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FLOOD CONTROL IN URBAN SETTLEMENTS Owners' Occupier Estate in Makurdi: A Case Study

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ABSTRACT

The issue of flooding in Makurdi is increasing in an alarming rate and it has become obvious more control is required of surface discharge from areas of road, housing and industries to proper water course in order to avoid excessive flooding downstream. The purpose of this work is to design an adequate drainage system that can remove excess storm water flow from an area of the Owners occupier Estate in Makurdi to proper water courses. Before this design a survey was carried out in this area to obtain its natural slope from the hydrological data of the area, the rainfall intensities for various rainfall duration were obtained based on Sharman's equation. The return period of twenty five years was used. Rational formula was used to estimate the various channel capacities of the drain. Having consulted relevant literature and guided by the federal ministry of works Highway manual, 2013, part 1, volume iv, the results obtained showed that the drainage sections provided can adequately handle the drainage capacities of the study area.

KEY WORDS- *Drainage, Run-off Coefficient, Rain fall intensity, Time of concentration flow velocity .etc*

1.1 INTRODUCTION

When it rains, some water naturally seeps into the soil. The rest makes its way through drainage systems, into rivers and creeks and eventually into the bay through storm water beach outlet.

The issue of flooding due to urban development is increasing in an alarming rate and has become obvious that greater control is required of surface water discharge to proper water course from areas

of roads, housings and industries, to avoid excessive flooding downstream

1.2 STATEMENT OF PROBLEM

The issue of flooding due to urban settlements is increasing in an alarming rate and it has become obvious that more control is required of surface water discharge to proper water courses from the areas of road, housing and industry to avoid excessive flooding downstream.

1.3 AIM AND OBJECTIVES

The aim of this work is to design a storm water drainage system for the Owner Occupier Estate in Makurdi town of Benue State.

The objectives of this work are;

1. To determine the catchment area and the expected flow
2. To take the level of the proposed site
3. To estimate the peak flow
4. To design the various pipe sections capable of carrying the expected run-offs
5. To use the available data to design the most economical drainage channels.

1.4 SCOPE OF STUDY

This work is focused on the design of the most economical storm water drainage system for flood control in Owner Occupier Estate in Makurdi Town, Benue state.

1.5 SIGNIFICANCE OF THE STUDY

Provision for adequate drainage is of paramount importance in road design and cannot be over-emphasised. The presence of excess of moisture within the road way will adversely affect the engineering properties of the materials with which it was constructed.

1.6 LOCATION OF STUDY

Owners’ occupiers’ estate Makurdi.

LITERATURE REVIEW

2.1 DRAINAGE DESIGN

Drainage systems are needed in developed urban areas because of the interaction between human activity and the natural water cycle. This interaction has two main forms: the abstraction of water from the natural cycle to provide a water supply for human life, and the covering of land with impermeable surfaces that divert rainwater away from the local natural system of drainage.. In many urban areas, drainage is based on a completely artificial system of sewers: pipes and structures that collect and dispose of this water. In contrast, isolated or low-income communities normally have no main drainage. Wastewater is treated locally (or not at all) and stormwater is drained naturally into the ground which usually causes flooding of such areas due to poor drainage systems which could emanate from negligence by the dwellers or poor design by the Engineers. (Butler and John 2004). Since the problem of flooding has come to stay and as a result, urban dwellers are devising ways in which they can cope with it. This study assesses the coping measures for the dwellers living in the Owner Occupier Estate of Makurdi town.

Classification of drainage cross-sections:-

There are different types of drainages with respect to their cross sectional areas, some of which are;

1. Rectangular or U-Shaped surface drainage
2. Oval shaped surface drainage
3. Trapezoidal surface drainage
4. Circular surface drainage

Rational Formula

The rational formula for computing peak flow is given as;

$$Q = CIA_d \dots\dots\dots 2.1$$

Q= Peak flow rate(m³/s)

C= Run- off coefficient (Dimensionless value)

A= Catchment area (Hectares or Km²)

I = Rainfall Intensity (mm/hr) up-stream of the point (Khana and Justo 2015)

Estimation of Run-Off Coefficient:-

Run-off coefficient varies considerably with the ground surface conditions, topography and soil characteristics.

