DRAINAGE IMPROVEMENT DESIGN FOR RIVER GINZO CHANNEL, KATSINA TOWN, NIGERIA

BY

MOHAMMED ALIYU ALIYU
M.SC/ENG/1911/2010-2011

DEPARTMENT OF WATER RESOURCES AND ENVIRONMENTAL ENGINEERING,
FACULTY OF ENGINEERING,
AHMADU BELLO UNIVERSITY, ZARIA.

SEPTEMBER, 2014

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND TO THE STUDY AREA

The capital of Katsina state is Katsina town. It is an old historical town, dating back to 1350 AD. The Hausa tribe is the largest ethnic group in the project area. The second largest group is the Fulani, who generally speak their own language (Fulfulde). Katsina Metropolis which is the study area has undergone some significant changes both in physical and population size since over a decade ago. This tremendous growth is traceable to 1987 when the state was created and the town of Katsina became the state capital. This led to the modification of land surfaces due to construction works, paving of land surfaces and roofing of buildings. Such modifications are expected to significantly affect the hydrological processes of the metropolis (Ibrahim, 2004).

Urbanization is the development of land into increased organic and inorganic loadings, increased residential, commercial, and industrial properties (Ayeni, 2009). Urban and suburban developments cause profound changes to natural watershed conditions by altering the terrain, modifying the vegetation and soil characteristics, and introducing pavement, buildings, drainage, and flood control infrastructure (Booth and Reinelt, 2010).. Hydrologic and geomorphic impacts are closely associated with an increase of impervious area resulting from urban development. Reported impacts have included: increased frequency of flooding and peak flow volumes, decreased base flow, increased sediment loadings, changes in stream morphology, stream temperature, and loss of aquatic/riparian habitat (May et al., 2006).

In terms of problems experienced in Sabuwar Unguwa of Katsina town due to flooding are: waterborne diseases such as diarrhea, dysentery, cholera and typhoid threaten disaster affected populations, especially the poor and vulnerable, due to lack of access to safe drinking water, medicine and hygienic food.

Storm water runoff from rare and intense storm events in Sabuwar Unguwa of Katsina town causes serious risks to lives and property. Although, there are already natural open channel in Katsina metropolis but the capacity is not comprehensive enough to meet the present day run-off resulting from increase in construction, paved roads, etc. The drains are blocked due to deposition of sediments, failure of side banks, refuse depositions, building of houses along the channel and flooding during heavy storm due to the inability of the channel to carry the volume of water. Therefore, there is need to design the system in order to produce the required capacity and minimize the incidence of blockage due to sediment and refuse depositions. Besides the flood related health problems described above, flooded homes and buildings can pose other significant health hazards and risks after floodwaters recede. First of all, electrical power systems including fallen power lines in some areas can become hazardous during cleanup activities. When entering and cleaning damaged buildings as well as endeavoring to restore utilities services such as broken bottles, woods, stones and walls may also cause fresh wounds and injuries when removing contaminated mud and cleaning damaged buildings. Lastly, a health hazard can also occur when hazardous dusts and molds remaining in the ducts blows by fans and ventilators such as windows etc of the buildings inhaled by those engaged in cleanup and restoration unless it is properly cleaned after flooding.

According to some researchers, flood can cause both emotional and physical stresses. However, various reports attribute a major health hazard of floods to mental stress or psychological distress due to exposure to extreme disaster events. Having experienced a devastating flood, seen loved ones lost or injured, and homes damaged or destroyed, flooding poses a long-term psychological impact on the flood victims. In addition, the cost and labor required to repair flood-damaged homes places severe financial and psychological burdens on the people affected, in particular the unprepared and uninsured. Post-flood recovery especially when it becomes prolonged can commonly cause mental disorders, anxiety, anger, depression, lethargy, hyperactivity, sleeplessness, and in an extreme case, suicides amongst the flood victims (Booth and Reinel 2010). Behavior changes may also occur in children such as an increase in bed-wetting and aggression. There is also a long-term concern amongst the affected that their homes would be flooded again in the future. Many reported morbidity problems caused by disasters including hypertension and cardiovascular disease and even leukemia and lymphoma may be stress-related (Noji, 2007). While more attention is usually paid to the cleanups and repairs of the damaged buildings and properties during the aftermath, it is also required for individual victims to look after him/herself and his/her family, and when appropriate to obtain proper emotional support from local authorities, relief agencies, psychological counselors, mentors, friends, relatives, etc (Genencher, 2005).

1.2 STATEMENT OF RESEARCH PROBLEM

Katsina metropolis is situated in the catchment area of Abdallawa River, which is the river that drains the city. Abdallawa River has its source from southern and Northern parts of Katsina metropolis. The town is drained by two main rivers, Ginzo and Tille which are prominent among the tributaries of Abdallawa River within Katsina metropolis. The two Rivers divided Katsina metropolis into two, forming two main drainage basins (Fig. 1.2 and 1.3). The Tille basin occupies the Northern part (Old City), while the Ginzo basin occupies the southern part (New developing area). The two rivers are perennial in flow, they nearly dry during the dry season, if not because of frequent discharges from domestic areas. The flow varies significantly with time throughout the rainy season.

Ginzo River channel was designed in this thesis due to the fact that the catchment has many paved roads, narrow gutters with poor drainage system and there is no laid out plan. Buildings are close to one another and the networks of roads are all scattered and narrow (Plates 1.1 to 1.5e). A greater proportion of the catchment is concretized, comprising roofs and paved roads, immediately it rains, almost all the rainfall drains away down to the river side since there is very low infiltration at upstream. In case of urban areas, particularly Katsina which is the study area main drainage channels are engulfed by urban expansion where considerable portion of the channel is within the built-up areas. Eventually the channel takes on characteristics distinguishable from its natural condition as a result of one man's activity or the other. These changes in condition may lead to devastating ecological problems to the urban settings (Ibrahim, 2004).



Plate 1.1: Ginzo River Channel along Sabon Unguwa at 40.7ft (12.4m) wide



Plate 1.2: Ginzo River Channel along Sabon Unguwa at 68.3ft (20.82m) Wide



Plate 1.3: Ginzo River Channel along Sabon Unguwa at 33.8ft (10.3m) wide



Plate 1.4: Ginzo River Channel Between K/Marusa and K/Sauri at 55.1 ft (16.8m) wide



Plate 1.5a: Dump Refuse along the Ginzo Channel



Plate 1.5b: Using GPS Along Ginzo Channel





Plate 1.5c: Among the Affected Areas at K/Marusa (Left) and K/Kaura (Right)



Plate1.5d: One of the Affected Area Along Ginzo Channel



Plate 1.5e: Nature of Bridges Along Ginzo River

1.3 AIM AND OBJECTIVES

The aim of the study is to design an optimum channel for storm conveyance in Sabuwar Unguwa, Katsina metropolis.

The specific objectives are:

i. To identify the catchment of the Ginzo River in order to calculate the flood flow
ii. To design an adequate drains and its components that can safely carry flood away from the neighborhood
iii. To economically analyze the design in such a way that value for money can be achieved.

1.4 SCOPE OF THE STUDY

The scope of this study is limited to:

i. Design the most economical open channel for Sabuwar Unguwa, Katsina town and
ii. Provide an economical means of solving the disruptions caused by flooding and water logging on the working area and major streets

1.5 THE STUDY AREA

The study area is Katsina metropolis, the capital of Katsina state of Nigeria. It lies between latitude $12^0.60'$ and $13^0.75'$ North of equator and at longitude $07^0.35'$ and $08^0.10'$ east of Greenwich.

The entire state is located on a height of about 500 meters above sea level and covers a land area of 3,370 square kilometers (S.R.R.B.D.A, 2011).

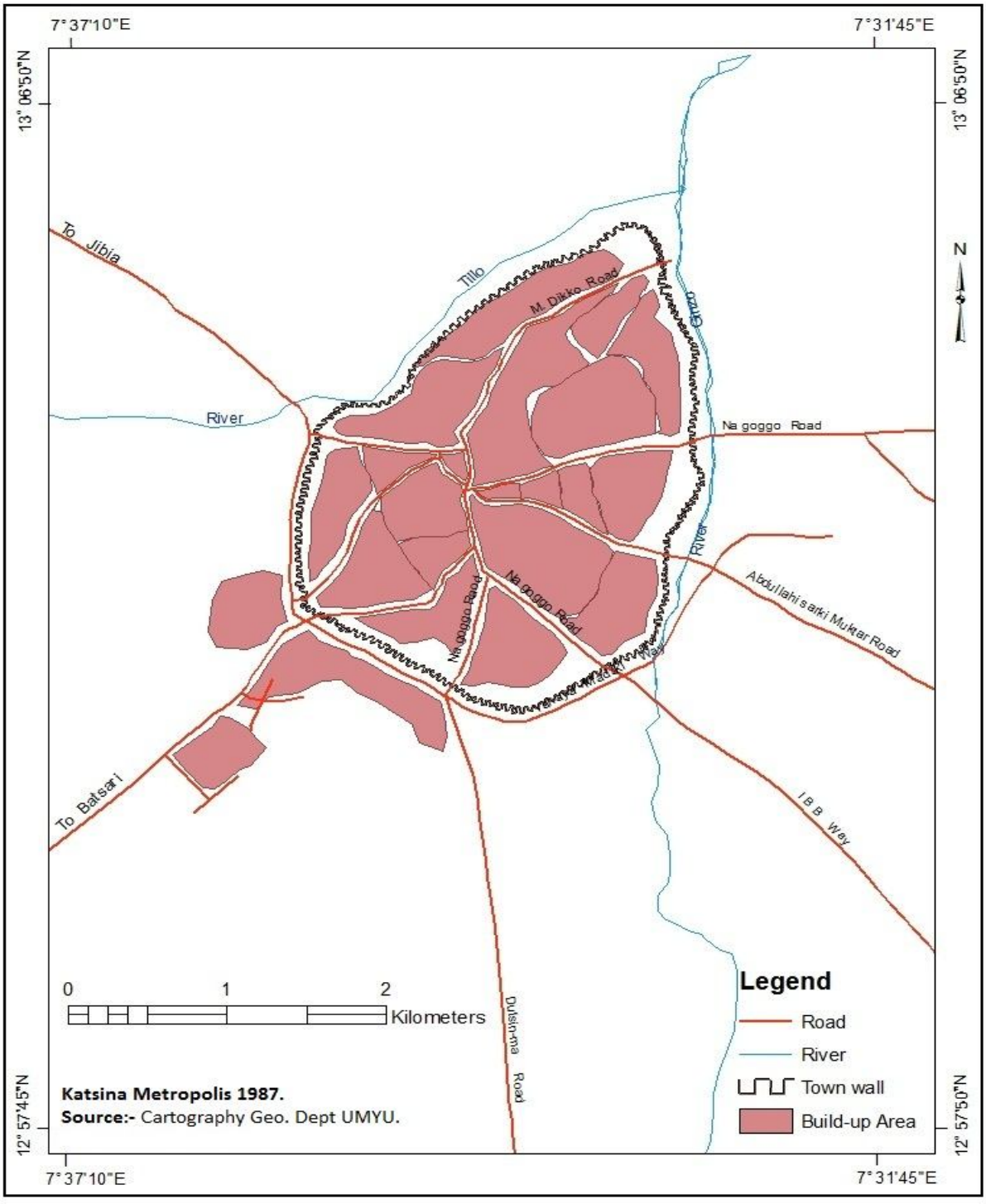
It is located on the central plain of Hausa land, at the extreme Northern part of the country, 48 kilometers away from the border with Kaduna State and Westward with Zamfara State. It also share borders with Kano and Jigawa States Eastwardly (Fig 1.1).



Source: Cartography, Geo. Dept. UMYU, Katsina (2012)

Figure 1.1: Map of Katsina State Showing Urban Katsina as the Selected Study Area

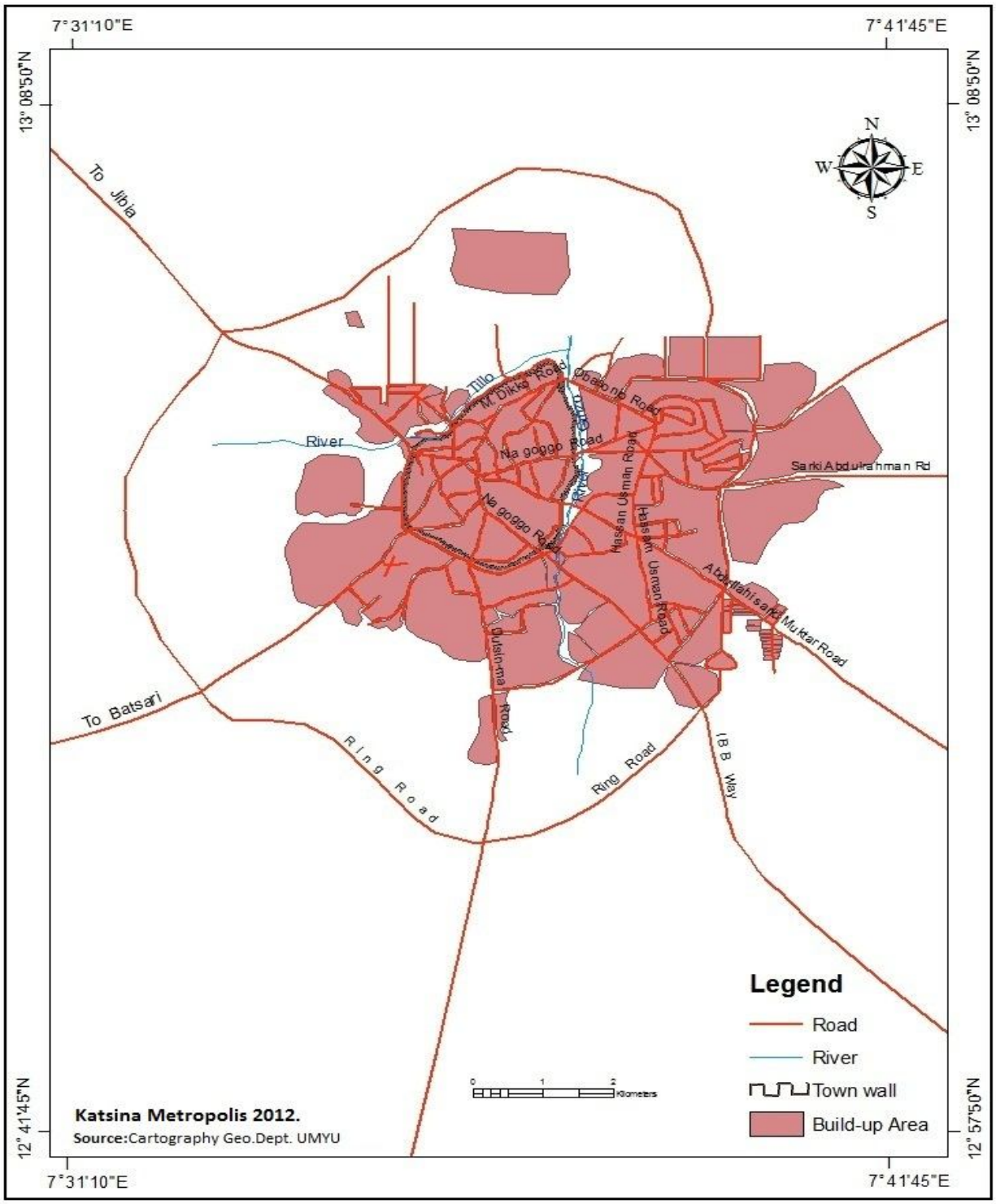
1.5.1 Population: Katsina has a fairly large population which has always been increasing. According to the 1952 population census, the population figure was 52,672. The population figure has been growing, especially from 1987 to 1991. From the last census conducted in 1991, Katsina has a population figure of 223,644, representing about 16.8 percent of the State population (Mabogunje, 2012).



Source: Cartography, Geo. Dept. UMYU, Katsina (2012)
Fig. 1.2: Katsina Metropolis, 1987.

Between 1952 and 1987, when the State was created, there was a population growth rate of 4.8%. This brought the population figure to about 141,871 in 1987. With the creation of the State, the rate shifted to 9.8% yearly, and 9.9% in 1992, but decreased to about 3.6% in the subsequent year. This is why the population in 2003 is given as 734,871 (Table 1.1). This translates to about 2000 persons per square kilometer in Katsina area. The population figure of National Population Commission Katsina was limited to 2003; therefore, the population figure of 2008 and 2012 was forecasted (NPC, Katsina, 2012). This expansion in the population is also matched by corresponding physical expansion of Katsina metropolis (Figures 1.2 and 1.3). With this increase in the rate of expansion, a lot of natural surfaces have given way to artificial surfaces in the metropolis. The buildings springing up in every part of the city: Roads and construction work has taken place and more areas are being concretized daily. Of course, these attributes can be related to the low infiltration capacities expected in the urban land surfaces within the metropolis.

Tables 1.2 and 1.3 are for monthly precipitation, maximum and minimum values of precipitation for Katsina town between 2006 – 2011.



Source: Cartography, Geo. Dept. UMYU, Katsina State (2012)
Fig: 1.3: Katsina Built-Up Area 2012

Table 1.1: Katsina Town Population Growth 1952-2011.

YEAR	POPULATION	INCREASE RATE (%)
1952	52,672	-
1987	141,872	4.8
1991	210,758	9.8
1992	231,749	9.95
1993	240,148	3.6
1994	248,551	3.5
1995	257,870	3.7
1996	266,708	3.4
1997	275,850	3.4
1998	285,304	3.4
1999	295,083	3.4
2000	315,058	3.4
2001	323,235	3.2
2002	323,235	2.6
2003	334,871	3.6
2008	391,086	5.8
2011	438,099	4.9

Source: NPC Katsina, (2012).

