



e-ISSN: 2319-8753 | p-ISSN: 2320-6710

# IJRSET

International Journal of Innovative Research in  
**SCIENCE | ENGINEERING | TECHNOLOGY**

# INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 9, Issue 11, November 2020

**ISSN** INTERNATIONAL  
STANDARD  
SERIAL  
NUMBER  
INDIA

**Impact Factor: 7.512**

9940 572 462

6381 907 438

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# Improvement of Storm Water Drainage System for Flood Risk Management in Birnin Kebbi Metropolis, Kebbi State Nigeria

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**ABSTRACT :** In this study, an attempt was made to design storm water drainage structures that can handle surface runoff effectively in Birnin Kebbi Metropolis North West Nigeria as structural measures for flood risk management. Among various methods of determining the quantity of surface runoff, the rational method is considered for this study. The data used are the available rainfall record of the study area for 20 years (1994 to 2014). The method entails the determination of the locations and volumes of existing drainage structures in the study area, determining the time of Concentration (ToC), Rainfall Intensity (I), Runoff Coefficient (C), and Return Period as design variables for estimating quantities of the discharge. Manning's equation was used to design the drainage sizes. From the results obtained, it was observed that some of the existing drainage structures in the area lack volumetric capacity to drain runoff effectively, thereby posing the risk of endangering lives and properties. It is therefore recommended that the estimated quantity of discharge should serve as a benchmark for the appropriate size of drainage structure to be constructed in view of emerging phenomenon like climate change.

**KEYWORDS:** Storm water, flooding, runoff, drainage, rainfall, runoff.

## I. INTRODUCTION

A storm drainage system is a system receiving, conveying, and controlling storm water runoff in response to precipitation and snowmelt. Such systems include: ditches, culverts, swales, subsurface interceptor drains, roadways, curb and gutters, catch basins, manholes, pipes, attenuation ponds and service lateral lines. The major drainage system comprises the natural streams and valleys and man-made streets, channels and ponds. The main purpose of a drainage design is to essentially eliminate the risk of loss of life and property damage due to flooding. Floods according to the study conducted by [1] occur in Nigeria in three main forms: coastal flooding, river flooding and urban flooding. Coastal flooding occurs in the low-lying belt of mangrove and fresh water swamps along the coast. River flooding occurs in the flood plains of the larger rivers, while sudden, short-lived flash floods are associated with rivers in the inland areas where sudden heavy rains can change them into destructive torrents within a short period. Urban flooding on the other hand occurs in towns, on flat or low-lying terrain especially where little or no provision has been made for surface drainage, or where existing drainage has been blocked with municipal waste, refuse and eroded soil sediments. Within the cities, human activities such as rapid industrialization and urbanization, population growth, exploitation of natural resources and location of infrastructures exacerbate occurrence of floods. Although flood is a natural occurrence, it often leads to disasters because of human-created vulnerability, which is a consequence of human-environment interactions. Poor drainage network as observed by [2] remains a contributing factor to flood occurrence in Nigeria. It is estimated that the required drainage channels in Nigeria is short by about 61.78%; and the existing ones are only about 30% maintained.

Floods are caused by various factors, including rainfall characteristics, drainage systems, and land use and water management in river basins. The concept of flood management according to research conducted by [3,4] must change because of urbanization, industrialization, and improvements in living standards. Flood management usually depends on terrestrial characteristics, local geography [5]. With the demand for development, urban areas in lowlands and other flood prone regions, along coastal settlements, river floodplains and in inland depressions, are growing worldwide [6].

To manage flood hazards, it is vital to implement an effective flood risk management concept. Although flooding cannot be eliminated, the consequences of flooding can be mitigated by appropriate actions. A systematic approach to flood risk management is to use the flood-prone lowlands efficiently. This leads to creating space for channel

Cross-section modification amongst others. Overall, implementation of appropriate actions to enhance flood security is possible and necessary to reduce the exposure and vulnerability of people and property to flood hazards. As urban settlements become denser due to economic activities and population growth, the likelihood of natural hazards inflicting heavy economic and human losses grows. This problem is further confounded by the growth of informal settlements subjecting the land to undue pressure. With land under pressure, these settlements that are develop in floodplains, in coastal zones, on steep hills, and in other areas vulnerable to natural hazards such as flooding, sea-level rise, landslides, are exposed to Massive floods such as those experiences in Nigeria in the year 2012, Thailand 2013, Southeastern Europe 2014, and South Carolina, United States 2015.[7].

