surface profiles are computed from one cross section to the next by solving the energy equation with an interactive procedure called the standard step method

Capability of modelling common types of hydraulic control structures with appropriate on and off features and having a GUI with pre and post-processing are strengths of this model, but HECRAS have some limitations such as it cannot simulate water quality processes and relatively difficult to use in conjunction with other water quality models. Likewise another limitation is that it cannot simulate groundwater levels. The basic data requirements for simulation are included: geometric data, study limit determination, river system schematic, cross section geometry, ineffective flow areas, reach lengths, energy loss coefficients, Manning’s n, Equivalent Roughness‘k’, contraction and expansion coefficients, steady flow data, boundary condition, flow regime. In this study the results that HEC-geo RAS extracted from TIN in ArcView, import to the HEC-RAS model for simulation. Then some additional required data that HEC-RAS needs for running, like steady flow data, boundary condition, Manning’s n and contraction and expansion coefficients must be imported. Selection of a suitable value for Manning’s n is very significant to the accuracy of the computed water surface profiles.

There are several references that can access Manning’s n value for typical channel. In this study applied slide source that agreed with Chow’s tables was used. Boundary conditions are another part of model that must be completed. Boundary conditions are necessary to establish the starting water surface at the ends of the river system. A starting water surface is necessary in order for the program to begin the calculations. In a sub critical flow regime, boundary conditions are only required at the downstream ends of the river system. If a supercritical flow regime is going to be calculated, boundary conditions are only necessary at the upstream ends of the river system. If a mixed flow regime calculation is going to be made, then boundary conditions must be entered at all open ends of the river system. One of the HEC-RAS capabilities is providing user cross section interpolation in some part that is necessary that have been used in this modelling. Ultimately after completing all

Results and Discussion

The River Geometry of the Study Area

The river geometry was drawn on a reach-by-reach basis using the Arc map tools and the Hec geo Ras extension. River reaches were drawn upstream to downstream in a positive flow direction using multi segmented lines. Each reach is identified by a river name (i.e. stream name) and reach name Figure 3 represent the channel geometry of River Niger as imported from GIS to HEC-RAS.

