DRAINAGE

Functional Plan on Drainage for National Capital Region

June 2016

NATIONAL CAPITAL REGION PLANNING BOARD

Ministry of Urban Development, Government of India

Functional Plan on

Drainage for National Capital Region

(Approved in the 65th Meeting of the Planning Committee of NCR Planning Board held on 28th April, 2016)

NATIONAL CAPITAL REGION PLANNING BOARD

MINISTRY OF URBAN DEVELOPMENT, GOVERNMENT OF INDIA

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National Capital Region Planning Board

FOREWORD

National Capital Region Planning Board (NCRPB) was established in 1985 through an Act of Parliament with the concurrence of the legislatures of the participating States. NCR is a unique arrangement of an inter-state region and has become a model of metropolitan regional development in the world. It is one of the largest multi-state rural-urban regions in the world with an urbanisation level of 62.2%, which is expected to reach 73.3% by 2021. NCR covers an area of 53,817 sq. km., comprising of NCT-Delhi; thirteen districts of Haryana sub-region; seven districts of Uttar Pradesh sub-region and two districts of Rajasthan sub-region.

The phenomenal population pressure and associated high urbanisation have necessitated provision of basic amenities/infrastructure, such as roads, water supply, sewerage, solid waste management and drainage at a huge scale. At the same time, conservation of ecologically sensitive features and ensuring development of the settlements on ground in a planned manner is a big challenge.

Drainage is one of the core components of the basic amenities/physical infrastructure, not only to protect the built environment from flood & storm water, but also to ensure overall environmental sustainability by means of conserving the natural features which are key components of the natural drainage regime of any settlement/region. Once efficiently integrated with the spatial plan of a settlement, natural drainage basins also assume immense recreational value, besides safeguarding the ecosystem. The natural drainage features, such as rivers, nallahs and other drainage features often stretch beyond the physical boundary of the States and therefore, examining drainage in a holistic manner at a regional level and thereafter preparation of Plan for the entire NCR is extremely important and relevant.

NCRPB prepared the Regional Plan with the perspective year 2021 for NCR, which was notified on 17th September, 2005, as per the provisions of Section 10 of the NCR Planning Board Act, 1985 for balanced and harmonized development of NCR.

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NCR Planning Board, in its 29th meeting, decided to prepare a Functional Plan on Drainage for NCR, for guidance of the participating States. In pursuance of this decision, a Study Group was constituted under the chairmanship of Engineer-in-Chief, Department of Irrigation, Govt. of Haryana with the Chief Regional Planner, NCRPB as the co-chairman. Other members of the Study Group includes Director, Central Water Commission (CWC), Govt. of India; Chief Engineers of Deptt. of Irrigation of the NCR participating States, U.P. Jal Nigam, Delhi Jal Board; Chief Town Planners/Chief Co-ordinator Planners of the NCR participating States, etc.
After extensive deliberations made in the six meetings of the Study Group, the draft Functional Plan on Drainage for NCR was prepared and the same was placed before the statutory Planning Committee of the Board for consideration. Planning Committee deliberated on the same in its 65th meeting held on 28.04.2016 and after discussions, the said Functional Plan was approved.

The Functional Plan on Drainage has closely examined various aspects which have an impact on the drainage system of any area, such as geology, geomorphology, physical features, hydro-meteorology as well as the existing drainage system of various sub-regions, pollution, etc., besides studying various norms & standards e.g. design criteria of drainage system in the participating States, CPHEEO norms, recommendations by National Disaster Management Authority (NDMA) on Drainage, etc. In order to ensure an efficient drainage system in NCR, the Functional Plan has given important recommendations on protection of natural drainage system; promotion of recreational use along drainage channels; preparation of Master Plan of inter-state regional drainage and for individual cities/towns; segregation of sewage and drainage, etc. The analysis/examination of various aspects and the recommendations will guide the NCR participating States in formulating Detailed Project Reports (DPR) on various components of drainage system in NCR.

This Functional Plan on Drainage for NCR would have to be detailed out by the participating States and their concerned agencies, by formulating district wise/settlement wise Plan of Action, wherever required, for implementation, after detailing out the projects and identification of sources of funding through convergence with other government programmes/schemes. Similarly, the Central Ministries will have to integrate this Plan with their respective Plans/Schemes.

I congratulate NCR Planning Board for its efforts to prepare "Functional Plan on Drainage for NCR", which would significantly contribute towards planning & designing the Drainage System of NCR in a sustainable manner. I am convinced that with the cooperation of the Implementing Agencies of the NCR Participating States, Central Ministries and enthusiastic support of the people, this Functional Plan would bring about a substantial improvement in the drainage infrastructure/facilities in NCR.

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National Capital Region Planning Board

ACKNOWLEDGMENT

The Functional Plan on Drainage for NCR has been prepared for guidance of the NCR participating States by means of detailing out the broad policies & proposals of the Regional Plan-2021 pertaining to drainage sector. This Plan is the result of concerted efforts by a number of individuals and institutions, who/which have played crucial role in successfully preparing & publishing the Plan.

First and foremost, I am grateful to Shri B K Tripathi, Member Secretary, National Capital Region Planning Board, who is the main driving force behind preparation of this Functional Plan. I am grateful to him for his vision, constant guidance & encouragement, without which this Plan would not have been completed.

I would like to extend sincere thanks to the members of the Study Group for providing invaluable inputs which have been extremely conducive in finalising this Functional Plan. I would like to specially acknowledge the immense contribution made by the Engineer-in-Chief, Department of Irrigation, Govt. of Haryana; Director (UT), Central Water Commission (CWC), Govt. of India; Chief Engineers/Additional Chief Engineers of Department of Irrigation of the NCR participating States of U.P., Haryana, Rajasthan and NCT-Delhi; Chief Engineer, U.P. Jal Nigam; Chief Engineer, Delhi Jal Board; Chief Town Planners/Chief Co-ordinators Planners of the NCR participating States of U.P., Haryana, Rajasthan and NCT-Delhi; Joint Director (Tech.), NCRPB, etc. during the course of preparation of the Plan.

I would like to acknowledge the sincere cooperation and constant support extended by the Central Government Ministries/Departments; NCR Participating State Governments and their Agencies/Departments, especially Department of Irrigation, who have not only helped in a big way by providing necessary information/data, but also spared their valuable time in multiple interactions which have immensely enriched the Plan. I would also like to thank the officers of the NCR Planning & Monitoring Cells of the four sub-regions of NCR who have efficiently coordinated with various departments and agencies in providing data in timely manner as well as for having provided valued inputs in the Study.

Last but not the least, I would like to acknowledge the concerted efforts by officers and staff of NCR Planning Board, who have made this endeavour a success and which has resulted in the publication of the Functional Plan on Drainage for NCR. I thank the team in NCR Planning Board, particularly Shri J. N. Barman, Consultant, NCRPB & former Director (Technical), NCRPB; Shri Rajesh Chandra Shukla, former Joint Director (Technical), NCRPB; Ms. Ruchi Gupta, Joint Director (Technical), NCRPB; and Shri Partha Pratim Nath, Deputy Director (Technical), NCRPB, who have worked very hard to make this possible.

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ABBREVIATIONS

BOD	Biochemical Oxygen Demand
BCM	Billion Cubic Metres
Bgl	Below ground level
^{0}C	Degrees Celsius
CETP	Common Effluent Treatment Plant
CGWB	Central Ground Water Board
CPHEEO	Central Public Health and Environmental Engineering Organisation
CPCB	Central Pollution Control Board
Cu. Mts	Cubic Metres
COD	Chemical Oxygen Demand
DJB	Delhi Jal Board
DO	Dissolved Oxygen
DPCC	Delhi Pollution Control Committee
EYC	Eastern Yamuna Canal
GNCTD	Government of NCT Delhi
Ha	Hectare
Ha m/Ham	Hectare metre/s
HFL	High Flow Level
Hr	Hour
HUDA	Haryana Urban Development Authority
I&FC	Irrigation and Flood Control
IMD	India Meteorological Department
Lpm	Litres per minute
M^3	Cubic metres
MCM	Million cubic metres
Mg/l	Miligram per litre
MGC	Madhya Ganga Canal
MLD	Million litres per day
Mm	Millimetre
MSL	Mean Sea Level
NCR	National Capital Region
NCT	National Capital Territory
NCT-D	National Capital Territory of Delhi
NDMA	National Disaster Management Authority
RIICO	Rajasthan State Industrial Development Investment Corporation
Sq.km	Square kilometer/s
STP	Sewage Treatment Plant
SYL	Satluj-Yamuna Link Canal
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
TC	Total Coliform

UPCB	Uttar Pradesh Pollution Control Board
UGC	Upper Ganga Canal
ULB	Urban local bodies
UT	Union Territory
WJC	Western Jamuna Canal
WMO	World Meteorological Organization
YAP	Yamuna Action Plan

CONVERSION FACTORS

1 acre feet	1233.486m^3
1 m^3	0.0008 acre feet
1 MCM	810.71 acre feet
1 acre feet	0.0012 MCM
1 cusec	2.4 MLD
1 MLD	0.4167 cusecs
1 gallon	4.5 litres
1 litre	0.2222 gallon
1 cumec	35.815 cusecs
1 cusecs	0.0279 cumecs
1 cusec	28 lps
1 lps	0.0357 cusecs
1 m^3	35.815 ft^3
1 ft^3	0.0279 m^3
1 BCM	1000 MCM
1 MGD	0.0045 MCM per day
1 MCM	222.2 MGD
1 MGD	4.5 MLD
1 MLD	0.22 MGD

GLOSSARY OF TERMS

Active flood plain	Active flood plan is the area on the two sides of a river that gets inundated by a flood having a mean recurrence interval of 2.33 years.
Afforestation	Afforestation is the planting of trees to restore or re-establish forest cover.
Backwater	Water level upstream from an obstruction which is deeper than it would normally be without the obstruction.
Catchment	A topographically defined area, draining surface water to a single outlet point. It may frequently include an area of tributary streams and flow paths as well as the main stream.
Channel	The bed and banks of a stream or constructed drain that carries all flows.
Design Storm	A selected rainfall event of specified amount, intensity, duration and frequency used as the basis of design.
Drain	A buried pipe or other conduit (closed drain). A ditch (open drain) for carrying off surplus surface water or ground water. (To) Drain to provide channels, such as open ditches or closed drains, so that excess water can be removed by surface flow or by internal flow. To lose water (from the soil) by percolation.
Drainage basin	A geographic and hydrologic subunit of a watershed.
Drainage channel	A drainage pathway with a well-defined bed and banks indicating frequent conveyance of surface and storm water runoff.
Drainage inlets	The receptors for surface water collected in ditches and gutters, which serve as the mechanism whereby surface water enters storm drains; refers to all types of inlets such as grate inlets, curb inlets, slotted inlets, etc.
Embankment	A structure of earth, gravel, or similar material raised to form a pond bank or foundation for a road.
Ecology	Ecology is the totality of relations between organisms and their environment. It includes the composition, distribution, amount, number and changing states of organisms within and among ecosystems.
Ecosystem	Ecosystem is a community of organisms and their physical environment, considered to function together as a unit, and characterized by a flow or energy that leads to trophic (or nutritional) structure and material cycling.
Environmental flows	Environmental flows are the regime of flows required to maintain the ecological integrity of a river and the goods and services provided by it, computed by Building Block Method (or other standard holistic methods).
Flow line	The bottom elevation of an open channel or closed conduit.
Flood zoning	Definition of areas, based on flood risk, within flood plain appropriate for different land uses.

Flood plain	Area susceptible to inundation by a base flood including areas where drainage is or may be restricted by man-made structures which have been or may be covered partially or wholly by flood water from the base flood.
Groundwater table	The free surface of the underground water that is frequently
	Subjected to conditions such as fluctuating atmospheric pressure with the season, withdrawal rates and restoration rates. Therefore, the groundwater table is seldom static.
Gutters	Portion of the roadway structure used to intercept pavement runoff and carry it along the roadway shoulder.
Grossly Polluting Industries (GPI)	Grossly Polluting Industries (GPI) are defined as the industry which is discharging wastewater more than 100KLD and/or hazardous chemicals used by the industry as specified under the Schedule-I, Part-II of The Manufacture, Storage and Import of Hazardous Chemical Rules of 1989 under Environment (Protection) Act, 1986.
Hydraulics	The study of water flow; in particular the evaluation of flow parameters such as stage and velocity in a river of stream.
Hydrograph	A graph showing stage, flow, velocity, or other characteristics of water with respect to time. A stream hydrograph commonly shows rate of flow; a groundwater hydrograph shows the water level or head.
Hydrology	The science of the behaviour of water in the atmosphere, on the surface of the earth and within the soil and underlying rocks. This includes the relationship between rainfall, runoff, infiltration and evaporation.
Infiltration trenches	Shallow excavations which have been backfilled with a coarse stone media. The trench forms an underground reservoir which collects runoff and exfiltrates it to the subsoil.
Infiltration	The downward movement of water from the soil surface at ground level into the underlying subsoil. Water infiltrates into the soil profile and percolates through it. The infiltration capacity is expressed in terms of mm/hr. Infiltration depends on the vegetative cover of the soil surface, while permeability depends on the soil texture and compactness.
Inlet	A form of connection between the surface of a ground and a drain or sewer for the admission of surface and storm water runoff.
Intensity	The rate of rainfall typically given in units of millimeters per hour (inches per hour).
Invert	The inside bottom elevation of a closed conduit.
Intensity-Duration Frequency Curves	IDF curves provide a summary of a site’s rainfall characteristics by relating storm duration and exceedance probability (frequency) to rainfall intensity (assumed constant over the duration).
Longitudinal slope	The rate of change of elevation with respect to distance in the direction of travel or flow.

Major system	This system provides overland relief for storm water flows exceeding the capacity of the minor system and is composed of pathways that are provided, knowingly or unknowingly, for the runoff to flow to natural or manmade receiving channels such as streams, creeks, or rivers.
Minor system	This system consists of the components of the storm drainage system that are normally designed to carry runoff from the more frequent storm events. These components include: curbs, gutters, ditches, inlets, manholes, pipes and other conduits, open channels, pumps, detention basins, water quality control facilities etc.
Open channel	A natural or manmade structure that conveys water with the top surface in contact with the atmosphere.
Open channel flow	Flow in an open conduit or channel that is driven by gravitational by pressure forces.
Pressure flow	Flow in a conduit that has no surface exposed to the atmosphere. The flow is driven by pressure forces.
Rain gardens	Rain gardens are part of the Low Impact Development (LID) paradigm for storm water management. Rain gardens consist of a porous soil covered with a thin layer of mulch into which the storm water runoff.
Rational method	A means of computing storm drainage flow rates (Q) by use of the formula Q=CIA, where C is a coefficient describing the physical drainage area, I is the rainfall intensity and A is the area.
Recharge	Replenishment of groundwater by downward infiltration of water from rainfall, steams and other sources. Natural recharge occurs without assistance or enhancement by man. Artificial recharge occurs when the natural recharge pattern is modified deliberately to increase recharge.
Retention	The process of collecting and holding surface and storm water runoff with no surface outflow.
Return frequency	A statistical term for the average time of expected interval that an event of some kind will equal or expected given conditions (e.g., a storm water flow that occurs every 2 years).
Retention/detention facilities	Facilities used to control the quantity, quality, and rate of runoff facilities discharged to receiving waters. Detention facilities control the rate of outflow from the watershed and typically produce a lower peak runoff rate than would occur without the facility. Retention facilities capture all of the runoff from the watershed and use infiltration and evaporation to release the water from the facility.
Runoff	The flow of water across the ground or an artificial surface generated by rain falling on it.
Sediment	Sediment is naturally-occurring material that is broken down by processes of weathering and erosion, and is subsequently transported by the action of fluids such as wind, water, or ice, and/or by the force of gravity acting on the particle itself.

Silt	A separate of soil consisting of parties between 0.002 and 0.02 mm in equivalent diameter.
Storm water	That portion of precipitation that does not naturally percolate into the ground or evaporate, but flows via overland flow, interflow, pipes and other features of a storm water drainage system into a defined surface water body, or a constructed infiltration facility.
Storm water drain	A particular storm drainage system component that receives runoff from inlets and conveys the runoff to some point. Storm drains are closed conduits or open channels connecting two or more inlets.
Storm water drainage system	Constructed and natural features which function together as a system to collect, convey, channel, hold, inhibit, retain, detain, infiltrate, divert, treat or filter storm water.
Storm water management	The process of controlling the quality and quantity of storm water to protect the downstream environment.
Uniform flow	Flow in an open channel with a constant depth and velocity along the length of the channel.
Water Bodies	Waterways, wetlands, coastal marine areas and shallow ground water aquifers.
Water quality inlets	Pre-cast storm drain inlets (oil and grit separators) that remove sediment, oil and grease, and large particulates from paved area runoff before it reaches storm drainage systems or infiltration BMPs.
Watershed	A geographic region within which water drains into a particular river, stream, or body of water. The watershed may be composed of several sub-watersheds and catchments and/or sub-catchments.
Water Course	Water Course (or “Surface Water Course”) is an overland channel (natural or manmade) through which water flows such as a river, stream, rivulet (“naalah”) or canal.
Wet ponds	A pond designed to store a permanent pool during dry weather.

EXECUTIVE SUMMARY

Background

National Capital Region Planning Board prepared the Regional Plan with the perspective year 2021(RP-2021) for the National Capital Region(NCR) as per the provisions of Section 10 of the NCR Planning Board Act, 1985 for balanced and harmonized development of the National Capital Region covering an area of 34,144 sq. km. which was notified on 17th September, 2005. Presently NCR covers an area of 53,817 sq. km. comprising of NCT Delhi, thirteen districts of Haryana sub-region, seven districts of U.P. sub-region and two districts of Rajasthan sub-region.

Drainage is the natural or artificial removal of surface and sub-surface water from an area. It is an important element of physical infrastructure and constitutes removal and disposal of surplus rain/irrigation water from the land. It has two aspects, namely, flood protection and removal of storm water. Topography, rainfall intensity, soil characteristics, irrigation methods, crops and vegetative cover are important factors for deciding the type and design of drainage system. Since urban expansion is inevitable, increased run off would require remodelling of the existing drains as well as provisions of new/supplementary drains, implementation of appropriate flood protection measures, protection of natural drainage course, improved ground water recharge, and other environmental improvement measures. National Capital Region is a part of well integrated drainage system of the Ganga basin. Extremely gentle gradient spreads almost all over the region and storm water discharge in any basin/sub-basin of NCR has regional bearing covering areas of States of Haryana, Rajasthan, Uttar Pradesh and NCT Delhi. Regional Plan-2021 has proposed policies for improvement of drainage in NCR, but a need was felt to examine various guidelines/design parameters and elaborate so that policy guidelines could be proposed. Board in its 29th meeting held on 24.5.2006 decided to prepare a Functional Plan on Drainage for NCR.

Methodology and Limitations

As per Seventh Schedule of Constitution of India, drainage is a state subject and Irrigation Departments of the State Governments have responsibility for drainage, irrigation and flood control. At the national level, Central Water Commission (CWC) is associated. Therefore, it was imperative to associate the representatives from CWC and NCR participating State Government Departments dealing with the drainage of NCR for the study.

A Study Group was constituted under the Chairmanship of Engineer-in-Chief, Department of Irrigation, Government of Haryana, Chief Regional Planner, and NCR Planning Board Co-chairman with Director (UT), Central Water Commission and Chief Engineers of UP Jal Nigam, Delhi Jal Board, Departments of Irrigation and Chief Town Planner/ Chief Coordinator Planners of NCR participating States as members with the mandate to identify the drainage system of NCR, collect data, review norms, analyze data, formulate strategies and to prepare Functional Plan on Drainage for NCR. Six meetings of the Study Group were held to discuss, finalize the strategies and prepare the Functional Plan for Drainage for NCR. The study has been conducted in-house on the basis of secondary data and is limited to regional drainage system. The Study Group observed that there is lack of uniformity in maintaining the data base by different NCR participating States. Data on carrying capacity of the drains was available with Irrigation Departments but data on flow of drains was not available. Similarly, data on pollution levels of Ganga and Yamuna Rivers was available at a few selected locations.

Subsequent to the notification of the RP-2021 in 2005, Mahendragarh and Bhiwani districts of State of Haryana and Bharatpur district of State of Rajasthan have been added in NCR vide Notification dated 01.10.2013. Further, Jind and Karnal districts of State of Haryana and Muzaffarnagar district of State of Uttar Pradesh have subsequently been added in NCR vide Notification dated 24.11.2015. The RP-2021 for NCR includes the then area of NCR which is 34,144 sq. km. and comprises of NCT-Delhi, nine districts of Haryana sub-region, six districts of U.P. sub-region and one district of Rajasthan sub-region. Since the Regional Plan including the newly added districts is still under preparation, the scope of the Functional Plan on Drainage for NCR is limited to the area of NCR as per the RP-2021.

Hydro Meteorological Aspects

Detailed hydrological investigation of the catchments of the river system traversing NCR and its adjoining States is of paramount importance for proper assessment of water resource potential and extent of flood and drainage problems. It has been observed from the meteorological data that about 79% of the rainfall in the National Capital Region occurs during monsoon and remaining 21% is accounted for by seasonal rain. The area receives average annual rainfall of about 614mm. Rainfall is caused by depressions/cyclonic storms and low pressure systems that form in the Bay of Bengal and Arabian Sea during monsoon season and travels over NCR area, Punjab, Haryana, Rajasthan, West UP, Uttrakhand and Himachal Pradesh and yield very heavy rainfall over these areas resulting in flooding in Yamuna and Ganga basins. It has been observed from the IMD data that there are 56 rain-gauge stations in NCR.

Density of Rain-Gauge stations is 610 km^2 per station area in NCR and meets the World Meteorological Organization (WMO) recommended density of 600 to 900 km^2 area per Rain Gauge Station.

Recommendations

Functional Plan examined various aspects related to geology, geo-morphology, physical features, hydro-meteorology, drainage system of various sub-regions, design criteria of drainage system in the participating states, CPHEEO norms, pollution, recommendations of National Disaster Management Authority (NDMA) on drainage, etc. and analysed various aspects and the recommendations made are given in the following paragraphs:

i) *Protection of Natural Drainage System:* Natural drainage system should be protected from all kind of encroachments, obstructions, dumping of solid wastes etc. and whenever diversions are inevitable, they should be properly designed and executed.

ii) *Promotion of recreational use along nallah land:* The land around nallahs should be developed as public open space i.e. gardens, parks, playgrounds, etc. so that residents of the city are encouraged to visit these lands for entertainment, jogging, morning walk, etc. This will minimize misuse by encroachment, etc. The treated effluent can be used for maintenance of greenery.

iii) *Reservation of adequate width for drains:* Development in urban areas increases the impervious surfaces, leading to increased run-off which results in higher flow of storm water in the drains. This requires increase in the section (depth & width) of drains. In addition to this, additional space is required to operate modern machines for cleaning of drains such as JCBs, bulldozers, dumpers, etc. The National Disaster Management Guidelines: Management of Urban Flooding-2010 prepared by National Disaster Management Authority, Govt. of India recommended that recreational/green buffer zone of different width may be adopted and adequate land should be earmarked in the Master/Development Plans for urban areas and in the revenue records in rural areas.

iv) *Parameters for Design of storm water drain:* Rational Method is widely used for design of urban drainage system and the same would continue to be used for designing Storm Water Drain in NCR. The Plan has recommended basic parameters to assess the quantum of surface run-off. Methods prescribed in CPHEEO Manual should be followed for designing of the channel dimensions.

v) *Preparation of Master Plan of Inter-State Regional Drainage:* Integrated planning and design of drains for the region should be done well in advance to fix the invert levels of the drains. Since regional drains pass through more than one District/ State, their agencies should come together for designing the drain as a single project. However, construction could be taken up by the concerned agencies of the District/ State maintaining the designed invert levels. It would be important to prepare the Master Plan for Drainage for a basin or sub basin and integrate it with higher order plans. The land requirement should be made available to the agencies responsible for reservation of the land.

vi) *Preparation of Master Plan for Drainage for Cities/Towns:* In order to ensure planned development of a city/town, Master Plan for drainage is required to be prepared incorporating/addressing the aspects such as identification and delineation of watersheds, sub-watersheds and catchment areas at "notified Planning Area" level and analysis of their slope and fluvial characteristics. Master Plan for drainage of a Towns/or a city should be prepared within the framework of Master Plan for Regional Drainage within which it falls. The catchment area should be the basis for planning and designing the storm water drainage system in all urban areas of NCR. Master Plan for Drainage should be prepared for towns and cities by the concerned State Government /Departments/ Agencies in close collaboration with Urban Local Bodies, Urban Development Authorities, River Basin Organization, and Scientific Institutions in a time bound manner. Master Plan for Drainage to be prepared for all Class-I towns of NCR in the First Phase.

vii) *Construction of roads to start from Edge:* It has been observed that even if adequate right of way (ROW) is provided for proposed roads in the Development Plan, the land is not available at the time for the construction/widening of roads. At the initial stage of development, road space requirement is less, therefore, construction of roads is undertaken up in parts and generally it is constructed in the centre of ROW and drains are developed. Major part of the ROW of the road is left unused and drains and footpaths are dismantled and reconstructed at the time of widening of the roads. This increases the cost of construction when the drain is being re-constructed. The land on either side of the road kept for expansion is encroached and it becomes difficult to retrieve the encroached land. This problem can be addressed by starting the construction of the road from edge and outermost part of the road is constructed first by constructing footpath, service road, drain and carriageway depending upon the requirement and land for widening of the road is left in the center merged with median. The roads can be widened towards the median depending upon the requirement. This will help in reducing the multiple expenses of constructing and re-constructing drains and footpaths along the roads on one side and appropriate slopes in the drains would be maintained as per Drainage Master Plan based on invert levels.

viii) *Regulation for Covering of Drain:* In urban areas, drains along the roads are allowed to be covered in front of gates to derive access from roads or otherwise which makes their cleaning difficult and ultimately leads to blockage of drains and flooding on roads. A standard design for removable drain covers at regular interval should be incorporated in building byelaws so that this problem can be avoided. It should be checked by the agency while granting building permission or at the time of providing occupancy certificate. A provision for recovering the demolition costs from the property owners, if any, should be integral part of Bye-laws.

It is recommended that the practice of covering the drains for construction of roads be discouraged. Even bridges/elevated road running over drains or along the alignment of drains should also be discouraged as pillars obstruct the flow of storm water and movement of cleaning equipment.

ix) *Construction of Bridges/Elevated Roads over Drains:* Where it is unavoidable and when all other options are exhausted, construction of bridges/elevated roads over drains should be permitted. However, efforts should be made to ensure that the construction be undertaken by the agency responsible for drain maintenance after taking into account the L-section and discharge capacity. The process of giving NOC to other Departments for road construction over drains should be discouraged, since after obtaining NOC, paying sufficient attention to the invert level and discharge capacity by other construction agencies may pose as a matter of concern. Once the bridge is constructed it becomes difficult to rectify the mistakes. The practice of bridge construction by RCC Hume pipes should also be discouraged as it also reduces the effective cross sectional area of drain.

x) *Segregation of sewage and drainage:* The major problem of urban drainage is mixing of sewage with storm water in drains. Drains are neither designed nor expected to carry the sewage. Urban areas should have separate sewerage and drainage network.

xi) *Treated waste to flow in drains:* Sewage should be treated in the Sewage Treatment Plants to desired level as specified by Central Pollution Control Board, Ministry of Environment, Forest & Climate Change (MoEF&CC), Government of India and then only it should be discharged into the drains. There should be a provision of penalty for agencies discharging un-treated sewage into the drains.

xii) *Industrial waste to be treated in CETP*: The characteristics of industrial wastes are different from domestic wastes. It is highly toxic and acidic compared to the domestic waste. Treatment of industrial wastes requires more efforts and the technology of treatment depends upon the type of industry and its waste. It is desirable that the industrial wastes are treated separately. If there are several industries, a Common Effluent Treatment Plant (CETP) should be developed.

xiii) *Decentralized Treatment Plants (Treat and Use Approach):* The traditional approach of conveying the sewage over long distances, treat and then dispose of in the natural stream find priority among Urban Local Bodies. It is recommended that sewage is treated locally and treated water is utilized for non-drinking purposes e.g. horticulture, gardening, car wash, air conditioning etc.

xiv) *Cleaning of Sewerage System:* It has been observed that in case of blockage, sewers are cleaned with using rope-cum-bucket machine which damages the skin of pipes thus exposing reinforcement. This reinforcement is corroded due to presence of H_2S gas in sewers ultimately causing crown collapse of the sewers (subsidence of sewer). In view of this, it is recommended that agency should clean the sewerage system using modern machines i.e. jetting-cum-suction machines. Age-old method of using rope-cum-bucket machine for cleaning of sewerage systems should be discontinued.

xv) *Regular Maintenance of Drain (cleaning):* The authorities responsible for maintenance have a cleaning schedule which needs to be adhered. Annual maintenance of drains being carried out before monsoon is very important and be completed before arrival of monsoon. The work should be started well in advance to ensure its completion in time. Since this work is repetitive in nature, standard tender document may be prepared and kept ready to save time. The Plan has suggested a desirable schedule and important actions required to be taken by concerned authorities.

xvi) *Institutional Arrangement*: It is observed that each NCR participating State has its own institutional arrangement for handling drainage system. There are multiple departments/agencies responsible for drainage management in urban areas. As there are several agencies there is lack of coordination in management in the drainage system. It is recommended that there should be a single coordinating Body for planning, design, construction and maintenance of drainage system in urban areas.

xvii) *Provision for Funds*: Poor financial condition of local bodies results in poor maintenance of drains. Local bodies need to look for innovative methods for resource generation.

xviii) *Capacity Building:* Presently, there is no formal training for the staff engaged in the maintenance (cleaning). Absence of any formal training has left them to learn while working. With the introduction of modern technology, the staff also needs to be trained to cope up with the technology. It is recommended that regular capacity building programmes for the staff be carried out.

xix) *Rain water harvesting:* It is recommended to harvest the surface run off by increasing recharge from the basins through various techniques, including natural as well as induced techniques, such as placing recharge structures in the drains; recharge trenches/wells; harvesting by means of reviving/recharging lakes and ponds; roof top harvesting, etc. as proposed in the Functional Plan for Ground Water Recharge and draft Functional Plan for

Water in NCR. Both the Functional Plans have also proposed to amend Municipal Acts, Building Bye-laws and other relevant provisions to promote rain water harvesting by all multi-storeyed complexes, commercial buildings and group housing societies and to maintain them for efficient recharge, which should be adopted.

xx) *Mass Public Awareness:* There is a need to create mass public awareness about the consequences of dumping plastic, domestic waste and street cleaning into drains. This should be campaigned via media and other awareness programmes to make people more responsible. Efforts should be made to encourage public to become proactive in reporting the events that need the attention of the public authority to keep the city drains clean. A system for such reporting should be developed which could be either via e-mail or toll free telephone number or SMS. Persons who participate in such system could be felicitated by the agency.

xxi) *Service Level Benchmarks*: As part of the ongoing endeavour to facilitate critical reforms in the urban sector, the Ministry of Urban Development has prepared "Hand Book of Service Level Benchmarking" in four key sectors namely, Water Supply, Sewerage, Solid Waste Management and Storm Water Drainage. The Ministry of Urban Development would facilitate the adoption of these benchmarks through its various schemes and would also provide appropriate support to ULBs that move towards the adoption of these benchmarks. It is recommended that all the NCR participating states and local level functionaries should use "Handbook of Service Level Benchmarking" in achieving the goal of improved service delivery.

1. INTRODUCTION

1.1 Background

National Capital Region Planning Board prepared the Regional Plan with the perspective year 2021 for the National Capital Region (NCR) as per the provisions under Section 10 of the NCR Planning Board Act, 1985 for balanced and harmonious development of the National Capital Region which was notified on 17th September, 2005.

The geographical area of NCR for which the Regional Plan-2021 was prepared was 34,144 sq. km. (Map 1.1 National Capital Region Regional Plan-2021: Constituent Areas) and includes the National Capital Territory of Delhi and parts of the States of Haryana, Rajasthan and Uttar Pradesh. The Administrative units were as follows:

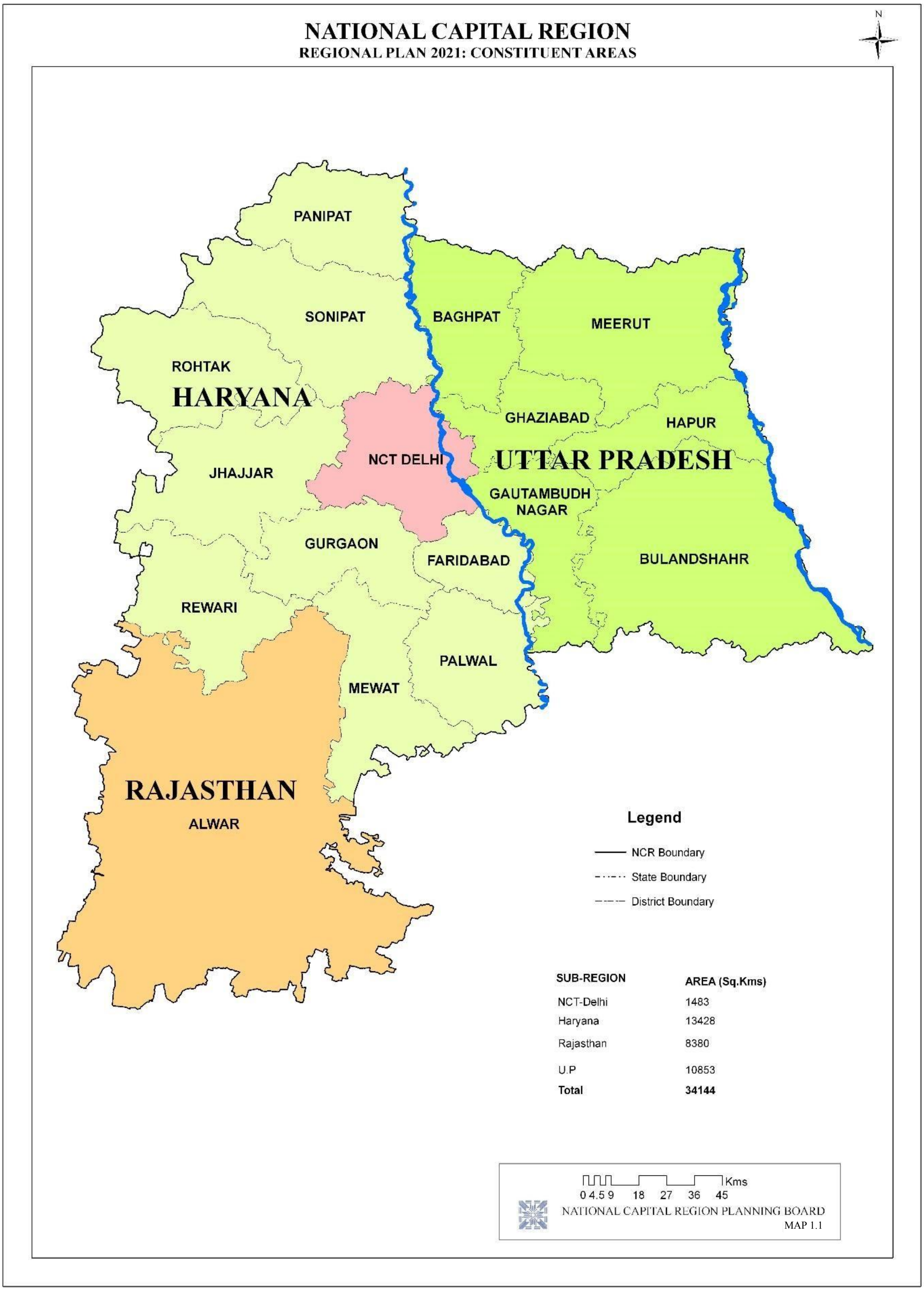
a) National Capital Territory of Delhi has area of 1,483 km^2 and this accounts for 4.4% of the total area of NCR.
b) Haryana sub-region comprises of Faridabad, Gurgaon, Rohtak, Sonepat, Rewari, Jhajjar, Mewat, Panipat and Palwal districts. This has an area of 13,428 km^2, which is 30.3 % of the area of Haryana State and 39.3% of the area of NCR.
c) Rajasthan sub-region comprises of Alwar district. This has an area of 8380 km^2 which is 2.5% area of Rajasthan and 24.5% of the area of NCR.
d) Uttar Pradesh sub-region comprises of five districts namely, Meerut, Ghaziabad, Gautam Buddha Nagar, Bulandshahr and Baghpat. The area of U.P. Sub-region is 10,853 km^2 which is 4.50% of the area of the State and 31.8% of the area of NCR.

Subsequent to the notification of the RP-2021 in 2005, Mahendragarh and Bhiwani districts of State of Haryana and Bharatpur district of State of Rajasthan have been added in NCR vide Notification dated 01.10.2013 and Jind and Karnal districts of State of Haryana and Muzaffarnagar district of State of Uttar Pradesh have subsequently been added in NCR vide Notification dated 24.11.2015. Accordingly, total geographical area of NCR now is 53,817 sq. km and includes entire NCT-Delhi, thirteen districts of Haryana sub-region, seven districts of U.P. sub-region and two districts of Rajasthan sub-region. However, as mentioned earlier, the scope of the Functional Plan is limited to the geographical area of NCR which was included in the Regional Plan-2021 for NCR, presently in force.

Section 16 of the National Capital Planning Board Act, 1985 provides for the preparation of Functional Plan after the Regional Plan has come into operation. It states that the Board may prepare with the assistance of the Committee, as many Functional Plans as may be necessary for the proper guidance of the participating States and of the Union Territory.

As drainage has been one of the important elements as defined in section 10(2) of the NCR Planning Board Act, 1985 and has regional bearing, it is important to prepare Functional Plan on Drainage. Board in its 29th Meeting held on 24.05.2006 decided to prepare a Functional Plan for drainage for NCR.

Map 1. 1 Regional Plan-2021: Constituent Areas of NCR



1.2 Provisions of Regional Plan-2021

In order to improve the regional and local drainage system in NCR, the Regional Plan-2021 has proposed the following strategies and policies:

(i) Regional Approach to Drainage

Integrated Regional Drainage Plan at the regional level and Drainage Master Plans at the district level should be prepared after critically examining each major drainage system under basins/sub-basins of NCR at micro level by the State Governments incorporating the improvement proposals for enhancing the quality of regional and local drains taking into account the present/future development and settlement pattern in the region. All the related works at the regional level should be coordinated by a single agency. The area drainage plan should be considered as an integral part of the Master Plan of the area and this drainage plan shall take into account the land development planning for the region. There is a need to conceptualize a drainage system before any area development program is taken up. No area development project/new town/colonies/industrial complex should be sanctioned or implemented unless integrated drainage plan is conceptualized and cleared by the designated authority. All developments in controlled areas falling in dark and over exploited block declared by CGWB should aim towards zero run off within the controlled areas. The ponds/lakes/wetlands (existing and proposed), bunds/check dams etc. should be developed/protected to increase the run off time of storm water in order to help in ground water recharging.