Since the total area was not homogenous,with component sub- areas having different values of C , a weighted runoff coefficient

$$C_w = \frac{C_1 A_1 + C_2 A_2 + \dots\dots\dots C_n A_n}{A_1 + A_2 + \dots\dots\dots A_n} \dots\dots\dots 2.2$$

Where A₁ ; A₂ ; A₃..... A_n = areas of sub –zones

C₁ ; C₂ ; C₃ C_n = runoff coefficients for the corresponding sub-zones

(Punmia, Pande, Ashok & Arun, 2009)

Rainfall intensity:-

It has generally been observed that greater the intensity of rainfall, shorter is the length of time it continues .As the duration of storm or flood increases, the maximum intensity of storm decreases. Sherman gave the following relationship between intensity and duration.

$$i = \frac{a}{(t+b)^n} \dots\dots\dots 2.3$$

Where;

- i = Rainfall rate (mm/hr)
- t = time of concentration
- a and b = constants to be determined for the determined for the area.
- (Punmia, Pande, Ashok & Arun, 2009)

Time of concentration:-

Time of concentration is a concept used in hydrology to measure the response of water shed to a rain event. It is defined as the time needed for water to flow from the remote point of water shed to the water shed outlet. It is the function of the topography, geology and land use within the water shed.

The time of concentration (t_c) for a drainage area consists of;

Inlet time or time of entry(t_e): it is the time taken by storm water to flow over roofs, ground, pavements etc to reach the drain.

Flow time (t_f): it is the time taken by the storm to traverse the drain from the inlet to the point under consideration.

$$t_f = \frac{\text{length of drain}}{\text{velocity in drain}} \dots\dots\dots 2.4$$

Thus the total time of concentration (t_c) at a given point in the drain for estimating the discharge at the point is given by;

$$t_c = t_e + t_f \dots\dots\dots 2.5$$

The velocity v_D in the drain is give as;

$$V_D = 0.33D^{2/3} S^{1/2} \dots\dots\dots 2.6$$

Where;

- D= Diameter of the channel in mm
- S= Slope of the channel

While the pipe flow

$$Q_D = 2.6 \times 10^{-7} D^{8/3} S^{1/2} \dots\dots\dots 2.7$$

Channel slope:-

Channel slope or gradient is the difference in elevation between two points on a stream divided by the distance between them measured along the stream channel. The flow velocity and thus power of the stream to do work is also directly related to the slope of the channel. The steeper the slope, the faster the velocity of flow.

$$S = \frac{h_f}{L} \dots\dots\dots 2.8$$

Where;

- h_f = vertical drop
- L = Length of channel

Flow velocity:-

The flow velocity of a stream is how fast the water is moving through a cross section. Flow velocity is determined by the balance between the down slope gravitational stress as a result of the slope of the stream and the loss or expenditure of energy in overcoming frictional resistance of the channel bed and side.

$$V \propto S^2$$

Rational Formula (Llyod Davis Method):-

The rational formula is given as;

$$Q = 0.00278CIA \dots\dots\dots 2.9$$

Where;

- Q = run-off rate (m³/s)
- C = Run –off coefficient
- I = Rainfall intensity (mm/hr)
- A= Drainage area (km² or hectares)

Continuity and Velocity:-

The continuity Equation is the statement of conservation of mass of fluid mechanics. For the special case of steady flow of an incompressible fluid, it assumes the following form:

$$Q = A_1V_1 = A_2V_2 \dots\dots\dots 2.10$$

Where Q= Discharge (cfs or m³/s)

A= Flow Cross sectional Area (sq. ft or m²)

