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# Addressing Delhi's Urban Flooding Problem

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Chapter 1

# Introduction

In the current scenario, whenever it rains for more than a couple of hours, the drain starts overflowing. Water is no more contained in its path but spills out to the roads and low-lying areas. Most cities in India face the problem of Urban Flooding, which is colloquially known as water-logging. Despite government officials claiming that all required measures to control urban floods have been taken, roads get inundated, causing traffic to jam and disrupting the pace of the city. The measures taken usually are spending crores annually, de-silting the drains before monsoon seasons and laying new drains of greater capacity to reduce the load on the existing system. This approach tries to remove water from a particular area without considering the next area where it might get collected. Thus, the traditional approach is not the solution but can possibly trigger water-logging.

The solution of this problem lies in the very heart of the problem, the planning and design of drainage system of the city. In the book, SOAK: Mumbai in an Estuary, Appadurai and Breckenridge say, “Design…solves the problem of flood not by flood control measures, but by making a place that is absorbent and resilient” (Anuradha Mathur, Dilip da Cunha, 2009). Traditional urban drainage systems focus on quantity as they aim to remove excess water away from urban areas as quickly as possible to avoid possible flooding incidents. Natural drainage involves flow of water and subsequent infiltration. Thus these urban drainage systems have caused an alteration in natural flow patterns, not necessarily having an effect locally, but they may cause problems elsewhere in the catchment area. Hence, it is must that a thorough study of the drainage pattern of an area is done before any physical planning.

Apart from the shortcoming in the traditional outlook towards drainage, urbanization also significantly alters the way water flows in an area. In natural areas, most rainfall soaks into the ground to replenish groundwater or is absorbed or transpired by plants, and a significantly smaller amount runs directly into rivers. In urban areas, the impervious surfaces created by buildings and pavement cause rainwater to flow quickly over the landscape, rather than soaking naturally into the soil or being absorbed by plants.  Even lawns, which have compacted soil can contribute to urban runoff. “A one-acre paved parking lot generates 16 times more runoff than a meadow of the same size. This increases the surface run-off and changes the stream flows and hence increases flooding” (Schueler, 1996). This urban run-off is also hazardous to the local hydrological system as it contains pollutants such as oil, heavy metals, bacteria, sediment, pesticides and fertilizers. Urbanisation has become a phenomenon which is difficult to reverse and many are even against its reversal. So to eliminate the ill effects of urbanisation, it is better to design a better urban world rather than reversing urbanisation. Urban flooding which is one of the ill effects of urbanisation can be reduced by designing an efficient Storm Water Management (SWM) system. Sustainable Urban Design System (SUDS) are one of the best practices for storm water management in the urban scenario. They are designed either to allow increased infiltration or retention in devices.

As the prevailing drainage system became inefficient and unsustainable as urbanisation increased, many countries followed the example of United Stated, France and Australia. “The main idea contained in the proposals presented for rainwater management in the urban milieu is maintenance of natural water flow mechanisms, or the use of structures that seek to “imitate” some process of the natural hydrologic cycle that was altered…. the main techniques used contemplate the use of structures that seek to reproduce water infiltration capacity in the soil lost due to im-permeabilization. As a result, a smaller volume of surface runoff is created, and there is a reduction in flooding problems" (Poleto & Tassi, 2011).

## Aim and objectives

The Aim of this paper is to address the problem of Urban Flooding in Delhi.

The Objectives is to find Sustainable approach to the Urban Flooding problem in Del-hi through design solutions. To achieve this, it is must to find the causes of Urban Flooding.

## Scope and Limit

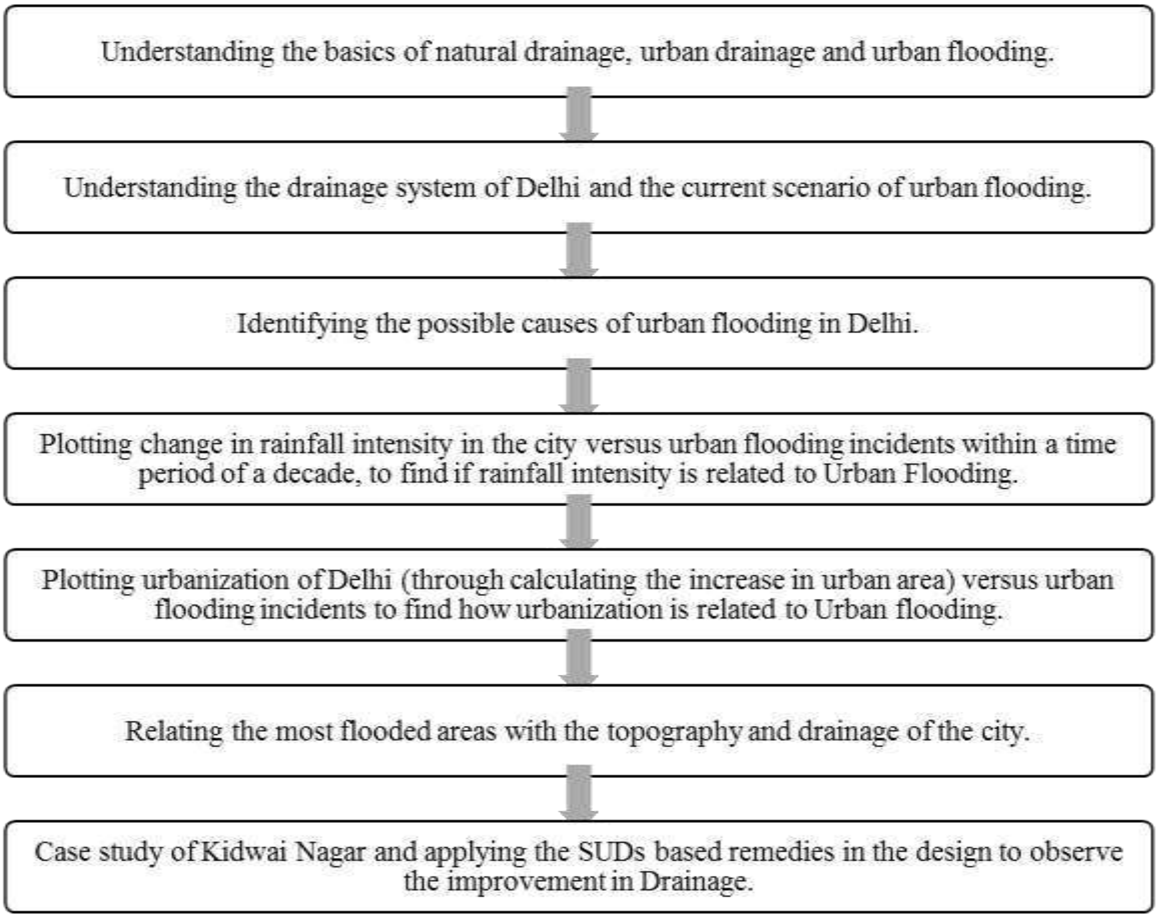
Though urban flooding also causes many ecological hazards, but this dissertation will not cover them. The dissertation is concerned with finding the causes of urban flood-ing.

