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WATER, CITY AND URBAN PLANNING

ASSESSING THE ROLE OF GROUNDWATER IN URBAN DEVELOPMENT AND PLANNING IN DELHI

Suresh Kumar ROHILLA

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SUMMARY

This paper emphasises that the quality of our lives is dependent on the quality of our environment, which, in turn, is dependent on the quality of land use as a result of urban planning. In the process of urbanisation, the subsurface environment, namely the presence or absence of groundwater is a key factor. This paper examines the role of groundwater in urban development and planning from the point of view of sustainability of the *in-situ* resource in the long term as an important source to meeting increasing water requirements of urban agglomeration. The study area for the paper is the National Capital Territory (NCT) Delhi and its peri-urban areas.

The existing urban agglomeration of Delhi is increasingly dependent on groundwater extraction to meet the constant water demand - supply gap. This is resulting in a rapid decline of the groundwater table in the NCT Delhi. In terms of the available and utilisable groundwater for domestic and non-domestic requirements, the existing city core as well as the peri-urban areas of Delhi have fallen into the category of overdrawn groundwater resources.

The paper examines the stages and patterns of urban evolution in the Delhi metropolis and its peri-urban areas and links the role of groundwater in urban development from the past to the present. With the help of a case study -'Dwarka sub-city' within the immediate urban extensions in NCT Delhi, the paper establishes the systemic role that groundwater plays in the various stages of urban development and planning in NCT Delhi and its peri-urban areas. Based on the findings, the paper suggests policy interventions in developing a land use strategy for urban areas reflecting concerns of sustainable use of groundwater in Delhi.

The above-stated research has been conducted by the author for his doctoral thesis submitted at Queen's University Belfast, Northern Ireland and has, in-part been supported by the Centre de Sciences Humaines, New Delhi.

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List of Acronyms

CGWB - Central Ground Water Board

CGWA - Central Ground Water Authority

CPCB- Central Pollution Control Board

DUA- Delhi Urban Area

DUAC- Delhi Urban Arts Commission

DDA - Delhi Development Authority

DJB - Delhi Jal Board

DFID - Department for International Development

GPCD- Gallons Per Capita Per day

IARI - Indian Agriculture Research Institute

INTACH – Indian National Trust for Cultural Heritage

LPCD - Litres Per Capita per Day

MLD- Million Litres per Day

M - Meter

MCD- Municipal Corporation of Delhi

NDMC- New Delhi Municipal Corporation

MSL- Mean Sea Level

MBGL - Metres Below Ground Level

NCT- National Capital Territory

NCR- National Capital Region

PU - Peri-Urban

KM - Kilometres

UA - Urban Agglomeration

UP - Uttar Pradesh

UN - United Nations

UNESCO - United Nations Educational, Social and Cultural Organisation

UT - Union Territory

Hindi terms used-

Abadi- original residential area in village

Gaon/gram- village

Jhuggi / Jhompri- slums/ squatters

Nalluh/ Nullah- drain

Nagar- Town

Panchayat- local (village level) democratic institution

Lal Dora- earmarked area in village for/ under residential use

Tehsil- administrative sub-division

Phirni- a circular road surrounding village (boundary of *abadi* area)

Jal- water

Vidyut- electricity

Jheel- lake or depression

Bundh- embankment

Kutchha- non concrete

1 Background

1.1 Introduction

Urban areas evolve through series of well-recognised stages as they gradually mature from small settlements into a city or urban agglomeration. This transformation is accompanied by infrastructural changes in water and sanitation (Howard and Israfilov 2002). They affect the behaviour and characteristics below and around them (Custodio 1997). Cities in the developed world have been through a number of distinct phases of development including industrialisation and post-industrialisation. In the early stages of transition, groundwater is initially drawn from shallow, unplanned private wells, and shallow wells give way to deeper wells and the quality of groundwater degrades. As a result surface water or groundwater needs to be transferred to urban centre(s) initially from peripheral areas, and ultimately from distant, remote, mainly surface water sources. In some parts of the world, particularly newly emerging mega cities and urban agglomerations in the developing world, the switchover to alternative water sources when groundwater level drops or water quality degrades has not accompanied urban growth and development. Groundwater withdrawal significantly exceeds the rates of aquifer recharge (a condition commonly referred to as over-abstraction or over-exploitation) in cities such as Mexico, Shanghai, Calcutta, Jakarta, and Manila (Chilton et al. 1997). These cities are amongst the first to document the impact of urban development on groundwater.

Also in the twentieth century it is estimated that the combined projected population of three developing countries in Asia namely China, India and Indonesia will be about 2.5 billion by 2015 (UN 2002). For the first time in human history, more people will live in cities rather than in rural areas. According to Mohan and Dasgupta (2005) as in the last 50 years, these countries will be urbanising much more than developed world countries. Thus, the overall sustainability is at stake in the rapidly growing mega-cities mainly located in the developing world. The need is to link urban growth and development processes with sustainable development, utilisation and management of water resources; both surface water as well as groundwater resources. In particular the groundwater resources need to be integrated in planning for these mega-urban regions. To address sustainable groundwater development, planners must incorporate an understanding of the subsurface into the standards of planning and practice and acknowledge the impacts of land use on groundwater and the hydro-geological complexity that occur in these areas (Howard 2002).

The subsurface environment (and particularly groundwater) plays an important role (equal to that of surface water sources) in the infrastructure development for water supply and drainage, the key requirements for the urbanisation process (Foster et al. 1993). However, the systematic role of groundwater in urban development has not been adequately addressed by planners while allocating land uses under planning process (Foster et al.1993; Howard 2002). The last two decades of research show that the subsurface environment, especially the presence or absence of permeable subsoil and shallow groundwater are the key resources in urban growth and development of an area (Khazai 1999). Remediation and problem resolution have taken priority over the proactive and preventive measures such as urban planning, resource management and groundwater protection (Howard and Israfilov 2002). Documenting the significant contributions of this invisible resource and identifying resource conservation, management and protection is needed through appropriate urban planning. This could ensure that groundwater becomes less of an urban problem and more an important element for sustainable urban growth and development, health and prosperity.

This research deals with the relationship between urban development and planning with regard to groundwater resource management in a rapidly growing city in the developing world. It aims to describe the urban development (past, present and future) and the role of groundwater in urban agglomeration of Delhi (India) with the help of a case study of Dwarka sub-city. The emphasis is to suggest practical interventions in urban planning for Delhi from the point of view of sustainability of the *in-situ* resource in the long term as an important source to meeting increasing water requirements of urban agglomeration.

1.2 Background of Research

The British experience in urban planning guided the formulation of town and country legislation in India. Post-Independence Indian planning continues to adopt the British planning norms (Mehta and Mehta 1989). The planning and design of the physical form of towns and cities is based on the statutory Master Plan. The planning and design of the physical form of urban agglomeration of National Capital Territory Delhi, the study area for the present research is also based on the Master Plan prepared under the Delhi Development Act of 1957 (Rebeiro 1995; Mehta and Mehta 1989).

Further, the urban form of a city is influenced by political, geographical, topographic and transportation-related factors. In developing world cities urban planning and development efforts have failed to deliver adequate housing and related infrastructure to the rapidly growing population. According to the United Nations it is estimated that around 30 to 40 percent inhabitants of several cities in the developing world live in unplanned or unauthorised built-up areas also referred to as informal settlements (UN-Habitat 2005). The scale and size of informal development varies and is city-specific. The changes in land use pattern (both planned and unplanned) define the resultant urban forms in growth and development of any urban settlements. Surrounding areas of urban centres are experiencing large rural-urban transformations along with their city core being under re-development or re-densification. Thus, urban growth and development patterns are both complex and dynamic.

In National Capital Territory Delhi, urban development is unique and complex as urban change and transformation is not only along the boundaries of the city but also within. The vacant land that is interspersed randomly in the existing urban area of the bustling metropolis is being developed by way of planned as well as unplanned development, re-development and densification. As per the notification issued under Section 507 of "The Delhi Municipal Corporation Act, 1957" the government had listed certain areas on the outskirts of Delhi as '*lal dora'* land. In the *lal dora* (village area demarcated for habitation) also called village *abadi area* the planning provision or building bye-laws are not applicable to (re)developments in the *abadi* area (refer to Appendix 1 notification by Government of India in the year 1963 exempting the *abadi* areas from development control and other related planning provisions). But an owner of a particular land/ property in an area is entitled to basic facilities such as water supply from municipal sources. These areas are attracting more population and activities on the same property or land. This involves construction and (re)development. Also the land in the city core is increasingly seen as a resource by planners. The open areas in the city or low density development is being developed, redeveloped (or re-densified) in a planned manner. The over all existing as well as emerging spatial organisation of activities and physical pattern in Delhi is not a static but dynamic and evolving urban form. In the urban agglomeration of Delhi, the interrelationship between land use and the hierarchy of activities are constantly changing. The effects of this urban dynamics can be summed up as developments involving drastic changes in the shape and size of the city, density of the city, land use and land value, economy, infrastructure and environment (Rohilla 2003). As a result the city as well as the periphery in the urban agglomeration of Delhi is constantly evolving. Urban development in the region consists of high density unplanned and planned developments within the existing city as well as unplanned and planned urban related land uses (residential, commercial, industrial and related infrastructure) in the form of various urban extensions on the periphery of the fast growing metropolis. The impact of such developments on the environment, transportation, infrastructure, and quality of life are now common issues. The development of infrastructure is not able to keep pace with the increase in population and activities in the rapidly urbanising areas (Rohilla 2003).

In the National Capital Territory, the demand for water is expanding dramatically while supply remains limited. All planning for water augmentation in Delhi is proposed to be largely dependent on surface water from distant sources of water supply for meeting the projected water demand of the anticipated population (Rohilla 2004).

During the last fifty years, the continuing influx of population has not been matched by proportionate increase in surface water availability. In order to accommodate this population large scale land development (conversion from rural to urban or redevelopment) has been undertaken and also large areas are under transition – from agricultural or open area to urban and built up area. The projection for the urban agglomeration of Delhi indicates that urban growth would increase manifold land development in the National Capital Territory Delhi to accommodate anticipated population growth and further add pressure to the overburdened *in-situ* groundwater resources. The emerging contiguous built up area would also limit the possibilities of aquifer recharge. The unfolding scenario could make future planning and development in the city completely subservient to environmental considerations. This research will clearly highlight planning and non planning processes and the role of groundwater in various stages of urban growth and development, identify issues and bring out areas for respective betterment. Further, it will review current planning approaches for practical and more meaningful urban development i.e., more integrated or interdisciplinary urban planning for sustainability of groundwater – *in situ* resources and overall sustainable urban development.

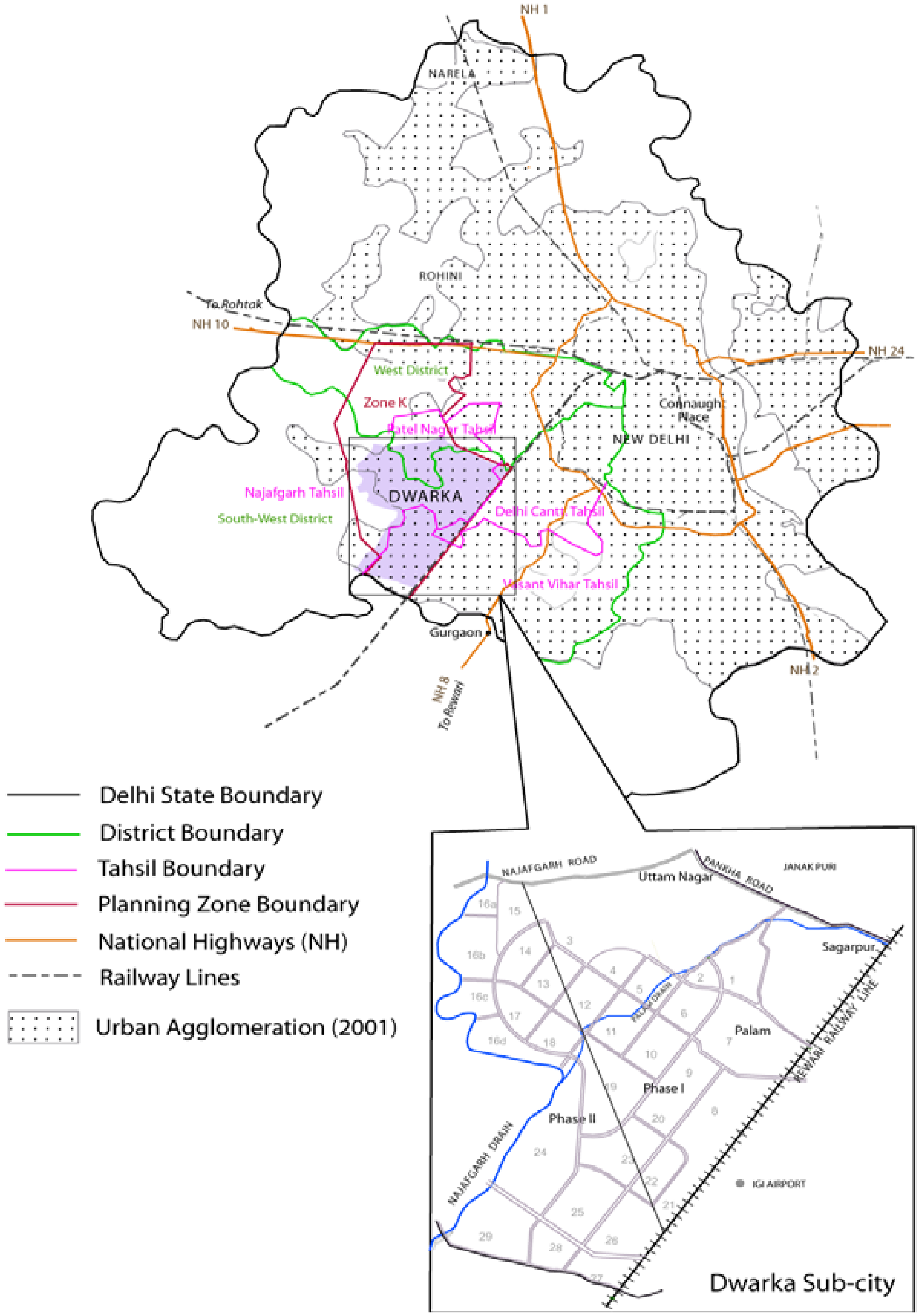
The focus of the research is narrowed to study Dwarka, the sub-city in the National Capital Territory Delhi. This detailed study of the sub-city for analytical purposes will be used to further examine the systemic role of groundwater resulting in continuous exploitation and over-dependence on groundwater resources in Dwarka sub-city region. Planned urban development in the sub-city was initiated in 1987, however, construction is still ongoing and the sub-city is in the process of transformation. The project area includes '*abadi*' areas of 11 villages and vast tracts of agricultural land of these villages now acquired for planned development purposes (i.e. transitional areas) as well as unauthorised built-up areas. The study examines the systemic role of groundwater in both planned as well as unplanned developments taking place within the sub-city in the process of transformation. The core of the research is to examine the place of groundwater in urban areas: as the first best or second best, or as transitory with dual systems, or dual systems to last as a long term water supply source.

1.3 Study Area Profile

The National Capital Territory of Delhi (the capital city of India) is the selected study area for this research. Figure 1 shows the location and regional setting of the study area. The Delhi region is part of the Indo-Gangetic alluvial plains and the climate of the region is semi-arid. To the east of the ridge, the drainage flows into the River Yamuna and to its west, into the south central part of South and South -West district.

Dwarka sub-city is located in south-west Delhi, adjacent to the western boundary of the Indira Gandhi International airport, at a distance of sixteen kilometres from the Central Business District - Connaught Place. Janakpuri (a planned residential housing scheme developed by DDA in the 1970s within the urbanisable area recommended in the Delhi Master Plan for 1962) is located in the north of the sub-city. Dwarka sub-city is located within the planning zone 'K' (Figure 1). The proposed land use in MPD 2001 identified the zone for urban extension and rural use. The administration of most of the sub-city falls under the jurisdiction of the South-west district.

Figure 1: Location and Regional Setting of the Study Area



Source: Prepared by author

1.4 Research Questions

The central research question being addressed in the study is - does groundwater play a decisive role in the planning of the metropolis? The study looks at the following sub-questions:

How and who does planning for land as well as water (especially groundwater) in an urban agglomeration over an extended spatial context? Here the study of the National Capital Territory Delhi and peri-urban areas is pertinent.

What role does groundwater play in the making (past and present) of the Delhi metropolis and its peri-urban areas?

Is there a systemic consideration for groundwater in various stages of urban development (in both planned as well as unplanned-unauthorised and illegal areas and land use type)?

How can current land use planning incorporate sustainability of groundwater in the planning of Delhi and its peri-urban areas? This includes suggesting policy interventions and developing a land use strategy based on the water systems approach or natural processes in urban planning for the study area.

In relation to the research questions set out, it is crucial to understand the nature of the relationship between groundwater and land use planning in the urban area (a metropolis and its peri-urban area). Also the dynamics of groundwater environments and planning processes are largely site and region specific. The following chapter will provide a background to this research in this context with the review of literature setting up the context and conceptualisation of this research.

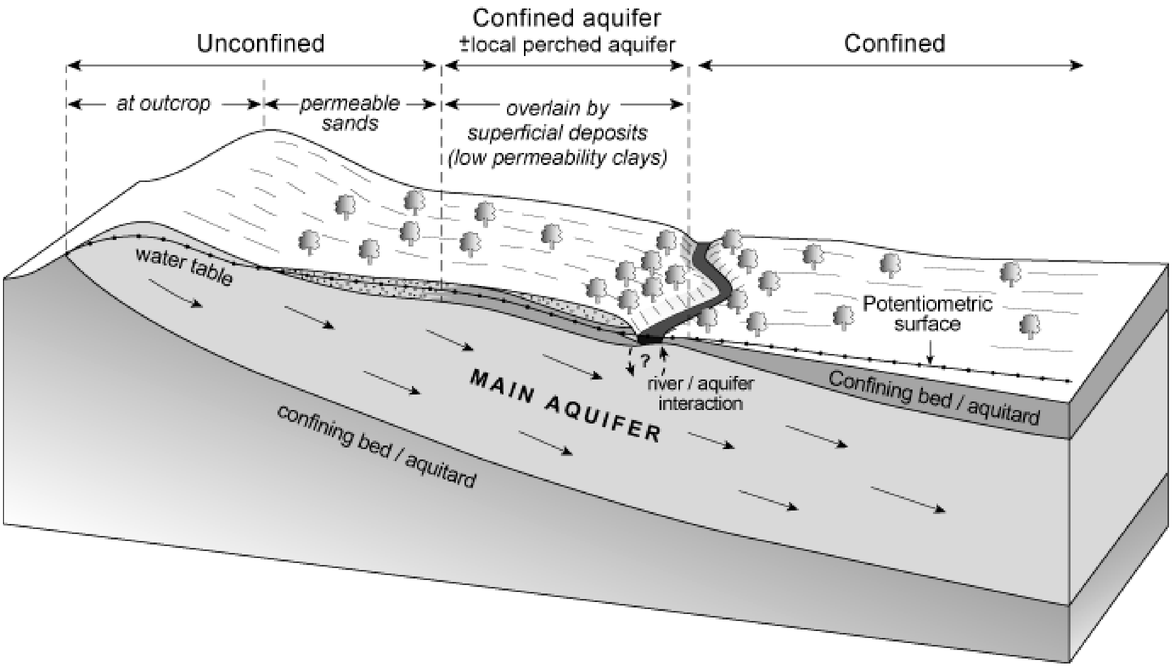
2 Conceptualisation of Research

2.1 Groundwater - 'Out of sight, out of mind'

The earth's waters exist both as surface waters and waters beneath the surface - groundwater and subsurface water. Groundwater is part of the Earth's water or hydrological cycle. When rain falls, a part infiltrates the soil and the remainder evaporates or runs off into rivers. An *aquifer* is defined as a permeable rock that stores groundwater and allows it to flow readily into a well or bore well or even underground strata that can transmit accumulated groundwater to outlets in rivers, springs and the sea (Morris et al.2003; Downing 1998). Subsurface materials with greater porosity and permeability have good groundwater resources. Groundwater systems are dynamic and water moves slowly following gradient from areas of recharge to areas of discharge. In large aquifers this may even take ten or even hundreds of years for water in this part of the hydrological cycle. Thus the water supplies from aquifers depend on the occurrence of aquifers that vary from area to area and also depend on the development of utilisable groundwater. There are generally three types of aquifers- *confined aquifers* or those which are 'sandwiched' between impermeable layers (recharge area may be small and far away), *unconfined aquifers* or those that extend to the surface (recharge area is large) and *perched aquifers* where groundwater remains like a pond above an impermeable layer within a larger unconfined system. Figure 2 shows the various types of aquifers along with their characteristics.

The aquifers beneath an urban or urbanising area are threatened due to excessive demand of good-quality groundwater. Urbanisation in an area results in rapid increase of population densities as well as in large scale concrete built up areas. This in turn influences the availability, quantity, quality as well as flow regime of underlying groundwater reserves in a region. While the increase in the number of water users increases groundwater extraction, buildings, roads and other impervious built-up surfaces decrease the infiltration and recharge possibilities.

Figure 2: Aquifer types and their characteristics



Source: Morris and Foster (2001)

Land use / land cover change results in lowering of the groundwater table and depletion of aquifers. The resulting impervious areas as well as modification of natural drainage systems in a region create a larger volume of high velocity run-off. Sometimes, in a region, this run-off "may be ponded or conducted to an unlined sewage system which in turn may provide good conditions for recharge to take place" (Khazai and Riggi 1999: 211). Rapid increases in salinity and nitrogen compounds as well as other wastes affect the groundwater quality in an area (Khazai and Riggi 1999; Foster et al. 1993). The consequences of these influences may be more serious in developing countries where urbanisation expansion is not normally planned (Khazai and Riggi 1999). It is also observed that, as compared to surface waters, scant attention is paid to the threats related to groundwater resources. "This omission is understandable; water stored in the ground beneath our feet is invisible and so its depletion or degradation due to contamination can proceed unnoticed" (Morris 2003:1). Groundwater is now recognised as an essential resource that requires protection such that the human race and the various ecosystems dependent on it can be sustained (Morris 2003).

Groundwater is a semi-renewable natural resource which is "at a given moment in time and at a given point in space- a recurrent but limited – and often uncertain supply, where this supply is not a function of initial (stock) levels but sometimes some other environmental factors" (Kuik and Verbruggen 1991: 16). Further, for the sustainability of groundwater, it is critical that the amount used of this conditionally renewable resource should (within a specified area and time span) not exceed the amount of new reserves formed. For instance the yearly extraction of groundwater should not exceed the yearly addition of groundwater reserves from rain and surface water in a given region. The quantity and quality of groundwater, in an area at a given time is also dependent, like in the case of surface water, on the water demand and usage limitations, pollution as well as decisions associated with land use planning and developmental activities. In any geographic area, since surface water and groundwater resources are interrelated, the over-exploitation of groundwater resources will ultimately affect surface water resources and vice versa. Also, land use impacts both groundwater and surface water flows and quality. "All groundwater originates on land" (Randolph 2004: 486) and impervious surfaces inhibit the infiltration and groundwater recharge. Hence, it is important to control land use developments and practices, which will potentially impact groundwater reserves in the region through land use planning. This research examines how to cope with finite groundwater resources with intensive use in urban areas and how land use planning can aid us in maintaining our groundwater resources for future generations. The next section describes the context of urban development and urban planning in this research.

2.2 Urban Planning and Development

Urban development refers to any physical extension of, or changes to, the uses of land (both planned and unplanned). The process involves construction or modification of buildings, the transport network, utilities and facilities, site development for removal of obstruction and related economic, social and political changes. The combination of the above-stated observable characteristics demonstrates it as a process or state of development involving large scale increase in the built up area. In order to create a desirable physical environment, the municipal perspective embraces the organisation of an area already built up or intended to be built up; consciously influencing land-use distribution. This activity of designing, organising or preparing the layout and condition of a city or town is called urban planning or urban land-use planning (Adams 1994). In this research, the focus is on urban areas. Thus, both terms 'land use planning' or 'urban planning' are used interchangeably.

Each city carries its planning at various levels within its political and administrative boundaries. Land use planning is a "process of identifying and analysing problems, defining goals and refining objectives, and developing and evaluating the options available to a community in pursuit of these goals and objectives" (Leung 2003: 1). According to Legget, "when planning starts, for community or region, the area is not the equivalent, therefore, of a piece of blank paper ready for the free materialisation of the ideas of the designer, but is rather an environment that has been exposed for a long period to the effects of many natural modifying factors" (1973:71). Land use planning, largely a public sector activity, can also at times include private activities such as economic development, health, housing and energy (Cullingworth and Caves 2003). Land use planning is a concept of spatial arrangement of identified land uses. It is an official statement of a legislative body which sets forth long-term or short term, city-wide or site-specific policies concerning desirable future physical development involving all or one particular type of land use (Leung 2003; Kent 1964). Land use decisions are usually about the type of use, amount of land for that use and location of that use. The objective is a planned environment which will enhance the quality of life. This research focuses on land use planning related to environmental management and urban development. An attempt is made to review the process of land use planning (urban planning),resultant urban developments and to examine how best it could be approached for protecting constituents of high quality environments with a particular focus on sustainable development of groundwater resources in the study area.