Table 1.2: Monthly Precipitation Figures in Katsina Town

Year	April	May	June	July	August	September	October	Total
2006	16.6	211.2	292.2	348.8	499.7	304.4	-------	1672.7
2007	--------	137.8	205.3	355.7	546.2	251.5	-------	1496.5
2008	--------	172.6	229.8	386.6	506.7	344.2	-------	1639.9
2009	22.1	128.6	131.8	334.9	489.1	256.1	18.1	1380.7
2010	9.8	104.6	238.8	296.6	556.3	322.1	-------	1528.2
2011	--------	149.4	232.1	320.7	269.6	251.8	39.4	1223.6

Source: Meteorology Unit of Umar Musa Yar'adua International Air-Port Katsina, 2012

Table 1.3: Max. and Min. Values of Precipitation Figure in Katsina Town

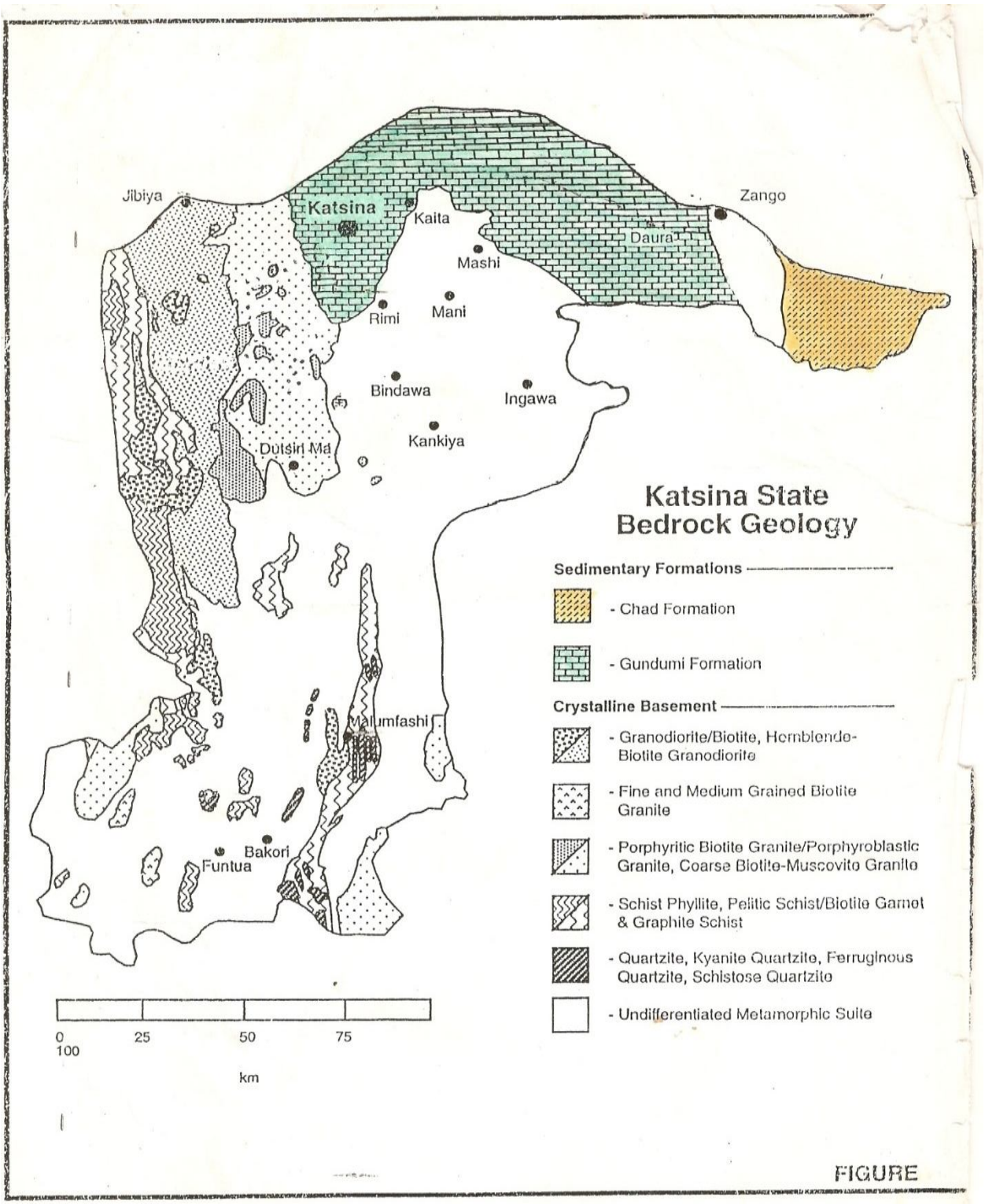
Year	Minimum (mm/month)	Maximum (mm/month)	Total Values (mm/year)
2006	16.6	499.7	1672.7
2007	137.8	546.2	1496.5
2008	172.6	606.7	1739.9
2009	18.1	489.1	1380.7
2010	9.8	556.3	1528.2
2011	39.4	320.7	1223.6
Yearly Mean Value		1406.9 mm/yr	

Source: Meteorology Unit of Umar Musa Yar'adua International Air-Port Katsina, 2012

1.5.2 Vegetation: The vegetation of the area corresponds absolutely with the climate. Hence the vegetation is predominant the Sudan type in response to the rainfall characteristics. The vegetation is characterized by sparse trees, grasses and shrubs. The trees are normally short, ranging from two to eleven meter with hard barks and narrow leaves. Most of the trees in the area are drought resistant, example, Baobao and Neem. But on the whole, shrubs dominate the area. The grasses of this area are also resistant to moisture scarcity and most of them have the ability to grow again when they die as a result of lack of moisture and regenerate in the next rainy season. In closely settled areas it was found that the natural vegetation has been modified but several trees have been planted such as Neem and Acacia Albida. A considerable growth of natural vegetation occurs in areas which are remote from human settlements or which are marginal or uncultivable (Maxlock Group, 2006).

1.5.3 Geology and Soil of the Study Area: Katsina town is slightly undulating and can in general be regarded as uniform. The rock of any area constitutes an important element of the land resources in as much as they influence, to a considerable extent, the nature of the land surface, the soils, the hydrology and the vegetation of such area. The study area is underlain, predominantly, by sedimentary formations (such as Gundumi formations) and

crystalline rocks (Fig. 1.4) of the basement complex. But in the Northern and Eastern parts of the town, cretaceous sediment overlaps the crystalline rock, which has accumulated over dry climate condition (Maxlock Group, 2006).



Source: RUWASSA, 2011.

Fig. 1.4: Katsina State Bed Rock Geology.

The soil type is Ferrugious tropical red and brown soil of the basement complex rocks in the area. The parent materials are composed of unconsolidated sands, the nature of which renders the area to be very porous and susceptible to erosion on the interfluves and upper slopes of underlying areas while on the seasonally flooded valley floors a high clay content heavier grey soil occurs.

The Katsina area touches the southern margin of the Mesozoic and Tertiary Lullemeden Basin of the southern Sahara. The crystalline basement complex of the massif of northern Nigeria covers the remaining portion of this area (Maxlock Group, 2006).

1.5.4 Hydrological Units exist in Katsina State: According to RUWASSA, (2011). The hydrological units in Katsina state are:

1. The large crystalline basement region in the south and central portion. Very little ground-water exists in this area, but it is suitable for the construction of dam.
2. A zone crystalline basement with buried valleys filled with cretaceous sandstones and conglomerates around Katsina town, a limited extraction of groundwater is possible in this area.
3. The cretaceous sediment basin in the north with basement ridges and inliers at Kaita and Dankama. An extraction of groundwater is possible in this area, but the construction of dams is out of question.

The Sunshine, Relative humidity, Temperature and Wind values (Tables 1.4 to 1.7) were obtained from Sokoto Rima River Basin Development Authority (S.R.R.B.D.A., 2011) are as follows:

1.5.5 Surface Wind: The project area is affected by two winds current: the harmattan from the northeast with northern and eastern components, and the monsoon from the southwest with western and to a less degree southern component. The harmattan predominates from November to March, the monsoon from May to September. In October and April both wind direction occur about equally because of the secondary movement of the low pressure belt proceeding southward or northward. The wind rarely blows from South-East or North-West.

Generally the wind speed at the surface is low, and yearly averages are 5 – 10 km/hr. Speeds exceeding 16km/hr last less 10 percent of the time. About 50 percent of the year is calm. Steadiness and speed of winds increase with the distance of the low pressure belt from the surface. Normally the wind freshens in the morning and fades away in the afternoon. The main wind direction of the year is easterly. Winds of up to Beaufort Force 7 can occur.

1.5.6 Katsina Sunshine: The clouds cover increases gradually to its maximum in August and decreases suddenly towards the end of the year. The mean amount of low clouds in Sokoto and Kaduna allows interpolation for other places in Katsina state. The cloud cover decreases toward the north.

Cloud cover and dust haze cause cold days and warm nights because of less incoming and outgoing radiation. Therefore, diurnal variations in temperature are least during cloudy or hazy days and highest during clear days. The mean duration, of bright sunshine varies with the length of day and the cloud cover. In the first month of the year, the duration of sunshine increases with the length of day and absence of cloud. Towards April, the cloud cover increases more rapidly than the length of day, leading to a secondary minimum.

Towards May to June, cloud cover increases less rapidly than the length of the day, leading to a secondary maximum of sunshine. In July, August and September, the cloud cover dominant and the duration of sunshine reach its minimum. A summary of the mean daily hours of bright sunshine of the meteorological stations of Katsina is shown in the Table 1.4

Table 1.4: Mean Daily Hours of Bright Sunshine

Observation Station	Period	Months											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Katsina	2004	-	-	-	-	-	-	-	-	8.8	-	9.7	10.1
	2005	9.0	-	8.1	-	-	-	-	7.1	8.5	8.7	-	10.5
	2006	9.8	-	9.0	6.2	8.8	6.2	6.7	7.0	7.8	8.6	9.6	7.6
	2007	9.4	9.0	8.4	8.9	9.4	8.6	7.8	4.3	7.8	8.5	7.6	7.0
	2008	9.4	8.9	7.6	8.8	8.2	4.9	8.8	7.1	8.1	8.8	7.9	7.6
	2009	7.9	9.0	7.2	8.2	7.5	6.6	7.1	7.0	7.8	8.9	8.6	9.0
	2010	9.0	7.5	8.2	-	7.7	7.2	8.2	6.3	7.9	9.4	9.4	8.8
	Mean	9.1	8.6	8.1	8.0	8.3	6.7	7.7	6.5	8.1	8.8	8.8	8.7
	Range	1.9	1.5	1.8	2.7	1.9	3.7	2.1	2.8	1.0	0.9	2.1	3.5

Source: S.R.R.B.D.A., 2011.

1.5.7 Relative Humidity: The boundary between the air masses of northern and southern origin is defined by a sharp decrease in humidity. The humidity in Katsina therefore, changes abruptly with the movement of harmattan or monsoon air. The general trend of the moving air masses has considerable secondary oscillations which might cause sudden differences in humidity from day to day.

Toward the rainy season the number of humid days increases gradually with the general northward movement of the south air, thus showing a moderate increase in the mean relative humidity. After the rainy season, northern air moves faster towards the south, resulting in a steeper decrease of relative humidity. Mean diurnal variation of the relative humidity are due to the diurnal temperature variations. The lowest temperature at about

06.00hrs is accompanied by the highest humidity; the highest temperature at about 15.00hrs corresponds to the lowest relative humidity. The tables below show the mean relative humidity in Katsina state. One can clearly recognize the decrease of the relative humidity in northern direction.

Table 1.5: Mean Percentage Relative Humidity

Observation Station	Period	Months											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Katsina	2004	-	-	37	-	-	-	-	-	64	-	-	13
	2005	-	-	15	-	-	-	-	75	71	39	20	12
	2006	14	7	8	12	44	51	67	76	70	31	18	15
	2007	15	10	13	13	45	54	69	79	69	31	14	19
	2008	12	10	14	31	44	60	62	72	62	41	18	19
	2009	-	-	-	-	-	-	-	-	-	-	-	-
	2010	21	19	12	20	45	53	75	80	72	45	24	25
	Mean	16	12	17	22	45	55	68	76	68	37	19	17
	Range	9	10	29	19	1	9	8	5	10	14	10	13

Source: S.R.R.B.D.A., 2011

1.5.8 Katsina Temperature: The temperature of the years 2004 to 2010 in Fahrenheit F is given: Means: 09.00hrs = 81.5^0F, 15.00 hrs. = 90.3^0F, Max = 92.0^0F, min = 65.9^0F. Extremes: Highest max = 108^0F, Lowest min = 41^0F. The mean yearly temperature derived from daily midrange values increases slightly towards the north over West Africa and reaches its maximum in the Sahara belt. In the north, yearly and diurnal variations of temperatures are less frequent, and the temperature extremes are moderate compared with the north of Nigeria.

The coolest time of the day is around 06.00hrs, the hottest time around 15.00 hrs. All over Katsina the hot season in March to May is very pronounced.

A short hot season follows the rainy season in November. Cool night and rather hot days are normal during the harmattan period in December, January and February. Little diurnal temperature variation can be observed in the rainy season in July, August and September.

The two hot seasons, the rainy season and the harmattan period appear also in mean monthly temperatures and in the highest recorded maxima. The lowest recorded minima show only one maximum in the rainy season and a minimum during the harmattan. Tables 1.6 and 1.7 give a summary of the monthly maxima and minima temperatures.

Table 1.6: Mean Daily Maximum Temperature

Observation Station	Period	Months											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Katsina	2004	-	-	-	23	-	-	-	-	33	-	33	-
	2005	29	35	39	-	39	-	32	31	32	34	33	33
	2006	31	32	36	39	39	37	32	30	31	34	31	29
	2007	27	34	38	39	39	37	32	29	32	34	33	29
	2008	30	33	37	-	37	34	34	32	34	36	31	30
	2009	31	35	36	38	35	33	30	-	30	32	30	32
	2010	27	-	35	36	33	31	-	-	-	-	30	27
	Mean	29	34	37	36	39	37	33	31	33	35	32	30
	Range	4	3	3	17	3	4	2	3	3	3	2	5

Source: S.R.R.B.D.A., 2011

Table 1.7: Mean Daily Minimum Temperature

Observation Station	Period	Months											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Katsina	2004	-	-	-	27	-	-	-	-	22	-	15	-
	2005	11	15	21	-	25	-	22	21	21	21	16	13
	2006	13	14	18	23	24	24	22	20	21	18	12	11
	2007	10	14	20	21	23	23	23	20	19	18	13	12
	2008	11	14	19	22	24	22	22	21	22	22	15	14
	2009	15	17	20	24	24	24	22	-	22	20	14	14
	2010	13	15	19	25	23	23	21	21	20	19	15	11
	Mean	12	15	20	25	24	23	22	21	21	20	14	13
	Range	5	3	3	16	2	2	2	1	3	3	4	3

Source: S.R.R.B.D.A., 2011

1.5.9 The Climate: The climate in the north of Nigeria is semi-arid. For six months of the year, there is no rain, and in some years, the rainfall is so light that crops fail and people leave their villages and travel long distances, sometimes leaving the Emirate, in order to obtain food. However, no part of Katsina can be described as desert, nor are there any sure signs that the climate is deteriorating. In some densely populated districts, the farmland is not highly productive, but even the driest and most impoverished areas support a large number of people on each square mile at a standard of living that, by African standards, must to be considered quite high. Nevertheless, the present situation gives some grounds for disquiet with regard to the future. The population is increasing and the people need more land than they used before.

The area of investigation has a short rainy season and a long intense dry season. During the "winter" season, descending tropical continental air from the desert extends far to the south. Katsina experiences relatively cool weather from November to March with daily maxima of 75^0F – 90^0F and minima of 50^0F – 60^0F. Through April and May, temperature increase and the daily maxima are 90^0F – 100^0F and minima 60^0F – 75^0F. As "Summer" approaches, tropical maritime air moves inland from the Gulf of Guinea and there is heavy precipitation throughout most of the area occupied by the moist air mass. The greater cloudiness is accompanied by a smaller temperature range. Rainfall is heaviest, immediately south of the inter-tropical front where convergence is strongest, and the rainfall peak in August is best defined at about the latitude of Katsina. Warm humid conditions persist for some weeks after the end of the rains.

CHAPTER TWO

LITERATURE REVIEW

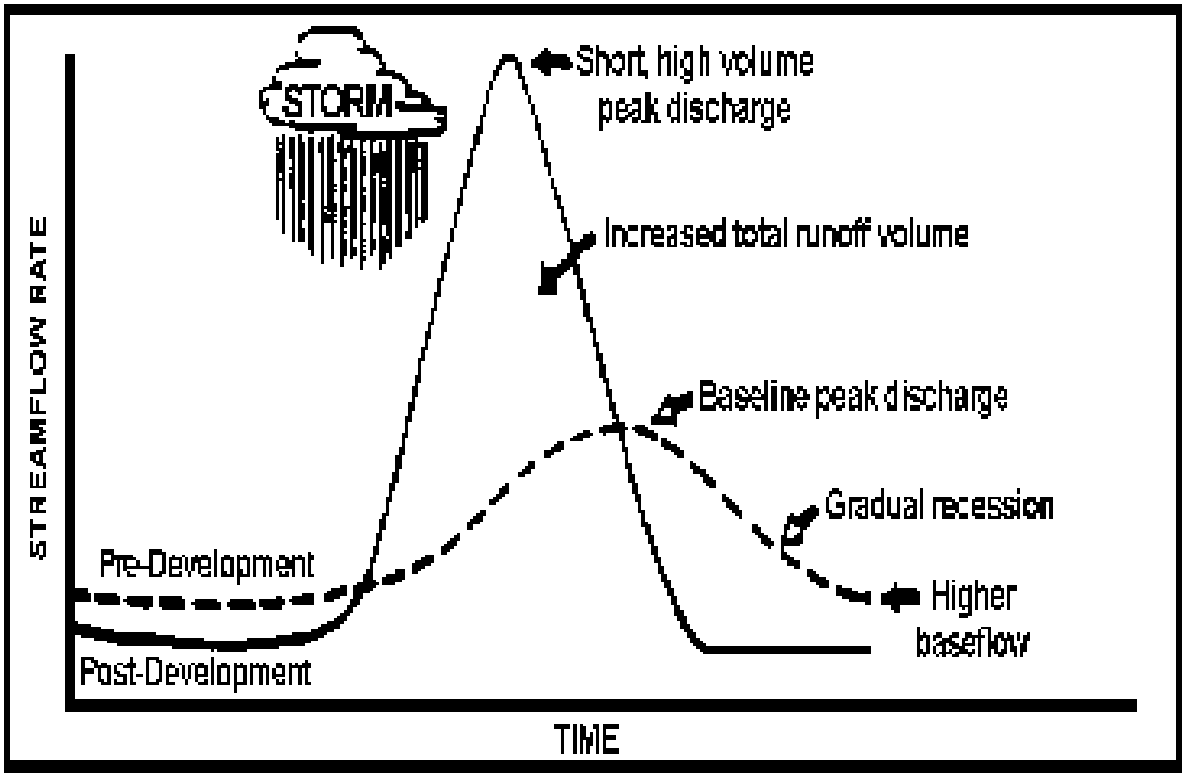
2.1 PREAMBLE

Flooding is caused when more rain falls than the land can absorb or water courses, drainage and sewerage systems can cope with. Pipes and drains may become blocked by debris. Water levels rise and spill over river embankments. Sewage rises in the sewers and escapes through drains, along with rodents. As a consequence flood water is often polluted by sewage, chemicals and also from animal faeces if water has run off fields. Polluted flood water can cause a wide range of infectious diseases such as diarrhoeal diseases (Ross, 2005).

Other risks are from injuries, drowning, chemical contact, being stranded, having no power or clean water and the stress and anxiety caused by these situations. These can affect a wide range of people. The most vulnerable are the very young, the elderly and those with certain pre-existing conditions for example, individuals on kidney dialysis and those whose immune system is not working well (Lozano et al, 2008).

In a study of 22 Puget Sound streams, May et al. (2006) found that the key index for gauging impacts on urban streams is total impervious area (TIA). Total impervious area is composed of rooftop and transport (e.g. roads and driveways) components. The rooftop component is typically disconnected impervious area where runoff is captured by yards and given opportunity to infiltrate. Transport imperviousness is directly connected to drainage systems and often results in greater hydrologic impact than rooftop

imperviousness. Research conducted in many geographical areas has similarly concluded that stream degradation occurs at approximately 10-20% TIA (Schueler, 2007).