## Hypothesis

1. The prime cause of urban flooding in Delhi is increasing urbanisation leading to increase in built-up area.

2. Applying the tenants of SUDS while designing can reduce the incidents of Urban Flooding.

## Methodology



## Chapter 2
# Drainage: Flow of Water

Hydrologic cycle is the global process of the earth's water movement. In general, urbanization disrupts the cycle by sealing the ground surface with imperviousness and compacted soils, shifting precipitation from the infiltration and subsurface run-off path to surface runoff path (Harris & T.Dines, 1988). This movement or flow of water can be called drainage.  An area drained by a river and its tributaries [flowing water] is it's called watershed (NatGeo, n.d.). The flow of water over this watershed is effected by

a. The type of soil (black soil, alluvial soil etc., depending upon the particle size and their cohesion)
b. The land cover (grass cover or soil or paved)
c. The topography (flat or sloped)

These features decide the Measurement of Permeability, Infiltration rate and Run-off Coefficient of water.

### Permeability, Infiltration and Run-off

Permeability is the measure of the capacity of soil to transmit water. It is the function of soil texture, soil water content, vegetation and inter-particle chemical deposits. Measurement of Permeability is the time taken for a millimetre of water to pass through a given quantity of soil. Permeability or rate of water transmission (k) is given by

K= water in mm / time in min.

Infiltration (Surface Permeability) is the amount of precipitation that is converted to surface run-off. If the rate at which water supplied to the surface exceeds the infiltration capacity, run-off occurs over the surface of ground.

Run-off is the water remaining from precipitation after the losses from evaporation, transpiration and seepage into the ground water. Run-off Coefficient is the ratio of Run-off to rainfall. Surface Run-off is the water that flows over the land.

### Flow Regime

The way water flows across the surface of water is called the Flow regime. There are three types of flow regimes, namely

a. Overland flow or sheet flow: A shallow flow of water, usually less than one inch deep, over plane surfaces.
b. Shallow concentrated flow: Usually begins where overland flow converges to form small rills or gullies and swales. Shallow concentrated flow can exist in small, man-made drainage ditches, paved or unpaved, and in curb and gutters.
c. Channel flow: Occurs where flow converges in gullies, ditches, and natural or man-made water conveyances (including pipes not running full). Channel flow is assumed to exist in perennial streams or wherever there is a well-defined channel cross-section. (Water/wastewater Distance Learnig Website).

### Flood and Urban Flooding

Flood is an overflow of large amount of water beyond its normal limits, especially over normally dry lands. Flood can be categorised based on

1. Duration
    a. Slow onset-flooding
    b. Rapid onset-flooding
    c. Flash floods
2. Location
    a. Coastal flooding
    b. Arroyos flooding
    c. River flooding
    d. Urban Flooding (National Institue of Disaster Management)

For this paper, we are concerned about Urban Flooding. “Flooding in urban areas can be caused by flash floods, or coastal floods, or river floods, but there is also a specific flood type that is called urban flooding. Urban flooding is specific in the fact that the cause is a lack of drainage in an urban area” (United Nations Economic and Social Commission for Asia and the Pacific). . Urban Flooding is an urban phenomenon and is faced in many cities all over the world. But the paper is concerned with urban flooding particularly in Delhi, though the findings can be applied elsewhere also.

The effects of Urban Flooding are not unknown and are faced annually, particularly during monsoons. To quote a few, the economic effects include loss of employment to daily earners, increase in prices for essential commodities, loss of revenue due to road and railway transportation interruption etc. Traffic congestion due to damage of roads, collapse of bridges and overall great public inconvenience due to impairment of transport and communication system (National Institue of Disaster Management).

The **causes of urban flooding** are also known worldwide. Sudden increase in rainfall intensity, inadequate and outdated drainage infrastructure, building on flood plains, filling up of depression points which otherwise helps is water detention during rain etc. Apart from increase in rainfall intensity, which is a natural phenomenon (though an implication of human activities) all the other causes are manifestation of one critical and rapidly growing trend: Urbanization. The objective of the paper is to find which of the above mentioned causes pertains to Delhi.

## Chapter 3
# Situation Analysis

Fast urbanisation in Delhi during last four decades resulted in increase in paved area and decrease in the agricultural land which used to act as a percolation zone and is continuously depleting (Net Agriculture area sown in 1950-51was 97067 ha, in 2005-06 is just 25000 ha out of total 148300 ha) (National Institue of Disaster Management). Taranjot Kaur Gadhok, a senior fellow in HSMI (HUDCO) states in an article, "A significant phenomenon which has been increasing during recent years is that of local flooding. Urban areas are characterized by a high area under impervious surfaces (Roads, pavements, houses etc). High rates of development along with the resultant loss of soft landscape has led to high surface water sun-off rates. This results in flash floods in the low lying areas even after moderate precipitation. Another factor adding to this effect is that of river because the river is already flowing at a higher level within its embankments. Thus, the water gets logged in the city areas and it takes several days to mechanically pump it out and bring the situation under control" (Gadhok T. K.). The need for more land to facilitate urban growth is another catalyst in the frequent urban flooding as in the case of Trans Yamuna region of the city. The topography of Delhi is such that the drainage system so created carried the rain water from the Western higher elevations to the East to drain in the Yamuna. Naturally the low-lying Eastern side was a part of the Yamuna flood plain and considered un-inhabitable due to frequent floods. Today, this Eastern part which is also known as the Trans Yamuna area houses about 20% of the total population of Delhi (City Development Plan Delhi). This area is frequently inundated during monsoon as it lies on a flood plain. Another effect of the need for more land to be urbanized, is that water bodies, low lying areas (water retaining plains), near or around the city which act as flood absorbers are gradually filled up and built upon due to urbanisation pressure. Earlier there were 800 water bodies in Delhi, which has now reduced to 600, which are also silted to a great extent (National Institue of Disaster Management). In a newspaper article from Times of India, Professor Manju Mohan of the Atmospheric Sciences department at IIT states that area under water bodies in Delhi have shrunk by 53% in over 10 years, from 1997 to 2008 (Jayashri Nandi, TOI, 2012). The consequence of this is that, Delhi now have fewer water retention points. This decreases the Time of Concentration, hence increasing the Peak discharge and does increasing the chances of Urban Flooding.[1]

In a report on Urban Flooding and Management, the National Institute of Disaster Management identifies inadequacy of the local drainage system as a factor contributing to Urban Flooding. Often water treatment plants like Bhagirathi, Haiderpur etc discharge sediments into storm water drains causing siltation. Thus reducing the capacity of the drains (National Institue of Disaster Management). It further states old drainage and sewerage system has not been overhauled nor is it adequate for the present drainage requirement. Back flow from main drains into city drains to sewers during high floods is a very common scenario.

