

ADDIS ABABA UNIVERSITY INSTITUTE OF TECHNOLOGY

**SCHOOL OF GRADUATE STUDIES
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**STUDY ON STORM WATER DRAINAGE SITUATION IN ADDIS
ABABA: "CASE STUDY FOR JEMO-III CONDOMINIUM SITE NEAR
GLASS FACTORY AREA"**

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**A thesis submitted to the School of Graduate Studies of Addis
Ababa University Institute of Technology in partial fulfillment of the
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supply and Environmental Engineering**

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I, Tillahun Tessema, do here by declare to the Senate of Addis Ababa University that this thesis is entirely original work and all other materials are duly acknowledged. This work has not been submitted for any academic degree award at any University.

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TABLE OF CONTENTS

1. Introduction	
1.1 General.....	1
1.2 Study Area.....	2
1.3 Problem statement.....	3
2. Objective of the study	4
2.1 General Objective.....	4
2.2 Specific Objective.....	4
3. Literature Review.....	4
3.1 Urbanization and Flood Management.....	4
4. Project Methodology.....	7
4.1 General	7
4.2 Storm water Design Flow.....	7
4.3 Design Consideration.....	8
4.4 Design Runoff Computation.....	9
4.5 Storm water Drain Sizing.....	14
4.6 Manhole Sizing and Spacing.....	16
4.7 Result Interpretation.....	29
5. Conclusion and Recommendation.....	30
5.1 Conclusion.....	30
5.2 Recommendations.....	30
Reference.....	31

ANNEXS

List of Tables

Table 4-1 Basic Assumptions and data required for rational method.....	9
Table 4-2 Runoff Coefficients for Composite Runoff Analysis.....	12
Table 4-3 Runoff Coefficients for different terrain.....	13
Table 4-4 Spacing of Access Holes.....	15
Table 4-5 Design Computation Sheet.....	18

List of Figures

Figure 1-1 Study Area.....	2
Figure 4-1 Nomograph for Estimating Overland Sheet Flow Times.....	10
Figure 4-2 Intensity-Duration-Frequency curve of Addis Ababa, Bole.....	14
Figure 4-3 Algorithm of Rational Method for Sewer Design.....	16

ABBREVIATIONS

AACRA = Addis Ababa City Road Authority

ES = Ethiopia Standard

L/s = Liters per second

NHD = Architectural Neighborhood Design

NMA = National Metrological Agency

IDF = Intensity Duration Frequency

Abstract

Flooding has long been recognized as the most damaging and costly natural hazard in many countries considering the frequency and influencing extent. Due to the rapid urbanization and the global climate change in the urban areas, the frequency of devastating floods tends to be higher and the loss of human lives and property show no sign of decreasing. In order to decide on minimizing the impact of floods an effective flood volume estimation model is required.

The proper design of any storm drainage system involves the accumulation of certain basic data, familiarity with the project site, and a basic understanding of the hydrologic and hydraulic principles and drainage standards associated with that design.

The rational method is the most common method in use for the design of storm-water drains, where the momentary peak flow rate is desired. The method provides peak runoff rates for small urban and rural catchment areas, less than 50 hectares (0.5 km²), but is best suited to urban storm-water drain systems and rural ditches. It shall be used with caution if the time of concentration exceeds 30 minutes. For the study area the storm-water sewer network has been analyzed based on the selected outfall facilities, selected network schematization and agreed designed criteria using interactive mathematical model on Excel.

This study shall contribute a lot to control the flooding problems of the study area and enhances the ability of planners, researchers and city development actors to formulate and implement sound policies to minimize undesirable future flooding impacts and management alternatives.

1. Introduction

1.1 General

Floods are natural disasters all over the world. The dynamism of nature is very difficult to understand. Out of many natural events; we get rainfall that saturates the soil depending on the density and duration of rainfall before forming any overland flow that joins the drainage systems. Floods are the results of excess rainfall that flows over the surface. The runoff content depends on the land use, rainfall intensity, topography, soil types and etc.

Currently Storm water flood problem in Addis Ababa becomes main threat to the life of the people especially for those living in the flood prone areas. Obviously, urban regions will have more impervious surface where infiltration cannot occur. On the other hand, rural drainage areas will have some water absorbed in the soil till it reaches saturation level and sends the rest to contribute to direct runoff. Dense vegetation provides vegetal retardance to overland flow. Hence land use classes, as obtained from the Municipality of the city, have an implicit hydrological significance in terms of water yield, peak flows and soil erosion (Gorte, 2000). Vegetation delays direct runoff from high intensity rainfalls in smaller catchments (Bruynzeel, 1990). Continuing deforestation leads to more sediment yield downstream, which causes damages in floodplain agricultural fields (Meijerink and Maathuis, 1997).