The planning process is usually initiated at the government level as it needs legislation and resources. Higher level governments are commonly involved only in setting out policies, standards and guidelines in various sectors which affect planning and developmental control at the local level (Rohilla 2003). Land use planning and developmental control functions at the municipality level are handled by planning departments and in some cases development authorities. Once the planned development in an earmarked area is completed as envisaged in the Development Plan or Master Plan, the development control and maintenance of these areas is the responsibility of local municipalities. "This function is affected by the policies and actions of other local governmental departments and agencies who pursue their own mandates, such as public works, parks and recreation, education, public transport, public transit and roads" (Leung 2003: 14). The planning of a host of complex and interconnected problems and actions taken in one policy area may affect another policy area. The layering of policies, the uneven distribution of resources and powers between the various departments and agencies result in continuing tensions which influence the planning process and coordination of infrastructure and land use systems within the city (Leung 2003; Kaiser and Chapin 1995).

2.3 Sustainability of Groundwater in Asia and India

Emerging crisis in Asian cities

By 2015 nearly half of the developing world is expected to live in cities and the rapid growth of cities is putting an increased strain on already over-stretched water resources. The main infrastructure requirement for the process of urbanisation is water supply. Large-scale urbanisation and development means increasing demands for water. Currently, the infrastructure for piped water supply is inadequate and urban reliance on groundwater is enormous. Groundwater is a reliable resource for meeting drinking and non - domestic water requirements both in terms of quantity and quality (King 2003). The other reason for the over-dependence on groundwater is that groundwater is easily accessible and its development costs are cheaper than other water sources. Table 1 shows that, in the developing world, and particularly in Asia where future urbanisation is likely to be concentrated, 50-100 percent of potable water supply in cities is derived from groundwater.

Table 1: Estimated extent of groundwater used for drinking water in Asia

Range (in Percent)	Countries
50-100	India, Bangladesh, Nepal, China, South Korea, Philippines, Indonesia, Sri Lanka, Thailand
25-50	Myanmar, Malaysia,
0-25	Laos, Cambodia, North Korea, Japan, Taiwan, Bhutan

Source: Based on information compiled -Morris et al. (2003:2)

The over-exploitation of groundwater can create problems such as water table draw down, land subsidence and salinity intrusions. These problems are either irreversible or can take years to abate. In the year 2000, more than 50 percent of mega cities (cities with population greater than 10 million) were significantly dependent on local groundwater. Table 2.5 shows that the Asia-Pacific region has the largest size of existing as well as projected urban population, an estimated 1000-2000 million, dependent on groundwater to meet their daily basic needs.

Table 2: Estimated Population served by Groundwater (for Drinking water supply)

Region	Population served (in millions)
Asia- Pacific	1000-2000
Europe	200-500
Central and South America	150
USA	135
Australia	3
Africa	NA
World	1500-2750

Source: Morris et al. (2003: 3)

In the Asian region a large number of mega-cities are undergoing rapid urbanisation. Cities are also emerging as the world's most life threatening environments affecting the behaviour and characteristics of subsurface and groundwater environments below and around them (IGES 2007; King 2003). Hence, concerns related to groundwater and urban development are more critical for Asian cities in the developing world because of the nature of urbanisation and groundwater dependency.

Groundwater Scenario in Urban India

The rapid growth of the urban population has been characteristic of the Indian economy, and it has remained comparatively higher than its South Asian counterparts (Ruet et al. 2002).

An analysis of the distribution of the urban population across size, class and categories reveals that the process of urbanisation in India has been concentrated in and around large cities. As a result the urban structure is becoming more and more top heavy (Kundu 2003). Out of India's 1027 million population, 285 million or 27.8 percent live in urban areas and about 37 percent of this urban population lives in these million plus urban agglomerations in India (Census 2001).

According to the 2001 Census, the percentage of households obtaining water from groundwater sources such as tube wells and hand pumps has gone up during the eighties as well as nineties, the increments here being higher than tap water. In particular, the exploitation of groundwater beyond a sustainable limit is alarming (Rohilla 2004b). Groundwater is an important source of drinking water in both rural and urban India. According to CGWB (2000) "nearly 90 percent of rural,50 percent of urban drinking and industrial supplies and more than 50 percent of irrigated agricultural water requirement are met from groundwater."

Many large cities in the country are partially or wholly dependent on groundwater supplies (CGWB 2000). "Even though no precise estimates of the utilisation of groundwater in urban complexes are readily available, it is considered that about 50 percent of urban water requirements are also met from groundwater" (CGWB 2000: 4). With existing as well as projected urbanisation, it is clear that groundwater will continue to be used on a much larger scale in order to fulfill domestic and non-domestic water requirements. The significant dependence on groundwater and sustainability of urban water supply is one of the major issues faced by Indian cities. Thus, there is a need for a better understanding of the urban hydrological scenario and developmental potential in sprawling urban centers.

2.4 Key Literature – Summary

There is literature related to water supply issues focusing on Delhi. Dutta & Tiwari (2005), Llorente and Zérah (2002) published their research that has looked into demand side analysis for Delhi's urban water utility considering water as an economic good. Other works include Ruet et al. (2002), Zérah (1998) dealing with the coping costs and pricing of water and Tovey (2002) focusing on institutional responses to water needs of the urban poor in Delhi. The literature on groundwater and urban development in NCT Delhi is relatively little with few exceptions like Trivedi (2001) who focuses on rural groundwater issues and Maria (2004) who traces the role of groundwater in urban water supply or the author's previous publications related to water augmentation in Delhi looking at feasibility of rain water harvesting in urban scape (Rohilla 2004a; Rohilla 4b and Rohilla 1999).

Land and water resources within a watershed exhibit a complex, symbiotic relationship and the patterns of inter-dependence are still poorly understood (MacKenzie 1996). Any settlement that grows from a tiny village or small urban settlements to become a city or part of an urban agglomeration affects groundwater resources in the region. Local groundwater is taken for granted and exploited resulting in depletion and pollution. When the cityscape is saturated or the adjacent area engulfed in an urban agglomeration (giving way to formation of new peri-urban areas) both the quantity and quality of groundwater are attributed to be inadequate for sustaining any further development. This, on the other hand strengthens the argument for import of water from distant sources. Sometimes the interlinking of rivers or the developing of well fields away from the city itself.

An estimate of the land area used for developing cities will certainly be more than double what is currently in use for urban development today. However the magnitude of its importance varies from country to country. Increasing the water demand-supply gaps in the existing water infrastructure in urban areas have resulted in increased exploitation of aquifers beyond sustainable limits.

Large scale urbanisation may result in impervious surface areas and reduced infiltration of water and less recharge (Foster 2001, Chilton 1997). Over abstraction of groundwater for urban use (domestic and non domestic) including industrial, mining and other water requirements results in a decline in water table or sometimes even resulting in land subsidence (for example in Mexico City and Bangkok). Sometimes excessive recharge from surface runoff, leaking water or sewers may result in flooding and cause concerns for public health (for example in Tehran). On the other hand, if water requirements are met from import of surface or groundwater from distant well fields, it may also result in a rise in the water table (for example in London) posing a major threat to the overall sustenance of networks and utilities/services of city (Morris et al. 2003; Howard and Israfilov 2002; Maksimovic and Tejada- Guibert 2001; Foster 2001; Chilton 1997). From the above-stated examples, it is evident that groundwater is a fragile resource. Excess use of groundwater or the sole reliance on distant sources of water supply with no use of *in-situ* groundwater resources could pose a major problem. On a closer investigation it emerges that it is urban planning in the public sector that allocates land for various uses and is determining the cumulative effects, resulting in the increasing pressure on water resources in general and groundwater in particular. With the widening demand-supply gap of water resulting in widespread over abstraction of groundwater, it is a challenge for urban planners to come up with a more integral form of planning to conserve locally available groundwater resources.

The review of existing literature reveals that the texts focus mainly on the importance of water vis-à-vis land use planning / urban planning in the developed world (France 2002; Honachefsky 2000; Clay 1979; Leget 1973; McHarg 1992). Over the past two decades water has become a major concern for urban planners in the developed world (UN-Habitat 2003;

Maksimovic 2001; Calder 1999). In particular, the relationship between declines in groundwater and its degradation and urban development has been highlighted (Morris et al. 2003; Howard and Israfilov 2002; Chilton 1997; Foster et al. 1993). These publications have documented the symptoms of the problem of groundwater in the urban environment and have clearly omitted discussions on the root cause. This research will move from a reactive to a proactive mode and examine the process of urban development (both planned and unplanned) and particularly urban planning (the root cause for shaping the urban landscape). This research will review the planning process (to accommodate suitable goals and policies) leading towards overall sustainable development along with sustainable management of locally available resources such as groundwater before tapping distant sources of water. This paper aims at providing a basis for groundwater to be seen as an instrument for sustainable urban growth and development that becomes less of an urban problem. Such an intervention requires understanding the role of groundwater in various stages of urban growth and integrating these considerations into land use plans. The next section will discuss the empirical research on groundwater and urban development in the process of metropolisation of Delhi over a period of time.

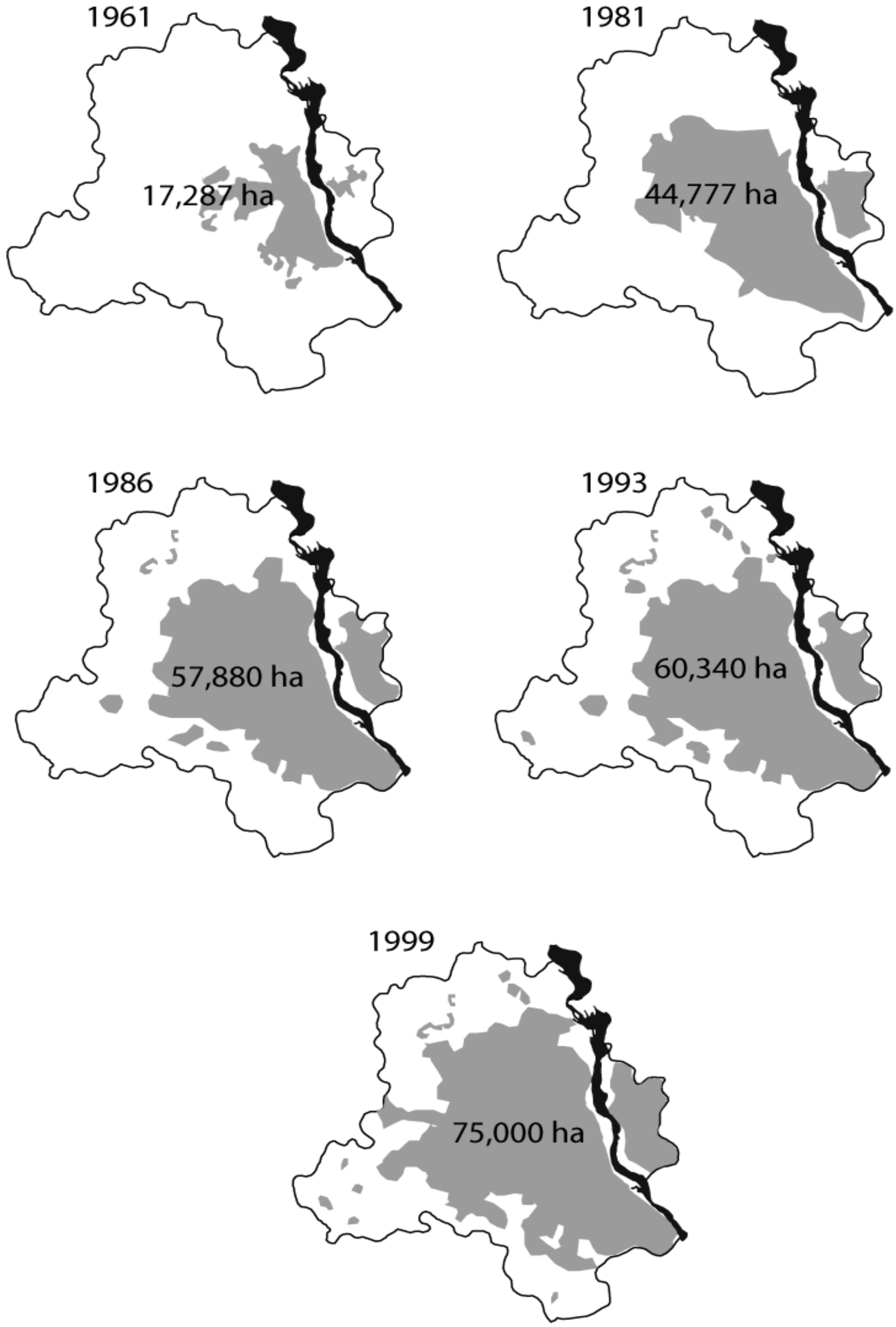
3 Planning and Urban Development in Delhi

3.1 Understanding Urbanisation and Planning Efforts in Delhi

NCT Delhi is witnessing rapid urbanisation and large scale transformation of land from rural, agricultural use to built-up and urban-related serviced land. As shown in Figure 3, NCT Delhi comprises a built-up urban mass equivalent to 50 percent of its total area (NCRPB 1999). The process of urban growth and development is complex and dynamic in the Delhi territory. Large spaces of undeveloped land have been encroached by unauthorised developments. With the rapid pace of urbanisation, the unauthorised or unplanned developments are a common feature within the city core as well as in the peripheral areas. The actual growth vis-à-vis planning efforts reveal that the planning process has failed to address the dynamic ground reality and that a considerable urban population lives in a remarkably different manner (DUEIIP 2001; Kumar 2000; Ali 2004).

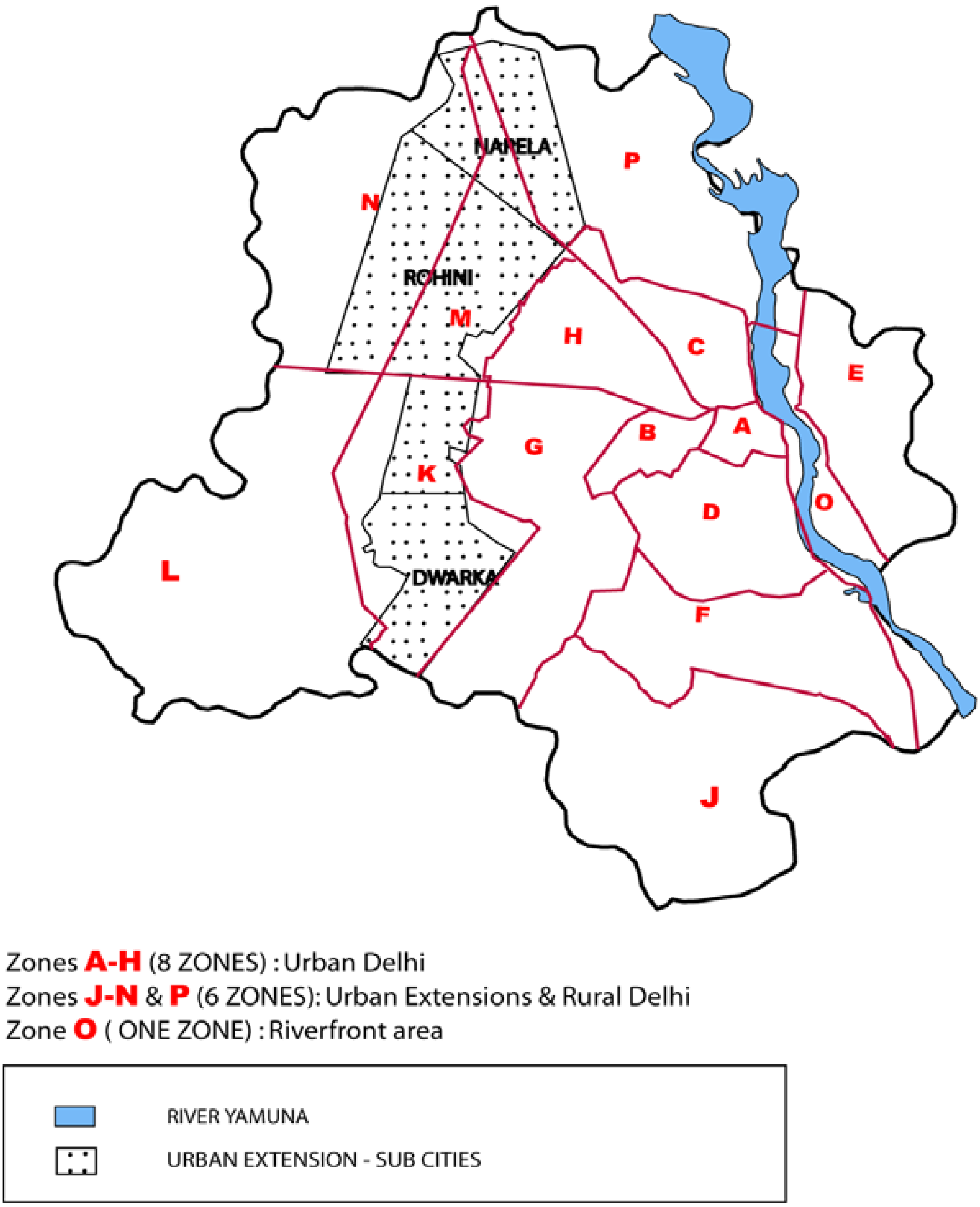
Post independence the rapid growth of population in Delhi led to rising land values, growing speculative trends and congestion. This caused deterioration in the quality of the environment with lack of sanitation, traffic hazards, slums and substandard unauthorised constructions in Delhi (Dupont 2001; Rohilla 2003; Bentinck 2000; Government of India 1959). The Government of India's approach towards large scale acquisition, development and disposal of land was found to be useful for the successful implementation of the first Master Plan. Hence it was adopted in the DDA Act of 1957 (Government of India 1959) as a major function of DDA for the implementation of the Master Plans and to achieve planned and orderly development for Delhi. The entire NCT is divided into 15 planning zones. Figure 4 shows the planning zones 'A'-'H' (urban), 'J'-'N' and 'P' (rural and urban extension) and zone 'O'(river front area) in the NCT of Delhi.

Figure 3: Urban growth and the development of the National Capital Territory of Delhi



Source: Rohilla (2007)

Figure 4: The Planning Zones in NCT Delhi (as per Master Plan 2001)



Note: MPD 1962 had sub-divided only 8 zones ('A'-'H') covering the Delhi Urban Area.

Source: Prepared by the author based on information compiled from DDA

In February 2007, six years after the end of the perspective for year 2001 of the MPD 2001, a Plan for Delhi 2021 was notified. According to the MPD 2021 "…about 702 sq. km. is estimated to have been developed as built-up areas accommodating the approximately 13.8 million population" (Government of India 2005: 8). The projected population of NCT Delhi or the population in Delhi by the year 2021 as per MPD 2021 is 23.0 million. MPD 2021 has recommended a three- pronged strategy for urban development to accommodate the projected population. Table 3 shows the population in various planning zones as in MPD-1962, MPD 2002 and MPD 2021. It compares the projected populations for various zones and urban extensions according to the various Plans with the actual census data for the years 1981 and 2001.

It is evident from Table 3 that the projected population for the Delhi Urban Agglomeration in 1981 (Zones A-H) was 5.26 million as per MPD 1962. The proposed population for the same land area increased to 8.97 million in MPD 2001 and to an astounding 11.4 million as per MPD 2021. The Delhi Urban Agglomeration 2001 urban limits which include Dwarka, Rohini (Phase III, IV, V) and Narela projects along with zones A-H are proposed to accommodate a total of 15.3 million people as per MPD 2021 with 11.4 million people in DUA 1981 urban limits (A-H zones) and 3.9 million people in Dwarka, Rohini III, IV, V and Narela projects. The projected population as per MPD 2021 is 23 million, hence a population of 7.7 million (23-15.3) remains to be accommodated. Out of these 7.7 million people, 2.9 million people already exist in present rural areas which include villages, census towns, unauthorised colonies and slum (*Jhuggi Jhopri)* clusters. The remaining population of 4.8 million people will have to be accommodated in future urban extensions. The initial estimates for accommodating this additional population of 4.8 million are based on an average of 250 persons per hectare. Following this estimate, around 20,000-22,000 hectares of land is required to be developed within a time frame of 15-16 years. Due to land constraints, future urban development is only possible along the fringes of already urbanised areas and along major transport corridors. The areas earmarked as rural or agricultural in the previous Master Plans (zone of J, L, N and P) are therefore always under pressure to be developed or built upon. The same zones have been identified in the MPD 2021 for future urban extension and development projects.

Table 3: Planning zone wise population in urban areas and immediate urban extensions

Proposed Population in various Delhi Master Plans					
Zones*	Population as per DMP-1962	Census 1981	Population as per MPD 2001	Census 2001	Population as per MPD 2021
A-Old City	0.32	0.62	0.42	0.57	0.57
B- City Extension	0.98	0.56	0.63	0.62	0.63
C-Civil Lines	0.38	0.53	0.75	0.67	0.78
D- New Delhi	0.63	0.49	0.75	0.58	0.81
E- Trans Yamuna	0.96	1.02	1.78	2.79	2.80
F-South Delhi I	0.82	0.82	1.27	1.71	1.97
G- West Delhi I	0.80	0.86	1.48	1.62	1.95
H- North West Delhi	0.92	0.51	1.86	1.22	1.86
Sub Total	5.26	5.45	8.97	9.87	11.40
Dwarka				0.59	1.70
Rohini III				0.09	0.16
Rohini IV & V				0.19	0.82
Narela				0.17	1.22
Sub Total			3.22	1.07	3.90
Grand Total			12.0	10.9	15.3

* DUA 1981 comprises of Zones A-H, DUA 2001 comprises of Zones A-H and the urban extension-Dwarka, Rohini III, IV and V and Narela Projects.

Source: Compiled from Delhi Master Plan 1962, Delhi Master Plan 2001 and Delhi Master Plan 2021.

With this proposed development, the National Capital Territory Delhi would emerge as a contiguous large urban agglomeration accommodating a projected population of 23.0 million people by the year 2021. The strong bias towards previous ideas evident in the earlier Plans still persists in MPD 2021. Further, the approach remains largely quantitative and sectoral. The DDA has not carried out a ground reality survey of the situation prevailing in 2001. The absence of adequate basic infrastructure has not been kept in mind before undertaking a revision of MPD 2001 and for the future projection of the population.

3.2 The Groundwater Scenario in the NCT of Delhi

The Central Groundwater Board (Delhi State Unit) has monitored and mapped the status of utilisable groundwater reserves for NCT for the years 1983, 1995 and 1999 (Figure 6.8). The general trend of groundwater in NCT Delhi is summarised in Table 4.

Table 4: The Groundwater Situation in Various Planning Zones in the NCT of Delhi

Trend	Planning Zones
Decline	A, B, C, D, F,G, H & E(Part) - Urban area J, K & L (Part)- urban extension and rural area
Rise/No Change	P, M & N (Part)- urban extension and rural areas
Rise	P, H & M- urban extension and rural areas

Source: CGWB 2005

It is evident that the existing DUA along with the immediate extension areas, (apart from Zone C, H and E (parts)) have shown a considerable decline in the water table and are overdrawing groundwater. These areas are also projected as accommodating large-scale urban development in the future. Hence, groundwater is being withdrawn to meet domestic and non-domestic water requirements in these areas and is playing an important role in sustaining urban development in the National Capital Territory of Delhi.

The previous chapter has underlined the importance of integrating groundwater in urban planning with planning and use of surface water for meeting the increased water requirements of the urban agglomeration of Delhi for the future. In view of the uncertainties attached with a water service infrastructure based on surface water it is imperative for Delhi to develop groundwater in a sustainable way and also incorporate the groundwater component in urban planning. The solutions presented for tackling the problem in NCT Delhi have so far been largely remedial (such as setting up an authority, declaring a ban on further boring of tube wells) rather than proactive measures such as urban planning, resource management and protection of groundwater.

The following chapter will establish the systemic role that groundwater plays in the various stages of urban planning and development in NCT Delhi and its peri-urban areas aided by a detailed examination of Dwarka sub-city.