(ii) Proposed Norms and Standards

The urban drainage system may be designed for maximum rainfall of five years frequency storm for internal as well as peripheral drains and ten years frequency storm for the main drains. The likely time of concentration for each case may be worked out and corresponding storm values adopted. Usually the system is designed for a maximum rainfall of one-hour duration.

a) The rural drainage system may be designed for three days rainfall of five years frequency to be drained in three days. An appropriate area dispersal factor should be adopted for computing the run off.
b) The coefficient of run off may be calculated for areas with composite land use pattern on the basis of anticipated land use in the new areas and existing land use pattern for the areas already developed.
c) Where it is not possible to work out the run off coefficient due to land use policies not indicated, run off coefficient not less than 0.2 may be adopted for rural areas with flat to moderate slopes and 0.4 for steeper slopes. For urban area, run off coefficient not less than 0.6 may be adopted in absence of adequate details of the areas.

(iii) Prevention of Storm Water Drains from Pollution

Measures should be taken to prevent the use of storm water drains for conveying sewage and dumping of solid wastes and sludge in open drains. Enforcement should be ensured under the

Environment Protection Act, 1986. Unauthorized development/encroachment/slum dwellings in the drainage system should be prohibited.

(iv) Irrigation Water

Where irrigation canal escapes including the tail escapes are out falling in the drains or in the neighbouring ponds, the provision for efficient draining of surplus irrigation water by enhancing their capacity should be made during monsoon and non-monsoon period while planning for improvement in the integrated Regional Drainage System.

(v) Provision of Funds

Provision of adequate funds should be made for upgradation and regular maintenance of the drains on the same lines as for the irrigation channels.

(vi) Plan of Action and Phasing of Implementation of Strategies/ Policies/ Proposals

In order to implement the policies of drainage in the region, it is imperative to have a phase wise plan of action so that the implementation of policies and proposals in the Regional Plan can be dovetailed with the five-year plans. Some of the activities which need to be implemented include preparation of Integrated Regional Drainage Plan at the regional level and Drainage Master Plans at the District level to manage regional and local drains, avert mixing of sewage and solid waste in storm water drains, creation of mass awareness, waste minimization through recycling of waste, regular maintenance and upgradation of drains etc.

1.3 Need for a Drainage Plan for NCR

Drainage is an important element of physical infrastructure and constitutes removal and disposal of surplus rain and irrigation water from the land, both in urban and rural areas. It has two aspects mainly flood protection and removal of storm water. NCR in general, is a part of well-integrated drainage system of the Ganga Basin. Though a scientifically designed drainage network exists in and around NCR, yet it has been observed that there are drainage problems, some of them are inter-state in nature. The extremely gentle gradient over the region restricts the development of drainage system. Attempts have been made by various agencies in the past to find solutions but due to lack of coordinated and concerted efforts and agreements among the concerned governments, no lasting solution has been implemented. There are problems of flooding and in extreme flood events damage to property, economic loss and damage to life are quite common. The problem is more severe in urban areas due to high concentration of population, economic activities and international impacts due to flooding of transport hubs like Airport etc. The flooding in urban area is on increase (Box 1.1). Selection of design flood by taking a calculated risk is underlying theme of flood management for ensuring desired level of safety. The idea is to avoid a wasteful over design or an under design. In addition to this, the drains passing through or nearby urban areas get polluted as they carry untreated domestic/industrial sewage. This poses a mammoth problem by polluting the water bodies on the downstream side of the drains carrying sewage. The storm water discharge in NCR is not local but has regional bearing covering areas of NCT-Delhi, Haryana, Rajasthan and U.P. Hence, it is necessary to plan the drainage system at regional level in an integrated manner with adjoining States.

Box 1.1 Increase the Urban Flooding

Increase in Urban Flooding

- 2005 – 26th July- 944 mm in MUMBAI led to WAKE UP CALL!
- 2006 – 22 Cities disrupted: SURAT worst affected
- 2007 – 35 cities disrupted: KOLKATA - thrice-3/06, 3/07, 23-25/09
- 2008 – Mumbai 162 mm -7th June 2008; Mumbai 142 mm-1st July 2008 (high tide of 4.33 m at 11:01)
- Ranchi/Jamshedpur 338.1 mm on 16th June 2008: also Kharagpur/Orissa
- Kanpur/Lucknow/Allahabad during 05-07 July 2008
- 2009 – Cyclone Aila caused disruption in Kolkata
- Mumbai 172 mm on 14th July 2009 – high tide was 3.89 m » Indore 240 mm on 16 July 2009; Porbandar – army called in
- Delhi 124 mm in 12 hours, peak 40 mm/h 27th July – chaos!
- 2010- Delhi flooded on 7 occasions
- Leh – Severe cloudburst on 6th August 2010; Flash flood caused 172 casualties and severe damage to infrastructure
- 2011- Mumbai, Varanasi, Bhopal, Delhi ……..Economy disrupted, people stranded, transport services severely affected:
- Airport submerged in 2005 - Visakhapatnam, Mumbai
- Vadodara: 2006
- Delhi Airport: 15th September, 2011
- Chennai: 2015
    - Massive disruption of infrastructure/services, widespread damage to property and lives.
    - The flood was necessitated by heavy rainfall in winter season and got aggravated by the blockage of the natural drainage system by excessive urban development.

1.4 Objective and Scope of the Study of preparation of Functional Plan for Drainage

The objective of the study is to prepare Functional Plan for Drainage in NCR. The Functional Plan will focus on the following:

a) Inter-state drains and major district drains out falling into inter-state drains.
b) The existing drainage system to be analyzed for adequacy and pollution level.
c) The study will propose the steps to be taken for improvement in quality of water flowing in drains.

1.5 Approach and Methodology

In the 29th Board Meeting of NCR Planning Board, Member Secretary, NCRPB indicated that Board would take up preparation of Functional Plan related to drainage management system of NCR. This Functional Plan was to be prepared in-house. Natural drainage system of a region is arrangement by nature evolved over centuries to remove the surplus rainwater. Initially the man-made intervention was to control floods. NCR is experiencing floods as well as drought. So, an arrangement is required to make to store the surplus water and use it for irrigation during lean period. The Irrigation and Flood Control Department of State Governments is handling this arrangement. This department has dual responsibility of flood control and irrigation. At the National level, Central Water Commission (CWC) is involved. Considering the federal structure it was necessary to involve the State Government Departments/Agencies and Central Ministries/Agencies dealing with the drainage of NCR. It was felt necessary to constitute a Study Group of Experts from the Departments/Agencies dealing with planning, design, construction and maintenance of drainage in urban and rural areas of NCR. Accordingly, NCR participating State Governments and CWC were requested to nominate Senior Officers as subject expert for the Study Group. The Study Group for preparation of Functional Plan-Drainage for NCR was constituted under the chairmanship of Engineer-in-Chief, Department of Irrigation, Govt. of Haryana and Chief Regional Planner, National Capital Region Planning Board as Co-Chairman with the representative of Central Water Commission, Govt. of India, Chief Engineers of UP Jal Nigam, Delhi Jal Board and Department of Irrigation and Chief Town Planners/Chief Coordinator Planners, Govt. of UP, Haryana, Rajasthan and Delhi as members. The composition of the Study Group is at Annexure-1.1. The scope of work of the Study Group was to identify the drainage system in NCR, identify problems & issues and make recommendations.

The Study Group was also requested to coordinate the data collection in their respective sub-region. There were six meetings of the Study Group in all to discuss and finalize the strategies and to prepare the report. Site visits were also undertaken to get the feel of the drainage problem at town level in NCR.

The detailed methodology for preparation of Functional Plan was discussed. The scope of the Plan was limited to inter-state drain and major district drains which outfall into inter-state drains. The drainage map available with NCR was to be updated by the State Government agencies. The study group was also requested to coordinate the data collection in their respective sub-region. The data was collected from the NCR participating State Governments. It was observed that different norms and standards are being followed by the respective State Governments. The norms given in the Regional Plan were different from CPHEEO and CPWD norms. The norms being followed by NCR constituent States were deliberated and feasibility of adopting uniform norms for NCR were also deliberated.

The Study Group observed that the existing drains in NCR are highly polluted causing problems to downstream users. The regional drainage system should be pollution free as its role is limited to removal of surplus rainwater. A polluted drain passing through the urban areas is a cause of concern not only because of foul odour but also due to spread of disease and pollution of ground water. The Study Group also addressed the issues and cause of pollution. The secondary data from Central Pollution Control Board and State Pollution Control Boards were collected, analyzed and suggested measures to be taken by the State Governments and their agencies for reduction of pollution in rivers and drains.

1.6 Limitation

The Functional Plan has been prepared on the basis of secondary data. The data on drainage system is being maintained by the agencies of the NCR participating State Governments. There is lack of uniformity in the data formats. The river flow data is maintained by CWC and river flow diversion data is maintained by Irrigation Department but the data of rivers Ganga and Yamuna are classified as confidential and hence not easily available. Further, the data on flow of drains is also not available, the data on carrying capacity of the drains is available with Irrigation Departments. The data on pollution levels of Ganga & Yamuna Rivers are available at a few selected locations on the websites of Central Pollution Control Board (CPCB) and State Pollution Control Boards.

2. THE REGION

2.1 Physical Setting

The National Capital Region lies between 27^{o} 03' and 29^{o} 29' North latitude and 76^{o} 07' and 78^{o} 29' East longitude and is characterized by the presence of the Ganga forming its eastern boundary, the Yamuna traversing north-south forming the boundary between Uttar Pradesh and Haryana, and the sand dunes and barren low hills of the Aravali chain and its outcrops in the west, flat topped prominent and precipitous hills of the Aravali range enclosing fertile valleys-and high table lands in the south-west, and the rolling plains dominated by rain-fed torrents in the south. The rest of the region is plain with a gentle slope of north-east to south and south-west. (Map 2.1 NCR: Physiography & Slopes).

2.2 Geology

The rock type exposed in the area belongs to Delhi Super-group of Lower Proterozoic age and consists of Quartzite of the Alwar Group, Phyllite and Slate of the Ajabgarh Group. The Quartzite's are massive, thickly bedded, hard, and compact and highly jointed and are intercalated with thin beds of Phyllite and Slates. The strike of the beds is NNE-SSW and dip westerly at moderate angles. These rocks are mostly covered by quaternary sediments and are exposed in isolated residual structural hills and pediments. These hills are exposed in south and south-west of Delhi at Delhi, Gurgaon, Rewari and Alwar. The rocks near Delhi consists of narrow strike-ridges and are moderately folded and are over folded in the south-east as a series of isoclines (Map 2.2 NCR: Lithology). Sub-region-wise details have been elaborated in subsequent paragraphs:

Haryana Sub- Region: The area comprises Delhi quartzite, both Alwar and Ajabgarh series of rocks, exposed as hill-ranges, in tiers of smaller magnitude and as sub-surface bedrock overlain by unconsolidated quaternary sediments or wind-blown sands (sand-dunes). There is a speculation that in some parts of the erstwhile Karnal district, from which has been carved Panipat districts of the NCR and in Sonepat, Siwaliks (Lower Miocene to upper Pliocene) i.e. Territory rocks, may also be underlying covered by the Quaternary Alluvium before they are succeeded underneath uncomfortably by the meta-sediments viz. the Delhi series of rocks. Siwalik rocks as such are not exposed on the surface in any part of the NCR in the Haryana State.

The Delhi supra group of rocks, as anywhere else, consist of quartzite, grits, schists, with or without post-Delhi intrusive as described earlier. Outcrops are seen in Faridabad, Gurgaon and Rewari districts.

The unconsolidated alluvial sediments of Quaternary era which dominate the districts of Panipat, Sonepat, Rohtak and parts of Faridabad, Gurgaon & Rewari districts comprise loose sands, clays with subordinate gravels, as interbedded lenticular strata, variable in thickness, more so in the vicinity of hard consolidated rock exposures/hills or ranges. Exploratory drilling carried out by the CGWB, down to a maximum of 460 m below ground level, has revealed the presence of some extensive clay layers, in these sediments. They are overlain by lenses of granular sediments (which cumulatively give rise to aquifer zones), with intervening thin clay bands.

It is also seen that the sands towards the top and above the first clay horizon, are coarser, medium to less coarse & more mixed with kankar and of a finer grade in the bottom most granular zone. On the whole the proportion of clay in the vertical column is more than that of granular zones.

UP Sub-region: The NCR-part of the U.P. State viz. the districts Ghaziabad, Bulandshahr, Meerut, Gautam Buddha Nagar and Baghpat are a part of the Ganga-Plain, which itself is geologically, a part of the northern Tertiary sedimentary basin, bounded on the west by the Yamuna, on the east by the Sapt-Kosi, on the north by the main boundary fault within the Shiwaliks and the Peninsular shield on the south.

A thick pile of sediments in the form of lenticular beds of sands of different grades, alternating with clays and occasional gravel beds are encountered in this area. They comprise the Quaternary Alluvium, which is subdivided into Newer and Older Alluvium, depending upon their geological age and occurrence whether in the recent flood plains and low-level terraces or the high level terraces respectively. Between the Older Alluvium and the Newer Alluvium the only lithological difference may be in the proportion of kankar. It is present in the Older Alluvium much more abundantly than in the Newer Alluvium.

The floor of the basin over which these sediments have been deposited is uneven, sloping towards the north. Accordingly, the thickness of these sediments may be more in the northern section than in the south i.e. as the southern plateau area is reached. Whereas in other parts of the Gangetic Plain, the thickness of alluvium up to 760 m has been drilled through, in the NCR part, tube wells or exploratory drilling is reported to have been done down to 300 m nearly within the alluvium without touching the bedrock.

Rajasthan Sub- Region: Delhi-Supra group of rock overlain uncomfortably by Quaternary Alluvium constitute the geological succession in the area. The Alwar series of rocks is predominantly an arenaceous facies of rocks. It consists of quartzite variegated coarse grained to grilty, micaceous or sericitic, felspathic or otherwise all intimately interbedded and form the base of this group in the present area. They have argillaceous rocks only subordinately associated with them. These rocks are traversed by steeply north dipping strike joints. Oblique joints are also present.

The Alwars are overlain by the Ajabgarh series of rocks, which are predominantly argillaceous and calcareous. They are phyllites, schists, calc-gneisses, marbles and dolomites etc. They generally occupy the valleys with their associated quartzites forming low-ridges. Vertical N-S trending bedding joints, oblique low dipping joints and horizontal joints traverse these rocks also.

***NCT of Delhi*:** The area comprises Alwar series of rocks, exposed as N-S or NNE-SSW running ridges or isolated exposures of hillocks. They are seen outcropping in the southern and south-eastern part of the Union Territory. The rest of the area is covered by Alluvium of variable thickness and composed of clays, silts, sands and subordinate gravels, pebbles interbedded.

The quartzite are hard, compact, massive and jointed outcrops tending NNE to SSW with steep easterly or south westerly dips. They are interbedded with quartz sericite schists and are also occasionally intruded by pegmatite and quartz veins.

The thickness of the Alluvium depends upon the bedrock topography, which appears to be undulating. Whereas Alluvium as thick as 10-30m only has been encountered, for example, near the Mall road and Vikramaditya Marg, there are areas e.g. in the vicinity of the Najafgarh drain where the depth to bedrock may be around 100 m. There are still other areas, for example, at Dhansa and Pindavala Kalon or Rohini sector where bedrock may or may not be even within 300 m. Lithologically, lenticular beds of sand in numbers one or more, with comparatively thick clay horizons intervening at different levels are encountered sub-surface during drilling. The predominance of argillaceous-fancies over the arenaceous one is thus noteworthy.

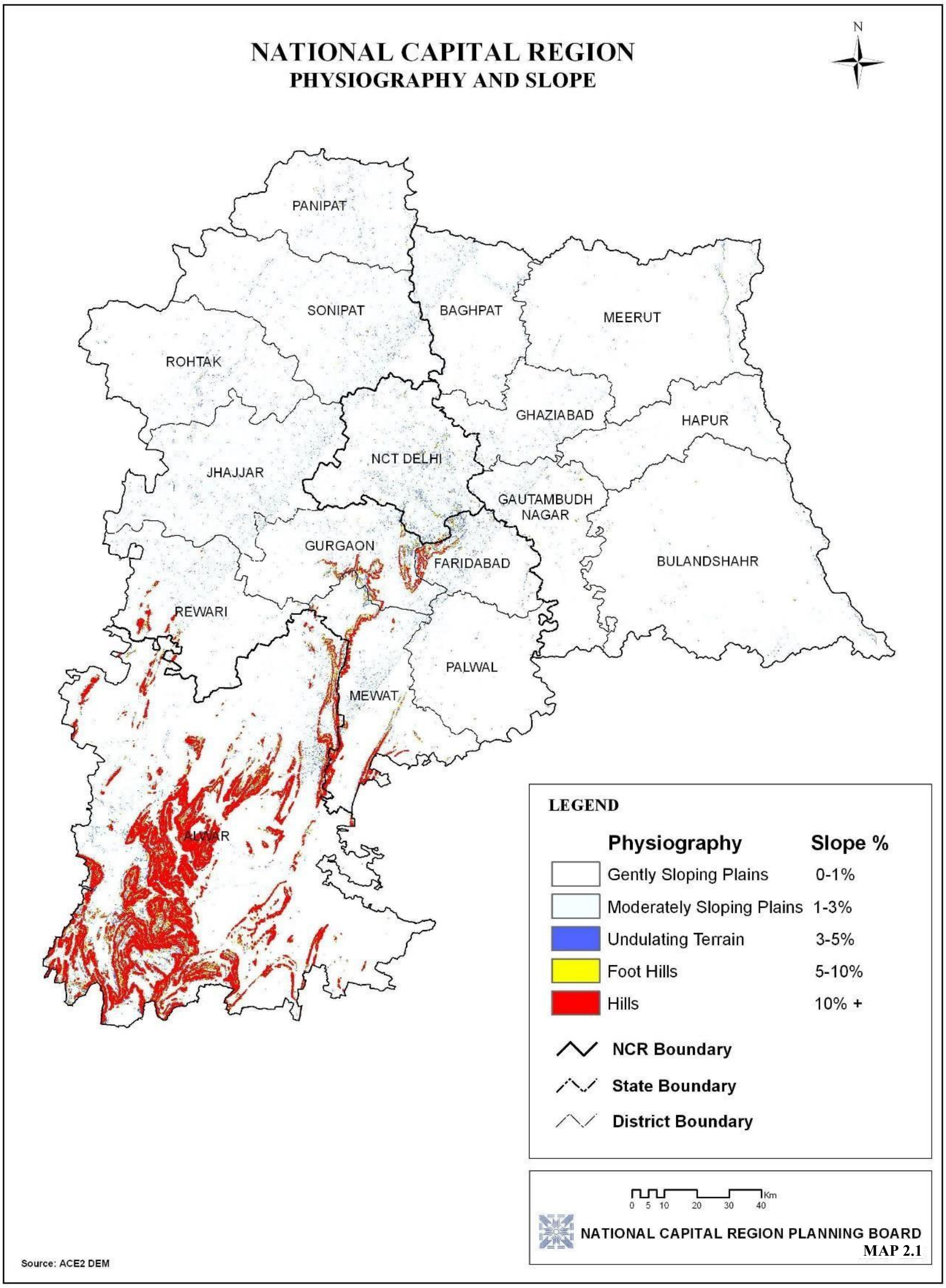
2.3 Geomorphology

Topographically the NCR has two major sub-units. The first one is the alluvial plains whose monotony is intercepted by isolated hillock or fairly continuous ridges of hard rock and the second one is sand dunes not more than 50 metres in elevation from the plain lands surrounding them. NCR terrain around Delhi, Haryana and U.P. constitutes such a plain. Sand dunes are prominent in parts of Haryana and Rajasthan and hard rock ridges bending NE to SW exists in south and south-west of NCR covering parts of the Alwar district and Delhi (Map 2.3 NCR: Geomorphic Units).

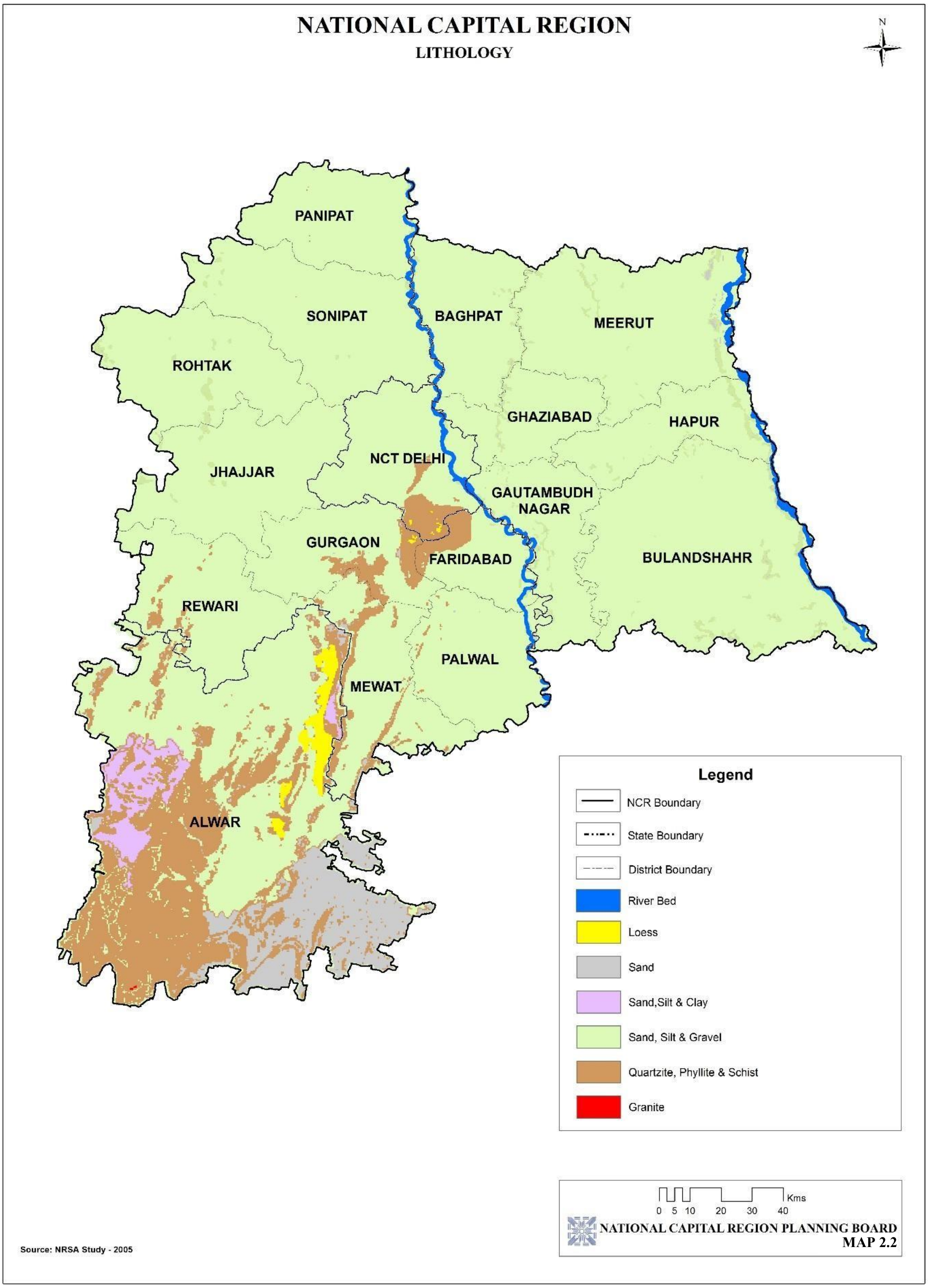
The Ganga, Yamuna and the Hindon form the perennial drainage in the area. These rivers enter in NCR from the North and flow towards the South. The Ganga sub-basin is a major part of the Ganga, Brahmaputra-Meghna basin, the largest river basin in India, extending over an area of 8.6 lakh km^2. The sub-basin occupies about 26% of the geographical area of the country covering almost the entire northern India including Yamuna basin. A clear watershed line (Map 2.4: Ganga –Yamuna Sub-Basin Map in NCR) divides the area between Ganga basin and Yamuna basin within NCR. The topography of main Ganga river system varies from rugged hills of Himalayas to alluvial plains. The soil generally consists of alluvium deposits in the Gangetic plains. The existing major irrigation schemes on the Ganga passing through NCR are the upper Ganga canal, lower Ganga canal and Madhya Ganga canal.

The Yamuna river system area is bounded by the Himalayas on the north and the Vindhyas on the south. On the east, it is separated from the main Ganga catchments by the ridge, and on the west, it is separated from Luni and Ghaggar basins by the ridge. Most part of catchments in Haryana and Uttar Pradesh lies in Gangetic alluvial plains. The important tributary of Yamuna in NCR region is the Hindon, which rises from southern slopes of Shivalik in Saharanpur district of U.P. and ultimately meets the Yamuna downstream of Okhla in NCT- Delhi. The drainage in the southern and south-western part is mostly ephemeral.

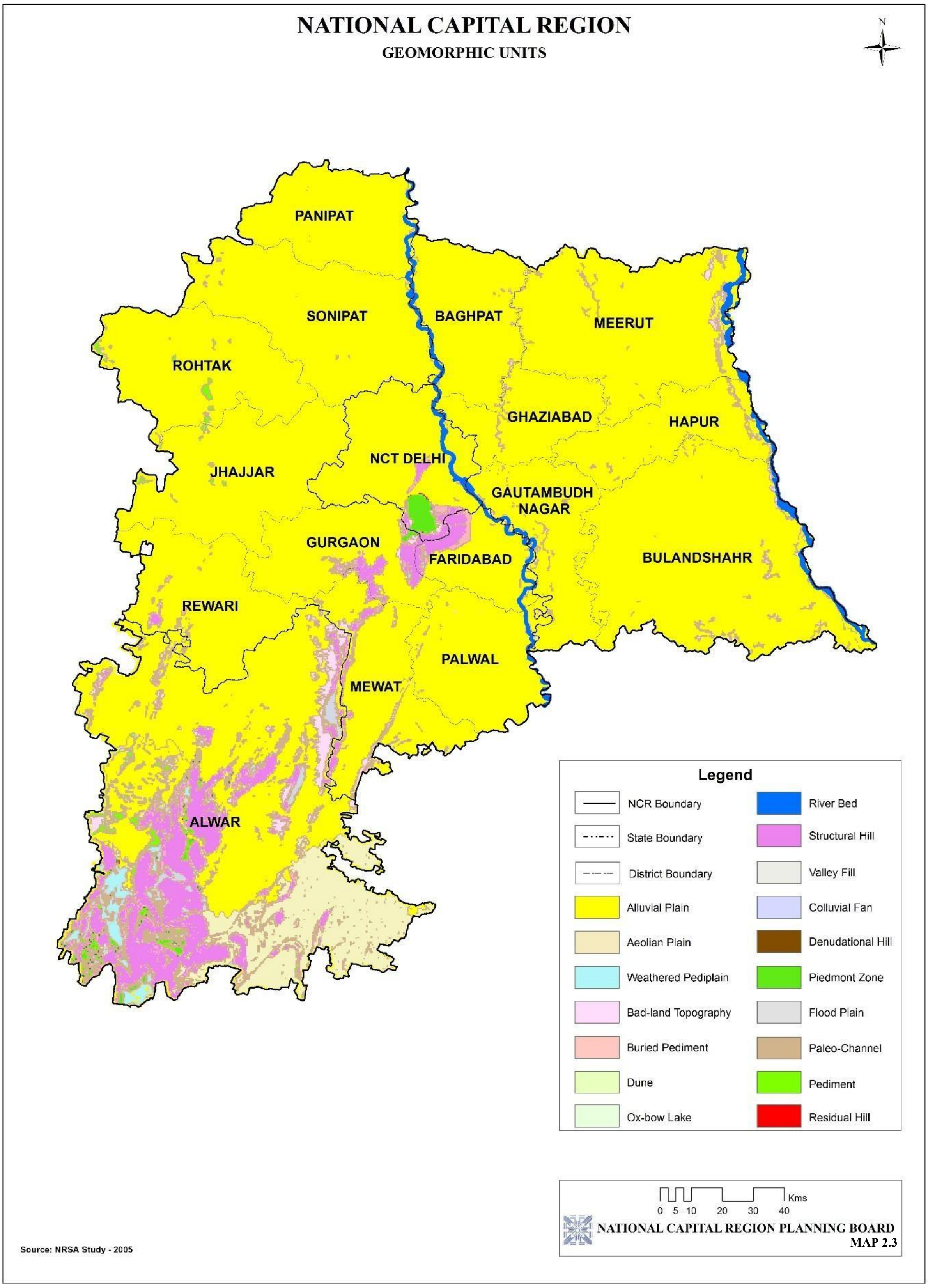
Map 2. 1 National Capital Region: Physiography and Slope



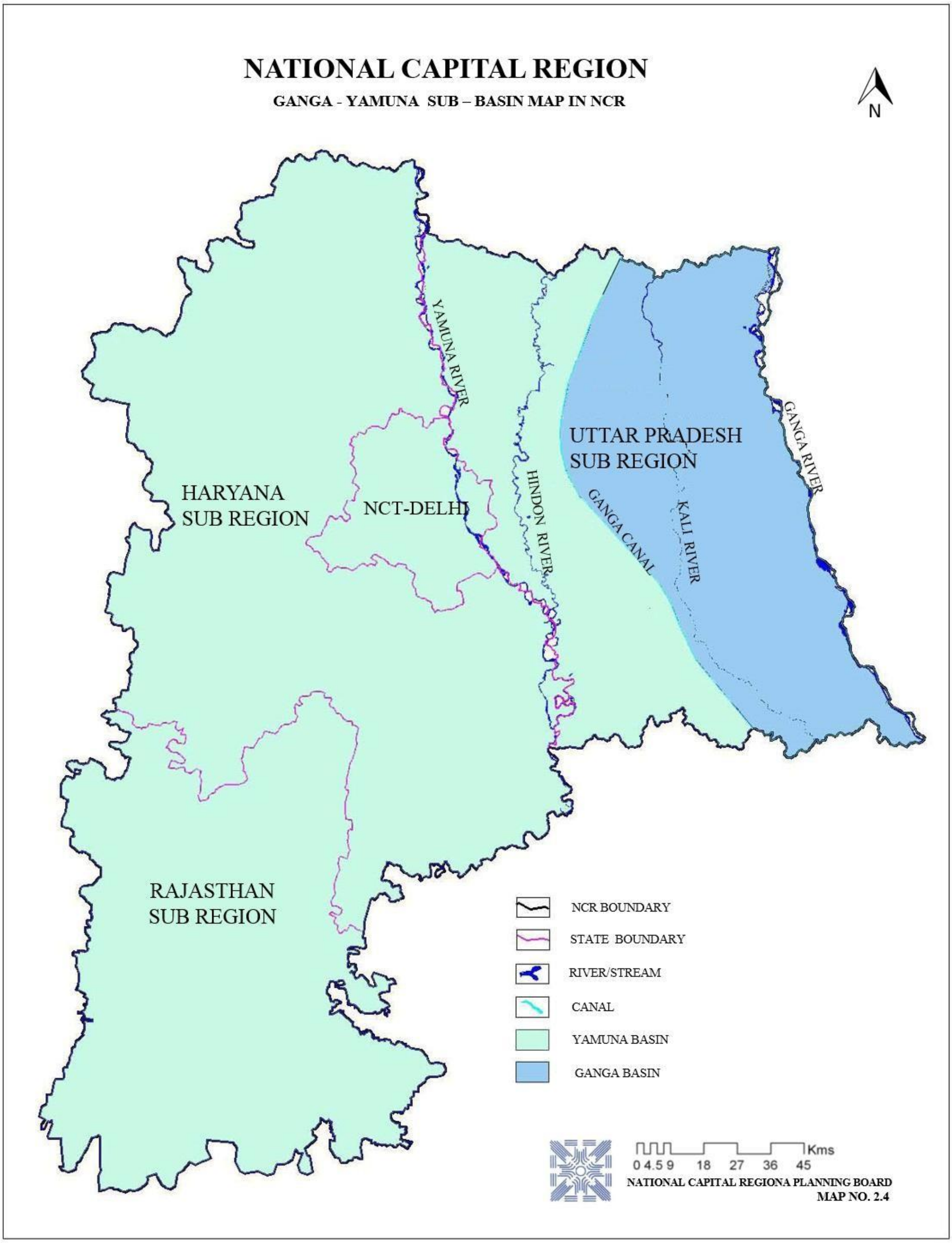
Map 2. 2 National Capital Region: Lithology



Map 2. 3 National Capital Region: Geomorphic Units



Map 2. 4 National Capital Region: Ganga-Yamuna Sub-Basin in NCR



The prominent one is Sahibi, which is not having a defined course and rises from hills in Jaipur district of Rajasthan about 5 km south of Behror and after flowing through Haryana enters NCT- Delhi through Dhansa Bund into Najafgarh Jheel and then joins the Yamuna in Delhi through Najafgarh drain. Krishnawati and Dohan are ephemeral streams flowing in to the southern part of Rohtak district. The existing major irrigation system passing through NCR are Western Yamuna Canal (Haryana), Eastern Yamuna Canal (U.P.), Agra Canal (U.P.) and Gurgaon Canal (Haryana and Rajasthan). Other details related to various drainage basins and sub-basins have been elaborated in Chapter 4 related to Drainage Management. Prominent structural hills in NCR are noticed around NCT- Delhi, Rewari, Gurgaon and Alwar. The residual hills are found in and around Rewari, Alwar and Delhi. The alluvial plain occupies a major portion of NCR and is formed by the Yamuna and the Ganga rivers. The sand dunes are present around Jhajjar and Rohtak districts in the western part of NCR.

2.4 Sub-region wise Other Physical Features

Haryana Sub-Region: The Haryana Sub-region comprises of alluvial plains consisting of Aeolian deposits and the low line hard rock ridges, isolated hard rock hillocks and sand dunes. In Faridabad district, the average altitude of the alluvial plain which is undulating type, ranges between 190 to 230 m above MSL. It is about 240 m in the Karnal district, which is adjacent district on Northern side of NCR. The slope is towards the south-east in Faridabad and southwards in Sonepat, Panipat and north east of Rewari districts. The only perennial drainage is once again the Yamuna River towards the eastern extremity of Haryana Sub-Region. The area has surface irrigation and drainage systems. It also has lakes like Badkhal which collect water from part of the Aravalli drainage. In this part, there are also several topographic depressions which create local water-logging during rains. The other physical features are given as under:

(i) Climate: The Haryana Sub-region of NCR falls in the subtropical steppe region of the climatic region of India. It is characterized by hot summer and mild to severe winter. The temperature in summer rises up to 48^{o} C. The rain is received from southwest monsoon and the average rainfall is between 50 and 70 cms.

(ii) Soils: Haryana Sub-Region comprises of soils of old Alluvial with sand dunes, soils of Aravali Hills, soils of recent floods.

(iii) Forests: As per the India State of Forest Report, 2013, the total forest cover of Haryana State is 1586 sq.km.constitutes 3.6% of which the forest area in NCR is 461 sq.km., which constitutes 3.4% of the total area of the Sub-region. Development of forest resources is of vital importance in preserving the environment and eco-system, which greatly influences the climatic pattern of the area. Their presence of forests is also essential to safeguard against flood.

(iv) Minerals: The sub-region is moderately rich in the mineral wealth. It produces kaolin (natural), Dolomite, Lime Kankar, Silica sand in sufficient quantity.

U.P. Sub-Region: The UP Sub-region part of NCR constitutes plain land, which is a part of important physiographic unit of country known as the Ganga plain. The average altitude within the NCR is about 205m above Mean Sea Level (MSL). The slope is towards South East but locally it stands modified as per the local drainage. The plain is a thick pile of loose sediment whose boundaries (far beyond the NCR) are defined by the Shivalik hills in the north and the peninsular shield in the south. Rivers Ganga & Hindon, their tributaries, and the canals taking off from the Ganga define drainage of the U.P. Sub-region.

(i) Climate: The climate of this sub-region is characterized by a cold winter, a hot summer and general dryness except during the south-west monsoon season. Air of oceanic origin reaches the districts in NCR only during the monsoon seasons. Temperature varies from mean maximum of 41^{o} C in summer to mean maximum of 21^{o} C in January while the minimum temperature drops down occasionally to about the freezing point of water and frost occur.

(ii) Soils: The sub-region mainly has sandy and clay soils. In Bulandshahar and some parts of Khurja there are certain pockets of sandy soil, which are barren. Meerut and Ghaziabad districts are mainly covered by older alluvium soil with occasional alkaline efflorescence. The soil very close to the rivers Yamuna and Ganga are sandy in nature**.**

(iii) Forests: The India State of Forest Report-2013 indicates that the total forest cover of UP State is 14349 sq.km. and constitutes 6% out of which 286 sq.km. falls in NCR which constitutes 2.6% of the total area of the Sub-region. This region has dry deciduous forests. The dominant trees are sal, sheesham and teak.

(iv) Minerals: The mineral in the Sub-region is very limited. It does not possess any major mineral deposits. The only mineral available in the sub-region is Kankar which is a clay product basically restricted to construction material.

Rajasthan Sub-Region: The physiography of Rajasthan Sub-region is characterized by range of Aravali hills girdling eastern boundary, south western part is covered by hillocks under dense forest covering partly Sariska Tiger Den Area, sand dunes and barren low hills of the Aravali range and its outcrops in the west. The rest of the sub-region is plain. Aravalli range exists here in the form of ridges and conspicuous isolated hillocks.

Morphologically the Rajasthan sub-region can be divided into (a) North-West part and (b) South-East part. North-West part is characterized by few hillocks and large tracks of plains, which is further sub-divided into two sub parts by Sahibi river. This part has a general slope towards North-East. South-East is also characterized by scattered hillocks and fertile agricultural land. These hills are low in the North-East but become prominent towards Alwar town. They form important topographic feature in Bansur, Kishangarh and Tijara Tehsils. Between these hills, they enclose valleys and high table land. Mandawar, Behror, eastern portion of Alwar and Rajgarh Tehsils are plain with scattered hills.

Sahibi River with its tributaries drains the area. It flows from South-West to North-East or North maintaining in general north eastern direction. It passes through Behror, Mandawar, Kishangarh and Tijara Tehsils. The river Chuhar Sidh rises in the hills of Alwar tehsil. There are a few hot water springs in Alwar district.

(i) Lakes and Tanks: There is no natural lake in Sub-region. However, there are a large number of artificial lakes and tanks. The major lakes are Jai Samand, Siliserh, Balota bund, Mansarowar, Vijay Sagar, Kuduki.

(ii) Climate*:* The Sub-region has a dry climate with a hot summer, a cold winter and a short monsoon season. The cold season starts from mid of November and prevails upto beginning of March. The hot season follows thereafter and extends up to end of June. The South-West monsoon season is from July to mid -September.

(iii) The average rainfall in the Sub-region is 61.6 cm. The south-west monsoon contributes nearly 90% of the annual rainfall. The variation in the annual rainfall from year to year is very large. On an average there are 30 rainy days. However, the sub-region compares favourably with the Rajasthan State average of 53.6 cm.

(iv) The temperature rises from March to June. May and June are the hottest months of the year. The mean daily maximum temperature in May is of the order of 43^{o} C and the mean daily minimum is about 28^{o} C. In May & June the maximum temperature may go up to 49^{o} C. The mean daily maximum and minimum temperatures in January are about 23^{o} C and about 8^{o} C respectively.