: Storm Sewer System design which is designed to manage the rain water that falls within the neighborhood as well as in the surrounding areas that affects the neighborhood environment in a manner to comply the country as well as the international Urban Storm Water Management Standards

This study thus intended to manage the Flood problems of the Jemo-III Condominium Site near Glass Factory and design a standard storm-water sewer

system with in the neighborhood and outside to enable proper collection, conveyance and safe disposal up to the receiving water bodies or recommended outfall points.

1.2 Study Area

The Jemo-III Condominium Site is located in central Ethiopia along the western margin of the main Ethiopian rift valley near Glass Factory batu to Ayer Tena before reaching to the so called “Koshe or solid waste accumulating site” and turning to the left about 2km from the ring road to the Chinese Glass Factory.



Fig. 1-1 Study Area

1.3 Problem Statement

In nature, the problems associated with excess storm water are diverse and extremely complicated. Floods inundate built up property, endanger lives and prolonged high flood stages that delay highway traffic and cause damage to bridge abutment and other structure (Dirk, 2001). The problem related to flood is crucial and important and therefore runoff estimation based on the urbanization is important to prevent and predict damage.

There are many environmental problems in Addis Ababa. However it seems that their nuisances are not perceived in same way. The city of Addis Ababa contains riparian areas in flood prone areas. The city has suffered from serious flood damages specially in the years 1978, 1994 and 1995 which caused serious social disturbances such as loses of human lives and properties(JICA and Region 14 Administration, 1998).

In addition to this the flood problem could be due to the limited number of inlet along the street and these inlets are clogged, clogging due to the solid waste disposal illegally.

The flooding problem affects the whole of Addis Ababa drainage network. According to a report (JICA and Region 14 Administration, 1998) 8000 people are directly affected by the damage, this report also claims that there are potential risk, increased by urban growth in several parts of the town.

The steep slopes in the study area could favor the speed and so increase the power of the flow, in the case of flood lower down. Owing to this situation and the lack of flood control projects in the city, the results of this study will be a good indicative for the city administration of Addis Ababa to tackle the flooding problems and its effect on the environment rationally.

2. Objective of the Study

2.1 General Objective

The general objective of this study is to investigate the impact of flooding and estimating the flow volume using rational method rainfall runoff modeling for a design storm with duration of 24 hours IDF curve and for a return period of 10 years.

2.2 Specific Objective

The specific objective of this study is

- ✚ Modeling storm runoff using Rational Method to identify the magnitude of flow
- ✚ Pipe sizing for proper disposal of the storm water.
- ✚ In addition to this to provide a recommendation on the future land use and climate change step up measures.

3. Literature Review

3.1 Urbanization and Flood Management

Urbanization is defined as the concentration of people in urban settlements and the process of changes in land use occupancy resulting from the conversion of rural land in to urban, suburban and industrial communities (Chander, 2000). The rate of urban growth is especially high in developing countries like Ethiopia. For example the 2008 census put the population of Addis Ababa of 3277000 (CSA, 2008).The higher demand of water results in higher urban sewerage because of increase in residential and commercial facilities such as building, pavements and parking lots, the built up or impervious areas in the urban area increases. Urbanization substantially alters rainfall runoff relations compared with those of natural drainage as increase in impervious area that accompanies urbanization reduces infiltration and evapotranspiration in the catchments. There is an increase in runoff peak and runoff volume, decrease in time

to peak, decrease in infiltration and reduction of recharge to ground water (Chander, 2000). Design of drainage facilities which do not account for this increased run off volume are inadequate and may result in heavy damage and loss of property. Therefore, this study estimated the flood discharge and then it will be helpful for design of suitable drainage system. The conversion of rural land to urban land usually increases erosion and the discharge and volume of storm runoff in watershed. It also causes other problems that affect soil and water. As part of programs established to alleviate these problems, engineers increasingly must assess the probable effects of urban development, as well as design and implementation measures that will minimize its adverse effects. (ERA, 2002)

Urban flooding studies are typically undertaken to analyze flooding problems in developed watersheds. Characteristics of these watersheds include:

- Engineering drainage systems throughout
- Relatively short response times
- Localized flood damage of properties adjacent to drainage channels

To meet the objective of an urban flood study, typically peak flow, total runoff volume, hydrograph timing, peak stage, and flood plain delineations are required.