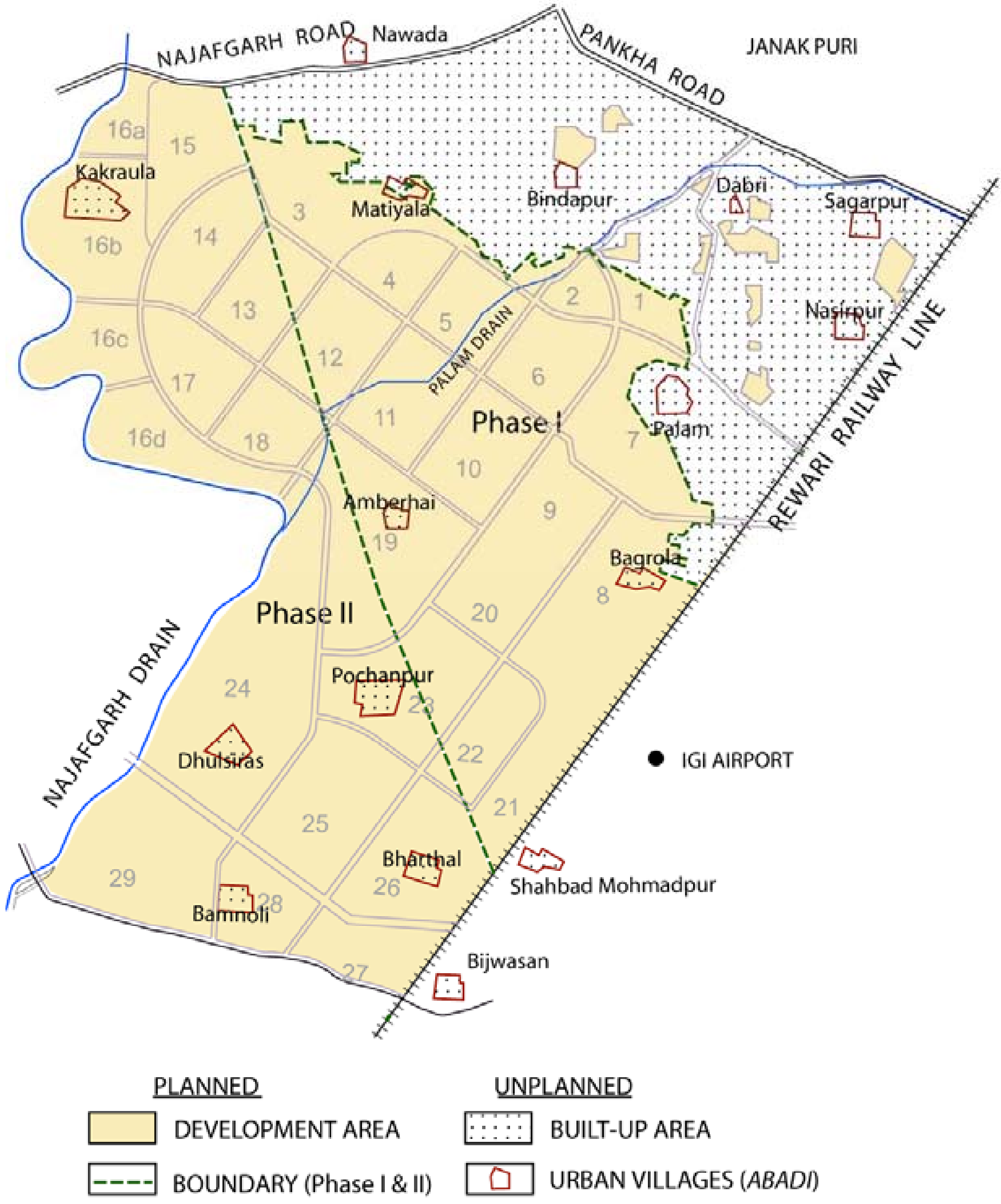
4 Case Study: Dwarka Sub-city

4.1 Planning and Development of Dwarka sub-city

Dwarka sub-city project site is located within planning zone 'K' as per MPD 2001. This planning zone is earmarked for urban extension in the Master Plan. A draft Zonal Plan for the planning zone 'K' was prepared by DDA but it failed to get an approval and hence was not published. The development of Dwarka sub-city project was made possible by way of change of land use and guided by a structure plan for the project, referred to as 'Development Plan - Dwarka' (Appendix 2). This shows the stages of approval and development. The sub-city was estimated to accommodate a population of approximately 1.1 million people. (The Master Plan of Delhi 2021 has projected a population of 1.7 million in the sub-city by 2021). The development of the sub-city is being undertaken in two stages referred to as Phase I and Phase II. The Development Plan proposed Phase I to accommodate 370,000 people and Phase II was to accommodate 340,000 people in planned developments. The remaining 350,000 people was estimated to be living in the built up area mostly in Phase I in unauthorised developments that came after the first Master Plan for Delhi and dispersed enclaves of unplanned developments of the original inhabitants in the form of village *abadi* areas.

According to the 1991 Census of India 75 percent of the total 3,50,000 population was located in Phase I of the sub-city, in and around village *abadi* areas of seven villages – Amberhai, Binda pur, Dabri, Palam, Sagarpur, Nasirpur and Matiala, Bagdola. The remaining population was located in Phase II; village *abadi* areas namely Pochanpur, Barthal, Bamnoli, Dhulsiras and Kakrola as enclaves of unplanned built up areas (see Appendix 3). In 1994 the twenty village *abadi* areas in Dwarka sub-city and adjacent urban extension were declared as 'urban villages' and administratively transferred to the MCD.

Figure 5: Profile of Dwarka sub-city



Source: Map drawn by the author based on information and maps compiled from the Project Site office of Dwarka sub-city (DDA).

These villages are now part of the Delhi Urban Agglomeration in the 2001 Census of Delhi and separate population figures for these rural settlements are not available. The progress monitoring report of DDA in the year 2005 estimated 6,00,000 people (including

50,000 in planned developments) residing in Dwarka sub-city. In terms of land development as recommended in the Development Plan for the sub-city, agricultural land acquired for different types of land use for planned development in the surroundings of these *abadi* areas is in transition (in Phase II the land is still under acquisition) and may take 5-10 years to be complete and functional. The following section will discuss in detail the preparation of the Development Plan including the various concepts and scenarios considered in formulating the present Development Plan. Further, the salient features of the Development Plan under implementation and the status of developmental works with particular reference to water related infrastructure proposed for the sub-city will be elaborated.

Preparation of the Development Plan

In the first Master Plan for Delhi (1962), the present site of Dwarka sub-city was part of the proposed green belt surrounding the projected area in the west of Delhi and part of this green belt were rural agricultural lands. However, with the rapid urban population growth in Delhi and an increase in the demand for housing, agricultural lands on the periphery of the Delhi Urban Area (1981) and the proposed green belt soon started undergoing transformation. Most of these developments were unauthorised, and unplanned developments were not according to the existing Master Plan. A revised Master Plan for Delhi (1981-2001, published in 1990) proposed the acquisition of an additional 14,000 to 20,000 hectares of land outside the DUA (1981) for development. The proposed land acquisition was to cater to the housing needs of a projected urban population of around 13 million (by 2001) in Delhi. Work on the land earmarked for development of urban extension began as early as January 1984 with the publication of a notification for the acquisition of about 3,550 hectares of land in south west Delhi (west of Indira Gandhi International Airport). In October 1986, about 50 percent of the notified area was acquired and was in the possession of DDA for planned development. By the time this acquisition of land took place considerable areas on the periphery of DUA 1981 were already urbanised. The Delhi Development Authority only managed to acquire some pockets within these unplanned built-up areas.

The first stage of the planning process for the sub-city was the preparation of a structural plan for the site. The objective of the project team was to develop a structural plan after integrating environmental concerns of the area. Conventional land surveying along with remote sensing techniques were employed and several background studies were undertaken before finalising the draft structural plan (Jain 1995).

A review of previous studies and personal communication with officials (planners and engineers) revealed that even at the initial stages of the preparation of the Plan, it was evident that there would be shortage of water in the proposed sub-city. Further, the Authority was aware that during monsoons, parts of the site area were flooded as rain water collected all along the high embankment of Najafgarh Drain. The background studies for groundwater prospects in the sub-city were based on remote sensing surveys and monitoring data and information regarding groundwater collected by Central Ground Water Board from its regular monitoring dug wells / piezometers located in and around the project area. These studies identified the development prospects of aquifers as well as the depth, quality and quantity of groundwater in and around the proposed Dwarka sub-city for potable groundwater and concluded limited availability of utilisable groundwater in the sub-city. The studies suggested that there was a need to conserve and plan the limited groundwater resources. The estimated availability of *in-situ* groundwater on the eve of urban development was around 10 MGD. This predicated water quantity was included in the estimation of the total water available for meeting the future water requirements of the sub-city. During preparation of the Plan, DDA failed to get an assurance from local water supply agencies regarding the provision of water (Ashish Kundra, Additional Chief Executive Officer DJB, personal communication, 28 July 2004). The draft plan for the sub-city proposed development of the utilisable 10 MGD of groundwater to meet the domestic and non-domestic water requirements of the sub-city. The remaining water requirements were to be met from surface water reservoirs / dams to be constructed in the Himalayas. Neither studies nor the plan envisaged what source of water would be required for the construction requirements of large scale developments proposed in the sub-city.

The initial draft of the Development Plan for the sub-city recommended a ‘zero run-off approach’ as a viable alternative for the sub-city project site overcoming the drainage constraints as well as replenishing groundwater in the development area (Jain 1995 and Gupta 1996). The conventional drainage system in the existing urban areas of the city normally comprises of a network of pipes which carry the storm water as well as sewage from individual houses to the main drain and this involves construction of large drains for run-off. The run-off water is then carried by these drains to the River Yamuna. The proposed ‘zero run-off’ concept, in turn, suggested a system of woodlands along the natural drainage gradient enabling run-off to follow natural course of drainage as far as possible and this did not involve construction of huge drains (to carry the rain water from the proposed sub-city) and a series of lakes to counteract the siphoning groundwater. This involved construction of embankments made up of non-concrete (*kutchha*) slopes or green landscaped lawns with gentle slopes. These slopes could be used for public use during the dry months and then left to be submerged during the monsoons. This concept aimed at optimum utilisation of land with negligible drain construction costs. Also the non-concrete surfaces would enhance groundwater recharge possibilities. The aim was to retain 100 percent rain water within the project site by using a series of retention ponds and sediment traps to temporarily cushion the run-off. These ponds, reservoirs and water bodies were to be located in the catchment zones of Najafgarh Drain on low lying areas earmarked for green areas. The land use of green areas was to be achieved by developing a Regional Park spread across 220 hectares of land all along the Najafgarh Drain with floating green areas around natural drainage valleys and a lake. The park was to be a a new frontier in outdoor recreation and ecology of the project area. The 'zero run-off' concept was proposed with the aim of reviving the tradition of reserving areas with outstanding environmental features and water for the community for cultural, religious and recreational activities (Jain 1995). The project proposed an increased use of drains by people for the maximum part of the year.

The implementation of this alternative 'zero-run off' concept required approval from the local municipal body; in this case, the Municipal Corporation of Delhi (MCD), Delhi Urban Arts Commission (DUAC) and the Delhi Development Authority (DDA). While DUAC and DDA had given their consent, the concept failed to get approval by MCD. The concept failed to get a clearance under the existing municipal engineering norms of drainage engineering. These norms were introduced by the British before 1947 and have not undergone any changes so far. The existing norms are based on the concept of cumulative discharge and are normally applicable to drainage systems which carry rain water directly into the river or in areas located near the riverfront (Gupta 1996). The norms (as recommended in MPD 1962) are now being applied for developing areas in the entire NCT Delhi; irrespective of their distance from the river and nature of the local physiographic characteristics or hydro-geological / geomorphological conditions (Government of India 1962). There have been no attempts to revise or update these norms in relation to the area proposed for development. Hence, the zero run-off proposals were rejected and the proposed drainage system in the draft Development Plan for Dwarka sub-city was revised according to existing MCD engineering norms for drainage (Appendix 4). The revised proposed development in the sub-city was to be guided by factors such as:

Topography and drainage (the Najafgarh *Nallah* (drain) and other drains guiding the landscape structure for the city;

Delineation of three major pockets of densely urbanisable areas away from resultant noise levels due to the presence of the international airport in the vicinity;

Four major possible road connections with the main city;

MRTS (Metro) or railways as the only viable solution to the public transport from the sub-city to overcome transport bottleneck.

The proposed urban built form, the urban design and the landscape plan was visualised after considering all the above mentioned factors. The sub-city, on completion, is projected to include a total area of 5,648 hectares of agricultural land converted and developed for urban use. Almost thirty percent of the proposed sub-city area in the north of the sub-city (adjacent to DUA 1981) was an unplanned built up area. These unplanned developments in the area had started well before 1988 when the planned development in the sub-city commenced. Thereby the proposed planned areas had enclaves of unplanned built-up areas in the form of village *abadi* areas.

Implementation Status of the Development Plan

The sub-city area was declared as a development area in 1987-88 and the Development Plan for Dwarka sub-city was approved in 1990. The notified plan included guidelines for development and the proposed land use, landscape, transport, services and urban design at a sub-city level. A review of the development of Dwarka sub-city shows the percentage of land allocated for different types of land use. At the sub-city level 49 percent of land is allocated for residential use, 20 percent for recreational use (includes green and open areas), 14 percent for transport-related infrastructure, 7 percent for commercial use and the remaining land is proposed for development for public / semi- public use, utilities and other government use.

The oil pipeline passing through the sub-city marks the boundary of the two phases. The development in Phase I started in 1988 and the proposed urban developments in this Phase are nearing completion. The planned development in Phase II commenced in 2000. Table 5 shows the land area and population in development Phase I and Phase II.

Table 5: Dwarka Sub-city Project- Land Area and Population

Dwarka Sub City	Land Area (in hectares)	Population
Phase I	1964	370,000
Phase II	1996	340,000
Built Up	1688	350,000
Total	5648	1,060,000 (1.06 million)

Source: Progress Monitoring Report for Dwarka (DDA, 2005) Unpublished Report

Figure 5 shows the Development Plan of Dwarka sub-city (Phase I and Phase II) including the existing unplanned area at the time of the notification of the approved Development Plan for the sub-city.

4.2 Water Augmentation Plan and the Water Supply Network

Status of the Proposed Water Supply Infrastructure

The Development Plan proposes to meet all domestic water requirements from piped water supply to be provided from proposed water treatment plants (located in the vicinity of the sub-city) to meet the future requirements of water (DDA 2005). The proposed source of raw water (40 million gallons per day) for the Dwarka WTP is the Western Yamuna Canal passing through the neighbouring state of Haryana. Hence, the raw water supply for the Dwarka WTP like other WTPs in NCT Delhi is also dependent on the augmentation of surface water through the construction of reservoirs and dams in the Himalayas (as recommended in the MPD 2001 in the broad city level water augmentation proposal). The Western Yamuna Canal transfers the raw water share of NCT Delhi in River Yamuna and its tributaries. The Development Plan has allocated 40 hectares of land for the construction of the plant. The bore-well water (groundwater) is to be used (untreated) for industrial and commercial use requirements. The recycling of water from sewage treatment plants has been suggested as a measure for meeting horticultural and industrial needs. All the newly constructed residential societies and establishments are adopting techniques for roof-top rain water harvesting and recycling of waste water.

The sub-city is divided into six command areas in accordance with population distribution in the proposed planned developments in order to ensure regular water supply. Each command area is to be served by a command tank (CT). Four command tanks are located in Phase I and two in Phase II. The raw water from the Western Yamuna Canal (the share of NCT Delhi in Yamuna River) would be used for running the Plant. Till date, two command tanks are in operation. The Development Plan does not provide for water infrastructure for the existing built-up and *abadi* areas. These areas are catered by DJB/ MCD.

Projected Water Demand

The Plan proposes that all domestic and non-domestic water requirements in the sub-city are to be met from piped water. The domestic water requirements include drinking, cooking, bathing, washing, watering of lawns, kitchen gardens, and water for flushing of toilets (where waste water carriage system are available). The non- domestic water needs include institutional needs, horticultural needs, industrial or commercial uses and fire fighting. In view of increasing standards of living, MPD 2001 uses a norm of 363 litres per capita per day (lpcd) for projecting the water demand for the urban population in NCT Delhi (see table 6.1 for the breakup of water supply norms recommended in the Master Plan).

The estimated domestic water requirement for the planned development at the rate of 225 lpcd works out to be around 35 mgd. The estimated total water requirement for the population in planned developments of the sub-city (calculated using the 2001 Delhi Master Plan norm of 363 litres (80 gallons) per capita per day (lpcd)) works out to be 261 million litres per day (58 million gallons per day).

Unaccounted Water Demand

The Development Plan water projections and required water supply infrastructure do not take into account the water demand of unplanned areas (unauthorised and village *abadi* areas).If the water requirement of 30mgd for the estimated 350,000 population residing in unplanned areas in the sub-city is added to the estimated total water requirement for the sub-city for the population of 1.1 million people (both planned and unplanned) works out to be 88 mgd (58mgd + 30mgd).

In addition to the above, the construction water requirements for both planned and unplanned areas are also not accounted for while calculating the water demand for the sub-city. There are no published or prescribed water supply norms for the construction requirements. According to the personal communication with DJB officials, the construction water requirement is generally five times or more then the per capita water supply norm (363 lpcd) prescribed by the Master Plan. Even a lower estimate (20 % percent) for estimating construction water demand in areas means an additional 88 mgd of water supply.

It is evident from the above discussion that there is a wide water demand-supply gap. The Development Plan proposes a WTP with a capacity of 40 mgd to cater to the piped water supply for the projected population in planned developments. The remaining industrial as well as commercial water requirements are recommended to be met from groundwater. The planning provision such as allocation of land for WTP, the required water supply pipe network and other facilities including command tanks or pumping stations are proposed for meeting the projected requirements of planned developments. The Development Plan does not take into account the existing or projected water requirement of the unauthorised and unplanned developments that currently exist in the sub-city project area. The unauthorised and unplanned developments existing as enclaves of built-up areas in between the areas earmarked for planned development and housing an estimated population of 350,000 are in physical reality a part of the urban growth and development. Hence, the provisions of the Development Plan fails to meet the total water requirement of the sub-city.

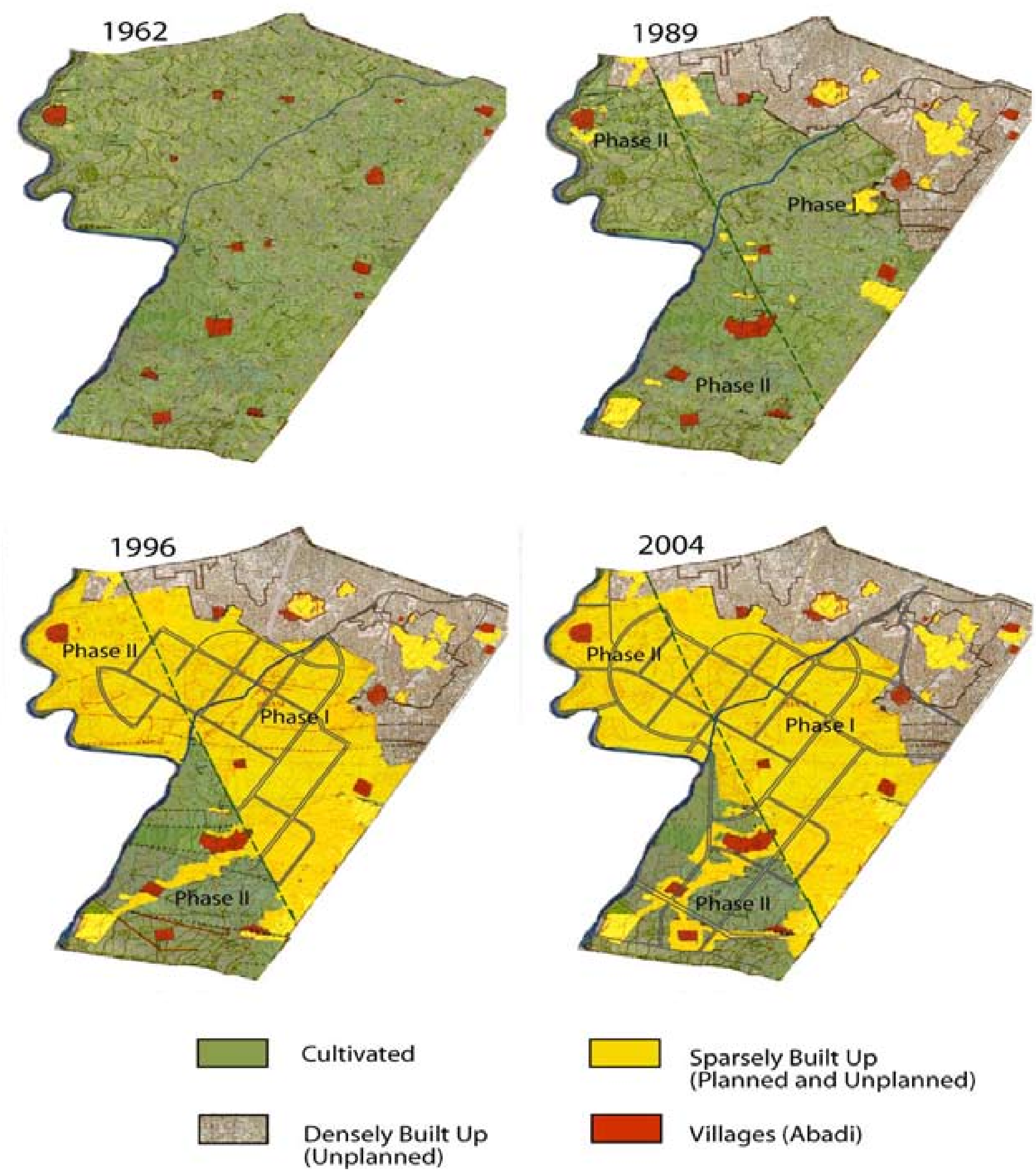
4.3 Stages of Urban growth and Development of Dwarka sub-city (1962- 2004)

The previous sections reviewed the Development Plan for Dwarka sub-city and the status of planned developmental works in the sub-city including provisions for water supply. This section analyses urban growth and development of Dwarka sub-city. Figure 6 shows urban growth and development in Dwarka sub-city during the various stages.

The stages of development are based on land use map of DMP 1962 (scale 1: 250,000) the 1988 site area analysis map of the Development Plan for Dwarka sub-city (scale 1: 25,000) from DDA, the topographical sheet (special map series) ‘Delhi and its environs’ 1996 (scale 1:50,000) and satellite images of 2004. The proposed development phases (Phase I and II including built-up area) were superimposed using G.I.S techniques and software. The process of urban development has been conceptualised in four stages of transition. The stages (discussed in detail in the next chapter) are as follows: rural stage (1962-76): at the time of DMP 1962; early transition stage (1977-88): at the time of preparation of the Development Plan and MPD

2001, Transition Stage (1989-1994): beginning of urban development of Dwarka sub-city, Late Transition Stage (1995 - present).

Figure 6: Stages of urban growth and development of Dwarka sub-city



Source: Map drawn by the author based on information and maps available from DMP 1962, MPD 2001 and the Development Plan for Dwarka sub-city.

The next section will present in detail the process of urban development through various conceptualised stages (rural to urban) in Dwarka sub-city. The detailed study of Dwarka sub-city serves as a model for projecting the growth of the urban agglomeration of NCT Delhi and understanding the role of groundwater in various stages of transition in the process of urban development. The study is based on secondary data sources (both published and unpublished reports and maps), interviews of water users, other stakeholders and personal communication with officials in concerned government agencies during field work. Furthermore, G.I.S mapping and map overlay techniques have been employed for analytical purposes.

5 Role of Groundwater in Urban Development

5.1 Assessing the systemic role of groundwater in the development of Dwarka

This section attempts to understand the various sources of water supply and groundwater use in various parts of Dwarka sub-city. The discussion is divided into two main sections. The first section discusses the findings of the GIS super-imposition techniques; the research method employed for understanding the systemic role of groundwater in the development of Dwarka sub-city. The technique involved superimposing the maps of groundwater quality as well as quantity over those of urban growth and development in each conceptualised stage of transition (rural to urban). The second section presents the results of interviews with both experts (mostly representatives of agencies involved, village heads and other professionals) as well as water users in Dwarka sub-city. The interviews helped in assessing the issues related to groundwater availability and consumption in the region.

The superimposition techniques involved overlaying of groundwater related information over change of the type of land use in the various stages of Dwarka sub-city (described in the previous chapter). Groundwater related information and maps from 1960 – 2005 used for presentation and superimposition using G.I.S techniques are accessed from the Central Ground Water Board. The stages of development of the sub-city are rural, early transition, transition and late transition.

5.2 Changes in the Groundwater Quantity

Water Fluctuation

Super-imposition data used:

Water table fluctuation in the rural stage (Figure 7)

Water table fluctuation in the early transition stage (Figure 8)

Water table fluctuation in the transition stage (Figure 9).

Water table fluctuation in the late transition stage (Figure 10)

Figure 7-10 shows the changes in the built-up area (urbanisation) during the various stages of the urban development of Dwarka sub-city and the corresponding fluctuation in the water table of the region. *It is evident from the data that there is more fluctuation in water (0-2* *mgbl to 4-8 mgbl and even above 8 mgbl) when the sub-city went from the rural stage to the early transition stage* (Figure 8). During this phase, the agricultural lands were acquired and the construction work began for the development of the sub-city. It can be assumed that there was a bulk use of groundwater resources during this stage of the development of Dwarka sub-city. It is also evident that, once the development work began, there were changes in the water table in all the stages of transition.

Figure 7: Water table fluctuation in the rural stage of Dwarka sub-city (1962-76).

