# Evaluation of Drainage System in Part of Lokoja Town in Kogi State, Nigeria

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***Abstract***
*Several cities and towns in Nigeria are faced with flooding problems emanating from the effects of climate change, urbanization and population growth. This challenge is more critical in some parts of Lokoja Kogi state, given the recent flooding scenarios witnessed in parts of the city. The floods that occurred during these periods were occasioned by high rainfall intensity coupled with inadequate drainage system. This study used the Rational Method (RM) for peak flow analysis to estimate the peak flow of the study area. To achieve this, the study area was divided into five catchments 'A', 'B', 'C', 'D' and 'E' respectively with their subsequent peak flows analyzed using rational method of storm design. The results obtained shows that the highest peak flow rate of 4.32 $m^3$/s occurred at catchment "C" with area of 206.24 ha. Catchments 'B', 'D' and 'E' had flow rates 3.20 $m^3$/s, 2.85 $m^3$/s, 3.13 $m^3$/s, respectively. Besides, the failure of drainage at shed 'C' was grossly due to inadequate size of the drains. The obtained peak flow rate of 4.32 $m^3$/s is higher in comparison to the existing drainage capacity of 2.105 $m^3$/s of geometry of 1.2 m width and depth of 1m. Hence this could be the possible factor responsible for the perennial flooding given that the peak flow is quite higher than the designed capacity. The failure of the drainage at catchment 'C' was grossly due to inadequate size of catchment 'B', 'D' and 'E'*

**Key words:** *flooding, climate change, peak flow, urbanization, catchment*

## Introduction

Drainage systems are constructed to ensure that waste water and sewage is transported neatly to disposal points, thereby keeping the environment well drained and free of waste. The following examples make up a good drainage system; drainage pipes, closed ditches having pipe drains, channels and conduits. Nigerian coastal cities are daily inundated with flood waters, and millions of properties have been destroyed and lives lost (Eze, 2008). Poor drainage systems are often associated with street flooding, and this has become critical environmental problems in coastal cities of Nigeria such as Lagos, Port Harcourt, Ondo, Warri, Uyo, and Calabar (Eze, 2008). These towns which are quite close to the Atlantic Ocean experience heavy flooding especially during the rainy season. However, it is not waters from the Ocean that usually floods these cities but the heavy rains, and the low nature of the topography and the poor drainage networks. Aderamo (2008) listed land use problems, increased paved surfaces, river channel encroachments, poor waste disposal techniques, physical development control problems, gaps in basic hydrological data and cultural problems as major causes of street flooding in Nigerian cities.

The assessment of drainage facilities in part of Lokoja Township is required because of expanding populace, particularly in urban areas, where the population now surpasses that of the rural communities (Alabi, 2012). With the extra issues that a changing climate brings, there is obviously going to be water management issues with expanding pressure on the different urban areas. This has been credited to both the climate and demographic changes (Birkmann *et al*., 2010).

**Hydrological and Meteorological Characteristics**

The yearly precipitation in the range is between 1016 mm and 1524 mm with its mean yearly temperature not falling underneath $27^0$C ( Ifatimehin and Musa, 2008). The rainy season lasts from April to October when the dry season lasts from November to March. The land ascends from around 300 meters along the Niger-Benue confluence, to the heights of the vicinity of 300 and 600 meters over the ocean level in the uplands. Lokoja is drained by Niger and Benue waterways and their tributaries. The confluence of the Niger and Benue rivers which could be seen from the highest point of Mount Patti is situated inside the study area. The River Benue is traversable to the extent Garua in the rainy season floods, yet up to Makurdi in Benue State in the dry season (Suleiman, *et al*. 2014).