(v) Soils: In Alwar district of the Rajasthan Sub-region, there are three different types of soils viz (a) Loamy soils in parts of Alwar and Behror Tehsils, (b) Sandy soils in Tijara, Behror, Mandawar and Kishangarh Tehsils. These areas are less fertile owing to their moisture retaining capacity and (c) clay loamy in low lying tracks such as beds of tanks in Ramgarh and Alwar tehsils.

(vi) Forests: The total forest cover of Rajasthan state as per the India State of Forest Report-2013 is 16086 sq.km constituting 4.7% of the State out of which the forest area in NCR is 1203 sq.km. which constitutes 14.4% of the total area of the Sub-region. The forest are mostly found in small patches in the northern and eastern slopes of Aravalli range. The main species found in the forests are dhok, raunj, khair, asan, bahera, salar, bamboo, jhighan, dhak, ber, tendu, Thor, etc.

(vii) Minerals: The chief minerals reported to occur in the sub-region are barites, feldspar, quartz, china clay, iron ore, copper ore, lead ore, soap stone, dolomite etc. along with building stones (flat stones, marble, and masonry stones). The hills of the south and southwest are fairly rich in minerals, such as copper, iron and lead, but they are not being exploited extensively.

NCT of Delhi: National Capital Territory of Delhi, is the capital of India is highly urbanized area. It comprises of mostly alluvial plain land with a long rocky ridge extending roughly from north-east to south-west. Aravalli Hills enters the southern border and ends in the north of Delhi on the west bank of the Yamuna.

(i) Climate: The climate of Delhi is semi-arid with extreme summer and winter. The cold wave from the Himalayan region makes winters very chilly. In summer, the heat wave is immense and the minimum and maximum temperature variation is 27 to 45^{o} C and in winter temperature variation is 3 to 22^{o} C. Storms are common during summer in May and June when day temperature exceeds 40^{o} C.

(ii) Soils: The soils of Delhi are mostly alluvial in origin and on both sides of the river, they are influenced by annual rainfall and flooding of Yamuna water due to monsoon rains. It comprises sandy loam, and loam.

(iii) Forests: As per the India State of Forest Report, 2013, the total forest cover of NCTDelhi State is 179.81 sq.km. which constitutes 12.1% of the Sub-region. Vegetation of Delhi is typical Northern Tropical Thorn Forest Type. Among trees Accacias such as nilotica, leucophloea, catechu, modesta, butea monosperma (dhak), cassia fistula, salvadora persica, Anogeissus latifolia with abundance of prosopis julifora.

(iv) Mineral: The sub-region does not have any minerals of economic importance except road construction materials and some china clay deposits. The building and road construction material comprises of sand, stone and bajri. Quarrying of sand is at Okhla, Badarpur and Bhatti. Kaolin is used as principal raw material for refractory, brick industries and Chinaware. In view of environmental consideration the quarrying and crushing of stones has been banned in NCT- Delhi.

3. HYDROMETEROLOGY

3.1 Introduction

Hydrometeorology is a branch of meteorology and hydrology that studies the transfer of water and energy between the land surface and the lower atmosphere. Detailed hydrological investigation of catchments of the river system traversing NCR and its adjoining States are of paramount importance for proper assessment of water resource potential and extent of flood and drainage problems.

3.2 Hydro-meteorological Aspect

In the NCR about 79% of the rainfall is contributed by summer monsoon and remaining 21% by other seasonal rains. The area receives total annual rainfall of 614mm/hr. Depressions/cyclonic storms and low pressure systems that form in the Bay of Bengal and Arabian Sea during monsoon/post monsoon season travel generally in their final phase over NCR area, Punjab, Haryana, Rajasthan, West UP, Uttaranchal and Himachal Pradesh and yield very heavy rainfall over these areas resulting in flood in Yamuna and Ganga basin.

3.3 Rain Gauge Stations

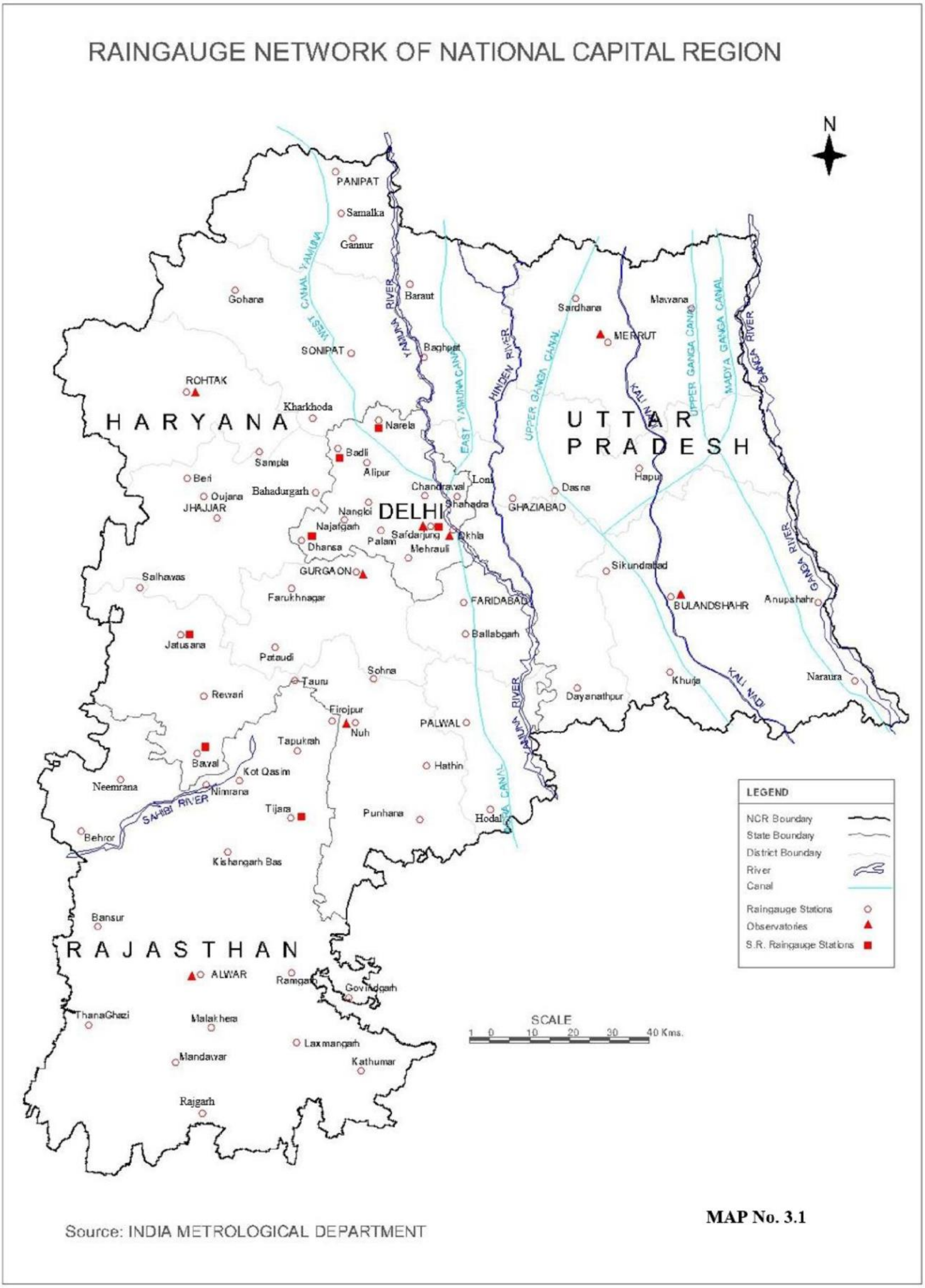
World Meteorological Organization (WMO) has recommended density of Rain Gauge Station in plain area as 600 to 900 km^2 per station. NCR has an area of 34,144 km^2 and there are 56 Rain Gauge stations (Map 3.1: Rain Gauge Network in National Capital Region). The density of Rain Gauge stations works out to be 610 $km.^2$ in NCR and meets the WMO standard. The sub-region wise Rain Gauge station distribution is given in Table 3.1.

Table 3.1Rain Gauge Stations in NCR

Sub-Region	Area (km^2)	No. of Rain Gauges Stations
Haryana	13,413	25
NCT-Delhi	1,483	12
Rajasthan	7,829	8
U.P.	10,853	11
NCR	**34,144**	**56**

Source, India Metrological Department, Govt. of India

Map 3.1 Rain Gauge Network of National Capital Region



3.4 Important Features of Climate of NCR

The geographical location of NCR about 2,000 km away from Bay of Bengal coast and U.P. hills in the northeast and semi-arid region of Rajasthan in the southwest determines the climatic conditions of NCR area. The total area of National Capital Region extends over 34,144 km^2. It is about 217 km wide and 234 km long plain area. Yamuna River flows north to south in the central region NCR part and Ganga River flows along the eastern boundary of NCR. A long rocky ridge of insignificant height of the Aravali Systems range extends roughly from north-east direction to south- west direction.

3.4.1 Important Weather Systems

Following important weather systems give significant rainfall in different parts of NCR and adjoining States:

3.4.2 Western Disturbances

Western disturbances are shallow but extensive low-pressure systems and travel across the northern India from west to east. On an average, six western disturbances pass through the Northern region of the country each month during winter season but all are not active.

It begin to get active from middle of December, remain there for a day or two over Punjab and sometimes intensify. These disturbances have higher frequency in January and February over Haryana, Punjab, Himachal Pradesh & Western U.P. Hills and results in rainfall in plains and snowfall in higher reaches of hilly regions. During this season, Delhi, Punjab and Haryana get normally 5 to 6 cm rainfall. Occasionally, these western disturbances also bring rain to the central parts of the country. It is of great economic importance over most of the areas. The crop of wheat in the northern and central areas of country depends upon this winter rainfall. The period from December to February is generally very unpleasant due to biting cold wind when a series of severe cold waves are associated with western disturbances affect the region.

3.4.3 Thunderstorms/ Dust storms

The weather during the period March to June is of gusty afternoon winds and convective phenomena like dust-devils, dust-storms, thunderstorms and hail prevails. Western disturbances continue to travel across the region eastwards, the cold fronts in their rear being generally associated with dust-storms or dry thunderstorms. Moderate to strong westerly dry land winds prevail especially in March and April. Thunderstorms and dust-storms increase in frequency with the progress of the season in West Uttar Pradesh and in the Kumaon Hills. Where less moisture is available, the convection generates violent squalls and dust-storms.

These violent squalls and dust-storms are called “Andhis” charged with dust, the atmosphere becomes hazy. Occasionally in May and June, after extensive dust-storms in the west, the air over East and North Punjab and in Uttar Pradesh becomes charged with fine dust which reduces visibility considerably; this dust-haze often extends to heights over 3 km.

Rainfall is rare in the plains in April and May. In June, it occurs intermittently in West Rajasthan and East & North Punjab, especially near the hills. This is the season of dust storms and thunderstorms; earlier in the season there is little rain; but the associated rainfall increases as the season advances.

3.4.4 Southwest Monsoon

The agriculture of the greater part of India depends upon the rainfall of the southwest monsoon that accounts for nearly 90% of the rainfall of the whole year, except in the southern parts of the country. Towards the end of May, south-east trade winds in the Indian Ocean advances rapidly northwards across the equator into the Arabian Sea and the South Bay of Bengal and in course of about a fortnight, the monsoon enters the Indian area in two main currents, the Arabian Sea and Bay of Bengal currents. The former gives heavy rain to the coastal districts south of Bombay and on the hills of Western Ghats. After crossing the Ghats, the monsoon winds branch into two streams. The southern stream blows across the peninsula and the northern part crosses Kathiawar coast, gives rain mostly in the coastal districts and then near Aravali hills and Punjab & Kumaon hills but very little rain in the plains of Rajasthan. The Bay of Bengal currents also split into two branches. One advance up the Burma Coast, and the other, which crosses the West Bengal coast, is directed westwards up the Ganga plain by the deflecting action of the mountains to the east and north of West Bengal.

The trough of the low pressure exists throughout the monsoon season between the westerly winds of the Arabian Sea and easterly winds of the deflected Bay of Bengal current. The eastern end of the trough usually extends into the Head Bay of Bengal just before the formation of the depression there. As the depression moves westward from the Head Bay of Bengal, rainfall extends to Bengal, Orissa, Bihar and Madhya Pradesh. By this time, the Arabian Sea current is also strengthened and the rainfall is carried by the depression to Rajasthan and Gujarat before it merges in the seasonal low pressure over Northwest India. Sometimes the depression curves are round and eventually break up in the sub-mountain regions of Punjab and hill districts.

In the absence of these depressions, the distribution of rainfall in the season is strongly influenced by the orography and the position of the monsoon trough. During September occurs the gradual weakening of the monsoon and its withdrawal from northwest India. The depressions form in more southerly latitudes and after advancing initially westwards into land area, take a more north westerly or northerly course towards Himalayas where they break up. These cause occasional spells of heavy rain occurs in Punjab, Kumaon Hills and their adjoining areas/plains. The monsoon withdraws from Northwest India by the third week of September and from Western Uttar Pradesh by the end of September.

3.4.5 Cyclonic Storms/Depressions

During October and November, cyclonic storms form in the Bay of Bengal and carry heavy rainfall along their track and later in the season, they mostly strike the Coromondel coast and produce very heavy rainfall in southeast India.

After the withdrawal of the monsoon, clear bright weather prevails during the season. Occasionally, western disturbances cause clouding in Kashmir, Punjab and Himalayas. A few days of thunder may be experienced in East and North Punjab and near the Aravali Hills. A series of cold waves associated with western disturbances affect the States of Rajasthan, Haryana, Punjab and Uttar Pradesh. Under the influence of western disturbances rainfall occurs over the region.

3.5 Rainfall

In India rainfall is measured at 0830 IST every day. Description terms for the spatial distribution and intensity of rainfall given in Table 3.2.

Table 3.2 Description Terms of Rainfall

I. **Spatial Distribution of Rainfall**		
Distribution	**No. of Places**	**Description**
Isolated	One or two places	<25% of stations gets rainfall
Scattered	At a few places	(26-50)% of stations get rainfall
Fairly Widespread	At many places	(51-75)% of stations get rainfall
Widespread	At most places	(76-100)% of stations get rainfall
Dry	-	No station reported rainfall
II. **Intensity of Rainfall**		
Descriptive Term used	**Rainfall amount in mm (24 hours)**	
No Rain	0.0	
Very Light Rain	0.1-2.4	
Light Rain	2.5-7.5	
Moderate Rain	7.6-35.5	
Rather Heavy	35.6-64.4	
Heavy Rain	64.5-124.4	
Very Heavy Rain	124.5-244.4	
Extremely Heavy Rain	>244.5	
Exceptionally Heavy Rain	When the amount is a value near about the highest recorded rainfall at or near the station for the month of season. However, this term will be used only when the actual rainfall amount exceeds 120 mm.	

Source, India Metrological Department, Govt. of India

The District-wise average rainfall data for the 50 years (1951-2000) for NCR shows that Meerut district received maximum average rainfall (1918.0 mm) followed by Ghaziabad (766.3 mm), Bulandshahr (779.90mm) and NCT-Delhi (747.1 mm). While Jhajjar district received the lowest rainfall (489.0 mm) followed by Rewari (492.2 mm), Gurgaon (544.40 mm) and Palwal followed by Mewat (572.0 mm). Average rainfall for 50 years is given in Table 3.3.

Table 3.3 District-wise average Rainfall Data of NCR (normal -1951-2000)

District/Sub-Region	Normal Rainfall (mm)
NCT-Delhi	747.1
Haryana	
Jhajjar	489.0
Rewari	492.2
Faridabad	697.6
Gurgaon	544.0
Mewat	572.0
Palwal	508.1
Panipat	624.1
Rohtak	618.0
Sonipat	644.2
Uttar Pradesh	
Meerut	918.0
Ghaziabad	766.3
Bulandshahr	779.0
Baghpat	646.7
Gautambudh Nagar	669.3
Rajasthan	
Alwar	630.9

Source, India Metrological Department, Govt. of India

The mean annual rainfall for 45 years (1930-1970) is 754 mm with the maximum of 1230 mm in 1964 and the minimum of 321.8 mm in 1938. The rainfall was also quite high in 1975 when it was 1197 mm. Of the total rainfall, 90% occurs during the months of July and September by Southwest monsoon and the rest during the winter. The rainfall is generally erratic and is not too frequent, but several times precipitation is very heavy and floods occurred in 1924, 1947, 1956, 1976, 1977, 1978 and 2010 in NCR.

4. DRAINAGE MANAGEMENT

4.1 Introduction

Drainage is removal of surplus rainwater or irrigation water from the land. Surplus water is as harmful to crops as inadequate water. Excess water in the root zone of crops reduces the essential air circulation affecting the growth of the plant as well as the yield. Water logging may also lead to salinity of soil making it unfit for cultivation. In addition, sustained water logging degrades environment and is also a health hazard. Further, urban drainage also suffers from flooding and poor maintenance of sewerage system as whenever the sewerage system gets blocked, the sewage is diverted to the nearby drains. It is imperative to study morphology in the river basin and also the existing drainage system and its management in NCR.

4.2 Morphology

Morphologically National Capital Region can be divided into two divisions:

i) Ganga-Yamuna Doab
ii) Area West of the Yamuna river

4.2.1 Ganga-Yamuna Doab

Ganga-Yamuna Doab comprises of six districts of UP sub-region, namely Meerut, Ghaziabad, Bulandshahr, Baghpat and Gautam Buddha Nagar and Hapur. This seemingly featureless plain lacks topographic prominence and the monotony of physical landscape is broken at places by the river bluffs, leaves, dead arms of river channels and the river channels. The area is covered by new alluvium (Khadar) and older alluvium (Bhanger). Bhanger is found all over Doab while there are finger like extension of khadar along with main rivers/streams. Due to presence of fertile soil, level land and canal irrigation, the area is intensively cultivated and supports a high density of population.

4.2.2 Area West of the Yamuna River

The slope of the alluvial plains from the Shiwaliks is towards the southwest upto Najafgarh drain and then towards the north. North of Delhi, the old high bank of Yamuna forms the summit level of the plain. In the extreme south of these plains, are the out layers of the Aravali's, which are intensely folded and eroded. One arm of the Aravali forms a continuous range terminating in Delhi and in between there are only low hills to the west of Bawal and Rewari towns. North of Aravali extensions, the whole tract are traversed by the number of sand ridges, which mostly run north-south and form higher prominences in the physical landscape. The only major river in this extension is the Sahibi, which flows, in a south-west, north-east direction. It is ephemeral and ends up in the sandy region of Haryana, but sometimes during heavy rains, it drains into the Najafgarh depressions and joins the Yamuna.

The region in general is a part of well-integrated drainage system of the Ganga. Almost all streams follow northwest, southeast course concomitant with the slope of the land. The extremely gentle gradient almost all over the region restricts the de-gradational activities of the streams. Wide flood plains and high bank are common features in the course of the Ganga and the Yamuna along with silt and clay deposits.

4.3 Drainage System of U.P. Sub-Region

The entire U P Sub-region falls in Ganga-Yamuna Doab division. Gravity drainage is available throughout the region due to the gentle slope of the sub- region from north to southeast, which acts as deterrent to the drainage/flood problem created by vagaries of the river Ganga, Yamuna and their tributaries. Entire area is generally well drained by a good network of natural and man-made channels. Ground elevation falls from about 230 m above MSL in the north to almost 190 m above MSL near the south end of the sub-region. Besides the Ganga and Yamuna, other important rivers/steams in the area are Hindon, Kali Nadi, Neem Nadi, Karwan Nadi and Chhoiya Nadi. The Existing Drainage System of U.P. Sub-region is given in Map No.4.1. (Drainage Master Plan of U.P. Sub-region).

Natural drainage is provided by numerous drains, which flow from north to south. Within this region there are low lands called "Khadar" formed due to meandering of rivers in the past. The existing good network of the surface drains in the area is sufficient to drain out excess of rainfall during even heavy precipitation of monsoon season.

4.3.1 Flood Plains and adjoining area of river Ganga

Ganga flood plain in UP Sub-region is confined well within the Ganga River and Anoopshahr branch of Upper Ganga Canal from Garmukteshwar upto the border of district Bulandshahar - Aligarh. In the upper portion in the districts of Meerut and Ghaziabad, the flood plain extends upto Madhya Ganga canal. Few drains taking water of this area to Ganga River are Sota Nala, Bhuri Ganga, Paswara, Jharina nala, etc.

Between Anoopshahr Branch and Madhya Ganga canal; and in the lower part between Anoopshahr Branch and Ganga flood plains, there are large patches of land where the density of drainage channel is very low. However, drainage channels like Mehalwala Naalah, Buklana Naalah, and Phuladhara naalah are draining the area.

4.3.2 Kali Nadi Basin

Nagin Nadi originates at some distance north of Meerut and after joining Khatauli drain and Chandsumad drain, it becomes Kali Nadi. It flows southwards for some distance and then southeast further down to join river Ganga. It has Chhoiya Nadi as its important tributary. It caters drainage area lying between Upper Ganga Canal and Anupshahr branch in the districts of Meerut and Ghaziabad. The remaining area lies between UGC and Lakhoati branch upto the Border of Bulandshahar-Aligarh districts.

There are numerous other drains existing in this basin that help in draining the excess water. Some of the important drains are Udaipur drain, Dadri drain, Daulatpur drain, Abu nala 69, Abu nala 73, Bahadurpur drain, Fazilpur drain, Jalagarh drain, Pathanpur drain, Jajokhar drain, Jani drain, Shekupur drain, Kadrabad drain, Deorala drain, old Bahal drain, Chhoiya nadi, etc. Total length of drains in this system is 388.68 km.

4.3.3 Chhoiya Nadi Sub-Basin

It forms a sub-basin in Kali nadi basin. It originates by joining of Niloha drain, Chhoiya drain and Gagsauna. It joins the Kali nadi near Hapur. It has several tributaries like Phalaoda drain, Gagsauna drain, Gadina drain, Chhoiya drain, Miloha nala, Kaula drain, Mawana drain, Bali drain, Kithore drain, Rajdhana drain, Ikla drain, etc.

4.3.4 Neem Nadi Basin

Neem Nadi originates from north of Ghaziabad-Bulandshahr boundary and flows through the Bulandshahr district and the basin confines between the Lakhaoti branch and Anupshahr branch. Several drains outfall into the Neem nadi, which are Dhanpur drain, Ratupur drain, Ladpur drain, Siyana drain, Sankhari drain, Barauli drin, Bajsara drain, Deogawan drain.

4.3.5 Hindon River Basin

Hindon river rises on the southern slopes of the Shivalik in Saharanpur district and after traversing a distance of almost 265 km, it outfalls into river Yamuna. Its main tributaries Kali (West) and Krishni. The catchment area of the Hindon River is 7083 sq km in which 5512 sq. km. falls in UP sub-region of NCR. The river Hindon and Krishni are not perennial and carry water during monsoon and remains dry during the summer. A part of Hindon channel called Hindon Cut acts as a link between Yamuna and Upper Ganga Canal through Jani Escape, main drains in the Hindon Basin are Kandal drain, Quasinpur drain, Tera drain, Dhakauli drain, Siwal drain, Patholi drain, Sarhana drain, Ujhera drain, Pala drain etc.

4.3.6 Karwan Nadi Basin

In between the Kali nadi basin and the Yamuna River, there is Karwan nadi which is a tributary of river Yamuna. Upper reach of the Karwan nadi basin falls in the NCR Subregion of UP. The drainage basin is bounded by Mat branch and Upper Ganga canal. Some important drains are Jarcha drain, Koanora drain, Nizampur drain, Sikandarabad drain, Kanaripur drain, Aliabad drain, Gangrauli drain, Siryal drain, Sonda drain, Hazrat drain, etc.

4.3.7 Yamuna Sub-basin in UP Sub-Region

In Uttar Pradesh, Yamuna catchments extends up to eastern Yamuna canal in the upper reach (upto Delhi border) and there after Mat branch forms the boundary of Yamuna catchment upto southern end of NCR UP sub-region. There are 14 main drains out falling in the Yamuna in UP Sub-region. They are Tuguna drain, Kurri lumb drain, Chhapraul drain, Sonali drain, Baraut drain, Barauli drain, Alwalpur drain, Surajpur drain, Nodia main drain, Bilaspur drain, Usmanpur drain, Pathwal drain, Sobara drain, Hirnoti drain, etc.

4.3.8 Status of existing drainage system

In Uttar Pradesh, so far drainage plans have been prepared considering the area lying in an administrative district as a unit. This has been done largely from the point of view of administrative convenience. A good network of surface drains consisting 41 major drains have been developed in different drainage basins to drain off excess run off during heavy precipitation in monsoon season. In UP Sub-region the intensity of natural drainage system is about 0.054 km/ km^2 to 0.227 km/ km^2**.** As per the information provided by Irrigation Department, Govt. of UP, there are 41 trunk drains falling into the river Yamuna, Hindon and Kali. Detailed information relating to length, catchment area and head discharge of the seven trunk drains directly falling in river Yamuna, eleven trunk drains falling in Hindon river and eighteen trunk drains falling in Kali Nadi are given in Table nos.4.1, 4.2 and 4.3 respectively. There is no river or major drains falling into Ganga River in NCR since most of the part of UP Sub-region falls in Yamuna Sub-basin.

Table 4.1 Details of Trunk Drains falling in Yamuna River in UP Sub-Region

Sl. No.	Name of Trunk Drain	Length (km)	Catchment area (Sq Mile)	Head Discharge (Cusec)
1	Lumb	20.51	30	300
2	Chhaproli	3.62	2	20
3	Sanoli	11.36	14	140
4	Badot	6.28	25	200
5	Surajpur	8.04	25	125
6	Noida Main Naala	17.10	70.34	3210
7	Pathwaya Naala	33.00	49	245

Source: Irrigation Department, Govt. of UP

Table 4.2 Details of Trunk Drains falling in Hindon River in UP sub-region

Sl. No.	Name of Trunk Drain	Length (km)	Catchment area (Sq Mile)	Head Discharge (Cusec)
1	Teda	20.51	55	275
2	Dola	22.53	24	172
3	Sanoli	11.36	14	140
4	Radhana Naala	4.50	9	48.3
5	Sardhana Naala	17.60	50.65	446
6	Sivaal Naala	16.60	17	170
7	Saunda Naala	13.80	11.5	115.1
8	Mortha Naala	8.10	4.1	41
9	Dasna Naala	19.31	30	150
10	Aloda Cut	2.80	2	10
11	Thasraana Cut	1.90	1.6	8

Source: Irrigation Department, Govt. of UP

Table 4.3 Details of Trunk Dains falling in Kali Nadi River in UP sub-region

Sl. No.	Name of Trunk Drain	Length (km)	Catchment area (Sq Mile)	Head Discharge (Cusec)
1	Aabu Naala-71	33.8	53	462
2	Aabu Naala-73	30.8	50.76	191
3	Pathanpura Naala	4.2	6.37	14
4	Kaadrabad Naala	54.4	201.2	2010.5
5	Nagin Nadi	22.4	114	1137.3
6	Jainpur Drain	5.86	4	20
7	Bulandshahr Drain	4.22	3	15
8	Neemkhera Drain	2.61	2	10
9	Bhatola Drain	5.18	6	30
10	Devraala Drain	4.82	6	30
11	Fatehpur Cut	1.31	0.5	2.5
12	Mohmadpur Drain	6.9	4	20
13	Kazimpur Devali Drain	2.81	1.5	7.5
14	Chandpur Drain	0.4	0.5	2.5
15	Taalivpur Drain	0.48	0.5	2.5
16	Chhoiya Naala	59.8	280.8	280.6
17	Neem Nadi Naala	94	136	-
18	Baraal Drain	36	65	325

Source: Irrigation Department, Govt. of UP

Major drainage features in Uttar Pradesh sub-region are shown in **Map 4.1.**

4.4 Drainage System of NCT-Delhi

The only river, which flows in Delhi, is Yamuna. It originates from Yamunotri Glacier in Himalaya. It covers a large distance and emerges into the plains of Uttar Pradesh in Saharanpur district. In this reach the river is trapped for irrigation through the Eastern and Western Yamuna Canal taking off from Hathni Kund Barrage (old Barrage – Tajewala head works). It then flows for about 230 kms forming the boundary between Haryana and UP until it enters the NCT of Delhi near the village Palla. It traverses through the NCT of Delhi covering a distance of about 50 kms and then its water is diverted at Okhla weir into the Agra Canal and from thereon into Gurgaon Canal for irrigating large fertile tracts in Uttar Pradesh and Haryana states.

In the NCT-Delhi; the Delhi ridge forms the main watershed. The drainage in the area east of the ridge is towards the Yamuna. In the west of the ridge the drainage water passes in the Najafgarh drain that again joins the Yamuna near Wazirabad barrage.

4.4.1 Drainage basins of NCT-Delhi

The drainage system of Delhi is such that all waters collected through main drains, link drains and small rivulets are discharged into Yamuna. On the basis of the topographical characteristics

NCT Delhi has been divided into five drainage sub-basins namely; Najafgarh, Alipur, Shahdara, Kushak Barapulla and Mehrauli.

i) Najafgarh Sub-Basin

In addition to a large tract of land in Haryana State, the Najafgarh basin covers the southwestern part of the NCT-Delhi. Najafgarh basin has been further classified in four sub-basins i.e. Najafgarh block, Kanjhawala sub-basin, MCD area and Delhi Cantonment area. There are three major drainage systems in Najafgarh basin i.e. Najagarh drain, Mangeshpur drain and Palam drain. Details of drains are given below:

Najafgarh drain: Najafgarh drain together with its branches serves a catchment area of 1,315 km^2. It starts from Dhansa bund where it is called Dhansa outfall channel and joins Yamuna downstream of Wazirabad. Mangeshpur and Palam drain outfall in Najafgarh drain. Total length of the drain in NCT Delhi is 62 km. Najafgarh Jheel is a natural depression and it is having catchment area 567 km^2 and it receives some water during the heavy rainfall in Haryana and Rajasthan through link drains connected from Jahajgarh Jheel and Sahibi Nadi.

Mangeshpur Drain: This drain starts from Mundrola village in Haryana and joins Najafgarh drain at about 0.8 km below Kakraola regulator. With the construction of diversion drain No. 8 in Haryana part of the upstream catchment of West Jua drain, Thana Khurd drain and Mandrolla drain have been diverted into diversion drain No. 8 which directly flows into the Yamuna. At present the total catchment area served by Mangeshpur drain at its outfall is 288.08 km2.

Palam Drain: Palam drain rises from hilly areas of south Delhi and after running through cantonment joins Najafgarh Drain. Palam link drain, Nasirpur drain & Palam pond drain outfall in Palam drain. It collects discharge from hilly, urban & rural areas having total catchment of 51.78 km2.

Karari Suleman Nagar Drain: It starts from a Pond near Puthkalan village and after running in west and south directions joins Najafgarh drain. Two link drains i.e. Mubarakpur and Mithari outfall in this drain.

Nangloi Drain: This drain takes off from a pond near village Puth khurd in Alipur Block. It is about 19.31 km long. It joins Najafgarh drain from left. Total catchment area of the drain is 68.87 km2.

ii) Alipur Sub-Basin

The basin is situated on the western bank of river Yamuna and on the northern part of NCTDelhi. The basin is bounded by the Delhi tail distributary of the Western Yamuna canal on its west, Shahalam Bund on its south, river Yamuna on the east and diversion drain No-8 of Haryana on the north. The Najafgarh basin is adjacent to the Alipur Basin on the west. The total area of this basin is 170 km^2 and is generally sloping towards river Yamuna in the east. Storm water from adjacent catchments north of Delhi-Haryana boundary directly comes to the

Alipur Basin. The discharge from 49.2km^2 of area, is being catered by the drain No. 6. The area is drained by Bawana Escape, Drain No. 6 and Burari drain and other minor drains.

Details of drains are given below:

Bawana Escape: The Bawana escape is the major drain for Alipur Basin. The catchment area is about 181 km2. The link drains through which the basin is linked into the Bawana escape are Ghaga link, Sanoth link, Narela link, Nayabans link and Alipur link. In addition to functioning as drain to dispose off storm water, Bawana escape also functions as escape for Delhi Tail distributary.

Drain No. 6: Drain No. 6 which was originally the tail end of a drain from Haryana which carried large volume of discharge. The diversion through drain No. 8 has reduced the discharge considerably. Presently the drain No. 6 has a length of 13 km and a total catchment area of 93.50 km2. The link drains outfalling in this drain are Bankner, Tikrikhurd and Hamidpur.

Burari Drain: Another important system of drains in Alipur basin is Burari creek and Burari drains. Considerable urban discharge from Model Town area is discharged into this drain.

iii) Shahdara Basin

Shahdara Basin area is located on the eastern bank of river Yamuna and bound by river Yamuna on the west, Hindon on the east and UP on north and south. Shahdara basin is below the high flood level of Yamuna and rise of water level in Yamuna causes problem of water logging. Marginal embankments (Shahdara Marginal bund and left marginal bunds) were constructed in 1955 -56 to protect the area from flooding.

Earlier most of the run off from North of GT Road used to be pumped into Yamuna during average flood stage and failure of pumps used to result in flooding. Modified drainage system with arterial drains No. I & II were constructed to improve the situation. Drain No. 1 starts from North of arterial highway and drain No. II starts from North of GT Road near UP Border. Later Drain NO. I & II join and the combined drains run parallel to Hindon cut canal and then fall into river Yamuna down stream of new Okhla Barrage.

iv) Kushak Nallah- Barapulla Nallah System

This basin drains mainly the discharge from Mehrauli block and part of urban area of Delhi. The drains carry flashy discharge on account of considerable run off coming from urbanized areas and sloppy, hilly areas. The total length of Kushak drain and Barapulla drain is 12.87 km and 2.23 km respectively. Most of the drainage channels in NDMC area fall into this system. The Kushak Nallah enters MCD area near INA market and Defence Colony Nallah joins it.

v) Mehrauli Basin

It is located on the southern part of NCT Delhi and covers an area of 160 km^2. It can be further divided into three units as given below:

Hard rocky area on the ridge: Southern boundary of NCT Delhi has a rocky ridge. In the south quartzites are exposed near Chirag Delhi, Kalkaji, Tughlakabad & Chattarpur area.

Alluvial plain: Alluvial plain is in the north-eastern side of Mehrauli ridge extending up to Agra canal. The general slope is towards river Yamuna. The alluvial plain on northern side of Mehrauli ridge extends up to Najafgarh Jheel on the west.

Submergible Khadar Land: It is situated between left bank of Agra canal and river Yamuna. Drainage is not a problem in this area. However, soil erosion and maintenance of soil fertility are the major concerns from cultivation point of view.

Several nallas start from the ridge. During monsoon these nallas carry rainwater from rocky terrain and agriculture area. Mainly there are six sub-basins of drainage system as given below:

i) Drainage into Najafgarh Jheel
ii) Drainage from North West corner draining into Najafgarh drain.
iii) Drainage from the northern slope discharging into Chirag Delhi drain.
iv) Drainage direct to Agra canal
v) Drainage above Ali Super Passage

Delhi has natural and man-made drains. The total length of man- made drains is 700 km spread over 12 municipal zones. All drains of Delhi ultimately out fall into Yamuna River. The Existing Drainage System of NCT-Delhi is given in Map No. 4.2 (Drainage Map of NCT Delhi).

Major drainage features in NCT-Delhi sub-region are shown in **Map 4.2.**

4.5 Drainage System of Haryana Sub-Region

There are two drainage catchments in Haryana, one drains through river Yamuna and the other through river Ghaggar. The area being drained through river Yamuna originally had only two outlets, first through Najafgarh drain in Delhi and second through Goverdhan drain in U.P. The Existing Drainage System of Haryana Sub-Region is given in Map No.4.3 [Drainage System NCR (Haryana and Rajasthan Sub-region)] In order to improve the situation in NCT -Delhi and also to provide relief in Haryana, diversion drains were constructed in Northern part of this catchment namely Chautang diversion, diversion Drain no. 2 and diversion Drain no. 8. Although these have reduced the pressure on Najafgarh drain, still there is a considerable pressure from Sahibi Nadi and Drain no. 8, which joins at Surethie. Haryana sub-region has been divided into following sub-basins:

i) Main Drain No. 2 Sub-Basin

The Drain no. 2 with its tributaries like Munak drain, Panipat main drain, Begumpur drain and Pundri drain caters the area falling between western Yamuna canal on the western side and the Yamuna River on the eastern side. In the upper reach Drain no. 2 is known as Indri drain which gets the discharge from Phurlak drain, Nahar Kuna Hansi Nadi. Drain no. 2 has its outfall in

Yamuna River near village Khozkipur. The total length and capacity of this drain is 59.30 km. and 6325 cusecs respectively.

ii) Nai Nallah Drain and Diversion Drain No. 8 Sub-Basin

Nai Nallah drain off takes from Anta Syphon under Hansi Branch near village Chachrana. It flows down and passes by the side of Gohana town. Just south of Gohana tributary drain no. 4 joins it. Nai Nallah drain outfalls into drain no. 8. This drain caters to part of Jind and Sonepat district up to Gohana town. Some of the drains falling into Nai Nallah drain and diversion drain no. 8 system are tributary drain nos. 1, 2, 3, Dobetta drain, West Jua drain, Khanda drain etc. Diversion drain no. 8 originates from drain no. 8 near Gohana town and ultimately outfalls into the river Yamuna just upstream of northern border of Delhi.

iii) Main Drain No. 8 Sub-Basin

Nai Nallah near village Mahra is named as main drain no. 8 from where diversion drain no. 8 off takes. Drains falling in the main drain no. 8 are Ishapur Kheri, Bandheri, Dhanana, Chhapra, Makroli, Jasia, Kanheli, Bishan, Wazirpur, Dubal Dhan, Garhwal, Bhambewa etc. Water of drain no. 8 outfalls into Jahajgarh jheel which is low lying depression in Haryana.

iv) Kultana-Chudania-Bhupania (KCB) – Bahadurgarh Drainage Sub-Basin

KCB drainage system drains Bahadurgarh area of Jhajjar district. The tributary and link drains falling in KCB system are Mattan link drain, Kassar drain, Sankhol link drain, Mandothi link drain. KCB drain outfalls in to Mangeshpur drain, which ultimately outfalls in river Yamuna through Najafgarh drain. The total length of KCB drain is 45.91 km and its catchment is 143 km^2.

v) Nuh-Kotla-Ujina and Ujina Diversion Drainage Sub-Basin

This drainage system caters for Mewat district and southern part of Faridabad district. Ujina drain off takes from Ujina Lake. Kotla, Nuh and Chandeni drains out fall into Ujina drain. The other drains joining this system are Ter, Badli, Hingan Pur, Neem Khera, Kherli Kankar, Kawaja Kalan, Ribber. Landoha nala flows into Haryana from Rajasthan and is joined by Nuh drain and then flows to Rajasthan through Ujina drain. The only exit of the flood water is through drainage system of Ujina in Haryana, Pahari in Rajasthan and Goverdhan in U.P.

vi) Gaunchi- Drainage Sub-Basin

Gaunchi main drain starts from Gurgaon canal and traverses a distance of 70 kms catering to a catchment of 671 km^2 before it outfalls into Yamuna. This caters to the drainage of small part of Mewat district and major part of Palwal district. The important drains out falling into this system are link drain No. 1, Bijapur Link drain, Extension Badha link drain, Palwal drain, Ranika link drain, Gehlab link drain, Mitrol link drain, Khatela link drain, Gudrana link drain, Banchari link drain, Khirbi link drain, Bhanguri link drains etc.

vii) Urban Drainage System in Haryana

The urban drainage system of various towns in Haryana Sub-region is as follows:

Panipat: The urban drainage of Panipat town falls into Panipat drain originating from Panipat and having ultimate outfall into river Yamuna near village Jalmana.