V= Mean cross sectional velocity (fps or m/s), perpendicular to the flow area

Channel Capacity:-

Most of the channel analysis procedures use the Manning’s Equation for uniform flow as a basis for analysis

$$V = \frac{Z}{n} R^{\frac{2}{3}} S^{\frac{1}{2}} \dots\dots\dots 2.11$$

Where:

V=Velocity in cfs or m³/sec

Z=1.486 for English measurement units and 1.0 for metric

n= Manning’s roughness coefficient (a coefficient for quantifying the roughness characteristics of the channel)

R= Hydraulic radius (ft or m) =A/WP

WP=Wetted perimeter of flow (the length of channel boundary in direct contact with the water) (ft or m)

S=slope of the energy grade line (ft/ft or m/m)(for uniform, steady flow, S=Channel slope. Ft/ft or m/m)

Combine Manning’s Equation with continuity Equation to determine the channel uniform flow capacity as shown in Equation 3.32

$$Q = \frac{Z}{n} AR^{\frac{2}{3}} S^{\frac{1}{2}} \dots\dots\dots 2.12$$

Where:

Q=Discharge (cfs or m³/s)

Z=1.486 for English Measurement units and 1.0 for metric

A= Cross sectional area o flow (sq. ft or m²)

Conveyance:-

In channel analysis, it is often convenient to group the channel cross sectional properties in a single term called the conveyance (k) shown in Equation 2.13

$$K = \frac{Z}{n} AR^{\frac{2}{3}} \dots\dots\dots 2.13$$

Manning’s Equation can be written as:

$$Q = KS^{\frac{1}{2}} \dots\dots\dots 2.14$$

4. ENERGY EQUATIONS

Assuming channel slopes of less than 10 %, the total energy head can be shown as Equation 2.16

$$H = \frac{P}{Y_w} + Z + \alpha \frac{V^2}{2g} \dots\dots\dots 2.15$$

Where:

H = total energy head (ft or m)

P = pressure (lb/sqr.ft or N/m²)

Y_w = unit weight of water (62.4 lb /cu.ft or 9810 N/m³)

Z = elevation head (ft or m)

$\frac{V^2}{2g}$ = average velocity head, hv (ft or m)

g = gravitational acceleration (32.2 ft./ s² or 9.8 m/s²)

α = Kinetic Energy Coefficient

V = Mean Velocity (fps or m/s)

In open channel computations, it is often useful to define total energy head as the sum of the specific energy head and the elevation of the channel bottom with respect to some datum.

$$H = Z + d + \alpha \frac{V^2}{2g} \dots\dots\dots 2.16$$

Where:

d = depth of flow (ft or m)

For some applications, it may be more practical to compute the total energy head as a sum of the water surface elevation (relative to mean sea level) and velocity head.

$$H = WS + \alpha \frac{V^2}{2g} \dots\dots\dots 2.17$$

Where:

WS = Water surface elevation or stage (ft or m) = Z+ d

Specific energy Equation: If the channel is not too steep (slope less than 10%) and the streamlines are nearly straight and parallel, the specific energy, E, becomes the sum of the depth of flow and velocity head.

$$E = d + \alpha \frac{V^2}{2g} \dots\dots\dots 2.18$$

Froude Number:-

The Froude Number (Fr) represents the ration of the inertial forces to gravitational forces and is calculated.

$$Fr = \frac{v}{\sqrt{gdm}} \dots\dots\dots 2.24$$

Where:

V = mean velocity (fps or m/s)

g = acceleration of gravity (32.2 ft /s² or 9.81 m/s²)

dm = hydraulic mean depth = A/T (ft or m)

A = Cross sectional area of flow (Sq. ft or m²)

T = Channel top width at the water surface (ft. or m)

Steps to be followed in the design of Slab:-

1. Assuming suitable bearings (not less than 10 cm), find the span of the slab between the centres of bearings.
2. Assume the thickness of slab (take 4 cm per meter run of the span).
3. Find the effective span which is less of
 - i. Distance between centres of bearings and
 - ii. Clear span and effective depth.
4. Find the dead load and the live load per square meter of the slab.
5. Determine the maximum bending moment for a long for a one meter wide strip of the lab. The maximum bending moment per meter width of slab,

$$M = \frac{wl^2}{8} \dots\dots\dots 2.25$$

Where:

W =total load intensity per square meter of the slab

6. Equate the balanced moment of resistance to the maximum bending moment
 $Qbd^2 = Q \times 100 \times d^2 = M \dots\dots\dots 2.26$
 Find the effective depth “d” from the above Equation

7. Calculate the main reinforcement per meter width
 $A_s = \frac{M}{(Safe\ stress\ in\ steel) \times (lever\ arm)} \dots\dots\dots 2.27$
 Lever arm = 0.87d for MIS concrete.

$$spacing\ of\ bar = \frac{area\ of\ 1\ bar}{A_t} \times 100 \dots\dots\dots 2.28$$

DATA OR PARAMETER USED IN THE DESIGN

- Drain of Length, L
- Tie of Concentration, Tc
- Run-off coefficient, C=0.5 (residential settlement)
- Area, A of catchment
- Rainfall Intensity, i
- Storm Discharge, Q
- Channel Capacity, Qc
- Slope of Channel, S
- Return Period, T= 25 years

$$Q = CiA \dots\dots\dots 4.1$$

$$Q_c = AV \dots\dots\dots 4.2$$

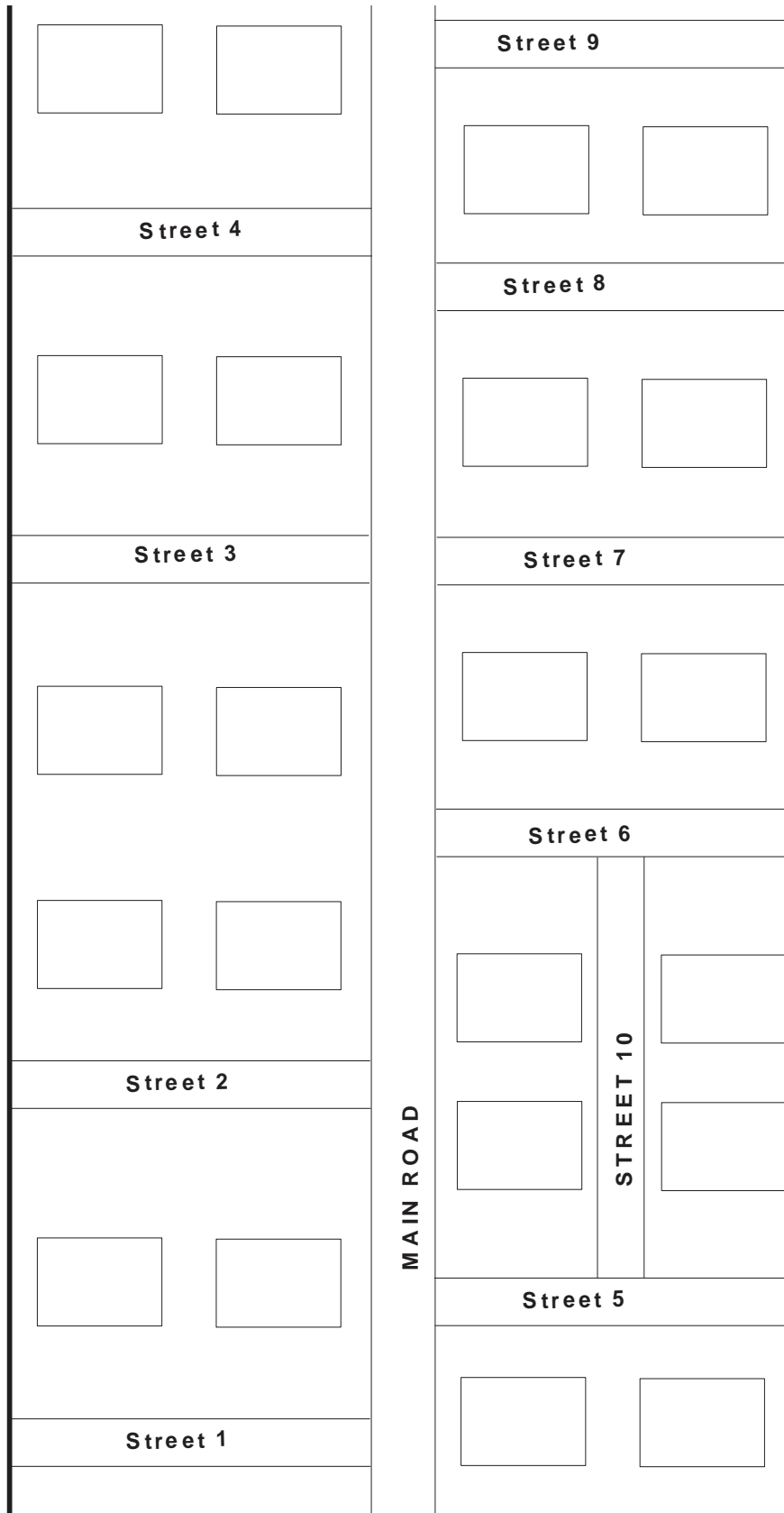
$$Tc = \frac{0.01947 (L)^{0.77}}{S^{1/2}} \dots\dots\dots 4.3$$

