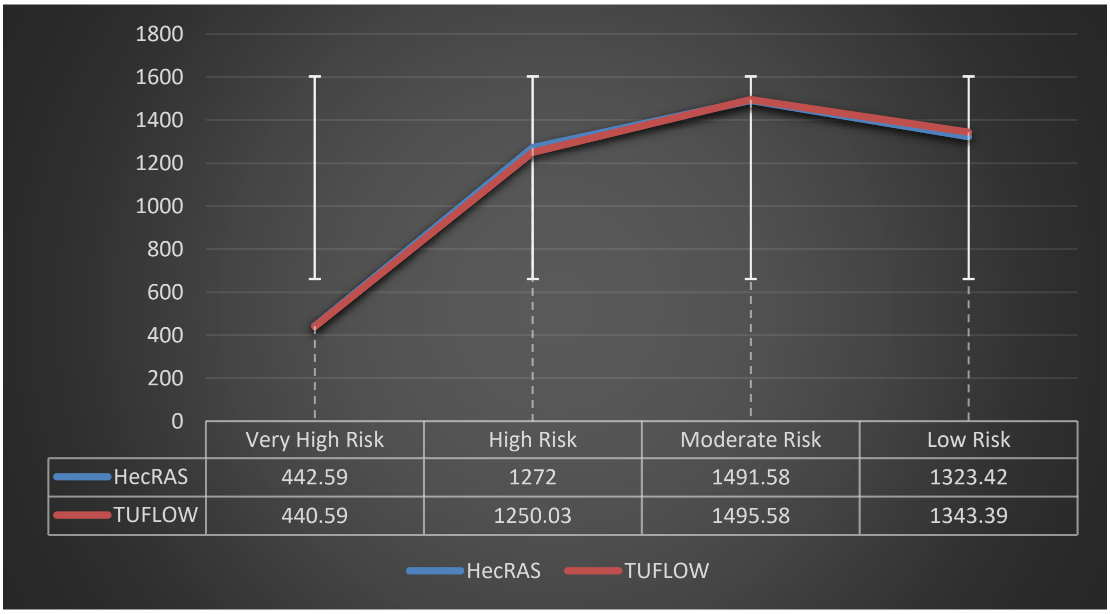


Fig 3.9 Histogram of flood vulnerability distribution from HecRAS and TUFLOW

4.6 Ground Validation of HecRAS and TUFLOW results

In order to determine the best fit model for flood modelling in the study area, ground validation is needed to determine the reliability and accuracy of the flood modeling results of HecRAS and TUFLOW. The modelled zones points were compared to flood points obtained from ground and these sample points were coded and compared using correlation coefficient. The results are illustrated in figure 3.10 and 3.11.

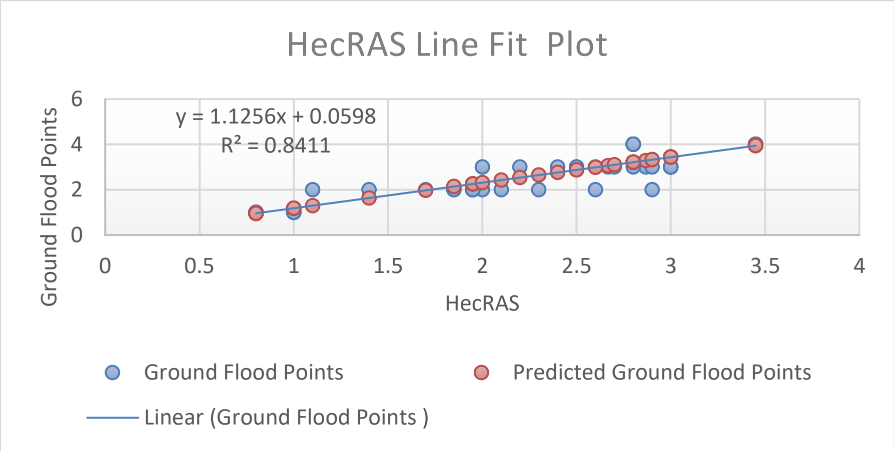


Figure 3.10: Line fit plot of HecRAS modelled result against ground flood points

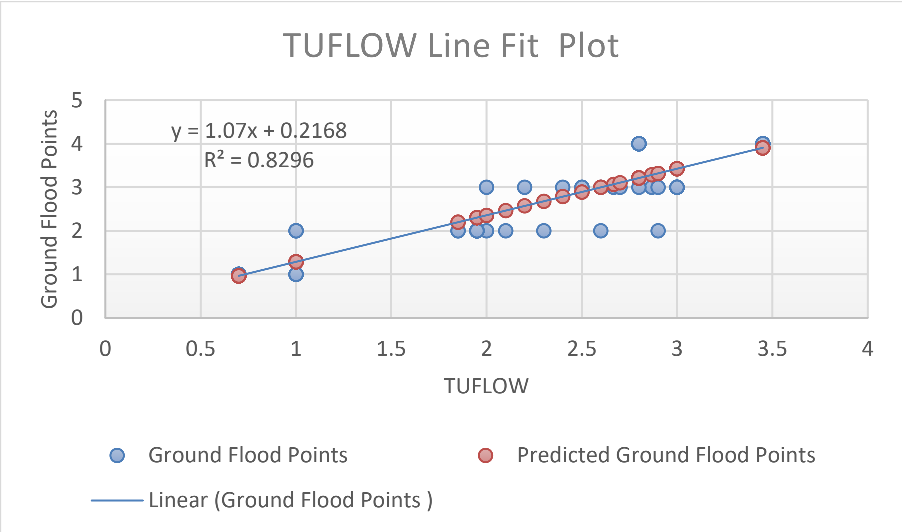


Figure 3.11: Line fit plot of Tuflow modelled result against ground flood points

4.0 Conclusion

Flooding in terms of its frequency and distribution river flooding remains as a frequent disaster that has to be faced by civilization in flood plain. The study was able to determine the flood frequency return as modeled by HecRAS to be a 25.43km^2 inundation extent in a 2-year return period, 28.09km^2 inundation extent for a 5-year period and 26.67km^2 inundation extent for a 10-year return period, increasing to its peak extent by 3.15% by the 5-year return period, then decreasing by 1.8% by the 10-year return period. The flood frequency return as modeled by TUFLOW also revealed a 24.97km^2 inundation extent for 2-year return period, 27.87km^2 inundation extent for a 5-year period and 26.10km^2 inundation extent for a 10-year return period, increasing to its peak extent by 3.67% by the 5-year return period, then decreased by 2.24% by the 10-year return period. The surface runoff potential revealed that 35.99% with an area of 1630.19 km^2 had low infiltration potential, 32.51% with an area of 1472.56 km^2 had moderate infiltration while 31.50% with an area of 1426.82 km^2 had high infiltration. This indicated that a large portion of the study area has a high potential of low surface infiltration which will lead to flooding during rainfalls. The modelled zones points were compared to flood points obtained from ground using correlation analysis and the results revealed that HecRAS modelled result obtained a coefficient of 0.8411 and standard error of 0.44 against the ground flood points, TUFLOW modelled result obtained a coefficient of 0.8296 and standard error of 0.46 against the ground flood points These results indicated that HecRAS came out on top as having the best fit to the ground flood points.

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