The responsibility of construction and maintenance of drains all over the city has been distributed amongst (City Development Plan, Delhi)

- Irrigation and Flood Control Department (for large drains)
- Delhi Jal Board (DJB) (for drains over 1000 Cusec discharge)

[1] For Time of concentration and Peak discharge refer to page number 16.

- MCD (Municipal Corporation of Delhi), NDMC (New Delhi Municipal Corporation) and DJB (for conservation, maintenance (including de-silting) of the drains in their respective areas.

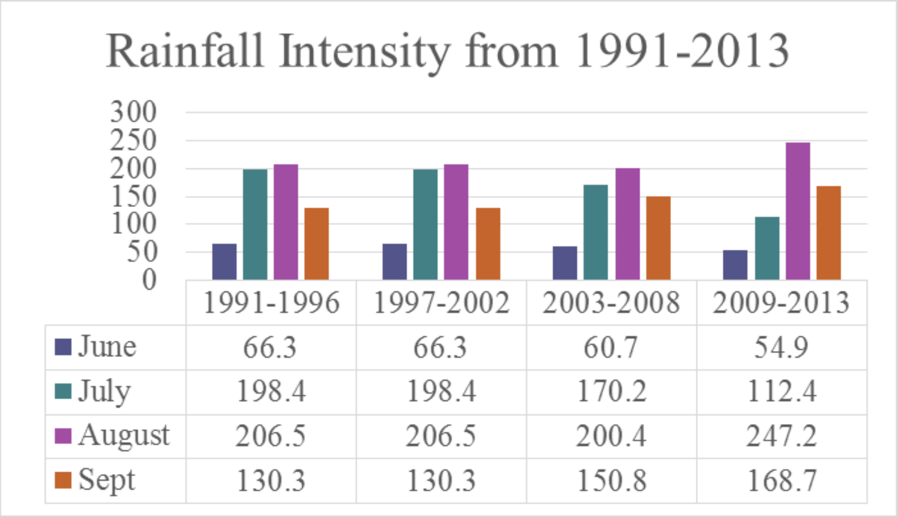
The five major drainage basins of Delhi are - Najafgarh Basin, Barapulaah Basin, Alipur Basin, Shahadra Basin and Khanjawal Basin.

## Rainfall Intensity and Urban Flooding

Often increasing incidents of Urban Flooding has been related to rainfall intensity, as increasing rainfall intensity increases the peak discharge[2]. But, data collected from India Meteorological Department shows that rainfall intensity in Delhi has been fairly constant for over two decades: 1991-2013. To the contrary, urban flooding has been constantly increasing (Fig 2).

**Hence, in case of Delhi, increasing urban flooding incidents cannot be related to rainfall intensity.**

[2] For Peak discharge refer page number 16.



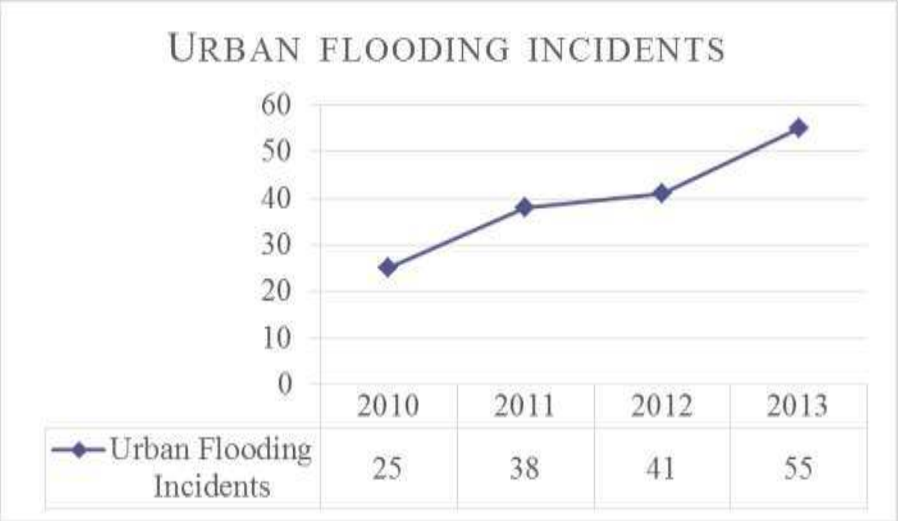




**Figure 1 Rainfall Intensity and Urban Flooding Incidents**

## Trend of Urbanization in Delhi

Post-independence, Delhi has been constantly growing, both in terms of population and urban area. The Economic Survey of Delhi for the year 2005-2006 states that in 1961, total area of the Union Territory that had been urbanized was 326.54 sq.km (22%). This increased to 591.90 sq.km in 1981 which accounts for 40% of total area. From 1991 to 2001, the urban area increased from 700.23 sq.km (47%) to 924.68 sq.km (62%).