Source: A Hand Book of Applied Hydrology (2010)
Fig. 2.1: Hydrologic Impact of Urbanization to Stream Flow

Numerous studies have reported similar hydrologic impacts due to urbanization. Increases in peak flow magnitudes, occurrences and decreases in base flows are typically observed. An increase in TIA decreases the volume of precipitation allowed to infiltrate into the soil during a storm event; therefore increasing the volume of surface runoff. If the surface runoff is directly connected to the stream system through roads or storm drains, the stream will produce an increased peak flow magnitude in a shorter time-period than observed in an undisturbed stream system (Siddique, et al, 1991). Hammer (2002) and Hollis (2005) found that peak flows with recurrence intervals of 2-years increased by factors of two,

three, and five with 10, 15 and 30 percent impervious development, respectively. Hollis also concluded that the effects of urbanization are greatest with more frequent storm events and diminish as flood size and recurrence interval increase. The increase in surface runoff and decrease in infiltration reduces the natural groundwater storage that becomes available for summer base flow (Schueler, 2000). Streams influenced by urbanization in the San Francisco Bay area have been documented changing from perennial to flashier intermittent streams with non-existent base flows (Mangarella and Gary, 2002).

Urbanization also affects the availability of sediment supplies and stream channel morphology. Available sediment sources can increase during urban construction and then decrease because of the increased stability of the urban landscape. Also, stream channel morphology adjusts to the increase in frequency of channel forming flows. Channel adjustments are often characterized by enlargement including: widening and down cutting of the streambed. As an indicator for channel destabilization, Booth et al. (2009) used the increase in percent impervious area. In the Pacific Northwest Booth (2010) and Reinelt (2005) suggest a threshold of 10% TIA for urban stream stability. This widening and destabilization of the channel has resulted in habitat degradation. The EPA (2011) reported that increased erosion in urbanized channels is a significant cause of fish habitat degradation. May et al. (2000) found that as the TIA exceeded 20%, fine sediment (<0.85 mm) usually exceeded 15%, which is the level at which sediment becomes harmful to salmonids. Aquatic insects were significantly reduced as fines exceeded 15%. The fish community became less diverse with increasing TIA, with most impacted systems retaining only cutthroat trout.

Management strategies can be useful to minimize and mitigate many of the impacts of urbanization. Mangarella and Palhegyi (2002) review many different management programs that have been implemented nationwide. Typically, these programs focus on implementing Best Management Practices (BMP's) to maintain natural functions of the hydrologic and geomorphic processes, protect riparian corridors, and integrate storm water control measures into development to mitigate expected impacts. Some suggested actions include: maintaining the natural rainfall-runoff ratios, protecting hydrological sensitive areas, sediment sources, and sensitive habitat areas, minimize and hydraulically disconnect impervious areas, such as rooftops, rain gutters, parking lots and roads, minimize topography changes and soil compaction, cluster development in less sensitive areas, integrate flood control and water quality structure into the landscape, and stream channel day lighting.

Channels are assumed to be in equilibrium with present flow: that is, a balance between water discharges, sediment transports, erosion and deposition such that even where channels move across their flood plain they tend to maintain a fairly constant size. This equilibrium state may change as a result of human activity such as the process of urbanization and urban development (Knighton, 2003).

One of the important geographical processes is the activity in a drainage system. A drainage system is initiated when a new land surface is formed by uplift of the sea floor. Stream begins to flow over it and excavate valleys, their courses mainly directed by the general slop of the surface but also controlled by any irregularities which it may possess. In course of time a valley becomes deepened and widened, and the river is extended by tributaries (Knighton, 2003).

River channels adjust themselves in size and shape in response to the amount of water they carry. In small drainage basins, discharges are low and channels small, but in large drainage basins, the river channels become larger because they are carrying more water. Many studies such as Smith and Stopp, 2009, revealed that as the size of drainage basin increases so does the size of river channel and that the relationship is approximately linear when the data are plotted on graph paper. Within areas of similar climate, this broad trend will be fairly consistent unless other conditions increase or decrease the amount of water available within the river system.

2.2 PRECIPITATION: precipitation includes rainfall, snowfall, and other processes by which water falls to the land surface, such as hail and sleet. The formation of precipitation requires the lifting of an air mass in the atmosphere so that it cools and some of its moisture condenses. The three main mechanisms of air mass lifting are frontal lifting, where warm air is lifted over cooler air by frontal passage: orographic lifting, in which an air mass rises to pass over a mountain range; and convective lifting, where air is drawn upwards by convictive action, such as in the center of a thunderstorm cell. Convictive cells are initiated by surface heating, which causes a vertical instability of moist air, and are sustained by the latent heat of vaporization given up as water vapor rises and condenses. (Ibrahim, 2004).

2.3 SURFACE DRAINAGE SYSTEM

These systems apply to land in ground water systems and cannot be used because of the inadequate infiltration or percolation characteristics of the main root zone and/or inadequate hydraulic conductivity in the substrata. In flat lands, a drainage system is required to discharge water coursed by excessive rainfall or irrigation over the soil surface.

Two major components are essential: a graded and smooth ground surface free of small depressions with an appropriate slope to enable the surface runoff to flow without producing soil erosion: and surface drainage and shallow ditches to convey the drainage water towards the outlet into the main drainage system (Igboro, 1997).

2.4 DESIGN CRITERIA FOR DRAINAGE CANALS

2.4.1 The Quantities of Properly Designed Channels Include:

i. A flow velocity that neither scours nor causes sedimentation

ii. Sufficient capacity to carry the design runoff

iii. Adequate flow depth to drain the land

iv. Stable side slopes which will not cave into the drainage canal

2.4.2 Design Capacity of Drainage Canal: the Design Capacity of Drainage Canal is influenced by:

v. Rainfall

vi. Size of drainage basin (catchment area)

vii. Soil characteristics

viii. Vegetation

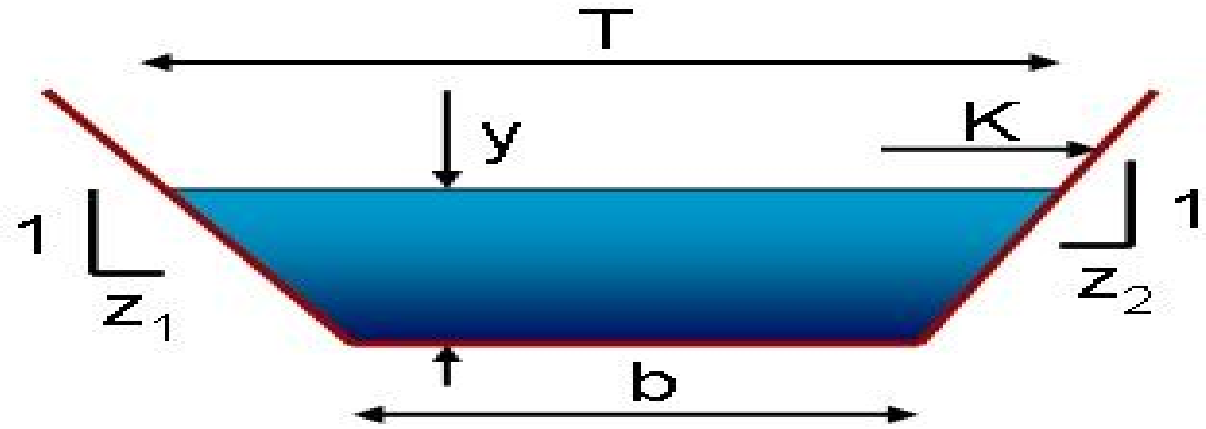
ix. Topography of the catchment area

x. Degree of protection in catchment area

It should be noted that the hydraulic design of drainage canals may be based in all cases on steady uniform flow (discharge is constant in time and also constant along the length of the canal section concerned).

Many natural and man-made channels are approximately trapezoidal. This calculation uses the most commonly used equation for analyzing open channels: the Manning equation. It

is the equation beginning with the velocity is equal to discharge of an area divided by the area; the Manning equation is best used for uniform steady state flows. Uniform means that the cross-sectional geometry of the channel remains constant along the length of the channel, and steady state means that the velocity, discharge, and depth do not change with time. Though these assumptions are rarely ever strictly achieved in reality, the Manning equation is still used to model most open channel flows where conditions are relatively steady and for reaches (portions of rivers) that have a reasonably constant cross-section for a long enough distance that the depth remains fairly constant (Igboro, 1997).



Source: A Hand Book of Applied Hydrology (2010)
Fig. 2.1: Cross Section of Trapezoidal Open Channel

The Manning equation is a semi-empirical equation. Thus, its units are inconsistent. The factor, k, has units which allow the equation to be used properly.

A = Flow cross-sectional area, determined normal (perpendicular) to the bottom surface.

B = Channel bottom width.

F = Froude number. F is a non-dimensional parameter indicating the relative effect of inertial effects to gravity effects. Flows with **F<1** are low velocity flows called subcritical**.** **F>1** are high velocity flows called supercritical. Subcritical flows are controlled by downstream obstructions while supercritical flows are affected by upstream controls.

F=1 flows are called critical.

G = acceleration due to gravity = 32.174 ft. /s^2 = 9.8066 m/s^2. G is used in the equation for Froude number.

K = unit conversion factor = 1.49 if English units = 1.0 if metric units.

N = Manning coefficient. N is a function of the channel material, such as grass, concrete, earth, etc. Values for n can be found in the table (2.1) of Manning's n coefficients shown below.

P = Wetted perimeter. P is the contact length between the water and the channel bottom and sides

Q = Discharge or flow rate [m^3/s].

R = Hydraulic radius of the flow cross-section

S = Slope of channel bottom or water surface [L/L]. Vertical distance divided by horizontal distance.

T = Top width of the flowing water

V = Average velocity of the water [L/T].

y = Water depth measured normal (perpendicular) to the bottom of the channel. If the channel has a small slope (S), then using the vertical depth introduces only minimal error.

Z1, z2 = Side slopes of each bank of the channel. These slopes are computed as horizontal distance divided by vertical distance.

Ø = Angle formed by S.

2.4.3 Channel Design Procedure: This procedure presents the theory, design criteria, basic equations, and design procedures necessary to hydraulically design of open channels. When designing open channels, the designer must be knowledgeable about the types of

flow channel, design characteristics and the basic hydraulic equations. With this background information, the designer may design stable channels through application of the flexible lining criteria and design techniques discussed in this procedure. The design procedures are: Flexible Lining Design, Steep Side Slope Protection and Bend Protection Design (Igboro, 1997).

2.5 ARTIFICIAL CHANNELS

These are channel made by man. They include irrigation canal, navigation canals, spillways sewers, culverts and drainage ditches. They are usually constructed in a regular cross section shape throughout and are thus prismatic channel. They are commonly constructed of concrete, steel or earth and have the surface roughness reasonably well defined (although this may change with age particularly grass lined channels). Analysis of flow in such well-defined channels will give reasonably accurate results (Plates. 2.3 to 2.6).



Plate 2.3: Rectangular Artificial Channel constructed of concrete and modular blocks. These types of Configuration present a public safety concern during storm events.



Plate 2.4: Trapezoidal Artificial Concrete Channel



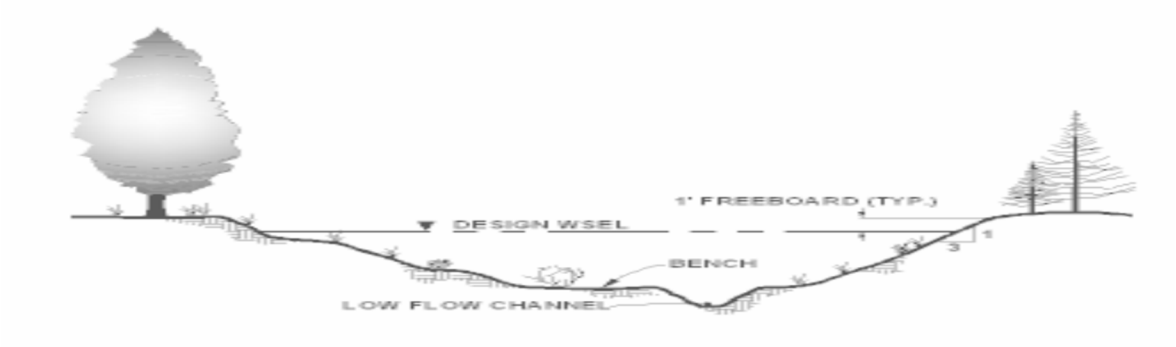
Plate 2.5: Large Drainage way with Reinforced sod Channel lining to maintain stability downstream sinkhole construction**.**



Plate 2.6: Large, Retrofitted Urban Composite Channel using Articulated Concrete Blocks

2.6 NATURAL CHANNELS

Natural channels can be different they are neither regular nor prismatic and their material of construction can vary widely (although they are mainly of earth this can possess many different properties) (Booth, 2009). The surface roughness will often change with time distance and even elevation. Consequently it become more difficult to accurately analyses and obtain satisfactory results for natural channels than it does for man-made ones, the situation may be further complicated if the boundary is not fixed i.e. erosion and deposition of sediments (Douglas, 2001).



Source: A Hand Book of Applied Hydrology (2010)
Fig. 2.3 Natural Channel

2.7 RAINFALL

The main component of hydrological cycle forming the principal source of water on the global land area is precipitation, which can be liquid or solid form except for melting snow already lying on the ground. It is the liquid form of rainfall, which gives large quantities in shorter duration and thereby gives the drainage engineer the greater cause for concern (Johnson, 2003).

2.8 RUNOFF

In most cases the runoff from rainfall determines the peak discharge in the drainage pathways. Therefore, the basics of the rainfall runoff process have to be understood for a correct design of discharge and storage capacities in each pathway.

For description process, distinction is made between paved and unpaved surfaces.

2.8.1 Paved Surfaces: Roofs and any kind of pavements are considered paved areas. A greater part of rainfall is contributing discharge to the channel, while smaller portions are loss by wetting, depression storage evaporation and infiltration.

2.8.2 Unpaved Surfaces: Bare and green areas are considered unpaved. Its runoff depends on climatic condition and other factors. Assumptions can be made that unpaved surface does not contributes to the discharge of the channel if the potential loss exceed rainfall depth of a storm

2.9 DESIGN CHARACTERISTICS

Inflow from the Sides: Channels that intercept surface flow from the sides must incorporate into their design criteria that follow:

1. The lining shall be carried to an elevation slightly below the ground level.
2. A cut-off wall must be placed at the top of the lining to prevent undermining.
3. Pipes discharging into the channel shall be flush with the channel lining.
4. Drainage: If hydrostatic pressure is foreseen, both weep holes and a subsurface drainage system behind the sidewalls are required.

2.9.1 Method of Run-off Estimation

Drainage engineers have developed formulas to determine the discharge of storm water; some of such formulas are:

a. The Rational Method
b. The Unit Hydrograph Method
c. The Road Research Laboratory Method
d. Graphical Peak Discharge Method
e. Tabular Method
f. Soil Conservation Service Method, etc.

A. The Rational Method

Among the various methods used in the design of channels section, here in this thesis the rational method is applied. Several methods have been employed by engineers to determine the sizing requirements for storm sewer. The most popular is the rational method. In American literature, the method was first mentioned in 1889 by Knichling for a determination of peak runoff for sewer design in New York. However, the principle was expounded much earlier by the Irish man Mulvaney (1851). In the United Kingdom (UK), the method is often referred to as the Lioyd-Davies method owing to the implication ascribed to a paper of the year: 1996.

This method assumed that the peak discharge occurs at a time of concentration (Tc) after the beginning of the rain storm when the entire basin starts contributing to runoff. The parameters Tc and C are assumed to be constant. The time of concentration is usually taken as the time for water to flow from the most remote part of the drainage area to reach the

point being considered and is computed assuming that flow velocities are constant (Ismail, 1995).

B. Unit Hydrograph Method

The unit-hydrograph, a concept attributed to Sherman 1932 is defined as the hydrograph of the surface runoff resulting from unit effective rainfall occurring in a unit of time such as one hour or one day and produced uniformly in time and space over the total catchments area.

A unit hydrograph of a water-shed is defined as direct run-off hydrograph (DRH) resulting from one unit of excess rainfall generated uniformly over the drainage area at a constant rate for an effective duration.

In practice a T hour unit hydrograph is defined as resulting from a unit depth of effective rainfall falling in T hour over the catchments. The magnitude for choosing T depends on the size of the catchments and the response time to measure rainfall effect.

The following assumptions are made which assist in its application:

i. The ordinate of all direct runoff hydrograph of a common base time are directly proportional to the total amount of direct runoff represented by each hydrograph.
ii. The excess rainfall is uniformly distributed throughout the whole drainage area.
iii. The excess rainfall has a constant intensity within the effective duration.
iv. The base line of direct runoff hydrograph, resulting from an excess rainfall of given duration is constant.
v. For a given watershed, the hydrograph resulting from a given excess rainfall reflects the unchanging characteristics of the watershed.

The assumption (IV) is never satisfied in practice because of the base length of the direct runoff hydrograph independent on the method of separation of the base flow from the direct runoff.

The assumption of hierarchy or superposition does not hold, since flood runoff is essentially a non-linear process. When less ideal storm is used, the unit hydrograph is likely to be less accurate. The unit has a specific duration such as six-hour unit hydrograph, 12-hour unit hydrograph etc., it is arbitrary and subjective. The unit hydrograph cannot be used for very large catchments (Ismail, 1995).

C. Transport and Road Research Laboratory Method

A method of flood estimation has been developed by the transport and road research laboratory of the U.K. for the determination of peak rates of flow from natural catchments for selected periods of storm rainfall. This method is applicable to catchments with an underlying deposit nearest the surface of clay or boulder clay.

The method is not intended for the estimation of complete hydrographs but resembles the rational method. The work has been based on rainfall and run-off data recorded on the continued basis for several years.

2.10 FACTORS AFFECTING RATIONAL METHOD:

Normann (2005), down listed the factors affecting the rational method with the relevant formulae. The factors are as follows:

2.10.1 Time of Concentration: The rational formula assumes that the peak discharge occurs at the time of concentration (Tc) after beginning of the storm when the entire basin starts contributing to the runoff. The time of concentration is the time for water to flow from the most remote part of the drainage area to reach the point being considered. The

time of concentration for runoff to reach the drainage channels varies with the surface slope, nature of the soil, length of the path of surface flow and other factors such as wetting, depressions storage evaporation and infiltration.

2.10.2 Inlet Time: The inlet time is affected by characteristic and slope of the ground surface, its selection has considerable influence upon rainfall intensity rate. The inlet time may be as short as 5 minutes for closely spaced street inlets of ample size on areas with highly developed or with steep slopes, or 10 to 15 minutes on flatter slopes with greater inlet spacing. In certain cases, an inlet time up to 20 to 30 minutes may be considered for relatively flat residential areas with inlet spaced at relatively long distance and where some surface pounding is not objectionable (Aminu, 2002).

2.10.3 Catchments Area: For rational method, the catchments area is important in determining it accuracy, since it assumes uniform rainfall distribution over the area. The slope of catchments affect runoff, the more steeply the ground surface, the more rapidly will surface runoff travel, so the concentration time will be shorter and flood peaks higher, infiltration capacities tends to be lower as slopes get steeper.

The shape and orientation of catchments also affect runoff – when a rainstorm does not cover the whole catchments at once but moves over it from one end to the other. It takes less time for larger areas with narrow width to contribute to the discharge at the outlet of drainage basin.

It is therefore important that the catchments area must be accurately determined for rational method. A good way of achieving this is to divide the entire area into sections and

each sections contributing to a point of inlet and this can be done with a good topographic maps, showing contour lines or by carrying out field survey (Stopp, 2002).