According to the study by Smith, [8], every year over 20,000, lives are affected by flood disaster worldwide, and the reason lies in the widespread geographical distribution of river flood plains and low laying coasts together with the long-standing attraction for human settlement. Severe flooding events have become a frequent phenomenon facing communities and authorities in Nigeria each year, for example in 2010 and 2011 extreme flood events resulted in devastation and economic damages worth millions of dollars in the affected urban cities such as Lagos, Kano and Ibadan and rural settlements in communities in Sokoto and Kebbi State [9]. Recently, in the year 2020 according to the report many houses were submerged in water due to flash flood in Tudun wada area of Birnin Kebbi, Kabala Coustin of Kaduna, among other many places causing huge loss of properties and threatening the safety of the occupant in those affected areas. Birnin Kebbi has been experiencing perennial floods with grave consequences to lives and property. Apart from the inadequacy of drainage channels, other causes of the perennial flood includes Poor construction in terms of size, capacity, volume and pressure of storm waters that channels are expected to carry, blocked drains which result from indiscriminate dumping of waste into drains and construction of buildings on or across drainage channels or water ways and indiscriminate earth excavation for building materials leaving behind borrow pits that collect waters which overflows or inundated adjoining areas are also part of the causes.

The expansion of cities increases the risk of major flood disasters. Recent thinking about flood prevention according to the adoption strategies by Obgoi [6] stresses the importance of restricting city expansions into flood-prone areas, flood-proofing cities and accommodating floods by reserving space for water. These ideas require innovative city design, cooperation between city planners and water managers, and a policy that connects various levels of government with business and the public. After urbanization, runoff carries solids particles from automobile wear and tear, dust and dirt, and winter sand, nutrients from residential fertilizers, metals such as zinc, copper, and lead, hydrocarbons leaching from asphalt pavement materials, spilled oils and chemicals, and bacteria from domestic animals. This change of runoff quality causes a general degradation of water quality in the receiving waters, thus causing negative impact to the environment.

The aim of this research is to improve the existing drainage system in Birnin Kebbi for flood risk management through redesigning of the drainage facility in Birnin kebbi North West Nigeria.

## II. STUDY AREA

Kebbi State is located approximately between Latitudes 10° and 30°N and Longitudes 3° and 6°W. It occupies most of the western and southern portions of the former Sokoto State. Birnin Kebbi, the study area Fig 2.1 (12°27'13"N 4°12'01"E) is located on the northwest axis of the State further downstream along the extensive valley of the Rima River. It is the capital city of Kebbi State and headquarters of the Gwandu Emirate. The Relief in the area is generally gently rolling to undulating. The elevations throughout the area are mostly less than 300m (Birnin Kebbi Master Plan 1980-2000). The landscape of Birnin Kebbi according to the assessment carried out by [10] is dominated by extensive flood plains. The Rima and Shella rivers are located in the north and south east of the town respectively. Both rivers have broad flood plains. The Rima river system has major tributaries like Gawon, Zamfara and Gubinka. These tributaries rise in the Basement Complex region of Sokoto State and flow westward to join the Rima. Kebbi State enjoys a Tropical Continental type of climate characterized by distinct wet and dry seasons. The Tropical Maritime and Tropical Continental air masses determine the two dominant seasons in the area. The wet season lasts from May to September while the dry season lasts for the remaining period of the year. Mean annual rainfall is about 800mm. In Birnin Kebbi and environs, the highest mean daily temperature is about 37°C recorded at the peak of the dry season just