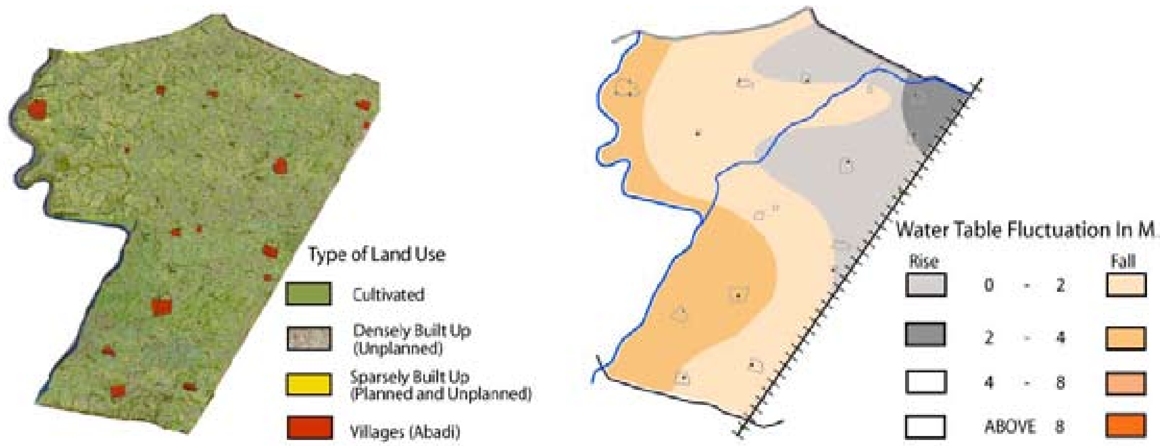
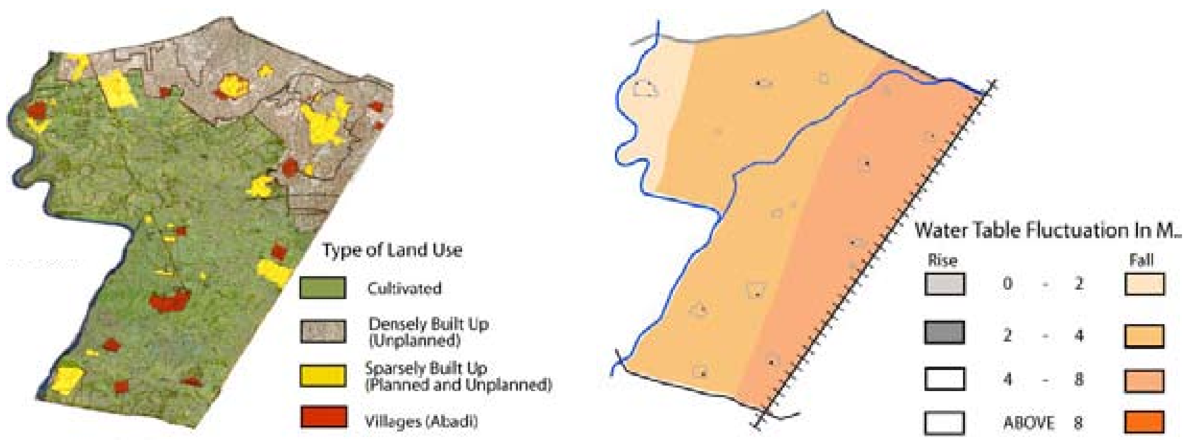


Figure 8: Water table fluctuation in the early transition stage of Dwarka sub-city (1977-88).



Source: Prepared by author with information and map accessed from CGWB.

Figure 9: Water table fluctuation in transition stage of Dwarka sub-city (1989-94).

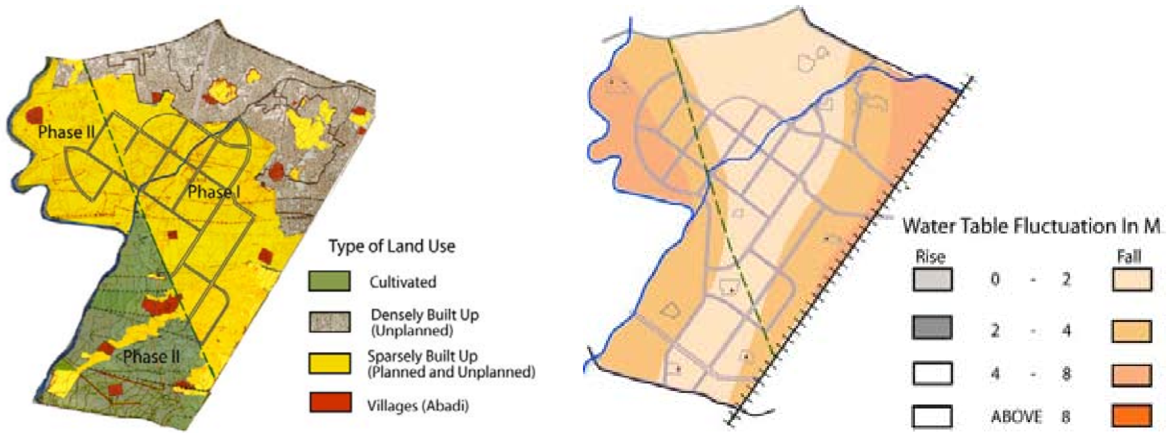
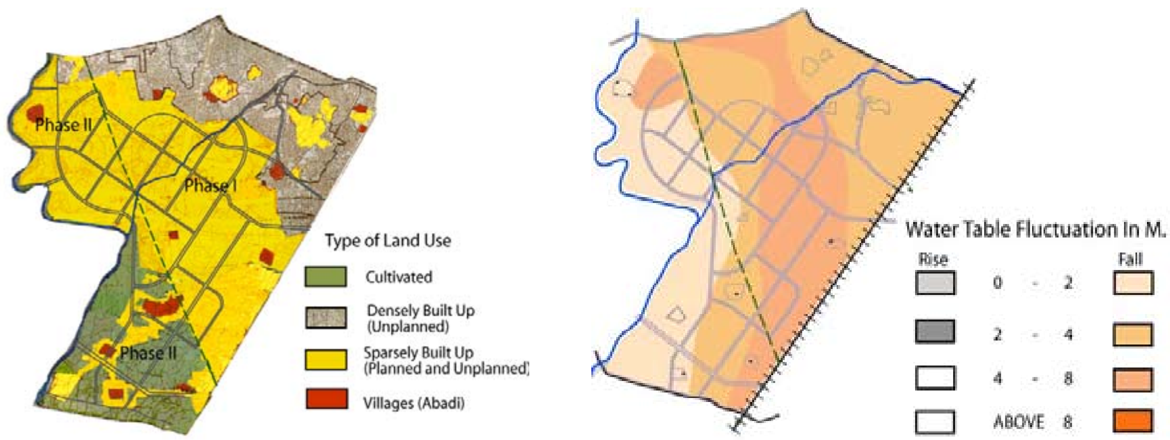
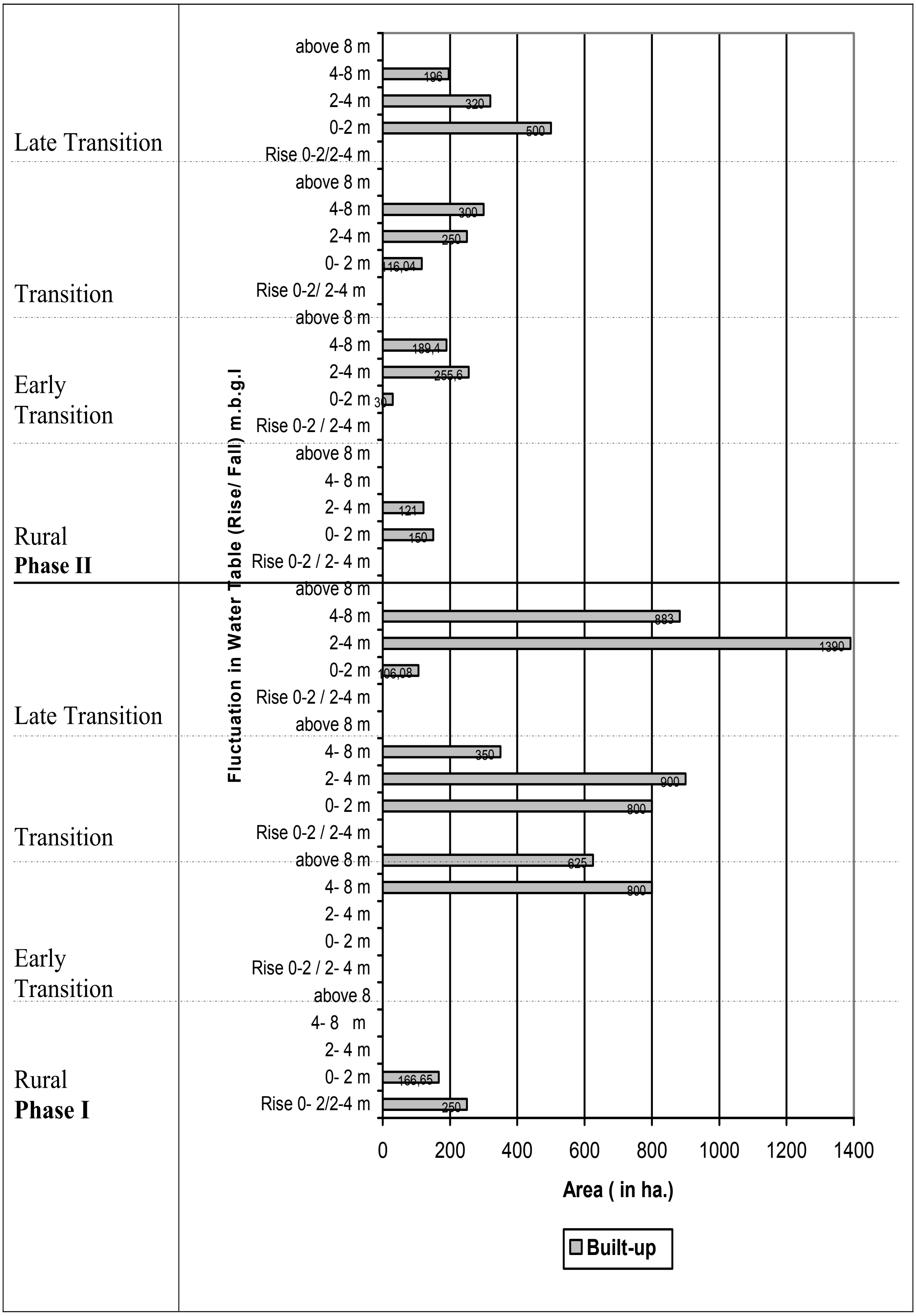


Figure 10: Water table fluctuation in late transition stage of Dwarka sub-city (1995-2004).



Source: Prepared by the author with information and map accessed from DDA and CGWB.

Figure 11: Water table fluctuation in Dwarka sub-city



Depth of Groundwater

Super-imposition data used:

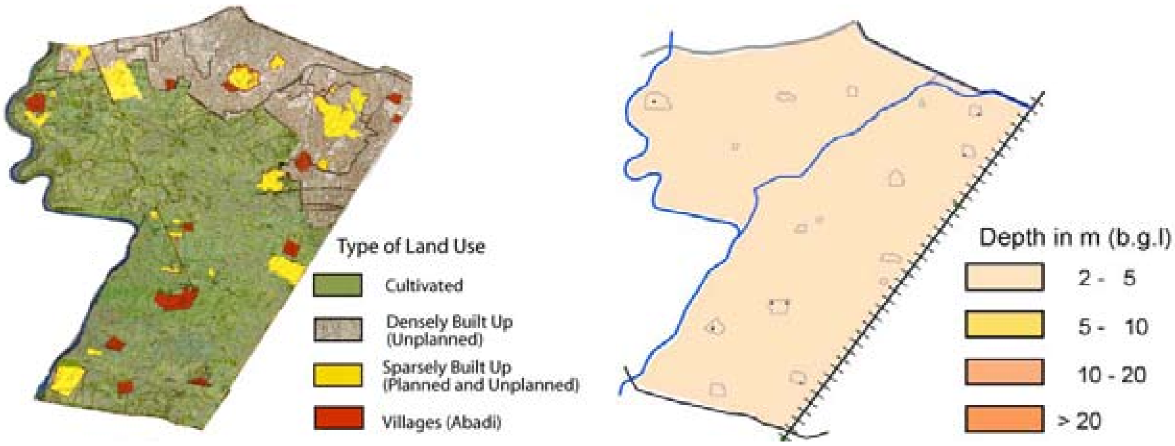
Depth of groundwater in early transition stage (Figure 12)

Depth to groundwater in transition stage (Figure 13).

Depth to groundwater in late transition stage (Figure 14)

Figure 15 shows the changes in the built-up area (the urbanisation) during the various stages of the urban development of Dwarka sub-city and the corresponding changes in the depth of groundwater. In the rural stage (before the urban development) the groundwater was available at a depth of 2-5 metres (below ground level) in the entire area of the sub-city. As the urban development of the sub-city progressed (transition stage and increase in built-up area), the groundwater was available only at greater depths; as deep as 10-20 metres below ground level. The changes in depth to groundwater table in a region are directly related to the built-up area (Figure 12-15).

Figure 12: Depth of groundwater in early transition stage of Dwarka sub-city



Source: Prepared by the author with information and map accessed from DDA and CGWB.

Figure 13: Depth of groundwater in transition stage of Dwarka sub-city (1989- 94).

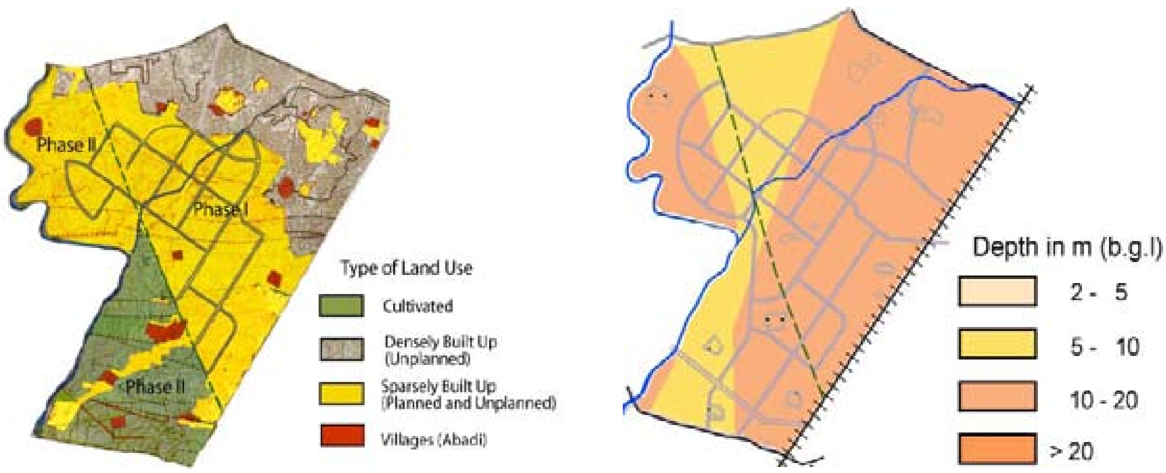
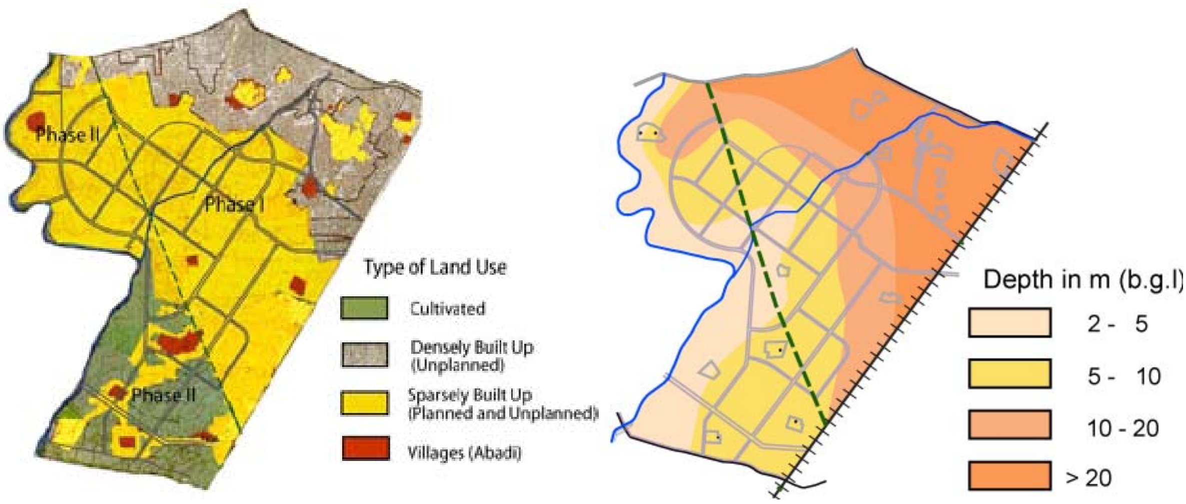
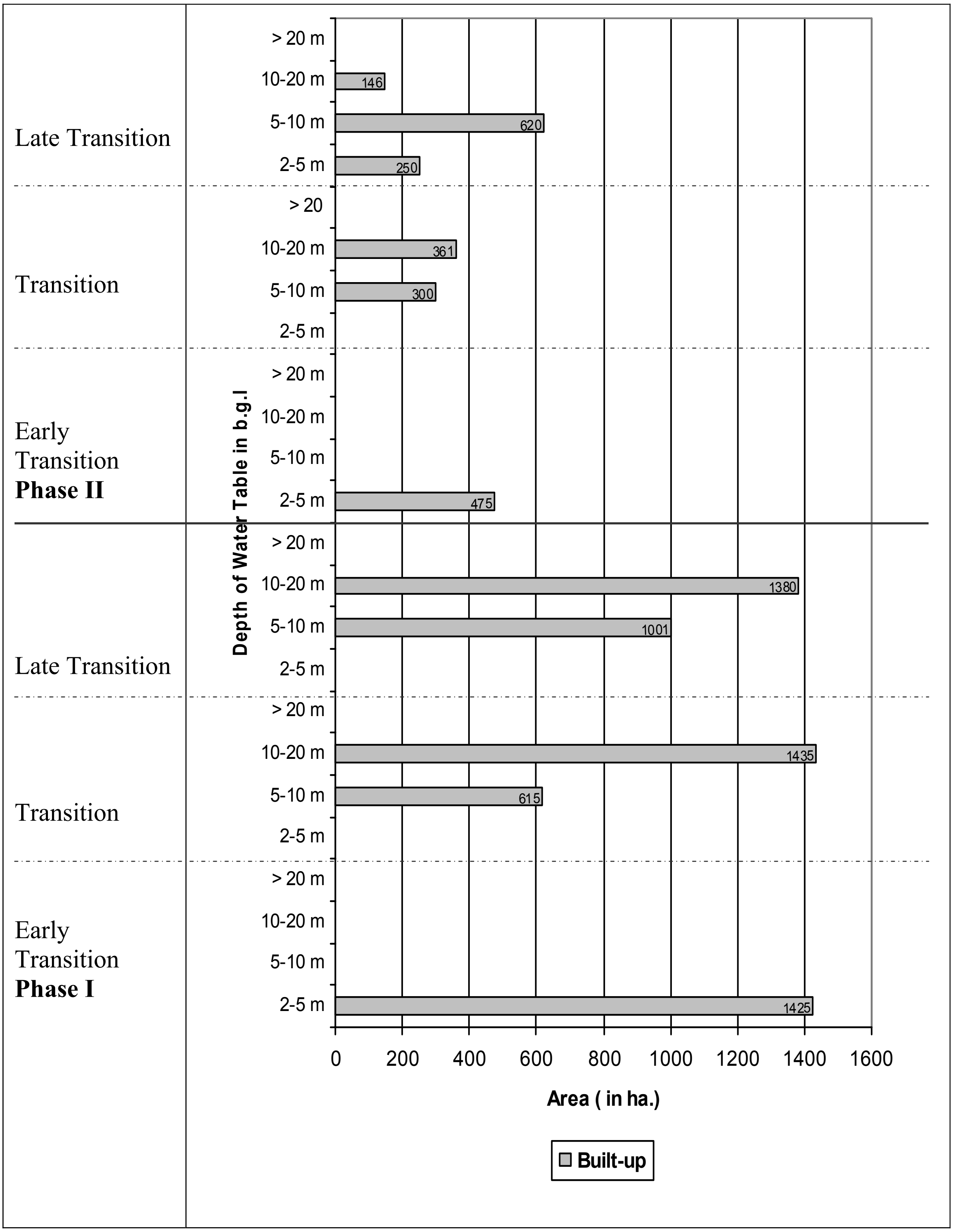


Figure 14: Depth of groundwater in late transition stage of Dwarka sub-city (1995-2004)



Source: Prepared by author with information and map accessed from DDA and CGWB.

Figure 15 : Depth of groundwater in Dwarka sub-city



5.3 Changes in the Quality of Groundwater

Availability of Freshwater

Super-imposition data used:

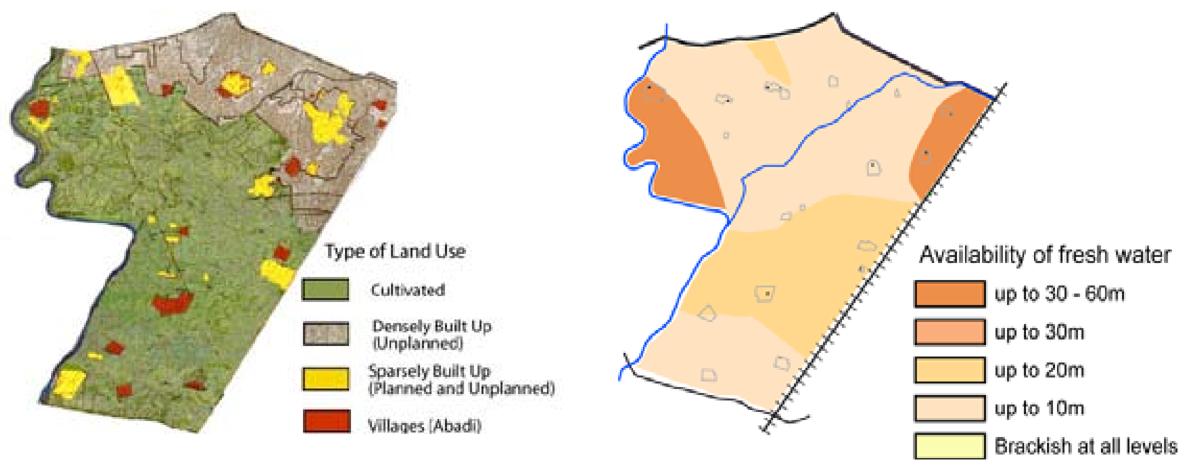
Availability of fresh water (potable groundwater) in the early transition stage (Figure 16).

Availability of fresh water (potable groundwater) in the transition stage (Figure 17).

Availability of fresh water (potable groundwater) in the late transition stage (Figure 18).

Figure 18 shows the changes in the built-up area (urbanisation) during the various stages of urban development of Dwarka sub-city and corresponding changes in the availability of fresh water. *During the early transition stages (the beginning of urban development) fresh water was available at shallow depths in the sub-city region.* With urban development, the depth of availability of freshwater has been declining; available up to 10 metres below ground level in the early transition stage and available up to 30 metres below ground level in the late transition stage. The salinity of water (brackish water) has increased with the decrease in the depth of water table. *With urban development nearing completion, only brackish water is available in the sub-city* (Figure 18).

Figure 16: Availability of fresh water in early transition stage of Dwarka sub-city



Source: Prepared by the author with information and map accessed from DDA and CGWB.

Figure 17: Availability of fresh water in the transition stage of Dwarka sub-city (1988-95).