2.10.4 Runoff Coefficient: Pondage in depression, evaporation, absorption and other factor reduce the runoff, so that not all the rainfall even on impervious surfaces, reaches the channel inlets. The longer the storm duration, the longer may be the percentage of rainfall runoff.

Estimate of relatively proportion of pervious and impervious area can be made by considering the present development of a number of typical areas in the more completely developed section of the city for which storm servers are to be designed (Table 3.1). The proportion of pervious and impervious areas probably affects the runoff as much as any other factor.

Table 2.1 Runoff Coefficient uses for Urban Areas.

DESCRIPTION OF AREA	RUNOFF COEFFICIENT
Business	
Downtown	0.70 to 0.95
Neighbour hood	0.50 to 0.70
Residential	0.30 to 0.50
Single family	0.40 to 0.60
Multi-units detached	0.60 to 0.75
Multi-units attached	0.25 to 0.40
Residential (Sub-urban)	
Apartment	0.50 to 0.70
Industrial	0.50 to 0.80
Light	0.60 to 0.90
Heavy	0.10 to 0.25
Park, cemeteries	0.20 to 0.35
Play grounds	0.20 to 0.40
Railway yard	0.20 to 0.40
Unimproved	
CHARACTER OF SURFACE	**RUNOFF COEFFICIENT**
Pavement	
Asphalt and concrete	0.70 to 0.95
Brick	0.70 to 0.85
Roofs	0.70 to 0.95
Lawn, sandy soil	
Flat, 2 percent	0.05 to 0.10
Average, 2 to 7 percent	0.10 to 0.15
Steep, 7 percent	0.15 to 0.20
Lawn, heavy soil	
Flat, 2 percent	0.13 to 0.17
Average, 2 to 7 percent	0.18 to 0.22
Steep, 7 percent	0.25 to 0.35

Source: A Hand Book of Applied Hydrology, by Chow, 1987

2.10.5 Rainfall Intensity: In determining rainfall intensity, in other for use in the rational formula, it is observed that the greater the intensity of rainfall, the shorter the duration. It is therefore important that a sewer designer requires some relationship between the duration and expected intensity of rainfall. The intensity of rainfall varies for different part of the country. The intensities can be obtained for different areas either by using curves or use of an equation.

2.10.6 Permissible Velocities: In other to prevent sedimentation and vegetation growth in channels, the minimum permissible velocity is important in the design. Surface water contains suspended solids which could be deposited if the drains are not steep enough.

Therefore, there is need to construct the sewers with optimum velocities that will prevent sedimentation and wearing away of the channels. This velocity can be obtained by making the gradient of the channel steeper than that of the ground surface. The permissible velocity should not be less than 0.6m/s as recommended by Chow.

2.11 Channel Material and Lining: The materials used for lining of the channel and the body of a build-up channel include concrete, cement, sand, block, stone masonry etc., the selection depends mainly on the availability and the cost. For this thesis, the channel section is a trapezoidal cross-section, lined with reinforced concrete, with n value of 0.015.

Table 2.2: Shows the Ranges of n for Natural Channels and Excavation With or Without Lining

Channel Material	**Manning Coefficient (n)**
Metals	0.010 – 0.024
Lucite, glass, cement	0.009 – 0.013
Concrete	0.011 – 0.045
Wood	0.012 – 0.017
Clay	0.013 – 0.016
Gravel bottom canal	0.020 – 0.033
Masonry lining	0.025 – 0.032
Asphalt	0.013 – 0.016
Vegetal lining	0.030 – 0.500

Source: A Hand Book of Applied Hydrology, (2000)

2.12 SURVEYING

It is beautifully said that, ‘if you fail to plan, then you plan to fail'. Surveying is the art of determining the relative position of distinctive features on the surface of the earth or beneath the surface of the earth, by means of measurements of distances, directions and elevation. And the aim of survey is: To determine the longitudinal profile of the proposed drain, to determine the amount of earth work during the time of construction, to determine the invert level of the main drain (Agor, 2008). The type of survey and description of the methods are as listed below:

a) **Leveling:** The art of determining relative altitudes of points on the surface of the earth or beneath the surface of the earth is called leveling.

b) **Booking and Reduction of the Level:** Booking and Reduction of the levels may be done by the following two methods:

2.12.1 Rise and Fall Method: In this method, the different of level between two consecutive points for each setting of the instrument is obtained by comparing their staff reading.

The different between their staff reading indicates a Rise if the Back staff reading is more than the Foresight (FS) and a fall is less than the foresight. The Rise and Fall worked out for all points give the vertical distance for each point relative to the reading one. If the reduced level of the Back staff (BS) point is known then Reduce level (RL) of the following point may be obtained by adding its rise or subtracting its Fall from the Reduce level of preceding point as the case may be.

2.12.2 Height of Collimation Method: in this method Height of the Instrument (HI) is calculated for each setting of the instrument by adding the Back Sight (BS). The reduce level of the first station is obtained by substituting its Foresight (FS) from the instrument height (IH). For the second setting of the instrument, the height of the instrument is calculated by adding the back sight taken on the first station to its reduced level. The reduced level of the last point is obtained by subtracting the fore sight of the last point from the height of the instrument at the last setting. If an intermediate sight is observed to an intermediate station, its reduced level is obtained by subtracting its foresight from the height of the instrument for its setting.

2.13 Basic Concept for Channel Design

According to Matthews (1991), in design of urban drainage system, the area most comprises of mainly residential. The area is to be surveyed for design purposes of the drainage. The criteria involved in drainage design are basically hydrological and hydraulics design (Schall et. Al, 2008).

2.13.1 Hydrological Design Concept: In the hydrological design, the factors to be considered are: the geographical and geology characteristics, the probability of occurrence of an event and the rainfall data such as Rainfall Intensity, etc.

2.13.2 Hydraulics Design Concept: The quantity of runoff that the drain would hold is important for the design of urban drainage. It is not very convenient and not practicable to measure the flow directly. The estimated runoff from the rational method formula is also used for the design flow.

The cross sectional flow of the channel is also essential, since it is affected by the ratio of area of flow to the wetted perimeter, and the value of the hydraulic mean depth. For a uniform flow, the mean velocity and discharge depend on the hydraulic depth and the bed slope.

The optimum slope of the channel is that producing a maximum discharge for a given area, bed slope, surface roughness and that with smallest wetted perimeter. Channel with minimum wetted perimeter requires least amount of lining material. The optimum cross section would be the cheapest. The following parameters are to be considered in the design of urban drainage system (Ismail, 1995).

Where:

F = free board

Y = depth of flow

B = width of channel

Z = channel slope

n= Manning Coefficient of roughness

S= Bed Slope

2.14 Bill of Engineering Measurement Evaluation

It is essential for the purpose of contract documents to determine the cost of construction. The purpose of contract documents is to portray clearly by words and drawings the nature and the extent of the work to be performed and conditions known or anticipated under which the work is to be executed.

Frequently, the work is divided into various items with either unit price or lump sum bids received for each item of work. The contract document must limit these items to obviate all possible confusion in mind of bidder with regard to methods of measurement and payment. The sub-division of the work often is based on local customs or customs and convention of the designing engineer.

The unit price bids have been used most generally where quantities of framework are likely to be adjusted or varied during construction (Aminu, 2002).

2.14.1 Preparation of Bill of Engineering Measurement: In practice, it has been found that a schedule can be made setting out the quantity of each type of work in recognized units of measurement and that estimated prices can be built up for the labour and material involved in each unit. This schedule is the bill of quantities. Appendix 'B' shows the details of 'taking off' (Calculations).

The preparation of a bill of quantity divides itself into three distinct stages:

a) The measurement of the dimensions from the drawings by the "Take off".
b) The working out of the volumes, areas, (Known as squaring the dimensions), the casting up their totals and the entering of all the results on the abstract, which will collect and classify them in a recognized order preparatory to the writing of the bill.
c) The casting up of the abstract, the reducing of totals to recognized units, and transfer of the results to a schedule or bill having money columns ready for pricing out.

2.14.2 General Quantities Estimate: The bill of quantities usually formed is the contract documents, the contract providing that the quantity of work comprised in the contract shall be that set out in the bill of quantity. In such a case, the builder is expected to do and the

employer to pay for neither more nor less than the quantities given, an arrangement which is fair to both parties. It will thus be seen how important accuracy is in the preparation of the bill, and how a substantial error might lead a building owner to enter into a constant which involves a sum considerably beyond that he contemplated. It must not be forgotten that the bill of quantities in its normal use produces only an estimate.

CHAPTER THREE

MATERIALS AND METHODS

3.1 MATERIALS

3.1.1 Instrument Description for Precipitation:

According to Meteorological Unit of Umar Musa Yar'Adua International Air Port Katsina, the Instruments used for precipitation records are as follows:

a) Rainfall recorder according to Hellmann from Thies-Clima No. 5.4016.03.00-2001
b) Grey lacquered design (receiving funnel according to W.H.O. recommendations)
c) Built-in floating chamber with siphoning device
d) Float gauge
e) Recording device
f) Recording clockwork
g) Leveling indicator.

3.1.2 Accessories for Precipitation Instrument: these are the instrument used for the precipitation records. The instruments are listed below

i. Exchangeable dirt filter
ii. Spare siphoning tube
iii. Collection can with cover and
iv. Measuring cylinder

3.1.3 Description of An Area for Precipitation in the Study Area: The following areas are the area, measurement and units used for precipitation record with respect to this thesis.

i. Receiving surface 200cm^2
ii. Measuring range 0 – 10 mm precipitation
iii. Capacity of collection can: 4.51
iv. Measuring cylinder capacity: 200 cm^2 division 0 – 10 mm (1/10 mm)
v. High of housing 1200mm
vi. Nominal registering time: 31 days
vii. Paper feel: 20mm/h
viii. Length of chart: 16mm

3.1.4 Registered Values of Precipitation:

a) Intensities (mm/decade)
b) Total decadal values (mm/decade)
c) Total monthly values (mm/month)

The recorded periods are the rainy seasons and the River is seasonal in flow.

3.1.5 Recorded Stations: The following areas are the selected points by the Sokoto Rima River Basin Authority where rain gauges were fixed, the areas are as follows:

Katsina Town, Dutsin Ma, Karaduwa, Mangahi, Dan Ali, Gora. For the results of the precipitation records, please see the Tables: "Precipitation records" (in Appendix D).

3.1.6 Leveling Instrument: The instrument used for leveling is known as a level (Anurag, 2003). It consists of the following:

i. A Telescope to provide a line of sight
ii. A level tube to make the line of sight horizontal

iii. A leveling head to bring the bubble of the tube level at the center of its run

iv. A tripod to support the above three part of the level,

v. A tape which is also needed for measurement to make the equipment complete

3.2 METHODS FOR PEAK DISCHARGE OF URBAN DRAINAGE SYSTEM

The method used for peak discharge of urban drainage system in this thesis is Rational Method because of it is simplicity, less time consumption, labour and reliability.

According to McCuen (2010), the calculation of peak storm water runoff rate from a drainage area is often done with the Rational Method equation Q = CIA (U.S. units), or Q = 0.278CIA (S.I. units) where:

A = the area of the watershed (drainage area) that drains to the point for which the peak runoff rate is needed (**acres** for U.S. units) (**ha** for S.I. units)

C = runoff coefficient for drainage area A. A physical interpretation is the faction of rainfall landing on the drainage area that becomes storm water runoff. (Dimensionless for both U.S. and S.I. units)

i = the intensity of the design storm for peak runoff calculation (**in/hr** for U.S. units) (**mm/hr** for S.I. units) **Q** = the peak storm water runoff rate from the drainage area, A, due to the design storm of intensity, i. (**cfs** for U.S. units) (**m^3/s** for S.I. units).

3.2.1 Explanation of the Units: For the SI version of the equation (Q = 0.278 CiA), the 0.0028 factor is needed to convert ha to m, mm to m, and hr to sec as follows:

Q = (mm/hr) (ha) (10,000 m^2/ha) (1 m/1000 mm) (1 hr/3600 sec), or

Q = 0.278 CiA, with i in mm/hr, A in ha, and Q in m^3/s

At first glance the units don't appear to be correct for the specified U.S. units. The equation actually gives Q in acre-in/hr. The conversion factor, however, is 1.008 cfs/(acre-in/hr), and based on the precision with which the runoff coefficient can be determined, this conversion is typically taken to be 1, thus giving Q in cfs for rainfall intensity in in/hr and drainage area in acres.

The calculation of peak storm water runoff rate from the equation, Q = CiA, is quite straightforward if values are known for C, i, and A. Values for the drainage area, A, and the runoff coefficient, C, can typically be obtained without much trouble. Determination of the design rainfall intensity, i, usually requires the most effort (McCuen, 2010).

Following this formula, assumptions are made to assist in its application:

i. Runoff coefficient is constant
ii. No variation in the rate of rainfall with time
iii. No storage effects (back water) in the sewer system
iv. No variation in the rate of increase in contributing area
v. Antecedent condition
vi. The storm sequence

vii. Non-uniform rainfall, etc. are not taken.

This method is recommended and accurate for small catchments, and is acceptable for drainage areas of up to 200 acres (0.8092km^2) where only the peak discharge is of concern

3.2.2 Factors Affecting Rational Method: Normann (2005), down listed the factors affecting the rational method with the relevant formulae. The factors are as follows:

i. **Time of Concentration (Tc):** The time of concentration for storm water drainage is given by:

$$\boldsymbol{T_C} = \boldsymbol{T_I} + \boldsymbol{T_F} \quad (3.1)$$

ii **Inflow Time:** The inflow time can be calculated using the empirical formula

$$T_F = \frac{0.00013L^{0.77}}{S^{0.385}} \quad (3.2)$$

iii **Rainfall Intensity:** The equation of intensity-duration curves are often more convenient. The equation for rainfall intensity is given as:

$$I = \frac{a}{t+b} \quad (3.3)$$

a and b = locality constants, and for duration greater than two hour, then

$$I = \frac{C}{t^n} \quad (3.4)$$

Where: **c** and **n** are locality constant.

3.2.3 Intensity-Duration-Frequency Relationships: In 1935 Bilham published his well-known article on these relationships in the United Kingdom. This contained a graph. The graph used the subjective phraseology of very rare remarkable and noteworthy rather than frequency of occurrence. However, the frequencies were calculable from the formula.

$$n = 1.25t\,(r + 0.1) - 3.5 \quad (3.5)$$

Where: n = number of occurrence in 10 years

r = depth of rain in inches

t = duration of rain in hours

The work was revised and extended by Holland (1988), who showed that Bilham equation overestimated the probability of high intensity rainfall that is above by about 35mm/hr. (Ibrahim, 2004).

3.2.4 Probability Concept in Design: Reis (2007) summarized the formulae which according to him used for the design concept of urban drainages. The concept can be defined as the average interval in years between the occurrence of a rainfall of specific magnitude and an equal or longer rainfall. It can be found by using the following relationship.

$$T = \frac{N+1}{M} \quad (3.6)$$

Where: T = return period (in years)

N = number of years of records

M = rank

In this method rainfall data with the same duration are grouped together, and the highest data recorded is placed first and continue in descending order. This process of arrangement is called ranking.

If an event has a true recurrence interval of returned period (T) in years, then the probability (p) will be equal or exceed in any one-year is given as:

$$P = \frac{1}{T} \quad (3.7)$$

The probability that the event will not occur in a given year is 1 – P

The probability (K) that at least on event which is equal or exceed the return period (T) event will in any series number of year (N) is:

$$K = 1\,(1-P)^N \tag{3.8}$$

Gumbel proposed that the probability (p) of the occurrence of a value equal to or greater than any value x can be expressed as

$$P = 1 - e^{-c-b} \tag{3.9}$$

Where: e = is the exponential function

b = is given as

$$b = \frac{1}{0.77976\propto}\ (x - x + 0.45) \tag{3.10}$$

Where: x = rainfall magnitude

$\bar{x}$ = arithmetic mean

σ = standard deviation of the series computed

$$\sigma = \frac{\left(x-\bar{x}\right)^2}{N-1} \tag{3.11}$$

When N = number of years recorded

Horizontal Channel: Ragan (2002), in hydraulic design series gives the following trapezoidal formulae as:

$$A = (b + zy)y \tag{3.12}$$

$$P = b + 2y\sqrt{1 + Z^2} \tag{3.13}$$

$$R = \frac{Area\ of\ channel}{wetted\ perimeter} \tag{3.14}$$

For Optimum Cross Sections**:** Ragan (2002), in hydraulic design series also gives the following trapezoidal formulae as:

$$R = \frac{Y}{2}\ and\ Z = \frac{1}{\sqrt{3}}$$

$$\frac{(b+zy)y}{b+2y\sqrt{1+z^2}} = \frac{y}{2}$$

$$2b + 1.6y = b + 2.67y$$

$$2b - b = 2.67y - 1.16y$$

$$b = 1.15y \tag{3.15}$$

Manning Equation: Ragan (2002), in hydraulic design series also gives the following trapezoidal formulae as:

$$Q = \frac{1}{n}AR^{2/3}S^{1/2} \tag{3.16}$$

Where:

Q = discharge in m^3/s

A = area in m^2

R = hydraulic radius in m

n = Manning coefficient of roughness

S = bed slope

But b = 1.15y and z = 0.58

Substituting into Manning Equation

$$Q = \frac{1}{n} AR^{2/3} S^{1/2}$$

$$Q = \frac{1}{n}(b + zy)Y.\left(\frac{y}{2}\right)^{2/3} S^{1/2}$$

$$\frac{Qn}{S^{1/2}} = (1.15y + 0.58y)Y.\left(\frac{y}{2}\right)^{2/3}$$

$$\frac{Qn}{S^{1/2}} = \frac{2.09y^2}{1.587}.y^{5/3}$$

$$\frac{Qn}{1.317S^{1/2}} = .y^{8/3}$$

$$y = \left[\frac{Qn}{1.317S^{1/2}}\right]^{3/8} \qquad (3.17)$$

For most economic section of trapezoidal open channel, we have

$A = 1.73Y^2,\ B = 1.6Y,\ P = 3.5Y\ and\ R = \frac{Y}{2}$

$$Y = \left(\frac{0.92Q_n}{S^{1/2}}\right)^{3/8} \qquad (3.18)$$

3.2.5 Free Board: This is the vertical distance from the top of the channel to the water surface at design condition. Its purpose is to prevent waxes or fluctuation in water surface from overflowing the sides. Therefore free boards varying from less than 25% to greater than 50% of the depth of flow are commonly used in design. (Schueler, 2000). For this thesis, 25% of the depth of flow is used. The design of the channel section is based on optimum hydraulic section criterion.

3.2.6 Determination of Side Slope (Z)

For trapezoidal section

$$A = (b + yz)y \quad (3.19)$$

But for most economic section: A = 1.7321Y^2 and B = 1.548Y Substituting A and B

$$1.7321Y^2 = (1.548Y + ZY)Y, \qquad Z = 0.58$$

For this particular project, as recommended, a reconnaissance survey was first carried out, then leveling of the area along which the channel should be designed. And for the booking and reduction of levels, the height of Collimation method was adopted because of it's more rapid and saves a considerable time and labour, and it's well adopted for reduction of levels for construction work such as longitudinal or cross-sectional leveling equation. Then a topographic map covering the area contributing to the runoff is considered in the computation of discharges.

For an area to be surveyed accurately, site acquaintance is importance, it involve walking over the entire area, so as to know where to position the survey line. For this project an interval of 50 Meters was measured and pegged out through the whole area (Ibrahim, 2004).