Sonepat: The urban drainage of Sonepat town falls into drain No. 6 originating from Smalkha and passing through Sonepat town. The Drain No. 6 having outfall into Drain No. 8 which originates from Nai Nala near Gohana. The Drain No. 8 ultimately falls into river Yamuna near Delhi border.

Gurgaon: The storm water drainage of Gurgaon is divided into six zones having outfall into Najafgarh Jheel falling on the western part of the town having further outfall into river Yamuna through Najafgarh drain.

Faridabad: The drainage of Faridabad is through two drains. The eastern & northern Faridabad is covered by Buria Nallah having initial capacity of 280 cusecs which outfall into river Yamuna near village Manjhawali having capacity 1700 cusecs. The South-west part of the town is connected with Gaunchi drain originating from village Gaunchi near Ballabhgarh having initial capacity of 900 cusecs which ultimately falls into river Yamuna near village Maholi after covering the catchment area of district Palwal. The outfall capacity of Gaunchi drain is 6000 cusecs.

Palwal: The drainage of Palwal town is mainly through Palwal link drain falling on which is further connected with Gaunchi drain near village Kairaka having ultimate outfall into river Yamuna.

Rewari: The storm water drainage of Rewari is through escape channel constructed by Irrigation Department having outfall into Sahibi Nadi near Khalilpur Railway station.

4.6 Drainage System of Rajasthan Sub-Region

There is no perennial river system in Rajasthan sub-region. Sahibi, Ruparel and Chuharsidh are the main seasonal rivers, which flow through the sub-region. Several other rivers and tributaries have been impounded at suitable sites which are used for irrigation. Sahibi Nadi rises from hills of Bairath near village Barijori about 8 km north-west of Shahpura in Jaipur district of Rajasthan. After flowing almost southwest to north-east direction about 145 km in Rajasthan, it enters Haryana state beyond Kot Qasim. One of its major tributaries in Rajasthan joining it on its left bank at 88 km is Sota. On its right bank a number of small hilly streams join it at Masani (National Highway No.8) in Rewari district. The Ruparel River also known as the Barah or Loswari, rises from Udainath hills, Thana. Ghazi tehsil and passes through southern part of sub-region terminating in Bharatpur district. It passes through Alwar sub-division. There are number of bunds like Baleta, Siliserh and Jai Samand on its tributaries. Chuhar Sidh Nadi rises from Chuhar Sidh hills in Alwar tehsil and flows from west to east up to Piproli from where it changes its course towards north and finally enters in Haryana. On

Chuhar Sidh and its tributary several bunds are situated, i.e. Vijay Sagar, Training Bund and Chandali. There is no natural lake in Sub-region. However, there are a large number of artificial lakes and tanks. The major lakes are Jai Samand, Siliserh, Balota bund, Mansarowar, Vijay Sagar, Kuduki.

Major drainage features in Haryana and Rajasthan sub-regions are shown in **Map 4.3 & 4.3(A).**

4.7 Existing Inter-state Drains in NCR

The Study Group has identified 11 existing inter-state drains flowing through the territories Haryana, UP, NCT-Delhi and Rajasthan states in NCR. The NCR participating States required to interact with concerned states during design, construction and maintenance of these drains.

The major identified inter- state drains of NCR are given below:

i) Between Delhi and Haryana

(a) Drain No 6, which originates near Ganaur town of Sonepat district of Haryana sub-region and flows mostly in the North-South direction and outfalls into Diversion Drain No. 8 (which originates from Nai Nallah near Gohana town in Sonepat district and joins Yamuna River).

(b) Drain No 8, which originates from the junction point of Nai Nallah and Diversion Drain No. 8 near Gohana and flows through Rohtak, Jhajjar and Gurgaon districts of Haryana sub-region and outfalls into Najafgarh lake (which is spread both in NCT-Delhi and Haryana sub-regions), from which the Najafgarh drain originates and outfalls into Yamuna river.

(c) Mungeshpur drain, which originates near Kharkhoda in Sonepat district of Haryana sub-region; flows mostly in the North-South direction through Jhajjar district; enters in NCT-Delhi sub-region near Bahadurgarh and thereafter outfalls into Najafgarh drain.

(d) Kultana-Chudania-Bhupania (KCB) Drain, which originates near Rohtak town (South of Rohtak, near Rohtak-Jhajjar Road); flows through Jhajjar district; enters in NCT-Delhi sub-region near Bahadurgarh and thereafter outfalls into Mungeshpur drain.

(e) Bhuria Nala, which flows through Faridabad town in Haryana sub-region and outfalls into Yamuna River near Okhla in NCT-Delhi sub-region.

(f) Ali Drain, flows through Faridabad district of Haryana sub-region and NCT-Delhi sub-region and outfalls into Yamuna River.

ii) Between Delhi and Uttar Pradesh

(g) Relief Drain along S M bund near Khajuri/ Karawal Nagar in Ghaziabad district of Uttar Pradesh sub-region and flows mostly in North-South direction and joins Ghazipur drain near Ghazipur village of NCT-Delhi sub-region.

(h) Drain near Maharajpur outfalling into trunk Drain no 2, which originates near Ghaziabad district in Uttar Pradesh sub-region and flows mostly in North-South direction and outfalls into Yamuna River near Ghazipur in NCT-Delhi sub-region. .

iii) Between Haryana and Rajasthan

(i) Sahibi Nadi flows through Alwar district of Rajasthan sub-region and Jhajjar, Gurgaon and Rewari districts of Haryana sub-region.

(j) Londoha Nallah flows through Bharatpur district of Rajasthan sub-region and Firozepur Jhirka in Mewat district of Haryana sub-region and thereafter joins Ujina Lake in Mewat district.

(k) Ujina Drain flows mostly in the North-South direction and originates from the Ujina Lake on its Southern part (on the Northern side of the Ujina Lake, lies the Nuh drain, which is an extension of the Ujina drain) and joins the Pahari Kaman Goverdhan Drain in Bharatpur district.

Major existing drainage features at NCR level are shown at **Map 4.4.**

5. PLANNING AND DESIGN OF SURFACE DRAINS

5.1 Introduction

The principal source of water stagnating on the fields and in low-lying areas in the monsoon is rainfall confined mostly to the four months from June to September. Major rivers and rivulets overflow their banks adding to the local drainage congestion. Drainage congestion caused due to natural factors or due to improper planning, affects agricultural production. In flat areas disposal of storm run-off through natural drainage takes considerable time due to adverse topographical features. In some cases such as in flat bowl shaped basins, natural outfalls do not exist. Even when the natural drainage has an outlet to a river, the area is not drained as long as the river continues to be in floods thus denying drainage by gravity. The resulting drainage congestion or accumulation of water on land affects crops, as most crops cannot withstand submergence beyond a particular depth for long duration. Problems of drainage are also created on account of inadequate waterways structures like bridges and culverts. Railway lines and roads constructed across natural drainage lines obstruct free flow of drains.

Drains are provided with the objective of quickly relieving excess water from agricultural areas, urban areas and other land areas and disposing off surplus water. Proper disposal of surplus rainwater is essential to avoid its percolation down to the water table and consequent water logging problems. Drains are also constructed for leaching agricultural lands to prevent salt accumulation. It is imperative to plan and design surface water drains appropriately so as to dispose of surplus rain water within minimum time.

5.2 Existing Design Criteria for Drains

There is wide variation in design criteria due to factors such as topography, intensity and pattern of rainfall, soil characteristics and nature of crops, intensity of development etc. Some states adopted the empirical formula like Dicken's, Ryve's or Boston Society formula and in some states the practice have been evolved after taking into consideration the type of crop, tolerance, submersion and duration, intensity of rainfall and optimum time of disposal while in some other States no scientific basis or rational approach has been adopted.

In NCR also the constituent States have adopted different methods for the design of drainage channels. In the design of surface drainage network, the following are the basic elements:

i) **Design storm rainfall**: Duration and frequency of rainfall for which the protection should normally be provided to the agriculture in rural area and to the people in urban area.
ii) **Tolerance period:** Time of submersion to avoid significant damage.
iii) **Run off factor:** Applicable for design storm rainfall of selected duration and frequency.
iv) **Design of drainage:** Design of a channel that is capable of draining out the computed run off within the tolerance period. The design provides the details of cross section, slope, and type of surface.

5.2.1 Existing Design Criteria for Drains in Uttar Pradesh

The Technical Advisory Committee (TAC) of UP State constituted in 1978 recommended the following design criteria:

i) Three-day rainfall storm with 15 years return period worked out from long-term data should be taken as the design storm rainfall for the drains.
ii) Runoff should be taken as 15% for Western Zone of UP and 30% for the Eastern zone. Entire area of UP sub-region of NCR lies in Western Zone.
iii) The allowable period of submergence should be taken as 7 days for areas where the principal crops grown are paddy and sugarcane and 3 days where the crops are Maize, Jowar and Bajra etc.
iv) Waterway of masonry works should be provided for 1.5 times the design discharge of the drains, and foundations be designed for 30% extra discharge over waterway design discharge.

The TAC suggested that further detailed investigations should be carried out in the field and if necessary the recommendations be modified suitably. It had also been recommended that the maximum allowable periods of submergence for the various crops be verified from the Agriculture Department.

The 3-day maximum rainfall of 15 years return period and the runoff factors recommended by the TAC for the districts of UP sub-region of NCR are given in Table 5.1.

Table 5.1 Design Criteria for UP sub region

Sl. No.	District	3 day maximum rain fall of 15 yrs. Return period (mm)	Drainage Factors in Cumec/sq. km. with submergence of	
			7 days	3 days
1.	Ghaziabad (30% runoff)	430.96	0.21	0.49
2.	Meerut (15% runoff)	254.06	0.06	0.15
3.	Bulandshahr (15% runoff)	307.61	0.08	0.18

Source: Technical Advisory Committee, UP, 1978

5.2.2 Design Criteria for Drains in Haryana

The existing system of drainage in the Haryana state was designed on the basis of an empirical Boston Society formula:

$Q = C\,A^{1/2}$, where
Q = Discharge in cusecs
A = Catchment area in square miles
C = Coefficient to account for catchment characteristics and its value for Haryana area was taken as 200.

In working out the drain capacities, an ad-hoc reduction factor was applied depending upon catchment area as given below on the premise that relatively smaller sections gave better hydraulic performance than those designed for peak discharge.

Table 5.2 Reduction factor for discharge in Haryana sub region

Sl.No.	Catchment Area	Reduction Factor
i)	Upto 100 $mile^2$ (258.9 km^2)	1/12
ii)	100 to 250 $mile^2$ (258.9-645 km^2)	1/8
iii)	Above 250 $mile^2$ (645 km^2)	1/4

The intensity of rainfall adopted is 25mm per hour and run off coefficient is 1/8 for designing of storm water drainage channels in Haryana urban area. Banks of carrier drains and cross drainage works are designed for peak hours.

5.2.3 Existing Design Criteria for Drains in Delhi

Recommendations of Reddy Committee 1959: Reddy Committee was constituted in 1959 to study the problems of flooding/drainage congestion and suggest remedial measures. Reddy Committee recommended the following criteria for Drainage system design for Delhi:

Rural Area: The drainage system for the rural areas of Delhi should be so designed as to restrict flooding to a maximum period of three days with return period of five years. The maximum three days precipitation likely to occur once in five years is 208 mm (8.2 inch), which works out to a run off of about 10 cusecs per sq mile (0.11 cumec/km^2) of catchment area. The run off coefficient adopted is 0.15. For semi hilly rural drains the run off coefficient adopted is 0.30 leading to run off of about 0.22 cumec/km^2. The Committee recommended remodelling to be carried out on this basis and suggested that run off factor for hilly area be suitably increased.

Urban Area: The drains in urban areas are to be designed for 1-hour rainfall depth of 43.7mm with a return period of 2 years. An areal distribution factor of 90% and run off coefficient of 35% has been adopted for arriving at the run off of 0.5 inches per hour or 0.5 cusec per acre i.e. 3.8 cumec/Km^2.

Master Plan for Drainage (1976)

In order to address the problems of flooding in Delhi, after the Reddy Committee, Moti Ram Committee (1965), S.P. Jain Committee (1968) & Tripathi Committee were constituted. Irrigation & Flood Control Department of NCT-Delhi prepared a Master Plan for Storm Water Drainage (SWD) for Delhi in June, 1976 which was considered by Technical Experts Committee (TEC). The TEC approved the Plan in general and decided that the Master Plan to be utilize-d as an Outline Plan. However, the drainage norms could not be finalized by TEC.

This Plan was based on following:

Urban Areas

i) Time of Concentration	=	0.5 hr
ii) Storm Intensity (2 yr return period)	=	63.5 mm (2.5 inch/hr.)
iii) Average run off factor	=	0.6
iv) Average run off Q	=	2.5x0.6
		=1.5 inch/hr (i.e. 1.5 cusec/acre) or
		=10.5 Cusecs/Km^2

However, flooding of streets for an hour or so may be allowed and drains were designed for 1 cusec/acre.

The intensity of rainfall for one hour-storm duration for various return periods was indicated as under:

i) 2 Yrs return period	:	43.7 mm/hr. (1.72 inch/hr.)
ii) 5 Yrs return period	:	58.2 mm/hr. (2.29 inch/hr.)
iii) 10 Yrs return period	:	63.2 mm/hr. (2.73 inch/hr.)
iv) 25Yrs return period	:	83.8 mm/hr. (3.30 inch/hr.)

It was further stipulated in the above mentioned Report that whenever, Master Plan 2001 is prepared by DDA, Master Drainage Plan shall be re-considered and updated.

5.3 Planning and Design of Drainage System for Urban Area

The characteristics of urban areas are different from rural areas. Due to high concentration of population and economic activities in urban area the loss to life and property is much higher compare to rural area. This necessitates a different approach for design of storm water drains in urban areas. Various agencies have prepared Design Manuals for Drainage which have been discussed in subsequent paras.

5.3.1 Design Manuals: National and International

The Central Public Health and Environmental Engineering Organization (CPHEEO), under the Ministry of Urban Development (MoUD), Govt. of India have published the "Manual on Sewerage" (1993). This manual has given extensive guidelines for sewer design, but has given only a small section for storm drainage design. However, even this was not being followed by many cities in the past. This Manual mentions a uniform design rainfall intensity of 12-20 mm/hour for all cities and does not take into account the spatial distribution of rainfall over India or within the cities. Systems designed with these values will cause flooding, whenever rainfall intensity values exceed 20 mm/hour. However, while taking up projects under JNNURM, rainfall data obtained from Self-Recording Rain Gauge stations is followed, which takes into account the rainfall pattern of the cities. The Ministry of Urban Development

(MoUD) has constituted an "Expert Committee for the preparation of Urban Storm Drainage Manual". The comprehensive Urban Storm Drainage Design Manual is under preparation.

The Indian Roads Congress (IRC) brought out guidelines on urban drainage in 1999 (SP-501999, IRC). This provides guidance for drainage design for roads, but does not provide design information on rainfall intensities to be adopted for various cities. For example, it mentions that Mumbai drains are being designed for 50 mm/h and Chennai for 25 mm/h, but does not provide guidelines for future planning for other Indian cities. This will take into account current international practices, the locations specific factors and rainfall pattern of the cities and future needs.

Most countries have dedicated Codes and Manuals for storm water drainage design. USA has the "Urban Drainage Design Manual", published by the Federal Highway Administration of the US Department of Transportation (2009, Revised in August, 2013 Third Edition). Moreover, each state/ country has brought out its own Manual and, in many cases, even individual cities have their own city-specific Manual. These are updated regularly, some of them are on an annual basis. European countries are now following a common code on "Drainage and Sewer System Outside Buildings". In Australia, the "Australian Rainfall and Runoff Manual" (2008, 4th edition) is used in the various states of Australia, while the north-eastern state of Queensland, which experiences the monsoon type rainfall, has its own storm water drainage manual. The national meteorological agencies in most countries have developed Intensity- Duration-Frequency (IDF) curves from the rainfall records and provide these to the design engineers for carrying out urban drainage design.

For better urban flood management, many cities like Bangkok, Tokyo, Singapore, etc., have developed a real-time satellite-radar-rainfall based warning system with adequate number of radars and ARGs. Regular de silting of drains is also carried out on a time bound schedule in many important cities.

5.3.2 National Disaster Management Manual

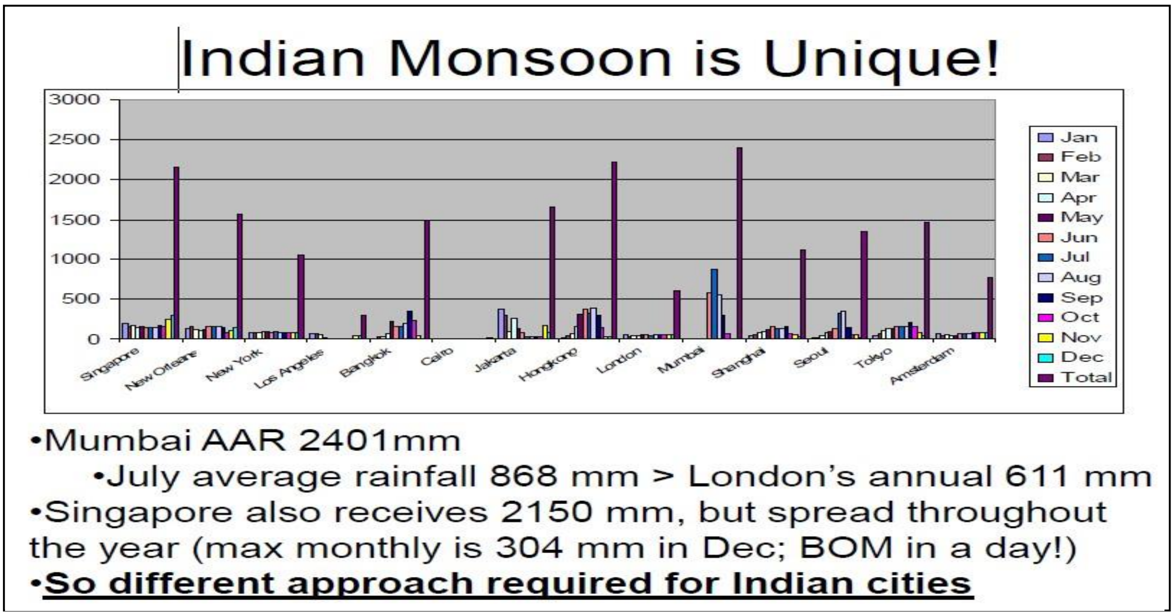
Manual prepared by National Disaster Management Authority for National Disaster Management has dealt this issue in detail. The same has been discussed below:

i) Catchment as basis for Design: States and cities have political and administrative boundaries. However, rainfall and runoff processes are independent of these boundaries, and depend on the watershed delineation. The outline of the drainage divide must follow the actual watershed boundary rather than the administrative boundaries. Each urban area may consist of a number of watersheds. A watershed is the geographic region within which water drains into a stream, river, lake or sea. The watershed may be composed of several sub watersheds and catchments. The catchment is the area draining surface water to a particular location or outlet point. Catchment will be the basis for planning and designing the storm water drainage systems in all Urban Local Bodies (ULBs).

ii) Contour Data*:* Accurate contours are necessary for determining the boundaries of a watershed/catchment and for computing directions of flow. Detailed contour maps at required resolution should be prepared for proper delineation of drainage catchments. Contour mapping of urban areas will be prepared at 0.2 to 0.5 m contour interval for detailed delineation of the watershed/catchment for planning drainage systems.

iii) Rainfall Variations: The conventional practice for designing of a drainage system is to choose an appropriate, statistically relevant design storm to establish the storm water flows to be conveyed, based on existing national and international practices. Design storms can be estimated from rainfall data records where available. Rainfall is the main driver of runoff processes.

Box 5.1 Indian Monsoon is Unique



The frequency and intensity of rainfall in India, not only shows a great variation but the intensity of rainfall also is generally much higher than in many other countries. There is wide variation of rainfall amongst the cities and, even within the city, rainfall shows large spatial and temporal variation; Due to the high variability of rainfall in space and time, rainfall measurements are required at high temporal and spatial resolution from dense Rain Gauge networks for the adequate design of new systems and/or renovation of existing drainage systems. Up to date Intensity Duration frequency (IDF) relationships need to be used to maintain design standards for new systems and retrofitting/replacement of old urban drainage systems.

iv) Thunderstorm Rainfall Intensity: Special consideration should be given to rainfall caused due to thunderstorms, which result in high intensity rainfall in short durations (e.g. 15 mm rainfall in 15 minutes i.e. 60 mm/h). Delhi and many other cities faced severe disruption due to flooding in 2009 and 2010, caused by thunderstorms embedded in monsoon systems which overwhelmed the drainage systems, designed for much lesser values of the rainfall intensity. By the very nature of formation, it is observed that severe thunderstorms result in rainfall intensities of the order of 50-70 mm/h which cause flash flooding. Hence, the frequency of thunderstorms becomes an additional consideration for planning future urban drainage systems.

a) IDF curves should be developed for each city, based on extraction of data from the raw data charts at 15 minutes resolution and from Automatic Weather Stations (AWS) at 5minutes resolution, and

b) IDF relationships will be adjusted taking into account climate change impacts and urban heat island effects. At the very least, a trend analysis of short duration rainfall intensities will be carried out and if an increasing trend in the recent years is shown, higher intensities than those provided by IDF relationships will be used for resizing existing systems and design of new systems, especially for critical infrastructure like airports, major roads and railway tracks.

v) Design Flow: To protect residential, commercial, industrial and institutional buildings in urban areas, safe management and passage of water, resulting from frequent storm events (hydrologic design aspects) and adequate capacity (hydraulic design aspects) ~~must~~ be considered. In the context of urban drainage, the main objectives of hydrologic analysis and design are to estimate peak flow rates and/or flow hydrographs for the adequate sizing and design of conveyance and quantity control facilities. To estimate peak flow rates, knowledge of the rainfall intensity, its duration and frequency is required for preparing satisfactory urban drainage and storm water management projects. Due to limited data, statistics and probability concepts are used in hydrologic analysis. Current international practice involves frequency analysis of rainfall intensities, based on extreme value distributions with adjustments for climate change effects. Intensity-Duration-Frequency (IDF) curves are required to be developed for systematic analysis. However, the return period concept has an element of subjectivity. Increasing rainfall intensities induced by climate change, urban heat islands and other factors will possibly result in varying return periods for a given intensity of rainfall. The rainfall intensity to be used for design will also depend on the time of concentration. Higher the catchment area, higher will be the time of concentration and lower will be the design rainfall intensity, other factors remaining the same.

Peak flow rates can be estimated using the Rational Method. However, for computation of water level profiles in the drainage systems or channels/rivers, suitable software for flood routing should be used. The available public domain software are the HEC-HMS for hydrologic modelling of the watershed, HEC-RAS for river modelling, both developed by the US Army Corps of Engineers and SWMM (Storm water Management Model) for sewer/ drainage design, developed by the US Environmental Protection Agency. These software's are available on web.

vi) Runoff Coefficient for Long Term Planning: Keeping in view the projected rate of urbanization, it is imperative to consider a 50-year planning horizon. Due to development that is bound to take place during this period, it will be difficult to upgrade the underground drains once they are laid. Therefore, it is recommended that all future drainage plans for urban areas should be carried out, taking these factors into consideration. All future storm water drainage systems will be designed taking into consideration a runoff coefficient of up to C = 0.95 for estimating peak discharge using the rational method, taking into consideration the approved land use pattern of the city.

5.3.3 Drainage Design as per Manual on Sewerage and Sewage Treatment CPHEEO, Ministry of Urban Development (1993).

Estimation of Storm Runoff:

Storm runoff is that portion of the precipitation, which drains over the ground surface. Estimation of such runoff reaching the storm sewers therefore is dependent on intensity and duration of precipitation, characteristics of the catchment area and the time required for such flow to reach the sewer is runoff time. The storm water flow for this purpose may be determined by using the rational method, hydrograph method, rainfall-runoff correlation studies, digital computer models, inlet method or empirical formulae.

The empirical formulae that are available for estimating the storm water runoff can be used only when comparable conditions to those for which the equations were derived initially can be assured.

A rational approach, therefore, demands a study of the existing precipitation data of the area concerned to permit a suitable forecast. Storm sewers are not designed for the peak flow of rare occurrence such as once in 10 years or more but it is necessary to provide sufficient capacity to avoid too frequent flooding of the drainage area. There may be some flooding when the precipitation exceeds the design value, which has to be permitted. The frequency of such permissible flooding may vary from place to place, depending on the importance of the area. Though such flooding causes inconvenience, it may have to be accepted once in a while considering the economy effected in storm drainage costs.

The maximum runoff, which has to be carried in a sewer section should be computed for a condition when the entire basin draining at that point becomes contributory to the flow and the time needed for this is known as the time of concentration (tc) with reference to the concerned section. Thus estimating the flow to be carried in the storm sewer, the intensity of rainfall that lasts for the period of time of concentration ~~is the one~~ to be considered contributing to the flow of storm water in the sewer. The Rational Method is more commonly used for designing drainage.

i) Rational Method

Runoff - Rainfall Intensity Relationship

The entire precipitation over the drainage district does not reach the sewer. The characteristics of the drainage district, such as, imperviousness, topography including depressions and water pockets, shape of the drainage basin and duration of the precipitation determine the fraction of the total precipitation, which will reach the sewer. This fraction known as the coefficient of runoff needs to be determined for each drainage district. The runoff reaching the sewer is given by the expression,

$Q = 10\,C\,I\,A$

Where

'Q' is the runoff in m^3/hr;

'C' is the coefficient of runoff;

'I' is the intensity of rainfall in mm/hr and

'A' is the area of drainage district in hectares.

ii) Storm Frequency

The frequency of storm for which the sewers are to be designed depends on the importance of the area to be drained. Commercial and industrial areas have to be subjected to less frequent flooding. The suggested frequency of flooding in the different areas is at Table 5.3.

Table 5.3 Frequency of Storm

Type of Areas	Frequency
a) Residential areas	
i) Peripheral areas	Twice a year
ii) Central and Comparatively high priced areas	Once a year
b) Commercial and high Priced areas	Once in 2 years

iii) Intensity of Precipitation

The intensity of rainfall decreases with duration. Analysis of the observed data on intensity duration of rainfall of past records over a period of years in the area is necessary to arrive at a fair estimate of intensity-duration for given frequencies. The longer the record available, the more dependable is the forecast. In Indian conditions, intensity of rainfall adopted in design is usually in the range of 12mm/hr to 20mm/hr.

The rainfall data from automatic rain gauges should be analyzed to develop duration-intensity curve for design frequency and from it relationship may be expressed by a suitable mathematical formula, several forms of which are available. The following two equations are commonly used:

(i) $I = a/(t.n)$

(ii) $I = a/(t + b)$, where,

I = intensity of rainfall (mm/hr)

t = duration of storm (minutes) and

a, b and n are constants

The available data on I and t are plotted and the values of the intensity (I) can then be determined for any given time of concentration, (tc).

iv) Time of Concentration

It is the time required for the rain water to flow over the ground surface from the extreme point of the drainage basin and reach the point under consideration. Time of concentration (tc) is equal to inlet time (t) plus the time of flow in the sewer (t). The inlet time is dependent on the distance of the farthest point in the drainage basin to the inlet manhole, the shape, characteristics and topography of the basin and may generally vary from 5 to 30 minutes. In highly developed sections, the inlet time may be as low as 3 minutes. The length of the sewer and the velocity of flow in the sewer determine the time of flow. It is to be computed for each length of sewer to be designed.

v) Runoff Coefficient

The portion of rainfall, which finds its way to the sewer, is dependent on the imperviousness and the shape of tributary area apart from the duration of storm.

a) Imperviousness

The percent imperviousness of the drainage area can be obtained from the records of a particular district. In the absence of such data, the following may serve as a guide.

Table 5.4 Imperviousness of the drainage area

Type of area	Imperviousness %
Commercial and Industrial area	70 to 90
Residential area: i) High density ii) Low density	 60 to 70 35 to 60
Parks & undeveloped areas	10 to 20

The weighted average imperviousness (I) of drainage basin for the flow concentrating at a point may be estimated as

$$\frac{A1I1 + A2I2 ....}{A1 + A2 + ...}$$

where,
A1, A2 = drainage areas tributary to the section under consideration
I1, I2 = imperviousness of the respective areas and
I = weighted average imperviousness of the total drainage basin.

b) Catchment Area

The drainage areas should be indicated clearly on the map and measured for each length of storm sewer. The boundaries of each catchment are dependent on topography, land use nature of development and shape of the drainage basins. The incremental area may be indicated separately on the compilation sheet and the total area computed.

c) Duration of storm

Continuously long light rain saturates the soil and produces higher coefficient than that due to heavy but intermittent rain in the same area because of the lesser saturation in the latter case.

Runoff from an area is significantly influenced by the saturation of the surface nearest the point of concentration, rather than the flow from the distant area. The runoff coefficient of a larger area has to be adjusted by dividing the area into zones of concentration and by suitably decreasing the coefficient with the distance of the zones.

d) Computation of Runoff Coefficient

The weighted average runoff coefficient for rectangular areas, of length four times the width as well as for sector shaped areas with varying percentages of impervious surface for different times of concentration are given in **Table 5.5**. Although these are applicable to particular shapes of areas, they also apply in a general way to the areas which are usually encountered in practice. Errors due to difference in shape of drainage are within the limits of accuracy of the rational method and of the assumptions on which it is based.

Table 5.5 Runoff Coefficient

Duration, time, minutes	10	20	30	45	60	75	90	100	120	135	150	160
Weighted Average coefficient												
1) Sector concentrating in stated time												
(a) Impervious	.525	.588	.642	.700	.740	.771	.795	.813	.828	.840	.850	.865
(b) 60% impervious	.365	.427	.477	.531	.569	.598	.622	.641	.656	.670	.682	.701
(c) 40% imperious	.285	.346	.395	.446	.482	.512	.532	.554	.571	.585	.597	.618
(d) Pervious	.125	.185	.230	.277	.312	.330	.362	.382	.399	.414	.429	.454
2) Rectangle (Length = 4 x width) concentrating in stated time												
(a) Impervious	.550	.648	.711	.768	.808	.837	.856	.869	.879	.887	.892	.903
(b) 50% Impervious	.350	.442	.499	.551	.590	.618	.639	.657	.671	.683	.694	.713
(c) 30% Impervious	.269	.360	.414	.464	.502	.530	.552	.572	.558	.601	.614	.636
(d) Impervious	.149	.236	.287	.334	.371	.398	.422	.445	.463	.479	.495	.522

Hydraulic Models

The purpose of the hydraulic analysis is to evaluate the adequacy of the existing storm drainage system (major drains only) and to determine design options for inadequately sized channels. Channels and storm drains are simulated using the flow data generated in the hydrology model. Storm drains are simulated using Manning's equation as below:

$V = (R^{2/3} \times S^{1/2})/n$, where,
V = Velocity (m/s); n = Friction Factor;
R = Hydraulic Radius (m); and S = Channel Slope (m/m)

Friction factor (n) is given below:

Cement Concrete with Good finish	= 0.013
Concrete channel, wood toweled	= 0.015
Earth channel, ordinary condition	= 0.025

Earth channel, poor condition = 0.035
Earth channel, partially obstructed with debris or weeds = 0.050

Limitations of Rational Method

Although Rational Method is widely used for designing drainage system it has certain limitations, which are as under:

Assumptions

i) Peak flow occurs when the entire watershed is contributing to the flow
ii) Rainfall intensity is the same over the entire drainage area
iii) Rainfall intensity is uniform over a time duration equal to the time of concentration
iv) Frequency of the computed peak flow is the same as that of the rainfall intensity, i.e., the 10-year rainfall intensity is assumed to produce the 10-year peak flow
v) Coefficient of runoff is the same for all storms of all recurrence probabilities

Limitations:

i) Best suited for estimation of design peak runoff
- Inlet design
- Storm drainage system design
- Area limitation < 200 acres (80 hectares)

ii) Area of drainage needs to be assessed accurately
iii) Has no capability to calculate detention or reservoir routing flows

5.3.4 Intensity Duration Frequency Curve for Delhi

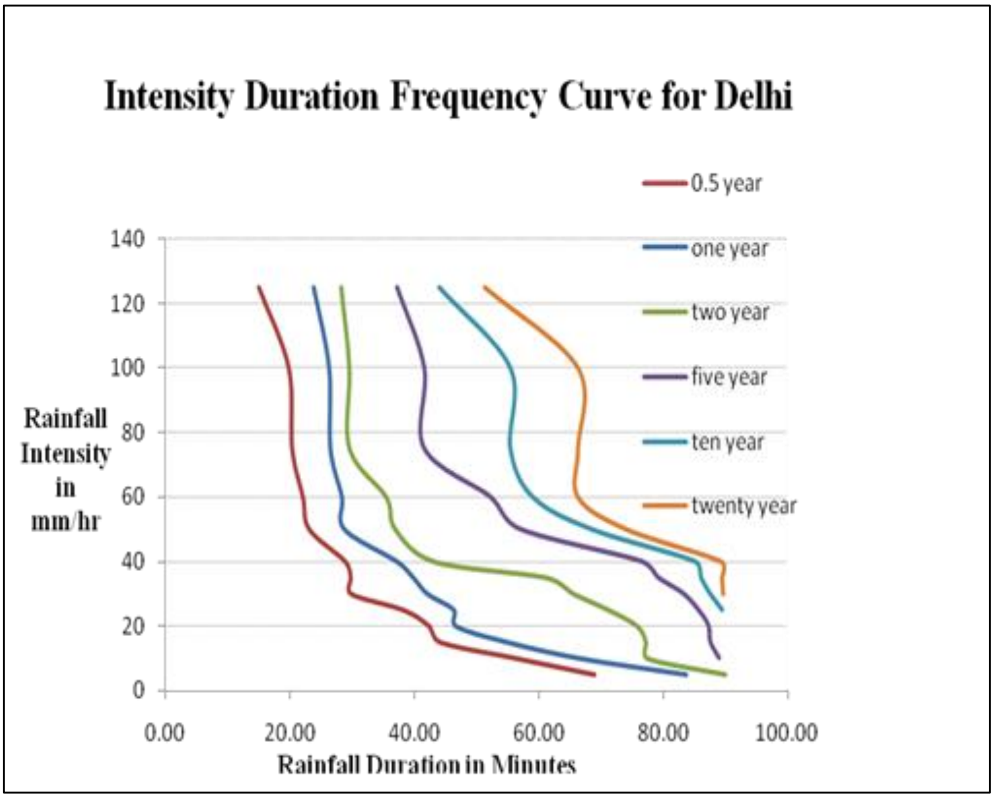
Rainfall data of Delhi for the period 1984 to 2006 (23 years) have been used to develop the Intensity Duration Frequency (IDF) Curve for Delhi. Data on number of occurrence of rain of particular duration and intensity as given in Table 5.6 has been used to develop the IDF Curve for Delhi.

Table 5.6 Rain fall data of Delhi (1984 to 2006) indicating number of occurrences of rain of given intensity & duration

Time (in min)	Rain fall intensity (in mm/ Hr)												
	5	**10**	**15**	**20**	**25**	**30**	**35**	**40**	**50**	**60**	**75**	**100**	**125**
15	346	346	344	319	265	229	177	162	79	72	66	63	46
30	256	252	206	151	73	44	44	37	18	17	10	10	7
45	128	95	37	24	24	18	12	8	7	7	3	3	2
60	58	31	16	15	13	13	12	8	4	2	2	2	0
75	38	13	13	12	11	9	6	5	1	0	0	0	0
90	12	4	3	3	2	1	1	1	0	0	0	0	0

From above Table for different frequency find duration for different intensities as given in Appendix 5.1. The duration and intensity can be expressed by equation for each frequency. The plot of above is an Intensity Duration Frequency curve. Such curve should-be developed for each city. The IDF Curve developed given in the above for Delhi is given below:

Figure 5-2 Intensity duration curve for Delhi



5.3.5 Refinement in Runoff Estimations

"Urban Drainage Design Manual", published by the Federal Highway Administration of the US department of transportation (2013, 3rd Edition) stipulates three representations of rainfall which can be used to derive flood flows: constant rainfall intensity, dynamic rainfall, and synthetic rainfall events. Constant Rainfall Intensity method follows Intensity-Duration Frequency curves.

Dynamic Rainfall (Hyetograph)

In any given storm, the instantaneous intensity is the slope of the mass rainfall curve at a particular time. The mass rainfall curve is simply the cumulative precipitation, which has fallen up to a specific time. For hydrologic analysis, it is desirable to divide the storm into convenient time increments and to determine the average intensity over each of the selected periods. These results are then plotted as rainfall hyetographs. Hyetographs provide greater precision than constant rainfall intensity by specifying the precipitation variability over time, and are used in conjunction with hydrographic (rather than peak flow) methods. Hyetographs allow for simulation of actual rainfall events, which can provide valuable information on the relative flood risks of different events and, perhaps, calibration of hydrographic models.

Synthetic Rainfall Events

Drainage design is usually based on synthetic rather than actual rainfall events. The Soil Conservation Service (SCS) 24-hour rainfall distributions are the most widely used synthetic hyetographs. These rainfall distributions were developed by the U.S. Department of Agriculture, Soil Conservation Service (SCS) (13) which is now known as the Natural Resources Conservation Service (NRCS). The SCS 24-hour distributions incorporate the intensity-duration relationship for the design return period. This approach is based on the assumption that the maximum rainfall for any duration within the 24-hour duration should have the same return period. For example, a 10-year, 24- hour design storm would contain the 10-year rainfall depths for all durations up to 24 hour as derived from IDF curves.

6. ENVIRONEMNTAL IMPACT

6.1 Introduction

Any development activity invariably involves some changes in the existing natural environment. Of late, there has been a considerable awareness regarding the need for preservation of existing environment and ecology. While large-scale disturbance in the environment is not desirable, a country cannot afford not to carry out the development process for increasing human population and its need. Therefore, environmental program will have to be based on the implicit policy of "Development is necessary". The goal cannot be only conservation or protection of natural environment resources but the conservation of productivity of primary natural resources to ensure that their productivity does not deteriorate on account of development activities. In other words the philosophy would be to limit the erosion of environment quality to the minimum possible extent with the developmental needs where it cannot be avoided.

6.2 Environmental Impact Associated with various methods of flood control

The water resources project particularly flood control and drainage improvements have certain environmental consequences. These are health effect, sub-merging of land, water logging, deforestation, siltation of reservoirs, etc.

6.2.1 Health

Creation of large water bodies like storage reservoirs result in water borne diseases. Storage reservoir for flood moderation, detention basins and hydraulically inefficient drainage channels particularly which are designed for rare storms may cause this kind of environmental effect. Proper maintenance of drainage channel is the remedial measure.