**Materials and Methods**

**Study Area**

The study area is located between latitude $7^o$45´27.56´´ and $7^o$51´04.34´´N and longitude $6^o$41´55.64´´ and $6^o$45´36.58´´E, within the lower Niger-Benue trough. The map of the study area is shown is fig 3.1. It has an estimated landmass of 63.82 sq. km. It shares boundaries with Niger, Kwara, Nassarawa states respectively and the Federal Capital Territory to the north; Benue state to the East; Adavi and Okehi Local Government Areas (LGAs) by the south and Kabba Bunu LGA. (Adeoye, 2012)

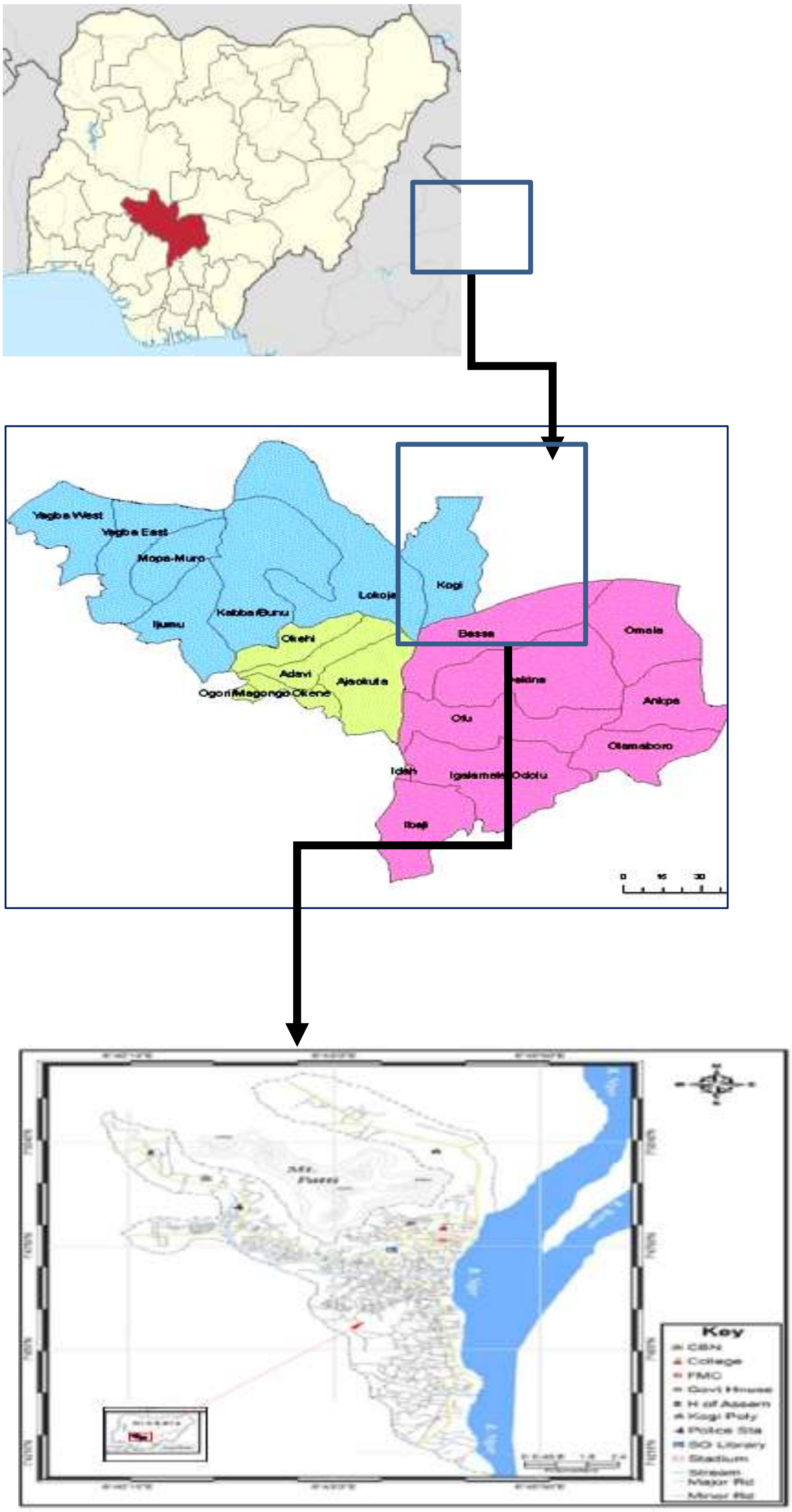


**Figure 1: Study area**

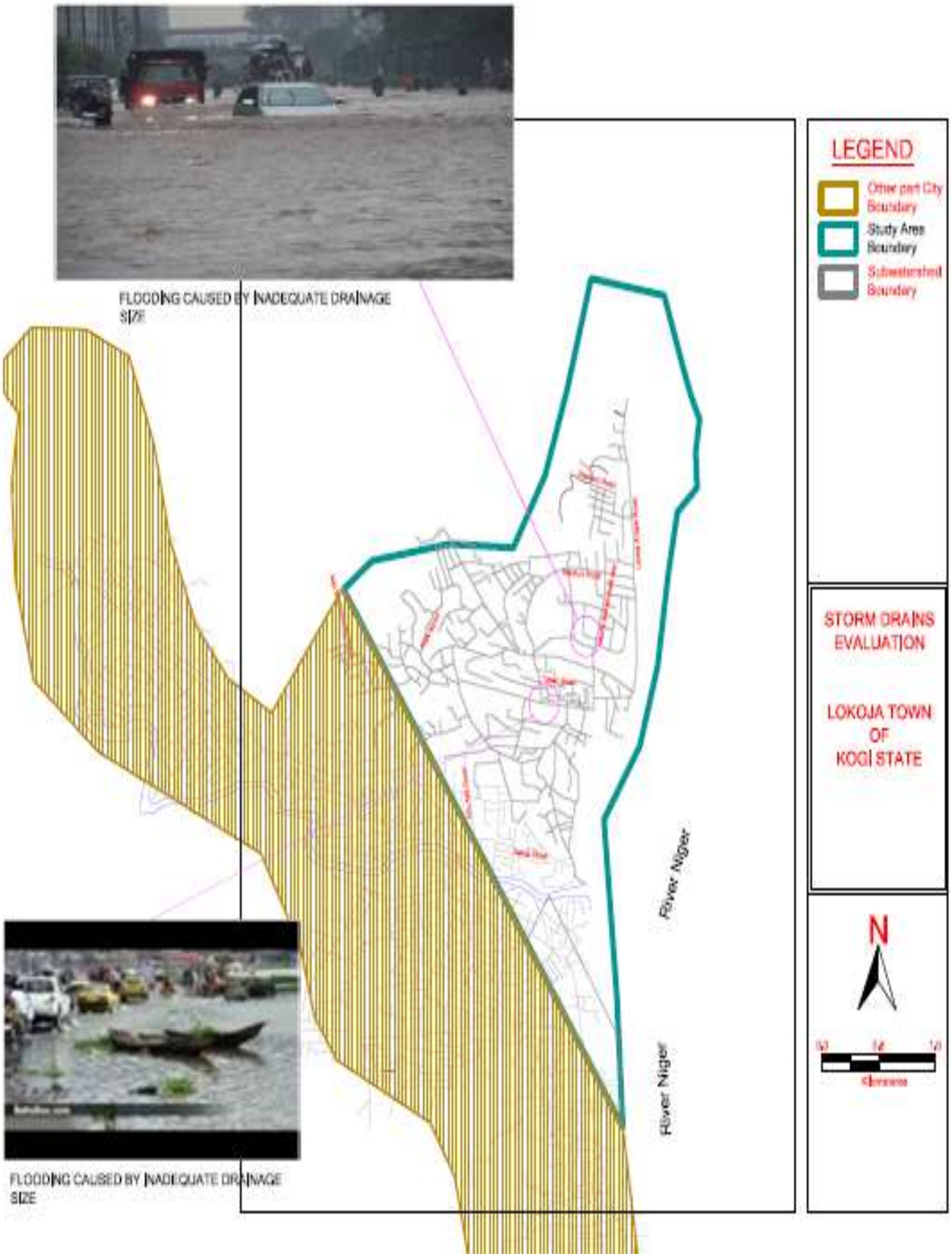


**Figure 2: Road network map of lokoja in Kogi state, Nigeria**
**Source: (Google earth and civil 3D)**

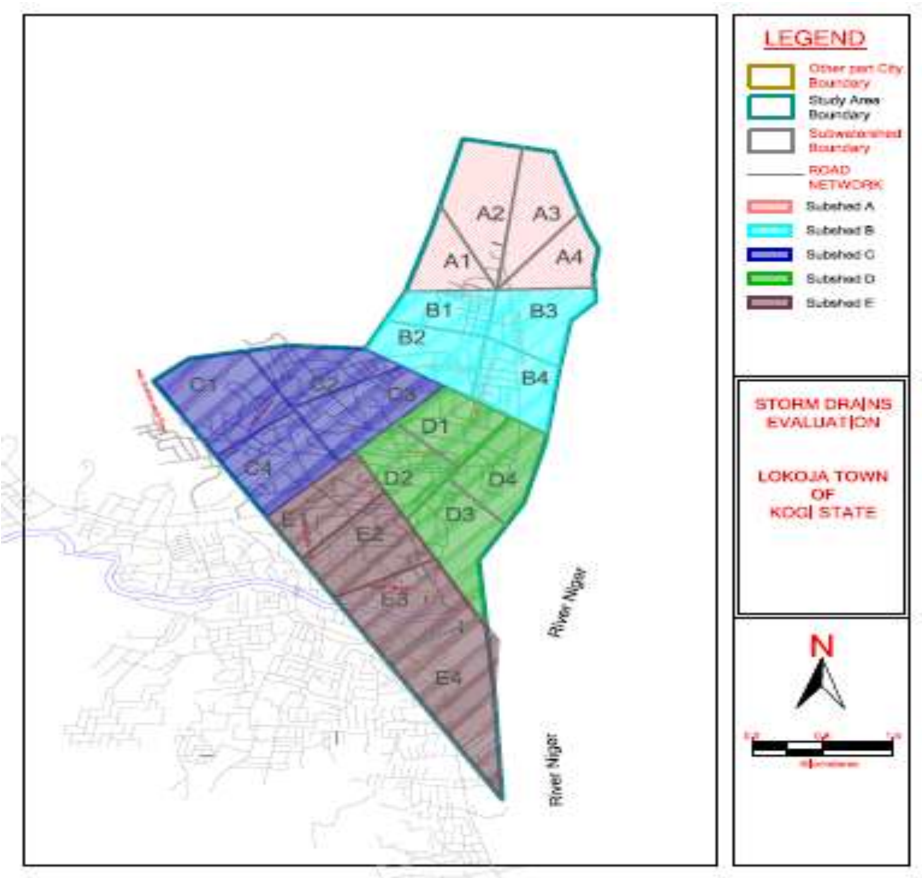


**Figure 3: study Area divided into Sub-catchments and road network**
**Source: (Google earth and Civil 3D)**

**Analysis of Sampled Catchment Areas**
**Rational Method**

The rational method assumes that: (Merit, 1976):

