Mainstreaming Rainwater Harvesting in Noida

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Maps in this report are indicative and not to scale.

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Abbreviations

CGWB: Central Ground Water Board

CT: Census town

EC: Electrical conductivity

GIS: Geographical Information System

LPM: Litres per minute

MBGL: Metres below ground level

MCM: Million cubic metres

MLD: Million litres per day

MSL: Mean sea level

NCR: National Capital Region

NCT: National Capital Territory

PPM: Parts per million

Pz: Piezometer

RWH: Rainwater harvesting

SPA: School of Planning and Architecture

ToR: Terms of reference

WAPCOS: Water and Power Consultancy Services

Glossary

Aquifer: An underground rock or soil that stores large amounts of water without loss through evaporation or pollution. It yields water and allows its movement under certain conditions.

Artificial recharge: Any man-made scheme or facility that adds water to an aquifer.

Bore well: Small-diameter wells, generally deeper than the open wells.

Catchment: A geographical area defined by topography from where all runoff water drains into a reservoir. Often used as a synonym for a watershed or a river basin.

Confined aquifer: An aquifer that is overlain and underlain by an impermeable rock mass. Confined aquifers receive recharge from distant sources. The ability of a confined aquifer to hold water is much lower than that of an unconfined aquifer.

Conveyance system: A component of RWH systems that includes gutters and pipes which carry water from the catchment to the storage tank or recharge well. The filter screens and first-flush diverters are also included in this component.

Electrical conductivity: A measure of the ability of water to conduct electrical current. Its magnitude depends on the dissolved mineral content of the water.

Evapotranspiration: The quantity of water transpired (given off), retained in plant tissues, and evaporated from plant tissues and surrounding soil surfaces.

Floodplain: An area adjacent to a stream or river that experiences occasional or periodic flooding.

Groundwater: The water retained in the inter-granular pores of soils or fissures of rocks below the water table.

Groundwater flow: The movement of water through openings in sediment and rock. It occurs in the zone of saturation.

Permeability: The property of soil or rock that allows the passage of water through it.

Piezometer: An instrument used to measure the pressure head in a pipe, tank or soil. It usually comprises a small pipe or tube connected or tapped into the side or wall of a pipe or tank and connected to a manometer pressure gauge, water or mercury column or other device for indicating pressure head.

Porosity: Porosity is a measure of how much of a rock or soil has open space. This space can be between grains or within cracks or cavities of the rock.

Porous pavement: Pavement that provide storm-water infiltration while serving as a structural surface.

Recharge: The process of surface water (from rain or reservoirs) joining the ground aquifer.

Runoff: Water that flows away from a surface after falling on the surface in the form of rain.

Storm-water drain: Constructed opening in a road system through which runoff from the road, buildings and green surfaces flow into an underground system.

Surface flow: Water found in ponds, lakes, inland seas, streams and rivers.

Total dissolved solids: The amount of chemical substances in a solution, usually estimated from a determination of electrical conductivity; also total soluble salts and total dissolved ions.

Unconfined aquifer: An aquifer exposed to the surface but with an underlying confining layer. It has both a saturated as well as an unsaturated zone.

Water table: The standing-water level of unconfined groundwater below the earth's surface, which may be undulating.

Executive summary

The rainwater harvesting (RWH) potential of Noida is about 27.73 million cubic metres (MCM) (i.e. 27,730 ml), which can meet 26.63 per cent of Noida's water demand annually.

An additional 5 MCM (5,000 ml) unutilized Yamuna floodwater can also be harvested to augment the water supply.

A reduction in water demand by 26.6 per cent can be achieved if the full potential of rainwater is used in Noida.

Water management in urban areas is challenged by rapid urban growth and decreasing water availability. With rapid urbanization and large areas coming under roofs and concrete structures in Noida area (203.16 sq. km), natural recharge to groundwater has drastically reduced. There is a need to adopt an integrated approach of sustainable water management for urban areas. Meeting the ever-growing requirements of water is a key challenge in the overall development of Noida.

Noida is a satellite town in the National Capital Region (NCR) of Delhi, with a rapidly increasing urban population. Groundwater (80 per cent) is currently the major source of water supply in Noida. It has shown a significant declining trend (up to 40 mbgl) because of over-extraction. Since the area is surrounded by the river Yamuna and partially encircled by the Hindon, all the storm water drains into it. However, because of increased paved areas and declining waterbodies in Noida, the area cannot sustain high rainfall intensity—it can sustain a maximum of 18.85 mm/hr—and is prone to floods and waterlogging as well as depleting groundwater levels.

The overall deteriorating water situation in Noida both in terms of quantity and quality highlights the need for immediate interventions by way of using local water resources. If rainwater is utilized as a resource and managed properly, it has great potential to increase water supply, meet the water requirements of an increasing urban population and increase the overall economic potential of the area.

The purpose of this report is to prepare a road map for mainstreaming rainwater harvesting (RWH) in the city. To accomplish this, a comprehensive exercise has been attempted to evaluate the recharge potential of the entire area of Noida as well as runoff available for recharge based on baseline data.

Assuming annual average rainfall is 750 mm, the RWH potential is calculated for different types of land uses, such as floodplain, residential areas, industrial areas and green areas. The recharge potential for each area type is estimated assuming the land cover as rooftop, paved and open area—potential runoff that may generate during rainy season is accordingly estimated. This analysis is juxtaposed with a study of site conditions, such as soil suitability, water table and topography, to further categorize the methods and techniques of RWH systems.

In order to demonstrate the feasibility of groundwater recharge in different land-use types, sample sectors have been identified for residential, industrial and green areas. The concept of urban planning is used, along with tools such as GIS and AutoCAD, and RWH potential maps are prepared for selected sectors. The water flowing in existing drains in Noida is not recommended for groundwater recharge since it is high in chemical and organic pollutants, including sewage. This study also showcases the overall feasibility study of various technologies to enhance the availability of water in time and space according to applicability in different sectors of Noida.

Assuming evaporation losses as 20 per cent, the overall RWH potential of Noida is about 27.73 MCM, which can lead to a reduction in annual water demand of up to 26.63 per cent. Further, the aquifer is medium- to fine-grained sand with occasional coarse-grained sand, suitable for water recharge. Apart from this, the share for NCR districts in the floodwaters of Yamuna sub-basins that remains unutilized can be harnessed by recharging the aquifer through floodplain recharge structures in the space available in the Yamuna floodplain. In the case of Noida, the total runoff available from the river Yamuna is about 50 MCM, of which 10 per cent can be harvested. The implemented RWH system in Noida can be an alternative source of water supply apart from water supply for bulk uses, such as horticulture.

The attempt here is to combine traditional wisdom with modern engineering techniques, including the development of advanced urban planning and design concepts to recommend potential RWH strategies and structures at identified sites in Noida.

1 Introduction

Rain is the first form of water in the hydrological cycle, and hence a primary source of available water. Rivers, lakes and groundwater are secondary sources of water. Currently, we depend entirely on such secondary sources of water. The ultimate source of water, rain, feeds all secondary sources of water.

India has a rich tradition of rainwater harvesting (RWH). But modern water-management relies heavily on the cost-intensive long-distance transfer of water to meet the widening gap between demand and supply and includes overexploitation of in-situ groundwater resources. Making optimum use of rainwater where it falls and sustainable water management requires understanding the value of rain.

RWH is a process of capturing rainfall and preventing its runoff, evaporation and seepage for its efficient utilization and conservation. The best option is to harvest rainwater where it falls and store it appropriately (on the surface or in the aquifer) for eventual recovery and use when required. RWH is also an effective tool to utilize large quantities of quality water which otherwise goes waste or causes flooding/waterlogging.

Monsoons in India are a great asset, provided we take advantage of this bounty of nature. The rise, fall and potential of India's traditional water harvesting systems is well documented in CSE's publication, 'State of India's environment—A citizen's report', *Dying Wisdom*.[1]

With rapid urbanization and its concomitant increase in area coming under roofs and concrete structures, water utilities have focused on water augmentation but failed to combine traditional wisdom with modern engineering. The overall deteriorating water supply situation in Noida in terms of both quantity and quality propelled CSE to take up this project to prepare a roadmap to mainstream RWH in the city.

Noida, the city of the future, requires an unparalleled infrastructure of sustainable water management. However, the unregulated and increasingly unsustainable exploitation of aquifers has led to a decline in the watertable and deterioration in the quality of groundwater in the area. The projected increase in the proportion of hard surface has further increased runoff while decreasing percolation in the area. The realization is now dawning that rainfall collection (runoff and flood discharge) constitutes a major step towards resource efficiency and conservation that will lead to sustainable urban water management in Noida.

The aim of the project is to help Noida become the first city in the NCR to showcase its commitment to adopting good practices in sustainable water management.

1.1 OBJECTIVES AND SCOPE OF WORK

This report evaluates the land-use and hydrogeological set-up of Noida, including RWH potential vis-a-vis availability of rainwater. Our research provides a comprehensive RWH plan along with land use-specific suggestive designs. It scientifically establishes the necessity and potential of RWH in the area that may vary from site to site. The scope of the work is briefly explained under terms of reference (ToR) in the following sections.

The ToR of the project is as follows:

- To assess the existing and projected water scenario in Noida
- To map sources of water supply, both groundwater and surface water (including status of waterbodies), and assess resource sustainability

- To assess RWH potential (including identification of groundwater recharge zones) in and around Noida aimed at groundwater resource sustainability at the city level
- To identify opportunities for RWH in areas both already developed and proposed to be developed
- To prepare a blueprint for mainstreaming (promotion and implementation) city-level RWH proposals, including water-sensitive design and planning in Noida

The objectives are designed to assess current opportunities and constraints in Noida for providing mainstreaming RWH (see *Table 1: Framework and objectives*). The first two objectives give an overall picture of the existing water scenario in Noida, which are supported by baseline data on water availability from surface water and groundwater. The next two objectives focus on an analysis of the study area to calculate rainwater potential and identify suitable sites for the RWH plan. Criteria such as rainfall, land availability and soil conditions are taken into consideration to assess the potential. The last objective illustrates the overall prospects of RWH in Noida, along with recommended methods and costs in selected areas of Noida.

1.2 APPROACH AND METHODOLOGY

This report adopts a holistic approach through integration of various data and maps for the estimation of rainfall runoff and recharge potential, bringing the entire set of outputs together. Accordingly, data on various parameters and spatial thematic layers have been generated after processing the available spatial data.

The baseline thematic maps are used together with average annual rainfall and catchment area efficiency (runoff coefficient) to estimate the volume of RWH potential for the targeted interventions, grouped as built-up, paved/road, green and unpaved areas. As an outcome,

Table 1: Framework and objectives

	Methodology	Chapters
Objectives 1 and 2	Existing water scenario → Groundwater; Surface water; Resource sustainability	• Study area—profile of Noida • Water scenario—water supply and availability, hydrogeological set-up, drainage system, waterbodies and water quality
Objectives 3 and 4	Analysing RWH potential → Recharge area potential according to geomorphology; Analysing runoff generation with regard to rainfall and land-use type	• Land use—distribution, areas and pattern • Geomorphic set-up • Climatic conditions
Objective 5	Mainstreaming RWH according to different methods and land-use type	• RWH concepts and methods • Prospects and proposal for RWH

it highlights the potential and opportunities in different land-use categories (residential, industrial and green areas) in Noida.

Rainwater can be harvested by two methods—by surface storage facilities or through groundwater recharge into unconfined/semi-confined aquifers. Catchment areas for collection of rainwater include rooftops, compounds, roads, parks, bare grounds and other potentially open spaces.

For any RWH system, the most important components that need to be examined include:

- Area contributing to runoff (existing/projected), i.e. how much area and land-use pattern—industrial, residential and general built-up pattern of the area and water-related infrastructure
- Hydro-meteorological and physical characters—rainfall duration, general pattern and intensity of rainfall, topography and soil
- In case of artificial recharge to groundwater, hydrogeological set-up and recharge potential of underlying aquifers
- Hydrogeology of the area, including nature and extent of aquifers, depth to water levels and chemical quality of groundwater

The suggested ToR include information about pre-monsoon and post-monsoon analysis, in terms of land use as well as mapping of waterbodies and other potential recharge sites, including interpretation and mapping of the features as follows:

- Areal variation in the infiltration of capacity, including drainage analysis and lineament analysis
- Areas of shallow and deeply weathered landscapes, fracturing/structural features in relation to drainage and hydrological control of dykes (if any)
- Geo-morphological-based terrain mapping with river/streams (gaining/losing reaches)

An analysis of all the available data forms the base for identifying the area for RWH. In addition, other information and data considered includes geological boundaries, hydraulic boundaries, inflow and outflow of waters, storage capacity, porosity, hydraulic conductivity, transmissivity, water resources available for recharge, natural recharge, water balance, depth of aquifer and tectonic boundaries.

The roadmap for mainstreaming RWH in Noida is based on examination of the availability of space, availability of runoff, depth of water table, lithology of the area, advanced urban planning and design concepts, including the state-of-the-art techniques such as remote sensing and Geographical Information System (GIS).

The above parameters are integrated to identify opportunities for a cost-effective as well as land use-specific potential for RWH. The analysis is supported by results of the study based on interpretation of additional data provided by Noida Authority and other reports/ articles.[2]

2 Study area

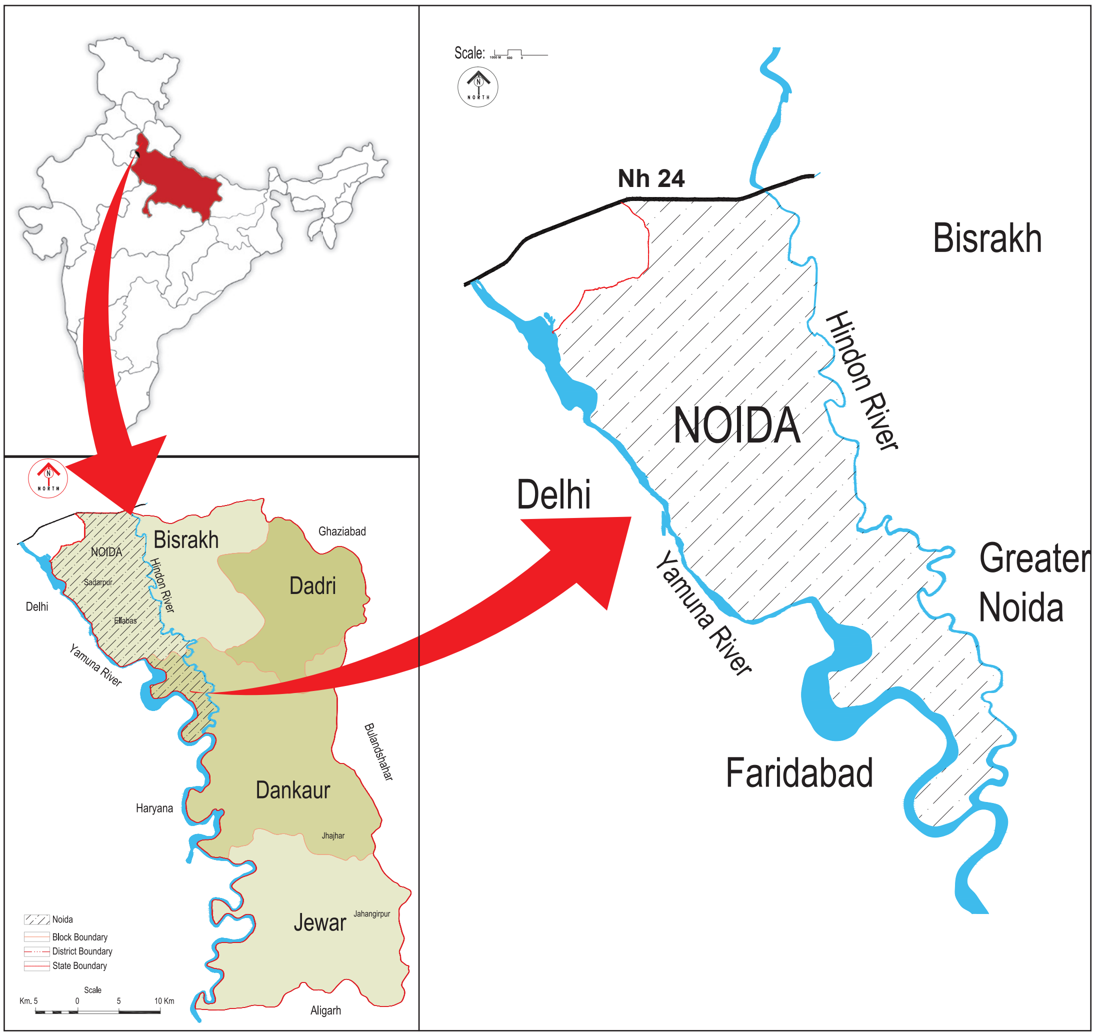
Noida city, in Gautam Budh Nagar district in the state of Uttar Pradesh, is a major satellite city of the NCR. The district has three tehsils, i.e. Dadri, Jewar and Gautam Budh Nagar, and four blocks, i.e. Bisrakh, Dadri, Dankaur and Jewar. Noida lies in Bisrakh census development block.

The city is bound by the river Yamuna and the national capital city of Delhi in the west and the southwest, National Highway 24 and the city of Ghaziabad in the north, the river Hindon and Greater Noida in the east, and the confluence of the rivers Yamuna and Hindon in the south (see *Map 1: Location of Noida*). It lies between 28º18’12.54” N to 28º22’36.72” N latitudes and 77º10’28.97” E to 77º15’19.83” E longitudes along the eastern and southeastern boundaries of the National Capital Territory (NCT) of Delhi.

2.1 DEMOGRAPHIC PROFILE

The history of Noida can be traced to 1972, when it was planned as an integrated town for a projected population of 3.75 lakh workers engaged in manufacturing and allied activities, with a proposed urbanizable area of 3,360 hectare (ha).

Map 1: Location of Noida



Source: Google Maps image, 2016

As per the 1981 Census, Noida notified area had a population of 36,972. This was the aggregate population of 72 inhabited villages included in the notified area. In 1991, Noida achieved the status of a Census Town (CT). By this time, 29 of its villages were urbanized and constituted the developed urban limits of Noida with a population of 146,514 people. In addition to this population, 34,489 people lived in 43 inhabited villages. Thus the total population living within the notified area of Noida increased to 181,003 in 1991 and was 3.05 lakh in 2001.

In 1991, the notified area of Noida comprised 81 revenue villages of which 29 were urban villages (falling within the developed urban limits of Noida CT) and 10 uninhabited. Noida CT is the only urban centre within the notified area. In 2001, the population of the urban villages were not given separately; instead, their population was counted as part of the population of Noida CT and thus the total number of villages is reduced to 52, including nine uninhabited villages (see *Table 2: Number of villages in Noida: 1991 and 2001*).

The developed urban area of Noida occupies its northern half. The southern half is predominantly rural, with scattered settlements. It is, however, also urbanizing at a rapid rate.

The city's population has grown at a rapid rate, nearly 400 per cent during 1981–91 and 108 per cent during 1991–2001. This is not surprising because 1981–2001 represented the take-off stage of the new town, which was founded in 1978. A 1995 study by the School of Planning and Architecture (SPA), New Delhi, suggested that as much as 20 per cent of Noida's population lived in jhuggi clusters. This population must have grown substantially.[1]

Noida's population—reported as 6.42 lakh in 2011—is projected to increase to 25 lakh in 2031.[2] The population figures based on the commitments of residential properties in the planned area including potential population growth in the village abadi areas are shown in the following (see *Table 3: Estimated population of Noida for 2031*).

2.2 SETTLEMENT SIZE

Settlements falling within the notified area of Noida have a wide range of population sizes. Some villages, such as Haraula, Nithari, Ragunathpur, Atta, Chalera and Khora, which had predominantly urban sectors, grew to have relatively large populations by 1991 (above 10,000) as per the 1991 Census. Many other large villages, such as Bhangel, Hajipur, Sorkha, Sadarpur and Sharphabad, had predominantly developed sectors during 1991–2001. These urban villages increased in population size and attracted commercial, institutional and household manufacturing activities.

Table 2: Number of villages in Noida: 1991 and 2001

1991				2001			
Urban	Rural	Uninhabited	Total	Urban	Rural	Uninhabited	Total
29	42	10	81	-	43	9	52

Source: Census of India: 1991 and 2001

Table 3: Estimated population of Noida for 2031

Item	Unit no./area	Persons per unit	No. of persons
Number of flats constructed by Noida	34,507	4.5 persons per household	155,281
Number of plots developed by Noida	24,587	13.5 persons per plot	331,924
Number of plots for farmers	3,500	13.5 persons per plot	47,250
Group housing area allotted before December 2008	628.68 ha	700 persons per household	440,076
Group housing area allotted after December 2008	396.77 ha	1,650 persons per household	654,671
Land transfer to Yamuna Expressway Authority	500 ha	As per approved layout plan	220,500
Special Economic Zone area (1,000 ha)	100 ha	1,650 persons per household	165,000
Village abadi	1,231 ha	400 persons per household	4,92,400
Total population			2,507,102

Source: Noida Authority, 2011 'Master Plan for Noida-2031'

3 Water scenario

The existing demand for and supply of water, its availability, projected demand, sources for augmentation of water supply, drainage, storm-water management, current status of policy and implementation of RWH have been studied in detail and are discussed below.

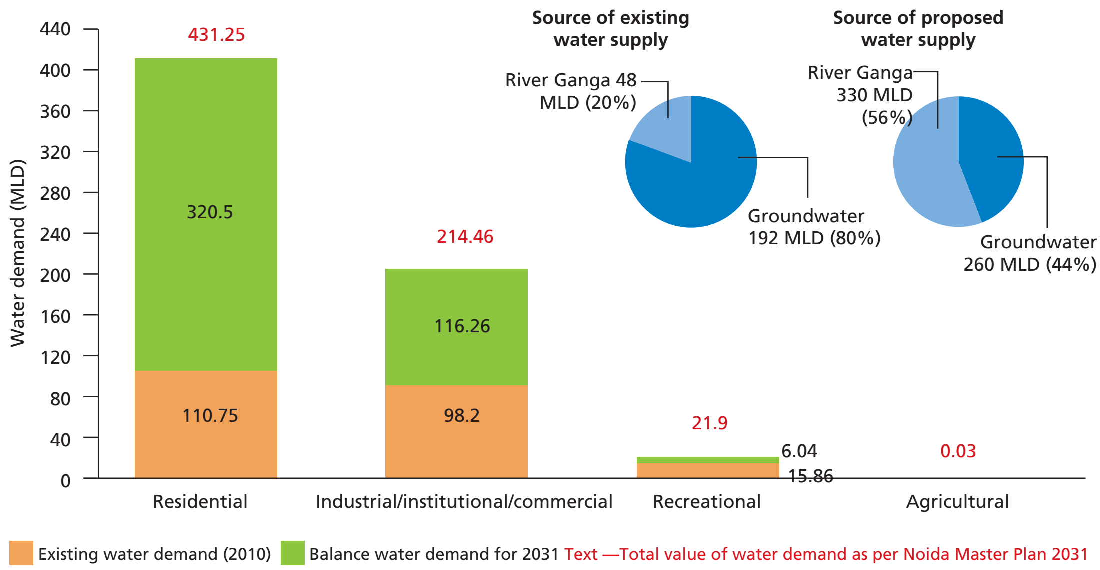
3.1 WATER SUPPLY

Noida's demand for water in 2010–11 was around 225 million litres per day (MLD) and is projected to increase to 668 MLD in 2031. The current water supply sources are both groundwater and surface water. Groundwater extraction is through tube wells/ranney wells, which contribute 80 per cent (192 MLD); the remaining 20 per cent (48 MLD) is from the river Ganga from a point on the Ganga Canal (see *Graph 1: Comparison of water demand in Noida [2010–30]*).

According to the master plan of water supply and sewerage system for Noida, prepared by Water and Power Consultancy Services (WAPCOS), the total existing water supply production capacity is around 240 MLD and there is no water shortage. Fresh groundwater is available up to a depth of 25–35 metres below ground level (mbgl), below which water is saline.[1]

To meet the projected increase in water demand, the number of existing tube wells and ranney wells is likely to increase. The 382 tube wells (including 200 tube wells in recreational parks) may increase to 730 (including 300 tube wells in recreational parks) and ranney wells from 6 to 12. According to the Noida Master Plan, approximately 330 MLD (50 per cent) of the water supply will be sourced from the Ganga in 2031 but considerable projected water demand (over 50 per cent) in Noida will continue to be sourced from groundwater. There are plans to bring Ganga water to mix with groundwater to improve the quality of water supply in terms of hardness of water.[2, 3]

Graph 1: Comparison of water demand in Noida (2010–30)



Water use norms: Residential—172.5 LPCD, industrial/institutional/commercial—45 KL/day/ha, Recreational—9 KL/day/ha, agricultural—0.07 KL/day/ha

Source: Noida Authority 2011, 'Master Plan for Noida 2031'

3.2 HYDROGEOLOGICAL SET-UP

Groundwater is the main source (over 80 per cent) of water supply for Noida. The increasing population and spurt in development activities in Noida, especially due to the new industrial units in last decade, have led to intensive withdrawal of groundwater. Increasing withdrawals and deficit recharging has resulted in decline in groundwater level.

The geographical area of Bisrakh block, under which Noida falls, is about 334.76 sq. km and its net annual replenishable groundwater resource in the saturated zone of aquifer has been assessed as 7,735.62 ha m. The block has been categorized as overexploited. The resources estimated pertain to the fluctuation zone.[4]

Based on the secondary data collected and collated from various central/state agencies, including Central Ground Water Board (CGWB), attempts have been made to derive the aquifer disposition, their hydraulic properties as well as the development and recharge potential of underlying aquifers.[5] Hydrogeologically, Noida has mainly young alluvium comprising quaternary sediments whose thickness increases from west to east and towards the northeast. The subsurface alluvium in the area varies from 115 m to 450 m. In the Hindon–Yamuna common floodplain area, the thickness of quaternary sediments, including alluvial deposit, varies from 300 m in the north to 115 m in the central part of the western side of the Hindon River.

Near the surface, however, sediments are dominantly clay particles. These are covered by fine- to medium-grained sandbeds of variable thickness, with clay typical of fluviatile and riverine sedimentation. The sequence of sand and clay sediments continue down to the depth of about 120 mbgl. Kankar also occurs as thin beds of limited lateral extent as well as disseminated in the clay. Groundwater in the study area occurs under unconfined condition down to the depth of about 40 m, below which it occurs under unconfined to semi-confined condition, depending on the thickness and lateral extent of overlying clay layer or proportion of clay.

Generally, groundwater in the saturated zone of aquifer is fresh. As one goes down, however, increase in total dissolved solids (TDS) categorizing it as marginally brackish water reflected in terms of high electrical conductivity value has been observed in places. The quality of groundwater is brackish to saline as we go deeper. Occurrence of saline water at shallow depths in Noida area is an issue of concern. Similar conditions are expected to be encountered in the surrounding areas of the district. The master slope of water table is from northeast to southwest.

3.2.1 Groundwater regime

Groundwater is a dynamic system. It remains under the influence of time-dependent recharging and discharging factors. Due to this continuous influence, water levels of the aquifer system fluctuate and the range depends on the period of influence. The recharge to the groundwater system is controlled by many factors such as rainfall, seepage from reservoirs, lakes, ponds, rivers and irrigation, etc.

The monitored groundwater from CGWB data has been presented and the overall picture of groundwater storage behaviour due to continuous abstraction of groundwater analysed. Monitoring was carried out four times in a year, i.e. January, May, August and November. The water level data of May and November are taken as the level at pre- and post-monsoon respectively (see *Table 4: Depth to water level data of Noida: 2013 and 2014*).

The groundwater monitoring in the Gautam Budh Nagar district is being carried out by both state and central agencies. The district has seven observation wells being monitored by CGWB which consists of open wells and piezometer (Pz).[6]

Table 4: Depth to water level data of Noida: 2013 and 2014

Location	Type of monitoring structure	Depth to water level (mbgl)						
		Jan 2014	May 2014	Aug 2014	Jan 2013	May 2013	Aug 2013	Nov 2013
Sector 62A	Tube well (Pz)	24.56	25.39	26.35	21.55	23.08	23.62	24.25
Sector 92		10.58	10.38	10	10	11.8	9.68	10.28
Sector 72		22.57	24.14	24.37	21.53	21.03	21.41	21.1

Source: Groundwater monitoring data, 2013–14

According to Singh et al. (2011), the elevation of Noida's water table is 190–206 m above the mean sea level (MSL).[7] The master slope of water table is from the north, east, south and west (*see Map 2: Groundwater level elevation in Noida*). Both the rivers Yamuna and Hindon are in general affluent in nature.