From the graphs below, it is evident that as the urban area increases, number of incidents of Urban Flooding also increases. **Therefore, increasing incidents of Urban Flooding is directly related to increasing urban area.**

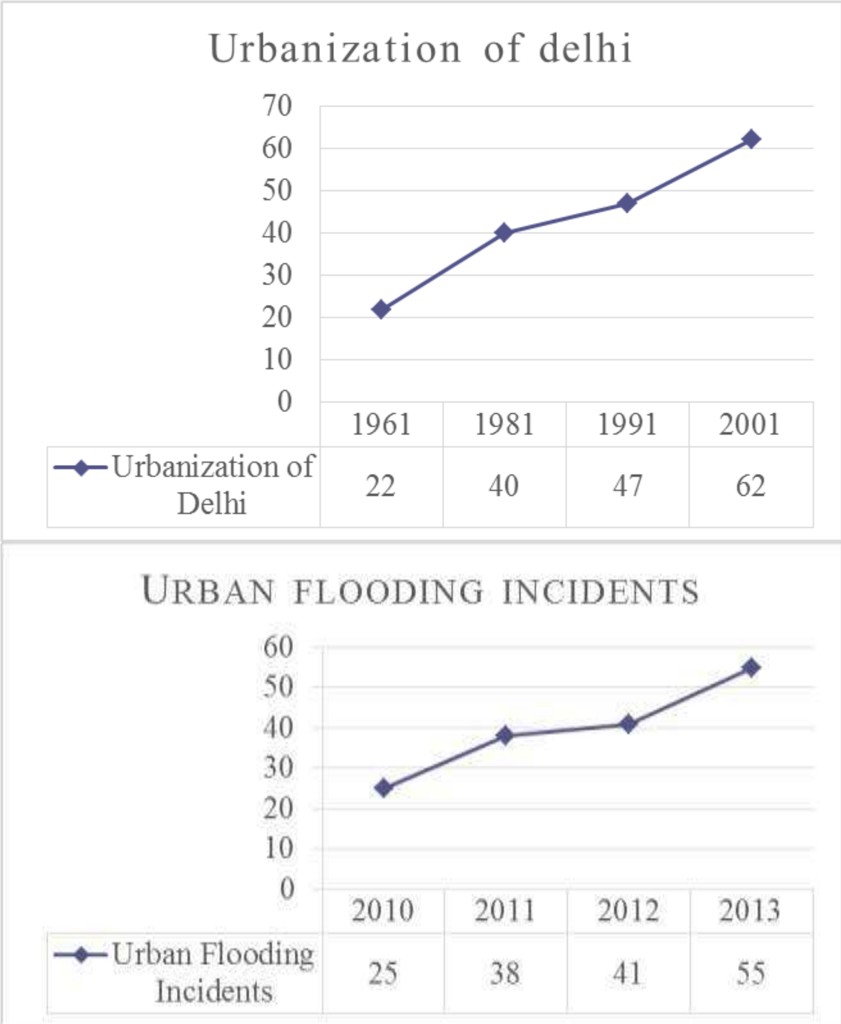



**Figure 2 Urbanization and Urban Flooding Incidents**

## Topography of Delhi, its Drainage System and Urban Flooding

The area represents a mature topography with vast gently undulating plains, low linear ridges and isolated hillocks. The ridge occupies the south central part of Delhi and extends up to western bank of Yamuna River as seen near Okhla in south and Wazirabad in north-east. The general elevation of the plains varies between 213 and 305 m above m.s.l (mean sea level) and the ridges rise 40 to 50 m above the plains. Yamuna

River flows across Delhi in a south-southeasterly direction with vast flood plain, marked by a bluff of 3 to 4 m on either bank as seen near Narela towards west and near Baghpat towards east. The area towards east of ridge has a gentle slope of 3.5 m/km towards Yamuna, and a number of tributary streams and nalas drain into Yamuna. The area towards west of ridge representing Older Alluvial Plain is mostly covered by sand dunes and has a westerly slope. All the nalas debouching from the western flank drain into a broad inland basin described as Sahibi-Najafgarh basin (Geological Survey of India, GSI, 2011).

Given the presence of a gentle slope towards east of ridge, drainage of water is facilitated in Mehrauli basin, which falls under this area. The Barapullah Drain, drain, caters to the entire South Zone area through numerous branches including the Kushak, Nauroji Nagar, Kidwai Nagar, Chirag Delhi and Lajpat Nagar drains, the combined water from which fall into the river Yamuna below the Interstate bus terminus at Sarai Kale Khan.

As such, there shouldn't be any incident of water logging in this area. But rapid urbanization in this area has led to flattening of the slope and an increasing urban area. Thus, this area now encounters the highest number of Urban Flooding incidents. According to Delhi Traffic Police reports, Chirag Delhi flyover, Lala Lajpat rai Marg, Munirka, Saket Metro Station, Lado Sarai etc., are areas falling in this region which are most flooded. Figure 2 shows the same on a topographic map of Delhi, with an overlay of the drainage map. The most urban flooded areas of 2013 has been marked.