(Davis, CA, 2001). Early works in urban hydrology were concerned with effect of urbanization on the flood potential of urban watersheds. The effect of urbanization on the flood hydrograph includes increased total runoff volume and peak flow rates. In general major changes in flow rates in urban watershed are due to the following:

- The volume of water available for runoff increases because of the increased impervious cover provided by parking lots, streets, and roofs, which reduce the amount of infiltration.

- Changes In hydraulic efficiency associated with artificial channels, curbing, gutters, and storm drainage collection systems increase the velocity of flows and the magnitude of flood peaks.

To assess urban development, future developments as well as those existing should be considered. Therefore, when inspecting an area near an expanding urban center, the local government should be contacted and a projected land-use map secured.

Knowledge of projected urban land use is of considerable importance because the rainfall runoff response of an urbanized drainage basin is usually significantly different from the response the same basin would experience in a no urbanized condition. If urbanization becomes a factor in a flood study, the projected urban development map should be obtained from a reliable governmental source and included in the flood study report. (Yiping, Guo, 2001)

All parts of a watershed can be considered either pervious or impervious. The pervious part is that area where water can readily infiltrate into the ground. The impervious part is the area that does not readily allow water to infiltrate into the ground, such as areas that are paved or covered with buildings and sidewalks or compacted unvegetated soils. In urban hydrology, the percentage of pervious and impervious land is important. The percentage of impervious area increases when urbanization occurs and the rainfall-runoff relationships change significantly. The total amount of runoff volume normally increases, the time to the runoff peak rate decreases, and the peak runoff rates increase. When analyzing a watershed for design purposes the probable future percent of impervious area must be estimated (ERA, 2002).

4. Project Methodology

4.1 General

For the design of a standard storm-water sewer system to enable proper collection, conveyance and safe disposal up to the receiving water bodies or recommended outfall points the study and design work comprises:

- Data collection and analysis
- Storm-water sewer system design

Accordingly, the project site is visited to carry out field studies and investigations which includes identification of possible existing outfall water bodies or streams in the vicinity of site as per its architectural neighborhood design. Topographic and profile surveys of the envisaged storm water drainage system as an input for the design of external storm-water sewer system has been carried out.

4.2 Storm-Water Design Flows

The method for determining the rates of storm-water runoff transported by storm-water sewers is still imprecise, particularly in the developing countries like Ethiopia which has no quite enough and reliable metrological data, although much progress has been done during the recent years.

Such progress has come about with increased technical knowledge of hydrologic events and characteristics in relation to the rainfall-runoff, particularly the large amount of data available for study and correlation of rainfall, runoff, topography and development.

The proper design of any storm drainage system involves the collection of certain basic data, familiarity with the project site, and a basic understanding of the hydrologic and hydraulic principles and drainage standards associated with design.

In designing appropriate storm-water drainage system of the site the following primary design procedures were followed:

- Areal topographic map of Addis Ababa city (the so called Nortech Map) has been used in addition to the ground survey data collected at some outfall points.
- The neighborhood design of the study areas have been used as a land use map. The land use pattern, the nature of the physical development of the area(s) to be served by the storm-water drainage system, and the ultimate pattern of drainage (both overland and by storm drains) to some existing outfall location.
- Rainfall intensity data is very crucial for runoff computation. Unfortunately, it was not possible to generate Intensity, Duration, and Frequency (IDF) curve from rainfall records collected from National Meteorology Agency (NMA) because of missing data records. For this design purpose the IDF curve prepared by Addis Ababa City Road Authority (AACRA), 2003 has been used.
- Existing drainage system components like road crossing drainage facilities and the nearby small streams.

4.3 Design Considerations

Some of the basic design considerations of storm-water drainage system are briefly presented as follows:

- Except in very unusual circumstances, storm drains should discharge to a single outfall. A storm drain that branches, thereby distributing the discharge, shall be avoided.
- Storm drain pipes should not decrease in size in a downstream direction regardless of the available pipe gradient.
- Because storm-water sewers usually receive large quantities of grit, they should be designed with higher velocities (and corresponding minimum slopes). A

minimum velocity of 0.9 m/sec is common. Special circumstances may require higher minimum velocities.