An elevation of 528.82m Above the Sea level (A.S.L) was identified from existing level at adjacent Katsina Steel Rolling Mills (DANA) and ended up at Kofar Sauri behind the city wall with an elevation of 515.04m A.S.L. A survey data shown in the A3-paper attached, (Table 4.6 to 4.8). And the Map of Ginzo channel flood plain for this thesis is shown in (Fig. 3.1 to 3.7a) (Attached papers). Meanwhile, the channel cross section shows in (Fig. 3.7b and 3.8a to 3.8c) (attached papers). In addition to this, the design profiles for this channel are also attached, shown in (Fig. 4.3 to 4.11).

3.4 SITE SELECTION FOR DATA COLLECTION

The success of any research work is so much determines by the appropriateness of the sources of data used in carrying out the work. Sources of data and techniques applied in a research determined as well as the nature and characteristics of the work.

An effective Engineering design work of drainage system deals with data information. Some of these data exist while others will have to be acquired. All these data will be collected and analyzed. As such for the purpose of this work, the following data are to be known before designing:

1. Topography of the area
2. Sub-drainage areas allocated to each sewer
3. Sewer system layout
4. Storm waste-water production
5. Soil condition along the proposed sewer track
6. Choice of the sewer material

Initially, Katsina metropolis was divided into two catchments: Katsina old city and new developing area as stated in chapter one: that the Tille basin occupies the Northern part (Old city) while the Ginzo basin occupies the Southern part (New developing area). Here in this project only Ginzo channel is to be considered.

3.3.1 Characterization of Project Area: The new developing area was grouped into the following locations: Bare open space, bare built up areas, open grassland and farmland (area of continuous cultivation).

1. **Old City:** though the old city was not wholly considered some parts of the old city drains into the new Developing area.
2. **New Develop Area:** The new developing area is larger than the old city to almost twice its area. New developing area occupy the Southern part of the city and stretches from east to west of the city cutting across the city wall, it is the catchment area which occupies the area where there is rapid expansion which follows the direction of Kankara, Kano, Daura, and Kaita roads. These catchments comprises the GRA, Kofar Marusa Layout (the modern part of the city), the half of the ancient city, the industrial area, and many academic and social institutions. These makeup the **built-up areas** of the catchment.
3. **Farmland:** The farmland of continues cultivation can be found at the mouth of the river near Kofar Sauri behind city wall, GDSS Kofar Sauri, and upstream behind GGCK around new stadium and around GRA Juma'at Mosque.
4. **Bare Open Space:** The bare open spaces are found scattered everywhere in this catchment area. The prominent ones included Sabon Layi Police Compound, SUNCAIS's play-ground, Emir's Palace ceremonial ground, Filin Samji play-ground, UPE and Garama primary school play-ground.
5. **Open Grassland:** The open grassland areas are the GRA children's park, Lambun Khadija Park, Lugard Park, Kofar Marusa Fadama land, and lastly the area between Kofar Durbi and Kofar Sauri Fadama and Forested land.

Table 3.1 Katsina new Developing Area and some part of Old City

Identification of an Area	Description of an Area	Name of an Area	Total Area Covered (km^2)
WAKILIN KUDU 1	❖ Farm land ❖ Built-up Area	GDSS k/sauri Adjecent Katsina steel Rolling mills to s/unguwa	0.22 0.41
WAKILIN KUDU 2	❖ Built-up Area ❖ Bare Open Space ❖ Farm land	k/kaura new lay out S/layi Police Compound B/hind GCK Katsina	0.3 0.21 0.5
WAKILIN KUDU 3	❖ Built-up Area ❖ Farm Land	GRA Children parkK/marusa Low cost and Ida quarters UPE and Garama Play Ground and After GRA Jumat Mosque	0.4 0.11
WAKILIN GABAS	❖ Open Grass Land ❖ Bare Open Space ❖ Built-up Area	Lambun Khadija Park SSUNCAIS's Play Grd K/durbi quarters and Area council	0.13 0.33 0.91
WAKILIN YAMMA 1	❖ Built-up Area ❖ Open Grass Land ❖ Bare Open Space	Tudunmatawalle and R/dadi quarters Luggard Park Emir's palace Ceremonial ground and FilinSanji Play Ground	0.31 0.08 0.12
WAKILIN YAMMA 2	❖ Farm Land ❖ Built-up Area	B/hind new Stadium Katsina Bayan Abattoir and K/yandaka	0.48 0.63

Source: Katsina State Land and Survey Department, 2011.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 PREAMBLE

One of the important aspects of every research work is to come out with appreciable results which will accurately give the desired outcome. As such the results of this work are tabulated in Table 4.1 and 4.2 below. The depth of designed channel is too deep considering the channel crossed along the densely populated areas. The design shows that: the minimum depth of designed channel is 1.4m and the maximum depth of designed channel is 3.1m, the minimum width of designed channel is 0.8m while the maximum width is 2.9m (Table 4.1). But the actual (natural) width of the channel is between 10.3m to 20.82m as shown in (Plates1.1 to 1.5e). Therefore, for the safety purposes, the channel is adjusted using Trial and Error method. In the adjustments (Table 4.2): the depth of designed channel in section one does not changed but the width changed from 0.8m to 1.3m. From section two to section six, the width of designed channel varies based on the volume of the storm water it carries, in which the depth of designed channel kept constant all through as 1.5m including freeboard. (Appendix 'C') shows the detail calculations of table 4.1.

Table 4.1: Design for the Trapezoidal Channel Drains for Katsina Metropolis

Description of an Area	Area (km^2)	C_{WET}	Q (m^3/s)	Y (m)	B (m)	R (m)	P (m)	A (m^2)	V (m/s)	S	f (m)	H (m)
Area 1	0.63	0.4	5.50	1.1	0.8	0.55	3.8	2.1	2.6	.0072	0.28	1.4
Area 2	1.02	0.33	12.61	1.5	1.7	0.73	5.2	3.8	3.3	.0072	0.38	1.9
Area 3	0.51	0.61	19.21	1.73	2.0	0.93	5.9	4.9	3.9	.0074	0.43	2.2
Area 4	1.36	0.54	34.81	2.2	2.6	1.10	7.6	8.2	4.2	.0071	0.55	2.8
Area 5	0.51	0.54	40.61	2.31	2.7	1.12	7.9	8.9	4.6	.0068	0.58	2.9
Area 6	1.12	0.42	50.51	2.5	2.9	1.22	8.7	10.6	4.8	.0065	0.63	3.1

Source: Field Work, 2012

Table 4.2: Adjusted Values of Ginzo River Channel

Description of an Area	Y (m)	∑Q (m^3/s)	A (m^2)	B (m)	T (m)	Freeboard + Y (m)
Area 1	1.1	5.50	2.1	1.3	2.7	1.4
Area 2	1.2	12.61	3.8	3.0	4.4	1.5
Area 3	1.2	19.21	4.9	4.1	5.5	1.5
Area 4	1.2	34.81	8.2	7.4	8.8	1.5
Area 5	1.2	40.61	8.9	8.1	9.5	1.5
Area 6	1.2	50.51	10.6	9.8	11.2	1.5

Source: Field Work, 2012

4.2 REINFORCEMENT DETAILING

To resist cracking of concrete BS8110 Code of practice specifies that details such as the minimum area of reinforcement required in a section and limits to maximum and minimum spacing of bars. Calculations are based on strip slab design. Appendix 'A' gives the detail of reinforcement calculations.

Table 4.3: Sectional Area and Bar Spacing

Sectional areas per meter width for various bar spacing (mm^2)									
Bar size (mm)	Spacing of bars								
	50	**75**	**100**	**125**	**150**	**175**	**200**	**250**	**300**
6	566	377	283	226	189	162	142	113	94.3
8	1010	671	503	402	335	287	252	201	168
10	1570	1050	785	628	523	449	393	314	262
12	2260	1510	1130	905	754	646	566	452	377
16	4020	2680	2010	1610	1340	1150	1010	804	670
20	6280	4190	3140	2510	2090	1800	1570	1260	1050
25	9820	6550	4910	3930	3270	2810	2450	1960	1640
32	16100	10700	8040	6430	5360	4600	4020	3220	2680
40	25100	16800	12600	10100	8380	7180	6280	5030	4190

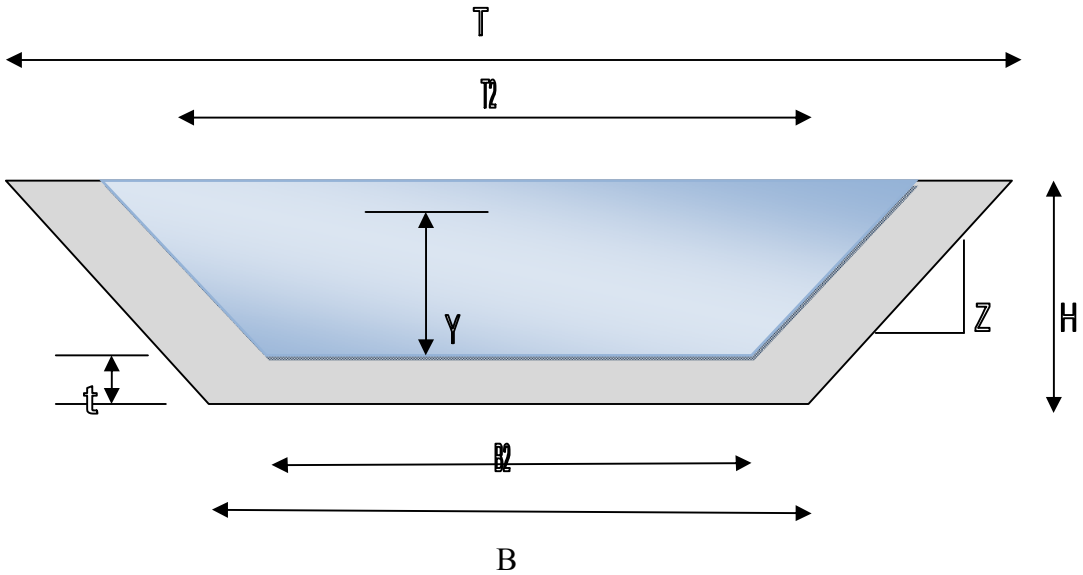


Fig. 4.1: Channel Parameters

Where: T is the top width

T_2 = Top without thickness of concrete

y = Depth of flow

t = The concrete thickness

B_2 = Bottom width without concrete thickness

B = Bottom width

Z = Side slope

H = Overall depth of the channel

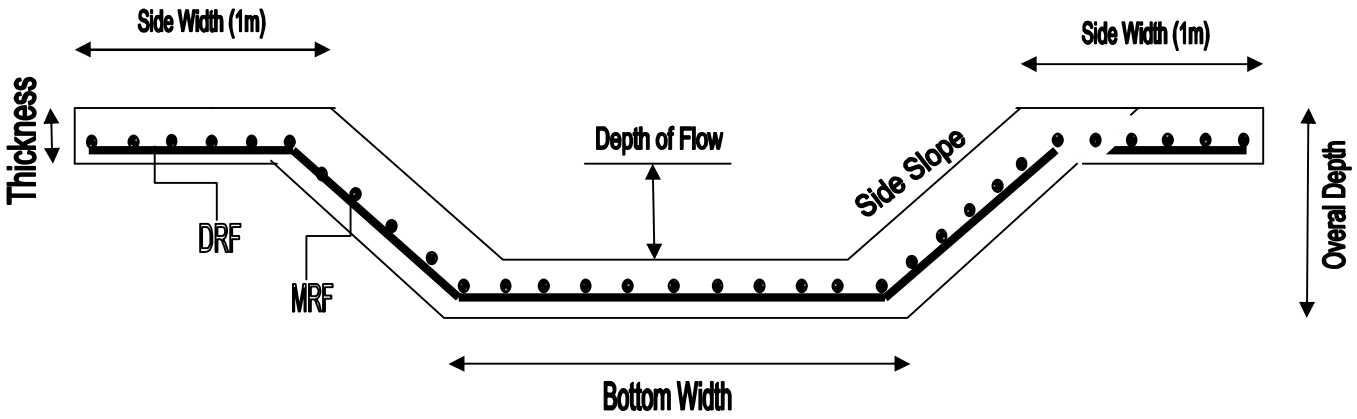


Fig. 4.2: Sectional view of Ginzo Channel

Table 4.4: Shows the Various Bar Diameters and Spacing

Section	G/L	I/L	▽H	S	L m)	B (m)	T (m)	H(m)	M_{RF}	D_{RF}	t(mm)
1	526.96	525.24	1.72	0.017	250	1.3	2.7	1.4	T10@300	T10@300	230
2	524.48	523.56	0.76	0.008	250	1.3	2.7	1.4	T10@300	T10@300	230
3	524.41	523.31	0.85	0.009	250	1.3	2.7	1.4	T10@300	T10@300	230
4	523.56	522.93	0.63	0.006	250	3.0	4.4	1.5	T12@200	T12@250	230
5	522.93	522.21	0.72	0.007	250	3.0	4.4	1.5	T12@200	T12@250	230
6	522.93	520.97	1.24	0.012	250	3.0	4.4	1.5	T12@200	T12@250	230
7	520.92	519.00	1.28	0.013	250	4.1	5.5	1.5	T12@150	T12@175	230
8	519.64	519.02	0.62	0.006	250	4.1	5.5	1.5	T12@150	T12@175	230
9	519.02	519.01	0.01	0.001	250	4.1	5.5	1.5	T12@150	T12@175	230
10	519.01	517.46	1.55	0.016	250	7.4	8.8	1.5	T16@150	T16@150	230
11	517.46	517.36	0.07	0.001	250	7.4	8.8	1.5	T16@150	T16@150	230
12	517.39	515.47	1.92	0.019	250	7.4	8.8	1.5	T16@150	T16@150	230
13	515.47	514.36	1.11	0.011	250	7.4	8.8	1.5	T16@150	T16@150	230
14	514.36	514.27	0.09	0.001	250	8.1	9.5	1.5	T16@125	T16@175	230
15	514.27	513.45	0.82	0.008	250	8.1	9.5	1.5	T16@125	T16@175	230
16	513.45	512.01	0.49	0.019	250	8.1	9.5	1.5	T16@125	T16@175	230
17	512.01	511.52	1.93	0.005	250	8.1	9.5	1.5	T16@125	T16@175	230
18	511.52	511.77	0.24	0.002	250	9.8	11.2	1.5	T16@100	T16@125	230
19	511.77	511.00	0.77	0.008	250	9.8	11.2	1.5	T16@100	T16@125	230
20	510.71	510.21	0.5	0.005	250	9.8	11.2	1.5	T16@100	T16@125	230

M_{RF}: Main Reinforcement, D_{RF}: Distribution Reinforcement, G/L: Ground Level, I/L: Invert Level, t: Thickness

Table 4.5: Billing Sheet

BILLING SHEET						
Code	Description	Unit	Quantity	Rate	Price (N)	K
	Top Soil Excavation Excavation to remove top soil average depth not exceeding 1.00m	M^3	3877.50	900	3489750	00
E125	Earth Work: (Class E) Excavation to reduce level commencing from stripped level: Max. average depth not exceed 1.00m, material for reuse.(D20-222/1	M^3	61661.50	1200	73993800	00
F411	Concrete Blinding (class F) Provision and placing of weak concrete blinding 50mm thick	M^3	1457.7	7500	10931250	00
F641	Reinforced Concrete (class F) Provision and placing of reinforced concrete	M^3	19804.24	15000	297063600	00
	Form Work Sawn form work to side and faces of incline slab not exceeding 500mm thick, not exceeding 3000mm high.	M^2	17745	290	5146050	00

G52 1	Reinforcement(class G) 12,16mm mild steel reinforcement B.S 8110: (Main and Distribution reinforcement)	Kg.	810631.67	200	162126334	00
	TOTAL				552,750,784	

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

As recommended for any successful engineering design, all necessary data were collected and a method of design was chosen (Rational Method) which is known to be the most commonly used in urban drainage for its acceptable result.

From this data provided, the discharges from different contributing areas were computed, and optimum channel cross-sections were determined. To each depth of flow computed, a certain height known as free board, which is greater than 25% of the depth of flow as recommended by Chow, was added to obtain the depth of the channel. This to prevent waxes in water from overflowing during occasional peak discharges greater than design discharges.

Flow velocity in channels are within the range of minimum and maximum permissible velocities of 0.6m/s and 3.5m/s respectively to prevent sediment deposition and abrasion of the channel's beds and sides.

Concrete lining with corresponding reinforcement and form work were computed and the cost of the construction work was estimated.

5.2 RECOMMENDATIONS

i. The government should demolish all the houses built along the Ginzo River channel with compensations.

ii. A proper, effective and adequate solid waste management should be adopted in the study area.

iii. Government should provide and effective point for refuse disposal in the study area such as incinerators. This will help prevent the dumping of refuse in the river.

iv. The government should prohibit the building of houses across and near the river.

v. There is need for public awareness regularly for the implication of dumping refuse along the channel as well as maintenance.

REFERENCES

Aminu, A. S (2002) A note on the recent flood in Katsina, Nigeria. Savanna (A Journal of the Environmental and Social Sciences.) No. 1, pp.22-25.

Ayeni, M. A. O. (2009) Patterns, Process and Problems of Urbanization, in 1--- eds. A Geography of Nigerian Development. Heineman Educational Books, (Nigeria). Pp. 156-174.

Agor, R. (2008): A Textbook of Surveying and Leveling 6th Edition. Kanna Publishers, Delhi.

Anurag, K. (2003). Element of Civil Engineering. Charotar Published House, India

Booth, D. B., (2009). Urbanization and the Natural Drainage System–Impacts, Solutions and Prognoses. Northwest Environ. J. 7(1):93–118.

Booth, D. B., and Reinelt, L. (2010). Consequences of Urbanization on Aquatic Systems Measured effects, degradation thresholds, and corrective strategies, pp. 545–550 In: Proceedings Watershed '93 A National conference on Watershed Management. March 21–24, 2010. Alexandria, Virginia.

Booth, D.B. and Jackson C.R. (2010). Urbanization of Aquatic Systems: Degradation Thresholds, Storm water Detection, and the Limits of Mitigation. Journal of the American Water Resources Association, vol. 33 (5), pg 1077-109

Chow, V. T. (1987) A hand book of applied hydrology, a compodium of water resources technology. McGraw. Hill Book Co. New York.

Cartography, Geography Dept. Umar Musa Yar'adua University, Katsina State, (2012).

Center for Disease Control and Prevention,(2004). *Key Facts about Flood Recovery*. Fact Sheet 10 September 2004. Atlanta. CDC

Center for Disease Control and Prevention,(2004). *Reentering Your Flooded Home*. Fact Sheet 27 October 2004. Atlanta. CDC

Center for Disease Control and Prevention, (2005). *After a Flood*. Fact Sheet 6 April 2005. Atlanta. CDC

Center for Disease Control and Prevention (2005) *How to Protect Yourself and Others from Electrical Hazards Following a Natural Disaster*. Fact Sheet 29 August 2005. Atlanta. CDC

Center for Disease Control and Prevention (2005) *Disinfecting Wells Following an Emergency*. Fact Sheet 10 September 2005. Atlanta. CDC

Detroit Health Department, et al. (2004) *Imminent Health Hazard Emergency Response Reference for Regulators*

Environmental Health Center (2001) *Air Quality Problems Caused by Floods* (http://www.nsc.org/ehc/indoor/floods.htm) Washington DC. National Safety Council

Federal Emergency Management Agency (2005) *Storm Drenching May Foster Mold Growth and Become a Health Hazard*. Release Number: 1612-014. 30 November 2005. Atlanta. FEMA

Government of Western Australia. *Asia Tsunami* (http://www.health.wa.gov.au/tsunami/professionals.cfm) (2005).

