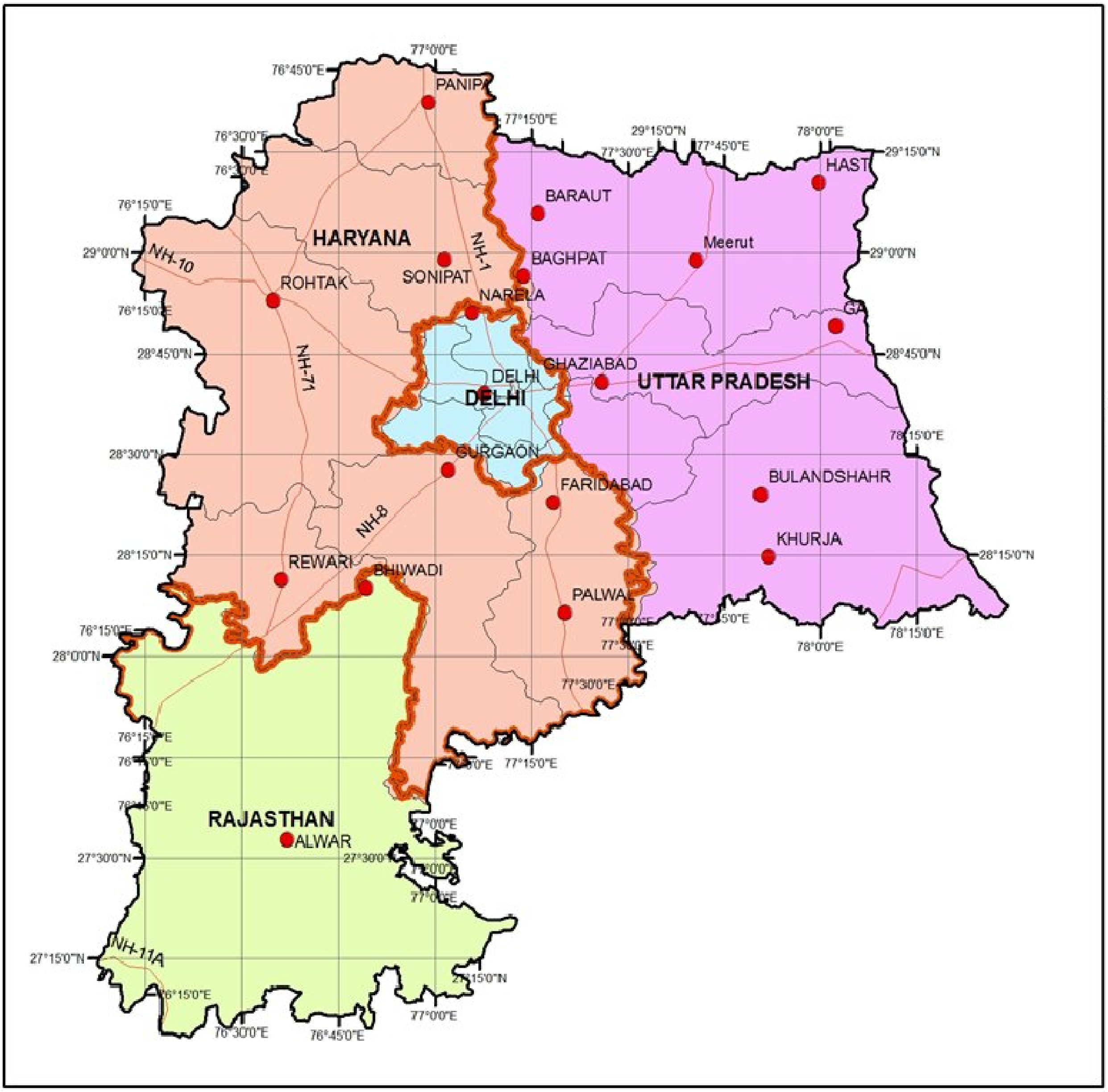
PROPOSAL FOR

GROUND WATER RECHARGE IN NATIONAL CAPITAL REGION (NCR)



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A COMPREHENSIVE PROPOSAL FOR GROUND WATER RECHARGE IN NATIONAL CAPITAL REGION (NCR)

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Executive Summary

The National Capital Region (NCR) covers an area of 33578 Sq. Km and includes parts of the states of Haryana, Rajasthan and Uttar Pradesh besides the entire NCT of Delhi. With growing population, the water supply has been a major issue for the region. River Yamuna is the major drainage and source of surface water in the area. Ground water is the second major for meeting its water requirements. Due to heavy withdrawal of ground water, water levels have declined in most parts of NCR and alarmingly in NCT of Delhi.

In the NCR matching long-term withdrawals of groundwater to recharge is the principal objective of sustainable groundwater resource planning. Maintaining the water balance of extraction and recharge is vital for managing human impact on water and ecology. Management of groundwater resources, projecting the future development possibilities and socio-economic as well as environment impact assessment, can be achieved through effective implementation of water harvesting and artificial recharge measures.

Natural replenishment of ground water reservoir is a slow process and is often unable to keep pace with the excessive and continued exploitation of ground water resources in various parts of the country. Rain water harvesting and artificial recharge to ground water efforts are basically aimed at augmentation of the natural movement of surface water into ground water reservoir through suitable engineering construction techniques.

Evolving a groundwater recharge strategy appropriate to NCR needs to begin with an appreciation of the variety of factors that can contribute through various kinds of recharge structures. Harvesting of rain water and excess monsoon runoff which is going unutilized, to create additional ground water storage is the most attractive and technically feasible option. The sub surface reservoirs can store substantial quantity of water. Artificial recharge aims at augmenting the natural replenishment of ground water storage by methods of construction, spreading of water, or by artificially changing natural conditions. It is useful for reducing overdraft, conserving surface run-off, and increasing available ground water supplies. Recharge may be incidental or deliberate, depending on whether or not it is a bye-product of normal water utilization.

In addition, in the NCR area there is a large scope for reviving numerous small and medium water bodies, lakes by way of catchment treatment and de-siltation work. In the flood plain areas there is ample scope for induced recharge from river. Similarly, the areas surrounding the ridges may be duly treated to allow more and more subsurface recharge by way of constructing trenches and other suitable structure such as gully plugs, gabion structures etc. The people's movement needs to be sparked off for roof top rain water harvesting in urban areas.

The broad objective of the present effort is to formulate technically viable proposal enabling funding agencies to implement a comprehensive and scientifically viable water conservation, artificial recharge and rain water harvesting program in the entire NCR, on loan/grant basis. The implementation strategy will have active community participation and awareness generation programs.

The NCR area has been classified into various sub units based on administrative boundary and further on geomorphic setup so as to recommend technical viable options for rain water harvesting and artificial recharge. The primary classification is based on the administrative division represented in the form of Sub-Region i.e. NCT Delhi Sub-Region, Haryana sub–region, UP sub-region and Rajasthan (Alwar) sub-region.

The National Capital Region (NCR) is broadly represented by two distinct physiographic units, viz. i) the Alluvial plain and ii) area occupied by Quartzite ridges other than the flood plain areas along the major streams such as Ganga, Yamuna and Hindon. It is underlain by geological formations ranging in age from Pre-Cambrian to Recent. The Alwar group of rocks covers vast areas in the southwestern parts in Alwar district, parts of Rewari and Gurgaon district in Haryana and south-eastern parts of NCT of Delhi. Apart from the above mentioned Precambrian rocks, the entire area is occupied by Quaternary Alluvial deposits. The thickness of alluvial deposits in the northern, eastern, north eastern and south eastern parts is considerable whereas it is less in the remaining parts of the area.

Based on the available subsurface drilling data and hydrogeological parameters, the NCR can be broadly divided into three distinct areas. In the area adjoining Meerut, Panipat and Hapur fresh water aquifers exist down to 450 m depth and the tube wells yield 150 m^3/hr or more for moderate draw-downs. Bulandshahr, Khurja, Faridabad (Part), Ghaziabad, Noida and Loni fall in the second category of area with adequately thick fresh ground water aquifers down to 50 m to 300 m depth and are underlain by saline ground water. Tube wells in this zone yield 50 m^3/hr to 150 m^3/hr for moderate to heavy drawdown. In Noida, thickness of fresh water aquifer is very limited and the existing shallow tube wells yield very poor discharge. The remaining towns including NCT of Delhi fall third category having limited thickness of fresh water aquifers and hard rock aquifers. The yield from these aquifers is low to moderate (50 m^3/hr or less) for moderate to heavy draw-downs.

Ground water in the consolidated rock formations occurs under unconfined conditions and is restricted to the weathered and fracture zone having secondary porosity. Tube wells constructed in these formations have low yield prospects which are of the order of 5 – 20m^3/hour for appreciably large drawdown. In the major part of Uttar Pradesh, depth of water table lies between 5m to 10m. In Alwar district of Rajasthan, water table rests between 10m to 20m and in some areas, it is deeper than 20m.

The specific conductance of shallow ground water varies greatly in the NCR area from being as low as 290 micro siemens /cm at 25^o C to as high as 16,000 micro siemens /cm at 25^o C. In a major part of the area, the shallow ground water is fresh (EC up to 3000 micro siemens /cm at 25^o C). Areas with brackish quality of water (EC between 3000-6000 micro siemens /cm at 25^o C) occur in north western parts of Sonepat district, northern and north western parts of Rohtak district, northwestern and south western parts of NCT of Delhi, north-west and northern parts of Gurgaon district, western parts of Rewari district, southwest parts of Faridabad district and southwestern parts of Bulandshahar district. Saline ground water (EC more than 6000 micro siemens /cm at 25^o C) also occurs in almost the same areas as those of brackish water areas excepting Bulandshahar district. There are no saline ground water areas in the U.P. sub-region

As such the entire NCR area including Delhi State falls under the semi-arid climatic region. The average annual rainfall in the area varies greatly from as low as 300 mm in the western parts to about 850 mm in the central and north-eastern parts. The normal annual rainfall for Delhi sub region is more than 600 mm and that for the Rajasthan sub-region is more than 500 mm. Haryana sub-region is observed with normal annual rainfall to the tune of 650 mm while in Uttar Pradesh sub region it is to the tune of more than 700 mm. It is estimated that on an average year, 1.0212 BCM/ year of water lost from NCR due to interception and subsequent evaporation, out of which 0.8753 BCM/ year of loses takes place during monsoon period of year.

The total magnitude of rain water over the year is estimated for an average year. NCR receives 22542 MCM of water, out of which 16906.5 MCM of it precipitates during monsoon season. The monsoon season starts from July and ends by September. Maximum amount of rain water falls over the Sub-region of Uttar Pradesh. On an average year NCT of Delhi receives 907.3 MCM/ year of water in the form of rain fall. A portion of rain water falling over NCR infiltrates into the ground and another portion appears in the form of surface run-off.It is estimated that on an average, 6272.3 MCM/ year of water is lost (un-used) as surface runoff from NCR, out of which 4584.4 MCM/ year of it takes place during monsoon season of the year. The annual ground water availability for the NCR area has been worked out to the tune of 8.48 BCM and net annual extraction of ground water works to 7.58 BCM.

In the present report an attempt has been made to analyze the various inputs required for planning rain water harvesting and artificial recharge measures along with the constraints and present the viable options in terms of functional plan. The gist of regional wise functional plan is as below.

In the Haryana Sub Region of NCR, the entire geographical area has been broadly divided into seven typical units in order to suggest area specific water harvesting and artificial recharge measures. The major area types are rural, urban, abandoned quarries , agricultural fields and river flood plains other than major buildings in urban areas for which roof top rain water harvesting has been proposed. In the Rural areas the most viable option for water harvesting and recharge suggested is through ponds , the existing ponds may be desilted with provision of vertical shafts driven up to water level. Nearly 5000 such structures have been recommended to be institutionalized which may be able to recharge to the tune of 100 MCM of water in to the ground. Similarly, in the Urban areas, the park type recharge structures have been proposed. As per the existing information about existing number of park, nearly 3000 such structures have been recommended to be constructed , which may recharge to the tune of 150 MCM of water in to the ground. The Yamuna flood plain areas offer good potential for recharge adopting the basin and pit method. The basic idea is to conserve the flood water in the loose sands to allow more and more percolation. In this context around 150 Basin recharge structures and about 150 river recharge pits have been suggested to be constructed, the feasible areas within the flood plain has also been demarcated. It has been envisaged that by implementing the proposed plan, nearly a volume of 420 MCM can be augmented to ground water storage which can be suitably developed at the time of requirement.

National Capital Territory, Delhi Region occupies an area of 1483 Sq. Km. Out of this, about 145 Sq. km area comprising of weathered quartzite rock in the ridge. It has been proposed that approximately 250 trenches may be constructed along the ridges through which the rain water can be harvested, which may add to ground water to the tune of 2.5 MCM. Nearly 200 ponds with vertical shafts and 500 de-silting of ponds have been proposed in the area In an area of about 95 sq. km of flood plain within the NCT-Delhi area about 100 basin recharge structures and 100 River recharge Pits have been proposed in the flood plain area. A total of 300 abandoned quarries have been proposed to be restored and revitalized for channelizing the runoff in the Abandoned quarries which will able to recharge nearly 6 MCM to ground water . In the urban areas broadly two types of recharge structures have been proposed, a substantial quantity of rain water goes as storm runoff from the paved areas and roads, which can be harvested by constructing trenches with shafts, around 4000 such structures have been proposed in the entire NCT area. A total of 2000 Park Type recharge structures have been proposed in NCT-Delhi, combined together, about 140 MCM of water can be recharge to ground water after successful completion of these structures. The other important scope for water harvesting exists from the roof top of major Institutional buildings, schools, Industries and Govt. office buildings nearly a volume of about 30 MCM of water may be recharged to ground water through roof top..

The Uttar Pradesh sub Region in the rural areas desilting of about 500 ponds and construction of about 2000 vertical shafts has been proposed which will be able to recharge ground water to the tune of 70 MCM It is proposed to construct 75 each of Basin Recharge structures and River recharge pits in the flood plain area , area identified for recharge measures in Ganga flood plain In the Urban areas Parks can be utilized for water harvesting and by suitable modifications and constructing Park type recharge structures as discussed in previous chapters. A total of 1000 such structures have been proposed in the regions which will be able to recharge ground water to the tune of 50 MCM. Similarly, in the urban areas the Institutions, school buildings, hospitals and Industries can be used for roof top rain water harvesting.

Alwar Sub Region the recommended Functional Recharge Plan includes construction of trenches all along the 75 kms of fringe areas of Aravalis as well as in the upper slope segments, with a provision of backfilling with local boulders and pebbles. The lower order streams originating from the hills can be suitably trained and harnessed by constructing Check dams and gabion structures, a total of 600 such structures have been recommended. In the flood plain area of Sahibi river around 80 basin recharge structures and pits have been recommended. A total of 1250 Village ponds has been recommended for the region with a capacity to recharge 35 MCM of water to underground reservoir It has been estimated that an additional volume of about 181.5 MCM of water can be recharged in the sub region with the recommended structures.

The proposed functional recharge plan envisages construction of about 45,755 recharge structures in the NCR area which will be able to additionally recharge a volume of 1051 MCM of ground water in the aquifer with a cost of approximately 1823.48 crores. It is recommended that all the initiatives being taken up in NCR area related to water resources development which also include water conservation, rain water harvesting and artificial recharge may be converged and an integrated approach should be adopted by leveraging the advantages of each other's so as to achieve the desired objective in the best possible and efficient manner.

1. Background

1.1 Context:

The National Capital Region (NCR) covers an area of 33578 Sq. Km, It includes parts of Haryana, Rajasthan and Uttar Pradesh besides the entire NCT of Delhi. The spurt in urbanization in past few decades with urban growth rate increasing from 45.87 during 1971-1981 to 56.25% during 1991-2001, in addition to urbanizing the large number of rural areas has posed several associated environmental problems. The water supply has been a major issue for the region. River Yamuna is the major drainage and source of surface water in the area. Due to high pollution load in Yamuna and interstate water sharing issues, the NCR area is highly dependent on ground water sources for meeting its water requirements. Advances in technology have resulted in enormous increase in extraction of ground water, the world over, and NCR is not an exception, thereby disturbing natural ground water balance. Water levels have declined in most parts of NCR and alarmingly in NCT of Delhi.

Rainfall is the major source of ground water recharge, which is supplemented by other sources such as recharge from canals, irrigated fields and surface water bodies. The rainfall is unevenly distributed. The amount of ground water withdrawal and situation of low rainfall are factors responsible for overall stress on ground water. Groundwater resource management is not a new field of activity, some aspects have been practiced for a long time in our country. Traditionally, such practices have been developed one by one with time whenever the need arose, sometimes without fully recognizing the principles of ground water management. A wealth of professional creativity, however, has been accumulated in the numerous approaches and tactics for water management that have been developed over the years in several parts of the world.

Ground water resources development and related engineering activities have gained paramount importance as the risks from pollution to resource have increased year after year. As a result, the interferences are becoming more and more pronounced which brings about a growing need for integrated management of the resources. Progress in water resource sciences and improved computational facilities have paved the way to an integrated approach.

In the NCR matching long-term withdrawals of groundwater to recharge is the principal objective of sustainable groundwater resource planning. Maintaining the water balance of extraction and recharge is vital for managing human impact on water and ecology. Management of groundwater resources, projecting the future development possibilities and socio-economic as well as environment impact assessment, can be achieved through effective implementation of water harvesting and artificial recharge measures.

The need of the hour therefore is a long term planning for effective and efficient management of this precious resource as well as to bring in additionality to depleting water resources by adopting a holistic approach. Ground water management deals with a complex interaction between human society and physical environment and presents a difficult problem of policy design. Aquifers are exploited by human decisions and over exploitation cannot be always defined in technical terms, but as a failure to design and implement adequate institutional arrangements to manage people who exploit the ground water resources.