- Non scouring flow velocity of cement concrete storm drain should not exceed 2.5m/s.
- Minor drainage structures like storm drains and inlets are recommended to be designed to 10 years design frequency of runoff to avoid inundation of the roadway.
- 40% -45% built up area is assumed in the public service, leased land and commercial areas.
- Geometric data obtained at the first design point of each major drainage line will be considered to design both upstream and downstream part of the reach.
- Manhole size and spacing determined as per AACRA design standard.

4.4 Design Runoff Computation

The quantity of storm-water runoff may be determined for storm-water sewer design by any of the following methods: Empirical Formulas, The Rational method, Rainfall-runoff correlation studies, Hydrograph methods, the inlet methods and Digital computer models. The method selected depends on the local geographic and hydrologic conditions, the availability of past rainfall and runoff data, the size of drainage area, the degree of protection needed.

Of the methods listed, the rational method is the most common method in use for the design of storm-water drains, where the momentary peak flow rate is desired. The method provides peak runoff rates for small urban and rural catchment areas, less than 50 hectares (0.5 km²), but is best suited to urban storm-water drain systems and rural ditches. It shall be used with caution if the time of concentration exceeds 30 minutes.

Table4-1: Basic Assumptions and data required for rational method

Method	Assumptions	Data Needs
Rational	<ul style="list-style-type: none">▶ Small catchment (50ha)▶ Time of concentration <1hr▶ Rainfall uniformly distributed in time and space▶ Runoff is primarily overland flow▶ Negligible channel storage	<ul style="list-style-type: none">▶ Time of concentration▶ Drainage area▶ Runoff coefficient▶ Rainfall intensity

The rational method: In the rational method, the following relationship is used:

$$Q = 0.00278 CiA$$

Where:

Q = maximum rate of runoff, m³/sec

C = average runoff coefficient

i = average rainfall intensity, mm/hr

A = catchment area tributary to the design location, ha

Briefly, the computation of storm-water runoff rate, using the rational method, requires the following basic data be determined:

a) Time of Concentration, T_c Computation

The time of concentration is the time required for water to flow from the hydraulically most remote point of the catchment area to the point under investigation. For each drainage area, the following parameters shall be determined:

- ▶ The distance (L) from the outlet of the drainage area to the most remote point.
- ▶ The average slope (S) for the same distance

- The nomograph shown below has been used to get T_c . It includes flow length, average surface slope and surface cover.

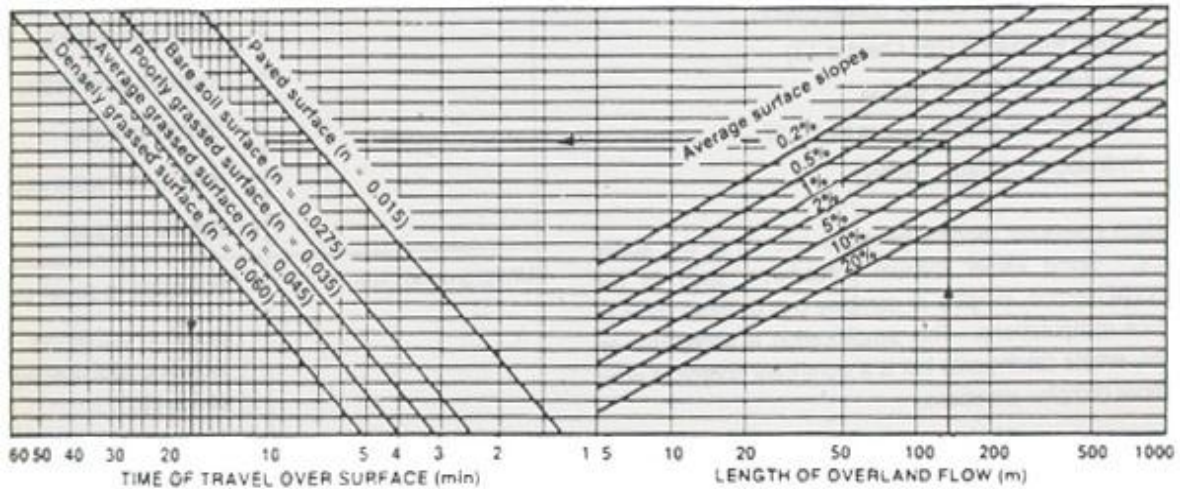


Fig. 4-1: Nomograph for Estimating Overland Sheet Flow Times

The following procedure has been used for estimating time of concentration:

1. The flow path is divided into reach lengths along which flow conditions remain reasonably consistent. Characterizing the progression of runoff along a travel path as either overland (or sheet) flow, shallow concentrated flow, or concentrated channel or conduit.
2. For each identified reach length, the travel time is estimated using a method that is appropriate for the flow conditions. For example for channel flow Manning Equation and for overland sheet flow nomograph is applied.
3. The total time is determined by adding the individual travel time.
4. An alternate flow path is selected and repeating steps 1 and 2, as necessary.
5. The path that results in the longest time is selected. This is the time of concentration (t_c), that is, $T_{c=} T_c$ (max).

b) Runoff Coefficient, C

The assignment of the runoff coefficient (C) is somewhat subjective. At the time the rainfall producing runoff occurs, the coefficient varies with topography, land use, vegetal cover, soil type, and moisture content of the soil. In selecting the runoff coefficient, the future characteristics of the neighborhood have considered. For land use having variation within a watershed, C value of individual segment is considered, and weighted runoff coefficient value calculated.

The following table suggests ranges of C values for various categories of ground cover. This table is typical design guides found in AACRA design manual and most civil engineering texts dealing with hydrology.

Table 4-2: Runoff Coefficients for Composite Runoff Analysis

Surface	Runoff Coefficients
Street Asphalt	0.70 - 0.95
Street Concrete	0.80 - 0.95
Drives and walks	0.75 - 0.85
Roofs	0.75 - 0.95
Playing Ground	0.30 - 0.40
Bussiness-neighborhood areas	0.30 - 0.70
Parks, cemeteries	0.10 - 0.25

Source: Hydrology, Federal Highway Administration, HEC No. 19, 1984

The total catchment area that drains to the project sites includes peripheral areas that require special consideration from the land use point of view. These areas are mainly bare lands with very few vegetation cover having different surface slopes. The soil investigation report of Jemo III indicates that the soil contains clayey silt with little sand. According to Ethiopian hydrologic soil group, the soil type can be grouped under group D.

Runoff Coefficient, C for Pervious Surfaces of Group D Hydrologic Soil and Slope Ranges.

Table 4-3: Runoff Coefficients for different terrain

Terrain Type	Runoff Coefficient C
Flat, <2%	0.15-0.20
Rolling, 2-6%	0.20-0.25
Mountain, 6-15%	0.28-0.38
Escarpment, >15%	0.38-0.48

c) Rainfall Intensity

The rainfall intensity, i is the average rainfall rate in mm/hr for specific rainfall duration and a selected frequency. The duration is assumed to be equal to the time of concentration. For drainage areas in the study area, IDF curve prepared for Bole

airport station by AACRA has been used to get the rainfall intensity for 10 years return interval.