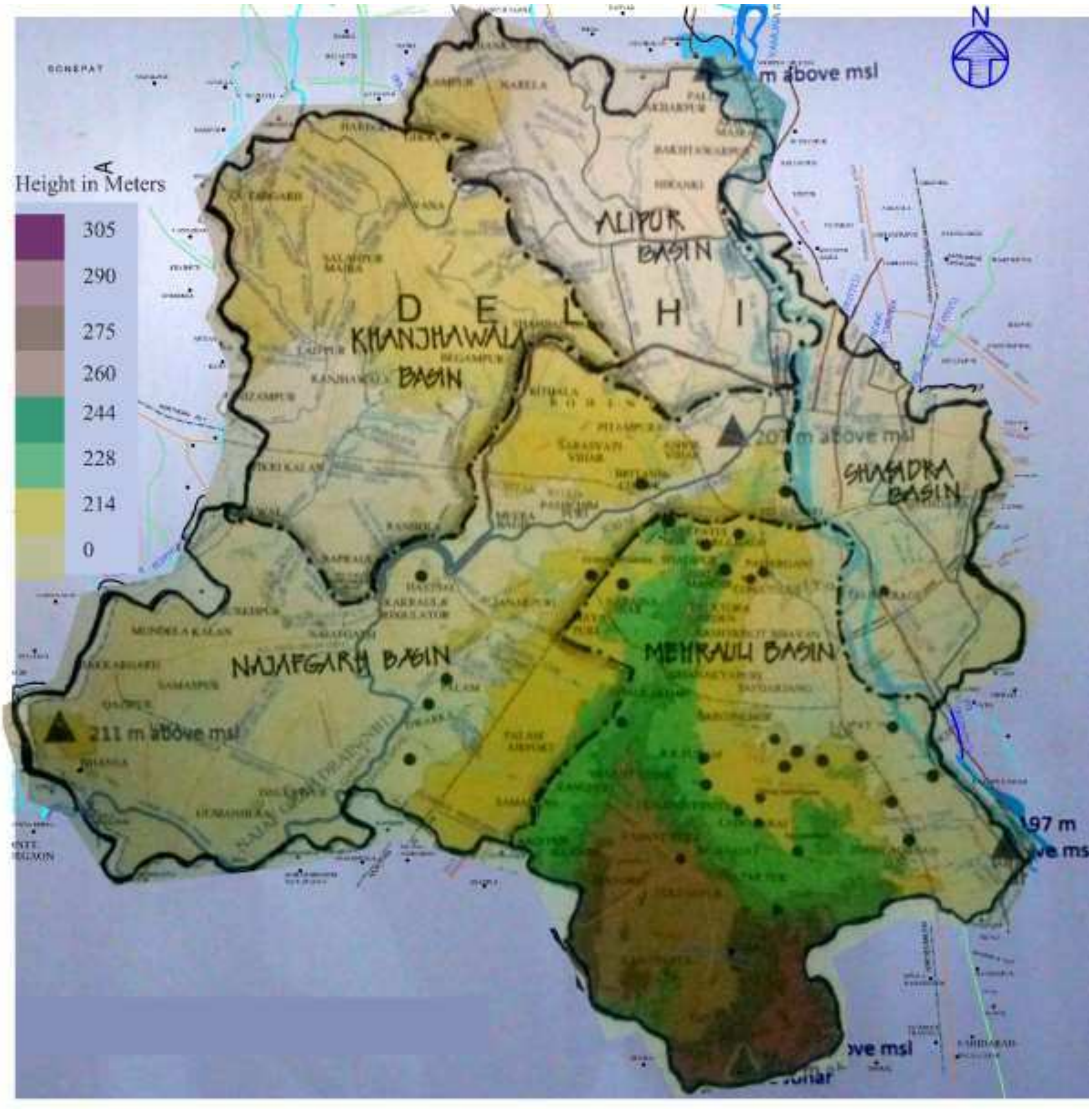



**Figure 3: Map showing most urban flooded area in Delhi**

**Thus, in case of Delhi, increasing urbanization and not rainfall intensity, causes Urban Flooding incidents.** The situation thus demands for an improved and sustainable Storm Water Management keeping in mind the trend of urbanization and the natural water drainage.

## Chapter 4

# Storm Water Management through Sustainable Urban Drainage System.

### Storm Water Management

Urbanisation has become a phenomenon which is difficult to reverse and many are even against its reversal. So to eliminate the ill effects of urbanisation, it is better to design a better urban world rather than reversing urbanisation. Urban flooding which is one of the ill effects of urbanisation can be reduced by designing an efficient Storm Water Management (SWM) system. The Washington State Department of ecology define SWM as "Storm Water Management is managing the quantity and quality of storm water" (WSDE, 2000). It focuses on the estimation of Runoff from Rainfall (Harris & T.Dines, 1988).

### Sustainable Urban Drainage Systems (SUDS)

As the prevailing drainage system became inefficient and unsustainable as urbanisation increased, many countries followed the example of United Stated, France and Australia. "The main idea contained in the proposals presented for rainwater management in the urban milieu is maintenance of natural water flow mechanisms, or the use of structures that seek to "imitate" some process of the natural hydrologic cycle that was altered…. the main techniques used contemplate the use of structures that seek to reproduce water infiltration capacity in the soil lost due to impermeabilization. As a result, a smaller volume of surface runoff is created, and there is a reduction in flooding problems" (Poleto & Tassi, 2011).

**Sustainable Urban Drainage Systems** are a natural approach to managing storm water drainage by slowing and holding back water that runs off from a site (NetRegs, n.d.).It is also known as Sustainable Drainage System, omitting Urban as the system is applicable to rural areas as well. SUDS are one of the best practices for storm water management in the urban scenario. They are designed either to allow increased infiltration or retention in devices. The goals of SUDS are quantitative control of surface runoff, improvement in the quality of water from surface runoff, conservation of natural characteristics of bodies of water, balance of hydrological variables in watersheds.

Type of SUDS system are permeable pavement, Semi permeable pavement, Detention and retention reservoirs, Infiltration trenches, Infiltration gullies, Infiltration wells, Micro reservoirs, Rooftop reservoirs, Green roofing, Underground reservoirs, Grassed strip etc.

As mentioned above, the first step to any form of SWM is to calculate Run-off. To estimate Runoff, the simplest method used is the Rational Method.

### Rational Method

The Rational Method calculates runoff by determining the Peak Discharge from small drainage area.

**Peak Discharge** is the greatest amount of runoff coming out of the watershed at any one time (Water/wastewater Distance Learnig Website). The rational method is most appropriate for calculating urban runoff as it becomes more accurate as the amount of impervious surface, such as pavements and rooftops increases. For this method it is assumed that a rainfall duration equal to the Time of Concentration results in the greatest peak discharge.

**Time of Concentration** ($t_c$) is the time water takes to flow from the most distant point in a watershed to its outlet (Harris & T.Dines, 1988).

The formula used in Rational Method is:

**Q = KCIA**

Where Q = Peak discharge of runoff in $m^3$

K= Constant (0.0028 or 1/360 for SI units)

C= Runoff coefficient

I= Rainfall Intensity at time of concentration in mm/ hr

A= Watershed area

The general procedure for determining peak discharge using Rational Method is as follows (Water/wastewater Distance Learnig Website)

Step 1: Determine the drainage area in Acres.

Step 2: Determine the runoff coefficient (C)

Runoff coefficient is dependent on the surface cover type. The Timesavers Standard for Landscape Architecture provides for the recommended rational formula Runoff coefficients. In case the drainage area contains multiple land cover or soil types, then Weighted Average Runoff Coefficient ($C_{avg}$) is calculated.

$C_{avg} = \sum$ (Area X Runoff Coefficient of that area) / Total Area

Step 3: Determine Time of Concentration ($t_c$).

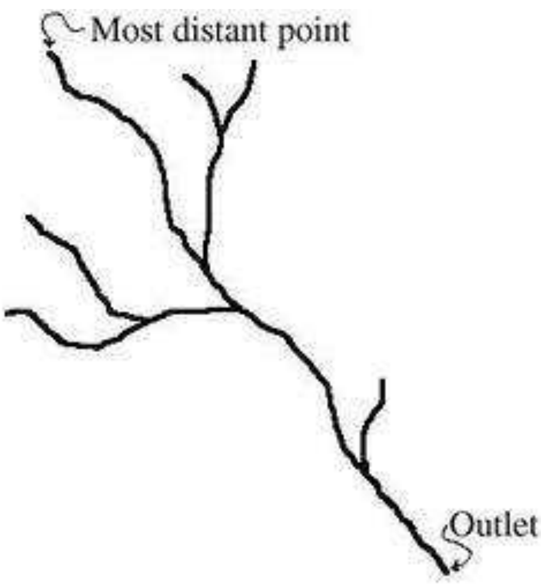



Figure 4Time of Concentration (Water/wastewater Distance Learning Website)

$t_c$ is determined by calculating the hydraulic path and travel time ($t_t$).