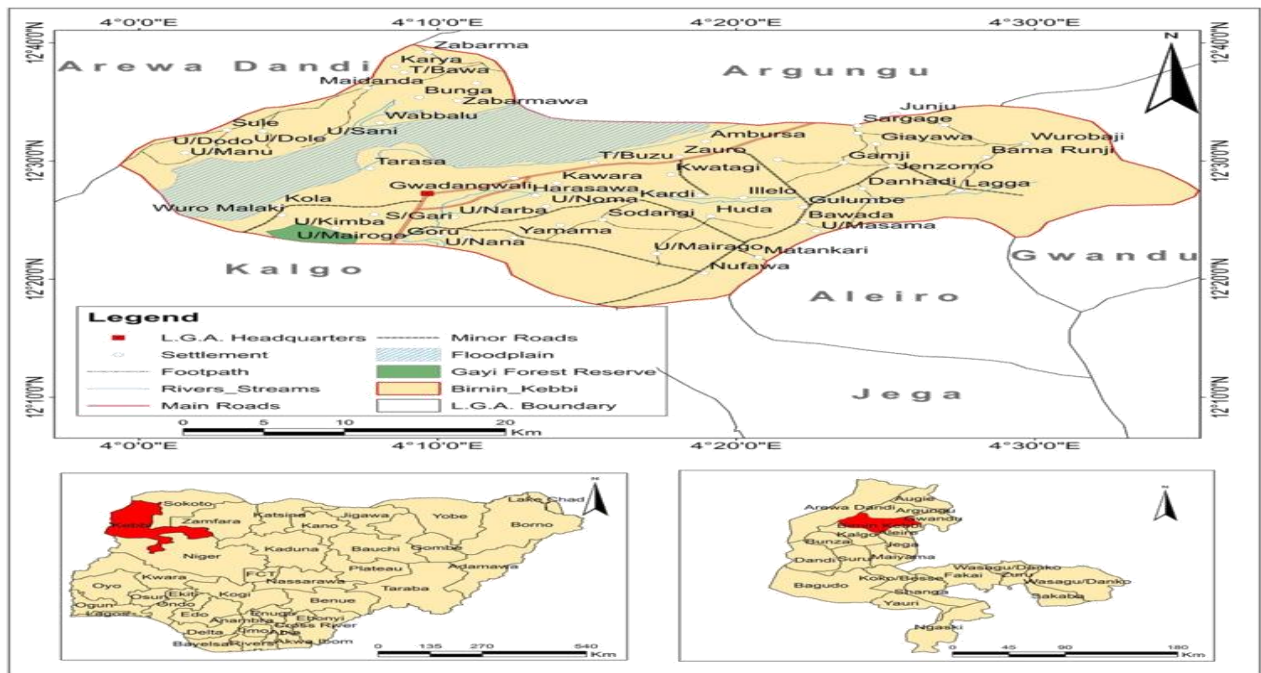


Figure 1: Modified from Administrative map of Kebbi State

before the onset of the rains in April while the lowest of about 11°C is recorded at the peak of the harmattan period. The

geological characteristics of Birnin Kebbi include thick and vast sequences of sedimentary deposits of the Sokoto basin, which underlie about 50% of the area. The Precambrian basement complex rocks are underlying the rest.

The principal soils within the Birnin Kebbi region are the vertisols. These are heavy, cracking clayeysoils with more than 35% clay have shrinking and swelling properties. The soils are high in minerals but have problems associated with spillage, poor drainage, flood and erosion



**III. EXISTING DRAINAGES FACILITY IN THE AREA**

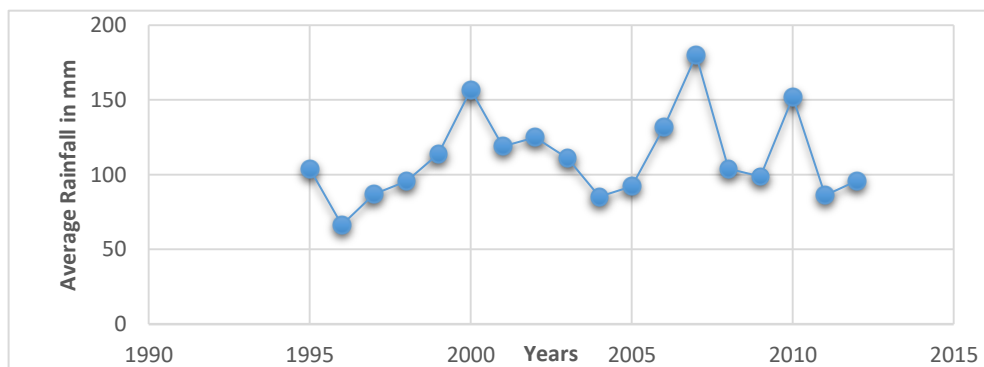
There are existing drainage facility in the area about 32% for open drain and 8% for covered drain totaling 40% of the required drain the remaining 60% of the study area as shown in Figures 3.2-3.8 lack adequate facility to effectively drain storm water in the area. The areas mostly without a drain are new layout or developing areas. Some of these drains as shown in Figures 3-8are 4Km Rafin Atiku drainage channels emptying storm water to Shella rivers with an average width and depth of 1.5 meters, 3 KM Tudun wada drains emptying storm water to Rima Rivers, the remaining are tabulated in Table A.1.