$$i = \frac{16.43 T^{0.51}}{T^{0.62}} \text{ (Rainfall intensity model for Makurdi) according to Sherman Equation} \dots\dots\dots 4.4$$

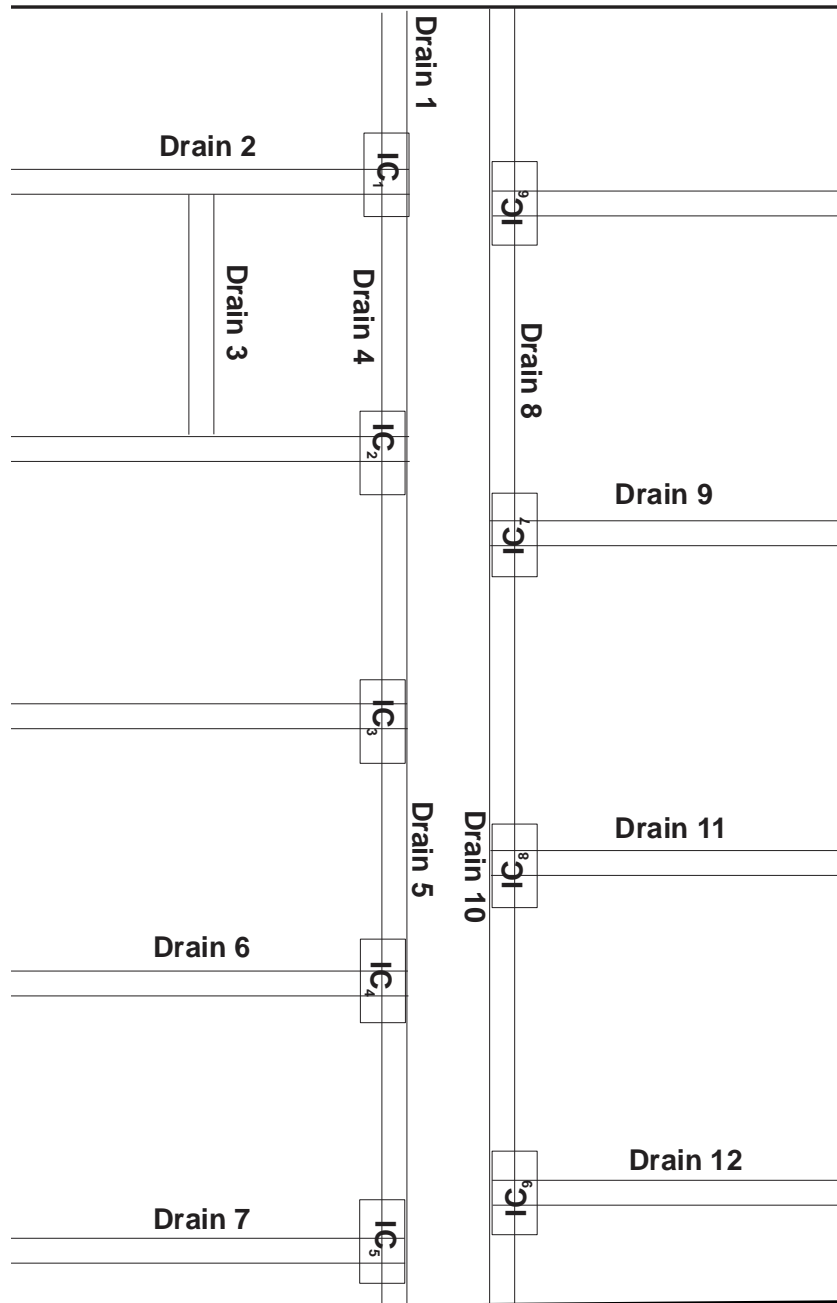
t = Time of concentration in hour