The methodology approach for the sequence of stages of activities to be carried out:

1 obtain map from google earth, with Civil 3D software, generate the contour of the study area lokoja, then trace out the existing road network of lokoja from the geo-referenced Google earth image in Civil 3D software as shown in Figure 2

2 Then divide each catchment into A, B, C, D and E, and later sub-divide these catchments in smaller catchment not greater than 80 hectare, i.e A1, A2, A3 and A4. This is shown in Figure 4 which also has colour code differentiating the various sub-catchments.

3 Physical measurement on study area was carried out to verify road width, drainages and their respective positions.

4 From the map in figure 4 it various land uses was determined, i.e densely populated areas, less densely populated areas, farm land etc.

5 Determine the areas of the sub-catchments, the slope, and the length of all the sub-catchment in figure 4

6 Apply the Kirpich's equation to determine the time of concentration and the modified Kirpich equation (new time of concentration equation) were used to compute (Tc ) With the time of concentration determined, the rainfall intensity using a return period of 5yrs specified for drainage design. The rational model and manning's equation were used to generate the peak flow runoff, maximum velocity and design discharge capacity of the drainage

Channels given as:

$$Q = CIA \tag{1}$$

where,
Q is the quantity of runoff in ($m^3$/s);
C is the coefficient of runoff;
I is the rainfall intensity in (mm/hr);
A is the tributary or catchment area in ($km^2$)

$$I = KTmtn_1 \tag{2}$$

where
K, m, and $n_1$ are parameters dependent on the regions as classified in table 1
T is the return period (yrs); and "t" is the rainfall duration in (hrs). If t<1, $n_1$ is replaced by $n_2$ and "I" is the Rainfall Intensity (mm/hr) the value of I is obtained from equation 2 and the corresponding parameters were obtained from Table 1, and the T which is the return period (years) of 5years is adopted for this thesis because Plate 2 gives details of return period for urban road design.