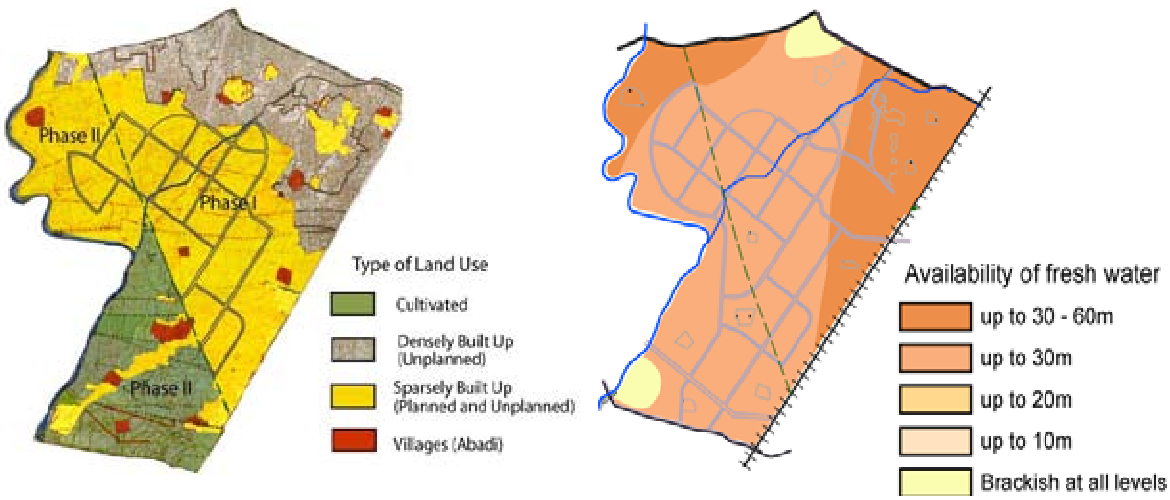
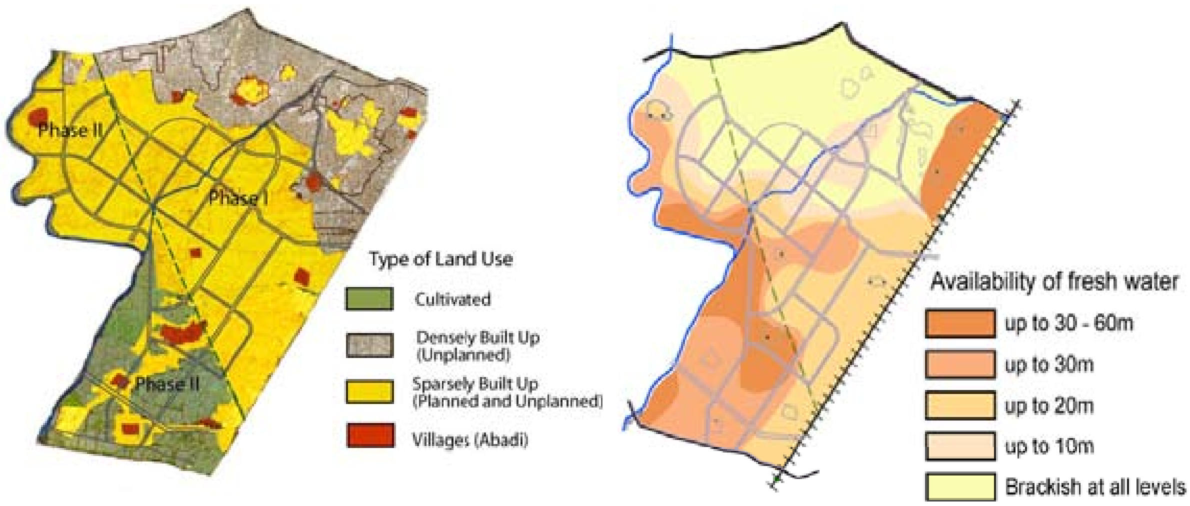
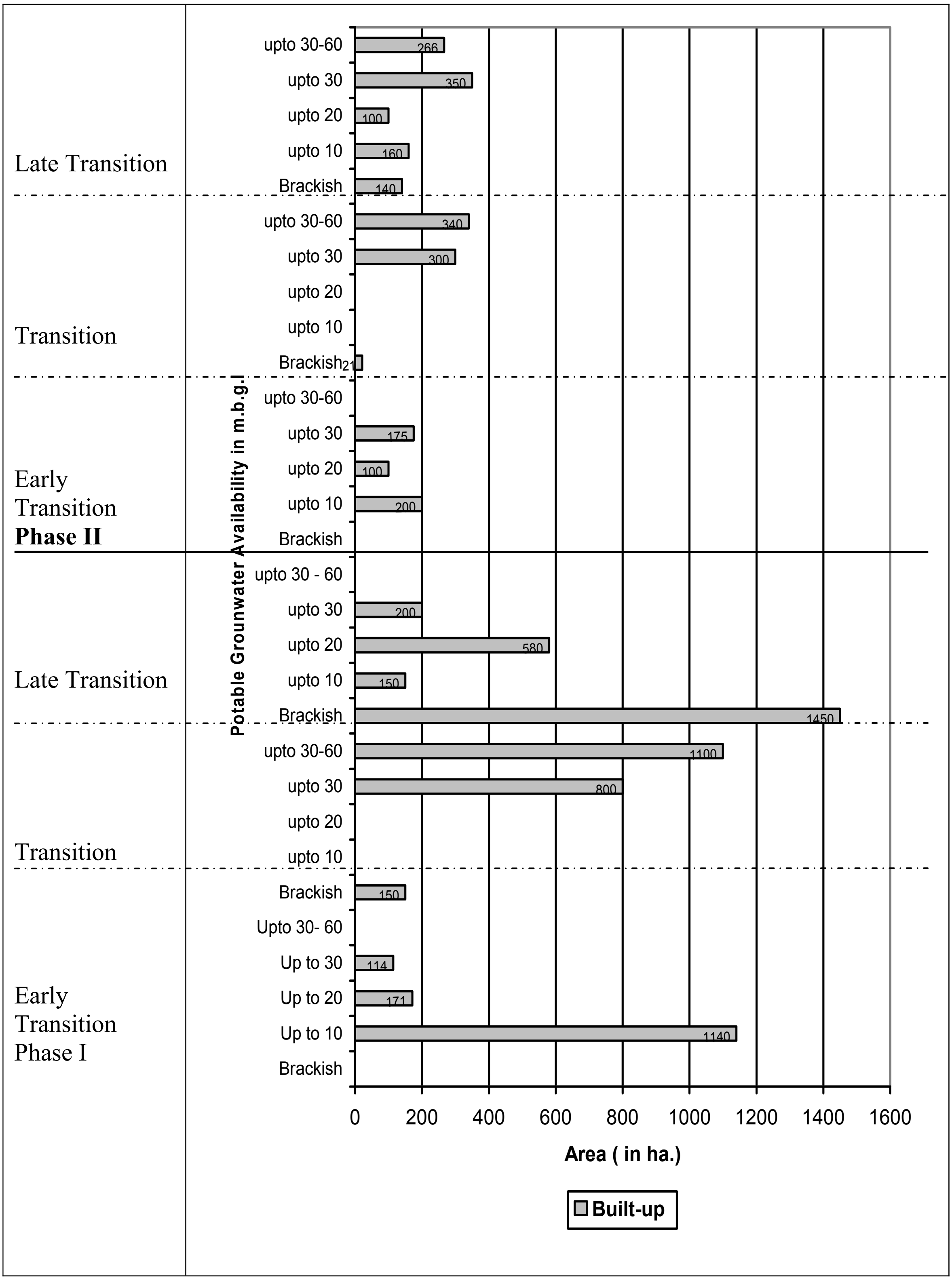


Figure 18: Availability of fresh water in late transition stage of Dwarka sub-city (1995-04).



Source: Prepared by author with information and map accessed from DDA and CGWB

Figure 19: Availability of fresh groundwater in Dwarka sub-city



Electrical Conductivity in Groundwater

Super-imposition data used:

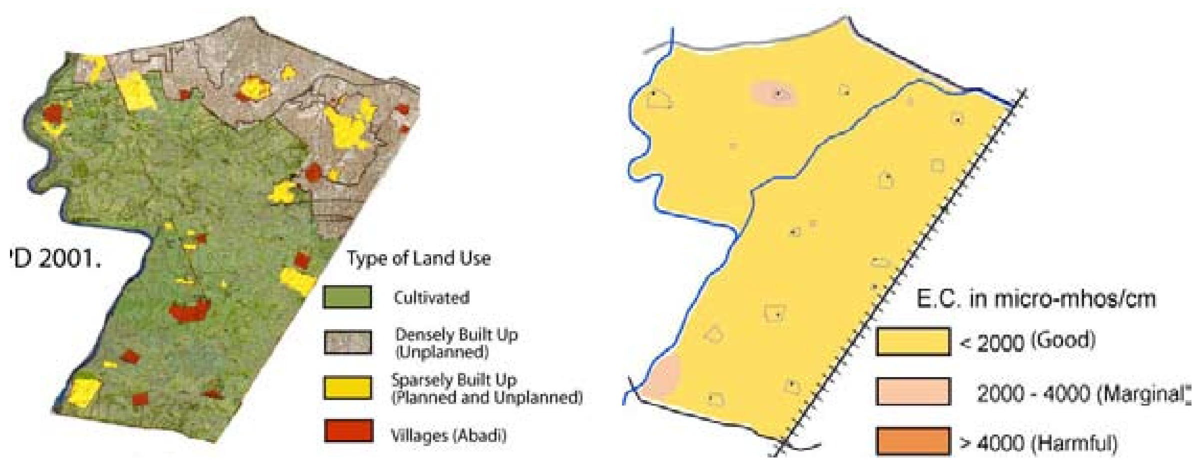
Electrical conductivity in groundwater in the early transition stage (Figure 20)

Electrical conductivity in groundwater in the transition stage (Figure 21).

Electrical conductivity in groundwater in the late transition stage (Figure 22)

Table 20-22.4 shows the changes in the built-up area (urbanisation) during the various stages of urban development of Dwarka sub-city and corresponding changes in the electrical conductivity (of shallow groundwater). The table shows that in the early transition stage the sub-city region had good quality groundwater (EC <2000 mhos/cm). *In the late transition stage, with the increase in quantities of brackish water (shallow level), the electrical conductivity has increased considerably; as high as above 4000 mhos/cm (harmful)* (Figure 22).

Figure 20: Electrical conductivity in groundwater (at shallow depth) in early transition stage of Dwarka sub-city (1977-88).



Source: Prepared by author with information and map accessed from DDA and CGWB

Figure 21: Electrical conductivity of groundwater (at shallow depth) in transition Stage of Dwarka sub-city (1989-95).

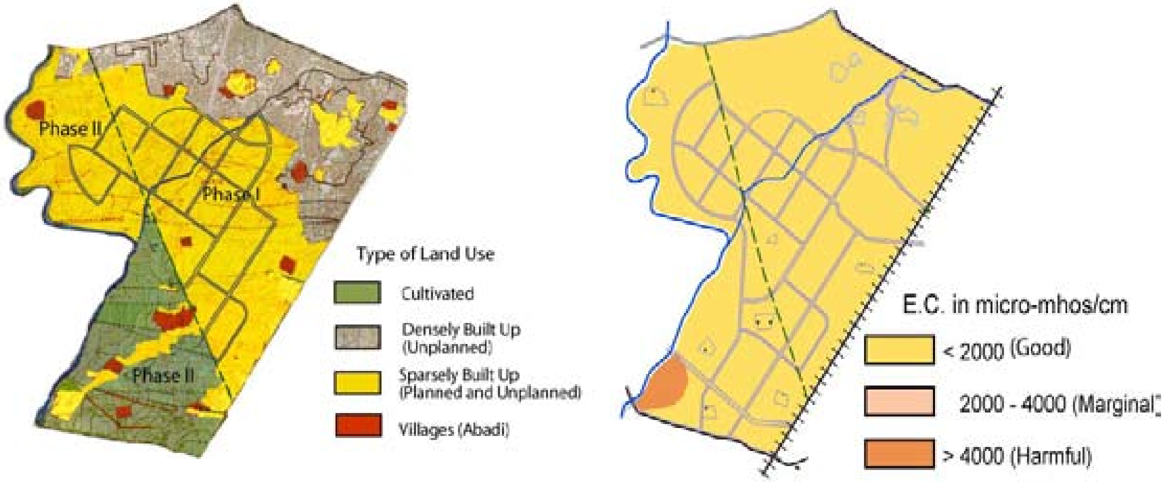
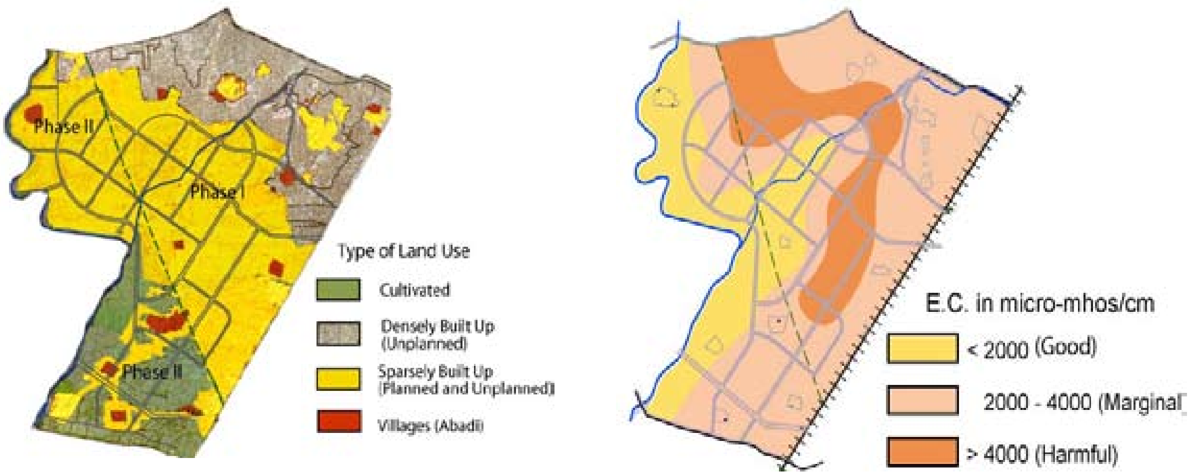
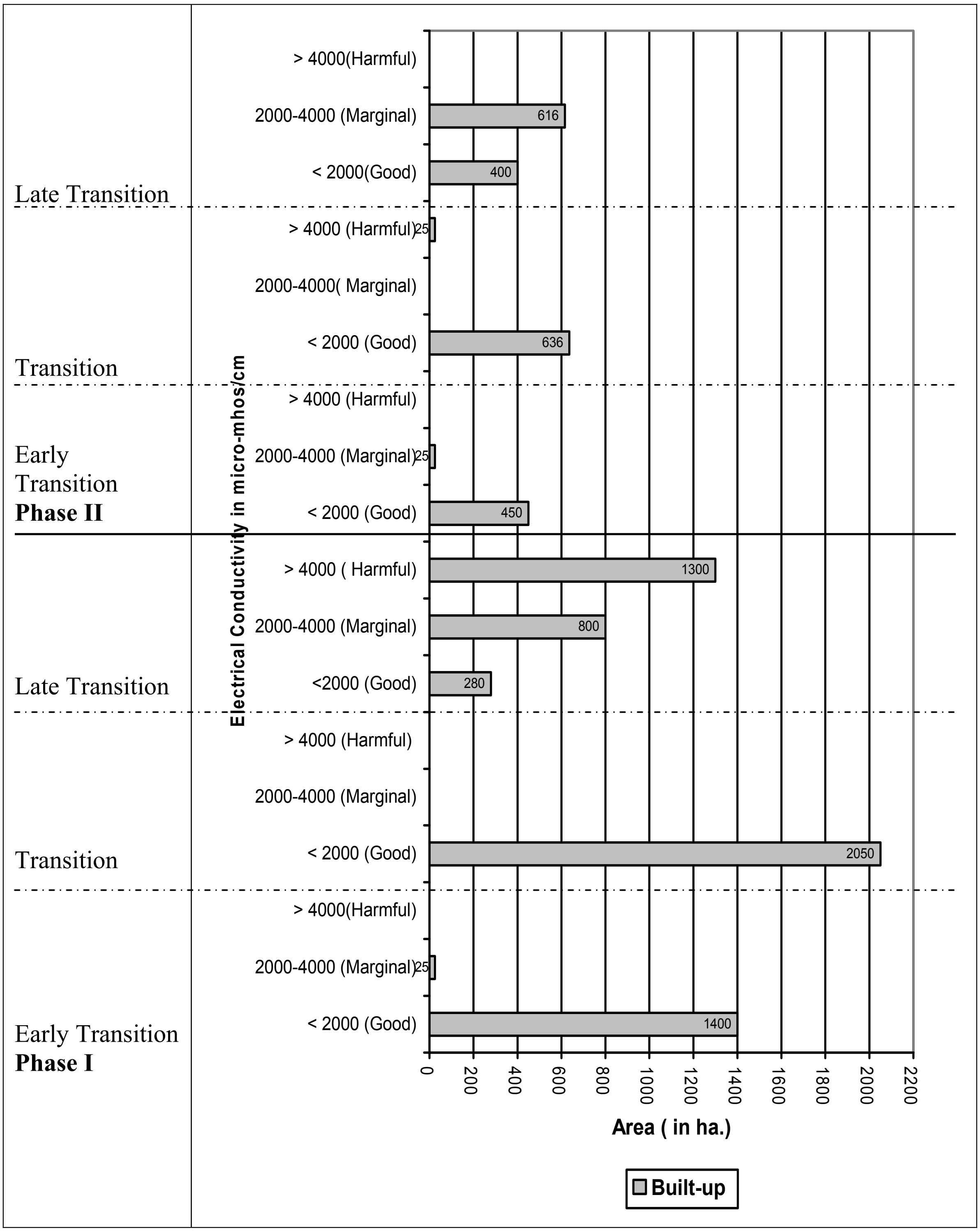


Figure 22: Electrical conductivity of groundwater (at shallow depth) in late transition Stage of Dwarka sub-city (1995-04).



Source: Prepared by author with information and map accessed from DDA and CGWB

Figure 23: Electrical conductivity in groundwater at shallow depth in Dwarka sub-city.



Interpretation of the G.I.S superimposition of groundwater information on change of land use concludes that *urban development in terms of an increase in built up areas affects both the quantity and quality of underlying groundwater.* This is evident from the differences in groundwater characteristics as urban development proceeds from urbanised Phase I to Phase II.

Phase I (95 percent built-up area) has a maximum fluctuation (i.e., between 4-8 metres). Similarly the depth of groundwater has also been rapidly declining with an increase in the built-up area. In Phase I the groundwater that was initially available at shallow depth is now available at a depth of 10-20 m.b.g.l. In Phase II with developmental works having just commenced, groundwater characteristics are already showing similar trends as were evident in the early stages of transition in Phase I. In Phase I the available groundwater at all levels is brackish (harmful).

In Phase II the signs of decline in the quality of groundwater can clearly be associated with an increase in the built-up area (a trend similar to the early stage of transition in Phase I). The available quality of *in-situ* groundwater resources have been declining and in many areas only brackish groundwater is available. It is clear that the dependence on groundwater in urban development is enormous; its use tends to be underestimated. *The management of groundwater, which plays an important role in urbanisation, is excluded from urban planning and the development process.* Stemming from research design the next section discusses the results and findings of responses to interviews of water users and various actors.

5.4 Groundwater Scenario: Availability, Sources and Water Use

This section discusses the underestimated, unrecognised but systemic role of groundwater in Dwarka sub-city. Its aim is to identify who, what, why, when and how in relation to the role of groundwater in urban development and planning during each conceptualised stage in the process of urban development. The aim is to understand the phenomenon at a city level in the urban agglomeration of Delhi using the sub-city as a model and recommend practical interventions in developing a more integral form of urban planning for sustainable use of groundwater resources in NCT Delhi. Methodologically, this section discusses the result of interviews conducted during field work. Face to face interviews were conducted with water users and various actors involved in urban development and groundwater management of sub-city. The purpose of conducting interviews was to assess the theoretical construct developed and discussed in previous chapters. The aim of this section is to understand the phenomenon at a local level,a micro level detailed analysis. A list of the interviewees (experts) is presented in Appendix 5. For the purpose of analysis, water users interviewed have been categorised into various groups. Table 6 shows the categorisation of water users for analysis. The responses have been analysed within the framework of the conceptualised stages of urban development of the sub-city in transition (rural to urban). The analysis is done separately for: planned as well as unplanned or unauthorised households; and planned as well as unplanned or unauthorised establishments.

Table 6: Categories of Water User (interviewees)

S.No	Water User	Code
1	Planned Households (DDA)	P-DH
2	Planned Households (CGHS)	P-CH
3	Planned Resettlement Housing for *Jhuggi Jhopris*	P-RH
4	Planned Establishments (such as schools, hospitals, hotel and restaurants, offices, shops and other small business premises)	P-E
5	Unplanned Unauthorised Households	UP-UAH
6	Unplanned Village *Abadi* Households	UP-VAH
7	Unplanned Unauthorised Establishment (such as schools, nursing homes, banquet halls, automobile service station, hotel and restaurants, offices, shops and other small business premises)	UP-UAE
8	Unplanned Village *Abadi* Establishment (such as schools, nursing homes, banquet halls, automobile service station, hotel and restaurants, offices, shops and other small business premises)	UP-VAE

The questionnaire was divided into four main sections. The first section included questions related to the background of water users. The second section included questions related to the nature or characteristics of households or establishments surveyed. The third section aimed at collating information on the role of groundwater in urban development and identification of issues such as:

What are the different sources of water for different water requirements during the conceptualised stages of transition, in particular, source and quantity of construction water (the major consumer of water in the urbanisation process)?

Who supplies or arranges the water supply for construction activities?

What was the quality of groundwater before construction and after construction activities?

What is the level of accessibility and availability of municipal water supply to households as well as establishments before and after construction?

What is the source and quality of municipal water supply?

What is the level of treatment of groundwater if supplied as source of municipal piped water or when arranged privately by household or establishments themselves?

Also a few general questions were posed to respondents asking them to rank the importance of groundwater as a source of water supply in different conceptualised stages of urbanisation and to identify problems and issues in quantity or quality of municipal water supply (river water or groundwater), groundwater being withdrawn privately or other supplementary sources of water being supplied in the stage of transition. The fourth and the concluding part of the questionnaire consisted mainly of open ended questions seeking views, suggestions and opinions of water users regarding management of groundwater. The questions posed were:

Has the availability or non-availability of groundwater directly or indirectly influenced the decision to locate respective households or establishments in that particular area?

Is the respondent aware of the decline in quality or quantity of groundwater that has taken place over time in the area? Is the respondent aware that, if the area is declared a 'notified' area, any further groundwater withdrawal needs to be registered and new installations of groundwater extraction mechanisms need to seek prior approval from regulatory agencies

In addition some general questions were also posed to the respondents for seeking water users' opinion regarding the need for conserving groundwater resources for future source of water supply and to know if preventive approaches like urban planning could be extended to address sustainable groundwater management.

The results and analysis in the following section substantiate the analysis in the previous section. The analysis in the next section clearly indicates that private agencies, individuals as well as public agencies (such as DDA, DMRC) are withdrawing groundwater. In many instances even public agencies are not seeking mandatory approval for extracting groundwater as the sub-city is a notified area for regulation and monitoring of groundwater. Key findings of the field work are summarised in the discussion in the next section and the responses to some critical variables are presented in graphic and tabular format. The analysis is done for each stage of transition in both the development phases – Phase I and Phase II. Photographs taken during field work are also presented to support the analysis.

Characteristics of Households and Establishments Surveyed

Building characteristics were analysed to understand the scenario of the availability of existing municipal water and the role of groundwater in the urban development Box 8.1 presents qualitative responses in these interviews.

Box 8.1 Characteristics of Households and Households Surveyed

Households

"DDA makes flats. I do not have any idea about construction. My family moved into the flat after three years of allotment". (*Resident, Phase I: P- DH*).

"DDA allotted the plot to our co-operative group housing society in 1990. CGHS executive committee was responsible for the construction of the building. The construction took over two years". *(Resident, Phase I: P- CH)*.

"The house was built in 1944 by my grandfather. When he got married in 1970, my father constructed another floor on the building. Later when my uncle got married one more room, a toilet and a kitchen were added in 1976. The building was re-developed in 1994 with two shops at the ground floor and an additional second floor". *(Resident, Palam Village Phase I: UP-VAH).*

"I purchased a plot in 1986 from a property dealer. The construction of the house started after six months and was completed in five months. I moved into this house immediately after completion of the construction". *(Resident, Phase I: UP-UAH)*.

Establishments

"The owner bought this from Ansals (private developer). I have taken this shop on rental lease. I do not think that even the owner knows how long it took for construction of this shopping complex. This shop premise was not in the business for two years as not many flats in the neighbourhood were occupied" *(Phase I: P-E).*

"In 1990 we bought this plot. I constructed these five shops on the ground floor and two rooms, a kitchen and toilets on the first floor. I gave the construction work to a contractor and it took around four months to construct this building". *(Restaurant Owner, Phase I: UP-UAE*).

"I do not know how much time it took to construct this shop. My grandfather was a famous *halwai* (sweet-maker) in this area and the family has been running this business from this shop" *(Restaurant/ Sweet-shop owner, Dabri Village: UP- VAH)*.

Number of Floors in the Building, Type of Construction and Duration of the Construction

The built-up area in the sub-city can be classified as a high density development. The buildings are above 40-50 feet height with four floors (average) in the planned households and establishments; ground floor + 3 floors except resettled slum households. 75 percent of DDA housing (P-DH), the main developer of households in the area, has G + 3 floor building. A large number of developed plots are allotted to co-operative housing societies (P-CH) for development. 85 percent of co-operative housing has 6-8 floors (high rise buildings) and the remainder 15 percent have 9 floors. The DDA along with municipal agencies has developed several pockets in the development area under slum rehabilitation and re-settlement schemes (P – RH). These households are normally single storied buildings. The unauthorised development (UP-UAH and UP-UAE) and unplanned development (UP-VAH and UP-VAE) are high-density low-rise developments.

It is evident that planned constructions take longer (even up to 5 years) in comparison to unplanned construction; 6 months or even less than 6 months. While planned constructions are largely new constructions, unplanned and unauthorised developments (70-90 percent) undergo frequent redevelopment, reconstruction or extension on the same site.

Level of Occupancy in Planned Households

Table 7 presents the occupancy level of various housing stock in the sub-city (based on the responses from surveyed DDA and Co-operative society representatives).