6.2.2 Water Logging

NCR experiencing water logging problems in some areas mainly due to rise of ground water level because of seepage from canals and inadequate drainage systems. The problem of water logging and consequent salinity result in reduction of cultivated area hence the agricultural land needs to be completely remedied to save cultivable area from logging and salinity. Adequate drainage system can reduce this problem. In addition to this, ground water level with respect to time should be monitored in the water logging affected areas, to detect tendency of the ground water to rise and to create conditions of water logging and also increase in salinity. Conjunctive use of surface and ground water should be promoted which helps in prevention of water logging and decrease in salinity.

6.2.3 Deforestation

Construction of water resource projects, urban development projects, construction of transport networks (roads railways) etc. often involves destruction of forests or vegetation cover. The loss of forest / vegetal cover resulting in rapid surface run off and reduce ground water recharge and soil erosion. It is necessary to have immediate control on deforestation and construction activities in the areas involving destruction of forest/vegetal cover.

6.3 Core Water Quality Monitoring Parameters

In order to address the water-related environmental problems, it is necessary to have accurate information and to know precisely what the problem is, where it is occurring, how serious it is, and what is causing it. Such information is necessary for determining cost-effective and lasting solutions to water-related problems. The goal should be to provide appropriate picture of current water-quality conditions and trends in water quality and water uses, and also to facilitate the identification of emerging issues and future priorities. The water quality monitoring is performed with following objectives:

- For rational planning of pollution control strategies and their prioritisation;
- To assess nature and extent of pollution control needed in different water bodies;
- To evaluate effectiveness of pollution control measures already in existence;
- To evaluate water quality trend over a period of time;
- To assess assimilative capacity of a water body thereby reducing cost on pollution control;
- To understand the environmental fate of different pollutants; and
- To assess the fitness of water for different uses.

The monitoring activities under national network serve various assessment goals. These goals are determination of natural freshwater qualities in the absence of significant direct human impact, determination of long-term trends in the levels of critical water quality indicators in freshwater resources and determination of the fluxes of organic matter, suspended solids, nutrients, toxic chemicals and other pollutants from major river basins to the seawater/coastal water interfaces. To meet the objectives and goals, highly selective network of strategically located monitoring stations is created and operated by CPCB in the major, medium and minor watersheds of rivers, lakes, ponds, tanks, creeks, drains, canals and subsurface aquifers in the country. Three types of monitoring stations are set up for monitoring i.e. baseline, trend and impact or flux stations.

Groundwater quality problems have reached to a cause of concern throughout the country. Increase in salinity and use of agrochemicals mandate the monitoring of trends in important aquifers, particularly in the arid and semi-arid climate belt. Trace contaminants, Fluoride and Nitrates, by levels and trends, are the primary monitoring concerns for aquifers in agriculture, industrialized and grossly polluted areas. Monitoring of groundwater quality needs to be strengthened for parameters from pollution point of view.

The Central Pollution Control Board has classified water resources and designated best uses or setting water quality objectives for different water bodies. The water quality criteria for various uses of fresh water based on designated uses is given in Table 6.1.

Table 6.1 Water Quality Criteria for Various uses of Fresh Water based on Designated Best Use

Designated-Best-Use	Class of water	Criteria
Drinking Water Source without conventional treatment but after disinfection	A	1. Total Coliforms Organism MPN/100ml shall be 50 or less 2. pH between 6.5 and 8.5 3. Dissolved Oxygen 6mg/l or more 4. Biochemical Oxygen Demand 5 days 20°C 2mg/l or less
Outdoor bathing (Organized)	B	1. Total Coliforms Organism MPN/100ml shall be 500 or less 2. pH between 6.5 and 8.5 3. Dissolved Oxygen 5mg/l or more 4. Biochemical Oxygen Demand 5 days 20°C 3mg/l or less
Drinking water source after conventional treatment and disinfection	C	1. Total Coliforms Organism MPN/100ml shall be 5000 or less 2. pH between 6.5 to 8.5 3. Dissolved Oxygen 4mg/l or more 4. Biochemical Oxygen Demand 5 days 20°C 3mg/l or less
Propagation of Wild life and Fisheries	D	1. pH between 6.5 to 8.5 2. Dissolved Oxygen 4mg/l or more 3. Free Ammonia (as N) 1.2 mg/l or less
Irrigation, Industrial Cooling, Controlled Waste disposal	E	1. pH between 6.0 to 8.5 2. Electrical Conductivity at 25°C micro mhos/cm Max.2250 3. Sodium absorption Ratio Max. 26 4. Boron Max. 2mg/l
	Below-E	Not Meeting A, B, C, D & E Criteria

Source: Central Pollution Control Board, MOEFCC, Government of India

6.4 Monitoring of Water Quality in Major Rivers in NCR

Central Pollution Control Board started national water quality monitoring in 1978 under Global Environmental Monitoring System (GEMS), Water Programme. Monitoring Programme was started with 24 surface water and 11 groundwater stations. Parallel to GEMS, a National Programme of Monitoring of Indian National Aquatic Resources (MINARS), was started in 1984, with a total of 113 stations spread over 10 river basins. The present network comprises of 870 stations on rivers, lentic water bodies and subsurface waters. Central Pollution Control Board monitors the pollution level in the rivers Ganga and Yamuna. In NCR samples are collected at

Garhmukteshwar & Narora from Ganga River and at Kalanaur, Sonepat, Palla, Nizamuddin Bridge from Yamuna River and from Agra Canal.

6.5 Condition of Major Rivers in NCR

In NCR, there are two perennial rivers Ganga and Yamuna. Due to diversion of water to various canals for irrigation purposes, the flow in the rivers has decreased. In addition to this, the drainage channels carrying untreated sewage ultimately discharge into these rivers. Due to insufficient flow in the rivers, it gets polluted and unusable for a long distance on the down streamside. In addition to above there are several industries which discharge their polluted water into the rivers.

6.5.1 Ganga River

Ganga River originated from Gangotri covers a length of about 2,525 km with a basin area of 8, 62,000 sq. km is the largest river basin of the country. The annual average rainfall in the basin varies from 39 cm. to 200 cm. with an average of 110 cm. About 80% of the rainfall occurs during the monsoon months i.e. from June to October. Due to large temporal variations in precipitation over the year, there is wide fluctuation in the flow characteristics of the river. Numerous cities located in the Ganga basin generate and discharge huge quantities of wastewater, a large portion of which eventually reaches the river through natural drainage system. Ganga River forms the eastern most boundary of the NCR and flows southerly directions for the entire length area. Before reaching NCR, Ganga River flows through the main towns of Rishikesh, Hardwar and Bijnor. Ganga River in NCR .The pollution level is monitored at two locations in NCR i.e. Garhmukteshwar and Narora. Water quality data in respect of Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD) (five days) for river Ganga at Garhmukteshwar is given in Table no.6.2.

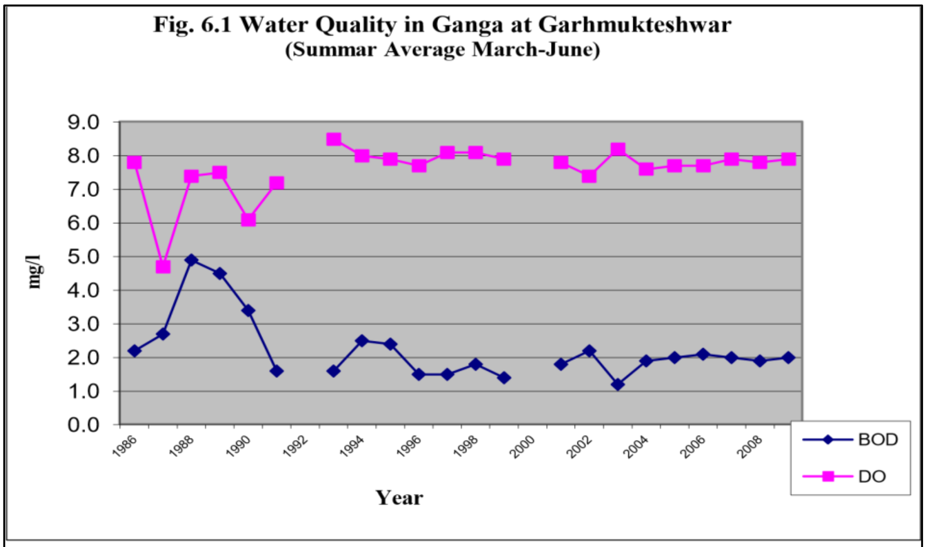
Table 6.2 Water Quality Data for River Ganga at Garhmukteshwar

Summer Average March-June			
Sl. No	**Year**	**Dissolved Oxygen (mg/L)**	**Biochemical Oxygen Demand (mg/L)**
1	1986	7.8	2.2
2	1987	4.7	2.7
3	1988	7.4	4.9
4	1989	7.5	4.5
5	1990	6.1	3.4
6	1991	7.2	1.6
7	1992	-	-
8	1993	8.5	1.6
9	1994	8.0	2.5
10	1995	7.9	2.4
11	1996	7.7	1.5
12	1997	8.1	1.5
13	1998	8.1	1.8

14	1999	7.9	1.4
15	2001	7.8	1.8
16	2002	7.4	2.2
17	2003	8.2	1.2
18	2004	7.6	1.9
19	2005	7.7	2.0
20	2006	7.7	2.1
21	2007	7.9	2.0
22	2008	7.8	1.9
23	2009	7.9	2.0

Source: Central Pollution Control Board, MOEFCC (DO and BOD levels at other location are at Annexure 6.2)

Figure 6-1 Water quality in Ganga at Garmukteshwar (Summer Average March-June)



Source: Central Pollution Control Board, MOEFCC

It is observed from the above table that the BOD level was 4.9 mg/l (above acceptable limits) in 1988 which dipped to 4.5 and 3.4 in year 1989 and 1990 respectively. After 1990, the BOD level remained consistently within acceptable limits. In the case of DO, it remained within acceptable limits consistently after 1988 (Table-6.2 and Fig.6.1). The data available at web site of UP Pollution Control Board indicates water of Ganga River is of category D i.e. fit for propagation of wild life and fisheries. The water is not fit for outdoor bathing or to be used as drinking water source after conventional treatment and disinfections (Annexure 6.1. In NCR though the DO and BOD are within permissible limits, but even these parameters indicate highly polluted situation on the downstream of Kanpur beyond NCR.

The river is polluted not only due to discharge of urban wastewater and pollutants but also discharge of industrial wastes and leakage of industrial pollutants into the river/water courses directly. The State Pollution Control Board at the state level and the Central Pollution Control Board, Ministry of Environment, Forests and Climate Change at the central Government level monitors the pollution in the Rivers. As per data available on the website of Ministry of Environment, Forests and Climate Change, in January, 2010 there are 481 Grossly Polluting Industries in Ganga basin having BOD load of 100kg/day or more. The data indicates that

353 units (73 %) are operating satisfactorily 53 (11%) units are not operating satisfactorily and 75 units (16%) have been closed down. Of the 481 polluting industries, 386 polluting industries located in the river basins of Ganga, Yamuna, Hindon and Kali which are flowing through the NCR. The data indicates that 291 units (75 %) are operating satisfactorily 31 (8 %) units are not operating satisfactorily and 64 units (17 %) have been closed down. The Grossly Polluting Industries having BOD load of 100kg/day or more in Ganga Basin in NCR (January, 2010) given in Table 6.3 and Figure 6.2.

Table 6.3 No. of Grossly Polluting Industries Discharging Effluents in Ganga Basin in NCR (2010)

Sl. No.	Rivers	OPRS	OPRNS	UCL	Total
1	Ganga	96	21	38	155
2	Hindon	25	1	4	30
3	Kali	45	0	10	55
4	Yamuna	125	9	12	146
	Total	**291**	**31**	**64**	**386**

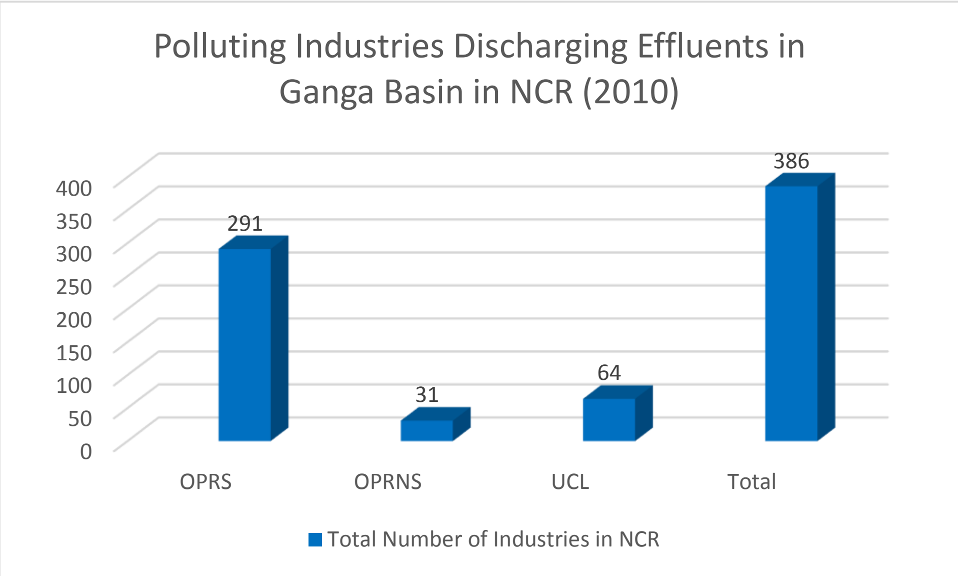
Legend

OPRS: ETP operating satisfactorily

OPRNS: ETP not operating satisfactorily

UCL: Unit closed

Figure 6-2 Total Number of Polluting Industries Discharging Effluents in Ganga Basin in NCR (2010)



6.5.2 Yamuna River

The Yamuna River from its origin near Yamunotri to its confluence with Ganga River at Allahabad is about 1,376 km. is the largest tributary to Ganga River and it accounts to about 40% of Ganga basin. The total basin area of the river is 3,66,223 km^2 which covers part of geographical area in the states of Uttaranchal, Uttar Pradesh, Himachal Pradesh, Haryana, NCT Delhi, Rajasthan and Madhya Pradesh. The flow of the Yamuna River varies significantly during monsoon and non-monsoon seasons. The river constitutes maximum flow i.e. around 80% of the total annual flow during monsoon period. During non-monsoon period it gets segregated into four independent segments due to the presence of three barrages from where almost the entire river water is being diverted for various human needs. The main cities and towns located along the Yamuna river are, Hathinkhurd and ,Yamuna Nagar upstream ,Panipat, Sonepat, Bagpat ,Delhi, Noida, Greater Noida, Faridabad, Ballabgarh, Palwal within NCR and Mathura,Agra Etawah and Hamirpur Allahabad downstream. Water quality of river Yamuna is regularly monitored by CPCB at 22 locations covering entire stretch.

The DO and BOD levels are within acceptable limits up to NCT Delhi border. In fact, the condition of river Yamuna deteriorated due to abstraction of significant quantity of river water at Wazirabad Barrage, leaving almost no fresh water in the river, which is essential to maintain the assimilation capacity of the river.

Table 6.4 Water Quality of River Yamuna at Palla

S. No	Year	DO(mg/L) Acceptable >5 mg/L	BOD(mg/L) Acceptable < 3 mg/L
1	1996	13.95	6.00
2	1997	11.15	4.50
3	1998	8.40	1.00
4	1999	7.30	1.70
5	2000	8.67	1.50
6	2001	7.80	1.50
7	2002	7.50	3.30
8	2003	7.50	1.50
9	2004	8.00	1.70
10	2005	8.20	2.00
11	2006	8.00	4.80
12	2007	9.40	5.25
13	2008	8.30	1.30
14	2009	7.10	2.50

Fig. 6.2 Water Quality of Yamuna at Palla

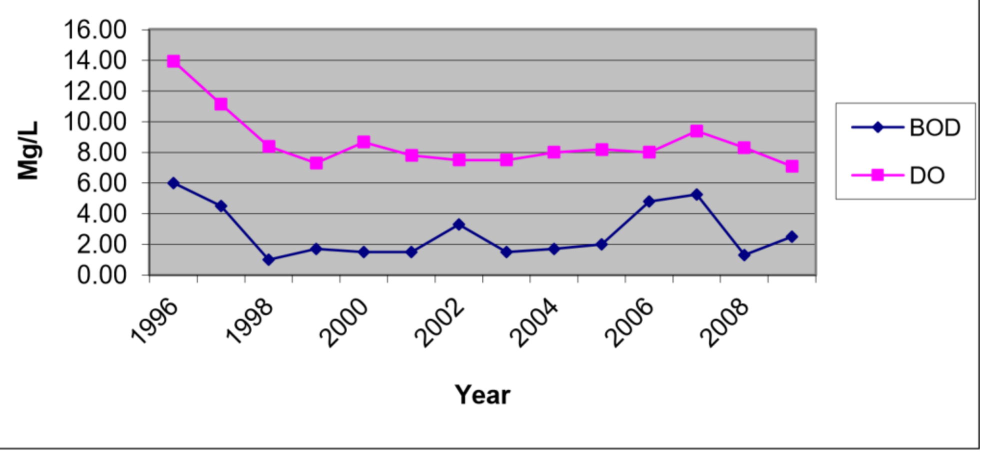
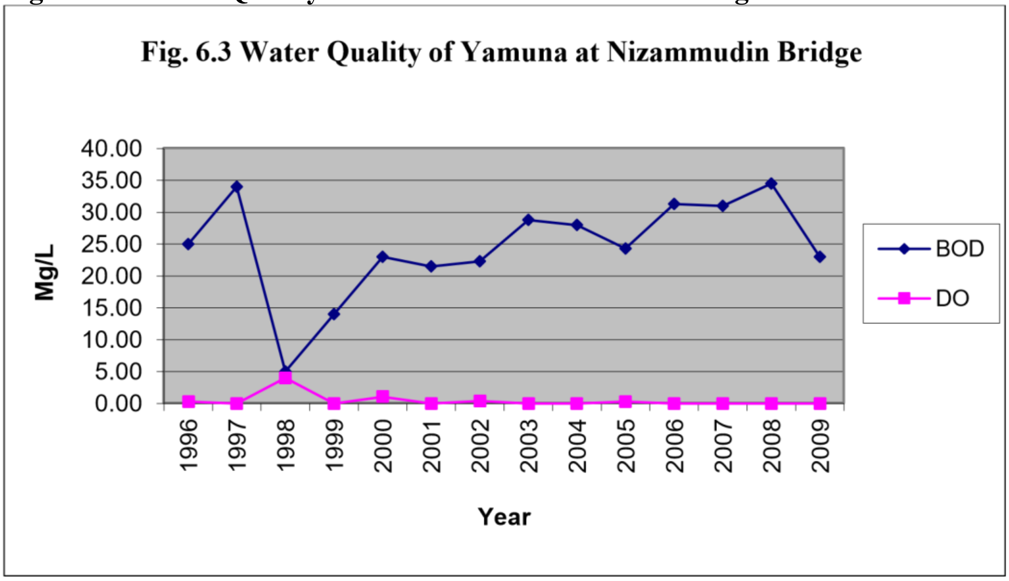


Table 6.5 Water Quality of River Yamuna at Nizamuddin Bridge

Summer Average March-June

Sl. No	Year	DO (mg/L) Acceptable>5 mg/L	BOD (mg/L) Acceptable<3 mg/L
1	1996	0.30	25.00
2	1997	0.00	34.00
3	1998	4.00	5.00
4	1999	0.00	14.00
5	2000	1.03	23.00
6	2001	0.00	21.50
7	2002	0.40	22.30
8	2003	0.00	28.80
9	2004	0.00	28.00
10	2005	0.30	24.30
11	2006	0.00	31.30
12	2007	0.00	31.00
13	2008	0.00	34.50
14	2009	0.00	23.00

Figure 6-5 Water Quality of Yamuna at Nizammudin Bridge



It is important to note that downstream to Tajewala Barrage there is no water in Yamuna river. The minimum quantity of water as per the water distribution agreement is not flowing in the river. Whatever water flowing in the river at some locations is due to drain water joining the river. The water of these polluted drains is inadequate to maintain the flow in the river. After flowing for a few kilometres in the river water percolates into the ground and the riverbed becomes dry. The polluted water percolating into the ground could cause irreversible pollution of ground water.

There are 22 major drains carrying polluted water to the river Yamuna Delhi. The list of existing drain along with the BOD load being discharged into the river is given in Table 6.6

Table 6.6 BOD Load Contribution to River Yamuna by different Drains in Delhi

Sl. No	Drain	BOD load			%age BOD contribution
		Min	Max	average	
1	Najafgarh Drain	64.60	459.53	121.57	32.99
2	Shahdara Drain	27.75	203.40	64.71	17.56
3	Sarita Vihar Drain	7.74	86.86	39.93	10.83
4	Sen Nursing Home Drain	8.50	66.65	28.17	7.64
5	Maharani Bagh Drain	8.75	60.51	23.99	6.51
6	Drain No. 14	3.70	44.39	21.41	5.81
7	Drain Near Sarita Vihar Bridge	7.18	56.60	17.25	4.68
8	Barapulla Drain	0.06	103.20	14.30	3.88
9	Civil Mill Drain	3.55	28.00	12.89	3.50
10	Delhi Gate Drain	4.58	25.41	10.61	2.88
11	ISBT Drain	0.85	9.34	3.42	0.93
12	Drain at LPG Bottling Plant	0.32	6.29	2.33	0.63
13	Magazine Road Drain	0.36	3.93	1.61	0.44
14	Tonga Stand Drain	0.25	8.16	1.50	0.41
15	Tehkhand Drain	0.38	2.77	1.43	0.39
16	Sweepers Colony Drain	0.07	1.76	0.73	0.20
17	Tuglakabad Drain	0.23	1.71	0.68	0.18
18	Drain No. 12 A	0.17	3.19	0.63	0.17
19	Metcalf House Drain	0.19	1.95	0.54	0.15
20	Kalkaji Drain	0.05	1.71	0.49	0.13
21	Khyber Pass Drain	0.03	1.05	0.25	0.07
22	Moat Drain	0.03	0.26	0.10	0.03
	Total	**139.34**	**1176.67**	**368.54**	**100.00**

Source: Central Pollution Control Board Annual Report, 2001-02

A comparison of water quality data (BOD and DO) at Palla village (Table 6.4 and Fg,6.2) located upstream of Wazirabad Barrage and that of at Nizummuddin Barrage downstream (Table 6.5 and Fig.6.3) clearly indicates that pollution is added in Delhi. BOD at Palla recorded 2.5 which is well within acceptable limit of 3 mg/l**)** while at Nizummuddin Bridge it is 23 i.e. more than nine times. In the case of DO, it consistently recorded zero since 2006 which is much lower than the acceptable limit of 5 mg/l.. (Fig.6.3) .The Total Coliform level (Fig. 6.5) exceeds acceptable limits sometimes even in Yamunotri. Delhi Pollution Control Committee (DPCC,) Government of NCT- Delhi also monitors water quality of Yamuna

River. Water Quality Status Report March,2015, given at Annexure 6.2 indicate that highest BOD (62 mg/l recorded at Khajori Paltoon pool (38 mg/l) downstream Najafgarh drain followed by Kudesia Ghat (45 mg/l) and after meeting Shahdara drain downstream Okhla Barrage also establishes the same the fact.

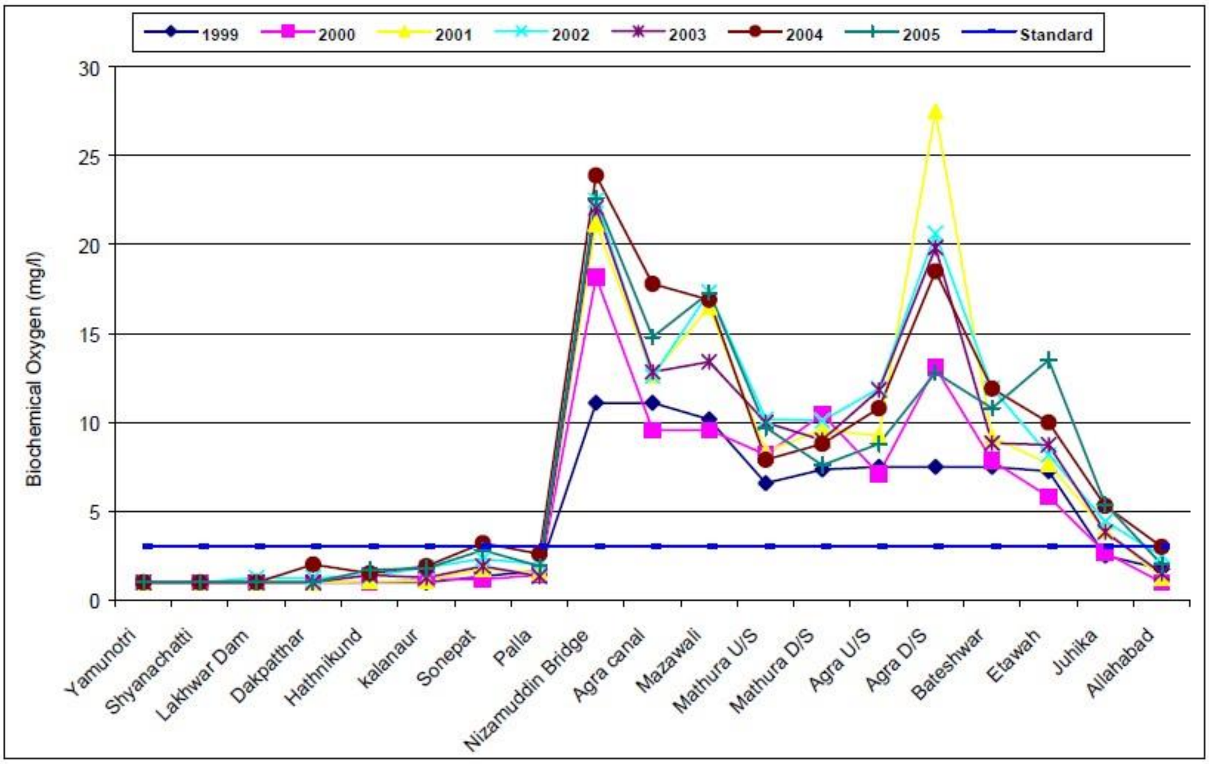
Yamuna River receives about 84 percent of the total BOD load through major drains and rest through canals. About 90 percent of the total discharge joins the river through these drains and rest to canals. Najafgarh and Shahdara drains continue to remain highest contributors to BOD load and discharge. These two drains contribute about 66 percent of BOD load and about 72 percent of total discharge. DPCC, Government of NCT- Delhi also monitors water quality of drain in Delhi. The water quality status of drains out falling Yamuna River as of April,, 2015 given at Annexure-6.3 also indicates the same fact.

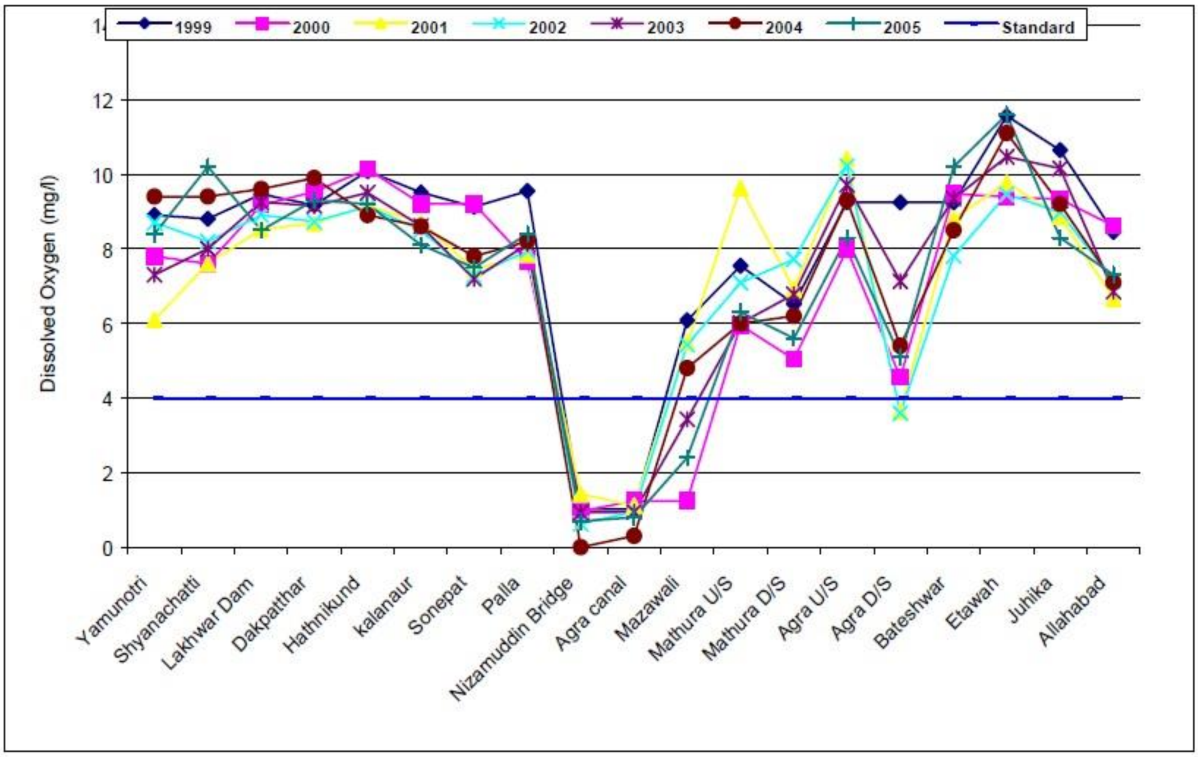
6.5.3 Monitoring of Sewage Treatment Plants in NCR

CPCB monitors the performance of Sewage Treatment Plants (STP) of NCR. Sewage Treatment Plants in Delhi have the total installed capacity of 2,305 MLD whereas utilization capacity is 1,252 MLD i.e. 53%. Performance Evaluation Analytical results of various STPs in Delhi are given at Annexure 6.4 It is evident from the data that with respect to BOD, STPs at Vasant Kunj Phase-I and Okhla Phase I to IV do not meet the General Standards for Discharge of Environmental Pollutants into inland surface, public sewers, land for irrigation, marine coastal areas under Schedule-VI of The environment (Protection) Rules, 1986, while STPs at Okhla Phase–II do not meet the General Standards for COD. DPCC, GNCT-Delhi monitors the operation of 13 Common Effluent Treatment Plant (CETP) regularly. The details of the CETP wise Analysis Reports pertaining to February/March, 2015 are at Annexure-6.4.

CPCB monitored the status of performance of 10 STPs in Sonepat, Panipat, Faridabad and Ballabgarh in Haryana Sub-region and Ghaziabad & Noida, in UP Sub-region of NCR. Analytical results of these STPs given at Annexure6.5 indicates that in respect to BOD ,two STPs at Panipat, Faridabad- Mirzapur, Ballabgarh, Indirapuram and Vijay Nagar do not meet the General Standards for Discharge of Environmental Pollutants into inland surface, public Sewers, land for irrigation, marine coastal areas under Schedule-VI of The Environment (Protection) Rules, 1986. The STPs at Sonepat, Panipat, Jattal Road and Ballabgarh do not meet COD Standards.

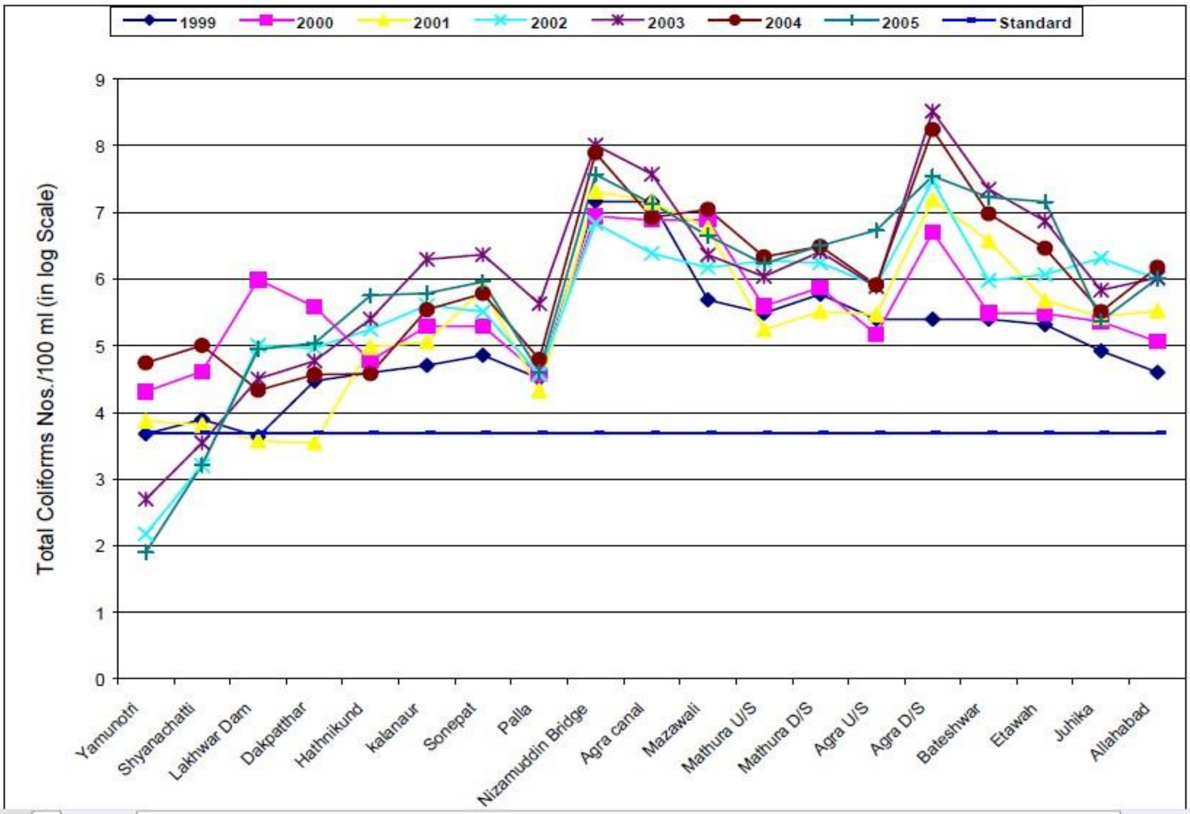
Figure 6-6 Longitudinal Profile of BOD and DO in Yamuna

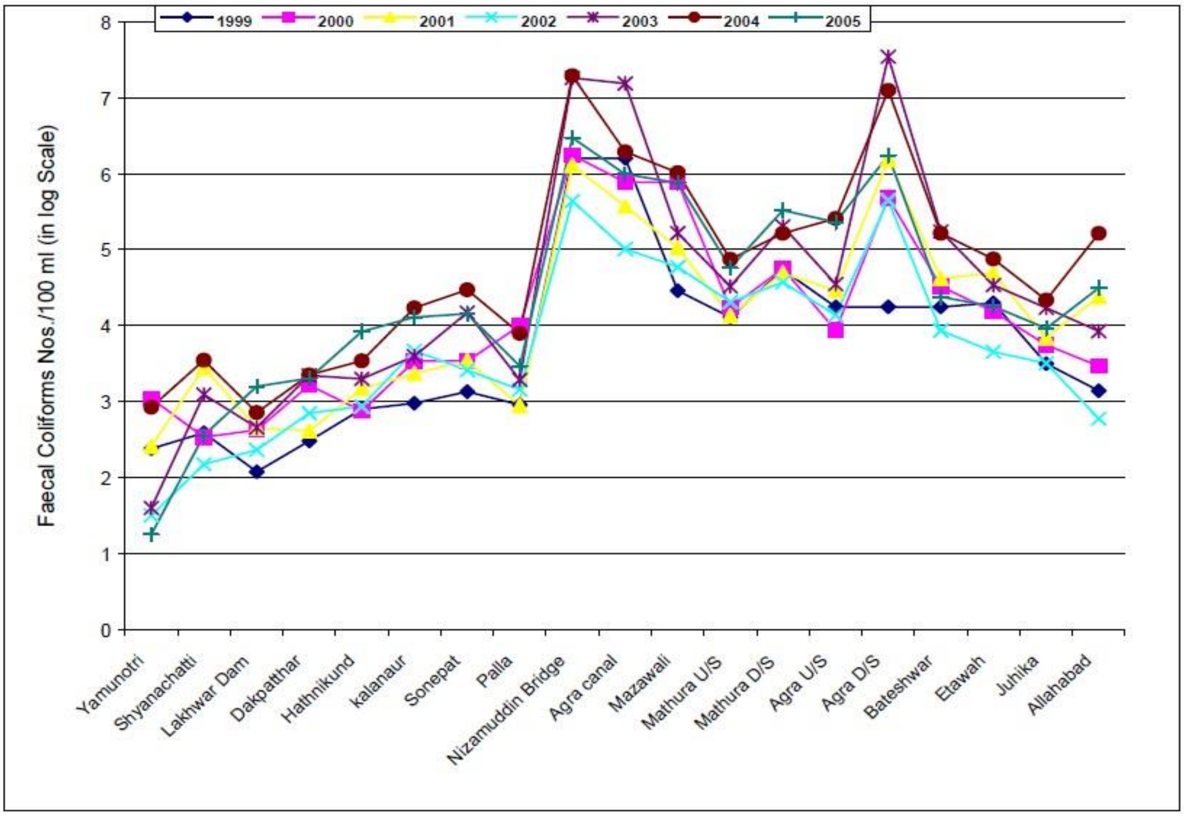




Source: Report on Water Quality Status of Yamuna River 1999-2005, Central Pollution Control Board MOEFCC

Figure 6-7 Longitudinal Profile of Total and Faecal Coliform in Yamuna River





Source: Report on Water Quality Status of Yamuna River 1999-2005, Central Pollution Control Board, MOEFCC

The desired and existing Water Quality Levels at Various Sampling Station in water bodies of UP – 2010 given in Table 6.7 shows that existing category in respect of river Ganga, Hindon and

Yamuna is B i.e. the best designated use is out door bathing whereas the existing category in all these rivers is below the desired category. This warrants an urgent need for necessary action for strict control of pollution in these rivers.