1.2 Need for Comprehensive Recharge in NCR

Ground Water as common pool resource has been typically utilized in an open access framework, within which, resource ownership is according to a "rule of capture". When no one owns the resources, users have no incentive to conserve for future, and self interest of individual users leads them to overexploit.

During the past decade (1993-2003) almost the entire NCR area has witnessed decline in ground water levels. The decline has been higher in areas underlain by fresh ground water as compared to areas having marginal to saline ground water. Steep decline in water level has been reported from Alwar district of Rajasthan and some parts of NCT, Delhi.

Natural replenishment of ground water reservoir is a slow process and is often unable to keep pace with the excessive and continued exploitation of ground water resources in various parts of the country. This has resulted in declining ground water levels and depletion of ground water resources in several areas of the country & NCR as well **(Fig.1.1)**. Rain water harvesting and artificial recharge to ground water efforts are basically aimed at augmentation of the natural movement of surface water into ground water reservoir through suitable engineering construction techniques. Such techniques inter-relate and integrate the source water to ground water reservoir and are dependent on the soil, topography and hydrogeological situation of an area. Occurrence of rainfall in NCR is mostly limited to about three months in a year, with the number of rainy days ranging from around 80 to 100. The natural recharge to ground water reservoir is restricted to this period only in a major part of the country. Artificial recharge techniques aim at extending the recharge period in the post-monsoon season for about three or more months, resulting in enhanced sustainability of ground water resources during the lean season.

Evolving a groundwater recharge strategy appropriate to NCR needs to begin with an appreciation of the variety of factors that can contribute through various kinds of recharge structures. Harvesting of rain water and excess monsoon runoff which is going unutilized, to create additional ground water storage is the most attractive and technically feasible option. The sub surface reservoirs can store substantial quantity of water. Artificial recharge aims at augmenting the natural replenishment of ground water storage by methods of construction, spreading of water, or by artificially changing natural conditions. It is useful for reducing overdraft, conserving surface run-off, and increasing available ground water supplies. Recharge may be incidental or deliberate, depending on whether or not it is a bye-product of normal water utilization.

As a matter of fact, artificial recharge is a process of induced replenishment of ground water reservoir by human activities. The process of supplementing may be either planned such as storing water in pits, tanks etc. for feeding the aquifer or unplanned and incidental to human activities like applied irrigation seepage from canal, lakes and ponds as well as leakages from pipes etc.

In addition, in the NCR area there is a large scope for reviving numerous small and medium water bodies, lakes by way of catchment treatment and de-siltation work. In the flood plain areas there is ample scope for induced recharge from river. Similarly, the areas surrounding the ridges may be duly treated to allow more and more subsurface recharge by way of constructing trenches and other suitable structure such as gully plugs, gabion structures etc. The people's movement needs to be sparked off for roof top rain water harvesting in urban areas.

1.3 Objectives of the proposal

The broad objective of the work is to formulate technically viable proposal enabling funding agencies to implement a comprehensive and scientifically viable water conservation, artificial recharge and rain water harvesting program in the entire NCR, on loan/grant basis. The implementation strategy will have active community participation and awareness generation programs. It has been planned to collate the proposal so as to give brief of various measures of rain water harvesting and artificial recharge, its role in sustainable management of water resources, implementation strategies and way forward.

1.4 Project Brief

The NCR is a water scarce region, but can have sufficient water if this resource is conserved and managed properly. The quantity of water available in NCR from surface sources such as canal transfers, share of NCR in the flood waters from upstream dams and reservoirs etc. is relatively fixed. Groundwater has emerged as a major source of water supply for drinking, agricultural, industrial & allied purposes in NCR. It is estimated that groundwater at present contributes about 6350 MCM/ year to the water needs of NCR and forms the third major source of water for NCR. At present, there is excessive pumping of groundwater in most districts of NCR. This over-exploitation has resulted in depletion and deterioration of both quantity and quality of the resource. It is estimated that over a year, the ground water reserves of NCT Delhi deplete by 190 MCM resulting in an average depletion of water table by 2 m per year, which is alarming.

Acceding to estimations of Central ground Water Board, 7 out of 9 blocks in NCT-Delhi, 25 out of 42 blocks in Haryana Sub-region, all blocks in Rajasthan Sub-region and 4 out of 45 blocks in UP Sub-region have been categorized as over-exploited or critical, which requires special interventions. Fresh water aquifers are under stress all over NCR. In some areas like NCT of Delhi and Alwar district, the water table has declined alarmingly, approaching more or less to a stage of complete depletion of the resource.

There is therefore an urgent need to increase ground water recharge to compensate for annual average deficit. It is imperative that a comprehensive strategy is formulated and massive programs of groundwater recharge is implemented to address the current and future demands.

The Regional Plan 2021 has put forward policies for conservation of water including protection of land for ground water recharging, recharge of aquifer, and creating public awareness. These would have to be translated into action plans, with suitable institutional & legal framework.

Recharging the dynamic ground water aquifers through different techniques is a feasible and sustainable method of increasing the availability of water for NCR and that too in a very eco-friendly manner.

The need for preparation of a plan for groundwater recharge for NCR was highlighted before Empowered Committee in its 3rd Meeting held on 25.02.09 and the following decisions were taken:

- All the constituent States of NCR would implement the policies of rainwater harvesting more effectively in their respective sub-regions and for that would consider changes in building bye-laws or a new legislation as needed. An Action Plan for Groundwater Recharge be prepared for rural and urban areas by the constituent States of NCR.
- The schemes of construction of check-dams for ground water recharging and "deepening of village ponds and lakes would be taken up by the constituent States under the existing employment schemes.
- Integrated Water Management Plans would be prepared by the constituent States including recycling of waste water for their respective district and sub-regions. Steps will be taken to conserve water, reduce losses and promote use of water saving flushing cisterns, etc. suitable public education campaigns as felt necessary would be launched.
- Each participating State would prepare a unified ground water policy in NCR and would ban ground water exploitation in dark areas identified by Central Ground Water Board. In this regard, the constituent States would adopt the Model Bill, which was issued by Ministry of Water Resources, Government of India in January, 2005 to regulate and Control the Development and Management of Ground Water in their respective Sub-regions.

In order to enable/ facilitate the implementation of these decisions by the concerned State Governments/ agencies, it was decided that NCR Planning Board may outsource the work for the preparation of a comprehensive proposal or master plan for groundwater recharge in NCR. NCR Planning Board has appointed **Dr S. K. Sharma, Ground Water Expert and Ex Member, Central Ground Water Board** to prepare this document.

1.4.1 Scope of Work

The NCR Planning Board has carried out a Study of Water Supply and Its Management in NCR through WAPCOS for which an Interim Report has been prepared. In this report the Consultant has carried out study with regard to groundwater recharging in NCR as one of the components. The Consultant would use this report to further elaborate the same to identify the projects for groundwater recharging and prepare a comprehensive & implementable groundwater recharging feasibility project report which could be posed for funding to various agencies. The Consultant would also carry out the study and surveys as necessary to fill the data gaps which would be required for the preparation of sustainable projects. The coverage would include the following:

A. **Need for ground water recharging**

B. Literature survey & database including:

- Review of the studies already carried out

- Documentation of work done, steps already taken, projects completed in both urban and rural areas for water recharging using different techniques like rainwater harvesting, recycled waste-water, flood waters etc.
- Detail description of success stories in NCR to achieve water harvesting in both urban and rural areas.
- Details of pending projects related to groundwater recharge and revival of lakes etc.
- Evaluation of impacts of on-going recharging efforts in NCR
- Evaluation of benefits of current recharging efforts

C. Groundwater Recharging in Urban Areas

- Examining existing building by-laws for roof top rain water harvesting in NCR States

  i. By-laws for new buildings

  ii. Legislation for new buildings

  iii. Legislation for old buildings

  iv. By-laws/ legislations/ instructions for groundwater recharge of open spaces like parks, open land, riverbeds, water bodies etc.

  v. Framing of new guidelines, if needed

- Identification of locations for groundwater recharge.
- Choice of methods, techniques and broad designs of recharging with reference to sub-regions of NCR with focus on flood plain recharge and rejuvenation of water bodies (ponds).
- Details of park-type urban recharge installations and their applicability
- Availability of water sources for recharging i.e. surface water, imported water or treated waste water
- Possibility of using urban storm water for recharging of aquifers through infiltration basins
- Suggested line of action, proposals, technologies and estimates

D. Groundwater Recharging in Rural Areas

- Legal provisions for management of groundwater in rural areas
- Identification of areas/ locations for recharge based on hydrological and hydro-geological conditions
- Identification of suitable technologies

i. for recharging ground water in Aravalli foothills

ii. for lakes, ponds and other water bodies for improving water availability/ causing recharge to underground stratum

iii. for areas with saline groundwater

iv. for use of saline water - conjunctive use, brackish water fisheries, salinity resistant farming

- Proposal to improve groundwater quality

E. Working out the block cost of the proposals

F. Funding arrangement for projects of groundwater recharge

- Sub region-wise shelf of projects for groundwater recharge

i. Projects already available which can be taken up under various schemes

ii. Projects to be prepared

2. Administrative Setup of NCR

The National Capital Region covers an area of 33578 Sq.Km. It includes parts of Haryana, Rajasthan and Uttar Pradesh besides the entire NCT of Delhi. The part of Haryana includes districts of Panipat, Sonipat, Rohtak, Jhajjar, Rewari, Gurgaon, Mewat and Faridabad and covers an area of 13413 Sq.Km. Rajasthan includes district Alwar and covers and an area of 7829 Sq.Km. Uttar Pradesh includes districts of Baghpat, Meerut, Ghaziabad, Gautambudh Nagar and Bulandshahar and covers an area of 10,853 Sq.Km. The NCT of Delhi covers an area of 1483 Sq.Km. The administrative map of the NCR area with state Region and district boundary is shown in **Fig. 2.1.**

In the present proposal an attempt has been made to classify the entire NCR area into various sub Regions based on the administrative and geomorphic set up of the area. Depending upon geo-morphological and physiographic conditions as well as conditions suitable for recharge and availability of source water the approach for water harvesting and artificial recharge has been recommended.

2.1 Area Classification

The NCR area has been classified into various sub units based on administrative boundary and further on geomorphic setup so as to recommend technical viable options for rain water harvesting and artificial recharge. The primary classification is based on the administrative division represented in the form of Sub-Region. The details of sub-region is as below.

2.1.1 Sub-Regions

The area classification into sub Regions is based on the administrative units and represent four States covered under NCR i.e. NCT Delhi Sub-Region, Haryana sub–region, UP sub-region and Rajasthan (Alwar) sub-region. Most of the data availability and compilation is based on the Sub Region concept. For planning however, various management measures including rain water harvesting and artificial recharge. Classification has been made based on the geomorphic set up of the area. The Sub Region map of the NCR area is given in **Fig 2.2.**

2.1.2 Geomorphic Divisions

The entire NCR can be broadly divided into four major Geomorphic units , namely alluvial plain areas, Flood plain areas , Structural hills mostly represented by Aravalis and Oxbow lakes and isolated water bodies located in depression. Since, the suitability of various water recharge measures and techniques are mostly guided by geomorphology of the area, this classification is considered relevant. In the final recommendations it has attempted to classify various sub Regions into hilly areas, flood plain areas and alluvial plains. The geomorphic map of the NCR area is shown in **Fig. 2.3.** From the map it can be observed that the entire NCR area is occupied by alluvial deposit dotted with structural hills mostly in the NCT area and part of Alwar district of Rajasthan. In the eastern side the NCR area is bounded by river Ganga and in the west, river Sahibi is the major drainage. River Yamuna flows almost in the central part of NCR area.

2.1.3 Rural and Urban Areas

For the purpose of suitability of various rain water harvesting and artificial recharge techniques the land use classification has been given the priority. Different land use in terms of urban and rural areas have been identified and given in **Fig. 2.4.** In the Urban areas, altogether different techniques need to be adopted for rain water harvesting; similarly in the rural areas the priorities may be different.

3. Physiography & Hydrogeology

The suitability or feasibility of an area for ground water augmentation and recharge is mainly dependent upon the (i) prevailing ground water conditions such as pre and post monsoon water level of the area (generally the area having deeper water level is more suitable for recharge), (ii) the rock types, (iii) aquifer parameters and potential to accept water as well as (iv) the availability of source water.

The NCR area is broadly represented by two major geomorphic units, the alluvial plains occasionally traversed by quartzitic ridges and flood plains of three main river systems passing through the region. The geomorphic set up of the area makes it more or less suitable for harvesting the rain water through suitable interventions and utilizing it for recharge purposes. As far as ground water regime scenario is concerned, the entire NCR may be classified as water stressed areas as a result of severe decline in ground water levels during last few decades. The ground water withdrawal in the area has increased many folds.

The rainfall offers the major source of water. There is a need to adopt suitable rain water harvesting measures in the area to conserve more and more water and allow it for ground water recharge. River Ganga forms the eastern most boundary of NCR, Yamuna and Hindon are two other major rivers in the central and eastern part covering Haryana, Delhi and Uttar Pradesh. The south western part is devoid of any perennial river except river Sahibi passing through Alwar region which is ephemeral in character. The catchment area of these river systems need to be suitably trained for rain water harvesting and enhancing the ground water recharge. Similarly, the surplus run off being generated in the area is to be utilized for ground water recharge through suitable engineering techniques. The flood water can be utilized for recharging. Other than these conventional methods the NCR area provides ample opportunity for ground water recharge through existing ponds, tanks and water bodies. Roof top rain water harvesting in the urban and per urban areas has lot of scope in the NCR to provide sustainability to ground water sources. With the changing scenario and water scarcity we may have to resort to alternative technologies of recycling and reuse of water also for various uses so as to reduce the overall stress on the fresh water. Even the recycled water may be used for recharge after ensuring the water quality.

3.1 Physiography & Drainage

The geo-morphological set up, physiography and drainage network of the area has quantifiable influence on the occurrence and distribution of ground water. Geo-morphology of an area has strong bearing on various management measures as well as the deciding factors for water harvesting and recharge to ground water. Hence, any study related to planning the development and management of ground water including recharge would require a detailed understanding of the geomorphic units present in and around the area, the prevailing topographic slopes and local as well as regional drainage of the area.

In the present study an attempt has been made to elaborate the regional geomorphology of NCR. The National Capital Region (NCR) is broadly represented by two distinct physiographic units, viz. i) the Alluvial plain and ii) area occupied by Quartzite ridges other than the flood plain areas along the major streams such as Ganga, Yamuna and Hindon. The geo-morphological map of NCR is shown in

Fig. 2.3. The Alluvial plain which falls mostly in Haryana, Delhi and U.P. is almost flat and is interrupted by sand dunes and quartzite ridges. Sand dunes are most prominent in the south-western part of the area falling in Rewari district of Haryana and Alwar district of Rajasthan. The dunes have a NE-SW to E-W trend. These are longitudinal type of dunes.

The quartzite ridges are prominent in the southern and south-western parts of the area. These ridges have a NE-SW trend. The ridges rise up to about 650 m above mean sea level (a msl). In general, the hills decrease in height from south and south west to north and west to east. The valleys between the hills are wide and stretch for many kilometers. Flattened hill tops form plateaus.

The slope of land in the northern part of NCR is towards south and south-west up to almost the center of the area. The land slopes towards north in the south-western parts of the area, while it is undulating between the Yamuna and the Ganga.

There are three perennial rivers in the area viz. the Ganga, the Yamuna and the Hindon. The Ganga forms the eastern most boundary of the area and flows in a southerly direction for the entire length of the area. The Yamuna forming a boundary between Haryana and Uttar Pradesh also flows in a southerly direction and almost bisects the area. Hindon River also flows in southerly direction. There are many other small streams falling in U.P. viz. Karavan Nadi, Kali Nadi, Nim Nadi, all flowing towards south.

The southern and south-western parts of NCR are is devoid of any perennial rivers. The line of natural drainage in this part is from south-west to north-east or north naming Sahibi Nadi, which is ephemeral, enters the area at about 5 kms south of Behror in Alwar district. It flows in a north-east direction towards Rewari. In carries away the water of the western slope of the central range of Aravalli hills. Another ephemeral stream in the area is Ruparch which is in the extreme south of the area falling in Alwar district. The Flood plain & drainage map of the NCR area is given in **Fig. 3.1.**

Land use of NCR has changed considerably over the years due to rapid urbanization. The agricultural lands are repeatedly modified and more & more areas are shifted from cultivation and being utilized for other uses.

3.2 Hydrogeology

The NCR area is underlain by geological formations ranging in age from Pre-Cambrian to Recent. The following stratigraphic sequence is generally met within the area:

Age	**Group**	**Formation**
Pleistocene and Recent (Quaternary)	Quaternary Alluvium	Recent alluvium comprising sands ‘kankar’, gravel, silt, clay etc.
		Older alluvium and piedmont gravels, pebbles, cobbles, sand, clay and calcareous concretions.
Unconformity		

Age	Group	Formation
Post Delhi Intrusive		Quartz viens, pegmatites, granites, amphibolites.
Pre-Cambrian Delhi Super Group	Ajabgarh group, Alwar group	Quartzite, Phyllites, mica schist Calc-schist, Gneiss, Marble, basic flows Quartzite, Conglomerate and minor schist.

The Alwar group of rocks cover vast areas in the southwestern parts in Alwar district, parts of Rewari and Gurgaon district in Haryana and south-eastern parts of NCT of Delhi. This group of meta-sediments forming NNE-SSW strike ridges is characterized by dominance of arenaceous facies consisting of quartzites of varied types. These quartzites are well jointed and cross bedding and ripple marks are primary sedimentary structures well developed in these formations.

The Ajabgarh groups of rocks occur in the eastern extremity of Alwar district. The formations are represented by argillaceous and calcareous rocks as compared to the Alwar group . The main rock types are marbles, calc gneisses, calc-silicate rocks, phyllites and mica schist. The general strike of the formations is north-south to north east southwest with westerly dips. Joints and closely spaced fractures are very common. The formations of the Delhi group are much disturbed tectonically as is evidenced by numerous major and minor faults, folds, joints and fractures. The major faults are generally parallel to the Great Boundary Fault of Rajputana. A number of acid and basic intrusive occur in the rocks of Delhi group. Granite, pegmatite and quartz veins are widely distributed in both the Alwar and Ajabgarh formations.