Table 7: Level of Occupancy in Housing Stock vis-à-vis Availability of Potable Groundwater

Availability of Potable groundwater	Type of Group Housing Societies					
	DDA Societies		CGHS Societies		Total	
	Total	Vacant	Total	Vacant	Total	Vacant
Phase I						
Brackish at all level	2046	1123 (54.8)	1196	329 (27.50)	3242	1452 (44.7)
Potable up to 10 m	1244	763 (61.33)	956	52 (5.43)	2200	815 (37.04)
Potable up to 20 m	-	-	769	75 (9.75)	769	75 (9.75)
Potable up to 30 m	-	-	-	-	-	-
Potable up to 40 m	-	-	-	-	-	-
Sub Total	3290	1886 (57.32)	2921	456 (15.61)	6211	2342 (37.70)
Phase II						
Brackish at all level			-	-		
Potable up to 10 m			-	-		
Potable up to 20 m	1036	515 (49.71)	-	-	1036	515 (49.71)
Potable up to 30 m	1568	1068 (68.11)	-	-	1568	1068 (68.11)
Potable up to 40 m	420	340 (80.95)	-	-	420	340 (80.95)
Sub Total	3024	1923 (63.59)	-	-	3024	1923 (63.59)
Total	6314	3809 (60.32)	2921	456 (15.61)	9235	4265 (46.18)

Source – Compiled by the author based on interview responses.

Household societies / households were sampled from all five different zones in the sub-city demarcated by CGWB on the basis of the depth of availability of potable groundwater in 2004-05. In Phase I, 57 percent of DDA Housing and 38 percent of CGHS were vacant (responses from building society representatives). In Phase II, 64 percent of DDA Housing was vacant and the construction work of CGHS was yet to commence. The low occupancy was mainly due to inadequate or non-availability of amenities and facilities such as water and power supply. The analysis also shows that low occupancy in DDA Housing (55 percent) as well as CGHS housing (45 percent) in Phase I lies in the zone with brackish groundwater at all levels. The occupancy is also low (61 percent of DDA Housing and 37 percent of CGHS housing) in the zone with potable groundwater up to 10 mbgl. Phase II is also witnessing low occupancy of DDA Housing (potable groundwater availability between 20-40 mbgl).

In order to understand the source of municipal water supply, accessibility and availability of municipal supply for domestic and non-domestic water requirements the interview responses of households and establishments surveyed are discussed in the following section. The responses related to select critical variables have been obtained for each conceptualised stage of transition (discussed later in this section).

Accessibility and Availability of Municipal Water Supply

Most of the households in planned DDA Housing and CGHS (75 to 95 percent) are connected to the piped water supply network. The village *abadi* areas (75 to 95 percent) are connected to the municipal supply through tube-wells. The resettlement water users (100 percent) also have access to municipal water supply. Planned CGHS housing (95 percent of the housing societies) have provisions for dual water supply. Planned DDA Housing and planned establishments do not have provisions for a dual water supply. Unauthorised areas are not connected to the municipal supply and also lack dual water supply system. It can be assumed that these are solely groundwater-dependent water users. The municipal water supply is not enough to meet domestic (65 percent DDA Housing, 80 percent CGHS and 100 percent Establishments) as well as non-domestic (40 percent DDA Housing, 77 percent CGHS and 75 percent Establishments) water requirements of all planned developments. However in case of village *abadi* areas water users, 75 percent were able to meet their requirements with the existing supply (groundwater from tube-wells). The remaining water users were those who did not have access to municipal supply. The unauthorised developments also do not have access to municipal supply.

Share of Groundwater in Municipal Water

The source of the municipal water supply in 33 percent DDA Housing, 23 percent CGHS housing and 17 planned resettlement water users was river. The source of municipal water supply for the remaining households was a mix of groundwater as well as surface water. The source of municipal water supply in village *abadi* areas are DJB tube wells. The unauthorised developments are not connected to municipal water supply. Planned establishments are also not connected to municipal piped water supply.

5.5 Role of Groundwater in Urban Development in various stages of urban development

The data obtained from interviews was analysed for various stages of urban development. This was important to understand the role of groundwater in the urban development of the sub-city. The extent of groundwater use or dependency of water users (for domestic or non-domestic water use) is taken as the criteria to assess the role of groundwater. The following section presents the analysis for the various stages.

Source of Water Supply (*Figure 24*)

In Phase I, until the transition stage, 80 - 100 percent of planned households and establishments had groundwater supply from deep bore wells or water tankers. The source of water supply for these tankers was also groundwater obtained through tube wells located in the vicinity. In the early transition stage of Phase I, 64 percent of planned resettlement water users were dependent on hand pumps; the remaining had water supply from tube well in the vicinity. By the transition stage, only 30 percent of water users were dependent on hand pumps due to a decline in the water table; increasing the dependency on tube wells and water tankers. Until the transition stage, hand pumps were the source of water supply for 85 percent unplanned households and establishments.

In the late transition stage, the source of water supply to 44 percent of planned DDA housing and 18 percent of planned CGHS housing was surface water. The water supply was through the developed water network and DDA water tankers (discussed in detail in the following section). During this stage, there was a significant decline in the percentage of hand pump or well-dependent water users (shallow ground water) in unplanned households and establishments. Only 4 percent of unplanned village *abadi* water users, 16 percent of unplanned and unauthorised establishment water users and 12 percent of unplanned village *abadi* establishments were dependent on shallow water sources such as hand pumps and wells. These water users had shifted to bore wells or water tankers providing water sourced from deep-bore tube wells located in the vicinity. This shift can be attributed to a rapid decline in the water table and drying up of hand pumps and wells (shallow water sources). *This highlights the affects of large scale withdrawal of groundwater for planned developmental work, mainly construction in the early transition and transition stage.*

In early transition and transition stages of Phase II, there were no planned households or establishments except the planned resettlement housing. The percentage of planned resettlement housing water users dependent on bore wells and tankers increased from 60 percent to 100 percent in late transition. The unplanned households and establishment water users were largely dependent on water supply from hand pumps and wells (groundwater at shallow depth). In the late transition stage developmental works had just commenced in this area. The construction work of a considerable number of DDA housing was complete (ready for allotment). In the remaining planned DDA housing (with low occupancy), the source of water supply was deep bore wells or tankers (water sourced from tube well located in the vicinity).

Groundwater in Domestic Water Supply (*Figure 25*)

Until the Phase I transition stage, the domestic water supply was largely groundwater dependent. A mix of surface water and groundwater was being supplied to 20 percent planned resettlement housing, 10 percent unplanned village *abadi* households and 10 percent unplanned village *abadi* establishments.

In the Phase I late transition stage groundwater was still contributing to a large extent to domestic water supply; 60 percent in planned DDA housing and 80 percent in planned CGHS housing. A mix of surface water and groundwater was the source of domestic water supply for the remaining water users.

Phase II groundwater, from early transition till date (in 2004), is the main source of domestic water supply in unplanned households and establishments; both unauthorised and village *abadi* areas.

Source of Bulk Water: Construction Sector Water Requirements (*Figure 26*)

It is clearly evident that, in both phases, bulk construction water requirements for planned households and establishments is solely met from deep bore wells and water tankers. As discussed earlier, the source of water supply to water tankers is also groundwater from tube wells or deep bore wells located in the vicinity.

In Phase I during early transition and transition 64 percent of unplanned village *abadi* households and establishments were using water from tube wells or tankers for construction. Above 80 percent unplanned and unauthorised households and establishments were using water from hand pumps and wells for construction. Planned resettlement housing (77 percent) however was able to meet their construction water requirements from shallow water sources such as hand pumps and wells.

In the late transition stage of Phase I, 85 percent of unplanned and unauthorised households and establishments were now using water from bore wells and water tankers for construction. Only 20 percent of the planned resettlement housing was meeting their construction water requirements from shallow water sources; the remaining 80 percent were dependent on tube wells.

In Phase II until late transition, a considerable construction water requirement was being met from hand pump or wells. However, the share of groundwater from bore wells and tankers was also increasing. In late transition, 85-90 percent of unplanned households and establishments; both unauthorised and village *abadi* areas, were using water from bore wells and tankers for construction.

Figure 24: Source of water supply during various stages of transition in Dwarka sub-city

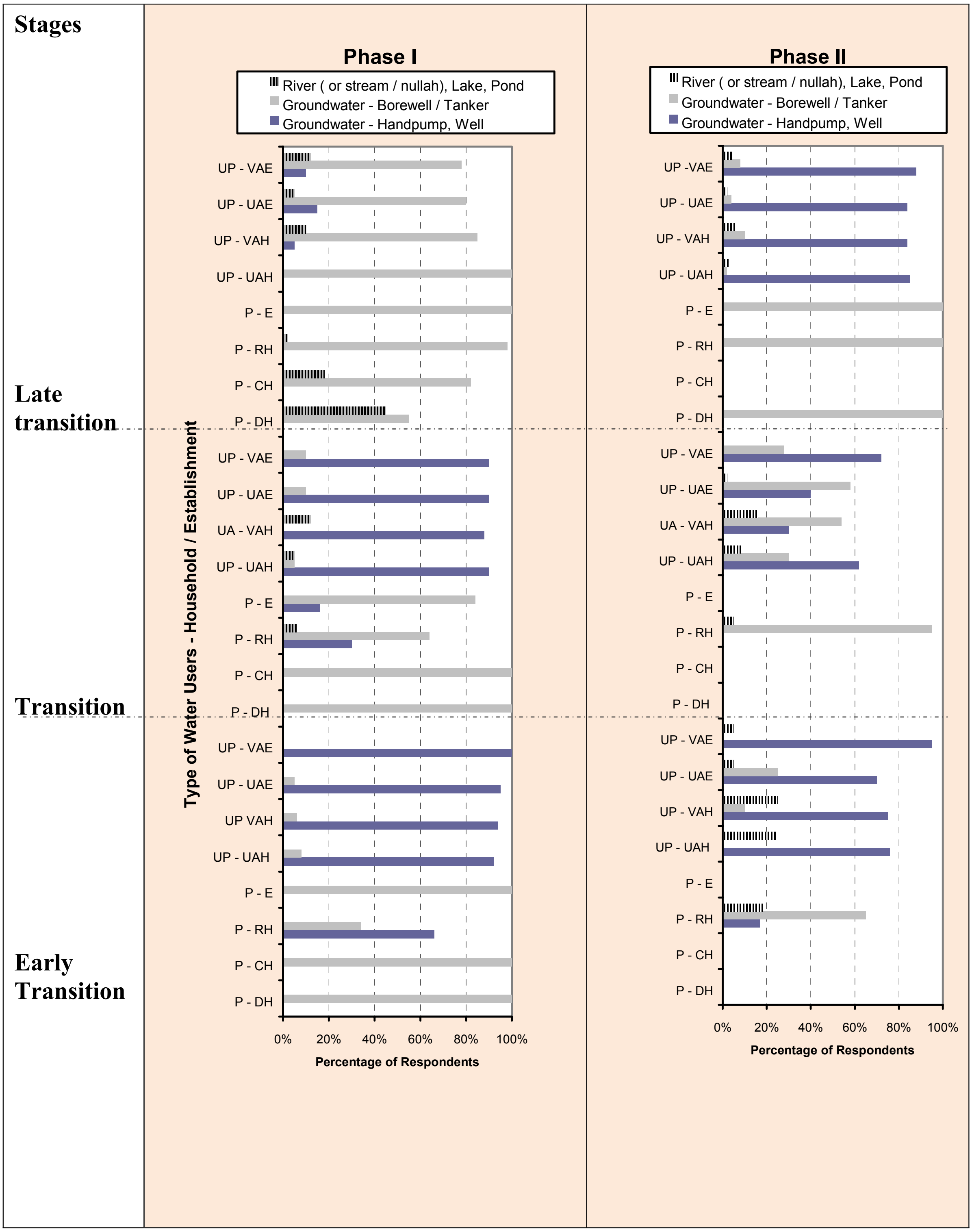


Figure 25: Groundwater in the domestic water supply during various stages of transition in Dwarka sub-city

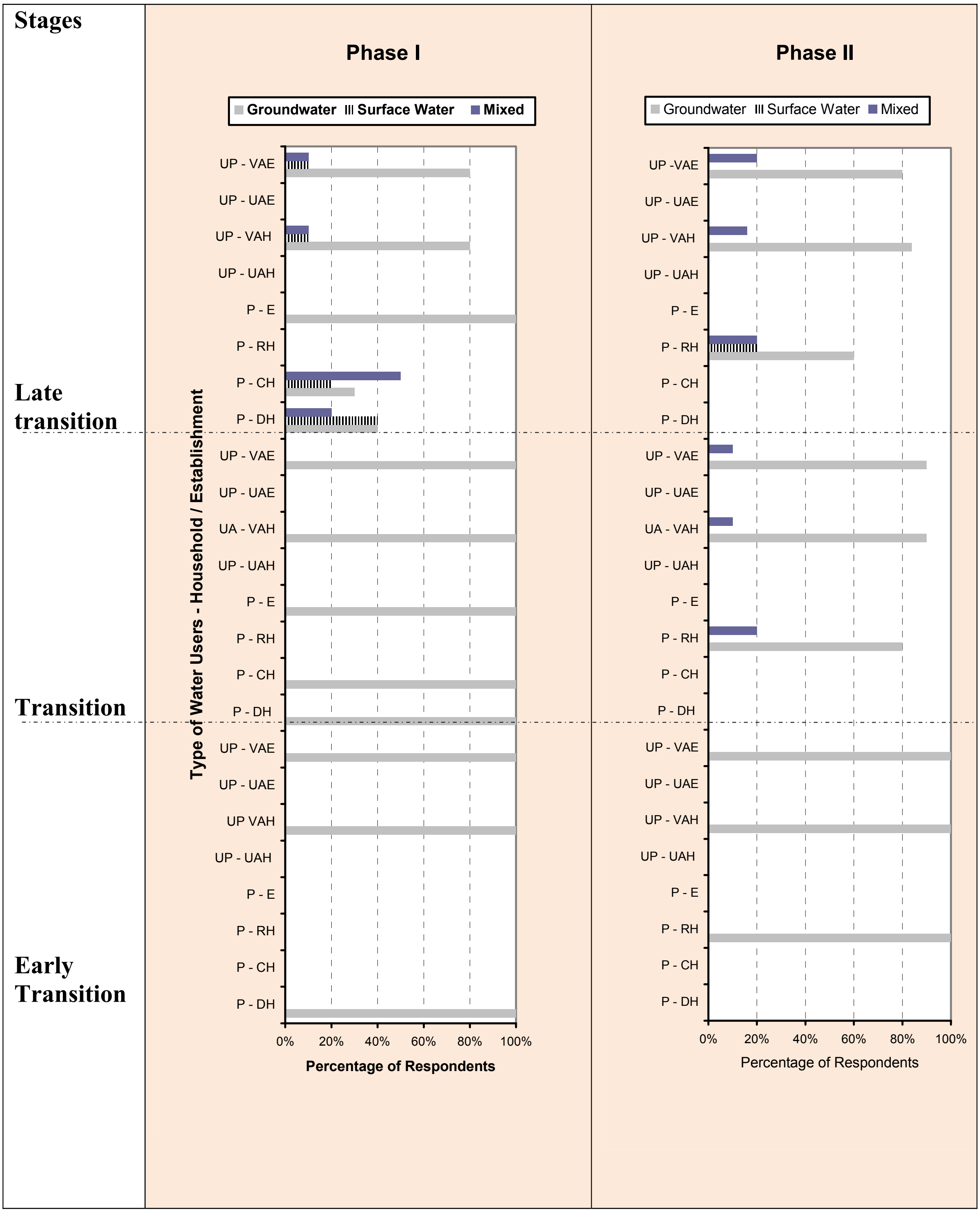
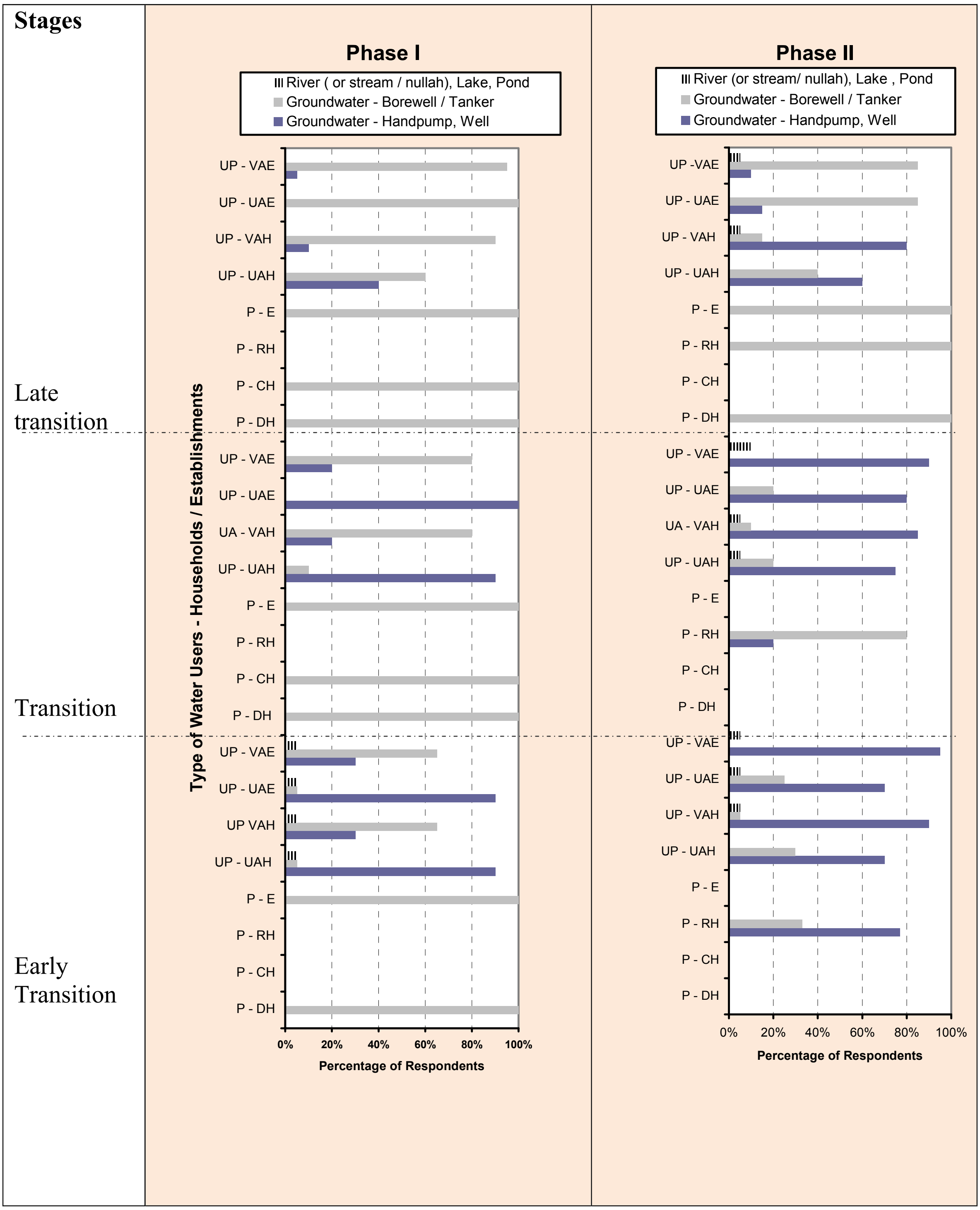


Figure 26: Source of water for bulk use (construction) during various stages of transition in Dwarka sub-city



Groundwater has played a major role in all stages of urban development of Dwarka sub-city. It has been the main source of water supply for both domestic and non-domestic water use in planned as well as unplanned developments. However, the bulk use of groundwater for construction is removing the limited potable groundwater available at shallow depths. This has affected the potential role of groundwater as a water source in two ways. First, it has resulted in a decline in the water table. Second, it has resulted in the decline in the quality of groundwater with an increase in salinity with depth.

The water users' interview data analysis supports the G.I.S based results (previous section). Based on the responses of key actors, the next section will discuss problems and issues related to planning and management of groundwater. These include awareness and concerns of water users as well as the role of urban planning in protection and management of groundwater.

5.6 Responses of Key Actors

In the following section, groundwater (and related issues) are highlighted based on semi-structured interviews with key actors that have important role in decision making or those that have knowledge about research areas. The interviewees include representatives of various government agencies, village heads, municipal councillors, civil society groups, non-governmental organisations (NGOs) and resident welfare association (RWAs). The agricultural land of villages has been acquired for planned development purposes in the sub-city. To understand the historical context (before the planned development Plan in the area), village heads and senior villagers having knowledge about the research area have been interviewed. This also helped in understanding the growth and development of unauthorised developments and filled information gaps in the changing water scenario - water users, sources of water supply and groundwater characteristics. Later in the transition and late transition stages the government institution and agencies were the key actors. Hence the planners and engineers of public agencies DDA, DJB, CGWA and CGWB were interviewed. The interviewees also include representatives from non-governmental organisations such as INTACH that have played an important role in addressing the concerns of groundwater management in Delhi. The other interviewees include representatives from private water suppliers, managers of company selling water purification systems and estate / property developers.

Early Transition

In the early transition stage potable groundwater was available at shallow depth in Phase I and II. All drinking water requirements of the village *abadi* area were met from individual hand pumps or community hand pumps installed and maintained by DJB. The traditional water bodies such as village ponds, wells were also extensively in use as sources of water supply.

According to Ward Councillor (*Matiala* Village in Phase I),

> "Water to the abadi area is supplied by DJB since 1975.DJB had installed hand pumps when the water table was 12-15 m.b.gl".

Similarly the village head (*Bamnoli* Village in Phase II) stated,

> "There were three village ponds, wells and few hand pumps to meet water supply. DJB maintained hand pumps were in use until the past ten years".

In the 1980s the Janakpuri residential scheme was developed by DDA in DUA 1981. In the absence of planning controls, the rural area across Pankha road had a marked concentration of unauthorised concentration (discussed in detail in the previous chapter).

According to the village head, (*Palam* Village in Phase I),

> "Palam is one of the biggest villages in the area. A large number of unauthorised colonies such as Raj Nagar (I, II, III), Sadh Nagar, Mahavir Enclave (I, II, III) and Vijay Enclave are developed on agricultural land of Palam. The depth of the water table in 1962 was 5-8 m.b.g.l. The individual households had hand pumps to meet their water requirements".

In Phase II also unplanned built-up developments have come up. According to the former village head (*Kakraula* Village in Phase II) who is also the present Deputy Mayor, MCD:

> "In the 1980s villagers sold their agricultural land to property dealers who later developed eight unauthorised colonies - Hari Nagar, Nishad Park, Patel Garden, Kakrola Dairy, Bharat Vihar, Vikas Vihar, Duggal Farms and Shyam Vihar. In the beginning these colonies were dependent on individual hand pumps but now the hand pumps are all dried up. At present 90 percent of unauthorised developments outside the village are dependent on private water tankers".

Since DDA notified the Development Plan and by the time the authority had the actual possession of land identified for proposed developmental works considerable area in the sub-city was already built up with unauthorised development.

According to the village head*,* (*Pochanpur* Village in Phase II):

> "The land of the village was acquired by DDA in three stages – 1986-87, 1992 and recently in 2002. By the time the possession of the required land took place, three residential colonies – Major Bhola Ram Colony (in north), Pochan Pur Block A & B (in South) were built up unauthorised".

Transition Stage

During the transition stage DDA was in possession of land required for the development of Phase I of the sub-city. This was followed with the beginning of large scale construction related DDA housing societies and related infrastructure. Initially the construction water demand and later the entire domestic as well as non-domestic water requirements of the unauthorised developments were solely dependent on shallow hand pumps. In the 1980s DJB bored tube wells to supply piped water in *abadi* areas.

According to the village head*,* (*Palam* village in Phase I),

> "DJB has installed a total of seven tube wells. The depth to water table in 1962 was 5-8 m.b.g.l and was around 40 – 45 m.b.g.l when the developmental works commenced in Phase I. Individual households had hand pumps that have all been abandoned due to a decline in the water table".

According to the former village head (*Kakraula* Village in Phase II),

> "In Kakraula Village DJB has installed four tube wells and supplies water 1 or 2 hour each day. A large number of individuals also have jet pumps. Due to the continuous use of tube wells and jet pumps in this area, groundwater is rapidly declining".

Also the village head (*Bharthal* village in Phase II) stated:

> "In the 1980s the water table in the area was around 8 - 10 m.b.g.l. DJB installed a few hand pumps for community use. Eight tube wells bored to supply potable water to households with piped water connections. All hand pumps in the area have dried up due to the lowering of the water table including two tube

> wells having been abandoned. Other tube wells were re-bored to tap deeper aquifer"..

This stage witnessed an increase in water demand in unauthorised households and establishments which were dependent on groundwater (available at shallow depths). Further, there was continuous redevelopment in village *abadi* areas due to lack of development controls. A considerable number of households and establishments were withdrawing groundwater from deeper aquifers with electricity run jet pumps (also called submersible pump) replacing the hand pumps. Many households with piped water supply received municipal water, daily at fixed intervals (30 – 60 minutes in morning as well as evening). These individuals have installed pumps connected directly to water supply line which enables water storage in tanks (overhead rooftop tanks or underground storage tanks).

According to the village head (*Palam* Village in Phase I),

> "In the village DJB tube well water is supplied through piped water supply network two times every day. The water is supplied for one hour in the morning and two hours in the evening. Due to low pressure in the water being supplied, individual households or establishments have installed booster pumps".