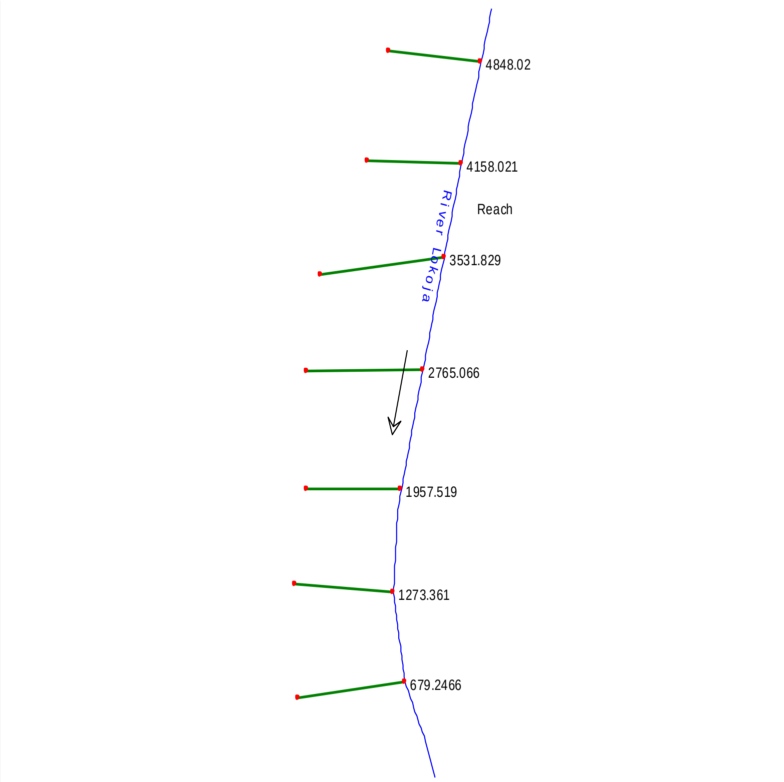


Figure 3: The river geometry imported from GIS to HEC-RAS

Following the modelling of the river geometry imported into HEC-RAS, the mean cross section for the flooded month and non-flooded month is shown in Figure 4. It represent River Niger in the month of august, September, October and November One of the most important results of HEC-RAS simulation is preparing different water surface profiles of different-year floods. It can be observed in Figure 4(a) and 5(d) that the mean water level did not exceed the bank station, hence it will be concluded that the River Niger is effectively contained in the non-flooded month and there was no indication of flooding in the in the month of August and November of the study area. The lower region was also characterized by severe water discoloration, foul doors, and an abnormally high mosquito population. Previous research by (Sangodoyin 1996, 2002) had identified this region as the most vulnerable to flooding, and HEC-RAS modelling performed during this study confirmed the finding.

Figure 4 presents the differences between cross section profiles of flooded and non-flooded months of River Niger in 2015. Where: (a) is mean profile for the month of August; (b) is mean profile for the month of September; (c) is mean profile for the month of October; and (d) mean profile for the month of November. It is obvious that in the flooded months, water September (b) and October (c) respectively, water overflows its boundary. In a similar manner for better comparison, Figure 5 is the simulated water elevation from HEC-RAS for the flooded and non-flooded months, The highest water elevations was measured in these months with the highest stream flow (i.e. the higher the stream flow, the higher the water elevation), as the flow of water increases, the elevation of water also increases as shown in Figure 5 (a) and (d). The HEC-RAS model has been able to identify those particular sections of the River Niger course that are susceptible to high water elevation levels which are significant indicators to flooding events (Adewale, 2010). Areas around the flood plain were inundated due to encroachment into flood plains.