Gerencher, K. (2005) *Flood Waters Found Contaminated* (http://www.marketwatch.com/News/Story/Story.aspx?guid=%7B88A73C50-603B-474D-AED1-9A57341A0F0E%7D&siteid=google)

Gregory, K. J and Walling, D. E. (1999). Drainage Basin form and Process (Edward Anold), London.

Hammer, T. R., (2002). Stream and Channel Enlargement due to Urbanization. Water Resources Research, 8: 1530-1540

Hollis, G. (2005). The Effect of Urbanization on Floods of Different Recurrence Intervals. Water Resources Research, 11(3): 431–435.

Igboro, S.B. (1997). Design of Main Storm Drainage System for Samaru Town. Department of Water Resources and Environmental Engineering, ABU Zaria

Ibrahim, I. (2004). Soil Infiltration Capacity in Urbanized River Basins in Katsina Metropolis, Katsina State. Dept. Geography BUK, Unpublished M.sc. Thesis.

Indonesia Relief (2005) Rebuilding After the Tsunamis: Addressing Infectious Diseases in Indonesia. 12 April 2005 (http://www.indonesia-relief.org/mod.php?mod=publisher&op=viewarticle&cid=27&artid=654)

Ismail A. A. (1995). Storm Water Hydrological Characteristics of Semi Urban Water Shed M.Sc. Unpublished Thesis. Department of Water Resources and Environmental Engineering, ABU, Zaria.

Johnson, F.L., and Chang, F.M., (2010). Drainage of Highway Pavements, Hydraulic Engineering Circular, No. 12, FHWA-TS-84-202. Washington, D.C

Knighton , D. (2003). Fluvial Forms and Processes. Edward Arnold Ltd, Baltimore, Maryland

Lozano, F. S., Elizondo, Q. D., Farfan, A. J., Lorono, P. M., Garcia, R. J., Gomez, C. S., et al. (2008), Use of Google Earth to strengthen public health capacity and facilitate management of vector-borne diseases in resource-poor environments. *Bull World Health Organ* 2008; 86: 718-25 doi: 10.2471/BLT.07.045880 pmid: 18797648.

Leptospirosis Information Center: Online Advice and Resources for Human Leptospiral Infection (http://www.leptospirosis.org/)

Matthews, M. H. and Foster I.D.L (1991) Fieldwork Exercises in Human and Physical Geography.

Maxlock Group, (2006). Katsina Physical Setting and Structures Plan, Katsina Group, Dept. of Land and Survey, Katsina State, Nigeria.

Mabogunje, (2000), The Katsina Proposed Site Plan, Urban design and structures. Dept. of Land and Survey, Katsina State, Nigeria.

Meteorological Unit, Umar Musa Yar'adua International Air Port, (2012). Katsina, Katsina State, Annual Record for Climate Change and Weather Forecast.

McCuen, R. H., (*2010).* Hydrologic Analysis and Design, 2nd Ed*,* Upper Saddle River, NJ, ; Institute of Global Environment and Society Inc. 4041 Powder Mill Road, Suite 302, Calverton, MD 20705

May, C. C., Cooper, R. H., Karr, B. J., Mar, E. W., and Wydzga, A. (2006). Assessment of Cumulative Effects of Urbanization of Small Streams in the Puget Sound Lowland Ecoregion. A paper presented at the Urban Streams Conference held at Arcata, CA on November 15-17, 2006.

Mangarella, P. and Gary, P. (2002). Santa Clara Valley Urban Runoff Pollution Prevention Program: Hydro modification Management Plan Literature Review. GeoSyntec Consultants, Walnut Creek, CA

Management Manual, section on the Rational Method 3. U.S. Soil Conservation Service, Technical Note - Hydrology No N4, June 17,

Montana Department of Public Health and Human Services (2005) *Flood Cleanup Health Tips*

Moulton, L.K., 2000. Highway Sub Drainage Design, Publication No. 3 FUWA-TS-80-224.

Mcluen, R.H., Johnson, P.A., and Ragan, R.M., 2002. Hydrology, Hydraulic Design Series No. 2, Second Edition.

National Population Commission, (NPC) Katsina. (2012): Annual Population Statistic of Katsina State

North Carolina Department of Health and Human Services. *After the Flood… Getting Back into Your Home Safely* (http://www.dhhs.state.nc.us/docs/hurricane_afteraflood.htm)

North Dakota State University (NDSU) Extension Service. *Coping with Floods*. Various articles on health hazards and mental stress associated with floods under this title. (http://www.ag.ndsu.edu/disaster/floods/)

Noji, E. (2007) *the Public Health Consequences of Disasters*. New York. Oxford University Press

Normann, A.M., Houghtalen, R.J., and Johnston, W.J., 2005. Hydraulic Design of Highway, Hydraulic Design Series No. 5 Publication NY. FHW-NHI-01-020. Federal Highway Administration, Washington, D.C.

Public Health Laboratory Service (PHLS). 2000. *Provisional Guidelines on the Public Health Implications of Flooding*. London. (http://www.hpa.org.uk/infections/topics_az/flooding/guidelines.htm)

RUWASSA, (2011). Katsina Bed Rock Geology and Systematic Survey for the 34 Local Government of Katsina State

Ragunath, H. M. (1991). Hydrology Principles Analysis and Design Wiley Eastern Limited

Ross, E. (2005) *No Major Disease Outbreaks Yet, But Health Officials Say Clean Water and Sanitation are Key to Preventing Life-threatening Cholera, Typhoid and Dysentery*. AP Worldstream. Jakarta (http://www.sfgate.com/cgi-bin/article.cgi?f=/news/archive/2005/01/01/international1508EST0500.DTL)

Rein, K.G., 2007. The National Stream Flow Statistic Program: A Statistical Analysis, U.S. Geological Survey.

Sokoto Rima River Basin Development Authority, (SRRBDA), (2011): Annual Reports for Inter States Hydrological Records

Schueler, T. (2007). Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs. Metropolitan Washington Council of Governments, Washington, DC.

Schueler, T. (2000). Environmental Land Planning Series: Site Planning for Urban Stream Protection. Prepared by the Metropolitan Washington Council of Governments and the Center for Watershed Protection, Silver Spring, Maryland.

Siddique, A. K., et al (1991) *1988 Floods in Bangladesh: Pattern of Illness and Causes of Death*. Journal of Diarrhoeal Diseases Research 1991 December; 9(4): 310-4.

Schall, J.D., Richardson, E.V., and Moris, J.L., 2008. Introduction to Hydraulic Design Series No. 4, FHWA-NHI-08-090.

Savey, V.B., Thomas, J.R., Stricker, V.A., and Wilson, K.V., 2003. Flood Characteristic and Urban Water Sheds in the U.S.

U.S. Environmental Protection Agency, (2011). Results of the Nationwide Urban Runoff Program. U.S. Environmental Protection Agency, Water Planning Division, Washington, DC

World Health Organization, (2012) *Three Months after the Indian Ocean Earthquake-Tsunami*. (http://www.who.int/hac/crises/international/asia_tsunami/3months/report/en/index.html

APPENDIX: A
REINFORCEMENT DETAILING

Section 1– 3 is Identical

According to BS8110, assuming h = 150mm

1. Main reinforcement:

$$A = \frac{0.15bd}{100}$$

$H = d+CC+Ø/2$

Where:

D = effective depth of the slab

H = overall depth

CC = Concrete cover

Ø = Diameter of the bar

D = 150 – 25 – 6

D = 119mm Use: 120mm B = 1300mm H = 1400mm

$$A_{min} = \frac{0.15\times1300\times120}{100} = 234mm^2$$

From table 4.3 reinforcement metric data

Provide T10@300 ($262mm^2$)

2. Secondary Reinforcement

$$A_{min} = \frac{0.12bd}{100}$$

$$A_{min} = \frac{0.12\times1300\times120}{100} = 187.2mm^2$$

From table 4.3 provide T10@300 ($262mm^2$)

Section 4 – 6 is Identical

1. Main reinforcement:

$$A = \frac{0.15bd}{100}$$

D = 150 – 25 – 8

D = 117mm Use: 120mm

B = 3000mm

H = 1500mm

$A_{min} = 540mm^2$

Provide T12@200 ($566mm^2$)

3d = 360 S<3d thus, the design is safe

2. Secondary Reinforcement

$$A_{min} = \frac{0.12bd}{100}$$

$A_{min} = 432mm^2$

From table 4.3 provide T12@250 ($452mm^2$)

S<3d the spacing is safe

Section 7 – 9 is Identical

1 Main Reinforcement:

$$A = \frac{0.15bd}{100}$$

D = 150 – 25 – 8

D = 117mm Use: 120mm

B = 4100mm

H = 1500mm

$A_{min} = 738mm^2$

Provide T12@150 ($754mm^2$)

S<3d thus, the design is safe

2 Secondary Reinforcement

$A_{min} = \frac{0.12bd}{100}$

$A_{min} = 590.4mm^2$

From table 4.3 provide T12@175 ($646mm^2$)

S<3d the spacing is safe

Section 10 - 13 is Identical

1 Main reinforcement:

$A = \frac{0.15bd}{100}$

D = 150 – 25 – 8

D = 117mm Use: 120mm

B = 7400mm

H = 1500mm

$A_{min} = 1332mm^2$

Provide T16@150 ($1340mm^2$)

S<3d thus, the design is safe

2 Secondary Reinforcement

$A_{min} = \frac{0.12bd}{100}$

$A_{min} = 1065.6mm^2$

From table 4.3 provide T16@150 ($1340mm^2$)

S<3d the spacing is safe

Section 14 - 18 is Identical

1 Main reinforcement:

$$A = \frac{0.15bd}{100}$$

D = 150 – 25 – 8

D = 117mm Use: 120mm

B = 8100mm

H = 1500mm

$A_{min} = 1458mm^2$

Provide T16@125 ($1610mm^2$)

S<3d thus, the design is safe

2 Secondary Reinforcement

$$A_{min} = \frac{0.12bd}{100}$$

$A_{min} = 1166.4mm^2$

From table 4.3 provide T16@175 ($1150mm^2$)

S<3d the spacing is safe

Section 18 - 20 is Identical

1 Main reinforcement:

$$A = \frac{0.15bd}{100}$$

D = 150 – 25 – 8

D = 117mm Use: 120mm

B = 9800mm

H = 1500mm

$A_{min} = 1764mm^2$

Provide T16@100 (2010mm^2)

S<3d thus, the design is safe

2 Secondary Reinforcement

$A_{min} = \frac{0.12bd}{100}$

$A_{min} = 1411.2mm^2$

From table 4.3 provide T16@125 (1610mm^2)

S<3d the spacing is safe

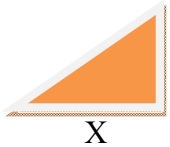
APPENDIX: B
TAKING OFF CALCULATION SHEETS

Table B1: Taking off for Ginzo River Channel

			TAKING OFF SHEET MEASUREMENT FOR OPEN STORM SEWER DRAINAGE SYSTEM Top Soil Excavation Excavation to remove top soil average depth not exceeding
3/			1.00m
	250 1.30 0.15		Section 1 to 3 is identical
		146.25	
3/	250 3.00 0.15		Section 4 to 6 is identical
		337.50	
3/	250 4.10 0.15		Section 7 to 9 is identical
		461.25	

4/ 250 7.40 0.15			Section 10 to 13 is identical
		615.00	
4/ 250 8.10 0.15			Section 14 to 17 is identical
		1215	
3/ 250 9.80 0.15			Section 18 to 20 is identical
		1102.5	
	TOTAL	3877.50	

Table B2: Earth Work for Ginzo River Channel

			Earth Work: (Class E) Excavation to reduce level commencing from stripped level: Max. average depth not exceed 1.00m, material for reuse. (D20-222/1)
3/	250 1.30 1.98		Section 1 to 3 is identical  1.4 X Sinα = 1.4/x, ⇨ x = 1.98m
		1930.50	
3/	250 3.00 2.12		Section 4 to 6 is identical  1.5 X Sinα = 1.5/x, ⇨ x = 2.12m
		4770.00	
3/	250 4.10 2.12		Section 7 to 9 is identical
		6519.00	

			Section 10 to 13 is identical
4/	250 7.40 2.12		
		15688.00	
4/	250 8.10 2.12		Section 14 to 17 is identical
		17172.00	
3/	250 9.80 2.12		Section 18 to 20 is identical
		15582.00	
	TOTAL	61661.50	E.1.2.5

Table B3: Concrete Blinding for Ginzo River Channel

			Concrete Blinding (class F) Provision and placing of weak concrete blinding 50mm thick Section 1 to 3 is identical
3/	250 1.30 0.05		
		48.75	Section 4 to 6 is identical
3/	250 3.00 0.05		
		112.5	Section 7 to 9 is identical
3/	250 4.10 0.05		
		153.75	

4/	250 7.40 0.05		Section 10 to 13 is identical
		370.00	
4/	250 8.10 0.05		Section 14 to 17 is identical
		405	
3/	250 9.80 0.05		Section 18 to 20 is identical
		367.50	
	TOTAL	1457.50	

Table B4: Reinforced Concrete for Ginzo River Channel

			Reinforced Concrete (class F) Provision and placing of reinforced concrete
3/	250 7.26 0.23		Section 1 to 3 is identical 1+1.98+1.3+1.98+1 = 7.26m
		1252.35	
3/	250 9.24 0.23		Section 4 to 6 is identical 1+2.12+3.0+2.12+1 = 9.24m
		1593.90	
3/	250 10.34 0.23		Section 7 to 9 is identical 1+2.12+4.1+2.12+1 = 10.34m
		7755.69	

4/	250 13.64 0.23			Section 10 to 13 is identical 1+2.12+7.4+2.12+1 = 13.64m
		3137.20		
4/	250 14.34 0.23			Section 14 to 17 is identical 1+2.12+8.1+2.12+1 = 14.34m
		3298.20		
3/	250 16.04 0.23			Section 18 to 20 is identical 1+2.12+9.8+2.12+1 = 16.04m
		2766.9		
	TOTAL	19804.24		F641

Table B5: Form Work for Ginzo River Channel

			Form Work Sawn form work to side and faces of incline slab not exceeding 500mm thick, not exceeding 3000mm high. Section 1 to 3 is identical 1.98 – 0.23 = 1.75m
3/2/	250 1.75		
		2625.00	Section 4 to 20 is identical 2.12 – 0.23 = 1.89m
16/2/	250 1.89		
		15120.00	
	TOTAL	17745.00	

Table B6a: Main Reinforcement for Ginzo River Channel

			Reinforcement(class G) 12mm mild steel reinforcement B.S 8110 **MAIN REINFORCEMENT** Section 1 to 3 is identical (7.26/0.3) + 1 =25.2 Number 25.2 × 250 = 6300 Number
3/	6300.00		
		18900.00	
3/	45400.00		Section 4 to 6 is identical (9.24/0.2) + 1 = 47.2 Number 47.2 × 250 = 11800 Number
		1593.90	
3/	17483.33		Section 7 to 9 is identical (10.34/0.15) + 1 = 69.93 Number 69.93 × 250 = 17483.33 Number
		52449.99	

			Section 10 to 13 is identical (13.64/0.15) + 1 = 91.93 Number 91.93 × 250 = 22983.33 Number
4/	22983.33		
		91933.33	
			Section 14 to 17 is identical (14.34/0.125) + 1 = 115.72 Number 115.72 × 250 = 115720.00 Number
4/	28930.00		
		115720.00	
			Section 18 to 20 is identical (16.04/0.1) + 1 = 161.40 Number 161.4 × 250 = 40350.00 Number
3/	40350.00		
		121050.00	
	TOTAL	445453.32	G521

Table B6b: Distribution Reinforcement for Ginzo River Channel

			Reinforcement(class G) 12mm mild steel reinforcement B.S 8110 **DISTRIBUTION REINFORCEMENT** Section 1 to 3 is identical (250/0.3) + 1 = 834.33 Number (1.3+1.98+1.98+1+1) = 7.26m Add bend: 0.1×2 = 0.2m Hence, 7.26+0.2 = 7.46m,
3/	6224.10		7.46×834.33 = 6224.10 bars
		18672.31	Section 4 to 6 is identical
3/	9449.44		(250/0.25) + 1 = 1001 Number Therefore, 9.24+0.2 = 9.44m 9.44×1001 = 9449.44 bars
		28348.32	
3/	15067.67		Section 7 to 9 is identical (250/0.175) + 1 = 1429.57 Number Therefore, 10.34+0.2 = 10.54m 10.54×1429.57= 15067.77 bars
		45203.00	

4/	23080.55		Section 10 to 13 is identical (250/0.15) + 1 = 1667.67 Number Therefore, 13.64+0.2 = 13.84m 13.84×1667.67 = 23080.55 bars
		92322.21	
4/	20785.95		Section 14 to 17 is identical (250/0.175) + 1 = 1429.57 Number Therefore, 14.34+0.2 = 14.54m 14.54×1429.57 = 20785.95 bars
		83143.79	
3/	32496.24		Section 18 to 20 is identical (250/0.125) + 1 = 2001Number Therefore, 16.04+0.2 = 16.24m 16.24×2001 = 32496.24 bars
		97488.72	
	Total	365178.35	
	445453.32 365178.35	445453.32 365178.35	Add main reinforcement and distribution reinforcement
	OVERALL		

	TOTAL	810631.67	G521

APPENDIX: C

COMPUTATION OF DISCHARGES AND VELOCITIES USING RATIONAL METHOD

Area 1

Farm Land:	$A = 0.22km^2$	S = 0.0037	C = 0.10
Built-Up Area:	$A = 0.21km^2$	S = 0.0037	C = 0.7
Paved Area:	$A = 0.11km^2$	S = 0.0036	C = 0.825
Unpaved Area:	$A = 0.09km^2$	S = 0.0037	C = 0.2

$$C_{WET} = \frac{A_1C_1+A_2C_2+A_3C_3+A_4C_4}{A_1+A_2+A_3+A_4}$$

$$C_{WET} = \frac{220000\times0.1+410000\times0.7+110000\times0.8+90000\times0.2}{630000} = 0.4$$

79.11mm/hr. is the Rainfall Intensity for Katsina Town given from Umar Musa Yar'Adua International Air Port, Katsina.