The depth to water map has been prepared using the water-level data of the pre-monsoon, 2014, as obtained from CGWB (see *Map 3: Pre-monsoon depth to groundwater level in Noida, 2014)*. Similarly the decadal water-level fluctuation map, which is in comparison with pre-monsoon water level for 2014 with the decadal mean (2003–13), has been prepared to depict long-term water-level changes (*see Map 4: Pre-monsoon water level fluctuation in Noida, 2013*).

The decadal water-level fluctuation map clearly indicates that there is a significant decline in water level in major parts of Noida to the tune of more than 4 m. There is in general also a fall in the water level in other parts of Gautam Budh Nagar district in the range of 0 to 4 mbgl.

A long-term analysis of the time series of depth of water-level data indicates that water levels are rapidly falling and have gone down to more than 25 mbgl in some pockets of Noida. Water-level data has been graphically presented to indicate the groundwater situation in various sectors (*see Graph 2: Depth of groundwater in Noida during 2012-14*).

The gradual decline in groundwater level has been a major concern in Noida area in the past as well and has attracted media attention.[8, 9] Underdeveloped parts of the city depend heavily on groundwater to meet domestic as well as irrigation water requirements and are reporting alarming decline in groundwater levels.

3.2.2 Aquifer system and properties

A three-tier aquifer system has been identified in Noida up to a depth of 450 mbgl. The first aquifer system extends down from a depth of 125 mbgl to 200 mbgl in the northern part of the district. The thickness of the aquifer decreases in the western part of the district and depth of bedrock is shallow. The aquifer material is medium to coarse-grained sand, the exception being the trans-Hindon area.[10]

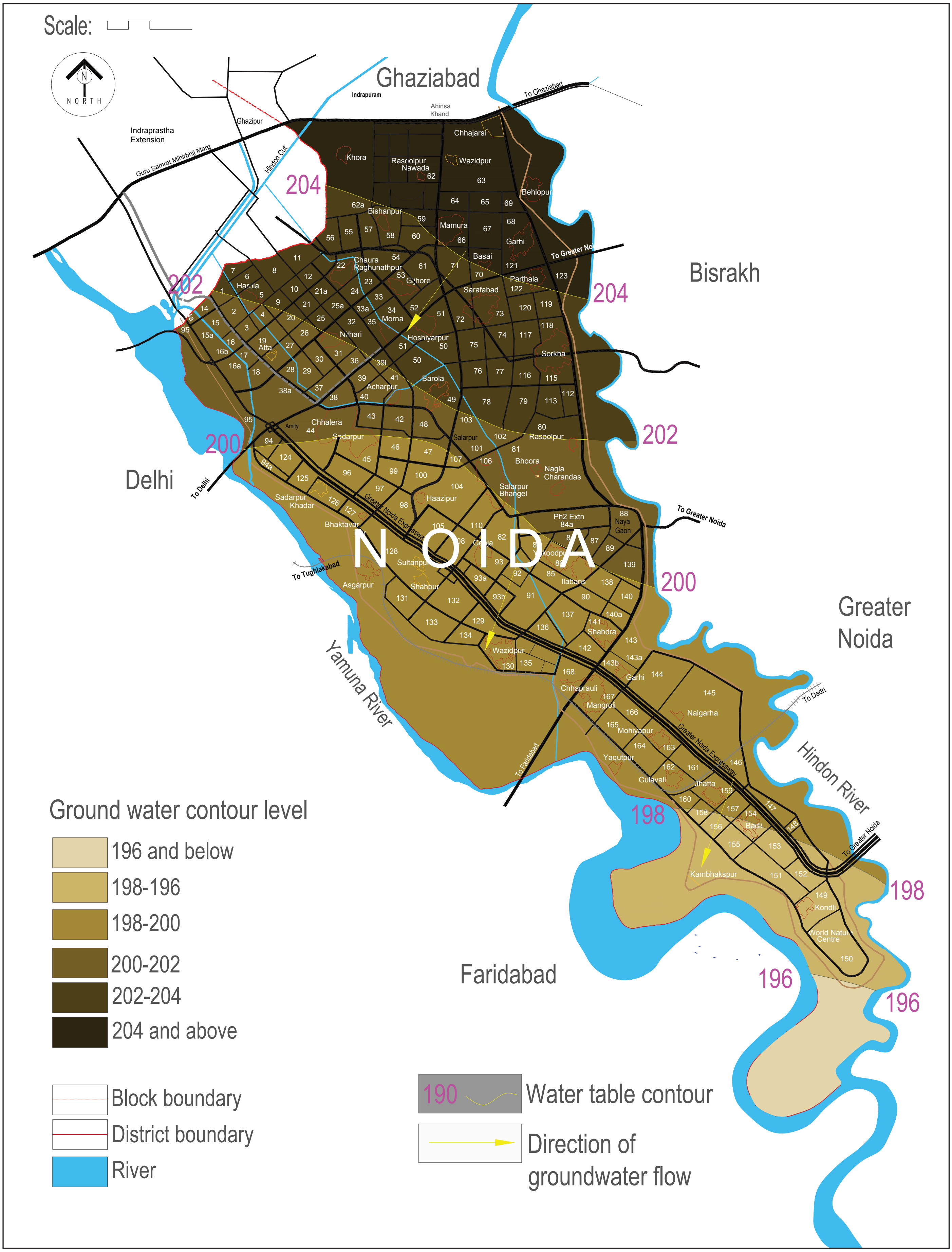
The second aquifer system exists in the depth ranges of 170–350 mbgl. The aquifer is medium to fine-grained sand with occasional coarse-grained sand. The tube wells yield 1,000–2,000 litres per minute (LPM), with a considerably high drawdown.[11]

The third aquifer system occurs below 350 m and continues down to an explored depth of 450 mbgl. Since no tube well has been constructed in this aquifer group, aquifer parameters are not known. As per the electrical log, the quality of water formation seems to be good.

Invariably, the first aquifer is exploited in Noida to meet drinking water needs.

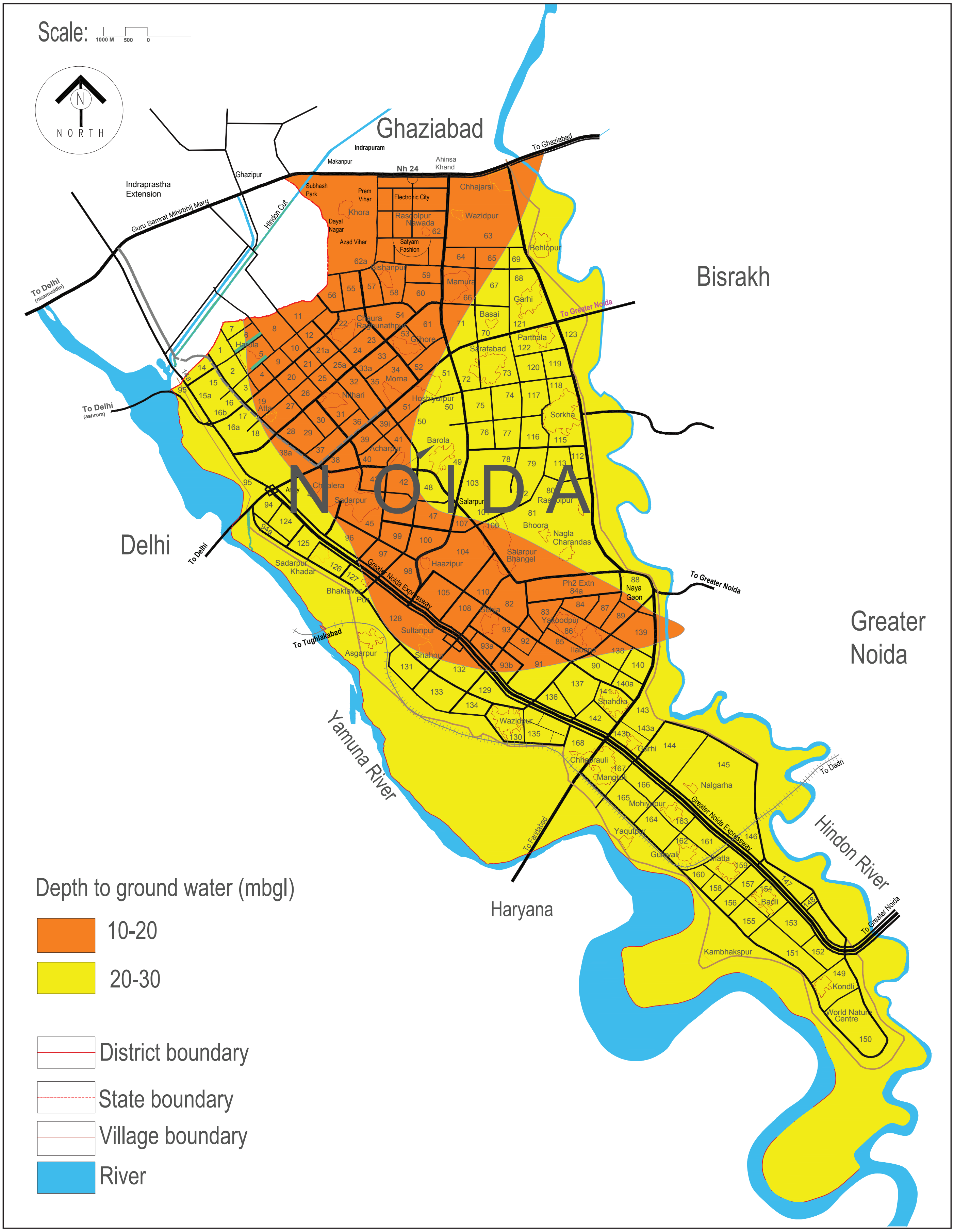
The thickness of aquifers is variable over Noida, ranging between 30 m and 40 m. It was

Map 2: Groundwater-level elevation in Noida



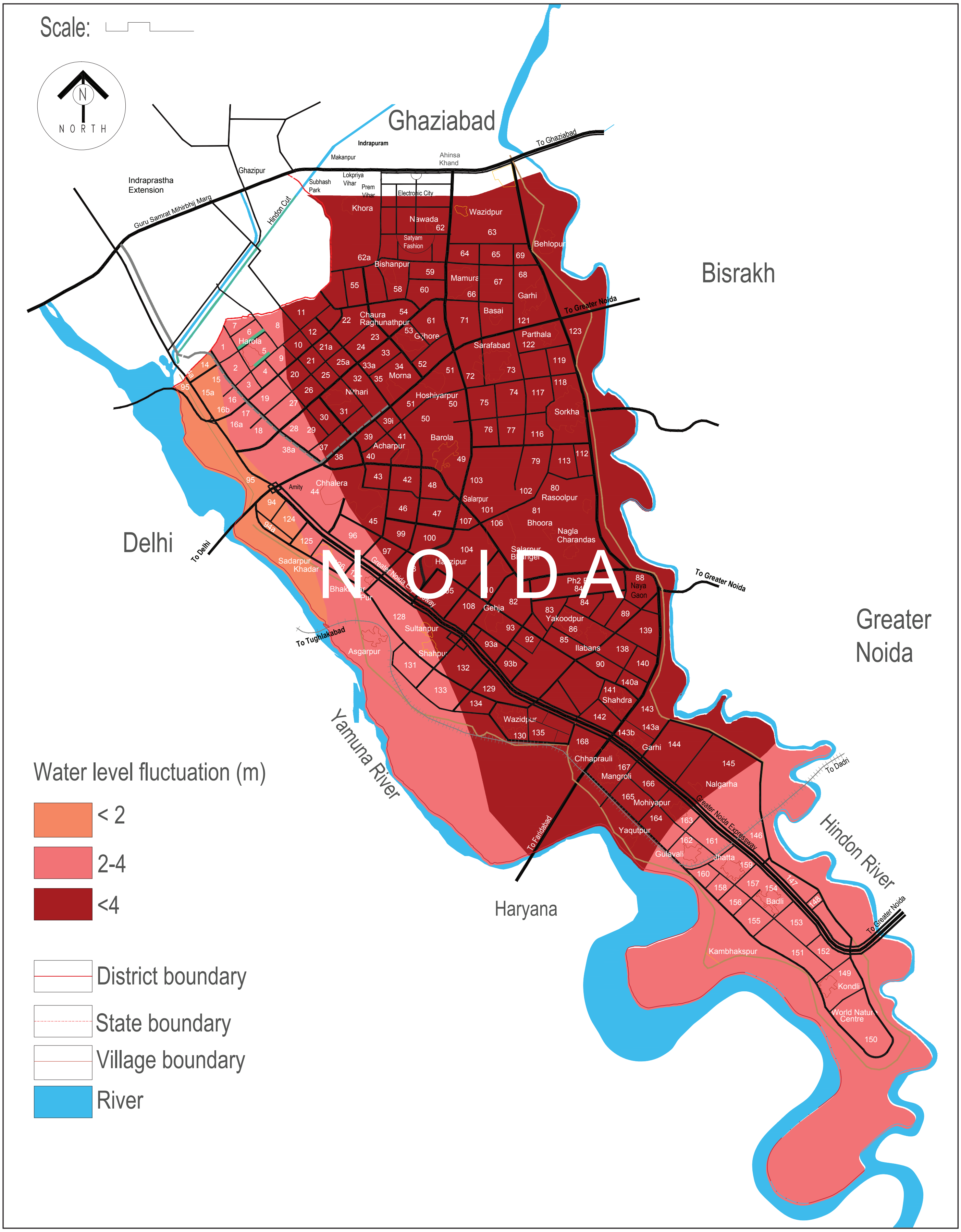
Source: B.C. Joshi 2010, 'District Brochure of Gautam Budh Nagar, U.P. (A.A.P: 2008-2009)'

Map 3: Pre-monsoon depth to groundwater level in Noida, 2014



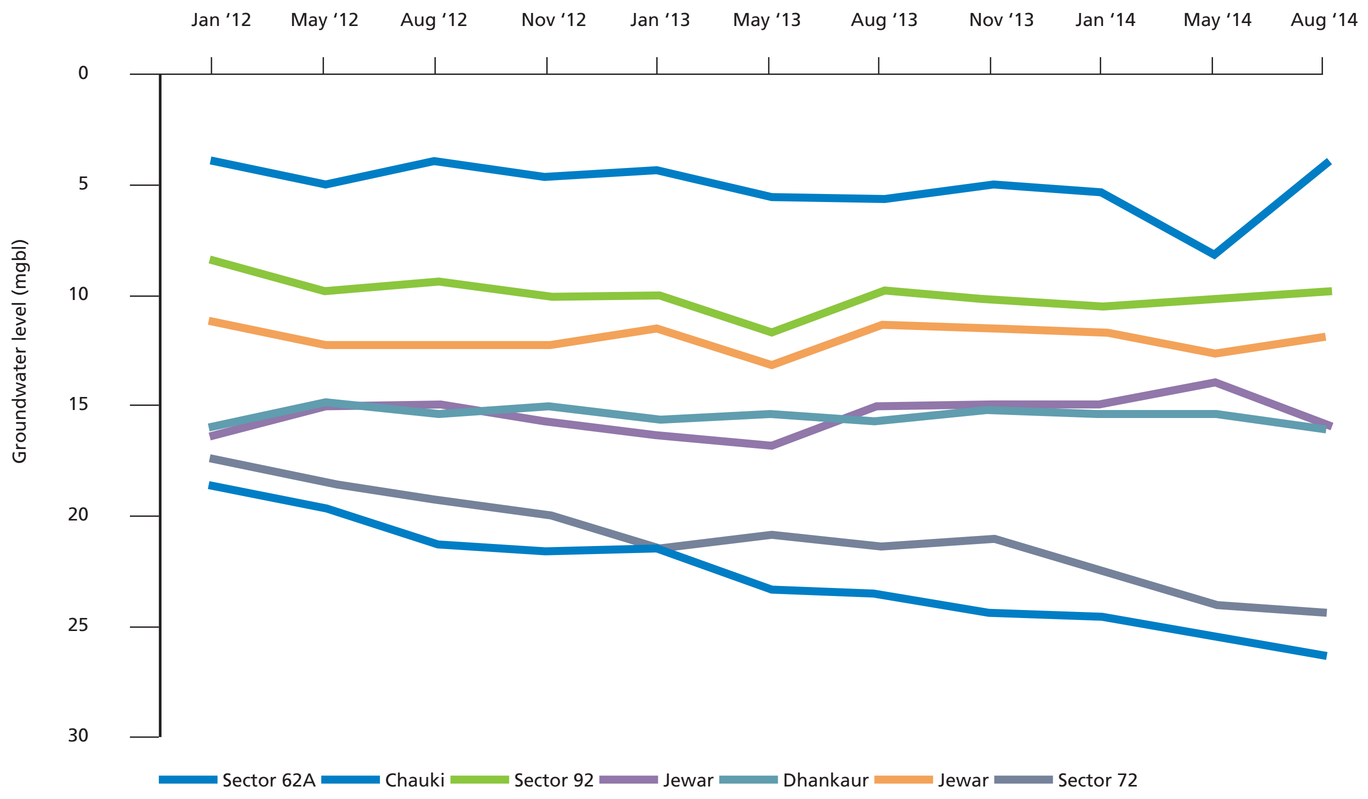
Source: Groundwater monitoring data, 2013–14 and CSE, 2016

Map 4: Pre-monsoon water-level fluctuation in Noida, 2013



Source: Groundwater monitoring data, 2013–14 and CSE, 2016

Graph 2: Depth of groundwater in Noida during 2012–14



Source: Groundwater monitoring data, 2013–14, CGWB 2014

observed that generally the thickness of alluvial sediments increases in southeast parts of Noida city. The river Hindon follows a fault contact and the depth to the bedrock east of the Hindon suddenly increases.[12] The state government has constructed various tube wells at a depth of 80 m to as much as 350 mbgl. The discharge of these structures generally ranges between 8 and 16 litres per second (lps) with moderate draw down of 3–6 m. Few wells have reported exceptionally high yield of around 500 lps.

3.2.3 Groundwater quality

The quality of groundwater is a pressing issue in Noida. The different hydro-geochemical processes, such as dissolution, mixing, ion exchange processes along with the weathering of silicate and carbonate minerals, control the chemistry of groundwater, the major contributor in Noida's water supply.

The thickness of the freshwater aquifer is very limited in Noida and existing shallow tube wells yield a very poor discharge. The brackish/saline groundwater is recorded at shallow depths. In the area between the rivers Yamuna and Hindon, the quality of groundwater is brackish to saline with depth, and the groundwater quality deteriorates with depth. The fresh–brackish water interface lies at a depth ranging between 30 and 80 m. However, the shallow water table and presence of potential aquifers within 150 m depth beneath the Yamuna floodplains provide scope for use of groundwater for local domestic/drinking use in different towns and villages.[13, 14]

The iso-conductivity of groundwater of Noida is very high and reported to be about 1500–2000 µ mhos/cm at 25°C (see *Map 5: Iso-conductivity of groundwater in Noida*). According to the State Pollution Control Board laboratory the lead concentration is higher in groundwater and the hardness in groundwater is also reported high in few areas. The hardness above the permissible limit for drinking water has been attributed to the presence of magnesium and calcium.[15, 16]

The electrical conductivity (EC) ranges from 1,500 to 2,000 µ mhos/cm at 25°C in Noida. The groundwater is alkaline and fresh to brackish in nature.[17] CGWB reports on availability of freshwater in Noida records EC at about 1,250 microhos/cm, which is high compared to other areas of Gautam Budh Nagar district. The presence of nitrogen trioxide compound and fluoride in Noida's groundwater is negligible or not present. The iron content is also within permissible limits in all locations of Gautam Budh Nagar district.

It has been observed that certain major ions and heavy metal concentrations in groundwater exceed the desirable limits for drinking water in many places in Noida. Concentrations of TDS, Cl, Na, SO_4, TH, Fe, Mn, Pb, Ni, Al and B at many sites are beyond the safe limits of drinking water, indicating contamination by untreated industrial and domestic waste effluents.

The drinking water supply in Noida Sector 10, for instance, contains 2,000 parts per million (ppm) of TDS against the maximum permissible 500 ppm. The total hardness of the water supply is 850 ppm against a maximum of 300. The water's alkalinity is 200 mg per litre as against 120, and the level of chlorides is 700 ppm against the acceptable limit of 250 (*see Graph 3: Qualitative analysis of drinking water supply of Sector 10, Noida*).[18]

A sample taken from Sector 20, Noida shows the hardness to be 2,000 ppm against the maximum permissible 500, TDS 750 against 300, alkalinity 200 mg against 120 mg and chlorides to be 675 ppm against the permissible 250 ppm. In Sector 61, the TDS recorded is 1,400 ppm against the permissible maximum of 500 and the hardness 600 against the permissible maximum of 300 ppm. A sample taken from Sector 28 shows that the TDS is 1,990, total hardness 776 ppm and chlorides are 655 ppm (see *Graph 4: Qualitative analysis of drinking water supply of Sector 20, Noida*).[19]

3.3 DRAINAGE SYSTEM

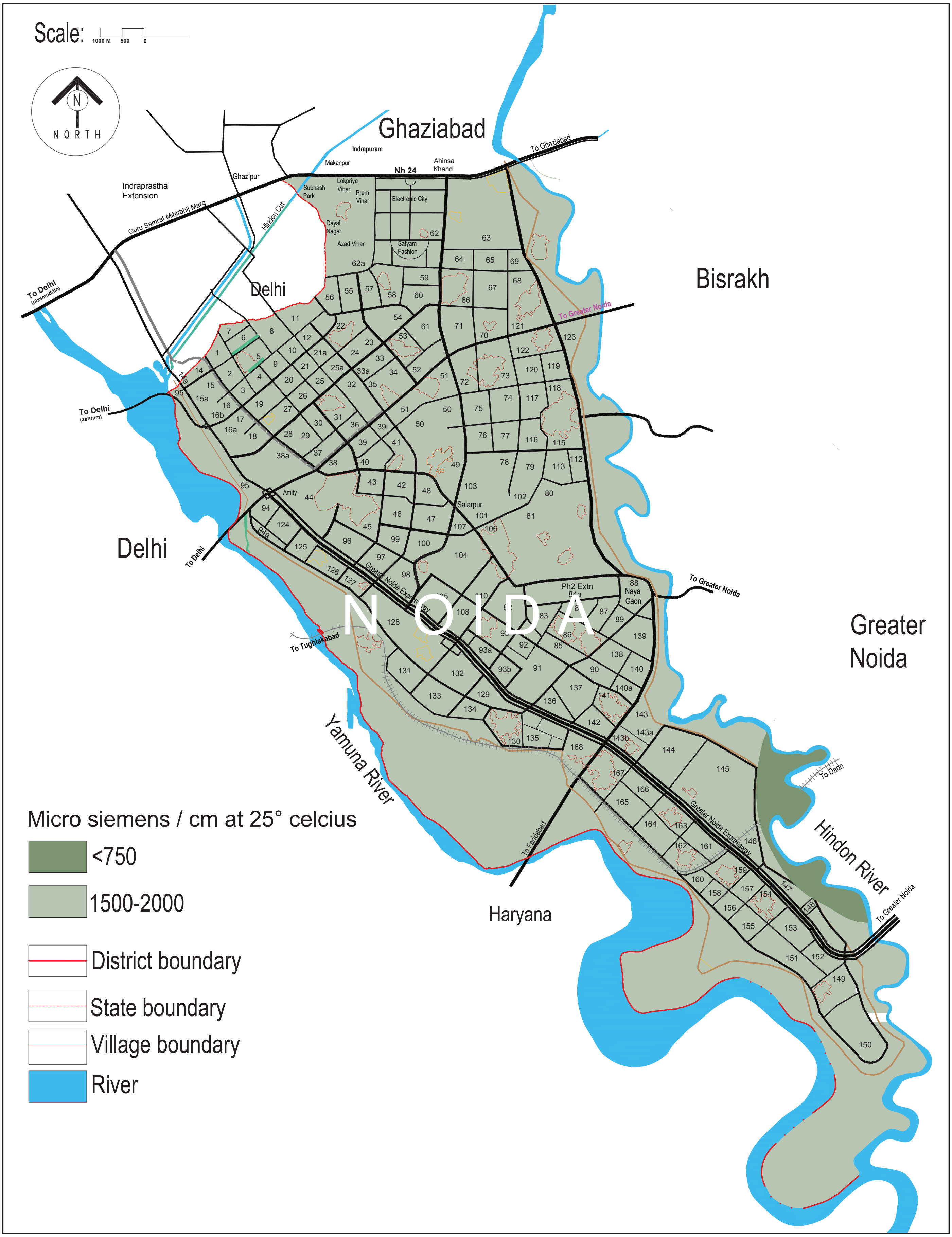
Storm water from Noida drains into the rivers Yamuna and Hindon, both flowing southwards. The area has several natural drains that follow a northeast to southwest slope. Several ponds also help absorb some storm-water surface flows.

Noida is low-lying and prone to floods and water logging. The main threat of flooding is from the rivers Yamuna and Hindon, which are adequately fortified by bunds. Noida Authority has proposed to strengthen the Yamuna embankment by constructing a four-lane permanent road on the embankment. A new embankment beyond the present one is also proposed to protect the city from the eventuality of flood in the Yamuna River. Noida currently cannot sustain a rainfall of equal or greater intensity than 18.85mm/hr. The present intensity of rainfall in Noida is, however, about 90 mm/hr and the area is hence subject to severe flooding (see *Map 6: Flood-prone areas in Noida*).[20]

Aside from the natural drains and waterbodies, a major man-made drain, Hindon Cut, has been constructed in the northwest of Noida. This drain is used by irrigation authorities to divert excess floodwaters of the Hindon into the Yamuna at a point near the western boundary of Noida.