**Table 1 Dimensions of the existing drainages in Birnin Kebbi**

S/N	Locations	Drainage Dimensions	
		Existing dimensions in (m)	Designed/require dimensions (m)
1	Badariya area	1.5X2	2x2.6
2	Rafin Atiku area	2x2.5	3.2x3.7
3	Makerar Gandu/Illelayari	1.5x2	3.2x3.8
4	Nassarawa I & II	2x2.5	3.5x3.7
5	Gesse I & II	2x2.5	1.8x2.5
6	Gwadangaji Quarters	0.5X1	2.5.x3.3
7	Adamu Aleru Estate Housing	1x1.2	2.3x3
8	Bayan Kara New Layout	Nil	3.2x3.5
9	Bypass New Layout	Nil	3.0x3.6

**IV. DATA USED**

Records of rainfall for the year (1994 – 2014) Figure 3.1 were obtained from Kebbi State Agricultural and Rural Development Authority (KARDA).



**Fig 2 Average annual rainfall for Birnin Kebbi (1994-2014)**



Fig 3 Flooded Rafin Atiku area



Fig 4 Flooded Bayan Kara area (Newlayout)



Fig 5 Drainage facility in Adamu Aleru Estate



Fig 6 Gully In badariya area



Fig 7 Drainage facility in Tudunwada area



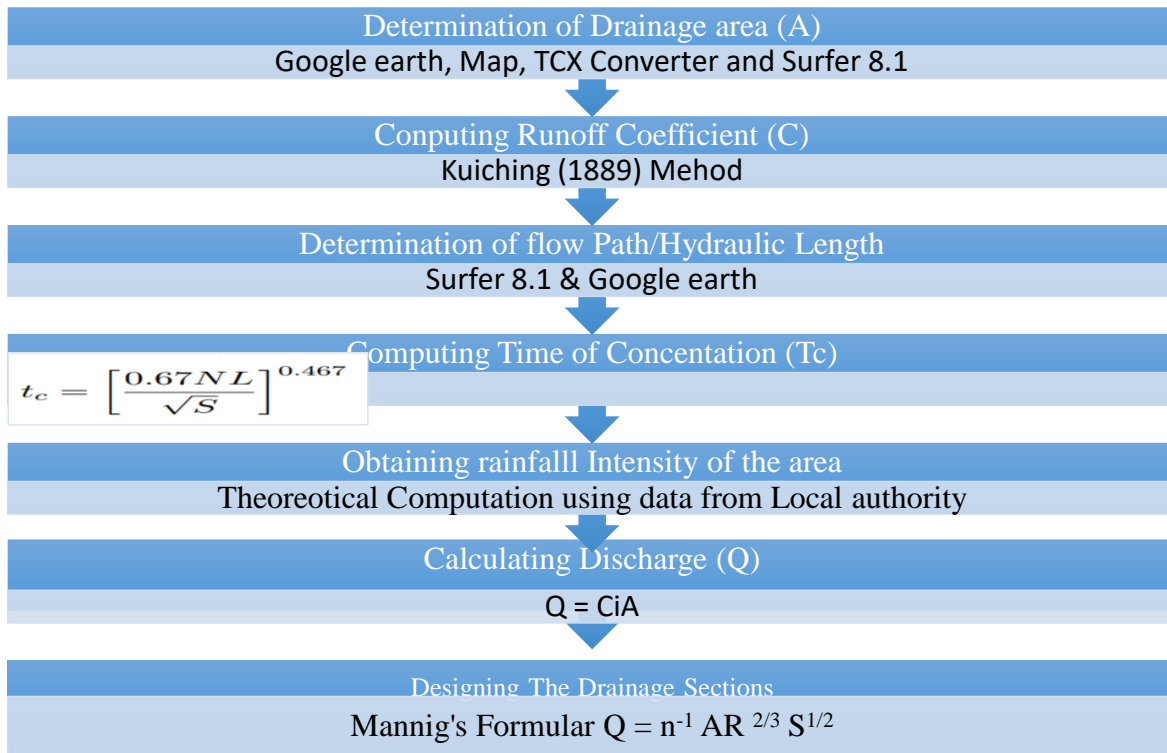
Fig 8 Flooded Adamu Aleru Estate

## V . METHODS

The method use in the study can be schematically summarized in the flow chart as follows:



Fig 3.8 Gully at Badariya area, Birnin Kebbi



**VI .DESIGN PRINCIPLE**

**VII. RATIONAL METHOD**

Rational method developed and used by [11], and was later revisited by [12] is the oldest method still probably the most widely used method for design of storm drains. The idea behind the rational method is that if a rainfall of intensity (I) begins instantaneously and continues indefinitely, the rate of runoff will increase until the time of concentration ( $t_c$ ) when the entire watershed is contributing to flow at the outlet. The product of rainfall intensity (I) and watershed area (A) is the inflow rate of the system, (IA) and the ratio of this rate to the rate of peak discharge Q which occurs at  $t_c$  time is termed the runoff coefficient (C)

**VIII. ESTIMATING RUNOFF QUANTITY**

Rational method was adopted to design the drainage facility for the study area. Having analyze the available rainfall, a rainfall intensity of 50mm/hr was adopted for the design. Considering the topography of the Birnin Kebbi metropolis, nature of its settlement, slope and for effective and efficient design, the study area was divided to 9 sub areas, and for each area the coefficient of runoff (C) was computed separately. For the new layout the range of (C) is found to be between 0.64 – 0.7, while the new layout has about 0.59 – 0.66. From the formula below the quantity of runoff was computed:

$$Q = 0.0028 CIA \quad (1)$$

Where Q = the Runoff in m<sup>3</sup>/Sec. I = rainfall intensity in mm/hr A = Area in hectares

C = Coefficient of runoff

**IX. TIME OF CONCENTRATION (T<sub>c</sub>) AND RAINFALL INTENSITY**

From Kerby Hathaway method the time of concentration of rainfall was obtained using the following formula:

$$(2) \quad t_c = \left[ \frac{0.67NL}{\sqrt{S}} \right]^{0.467}$$

Where

$t_c$  = time of concentration N = Kerby’s roughness parameter table, S = Overland flow slope



L = Length of the hydraulic channel

**X.HYDRAULIC DESIGN**

Manning’s formula was used to determine the channels dimensions, velocity and its slope, using 20 years return period.

Choosing rectangular Drainage System;

From manning’s formula is

$$Q = \frac{A}{n} R^{\frac{2}{3}} S^{\frac{1}{2}} \quad (3)$$

Where

Q = the discharge m<sup>3</sup>/s, A = the crosssectional area of the stream/Line Drain (m<sup>2</sup>) R = the hydraulic radius (m) (area/wetted perimeter of the channel) = A/P, S = the slope of the water surface n = the roughness coefficient of the channel = 0.015 using smooth finish concrete.

The administrative map of Kebbi State was obtained from the Kebbi State Ministry of Lands and Survey and was used to familiarize with geographical information of the area. Furthermore Google earth application was also use to further classify the area in to nine major catchment areas. The map of the study area was further geo-referenced and digitized. The different layers of the digitized map were loaded into online GPS visualizer where the altitude of the area is been computed. The georeferenced values were further rearranged through CX Converter and exported to Microsoft Excel sheet. The excel sheet data were overlaid in Surfer version 3.0 software leading to the determination of counter and the watersheds areas. The dimensions of the drainage facilities are as depicted in Figures 9- 17