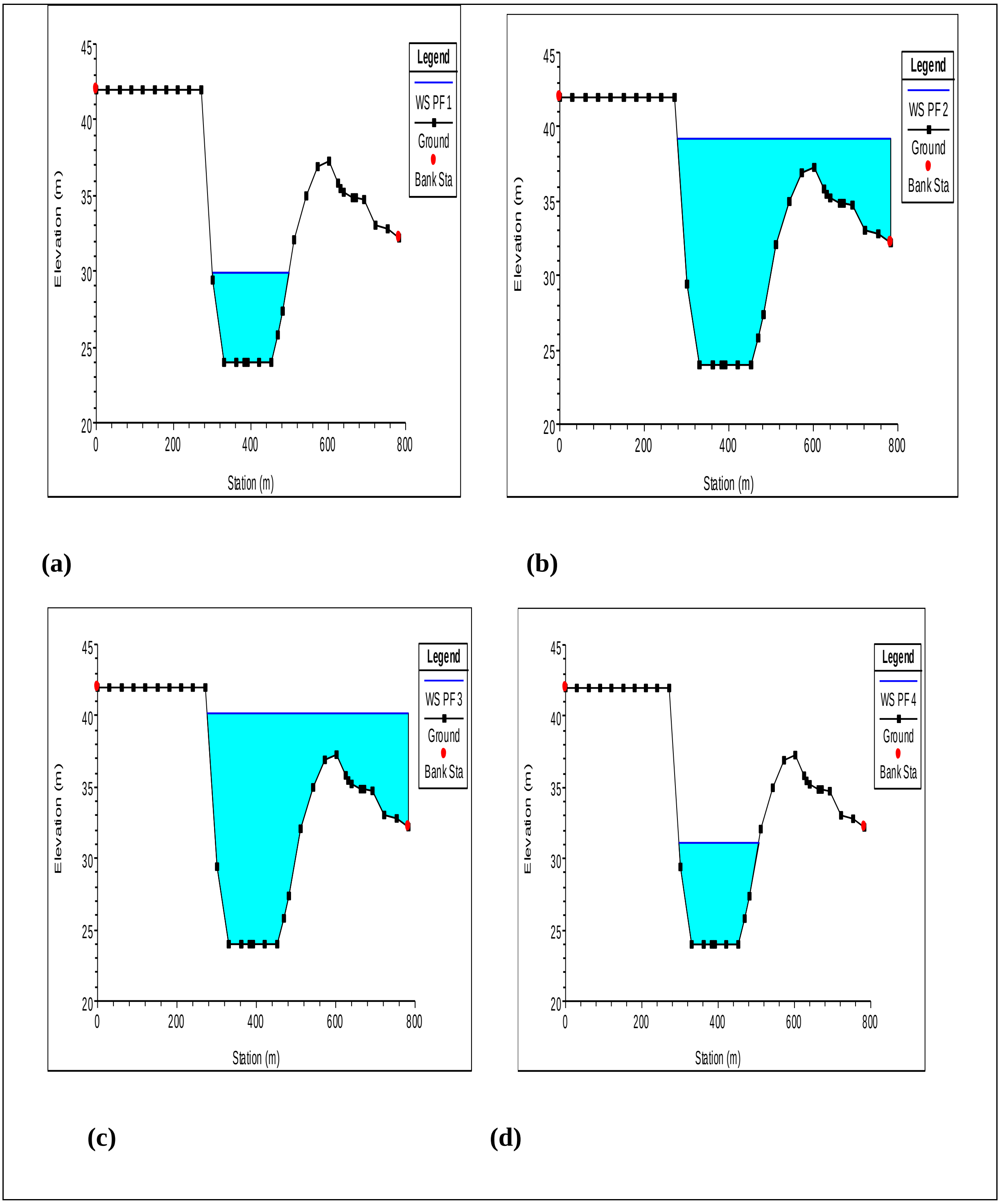