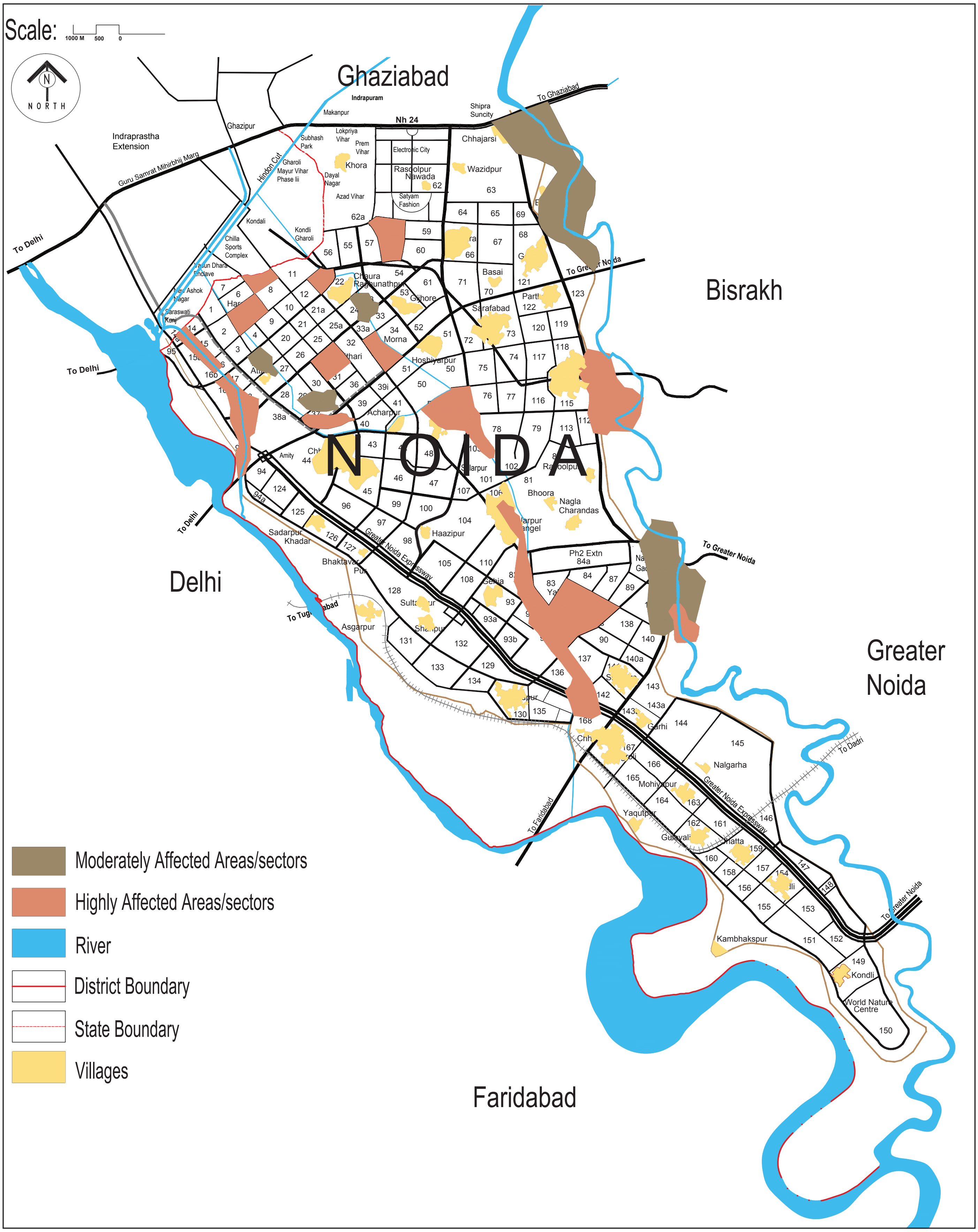
Two other major drains exist in the area. One flows through Sectors 14, 15 and 16 and falls into the river Yamuna southwest of Sector 16. The other drain, Noida Drain, flows through the southern part of the area and falls into the river Yamuna upstream of the Yamuna–Hindon confluence point. This drain is currently used as the outfall channel

Map 5: Iso-conductivity of groundwater in Noida



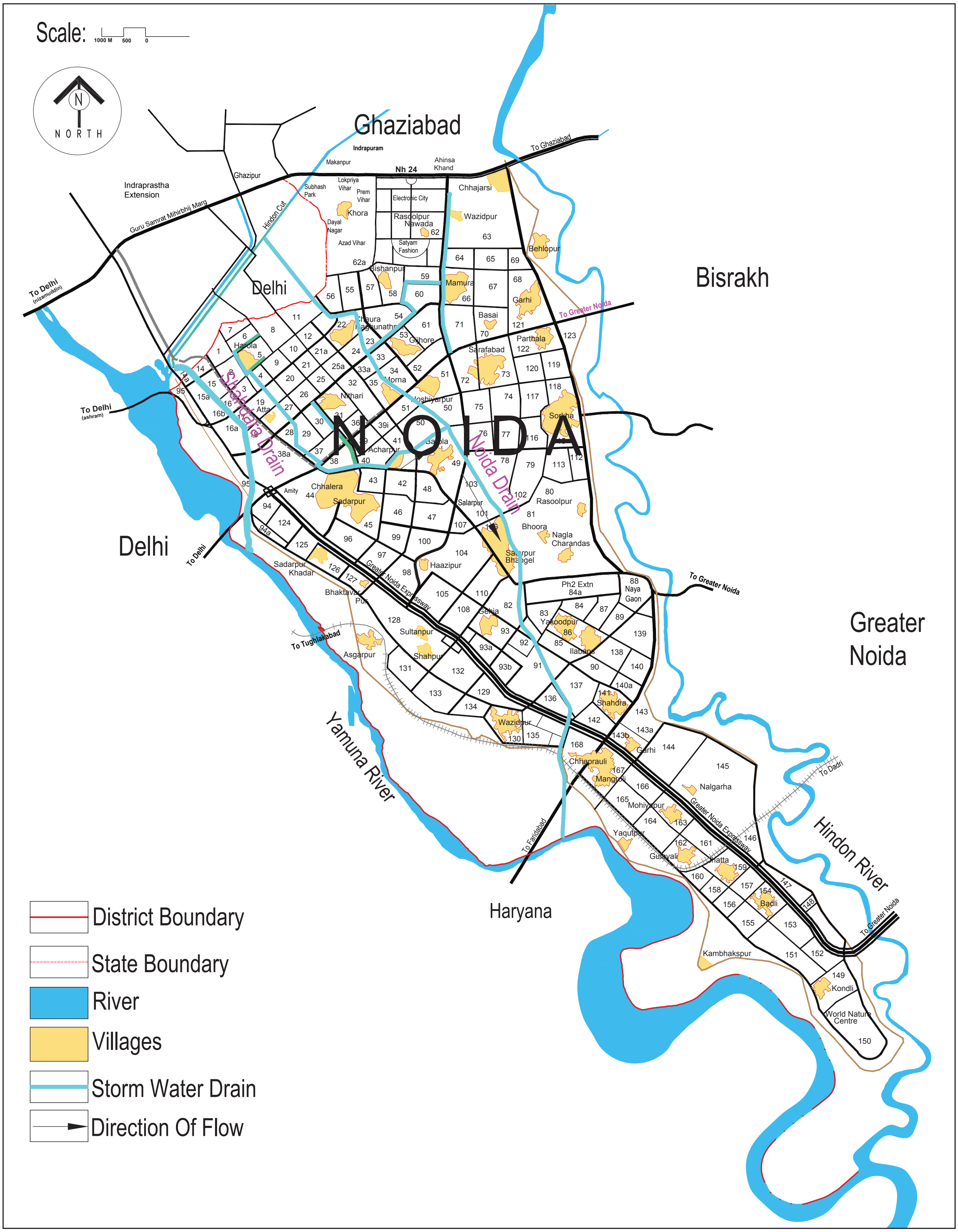
Source: *B. Kumar 2004, 'Transformation of urban villages: Case study of NOIDA and Greater Noida', Thesis (Phd), ITPI, New Delhi*

Map 6: Flood-prone areas in Noida



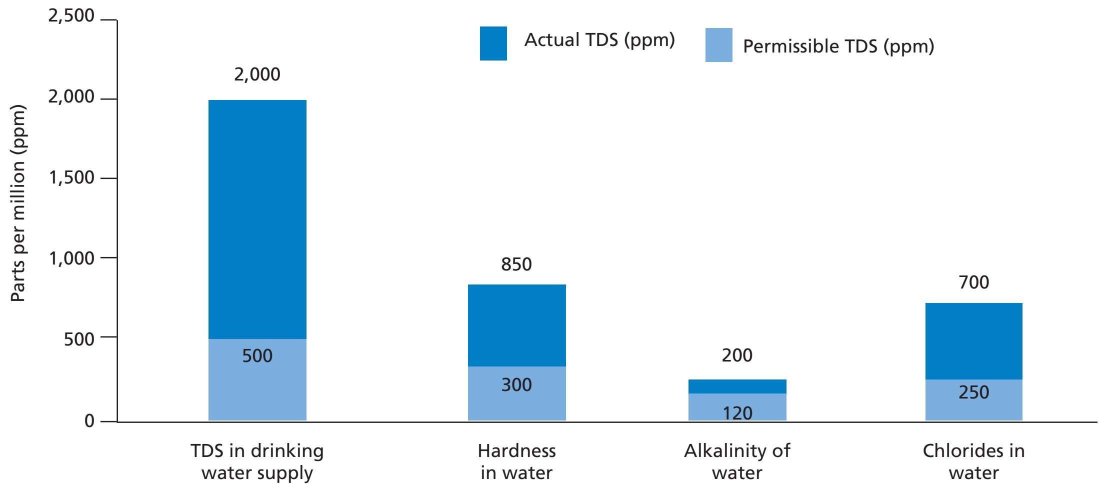
Source: J. Singh, ed. Disaster management: Future challenges and opportunities, R.B. Singh and S. Singh 2007, 'Challenges of flood disaster management: A case study of Noida: A GIS approach', New Delhi: IKM Publications, 95–112

Map 7: Location of storm-water drains in Noida



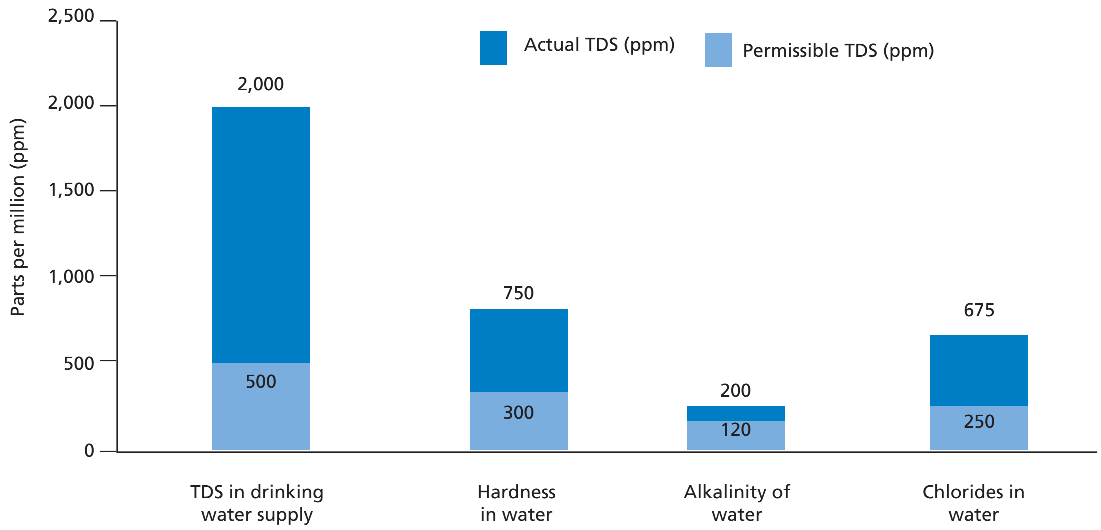
Source: Survey of India 2007, 'Open series map'. No. H43X6; Scale 1:50,000

Graph 3: Qualitative analysis of drinking water supply of Sector 10, Noida



Source: A.K. Singh, B. K. Tewary, A. Sinha 2011, 'Hydrochemistry and quality assessment of groundwater in part of NOIDA metropolitan city, Uttar Pradesh', Springer, Journal of Geological Society of India *78, 523-540*

Graph 4: Qualitative analysis of drinking water supply of Sector 20, Noida



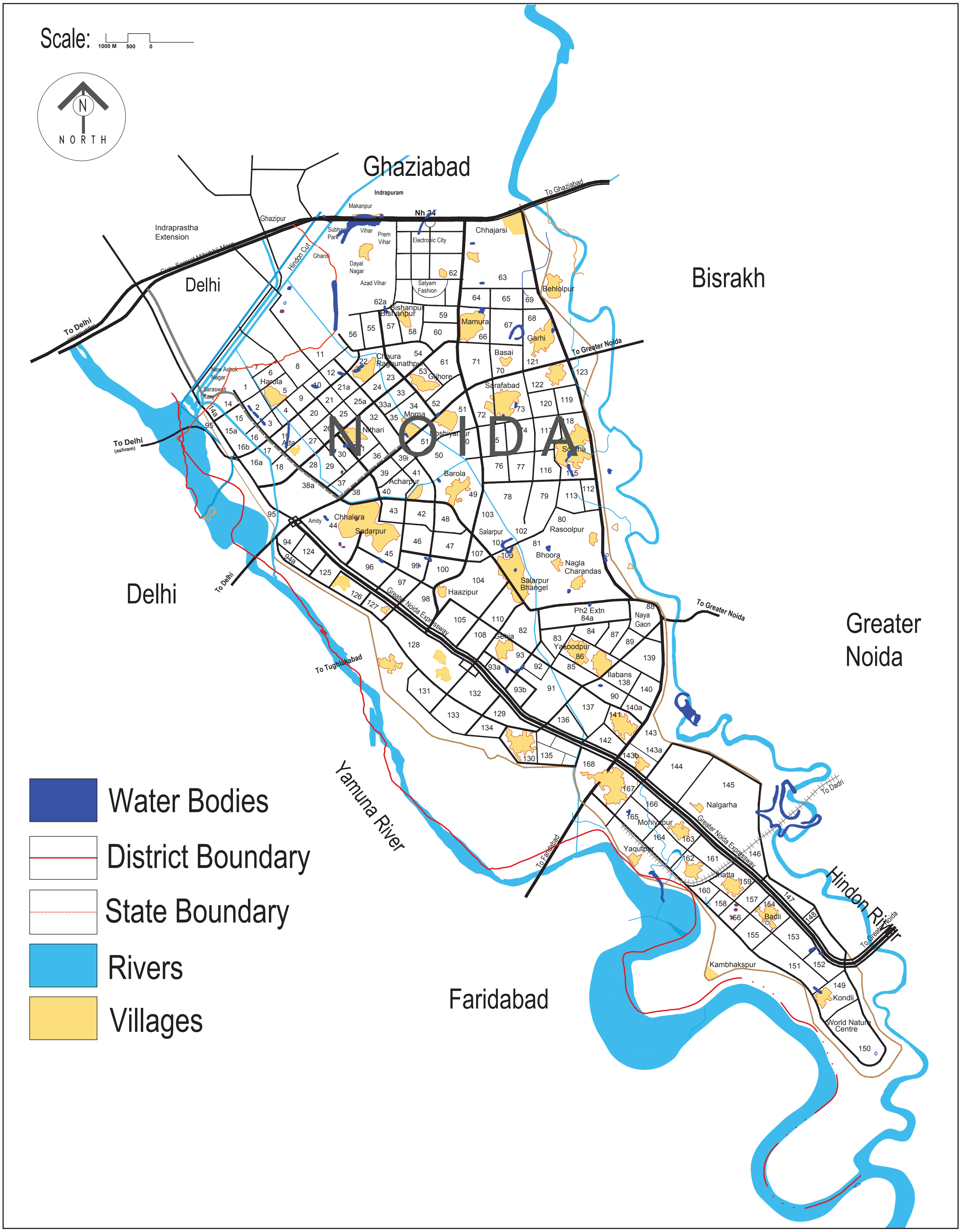
Source: A.K. Singh, B.K. Tewary, A. Sinha 2011, 'Hydrochemistry and quality assessment of groundwater in part of NOIDA metropolitan city, Uttar Pradesh', Springer, Journal of Geological Society of India *78, 523–40*

for drains servicing most of Noida (see *Map 7: Location of storm-water drains in Noida*). The increased runoff due to more built-up area has caused an increase of pressure on the existing drains. The drains along the commercial areas of Noida city have been encroached on at several places. The dumping of solid waste and discharge of untreated wastewater into these drains is the major cause of deteriorating river water quality in both rivers Yamuna and Hindon.

3.4 WATERBODIES

Noida is a low-lying area, with several waterbodies that are currently filled up, built on or encroached on (see *Map 8: Waterbodies in Noida in 1976*). At the same time, several ponds and drainage channels are lost due to lack of water-sensitive urban design and planning.

Map 8: Waterbodies in Noida in 1976



Source: Survey of India 2007, 'Open series map'. No. H43X6; Scale 1:50,000

3.5 EXISTING LAWS AND POLICIES ON RWH IN NOIDA

The building by-laws amended by the UP government has made rooftop RWH mandatory for all the buildings (government and institutional) with or more than 1,000 sq. m area (refer to notification in the *Annexure*). The notification has made RWH mandatory for all new housing schemes, plots, buildings and group housing schemes, along with a network of pipes for RWH. Noida Building Regulation and Directions (2006), however, specifies RWH provision be made by the allottee in case plot area is more than 300 sq. m in all categories.[21]

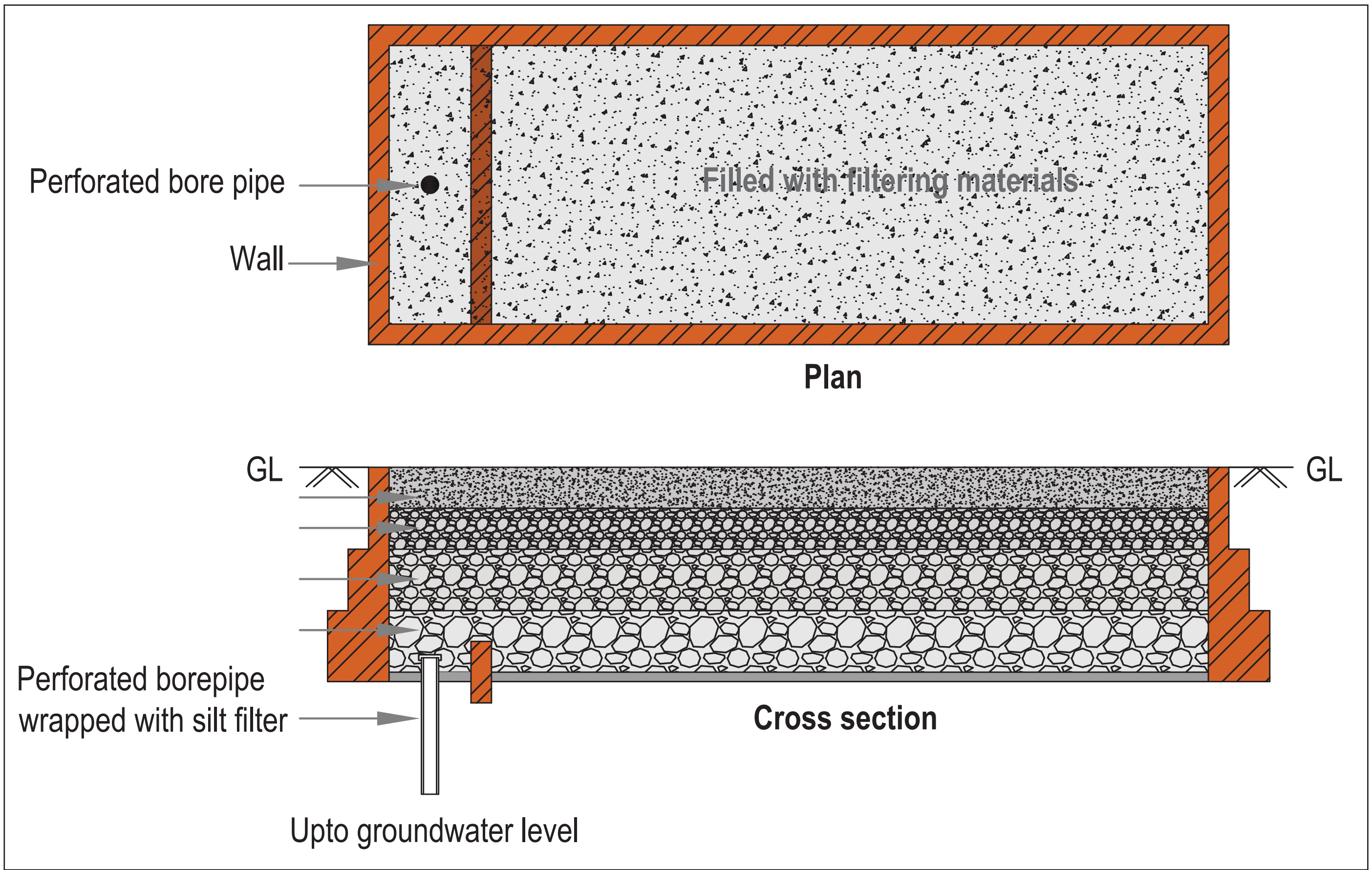
For housing schemes of 20 acres and above, it is mandatory to develop ponds/waterbodies in 5 per cent of the total proposed area (*Annexure*).

Vast areas in Noida are developed and maintained as green and open public spaces. The authority may allow, in exceptional circumstances, the development of public utilities on a maximum of 2 per cent of the total land of a park or green belt. However, RWH or recharge systems or waterbodies shall be allowed in parks and green belts.[22]

3.5.1 Status of RWH in Noida

Along with RWH being enforced in residential and industrial plots of over 300 sq. m, the horticulture wing of Noida Authority has also started RWH in parks and green areas. The civil maintenance wing of Noida Authority constructs and maintains RWH systems in all government/Authority premises.[23] For the past two years, the horticulture department of Noida Authority has implemented several RWH structures in parks and green belts to solve the problem of flooding in specific areas (see *Diagram 1: Recharge well for parks and green areas in Noida*).

Diagram 1: Recharge well for parks and green areas in Noida



Source: Horticulture Department, Noida Authority

4 Land use

Noida had around 4,527 ha of developed land in 1998. The city's proximity to NCT Delhi resulted in rapid development in the last two decades. As it is part of the Yamuna floodplain—and in view of the environmental and ecological sustainability of the area—proper planning was imperative.[1] The state government notified the entire area between the rivers Hindon and Yamuna under Noida, covering approximately 20,316 ha of land and 81 villages in the Master Plan for Noida in 2011.[2] A total of 7,789 ha of land was proposed to be developed in Noida as per the Master Plan for 2011.[3]

The city was planned with a focus on industrial development. Effort was made, however, to provide complementary facilities with a view to achieving integrated development. Thus, simultaneous with industrial sectors, areas have been developed for residential, commercial, institutional, and government and semi-government activities, along with physical infrastructure for transportation, electricity, water supply, sewerage, drainage and garbage disposal. The Master Plan also provides for the development of recreational facilities and social infrastructure relating to education, health, social and cultural needs of the people. Other public facilities relating to telecommunication, marketing, police protection, fire safety, milk supply and petrol stations are also being provided in a phased manner.

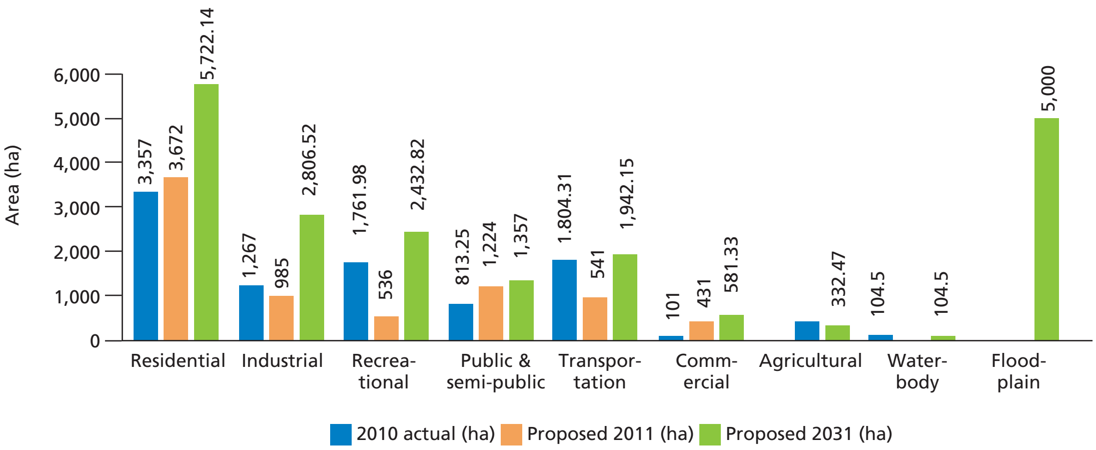
4.1 EXISTING LAND-USE PATTERN

Noida is a fast-growing city with actual development much more than proposed urbanizable limits defined in Master Plans 2001 and 2011. Land-use changes over past three decades are presented in *Graph 5: Land development in Noida from 2001 to* 2031.[4, 5, 6]

The total proposed urbanizable area of about 15,280 ha has been divided into sectors and facilities have been distributed in almost every area of the city. Projections show that by 2031, when the city population is expected to reach 25 lakh, its overall population density will be about 164 persons per ha.

A detailed analysis indicates that 61 per cent of the total proposed area (excluding floodplains) to be urbanized was developed for different land uses by January 2010 and approximately 1,000 ha of land is in the process of development. The expansion of urbanization in spatial terms is shown in *Map 9*: *Urban growth in Noida 1976–2006.*

Graph 5: Land development in Noida from 2001 to 2031



Source: Noida Authority 2011, 'Master Plan for Noida-2031'; Noida Authority 1989, 'Master Plan for Noida-2011' and Noida Authority 1983, 'Master Plan for Noida-2001'

Map 9: Urban growth in Noida 1976–2006

Source: M. Mohan 2000, 'Geospatial information for urban sprawl planning and policies implementation in developing country's NCR region: A study of Noida', JMI Central University, New Delhi

4.2 PROPOSED LAND-USE PLAN

The pace of development surpassed the anticipated growth rate of Noida, resulting in the need for a revised Master Plan. The revised plan was prepared keeping in mind that since an expressway to link Noida with Greater Noida was proposed to be constructed in the immediate future, unplanned development (especially commercial uses) was likely all along the length of the expressway in the absence of a plan to control it. It was decided to get a master plan prepared for the total area under the jurisdiction of Noida Authority.[7, 8, 9]

Noida is planned on a gridiron pattern. The major roads are planned horizontally from southwest to northeast, interconnected by perpendicular roads forming a grid and dividing the area into sectors. It was planned as a self-contained integrated city. Its high-density residential areas are located close to workplaces. Commercial centres are well distributed, with the main commercial hub in the city centre. The sub-district centres are distributed with respect to residential catchment areas. Residential sectors are to be developed at varying densities. A few sectors have been planned for high-density group housing with provision of large recreational/green areas. The central park and major public and semi-public uses are located so as to run linearly in a north–south direction more or less centrally through Noida. The graphical representation of areas under different land use and its historical developments is given in *Graph 6: Comparison of land development of Noida: 2010 and 2031.*

Table 5: Land-use distribution of Noida: 1998, 2011, 2021 and 2031 gives the land-use distribution for Noida in 1998 and also proposed land uses in Master Plans for 1998, 2011, 2021 and 2031. It is observed that in 2031, when Noida's population is expected to reach 25 lakh, the overall density of the city will be at a low of 164 persons per ha. The area for residential development would increase to 5,722.14 ha.

The land development proposed over two decades for Noida is presented in *Map 10: Proposed land-use plans of Noida: 2001–31.* Various land uses identified in the proposed Master Plan are briefly discussed along with its relevance in planning RWH systems.