Large scale construction or redevelopment in village *abadi* areas took place during this stage. DDA also commenced large scale construction activities on land designated for planned residential housing, establishment and other related infrastructure. Some CGHS societies that had been allotted plots too initiated construction. Figure 27 shows the construction in Phase I that has been going on since 1988. All construction water requirements were solely met from in-situ ground water resources arranged by the developer or private contractor hired for civil works.

Figure 27: Construction activity in the Dwarka sub-city

P-CH under construction

UP-UAH and UP-UAE under construction , re-construction and re-development

Construction of the Delhi Metro Corridor and related facilities

Construction of related infrastructure

The Chief Engineer, Dwarka sub- city briefed on the construction water use and source of water. He stated:

> "Construction is bulk water use activity in the sub-city. All the construction water requirements are, at present, being met from groundwater available in and around the site of civil works or other developmental and building activity. Over a period of time the quality of groundwater has declined. DDA and private contractor's executing the project construction treat the groundwater if the quality found is not suitable for construction use and / or within prescribed permissible limits. In practice, within the sub-city mostly the available groundwater is saline. For treatment of saline water hydrochloric acid or Imli (tamarind water) is added or a wash is given to constructed structures".

Superintending Engineer, Dwarka sub-city briefed about the civil works and related water supply arrangement for the construction. He stated,

> "Central Public Works Department rates for civil works recommend one Rupee per 100 Rupees of civil work to be given against arrangement of water to the contractor hired by the DDA to carry out construction in each contract. It is the contractor's responsibility [who executes project / civil work] to arrange water".

During the transition stage the water requirements in the development area are mainly for on-going construction. The housing stock that is ready was not yet allocated, sparsely occupied or not yet occupied due to pending completion of proposed water and power supply infrastructure. Few housing societies in Phase I both DDA and CGHS were sparsely inhabited. In Phase II near Kakraula slums relocated from cities were resettled in development areas (discussed in previous chapters). There was no progress on the availability of water from identified sources of municipal water from the network till late transition.

Late Transition Stage

According to the Ward Councilor, the groundwater quality was declining considerably in the area and Phase I had no potable groundwater.

> "In *Matiala* the water table has declined and is 30-35m.b.g.l. The groundwater now available is salty. DJB supplies a mix of River Yamuna water and groundwater through water tankers. DJB sends 2-3 water tankers per day to the locality. Water tankers are filled from DJB tube wells installed along Najafgarh drain. Water tankers are filled from DJB tube wells installed along drain".

Similarly, according to the representative of the resettled slum colony in Sector 15 Pocket C in Phase II:

> "Few years back few children died due to water borne diseases after consuming water from hand pumps. Since then DDA supplies water through tankers to the camp for domestic purposes. Three tankers supply water at fixed points in the camp each day. The tanker is parked at a fixed location and inhabitants collect water and store it for meeting the drinking and domestic water demand. DDA has also installed a tube well in the locality to meet the non-domestic water requirements for the inhabitants and overall the water supply is satisfactory".

The Chief Executive Officer, DJB updating the current status of water related infrastructure in the sub-city stated:

> "Till date DDA doesn't even have possession of the land to be handed over to DJB for construction of the proposed Dwarka water treatment plant. All the reservoirs identified for raw water augmentation in the Development Plan for the sub-city is, till date, in the planning stages. The only possibility of water augmentation is from the construction of the parallel channel to bring raw water from Munak to Haiderpur eliminating the current losses in the current carrying system and diverting the surplus to Dwarka. This is an inter-state issue".

According to the former Engineer in Chief (DJB) this was possible with the Haryana Government's co-operation and agreement to construct a parallel channel to the existing channel carrying water to Haiderpur water treatment plant. In spite of pressure from the Government of Delhi on the Government of Haryana, the work on the parallel channel has not yet commenced and is expected to take 2-3 years or more (personal communication, 28 June 2004).

According to media reports (Asian Age 1998, Indian Express 1998) Dwarka sub-city has been reeling under water crises and INTACH (a non-governmental organisation working in the field of natural resources conservation and management) carried out feasibility studies to explore the possibilities of *in-situ* augmentation of water at the macro level. Based on INTACH reports, the Government of Delhi initiated a project titled 'Techno-Feasibility study for on-channel recharge on the Najafgarh drains' to be undertaken by INTACH. The Delhi Government also started several water-harvesting schemes.

The project estimated a 8 to 10 million gallon water augmentation. Post monsoon the drain that used to dry up was proposed to be filled by storing flood waters and urban run-off estimated from the sub-city. The study proposed to convert the Najafgarh drain into a linear lake and increase the volumetric water holding capacity by de-silting and deepening the drain below designed bed level (Rohilla 1998). According to Advisor INTACH:

> "The first phase of the project has been implemented by the Irrigation and Flood Control Department of the Government of Delhi. The stored water recharges the groundwater. Phase II of the project plan is to install tube wells and extract the groundwater on a sustainable basis. The tube well groundwater can be connected to feed piped water supply proposed in the sub-city"

In addition to the above, INTACH has carried out a detailed study of off-channel storage along the Najafgarh drain in low lying areas (for DDA). The project proposal identified a depression having a surface area of 75 hectares that could be extended after change in proposed land use and civil works to 150 hectares .The land use plan had earmarked parts of this depression area for residential housing schemes, semi-public and public use such as five star hotels. It was estimated that, if the project is implemented, around 2.5 million gallons per day of water augmentation was possible. According to Advisor, INTACH:

> "DDA was not keen to implement the project as it involved changes in the land use plan and the benefits of this project in terms of additional availability were small. The entire sub-city can obviously not rely on this resource to address the water shortage and the on-channel recharge along the drain was never taken up for implementation. They wanted an alternative resource as a temporary measure to sustain the total projected water requirements that were required for the proposed water treatment plant at Dwarka until other ' big projects' were completed and they could also justify the other proposed water supply related infrastructure such as command tanks, main pipe network that was already in place or under construction".

In order to control continuous exploitation of groundwater, to ensure that the rate of withdrawal does not exceed the rate of replenishment in 1997 the Central Government of India constituted the Central Ground Water Authority (CGWA) discussed earlier in this research. The authority has issued mandatory regulatory directives to conserve and protect groundwater in vulnerable areas.

According to Member Secretary, CGWA:

> "In March 2002, the CGWA has made mandatory the adoption of rain water harvesting and groundwater recharge systems for all residential societies, schools, hotels, industrial establishments with a plot area greater then 100 square metres. The first deadline for adopting rain water harvesting was fixed as May 2001 but it had been extended several times till date".

In 2003 (due to a court intervention) the Government of Haryana was directed to release some additional raw water to Delhi as temporary relief. The raw water is transferred through the Western Yamuna Canal at Nangloi water treatment plant located in west Delhi and after treatment to the sub-city. According to CEO, DJB in 2004 around 5 mgd water was released to the sub-city – CT 2 (personal communication, June 2004). In addition to the water requirements of built up (unplanned households and establishments) as well as other unaccounted for and underestimated bulk construction water requirements according to Director Planning (Dwarka) in 2004, DDA estimated the existing water demand to be around 10 mgd and leaving a considerable demand- supply gap. The following section will discuss the municipal water from the network in both Phase I and II.

Municipal Water from the Network

According to the Superintending Engineer, Dwarka sub-city -

> "The raw water availability in the sub-city is not good. CT 2 and CT 4 are functional and the water comes from Nangloi water treatment plant to CT 2 and pumped to CT 4. DJB supplies around 5 mgd of water. 3 mgd is for the existing water requirements of the development area and 2 mgd is for remaining built up area in the sub-city. Due to on way tapping of the main water network around 2.5 – 3 mgd is reaching at CT. The construction works on CT 1 and CT 5 is towards completion. It is not possible to maintain water supply pressure in more than 60 percent of the sparsely populated households. The DDA tankers with water from the network or DDA tube wells supply water…Generally the complaint of water quality is related to colour and smell in water supplied or brackishness due to mixing of groundwater with water from network supply from river. Over time however consumers tend to give additional treatment such as boiling, water purification or RO system".

Tables 8 and 9 show the average number of water tankers supplied by DDA to housing societies or establishments.

Table 8: Daily Water Supplied by DDA Tankers* from Command Tank 2.

Housing Societies	Number of Tankers
DDA Societies	
Phase I -	
Nasir Pur - 256 Janta, Pkt 10, 208 Janta, 328 LIG Site, 1845 SFS Site, 176 LIG, 472 Janta	22
Sector 1 - DDA Office	1
Bindapur - DDA Pkt	5
Sub-Total	28
Phase II	
Sector 14 - 360 MIG	4
Sector 15 - JJ	11
Sub - Total	15
CGHS	
Phase I	
Nasirpur - Ideal, Vrindavan, Kumidi, Great Capital	6
Sector 4 - Aiswarya,, Delhi Public School, Saheta, Badrinath, South Delhi, Panchsheel	6
Sub-Total	12
Total	55

Table 9: Daily Water Supplied by DDA Tankers from Command Tank 4.

Housing Societies	Number of Tankers
DDA Pocket	
Phase I	
Sector 11 - Pkt 2	1
Sector 12 – Pkt 2	4
Sub-Total	5
Phase II	
Sector 13 - 628 MIG – A, 717 SFS – 1, 804 SFS – B	12
Sector 14 - 976 LIG – 1, 864 LIG - 2, 360 MIG – B	22
Sector 17 - 304 MIG – E, 292 MIG – D, 150 MIG – A	4
Sector 18 - Vijay Veer Vikas, Pkt 3	7
Sector 23 – DDA Staff Housing	1
Sub-Total	46
CGHS	
Phase I	
Sector 12 (Ishwar, Shyadri, Vidyut, Southern, Ashoka)	11
Sector 13 (Audh Vihar)	2
Sector 22 (AIMO, Upkari, Himhit)	5
Sub-Total	18
Total	69

Source: Office of the Chief Engineer, DDA Dwarka Project Office (July 2004).

* Average of the number of tankers in a week i.e., during the month of July 2004.

The municipal water supply is not adequate (Times of India 2004). There is still a wide demand-supply gap in water supply. All remaining water demand is dependent on groundwater resources. The decline in the water table has resulted in an increase in the salinity of groundwater in built up areas. The brackish groundwater available in the area is converted into fresh water by RO water maker (purification systems) available in the market. According to a sales manager of '*Life care systems*' that is one of the main providers of such water systems in the area,

> "Over the last few years there has been considerable rise in the demand for water purification and treatment system in this area. The company was earlier selling simple water filter and purification systems. In the 1990s we sold 1-2 simple water purification systems in a week or more. But in the last few years there has been a lot of demand for reverse osmosis (RO) water purification systems that can treat salinity in groundwater. In the last few years on average

> 2-3 RO water treatment systems are being sold everyday. The system costs around Rupees 14,000/- including installation. A cartridge costing 600 Rupees needs to be replaced approximately every six months for water treatment using RO system at water users' end. The RO system is a small unit and can be installed in a kitchen before the water outlet to treat brackish groundwater".

The lack of adequate accessibility and availability of the service utility lead individuals and related public and private agencies to consider various resources to fulfill water requirements. These resources are directly or indirectly dependent on groundwater. These resources are based on different considerations such as availability, the perception of quality and the cost of water. These resources can be broadly divided under two categories - public and individual.

Public Water Supply

The main agencies involved in the urbanising area are DDA, DJB and various public and private institutions such as Delhi Metro Rail Corporation, Irrigation and Flood Control Department. Various other agencies are involved in the provision of physical and social infrastructure to support including private developers (hired by the agencies to execute civil works or have been allotted land for development of particular use or an activity such as development of commercial complexes). There is no centralised source of information regarding groundwater resources being utilised. The following paragraphs present the responses of key actors summarising DDAs' and DJBs' dependence on groundwater resources.

The Chief Engineer, Dwarka stated the strategies and sources of water and proposals to manage increasing water requirements of the sub-city in the next five years. He stated:

> "In addition to the water being supplied by DJB, DDA has 37 tube wells. At present 17 tube wells are working and used to meet domestic / non -domestic water requirements in the sub-city'. The remaining tube wells are abandoned due to poor quality of groundwater. In addition, plans are to install a tube well next to CT 2 and CT 4 to meet the crises and feed the network to maintain the required water supply pressure. Wherever in the development areas, if it is not possible to maintain the water supply in the piped network, plans are to fill tankers from these tube wells and supply water in the occupied households".

In 2004 of the 37 tube wells, only 17 tube wells were operational; 13 in Phase I and 4 in Phase II. In addition, the DDA Horticulture Department has seven operational tube wells in Phase I for horticultural and gardening purposes. Table 10 shows the number of DDA tube wells bored and operational at present. In 2004 DDA had 58 deep bore tube wells and 10 shallow tube wells.

Table 10: DDA Tube Wells in Dwarka Sub-City

Location	No of Tube Wells Deep Bore 50 -80 m.b.g.l	Number of Tube Wells Shallow Bore Less then 20 m.b.g.l	Number of Operational Tube Well
Phase I	47	6	13
Phase II	4	4	4
Total	51	10	17

Source: Office of Chief Engineer, Dwarka Sub-city (2004)

In order to fulfill the demand supply gap it is common practice for DDA to supply tube well water to users through water tankers or even mix the tube well with municipal water from the network (River Yamuna). Water tankers were sent mainly to various housing societies (discussed in the previous section e.g Table 8 & 9 of this Chapter).

The establishments in general arrange water from private tankers, private water vendors or depend on bottled mineral water (to be discussed later in this discussion). DJB is supplying tube well water to users with piped water connection to some regularised (earlier unauthorised) residential schemes in Phase I and the village *abadi* areas in the sub-city (discussed earlier). In 2004 DJB was supplying water from 176 operational tube wells (out of a total 208 tube wells). Phase I had 140 tube wells. It is important here to mention that 100 tube wells in Phase I were maintained by DJB to supply water to unplanned built up areas. Table 11 presents the number of DJB tube wells in village *abadi* areas and other unplanned built up areas.

Table 11: DJB Tube Wells in Dwarka Sub-city

Location	**Number of Tube Wells**	**Number of Operational Tube wells**	**Depth of Bore m.b.g.l**	**Depth to Water Table**
Phase I				
Nasirpur	4	2	60-70	50
Palam	11	8	60-70	50
Bagrola	3	3	50-55	45
Amberhai	4	4	30-40	40
Sagarpur	12	11	70-80	60
Dwarka - Sector 1 (5), Sector 7(4), Sector 8 (3)	12	12	40-60	40-50
Other	74	100	70-80	50
Sub - Total	168	140		
Phase II				
Kakraula	5	3	40-50	30
Dhulsiras	4	4	30-40	10
Bharthal	6	6	20-30	20
Pochanpur	2	2	30-40	20
Bamnoli	3	3	25-30	10
Others	20	18	30-40	10-20
Sub-Total	40	36		
Total (Dwarka sub-city)	208	176		
Total (Najafgarh Zone)	240	228		

Source: DJB, World Bank Cell (2004)

Private Water Suppliers

In spite of the DDA and DJB arrangements of municipal water supply from network and tube wells there is always a demand-supply gap. Private vendors take advantage of insufficient public water supply. Figure 8.40 shows private water tankers being filled at private water vendors and tube wells in Kakraula village Phase II. According to a private water vendor in Kakrola village (Phase II) (explaining the mechanisms and private water supply scenario in the sub-city):

> "In Dwarka there are five private tube well water suppliers. I am one of them and I run a tube well that was installed in 1980 at a depth of 30 mbgl. The water table has remained constant and the quality of groundwater is good from the day of installation. I take Rs. 50 per tanker for filling the water tanker. On an average I fill 5-6 water tanker every day. I am informed that the contractor or tanker owner sells the water for Rs. 400-500 per tanker from households or from the builders".

In addition offices, shops, restaurants and other small establishments have come up in the sub-city. However, there is no municipal supply from the network mainly to such premises. Private water suppliers sell purified drinking water in small plastic containers. A property dealer (real estate developer) provided an overview of private drinking water supply to establishments:

> "All over Dwarka sites are under construction for households and establishments using the tube well water drawn on the site itself or from water tankers provided by private water vendors selling water from tube wells to residential areas. After completion of construction the tube well water quality is observed to be unfit for drinking purposes due to an increase in salinity with deep bored tube wells. For drinking water a large number of establishments depend on private water vendors. The source of this water is tube well in the sub-city or in the vicinity that is treated (filtered / purified). The purified water is supplied in plastic containers or flasks that also keep the water cold to establishments and is sold for around Rs. 15-20 per container of 20 litres".

Figure 28 shows the cycle rickshaws with plastic containers and flasks filled with purified / filtered water being supplied by private suppliers to smaller establishments.

Figure 28: Private water supply to establishments

a) Non- domestic water supply for establishments by private supplier
(the plastic containers on cycle rickshaws filled with water sourced mainly from tube wells located in and around the area is common sight in the sub-city).

b) Domestic water supply to small establishments / offices by private suppliers
(the plastic containers / cool jugs [12-15 litres capacity] filled with filtered water mainly from tube wells located in and around the area is common sight in the sub-city).

According to Executive Engineer, DJB (Najafgarh zone),

"DJB has given no assurance of additional raw water availability before 2008-09. In spite of the sub-city already reeling under acute shortage of water, DDA is going ahead with the development of residential schemes and other developmental works in Phase II. It is estimated that DDA has around 6,000 apartments constructed and ready for allotment".

Executive Engineer DDA confirms this and states,

"In Sector 16-B about 4000 houses are ready and allotted to various government departments i.e., BSF, C.I.S.F, Delhi Police etc. But residents have not shifted as there is no water supply. Sector 16 B is fed through CT 5 networks for which the tender was recently floated and the selection of contractor to execute the work is under process. The whole process will take considerable time and till such time as the DDA can not afford to keep these flats vacant, investment will be blocked.

We are looking for alternatives for potable water. The villagers of nearby Kakraula village and others have inquired about old wells from where they were taking drinking water. Groundwater quality tests reveal potable groundwater at shallow depth along Najafgarh drain is informed to be fit for drinking after treatment. The data on groundwater and local enquiry reveals we can meet 50 percent of the drinking water requirements of these 4000 flats by installing tube wells on the site of these wells. Before supplying the water we propose to give chlorination treatment and make it fit for drinking. The total cost of the project is estimated to be around 35 lacs. Till Dwarka WTP is ready we are planning to connect CT 5 and CT 4 with a separate line. Tenders are likely to be called shortly. The proposition is costlier and likely to be not in use at a much later date when DJB makes water fully available ".

Apart from village *abadi* areas and unauthorised developments that are solely dependent on groundwater, planned developments too are relying on groundwater as an important source of water supply. According to Director, CGWB (Delhi State Unit):

"In the absence of adequate supply of municipal supply from network increasingly all water requirements are directly or indirectly being met from groundwater resources. We have submitted a proposal to develop groundwater on sustainable basis. This would also help us regulate and monitor any further groundwater extraction in the sub-city. The scheme proposes to get 5 mgd water through 70 shallow tube wells along the Najafgarh drain and another 5 mgd of fresh to marginal water through 70 tube wells with the sub-city. The extracted water will feed the same water network line alternately".

CGWB emphasises the point that the project would limit the indiscriminate abstraction of groundwater by individuals and agencies. However the Director, Planning (Dwarka) stated that "the proposal by CGWB is not yet subject of study from the DDA" (Personal communication 2004).

The analysis and discussion in this chapter are based on data obtained from secondary sources, GIS superimposition as well as interviews with water users and experts (triangulation). The triangulation and mixed methods helped in obtaining information on the unaccounted and underestimated role of groundwater in the complex and multidimensional process of urbanisation (various stages of development). The superimposition helped in understanding the relationship and inter-dependability of urban development and groundwater. The interviews and data combination from public and private agencies and individuals highlighted the complexity involved in addressing sustainable use of groundwater in urbanising areas. The detailed analysis of planned and unplanned household and establishments through various stages of urban development underlined the importance of enormous heterogeneity in settlement type and importance of micro level analysis in urban planning and development. Key actors having knowledge about the research area provided insights into the historical context and the hydro-geomorphological characteristics of the area. Experts from autonomous agencies like INTACH and CGWB (involved in micro level interventions such as designing strategies to improve the current situation and addressing concerns of sustainable groundwater water management) provided evidence of the lack of insights at a micro-level in the current urban planning process. The analysis therefore provides enough evidence to understand urban development and planning in the sub-city as well as Delhi and its peri-urban areas.

6 Conclusions

6.1 Summary

The research aimed to examine the role of groundwater in the urban development of Delhi (past, present and future) and its peri-urban areas. In order to achieve the aim of this research several objectives were identified (Chapter One).

The key assumptions that were to be tested in the research were as follows:

- Planning for the development of groundwater resources requires information on the hydrological and geological aspects of the region. Characteristics of the aquifer systems are not the same in all places.
- Urbanisation- induced changes in land use affect the quality as well as quantity of groundwater. Urban growth and development in Third World cities (particularly in India) is being sustained using groundwater exploitation.
- Sustainable development of groundwater can be achieved using preventive approaches such as urban planning. Decisions based on the best obtainable detailed scientific information offer a hope for sustainable use of groundwater in urban development.
- Effective groundwater management in urban areas requires understanding of water-related information of the city vis-à-vis existing urban and regional planning as well as future growth.

Given the nature of the research, both qualitative and quantitative approaches are important and useful. This led to a selection of a "mixed methods" approach to develop a research framework to consider research questions (discussed in the following section). The research design adopted a stage-wise transformative process of mixed methods. The approaches associated with field methods such as observations, document analysis and interviews (qualitative data) were combined with water user surveys (quantitative data) and employed to overcome biases and limitations through triangulation of various data sources.

The literature highlighted that each city carries its (urban) planning at various levels within its political and administrative boundaries.

This research argued that urban planning is a statutory set of guidelines which provides a conception of the spatial arrangement of identified city-wide land uses. Urban planning is a very effective preventive tool in addressing the problem of over-exploitation of groundwater in the Delhi metropolis. This problem is attributed to an unreliable water supply from the long distance transfer of water. This situation led the author to examine the planning efforts in NCT Delhi and its peri-urban areas.

Exploration of this inquiry involved reviews of the planning efforts in NCT Delhi since the first Master Plan (MPD 1962). The review aimed to identify: provisions for water supply; provisions for groundwater protection; and groundwater management as a source of existing or future water supply. This review was used as a baseline for analysing the main problems related to groundwater in the study area.

The main issues are summarised as follows:

- Over exploitation of groundwater resources (rapid fall of the water table as well as deterioration of groundwater quality in this region) during the past fifty years. It showed that in the past 15-20 years the area of maximum decline is in the city as well as the immediate urban extensions on the fringe undergoing transition (rural to urban).The situation was worse in the burgeoning urban extension as it is located at the tail end of the piped water supply system.
- Present urban planning processes lack balance with existing urban growth and development of the urban agglomeration of Delhi. Land use planning has failed to integrate areas with specific hydro-geomorphological characteristics that determine groundwater availability or sometimes even limitations of the aquifer in an area.
- The unplanned village *abadi* areas and unauthorised developments are outside the planner's remit. In terms of water supply and management the present and future water requirement of these areas is not accounted for. In particular it highlighted the lack of vision and non-existence of an integrated policy of urban development and groundwater resources management in the NCT of Delhi.

It is also worth mentioning the limitations of the research. The first limitation is related to availability of data in order to understand interdependency and inter-relationship of groundwater with urban development in NCT Delhi. The CGWB monitoring results are based on national hydrograph stations (in case of NCT Delhi 27 dug wells and 56 piezometers are taken as control points). The depth of water table, water fluctuation and availability of potable groundwater information based on monitoring results from these control points is used to estimate the utilisable groundwater reserves in the NCT Delhi and its peri-urban areas. The information on increase in the built up area available from land use information from Master Plans or Regional Plans for the nearest time period was superimposed using G.I.S over planning zones to develop the research propositions.

Second, there was limited information from document analysis (CGWB reports, Master Plans or Work Studies) which could be used to support inter-relationship and interdependency of groundwater and urban development process. For example the Master Plans lacked information related to unauthorised or unplanned developments. Water supply norms and standards used for projecting water infrastructure in Master Plans do not include unauthorised or unplanned development area. The document analysis established that all sources of municipal water augmentation were proposed to be mainly from distant reservoirs located in neighbouring states. The resulting water demand-supply gap is being met from alternative sources of water mainly, from *in-situ* groundwater resources. The water demand-supply gap of planned water requirements is being met by both public agencies and individuals from various groundwater sources. MCD water supply in the village *abadi (rural or urban villages)* areas is also from groundwater sources; shallow hand pumps or tube wells.

The solutions presented to tackle the problem of over-exploitation of groundwater in NCT Delhi have so far been largely remedial (such as setting up an authority, declaring a ban on further boring) rather than long-term and proactive and preventive measures such as urban planning, resource management and protection of groundwater.

It was crucial to make a case for sustainable groundwater management by documenting and highlighting the systemic role of groundwater that has been, many a time, unaccounted and underestimated. Groundwater must form an integral part of Delhi's urban planning and development process. This setting gave place to the main concern:

Is there a systemic consideration for groundwater in various stages of urban development (in both planned as well as unplanned-unauthorised and illegal areas and land use type)?