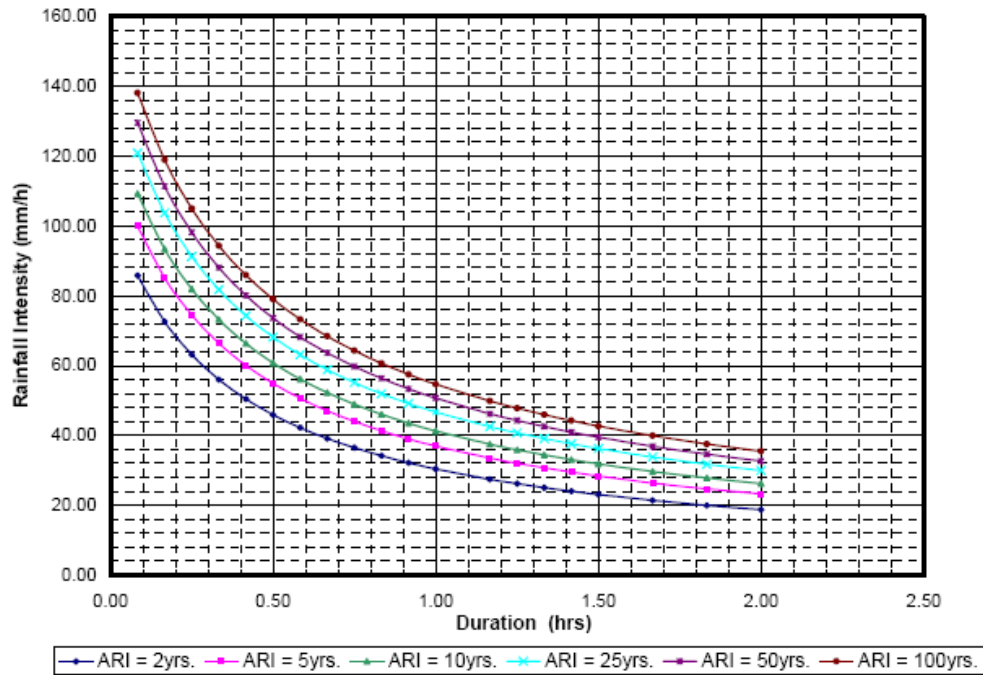


Fig. 4-2: Intensity-Duration-Frequency curve of Addis Ababa, Bole

4.5 Storm-Water Drain Sizing

After the preliminary locations of inlets or manholes, connecting pipes and outfalls have been determined, the next is the computation of the rate of discharge to be carried by each reach of the storm drain, and the determination of the size and gradient of pipe required to convey this discharge. This is done by starting at the upstream reach, calculating the discharge using rational method discussed above and sizing the pipe, then proceeding downstream, reach by reach to the point where the storm drain connects with other drains or the outfall.

The rate of discharge at any point in the storm drain is not necessarily the sum of the inlet flow rates of all inlets above that section of storm drain. It is generally less than

this total. The time of concentration is most influential and as the time of concentration grows larger, the rainfall intensity to be used in the design grows smaller.

Storm drains has been sized on the assumption that they will flow full or partially full under the design discharge but will not flow under pressure head. The Manning's formula is used for capacity calculations. An open channel having an economical circular section has been used in the design. The proportions between the hydraulic parameters that are used during design are shown below.

$$\text{Flow depth (m)} = 0.938D$$

$$\text{Design Flow} = 1.17V$$

The storm-water sewer network has been analyzed based on the selected outfall facilities, selected network schematization and agreed designed criteria using interactive mathematical model on Excel. In general, such a mathematical model of a storm-water sewer network consists of the following two major components:

- i) The hydraulic computation program which controls input and output, makes all necessary analysis and design, presenting the results, and performs data verification and conformity tests;
- ii) The input file, which describes the various components of the network such as drain pipeline, pipe type and diameter, roughness, junction manholes and other facilities like outfall points etc.

The result that expected from the mathematical model therefore depend on these components and finally the simulation results interpreted with care to get the optimal pipe size from the economic and efficient hydraulic operation point of view.

4.6 Manhole Sizing and Spacing

Access holes are utilized to provide entry to continuous underground storm drains for inspection and cleanout. The spacing of access holes is in accordance with the criteria in table 2-4 below.