Apart from the above mentioned Precambrian rocks, the entire area is occupied by Quaternary Alluvial deposits. The thickness of alluvial deposits in the northern, eastern, north eastern and south eastern parts is considerable whereas it is less in the remaining parts of the area. The alluvial deposits consist of silt, clay, kankar, sand, gravel and pebble beds. The major river courses and tributaries and intermontane valleys are occupied by Quaternary alluvium.

Ground water occurs in alluvium and weathered / fractured hard rocks. Sand, gravel and silt-kankar constitute potential aquifer zones in alluvium. Shallow aquifer systems in alluvium are generally under unconfined conditions and deeper aquifer systems are under semi-confined / confined conditions. Highly potential ground water structures can be installed in these aquifer systems. Weathered / fractured hard rocks having secondary porosity constitute poor to moderately potential aquifer zones which can sustain low capacity ground water structures, locally. The hydrogeological map of the NCR area is given in **Fig. 3.2**

3.2.1 Aquifer Systems

Extensive exploratory drilling has been carried out by Central Ground Water Board and other agencies in NCR areas falling in Haryana, Rajasthan and NCT of Delhi and also to some extent in the areas falling in U.P. It is observed from the exploratory well drilling data that in the areas underlain by alluvial deposits, the shallow aquifers hold ground water in unconfined state while deeper aquifers are leaky confined/confined. Individual tubewells drilled down to more than 300 meters depth in the eastern most parts (along the Ganga) and northern parts (along the Yamuna in districts of Panipat and Sonepat), generally yield more than 150 m^3/hour for reasonable draw downs. The transmissivity of aquifers in these parts generally varies between 1000 to 3000 m^2/day. Wells constructed in eastern parts of Sonepat district, eastern fringe of NCT of Delhi and along both sides of the Yamuna falling in U.P. and Haryana generally yield between 100-150 m^3/hr of ground water. The aquifers in this area are fairly thick and productive. Tubewells constructed down to 100-150 m depths along Sahibi river and in the western parts of Rewari district have moderate yields ranging between 50 – 100 m^3/hour.

The remaining areas underlain by alluvium, sustain limited well yields up to 50 m^3/hour. The aquifers in this area are also fairly thick but discontinuous. **Fig 3.3** depicts aquifer systems in upper Yamuna Basin covering parts of the NCR area. Study of deep boreholes drilled by C.G.W.B. in the Ganga basin part of NCR covering districts of Meerut, Ghaziabad and Bulandshahar has revealed the occurrence of deep fresh water aquifers within 450 m depth. **Fig 3.4 & 3.5** depicts aquifer systems in part of Ganga basin falling in Ghaziabad and Meerut districts of NCR. These are grouped depth wise as aquifer group I, II and III occurring in the depth range of 190 m to 350 m and beyond 350 m. There is no ground water quality deterioration in areas north of Ghaziabad up to the drilled depth of 450 m.

Based on the available hydrogeological data, the NCR area has been divided in three area namely ‘A’, ‘B’ and ‘C’. **Figure 3.6** depicts aquifer potential map of NCR. In the area ‘A’ fresh water aquifers exist down to 450 m depth and the tube wells yield 150 m^3/hr or more for moderate draw-downs. Only Meerut, Panipat and Hapur town fall in this area. In the ‘B’ category area, limited to adequately thick fresh ground water aquifers exist down to 50 m to 300 m depth and are underlain by saline ground water. Tube wells in this zone yield 50 m^3/hr to 150 m^3/hr for moderate to heavy drawdowns. Bulandshahr, Khurja, Faridabad (Part), Ghaziabad, Noida and Loni fall in this ‘B’ area. In Noida, thickness of fresh water aquifer is very limited and the existing shallow tube wells yield very poor discharge. The remaining towns including NCT of Delhi fall in ‘C’ category area having limited thickness of fresh water aquifers and hard rock aquifers. The yield from these aquifers is low to moderate (50 m^3/hr or less) for moderate to heavy draw-downs.

Ground water in the consolidated rock formations occurs under unconfined conditions and is restricted to the weathered and fracture zone having secondary porosity. Tubewells constructed in these formations have low yield prospects which are of the order of 5 – 20m^3/hour for appreciably large drawdown **(Fig 3.7 to 3.10)**.

3.2.2 Ground Water Regime

In the major part of Uttar Pradesh, depth of water table lies between 5m to 10m. In Alwar district of Rajasthan, water table rests between 10m to 20m and in some areas, it is deeper than 20m. In Haryana, shallow water table conditions exist in the district of Rohtak and Jhajjar, being in depth range of 2m to 10m. Water levels are deeper in the southern parts of Haryana, covering parts of Gurgaon, Faridabad and Rewari. However in Mewat district and parts of Faridabad, shallow water levels in the depth range of 2m to 5m also exist. **Fig. 3.11** depicts depth to ground water levels in NCR.

During the past decade (1999-2008) almost the entire NCR area has witnessed decline in ground water levels. The decline has been higher in areas underlain by fresh ground water as compared to areas having marginal to saline ground water. In Alwar district of Rajasthan, the water levels have declined all over the district by 2 to 4 m. In most parts of Uttar Pradesh and Haryana the decline is in the range of 0-2m. In southern Haryana covering parts of Gurgaon, Rewari and Faridabad district exhibit a decline in the range of 2 to 4m.

The water table generally follows the surface topography of the area. The altitude of water table varies from 175 m above mean sea level (a msl) at Hodal in Faridabad district to 309 m above msl at Tatarpur in Alwar District. An elongated ridge trending NW-SE direction from Baraut to Hapur in U.P, act as a recharge zone with the water table sloping away from it in all directions with a gradient of 1 to 2 m per kilometer. The Ganga is gaining stream in the right bank. The ground water flow direction in a major part of the area is towards the rivers draining the area.

A prominent ground water discharge area is located in the central parts of Rohtak district and another in the south western parts of Delhi where the ground water table is converging from all the sides. The quartzite ridges in Delhi, Gurgaon and Alwar districts form a ground water divide with the water table sloping away from it in both, east and west directions with gradients of about 3 to 5 metres / km. Hydraulic gradient in south western parts falling in Rewari district is as high as 10 m/km. The flow direction from south and south western areas is towards the Sahibi river and subsequently to the ground water discharge area in central parts of Rohtak district and southwestern parts of Delhi. Central parts of Gurgaon and Faridabad districts are also discharge areas with the flow direction converging near Hathin in Faridabad district and ultimately flowing out to the Yamuna. The hydrogeological map as given in **Fig 3.2** depicts water table elevation map of the Region.

3.2.3 Ground Water Quality

The specific conductance of shallow ground water varies greatly in the NCR area from being as low as 290 micro siemens /cm at 25^o C to as high as 16,000 micro siemens /cm at 25^o C. In a major part of the area, the shallow ground water is fresh (EC up to 3000 micro siemens /cm at 25^o C). Areas with brackish quality of water (EC between 3000-6000 micro siemens /cm at 25^o C) occur in north western parts of Sonepat district, northern and north western parts of Rohtak district, northwestern and south western parts of NCT of Delhi, north-west and northern parts of Gurgaon district, western parts of Rewari district, southwest parts of Faridabad district and southwestern parts of Bulandshahar district. Saline ground water (EC more than 6000 micro siemens /cm at 25^o C) also occurs in almost the same areas as those of brackish water areas excepting Bulandshahar district. There are no saline ground water areas in the U.P. sub-region. **Fig 3.12** depicts EC distribution in shallow ground water in NCR.

3.3 Climatic conditions

The overall climatic conditions and rainfall pattern plays a vital role in assessing the ground water availability in time and space and scope for water harvesting and recharge to ground water . The amount of rainfall received in the area is major input and the only source of ground water recharge in the non irrigation commands. Other than the quantity of rainfall the intensity and duration of rainfall is equally important, as far as ground water recharge is concerned. Similarly, temperature, humidity and several other climatic factors influences a lot in overall budgeting of ground water. The regional climatic conditions have been studied through analysis of data collected from different sources for the entire Delhi area.

As such the entire NCR area including Delhi State falls under the semi-arid climatic region. The climate of the area is mainly influenced by its inland position and the prevalence of air of the continental type during the major part of the year. Extreme dryness with hot summer and cold winter are the characteristics of the climate. Only during the three-monsoon months July, August, and September doses air of oceanic origin penetrate to NCT Delhi and causes increased humidity, cloudiness and precipitation. The year can broadly be divided into four seasons. The cold season starts in late November and extends to about the beginning of March. This is followed by the hot season, which lasts till about the end of June when the monsoon arrives over the district. The monsoon continues to the last week of September. The two post monsoon months October and November constitute a transition period from the monsoon to winter condition.

3.3.1 Rainfall & Evaporation

Major parts of the NCR fall in the Gangetic plains comprising of alluvial formations. The southern part of NCR, comprising of district of Alwar and Mewat fall under the central mountains mainly in Arawali hills, which extends up to Southern Delhi. The climatic condition over the NCR varies from humid Sub-Tropical climate in eastern parts of NCR consisting of districts in sub-region of Uttar Pradesh to Semi-arid or Steppe in western parts of NCR consisting of districts in sub-region of Haryana and Rajasthan. The central sub-region of Delhi falls under two climatic regions namely semi-tropical and semi-arid climatic regions. The southwestern parts of Alwar district in Rajasthan sub-region falls under arid climatic region. The vegetation and forest cover over the NCR varies according to climate. The tropical vegetation is found in north eastern parts of NCR comprising of districts of Baghpat and Meerut. The tropical dry deciduous forests grow in eastern parts of NCR while the tropical thorny bushes are found in semi-arid and arid regions of NCR i.e. western, central and southern parts of NCR.

The average annual rainfall in the area varies greatly from as low as 300 mm in the western parts to about 850 mm in the central and north-eastern parts. **Fig 3.13** depicts Isohyetal map of NCR. The data of the Rainfall for the NCR region has been examined and following observations are made. Record of rainfall indicates that the rainfall increases from the west and southwest to the north east. The normal annual rainfall for Delhi sub region is more than 600 mm and that for the Rajasthan sub-region is more than 500 mm. Haryana sub-region is observed with normal annual rainfall to the tune of 650 mm while in Uttar Pradesh sub region it is to the tune of more than 700 mm. About 81% of the annual rainfall is received during the monsoon months viz. July, August and September. The rest of the annual rainfall is received as winter rain and as thunderstorm rain in the pre and post monsoon months. The variation of rainfall within the sub-regions from year to year is large. In NCT Delhi area the rainfall increases from west to east.

The month-wise Normal Rainfall with Rainy days and Evaporation losses for the meteorological site at Delhi airport is given in **table-3.1.**

Table 3.1 : Rainfall and Evaporation (Monthly Average for the period 1901-2002)

Month	Jan	Feb	Mar	Apr.	May	Jun	July	Aug	Sep	Oct	Nov	Dec
Rainfall (in mm)	14.93	13.11	8.94	6.74	12.02	43.97	177.72	180.75	93.51	7.75	4.92	5.09
Rainy days	1.2	1.0	0.8	0.5	0.8	2.1	7.4	7.9	4.0	0.8	0.1	0.4
Evaporation (in mm/day)	4.45	5.22	6.41	7.91	8.62	8.1	6.64	5.85	6.3	6.67	5.81	4.7

Source: Indian Meteorological Dept.

Losses due to Interception and Evaporation

A part of rain water gets intercepted by vegetative cover (leaves of plants/ trees) and does not make it to the ground surface. Another small part of it gets stored in small ponds and depressions (excluding seepage quantity) and is finally lost to atmosphere due to evaporation. The quantitative magnitude of these losses depends upon several parameters such as basin topography and type of vegetation cover and drainage pattern. Since, these losses do not contribute to water supply in any manner; these are estimated for each district for rains during monsoon and non-monsoon seasons. The study carried out by various agencies, as compiled by WAPCOS the evaporation losses during monsoon season vary from 0.02853 BCM/ year to 0.19083 BCM/ year whereas its variation over the non-monsoon season is between 0.004755 BMC/ year and 0.3180 BMC/ year. During the year, 0.03969 BCM/ year of water is lost due to evaporation from NCT of Delhi.

It is estimated that on an average year, 1.0212 BCM/ year of water lost from NCR due to interception and subsequent evaporation, out of which 0.8753 BCM/ year of loses takes place during monsoon period of year. The annual average estimates of interception and evaporation losses for the four sub-regions of NCR namely Haryana, Uttar-Pradesh, Rajasthan and NCT of Delhi are summarized in **Table 3.2**.

Table 3.2: Annual interception and evaporation losses for sub-regions of NCR.

Sl. No.	Name of the Sub-region	Interception and evaporation losses in BCM	
		Monsoon	Non-monsoon
1	Haryana	0.3065	0.0511
2	Rajasthan	0.1908	0.0318
3	Uttar-Pradesh	0.3439	0.0573
4	NCT of Delhi	0.0340	0.0057
Total of NCR		**0.8753**	**0.1459**
Source : WAPCOS Report on NCR			

This portion of water is lost to the atmosphere and cannot be economically harnessed. Further it only constitutes a very small portion (roughly 4.375 %) of rain water.

3.3.2 Temperature

The cold season starts towards the latter half of November when both day and night temperature drop rapidly with the advance of the season. January is the coldest month with the mean daily maximum temperature at 21.3°C and the mean daily minimum at 7.3°C. In the NCR area the extreme climatic conditions are observed during the winter months, the cold waves are common and some times the temperature go down to the freezing point. From about the middle of March, temperature begins to rise fairly rapidly. May and June are the hottest months. While day temperature is higher in May the nights are warmer in June. From April the hot wind known locally as 'loo' blows and the weather is unpleasant. In May and June maximum temperature sometimes reaches 46°C to 47°C. With the advance of the monsoon into the area towards the end of June or the beginning of July, day temperatures drop appreciably while the night temperatures remain high. In October the day temperatures are as in the monsoon months but the nights are cooler.

The air over NCR is dry during the greater part of the year. Humidity is high in the monsoon months. April and May are the driest months with relative humidity of about 30% in the morning and less than 20% in the afternoon. During the monsoon period especially in July and August skies are heavily clouded and often overcast. In the rest of the year skies are clear or lightly clouded. But in the months January, February and early March skies become cloudy and overcast when the NCR is affected by western disturbances.

Winds are generally light during the post monsoon and winter months. They strengthen during the summer and monsoon months. Except during the monsoon months, winds are predominantly from a westerly or northwesterly direction and tend to be more northerly in the afternoon. Easterly and southeasterly winds are more common in the monsoon months. April to June is the period with the highest incidence of thunderstorms and dust storms. Some thunderstorms give rise to violent squalls (*Andhis*). While some of the thunderstorms are dry others are accompanied with heavy rain and less frequently with hail. Thunderstorms also occur in the winter months in association with western disturbances. Sometimes dense Fogs occur in the winter months.

4. Water Availability & Recharge Prospects in NCR

Assessment of the water availability in an area is one of the important task and invariably this activity should precede any water resource planning be it a development or management scheme. Various attempts have been made from time to time to assess the availability of water in NCR area at different seasons.

The availability of water in an area in different time period is the deciding factor which helps in planning various water supply and conservation measures. Rainfall is the major source of water, the total annual volume of rainfall received in an area along with number of rainy days and intensity of rainfall gives broad idea about runoff generated, evapo-transpiration losses and contribution to ground water as natural recharge. In addition, the water carried by various rivers and streams in the area is another important source of water which can be optimally utilized in the stretch passing through the area by ensuring the required minimum downstream flow for sustenance of aquatic life as well as to meet the committed flow, if any, in the downstream.

4.1 Sources of Water

Presently NCR receives water from several sources. These can be grouped as following.

- Rainfall
- Canals & Surface Water Bodies
- Ground water
- River basins
- Dams
- Lakes and Ponds
- Treated sewage for re-cycling

Every year NCR receives plenty full of rain fall . A part of it gets directly consumed in growing crops and vegetation in NCR; another part recharges aquifer and remaining rain water flows down the natural drainage system as surface runoff. A detailed analysis of these is presented subsequent sections.

Existing canals transfer a very significant quantity of water to NCR for various uses such as agricultural use, domestic consumption and industrial consumption. Western Jamuna Canal (WJC) and Agra Canal systems supply water Haryana-sub region of NCR. Similarly, UP sub-region of NCR is supplied water via Upper Ganga Canal (UGC), Eastern Yamuna Canal (EYC) and Madhya Ganga Canal – Phase I (MGC-I) systems. NCT Delhi is supplied drinking water from Western Jamuna Canal system and Upper Ganga Canal system. Presently, Rajesthan sub-region of NCR (Alwar district) does not receive supply from any canal system. However, there are a few pond irrigation schemes in Alwar district. The branch canals, distributaries and minors from these canal system form a thick web of inter nested canals all over NCR except Alwar district. The map showing the major canal system in NCR is given in **Fig. 4.1.**

A part of water flowing in canals seeps down the aquifer formations and recharges aquifer; remaining part of it is supplied for agricultural, domestic and industrial use. A part of the water applied to agricultural fields gets consumed in growing crops and remaining part is lost as deep percolation losses (recharge of aquifer) and tail-cluster over flows.

The Ground water forms the third major source of water for NCR which has plentiful ground water stored in aquifer formations. A detailed analysis and discussion on ground water resources of NCR in presented in next chapter and briefly discussed in subsequent sections. It also discusses the rain-water harvesting projects that are constructed to augment aquifer recharge.