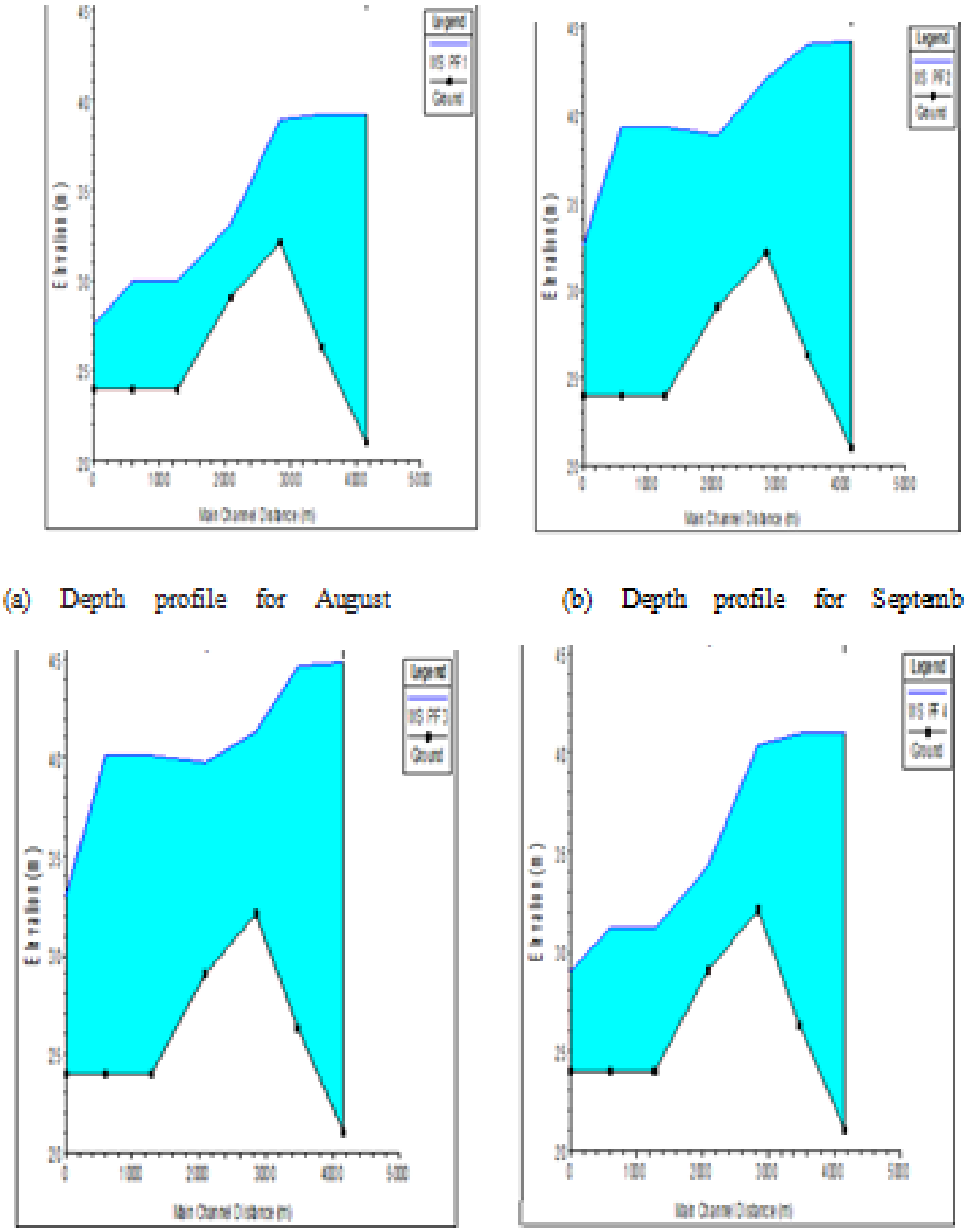