4.3 RESIDENTIAL AREAS

Out of the 9,211 ha of developed area in Noida, about 3,358 ha, i.e. 36.45 per cent, is under residential use. Actual development of residential land is more than what was expected by 2011 and it is also reflected in the high growth rate of population during the last decade. Most of the development for residential sectors took place in the 1980s. At least 33 sectors were developed in an area of 1559.45 ha. Noida Authority has allotted approximately 1,025.45 ha land as developed group housing plots, which would accommodate about 10 lakh people. The Authority has already constructed over 34,500 residential units and developed about 30,000 residential plots for different income categories.[10]

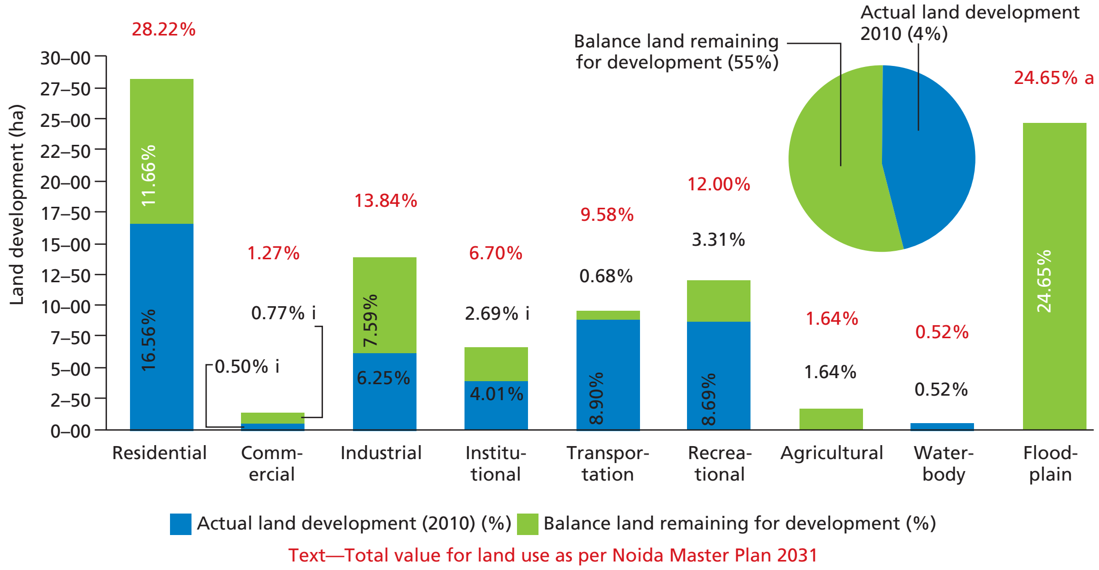
An average sector measures about 55 ha and is proposed to have a mixed form of development, by type, size of dwelling units, and pattern and mode of development, viz. group housing or plotted, and public housing or private constructed, to cater to appropriate socioeconomic mixes. Residential area development comprises mainly the following three types:

- Village abadi and extension area
- Medium-density residential area
- High-density residential area

4.4 INDUSTRIAL AREAS

Noida Master Plan 2031 has 2,806 ha (18.37 per cent) of land proposed for industrial use for 2031. Industrial development in Noida has been in three phases. A total of about 1,267 ha of industrial area had been developed till 2010 and by 2031 a total area of about 2,806 ha is planned to be developed. Noida Export Processing Zone is developed close to the

Graph 6: Comparison of land development of Noida: 2010 and 2031



Source: Noida Authority 2011, 'Master Plan for Noida-2031'; Noida Authority 1989, 'Master Plan for Noida 2011' and Noida Authority 1983, 'Master Plan for Noida 2001'

Table 5: Land-use distribution of Noida: 1998, 2011, 2021 and 2031

Land use category	Existing land use (1998)		Master Plan (2011)		Proposed land use (2021)		Proposed land use (2031)	
	Area (ha)	Per cent	Area (ha)	Per cent	Area (ha)	Perc ent	Area (ha)	Per cent
Residential	1,607	35.5	3,672	47.2	5,334	35.7	5,722.14	37.45
Commercial	36	0.8	431	5.5	564	3.77	581.33	3.80
Industrial	1,092	24.1	1,224	15.7	3,001	20.0	2806.52	18.37
Public/semi-public	571	12.6	985	12.7	1,219	8.15	1357.97	8.89
Recreational	208	4.6	536	6.8	1,513	10.11	2432.82	15.92
Transportation	1,013	22.4	941	12.1	2,211	14.78	1942.15	12.71
Agriculture	NA	NA	NA	NA	1,001	6.67	332.47	2.18
Canal	NA	NA	NA	NA	121	0.81	104.50	0.68
Total	4,527	100.0	7,789	100.0	14,964	100.0	15279.90	100.00

Source: Noida Authority 2011, 'Master Plan for Noida-2031'; Noida Authority 1989, 'Master Plan for Noida-2011' and Noida Authority 1983, 'Master Plan for Noida-2001'

Industrial Area Phase II. In the first phase, about 217 ha of land has been developed for plots and flatted factories. In the second phase, another 500 ha of land is proposed for expansion of the zone.[11]

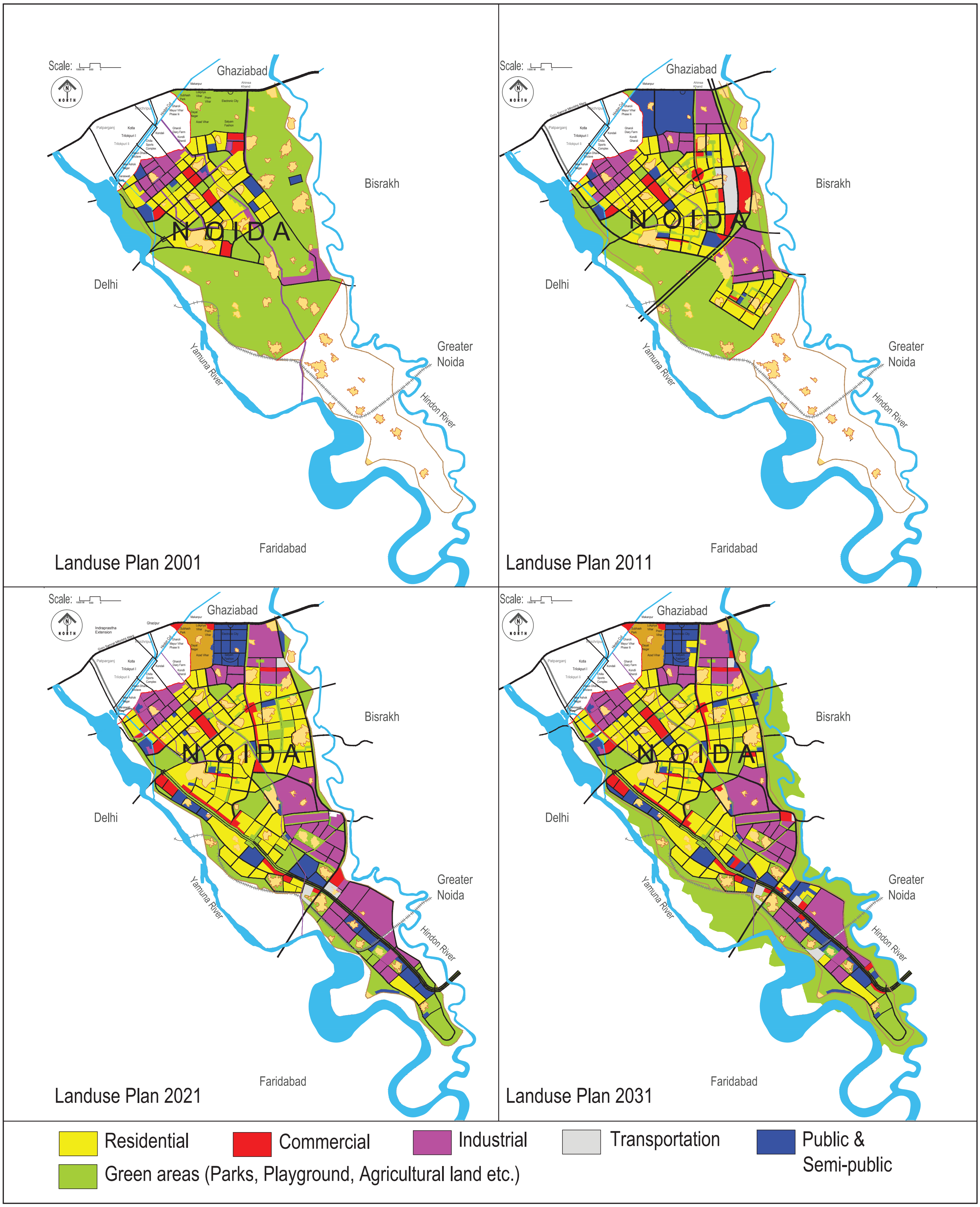
4.5 COMMERCIAL AREAS

Sector-level shopping centres and local-level convenient shopping centres have been developed in all the sectors of Noida. The total area proposed for commercial land use is about 581.33 ha. Besides this, commercial facilities have been provided at the sector, block and cluster levels. But these provisions are treated as part of residential areas and hence not included in the calculations for commercial areas as part of land-use analysis. Till 2010, about 102 ha land in different part of city is developed and used for commercial activities.[12]

4.6 INSTITUTIONAL AREAS

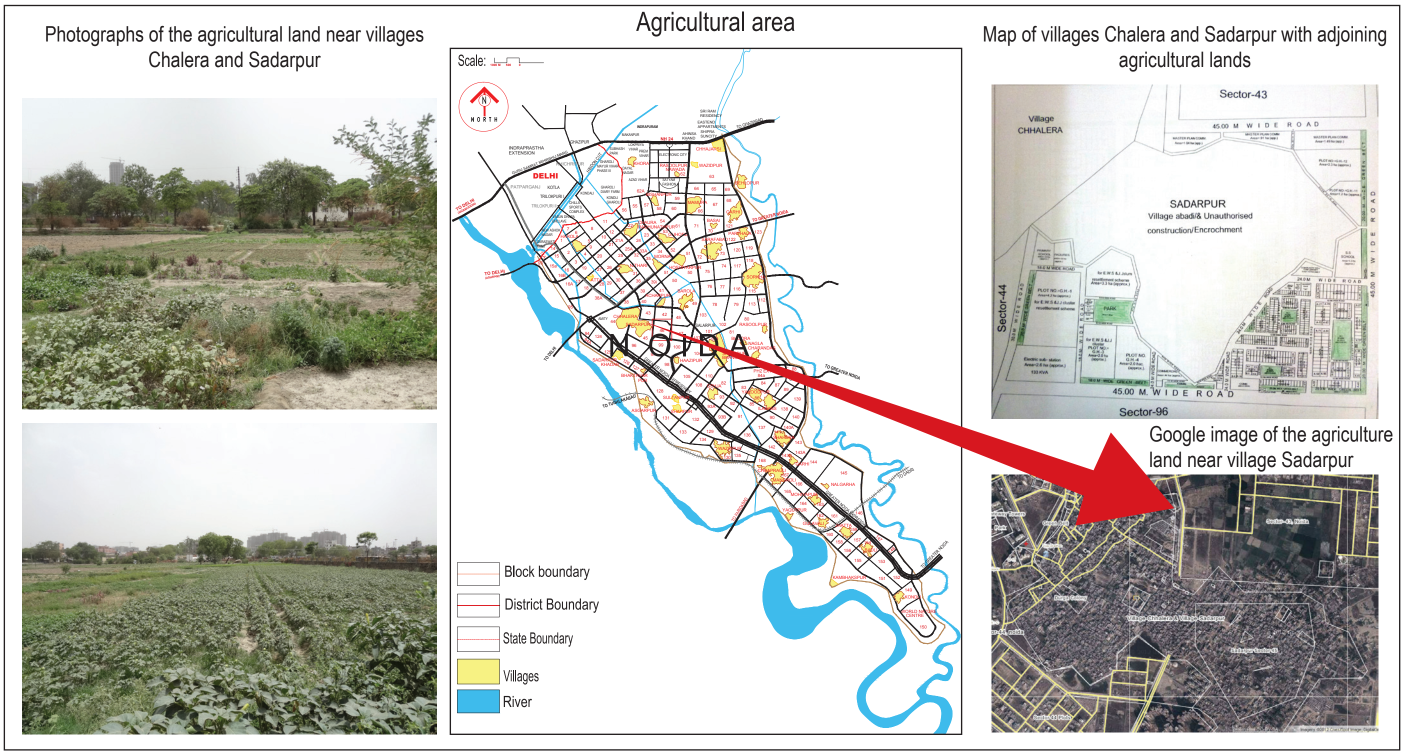
Noida Authority has allotted about 493 ha of land for various educational institutions and 19.67 ha land for research and training centres. It has allotted about 51.20 ha of land to national-level institutions, about 427.25 ha of land for IT, and about 161 ha of land for corporate offices and social/cultural and religious activities. Approximately 813.28 ha of

Map 10: Proposed land-use plans in Noida: 2001–31



Source: Noida Authority 2011, 'Master Plan for Noida-2031'; Noida Authority 1989, 'Master Plan for Noida-2011' and Noida Authority 1983, 'Master Plan for Noida-2001'

Map 11: Agricultural area near Sector 43, Noida



Source: Noida Authority 1989, 'Master Plan for Noida 2011' and CSE, 2015

land has already been developed under institutional and other community facilities and services in Noida. It constitutes about 8.83 per cent of total developed land by 2010. About 1,378 ha of land is proposed for institutions and other public/semi-public facilities at the city level. Institutional areas are located along the expressway and National Highway 24. Sectors 62, 125, 126, 127, 132, 136, 142 and 153 are exclusively planned for institutional facilities.

4.7 AGRICULTURAL AREAS

About 378.47 ha of land, mainly along the Yamuna embankment—between the embankment and different sectors—is proposed for agricultural use. The development of the land and its disposal for specific purposes will be planned so that its prime character remains open and broadly green in nature. It is proposed to develop this area primarily for farmhouses, with a provision of a maximum of 10 per cent covered area on the ground and 90 per cent area of developed farmhouses will remain open and broadly green in nature (see *Map 11: Agricultural area near Sector 43, Noida*).

Waterbodies exist in different parts of the city. It is proposed that all the waterbodies will be developed and maintained by the Authority. A part of green areas will be developed as planned green belts. Areas can be allotted from green developed areas and green belts to act as groundwater recharge systems. Building construction will not be allowed on plots reserved for waterbodies or on plots recorded as waterbodies in the revenue records.

4.8 RIVERFRONT DEVELOPMENT AREAS

Noida has proposed over 5,000 ha of land as riverfront development areas. This entire area is proposed to be kept green and open. It is, however, proposed that the riverfront areas be developed for recreational and tourist activities, with the provision of temporary and removable structures on 1 per cent of the area for a specific development project. Noida is a sensitive area and needs a detailed study to understand the cycle of flood occurrence, groundwater recharge potential and requirement, and potential for reclamation. The floodplain areas could be developed as reservoirs that could be used for holding back local/regional runoff.[13, 14]

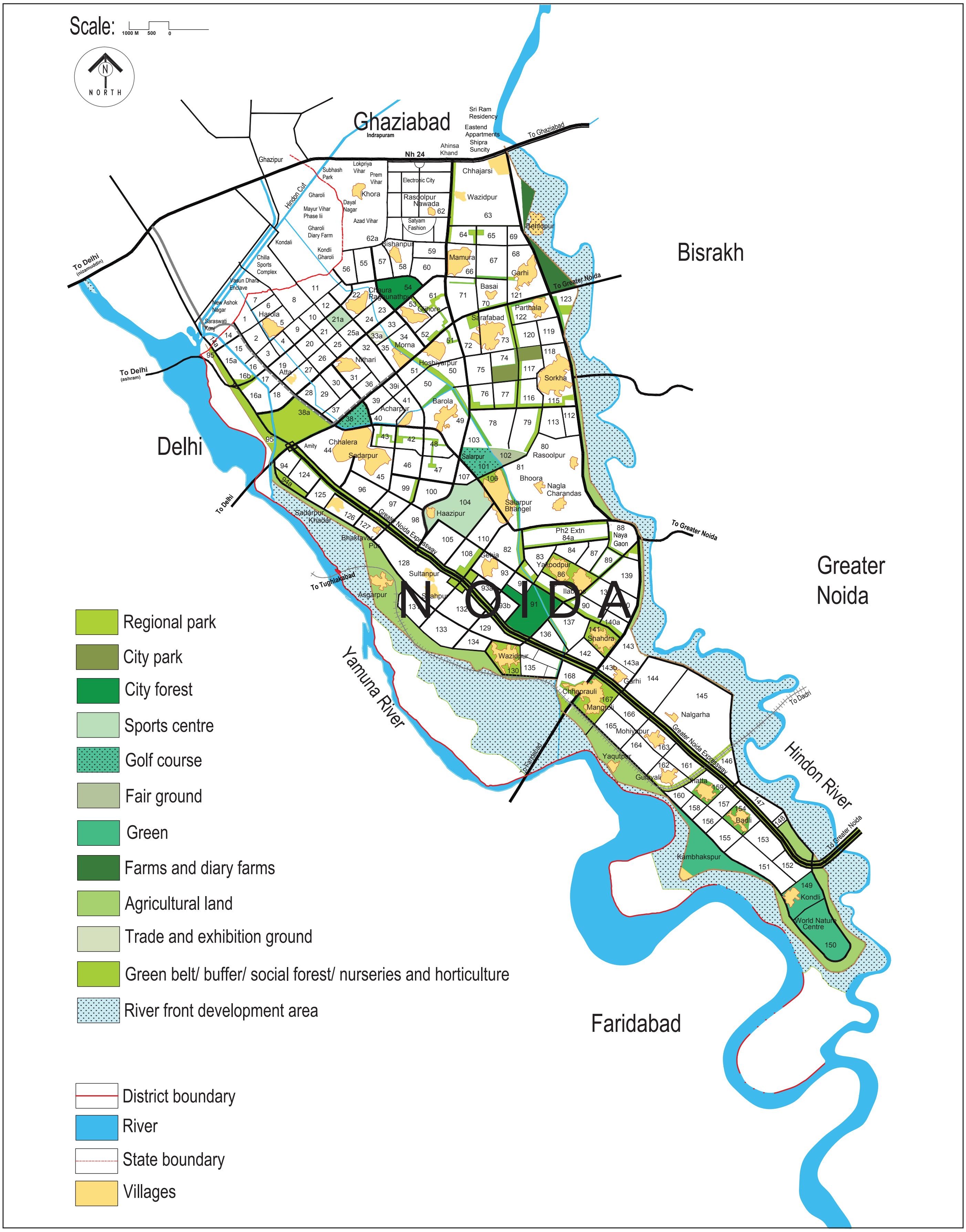
4.9 RECREATIONAL AREAS

Three types of recreational areas are proposed in Noida: parks, playgrounds and green belts. About 2,433 ha land has been proposed for recreational purposes. Almost all the sectors have a provision of 10–12 per cent of land for parks, playgrounds and other open spaces. In 2010, about 1,762 ha were already developed for recreational purposes, with considerable area under parks.

Noida Authority has proposed large spaces as recreational green areas in different places in the city. The development of parks is proposed in sectors where people live and buildings or industrial units have been developed. So far, 650 parks have been developed in Noida, with a total area ranging from 0.1 acre (0.04 ha) to 8 acre (3.23 ha). On average, there are 10 parks in each sector. The location of open areas, which have an important bearing in planning RWH in Noida, is shown in *Map 12: Location and type of open areas in Noida.*

The parks are to be developed and maintained as green and open public spaces. In exceptional circumstances, however, the Authority may allow the development of public utilities on a maximum of 2 per cent of the total land of a park or green belt. RWH, recharge systems and waterbodies are to be allowed in parks and green belts.

Map 12: Location and type of open areas in Noida



Source: Noida Authority 2011, Master plan for Noida 2031 and CSE, 2015

5 Geomorphic set-up and climatic conditions

The geomorphology and physiography plays significant roles in the occurrence and movement of water in an area. They are also key parameters in planning rainwater harvesting interventions.

CSE reviewed the geomorphic setting of Noida. The entire area of Noida is part of Ganga–Yamuna floodplain, with the eastern boundary marked by the Ganga River and the western boundary by the Yamuna. Situated almost in the old floodplain of the rivers Yamuna and Hindon, it represents an almost monotonous flat plain, dissected by drainage of different order.

5.1 MORPHOLOGY

Morphologically, the area can be divided into three morphological units:

(i) Older alluvial plain
(ii) Older flood plain
(iii) Active flood plain

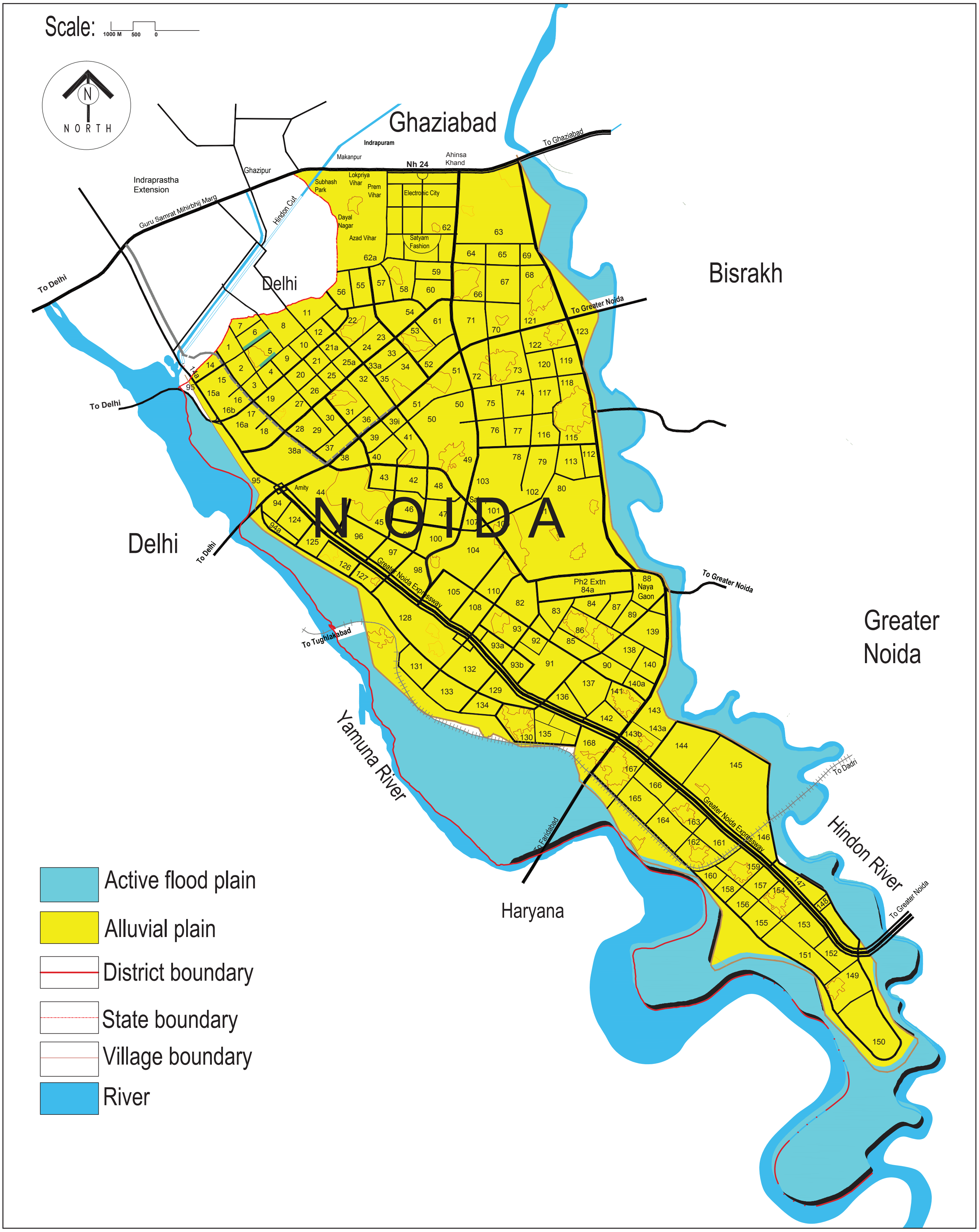
The banks of rivers are steep and ravenous. The older alluvium occupies the entire upland and the area of interfluves occurring between major drainage ways, i.e. Yamuna–Hindon and Hindon–Ganga. At places, close to the river, the process of erosion by surface runoff explains the formation of narrow ravines. Ravines form undulating topography along the Hindon and Bhuriya Nadi, situated between Bisrakh and Dankaur and in the Jhajhar area. Kankar is seen exposed and forming mounds. The floodplain of the Yamuna in the western part of the district is designed with remnants of old meander scars, oxbow lakes and relict drainages along the river.[1]

The physiography and terrain condition of the area is generally plain with a gradual slope that is 0.2–0.1 per cent from northeast to southwest. Noida stands at a low altitude of 200 m above MSL except for the pockets near Parthala Khanjarpur village (Sector 122)—the entire area north of the golf course (Sector 38) and industrial Sectors 80–84. The minimum elevation is 195 m above MSL near Sectors 145–146 in the southeastern part of the area (see *Map 13: Geomorphic map of Noida*).[2]

As far as the ground altitude is concerned, Noida is located at the lower elevation as compared to its immediate surroundings in the NCR. The general ground level of Noida is lower than the high flood level of the river Yamuna. The area has been reclaimed to construct embankments along the rivers Yamuna and Hindon. The construction of the embankments along the rivers Yamuna and Hindon has prevented flooding in the area. However, the general low-level topographic feature of the area is a constraint for effective storm-water and sewage disposal. Heavy rainfall, overflow or backflow of water and any breach in the embankments in the event of unprecedented floods in the Yamuna may result large area inundated under floodwaters. A digital elevation model of the area has been prepared (see *Map 14: Digital elevation model of Noida*).

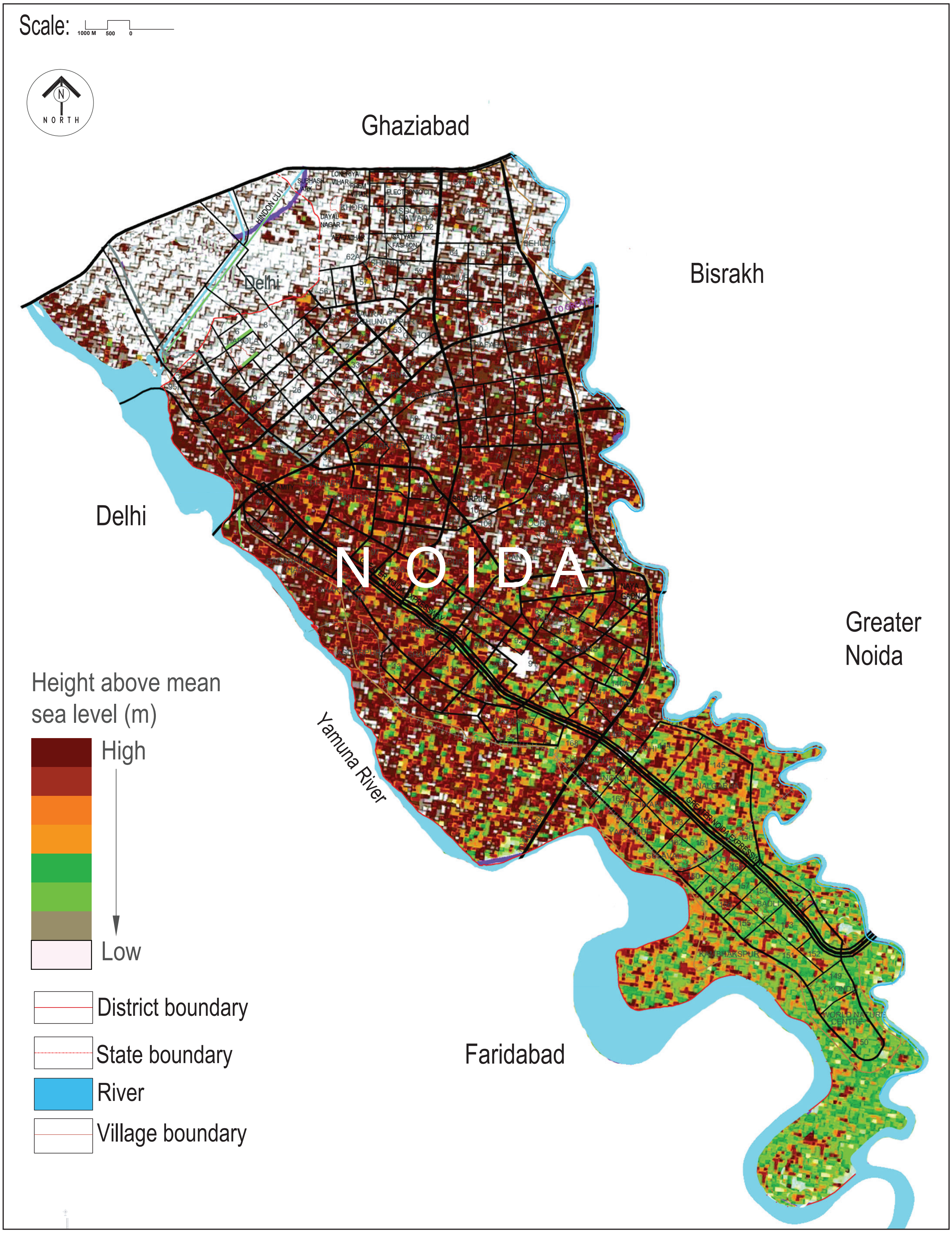
The capabilities of remote sensing integrated with GIS have been successfully used for delineating surface and near-surface features of groundwater. High-resolution digital data from satellites available in the public domain provide good information pertaining to geomorphic features. Remote sensing uses pattern recognition techniques and can rapidly and accurately assess features such as waterlogged areas and abandoned paleo channels, generally not visible in field investigations. In the present study, CARTOSAT data is used for identification of geomorphic features for delineation of potential areas for RWH and recharge. Integration of the geomorphological features with hydrogeological features are

Map 13: Geomorphic map of Noida



Source: S. Mukherjee, 2015, 'Satellite based GIS analysis of Noida: Noida Development Authority'

Map 14: Digital elevation model of Noida



Source: Centre for Science and Environment, 2016

used to identify potential area for groundwater development/ conservation.[3]

In the present case, however, the data is visually interpreted for feature identifications and demarcating their extent in space. Professor Saumitra Mukherjee, Jawaharlal Nehru University, New Delhi, conducted a study in Noida, using LANDSAT, ASTER and CARTOSAT pan-satellite data, along with the topographic maps. The data sets were examined to generate a texture analysis for the entire Noida area to identify suitable areas for RWH. Satellite data interpreted in the form of thematic layers of geomorphology, paleo channels and clay/soil type of Noida area demonstrate the applicability of such studies in the present context.[4]

Paleo channels (see *Map 15: Paleo-channel map of Noida*) are most suitable for recharge as they generally have relatively coarse sediments with high porosity and permeability.