In addition to these, every year, a significant quantity of flood waters from catchments upstream of NCR is passed through the natural drainage system of NCR. Presently NCR receives water from Sutlej sub-basin, Beas sub-basin, Ravi sub-basin, Yamuna sub-basin, Ganga sub-basin and Ramganga sub-basin. The monsoon flood water of these sub-basins is stored in dams and storage reservoirs. Presently, NCR is supplied water through these. There are several dams and storage reservoirs that supply water to NCR namely, Ranjit Sagar Dam, Pong dam, Pandoh dam, Bhakhra dam, Tehri dam and Ramganga dam. There are several lakes, ponds and bunds that contribute to surface storages with in NCR. In addition to few big lakes, there are at least 1 to 3 small ponds present in every village, town and district. In addition to capturing surface runoff, lakes also receive water that overflow tail clusters of canals via natural drains. Further during summer months, these ponds are filled by perennial canals. Several pond storages based minor irrigation schemes have also been developed primarily in Alwar district of NCR. In addition to these, there is a non-conventional source of water that is available in the form of treated sewage. Presently, it is being used for irrigation.

Since, one of the major input is availability of source water in the entire planning for water conservation and recharge to ground water , hence an attempt has been made to analysis and discuss some of the major water sources and their estimation in subsequent sections.

4.1.1 Rainfall

Annually, NCR receives plentiful of rains with wide spatial variations. It varies from 850 mm in Meerut district in eastern parts of NCR to 300 mm in Rewari district in western parts of NCR. The central portion of NCR comprising of NCT of Delhi, on an average receives 611.70 mm of rain fall per year. The Isohyetal map of annual normal rainfall is given in **Fig. 3.13.**

The distribution of annual monsoon rain water over cultivable and non-cultivable land of NCR has been worked out and the quantity of rain fall that directly falls over the cultivable command area during Kharif crop varies from 352.0 MCM/ year to 2481.9 MCM/ year whereas its variation over the non-cultivable portion of the land is 83.9 MCM/ year to 1334.7 MCM/ year. During this period the rainfall over NCT of Delhi over the build-up portion is estimated to be 344.1 MCM/ year a significant portion of this water can be utilized for rainwater harvesting. However, its magnitude over the non-built up areas that contribute to growth of vegetation, ground water recharge, etc in NCT of Delhi during monsoon is 336.3 MCM/ year.

Similarly, the distribution of non-monsoon rain water falling over cultivable and non-cultivable land of NCR is also worked out and the quantity of rain water that directly falls over the cultivable land of NCR during Rabi season varies from 134.0 MCM/ year to 827.3 MCM/ year whereas its variation over the non-cultivable portion of the land is between 27.96 MCM/ year to 444.9 MCM/ year. During this period the rainfall over NCT of Delhi over the build-up portion is estimated to be 114.7 MCM/ year, a significant portion of which can be utilized for rainwater harvesting. However, its magnitude over the non-built up areas that contribute to growth of vegetation, ground water recharge, etc in NCT of Delhi during non-monsoon is 112.1 MCM/ year.

The total magnitude of rain water over the year is estimated for an average year. NCR receives 22542 MCM of water, out of which 16906.5 MCM of it precipitates during monsoon season. The monsoon season starts from July and ends by September. The magnitude of monsoon rain water varies from 520.6 MCM/ year for the Gurgaon district in western parts of NCR to 3816.6 MCM/ year for Alwar districts in southern parts of NCR. Similarly, on an average, the central sub-region of Delhi receives 680.5 MCM of water during monsoon every year.

The non-monsoon rainfall occurs between December and March over NCR. The, annual average distribution of magnitude of non-monsoon rain water over NCR varies from 173.5 MCM/ year in Gurgaon district in western parts of NCR to 707.4 MCM/ year in BulandShahar district in eastern parts of NCR. The NCT of Delhi receives 680.5 MCM/ year of rain fall during monsoon and 226.8 MCM/ year during non-monsoon seasons. The annual average estimates of monsoon and non-monsoon rain water for the four sub-regions of NCR are summarized in Table4.1 below.

Table 4.1: Distribution of annual rain fall water in sub-regions of NCR.

Sl. No.	Name of the Sub-region	Quantity of Monsoon water in MCM/ year			Quantity of Non-Monsoon water in MCM/ year		
		Cultivable	Non–Cultivable	Total	Cultivable	Non-cultivable	Total
1	Haryana	4470.7	1606.0	5531.3	1490.2	353.5	1843.8
2	Rajesthan	2481.9	1334.7	3816.6	827.3	444.9	1272.2
3	Uttar-Pradesh	3705.5	3172.6	6878.1	1235.2	1057.5	2292.7
4	NCT of Delhi	0336.3	344.1	680.5	112.1	114.7	226.8
Total of NCR		**13476.3**	**7246.8**	**20723.1**	**4492.1**	**2415.6**	**6907.7**

Source : WAPCOS Report on NCR

Maximum amount of rain water falls over the Sub-region of Uttar Pradesh. On an average year NCT of Delhi receives 907.3 MCM/ year of water in the form of rain fall. A portion of rain water falling over NCR infiltrates into the ground and another portion appears in the form of surface run-off.

Rainfall Components of Surface runoff

The quantitative magnitude of surface runoff depends upon several parameters such as basin characteristics, soil type, land use pattern, vegetation cover, drainage pattern etc. Since the surface runoff depends upon the land use and land cover pattern, the surface runoff has been computed separately for cultivable areas and non-cultivable areas of NCR. It is established in hydrology that the surface runoff from forested and non-cultivable lands are smaller than surface runoff from the cultivable lands. The surface water yield (surface runoff) from cultivable command area during monsoon season is estimated to vary from 105.6 MCM/ year to 744.6 MCM/ year whereas its variation over the non-cultivable portion of the land is estimated to be between 16.78 MCM/ year and 266.9 MCM/ year. During this period the surface runoff from non-built up areas of NCT of Delhi is estimated as 84.1 MCM/ year whereas surface runoff from built-up areas of NCT Delhi as 189.3 MCM/ year.

Similarly, the distribution of surface runoff due to non-monsoon rains from cultivable and non-cultivable land varies from 35.2 MCM/ year to 248.19 MCM/ year whereas surface runoff variation from non-cultivable land varies from 5.59 MCM/ year to 88.98 MCM/ year over the NCR. During this period the surface runoff from built up areas of NCT of Delhi is estimated to be 40.206 MCM/ year whereas surface runoff from built-up areas of NCT Delhi is estimated to be 63.09 MCM/ year.

The total magnitude of surface runoff over the year is obtained by summing up these components. It is estimated that on an average, 6272.3 MCM/ year of water is lost (un-used) as surface runoff from NCR, out of which 4584.4 MCM/ year of it takes place during monsoon season of the year. Estimates of annual surface water yield for the four sub-regions of NCR namely Haryana, Uttar-Pradesh, Rajasthan and NCT of Delhi are summarized in **Table 4.2**.

Table 4.2: Distribution of annual surface runoff yield for sub-regions of NCR.

Sl. No.	Name of the Sub-region	Quantity of Surface runoff in MCM/ year					
		Monsoon			Non-monsoon		
		Cultivable	Non–cultivable	Total	Cultivable	Non-cultivable	Total
1	Haryana	1341.2	212.1	1553	447.1	70.7	517.8
2	Rajasthan	0744.6	266.9	1011	248.2	89.0	337.2
3	Uttar-Pradesh	1111.7	634.5	1736	370.6	211.5	582.1
4	NCT of Delhi	84.1	189.3	273	28.0	63.1	91.1
Total of NCR		**3281.5**	**1302.9**	**4584**	**1093.8**	**434.3**	**1528.2**

Source : WAPCOS Report on NCR

Maximum surface runoff occurs from the Sub-region of Uttar Pradesh. The rains over NCT of Delhi contribute to 364.5 MCM/ year of surface run off. This quantity of surface runoff remains unused and flows down the natural drainage system and joins the flood waters of river Yamuna and Ganga and finally flows into the Bay of Bengal. The challenge lies in utilizing this runoff water locally in river sub-catchments of NCR. The problems and issues associated with utilizing this water are discussed in subsequent sub-sections.

In the present proposal an attempt has been made to formulate functional recharge plan in NCR region so as to optimally utilize the rainfall-runoff generated in the area for augmenting ground water storage and conserving the water for future utilization.

4.1.2 Unused flood water in NCR

The water carried by various rivers and streams in the area is another important source of water which can be optimally utilized in the stretch passing through the area by ensuring the required minimum downstream flow for sustenance of aquatic life as well as to meet the committed flow, if any , in the downstream. The sub-region wise summary of share of NCR in un-used flood waters of different sub-basins is presented in **Table 4.3** below

Table 4.3 : Share of sub-regions of NCR in flood waters of river basins.

Sl.No	Sub-Region	Quantity of un-used flood water share in BCM/ year				
		Name of the sub-basin				
		Ganga basin	Yamuna basin	Kali-Hindon basin	(Beas+Ravi) +Satlej basin	Total
1	Haryana	1.5456	0.5485	0.0000	5.986	**8.080**
2	Uttar Pradesh	6.9815	0.0497	0.4695	0.0	**7.501**
3.	Rajasthan	0.0000	0.0000	0.0000	4.50	**4.5**
4.	NCT Delhi	0.7126	0.1579	0.0000	0.0	**0.871**
	Total for NCR	**9.2397**	**0.7561**	**0.4695**	**10.486**	**20.952**

Source : WAPCOS Report on NCR

In above table the share of unused flood water can be re-allocated considering NCR as one entity. The share for NCR districts in flood waters of all sub-basins that flows down the river and presently remains un-utilized is presented above. The challenge lies in utilizing 20.952 BCM/ year of available unused flood water.

As per the latest report of National Capital Region Planning Board (NCRPB) entitled **" Regional Plan 2021 , NCR"** the future availability of water from all sources has been assessed as follows.

Table 4.4: Future Availability Plan

Sl.No.	Source of water	Treatment plant	Withdrawal (MGD)

1	Yumuna river	Wazirabad, Chandrawal	210
2	Bhakra storage and Western Ganga Canal	Hyderpur, Nangloi	240
3	Upper Ganga Canal	Bhagirathi	100
4	Water Expected from Tehri Dam	Sonia Vihar	140
5	Surface Water	Delhi parallel Branch	20
6	Ground Water	Tubewells	125
	Total		**835**

Source : WAPCOS Report on NCR

4.1.3 Ground Water

The Ground water forms the third major source of water for NCR which has plentiful ground water stored in aquifer formations. A detailed analysis and discussion on ground water resources of NCR is briefly discussed. The subregion-wise availability of ground water resources of National Capital Region (NCR) is described below;

Annual Replenishable Ground Water Resource

The position of annually replenishable ground water resource of NCT Delhi sub-region is described below:

I. NCT Delhi Sub-Region

The main source of ground water recharge is rainfall. The other sources of recharge include canal seepages, recharge from surface irrigation, recharge from surface water bodies and water conservation structures such as check dams and roof top and related water harvesting system in NCT Delhi area.

According to Central Ground Water Board net annual ground water availability of nine districts of NCT Delhi sub-region is 0.28 BCM. The total annual estimated ground water extraction is of the order of 0.48 BCM. The stage of ground water development is 170%. The stage of ground water development in North districts is 35% where it is more than 85% to more than 100% in remaining six districts of NCT. The annual ground water extraction & use is highest in south-west district where domestic sector is main consumer and North-west district is largest user of water for industrial & irrigation purposes. Based on level of ground water use in relation to availability, the CGWB has categorized various districts of NCT into over-exploited category excepting Central and North districts **(Fig. 1.1)**.

The net annual ground water availability and annual extraction of ground water for four sub-regions of NCR are given in **Table 4.5 below**.

Table 4.5: Position of Annual Availability and use of Dynamic Ground Water Resources of NCR

	Sub – Region	Annual Ground Water Availability (BCM/yr)	Net Annual Ground Water Extraction (BCM/yr)
I	NCT Delhi Sub-Region	0.28156	0.47945
II	Rajasthan Sub-Region (Alwar District)	0.79036	1.14391
III	Haryana Sub-Region	264116	2.72040
IV	Uttar Pradesh Sub-Region	476385	3.25421
	Total	**8.47693**	**7.59797**

Source : WAPCOS Report on NCR

II Rajasthan Sub-Region

The Alwar district of Rajasthan alone falls in NCR Area as per Rajasthan State is concerned. The net annual ground water availability for Alwar District covering Rajasthan Sub-region of NCR is 79036 Hectare meter. The annual replenishable ground water resource, the component of annual extraction, & stage of ground water development for Alwar area is given below in **Table 4.6 below.**

Table 4.6: Ground Water Availability of Rajasthan Sub-region of NCR (in BCM/Yr)

1)	Annual Replenishable Ground Water Resource	0.86641
2)	Natural Discharge in Non-Monsoon Season	0.07605
3)	Net Annual Ground Water Availability	0.79036
4)	Ground Water Extraction	**1.14391**
	a) For Irrigation	1.07981
	b) For Domestic & Industrial Use	0.06410
5)	Stage of Ground Water Development	123%

From above, it can be seen that the Alwar district as such is categorized as over-exploited since overall extractions exceed the natural annual availability of ground water. The position when viewed for individual blocks of Alwar district is somewhat different as brought out in detail in subsequent reporting.

III Haryana Sub-Region

The Haryana sub-region of NCR comprises districts of Gurgaon, Mewat, Faridabad, Jhajjar, Panipat, Sonepat and Rewari. The net annual ground water availability and annual extraction for various types of uses is as given in **table 4.7 below:-**

Table 4.7: Ground Water Availability of Haryana Sub-region of NCR (in BCM/Yr)

1.	Total net Annual Ground Water Availability	2.64116
2.	Annual Ground Water Extraction for irrigation, domestic & industrial uses.	2.72040

The overall stage of ground water development ranges from 51% for Faridabad district to as high as 145% for Gurgaon district.

IV Uttar Pradesh Sub-Region

The districts of Meerut, Baghpat, Ghaziabad, Gautam Budh Nagar and Bulandshahar comprise Uttar Pradesh part of NCR Sub-Region. The net ground water availability and annual ground water extraction for Uttar Pradesh sub-region of NCR are as given in t**able 4.8** below**:-**

Table 4.8: Ground Water Availability of Uttar Pradesh Sub-region of NCR (in Ham/Yr)

1.	Net Ground Water Availability	476385
2.	Annual Ground Water Extraction	325421

Ground Water Overexploited Areas:

For various sub-region of NCR, the ground water overexploited areas are examined in detail with a view to recommending controlled withdrawals of ground water in such areas as well as exploring the possible ground water recharging measures to improve upon the availability of ground water of critical and overexploited blocks. Listed below in **table 4.9,** are the numbers of community development blocks that fall in overexploited and critical category and which deserve special study to find solutions to problems of water supply.

Table 4.9: Region wise categorization of block units in four regions of NCR

Sl.No.	Sub Region	Over exploited block	Critical block
1.	NCT sub region	7*	-
2	Haryana sub region	8	6
3	UP sub-region	1	1
4	Rajasthan sub-region (Alwar area)	11	2
5	7* districts (erstwhile Najafgarh and Mehruli blocks)		

(Source : CGWB Report on Dynamic Ground Water Resources, as per 2004)

In Storage Ground Water Reserves:

In addition to annual availability of replenishable ground water resource there is also the availability of large quantities of deeper ground water resource which are also partly recharged from foot-shills of Himalayas as well as from vertical leakage of overlaying water table aquifers. The CGWB has made an estimate of such **"Secular Reserves"**, for four sub-regions of NCR. The magnitude of these reserves available in multi – layered sequence of alluvial sediments are given in **table 4.10** below.

Table 4.10: Ground Water Storage inn NCR

SL.No	Sub-region	Ground water storage (in MCM)
I	**NCT sub-region**	3479
II	**Uttar Pradesh sub-region**	
	a) Bullandshahar	51854
	b) Ghaziabad	38628
	c) Meerut	67269
	Sub Total	**157751**
III	**Haryana sub - region**	
	a) Panipat	11500
	b) Sonepat	7908
	c) Faridabad	1570
	d) Rhotak	628
	e) Rewari	237
	f) Gurgaon	214
	Sub Total	22057
IV	**Rajasthan sub region**	
	(Alwar area)	534
	Total	**183821 (MCM)**

It has been established by CGWB that there is huge quantity of ground water down to 250 - 300 meters depth occurring below the lowest levels of ground water fluctuations in various above mentioned sub-region of NCR. These reserves can meet the drinking water & other water requirement of towns / villages that fall in the National Capital Region. These reserves when put to controlled development in combination with surface water as well as through water conservation measures would meet most of the projected demands of water supply of NCR for different types of usages.

4.1.4 Lakes, Ponds and Water Bodies

Numerous ponds are located near villages, towns in NCR. These ponds are of small storage capacity. The ponds in urban areas have eutrified and have been rendered out of use. However, the ponds near villages are used for cattle bathing. During summer months, the irrigation departments supply water to these ponds via field channels. Hence, most of the small ponds of NCR are connected with canals and water is routinely transferred to these. However, there are major lakes and ponds some of are discussed below.

Haryana Sub-region

There are several small ponds in almost all districts of NCR. Typically there are 68 lakes and bunds in Gurgaon district. Similarly, 37 lakes and bunds are there in Faridabad district of NCR. A few of the major lakes in these districts are discussed below.

Badkhal Lake: It has average capacity of 260 ha m and primarily being used for recreational purposes. The bed of the lake is rocky and it is presently silted. Due to extensive mining on three sides of the lake, deep depressions have been created. These depressions do not permit rain water to reach the lakes.

Kotla Lake: This 4000 ha m capacity lake often does not get filled. This is being used for minor irrigation. The economics to increase the storage capacity of the lakes requires to be worked.

***Dumdama Lake*:** This 300 ha m capacity lake is being used for recreational purposes. Its capacity can be increased by further land acquisition.

In addition to these, every village and town in various districts of NCR has at least one small pond. Over years, the ponds in urban areas have become eutrified. The challenge lies in effectively utilizing the available capacity of these surface ponds and storages.