Figure 4: Differences between cross section profiles of flooded and non-flooded months of River Niger in 2015. (a) mean profile for the month of August, (b) mean profile for the month of September, (c) mean profile for the month of October, (d) mean profile for the month of November.



(a) Depth profile for August

(b) Depth profile for September,

(c) Depth profile for October

(d) Depth profile for November.

Figure 5: Same as Figure 4 but for depth profiles of the respective months..

Figure 6 was obtained from HEC-RAS simulations and it depicts the extent and depth of inundation occurred during the flood of 2015. The depth of flood waters obtained ranges from 0.00455856m to 35.1279m and thus generates the water depths as a raster data. Figure 6 reveal the highest water depth recorded is also 35.1m. It also reveals the intensity of risk to which Lokoja is exposed to. The exposure of the area to a higher magnitude flood event is amplified with higher number of critical facilities getting affected by flood waters

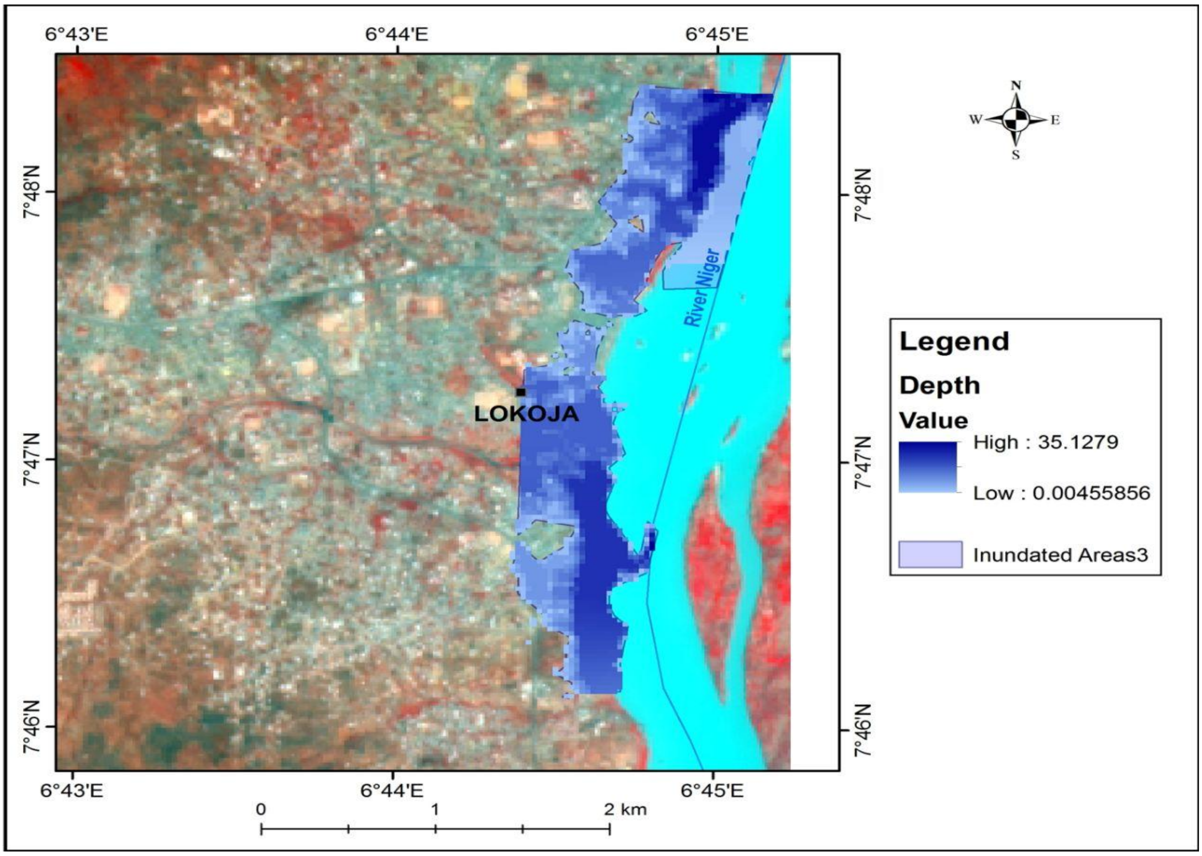


Figure 6: Depth of the flood waters from HEC RAS simulation of Lokoja

Validation of HEC-RAS Output by the Observed Data

The simulated output was validated by comparing the simulation output with the observed data of 2015 flood event from the National Waterways Authority (NIWA) Lokoja. NIWA observed that the inundation depth of River Niger as at the time of the flood event was 37m. The inundation depth level obtained through HEC-RAS simulation of the flooded month was 35m. The difference in the estimation (which is less by 2m) of the inundation depth level by HEC-RAS simulation could be attributed to the usage of Land use and Digital Elevation Model (DEM) data in the model. As the results yielded by the HEC-RAS model were very close to the observed data of 2015 flood, the model can be scientifically believed as valid to perform assessment of flood event for the study area. The model results indicated that most of the areas inundated in Lokoja were along the flood plain which is true with the observed data.

Assessment of Flood Extent in the Study Area

The infrastructure failure of any area is estimated from the potential vulnerability of its critical facilities in the face of a hazard. Hospitals, schools, waste water treatment and potable water plants, hazardous plants, transportation utilities such as airport, railroad, and bus stations are identified as critical facilities by (Odeh, 2002). Potential impact on these key facilities, which play a critical role in the functioning of the state capital, can paralyze the functionality of the area. The assessment is conducted by overlaying the street map and facilities of the study area on the extent and depth of inundation (HEC-RAS simulation results) occurred during the flood of 2015. The information analysed helps to determine or prioritize the mitigation measures that can make the area more disaster-resistant. The results presented in figure 7 shows that the study area is extremely exposed to flooding risk.as shown in Figure 7 On the issue of flooding, it becomes obvious in this study that newly developed areas along the Niger River are flood prone as indicated in the Figure below. Also it is clear that new development activities are growing along the river banks that are threat to flooding. The incidence of floods in the study area is caused by a combination of natural and human induced activities along the floodplains. Lokoja happens to be the confluence of the two largest rivers in Nigeria; Rivers Niger and Benue. The size and importance of these rivers coupled with increasingly growing human activities. The results indicated that the developed methodology was efficient in modelling and visualizing the spatial extent of different month's scenarios and in determining flooded areas at risk. It was found that changes in water elevations of the River Niger made the downstream areas more at risk.