The hydraulic length is the distance between the most distant point in the watershed and the watershed outlet. The travel time ($t_t$) for a portion of the hydraulic path is the length of time it would take a drop of water to flow across that area of land. The time of concentration ($t_c$) equals the summation of the travel times for each flow regime[3] along the hydraulic path.

The total Time of Concentration ($t_c$) is

$t_c = L_O + L_{SC} + L_C$

Where, $L_O$ is travel time for Overland Flow (sheet flow), $L_{SC}$ is travel time for Shallow Concentrated flow and $L_C$ is Channel Flow.

Step 4: Determine Intensity of Rainfall (I).

Intensity can be calculated based in the Time of Concentration $t_c$, using an IDF curve. Intensity Duration Frequency (IDF) curves specifies the rainfall intensity for a certain region. It includes several different curves, each of which corresponds to a different type of storm. Example, 2 year storm curves model the rainfall in the largest storm which typically occurs in the region once every two years.

This gives us all the variables of the equation Q=KCIA.

From the above equation, it is evident that Peak Discharge is directly proportional to Coefficient of Runoff, Area of water shed and intensity of rainfall. Since intensity of rainfall cannot be controlled and area of a water shed cannot be changed, the **main deciding factor for Peak Discharge is coefficient of runoff.** Another deciding factor

[3] For types of flow regimes and their definitions, Refer paragraph 2, page 7.

is the **Time of Concentration** as the rational method is based on the assumption that that rainfall duration equal to the Time of Concentration results in the greatest peak discharge.

## Chapter 5

# Case study: East Kidwai Nagar Housing

## Introduction

Urbanization essentially causes Urban Flooding by changing the value of Coefficient of Runoff and Time of Concentration. As more land gets urbanized, runoff increases as lesser water gets infiltrated. This is because more land gets paved and built on, reducing permeability. Urbanization also leads to detention points getting filled up. Combined with increased runoff, this increases the time of concentration and hence, more water flows faster to the outlet.

The situation can be improved by few simple design solutions. Through a study of Kidwai Nagar and using the Rational Method, we will find out the peak discharge of the existing housing (Fig 8). Then compare the Peak discharge of a proposed housing, designed in the same area, which incorporates few SUDS techniques (Fig 9).

## East Kidwai Nagar

East Kidwai Nagar is a residential accommodation for government employee. It is located in South West Delhi and comes under the Mehrauli Basin. Barapullah is the main drain which caters to Kidwai Nagar.

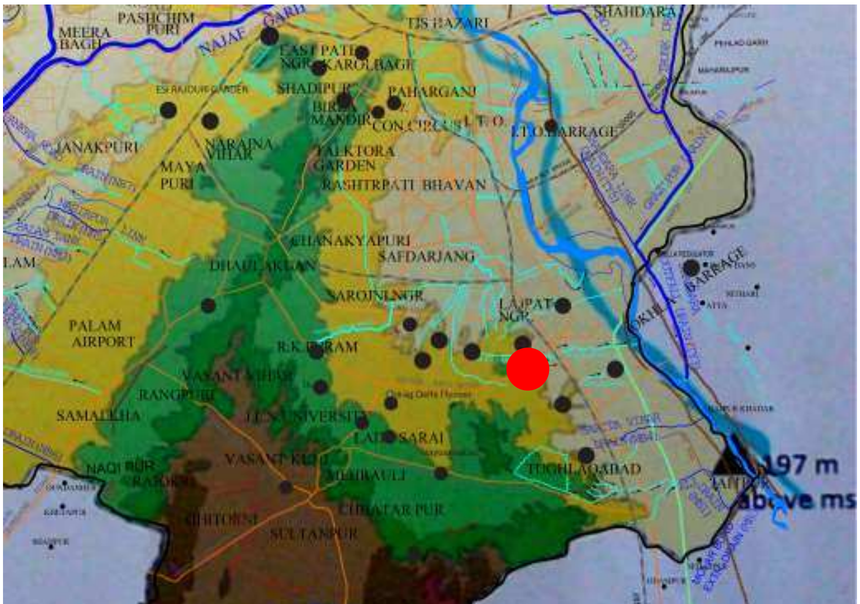


Figure 5 Drainage Basin of East Kidwai Nagar


Figure 6 East Kidwai Nagar

For the ease of calculation, a one hectare window is chosen such that all the water in that area drains towards one side (Fig 7). Within the window, the use of different material in the housing is identified and colour coded (Fig 8). This gives us coefficient of run-off for all materials used. The area under each material is measured.

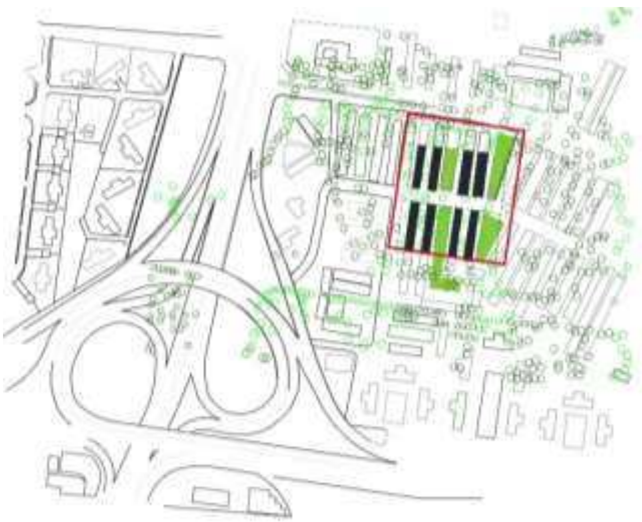


Figure 7 1 Hectare site for study

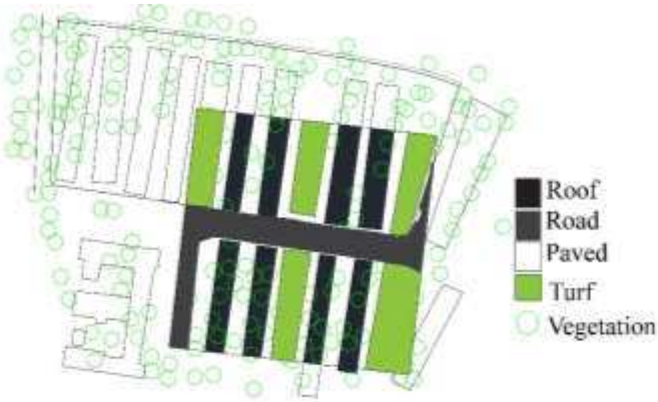



Figure 8 Housing scheme A

Number of DUs in one Ha: 60   F.A.R: 0.33

| S.NO | Material | Area sq. m (A) | Run-off Co-efficient (C) |
| --- | --- | --- | --- |
| **1.** | Roof | 2905 | 0.75 |
| **2.** | Brick Paved Area | 4720 | 0.75 |
| **3.** | Road | 1280 | 0.70 |
| **4.** | Vegetation | 1623 | 0.20 |
| **5.** | Turf | 1095 | 0.25 |

Using Q=KCIA

Rainfall intensity of Delhi: 90mm /hr.