Table 4-4: Spacing of Access Holes

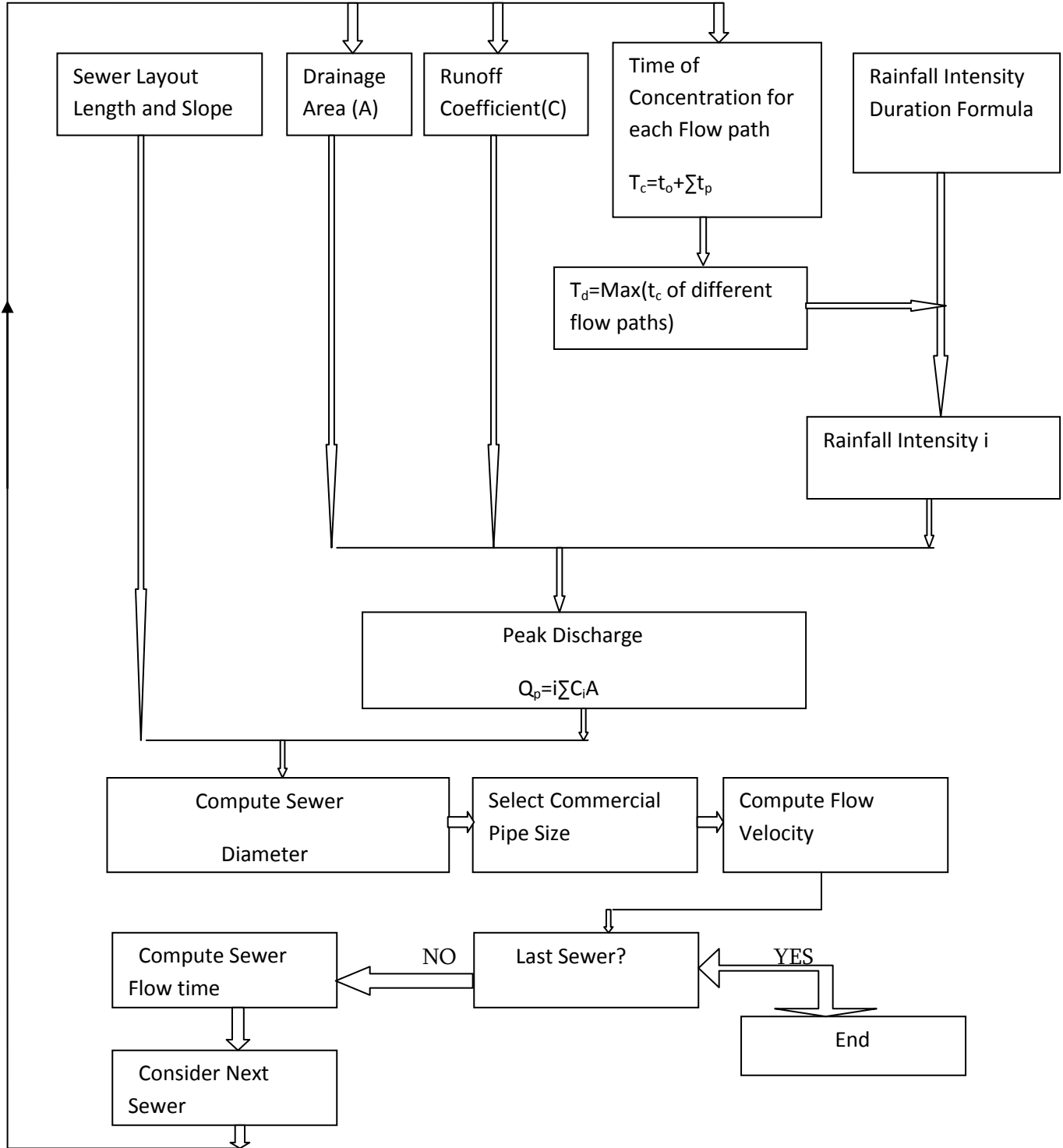
Size of Pipe (mm)	Maximum Spacing (m)
300 - 600	100
675 - 900	125
1050 - 1350	150
1500 - Up	300

Size of access hole is determined by the size of storm drain. When the storm drain pipe size is 450mm or less, a 1200mm diameter access hole need to be provided. When the pipe size is 525 to 1050mm inclusive, a 1500mm diameter access hole will be provided. When the storm drain pipe size is 1200mm or larger, a 1800mm diameter access hole or a special design access hole shall be provided.

Grate inlets is considered to use in each junction manholes in this design as it can perform satisfactorily over a wide range of gutter grades.