Table 6.7 Desired and Existing Water Quality Levels at Various Sampling Station in Water Bodies of UP – 2010

Name of river/sampling location	Desired Category	Existing Category	Pollution Characteristics
River Ganga			
Ganga Rajghat D/s Narora	B	C	T. Coliform
Ganga D/s Garhmukteswar	B	D	T. Coliform
Bulandshahr	B	C	T. Coliform
Hindon River			
Ghaziabad D/s Kuleshra Bridge	B	E	BOD, T. Coliform, Ammonia
Kali River			
Downstream of Modinagar to confluence with Ganga	C	Partly D/E	DO, BOD, Coliforms
Yamuna River			
At Nizammudin Bridge*	B	E	DO, BOD, Coliforms

Source: http://www.uppcb.com/river quality.htm

7. DISASTER MANAGEMENT

7.1 Natural Calamities

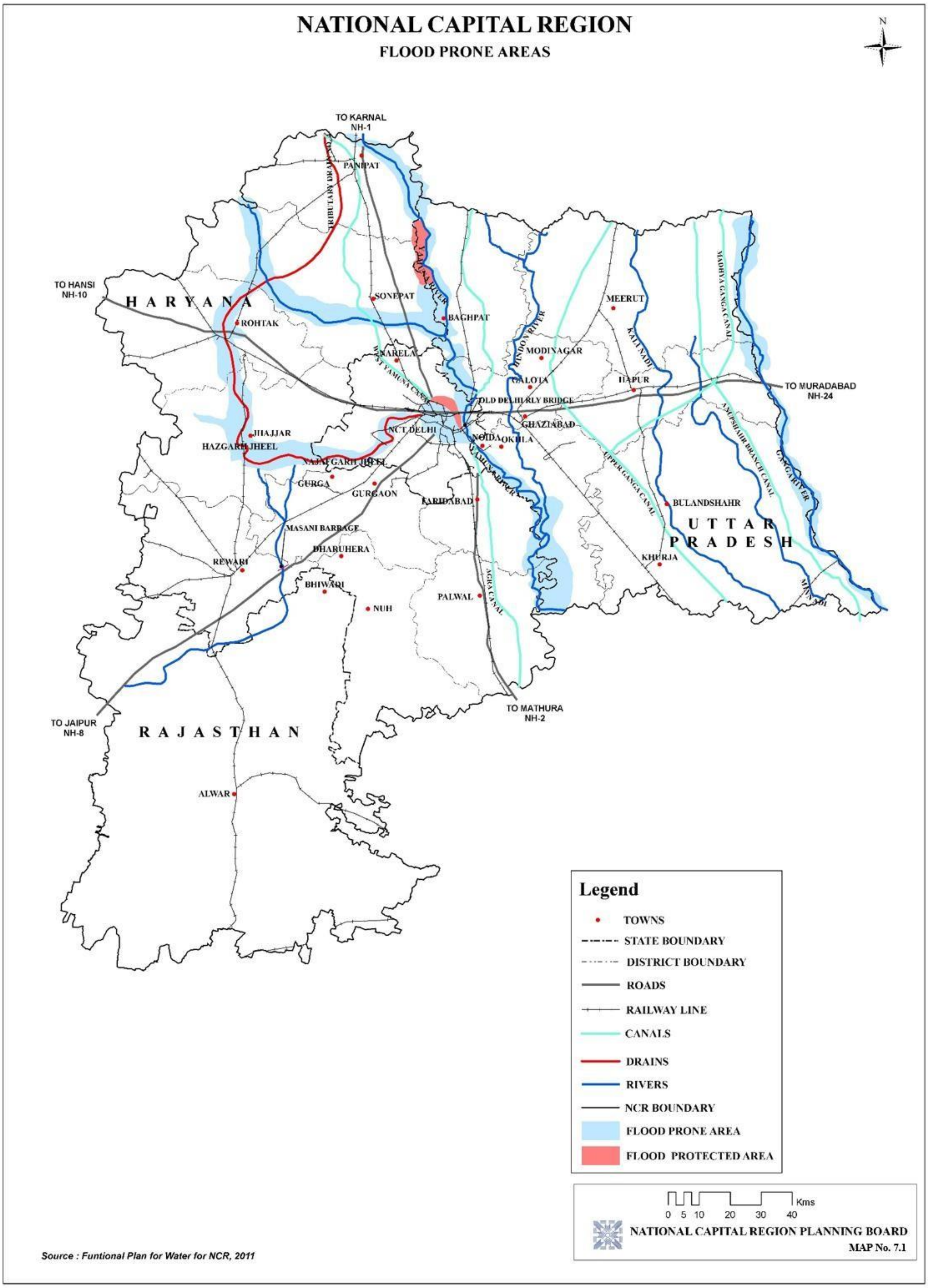
Geo-climatic conditions and rapid development of NCR makes it vulnerable to disasters, both natural disasters like flood, earthquakes, etc. and man-made disasters like fire, chemical or industrial accidents. While floods, as a recurring annual phenomenon, bring devastation in the region, earthquakes so far have caused higher casualties and emerged as a considerable threat. Natural calamities in NCR are elaborated in subsequent paragraphs.

7.2 Floods

The main causes of floods are heavy rainfall, inadequate drainage to carry away the rainwater quickly to streams/rivers, inadequate capacity of rivers to carry the high flood discharge, etc. Flash floods occur due to high rate of water flow and poor permeability of the soil. One of the reasons for damage of property and life due to floods is development of slums/unauthorized construction in the drainage channels, river beds etc. which are below high flood level area. Flood results in the outbreak of serious epidemics specially, malaria and cholera, simultaneously, scarcity of water.

Flood levels in Yamuna, the main river in NCR cross the danger level (204.22m.) almost every year and water spread out of the regime and reach the embankments. The flow and the expected flood levels of the river Yamuna in Delhi is forecasted by the Central Water Commission through hydrological and hydraulic observations on the upstream, particularly taken at Hathnikund headworks (about 130 km upstream) from where two canals namely Western Yamuna Canal (WYC) and Eastern Yamuna Canal (EYC). take off from the Yamuna river, Since the Hathnikund Barrage/headworks and the two canals have limited capacity, in the event of heavy precipitation in the catchment area of Yamuna and its tributaries, upstream of barrage the river downstream comes in spate, overflowing its banks and flooding the adjoining low lying areas. Also great damage is caused to areas deep inside the region because of the back flow in the drains which is otherwise meant to discharge excess water into the river. In addition, heavy precipitation within the region causes local flooding of streets and localities on a large scale. In recent years even moderate rainfall has resulted in local floods. Main reason for these local floods is high rate of runoff from urban areas which have been continuously growing at a very rapid rate. This problems of local floods is expected to aggravate in NCR because, almost the entire area is likely to get urbanized leaving very little scope for open and soft landscape surfaces, which help in absorbing runoffs and soften the impact of floods. The Flood Prone Areas in NCR has been shown in Map No. 7.1.

Map 7. 1 Flood Prone Areas in NCR



7.3 Regional Plan 2021- NCR Policies

Potential damage due to earthquake: Regional Plan 2021 stated that NCR falls in Seismic zone IV as per Seismic Zone map of Indian Standard IS 1893. This makes the area liable to

MSK intensity of "VIII" and is considered as High Risk Zone. Such intensity may cause severe damages some of which are listed below:

- Type A-Houses constructed with stone, rural structures, un-burnt bricks, clay etc. may suffer destruction causing gaps in walls, collapse of parts of buildings, loosening of cohesion of parts of buildings and collapse of inner walls.
- Type B-Buildings construction with ordinary bricks, large blocks, and natural stone and prefabricated type buildings may suffer heavy damage causing large & deep cracks in walls.
- Most buildings of Type C i.e., RCC buildings may have small cracks in walls, fall of large pieces of plaster, slipping off tiles, cracks/fall in chimneys etc.
- Fright and panic is caused among people, breaking off of branches of trees etc. takes place.

Liquefaction Effect: Groundwater, sand and soil combine during seismic shaking to form liquefaction during a moderate to powerful earthquake. When liquefaction takes place under buildings the foundations sink and the building collapse. Areas with sandy soil and groundwater close to the surface are far more at risk of liquefaction. Buildings can even sink into the ground if soil liquefaction occurs. Since NCR falls in Seismic Zone-IV, river beds / flood plains of NCR may be effected by liquefaction during occurrence of earthquake.

Floods: With regard to floods, Regional Plan-2021 has proposed that different areas in NCR, which are liable to flooding in rivers of return period of 5,10,25, 50 and 100 years, need to be identified on map for land use zoning at regional and Sub-regional levels. Participating States should prepare detailed Contour Maps for their respective Sub-regions on a scale of 1:15000 at a contour interval of 0.3 to 0.5 meter and mark areas that are flood prone.

Regional Plan-2021 for NCR identified rivers and tributaries of Yamuna, Ganga, Kali, Hindon and Sahibi, major lakes and water bodies such Badhkal Lake, Surajkund and Damdama and Siliserh lakes as Natural Conservation Zone and the broad policies for this zone are as under:

(i) The areas under water bodies i.e. rivers, ox-bow lakes, paleo-channels, lakes and ponds and their surrounding areas be kept free from any encroachment/development, to allow free flow of water. Construction activities for human habitation or for any other related purpose not be permitted. Suitable measures be taken the water bodies with the minimal flow/water level.

(ii) In the flood prone areas/river beds/banks, no construction or habitation activities be permitted. Flood Protection Plan be prepared by the concerned State Governments/ agencies. Policies proposed in the Disaster Management Chapter at para 15.5 be further elaborated in the Sub-regional Plans, Master/Development Plans and Flood Protection Plans.

7.4 Urban Flooding

Urban Flooding is different from rural flooding as urbanization leads to develop / constructed catchments Major cities in India have witnessed damage of vital infrastructure such as transportation, power and also incidents of epidemics. The main factors responsible for urban flooding are heavy rainfall during monsoons, increase in imperviousness which prevents percolation of rain water. Sudden release or failure to release water from dams can also have severe impact. In addition, the urban heat island effect has resulted in an increase in rainfall over urban areas. Global climate change is resulting in changed weather patterns and increased episodes of high intensity rainfall events occurring in shorter periods of time.

There has been an increasing trend of urban flood disasters in India over the past several years and number of major cities have been severely affected. The most notable floods are Hyderabad (2000), Ahmedabad (2001), Chennai (2004), Mumbai (2005,) Surat (2006), Kolkata 2007, Jamshedpur (2008) and Guwahati (2010). In the case of NCT Delhi, the flood of 1978 has been highest recorded flood when river water level reached to 207.49 m. at Old Railway Bridge and a large areas like Model town etc. were submerged under deep water. The flood of same magnitude (209.92) m.) occurred in 1988 in NCT-Delhi. Floods were also occurred in 2002, 2003, 2009 and 2010 in NCT-Delhi and submerged a large areas. Some of the factors responsible for urban flooding are discussed below:

7.4.1 Urbanization and pressure on land

Urban areas are centres of administrative, industrial and commercial activities and continue to attract migrants in large numbers in search of employment from different areas. Rapid urbanization puts a lot of pressure on land and as a result, habitations keep coming up in the natural/ low lying areas/flood plains. In Indian cities and towns, large habitations are coming up on river beds /low-lying areas, often encroaching over drainage channels. In some cases, houses are constructed even on top of nallahs and drains.

In the absence of a proper sewerage system, most of the habitations discharge their sewage into the existing storm water channels. The net result has been that the width of the natural drainage channels has become in adequate and the capacity for draining the rainwater has been greatly reduced result in flooding.

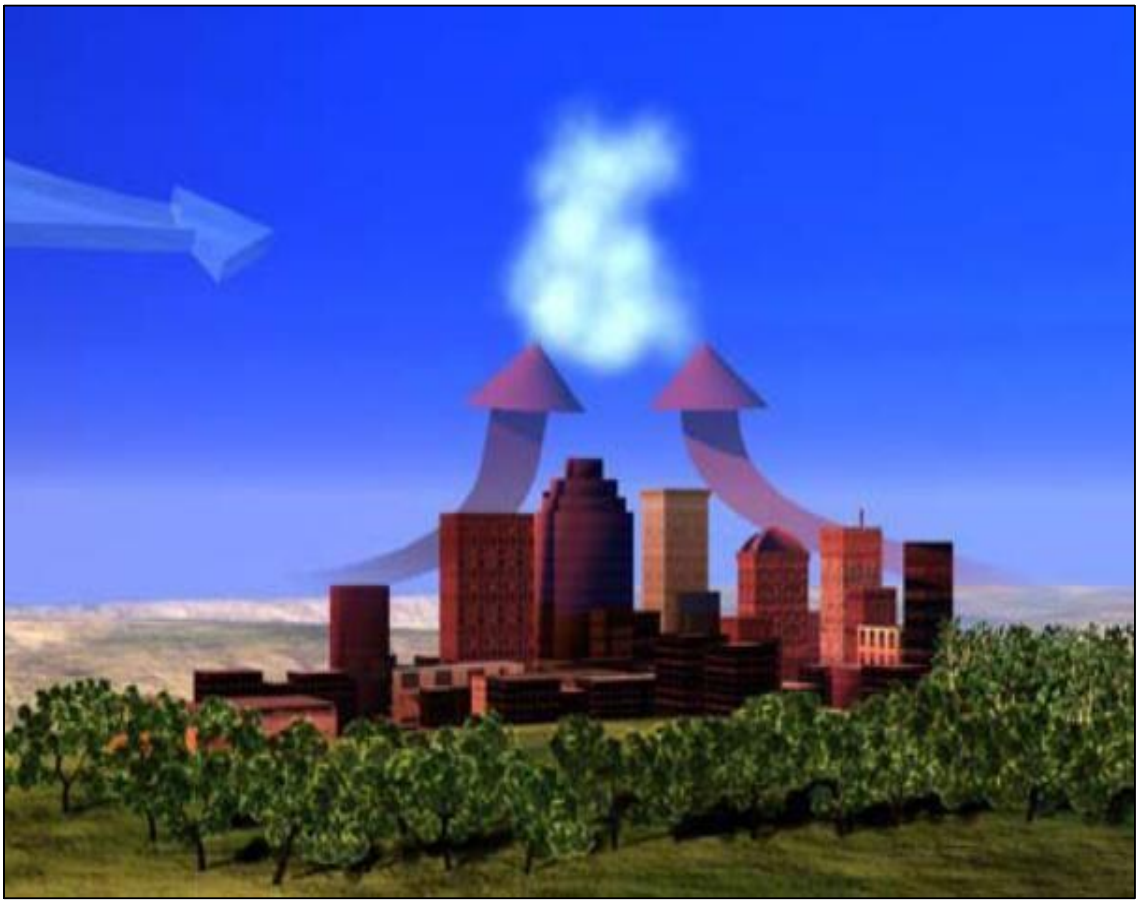
7.4.2 Increase in Imperviousness

Urbanization leads to increase in impervious areas in the cities/towns by way of constructed catchments i.e. roads, buildings, paved areas, and other concrete surface areas. The constructed catchments prevents percolation of rainwater and significantly increases the rate of runoff. This may increases flood peaks from 1.8 to 8 times and flood volumes by up to six times. Consequently flooding occurs very quickly due to faster flow times (in a matter of minutes

7.4.3 Urban Heat Island Effect - Increasing Rainfall

NDMA recognized that recent studies such as the Metropolitan Meteorological Experiment (METROMEX) conducted in St. Louis, USA, found that urbanization led to a 5-25 per cent increase in summer precipitation within and 5075 km downwind of the city. The Urban Heat Island Effect – the rising heat induces cloud formation while the winds interact with urban induced convection to produce downwind rainfall. (Figure 7.1 & Fig. 7.2) National Aeronautics and Space Administration (NASA) has indicated increased rainfall intensities over urban areas due to the Urban Heat Island Effect.

Figure 7-1 Rising Heat and Cloud Formation as a Result of the Urban Heat Island Effect



Source: National Aeronautics and Space Administration, USA

Moreover, in a study of urbanization effect on convective precipitation in Mexico, analysis of historical records of hourly precipitation for an urban station showed an increase in the frequency of intense (>20 mm/h) rain showers and that the day time Heat Island Effect was associated with the intensification of rain showers. In India, urban heat islands over Pune and Chennai have been reported. There has been an increase in the average annual rainfall of Hyderabad from 806 mm in 1988 to 840.

Figure 7-2 Winds Interact with Urban-induced Convection to Produce Downwind Rainfall

Source:*National Aeronautics and Space Administration, USA*

Factors contributing in Urban Flooding

Floods in urban areas can be attributed to one or a combination of different factors listed in Table 7.1.

Table 7.1 Factors Contributing to Urban Flooding

Meteorological Factors	Hydrological Factors	Human Factors
• Rainfall • Cyclonic storms • Small-scale storms • Temperature • Snowfall and Snowmelt	• Soil moisture level • Groundwater level prior to storm • Natural surface infiltration rate • Presence of impervious cover • Channel cross-sectional shape and roughness • Presence or absence of over bank flow, channel network • Synchronization of runoffs from various parts of watershed • High tide impeding drainage	• Land use changes (e. g. surface sealing due to urbanization, deforestation increase runoff and sedimentation • Occupation of the flood plain and thereby obstructing flows • Inefficiency or non-maintenance of infrastructure • Too efficient drainage of upstream areas increases flood peaks • Climate change effects, magnitude and frequency of precipitation and floods • Urban micro-climate may enforce precipitation events • Sudden release of water from dams resulting in backwater effect. • Indiscriminate disposal of solid waste • Failure to release water from dams resulting in back water effect.

Source: National Disaster Management Guidelines: Management of Urban Flooding, 2010

7.5 Role of Science and Technology

The management of urban flooding is an emerging subject, and as such it has to be treated holistically in a multi-disciplinary manner. There are many issues that need to be considered in order to develop sound, reliable and most representative urban flood/disaster management strategies. A significant part of this management framework is dependent upon the use of science and technology for improved monitoring, modelling/forecasting and decision-support systems. One way of improving the preparedness for urban flooding is by setting up a vulnerability-based geo-spatial framework to generate and analyze different scenarios (Refer **Box 7.1).** This will help in identifying and planning for the most effective/ appropriate actions in a dynamic way to incorporate day-to-day changes that take place in urban areas, having the potential to alter the prevailing vulnerability profile.

Box 7.1 Case Study Mumbai

Box-7.1: Case Study Mumbai
On 26th July 2005, Mumbai suffered severe flooding due to 944 mm rainfall in 24 hours. According to the Government of Maharashtra, over 60 % of Mumbai city was inundated to various degrees. At that time, there was no reliable real-time rainfall forecast mechanism and IMD was unable to issue advance warnings due to the lack of state-of-the-art equipment like tipping bucket rain gauges, etc. Thus, disaster managers had no means of knowing the spatial or temporal variation of rainfall in real-time. To improve the response and determine the spatial and temporal variation of rainfall in real-time, a network of 35 weather stations with tipping bucket rain gauges has been setup in the city by the MCGM and Indian Institute of Technology Bombay in June 2006. Majority of them are installed on the roof of the fire station control rooms. These rain gauges have been programmed to give rainfall intensity in realtime (every 15 minutes) to the emergency control room at MCGM headquarters through internet. The average rain gauge density is 1 per 16 km^2 and inter-station distances ranges from 0.68 km to 4.56 km. This network has enabled monitoring of rainfall in real-time and has been of immense benefit to disaster managers for mobilizing rescue and relief to the flood affected areas during the heavy rainfall since 2006. An automatic Doppler flow gauge has also been set up in the upstream reaches of Mithi River to measure the flow levels and issue early warnings. IMD is also in the process of setting up a DWR very shortly.

7.6 Flood Early Warning System

Flood protection is usually geared towards reduction of the impact of the flood loss and flood liabilities. The ultimate objective of urban flood management is to provide ways and means to deal effectively with the possible flooding in urban areas. The meteorological forecasts prepared by India Meteorological Department (IMD), largely include a description of the current and forecasted meteorological weather situation, supplemented by information on the anticipated rainfall, temperature, wind velocity etc. for larger regions. Urban area hydrological forecasts need to be worked out for urban sectors and also covering large-scale suburban areas for rendering effective local scale / watershed scale urban flood warning. Interpretation of the meteorological and hydrological situation on continuous basis by the ULBs is critical for effectively responding to the emerging flood scenario.

7.7 Need for Comprehensive Approach for Urban Flooding

The urban flooding needs special attention on account of severity of the damage incurred to the loss of life and property. The present approach of rescue and relief centric need to be transformed to comprehensive Disaster Management (DM) approach as given in the Table 7.2 below:

Table 7.2 Approaches to the Management of Urban Floods

Rescue and Relief Centric Approach	Focus on	Holistic DM Approach
(i) Primary focus on hazards and disaster events (ii) Single, event-based scenarios (iii) Basic responsibility to respond to an event	Emphasis	(i) Primary focus on vulnerability and risk issues (ii) Dynamic, multiple risk issues and development of possible scenarios (iii) Fundamental need to assess, monitor and continuously update exposure to changing conditions.
(iv) Often fixed, location-specific conditions (v) Command and control, directed operations (vi) Established hierarchical relationships (vii) Often focused on hardware and equipment (viii) Dependent on specialized expertise	Operations	(iv) Extended, changing, shared or regional, local variations (v) Situation-specific functions (vi) Shifting, fluid and tangential relationships (vii) Dependent on related practices, abilities and knowledge base (viii) Specialized expertise, squared with public views and priorities
(ix) Urgent, immediate and short time frames in outlook, planning, attention, returns	Time Horizons	(ix) In addition to short term measures, moderate and long time frames in outlook, planning and returns
(x) Rapidly changing, dynamic information usage, often conflicting or sensitive (xi) Primary, authorized or singular information sources, need for definitive facts (xii) Directed "need to know" basis of information dissemination, availability (xiii) Operational/public information based on use of communications	Information use and Management	(x) Accumulated, historical, layered, updated, or comparative use of information (xi) Open or public information, multiple, diverse or changing sources differing perspectives, points of view. (xii) Multiple use, shared exchange, inter-sectoral use of information (xiii) Nodal communication

Source: National Disaster Management Guidelines: Management of Urban Flooding -2010, NDMA, Government of India

7.8 National Disaster Management Authority (NDMA) Guidelines

The guidelines are an important step towards the Development of Plans for the management of urban flooding. National Disaster Management Guidelines have been prepared by National Disaster Management Authority to provide guidance to ministries/departments, States/UTs and urban local bodies for the preparation of their Disaster Management (DM) Plans. These guidelines call for a proactive, participatory, well-structured, failsafe, multi-disciplinary and multi-sector approach at various levels. The guidelines and key action points as suggested in National Disaster Management Guidelines-Management of Urban Flooding September 2010 are given below:

i) Ministry of Urban Development will be the Nodal Ministry for Urban Flooding.
ii) Establishment of the Urban Flooding Cell in Ministry of Urban Development, State Nodal Departments and Urban Local Bodies. iii) Establishing a Technical Umbrella for Urban Flood Forecasting and Warning both at the National Level and State/UT levels.
iv) Strategic Expansion of Doppler Weather Radar Network in the country to cover all Urban Areas for enhanced Local-Scale Forecasting Capabilities with maximum possible Lead-time.
v) Establishment of Local Network of Automatic Rainfall Gauges for Real-time Monitoring with a density of 1 in every 4 sq. km in all (2325) Class I, II and III cities and towns.
vi) IMD will establish a 'Local Network Cell.
vii) India Meteorological Department (IMD) will develop a Protocol for Sub-Division of Urban Areas on the basis of Watershed and issue Rainfall Forecast on the Watershed basis.
viii) Establishing Urban Flood Early Warning System.
ix) Catchments will be the basis for Design of Storm water Drainage System. Watershed will be the basis for all Urban Flooding Disaster Management Actions. All the 2325 Class I, II and III cities and towns will be mapped on the GIS platform.
x) Contour Mapping will be prepared at 0.2 - 0.5 m contour interval.
xi) Inventory of the existing storm water drainage system will be prepared on a GIS platform.
xii) Future Storm water Drainage Systems will be designed with a Runoff Coefficient of up to 0.95 in using Rational Method taking into account the Approved Land-use Pattern.
xiii) Pre-Monsoon De-silting of Drains will be completed before March 31 every year.
xiv) Involve the Residents' Welfare Associations (RWAs) and Community Based Organizations (CBOs) in monitoring this and in all Urban Flood Disaster Management (UFDM) actions.
xv) Every building shall have Rainwater Harvesting as an integral component of the building utility.
xvi) Encroachments on Drains and in Floodplains will be removed by providing alternative accommodation to the poor people. xix) Better Compliance of the Techno-legal Regime will be ensured. Establish the Incident Response System for Coordinated Response Actions.
xx) Establish the Incident Response System for Coordinated Response Actions.
xxi) Capacity Development at the Community and Institutional level to enhance Urban Flood Disaster Management (UFDM) capabilities.
xxii) Massive Public Awareness programmes covering Solid Waste Disposal, problems of Encroachments, relevance of Techno-legal Regime besides all other important aspects.
xxiii) Involve elected Public Representatives in Awareness Generation.

8. ISSUES & CHALLENGES AND RECOMMENDATIONS

8.1 Introduction

Drainage management plan aims at discharging storm water within a minimum time, control of floods, maintaining the drainage networks and improvement of environment in and around drainage networks. Analysis of existing drainage network in terms of their design, construction and maintenance and various problems and issues related to encroachment, discharging of sewage into the drains, dumping of solid wastes and pollution are required for formulation of recommendations for Drainage Functional Plan. In this Chapter various problems have been discussed, issues & challenges identified and recommendations made for the development of drainage system in the NCR.

8.2 Drainage System in NCR Issues and Challenges

NCR being inter-state region, its drainage systems are planned, designed, constructed and maintained by various Departments/Agencies /ULBs of four NCR participating states. The problems being faced regarding planning, design, construction and maintenance of drainage system are discussed below:

8.2.1 Piecemeal Approach for Designing Drainage System

The development/expansion of existing urban area takes place outward from the City Centre. Normally, high level lands are developed followed by low lying lands. The drainage systems are also developed along with the development of the areas. The invert level of the drains developed in this area are kept with a view to drain out the storm water from the developed land, which is relatively high-level land. In the event of low lying land developed subsequently, the water from low-lying areas cannot be drained out under gravity through the drains constructed for draining out the storm water from higher level due to difference in the invert levels. In addition to above, during flooding of the areas the back flow of sewer creates serious problem.

There is a need to plan and design the drainage system of the city based on catchment area and taking into consideration, topography, slope, rainfall intensity and future expansions of the urban areas in an integrated manner. Holistic approach of drainage of planning and development is important instead of piecemeal approach.

8.2.2 Area Specific Rainfall Analysis

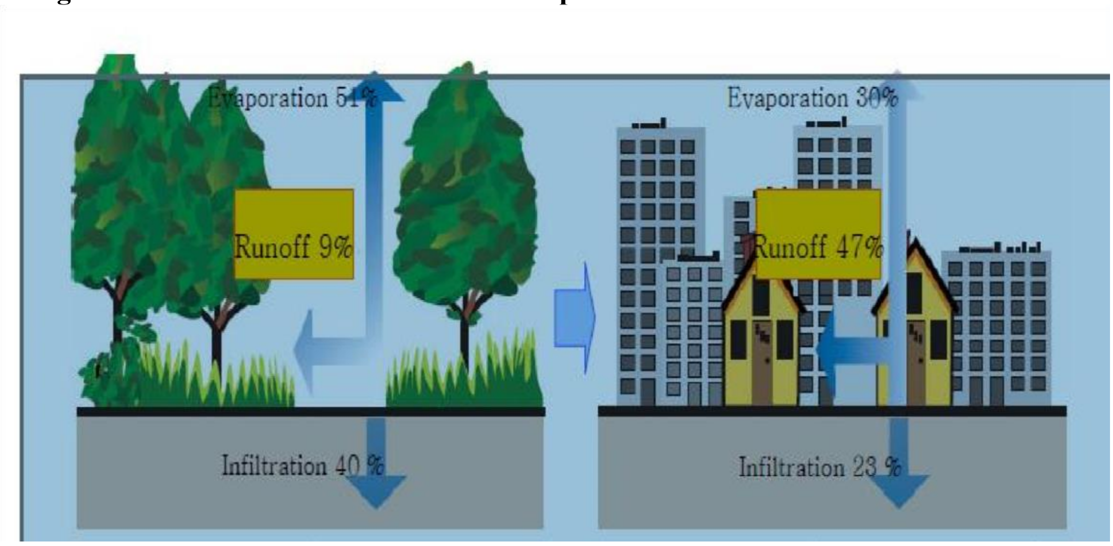
Among the important cities of India, the average annual rainfall varies from 2,932 mm in Goa and 2,401 mm in Mumbai on the higher side, to 669 mm in Jaipur on the lower side. The rainfall pattern and temporal duration is almost similar, which receive the maximum rainfall from the southwest monsoons. The average rainfall for the month of July in Mumbai is 868 mm and this far exceeds the annual average rainfall of 611 mm in London. Hence standard rainfall intensity cannot be adopted all over India/States.

Rainfall is the main driver of runoff process and intensity of rainfall is most important factor for designing the drainage system. It is often observed that the storm water drainage systems are designed for rainfall intensity of 12 - 20 mm/hr. which are easily overwhelmed whenever rainfall of higher intensity has been experienced. It has been observed that there is a variation of rainfall in the cities and the rainfall is expected to increase in the urban areas due to "urban heat island effect" discussed in Chapter 7 para 7.4.3. There is a need for area specific rainfall data and analysis for designing the Urban Drainage System.

8.2.3 Increase in Imperviousness in Urban Areas

The rainwater received on the land surface completes the water cycle by a combination of infiltration, evaporation (includes transpiration) and surface run off. With the urbanization, the built-up area increases and this reduces the scope for infiltration. Similarly in urban areas,

Figure 8-1 Run off before and after development



The tree and plantation cover decreases resulting in decrease in evaporation. Increase in built-up area and decrease in evaporation result in more surface run off. The comparison of run off before and after development indicates (Fig. 8.1) that after development surface run off has increased to 47 % from 9 % whereas infiltration has reduced from 40 % to23 % and evaporation reduced from 51% to 30 % which results in flooding. (Fig 8.1). There is a need to plan the developments in such a way that infiltration is not reduced and at the same time the surface run off is also not increased. There is a need to adopt the traditional approach to revive water bodies and also to increase the depleting water table.

8.2.4 Encroachment on Natural Drainage Channels in Urban Areas

Natural streams and watercourses have formed over thousands of years due to the forces of flowing water in the respective watersheds. Habitations started growing into towns and cities alongside rivers and watercourses. As a result of this, the flow of water has increased in proportion to the urbanization of the watersheds. Ideally, the natural drains should have been widened (similar to road widening for increased traffic) to accommodate the higher flows of storm water. But on the contrary, there have been large scale encroachments on the natural drains and the river flood plains. Consequently the capacity of the natural drains has decreased, resulting in flooding.

Generally the drains and linear patch of land on either side of the drain are neglected due to foul smell and filthy look due to drain. Because of this reason the land value along drain is lower compared to other lands in the city. Local authorities also neglect the nallah land and its surroundings because this land does not provide any source of income to them. The negligence by local authorities provides an opportunity for the encroachers to carry out construction activities on the lands along the nallahs. The encroachment also reduces the effective width of the drain, which further aggravates the problem in monsoon.

i) Construction Activity in Urban Area

On account of construction activity in urban area the water channels get blocked and sometimes the blockage is due to temporary use i.e. storage of construction material, dumping of malba and sometimes the blockage is permanent due to either land filling or construction on drain. While constructing the roads and railway lines, sometimes the drains are blocked and even if the provision is made for water channels beneath the railway line of roads, the width is reduced which affect the carrying capacity of the water channels leading to flooding of the area.

ii) High Land Value in Urban Area

In urban area the width of drains are reduced due to high land value. The adequate width required to drain the area is not provided due to scarcity of land. In monsoon water spreads over low-lying area. And during non-monsoon period the area of water spread gets reduced and the economic activity takes place in such land which becomes available during non-monsoon. In fact, some construction also take place to raise the level to avoid flooding. The land is not reverted back to its original level and it is not available for spread of rainwater in monsoon. It results in flooding the low-lying area adjoining drains.

iii) Construction of Bridges over Drainage Network

Increasing road networks for the urbanization and increase in urban population has resulted in construction of a large number of flyovers and bridges. It has been observed that due to shortage of land, the piers of roads and railway bridges constructed in major storm water drains and rivers in the cities. These may cause back water effects and flooding of the upstream catchments. There is a need to design all the roads and railway bridges in the cities crossing drains in such a way that they do not block flows resulting in back water effects.

iv) Covering of Drains/Construction over the Drainage Channels

A new phenomenon has been observed that in urban areas drains and natural nallahs are covered for urban activities use mainly for transportation and commercial activities due to scarcity of land in the cities. The covering of drains poses difficulty in cleaning and leads to reduction in the carrying capacity of the drains. To ease the traffic the covering of drain for construction of additional road space has been noticed in several cases as discussed below:

a) The drains have also been utilized for providing connectivity by constructing flyover or bridge upon nallahs. A flyover was constructed over the Barapula Drain for providing fast connectivity of the Commonwealth Games Village with Jawahar Lal Nehru Stadium in Delhi. In the case of flyover constructions the pillars/columns are constructed on the bed of the drains which hinders the cleaning process of the drain, as the cleaning machines cannot move in the drain bed and also partially block the storm water flow. This type of construction for flyovers, roads and market places should be avoided as far as possible.

b) The drains have been covered to construct roads over the drains. This gives temporary relief to the traffic as additional road space becomes available for flow of traffic. However, the cleaning of the drains becomes very difficult. Even if a shaft is provided in the center of the drains the machine cleaning the drain do not get to access the full base and as a result only the central part of the drain bed is cleaned leading to reduction in the capacity and results in flooding. In Seoul, capital of South Korea, Cheonggyecheon stream running through the centre of the City was covered and a six km long and 50-80 m wide road was created at existing drain. Subsequently, an elevated highway was constructed in 1976. Subsequently, it was demolished and reverted back to restoring the stream on environmental consideration. The details of the Chenoggyecheon Restoration Project is given in Box 8.1.

Box 8.1 Cheonggyecheon Restoration Project

Cheonggyecheon Restoration Project

Cheonggyecheon was a stream running from west to east through the center of Seoul city in South Korea. Its waters flowed down from Mt. Bugaksan and Mt. Inwangsang to the north, Mt. Naksan to the east, and Mt. Namsan to the south. The 600-year history of Seoul began when King Taejo, the founder of the Joseon Dynasty, moved the capital to Hanyang (today's Seoul) in 1394. Ever since, the Cheonggyecheon has been inextricably linked to Seoul's history.

The stream overflowed whenever there was heavy rain, and it was usually so polluted at all other times due to lack of flow that there was already talk of covering Cheonggyecheon during the early Joseon period.

Plan to cover Cheonggyecheon was formulated in 1926 but it was dismissed. The process of covering Cheonggyecheon started in 1937. The work was stopped once due to lack of fund and social unrest. The Cheonggyecheon road was created by covering Cheonggyecheon stream, which is 50-80m wide and 6 km long. The construction of Cheonggye Elevated Highway started in 1967 and was completed in 1976. It was four-lane two-way highway. Before the highway was dismantled, daily traffic volume was 168556 vehicles, with 65,810 on Cheonggye Road and remaining 102,747 on Cheonggye Elevated Highway. The structural components of Cheonggye Elevated Highway needed repair. Due to pollution in the stream even after the repair, the long-term stability of the structures could not be ensured. It was one of the reasons for Cheonggyecheon Restoration Project. The basic reasons for restoration project are to transform Seoul into a human-oriented and environment friendly city. The restoration project recovered artifacts of historic heritage and restored the pride of Korean people in their 600-year-old city.

The Cheonggyecheon Restoration Project started in 2003 with the demolition of Cheonggye Elevated Highway and structures covering the Cheonggyecheon stream. A total of 680,000 tonnes of waste were generated during the demolition work. Of this 100% of the scrap iron was recycled and 640,000 tonnes or 95% of the waste concrete and waste asphalt was reused.

The Cheonggyecheon was restored as an "urban stream in nature", a human oriented, environment friendly urban space with a waterfront and walks along the bank. It is most desirable for stream to receive water from its upper reaches. However, Cheonggyecheon is an intermittent stream i.e. it is normally dry and therefore requires additional flow to maintain certain depth of water throughout the year. The water for the restored Cheonggyecheon came from the Han River. The waterfront is planted with wide plants that grow well along bodies of water to create natural scenery. At the downstream section where Cheonggyecheon and Jungnangcheon streams join, a swamp and habitat for fish and birds are created so that nature and city can co-exist.

c) Individual property owners cover the roadside drains for access from the approach road. This phenomenon is more common in commercial areas where the land value is higher and the shopkeepers encroach upon drains for keeping the items of sale outside of their shop. This is the most common type of covering of drain. This can be permitted by allowing the covering of drain only in front of the entrance for access/approach to the road but the drain should not be covered all along the plot boundary.

v) Growth of plants in Drains

During non-monsoon period the drains have little or no water. However it has more moisture and also retains it for longer duration due to more organic content in the soil of drain. Further, even during small showers the nallah bed gets some water. It retains the moisture and this makes suitable conditions for growth of plants and vegetation. (Fig. 8.2 & 8.3). The grass and plants need to be regularly removed to maintain the carrying

Figure 8-2 Growth of grass in drain

vi) Silting of Drains

During the rain the velocity of water is high. This high speed flowing water washes the earth and carries with it soil, leaves, wood logs, dead bodies etc. The soil carrying capacity of water decreases with the reduction in velocity of water. After reduction in velocity of water, floodwater leaves behind this material in the drain. This reduces the carrying capacity of Drain. And to carry the same quantity of water wider drain is required. Otherwise the water spread (flooding) takes place. To maintain the same carrying capacity in a limited width, the drain need to be cleaned periodically.

Figure 8-3 Growth of grass & plant in drain

8.2.5 Pollution in Drainage System

The purpose of drains is to provide a safe passage to the water accumulated due to rainfall. The water of first few rains becomes acidic after absorbing sulphur dioxide and nitrogen oxides present in the atmosphere. Otherwise, rest of the time the rain water is pure but while being carried in drains it gets polluted due to human intervention like dumping of garbage, mixing of sewage, intrusion of industrial affluent etc. The reasons for pollution of drains are discussed subsequent paragraphs.

(i) Mixing of Sewage and Drainage

Storm water drainage is meant to carry storm water (rain water) or any other clean surface water. It is fundamentally neither suitable nor designed for carrying sewage or industrial wastewater or even septic tank effluent. Even the effluent from the sewage treatment plant cannot be discharged into drain unless it meets the norms set by the Bureau of Indian Standards (BIS) code and the Central Pollution Control Board. In urban areas it is desirable to have separate system for carrying the sewage and storm water. In accordance with this principle in cities, the drainage and sewerage systems are provided separately. The problem arises due to blockage in sewerage system resulting the back flow in houses and in nearby areas. In order to avoid back flow and immediate relief is given by puncturing the sewerage line and diverting the sewage to nearby drains. Thus in urban areas the drains also serves as a substitute to sewerage system, for which the drains are not designed. The raw sewage mixed with storm water directly flow to the major drains and ultimately to the rivers cause serious water pollution in rivers which are the major source of drinking water of supply effects the aquatic life. There is a need to plan and construct separate sewerage and drainage system and necessary measures may be taken so that sewage are not punctured during floods and drained into the drains.

In some cases, reverse conditions have been observed where drains are connected to sewer lines and the storm water runoff which is not required to be treated by the Sewage Treatment Plants (STP) find its way to STP resulting in increase the volume of waste water for treatment. The STPs are designed for certain capacity for the treatment of sewage only but the quantity of storm water runoff mixed with sewage becomes very high leading to overflowing of the STPs.

(ii) Disposal of Untreated Sewage in Drains

In some cities Sewage Treatment Plants have been constructed to treat the sewage and to discharge the treated effluent in the drains. However, the untreated sewage finds its way into drains. During the site visit,it was observed that the sewer lines were punctured before entering into the compound of the STP and the untreated sewage was allowed to flow in the drains (Fig.8.4 & 8.5).

It was also found that the STP was constructed under the Yamuna Action Plan but was not in operational condition due to lack of funds as no provision or budgetary assistance for operation and maintenance.