$Q_1 = 0.278\times0.4\times79.11\times630000\times10^{-6}$

$Q_1 = 5.5m^3/s$

$Y = [0.92Qn/S^{1/2}]^{3/8}$ where n = 0.015 Y = 1.1m

But the breadth b = 2×0.58y	b = 2×0.58×1.1	b = 0.8m
Hydraulic Radius R = Y/2	R = 1.1/2	R = 0.55m
Wetted Perimeter P = 3.46Y	P = 3.46×1.1	P = 3.8m
The area $A = 1.7321Y^2$	$A = 1.7321\times1.1^2$	$A = 2.1m^2$
The Velocity V = Q/A	V = 5.3/2.1	V = 2.6m/s
Free board f = 35%Y	f = 0.35×1.1	f = 0.39m
The total depth H = e+ y	H = 0.39+1.1	H = 1.49m

Area 2

Built-Up Area: $A = 0.15km^2$ $S = 0.00374$ $C = 0.7$

Paved Area: $A = 0.12km^2$ $C = 0.825$ $S = 0.0071$

Unpaved Area: $A = 0.035km^2$ $C = 0.2$ $S = 0.0072$

Bare Open Spaces: $A = 0.21km^2$ $S = 0.0072$ $C = 0.35$

Farm Land: $A = 0.5Km^2$ $C = 0.1$ $S = 0.0072$

$$C_{WET} = \frac{A_1C_1+A_2C_2+A_3C_3+A_4C_4+A_5C_5}{A_1+A_2+A_3+A_4+A_5}$$

$$C_{WET} = \frac{150000\times0.7+210000\times0.35+500000\times0.1+35000\times02+120000\times0.8}{1015000} = 0.33$$

$Q_2 = 0.278\times0.33\times79.11\times1015000\times10^{-6}$

$Q_2 = 7.11m^3/s$

Now: $Q = Q_1+Q_2$

$Q = 5.5+7.11$

$Q = 12.61m^3/s$

$Y = 1.5m$ $b = 1.74m$ $R = 0.73m$ $P = 5.2m$ $A = 3.9m^2$ $V = 3.3m/s$

$f = 0.53m$ $H = 2.03m$

Area 3

Built-Up Area: $A = 0.2km^2$ $S = 0.0073$ $C = 0.7$

Paved Area: $A = 0.19km^2$ $C = 0.825$ $S = 0.0073$

Unpaved Area: $A = 0.01km^2$ $C = 0.2$ $S = 0.0071$

Farm Land: $A = 0.11km^2$ $S = 0.0073$ $C = 0.1$

$$C_{WET} = \frac{A_1C_1+A_2C_2+A_3C_3+A_4C_4}{A_1+A_2+A_3+A_4}$$

$$C_{WET} = \frac{200000\times0.7+110000\times0.1+10000\times0.2+190000\times0.83}{510000} = 0.61$$

$Q_3 = 0.278\times0.61\times79.11\times510000\times10^{-6}$

$Q_3 = 6.6m^3/s$

Now: $Q = Q_1+Q_2+Q_3$

$Q = 5.5+7.11+6.6$

$Q = 19.21m^3/s$

Y = 1.73m b = 2.0m R = 0.93m P = 5.9m A = $5.2m^2$ V = 3.9m/s

f = 0.61m H = 2.3m

Area 4

Built-up Area:	A = $0.45km^2$	S = 0.0076	C = 0.7
Paved Area:	A = $0.31km^2$	C = 0.825	S = 0.0073
Unpaved Area:	A = $0.14km^2$	C = 0.2	S = 0.0076
Bare Open Spaces:	A = $0.33km^2$	S = 0.00764	C = 0.35
Open Grass Land:	A = $0.13Km^2$	S = 0.00765	C = 0.25

$$C_{WET} = \frac{A_1C_1+A_2C_2+A_3C_3+A_4C_4+A_5C_5}{A_1+A_2+A_3+A_4+A_5}$$

$$C_{WET} = \frac{450000\times0.7+330000\times0.35+130000\times0.25+310000\times0.8+140000\times0.2}{1360000} = 0.54$$

$Q_4 = 0.278\times0.54\times79.11\times1360000\times10^{-6}$

$Q_4 = 15.6m^3/s$

Now: $Q = Q_1+Q_2Q_3+Q_4$

$Q = 5.5+7.11+6.6+15.6$ $Q = 34.81m^3/s$

Y = 2.2m b = 2.6m R = 1.1m P = 7.6m A = 8.4m^2 V = 4.2m/s

f = 0.77m H = 3.0m

Area 5

Built-up Area: A = 0.16km^2 S = 0.0061 C = 0.7

Paved Area: A = 0.125km^2 C = 0.825 S = 0.0066

Unpaved Area: A = 0.03km^2 C = 0.2 S = 0.0063

Bare Open Spaces: A = 0.12km^2 S = 0.0066 C = 0.35

Open Grass Land: A = 0.08Km^2 S = 0.0063 C = 0.25

$$C_{WET} = \frac{A_1C_1+A_2C_2+A_3C_3+A_4C_4+A_5C_5}{A_1+A_2+A_3+A_4+A_5}$$

$$C_{WET} = \frac{155000\times0.7+120000\times.35+80000\times0.25+30000\times0.2+125000\times0.8}{510000} = 0.54$$

$Q_5 = 0.278\times0.54\times79.11\times510000\times10^{-6}$

$Q_5 = 5.8m^3/s$

Now: $Q = Q_1+Q_2Q_3+Q_4+Q_5$

$Q = 5.5+7.11+6.6+15.6+5.8$

$Q = 40.61m^3/s$

Y = 2.31m b = 2.7m R = 1.12m P = 7.99m A = 9.2m^2 V = 4.6m/s

f = 0.81m H = 3.12m

Area 6

Built-up Area: A = 0.215km^2 S = 0.0051 C = 0.7

Paved Area: A = 0.31km^2 C = 0.825 S = 0.005

Unpaved Area: A = 0.11km^2 C = 0.2 S = 0.0051

Farm Land: A = 0.48km^2 S = 0.005 C = 0.1

$$C_{WET} = \frac{A_1C_1+A_2C_2+A_3C_3+A_4C_4}{A_1+A_2+A_3+A_4}$$

$$C_{WET} = \frac{215000\times0.7+480000\times0.1+110000\times0.2+310000\times0.8}{1115000} = 0.42$$

$Q_6 = 0.278\times0.42\times79.11\times1115000\times10^{-6}$

$Q_6 = 9.9m^3/s$

Now: $Q = Q_1+Q_2Q_3+Q_4+Q_5+Q_6$

$Q = 5.5+7.11+6.6+15.6+5.8+9.9$

$Q = 50.51m^3/s$

Y = 2.5m b = 2.9m R = 1.22m P = 8.7m A = $10.83m^2$ V = 4.8m/s

f = 0.88m H = 3.4m

APPENDIX D

PRECIPITATION TABLES

Remark: According to the authorities of Umar Musa Yar'adua International Air-port: If there is indicated in the following Precipitation tables "No Records" the rainfall recorder has failed because of defective apparatus, lack of recording paper, exhausted writer etc.

Table C1: STATION: Katsina town 13^0 01'N $7^0$41'E Period: September 2006

PRECIPITATION RECORD							
PERIOD	DAY	TIME: Hours, minutes		Duration in minutes	Amount in mm	Rainfall intensity in mm/h	Total mm
		Beginning	End				
September	1st	22.10	22.15	5	0.3	3.6	
,,	4th	20.40	21.30	50	15.1	18.1	
,,	5th	0.30	3.00	150	0.8	0.3	
,,	6th	19.00	19.10	10	0.1	0.6	
,,	7th	3.20	8.20	300	6.8	1.4	
,,	8th	3.15	5.15	120	1.4	0.7	
,,	8th	18.05	18.10	5	0.8	9.6	
,,	9th	15.30	17.00	90	9.1	6.1	
,,	11th	2.20	5.45	205	15.5	4.5	
,,	13th	18.20	18.25	5	0.3	6.0	
,,	18th	17.25	17.40	15	4.1	16.4	
,,	20th	20.40	21.00	20	35.7	107.1	
,,		21.00	23.27	147	10.0	4.1	
,,	20th -21st	23.27	4.00	273	2.7	0.6	
,,	22nd	22.50	23.45	55	6.4	7.0	
,,	23rd	15.10	16.10	60	2.3	2.3	
,,	24th	3.40	3.45	5	0.1	1.2	
,,	26th	19.50	19.55	5	0.5	6.0	
,,	28th	18.45	19.00	15	2.1	8.4	
Total							

Table C2: Station: Katsina town 13^0 01'N $7^0$41'E Period: October 2006

PRECIPITATION RECORD							
PERIOD	DAY	TIME: Hours, minutes		Duration in minutes	Amount in mm	Rainfall intensity in mm/h	Total mm
		beginning	End				
October	8th	16.40	17.40	60	19.6	19.6	
,,	13th	15.15	16.10	55	12.2	13.3	
,,	17th	18.40	22.15	215	8.1	2.3	
,,	19th	22.21	22.30	20	0.1	0.3	
,,	20th	15.25	15.45	20	1.8	5.4	
,,	-	18.45	22.30	225	2.3	0.6	
,,	21st	6.01	6.20	10	0.1	0.6	
,,	23rd	15.40	17.10	90	18.0	12.0	
,,	24th	6.05	6.15	10	0.3	1.8	
,,	-	7.00	10.50	230	19.4	5.0	
	25th	17.30	18.0	40	15.9	23.9	

Table C3: Station: Katsina town 13^0 01'N $7^0$41'E Period: may 2007

PRECIPITATION RECORD							
PERIOD	DAY	TIME: Hours, minutes		Duration in minutes	Amount in mm	Rainfall intensity in mm/h	Total mm
		beginning	End				
May	5th	2.30	2.40	10	6.0	36	
,,	,,	3.40	4.20	40	14.0	20.9	
,,	,,	5.25	5.40	15	0.8	3.2	
,,	,,	7.25	7.40	15	2.2	8.8	
,,	8th	22.25	22.40	15	1.7	6.8	
,,	9th	22.10	22.20	10	0.9	5.4	
,,	18th	8.25	8.50	25	0.8	19.2	
	From 22nd to 26th may no records						

Table C4: Station: Katsina town 13^0 01'N $7^0$41'E Period: June 2007

PRECIPITATION RECORD							
PERIOD	DAY	TIME: Hours, minutes		Duration in minutes	Amount in mm	Rainfall intensity in mm/h	Total mm
		beginning	end				
June	From June 1st						
,,	until						
,,	June 4th						
,,	2007						
,,	no records						
,,							
,,	5th	4.45	5.51	66	0.3	0.3	
,,	7th	13.21	14.03	42	0.4	0.6	
,,	7th	15.52	15.17	25	0.7	1.7	
,,	8th	4.31	4.51	20	5.7	17.1	
,,		4.56	6.20	84	52.4	37.4	
,,		22.05	22.45	40	20.0	30.0	
,,	23rd	1.09	4.39	210	8.2	2.3	
,,		6.30	9.18	168	7.4	2.6	
,,	25th	17.24	17.36	12	15.8	79.0	
,,		19.15	19.30	15	1.2	4.8	
,,	29th	20.09	20.21	12	10.7	53.5	
,,		17.15	17.30	15	20.0	80.0	
,,	30th	18.30	21.26	176	3.4	1.2	
		12.25	12.38	13	9.8	45.2	
	31st no records						

Table C5: Station: Katsina town 13 01'N $7^0$41'E period: July 2007

PRECIPITATION RECORD							
PERIOD	DAY	TIME: Hours, minutes		Duration in minutes	Amount in mm	Rainfall intensity in mm/h	Total mm
		beginning	End				
JULY	1ST	0.00	2.09	129	6.5	3.0	
,,	2ND	6.45	6.51	6	0.1	1.0	
,,	5TH	21.11	22.03	52	2.7	3.1	
,,	7TH	22.03	23.54	11	13.5	7.3	
,,	9TH	23.42	24.00	1	14.4	4.8	
,,	10TH	0.00	0.24	18	2.4	6.0	
,,		0.39	1.45	24	1.7	1.5	
,,	16TH	17.44	17.52	66	0.5	37.5	
,,	17TH	6.16	7.06	8	3.5	4.2	
,,		8.36	9.30	50	0.6	0.7	
,,		10.03	10.51	54	6.1	7.6	
,,		10.55	13.30	48	8.5	3.3	
,,	21ST	14.09	14.12	155	0.8	16.0	
,,		14.54	15.18	3	0.4	1.0	
,,	22ND	0.55	1.30	24	1.4	2.4	
,,		2.00	7.00	35	7.6	1.5	
,,		19.30	22.30	300	4.6	1.5	
,,	23RD	2.57	3.54	180	1.4	1.5	
,,		5.00	6.15	57	1.7	1.4	
	From July 25th						
	until						
	July 31st 2007						
	no records						

Table C6: Station: Katsina town 13^0 01'N $7^0$41'E Period: August 2007

PRECIPITATION RECORD							
PERIOD	DAY	TIME: Hours, minutes		Duration in minutes	Amount in mm	Rainfall intensity in mm/h	Total mm
		beginning	end				
August	From August 1st to August 8th 2007 14.30h no records						
,,	8th	16.20	17.03	43	5.7	8.0	
,,		17.03	17.30	27	0.6	1.3	
,,	9th	7.00	7.33	33	0.1	0.2	
,,	10th	0.20	1.00	40	4.0	6.0	
,,		1.00	1.19	19	1.4	4.4	
,,		1.19	3.00	101	0.8	0.5	
,,	12th	22.27	23.12	45	0.4	0.5	
,,		23.12	23.20	8	5.3	39.8	
,,		23.20	23.48	28	2.0	4.3	
,,		23.48	23.57	9	1.0	6.7	
,,	15th	14.13	14.22	9	1.5	10.0	
,,		14.45	14.53	8	0.2	1.5	
,,	18th	12.55	13.00	5	0.5	6.0	
,,	20th	15.07	15.25	18	6.7	22.3	
	21st	22.30	22.38	8	10.0	75.0	
		22.38	22.51	13	1.1	5.1	
		22.51	24.00	69	1.4	1.2	
	24th	15.07	15.41	34	5.6	9.9	
		15.41	16.17	36	1.1	1.8	
		16.17	16.26	9	1.4	9.3	
		16.26	18.00	94	0.5	0.3	
		18.00	19.45	105	2.2	1.3	
	27th	7.01	7.17	16	13.7	51.4	
		7.17	7.42	25	1.6	3.8	
		7.42	8.07	25	0.6	0.5	
		10.15	10.21	6	0.2	1.0	
	28th	20	24	Bad records	0.1	142.7	
	29th	11.34	11.43	9	21.4	42.9	
		11.43	11.50	7	5.0	4.0	
		11.50	12.08	18	1.2	39.4	
		12.08	12.15	7	4.6	45.0	
		12.15	12.19	4	0.3	0.1	
	30th	12.19	13.07	48	0.1		
		22.33	Bad records		Min. 5.8		
Total							
Total							
Total							
Total							

Table C7: Station: Katsina town $13^0$1'N $7^0$41'E Period: September 2007

PRECIPITATION RECORD							
PERIOD	DAY	TIME: Hours, minutes		Duration in minutes	Amount in mm	Rainfall intensity in mm/h	Total mm
		Beginning	End				
September	1st	17.34	17.51	17	5.6	19.8	
,,	6th	1.72	1.42	15	0.1	0.4	
,,		21.08	21.12	04	0.4	6.0	
,,	7th	6.21	6.24	3	0.2	4.0	
,,	11th	17.00	17.06	6	0.3	3.0	
,,		18.00	1900	60	21.7	21.7	
,,	12th	18.33	18.39	6	0.1	1.0	
,,		22.18	22.21	3	0.1	2.0	
,,	16th	22.22	23.03	41	2.9	4.2	
,,	17th	19.36	20.33	57	11.9	12.5	
,,		21.57	23.09	72	0.8	0.7	
,,	18th	21.55	22.00	5	0.1	1.2	
,,		21.12	22.24	12	0.5	2.5	
,,		22.42	22.48	6	0.1	1.0	
,,	22nd	20.05	20.06	1	0.1	6.0	
,,		20.15	21.00	45	8.8	11.7	
,,		21.54	22.18	24	0.2	0.5	
,,	23rd	15.16	15.24	8	0.6	4.5	
,,	24th	17.50	18.00	10	0.9	5.4	
	28th	19.52	2.33	41	3.0	4.4	
	29th	20.12	21.12	60	6.7	6.7	
	30th	20.30	21.00	30	15.5	31.0	
		23.18	23.18	42	0.9	1.3	
Total							
Total							
Total							
Total							

Table C8: Station: Katsina town $13^0$1'N $7^0$41'E Period: April 2008

PRECIPITATION RECORDED							
Period	**Day**	**Time Hours, Minutes**		**Duration in minutes**	**Amount in mm**	**Rainfall intensity in mm per hour**	**Total**
		Beginning	**End**				
From April 1st until April 3rd No Record							
April	4th	6^{30}	6^{45}	15	0.6	2.4	
	5th	5^{15}	5^{30}	15	0.2	0.8	
		19^{42}	19^{48}	6	0.9	9.0	
	8th	1^{37}	1^{42}	5	3.8	45.6	
		16^{02}	16^{04}	2	0.5	15.0	
	9th	1^{38}	1^{54}	16	2.8	10.5	
	10th	15^{48}	15^{15}	3	0.3	6.0	
		16^{17}	16^{27}	10	4.3	25.8	
	11th	2^{26}	2^{42}	16	29.8	111.8	
		2^{42}	4^{06}	84	4.0	2.9	
From April 13th until April 26th – No Records							
	27th	3^{39}	3^{45}	6	3.2	32.0	
	28th	16^{27}	16^{42}	15	6.9	27.6	
		17^{56}	19^{39}	103	9.6	5.6	
	30th	5^{54}	6^{15}	21	0.3	0.9	

Table C9: Station: Katsina town $13^0$1'N $7^0$41'E Period: May 2008

PRECIPITATION RECORDED							
Period	**Day**	**Time Hours, Minutes**		**Duration in minutes**	**Amount in mm**	**Rainfall intensity in mm per hour**	**Total**
		Beginning	**End**				
May	2nd	6^{03}	7^{12}	69	14.2	12.3	
	3rd	6^{48}	7^{36}	48	30.6	38.3	
From May 3rd until May 10th 2008 – No Records							
	13th	15^{44}	15^{46}	2	1.0	30.0	
		22^{27}	22^{39}	12	0.7	3.5	
	14th	0^{28}	1^{39}	71	35.4	29.9	
	15th	20^{45}	21^{06}	21	0.3	0.9	
		21^{49}	22^{09}	20	0.3	0.9	
	16th	23^{30}	0^{30}	60	0.3	0.3	
		1^{36}	2^{00}	24	22.6	56.5	
From May 17th until May 31st – No Records							

Table C10: Station: Katsina town $13^0$1'N $7^0$41'E Period: June 2008

PRECIPITATION RECORDED							
Period	Day	**Time Hours, Minutes**		**Duration in minutes**	**Amount in mm**	**Rainfall intensity in mm per hour**	**Total**
		Beginning	**End**				
Recording started 8th June, 2008							
June	9th	3.20	3.40	20	1.5	4.5	
	9th	6.20	6.40	20	6.0	18.0	
	9th	9.00	15th 12.00	No records			
	15th	18.50	19.10	20	4.1	12.3	
	16th	18.20	18.35	15	9.6	38.4	
	16th	23.05	23.25	20	9.6	29.7	
	16th	23.25	17th 3.00	215	8.0	2.2	
	19th	3.20	5.00	100	7.6	4.6	
	21st	9.50	12.10	140	12.3	5.3	
	22nd	14.15	15.25	70	4.5	3.9	
	22nd	17.30	17.40	10	0.2	1.2	
	23rd	20.30	22.00	90	0.4	0.3	