Design of Storm Drainage System

Figure 4-3 ALGORITHM OF RATIONAL METHOD FOR SEWER DESIGN



Storm Drain Computation Sheet JEMO-III Near Glass Factory

Return period = 10 Year

Station		Length (m)	Drainage Area A (ha)		Runoff Coefficient C	A x C		Flow Time (min)			Rainfall Intensity (mm/h)	Total Runoff $0.00278CIA = Q$ (m ³ /s)	Diameter Pipe (m)	Capacity full (m ³ /s)	$A = 785 * D^2$	Velocity (m/s)		Invert Elev.		Slope of Drain (m/m)
From	To		Increment	Total		Increment	Total	To Upper End	In Section	T _c						Flowing Full	Design Flow	Upper End	Lower End	
DP 5	DP 6	69.2	0.58	0.58	0.37	0.21	0.21	10		10	94	0.056	0.3	0.23	0.07	3.19	0.79	2247.3	2244.6	0.039
MH 23	DP 6	120.8	0.46	0.46	0.58	0.27	0.27	10		10	94	0.070	0.3	0.20	0.07	2.85	0.99	2248.7	2244.6	0.031
DP 6	DP 7	77.4	0.72	1.764	0.36	0.26	0.74	10	0.7	10.7	92	0.190	0.3	0.21	0.07	3.02	2.69	2244.6	2241.9	0.035
MH-28	DP 7	86.1	0.66	0.66	0.38	0.25	0.25	10		10	94	0.066	0.3	0.16	0.07	2.29	0.93	2243.9	2242.2	0.02
DP 7	DP 8	73.8	0.72	3.144	0.57	0.41	1.4	10	1.1	11.1	91	0.355	0.4	0.48	0.13	3.82	2.83	2242.2	2239.1	0.038
MH-32	DP 8	85.4	0.72	0.72	0.36	0.26	0.26	10		10	94	0.068	0.3	0.15	0.07	2.11	0.96	2240.9	2239.4	0.017
DP 8	DP 9	70	0.5	4.367	0.51	0.26	1.92	10	1.4	11.4	90.5	0.483	0.4	0.45	0.13	3.56	3.84	2239.1	2236.8	0.033
MH-37	DP 9	117.4	0.47	0.47	0.51	0.24	0.24	10		10	94	0.063	0.3	0.14	0.07	1.98	0.89	2238.5	2236.7	0.015
DP 9	OF-1	64	0.81	5.647	0.36	0.29	2.45	10	1.7	11.7	89	0.606	0.5	0.79	0.20	4.00	3.09	2236.7	2234.7	0.031
MH 01B	DP1	66.2	0.26	0.26	0.36	0.09	0.09	10		10	94	0.024	0.2	0.06	0.03	1.99	0.78	2263.4	2261.7	0.026
DP1	DP2	70.9	0.2	0.46	0.46	0.09	0.19	10	0.42	10.4	92.7	0.048	0.2	0.10	0.03	3.17	1.52	2261.7	2257	0.066
MH5	DP2	94.9	0.46	0.46	0.38	0.17	0.17	10		10	94	0.046	0.2	0.06	0.03	2.06	1.45	2260	2257.3	0.028
DP2	DP 3	69.8	0.59	1.51	0.4	0.24	0.6	10	0.7	10.7	92	0.153	0.4	0.67	0.13	5.33	1.21	2257.3	2252.1	0.074
MH 10	DP 3	137.1	0.42	0.42	0.6	0.25	0.25	10		10	94	0.066	0.3	0.16	0.07	2.23	0.93	2255	2252.4	0.019
DP 3	DP 4	73.4	0.77	2.7	0.42	0.32	1.17	10	0.9	10.9	90.9	0.296	0.4	0.58	0.13	4.59	2.36	2252.1	2248	0.055
MH-16	DP 4	140.6	0.43	0.43	0.47	0.2	0.2	10		10	94	0.053	0.3	0.19	0.07	2.75	0.75	2252.1	2248	0.029
DP 4	OF-2	203.4	0.77	3.9	0.35	0.27	1.64	10	1.13	11.1	91	0.416	0.5	1.04	0.20	5.28	2.12	2248	2237	0.054

Table 4-5: Storm Drain Computation Sheet JEMO-III near Glass Factory



Fig 4-4: Design Layout

4.7 Result Interpretation

The hydrological and hydraulic analysis result of Jemo III near Glass factory site indicates that as it is possible to collect and convey storm runoff from the area making use of the existing road crossing drainage structures. These road crossing structures are used as outfall points for the catchment to dispose the collected storm water to the natural stream with appropriate modification, if required. There is only one natural stream that flows from west to east helps to dispose the collected runoff. This was one of the physical limitations in designing drainage system layout.

5 Conclusions and Recommendations

5.1 Conclusions

In this study, minor storm drainage system has been designed which has storm drain as major system component in addition to manhole and inlet for 10 years flood event. Although the design of a storm drain system entails many conventional procedures and design considerations, certain aspects of a storm drain system design require judgment. Design parameters and criteria have been established to decide layout and component location in an economical and physically feasible manner. Jemo III near Glass factory sites has two major storm drainage networks having unique outfall. From the catchment area of the above mentioned sites, the proposed number of drainage network enable to come up with economical system design. In this design closed concrete open channel is adopted.

5.2 Recommendations

The serious flood problems in the study area can be solved with integrated analysis of the river system, the storm water drainage system, and waste disposal system in the urban area, forestation and other conservation activities on the upper catchments of the study area and planned land use is definitely a successful way to go. If planning of urban development is done carefully, losses due to floods can be mitigated to a great extent.

Such storm water drainage system design at neighborhood level should be integrated with road design. Most of the cases the pavement drainage components are inadequate to convey runoff from different parts of the catchment. During construction, size of storm drain has to be provided equal to or the next commercially available size.

Part of storm drainage network in Jemo III near Glass factory site can be replaced with open ditch having rectangular cross section that can convey the same design flow of circular storm drain. However, this option has its own challenge when we come to lack of *awareness* among the people in managing and maintaining public ditches. Generally, it is imperative that the community awareness should be raised on environmental protection and sanitation.

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