The purpose of constructing the STPs for the treatment of sewage is defeated as the raw sewage is being discharged into the drain leading to Yamuna River. It is necessary that viability of operation and maintenance of STP is also evaluated at the stage of project formulation and budgetary provisions for operation and maintenance of STP may be considered at the proposal stage.

Figure 8-4 Sewage Flowing into Drain

iii) Disposal of Industrial Effluent in Drains

It has been observed that several industries divert their highly toxic effluent to the drains. The urban drains which are unfit to carry even domestic sewage are loaded with highly toxic industrial waste. These industrial wastes need special attention for treatment. The nature of the industrial wastes is different in character and a special chemical treatment is required depending upon type of the industry and the wastes.

In Panipat areas it was found that the industries store the effluent in underground tanks and dispose it off in the drains through tankers at convenient hours (Fig. 8.6), some of the industrial units inject the effluent directly into the ground, which leads to serious environmental pollution. The practice of discharging untreated industrial effluents into the drains and open ground need to be checked immediately on priority. There is an urgent need to construct Common Effluent Treatment Plant (CETP) and discharge the industrial effluents into the drains only after treatment. The treatment of the industrial waste is costly and may not be economically viable for individual industries. The cluster of industries may form an Association and carry out collection, conveyance and treatment of their industrial effluents in CETP.

Figure 8-5 Disposal of Untreated Industrial Waste in drain

iv) Dumping of Garbage and Malba

Improper disposal of solid wastes, and dumping of construction debris into the storm water also contributes significantly to reduction of capacity of the storm water drain.

This includes domestic solid waste, commercial and industrial waste, street sweepings and construction debris etc. (Fig. - 8.7). In rural area also agriculture waste, cow dung and other waste material is dumped into the drain especially during the non-monsoon period. The solid waste dumped into the drains blocks the flow of storm water and causes stagnation or flooding on the upstream side or spreading of water locally in the vicinity. Further, due to decomposition of the biodegradable material the foul smell deteriorates the environment and causes breeding of mosquitoes and water borne diseases. It has also been noticed that locally collected garbage is dumped near to cross drainage works of roads (Fig.8.8). There is an urgent need to protect the drainage system from dumping solid wastes.

Figure 8-6 Garbage dumping in Nallah

Figure 8-7 Garbage dumping - Blockage of cross drainage

v) Open Defecation, Disposal of Dead Bodies

In rural areas people do not have access to safe sanitation and in urban areas particularly in unauthorized colonies and squatter settlements people defecate along the drains in open area. In most of the cities, the removal of night soil by head loads is in practice and this finds its place directly into the nearby drains causing pollution.

In addition to above, water bodies and rivers are also used for disposal of human dead bodies, domestic and stray animals. In absence of aquatic animals who used to consume the dead bodies, the dead bodies thrown into the lakes and rivers do not get consumed and they decompose and cause more pollution.

vi) Pollution due to Vehicles

Water running off impervious motor-able surfaces tends to pick up leaked/spill over petrol or diesel, motor oil, heavy metals, and other pollutants from roadways. Roads and parking lots are major sources of polycyclic aromatic hydrocarbons (PAHs) pollution, which are created as combustion by products of gasoline and other fossil fuels, as well as pollution of the heavy metals e.g. nickel, copper, zinc, cadmium, and lead. Auto Garages and repair stations are also the sources of this kind of pollution.

vii) Pollution due to Fertilizers and Pesticides

The storm water runoff while flowing in lawns, nurseries, parks and agricultural fields picks up fertilizers and pesticides. Fertilizer and pesticides used on residential lawns, parks and golf courses and in agricultural fields is a significant source of nitrates and phosphorus pollutants in rivers and drains.

8.2.6 Operation and Maintenance of Drains

Proper Operations and Maintenance (O&M) are crucial for any system to be functional to the designed capacity and for its durability. Most of the storm water drainage and sewerage systems suffer to a great extent due to lack of proper and regular O&M. This equally affects both the major and the minor storm water systems. This has been discussed in detail below:

i) Pre-Monsoon De-Silting

It has been generally observed pre-monsoon de-silting does not commence and get completed on time and as such even the designed capacities are not operational. As a result of this, even lower intensity of rainfall results in flooding. Major drains and nallahs were originally waterways for rainwater to flow. However, due to large-scale urbanization and lack of required sewerage systems in place, sewage started getting discharged into these drains and nallahs.

ii) Removal of Sediment

Sediment is present on all urban catchment surfaces and much of this material finds its way into the drainage system. The amount of sediments that enters into the drainage system is limited by the degree of street sweeping and the effectiveness of the inlet catch basins or gully pots and their cleaning regime. Management of such sediment is rarely carried out, by the ULBs. In developing countries with larger amounts of sediment and weaker urban management systems, the extent and magnitude of sediment in the drainage system can have a significant impact on its performance. As with solid waste, sediments also greatly reduce flows. The duration of local flooding increases proportionately, with the extent to which the cross-section of the channel was filled with sediment. In many cases, the operational practices are poor, as clearing up drains is not done from the outlet end particularly in minor drains resulting in very little net benefit.

Due to non-availability of adequate flows in the minor drainage systems, frequent deposit of sediments occurs and it ultimately results in the loss of capacity to accommodate the flows during high intensity monsoon rainfall, thus compounding the existing situation, which is far from being satisfactory.

Lack of preventive maintenance of minor drains and sewerage systems is also very commonly observed. In some cities, some underground drains are over 100 years old and are now susceptible to collapse because of age and increased burden due to traffic load.

iii) Draining Storm water through Pumping

In a developed urban area, storm water from the low level lands surrounded by high-level lands are drained through pumping. Though technically it is feasible but practically it has not been found successful due to its high maintenance cost operational problems.

Pumps are used during heavy rainfall which occurs few days in a year whereas a pump has to be maintained in working conditions throughout the year. In the event of heavy rains and flooding, failure of electricity supply is very common and pump has to be operated through electric generator. An electric generator has to be kept stand by which add to the maintenance cost. During floods due to heavy rains the accessibility to the pump site may be difficult due to submergence of the approach road.

8.2.7 Institutional Issues

The drainage was considered a phenomenon of draining the rainwater to avoid the flooding and Irrigation Departments of the State Governments were responsible for the construction and maintenance of the storm water drains. The ownership of nallah land lies with this department. Even in the initial phase of urbanization the responsibility for development, construction and maintenance of urban drainage system was also with Irrigation Department. After the emergence of local bodies the small urban drains were designed to carry the storm water runoff from residential colonies and these drains were connected to the existing natural drains. The local bodies became responsible for the drains constructed by them and also discharging the responsibility for the cleaning and garbage removal from drains falling in urban area. Even though the ownership of the drain may be with the Irrigation Department, the responsibility of maintenance and cleaning rested with local body. Subsequently, the Urban Development Authorities were created to supply the developed land for urban use/activities at a faster pace. Storm water drains were also constructed in the area developed by the Development Authorities and these drains mostly outfall in the storm water drains maintained by Local Authority / Irrigation Department. There are also industrial towns developed by agencies i.e. National Thermal Power Corporation, Nuclear Power Corporation of India Ltd., who maintain their own drainage system within their township and mostly these drains outfall into the major drains of the area. The Cantonment Boards also construct and maintain storm water drains in the Cantonment areas. Thus there are several agencies involved in the handling of drainage of a region. In urban areas the agencies responsible for design, construction, maintenance the urban drainage system vary from State to State**.** The Departments/ Local Authorities/Agencies involved in design, construction and maintenance of drainage system in NCR are discussed below:

i) Haryana Sub-Region

In Haryana Sub-Region, the ownership of urban drains is with Public Health Engineering Department (PHED) and it is responsible for construction of new drains and widening of existing storm water drains and the ULBs are responsible for maintenance of storm water drains. Further, Haryana Urban Development Authority (HUDA), a State level agency maintains drains in areas developed by them. Similarly, Haryana State Industrial & Infrastructure Development Corporation (HSIIDC) is responsible for design, construction and maintenance of drains in their respective areas.

ii) U.P. Sub-Region

In U.P. Sub-Region, in municipal area, the construction of drains is carried out by UP Jal Nigam on deposit basis due to non-availability of technical manpower in ULB and the cost of construction is borne by ULBs. After construction of the storm water drains, maintenance work is carried out by ULBs. Wherever the Urban Development Authorities exist, the storm water drains in their area are constructed and maintained by Development Authorities till the developed area is handed over to the ULB for maintenance. Further, in UP, Housing Boards also develop colonies and Drainage System in the residential colonies are constructed by Housing Board and the maintenance is carried out by ULB after handing over of the area to the ULBs.

iii) Rajasthan Sub-Region

In the Rajasthan Sub-region, originally Public Health Engineering Department undertakes the construction and maintenance of the drainage system. Presently, the local bodies i.e. Municipality in Urban Area and Panchayat in rural areas are responsible for the maintenance of drainage system. In the industrial estates developed by Rajasthan State Industrial Development & Investment Corporation Ltd. (RIICO), the drains are constructed and maintained by RIICO.

iv) NCT-Delhi

The Irrigation and Flood Control Department, Govt. of NCT Delhi is overall responsible for drainage management in Delhi. The responsibility of construction and maintenance of the large drains (natural) is with this department. However, de-silting and disposal of the silt removed from drains is the responsibility of the respective local bodies, under whose jurisdiction the drain falls. Delhi Jal Board looks after drains with more than 1,000 cusec discharge. The Public Works Department, Government of NCT Delhi is responsible for the drains in identified pockets. The three Local Bodies – Municipal Corporation of Delhi, New Delhi Municipal Council and Delhi Cantonment Board – have the mandate to look after construction and maintenance of the drains in their respective areas.

It is observed that each NCR participating State has its own institutional arrangement for handling drainage system. There are multiple departments/agencies responsible for drainage management in urban areas. As there are several agencies there is lack of coordination in management in the drainage system.

v) Poor Maintenance of Drains

The drains need to be cleaned before the monsoon season to remove garbage, silt, malba and other materials, which creep into the drain during the year when there was no flow. During the no flow situation the growth of grass and plants takes place in the drain, which increases the friction co-efficient and reduces the capacity of the drain. To keep the drain in working condition regular maintenance and cleaning is required. As the heavy rain takes place in monsoon generally the cleaning of drains is completed before arrival of the monsoon to avoid flooding of the city and cramping the urban life in the first shower itself. Generally, the local body is the agency responsible for maintenance of drains and the annual cleaning has to be undertaken by them. The general observation is that the annual maintenance is not completed in time. Further the material removed from the drain is kept near the drain similarly the material removed from roadside drain is kept along roadside for several days. The foul smell and filthy look spreading in the locality makes the life miserable. After cleaning nala the removed material should be shifted to the disposal site immediately or at the most on the same day.

vi) Non Availability of Trained manpower in ULBs

The Agencies responsible (ULBs) for looking after the drains lack in trained manpower for construction and maintenance. Instead of strengthening the local bodies, the State Governments have taken different approach and the work for construction of drains are entrusted to different agencies, often due to shortage of manpower in the ULBs. For example, in Haryana, the construction of drains is done by Irrigation Department and similarly, UP Jal Nigam undertakes the work of construction of drains in UP. The responsibility of regular maintenance of drains remains with ULBs, which do not have trained manpower. This needs to be addressed.

vii) Non-Availability of Equipment

In addition to non-availability of trained manpower the ULBs, i.e. agency responsible for cleaning the drains, also do not have proper machineries and equipments to handle the work efficiently. The age-old method of manual garbage removal is adopted by the ULBs. There is a need to adopt latest mechanical method of garbage removal/cleaning to improve the maintenance of the drains.

viii) Resource Crunch in ULBs

Due to poor financial health of ULBs, the maintenance and cleaning of drainage system are seriously affected in the cities and towns. There is a need to provide adequate funds to the ULBs for regular maintenance and cleaning of drainage system in order to improve the drainage system so as to prevent loss of human life, property and agriculture land which is more than the cost of cleaning the drainage system.

8.2.8 Existing Approach

So far the efforts have been to provide a safe passage to the storm water up to nearby natural stream. In rural area whenever flooding takes place a view is taken about the carrying capacity of the existing drains and if required the widening/deepening or construction of new drains are undertaken to flush the floodwater in the river. In urban area a general engineering approach has been adopted by constructing the drains, cleaning it annually and allowing the storm water to join the natural stream/river.

The poor sanitation in Indian cities is a major hurdle in proper drainage system. Even in Delhi, the Capital of India, there are patches, where the removal of night soil is by head loads. This finds its place directly into nearby drain. And unless this problem is attended, the clean drainage system will remain as a dream. In our cities, wherever possible, the separate system has been provided. Sewer lines have been laid for disposal of sewage and surface water run-off is to be collected in drains and disposed of separately in existing natural streams. However, the problem occurs due to mixing of sewage and storm water. On noticing that Realising that rivers got polluted due to disposal of untreated sewage, in the past, several efforts have been made to treat the sewage in Sewage Treatment Plants before disposal. This centralized approach of collection, conveyance and treatment of sewage has not been successful due to various problems e.g. diversion of sewage into storm water drains, releasing of treated waste into drains where it mixes with untreated waste to finally flow into the river. An innovative approach require to be adopted to overcome this issue.

i) Inadequate Water for Dilution

Conventionally, the urban areas developed along major rivers. The city drains used to outfall in the river. Owing to the high volume of water being carried by the river, the effluent being discharged by the nallah used to get diluted and it was easily treated by the natural carrying capacity of the river water. Due to diversion of water and extensive use of water for irrigation upstream and the rivers downstream do not have adequate fresh water. For example, there are several drains in Delhi carrying untreated sewage and out falling into Yamuna River, which enters Delhi with no flow situation. In other words, Yamuna River, in the downstream of NCT Delhi carries whatever is disposed of by Delhi i.e. treated or untreated sewage. River has no fresh water for dilution of the wastewater discharged into the river. As there is no fresh water, the dilution does not take place, river's self-cleaning system is not able to cope up and the effluent being carried by the river. This has adverse impact on the downstream side. It signifies that all the domestic sewage and industrial wastes be treated before disposal into the river.

ii) Treatment before Disposal

The approach adopted so far has been centralized treatment and then disposal. Currently the attempt is to collect the sewage in the sewerage system, convey it to the treatment plant and dispose of the treated effluent into the stream. Though this approach has inbuilt flaw but it can be applied only to a city which has 100% coverage by sewerage system. None of the Indian cities have 100% coverage by sewerage system. In absence of 100% coverage by sewerage system, the approach of treatment before disposal is not successful because the drains are also carrying sewage which outfall in the river discharging untreated sewage.

iii) Centralized Treatment of Sewage

The Sewage Treatment Plants are normally located outside the city and whole sewage of the city has to be transported to the site of STP for treatment and thereafter the treated wastewater is disposed of into the river/drains. There is a need to treat the sewage locally and use the treated water for non-drinking purposes i.e. in gardening, horticulture, A.C. plants, cooling towers of the power plants etc. Micro Sewage Treatment Plants can be constructed throughout the city to treat and use the treated water locally. This will reduce the sewage conveyance cost and also ensure recycling of water.

iv) Need for Change in Technology

The sewerage system as sewage disposal technology was developed almost two centuries ago in Europe after industrialization. The same technology is being used without much improvement in technology which needs improvement.

8.2.9 Recent Initiatives

Delhi Jal Board has come up with a proposal of Interceptor Sewer. Interceptor sewers are large sewer lines that, in a combined system, control the flow of sewage to the STP. In a storm, they allow part of the sewage to flow directly into receiving stream, thus keeping it from overflowing onto the streets. Also used in separate systems to collect the flows from main and trunk sewers and carry them to STPs. The project is under consideration for approval by Government.

The success of Interceptor sewer has to be viewed in detail. Interceptor Sewer has been conceptualized and it is under implementation in Ahmedabad by Government of Gujarat. A brief of the project is given below:

> *In Ahmedabad, Sabarmati River flows through the city. There is development on either side of the river. Also* there *are some unauthorized colonies along the river. There are several sewage carrying small drains joining the river. Government of Gujarat is*

constructing Interceptor Sewer along Sabarmati River to arrest the untreated flow. It will collect the untreated sewage and surface run off from adjoining area, which would have joined the stream otherwise. This collection will be treated before disposal into the river. In case of heavy rainfall the surface run off will be heavy and it will overflow directly into the stream. Since there is limited rainfall in Ahmedabad, the phenomenon of overflowing is likely to occur seldom and with this assumption the project has been sanctioned.

8.2.10 Service Level Benchmarks

As part of the ongoing endeavour to facilitate critical reforms in the urban sector, the Ministry of Urban Development, Govt. of India has adopted National Benchmarks in four key sectors, namely, Water Supply, Sewerage, Solid Waste Management and Storm Water Drainage. Investments in urban infrastructure have, however, not always resulted in corresponding improvements in levels of service delivery. There is, therefore, a need for a shift in focus towards service delivery. The Handbook of Service Level Benchmarking developed and published by the Ministry of Urban Development, Govt. of India provides a standardized framework for performance monitoring in respect to water supply, sewerage, solid waste management and storm water drainage, and would enable State level agencies and local level service providers to initiate a process of assessment of the existing level of service delivery, performance monitoring and evaluation against agreed targets, finally resulting in the achievement of service level benchmarks identified in the Handbook. The Ministry of Urban Development would facilitate the adoption of these benchmarks through its various schemes and would also provide appropriate support to municipalities that move towards the adoption of these benchmarks.

8.3 Recommendations

Regional Plan-2021 has proposed that different areas in NCR, which are liable to flooding in rivers of return period of 5, 10, 25, 50 and 100 years, need to be identified on map for land use zoning at regional and Sub-regional levels. Participating States should prepare detailed Contour Maps for their respective Sub-regions on a scale of 1:15,000 at a contour interval of 0.3 to 0.5 meter and mark areas that are flood prone.

8.3.1 Preparation of Master Plan of Inter-state Drainage Basins

The Study Group has identified about 11 major inter-state regional drains between Delhi & Haryana, Delhi & UP and Haryana & Rajasthan. While designing the drains, it is necessary to maintain the slope of the drains to allow continuous flow in the drains by gravity and to avoid back flow. Considering the invert level of the final disposal point and slope of the drain, intermediate invert levels are decided. In view of this, integrated planning of regional drains in the NCR has to be carried out well in advance to fix the invert levels of the drains. The concept of Master Plan for Drainage basin should be adopted. It would be important to prepare the Master Plan for Drainage for a drainage basin or sub-basin and integrate it with higher order Drainage Basin Plans. Master Plan for Drainage for a drainage basins be prepared keeping in view the existing population, developments & land uses and also how the basin is proposed to be developed, its proposed population & land uses, The Plan should include L-section, invert levels, carrying capacity and width of the channels, cross section, land requirement and maintenance schedule. The land requirement should be made available to the Departments/Urban Development Authorities/Agencies responsible for reservation of the land (i.e. Town and Country Planning Departments in case of Haryana).

Master Plan for Inter -state Drainage Basins to be prepared jointly as a single project by the concerned State governments and their Departments/Agencies, River Basin Organization, and Scientific Institutions**.** However, construction could be taken up by the concerned State Governments/Agencies of the district/state maintaining the designed invert levels.

8.3.2 Preparation of Master Plan for Drainage for Towns/cities

Rainfall and runoff processes are natural phenomena and do not follow the administrative boundaries of states, districts /cities and ULBs and depend on watershed boundary. The outline of the drainage divide (a ridge or highland dividing two areas that are drained by different rivers or water bodies) follow the actual watershed boundary rather than administrative boundary. A watershed is a geographic region within which water drains into a stream, river or a lake. The watershed may be composed of several sub-watersheds and catchments. The catchment is the area draining surface water to a particular location or outlet point. Therefore, in order to ensure planned development of a city/town, Master Plan for Drainage should be prepared, after incorporating/addressing the aspects such as identification and delineation of watersheds, sub-watersheds and catchment areas at notified planning area level and analysis of their slope and fluvial characteristics. The following should be considered while preparing Master Plan for drainage for a city/town:

a) Master Plan for drainage of a town/city should be prepared within the framework of Master Plan for Regional Drainage within which it falls.
b) The catchment area should be the basis for planning and designing the storm water drainage system in all urban areas of NCR
c) Master Plan for Drainage should also include actionable items such as removal of encroachments; beautification of river banks, land alongside natural and man-made drains and other watercourses; banning/restrictions of undesirable activities; sewage collection, diversion, pumping, treatment, storage, transport, reuse of treated sewage and sludge etc.
d) Master Plan for Drainage should be prepared for towns and cities by the concerned State Government /Departments/ Agencies in close collaboration with Urban Local Bodies, Urban Development Authorities, River Basin Organization, and Scientific Institutions in a time bound manner. Master Plan for Drainage to be prepared for all class I towns of NCR in the first Phase.

8.3.3 Parameters for Design of Storm Water Drain

Rational Method for designing of urban drainage as given in paragraph 5.3.3 is recommended to be continued. However, the basic parameters should be as follows:

i) The basis for design of drainage system should be catchment area and not administrative boundaries.
ii) Rational method is applicable to maximum 80 ha. area only. For designing larger area, it should be divided into smaller units each having area less than 80 ha.
iii) Considering thunderstorms in NCR the rainfall intensity should not be less than 60mm/hr.
iv) Runoff coefficient should be 0.95 as suggested in National Disaster Management Guidelines prepared by NDMA, Govt. of India and which should be suitably adjusted by a reduction factor to be adopted based on local conditions and proposed land uses in the Master /Development Plans.

8.3.4 Buffer Along/Around Water Bodies

Expert Committee constituted by Ministry of Home Affairs, GOI had proposed amendments to Rules and Bylaws, relating to Layout approvals and Building Permissions, to address disaster management issues. The following recommendations of the Expert Committee relating to restrictions of building activity in the vicinity of areas may be adopted which will help in conservation of water bodies and prevent them from pollution:

The water bodies and watercourses be maintained as recreational/green buffer zone and no building activity other than recreational use be carried out within;

i) 100 m from the river edge outside Municipal Corporation /Municipal limits and 50 m within Municipal Corporation /Municipal limits. No permanent construction be permitted within the buffer zone.
ii) 50 m. from the boundary of lakes of surface area for 10 ha. and above,
iii) 30 m. from the boundary of lakes of an area of less than 10 ha/ponds/tank bed lands.
iv) 12 m. from boundary of major canal, streams nallahs, canals, etc.

8.3.5 Protection of Natural Drainage System

i) The natural drainage system has evolved with span of time taking the contours of the general slope of the terrain and ultimately meeting the river / streams within the sub- basin. It should be protected from all kind of encroachments, obstructions, garbage, etc.
ii) Encroachments on nallahs/drains/watercourses be removed
iii) In order to protect the natural drainage system, the nallahs/drains/water courses/flood plains should be delineated and boundaries fixed in new developments.
iv) The Master/Development/Zonal/Area Level Plans should provide concrete measures to protect the natural drainage system by means of proposing the finished/permissible levels

of developmental activities as well as incorporating suitable regulations in these Plans and/or Building Bye Laws and Development Control Regulations for maintaining the proposed finished levels.

8.3.6 Protection of Land for Drainage System

It has been observed that in regional drains and bigger drains in the cities, the landowners on either side of the drain encroach upon the drainage land and start activities like agriculture or construct houses in urban and rural areas. This restricts the accessibility of drains for cleaning, flow in the drain and also hinders widening of drains. There is a need for strict enforcement to check encroachment.

8.3.7 Promotion of recreational use on land along nallah

The land alongside nallahs should be developed for recreational use as public open space i.e. gardens, parks, playgrounds etc. which can be used for jogging, morning walk, etc. The development of the land alongside the nallahs would prevent encroachments and misuse. The treated effluent can be used for maintenance of greenery.

8.3.8 Reservation of land for Adequate Width for Drains

Run off coefficient increases with increase in impervious surface. Development/concretisation of urban areas increases the impervious surface and hence the run off coefficient increases. The low-lying land where the water used to accumulate also gets reduced due to land filling for the urban use/construction. This effectively increases the amount of surface run off and requires increase in the section of drains/widening of drains. In addition to this, heavy machines such as JCB, bulldozers, dumper used for regular cleaning of the drains requires space near the drains. Urbanization is resulting in encroachment to such spaces and a care should be taken to ensure feasibility that this space is not encroached and accordingly necessary provisions should be incorporated in the Master/Development Plans and Zonal/Sector Plans for urban areas and in revenue records in rural areas.

8.3.9 Construction of Roads to Start from Edge

It has been observed that even if adequate right of way (ROW) is provided for proposed roads in the Development Plan, the land is not available at the time of construction/widening of roads. At the initial stage of development, road space requirement is less, therefore, construction of roads is undertaken in parts and generally it is constructed in the centre of ROW. Accordingly, the median, carriageway and drains are developed. Major part of the ROW of the road is left unused on either side of the roads. Drains and footpaths are dismantled and reconstructed at the time of widening of the roads. This increases the cost of construction and impounding of water takes place on roads when the drain is being reconstructed. Many times the land on either side of the road kept for expansion is encroached and it becomes difficult to retrieve this land. It creates congestion on the roads. This problem can be addressed by starting the construction of the road from edge and outermost part of the road is developed first by constructing footpath, service road, drain and carriageway depending upon the requirement and land for widening of the road is left in the center merged with median. The road can be widened towards the median depending upon the requirement (Annexure 8.1). This will help in reducing the multiple expenses of constructing and re-constructing drains and footpaths along the roads on one side and appropriate slopes in the drains would be maintained as per Drainage Master Plan based on invert levels.

8.3.10 Regulation for Covering of Drain

In urban areas drains run along the roads and public is allowed to cover drains in front of their entrances for access from roads. It has been observed that the drains are covered along the property boundary especially in the commercial property. This results into covering of drains for a longer distance and cleaning becomes difficult which ultimately leads to blockage of drain and flooding on roads. A standard design for the drain for removable cover at regular interval should be incorporated in building byelaws so that the above problem can be avoided. It should be checked by the agency while granting building permission or at the time of providing occupancy certificate. A provision for recovering the demolition costs from the property owners, if any, should be integral part of Bye laws.

It is recommended that the practice of covering the drains for construction of roads should be stopped. Even the bridge/elevated road running over the drain along the alignment of the drain should also be discouraged as pillars obstruct the flow and movement of cleaning machines/ equipment's.

8.3.11 Construction of Bridge over Drains

Where it is unavoidable and when all other options are exhausted, construction of Bridges over drains should be permitted. However, efforts should be made that the construction be undertaken by the agency responsible for its maintenance, after taking into account the L - section and discharge capacity of the drain. The process of issuing No Objection Certificate (NOC) should be discouraged as the other Departments/agencies after getting NOC do not pay sufficient attention to the invert level and discharge capacity. Once the bridge is constructed it becomes difficult to rectify the fault/drawbacks. The practice of bridge construction by RCC Hume pipes should also be discouraged as it also reduces the effective cross sectional area of the drain.

8.3.12 Micro Treatment Plants (Decentralised Treatment and Reuse)

The traditional approach of conveying the sewage to a long distance and then treat it only to dispose of in the stream, does not find priority among Urban Local bodies as it hardly have any financial, economic and scenic importance to them. It is recommended that sewage is treated locally and the treated effluent is utilized for non- drinking purposes e.g. horticulture, gardening, car wash, air conditioning plants, etc. or it can be disposed of in drains.

8.3.13 Segregation of sewage and drainage

The major problem of urban drainage is mixing of sewage with storm water and discharge into the drains. The storm water drains are neither designed nor supposed to carry the sewage. The urban area should have separate sewerage and drainage network. It is recommended that separate drainage and sewerage system be planned and constructed and necessary measures to be taken so that sewage is not mixed with storm water drains during floods.

8.3.14 Treated waste water to flow in rivers, drains and water bodies

Sewage should be treated in the Sewage Treatment Plants to a desired level as specified by Central Pollution Control Board, MoEFCC, Government of India and then only treated sewage effluent should be discharged in the drains. There should be a provision of penalty for agencies discharging un-treated sewage in the rivers, drains and water bodies.

8.3.15 Cleaning of Sewerage System

It has been observed that in case of blockage or crown collapse of the sewers, sewage is diverted to nearby drains. In view of this, it is recommended that agency should clean the sewerage system using modern machines i.e. Jetting-cum-suction machines. Age-old method of using rope-cum-bucket machine for cleaning of sewerage systems should be discontinued immediately as it damages the skin of sewers, which is one of the main causes of subsidence of sewers.

8.3.16 Treatment of Industrial wastes in CETP

The characteristics of industrial wastes are very different from domestic wastes. Industrial wastes are highly toxic and acidic compared to the domestic wastes. Treatment of industrial waste requires more efforts and the technology of treatment depends upon the type of industry and its wastes.

It is desirable that the industrial wastes are treated separately. If there are several industries, a Common Effluent Treatment Plant (CETP) could be developed to discharge industrial effluents into the drains only after treatment.

8.3.17 Disposal of Industrial Effluent in Drains

The practice of discharging untreated industrial effluents into the drains and open ground need to be checked immediately on priority. Common Effluent Treatment Plant (CETP) may be constructed and the industrial effluents be discharged into the drains only after treatment. The cluster of industries may join together as an Association and carry out collection, conveyance and treatment of their industrial effluence in CETP.

8.3.18 Regular Maintenance (cleaning) of Drainage System

The authorities responsible for maintenance of drainage system should prepare a cleaning schedule which should be adhered to. The annual maintenance of drains being carried out before monsoon is very important and be completed before arrival of monsoon. The work should be started well in advance to ensure its completion in time. Since this work is repetitive in nature the standard tender document may be prepared and kept ready to save time. It is desirable that the following schedule is adhered to:

a) Pre-monsoon de-silting of all major drains will be completed by March end each year,
b) Besides the pre-monsoon de-silting of drains, the periodicity of cleaning drains should be worked out, based on the local conditions. The Roster of cleaning of such drains should be worked out and strictly followed,
c) All wastes removed both from the major and the minor drains should not be allowed to remain outside the drain for drying, instead the wet silt should be deposited into a seamless container and transported as soon as it is taken out from the drain. In exceptional cases, the silt may be allowed to dry for about 4 to 24 hours outside the drain before transporting the semi-solid silt for disposal,
d) Completion of work will be certified by representatives of local Residents' Welfare Associations (RWAs)/ Slum Dwellers Associations (SDAs) / Municipal Ward Committee members and Area Sabha members besides third party certification. An appropriate mechanism will be evolved to ensure this,
e) The Manual on Solid Waste brought out by the CPHEEO, MoUD, (2000) should be followed in cleaning shallow surface drains,
f) The amount of solid waste generated varies from catchment to catchment and depends on the type of locality, population, their affluence, etc. Suitable interventions in the drainage system like traps, trash racks can reduce the amount of solid waste going into the storm sewers. Due consideration should be given to internationally available technology for removal of solid waste from storm water drains.
g) De-silting of minor drains will be carried out as part of a regular preventive maintenance schedule. The catchment will be the basis for planning this, as a part of the watershed desilting master plan. Cleaning of minor drains should be taken up from the outfall to upstream side.
h) Ageing systems should be replaced on an urgent and regular basis,
i) Sewerage Master Plan should be prepared to improve the coverage of the sewerage system so that sewage is not discharged into storm water drains, and
j) Adequate budget will be provided to take care of the men, material, equipment and machinery. Special funds should be provided for the safety equipment of the personnel carrying out maintenance of underground man-entry sewers.

8.3.19 Blending of Traditional Approach with Modern Technology

The modern approach is based on the principle of draining storm water within a possible shortest time whereas the traditional approach was to maximize infiltration of rain water and storage. There is a need for blending the traditional approach with modern technology. The concept of "retain the rain water where it is received" need to be embedded in the planning and design of drainage system. With the increase in built-up areas due to urbanization/constructions, impervious areas has been increasing resulting in reduction in the rate of infiltration and consequently rapid increase in surface runoff and flooding. Attempt should be made to utilize the existing rain management facilities and retain the water wherever possible such as roadside, parking lots, houses, buildings, parks etc. A few of the examples of rain management facilities such as ponds, roof top gardens, rain gardens and grassed waterways are given in the Annexure. 8.2 and 8.3.

8.3.20 Development of Rain Gardens

Urban areas have impervious surfaces like roofs, walkways, and compacted lawn areas etc. The impervious cover in a typical city creates five times the runoff than typical vegetated area of the same size. An attempt should be made to provide pervious / porous surface around or near to impervious surfaces to enable the trapping of rainwater to reduce the surface run off. This can be achieved by providing rain gardens.

A rain garden is a porous planted depression that allows rainwater runoff from impervious surfaces to be absorbed. It provides for natural infiltration of rainwater into the soil, reduces peak storm flows, helping to prevent stream bank erosion and lowering for local flooding. (As opposed to flowing into storm drains and surface waters which causes erosion, water pollution, flooding, and diminished groundwater). Rain gardens (Fig. 8.9) can reduce the amount of pollution reaching creeks and streams by up to 30%.

Figure 8-8: Rain Garden along Pavement

The concept of Rain Gardens be incorporated in planning for public parks and on-site storm water management for larger residential areas and should form part of the Lay Out plans / Sectors/ zonal plans. Native plants are recommended for rain gardens because they generally don't require fertilizer and are more tolerant of one’s local climate, soil, and water conditions. The plants - a selection of wetland edge vegetation, such as wildflowers, sedges, rushes, ferns, shrubs and small trees - take up excess water flowing into the rain garden. Water filters through soil layers. Root systems enhance infiltration, moisture redistribution, and diverse microbial populations involved in bio filtration.

8.3.21 Rain Water Harvesting

The draft Functional Plan on Water for NCR has estimated that on an average, 6112 MCM/ year of water is lost (un-used) as surface runoff from NCR and has recommended to harvest the same by increasing recharge from the basins through various techniques such as placing recharge structures over drains, recharge trenches/wells, harvesting using lakes & ponds, etc. by increasing the run off time to recharge ground water which is natural way of recharging or induced recharge through various techniques such as revival/ recharge through lakes/ ponds, roof top rain water harvesting, etc. elaborated in the. Plan. It has also proposed to amend municipal acts, building bye-laws and other relevant provisions to promote rain water harvesting by all multi-storeyed complexes, commercial buildings and group housing societies and to maintain them for efficient recharge. The proposals for Rain water harvesting should be adopted.

8.3.22 Recycling

The fresh water resources are limited and efforts are required to be made to use recycled domestic effluents for non-domestic use such as irrigation, watering of lawns, car washing, cooling in power plants, A.C. plants, etc.

8.3.23 Project formulation

NCR participating State Governments/Agencies, ULBs may formulate development programme along with phasing for drainage development/improvement for the respective Sub-regions. The NCR Participating State governments/Agencies may identify major projects for development/improvement of inter-state Regional Drainage System and Sub-Regional Level/City Level to improve the drainage system and prepare DPR for obtaining loan assistance from NCR Planning Board for their implementation.

8.3.24 Institutional Arrangement

There are multiple departments/agencies responsible for planning, design, construction and maintenance of drainage system in urban areas due to which there is lack of coordination in management in urban drainage system. It is recommended that there should be a single coordinating Body for planning, design, construction and maintenance of drainage system in urban areas

8.3.25 Strengthening of Local Bodies

The Urban Local Bodies manage drains in urban area but do not have adequate resources. It is recommended that the ULBs be strengthened in terms of manpower, equipment and finance.

8.3.26 Provision for Fund

Urban Local Bodies have poor financial resources and due to which the maintenance of drains remains neglected. Adequate funds to be provided to the ULBs for regular maintenance and cleaning in order to improve the drainage system. Urban Local Bodies need to look for different kind of funding for strengthening their financial resources. The lands along the drains, which have the potential should be developed to generate a regular income and a part of this could be used for maintenance of the drains.

8.3.27 Capacity Building

Presently, the staff engaged in the maintenance of drains are not trained and learns while working. There is no formal training for the staff for maintenance work. With the introduction of modern technology, the staff also needs to be trained to cope up with the technology. Regular capacity building programmes should be carried out.

8.3.28 Public Awareness Programme

There is a need to create mass public awareness about the consequences of dumping plastic, domestic waste and street cleaning into drains. This should be campaigned via media and other awareness programmes to make people more responsible.

8.3.29 Public Participation in Vigilance

With mass awareness programmes citizen can be made aware and may also be encouraged to report irregularities being noticed by them. In fact people should be encouraged to report any incident, which comes to their notice and needs Government/Authorities intervention. The surveillance and reporting by public will have better coverage and will be more effective than any surveillance by the municipal staff. However, some steps need to be taken to encourage the public to become proactive in reporting the events that need the attention of the public authority.

8.3.30 Free Reporting System

The first step in inviting citizen to report the incident of intervention is to make an arrangement to receive the information in such a way so that the willing person can provide the information easily and free of cost. In this regard, either the information can be received via E-Mail or via a toll free telephone number/ SMS, which could be widely publicized to receive the call form public.

8.3.31 Felicitation of the Information Contributors

In addition to facility for free reporting system, an appreciation of the person by the agency responsible for the maintenance is must. It costs nothing but appreciation by a local authority makes the person to feel the importance of the action taken by him and also assures him regarding the utilization of the information by the authority. The person who has provided the information may be felicitated at public/ annual function by the agency responsible.

8.3.32 Specifications for Surfactants (Detergents)

The surfactants (detergents) being used in house ultimately reach in drainage system. In the domestic waste the difficult items to be treated are detergents. Though there are specifications for detergents to be used for washing of cloths but the cleaning of utensil is also carried out by detergents. There is a need to specify the toxic level in detergents, which need to be adhered to by the manufacturers as all the detergents find their way to water system.

8.3.33 Adoption of Service Level Bench Marks of MOUD:

As part of the ongoing endeavour to facilitate critical reforms in the urban sector, the Ministry of Urban Development has now adopted National Benchmarks in four key sectors-Water Supply, Sewerage, Solid Waste Management and Storm Water Drainage. The Ministry of Urban Development would facilitate the adoption of these benchmarks through its various schemes and would also provide appropriate support to ULBs that move towards the adoption of these benchmarks. The service level benchmarks guidelines for Storm water Drain as provided by MOUD are given in Annexure 8.4. It is proposed that all State and local level functionaries should use Handbook of Service Level Benchmarking in achieving the goal of improved service delivery.

8.3.34 Adoption of Urban Storm Drainage Design Manual of MOUD

The Ministry of Urban Development (MoUD), Govt. of India has constituted an “Expert Committee for the preparation of Urban Storm Drainage Manual”. The comprehensive Urban Storm Drainage Design Manual is under preparation/finalization. The Urban Storm Drainage Design Manual once published by the Ministry of Urban Development will be followed for design, construction and operation & maintenance of the drainage system in NCR.