Table C11: Station: Katsina town $13^0$1'N $7^0$41'E Period: August 2008

PRECIPITATION RECORDED							
Period	**Day**	**Time Hours, Minutes**		**Duration in minutes**	**Amount in mm**	**Rainfall intensity in mm per hour**	**Total**
		Beginning	**End**				
August	3th	15.20	16.03	43	4.5	6.3	
	5th	19.03	19.30	27	1.6	3.6	
	9th	7.00	7.33	33	0.1	0.2	
		0.20	1.00	40	4.0	6.0	
		1.00	1.19	19	1.4	4.4	
		1.19	3.00	101	0.8	0.5	

	11th	22.27	23.12	45	0.4	0.5	
		23.12	23.20	8	5.3	39.8	
		23.20	23.48	28	2.0	4.3	
		23.48	23.57	9	1.0	6.7	
	14th	14.13	14.22	9	1.5	10.0	
		14.45	14.53	8	0.2	1.5	
	17th	12.55	13.00	5	0.5	6.0	
	19th	15.07	15.25	18	6.7	22.3	
	23rd	22.30	22.38	8	10.0	75.0	
		22.38	22.51	13	1.1	5.1	
		22.51	24.00	69	1.4	1.2	
	25th	15.07	15.41	34	5.6	9.9	
		15.41	16.17	36	1.1	1.8	
		16.17	16.26	9	1.4	9.3	
		16.26	18.00	94	0.5	0.3	
		18.00	19.45	105	2.2	1.3	
	26th	7.01	7.17	16	13.7	51.4	
		7.17	7.42	25	1.6	3.8	
	27th	7.45	8.07	25	0.6	0.5	
		10.15	10.21	6	0.2	1.0	

Table C12: Station: Katsina town $13^0$1'N $7^0$41'E Period: May 2009

PRECIPITATION RECORDED							
Period	**Day**	**Time Hours, Minutes**		**Duration in minutes**	**Amount in mm**	**Rainfall intensity in mm per hour**	**Total**
		Beginning	**End**				
May	7th	1^{21}	1^{39}	18	1.5	5.0	
	8th	2^{58}	3^{01}	3	0.1	2.0	
		3^{24}	3^{32}	8	3.0	22.5	
	13th	13^{49}	14^{06}	17	12.4	43.8	
		14^{50}	14^{52}	2	1.3	39.0	
	16th	14^{54}	14^{57}	3	1.3	26.0	
	17th	0^{28}	0^{30}	2	0.1	3.0	
	18th	12^{33}	12^{35}	2	0.5	15.0	
From May 18th until May 29th No records							
	30th	1^{57}	1^{58}	1	0.1	6.0	
		2^{07}	2^{09}	2	0.2	6.0	
		3^{13}	3^{15}	2	0.9	27.0	
		15^{23}	15^{33}	10	6.8	40.8	

Table C13: Station: Katsina town $13^0$1'N $7^0$41'E Period: June 2009

PRECIPITATION RECORDED							
Period	**Day**	**Time Hours, Minutes**		**Duration in minutes**	**Amount in mm**	**Rainfall intensity in mm per hour**	**Total**
		Beginning	**End**				
June	1st	4.00	6.50	170	7.7	2.7	
"	"	9.00	11.50	170	0.1	0.04	
"	5th	0.40	3.00	140	1.3	0.6	
"	7th	2.20	3.05	45	10.0	13.3	

"	11th "	1.30	5.15	225	26.6	7.1	
"	14th	9.00	10.00	60	0.1	0.1	
"	20th	22.50	15th 0.25	95	9.8	6.2	
"	"	20.15	21.15	60	15.8	15.8	
"		21.50	24.00	130	3.5	1.6	
"	21st	0.00	2.30	150	1.3	0.5	
	No records from 22nd to 28th 11.15						
"	28th	18.00	19.15	75	10.3	8.2	

Table C14: Station: Katsina town $13^0$1'N $7^0$41'E Period: July 2009

PRECIPITATION RECORDED							
Period	**Day**	**Time Hours, Minutes**		**Duration in minutes**	**Amount in mm**	**Rainfall intensity in mm per hour**	**Total**
		Beginning	**End**				
July	2nd	19.40	21.15	95	3.3	2.1	
"	4th	18.10	18.30	20	2.2	6.6	
"	5th	22.55	6th 1.40	165	4.8	1.7	
"	6th	5.10	5.15	5	0.3	3.6	
"	9th	21.20	21.45	25	0.5	1.2	
"	13th	17.25	18.15	50	2.2	2.6	
"	14th	15.15	15.35	20	0.4	1.2	
"	14th	18.00	18.10	10	0.3	1.8	
"	15th	2.25	4.30	125	9.5	4.6	
"	16th	23.30	17th 2.30	180	7.9	2.6	
	Recorder defective from 17th 8.30 to 26th 10.00						

Table C15: Station: Katsina town $13^0$1'N $7^0$41'E Period: August 2009

PRECIPITATION RECORDED							
Period	**Day**	**Time Hours, Minutes**		**Duration in minutes**	**Amount in mm**	**Rainfall intensity in mm per hour**	**Total**
		Beginning	**End**				
August	1st	20.30	22.15	105	13.5	7.7	
	Recorder defective from 1st August 22.30 – 10th August 9.00						
"	11th	1.00	1.15	15	0.2	0.8	
"	12th	8.25	12.00	215	8.9	2.5	
"	13th	8.00	9.10	70	0.1	0.1	
"	14th	5.55	7.45	110	1.0	0.5	
	15th	7.05	10.30	205	12.3	3.6	
	17th	23.45	18th 3.45	240	9.3	2.3	
	18th	20.00	20.20	20	10.2	30.6	
	19th	14.35	14.50	15	0.2	0.8	
	"	19.00	19.25	25	0.2	0.5	

Table C16: Station: Katsina town $13^0$1'N $7^0$41'E Period: September 2009

PRECIPITATION RECORDED							
Period	**Day**	**Time Hours, Minutes**		**Duration in minutes**	**Amount in mm**	**Rainfall intensity in mm per hour**	**Total**
		Beginning	**End**				
September	5th	16.40	17.45	65	11.6	10.7	
	11th	2.10	2.20	10	0.1	0.6	
"	12th	13.50	14.15	25	2.7	6.5	
"	16th	11.40	12.20	35	1.7	2.9	
"	17th	17.40	22.10	270	4.6	1.0	
"	18th	0.00	0.15	15	0.1	0.4	
	End of recording 18th 9.15 Defective up to the end of rainy season						

Table C17: Station: Katsina town 13^0 01'N $7^0$41'E Period: may 2010

PRECIPITATION RECORD							
PERIOD	DAY	TIME: Hours, minutes		Duration in minutes	Amount in mm	Rainfall intensity in mm/h	Total mm
		beginning	End				
May	6th	2.51	3.10	19	6.0	18.8	
,,	,,	3.40	4.20	40	14.0	20.9	
,,	,,	5.25	5.40	15	0.8	3.2	
,,	,,	7.25	7.40	15	2.2	8.8	
,,	8th	22.25	22.40	15	1.7	6.8	
,,	9th	22.10	22.20	10	0.9	5.4	
,,	19th	5.25	5.40	15	0.8	3.2	
	From 19th to 26th may no records						
,,	27th	12.49	13.06	17	4.0	14.3	
,,	30th	21.48	22.03	15	5.8	23.2	

Table C18: Station: Katsina town 13^0 01'N $7^0$41'E Period: June 2010

PRECIPITATION RECORD							
PERIOD	DAY	TIME: Hours, minutes		Duration in minutes	Amount in mm	Rainfall intensity in mm/h	Total mm
		beginning	end				
June	From June 1st						
,,	until						
,,	June 6th 2010						
,,	no records						
,,							
,,	7th						
,,	7th	3.35	4.41	66	0.3	0.3	
,,	8th	13.21	14.03	42	0.4	0.6	
,,		15.52	15.17	25	0.7	1.7	
,,		4.31	4.51	20	5.7	17.1	
,,	23rd	4.56	6.20	84	52.4	37.4	
,,		22.05	22.45	40	20.0	30.0	
,,	25th	1.09	4.39	210	8.2	2.3	
,,		6.30	9.18	168	7.4	2.6	
,,	29th	17.24	17.36	12	15.8	79.0	
,,		19.15	19.30	15	1.2	4.8	
,,	30th	20.09	20.21	12	10.7	53.5	
,,		17.15	17.30	15	20.0	80.0	
,,	31st	18.30	21.26	176	3.4	1.2	
		11.25	11.38	13	9.8	45.2	

Table C19: Station: Katsina town 13 01'N $7^0$41'E Period: July 2010

PRECIPITATION RECORD							
PERIOD	DAY	TIME: Hours, minutes		Duration in minutes	Amount in mm	Rainfall intensity in mm/h	Total mm
		beginning	End				
JULY	1ST	1.00	3.09	129	7.5	3.5	
,,	2ND	6.45	6.51	6	0.1	1.0	
,,	5TH	21.11	22.03	52	2.7	3.1	
,,	7TH	22.03	23.54	11	13.5	7.3	
,,	9TH	23.42	24.00	1	14.4	4.8	
,,	10TH	0.00	0.24	18	2.4	6.0	
,,		0.39	1.45	24	1.7	1.5	
,,	16TH	17.44	17.52	66	0.5	37.5	
,,	17TH	6.16	7.06	8	3.5	4.2	
,,		8.36	9.30	50	0.6	0.7	
,,		10.03	10.51	54	6.1	7.6	
,,		10.55	13.30	48	8.5	3.3	
,,	21ST	14.09	14.12	155	0.8	16.0	
,,		14.54	15.18	3	0.4	1.0	
,,	22ND	0.55	1.30	24	1.4	2.4	
,,		2.00	7.00	35	7.6	1.5	
,,		19.30	22.30	300	4.6	1.5	
,,	23RD	2.57	3.54	180	1.4	1.5	
,,		5.00	6.15	57	1.7	1.4	
	From July 25th			75			
	until						
	July 31st 2010						
	no records						

Table C20: Station: Katsina town 13^0 01'N $7^0$41'E Period: August 2010

PRECIPITATION RECORD							
PERIOD	DAY	TIME: Hours, minutes		Duration in minutes	Amount in mm	Rainfall intensity in mm/h	Total mm
		beginning	End				
August	10th	18.20	19.03	43	7.7	10.7	
,,		17.03	17.30	27	0.6	1.3	
,,	11th	7.00	7.33	33	0.1	0.2	
,,		0.20	1.00	40	4.0	6.0	
,,		1.00	1.19	19	1.4	4.4	
,,	13th	1.19	3.00	101	0.8	0.5	
,,		22.27	23.12	45	0.4	0.5	
,,		23.12	23.20	8	5.3	39.8	
,,		23.20	23.48	28	2.0	4.3	
,,	17th	23.48	23.57	9	1.0	6.7	
,,		14.13	14.22	9	1.5	10.0	
,,	18th	14.45	14.53	8	0.2	1.5	
,,		12.55	13.00	5	0.5	6.0	
,,	22st	22.30	22.38	8	10.0	75.0	
,,		22.38	22.51	13	1.1	5.1	
,,		22.51	24.00	69	1.4	1.2	
,,	26th	15.07	15.41	34	5.6	9.9	
,,		15.41	16.17	36	1.1	1.8	
,,		16.17	16.26	9	1.4	9.3	
		16.26	18.00	94	0.5	0.3	
		18.00	19.45	105	2.2	1.3	
	27th	7.01	7.17	16	13.7	51.4	
		7.17	7.42	25	1.6	3.8	
		7.42	8.07	25	0.6	0.5	
		10.15	10.21	6	0.2	1.0	
Total							

Table C21: Station: Katsina town $13^0 1'N$ $7^0 41'E$ Period: September 2010

PRECIPITATION RECORD							
PERIOD	DAY	TIME: Hours, minutes		Duration in minutes	Amount in mm	Rainfall intensity in mm/h	Total mm
		Beginning	End				
September	4stS	18.34	18.51	17	8.6	28.7	
,,	6th	1.72	1.42	15	0.1	0.4	
,,		21.08	21.12	04	0.4	6.0	
,,	7th	6.21	6.24	3	0.2	4.0	
,,	11th	17.00	17.06	6	0.3	3.0	
,,		18.00	1900	60	21.7	21.7	
,,	12th	18.33	18.39	6	0.1	1.0	
,,		22.18	22.21	3	0.1	2.0	
,,	16th	22.22	23.03	41	2.9	4.2	
,,	17th	19.36	20.33	57	11.9	12.5	
,,		21.57	23.09	72	0.8	0.7	
,,	18th	21.55	22.00	5	0.1	1.2	
,,		21.12	22.24	12	0.5	2.5	
,,		22.42	22.48	6	0.1	1.0	
,,	22nd	20.05	20.06	1	0.1	6.0	
,,		20.15	21.00	45	8.8	11.7	
,,		21.54	22.18	24	0.2	0.5	
,,	23rd	15.16	15.24	8	0.6	4.5	
,,	24th	17.50	18.00	10	0.9	5.4	
	28th	19.52	2.33	41	3.0	4.4	
	29th	20.12	21.12	60	6.7	6.7	
	30th	20.30	21.00	30	15.5	31.0	
		23.18	23.18	42	0.9	1.3	
Total							

Table C22: Station: Katsina town $13^0 1'N$ $7^0 41'E$ Period: April 2011

PRECIPITATION RECORDED							
Period	**Day**	**Time Hours, Minutes**		**Duration in minutes**	**Amount in mm**	**Rainfall intensity in mm per hour**	**Total**
		Beginning	**End**				
April	3th	7^{30}	7^{45}	15	0.5	2.0	
	6th	5^{15}	5^{30}	15	0.2	0.8	
		19^{42}	19^{48}	6	0.9	9.0	
	7th	1^{37}	1^{42}	5	3.8	45.6	
		16^{02}	16^{04}	2	0.5	15.0	
	9th	1^{38}	1^{54}	16	2.8	10.5	
	10th	15^{48}	15^{15}	3	0.3	6.0	
		16^{17}	16^{27}	10	4.3	25.8	
	11th	2^{26}	2^{42}	16	29.8	111.8	
		2^{42}	4^{06}	84	4.0	2.9	
From April 13th until April 26th – No Records							
	27th	4^{39}	4^{45}	6	4.4	44	
	28th	16^{27}	16^{42}	15	6.9	28	
		17^{56}	19^{39}	103	9.6	5.6	
	30th	6^{54}	7^{15}	23	0.3	0.79	

Table C23: Station: Katsina town $13^0$1'N $7^0$41'E Period: May 2011

PRECIPITATION RECORDED							
Period	**Day**	**Time Hours, Minutes**		**Duration in minutes**	**Amount in mm**	**Rainfall intensity in mm per hour**	**Total**
		Beginning	**End**				
May	1st	6^{03}	7^{12}	69	14.2	12.3	
	4rd	6^{48}	7^{36}	48	30.6	38.3	
	11th	17^{44}	17^{46}			20	
		22^{27}	22^{39}			3.5	
	14th	0^{28}	1^{39}	3	1.0	29.9	
	15th	20^{45}	21^{06}	12	0.7	0.9	
		21^{49}	22^{09}	71	35.4	0.9	
	17th	23^{30}	0^{30}	21	0.3	0.3	
		2^{36}	3^{00}	20	0.3	75.3	
				60	0.3		
				24	30.1		

Table C24: Station: Katsina town $13^0$1'N $7^0$41'E Period: June 2011

PRECIPITATION RECORDED							
Period	Day	**Time Hours, Minutes**		**Duration in minutes**	**Amount in mm**	**Rainfall intensity in mm per hour**	**Total**
		Beginning	**End**				
June	9th	3.20	3.40	10	1.7	10	
	9th	3.20	3.40	20	6.4	19.2	
	13th	9.00	12.00	Bad record	4.1	12.3	
		18.50	19.10	20	9.6	38.4	
	15th	18.20	18.35	15	9.6	29.7	
		23.05	23.25	20	8.0	2.2	
		23.25	3.00	215	7.6	4.6	
	20th	3.20	5.00	100	12.3	5.3	
	20st	9.50	12.10	140	4.5	3.9	
	26th	14.15	15.25	70	0.2	1.2	
		17.30	17.40	10	0.9	5.3	

Table C25: Station: Katsina town $13^0 1'N$ $7^0 41'E$ Period: July 2011

PRECIPITATION RECORDED							
Period	**Day**	**Time Hours, Minutes**		**Duration in minutes**	**Amount in mm**	**Rainfall intensity in mm per hour**	**Total**
		Beginning	**End**				
July	2nd	19.40	21.15	95	3.3	2.1	
"	4th	18.10	18.30	20	2.2	6.6	
"	5th	22.55	6th 1.40	165	4.8	1.7	
"	6th	5.10	5.15	5	0.3	3.6	
"	9th	21.20	21.45	25	0.5	1.2	
"	13th	17.25	18.15	50	2.2	2.6	
"	14th	15.15	15.35	20	0.4	1.2	
"	14th	18.00	18.10	10	0.3	1.8	
"	15th	2.25	4.30	125	9.5	4.6	
"	16th	23.30	17th 2.30	180	7.9	2.6	
	Recorder defective from 17th 8.30 to 26th 10.00						

Table C26: Station: Katsina town $13^0 1'N$ $7^0 41'E$ Period: August 2011

PRECIPITATION RECORDED							
Period	**Day**	**Time Hours, Minutes**		**Duration in minutes**	**Amount in mm**	**Rainfall intensity in mm per hour**	**Total**
		Beginning	**End**				
August	1st	20.30	22.15	105	13.5	7.7	
"	11th	1.00	1.15	15	0.2	0.8	
"	12th	8.25	12.00	215	8.9	2.5	
"	13th	8.00	9.10	70	0.1	0.1	
"	14th	5.55	7.45	110	1.0	0.5	
	15th	7.05	10.30	205	12.3	3.6	
	17th	23.45	13.45	240	9.3	2.3	
	18th	20.00	20.20	20	10.2	30.6	
	19th	14.35	14.50	15	0.2	0.8	
	"	19.00	19.25	25	0.2	0.5	

Table C27: Station: Katsina town $13^0 1'N$ $7^0 41'E$ Period: September 2011

PRECIPITATION RECORD							
PERIOD	DAY	TIME: Hours, minutes		Duration in minutes	Amount in mm	Rainfall intensity in mm/h	Total mm
		Beginning	End				
September	4st	19.34	19.51	22	5.6	14	
,,	5th	1.72	1.42	15	0.1	0.4	
,,		21.08	21.12	04	0.4	6.0	
,,	7th	6.21	6.24	3	0.2	4.0	
,,	11th	17.00	17.06	6	0.3	3.0	
,,		18.00	1900	60	21.7	21.7	
,,	12th	18.33	18.39	6	0.1	1.0	
,,		22.18	22.21	3	0.1	2.0	
,,	16th	22.22	23.03	41	2.9	4.2	
,,	17th	19.36	20.33	57	11.9	12.5	
,,		21.57	23.09	72	0.8	0.7	
,,	18th	21.55	22.00	5	0.1	1.2	
,,		21.12	22.24	12	0.5	2.5	
,,		22.42	22.48	6	0.1	1.0	
,,	22nd	20.05	20.06	1	0.1	6.0	
,,		20.15	21.00	45	8.8	11.7	
,,		21.54	22.18	24	0.2	0.5	
,,	23rd	15.16	15.24	8	0.6	4.5	
,,	24th	17.50	18.00	10	0.9	5.4	
	28th	19.52	2.33	41	3.0	4.4	
	29th	20.12	21.12	60	6.7	6.7	
	30th	20.30	21.00	30	15.5	31.0	