5.2 SOIL CLASSIFICATION

The content of clay in Noida as shown in *Map 16: Soil content analysis map of Noida* is derived from the satellite. It determines the high infiltration topsoil, which is a key factor in planning RWH and groundwater recharge projects. Further, a detailed analysis of data pertaining to soil has been compiled and it is observed that the development of soils in the district can be ascertained to different erosional and depositional agents. Different morphological units have been bestowed with different types of soils. Generally, silty soil with varying percentages of clay and sand is found in Noida (see *Map 17: Soil classification map of Noida*).

5.3 IDENTIFICATION OF SUITABLE GROUNDWATER RECHARGE AREAS

According to the GIS and remote sensing, the suitable areas for recharge are identified in and around Noida. The layers of map, such as clay/soil map, paleo-channel map, digital elevation map and morphology map are overlaid to prepare the final suitability for recharge (see *Map 18: Suitable areas for groundwater recharge in Noida*).

These maps have been generated using visual interpretation on enhanced images providing an overview of potential recharge areas. The potential recharge locations are overlaid on with land-use and built-up area to estimate runoff generation and groundwater recharge potential.

5.4 CLIMATIC CONDITIONS

The climate of Gautam Budh Nagar district is sub-humid and characterized by two extreme types, i.e. hot summers and bracingly cold winters. Summers stretch from March to June, with the maximum temperature shooting up to about 45°C. The district experiences the hottest weather in June, with average mean temperature of 32.85°C, followed by May, with 31.9°C. During winter, which extends from October to February, the minimum temperature falls to about 4°C. The coldest month is January, with average mean temperature of 14.2°C, followed by December with 15.4°C.

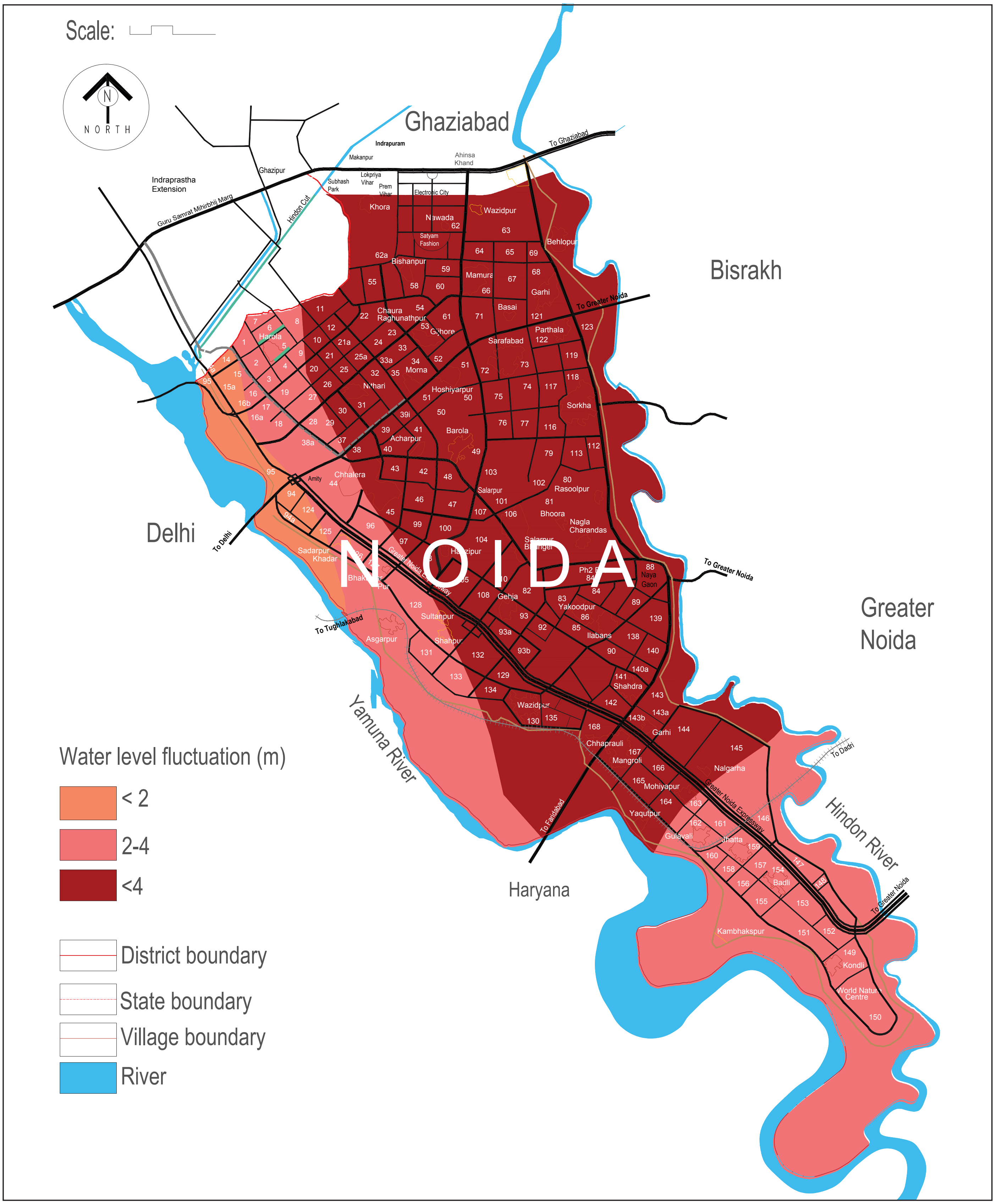
5.4.1 Rainfall

The monsoon lasts from the first week of July till the end of September. During the southwest monsoon, the relative humidity is high. After the monsoon withdraws, humidity decreases. The wettest months are July and August. Winters showers, which are scanty, are usually towards the end of December and sometimes in January. Average annual rainfall in Noida is 750 mm. The maximum rain falls in 40 days of the year and the maximum rainfall intently is 90–120mm/hr.[5]

Map 15: Paleo-channel map of Noida

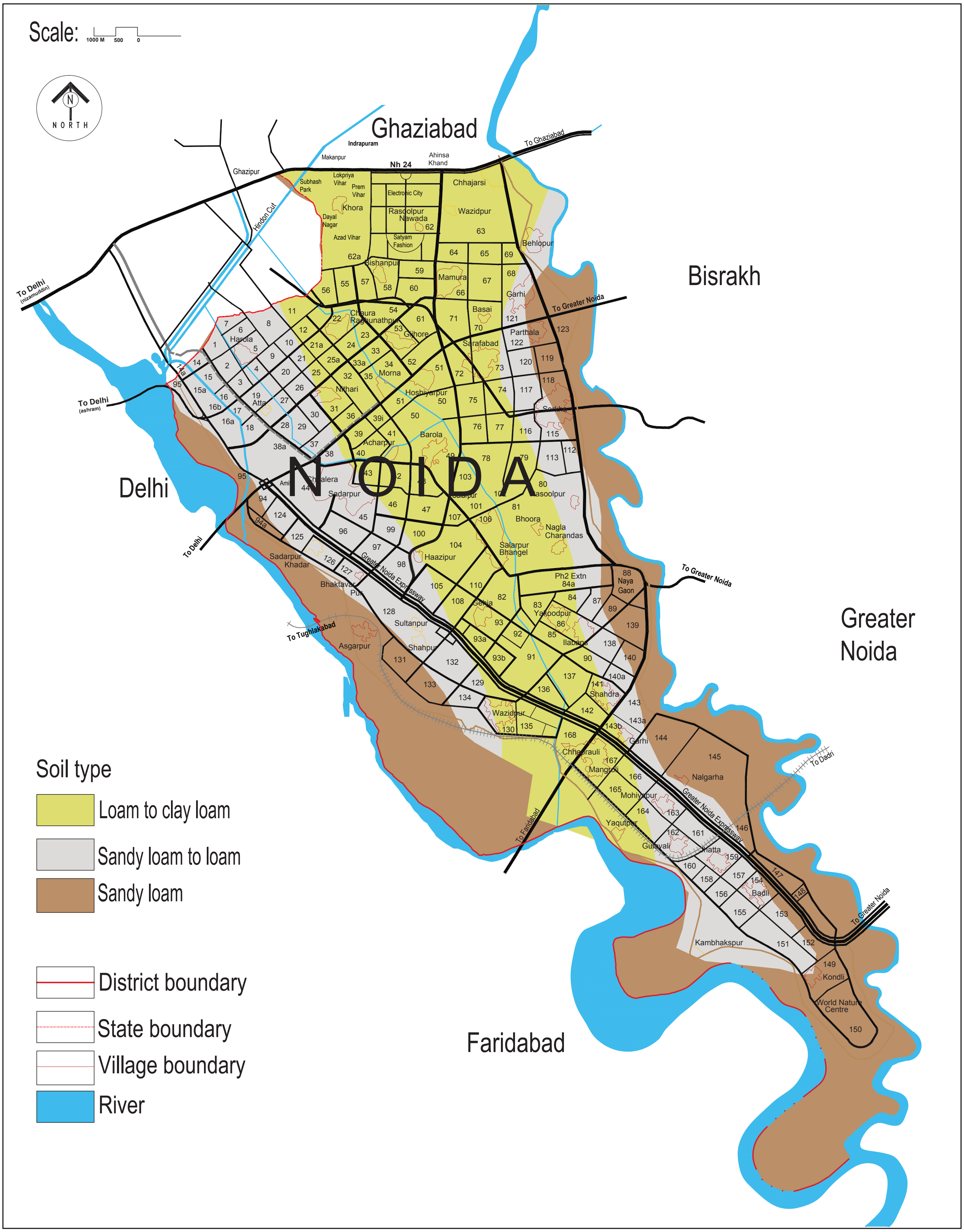
Source: S. Mukherjee, 2015, 'Satellite based GIS analysis of Noida: Noida Development Authority'

Map 16: Soil content analysis map of Noida



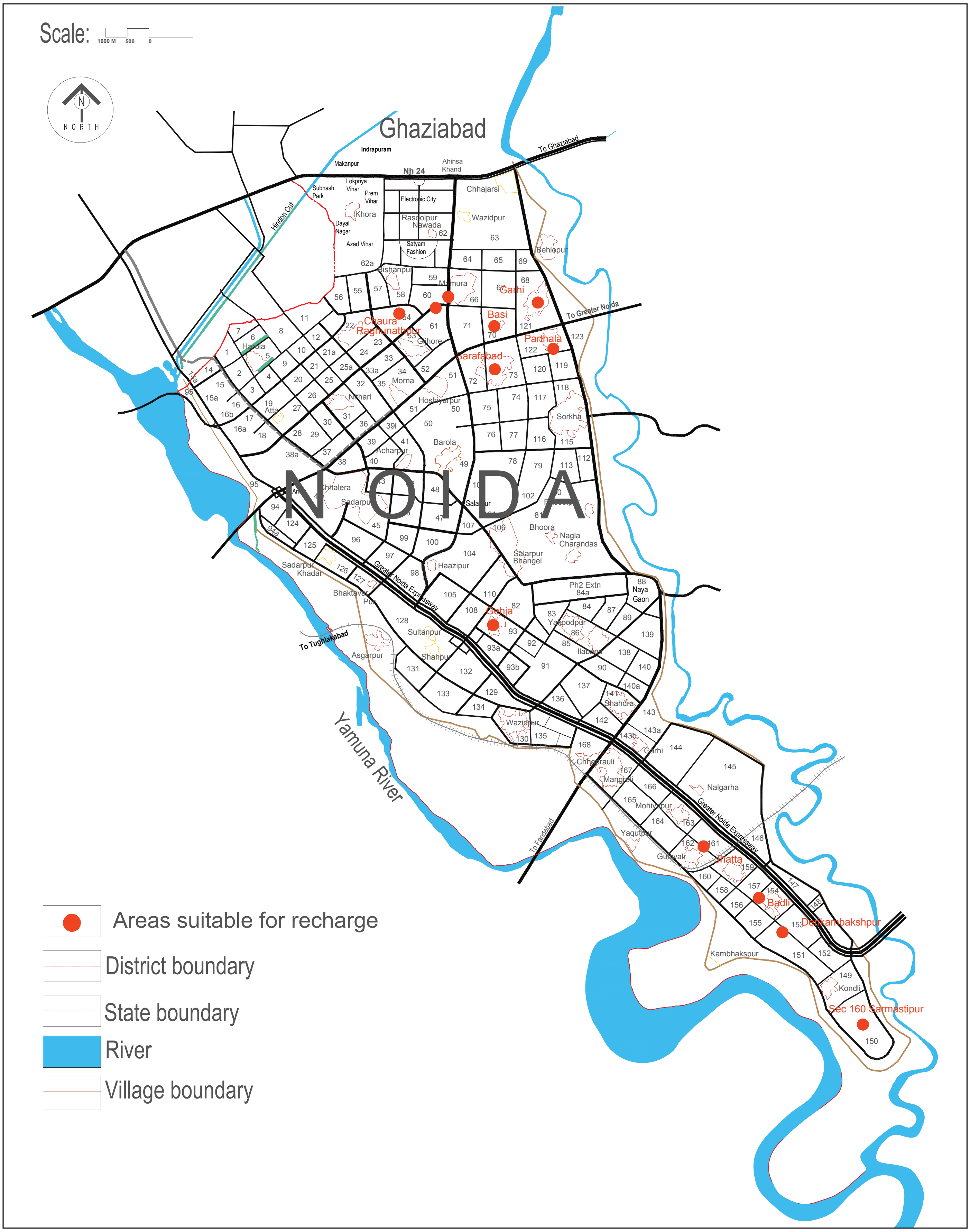
Source: S. Mukherjee, 2015, 'Satellite based GIS analysis of Noida: Noida Development Authority'

Map 17: Soil classification map of Noida



Source: J. Singh, ed. Disaster management: Future challenges and opportunities, R.B. Singh and S. Singh 2007, 'Challenges of flood disaster management: A case study of Noida: A GIS approach', New Delhi: IKM Publications, 95–112

Map 18: Suitable areas for groundwater recharge in Noida



Source: S. Mukherjee, 2015, 'Satellite based GIS analysis of Noida: Noida Development Authority'

5.4.2 Other climatic parameters

The mean monthly maximum relative humidity in August mornings in the district is 84 per cent. The mean monthly minimum relative humidity measured on May mornings is 41 per cent. The normal annual mean wind speed is 6.7 kmph; the highest normal wind speed is 9.2 kmph in June, followed by 8.3 kmph in May. The annual normal potential evapo-transpiration of the district is 1545.3 mm. The maximum rainfall occurs in June, followed by May with 225.3 mm and 222.2 mm, respectively. The relative humidity is maximum during August (up to 84 per cent) and minimum during May (up to 16 per cent).

6 Rainwater harvesting: Concept and methods

RWH involves the capture, storage and use of rainwater and runoff for domestic or agricultural purposes. Essentially, RWH systems use the principle of conserving rainwater 'where it falls', while recharging groundwater and storing it in receptacles.[1]

In urban areas, rainwater can be collected from the roof, paved and unpaved areas of houses, blocks of flats, colonies, parks, playgrounds, parking areas, schools, office complexes, lakes and tanks.

There are two ways to use harvested rainwater:
1) Through storage in receptacles and
2) By recharging the aquifer that depends on:
- Quantum of surface runoff available
- Rainfall pattern
- Land use and land cover
- Topography and terrain profile
  - Soil type and soil depth
  - Hydrological and hydrogeological characteristics

These factors have been discussed in preceding sections of the report to aid selection from among the following suitable methods for RWH systems in Noida:

6.1 ROOFTOP RWH

In urban areas, rooftop rainwater can be conserved and used for recharge of groundwater. This approach requires connecting the outlet of storm-water drains and pipes from rooftops to divert water to existing wells, tube wells, bore wells or specially designed recharge wells. Urban housing complexes or institutional buildings in Noida have large roof areas that can be used to harvest rooftop rainwater.

Rooftop RWH can also be adapted to meet domestic water requirements. Rooftop rainwater can be stored in specifically constructed surface or sub-surface tanks. Dependence on groundwater has increased manyfold and the natural recharge to groundwater has decreased due to urbanization, construction of buildings and paved area. In the built-up area of Noida rainfall from rooftops can be collected and diverted to open wells, tube wells and bore wells through filter media.[2]

Rooftop RWH plays an important role in the conservation of water. It involves collecting rainwater from the roofs of buildings and storing it in surface tanks or recharge to sub-surface aquifers. The run-off from rooftops can be used effectively for the artificial recharge of groundwater to replenish fast-depleting aquifers.

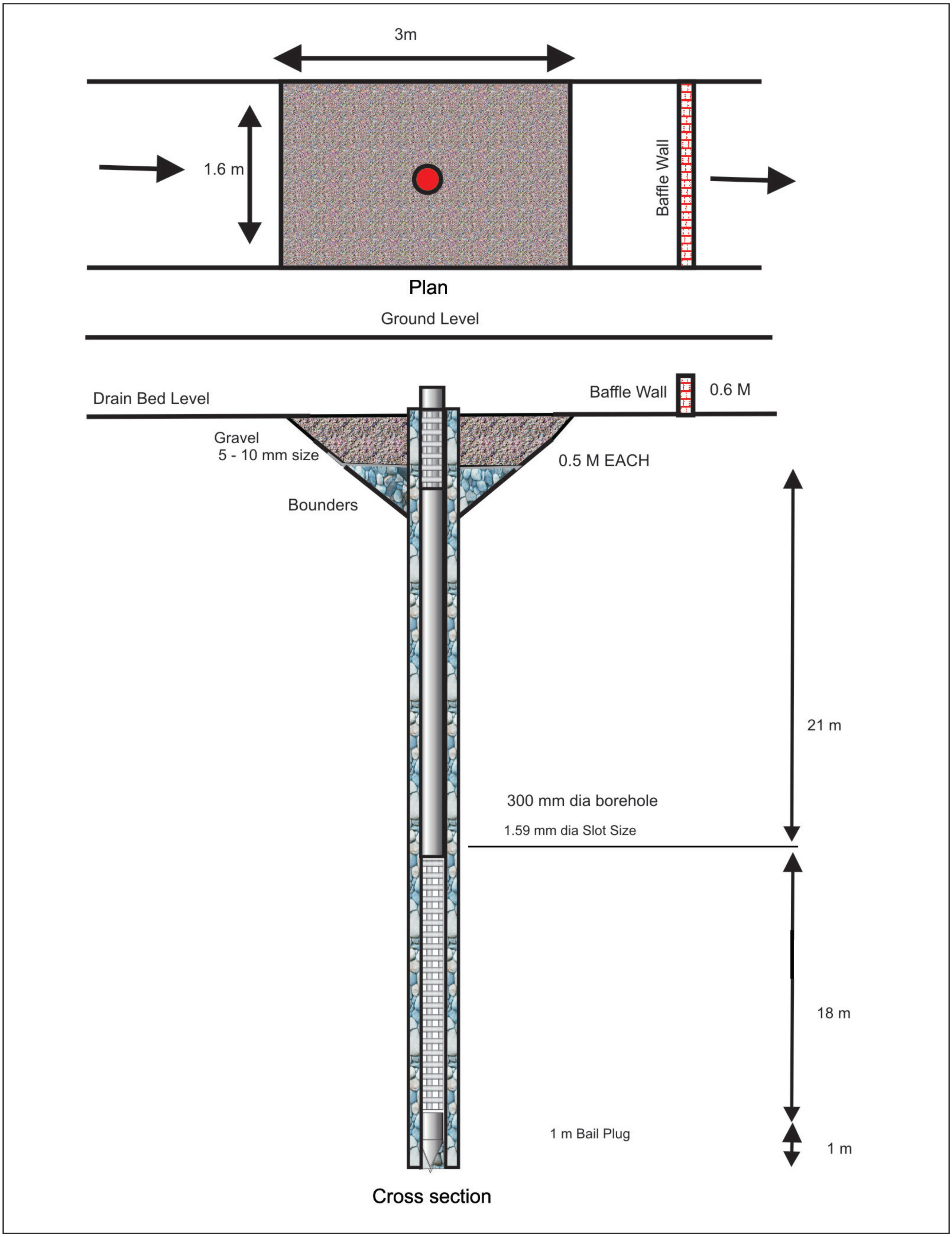
6.1.1 Recharge trenches with recharge wells

This type of recharge structure is used to recharge aquifers that are over-exploited by tube wells or pumping.

Aquifers with confining layers of low permeability are unable to replenish naturally from the surface and need direct injection through recharge wells (*see Diagram 2: Recharge through injection well*). These recharge systems comprise an injection pipe with opening against the aquifer to be recharged (see *Diagram 3: Recharge trench with injection well*).

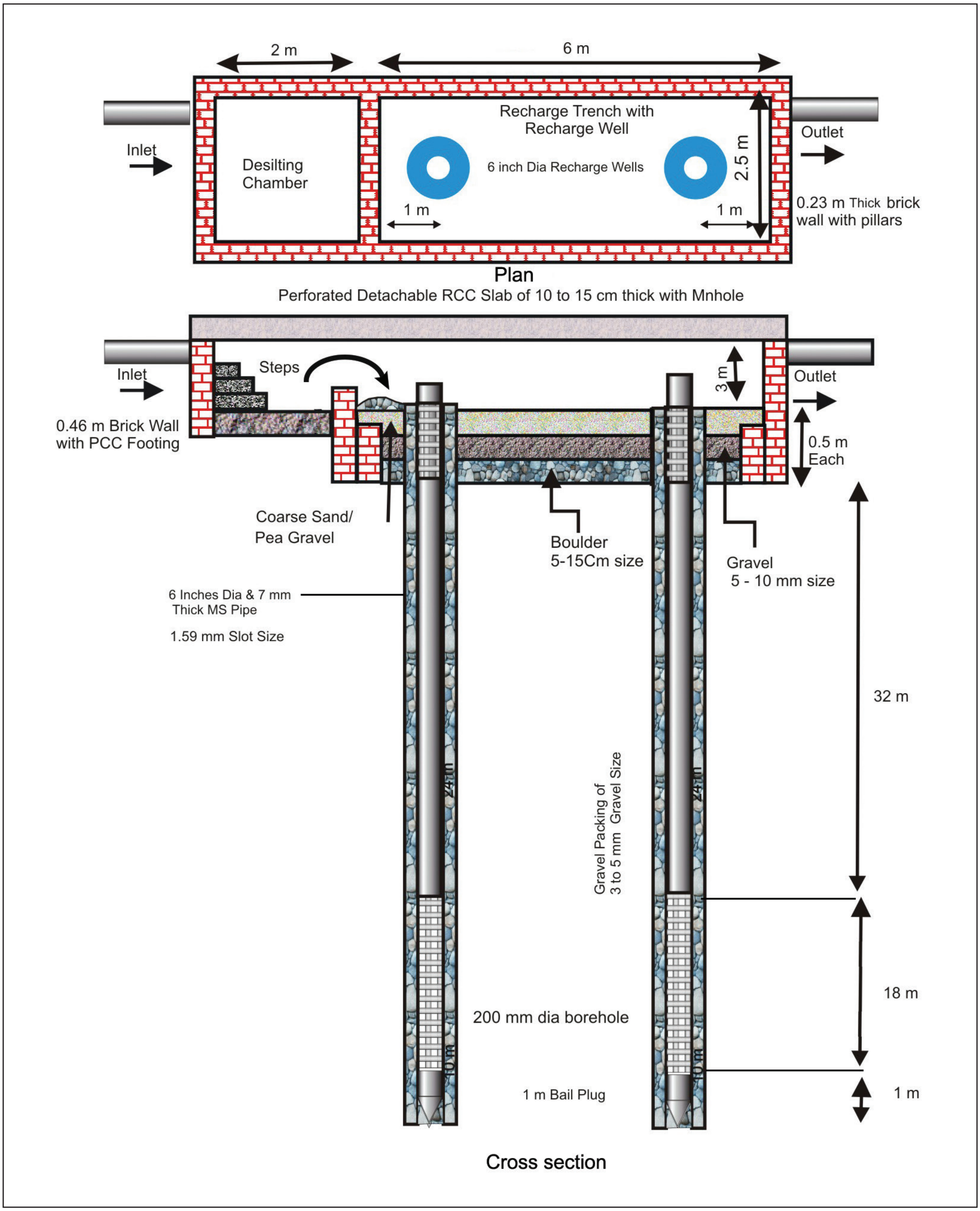
In the case of several permeable horizons separated by impervious rocks, a properly designed injection well may be constructed with a slotted pipe against the aquifer to be

Diagram 2: Recharge through injection well



Source: Functional plan for groundwater recharge in NCR, 2015

Diagram 3: Recharge trench with injection well



Source: Functional plan for ground water recharge in NCR, 2015

recharged. In practice, injection rates are limited by the physical characteristics of the aquifer.[3]

6.1.2 Recharge pits and shafts with recharge wells

In areas where the aquifer is overlain by poorly permeable strata, the recharge to groundwater storage by the water spreading method becomes ineffective or has very low efficiency. Recharge shaft is an artificial recharge structure that penetrates the overlying impervious horizon and provides effective access to surface water to recharge the aquifer. These structures are ideally suited to areas with deep water levels. In areas where a low permeable sandy horizon is within shallow depths, a trench can be excavated to a depth of 3 m and back-filled with boulder and gravel. The trench can be provided with an injection well to effectively recharge deeper aquifers (see *Diagram 4: Recharge shaft with bore well*). The diameter of shaft should normally be over 2 m to accommodate enough water. In the areas where rainwater has silt, the shaft should be filled with boulders, gravel and sand from the bottom to have an inverted filter.[4]

6.1.3 Storage structures for RWH

Runoff from rooftop can also be stored on-site. The stored water can be used for meeting various water requirements, both potable and non-potable.

Storage tanks for harvested rainwater can be built both underground and above the ground. They can be made out of a variety of materials, ranging from cast iron sheets and polyvinyl chloride to brick and concrete (see *Table 6: Types of storage tank).* For all tanks, some basic precautions must be taken during construction.

Underground storage tanks should be made watertight by plastering the insides with cement to about a three-quarter-inch thickness. Care should be taken to ensure that water does not leak into the soil. The top of the tank should have a large enough opening to clean the tank or undertake repairs.[5] Over-the-ground tanks, however, must be fitted with an inlet pipe at the top of the tank, outlet pipe at the bottom, a drainpipe to clean out the tank, overflow pipe and a valve with ball float assembly. Inlet, outlet or vent pipes must be fitted during construction, not after, to prevent leakages.