Dwarka sub-city was taken as a model to evaluate the systemic role of groundwater in stages of urban development. The investigation of this enquiry was based on G.I.S techniques using overlay techniques for micro level analysis of groundwater information available on

Dwarka sub-city from CGWB. The analysis highlighted that the increase in built up area affects both the quantity and quality of groundwater of underlying aquifers as follows:

- The water table fluctuations were considerably high (0-2 mbgl to 4-8 mbgl and even above 8 mbgl) during rural and early transition stages of urban development and the decline in water table corresponded with the increase in built-up area.
- Fresh water was available at shallow depths during the early transition stages of urban development and by the time the proposed developments were nearing completion, only brackish water was available in the sub-city.
- Electrical conductivity had increased as high as above 4000 mhos/cm (harmful) during the late transition stage.

It was clear that the role of ground water in urban development is enormous, but tends to be underestimated. These concerns were analysed with the help of a questionnaire survey of water users and key actors. The triangulation of quantitative and qualitative data helped the research study in understanding the role of groundwater in urban development of NCT Delhi and its peri-urban areas.

The analysis of planned and unplanned households and establishments through various stages of urban development in Dwarka sub-city underlined the importance of enormous heterogeneity of the settlement type in urban planning and development. The interviews and data combination from public and private agencies and individuals highlighted the complexity involved in addressing sustainable use of groundwater in urbanising areas. The detailed examination of the relationship and inter-dependability of urban development and groundwater in Dwarka sub-city at a micro level underlined the distinctiveness and complexities associated with urban dynamics in the study area that encompasses planned developments co-existing with unplanned and unauthorised developments unique to the study area (but not integrated as baseline data by urban planners).

Chapter 5 highlighted that the major water requirements in an area in transition e.g. construction sector water requirements are not even accounted for while planning for future water requirements in the NCT Delhi. The construction water requirements of both planned and unplanned or unauthorised developments are solely being met from *in-situ* groundwater. Furthermore, households or establishments occupying the developed area cannot switch over to river-based piped water supply. As discussed earlier, this problem is largely due to unreliable water supply from the long distance transfer of water. This explained why groundwater withdrawal that significantly exceeded the rates of recharge within the city as well as in the fringe areas was being developed as a planned urban extension in NCT Delhi. *It was clearly evident that urban development has not been accompanied by primary infrastructural changes such as water supply.*

Experts from autonomous agencies such as INTACH provided evidence of the lack of insights at micro-level in the current urban planning process. The successful demonstration of the feasibility project by INTACH e.g., water augmentation through on-channel and off-channel storage using the Najafgarh Drain and its catchment areas adjacent to Dwarka sub-city established the importance of understanding site-specific hydro-geomorphology and the missed opportunity by planners to promote sustainable utilisation of groundwater as an important source of water supply.

Fundamentally, the reason for using Dwarka sub-city as a model was a lack of full access either in time or space to the phenomena of interest and for guiding further study. It can be argued that, in principle, the model fitted in the contextual framework. Dwarka sub-city offered substantial evidence for strengthening the research frame established for understanding the phenomena in NCT Delhi and its peri-urban areas. According to the research frame, , understanding urban phenomenon requires not only theoretical influences but also experiential influences of the city's inhabitants and key actors (including policy makers). This justifies the methodological design used in this research which established linkages between activities, processes or interlinked levels of analysis to gain an interdisciplinary and holistic knowledge of the issue. This is contrary to just quantitatively measuring parts of urban development or sub-surface environments at particular point(s) in time to make predications about future state(s) for more sustainable development in urban context. This frame setting led to the next main concern:

How can current land use planning incorporate sustainability of groundwater in the planning of NCT Delhi and its peri-urban areas?

The policy options and interventions emerge not only from the issues and potentials discussed in previous discussions, but also from the general observations and experiences gained during field studies. In light of the complexity of decision making processes, it is clear that changes need to be adopted at all levels of the urban planning process. The following section includes recommendations that can be adopted to make urban development/planning more effective to address sustainable groundwater management.

6.2 Some recommendations

- The catchment planning approach can be used to draw up long term development perspectives. The planner should have at least an indicative urban development scenario vis-à-vis water availability in the region. Neighbouring states located in the River Yamuna basin are also dependent on river water for future water augmentation for the town and cities in respective of states that are rapidly urbanising. Each basin state has its share of river water. Delhi is already overdrawing its allocated share of river water in the River Yamuna sub-basin. Any additional water supply to inhabitants of Delhi is a serious inter-state issue. *Urban planning strategies should be developed or modified and promoted based on the knowledge of the constraints in river catchment area and future prospects of water supply from the river.*
- Groundwater is an important source of water in Delhi and its peri-urban areas but water provision in the Master Plans or Development plans have focused primarily on making use of functional aspects of centralised water systems, such as water intake and discharge, storage and treatment mainly dependent on raw water from the river. Past planning efforts have been chosen on the basis of insufficient knowledge and urban development and has taken insufficient account of local hydrological conditions. This means that it is not useful to develop generally applicable methods (norms, standard or development controls) for the entire NCT; rather *the characteristics of a natural system in (both over surface or sub-surface) each location should form the starting point for any further urban planning or development in the NCT Delhi and its peri-urban areas.*
- Water storage, habitat creation and natural water treatment need to be combined with new urban developments. This will benefit not only land use activities but also recharge the aquifer and the environment.
- Urbanisation results in more areas becoming concrete resulting in shrinking capacities for land to retain water. The Master Plans and Zonal Development Plans should designate 'protected groundwater recharge zones'. The areas with groundwater prospects can be reserved for 'clean' land uses such as nature conservation, forestry and organic farming, which may also be combined with light forms of outdoor recreation.

- Water supply norms and standards and infrastructure are commensurate with different stages of urban development. The stage of development of an area is important as the land development process may take 10-15 years or more before housing, establishments and related service infrastructure is developed. This research highlighted that groundwater is an important source of water for domestic as well as non-domestic water requirements. The role of groundwater in urban development as an important source starts along with land development (planned and unplanned or unauthorised). Construction bulk water requirements are solely met from in-situ groundwater sources but are not even accounted for in planning provisions in the Master Plans or Development Plans. *For sustainable development of in-situ groundwater the need is to integrate important but unaccounted for construction water requirements solely being met from groundwater while calculating the projected water requirement in an area.* Accordingly, planning provisions need to be made for water supply infrastructure. *The study of Dwarka sub-city highlighted that groundwater is not only an important supply of domestic water for the projected population but that the role of groundwater in each stage of urban development is not necessarily correlated to the size of population.* There is a need to evolve a planning provision in the form of norms and standards for calculating water supply requirements and development of related infrastructure depending on the development stage of the city and the area under development. The actual measures taken should depend on the hydro-geomorphological characteristics of the site and prevent withdrawal of *in-situ* groundwater resources beyond unsustainable limits. The development plan should estimate water requirements in each stage of development (rural/early transition to urban); identify local sources of water supply and groundwater development potential.
- Baseline data that encompasses planned and unplanned or unauthorised development is of critical importance. Urban planning exercise is as good as the baseline data used in evolving various policies and provision. The unplanned or unauthorised development in NCT Delhi is a ground reality and cannot be undone. *The establishment of baseline data that encompasses a complete picture with all planned and unplanned or unauthorised development is of critical importance in evolving more integral forms of urban planning to address groundwater protection and sustainability of groundwater as an important source of existing and future water supply in NCT Delhi.* The data (both quantitative and qualitative) yields a set of norms which establishes the minimum requirements for sustainable and healthy living in pursuit of sustainable urban development.
- Urban Planners can intervene in the development process through three main instruments – plans, control and promotion for a superior basis for decision

making. *A technician-planner with communication and mediation skills can successfully integrate scientific information related to groundwater and prepare a land use plan sensitive to sustainability of groundwater, and on the other hand engage with administrative mechanisms for changing the current state of affairs.* For example: the lack of communicative and mediating skills in the planning team involved in preparing the draft Development Plan for Dwarka sub-city failed to incorporate the core imperative 'zero-runoff concept' that could have helped change the current state of affairs with regard to water supply in the sub-city and timely address the concern of sustainability of groundwater in the sub-city. The need is for the planner to be an educator, facilitator and an interventionist. This can lead to participatory governance as well as help in evolving evidence based planning policies or provisions.

- Institutional, regulatory and legal mechanisms should be put in place for proper integration between urban planning and groundwater management. The exemptions provided by MCD should be re-examined to prevent large scale unauthorised constructions and misuse of lands in rural areas both within and outside *laldora.* DDA should exercise wider powers of regulation and control over newly urbanising areas (urban extensions) and the urbanisable area designated under the Master Plan. The study of Dwarka sub-city has clearly highlighted that land management policies and regulative measures must be clearly regulated. Further, existing multiplicity and overlapping of responsibilities between organisations concerned with land and water/groundwater management and the regulative mechanisms should be avoided. It would be useful if the Master Plan and Development Plan recommended clear action oriented policies to regulate land use, building activity, identify sources of water supply and the required infrastructure in the context of the following stages of development:
- Period prior to the Gazette notification of the Master Plan Delhi (MPD)
- Period between MPD notification and issue of notification for acquisition of land.
- Period between notification for land acquisition and actual completion of the acquisition process.
- Period between the start and completion of project development work.
- Period after completion of project development work and handing over of the area to MCD (or in case of water supply to Delhi *Jal* Board) for maintenance.
- DDA should extend its powers to control and regulate conversion of land use, building use and building construction activities within the village *abadi* areas, which are included in the DUA from the date of Gazette notification of the Master Plan. This is most crucial in the process of urban development as due

to village abadi areas' proximity to the urban area, speculation and unplanned and haphazard development is a common phenomenon. It was clearly evident from the study of Dwarka sub-city that urban villages come within the purview of the Delhi Municipal Corporation Act, 1957 and its amendment in 1994. MCD should delegate village *abadi areas* (urban village) to DDA for planning and design of infrastructure for eventual integration with the overall network. Further, the provision and up-gradation of infrastructure should be commensurate with the stages of transformation. The urban village and its acquired lands should be handed over to MCD for maintenance only after the completion of their development. This may prevent confusion between a frequent change of jurisdictions. The system of plan preparation and implementation should have periodic reviews to ensure linkages and integration of various functions, for example of local to metropolitan to city level and the regional context, to ensure integration and development of appropriate sources of water supply.

- Publicity of groundwater and urban development issues is important for generating awareness amongst citizens of Delhi. Master Plans or Development Plans comprise of development controls which can be used to encourage development (by allocating land for specific uses) or prevent (designating land as potential groundwater recharge area that needs to be protected). Development promotion by print and electronic media may be utilised to make people of NCT Delhi and its peri-urban areas aware of groundwater protection through urban planning as a step forward to enabling sustainable existing and future water supply to the area. The citizens or water users should be informed more about:

  the common man's duties, rights and responsibilities.

  Development Plans and Development Process, Land development process - changes and land values

  Potential groundwater recharge areas that will ensure sustainable municipal supply.

  Periodic status of review of water supply and related infrastructure

  Organisations involved in land and groundwater management with their function and responsibilities (including purpose and need for monitoring and regulation) control.

The suggested interventions in urban planning establish that sustainable groundwater development and management cannot be seen as a technical exercise. The integration of land and water management in NCT Delhi and its peri-urban areas require bridging the gap between disciplines, between competing water requirements of different sectors and water user groups, divided jurisdictions and attitudes, and differing values. The urban planner has to mediate in conflicts through design of land use planning solutions. This can lead to sustainable groundwater management and development as an important source of water supply with rapidly increasing water requirement in urban agglomerations of Delhi.

6.3 Wider contributions of the research

The objectives in this research have centred on the analysis of unique phenomena in a selected study area, but a number of empirical observations may have wider contributions. The pattern of urbanisation in Asian countries has been documented by Kasarda and Crenshaw 2006; Cohen 2004; Drakasis-Smith 1995 and discussed in chapter 2. The existing literature on urban environment problems in developing countries by commentators such as Vlachos and Braga 2001; Bossel 1999; Satterthwaite 1999 and Drakaksis-Smith 1995 at the macro level attempts to explain the consequence of rapid growth and the lack of provisions of basic services. However, they failed to adopt a holistic approach towards understanding the urbanisation process in developing countries.

This research based on field observations at both a macro and micro level contributes towards developing a better understanding of sustainable development in the urban context in a holistic manner. The empirical observations explain the urban dynamics and large scale changes in cities of the developing world that are continuously taking place over space and time. The existing literature on groundwater in urban environment in developing countries by scholars like Foster (1993); Khazai and Rigi and Morris (2003) and few others set out the need for understanding the nature of the relationship between groundwater and land use planning in the urban area. This research successfully brings out the unaccounted for and underestimated role of groundwater in urban development. The research contributes to the existing literature that highlights the need for addressing the root cause i.e., developing more integral forms of urban planning as intervention in urbanising areas for sustainable urban development such as sustainable use of *in-situ* groundwater resources.

6.4 Areas for further research

Over-exploitation of groundwater has led to the paradoxical situation of non-sustainable development of a scarce natural resource. This research explored the inter-dependency and inter-relationship of groundwater and urban development through various stages of transformation (rural to urban) to make a successful case for evolving a water sensitive urban planning process as a preventative approach for optimal development of *in-situ* groundwater resources in NCT Delhi. For planned development of any resource, its quantity and quality assessment in space and time is the prime pre-requisite. The refinement in the assessment of groundwater resource and the review of planning approaches and its update should be a continuous process. This research is only a starting point and should be treated as a base for further refinement and updates which are so essential in dealing with any dynamic resource like groundwater in the urban context - intrinsic complex and inter-related situation.

This research is the first attempt of its kind to give a comprehensive and realistic picture of unaccounted for and underestimated role of groundwater in urban development in NCT Delhi. Dwarka sub-city as a model supported by responses of water user (discussed in Chapter Five) succeeded in establishing that groundwater has played and will continue to play a key role in urban development of NCT Delhi and its peri-urban areas. The study has limitations of CGWB data that was used to develop assumptions and inadequate water responses due to sensitivity associated with the research topic. Further research can be extended by more observations regarding groundwater characteristics from data that can be collected by an increase in monitoring stations. To start with the various public agencies with groundwater extraction mechanisms could be used for monitoring groundwater for a select time period to build or modify (if required) assumptions regarding role of groundwater in urban development. Apart from the main land development agency DDA, several other public agencies such as DDA, DMRC, PWD, IF&FC are involved in the withdrawal of groundwater and can be useful as a monitoring station for a select time period. Further research should focus on a smaller area (maybe a planning zone) with exploratory wells to monitor groundwater characteristics. To overcome the sensitivity associated and the increased output of required information that would help in arriving at some precise quantification of groundwater usage for different activities, it would be useful to allow more time for extensive pre-testing of questionnaires. It might be useful to explore other social enquiry techniques such as focus groups (known for encouraging participation from people reluctant to be interviewed or who do not want to share information on their own) to reduce the high input to output ratio involved in arriving at accurate information due to the sensitivity of research topic.

This research will help urban planners in understanding the significant but under-estimated and unaccounted for role of groundwater in urban development and planning of

NCT Delhi. The present research has provided the first reliable and corroborating insights to back-up superior decision making for adopting changes in the existing planning process in favour of water sensitive urban planning in NCT Delhi. It should be noted, however, that this case study also seeks to provide a theoretical and analytical contribution with more general applications. Although the research is not representative of all South Asian cities or even India but the conceptual and methodological approach used may have wider implications in similar situations.

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Appendices

Appendix 1: Government of India –Delhi Gazette (No.37 Delhi Thursday September 1292/ Bhadra 21, 1985)

Delhi Administration

Published by Authority

Part I

Notification of Departments of the Delhi Administration other than Notification indicated in Part I.

(Municipal Corporation of Delhi)

Delhi, 24 August 1963

No.MMI/1731- In exercise of the powers conferred by sub-clause of clause (b) of Section 507 of the Delhi Municipal Corporation Act, 1957(66 0f 1957), the Municipal Corporation Delhi has with the previous approval of the Central Government, exempted the rural area from the provisions of the said Act mentioned in column 2 of the schedule given below to the extent given in column 4 of the said schedule.

The said exemptions shall be deemed to have come into affect from the 19th day of November, 1959.

Schedule

S.L.No.	Sections	Brief Description	Extent
1.	332, 333, 334, 335, 336, 342 and 347	Building Regulations	Only such portions of the rural areas as lie within the village *abadis* as defined in the revenue records (*firni*), provided that the exemption shall not apply to factories, warehouses, cold storages and slaughter houses.
2.	339, 420 and 421	Registration and control of dogs, licensing of butchers, fish-mongers and poulterers licensing of hawking articles etc., and licensing of eating houses etc.	The entire rural areas
3.	408	Licensing of markets.	Only such portions of rural as lie within the village *abadies* as defined in the revenue records (*firni*) provided that the exemption shall not apply to the (a) premises used for carrying out any of the trades or ration connected with trades mentioned in part leaf of the Eleventh Schedule to the Act, where more than 10 persons are employed; (b) That storage of articles mentioned against items 15, 53, 54, 55 of part II of the Eleventh Schedule be not exempted in the village *Abadi.*

Source: Land and Building Department, GNCT Delhi (2004)

Appendix 2

I) Dwarka Sub-City: Stages of Approval

S.No	Stage	Approving Authority	Date/ Year
1	Declaration of Development Area 171		8-06-1987
2	Declaration of Development Area 172		20-07-1988
	Approved Change of Land use Ph.I		30-01-1994
	Approved Change of Land use Ph.II		16-10-2000
3	Approval of Development Plan Dwarka	DUAC	04.09.1990
4	Change of Landuse Notification for Ph. I	MOUD	06.11.1993 & Corrigendum 30.08.1994
5	Change of Landuse Notification for Dwarka Ph.II	MOUD	16.10.2000
6	Zonal Development Plan (Zone - K Part)		
	a) Discussion TC, vide item 51/98	DDA	01.09.1998
	b) Approved by DDA vide item 7/2000	DDA	09.02.2000
	c) Objections / Suggestions received vide Public Notice	DDA	24.04.2000
	d) Screening Board	DDA	24.12.2000

II) Project Development at a Glance – Status at Glance 31.12.2004 (Source: DDA, 2005)

A) Location Phase - I in DDA Development Area No. - 171 & Phase - II in DDA Development Area No. -172

Bounded by -

Najafgarh Road and Pankha Road	North
Delhi- Rewari Railway line	East
Bijwasan Road	South
Najafgarh Drain	West

B) Area

Phase I (including Builtup)	3652 Ha.
Phase II	1996 Ha.
Total	5648 Ha.

C) Population

Phase I	3.78 lacs
Phase II	3.40 lacs
Built-up Area	3.50 lacs
Total	10.68 lacs

D) Distribution of Residential Use	**Phase I**	**Phase II**
	(In percentage)	
CGHS	55	25
Resettlement	13	20
Institutional Housing	5	5
Alternative Plots	8	15
DDA Housing	19	35

III) Land Acquisition Status

Phase - I	:	Total Area 1964 Ha.
Possession taken	:	958.88 Ha.
Phase - II	:	Total Area 1996 Ha.
Possession taken		742.32 Ha. + 680 Ha.

Balance	:	277.10 Ha. (Part of revenue area of Village Bamnoli & Bijwasan is yet to he notified & Possession of part of built-up area is not taken by DDA.)
Built-up Area	:	Total 1688 Ha.
Built-up area/Village Abadi		
Denotified from DDA		
Development		
Area on 21/1/2002	:	1790.67 Ha.

Source: As per records of DDA (Dwarka Site Office) Planning office

Appendix 3

SL No / Revenue Village	1961	1971	1981	1991	2001
1. Amber Hai	491	660	876	1192	MCD(U)
2. Bindapur	1241	862	17,200(CT)	36,148 (CT)	MCD(U)
3. Dabri	765	1210	2226	16,405	MCD(U)
4. Palam	4609	16730	76730(CT)	98975 (CT)	MCD(U)
5. Sagarpur	45	1571	3051	4112	MCD(U)
6. Nasirpur	619	881	28,550(CT)	87,366 (CT)	MCD(U)
7. Matiala	855	1937	3374	14,002	MCD(U)
8.Shahbad Mohamadpur	2296	2824	3704	5206	MCD(U)
9. Mirzapur	218	330	638	Uninhabited	-
10. Togan pur	122	7	876	Uninhabited	-
11.Loharheri	76	94	0	Uninhabited	-
12. Pochanpur	752	973	1415	-	MCD(U)
13. Nawada	946	1284	3833	18,100	MCD(U)
14. Bagdola	726	1026	170	2,108	MCD(U)
15. Barthal	1677	2521	3085	3,508	MCD(U)
16. Bamnoli	705	998	1376	2,209	MCD(U)
17. Dhulsiras	670	979	1311	1,815	MCD(U)
18 Kakrola	1589	2510	5769	8,284	MCD(U)
19.Bijwasan	3655	5791	CT	9439	MCD(U)
20. Sahupura	0	0	0	-	MCD(U)

Table: Population in Village Abadi Areas of Dwarka Sub-City

CT - Census Town (term coined by Census of India and classified as area with urban population.

Note – These villages have already been declared urbanised (under section 507 of Delhi Municipal Corporation Act 1957) adjacent to Delhi in Urban Extension Dwarka Project vide notification dated: the 24th October, 1994.

Source - Census of India 1981, 1991, 2001 and Development Plan for Dwarka sub-city

Appendix 4

Municipal Engineering Norms for Storm Water Drainage

According to the prevalent MCD norms the storm water drainage shall be designed by rational method using formula:

$$Q = A\ I\ R\text{, where}$$

Q = run off in cubic feet/ second

A = area in acres contributing to the point under design

I = co-efficeint of run-off of he area

R = average intensity of rainfall in inches per hour relating to two year

frequency and of duration equal to the time of concentration

The coefficient of run-off is calculated from tributary in each area to the point under design using the following values:

S.No	Type and Nature of Area	Run-off Factor
1.	Built up and paved areas (such as roads, streets)	0.90
2.	Green area (loomy)	0.30
3.	Green area (sandy)	0.20
4.	Unpaved area along roads	0.30
5.	Lawn and parks	0.15

Table: MCD Norms for calculating co-efficeint of run-off for the storm water drainage.

Source: Office of Chief Engineer, MCD (2005)

S.No	Type of Drain	Average Values of Run-off *
1.	Internal Drains	1 cusec/ acre
2.	Intercepting Drains	¾ cusec/ acre
3.	Main Drains	½ cusec/ acre

Table: MCD Norm for calculation of average values of run-off.

* These values have been worked out for rainfall intensity of 2.5 inches/ hour occurring once in two years.

Source: Office of Chief Engineer, MCD (2005).

Appendix 5: List of Experts and Key Players

a) List of Interviews of Key Government Officials (Delhi Administration, DDA, DJB, CGWB / CGWA and other agencies)

SLNo	Name	Designation	Place
1	Mr. Keshav Chandra	Deputy Commissioner (South West District)	D.C Office, Kapashera
2	Mr.Susheel Yadav	Sub Divisional Magistrate (Dwarka)	SDM office, Najafgarh
3	Mr.N.K.Gupta	Supertending Engineer (HQ) DDA	DDA(Dwarka) Project Office
4	Mr.H.S. Dharamsettu	Supertending Engineer (Dwarka), DDA	
5	Mr.Surinderjit Singh	Chief Engineer (Dwarka),DDA	DDA(Dwarka) Project Office
6	Dr.S.P.Bansal	Director (Planning) , Dwarka Project	DDA(Dwarka) Project Office
7	Mr.A.K.Jain	Commissioner (Planning) , DDA	DDA Office Vikas Minar
8	Mr.P.V.Mahasabdey	Director (MPD 2021)	DDA (MPD -2021) Office, Vasant Kunj
9	Mr. P.K.Tripathi	Chief Executive Officer (CEO), DJB	Delhi Jal Board (DJB)
10	Mr. Ashish Kundra	Additional CEO, DJB	Delhi Jal Board (DJB)
11	Mr. Uttam Kumar	Executive Engineer, DJB	Delhi Jal Board (DJB) World Bank Cell
13	Dr.S.B. Singh	Director (Delhi State Unit)	CGWB, Jamnagar House
14	Mr.D. Chakravorty	Scientist (Delhi State Unit) t	CGWB, Jamnagar House
15	Dr.Shasank Shekher	Scientist (Delhi State Unit)	CGWB, Jamnagar House
16	Mr. M.Rumani	Member Secretary, CGWA	CGWA Office Curzon Road
17	Dr.R.K.Mall	Scientist, CGWA	CGWA Office Curzon Road

b) List of interviews - (miscellaneous Key Players such as academic experts, consultants, NGOs, Builders/ Developers, Water Suppliers)

S.No	Name	Designation	Place
1	Dr.K.N.Bajpai,	Professor in Geology, Delhi University	at IARI PUSA, Delhi
2	Dr.P.S.Datta	Nuclear Research Lab, IARI	IARI , Delhi
3	Mr. Manu Bhatnagar	Advisor	INTACH, New Delhi
4	Mr.P.K.Jain	Former Engineer in Chief DJB and Consultant	Bahubali Extension, New Delhi
5	Mr.Ravi Gupta	Real Estate and Property Dealer-Gupta Properties	Dwarka
6	Mr.Sudesh Kumar	Water Tanker Supplier, Kakrola	Kakrola Village
7	A.K.Singh	Euro Aqua Sales Corp.	Dwarka
8	B.K.Sharma	Life Care Water Purifiers	Dwarka
9	Rakesh Singh	Aqua Royal Water Purifier	Dwarka