उ0प्र0 मे राष्ट्रीय राजधानी क्षेत्र का ड्रेनेज मास्टर प्लान

(मुख्य नदी, सहायक नदी एवं ट्रंक ड्रेन)

क्रम संख्या	ट्रंक ड्रेन का नाम	लम्बाई कि0मी0 मे
1	लूम्ब नाला	20.515
2	छपरौली नाला	3.620
3	सनौली नाला	11.364
4	बडौत नाला	6.200
5	अलावलपुर नाला	24.730
6	सूरजपुर नाला	8.045
7	किशनपुर नाला	2.407
8	कासिमपुर नाला	6.939
9	टेका नाला	20.515
10	बौला नाला	22.520
11	रायना नाला	4.500
12	सावधना नाला	17.600
13	सिवाल नाला	16.600
14	सीधा नाला	13.800
15	भिक्कनपुर नाला	14.400
16	भोरसा नाला	8.100
17	बासना नाला	19.310
18	आबू नाला मील 71	33.600
19	आबू नाला मील 73	30.800
20	खतौली नाला	54.400
21	कादराबाद नाला	54.400
22	नागिन नदी नाला	22.400
23	काली नदी नाला	75.500
24	छोइया नाला	58.000
25	महलवाला नाला	8.200
26	प्रवीना नाला	15.800
27	नीम नदी नाला	94.000
28	नोएडा मुख्य नाला	17.100
29	पल्ला चिटहेरा नाला	15.800
30	हसनपुर नाला	26.150
31	हावल नाला	20.120
32	बराल नाला	36.000
33	करवनदी नाला	92.630
34	नन्देक नाला	21.400
35	धराऊ बिचौला नाला	11.150
36	लुआं नाला	30.000
37	सीमना नाला	32.000
38	विलासपुर नाला	15.670
39	पथवाया नाला	33.000
40	निजामपुर नाला	19.400
41	अलिहाबाद नाला	20.700

इन्डेक्स

क्र सं	नाम	संकेत
1	सड़क	
2	मुख्य नाला नहर	
3	जनपद सीमा	
4	मुख्य नदी	
5	सहायक नदी	
6	ट्रंक ड्रेन	

MAP No. 4.1

सिंचाई विभाग, उत्तर प्रदेश

IRRIGATION AND FLOOD CONTROL DEPARTMENT, GOVT. OF N.C.T. OF DELHI. (DRAINAGE MAP)

DETAILS OF DRAINS UNDER CONTROL OF I & F.C. DEPARTMENT

Sl. No.	Name of Drain	Length (in km.)	Catchment Area (in Hect.)	Design Discharge (in Cusecs)
1.	Alipur Block-North Delhi			
	1. Supplementary Drain	34.50	1,26,000	5000
	2. Bawana Escape	19.79	18,231	681
	3. Drain No. 6	14.73	8,807	462
	4. Burari Creek	8.86	1,476	74
	5. Burari Drain	5.79	644	25
	6. Bankner Link Drain	5.50	3,348	118
	7. New Drain	5.40	28,038	1160
	8. Khera Khurd Drain	5.21	1,013	71
	9. Ghoga Link Drain	6.18	1,480	58
	10. Naya Bas Link Drain	3.00	829	32
	11. Sanoth Link Drain	3.00	1,062	41
	12. Alipur Link Drain	0.88	622	31
	13. Jagatpur Link Drain	2.80	250	10
	14. Tikri Khurd Link Drain	1.94	620	11
	15. Khera Kalan Drain (Link)	0.72	440	1.41
	16. Jahangir Puri Outfall	5.47	1619.43	1700
	17. Toe Drain	4.00	150.00	18
2.	Kanjhawala Block-West Delhi			
	1. Mungesh Pur Drain	36.85	47138	1820
	2. Bazidpur Drain	8.05	2202	85
	3. Bawana Drain	11.40	2590	100
	4. Daryapur Pond Drain (Covered Drain)	0.82	259	10
	5. Ladpur Link Drain	2.53	518	20
	6. Katewara Link Drain	1.55	518	8
	7. Jatikhor Link Drain	3.76	453	17.5
	8. Nangal Thakran Link Drain	2.59	155.4	6
	9. Bawana Jheel Link Drain	1.98	155.4	6
	10. Nangloi Drain	8.60	3561	111
	11. Madanpur Drain	8.23	4921	190
	12. Karari Suleman Nagar Drain	7.80	2875	168
	13. Sultanpur Drain	9.02	1657.6	60
	14. Rasulpur Link Drain	0.76	129.5	5
	15. Mundka Peripheral Drain	2.50	686.4	104
	16. Ranhola Pond Drain	0.85	259	10

Sl. No.	Name of Drain	Length (in km.)	Catchment Area (in Hect.)	Design Discharge (in Cusecs)
3.	Najafgarh Block-South West Delhi			
	1. Najafgarh Drain	57.40	1093900.00	10000
	2. Palam Drain	8.78	5125.60	3037
	3. Palam Link Drain	1.65	621.00	509
	4. Najaf Garh Pond Drain	1.95	51.80	60
	5. Nasirpur Link Drain	2.90	1038.60	1020
	6. Bijwasan Drain	4.20	2755.80	170
	7. Pankha Road Drain	5.30	818.00	1000
	8. Shahbad Mohammedpur Drain	0.56	2427.00	155
	9. Bhupania Chudania Drain (Including Haryana portion)	8.55	370.37	1430
	10. Mudhela Drain	12.50	1554.00	60
	11. Nangli Sakrawati Link Drain	2.34	20.70	24
	12. Dichaon Kalan Link Drain	0.48	12.95	13
	13. Kharkari Rondh Link Drain	1.53	12.95	15
4.	Trans Yamuna Area - North East and East Delhi			
	1. Trunk Drain No.I	13.62	6660.00	3037
	2. Trunk Drain No. II	4.54	2740.00	1766
	3. Shahdara Outfall Drain	5.943	6099.00	5562
	4. Ghazipur Drain	6.241	6741.90	5143
	5. Shahdara Link Drain	4.54	151.70	1159
	6. Karawal Nagar Drain	2.48	12.50	498
	7. Biharipur Drain	1.01	14.56	33
	8. Bund Drain	2.835	170.44	212
	9. Escape Drain No. I	3.00	100.00	283
	10. Escape Drain No. II	0.425	9.06	35
	11. Relief Drain	6.025	500.00	4
5.	Mehrauli Block - South Delhi			
	1. Ali Drain	2.780	3693.00	2500
	2. Asola Drain	2.610	951.05	235
	3. Molar Bund Extension Drain	1.40	48.56	60
	4. Sarita Vihar Drain	1.30	1294.99	2070

ABBREVIATION

1.	Alipur Block	AB
2.	Kanjhawala Block	KB
3.	Najafgarh Block	NB
4.	Trans Yamuna Area	TY
5.	Mehrauli Block	MB

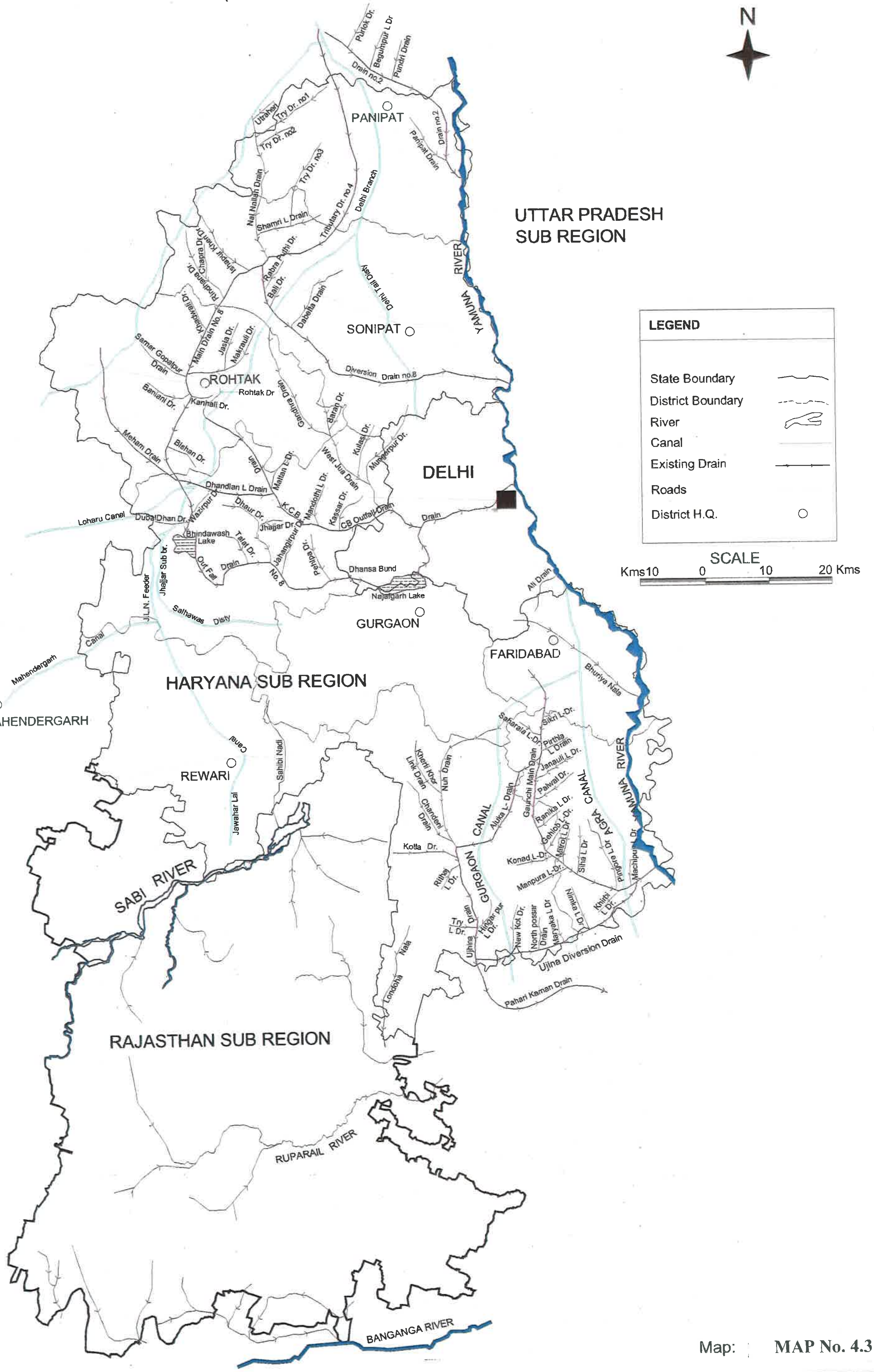
NOTE – THIS DRAWING IS INDICATIVE & SHOULD NOT BE USED FOR ANY OTHER PURPOSE

LEGEND

1.	Drains Under Control Of I & F.C. Department	
2.	Drains Under Control Of Other Departments	
3.	ROADS	
4.	RAILWAYS LINES	
5.	INTER STATE BORDER	
6.	RIVER COURSE	
7.	IRRIGATION CHANNEL	
8.	EMBANKMENTS.	

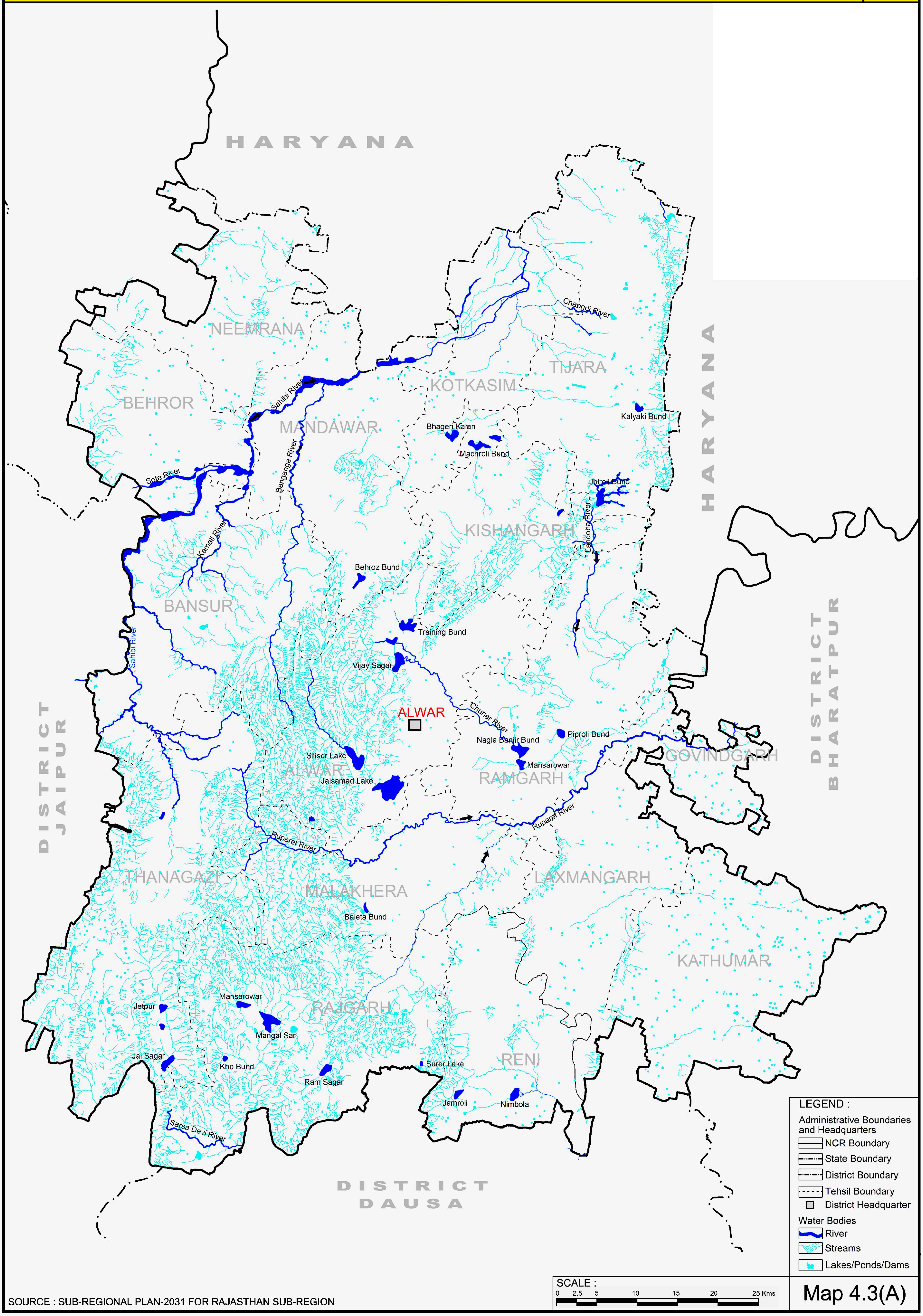
MAP No. 4.2

DRAINAGE SYSTEM NATIONAL CAPITAL REGION
(HARYANA AND RAJASTHAN SUB-REGION)



Map: MAP No. 4.3

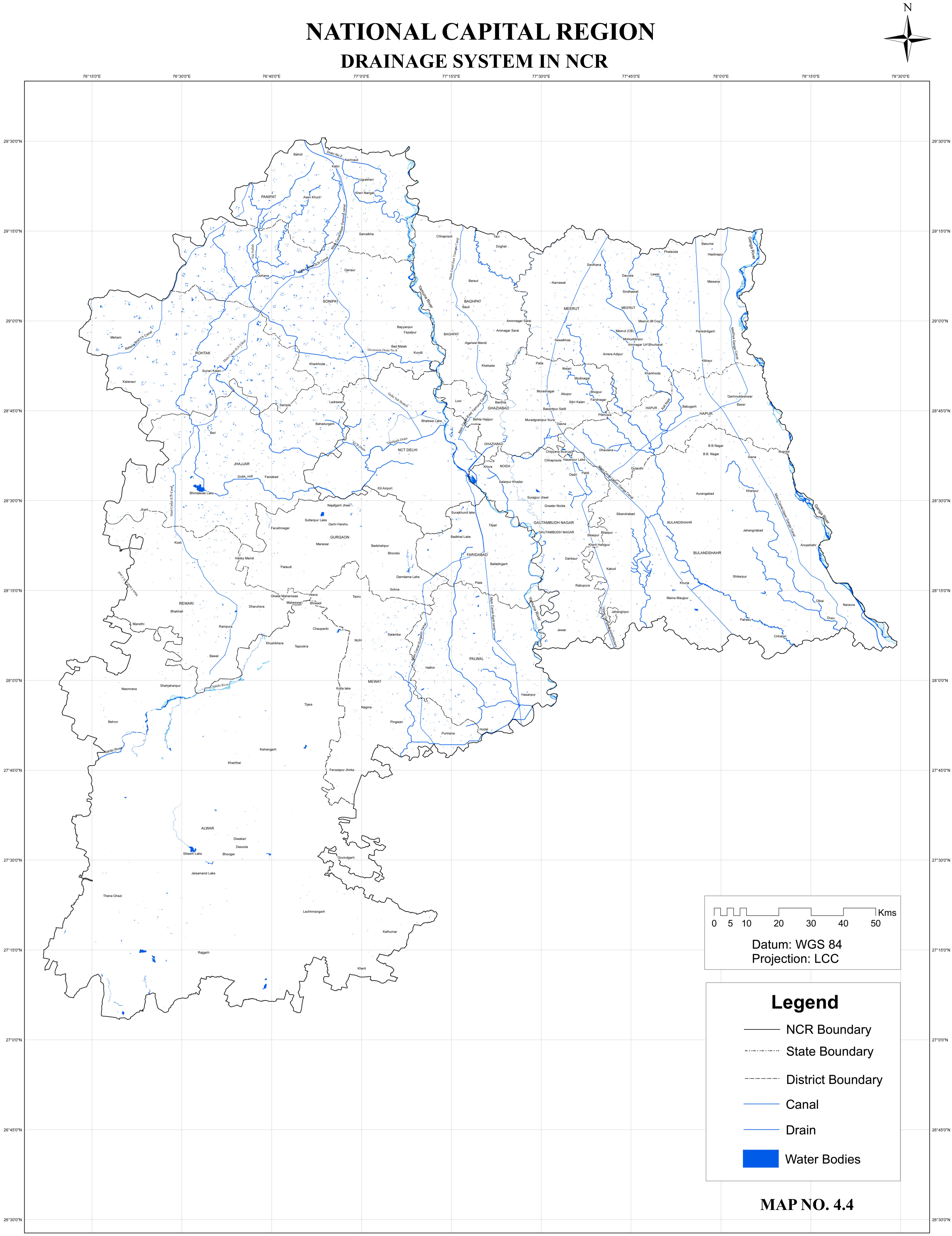
Detailed Drainage Features in Rajasthan sub-region



SOURCE : SUB-REGIONAL PLAN-2031 FOR RAJASTHAN SUB-REGION

NATIONAL CAPITAL REGION

DRAINAGE SYSTEM IN NCR



Source: IRS Resourcesat (LISS IV) -2012
with limited ground truth

NATIONAL REMOTE SENSING CENTRE
INDIAN SPACE RESEARCH ORGANISATION
DEPARTMENT OF SPACE
GOVT. OF INDIA, HYDERABAD

NATIONAL CAPITAL REGION PLANNING BOARD
MINISTRY OF URBAN DEVELOPMENT
GOVT. OF INDIA
NEW DELHI

ANNEXURES

Annexure 1.1 Composition of the Study Group for Preparation of Functional Plan for Drainage 2021 for NCR

1.	Shri J.S. Ahlawat (upto October, 2008) Shri Harnail Singh Engineer-In-Chief, Dept. of Irrigation, Govt. of Haryana	**Chairman**
2.	Shri Rajeev Malhotra, Chief Regional Planner, NCRPB	Co-Chairman
3.	Director (UT), Central Water Commission, North Wing, Sewa Bhawan, RK Puram, New Delhi	Member
4.	Chief Engineer, (Ganga), Department of Irrigation, Meerut Division, Govt. of UP.	Member
5.	Chief Engineer, UP Jal Nigam, Lucknow, Govt. of UP.	Member
6.	Chief Engineer, Lift Canal Unit, Irrigation Dept., Govt. of Haryana.	Member
7.	Additional Chief Engineer, Department of Irrigation, Govt. of Rajasthan.	Member
8.	Chief Engineer, Department of Irrigation, Govt. of GNCT-Delhi.	Member
9.	Superintending Engineer, Delhi Jal Board, Govt. of GNCT-Delhi.	Member
10.	Superintending Engineer, PWD, Water Supply & Sanitation Circle, Gurgaon	Member
11.	Chief Coordinator Planner, NCR Cell (UP), Town & Country Dept., Navyug Market, Commercial Building, IInd Floor, Ghaziabad (UP).	Member
12.	Chief Coordinator Planner, (NCR Cell), 3rd Floor, HUDA Office, Sector-6, Panchkula, Haryana.	Member
13.	Chief Town Planner (NCR), Nagar Niyojan Bhawan, J.L.N. Marg, Jaipur-302004, Rajasthan.	Member
14.	Associate Town & Country Planner, NCR Cell, Govt. of NCT-Delhi, R. No.507, 5th Level, B-Wing, Delhi Secretariat, I.P. Estate, N. Delhi	Member
15.	Joint Director, NCR Planning Board	Member Convener
16.	Subject Expert- with permission of the Chairman/Co-Chairman	Special Invitee

Annexure 6. 1: Desired and Existing Water Quality Levels at Various Sampling Station in Water Bodies of Uttar Pradesh (2009 & 2010)

Name of river sampling location	Desired category	Existing category 2009	Existing category 2010	Pollution characteristics
River Ganga				
1- Ganga Rajghat D/s Narora	B	C	C	TC
2- Ganga D/s Garmukteswar	B	D	D	TC
3- Kanpur Bithoor	B	C	C	TC
4- Kanpur U/s	B	C	C	TC
5- Kanpur D/s	B	D	E	TC
6- Kannauj U/s	B	C	C	TC
7- Kannauj D/s	B	D	D	TC
8- RAIBAREILLY – Dalmau	B	D	D	TC
9- Allahabad U/s	B	C	D	TC
10- Allahabad D/s	B	D	D	TC
11- Varanasi U/s	B	D	D	TC
12- Varanasi D/s	B	E	E	TC
13- Ghazipur – Tarighat	B	D	D	TC
River Yamuna				
14- Mathura U/sRanighat	B	D	E	BOD
15- Mathura D/s Ambedkar Drain	B	D	E	BOD
16- Vrindavan U/s	B	D	D	BOD
17- Vrindavan D/s Hasanghat	B	D	E	BOD
18- 18 Agra Kailashghat	B	D	E	TC
19- Agra-water works	B	D	E	TC
20- Agra D/s – Taj Mahal	B	E	E	TC
21- Etawah U/s	B	D	D	BOD

Name of river sampling location	Desired category	Existing category 2009	Existing category 2010	Pollution characteristics
22- Etawah D/s	B	D	D	BOD
23- Allahabad U/s	B	C	C	TC
Gomti River				
24- Sitapur – U/s	B	C	C	BOD/TC
25- Manghighat	B	C	C	BOD
26- Lucknow U/s Gaughati	B	C	C	TC
27- Lucknow D/s MMB Nala	B	D	D	TC
28- Lucknow Nishantganj Bridge	B	D	E	TC
29- Lucknow U/s Baraj	B	E	E	TC
30- Lucknow Pipraghat D/s	B	E	E	TC
31- Jaunpur D/s	B	D	D	TC
32- Ghazipur-Rajwari	B	D	D	TC/BOD
Sai River				
33- Unnao	B	D	C	TC
Hindon River				
34- Saharanpur D/s	B	D	D	BOD
35- Ghaziabad d/s Kuleshra Bridge	B	E	E	TC
Betwa River				
36- Hameerpur	B	D	D	TC
Kali River				
37- Kannauj	B	C	D	TC
RAMGANGA RIVER				
38- Kannauj before meeting Ganga	B	C	D	TC
SARYU RIVER				

Name of river sampling location	Desired category	Existing category 2009	Existing category 2010	Pollution characteristics
39- Ayodhya	B	D	D	TC
GHAGHRA RIVER				
40- Deoria	B	B	C	TC
RAPTI RIVER				
41- Gorakhpur	B	B	C	TC
RAMGARH LAKE				
42- Ramgarh lake	B	B	C	TC
43- Govind Sagar	B	B	D	TC
RIHAND DAM				
44- Sonebhadra Renukut U/s	B	C	C	TC
45- Rihand dam Renukut D/s	B	C	C	TC

Source: Compiled from data for yr. 2009 & 2010 from data available on website http://www.uppcb.com/river_quality.htm

Tolerance limits in respect of selected pollution characteristics for inland surface waters required for different uses as prescribed by the Indian Standards Institutions (1982).

Annexure 6. 2: Water Quality Status of River Yamuna (Date of Sampling 04-03-2015)

Sl. No.	Locations	pH	COD (mg/l)	BOD (mg/l)	DO (mg/l)	Total Coliform (MPN/100 ml)
Water Quality Criteria ('C' Class)		6.0-9.0	-	3 (max)	4 (min)	5000
1	Palla	7.5	12	1.4	8.3	-
2	Surghat (Downstream of Wazirabad Barrage)	7.6	24	6.6	7	-
3	Khajori Paltoon Pool (Downstream Najafgarh Drain)	7.2	228	62	NIL	-
4	Kudesia Ghat	7.3	144	45	NIL	-
5	ITO Bridge	7.4	96	28	NIL	-
6	Nizamudin Bridge	7.3	96	28	NIL	-
7	Agra Canal (Okhla)	7.3	72	27	NIL	-
8	After meeting Shahdara Drain (Downstream Okhla Barrage)	7.5	128	38	NIL	-
9	Agra Canal (Jaitpur)	7.2	88	33	NIL	-

Source: Delhi Pollution Control Committee, Govt. of NCT-Delhi

Note: Pure water has pH value of 7 and is neutral, i.e. neither acidic nor basic (alkaline)

Annexure 6. 3: Water Quality Status of Drains in NCT Delhi (08-04-2015)

Sl. No.	Name of Sample	pH	TSS (mg/l)	COD (mg/l)	BOD (mg/l)
	General Standard	5.5-9.0	100	250	30
1	Najafgarh Drain	7.3	228	260	70
2	Metcalf House Drain	7.4	30	76	22
3	Khyber Pass Drain	7.5	48	112	26.4
4	Sweeper Colony Drain	7.6	100	164	48
5	Magazine Road Drain	7.6	200	252	95
6	ISBT Drain	7.5	212	320	105
7	Tonga Stand Drain	7.6	216	352	130
8	Moat Drain	No Flow	No Flow	No Flow	No Flow
9	Civil Mill Drain	7.7	204	304	92
10	Power House Drain	7.5	320	352	110
11	Sen Nursing Home Drain	7.8	328	412	125
12	Drain No.12A	No Flow	No Flow	No Flow	No Flow
13	Drain No.14	7.4	44	40	11.2
14	Barapulla Drain	7.4	116	148	53
15	Maharani Bagh Drain	7.5	376	640	195
16	Kalkaji Drain	No Flow	No Flow	No Flow	No Flow
17	Sarita Vihar Drain (Mathura Road)	7.7	248	284	85
18	Tehkhand Drain	7.4	240	488	155
19	Tuglakabad Drain	7.3	212	384	126
20	Drain Near LPG Bottling Plant	No Flow	No Flow	No Flow	No Flow
21	Drain Near Saita Vihar Bridge	7.5	162	104	34
22	Shahdara Drain	7.5	248	392	115
23	Sahibabad Drain	7.1	456	824	270
24	Indrapuri Drain	7.6	304	476	145

Source: Delhi Pollution Control Committee, Govt. of NCT-Delhi

Annexure 6. 4: Status and Performance of Sewage Treatment Plants in NCT-Delhi

Sl. No.	Sewage Treatment Plants	Installed Capacity (MGD)	Present Utilisation (MGD)	BOD (mg/l)		COD (mg/l)		TSS (mg/l)	
				Inlet	Outlet	Inlet	Outlet	Inlet	Outlet
1.	Coronation Pillar Phase-I	10	19.95	87	9	301	58	437	26
	Coronation Pillar Phase-II	10+10		418	9	1592	58	722	28
	Coronation Pillar Phase-III*	10Total -46 including Oxidation Ponds		-	-	-	-	-	-
2.	Oxidation PondsTimarpur*	6	-	-	-	-	-	-	-
3.	Keshopur Phase-I*	12		-	-	-	-	-	-
	Keshopur Phase-II*	20		-	-	-	-	-	-
	Keshopur Phase-III*	40 Total-72		-	-	-	-	-	-
4.	Okhla Phase-I	30	122.74	147	47	464	172	491	73
	Okhla Phase-II	12		196	70	611	323	554	2
	Okhla Phase-III	37		196	36	611	114	554	69
	Okhla Phase-IV	45		112	33	381	119	272	58
	Okhla Phase-V	16 Total-140		115	24	521	115	332	63
5.	Narela	10	2.6	51	12	154	51	204	23
6.	Najafgarh	5	0.2	115	7	401	51	304	25
7.	Nilothi	40	9.45	178	19	583	89	316	43
8.	Dr. Sen Nursing Home Nalla	2.2	2.53	306	3	925	13	969	6
9.	Delhi Gate Nalla	2.2	2.43	106	4	446	14	248	24
10.	Yamuna Vihar Phase-I	10	11.77	134	8	319	57	221	47
	Yamuna Vihar Phase-II	10 Total-20		92	8	407	71	301	60
11.	Pappan Kalan	20	8.14	179	5	625	32	513	22
12.	Kondli Phase-I	10	45	219	28	466	71	286	91
	Kondli Phase-II	25		97	16	381	68	388	13
	Kondli Phase-III	10 Total-45		86	18	400	62	218	21
13.	Mehrauli	5	1.7	217	21	755	113	585	33
14.	Rohini	15	-	-	-	-	-	-	-
15.	Rithala (Old)	40	47.32	110	11	426	42	250	29
	Rithala (New)	40 Total-80	-	110	21		79		28

Sl. No.	Sewage Treatment Plants	Installed Capacity (MGD)	Present Utilisation (MGD)	BOD (mg/l)		COD (mg/l)		TSS (mg/l)	
16.	Vasant Kunj Phase-I	2	4.6	156	42	542	166	494	100
	Vasant Kunj Phase-II	3 Total-5		169	18	565	47	337	51
17.	Ghitorni	5	-	-	-	-	-	-	-
Total		**512.4 (2305 MLD)**	**278.43 (1252 MLD)**	***Note:*STPs are under augmentation***					

Source: Annual Report 2011-12, Central Pollution Control Board

Annexure 6. 5: Status and Performance of Sewage Treatment Plant in NCR

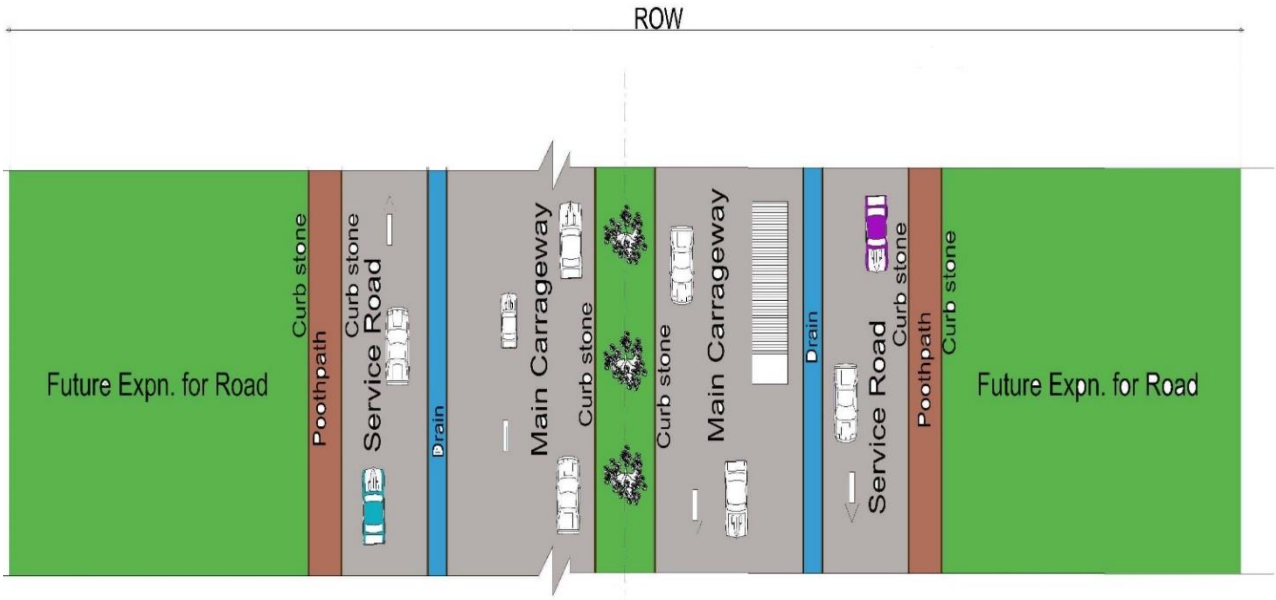
S. No.	Sewage Treatment Plant	Installed Capacity (MLD)	Present Utilization (MLD)	BOD (mg/L)		COD (mg/l)		TSS (mg/l)	
				Inlet	Outlet	Inlet	Outlet	Inlet	Outlet
Haryana									
1.	Sonepat	30	45	134	50	342	258	352	130
2.	Panipat Jattal Road	10	17	112	152	359	490	165	58
3.	Panipat-UASB-Siwah	35	50	107	44	533	234	58	182
4.	Faridabad Badshapur	65 (45+20)	45	186	(28 & 50)	549	(73 & 118)	435	(30 & 63)
5.	FaridabadMirzapur	45	24	140	70	404	180	275	84
6.	Ballabgarh STP	50	-	-	198	-	564	-	638
Uttar Pradesh									
1.	Noida Sec 54	23	23	165	14	478	56	126	19
2.	Noida Sec 50	33	30	126	14	345	55	82	25
3.	Indirapuram	56	56	152	52	434	122	227	28
4.	Vijay Nagar	73	73	180	47	516	132	165	35

Note : *"-" indicates that plants are under renovation / up-gradation.*

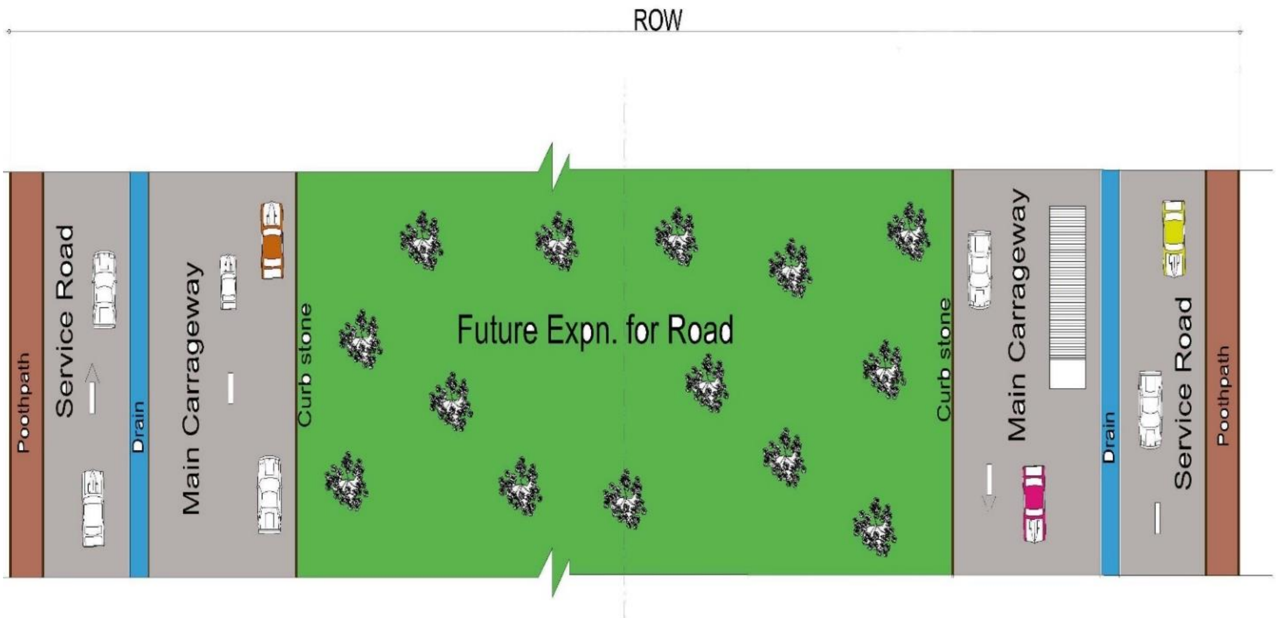
Annexure 8.1 PROPOSED METHOD OF ROAD CONSTRUCTION (Construction of Road from Edge)

PROPOSED METHOD OF CONSTRUCTION

(Construction of Road from Edge)



Existing practice of Road construction



Proposed Method of road construction

Annexure 8.2 RAIN WATER MANAGEMENT FACILITIES (Pond, Roof top gardens)

Annexure 8.3 RAIN WATER MANAGEMENT FACILITIES (Rain Garden, Grassed Waterway)

Rain Garden

- Transform convex garden, roadside green area into concave topography

Conceptual Diagram

Houses

Street-side

Grassed Waterway

- Transform concrete drainage pipes by the road and in parks into grassed waterways

Pavement (Between Roadside Trees)

Between Roads

Parking Lots

Annexure 8.4 Service Level Benchmarks for Storm Water Drainage

(As per the Handbook of Service Level Benchmarking published by the Ministry of Urban Development, Govt. of India)

COVERAGE OF STORM WATER DRAINAGE NETWORK

Indicator	**Performance Indicator**	
	Unit	**Definition**
Coverage of storm water drainage network	%	Coverage is defined in terms of the percentage of road length covered by the storm water drainage network
Data required for calculating the indicator	**Data Requirements**	
	Unit	**Remarks**
a. Total length of road network in the ULB	km	Only consider roads that are more than 3.5 m wide carriageway
b. Total length of primary, secondary and tertiary drains	km	Only consider drains that are trained, made of pucca construction and are covered.
Coverage of storm water drainage networks	**%**	**Coverage = [(b/a)*100]**

Rationale for the Indicator	
This indicator provides an estimation of the extent of coverage of the storm water drainage network in the city. This value should be 100 percent.	
Reliability of Measurement	
Reliability Scale	**Description of method**
Lowest level of reliability (D)	Not applicable
Intermediate level (C)	Estimated from city road maps, not updated in the past five years
Intermediate level (B)	Estimated from city road maps (that are detailed and to scale), which have been updated in the past five years.
Highest/preferred level of reliability (A)	Actual ground level surveys are carried out to measure drain and road length. Surveys are carried out to verify that drains are of pucca construction and covered.

Minimum frequency of measurement of performance indicator		Smallest geographical jurisdiction for measurement of performance	
Measurement	**Annually**	**Measurement**	**Ward Level**

INCIDENCE OF WATER LOGGING/FLOODING

Indicator	**Performance Indicator**	
	Unit	**Definition**
Aggregate number of incidents of water logging reported in a year	Number per year	The number of times water logging is reported in a year, at flood prone points within the city.
Data required for calculating the indicator	**Data Requirements**	
	Unit	**Remarks**
a. Identification of flood prone points within the ULB limits. The points may be named as A1, A2, A3… An	Number	Flood prone points within the city should be identified as locations that experience water logging at key road intersections, or along a road length of 50 m or more, or in a locality affecting 50 households or more.
b. Number of occasions of flooding/water logging in a year	Number per year	An occasion or incident of flooding/water logging should be considered if it affects transportation and normal life. Typically stagnant water for more than four hours of a depth more than six inches.
The aggregate number of instances or occasions of water logging/flooding reported across the city in a year.	Number per year	**Aggregate incidence = (b at A1) + (b at A2) + (b at An).**