Depth of channel y

Width of channel b = 2y



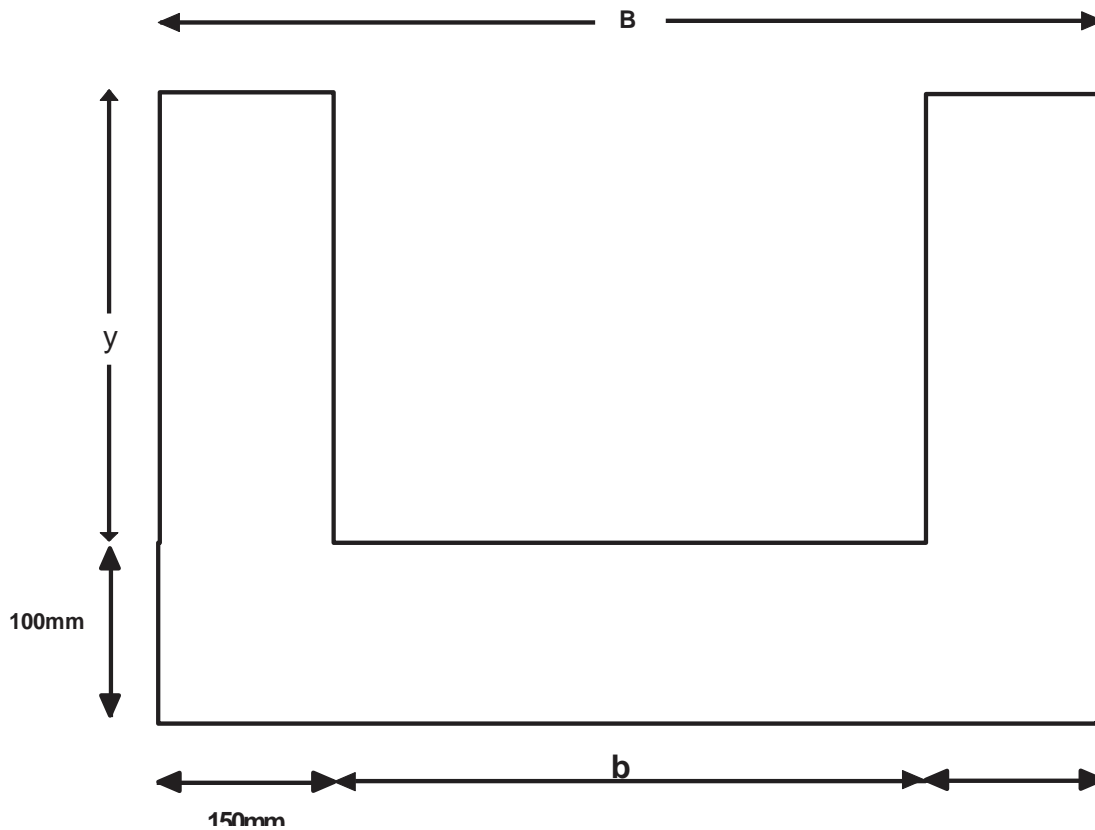
N/B; Tc is converted to t by dividing it by 60 i.e conversion from minute to hour.
The Layout for the Owners occupier estate (Figure 1)