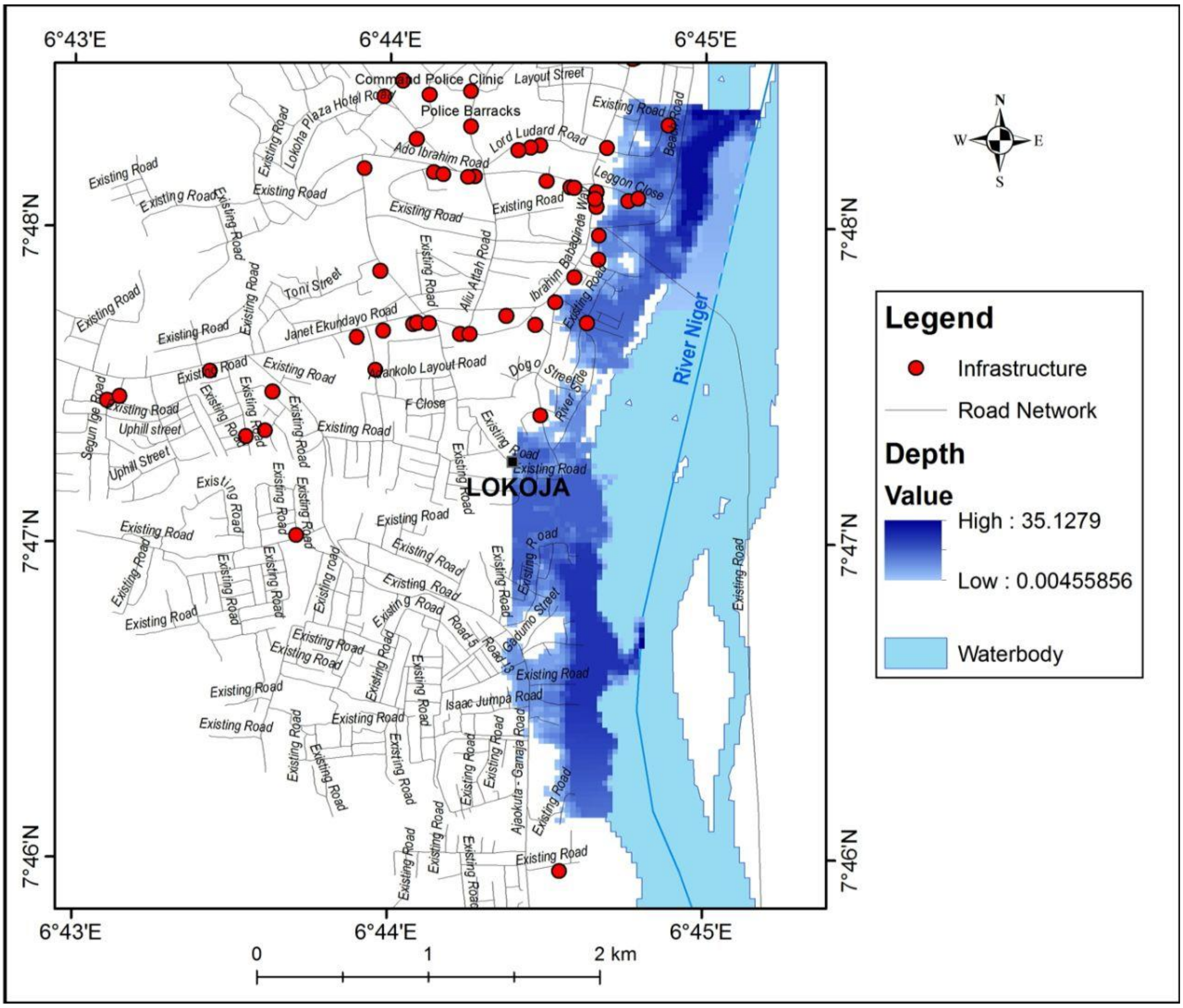


Figure 7: The Key Facilities of the Study Area Overlaid on the Inundation depth.

Conclusion

This research focused on integrating GIS tools to Hydraulic analysis. These tools could reasonably separate high hazard from low-hazard areas in the floodplain to minimize future flood losses this study presents a systematic approach in identifying flood hazard and subsequently in assessing the inundation of the area by the integration of hydrological models with GIS. The combination of Arc GIS and HEC-RAS 1-D flood simulation model indicate the capability of simulating flood events and spatially depicting the degree of exposure of the area towards a hazard event in terms of inundation extent and depth of water levels. The model can be said to have generated reliable quantified output. This hybrid approach provides quantified information on the water level depths and facilitates to access the data at any point of interest, the visualization and the quantification of the flood risks, as facilitated by this approach, can generate invaluable information and assist the decision making authorities to make informed choices towards mitigating the catastrophic effects of flooding disaster.

The assessment from the 2015 flood event simulated by HEC-RAS model reveals the intensity of risk Lokoja was exposed to. The exposure of the area to a higher magnitude flood event is amplified with higher number of critical facilities getting affected by flood waters The catastrophic effects of flooding disaster can be mitigated by integrating scientifically reliable information obtained from a risk assessment studies developed using this hybrid approach. The study highlights the need for flood control and mitigation strategies in the low areas.

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