K=0.0028

Q=KI [C1A1+C2A2+C3A3+C4A4+C5A5]

=0.0028*90 [0.75*2905+.75*4720+.70*1280+.20*1623+.25*1095]

=1817.7 cubic meter ≈ 1817 cubic meter

Thus, from the existing housing scheme, **peak discharge generated is 1818 cubic meter.**

Let us see what happens to the peak discharge within the same window, but a different housing scheme.

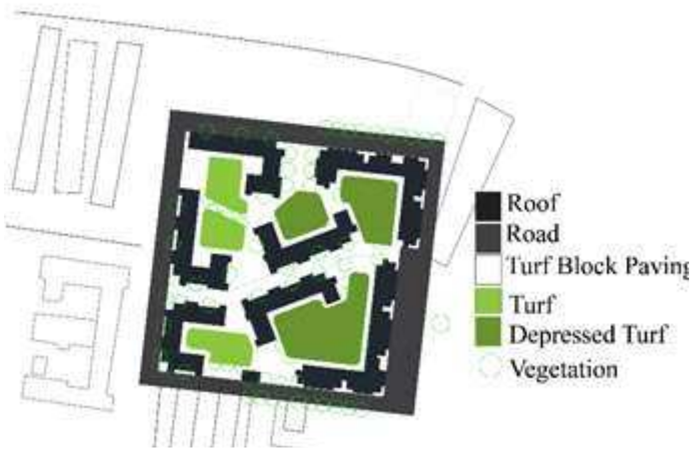



Figure 9 Housing scheme B

This housing scheme, by the author and her partner Gagan, has been designed as a part of their 3rd year Housing studio, in the same location. Their scheme included simple design solution based on SUDS to increase infiltration to recharge the ground water.

Number of DUs per Hectare: 324     F.A.R:2

| S.NO | Material | Area sq. m (A) | Run-off Co-efficient (C) |
|---|---|---|---|
| **1.** | Roof | 2930 | 0.75 |
| **2.** | Turf Block Paving | 2131 | 0.55 |
| **3.** | Road | 2858 | 0.70 |
| **4.** | Vegetation | 1440 | 0.20 |
| **5.** | Turf | 1095 | 0.25 |
| **6.** | Depressed turf | 1389 | 0.25 |

Using Q=KCIA

Rainfall intensity of Delhi: 90mm /hr.

K=0.0028

Q=KI [C1A1+C2A2+C3A3+C4A4+C5A5]

=0.0028*90[2930*0.75+2131*0.55+2858*0.70+1440*.020+1095*0.2+1389*0.25]

=1548.8 ≈ 1549 cubic meter.

Thus, from housing scheme B, **peak discharge generated is 1549 cubic meter.**

**Thus, 13% reduction in peak discharge.**

Apart from the reduction in Q value, the design also increases the Time of concentration by providing detention points. These detention points are nothing but play grounds depressed by 2' to detain water during rain, giving water time to infiltrate, recharging the ground water table as well as increasing time of concentration.

Housing scheme A has only 60 DUs/ Ha while Housing scheme B has 324 DUs/ Ha.

**Thus, a lower peak discharge can be achieved, even with a high density development.**

## CONCLUSION

Urbanization is a phenomenon which will take over the future of all land available. Land under agriculture, forest, grass lands is reducing exponentially. Climate conditions are changing, cities receive higher rainfall than the suburbs. Though at present Delhi didn't face any increase in rainfall intensity, but in future it might. As such, Urban Flooding incidents would grow even faster than now. If we depend on the traditional approach of solving Urban Flooding, not only will it be economically not feasible but ecologically unsustainable. Simple design solutions as adopted in Housing Scheme B, like pervious paving of turf blocks and depressed play areas can reduce the peak discharge and time of concentration, thus preventing urban flooding at the source. If one includes green roofs and other techniques of SUDS, the percentage of reduction will get significantly higher. The housing scheme may be a very micro level intervention, but preventing urban flooding at the source will later add up to reduce overall urban flooding incident.