Drain Layout (Fig. 4.2)

The above values are computed in the Table 4. 1 below;

Channel	Channel Length (m)	Catchment area (m ²)	Run off coefficient, C	Time of Concentration (min)	Rainfall Intensity (mm/hr)	Discharge, $Q \times 10^{-4}$ (m ³ /s)	Channel Type	Natural Slope	Manning's Coefficient (η)	Channel Size (b×y)(mm)	Flow Velocity (m/s)	Drain Capacity, Q_c (m ³ /s)	Tributary Area
1-2	43.60	4194.32	0.5	3.07	536.90	0.312	Rectangle	0.0135	0.015	600×350	1.490	0.312	Main Rd
4-2	96.20	4194.32	0.5	6.76	327.85	11.370	Rectangle	0.0100	0.015	1158×790	5.640	4.456	Street 5
7-3	91.10	5842.55	0.5	10.06	257.34	4.180	Rectangle	0.00039	0.015	900×650	4.640	2.090	Street 10
2-8	103.10	6330.34	0.5	8.32	288.35	0.385	Rectangle	0.0069	0.015	600×410	1.035	0.2535	Main Rd
8-14	161.70	15555.54	0.5	45.57	100.57	0.134	Rectangle	0.00046	0.015	600×400	0.908	0.218	Main Rd
9-11	120.70	11997.58	0.5	5.66	362.72	0.344	Rectangle	0.019	0.015	660×370	2.487	0.610	Street 7
12-14	80.90	5040.07	0.5	3.02	543.53	1.510	Rectangle	0.036	0.015	600×400	1.588	0.381	Street 9
15-16	69.90	5410.26	0.5	6.08	351.48	0.205	Rectangle	0.0071	0.015	600×350	1.260	0.264	Main Rd
18-16	77.40	5140.26	0.5	3.05	536.90	0.402	Rectangle	0.0330	0.015	600×450	1.490	0.403	Street 2
16-22	124.70	9651.78	0.5	9.24	270.60	0.225	Rectangle	0.0075	0.015	650×460	1.210	0.363	Main Rd
21-19	109.00	6703.50	0.5	4.66	412.56	0.290	Rectangle	0.024	0.015	600×420	1.530	0.385	Street 3
24-22	91.00	5751.20	0.5	9.46	266.33	0.191	Rectangle	0.0044	0.015	600×430	0.826	0.213	Street 4
6-8	96.20	6724.38	0.5	3.85	465.81	0.271	Rectangle	0.029	0.015	600×350	2.071	0.435	Street 6



SUMMARY

The drainage network for the owners occupier estate in Makurdi was suitably designed using the rational method. The available and the required data like the rainfall intensity frequency relationship was used to determine the section dimension for the drainage system.

Before the design, a survey was carried out on the study area in order to determine the natural slope for the drain layout. Suitable dimension ratios from the calculated discharges were used to determine the drainage sections.

5.2 CONCLUSION

The design is adequate and sufficient as it conforms to the highway manual part 1, Volume iv, of the federal ministry of works, federal republic of Nigeria, 2013.

The result obtained from the design showed that the drainage sections provided can satisfactorily handle the total discharge on the area efficiently and effectively to the tolerances demanded by a slope flatter than 0.3%. This local imperfection may cause Siltation, therefore a regular maintenance of the system is required that it may work to full capacity.

RECOMMENDATIONS

1. It is recommended that this work is been considered a model work in control of flooding in Urban settlements.
2. More research could be embarked on by environmental engineers on how to improve the living of residents of places prone to flooding.

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