**XI. RESULTS**

The dimensions of the redesigned drainage is as depicted in Figures 9- 17

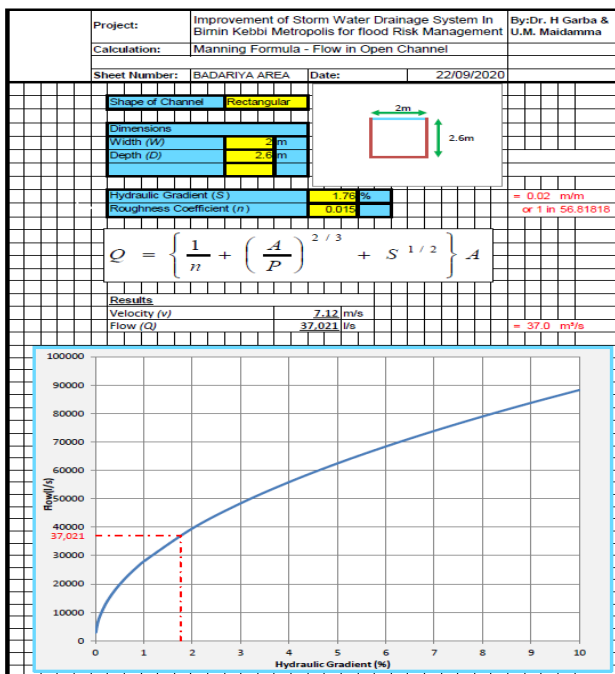


Fig 9 Badariya area

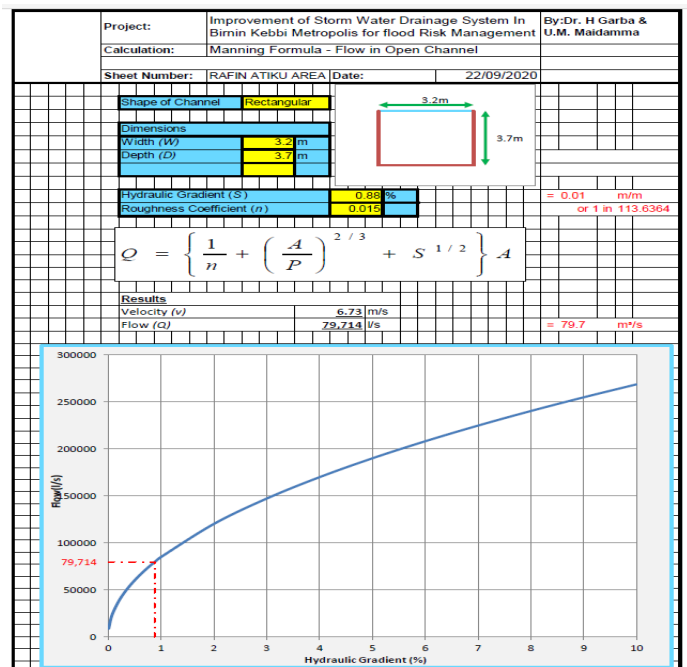


Fig 10 Rafin Atiku area



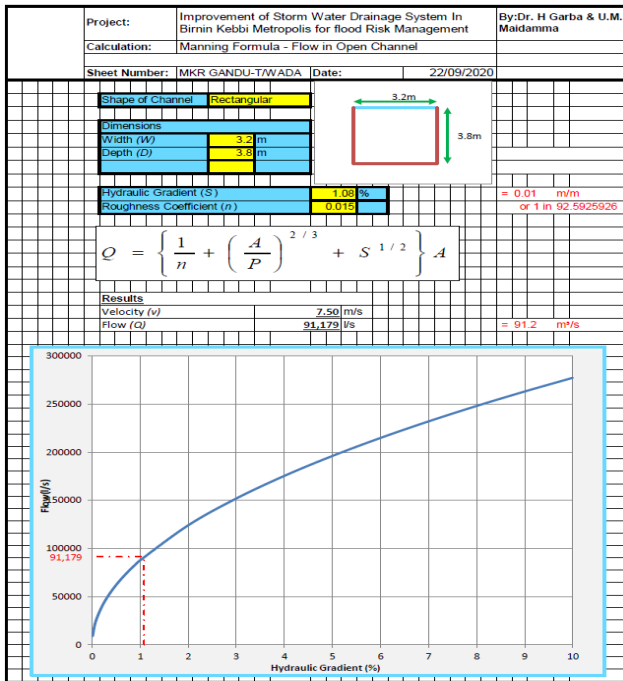


Fig 11 Makerar Gandu/Illelayi

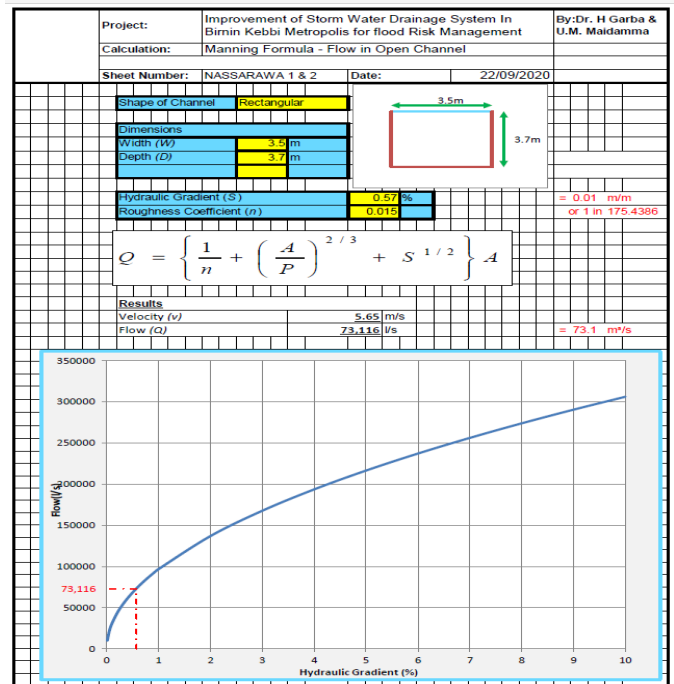


Fig 12 Nasarawa I & II

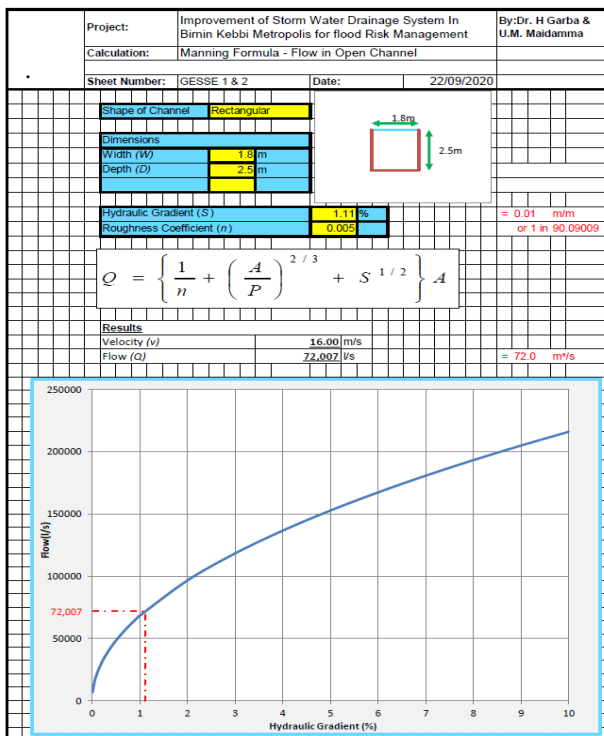


Fig 13 Gesse I & II

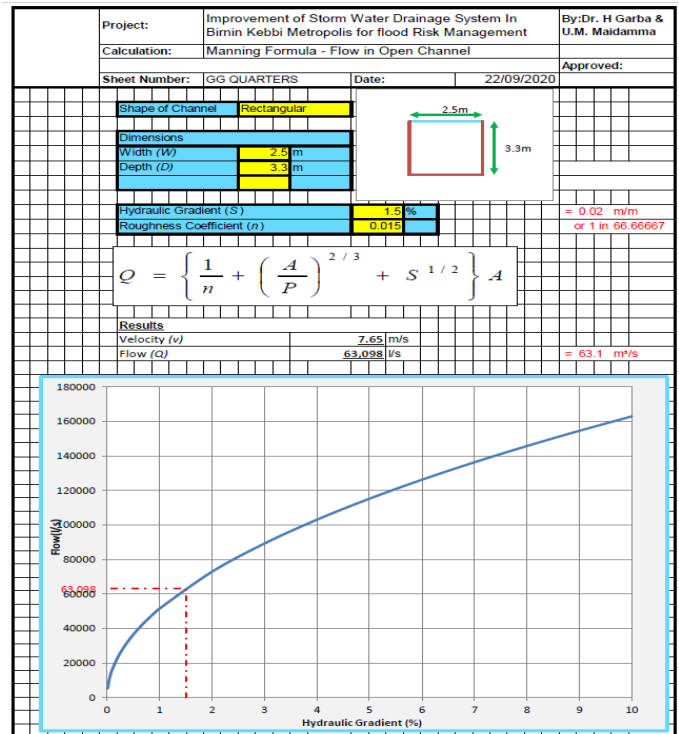


Fig 14 Gwandangaji Quarters

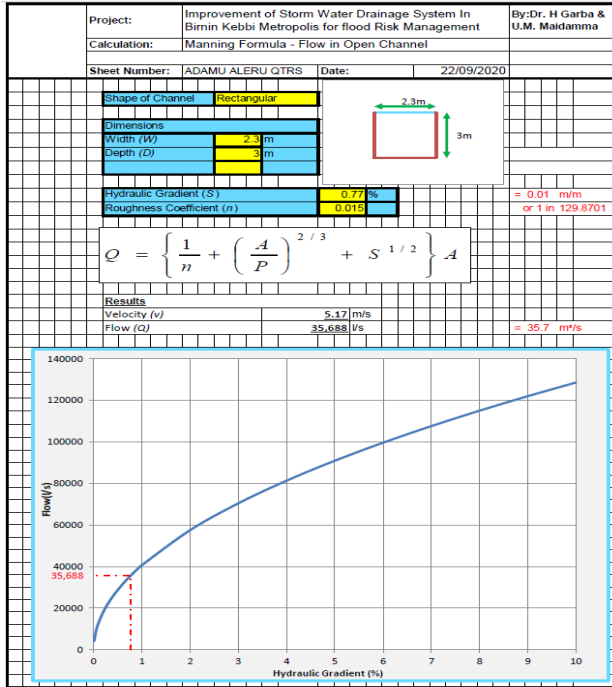


Fig 15 Adamu Alero Estate

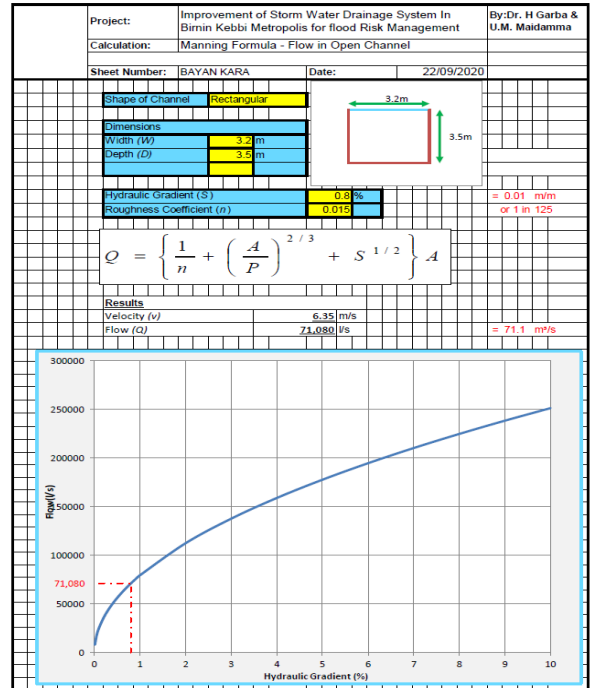


Fig 16 Bayan Kara New Layout

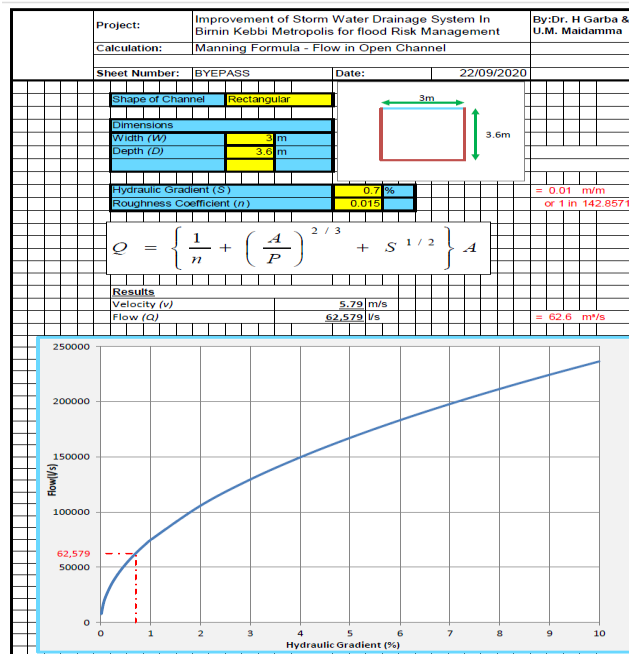


Fig 17 Bypass New Layout

## XII.DISCUSSION

Findings from the parameters of the rational formula reveals that only the area 'A' can be precisely defined by measuring the area of the sub catchment. The intensity (I) for the sub catchment depends on the analysis of point rainfall data, time of concentration, estimation of runoff coefficient (C) which depends on so many characteristics of the sub catchment like land use pattern, antecedent precipitation, soil moisture, infiltration, ground slope, surface and depression storage, shape of the drainage area, over land flow velocity etc., and this coefficient can vary with time also. The existing drainages system in the area failed to accommodate runoff due to insufficient geometric size. Additionally it was also discovered that some of the drainages system tends to be block with sand due to the soil type of the area, this significantly reduce the size of the designed channel.

## XIII.CONCLUSION

Rational method has been effectively used to design the storm water drainages structure of the Birnin Kebbi metropolis. All the drainages system in the area lack adequate capacity to drain storm water effectively and efficiently when compared with the drainage designed using recent hydrological data of the area, as a result of inadequacy in size, poor maintenance and deterioration of the hydraulic structure.

Therefore, it can be concluded that, the drainage structure designed, if implemented and constructed in the area, can reduce the risk of flood effectively.

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