Uttar-Pradesh Sub-Region

There are several small ponds in almost all districts of the sub region. However, there are no lakes or bunds of more than 100 ha –m capacity in NCR districts in Uttar-Pradesh. Every village and town has at least one small pond. Over the years, the ponds in urban areas have become eutrified and the challenge lies in effectively utilizing the available capacity of these surface ponds.

Rajasthan Sub-Region

The Alwar district has a number of storage and check dams. The rivulets feeding the check dam are:

- Dohan
- Krishnawati
- Masani

There are more than 100 check dams existing in Alwar district. In addition, some NGOs also have constructed check dams on participatory basis. The area is dry & desert effected but check dams have provided source of irrigation and drinking water. These structures contribute recharge to ground water. During the year 1996; more than half of the check dams had breached due to heavy rains causing sheet flow along villages. As such protective measures, flood protection measures besides strengthening of check dams & channel network is required. Perhaps the designs were not appropriate.

NCT Delhi Sub-Region

There are several lakes and ponds in NCT Delhi. These are primarily meant to cause ground water recharge. These are briefly discussed here under:

- ***Check dams at Drains*** **:** Rainwater is being impounded in 30 km length of Najafgarh Drain from Dhansa Regulator to Kakrola Regulator by Irrigation & Flood Control Department, by closing the gates of Kakrola Regulators. Additional storage capacity has been created in this channel by deepening of Najafgarh Drain in a length of about 6.5 kms. About 155 million gallons of water is impounded in this drain for use by cultivators of the adjoining areas. The impounded water of this drain is also diverted into Mundela Drain which has also been impounded in a length of 12.5 kms. From both these drains the villagers of Dhansa, Rawta, Galibpur, Sarangpur, Gummanhera, Jhuljhuli, Kanganheri, Chhawala, Paprawat, Pindwala, Kalan Goela, Kharkari Rondh and Khera Debar are benefited.
- ***Construction of Check dams*** **:** A total of 23 Check Dams have been constructed in Asola Wild Life Sanctuary by Irrigation & Flood Control Department, for harvesting the rainwater from hilly streams in Mehrauli block. These Check Dams have proved to be very effective in inducing ground water recharge and reviving the water bodies for meeting the water requirement in the sanctuary.
- ***Village ponds:*** Government of NCT of Delhi has developed and deepened about 70 ponds/johars in rural villages to ensure better rainwater harvesting and percolation of water to the ground water aquifers. As a result, about 170 million gallons storage capacity has been created. There are several more ponds that need to be developed and revived. The challenge lies in effectively utilizing the available capacity of these surface ponds and storages.
- ***Creation of other surface storages*** **:** The abandoned course of Bawana Escape near village Hiranki has been developed into a Water Body by Irrigation & Flood Control Department, with a surface area of about 37,700 sq. meters to impound waters of River Yamuna. During high floods the water of river Yamuna was also diverted into Bhalswa lake through supplementary drain. This can be done every year to fill up the lake.

4.1.5 Recycled Waste Water

There are several sewage treatment plants that have recently come up in Yamuna basin. The **Fig. 4.2 & Fig. 4.3** indicates the location of existing and proposed sewage treatment plants in NCR and NCT Delhi respectively. Presently only a part of urban sewage gets treated. It varies from 2.92 MCM/ year to 91.25 MCM/ year. NCT of Delhi produces 539.47 MCM/ year of sewage. This treated sewage is primarily being used for irrigation in most of the districts of NCR.

For example, in Delhi, 7.3 MCM/ year (20 MLD) of treated sewage from sewage treatment plant is being used by Indraprasth Thermal Power station. Remaining 7.3 MCM/ year (20 MLD) Sewage Treated water is being used for Horticulture at Rashtrapati Bhawan. Similarly, treated sewage from Vasant Kunj sewage treatment plant is being used by DDA for Horticulture. In addition to this, MoEF plans to set up the pilot scale STP (YAP – II) at Keshavpur wherein the effluent of STP will comply with drinking water standards.

This quantity of treated sewerage will increase with time. As per information, due to improvement in sanitation infrastructure, approximately 90% of urban and 30 % of rural sewage will get treated by 2021. The quantity of available treated sewage is summarized in **table 4.11** below.

Table 4.11: Quantity of Treated sewage in different sub-regions of NCR.

Sl. No	Sub-Region	Quantity of Treated Sewage in MCM/ year		
		Presently	2011	2021
1	Haryana	113.16	360.56	444.49
2	Rajasthan	0	93.49	124.60
3	Uttar-Pradesh	136.37	549.64	674.54
4	NCT Delhi	539.47	1741.64	2029.85
	Total NCR	**789**	**2745.33**	**3273.48**

Source : WAPCOS Report on NCR

4.2 Potential Recharge areas

The NCR area represents complex hydrogeological and geomorphic set up. Further, the drainage network also varies to the great extent, the eastern portion i.e. the UP region represents the *doab* area between two major rivers of the country, the river Ganga and Yamuna, whereas the southern portion of NCR , the Alwar region is almost devoid of any major stream except river Sahibi. The Alwar as well as NCT region is dotted with Aravali hills.

The potential recharge areas in NCR include the river flood plains of Ganga, Yamuna, Hindon and Sahibi. Flood plain areas are globally being used for induced recharge by the adjoining river. Flood plains offer dual advantage of heavy ground water withdrawal in lean season creating more space for recharge during flood season. A major part of NCR can be categorized as Rural area , in such areas the village ponds offers viable options for harnessing the rain water and recharge to ground water, either by de-silting the existing ponds to enhance the rate of infiltration or by constructing the vertical shafts within the pond. Similarly, the existing dug wells can be used for recharge with suitable provisions for filtering.

The Aravalis can also act as potential recharge areas, by constructing the trenches along the fringe of hills and sloping segments, further, the lower order streams can be harnessed by constructing the small check dams and gabion structures.

In the urban areas other than roof top rain water harvesting, the potential recharge areas are parks, suitable Park type structures may be constructed in the areas to conserve more and more water which will in turn recharge ground water. In addition, in the hilly areas, the abandoned quarries can be used to channelize the rain water harvesting and recharge to ground water. The recycled waste water are increasingly being used for recharge in several countries after necessary treatment, the possibility of using such waters need to be explored in NCR area , after ensuring quality.

4.2.1 Utilizing Potential Aquifers along Yamuna Flood Plains

Yamuna Active Flood Plain Aquifer System occupies an area of 97 Sq.km. Newer alluvium (Yamuna Sand), which is predominantly silty sand, mixed with clay and gravel acts as potential aquifer. Total thickness of Newer alluvium varies between 40 to 50 m. Aquifer system in Newer alluvium is unconfined with depth to water level occurring at shallow depths of 0.5 to 3.50 m bgl which sustain tube wells with yields ranging from 1400 to 2800 lpm(liter per minute). Transmissivity of the aquifer system varies between 730 m^2/day to 2100 m^2/day with hydraulic conductivity varying between 13 m/day to 60 m/day. In general, the quality of ground water is fresh at shallow depths (Fresh/Saline water interface is about 70 m at Palla, 30 m in Burari, about 45 m in Mayur Vihar area and about 28 to 30 m in Kalindi Kunj area) and becoming brackish to saline at deeper levels. The fluoride concentrations of ground water of Yamuna Flood plain by and large are below the permissible limit of 1.5 mg/l. It ranges from 0.18 to 3.10 mg/l. Excessive fluoride concentrations are observed in Burari-Bhaktawarpur-Jagatpur zone. High concentration of nitrate of about 174 mg/l is observed in Okhla Village, which may be due to the unhygienic conditions prevailing around the shallow hand pump.

The elevation of water table in Yamuna Flood Plain varies from 194 to 208 a msl (above mean sea level). The water table elevation shows that in the stretch extending from Palla in the north to Okhla barrage in the south, the ground water is feeding the river Yamuna. South of Okhla barrage, river is feeding the ground water probably due to impounding of surface water in Kalindi Kunj reservoir.

Five Potential areas have been identified to construct tube wells. These are Palla-Hiranki Sector, Sonia Vihar Sector, Usmanpur Sector, Nangli Rajapur Sector and Kalindi Kunj-Jaitpur Sector.

The detailed study including ground water flow modeling carried out by CGWB in collaboration with NIH has indicated that from the Palla sector nearly 49.7 MCM (30 MGD) of ground water withdrawal can be safely made through the existing battery of wells , this would avoid up-coning of saline water lying beneath in the area. Further, a complete withdrawal pattern has also been suggested by staggering the pumping in time and space. Assuming similar conditions, it has been estimated that nearly 615 MCM of fresh ground water resources is available in the entire flood plain of river Yamuna in the Delhi stretch. Extrapolating the results of Palla modeling , it has been assessed that nearly 153 MCM (92MGD) of ground water can be withdrawn from the flood plain without creating any environmental degradation in terms of up-coning of saline water from down below.

5. Water Harvesting & Recharge: Concepts and Techniques

5.1 Concept:

Our ancient religious texts and epics give a good insight into the water storage and recharge systems that prevailed in those days. Over the years rising populations, growing industrialization, and expanding agriculture have pushed up the demand for water. Efforts have been made to collect water by building dams and reservoirs and digging wells; some countries have also tried to recycle and desalinate (remove salts) water. Water recharge has become the need of the day. The idea of ground water recharging by harvesting rainwater is gaining importance.

In the forests, water seeps gently into the ground as vegetation breaks the fall. This groundwater in turn feeds wells, lakes, and rivers. Protecting forests means protecting water 'catchments'. In ancient India, people believed that forests were the 'mothers' of rivers and worshipped the sources of these water bodies. In India about three quarter of the cultivable area depends on in-situ rainfall contributing almost 50% of the national production. Production from such areas can be stabilized or even improved by reducing the run-off to conserve more water. Harvesting local rain water and reusing it for life saving irrigation and other purposes is not a new concept in India. Water harvesting and run-off recycling has four distinct components viz. collection (harvesting) of excess rainfall, efficient storage of harvested water, water application (including lifting and conveyance) and optimal utilization of applied water for maximum benefits.

The term artificial recharge has different connotations for various practitioners. The process of recharge itself is not artificial. The same physical laws govern recharge, whether it occurs under natural or artificial conditions. What is artificial? It is the availability of water supply at a particular location at a particular time. In the broadest sense one can define artificial recharge as procedure which introduces water in a pervious stratum.

The term artificial recharge refers to adopting mechanism for enhanced infiltration of surface water to the aquifer by human interference. The natural process of recharging the aquifers is accelerated through percolation of stored or flowing surface water which otherwise is not percolating in to the aquifers. It is also defined as the process by which ground water is augmented at a rate exceeding that under natural condition of replenishment. Therefore, any man-made facility that adds water to an aquifer may be considered as artificial recharge.

Artificial recharge aims at augmenting the natural replenishment of ground water storage by some method of construction, spreading of water, or by artificially changing natural conditions. It is useful for reducing overdraft, conserving surface run-off, and increasing available ground water supplies. Recharge may be incidental or deliberate, depending on whether or not it is a bye-product of normal water utilization.

Another school of thought says artificial recharge is a process of induced replenishment of the ground water reservoir by human activities. The process of supplementing may be either planned such as storing water in pits, tanks etc. for feeding the aquifer or unplanned and incidental to human activities like applied irrigation, leakages from pipes etc.

5.2 Water Recharge

Water recharge practices are adopted all over the world to meet the increasing water demand with outburst of population, development of industrial sector and rise in irrigation water requirements. With the development of technology new methods and mechanisms are being developed all over the world to conserve water as far as possible in all sectors. Most concepts of water recharge which we practice today were also adopted by our predecessor. However, with time improvements in technology have introduced new recharge techniques to achieve better results.

5.2.1 Ancient Practices:

Ancient civilization flourished close to water sources. As population grew, humans had to move away and a need for water shortage was felt. Water harvesting has been practiced in India and abroad for centuries but the designs of traditional structures varied from region to region controlled by several factors mainly the pattern of monsoon.

Rainwater harvesting and utilisation systems have been used since ancient times and evidence of roof catchment systems is recorded in early Roman times. Roman villas and even whole cities were designed to take advantage of rainwater as the principal water source for drinking and domestic purposes since at least 2000 B.C. In the Negev desert in Israel, tanks for storing runoff from hillsides for both domestic and agricultural purposes have allowed habitation and cultivation in areas with as little as 100 mm of rain per year. The earliest known evidence of the use of the technology in Africa comes from northern Egypt, where tanks ranging from 200-2000m^3 have been used for at least 2000 years – many are still operational today. The technology also has a long history in Asia, where rainwater collection practices have been traced back almost 2000 years in Thailand. The small-scale collection of rainwater from the eaves of roofs or via simple gutter into traditional jars and pots has been practiced in Africa and Asia for thousands of years. In many remote rural areas, this is still the method used today. The world's largest rainwater tank is probably the Yerebatan Sarayi in Istanbul, Turkey. This was constructed during the rule of Caesar Justinian (A.D. 527- 565). It measures 140m by 70m and has a capacity of 80,000 cubic metres.

Our ancient religious texts and epics give a good insight into the water storage and conservation systems that prevailed in those days. Over the years rising populations, growing industrialization, and expanding agriculture have pushed up the demand for water. Efforts have been made to collect water by building dams and reservoirs and digging wells; some countries have also tried to recycle and desalinate (remove salts) water. Water recharge has become the need of the day.

As a matter of fact, artificial recharge and rain water harvesting can be achieved by several means, such as

- **In situ harvesting:** Nadi, tanka, sand-filled reservoirs, ponds rooftop and hilltop collection of water.
- **Storage of water in aquifers** (artificial recharge of ground water), percolation tanks, anicuts, check dams, subsurface dams, barriers, injection wells etc.

- **Soil conservation methods** which helps to increase ground water recharge, gully plugging, contour bunding, afforestation, counter trenching, land leveling and bunding of fields.
- Enhancement of surface runoff collection: catchment treatment
- **Evaporation control:** chemical films, hydrophobic coating, spreading of thermocol sheets etc.

5.2.2 Area specific techniques

The selection of a suitable structure for artificial recharge of ground water depends on various factors. They include:

- Quantum of non-committed surface run-off available.
- Rainfall pattern
- Land use and vegetation
- Topography and terrain profile
- Soil type and soil depth
- Thickness of weathered / granular zones
- Hydrological and hydrogeological characteristics
- Socio-economic conditions and infrastructural facilities available
- Environmental and ecological impacts of artificial recharge scheme proposed.

5.2.3 Artificial Recharge & Roof Top Rain Water Harvesting

Artificial recharge systems are engineered systems where surface water is put on or in the ground for infiltration and subsequent movement to aquifers to augment groundwater resources. Other objectives of artificial recharge are to store water, to improve the quality of the water through soil-aquifer treatment or geo-purification, to use aquifers as water conveyance systems, and to make groundwater out of surface water where groundwater is traditionally preferred over surface water for drinking. Artificial recharge is expected to become increasingly necessary in the future as growing populations require more water, and as more storage of water is needed to save water in times of water surplus for use in times of water shortage.

Artificial recharge efforts are basically augmentation of the natural movement of surface water into ground water reservoir through suitable civil construction technique or other similar methods. Availability of source water is one of the important requirements for recharge schemes. It is assessed in terms of non-committed surplus run-off, which is going unutilized as per the water resource development pattern. The other basic requirement is the availability of sub-surface storage space in different hydrogeological situations. The topography and the soil condition of the area links the above two factors. Topography governs the extent of run-off and its retention where as the soil condition determines the extent of percolation. The artificial recharge technique interrelate and integrate the source water to ground water reservoir which in turn dependent on the hydrogeoloical situation of the area.

Artificial recharge projects are site specific. The replication of the techniques from similar areas is to be based on the local hydrogeoloical and hydrological environs. The first step in planning the project is to demarcate the area of recharge. The scheme can be implemented systematically in case a hydrologic unit like watershed is taken for implementation. However, localized schemes are also can be taken up to augment the ground water reservoir. Schemes are normally taken in the following areas:

- Areas where ground water levels are declining over a period of time.
- Areas where substantial amount of aquifer has already been desaturated.
- Areas where availability of ground water is in adequate in lean months and there is availability of surface water for recharge during rainy season.
- Areas where salinity ingress is taking place.
- Areas where there is quality problem in ground water

Roof top rain water harvesting can also be adopted to meet domestic water requirements. The roof top rain water can be stored in specifically constructed surface or sub-surface tanks. Dependence on ground water has increased many folds and the natural recharge to ground water has decreased, due to urbanization, construction of buildings and paved area. In urban areas water falling on roof tops can be collected and diverted to the open wells/ tubewells/ borewells through filter medium.

Roof top rainwater harvesting, which involves the collection of rainwater from the roof of the buildings and its storage in surface tanks or recharge to sub-surface aquifer play an important role in conservation of water. Thus, the need for artificial recharge of groundwater is beyond doubt and is the most powerful management strategy available to face the challenge of fast depletion in groundwater resources.

Techniques used for artificial recharge to ground water broadly fall under the following categories

Direct Methods

A) Surface Spreading Techniques

a) Flooding

b) Ditch and Furrows

c) Recharge Basins

d) Runoff Conservation Structure

i) Bench terracing

ii) Contour Bunds and contour trenches

iii) Gully Plugs, Nala Bunds, Check Dams

iv) Percolation Ponds

e) Stream Modification / Augmentation

B) Sub-surface Techniques

a) Injection wells (Recharge wells)

b) Gravity head recharge wells

c) Recharge pits and shafts

Indirect Methods

A) Induced Recharge from Surface Water Sources;

B) Aquifer Modification

i) Bore Blasting.

ii) Hydro-fracturing.

Combination Methods

In addition to the above, ground water conservation structures like Subsurface dykes (Bandharas) and "Fracture Sealing Cementation Techniques" are also used to restrict subsurface flows. Aquifer disposition plays a decisive role in choosing the appropriate technique of artificial recharge of ground water.