The value of "C" Coefficient of runoff was obtained from table 3 and the value "A" which is the area of sub-catchment was obtain by measuring the sub-catchment directly from figure 4 in squared metre. (Natsis, *et. al*. 2008)

$$\mathrm{Tc} = \frac{0.0194(L)0.77}{(S)^{0.5}} \tag{3}$$

$$\mathrm{Tc} = \frac{\mathrm{L}}{K(S)^{0.5}} \tag{4}$$

$$\mathrm{I} = \frac{\mathrm{L}}{(Tc)^{n}} \tag{5}$$

The appraisal of the existing drainage will be estimated by using equation 6 to estimate the capacity of existing drainage.
Manning equation:

$$\mathrm{Q}= \frac{1}{n}\ \mathrm{R}^{2/3}\ \mathrm{S}^{1/2}\ \mathrm{A} \tag{6}$$

Trapezoidal Channel flowing in open drain

$$\mathrm{R}= \frac{(\mathrm{T}-\mathrm{yz})\mathrm{y}}{T+2y\,(\sqrt{1+2^2-2})} \tag{7}$$

Rectangular Channel flowing in open drain

$$\mathrm{R}= \frac{\mathrm{by}}{b+2y} \quad \text{(Merit, 1976)} \tag{8}$$

**Results and Discussions**

**Appraising existing drains**

Figure 1 shows the typical road drainage network delineated from the area with highest peak flow to appraise the existing drainage network as shown in Figure 4.

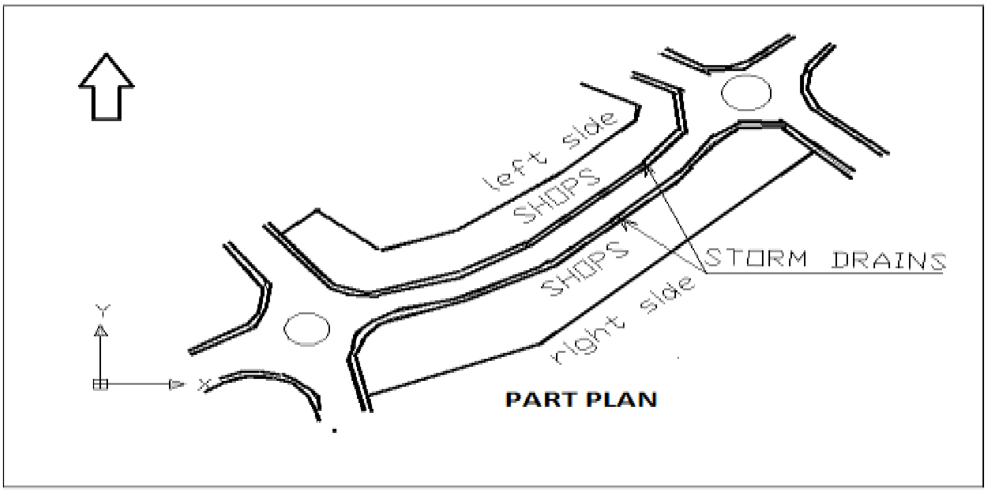


**Figure 4: Typical road network**

A rectangular channel with width 800 mm and a depth 800mm exist as shown in Figure 4 the carrying capacity of the channel is 1.5 $m^3/s$ as calculated in equation 9.

Existing drainage parameter:

Width of drainage = 800mm

Depth of drainage = 800mm

n = 0.009

S = 2.7

Manning equation from equation 6

$$Q = \frac{1}{n} R^{2/3} S^{1/2} A = 1.66 \; m^3/s \quad \text{and } V = 2.39 m/s \tag{9}$$

The peak flow capacity of the existing capacity of drainage Qc is 1.53$m^3/s$ lesser than the 1.66$m^3/s$, of the peak flow from the catchment C1.