6.2 PARK-TYPE STRUCTURES

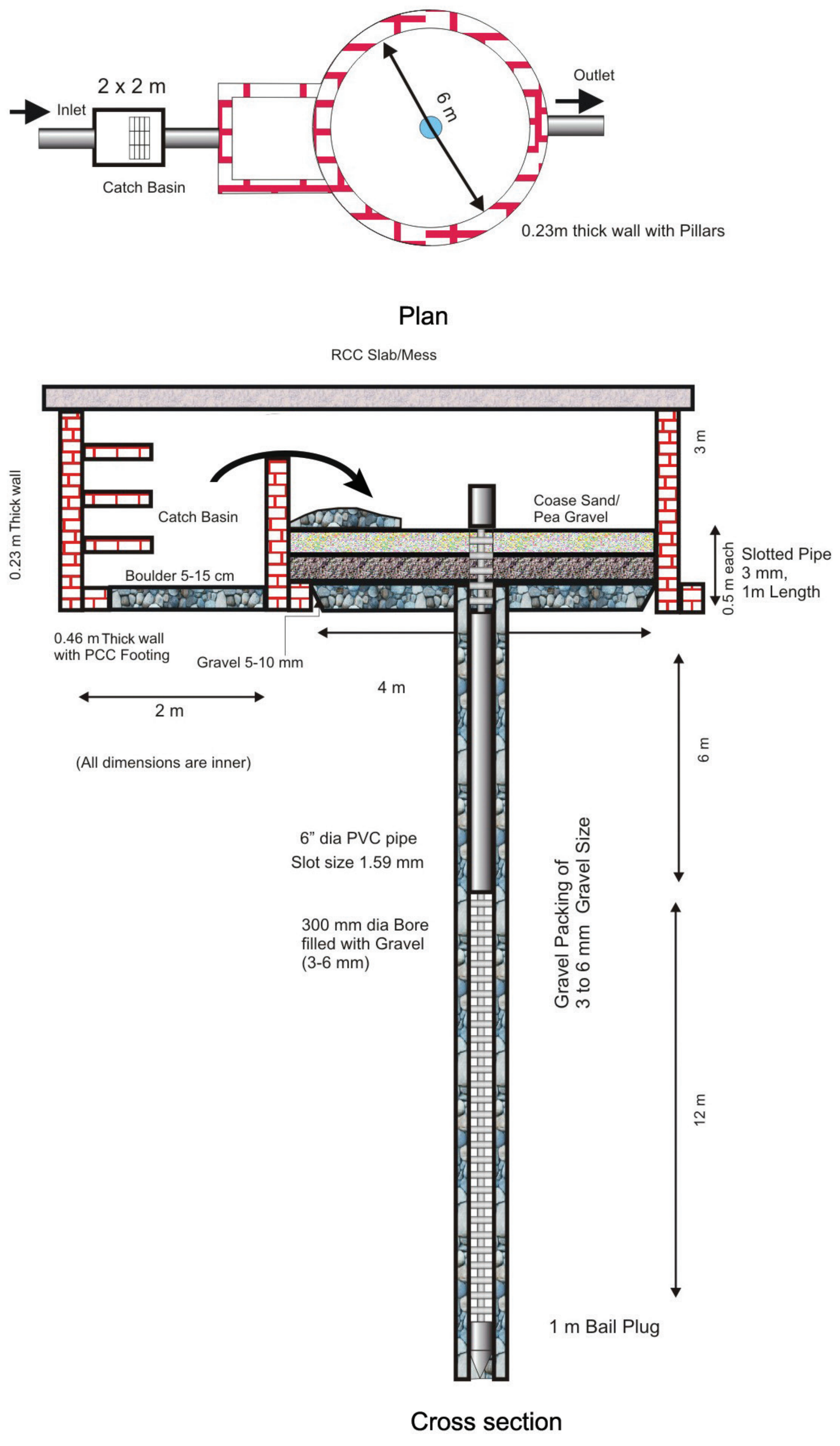
Parks are a common feature in residential colonies and institutional areas in Noida. They

Table 6: Types of storage tanks

Type	Characteristics	Life in years	Cost/litre
Polyethylene, polypropylene and other similar synthetic material	Lightweight, resistant to water, rustproof and easily transportable	10–15	Rs 3–5
Brick masonry	Long life and non-reactive. Should be maintained	15–30	Rs 3–4
Reinforced cement concrete	Durable and long lasting, but prone to cracking. If lined inside with ceramic tiles, it is potable	50–75	Rs 8–10
Ferro-cement	Made out of cement, sand and water. Strengthened with steel wire or mesh. Structurally more efficient than masonry but prone to cracking and requires maintenance	10–15	Rs 2–2.50
Galvanized iron	Cast iron, when coated with hot zinc, is called galvanized iron and this process makes the iron rustproof. Is lightweight and inexpensive. Zinc dissolves in potable water—the tank must therefore be lined inside with plastic. High maintenance required	15–20	Rs 3–4

Source: G. Kavarana and S. Sengupta 2013, 'Catch water where it falls: Toolkit on urban rainwater harvesting', CSE

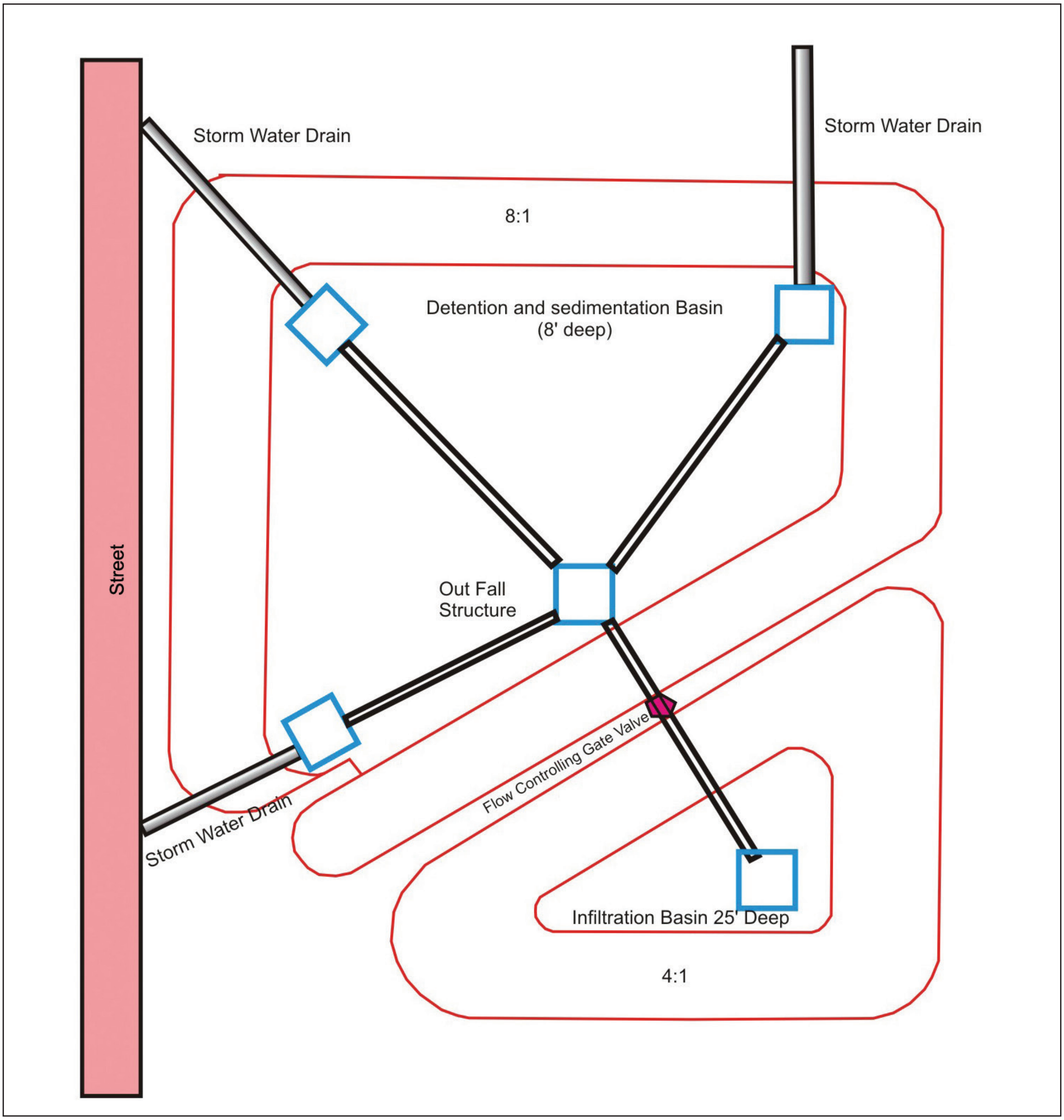
Diagram 4: Recharge shaft with bore well



Source: Functional plan for ground water recharge in NCR, 2015

can be used to recharge groundwater. Rainwater from the catchment of parks as well as surrounding areas can be diverted towards the excavated basin-type depression to accommodate rainwater from elevated surrounding areas. The water is recharged through a recharge shaft/recharge well or recharge pit, depending on hydro-geological conditions and depth of the unconfined aquifer. The structure used as a RWH system during the monsoon can be used as a playground during the rest of the year. Depth of excavation of park is such that the slope is in the ratio of 8:1 in the collector basin and 4:1 in the recharge basin (see *Diagram 5: Design of park-type recharge structure).*[6]

Diagram 5: Design of park-type recharge structure



Source: Functional plan for ground water recharge in NCR, 2015

6.3 SUSTAINABLE URBAN DRAINAGE SYSTEMS

The conventional approach to drain the runoff from built-up areas is through underground drainage systems that convey water from built-up areas. This conventional urban drainage system focuses on quantity as it aims to remove excess water from urban areas as quickly as possible to avoid possible flooding incidents. With Noida rapidly urbanizing, continued and deliberate water management to provide more space and time to moderate increased runoff can also contribute to recharging groundwater and creating assorted surface storages. This broad approach of rainwater harvesting, referred to as Sustainable Urban Drainage Systems (SUDS), can considerably contribute to augmenting local water-resources in Noida.

These measures can be undertaken in public open spaces, generally located outside the envelope of individual developments. Public open-space measures are characterized by their location within green spaces or other clearly defined public areas that can manage storage and conveyance of surface water runoff. Depending on the design and characteristics of the site, a convenient location where the intermediate source control area becomes part of accessible public open space. Different SUDS intervention, namely filter strips, swales, bio-retention areas/rain gardens, filter drains/trenches, detention basins, infiltration basins and porous pavement planning and design is discussed in detail in the following section.

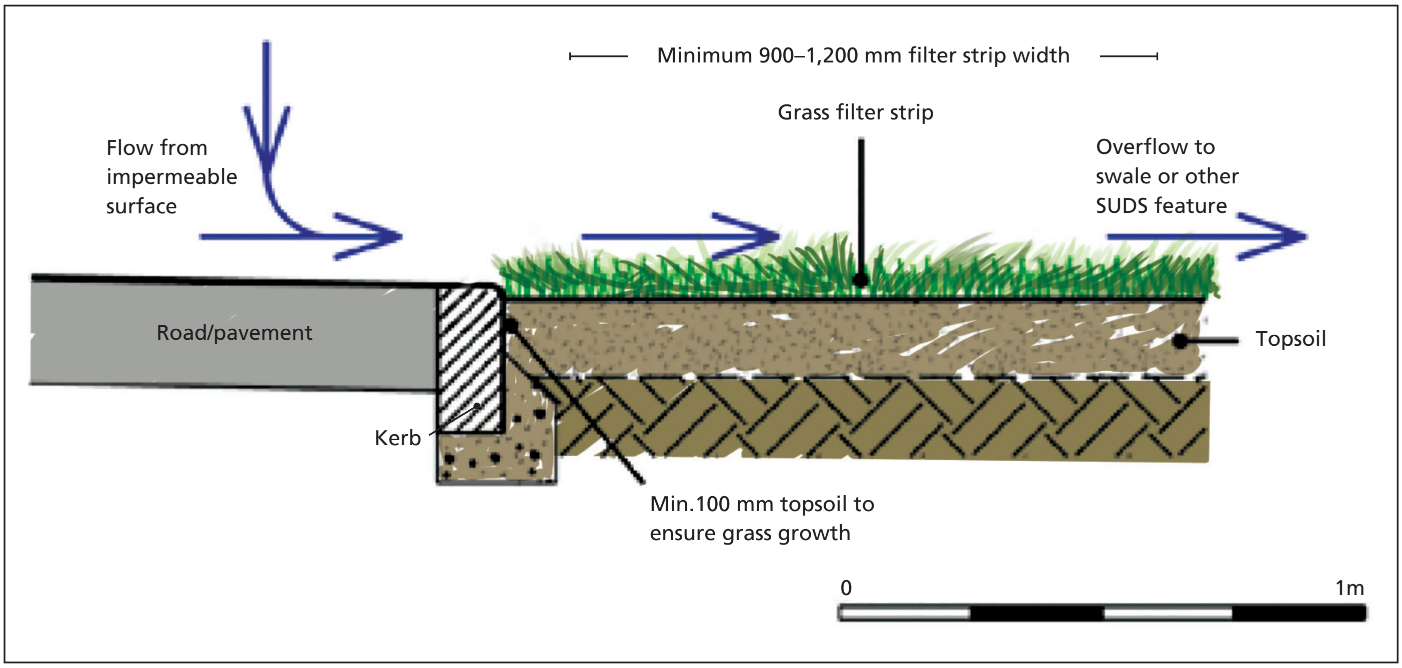
6.3.1 Filter strips

Filter strips are grass or other densely vegetated strips of land that collect surface water runoff as sheet flow from impermeable surfaces (see *Diagram 6: Cross section of filter strip*).[7]

6.3.2 Swales

Swales are linear vegetated channels with a flat base that encourage sheet flow of water through grass or other robust vegetation. They collect, convey and sometimes store surface water runoff, allowing water to soak into the ground where soil conditions are suitable (see *Diagram 7: Cross section of swale*).[8]

Diagram 6: Cross section of filter strip



Source: Centre for Science and Environment, 2016

6.3.3 Bio-retention areas and rain gardens

Bio-retention areas and rain gardens are planted areas that are designed to provide a drainage function as well as contribute to the soft landscape (see *Diagram 8: Bio-retention area plan*).[9]

6.3.4 Filter drains and trenches

Filter drains and trenches are linear excavations filled with stone that ideally collect surface water runoff laterally as sheet flow from impermeable surfaces. They filter surface water runoff as it passes through the stone allowing water to infiltrate into soil or flow (see *Diagram 9: Cross section of filter drains and trenches).*[10]

6.3.5 Detention basins

Detention basins are vegetated depressions in the ground, designed to store surface water runoff and either allow it to soak into the ground or flow out at a controlled rate. Within development, these basins are usually small-grassed areas, sometimes with a micro-pool or planted areas at a low point where some standing water can accumulate (see *Diagram 10: Detention basin plan).*[11]

6.3.6 Infiltration basins

The basins collect surface water runoff from small areas and are usually off-line to prevent siltation (see *Diagram 11: Infiltration basin plan*).

6.3.7 Porous pavement

Porous pavement can be used for streets, parking lots, sidewalks and other impervious surfaces for maintaining infiltration. It comprises porous asphalt, concrete, lattice pavers, concrete blocks or stones. The surface material is laid on a gravel sub-grade and surface voids are filled with sand or a sandy loam turf (see *Diagram 12: Cross section of porous pavement*). Storm water flows as well as percolates through the pavement into the underlying soil.[12]

The following types of porous pavements can be adopted:

- Porous asphalt: A very small proportion of fine aggregates. Interconnected void space provides the permeability characteristics; can withstand repeated traffic.
- Pervious concrete: Concrete with permeable spaces
- Single-size aggregate: Aggregates used without any binder, least expensive, high utility in areas with low-traffic conditions, such as parking stalls
- Porous turf: Used in parkings, counteracts heat island with water transpiration

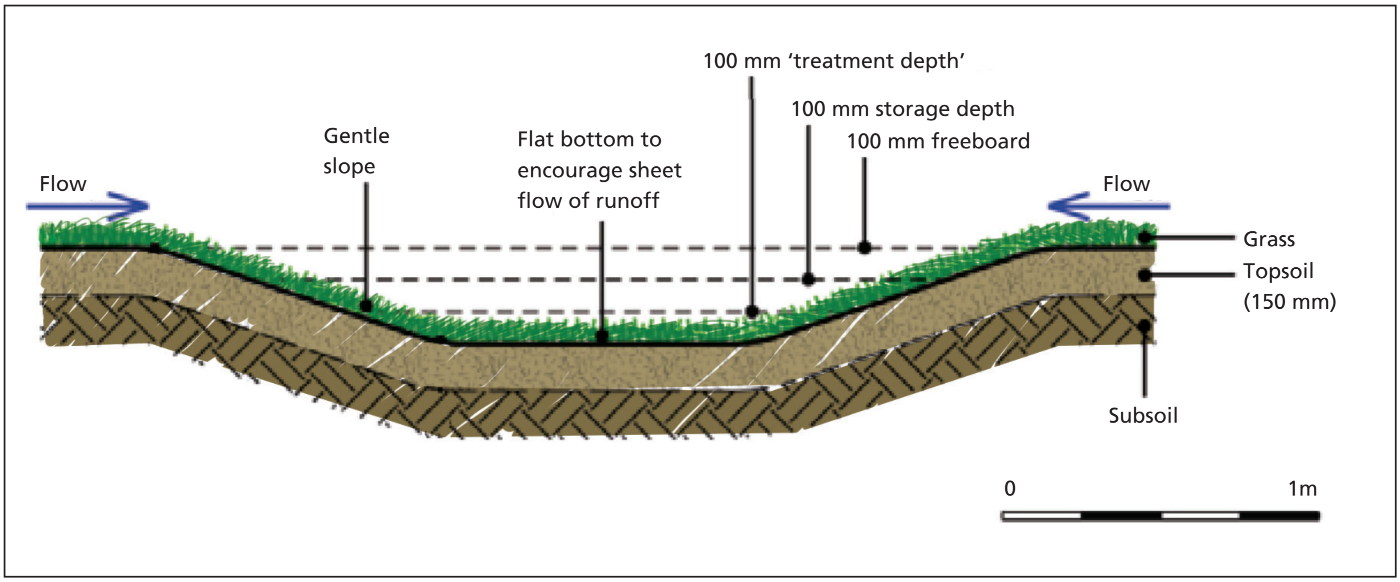
6.4 RECHARGE FROM URBAN MEGASTRUCTURES

Megastructures such as flyovers, airports and stadiums in cities cover huge areas with concrete that prevent natural recharge of groundwater. Such big structures generate large amounts of surface runoff during the rains—their runoff coefficient range varies from 0.6 to 0.8. To provide a conduit for rainwater to recharge aquifers, specific structures should be constructed in the vicinity of these civil megastructures.

Considerable runoff goes waste from road surfaces through storm-water drains. To harness available runoff, either trenches or shafts with recharge wells are constructed in series along the roadside at a spacing of 100–300 m, depending on the availability of runoff. The available runoff from flyovers can be harvested by making shafts or trenches with recharge wells along the storm-water drains.

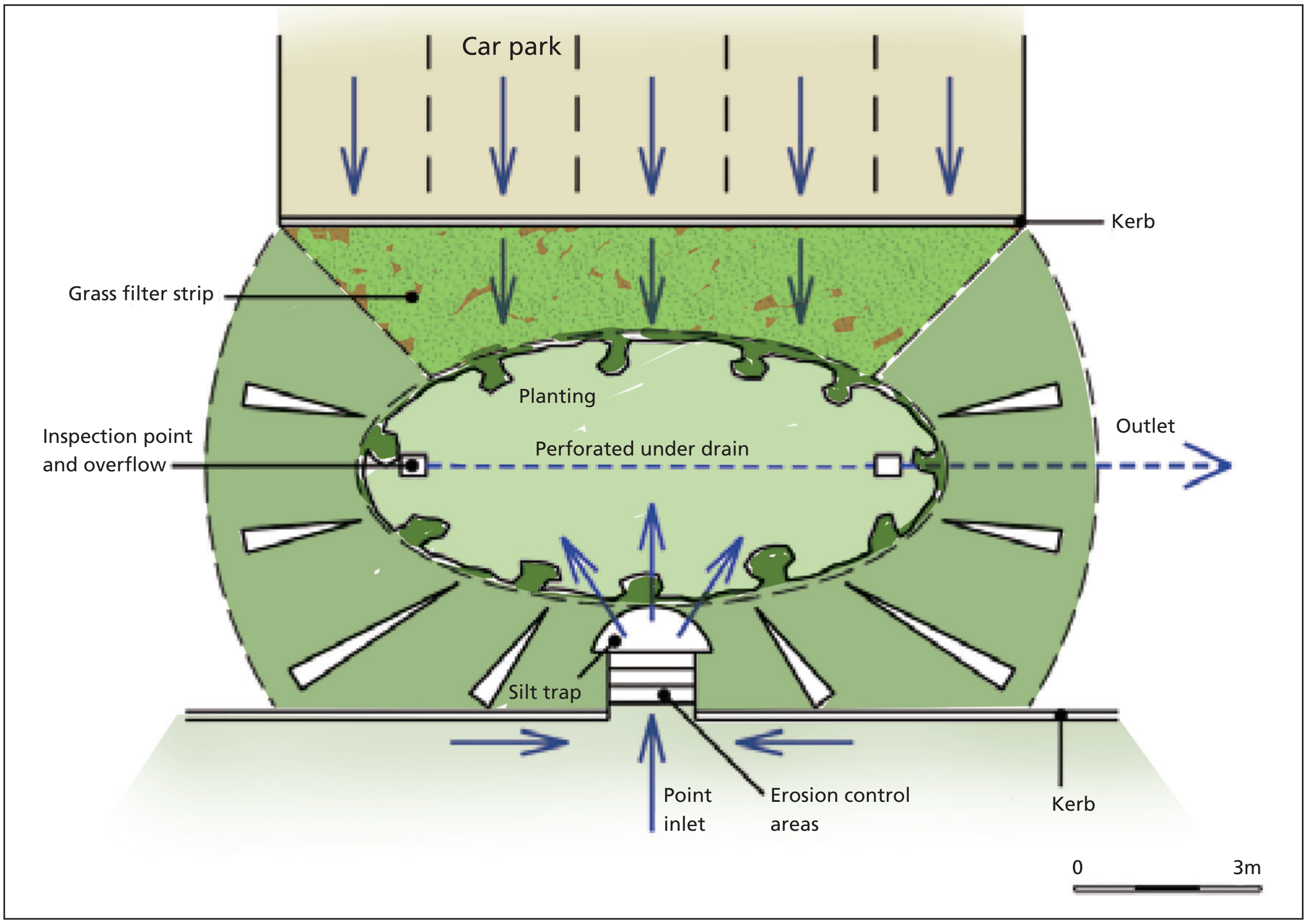
Trenches with length up to 20 m can be constructed with two or more recharge tube wells. They are generally recommended to tap runoff generated from whole campus/catchment of areas of 10,000–40,000 sq. m. As the runoff from the catchment comprises substantial silt, it can be removed by constructing a de-siltation chamber (see *Diagram 13: Recharge*

Diagram 7: Cross section of swale



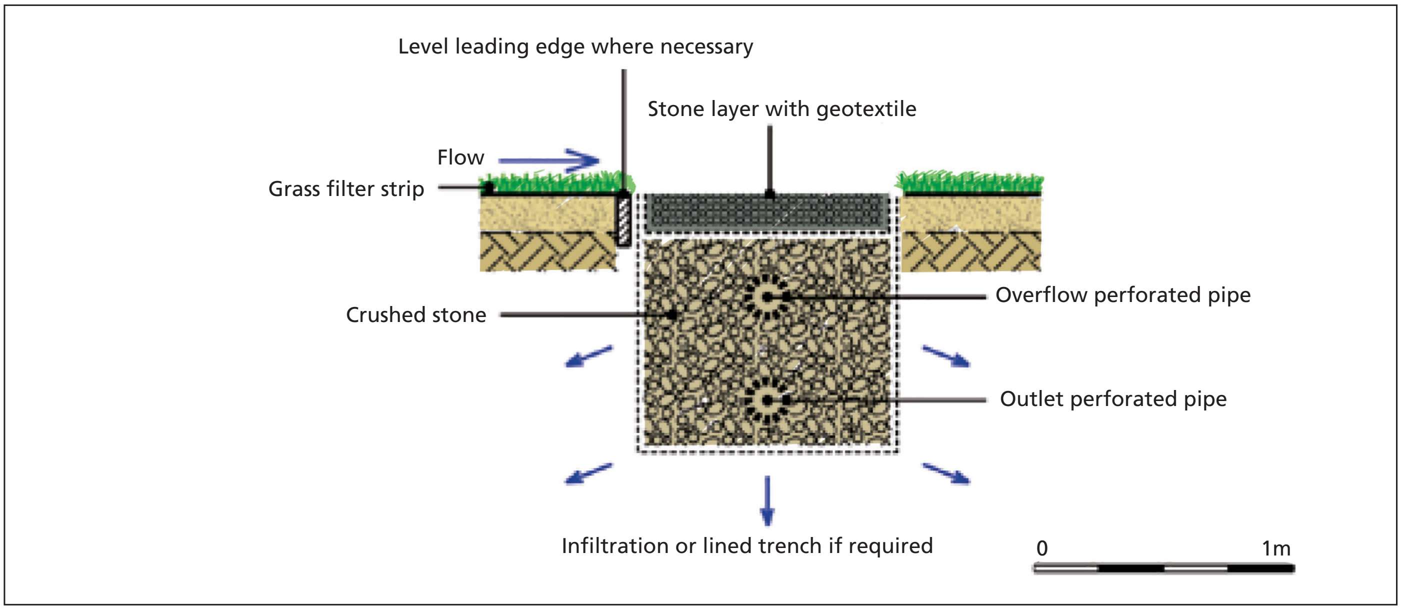
Source: Centre for Science and Environment, 2016

Diagram 8: Bio-retention area plan



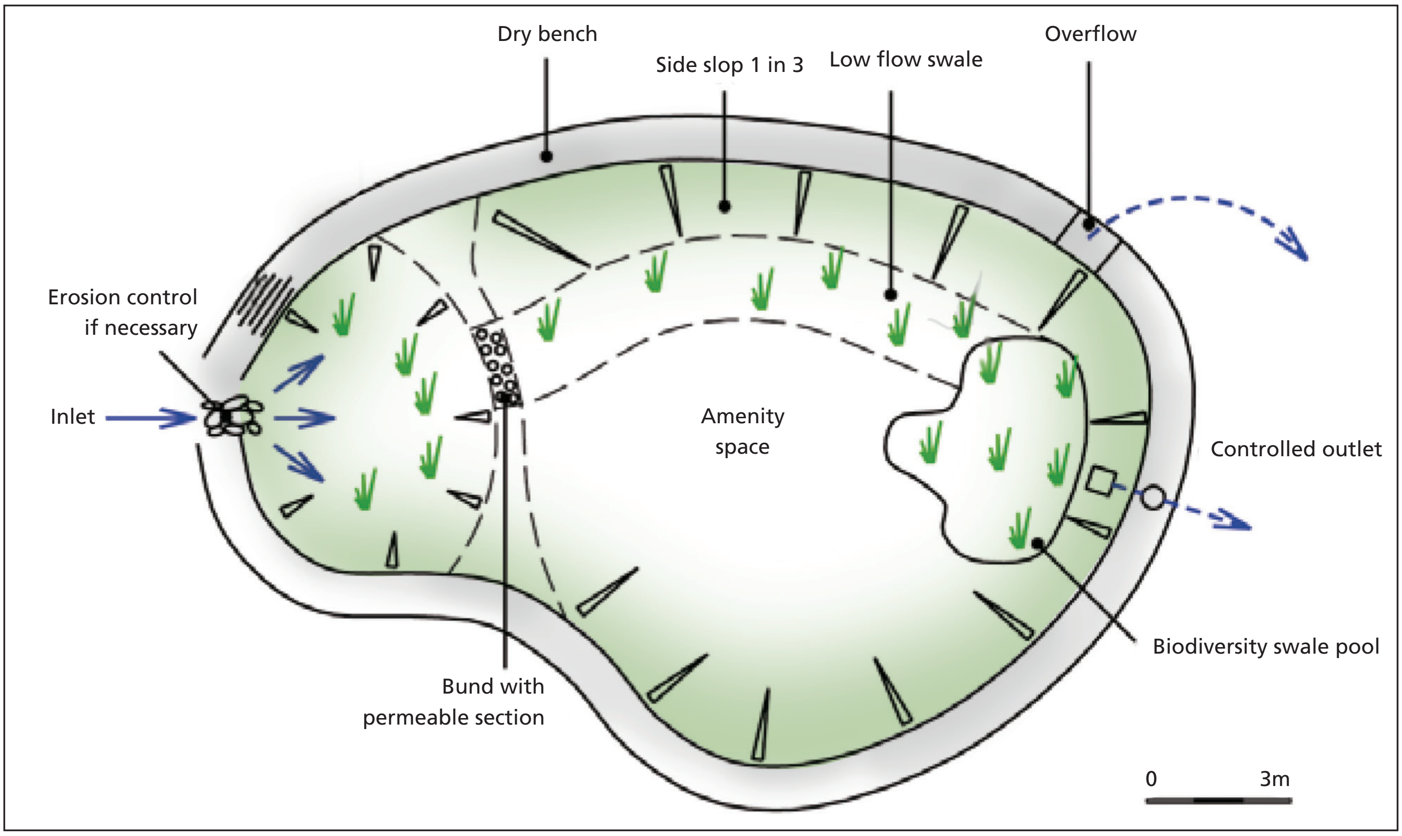
Source: Centre for Science and Environment, 2016