5.3 Methods of Recharge

Natural replenishment of ground water reservoir is a slow process and is often unable to keep pace with the excessive and continued exploitation of ground water resources. This has resulted in declining ground water levels and depletion of ground water resources in several areas. Artificial recharge efforts are basically aimed at augmentation of the natural movement of surface water into ground water reservoir through suitable civil construction techniques. Such techniques/methods inter-relate and integrate the source water to ground water reservoir and are dependent on the hydrogeological situation of an area. Roof top Rain water harvesting and artificial recharge to ground water for urban and rural areas are elucidated below:

5.3.1 Rooftop Rainwater Harvesting

In Urban areas, water is mainly required for domestic and related uses, and is mostly drawn from surface water bodies, rivers, streams and/or ground water sources. Rooftop rainwater harvesting is an ideal alternative in such areas. Appropriate storage facility can be created to store rooftop rainwater depending on availability of space. Rainwater harvesting in urban areas helps not only in meeting at least a part of the water requirement but also prevents storm runoff and flooding of roads during heavy rains. It also reduces the pumping costs and reduces the stress on ground

In rural areas, ponds, streams and wells have traditionally been used as sources of water for drinking, livestock and other domestic uses. In recent years, bore wells with hand pumps and small water supply schemes have almost replaced these traditional sources of water. Yet, in many rural habitations, these sources have not been able to supply water to the rural households round the year, due to various reasons. Domestic Rooftop Rainwater Harvesting System (RRHS) provides a viable solution to bridge the gap between demand and supply of water in such areas, especially during periods of water scarcity. Specifically, RRHS is applicable in:

- Areas where traditional water sources like ponds, streams and wells dry up during summer.
- Areas with problems of ground water salinity such as coastal areas.

- Areas where ground water has high concentration of harmful chemical constituents such as fluoride, iron and arsenic.
- Areas where water sources are contaminated due to pollution from various sources.

The advantages of RRHS over conventional water supply systems in rural areas are:

- A dependable, economical and durable source of water for drinking and cooking purposes to the rural households, especially during periods of water scarcity.
- Available at the doorstep of the house.
- Easy access to the source of water improves the health and hygiene of family.
- Time spent in fetching water from distant water sources is considerably reduced. This generally being the responsibility of women, the time saved could be productively used for themselves and their family.
- Rain water from rooftop is free from contamination and pollution, and generally found clean and potable.
- Requires simple maintenance.
- Construction and maintenance are simple and does not require sophisticated tools or technology.

5.3.2 Recharge to Ground Water

Occurrence of rainfall in India is mostly limited to about three months in a year, with the number of rainy days ranging from around 10 to 100. The natural recharge to ground water reservoir is restricted to this period only. Artificial recharge techniques aim at extending the recharge period in the post-monsoon season for about three or more months, resulting in enhanced sustainability of ground water resources during the lean season.

In arid regions, rainfall varies between 150 and 600 mm/ year with less than 10 rainy days. A major part of the precipitation is received in 3 to 5 major storms lasting only a few hours. The rates of potential evapo-transpiration (PET) are exceptionally high in such areas, often ranging from 300 to 1300 mm. In such cases, the average annual PET is much higher than the rainfall and at times as high as ten times the rainfall and the annual water resource planning has to be done by conserving the rainfall, by storing the available water either in surface or in sub-surface reservoirs. In areas where climatic conditions are not favorable for creating surface storage, artificial recharge techniques have to be adopted for diverting most of the surface storage to the ground water reservoirs within the shortest possible time.

In hilly areas, even though the rainfall is comparatively high, scarcity of water is often felt in the post-monsoon season, as most of the water available is lost as surface run-off. Springs, the major source of water in such terrains, are also depleted during the post monsoon period. In such areas, rainwater harnessing and small surface storages at strategic locations in the recharge areas of the springs can provide sustainable yields to the springs by increasing the recharge during and after rainy season.

Purpose and Principles of Artificial Recharge of Ground Water

There are many reasons why water is deliberately placed into storage in ground water reservoirs. A large percentage of artificial recharge projects are designed to replenish ground water resources in depleted aquifers and to conserve water for future use. Other such projects recharge water for various objectives such as control of salt-water encroachment, filtration of water, control of land subsidence, disposal of wastes and recovery of oil from partially depleted oil fields.

Source Water

From the point of view of artificially storing water for future use, the basic requirement is to be able to obtain water in adequate amounts and at the proper times in order to accomplish this goal. Some schemes involve the impoundment of local storm run-off, which is collected in ditches, basins or behind dams, after which it is placed into the ground. In other localities, water is sometimes brought into the region by pipeline or aqueduct. In the latter case, the water is an import, and represents an addition to whatever natural water resources occur in the region. A third approach is to treat and reclaim used water being discharged from sewer systems or industrial establishments.

5.4 Advantages and Disadvantages

The planning of rooftop rainwater harvesting systems in an area needs to be done in terms of its technical suitability, social acceptance and economic viability. Artificial recharge is becoming increasingly necessary to ensure sustainable ground water supplies to satisfy the needs of a growing population.

Some of the major advantages and disadvantages of artificial recharge to ground water as compared to surface water storage are listed below

Advantages

- Subsurface storage space is available free of cost and inundation is avoided
- Evaporation losses are negligible
- Quality improvement by infiltration through the permeable media
- Biological purity is very high
- It has no adverse social impacts such as displacement of population, loss of scarce agricultural land etc
- Temperature variations become minimum
- It is environment friendly, controls soil erosion and flood and provides sufficient soil moisture even during summer months
- Water stored underground is relatively immune to natural and man-made catastrophes
- It provides a natural distribution system between recharge and discharge points
- Results in energy saving due to reduction in suction and delivery head as a result of rise in water levels

Disadvantages

- Additional cost of pumping the ground water

- Complex operation
- Degradation from pollution sources can be long lasting if not taken up carefully
- Institutional, organizational and legal problems due to ground water being a common pool resource.

6. Legal Aspects of RWH and Ground Water Recharge

6.1 Legal Provisions

India does not have an exclusive and comprehensive water law. Water-related legal provisions are dispersed across various irrigation Acts, central and state laws, constitutional provisions and court decisions.

Constitutional provisions

Water is included in the Sate list of 7th schedule of the Constitution of India and hence all activities related to planning, development and management of water resources are undertaken by the respective States through their Water Resources or Irrigation Departments. In many cases, State Governments have established autonomous Bodies and Corporations for development and management of water resources. Further, the Constitution provides for regulation and development of inter-State rivers and river valleys by the Union Government to the extent to which such regulation is declared by Parliament by Law expedient in public interest.

Entries Related to Water in State and Union Lists

Entry 17 of List II (State List) of the 7th Schedule
"Water, that is to say, water supplies, irrigation and canals, drainage and embankments, water storage and water power subject to provisions of entry 56 of List I'.

Entry 56 of List I (Union List) of the 7th Schedule
"Regulation and development of inter-state rivers and river valleys to the extent to which such regulation and development under the control of the Union is declared by Parliament by law to be expedient in the public interest."

Water ownership

India does not have any specific law defining ownership and rights over water sources. The rights are derived from several legislations and customary beliefs.

Rights over surface water

Rights over water in rivers and lakes are defined by land and state irrigation Acts. Formulated first in colonial times, these Acts explicitly state that the government has absolute right over this water. For instance, the Northern India Canal and Drainage Act, 1873, states that the government has the right to “use and control for public purposes the water of all rivers and streams flowing in natural channels, and of all lakes”. Irrigation Acts or their rules specify who can use canal water, and for what purpose. Only use rights -- not ownership rights -- are granted. Typically, use rights are granted only to people who have land in command areas.

However, in Maharashtra, lift irrigation schemes have been permitted to take water to lands outside the command area. Further, a new law allows 'bulk' users such as water users' associations to sell the water allotted to them. But such sale will be regulated by the authority that grants the bulk allotment in the first instance.

Rights over groundwater

Several court judgments in post-Independent India have affirmed that all natural resources -- resources that are by nature meant for public use and enjoyment -- are held by the State in public trust.

For instance in M C Mehta v Kamal Nath (1997)*,* the Supreme Court declared that "the State is the trustee of all natural resources"; as a trustee, the State has "a legal duty to protect the natural resources," and "these resources meant for public use cannot be converted into private ownership".

However, the legal position on whether groundwater is a resource meant for public use is fuzzy, and India has no law that explicitly defines groundwater ownership (Orissa did amend its irrigation Act to assert State right over groundwater, but this has been challenged in court).

Some grounds for determining groundwater rights are provided by the Indian Easement Act of 1882. An 'easement' is a right that the owner or occupier of certain land possesses, for beneficial enjoyment of that land. Examples of easements are right of way, right to light and air, and right to standing or flowing water not on one's land.

Section 7 (g) of the Indian Easement Act states that every landowner has the right to "collect and dispose" of all water under the land within his own limits, and all water on its surface that does not pass in a defined channel. Hence, by this Act, the owner of a piece of land does not, strictly speaking, "own" the groundwater under the land or surface water on the land; he only has the right to collect and use the water. However, it is customarily accepted across India that a well on a piece of land belongs to the owner of that land, and others have no right to extract water from the well or restrict the landowner's rights to use the water.

This belief and practice is indirectly supported by various laws such as land Acts and irrigation Acts that list all things on which the government has a right. These Acts do *not* mention groundwater.

Interpretations of the Transfer of Property Act of 1882 and the Land Acquisition Act of 1894 also support the position that a landowner has proprietary rights to groundwater; it is connected to the 'dominant heritage' (land) and cannot be transferred apart from the land.

But the right to property in India is not absolute. It is not a fundamental right and government has the power to restrict it in the interests of the larger public good. Thus, the government enjoys the right to take over anybody's land to construct dams, build roads, etc. While the government has to follow due process and pay due compensation (failure to do so can be challenged), its right to acquire the property itself is unchallengeable.

Further, the government is duty-bound by the directive principles of the Constitution to work towards social, political and economic justice and equity, and protection of the environment. For instance, Article 39 (b) lays down that: 'The State shall, in particular, direct its policy towards securing that the ownership and control of the material resources of the community are so distributed as best to subserve the common good.' Article 51-A (g) says it is the fundamental duty of every citizen 'to protect and improve the natural environment including forests, lakes, rivers…'

Hence, the government has the right as well as the *duty* to regulate use of groundwater in the interests of justice, equity and environmental protection. This duty was emphasised by a Supreme Court order that directed the Centre to constitute a groundwater authority. Accordingly, the Central Ground Water Authority was set up in 1986.

Right to water

The Constitution guarantees every citizen fundamental rights to equality, life and personal liberty. Article 15 (2) of the Constitution further states that no citizen shall be subjected to any restriction with regard to "the use of wells, tanks, bathing ghats".

Various courts have upheld that the right to clean and safe water is an aspect of the right to life. For instance, in Narmada Bachao Andolan v Union of India (2000), the Supreme Court said that "water is the basic need for the survival of human beings and is part of right to life and human rights as enshrined in Article 21 of the Constitution of India".

But judgments do not constitute law or policy; at best, they provide directions for the *formulation* of laws and policies. As yet, no laws or policies have been formulated asserting that water is a fundamental and inviolable right enjoyed by every citizen of the country.

The 'right to water' can therefore be obtained in India only on a case-by-case basis, by going to court.

Responsibility for providing water

It has been implicitly accepted that central and state governments have a primary responsibility for providing water for drinking, and, subsequently, for other purposes. Provisions for supplying drinking water have been made in all the Five-Year Plans, and the responsibility was made explicit in the Twenty-Point Programme drafted in 1975 and modified in 1982 and 1986.

Accordingly, a host of programmes have been framed and implemented at the central and state levels, such as the Accelerated Rural Water Supply Programme and the Rajiv Gandhi National Drinking Water Mission. A gamut of laws has also been drafted, including:

6.2 Existing Policies

National Water Policy

The Ministry of Water Resources, Government of India ("Ministry") is responsible for laying down policy guidelines and programmes for the development and regulation of country's water resources. Amongst others the Ministry has been allocated the function of "overall planning for the development of ground water resources, establishment of utilizable resources and formulation of policies of exploitation, overseeing of and support to State level activities in ground water development."

- There should be a periodical reassessment of the ground water potential on a scientific basis, taking into consideration the quality of the water available and economic viability of its extraction.
- Exploitation of ground water resources should be so regulated as not to exceed the recharging possibilities, as also to ensure social equity. The detrimental environmental consequences of overexploitation of ground water need to be effectively prevented by the Central and State Governments. Ground water recharge projects should be developed and implemented for improving both the quality and availability of ground water resource.
- Integrated and coordinated development of surface water and ground water resources and their conjunctive use, should be envisaged right from the project planning stage and should form an integral part of the project implementation.
- Over exploitation of ground water should be avoided especially near the coast to prevent ingress of seawater into sweet water aquifers.
- Drought-prone areas should be made less vulnerable to drought-associated problems through soil moisture conservation measures, water harvesting practices, minimization of evaporation losses, development of the ground water potential including recharging and the transfer of surface water from surplus areas where feasible and appropriate. Pastures, forestry or other modes of development which are relatively less water demanding should be encouraged. In planning water resource development projects, the needs of drought-prone areas should be given priority.

National Environment Policy

- As per the constitutional status the Center's power to legislate on groundwater is based on Environment Policy which suggests the following action points in relation to ground water :
- Take explicit account of impacts on groundwater tables on electricity tariffs and pricing of diesel.
- Promote efficient water use techniques, such as sprinkler or drip irrigation, among farmers. Provide necessary pricing, inputs, and extension support to feasible and remunerative alternative crops from efficient water use.
- Support practices of contour bunding and revival of traditional methods for enhancing groundwater recharge.
- Mandate water harvesting in all new constructions in relevant urban areas, as well as design techniques for road surfaces and infrastructure to enhance groundwater recharge.
- Support R&D in cost effective techniques suitable for rural drinking water projects for removal of arsenic and mainstream their adoption in rural drinking water schemes in relevant areas.

6.3 Existing by Laws in respect of Rain Water Harvesting & Artificial Recharge

NCT Delhi Sub-region

Model Bill circulated by the Union Ministry of Water Resources has underlined the broader issue of regulation and control of development of the groundwater in the country. The Model Bill provides for an independent regime for this purpose obviously looking to the geographical size of the States and multiple problems of regulation and development of groundwater in urban and rural areas of these States. Fortunately for Delhi this problem more or less restricted to urban area with rural pockets. For this, as explained above, there is already a provision in the Delhi Water Board Act authorising the Delhi Water Board to advise the other local authorities in consultation with the Central Government. (Vide proviso to section 9(1)(b)).

It is, therefore, thought appropriate that necessary powers are given to the Board by amending the existing Act, instead of going in for a new regime as the Delhi Water Board is a statutory body already having required technical know how for handling matters relating to regulation and control of development of groundwater.

The Bill accordingly, provides for the Amendment of the Delhi Board Act, 1998 as explained below.

(a) Amendment of long title: - Long title of the Act requires amendment to expand the scope of the Act for empowering Delhi Water Board (DJB) to regulate, control and develop; the groundwater supply in Delhi. This is as per the mandate of the Model Bill circulated by the Ministry of Water Resources.

(b) Definitions - Certain new 'definitions such as 'groundwater', 'sink',' user of groundwater' and 'well' will have to be inserted in the Act.

(c) Amendment of Section 9 - It is proposed to amend section 9(1)(b) to enlarge the scope of present provision to include therein the regulation, control and development of groundwater as per the Model Bill. The clause now provides "Planning for regulation, control and development of groundwater" as one of the functions of the Board instead of only exploration and management of groundwater.

(d) Insertion of new Chapter - A new Chapter III-A has been inserted in the Act, which provides for regulation, control and development of groundwater in Delhi. New section 35-A provides for declaration of notified areas for the regulation, control and development of groundwater. Sections 35-B and Section 35-C, respectively, provide for permission before sinking any well for use of groundwater and for registration of existing users in areas notified. In granting or refusing permission for new well or registration of existing one the Board shall have regard to:

(i) the purpose or purposes for which water is to be used;

(ii) the existence of other competitive users;

(iii) the availability of water;

(iv) quality of groundwater with reference to use;

(v) spacing of groundwater structures keeping in consideration the purpose for which water is to be used;

(vi) long term groundwater level behaviour;

(vii) any other factor relevant thereto.

Subsequent sections 35-D, 35-E and 35-F provide for powers to the Board for alteration, amendment and varying the terms of permit and registration and their cancellation Section 35-F in particular provides for entry, search, closing of water supply concerned and sealing of the water supply if situation so demands.

(e) Levy of user charges for use of groundwater - As explained in the beginning reading section 9(1)(b) and section 35 of the Act, the Board can levy user charges for use of groundwater. But a new section 35-H has been added **specifically** providing for levy of user charges by the Board to clarify the position beyond doubt.

(f) New offences have been added in the Fourth Schedule to the Act for effective implementation of the new provisions. The tenors of punishment have obviously been kept in tune with the existing penal provisions. The modified Bill is annexed at **Annexure-I**.

Haryana Sub-region

The building by laws amended by Haryana Government and roof top rain water harvesting has been mandatory for all the plots with more than 100 sq. yards area. The detailed notification is given in **Annexure-II**

UP Sub-region

In the building by laws amended by UP Government the roof top rain water harvesting has been made mandatory for all the buildings with roof area equal to or more than 1000 sq. m area. It has also been notified that roof top rain water harvesting will be made mandatory for all government & institutional buildings. The detailed notification is given in Annexure-III.

Rajasthan Sub-region

Rajasthan Government has included rain water harvesting and artificial recharge to ground water in its building by laws at suitable places in respect of development and construction of township in different cities of Rajasthan. As per the by laws minimum area for integrated township shall be 10 hectares in Jaipur, 6 hectares in Divisional Headquarters and 4 hectares in other Municipal Towns and District Headquarters.