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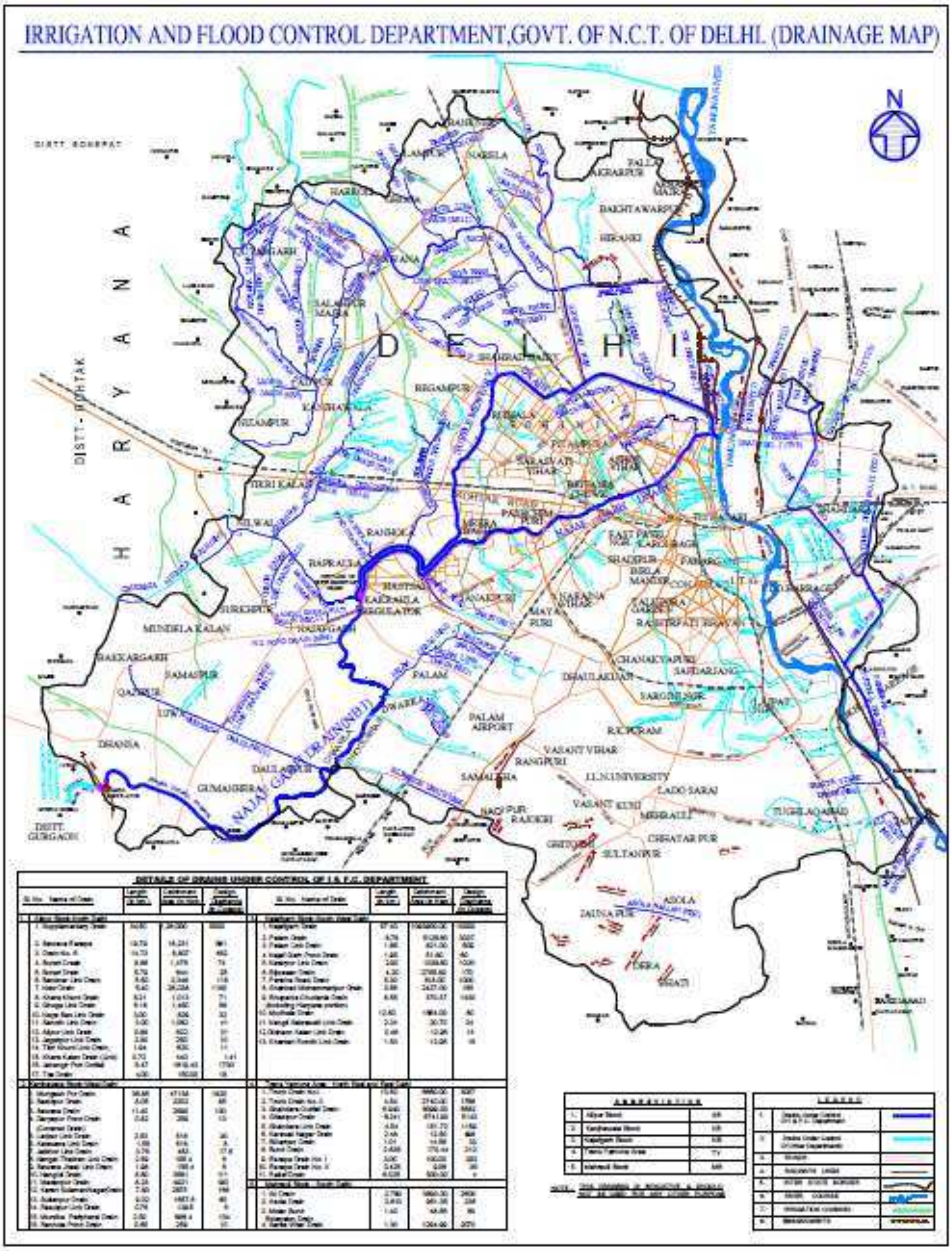
## Appendix A: Drainage Map of Delhi



## Appendix B: Rainfall Data from India Meteorological Department

HYDROMET DIVISION

INDIA METEOROLOGICAL DEPARTMENT

DISTRICT RAINFALL (MM.) FOR LAST FIVE YEARS

District : DELHI

Note : (1) The District Rainfall(mm.)(R/F) shown below are the arithmatic averages of Rainfall of Stations under the District.
(2) % Dep. are the Departures of rainfall from the long period averages of rainfall for the District.
(3) Blank Spaces show non-availability of Data.

| YEAR | JANUARY | | FEBRUARY | | MARCH | | APRIL | | MAY | | JUNE | | JULY | | AUGUST | | SEPTEMBER | | OCTOBER | | NOVEMBER | | DECEMBER | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | R/F | %DEP. | R/F | %DEP. | R/F | %DEP. | R/F | %DEP. | R/F | %DEP. | R/F | %DEP. | R/F | %DEP. | R/F | %DEP. | R/F | %DEP. | R/F | %DEP. | R/F | %DEP. | R/F | %DEP. |
| 2008 | 1.9 | -90 | 1.9 | -90 | 0.0 | -100 | 23.6 | 86 | 146.2 | 603 | 120.0 | 100 | 159.1 | -32 | 245.4 | 0 | 109.2 | -15 | 0.0 | -100 | 0.0 | -100 | 0.0 | -100 |
| 2009 | 4.0 | -80 | 5.5 | -70 | 8.4 | -46 | 4.5 | -65 | 31.4 | 51 | 16.6 | -72 | 119.0 | -49 | 156.3 | -36 | 192.9 | 50 | 2.0 | -92 | 17.5 | 230 | 1.9 | -77 |
| 2010 | 4.5 | -77 | 18.8 | 1 | 0.0 | -100 | 0.2 | -98 | 2.3 | -89 | 4.2 | -93 | 173.1 | -26 | 464.4 | 90 | 359.7 | 180 | 8.9 | -66 | 16.2 | 206 | 3.7 | -55 |
| 2011 | 0.2 | -99 | 45.3 | 178 | 3.4 | -78 | 7.0 | -21 | 23.0 | 19 | 123.8 | 107 | 43.0 | -81 | 213.0 | -13 | 145.5 | 32 | 0.0 | -100 | 0.0 | -100 | 0.0 | -100 |
| 2012 | 10.0 | -39 | 1.0 | -94 | 12.0 | -22 | 7.0 | -21 | 9.0 | -53 | 10.0 | -83 | 67.0 | -70 | 158.0 | -36 | 36.0 | -67 | 7.0 | -66 | 0.0 | -100 | 4.0 | -53 |

## Appendix C: Delhi Traffic Police List of Urban Flooded Areas for 2013

**Water logging points on dated 16-08-2013 are as under:-**

1. ESI Rajouri garden.
2. Vayusena bad.
3. Chirag delhi flyover.
4. Lala lajpat rai Marg under Defence colony fly over.
5. Adchini.
6. Harkesh nagar under fly over pull parlahd pur.
7. Pharganj chowk.
8. R K asharm.
9. Mandir marg T point.
10. Under Zakhira fly over.
11. Anand parbat gali no.10.
12. IIT chowk PTS.
13. ISBT to loha pull.
14. Devli mor.
15. Ashram chowk.
16. Munirka .
17. OP marg paschim marg.
18. AIIMS.
19. Under Hayat.
20. Police post Dhaula kuan.
21. Sector 12 RK puram in front of PWD office.
22. Bunito marg.
23. Brar square.
24. Luxmi nagar .
25. Karkari mor.
26. Madhuban chowk.
27. Ring road all heaven banquet.
28. Britania chowk.
29. MB road to sainik farm house gate.
30. Maidan garhi mehrauli.
31. Asian market mehrauli.
32. Saket metro station.
33. Dhaula peer 100 futa anuvart park mehrauli.
34. Andheria mor.
35. Lado sarai mehrauli .
36. Dalip sing cut mehrauli
37. Under Hanuman setu.
38. Apolo hospital service road.
39. CMG MTR pump.
40. Ali gaon service road.
41. Jasola u turn.
42. Jasola bridge.
43. Masjid cut .
44. Sharstri nagar metro station.
45. Dabri mor dwarka
46. Dwarka to delhi cantt side
47. Raja puri dwarka
48. Surya nagar dwarka
49. Dhansa stand
50. Bhadurgarh stand
51. Tura mandi
52. Meet nagar wazira bad road.
53. Nand nagari depot .
54. Harnam banquet wazira bad