Diagram 9: Cross section of filter drains and trenches



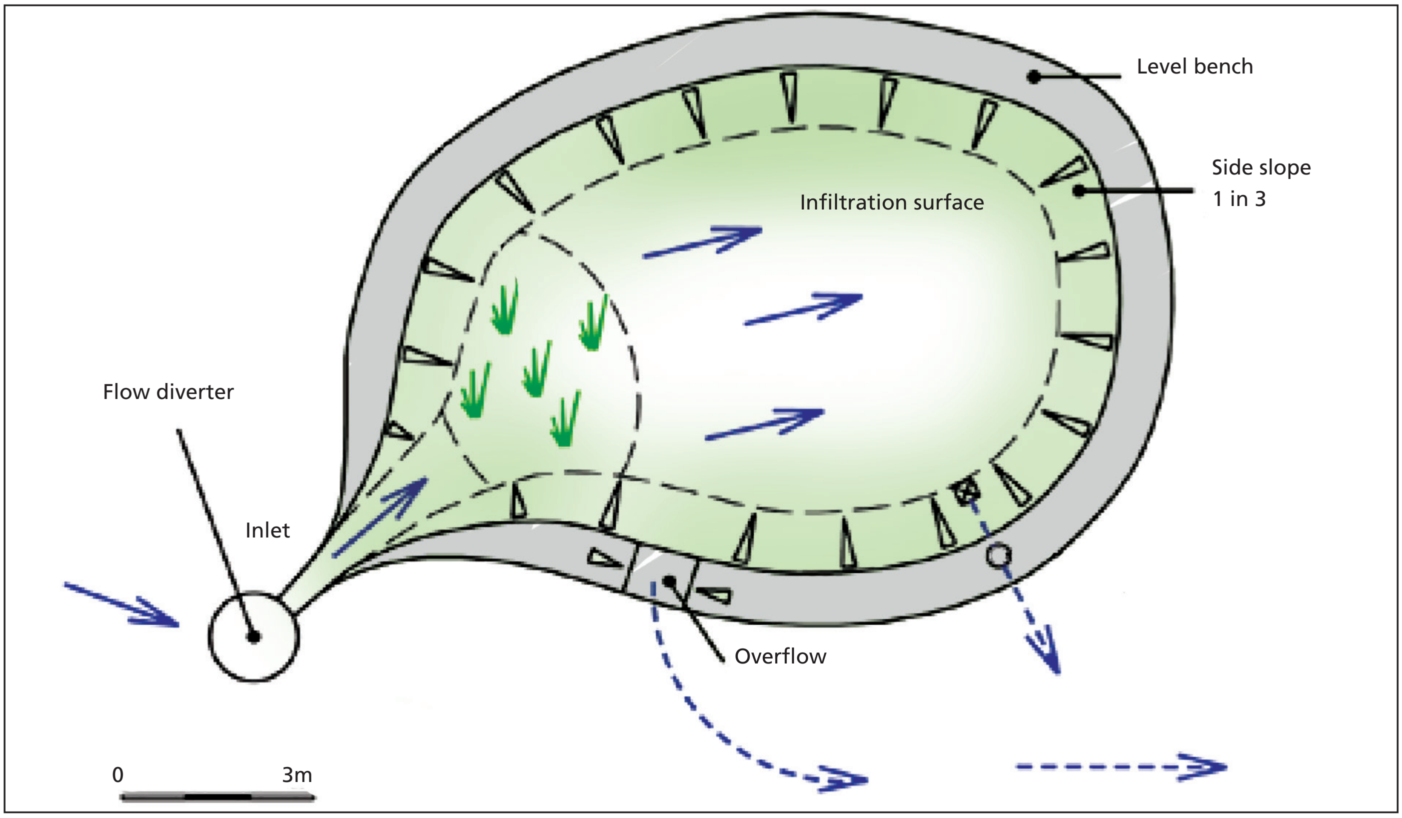
Source: Centre for Science and Environment, 2016

Diagram 10: Detention basin plan



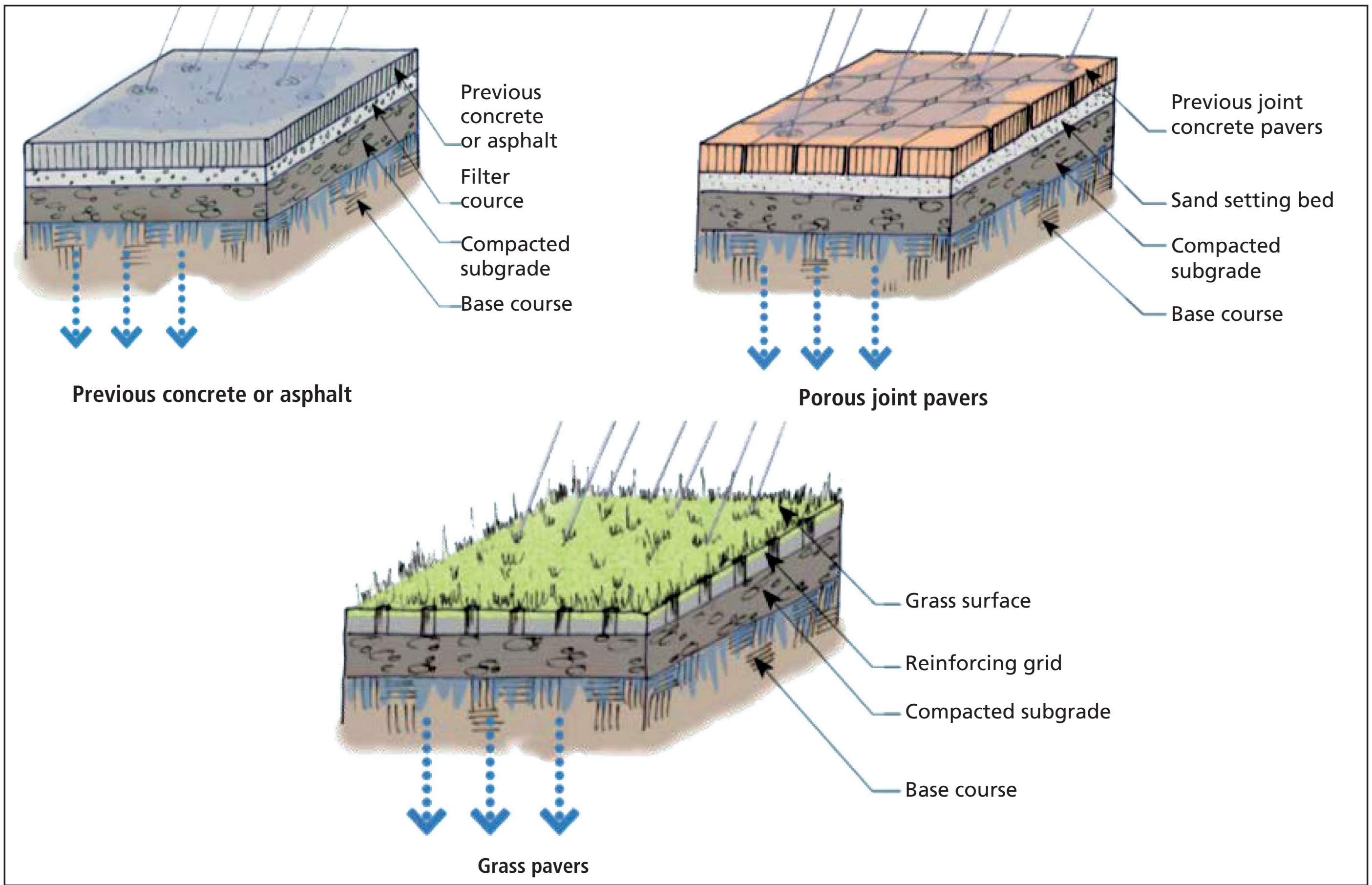
Source: Centre for Science and Environment, 2016

Diagram 11: Infiltration basin plan



Source: Centre for Science and Environment, 2016

Diagram 12: Cross section of porous pavement



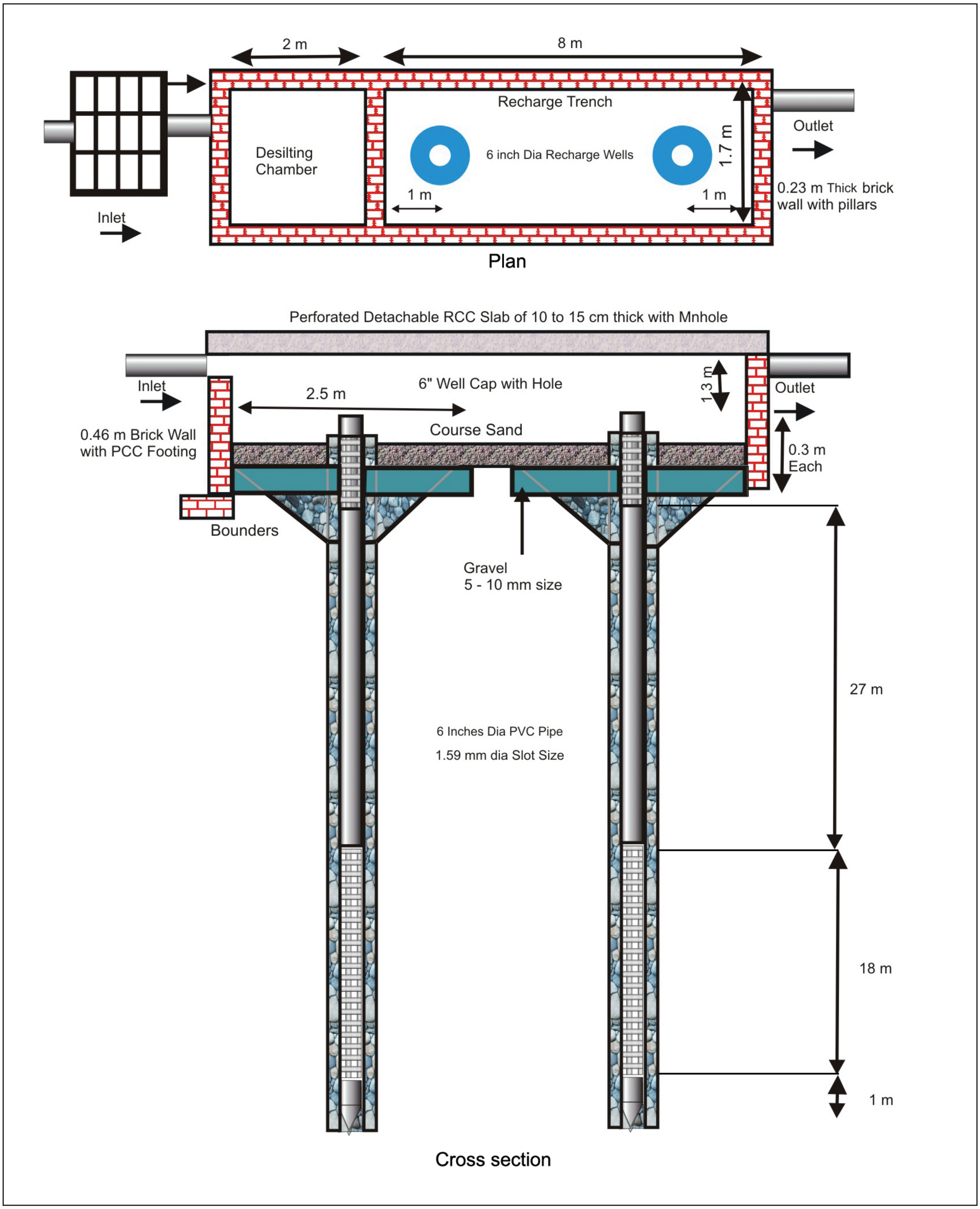
Source: UTTIPEC, Delhi Development Authority, Storm water management and retrofitting our urban streets for sustainable drainage, 2012, Oasis Designs Inc.

system for urban megastructures). Walls of recharge structures are not recommended to be plastered from both sides. Brick walls of the trench should be trapezoid for better stability. The main advantage of recharge trenches is that they can recharge runoff generated from large areas.[13]

If the trenches need to be constructed above 10 m length, supporting beams may be provided or, if possible, the trench should be divided into chambers of two or three to provide the requisite strength to the walls of the trench. The Bureau of Indian Standard code on sub-surface reservoirs may be consulted while constructing the recharge trenches. If the trenches are constructed in storm-water drains, where the polluted water is expected during the lean period or non-monsoon months, a bypass arrangement may be made so that no polluted water enters the recharge trenches.

During the rainy season, storm-water drains containing exclusively rainwater flows up to the brim. To harness available runoff, trenches with recharge tube wells are constructed inside the drain bed at a spacing of 100–300 m, varying with the availability of runoff. Depending upon the ratio of depth and slope of the drain walls, a baffle wall of height 0.6–1.0 m is constructed to retain water. Maintenance of catchments so that they are neat and clean should be ensured, and mixing of sewerage and other impurities should not be allowed. Dumping of unwanted items and scrap material in open spaces around storm-water drains should be prevented. Open storm-water drains should be covered with perforated detachable RCC slabs to maintain them and prevent pollution and contamination.

Diagram 13: Recharge system for urban megastructures



Source: Functional plan for groundwater recharge in NCR, 2015

7 Rainwater harvesting: Prospects and proposal

In the current scenario of availability of and demand for water in Noida and in view of the ever-growing requirement for water, RWH plays a pivotal role in sustaining water sources as well as improving inefficient management of groundwater resources of the area. Land use-wise RWH and artificial recharge potential needs to be quantified as well as localized in areas where potential recharge is identified. Artificial recharge becomes the most feasible option in Noida, since the area suffers from groundwater depletion but has high runoff availability.

Aquifers can be artificially recharged by three methods, namely surface spreading, watershed management (water harvesting) and recharge wells. Taking into consideration these approaches and methodologies, the area was studied extensively for geological, hydrogeological, geomorphological and climatological conditions and accordingly a RWH systems recharge to groundwater plan has been developed in Noida.

Two major source of water can be harvested during the monsoon to augment groundwater resources through artificial recharge techniques or otherwise to supplement water resource availability. One is floodwater in the Yamuna River, unused during the monsoon period, and the other is rainfall runoff during the monsoon. The availability of rainfall runoff has been estimated for all land-use types following standard practices of runoff coefficient and this has been discussed in the following sections.

7.1 POTENTIAL RECHARGE AREAS

In the present study of land use, the following areas have been considered for artificial recharge of groundwater:

- Floodplains
- Residential areas
- Industrial areas
- Green areas

In each type of area, three to four selected locations within Noida have been identified as a type area for RWH and artificial recharge of groundwater. Recharge potential for each type area is estimated considering the land cover as rooftop, paved and open area and accordingly the potential runoff that may generate during rainy season is estimated.

7.2 RELEVANCE OF LAND-USE TYPE FOR RWH

The pattern of land use of an area has great significance in planning RWH as interventions for different land-use types vary in time and space. The runoff coefficient, pollution level, land availability and percentage of built-up area determine RWH potential for a specific land use. Further, the availability of water in terms of quantity and for harvesting and recharge is fully controlled by the land use. One important concern in water harvesting and groundwater recharge is the quality of water proposed to be used as source water for recharge.

Since Noida has a sizable area under the industry, there is a need to ascertain the quantity of water available for these industries. Also, the bulk uses of the city, such as horticulture demand and road washing, can be catered for through harvested rainwater.

7.2.1 Planning for RWH in the floodplain area

The Yamuna and Hindon Rivers flow from Noida and have well-developed floodplains that can be used to recharge groundwater. The groundwater levels in the floodplains of both rivers are in general shallow to moderately deep. The quantum of unused Yamuna floodwater available is to the tune of 50 MCM while the requirement for NCT Delhi is around 158 MCM.[1] The share of unused floodwater can be reallocated, with NCR considered as one entity. The share for NCR districts in floodwaters of Yamuna sub-basins that flow down the river and are currently unutilized can be harnessed by recharging aquifers through floodplain recharge structures at spaces available in the Yamuna floodplains (see *Table 7: Recharge estimates of river recharge basins in Noida*). Groundwater levels are, however, shallow in these areas, which suggests making recharge only if additional space is created in the floodplain aquifers by overdeveloping the groundwater from the battery of tube wells.

The recharged water can be supplied to water-scarce areas where groundwater storage and recovery schemes are feasible. Basin spreading recharge is proposed, where water is recharged by surface spreading through basins by induced recharge from adjacent streams and lakes or through injection wells. Water may be recharged by releasing it into basins formed by excavation or by the construction of containment dykes or small dams. Horizontal dimensions of such basins vary from a few metres to several hundred metres. The most common system comprises individual basins fed by pumped water from nearby surface-water sources. Silt-free water avoids the problem of sealing basins during flooding. Even so, most basins require periodic scraping of the bottom surface when dry to preserve a percolation surface. Basins, because of their general feasibility and ease of maintenance, are the most favoured method of artificial recharge from the surface.[2]

Ditches or furrows, which are shallow, flat-bottomed and closely spaced to obtain maximum water-contact area, are another alternative. Gradients of major feeder ditches should be sufficient to carry suspended material through the system since deposition of fine-grained material clogs soil-surface openings. Water spreading in a natural stream channel may adopt any of the methods described of surface application; the primary purpose is to extend the time and area over which water is recharged (see *Diagram 14: Typical design for basin spreading recharge*).

Similar structures are proposed to be constructed in the feasible areas of the Yamuna and Hindon floodplains. An estimate of recharge along with cost is given in *Table 7: Recharge estimates of river recharge basins in Noida.*

7.2.2 Planning for RWH in residential areas

Four residential sectors, Sectors 82, 128, 71 and 78, have been analysed to showcase RWH planning. Built-up/paved/road areas, green areas and unpaved areas in each of these sectors have been calculated (*see Map 19: Identified residential areas in Noida for RWH*). Area details are given in *Table 8: Area distribution of selected residential sectors of Noida.*

Assuming annual average rainfall of 750 mm in Noida, runoff estimations have been worked out during monsoons (see *Table 9: Estimated runoff in selected residential sectors of Noida).* Based on the runoff estimated to be generated during rainfall, type and number of RWH structures have been planned (see *Table 10: Proposed planning for RWH in residential Sectors 82, 128, 71 and* 78).

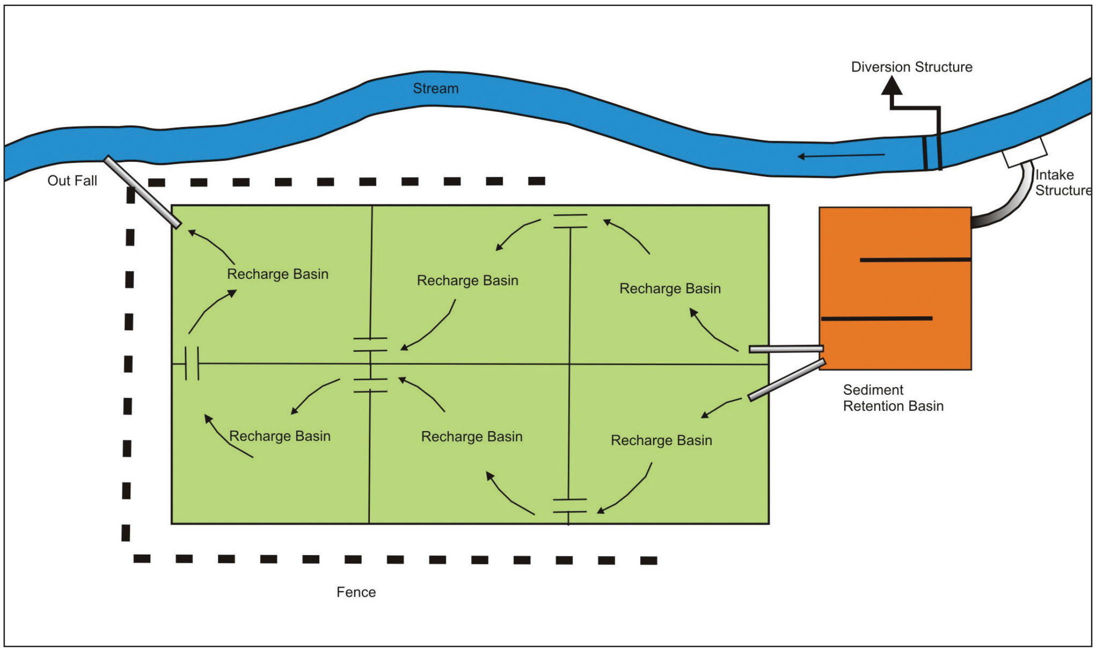
7.2.3 Planning for RWH in industrial areas

Four sample areas with industrial land use, Sectors 1, 2, 4 to 10, 32, 63 and 80, with total

Table 7: Recharge estimates of river recharge basins in Noida

Water recharge methods	Type of recharge structure	Number of recharging structures	Unit recharge capacity (thousand cubic metres)	Total recharge (thousand cubic metres)	Unit cost (lakh)	Total cost (lakh)
Basin spreading recharge method	Basin recharge structure	10	500	5,000	7.5	75

Diagram 14: Typical design for basin spreading recharge



Source: Functional plan for groundwater recharge in NCR, 2015

Table 8: Area distribution of selected residential sectors of Noida

Land use in residential sectors (sq. km)	Sector 82	Sector 128	Sector 71	Sector 78
Built-up and paved/road area	0.044	0.8	0.45	0.45
Green	0.094	0.48	0.159	0
Unpaved	0.47	0.19	0.091	0.27
Total	0.608	1.47	0.7	0.72

Source: Centre for Science and Environment, 2015

Table 9: Estimated runoff in selected residential sectors of Noida

Land use in residential sectors (cubic m)	**Sector 82**	**Sector 128**	**Sector 71**	**Sector 78**
Built-up and paved/road area	19,800	360,000	202,500	202,500
Green	52,875	36,000	11,925	0
Unpaved	7,050	21,375	10,237	30,375
Total	79,725	417,375	224,662	232,875

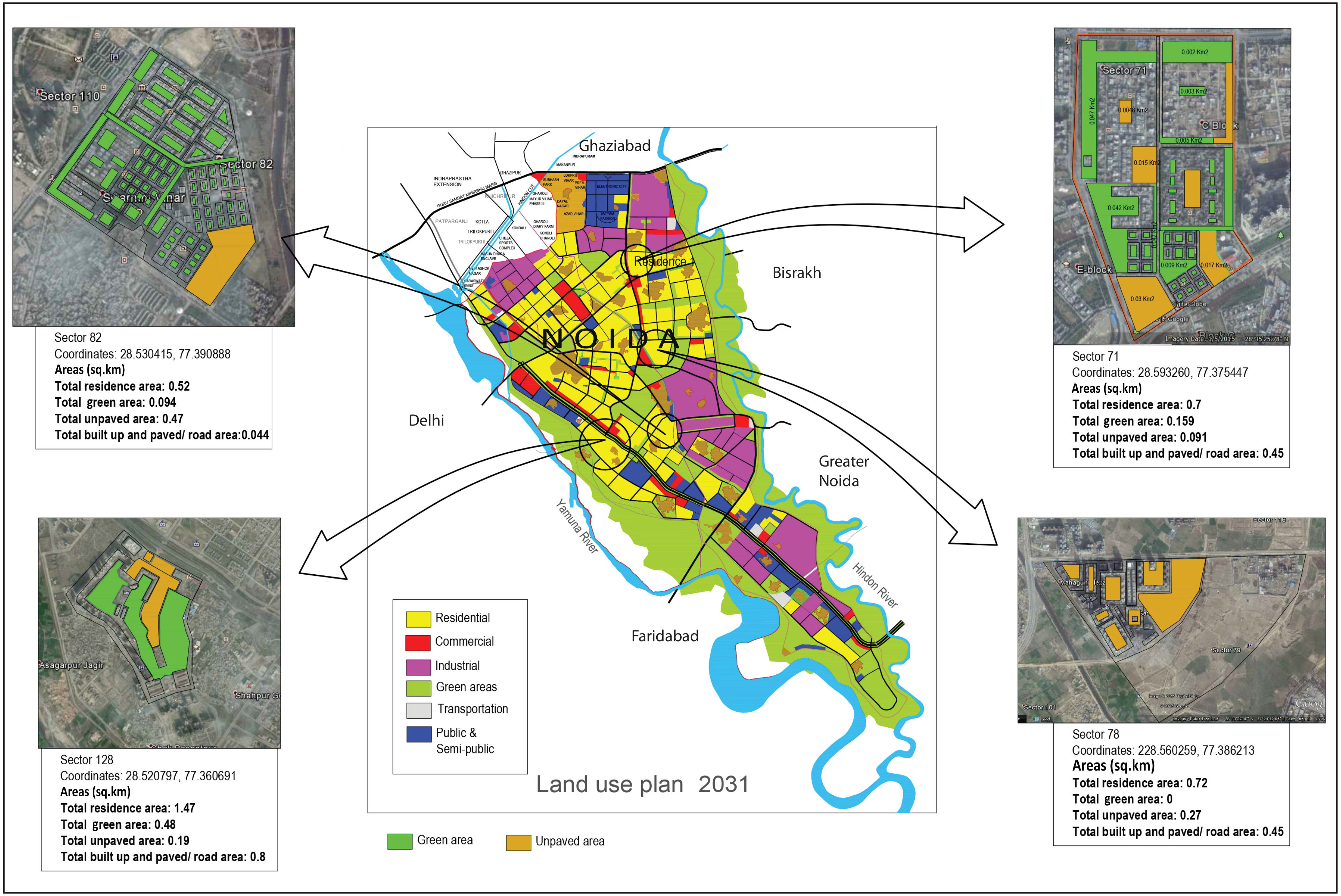
Source: Centre for Science and Environment, 2015

area of 1.113 sq. km, 1.11 sq. km, 8.69 sq. km and 6.448 sq. km, are identified for preparing the RWH plan (see *Map 20: Identified industrial areas in Noida for RWH planning*). These areas have different urban patterns that have been classified into built-up and paved/road areas with runoff coefficient 0.7, green area with runoff coefficient 0.1 and unpaved area with runoff coefficient 0.15, respectively (see *Table 11: Area distribution of selected industrial sectors in Noida).*

Assuming annual average rainfall of 750 mm in Noida, the runoff estimations have been worked out during the monsoon period (see *Table 12: Estimated runoff in selected industrial sectors of Noida*).