- Rain water harvesting provisions will be compulsory in all group housing projects and township schemes
- In township schemes “community water harvesting structures" will be constructed by local authority and all water outlets and drainages will be connected to this structure. This shall be strictly enforced by the Local Authority

6.4 Regulatory Measures taken/ proposed by States/UT Governments in the Country

As on date so far 18 States and 4 UTs have already made roof top rain water harvesting mandatory in their respective States/UTs. The names of these States/UTs are: Andhra Pradesh, Bihar, Goa, Gujarat, Haryana, Himachal Pradesh, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Nagaland, Punjab, Rajasthan, Tamil Nadu, Tripura, Uttar Pradesh, Uttarakhand, West Bengal, Chandigarh, Daman & Diu, NCT Delhi and Puducherry. Four States namely Meghalaya, Arunachal Pradesh, Orissa, Jharkhand and two Union Territories i.e. Lakshadweep and Andaman & Nicobar are also in the process of making such provision. Six States namely Chhattisgarh, Sikkim, Mizoram, Assam, J&K, Manipur and UT of Dadar & Nagar Haveli have not initiated action in this regard so far. Details of action taken by these States/UTs are given in Table below.

Table: States/ UTs which have made mandatory provision of Roof Top Rainwater Harvesting & Artificial Recharge to Ground Water

Sl. No.	State/UT	Provisions
1.	Andhra Pradesh	'Andhra Pradesh Water, Land and Tree Act, 2002' stipulates mandatory provision to construct rainwater harvesting structures at new and existing constructions for all residential, commercial and other premises and open space having area of not less than 200 sq.m. in the stipulated period, failing which the authority may get such rain water harvesting structures constructed and recover the cost incurred along with the penalty as may be prescribed.
2.	Daman & Diu	Daman Municipal Building Model Bye-laws and Zoning Regulation, 2002 exists which have provision for construction of sumpwell for recharge of ground water. The UT Administration has issued instructions to the local PWD for construction of roof top rainwater harvesting structures. Administration HAS has also advised the local bodies such as Municipality & District Panchayats to make provision for construction of roof top rain water harvesting structures. Local bodies has already initiated action in this regard.
3.	NCT. Delhi	Modified Building Bye-laws, 1983 to incorporate mandatory provision of roof top rain water harvesting in new building on plots of 100 sq.m. through storage of rain water runoff to recharge underground aquifer in NCT, Delhi.
4.	Goa	PWD, Goa has been asked to take up rain water harvesting structure for Government buildings. Rain water harvesting already implemented at Government Engineering College at Farmagudi, Ponda, Goa by the PWD. The PWD, Goa is studying various designs of roof top rain water harvesting for taking up other existing large Government buildings and for any new coming Government buildings under construction.
5.	Gujarat	Metropolitan Areas have notified rules under which no new building plan is approved without corresponding rainwater harvesting structure. The D/o Roads & Buildings have been directed to ensure that all major Govt. constructions including educational institutions had adequate rainwater harvesting facilities. The Urban Development and Urban Housing

		Department, Govt. of Gujarat has issued necessary order on 27.07.2004 under Section 122 of Gujarat Town Planning Act, 1976 to incorporate the rules for rain water harvesting in General Development Control Regulations (GDCR) of all Development Authorities in the State.
6.	Haryana	Haryana Municipal Building Bye-laws 1982 has been amended by Haryana Urban Development Department and Haryana Urban Development Authority to incorporate the provision of compulsory Roof Top Rain Water Harvesting.
7.	Kerala	Roof top rain water harvesting has become mandatory as per Kerala Municipality Building (Amendment) Rules, 2004 for all new buildings.
8.	Himachal Pradesh	Installation of rain water harvesting system has been made mandatory for all buildings to be constructed in urban areas of the State and no building plan without rain water harvesting system can be approved including schools, all Government buildings and rest houses. Construction of rain water harvesting system has also been made mandatory for all Schools, Govt. buildings and Rest Houses, upcoming industries, bus stands etc.
9.	Karnataka	The State has adopted a rain water harvesting policy to mandate this in all new construction. Banglore City Corporation has already incorporated mandatory rain water harvesting in Building Bye-laws. Other ULB's are being encouraged to do so. Action to amend building bye-laws in major cities having population of more than 20 lakh to make rain water harvesting mandatory has been initiated. Rural Development & Panchayati Raj Department has issued orders for implementation of roof top rain water harvesting in all Government buildings. State has also extended help to the individual people also to the tune of 20% rebate on tax payment for 5 years duration. A massive programme to implement roof top rain water harvesting in rural schools has been taken up by Rural Development & Panchayati Raj.
10.	Madhya Pradesh	Vide Gazette notification dated 26.8.2006, roof top rain water harvesting has been made mandatory for all types of buildings having plot size of more than 140 sq.m. Govt. has announced 6% rebate in property tax to individuals for the year in which the individual will go for installation of roof top rain water harvesting structures.
11.	Maharashtra	Maharashtra Government is promoting roof top rainwater harvesting under the "Shivkalin Pani Sthawan Yojana". It provides that all houses should have provision for rainwater harvesting without which house construction plan should not be sanctioned. Bombay Municipal Corporation and Pimpri - Chinchwad Municipal Corporation have made Rain Water Harvesting mandatory by enacting building bye-laws. Keeping in view the constraint of the available space, provision of rain water harvesting scheme has been made for Greater Mumbai Municipal Corporation Area and other municipal areas of the State.
12.	Nagaland	The State Government has already made provision for roof top rainwater compulsory for all new Government buildings.
13.	Puducherry	Approvals are issued to new constructions subject to the provision of rain water harvesting in building designs. PWD, Pondicherry has started constructing roof top rain water harvesting structures in the Government

		buildings since 2002. The UT Administration has made rules for installation of rain water harvesting system in all the new constructions.
14.	Rajasthan	Roof Top rain water harvesting has been made mandatory in State owned buildings of plot size more than 300 Sq.m with effect from 03.01.2006. For violation of building bye-laws, punitive measures, viz. disconnection of water supply, has also been made. The Govt. has made provision of compulsory installation of rainwater harvest system in all newly and existing construction building and Govt. offices vide order dated 31.05.200 and 12.12.2005 The State Government is also considering to modify Municipal Corporation Act making provisions of rain water harvesting.
15.	Tamil Nadu	Vide Ordinance No. 4 of 2003 dated July, 2003 laws relating to Municipal Corporations and Municipalities in the State have been amended making it mandatory for all the existing and new buildings to provide rain water harvesting facilities. The State has launched implementation of RWH scheme on massive scale in Government buildings, private houses/Institutions and commercial buildings in urban & rural areas. The State Government has achieved cent percent coverage in roof top rain water harvesting.
16.	Uttar Pradesh	The Govt. of U.P. has constituted mandatory rules for compulsory installation of Rain Water Harvesting system in all the new housing schemes/plots/buildings of all uses, group housing schemes with provisions of separate network of pipes for combined Rain Water Harvesting/Recharging system. Roof top rain water harvesting have been made mandatory for plots of 100-200 sq. mt. In Govt. Buildings (both new as well as old), installation of rain water harvesting structures has been made mandatory.
17.	West Bengal	Vide Rule 171 of the West Bengal Municipal (Building) Rules, 2007, installation of rain water harvesting system has been made mandatory.
18.	Punjab	Department of Local Government have amended and notified the building Bye-Laws and have made mandatory Rain Water Harvesting System in all buildings above 200 sq. yds.. The Punjab Urban Development Authority (PUDA) is in the process of amending the PUDA (Building) Rules 1996 for making this system mandatory. Bye-laws have been framed by Municipal Corporation of Ludhiana and Jalandhar to make rain water harvesting mandatory in new buildings.
19.	Uttarakhand	The Govt. of Uttarakhand (Awas evam Shahari Vikas) has made rules for compulsory installation of rain water harvesting system and directed to adopt rules in building Bye-laws vide order dated 15.11.2003. accordingly, all the Development Authorities had made partial amendments in the prevalent House Building and Development Bye-laws/Regulations.
20	Tripura	As per Rule-110 of the Tripura Building Rules, 2004, water harvesting through starting of rain water run off is mandatory in all new buildings having plinth area more than 300 sq. mtr for all types of uses and in group housing of any size.
21	Bihar	The State Government of Bihar has enacted "The Bihar Ground Water(Regulation and Control of Development and Management) Act, 2006 Chapter-III (Clause 18) of the Act stipulates provision of roof top rain water harvesting structures in the building plan in an area of 1000 sq. mt.

		or more while according approval for construction by the Municipal Corporation/other local bodies.
22	Chandigarh	In UT of Chandigarh, Bye-law requiring permission of Chandigarh Administration for withdrawal of ground water in Capital Project Areas exists. It was informed by Administrator of UT of Chandigarh vide his letter No. PS/ADMR-06/578, dated 22.08.2006 that all Projects will incorporate provision for rain water harvesting.

7. Proposed Ground Water Recharge Methods

7.1 Approach and Methodology

In the current water scenario of availability and demand of water in the NCR area and In view of the ever growing requirements, water harvesting and artificial recharge play a pivotal role in sustaining the water sources as well improving the inefficient management of ground water resources of the area. In order to do so, artificial recharge needs to be adequately addressed in strategy and planning, artificial recharge should target two spheres within the water sector, the Water Resource Management Sphere and Water Services Sphere. The region or sub region wise artificial recharge potential needs to be quantified. Localized areas where artificial recharge is required should be identified. This should include areas where water table has dropped due to high ground water abstraction, where a suitable water source is available which is going unutilized and where aquifer hydraulics and water quality characteristics are favorable for artificial recharge. . Further, there is a need to better understand the economics of artificial recharge. Internationally artificial recharge has been found to be far cheaper and more cost effective than other water resources development options.

In order to use underground reservoir to store a significant volume of water – possibly of the same order of magnitude as the annual runoff –with the intent to use it at later stage, it is necessary to ascertain the potential storage capacity of the ground water reservoir as well as its suitability for being recharged by the surface water and for easily returning the stored water when needed. The ground water reservoir should present sufficient free space between ground surface and water table to accommodate and retain the water to be recharge for the period during which water is not needed.

This condition requires accurate and detailed hydrogeological investigations including geological mapping, geophysics and reconnaissance drilling, in order to determine the configuration and the storage capacity of the underground reservoir. Artificial recharge of aquifers can be achieved using three different methods, namely **Surface Spreading, Watershed Management (Water Harvesting) and Recharge Wells.**

Depending upon geomorphologic and physiographic conditions as well as conditions suitable for recharge, availability of source water the approach for water harvesting and artificial recharge has been recommended suiting to the environment.

The suitability of an aquifer for recharging has been estimated from the following parameters;

- Surface material which has to be highly permeable so as to allow water to percolate easily.
- The unsaturated zone should present a high vertical permeability, and vertical flow of water should not be restrained by less permeable clayey layers.
- Depth to water level should not be less than 7 to 10m.
- Aquifer transmissivity should be high enough to allow water to move rapidly from the mound created under the recharge basin.

An adequate transmissivity for recharge is also a good indicator of the aquifer capacity to produce high well discharge and therefore easily to return the water stored.

Natural and Induced Recharge of the aquifer:

Should a significant natural recharge of the aquifer occur from the surface runoff and the deep percolation of rainfall, and should the average annual amount of recharge be of the same order of magnitude as the water demand, there would not be the need for any additional human interventions. On the contrary, any tentative modification of the natural course of surface water may significantly alter the groundwater renewable resources.

Induced natural recharge occurs when intensive exploitation of groundwater close to river results in an important depression of ground water level and in a water-inflow from the river. This phenomenon is well known in areas where river flows all the year: but it may also occur in semi-arid climates where a depression of the piezometric level of an aquifer underlying a temporary river creates the empty space in the aquifer which facilitates its recharge during floods.

Wide spectrums of techniques are in vogues which are being implemented to recharge the ground water reservoir. Similar to the variations in hydrogeological framework, the artificial recharge techniques feasible too, would vary accordingly. The artificial recharge techniques / structures, which are feasible in varied hydrogeological situation, are described as follows:

7.2 Flood Plain Recharge

In NCR Region mainly three major rivers are flowing which have well developed flood plains feasible for recharge to ground water **(Fig 7.1)**. Ganga is flowing in the eastern part in UP sub-region and forming an eastern boundary of NCR. The ground water levels in flood plain of Ganga River are in general shallow to moderately deep. The quantum of unused flood water which is available in Ganga River is enormous in respect to the space available in the flood plain aquifers. Therefore, ground water conditions are suggestive of the making recharge only if additional space is created in the aquifers of flood plain Ganga by over developing the ground water from Battery of Tube wells. This water can be usefully supplied to the areas of water scarcity. In such an area a ground water storage and recovery scheme is feasible.

7.2.1 Basin Spreading Recharge

Water commonly is recharged by surface spreading through basins or by induced recharge from adjacent streams and lakes or through injection wells. Water may be recharged by releasing it into basins formed by excavation or by the construction of containment dikes or small dams. Horizontal dimensions of such basins vary from a few meters to several hundred meters. The most common system consists of individual basins fed by pumped water from nearby surface water sources. Silt-free water avoids the problem of sealing basins during flooding. Even so, most basins require periodic scraping of the bottom surface when dry to preserve a percolation surface. Basins, because of their general feasibility and ease of maintenance, are the most favored method of artificial recharge from the surface.

Ditches or furrows, which are shallow, flat-bottomed, and closely spaced to obtain maximum water contact area, are another alternative. Gradients of major feeder ditches should be sufficient to carry suspended material through the system since deposition of fine-grained material clogs soil surface openings. Water spreading in a natural stream channel may use any of the methods described whatever method of surface application is adopted, the primary purpose is to extend the time and the area over which water is recharged.

A typical design of Basin recharge methods is given in **Fig. 7.2.** Similar structures are proposed to be constructed in the feasible areas of Ganga, Yamuna and Sahibi river flood plains as indicated in **Fig. 7.3 to 7.8.**

7.2.2 Stream Channel Recharge

Water spreading in stream channels involves operations to increase the time and area of water contact. Activities typically require upstream storage facilities to regulate stream flows and channel modifications to enhance infiltration. Ideally, upstream reservoirs should limit flows to rates that do not exceed the absorptive capacity to downstream channels. Types of stream channel improvements include:

- Widening leveling, scarifying or ditching of the channel.
- Permanent low check dams, which do not cause flood hazard.
- Temporary low check dams consisting of stream bed materials.
- L shaped finger levees constructed by bulldozer at the end of high-stream flow season.

Water spreading in a natural stream channel involves operations that will increase the time and area over which water is recharged from a naturally losing channel; this involves both upstream management of stream flow and channel modifications to enhance infiltration. Improvements of stream channels may include widening, leveling, scarifying, ditching to increase infiltration. In areas where streams zigzag through wide valleys occupying only a small part of the valley, the natural drainage channel can be modified with a view to increase the infiltration by detaining stream flow and increasing the streambed area in contact with water.

The channel is so modified that the flow gets spread over a wider area, resulting in increased contact with the streambed. The methods commonly used include a) widening, leveling, scarifying or construction of ditches in the stream channel, b) construction of L – shaped finger levees or hook levees in the river bed at the end of high stream flow season and c) Low head check dams which allow flood waters to pass over them safely. In addition, low check dams and dikes can be constructed across a stream where a wide bottom occurs; this acts as weirs and distribute the water into shallow ponds occupying the entire streambed. Steel weirs, earth dams, concrete dams, or inflatable rubber dams are used. Sometimes the dams are designed with a sacrificial section that washes out during high flows and is replaced when danger is over. When channels have small slopes and water depth, water is spread over the entire width of the channel or flood plain by placing T- or L- shaped earthen levees, generally less than lm high, in the channel. Bulldozers are used for pushing up the levees, using natural stream bed sand. If the levees are washed out by high flows, they are restoring again when the flood danger is over.

Stream channel modification can be employed in areas having influent streams that are mostly located in piedmont regions and areas with deep water table such as arid and semi arid regions and in valley fill deposits. The structures constructed for stream channel modification are generally temporary, are designed to augment ground water recharge seasonally and are likely to be destroyed by floods. These methods are commonly applied in alluvial areas, but can also be gainfully used in hard rock areas where thin river alluvium overlies good phreatic aquifers or the rocks are extensively weathered or fractured in and around the stream channel. Artificial recharge through stream channel modifications could be made more effective if surface storage dams exist upstream of the recharge sites as they facilitate controlled release of water. **Fig 7.10** gives the schematic design of River channel recharge.

7.2.3 Induced Recharge

Induced recharge involves pumping water from an aquifer, which is hydraulically connected with surface water to induce recharge to the ground water reservoir. Once hydraulic connection gets established by the interception of the cone of depression and the river recharge boundary, the surface water sources starts providing part of the pumping yield. Induced recharge, under favorable hydrogeological conditions, can be used for improving the quality of surface water resources due to its passage through the aquifer material. Collector wells and infiltration galleries, used for obtaining very large water supplies from riverbeds, lakebeds and waterlogged areas also function on the principle of induced recharge. The schematic diagrame of Induced recharge is given in **Fig. 7.11.**

Check dams constructed in the river channel upstream of the channel bifurcation help in high infiltration to the channel when wells located in the channels are pumped with high discharge for prolonged periods.

Design:

- Quality of source water, hydraulic characteristics and thickness of aquifer material, distance of the pumping wells from the river and their pumping rates are the important factors controlling the design of schemes for induced recharge.
- For implementation of successful induced recharge schemes from stream channels, pumping wells should be selected at sites where water in the streams has sufficient velocity to prevent silt deposition.
- Dredging of channel bottom in the vicinity of the existing pumping wells may have to be carried our periodically to remove organic matter and impervious fine material from the beds of the channel.
- For wells constructed in unconfined alluvial strata for induced recharge, the lower one-third of the wells may be screened to have optimum draw downs. In highly fractured consolidated rocks, dug wells penetrating the entire thickness of the aquifer should be constructed with lining above the water table zone and the curbing height well above the High Flow Level (HFL) of the stream.

7.3 Ridges

Central and southern part of NCR is characterized by the occurrence of quartzite ridges of Delhi super group. These ridges are trending NE-SW and occupying Rajasthan sub-region and part of Haryana sub-region in Alwar, Faridabad and Gurgaon districts. These ridges generate sufficient quantity of rainfall runoff during monsoon which can be harvested and recharge to ground water through appropriate methods as described below.