**Plate I: flooded area of catchment "C1"**
**Source: niajapals.com**

## Time of Concentration

A new time of concentration equation was utilized for the analysis of the drainage channels and the outcomes acquired from the analysis of the drainage of basins C, A and E having the highest runoff respectively, it demonstrated that a relationship exist between the precipitation intensity "I" and time of concentration "Tc". As time of concentration decreases, the precipitation intensity increases. At time of concentration of 22.14 mins, an intensity of precipitation of 42.23 mm/hr was seen in catchment C1 and the corresponding runoff is 5.12 $m^3/s$. Different estimations of spillover are in the appended table 1

## Peak Flow Estimation

Estimation of basin peak flow was done using the rational method and manning formula in equation 6 was used in estimating the peak flow capacity of each catchments existing drainage and the results for the sub-catchments are presented in table 1

**Table 1: Catchment Parameters and Resultant flow A1 – E1**

| PARAMETERS | A1 | A2 | A3 | A4 | B1 | C1 | D1 | E1 |
|---|---|---|---|---|---|---|---|---|
| L (m) | 937 | 850 | 950 | 1050 | 870 | 1002 | 1038 | 917 |
| S (m/m) | 2 | 6.8 | 2.7 | 2.7 | 3 | 2 | 5 | 5 |
| K | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 |
| M | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |
| N | -0.9 | -0.9 | -0.9 | -0.9 | -0.45 | -0.9 | -0.9 | -0.9 |
| C | 0.35 | 0.65 | 0.3 | 0.45 | 0.9 | 0.45 | 0.4 | 0.4 |
| A ($m^2$) | 465400 | 480000 | 542300 | 574700 | 376400 | 485600 | 344000 | 394600 |
| Q ( $m^3/s$) | 1.73 | 1.509 | 1.5 | 1.75 | 1.32 | 1.66 | 1.61 | 1.21 |

Comparison of the equations of time of concentration, uncovered a slight difference in runoff discharge going from 43.44 $m^3/s$ to 198.57 $m^3/s$ in basin A as appeared in Table 1 Notwithstanding, a reduction in runoff discharge was seen in basin A4 when the new time of concentration equation. The also observed that drainage dimension in the study area vary but generally the depth and width of the drainage are not adequate for the runoff volume flowing through them hence the incessant overflowing of the banks. This finding of this study is line with the studies of offiong et.al, (2008), offiong and Imoke (2008) Eze (2008), Jimoh (2008)
The study also reviewed the problems of flood in the Lokoja town was also as a results of the increasing built-up areas without proper recourse to urban planning rules, and additional concretion, could have accelerated infiltration excess over-land flow. A combination of saturation and infiltration excess overland flow could have been responsible, with the proximate determinants being the rainfall and topography. Although rainfall may have been higher than previous years, this could still have been lower than some other years prior to the present urbanizing phase of development that is being experienced.

## Conclusion

Distinctive techniques might be utilized in the design of drains, the techniques ranges from trial and error selection of the sizes and checking whether or not the velocity of flow and capacity are fulfilled. The design essentially aimed at the assurance of the drain section and slope. The study zone was separated into five catchments A, B, C, D and E individually with their consequent peak flows analyzed using rational method storm design. The outcomes demonstrated that catchment "C" with range of 206.24 ha gives the highest peak flow rate of 4.32 $m^3/s$ took after by sub-catchment A with the peak flow of 4.01 $m^3/s$, the rest of the sub-catchment B, D and E gave the peak flow these flow 3.20 $m^3/s$, 2.85 $m^3/s$, 3.13 $m^3/s$, respectively. Another finding was that drainages at shed "C" failed because of insufficiency in size. This study additionally demonstrated that the drainage system in sub-basin C is horribly inadequate at the downstream of the catchment because of the high peak flow with the existing drainage limit of 2.105 $m^3/s$ of a geometry of 1.2 m width and profundity of 1m in view of the insufficiency of the current seepage framework an extra seepage of 1.2m width and depth of 1 m because of the inadequacy of the existing drainage system an additional drainage of 1.2 m depth and a width of 2.0 m is recommended to be constructed at the downstream with an incline of 1.5 mm/m to suit overabundance runoff from the catchment. The downstream area ought to be destroyed to suit the previously mentioned sizes to clear the storm water. The government contract should be awarded to a competent company for the construction of under drainages covering the entire city of Lokoja, as surface drainages have created many problems to the resident including the loss of lives. And also NGOs should join hand in carry out massive awareness campaigns on the need for the people to stop dumping waste in the drainage channels.

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