Based on the runoff estimated to be generated during rainfall, for each type of land use, such as built-up area and green area, the type and number of RWH structures have been

Map 19: Identified residential areas in Noida for RWH



Source: Centre for Science and Environment, 2015

Table 10: Proposed planning for RWH in residential Sectors 82, 128, 71 and 78

Proposed planning for RWH in residential Sector 82, Noida						
Land use in Sector 82	**Runoff ('000 cubic metres)**	**Type of structure**	**Unit recharge capacity ('000 cubic metres)**	**Numbers of recharging structures**	**Unit cost (Rs lakh)**	**Total cost (Rs lakh)**
Built-up and paved/ road area	19.8	Well recharge/shaft driven trenches	10	2	5	10
Green	52.8	Well recharge/shaft driven trenches	10	6	5	30
Unpaved	7.050	Well recharge/shaft driven trenches	10	1	5	5
Total	79,725			33		45
Proposed planning for RWH in Sector 128, Noida						
Land use in Sector 128	**Runoff ('000 cubic metres)**	**Type of structure**	**Unit recharge capacity ('000 cubic metres)**	**Number of recharging structures**	**Unit cost (Rs lakh)**	**Total cost (Rs lakh)**
Built-up and paved/ road area	360	Well recharge/shaft driven trenches	10	36	5	180
Green	36	Park type recharge structure	50	1	7.5	7.5
Unpaved	21.37	Well recharge/shaft driven trenches	10	2	5	10
Total	417.37			39		197.5
Proposed planning for RWH in Sector 71, Noida						
Land use in Sector 71	**Runoff ('000cubic metre)**	**Type of structure**	**Unit recharge capacity ('000 cubic metres)**	**Number of recharging structures**	**Unit cost (Rs lakh)**	**Total cost (Rs lakh)**
Built-up and paved/ road area	202.50	Well recharge/shaft driven trenches	10	20	5	100
Green	11.92	Well recharge/shaft driven trenches	10	2	5	10
Unpaved	10.23	Well recharge/shaft driven trenches	10	1	5	5
Total	224.65			23		115
Proposed planning for RWH in residential Sector 78, Noida						
Land use in Sector 78	**Runoff ('000 cubic metre)**	**Type of structure**	**Unit recharge capacity ('000 cubic metre)**	**Number of recharging structures**	**Unit cost (Rslakh)**	**Total cost (lakh)**
Built-up and paved/ road area	202.50	Well recharge/shaft driven trenches	10	20	5	100
Green	0	-	-	-	-	-
Unpaved	30.37	Well recharge/shaft driven trenches	10	3	5	15
Total	232.87			23		115

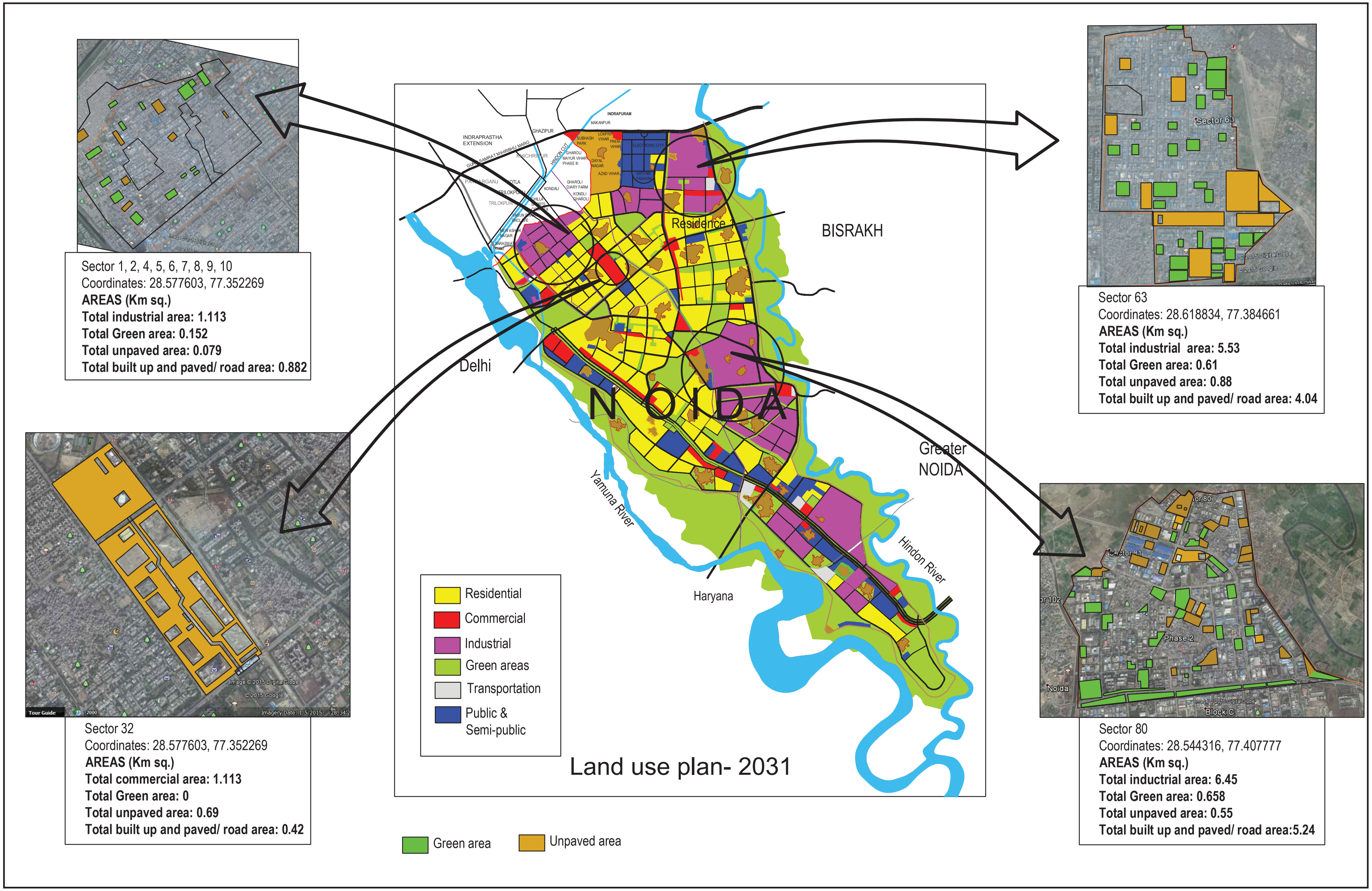
Source: Centre for Science and Environment, 2015

Table 11: Area distribution of selected industrial sectors in Noida

Land use in industrial sectors (sq. km)	Sectors 1, 2 and 4–10	Sector 32	Sector 63	Sector 80
Built-up and paved/road area	0.882	0.42	4.04	5.24
Green	0.152	0	0.61	0.658
Unpaved	0.079	0.69	4.04	0.55
Total	1.113	1.11	8.69	6.448

Source: Centre for Science and Environment, 2015

Map 20: Identified industrial areas in Noida for RWH planning



Source: Centre for Science and Environment, 2015

Table 12: Estimated runoff in selected industrial sectors of Noida

Land use in industrial sectors (cubic metres)	Sectors 1, 2 and 4–10	Sector 32	Sector 63	Sector 80
Built-up and paved/road area	396,900	1,89,000	1,818,000	2,358,000
Green	11,400	0	45,750	49,350
Unpaved	8,887.5	77,625	454,500	61,875
Total	417,187.5	266,625	2,318,250	2,469,225

Source: Centre for Science and Environment, 2015

Table 13: Proposed planning for RWH in industrial Sectors 1, 2, 4–10, 32, 63 and 80

Proposed planning for RWH in industrial Sector 1, 2 and 4 to 10, Noida						
Land use in Sectors 1, 2 and 4–10	**Runoff ('000 cubic metres)**	**Type of structure**	**Unit recharge capacity ('000 cubic metres)**	**Number of recharging structures**	**Unit cost (Rs lakh)**	**Total cost (Rs lakh)**
Built-up and paved/road area	396.90	Well recharge/shaft driven trenches	10	40	5	200
Green	11.400	Well recharge/shaft driven trenches	10	1	5	5
Unpaved	8.887	Well recharge/shaft driven trenches	10	1	5	5
Total	**417.187**			**42**		**210**
Proposed planning for RWH in industrial Sector 32, Noida						
Land use in Sector 32	**Runoff ('000 cubic metres)**	**Type of structure**	**Unit recharge capacity ('000 cubic metres)**	**Number of recharging structures**	**Unit cost (Rs lakh)**	**Total cost (Rs lakh)**
Built-up and paved/road area	189.00	Well recharge/shaft driven trenches	10	19	5	95
Green	0	-	-	-	-	-
Unpaved	77.62	Well recharge/shaft driven trenches	10	8	5	40
Total	**266.62**			**27**		**135**
Proposed planning for RWH in industrial Sector 63, Noida						
Land use in Sector 63	**Runoff ('000 cubic metres)**	**Type of structure**	**Unit recharge capacity ('000cubic metres)**	**Number of recharging structures**	**Unit cost (Rs lakh)**	**Total cost (Rs lakh)**
Built-up and paved/road area	1,818	Urban storm water recharge structures/well recharge/shaft driven trenches	10	180	5	900
Green	45.75	Well recharge/shaft driven trenches	10	4	5	20
Unpaved	454.50	Well recharge/shaft driven trenches	10	45	5	225
Total	**2,318.250**			**229***		**1,145**
Proposed planning for RWH in industrial Sector 80, Noida						
Land use in Sector 80	**Runoff ('000 cubic metres)**	**Type of structure**	**Unit recharge capacity ('000 cubic metres)**	**Number of recharging structures**	**Unit cost (Rs lakh)**	**Total cost (Rs lakh)**
Built-up and paved/road area	**2,358**	**Urban storm water recharge structures/well recharge/shaft driven trenches**	**10**	**235**	**5**	**1,175**
Green	**49.35**	**Well recharge/shaft driven trenches**	**10**	**5**	**5**	**25**
Unpaved	**61.87**	**Well recharge/shaft driven trenches**	**10**	**6**	**5**	**30**
Total	**2,469.22**			**246***		**1,230**

Source: Centre for Science and Environment, 2015

worked out (see *Table 13: Proposed planning for RWH in industrial Sectors 1, 2, 4–10, 32, 63 and 80*).

7.2.4 Planning for RWH in green areas

Some important green areas of Noida are the regional park, city park, the sport centre and golf course, with green land cover. These areas are potential catchments for harvesting rainwater during rainy seasons. Location map indicating four areas is given below (see *Map 21: Identified green areas for RWH in Noida*).

The area details and runoff generated—assuming annual average rainfall of 750 mm—is given in *Table 14: Estimated runoff in selected green areas of Noida.*

Based on the runoff estimated during rainfall, park type of recharge structures are proposed to be constructed for green area. Number of park type of RWH structures for each green area has been worked out (see *Table 15: Proposed planning for RWH in open areas of Noida*).

7.2.5 Proposed planning for RWH according to different sectors of Noida

The number of structures proposed in the above plan may vary in capacity and number, depending upon the availability of space for construction of these recharges structures.

The overall recommendation is provided as RWH structures in different location of Noida based on available soil.

Table 14: Estimated runoff in selected green areas of Noida

Green areas	Regional park	City park	Sport centre	Golf course
Area (sq. km)	1.27	1.24	0.28	0.34
Runoff (cubic m)	95,250	93,000	21,000	25,500

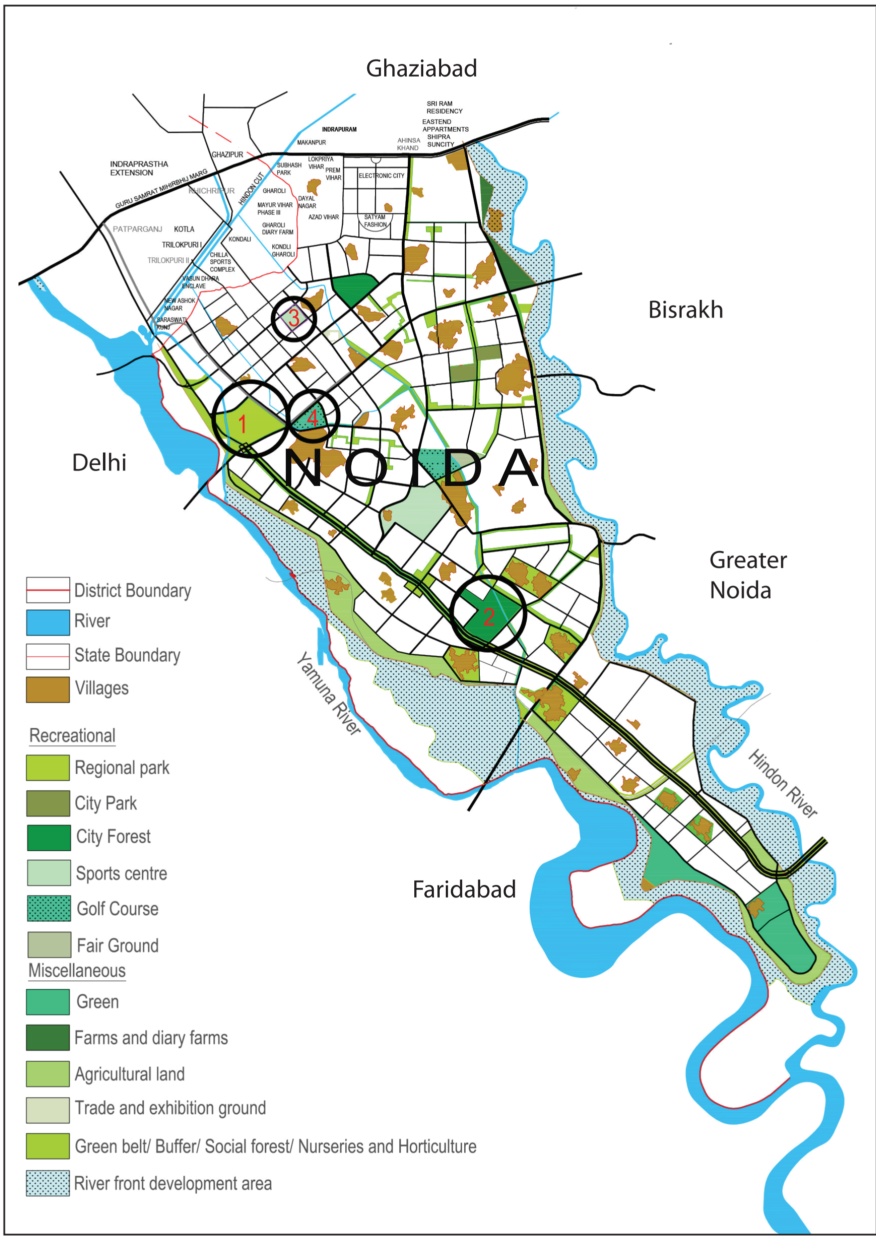
Source: Centre for Science and Environment, 2015

Table 15: Proposed planning for RWH in open areas of Noida

Area	Runoff ('000 cubic metres)	Type of structure	Unit recharge capacity ('000 cubic metres)	Number of recharging structures	Unit cost (Rs lakh)	Total cost (Rs lakh)
Regional park	95.25	Park type recharge structure /SUDS	50	2	7.5	15
City park	93.0	Park type recharge structure/SUDS	50	2	7.5	15
Sport centre	21.00	Well recharge/shaft driven trenches/SUDS	10	2	5	10
Golf course	25.50	Well recharge/shaft driven trenches/SUDS	10	3	5	15
Total	**234.75**			**9**		**55**

Source: Centre for Science and Environment, 2015

Map 21: Identified green areas for RWH in Noida



Areas (sq.km)

1. Regional Park : 1.27
2. City forest : 1.24
3. Sports centre: 0.28 (built up: 0.03, open:0.25)
4. Golf course :0.34

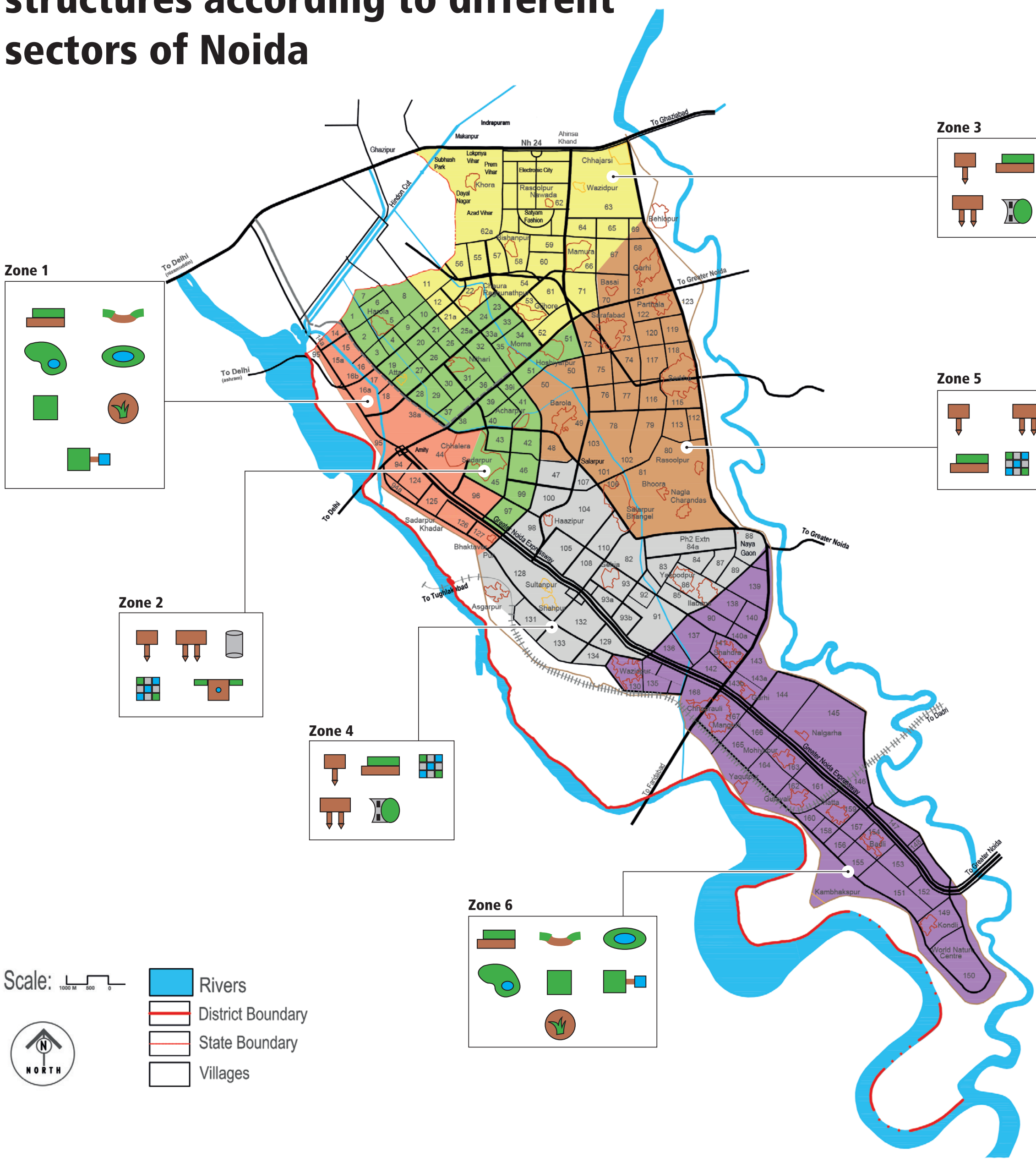
Coordinates: 28.562135, 77.335106

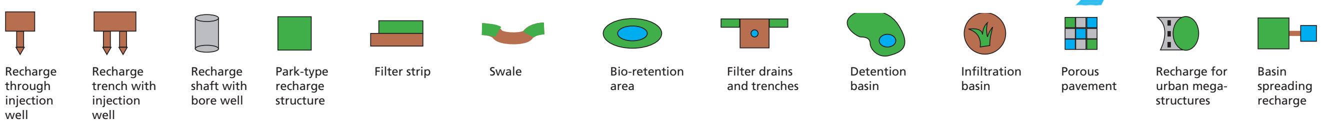
Coordinates: 28.513006, 77.399456

Coordinates: 28.590682, 77.340832

Source: Centre for Science and Environment, 2015

Recommendations for RWH structures according to different sectors of Noida





Zone	Area / Sectors	Soil and water level
Zone 1	North west part of the city near the river. (sectors 1, 2, 3, 14, 14A, 15, 151, 16, 16A, 16B, 17, 18, 38A, 44, 94, 94A 95, 96, 124, 125, 126, 127)	Silty sand extends upto 2-5.6 mbgl underlaind by fine sand upto 17-22 mbgl. Below this is an alternate layer of brownish sandy silt, silty sand and fine sand extending upto 30 mbgl. The ground water level is about 8.5-11.2 mbgl
Zone 2	North central part of the city. (sectors 4, 5, 6, 7, 8, 9, 10, 20, 21, 23, 24, 25, 25A, 26, 27, 28, 29, 30, 31, 32, 33, 33A, 34, 35, 36, 37, 38, 39, 39I, 40, 41, 42, 43, 45, 46, 51, 97, 99).	Clay layer upto 3-5mbgl followed by permeable layer represented by medium and fine sand after which a alternative layer of permeable and impermeable layer is present. The ground water level is about 22 mbgl.
Zone 3	Northern part of the city (sectors 11, 12, 21A, 22, 52, 53, 54, 55, 56, 57, 58, 59, 60, 62, 62A, 63, 64, 65, 66, 71).	Clay layer upto 3-5mbgl followed by medium to fine sand upto 40 mbgl then clay upto 50 mbgl after which a layer of sand is present. Ground water level is about 10-15 mbgl.
Zone 4	West central part of the city (sectors 82, 83, 84, 84A 85, 86, 87, 89, 91, 92, 93, 93A, 93B, 98, 100, 104, 106, 108, 110, 128, 129, 131, 133, 134)	Clay layer upto 3-5mbgl followed by medium to fine sand upto 50 mbgl then a thick layer of clay is present. Ground water level is about 5-9 mbgl.
Zone 5	East central part of the city (sectors 48, 49, 50, 51, 68, 69, 70, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 88, 101, 102, 103, 106, 112, 113, 115, 116, 117, 118, 119, 120, 121, 122)	Clay layer upto 3-5mbgl followed by sandy clay upto 15 mbgl and medium to fine sand upto 60 mbgl after which a layer of clay is present. Ground water level is about 10-15 mbgl.
Zone 6	Southern part of the city (sectors 90, 135, 136, 137, 138, 140, 140A, 142, 143, 143A, 143B, 144, 145, 146, 147, 148, 149, 150, 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 165, 166, 167, 168)	A layer of sandy clay is present on the surface upto 10 mbgl followed by medium to fine sand upto 30 mbgl and thick layer of clay upto 40 mbgl. Ground water level is about 6 mbgl.

Tear here

8 Conclusion

Current water management relies heavily on the cost-intensive long-distance transfer of water, including the overexploitation of in-situ groundwater resources, to meet the widening demand–supply gap. The city of Noida is no different.

Like any urbanizing city, Noida is facing huge water-stress issues, leading to over-extraction of groundwater in the area. The need of the hour is to consider rainfall as an important and manageable resource in water management plans.

This report gives an overarching framework of potential RWH systems that can be implemented in the area, depending on the physical and land use features. It highlights that the present water scenario and geomorphic set-up needs to be considered to recognize potential recharge areas (see Poster).

Implementation of RWH systems in Noida can contribute significantly to addressing the water demand–supply gap, dealing with water logging/flooding and recharging depleting aquifers. It is time that government agencies make deliberate efforts to make water everybody's business and work prudently towards implementation of RWH in the area.

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Annexure

प्रेषक, संख्या-1703 A/9 आ-1, 29-विविध/पृष्ठ (आ.ब.)

भोला नाथ तिवारी,
मुख्य सचिव,
उत्तर प्रदेश शासन।

सेवा में,

1. **समस्त प्रमुख सचिव/सचिव**
   उत्तर प्रदेश शासन।
2. **समस्त मण्डलायुक्त,**
   उत्तर प्रदेश।
3. **समस्त जिलाधिकारी,**
   उत्तर प्रदेश।
4. **समस्त विभागाध्यक्ष,**
   उत्तर प्रदेश।

आवास अनुभाग–1 लखनुऊ दिनांक 12 अप्रैल,

विषयः ग्राउण्ड वाटर के संरक्षण तथा रिचार्जिंग हेतु रेन वाटर हारवेस्टिंग पद्धतियों को अपनाए जाने के सम्बन्ध

महोदय,

आप अग्रगत हैं कि जीवन एवं पर्यावरण के अस्तित्व के लिए जल एक अनिवार्य प्राकृतिक संसाधन है। परन्तु ग्राउण्ड स्रोत के अनियोजित ढंग से मनमानी मात्रा से अति दोहन के कारण ग्राउण्ड वाटर स्तर तेजी से नीचे गिर रहा है तथा शहरी बढ़ती हुई आबादी को समुचित पेयजल की व्यवस्था प्रदान करना सम्भव नहीं हो पा रहा है। ऐसी स्थिति में यदि पेय जल के हेतु एवं ग्राउण्ड वाटर स्रोतों के संरक्षण, मितव्ययता, जल प्रयोग तथा रिजार्जिंग में समुचित जल–प्रबन्धन द्वारा संतुलन स्थापित किये गये तो निकट भविष्य में पेयजल का भारी संकट उत्पन्न होने की आशंका है। इसलिए जल संसाधन की संरक्षण एवं सुरक्षा हो। वाटर हार्वेस्टिंग की सरल, कुशल और कम लागत वाली पद्धतियों को अपनाए जाने की आवश्यकता है।

2. इस सम्बन्ध में मुझे यह कहने का निर्देश हुआ है कि रेन वाटर हार्वेस्टिंग एवं ग्राउण्ड वाटर के समुचित प्रबन्धन हेतु योग्य की संरचना तथा विकास एवं निर्माण के समय शासन द्वारा विचारोपरान्त निम्न व्यवस्थाएं सुनिश्चत किये जाने का निर्णय लिया गया।

2.1 **महायोजना/जोनल प्लान स्तर पर कार्यवाहीः**
नगरीय क्षेत्रों में प्राकृतिक जलाशयों, तालाबों, झीलों को चिन्हित कर महायोजना/जोनल डेवलपमेंट प्लान से इसके जल संरक्षण हेतु प्रविधान किए जाएं एवं इनके अन्तर्गत आने वाली भूमि को किसी अन्य उपयोग में प्रस्तावित न किया, साथ ही जलाशयों में निस्तारित करने हेतु प्रविधान किए जाएं, परन्तु औद्योगिक क्षेत्रों का प्रवाह उचित उसके उपरान्त हो इनमें मिलाया जाए।

2.2 **योजना/ले-आउट प्लान स्तर पर कार्यवाही**

(i) 20 एकड़ एवं अधिक क्षेत्रफल की विभिन्न योजनाओं के ले–आउट प्लान्स में पार्क एवं खुले क्षेत्रों के कुल योजना क्षेत्र के लगभग 5 प्रतिशत भूमि पर तालाब/जलाशय (Water Bodies) चलाई जाए, जिनसे ग्राउण्ड वाटर रीचार्ज हो सके। ऐसे जलाशय/तालाब का न्यूनतम क्षेत्रफल एक एकड़ होगा और उसकी गहराई 6 मीटर है।

(ii) 20 एकड़ से कम क्षेत्रफल की योजनाओं में उपराक्तानुसार तालाब/जलाशय बनाए जाएं अथवा पार्क/ग्रीन बेल्ट अन्तर्गत निर्धारित मानक के अनुसार एक कोने में रिचार्ज–वैल/रिचार्ज टैंक बनाए जाएं।

(iii) नई योजना बनाने से पूर्व क्षेत्र का ज्योलॉजिकल/हाइड्रोसाइक्लोजिकल सर्वेक्षण कराया जाए ताकि ग्राउण्ड वाटर रिचार्जिंग हेतु स्थानीय आवश्यकतानुसार उपयुक्त पद्धति को अपनाया जा सके।

(iv) पार्कों में पक्का निर्माण (पक्के पवगेट सहित) 5 प्रतिशत से अधिक न किया जाए तथा फुटपाथ व ट्रैक्स यथासम्भव परमिएबल या सेमी–परमिएबल ब्लॉक्स के प्रयोग से ही बनाए जाएं।

2.3 भवन निर्माण स्तर पर कार्यवाही

(i) 1000 वर्ग मीटर एवं इससे अधिक क्षेत्रफल के समस्त उपयोगी के भूखण्डों तथा सभी ग्रुप हाउसिंग योजनाओं में छतों एवं खुले स्थानों से प्राप्त होने वाले बरसाती जल को परकोलेशन पिट्स (Perculation Pits) के माध्यम से ग्राउण्ड वाटर चार्जिंग के लिए अनिवार्य किया जाए। इस हेतु भवन उपविधियों से भी व्यवस्था की गई है तथा उसी के अनुसार भवन मानचित्र स्वीकृत किए जाएंगे।

(ii) भविष्य में निर्मित होने वाले समस्त शासकीय भवनों में छत एवं खुले स्थानों से प्राप्त होने वाले बरसाती जल का ग्राउण्ड वाटर चार्जिंग के लिए आवश्यक व्यवस्था सुनिश्चित की जाए तथा इसके लिए आवश्यक धनराशि भवन की लागत से प्राविधनित की जाए।

(iii) पूर्व में निर्मित शासकीय भवनों में भी रूफ टॉप रेन वाटर हार्वेस्टिंग एवं रिचार्ज प्रणाली को अपनाया जाए तथा इसके लिए आवश्यक धनराशि की व्यवस्था सभी विभागों द्वारा अप. ने–अपने कार्यक्रमों के अन्तर्गत सुनिश्चित की जाए।

2.4 अन्य कार्यवाही

(i) सड़कों, पार्कों तथा खुले स्थान में वृक्षारोपण हेतु ऐसे पेड़ पौधों की प्रजातियों का चयन किया जाए जिनको जल की न्यूनतम आवश्यकता हो तथा जो कम जल ग्रहण करके ग्रीष्म त्रुति में भी हरे भरे रह सकें।

(ii) यदि सम्भव हो तो सड़कों के किनारे कच्चे रखे जाएं जिनमें ''त्रिक–ऑन–एज''/''लूज–स्टोन पेवमेंट'' का प्राविधान किया जाए ताकि ग्राउण्ड वाटर को चार्जिंग सम्भव हो सके।

रेन वाटर हार्वेस्टिंग एवं रिचार्ज प्रणाली के सम्बन्ध से अन्य जानकारी क्षेत्रीय निर्देशक केन्द्रीय भूजल परिषद लखनऊ के निर्देशक, भूगर्व जल विभाग, उत्तर प्रदेश तथा मुख्य अभियंता, लघु सिंचाई वृत्त, लखनऊ से प्राप्त की जा सकती है।

कृपया उपरोक्त निर्देशों का कड़ाई से अनुपालन करने हेतु अपने अधीनस्थ कार्यरत संस्थाओं को अपने स्तर से आवश्यक निर्देश जारी करने का कष्ट करें। इसके अतिरिक्त रेन वाटर हार्वेस्टिंग की विभिन्न पद्धतियों के व्यापक प्रचार–प्रसार हेतु भी आवश्यक कार्यवाही सुनिश्चित करने का कष्ट करें।

भवदीय
भोला नाथ तिवारी
मुख्य सचिव

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प्रतिलिपिः निम्नलिखित को सुचनार्थ एवं आवश्यक कार्यवाही हेतु प्रेषित,
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