7.3.1 Hill Toe Trenches

Hill Toe trenches are rainwater harvesting structures, which are constructed at the bottom of hill slopes as well as on degraded and barren but sloping waste lands in both high- and low- rainfall areas. Cross section of a typical contour trench is shown in **Fig.7.12**. The trenches break the slope at intervals and reduce the velocity of surface runoff. The water retained in the trench help in conserving the soil moisture and ground water recharge.

The size of the hill toe trench depends on the soil depth and normally 1 to 2 m wide and 1.5 to 2 m deep trenches are adopted. The size and number of trenches are worked out on the basis of the rainfall proposed to be retained in the trenches. The trenches may be continuous or interrupted and should be constructed along the contours. Continuous trenches are used for moisture conservation in low rainfall area whereas intermittent trenches are preferred in high rainfall area.

In steeply sloping areas, the horizontal distance between the two trenches will be less compared to gently sloping areas. In areas where soil cover is thin, depth of trenching is restricted and more trenches at closer intervals need to be constructed. In Rajasthan sub region in Alwar, the horizontal interval may vary from 10 m in steep slopes to about 25 m in gentle slopes.

7.3.2 Gabion Structures

This is a kind of barrier commonly constructed across small stream to conserve stream flows with practically no submergence beyond stream course. The boulders locally available are stored in a steel wire **(Fig.7.13).** This is put up across the stream to make a small dam by anchoring it to the streamside. The height of such structures is around 0.5 m and is normally used in the streams with width of about 10 to 15 m. The excess water overflows this structure leaving some storage water to serve as source of recharge. The silt content of stream water is deposited in the interstices of the boulders in due course to make it more impermeable.

7.3.3 Check Dams/Gully/Nala Plug

Check Dams are constructed across small streams having gentle slope and are feasible both in hard rock as well as alluvial formation **(Fig. 7.14).** The site selected for check dam should have sufficient thickness of permeable bed or weathered formation to facilitate recharge of stored water within short span of time. The water stored in these structures is mostly confined to stream course and the height is normally around 2 m. These are designed based on stream width and excess water is allowed to flow over the wall. In order to avoid scouring from excess run off, water cushions are provided at down streamside. To harness the maximum run off in the stream, series of such check dams can be constructed to have recharge on a regional scale.

A series of small bunds or weirs are made across selected nala sections such that the flow of surface water in the stream channel is impeded and water is retained on pervious soil/ rock surface for longer period Nala-Bunds are constructed across bigger nalas or second order streams in areas having gentler slopes. A nala bund acts like a mini percolation tank with water storage confined to stream course.

SITE CHARACTERISTIC AND DESIGN GUIDELINES

For selecting a site for Check Dams/ Nala Bunds the following aspects may be observed :

- The total catchment of the nala should normally be between 40 to 100 Hectares though the local situations can be guiding factor for this.
- The rain fall in the catchment should be less than 1000 mm/annum.
- The width of nala bed should be at least 5 meters and not exceed 15 meters and the depth of bed should not be less than 1 meter.
- The lands downstream of Check Dam/ Bund should have land under well irrigation.
- The rock strata exposed in the ponded area should be adequately permeable to cause ground water recharge through ponded water.

7.3.4 Abandoned Quarries

Haryana and Rajasthan and part of NCT Delhi sub-region is characterized by quartzites ridges of Aravali range. From years together the rock and sand mining activity was taking place in these areas. Now after intervention of Hon'ble Supreme Court the mining activity has been banned. As a result of mining activity abandoned queries in form of large cavity and depressions have been created. In mining areas for excavation of sand and rock material heavy pumping of ground water has been made. The unused abandoned queries can be utilized for recharge to ground water after making certain modifications. The depressions will be used as storage spaces where rain water will be stored. Revival and channelization of drainage around such abandoned queries by construction of embankments & modifications in surface drainage towards these depressions will provide surface storage of rain water during monsoon period.

As the quartzites are already fractured and jointed most of the water will automatically gets recharged to ground water. At places were fractured, weathered and jointed quartzites are not present recharge shafts will be constructed to the depth of existent fractures in sub surface which will facilitate the augmentation of ground water aquifers.

7.4 Alluvial Plains

Alluvial plains in NCR are mainly consisting of sand clay and their intermixture. The method of recharge in these areas depends upon the depth of unconfined aquifers as well as utilizing the existing abandoned ground water abstraction structures. Different type of recharge methods proposed for alluvium area of NCR is elucidated below.

7.4.1 Dug Well

In NCR there are thousands of dug wells which have either gone dry or the water levels have declined considerably. These dug wells can be used as structures to recharge ground water. The storm water, tank water, canal water, etc. can be diverted into these structures to directly recharge the dried aquifer **(Fig.7.15).** By doing so the soil moisture losses during the normal process of recharge, are reduced. The recharge water is guided through a pipe to the bottom of well, below the water level to avoid scoring of bottom and entrapment of air bubbles in the aquifer. The quality of source water including the silt content should be such that the quality of ground water reservoir is not deteriorated. In rural areas the rain water runoff can be channalized and recharged to dug wells through a filter.

7.4.2 Abandoned Hand Pump & tube wells

Almost in the entire NCR due to depletion in ground water levels several tube wells and hand pumps gets defunct. These abandoned Hand pumps and tube wells can be used as recharge wells after proper cleaning/development and constructing a recharge pit with de-silting chamber along with them. These wells have proper connectivity with ground water aquifers which got de-saturated with depletion of ground water levels. Therefore an effective recharge through these wells takes place

7.4.3 Recharge Pits & Shaft

In areas where phreatic aquifer is overlain by poorly permeable strata such as most of the areas of Haryana sub-region, Delhi sub-region and in few areas of Alwar sub region which is away from younger and older flood plain, the recharge to ground water storage by water spreading method becomes ineffective or has very low efficiency. This situation also occur in ponds/depressions where due to siltation an impermeable layer or lens is formed which affects hydraulic connection of surface water and unconfined aquifers. Recharge shaft is an artificial recharge structure which penetrates the overlying impervious horizon and provides affective access to surface water for recharging the phreatic aquifer. These structures are ideally suited for areas with deep water levels. In areas where low permeable sandy horizon is within shallow depths, a trench can be excavated to 3 m depth and back-filled with boulder and gravel. The trench can be provided with injection well to effectively recharge the deeper aquifers **(Fig.7.16a & b).** The following are site characteristics and design guidelines:

To be dug manually if the strata is of non-caving nature. If the strata are caving, proper permeable lining should be provided. The diameter of shaft should normally be more than 2 m to accommodate more water and to avoid eddies in the well.

In the areas where source water is having silt, the shaft should be filled with boulder, gravel and sand from bottom to have inverted filter. The uppermost sandy layer has to be removed and cleaned periodically.

When water is put into the recharge shaft directly through pipes, air bubbles are also sucked into the shaft through the pipe which can choke the aquifer. The injection pipe should therefore, be lowered below the water level, to avoid this.

7.4.4 Percolation Tank

Percolation tank is an artificially created surface water body, generally constructed in a highly permeable land area, so that the surface run off is made to percolate and recharge the ground water storage **(Fig 7.17).** In areas where land is available in and around the stream channel section, a small tank is created by means of earthen dams across the stream. The tank can also be located adjacent to the stream. The percolation tank should have adequate catchment area. The hydrogeological condition of site for percolation tank is of utmost importance. The rocks coming under submergence area should have high permeability. The degree and extent of weathering of rocks should be uniform and not just localized.

The percolation tank should be located down stream of runoff zone, preferably towards the edge of piedmont zone or in the upper part of transition zone (Land slope between 3 to 5%). The aquifer zone getting recharged should extend downstream into the benefited area where adequate number of ground water structures should be available to fully utilize the additional recharge.

The purpose of percolation tank is to conserve the surface run off and diverts the maximum possible surface water to the ground water storage. Thus the water accumulated in the tank after monsoon should percolate at the earliest, without much evaporation losses. Normally a percolation tank should not retain water beyond February.

The size of a percolation tank should be governed by the percolation capacity of the strata in the tank bed rather than yield of the catchment. For, in case the percolation rate is not adequate, the impounded water is locked up and wasted more through evaporation losses, thus depriving the downstream area of the valuable resource.

7.4.5 Recharge Trench with injection well

The recharge trench/injection well are suitable in already over exploited areas with declining trend of water levels, and presence of upper confining layers of low permeability due to which the aquifers are unable to replenish naturally from the surface and needs direct injection through recharge wells **(Fig 7.18).**

In alluvial areas injection well recharging a single aquifer or multiple aquifers can be constructed in a fashion similar to normal gravel packed pumping well. The only difference is that cement sealing of the upper section of the well is done in order to prevent the injection pressures from forcing leakage of water through the annular space of borehole and well assembly. An injection pipe with opening against the aquifer to be recharged may be sufficient. However, in case of number of permeable horizons separated by impervious rocks, a properly designed injection well may be constructed with slotted pipe against the aquifer to be recharged. In practice the injection rates are limited by the physical characteristics of the aquifer. In the vicinity of well, the speed of ground water flow may increase to the point that the aquifer is eroded, especially if it is made up of unconsolidated or semi-consolidated rocks. In confined aquifer confining layers may fail if too great pressure is created under them. If this occurs, the aquifer will become clogged in the vicinity of the borehole and/or may collapse.

7.5 Urban Areas

Water supply in urban areas is mostly from surface sources like natural or impounded reservoirs as well as from ground water sources. As the population density is more sources are planned and constructed to take care of the water requirements of the population throughout the year. Ground water is in use in areas where the surface water supplies are either not reaching or are not adequate. Land use for constructed areas is more in comparison to open and barren land usage in urban areas. Therefore small but effective recharge structures are required which occupy smaller space and provide optimal recharge to ground water. Roof top Rain Water harvesting is one of such technique that can be adopted for urban areas of NCR sub regions.

The concept of rainwater harvesting involves 'tapping the rainwater where it falls'. A major portion of rainwater that falls on the earth's surface runs off into streams and rivers and finally into the sea. An average of 8-12 percent of the total rainfall recharge only is considered to recharge the aquifers. The technique of rainwater harvesting involves collecting the rain from localized catchment surfaces such as roofs, plain / sloping surfaces etc., either for direct use or to recharge the ground water resources.

7.5.1 Roof Top rain Water Harvesting

In Urban areas, the roof top rain water can be conserved and used for recharge of ground water. This approach requires connecting the outlet of storm water drains and pipes from roof top to divert the water to existing wells/ tube wells/ bore well or specially designed recharge wells. The urban housing complexes or institutional buildings have large roof area and can be utilized for harvesting roof top rain water.

7.5.2 Park Type Structures

In urban agglomerate of residential colonies and institutional areas parks are very common feature and can be fruitfully utilized for recharge to ground water. Rainwater from the catchment of park as well as surrounding area is diverted towards the park which is excavated in a basin type depression to accommodate the rainwater from the elevated surrounding area. The water is recharged through recharge shaft/ recharge wells **(Fig 7.19a & b)** or recharge pit depending upon the hydrogeological conditions and depth of unconfined aquifer. The structure is used as rain water harvesting and recharge structure during monsoon and same is used as play ground in other seasons. Depth of excavation of park is such that the slope is in the ratio of 8:1 in the collector basin and 4:1 in the recharge basin as indicated in **Fig. 7.19b.**

7.5.3 Storm water harvesting

During rainy season, storm water drains exclusively containing rain water flow up to brim. To harness the available runoff, trenches with recharge tube wells are constructed inside the drain bed itself at a spacing of 100 to 300 m depending the availability of runoff. Depending upon the ratio of depth : slope of the drain walls, a small baffle wall of 0.6 to 1.0 m height is constructed to retain the water. Maintain the catchments neat and clean, no mixing of sewerage and other water should be allowed and open spaces around the storm water drains should be prevented from dumping of unwanted items and scrap material. Open storm water drains are covered with perforated detachable RCC slabs to maintain these drains and prevent pollution and contamination. **Fig. 7.20** gives the design of such recharge structures.

7.5.4 Recharge from Mega Urban Structures:

In urban areas mega structures like flyover, Airports, Stadium etc. covers huge area with concrete and prevents natural recharge to take place. Such giant civil structures generates large amount of surface runoff during the rains because of their runoff coefficient range varying from 0.6 to 0.8. In order to provide a conduit to rain water to reach to aquifer certain recharge structures should be constructed in the vicinity of these mega civil structures.

From the road surface lot of runoff goes waste through storm water drains. To harness available runoff, either trenches or shafts with recharge wells are constructed in series along the road side at a spacing of 100 to 300 m depending upon the availability of runoff. In Delhi 45 Flyovers and 26 Subways projects have been executed or being executed. These flyovers will generate enormous amount of surface runoff. The available runoff from the flyovers can be harvested by making shaft or trenches with recharge wells along the storm water drains.

Trenches with length up to 20 m can be constructed with two or more than two recharge tube wells. Generally these trenches are recommended tapping runoff generated from whole campus/catchment of areas ranging from 10000 Sq.mt to 40000 Sq.mts. As the runoff from the whole catchment consists of lot of silt, the same can be removed by constructing a de-siltation chamber as shown in the **Fig. 7.21**. Walls of recharge structures are not recommended to be plastered from both the sides. Brick wall of the trench shall be constructed in trapezium manner to have better stability (0.46 m-0.34 m-0.23 m thick brick wall). The main advantage of recharge trenches is that they can recharge runoff generated from large areas.

If the trenches need to be constructed above 10 m length, supporting beams may be provided or if possible divide the trench into chambers of 2 or 3 to provide the requisite strength to the walls of the trench. BIS code on sub-surface reservoirs may be consulted while constructing the recharge trenches. If the trenches are constructed in storm water drains where the polluted water is expected during the lean period or non-monsoon months, a bye pass arrangement may be made so that no polluted water enters into the recharge trenches.

7.6 Ponds, Lakes and Water Bodies

The protection, management, and restoration of water bodies is of crucial importance as they are also one of the contributors to the fresh water resource in NCR, as a means to recharge the groundwater, and for the improvement of the urban environment. Among these numerous water bodies, mainly Haryana, NCT Delhi and UP sub-regions has most of the water bodies as compared Rajasthan sub-region which is devoid of such surface water storages. In NCT Delhi itself about 38 lakes or natural depressions exists, many of which are at the verge of extinction due to rapid urbanization of the city. Delhi Tourism has identified as many as 15 ancient lakes within the city limit for reclamation and restoration of water quality. **Fig.7.22** indicates the location of water bodies in NCR.

7.6.1 Village Tank with Shaft

The existing village tanks which are normally silted and damaged can be modified to serve as recharge structure in case these are suitably located to serve as percolation tanks. In general, no "Cut Off Trench" (COT) and Waste Weir is provided for village tanks. Desilting, coupled with providing proper waste weir and COT on the upstream side, the village tanks can be converted into recharge structure. Several such tanks are available which can be modified for enhancing ground water recharge. Studies, however, are needed to ascertain whether the village tanks are suitably located to serve as recharge structures. Some of the tanks in Maharashtra and Karnataka have been converted into percolation tanks.

7.6.2 Water Bodies through Recharge Shaft

These ponds, lakes and water bodies are required to be reclaimed and restored for storing the rain water during monsoon and augmenting the same to ground water storages by constructing recharge shafts adjacent to them. The recharge shafts should be constructed in a way that only excess water is being recharged to ground water and minimum water level is maintained in water bodies for their sustenance and environment. Before adopting such water bodies for recharge to ground water there is urgent need to restore these water bodies by construction of proper bunds, cleaning of water bodies and excavation and silt removal from the bottom of the ponds.

7.6.3 Ground Water Dams or Sub Surface Dykes

These are basically ground water conservation structures and are effective to provide sustainability to ground water structures by arresting sub surface flow **(Fig.7.23)**. A ground water dam is a sub surface barrier across stream which retards the natural ground water flow of the system and stores water below ground surface to meet the demands during the period of need. The main purpose of ground water dam is to arrest the flow of ground water out of the sub-basin and increase the storage within the aquifer. By doing so the water levels in upstream of ground water dam rises and saturating the otherwise dry part of aquifer.

The underground dam has following advantages: -

- Since the water is stored within the aquifer, submergence of land can be avoided and land above reservoir can be utilised even after the construction of the dam.
- No evaporation loss from the reservoir takes place.
- No siltation in the reservoir takes place.
- The potential disaster like collapse of dams can be avoided.

7.7 Sewerage & Waste Water Recharge

Treated wastewater reuse is conventionally carried out through direct application and/or mixed with fresh surface water wastewater in irrigation. Another way of reusing wastewater is through

Artificial Recharge (AR) of the aquifer system with partially treated wastewater. Where soil and groundwater conditions are favorable, a high degree of upgrading can be achieved by allowing waste water after necessary treatment to infiltrate into the soil and move down to the groundwater. The unsaturated zone then acts as a natural filter and can remove essentially all suspended solids, biodegradable materials, bacteria, viruses and other microorganisms. Significant reductions in nitrogen, phosphorus, and heavy metals concentrations can also be achieved. This gives an advantage of AR with wastewater over the direct application method. This process is known as **Soil-Aquifer Treatment (SAT)**. Another advantage of AR over application of wastewater, is the fact that water recovered from an AR system is not only clear and odour-free but also comes from a well, drain or via natural drainage to a stream or low area, rather than from a sewer or sewage treatment plant.

Proposed AR/WW scheme is to provide additional water source that can be an added dimension to the NCR water resources plans. Proposed application of this technology is presently confined only to providing water for irrigation purposes at reclaimed areas. The selection of possible locations for AR/WW was controlled by a set of hydrogeological, planning, and environmental considerations. On top of these considerations is the availability and effectiveness of treatment plants.

Hydrogeological considerations: Based on other recharge experiments (i.e. fresh water recharge) in many of the western countries, the following intrinsic characteristics of the aquifer were recommended to ensure successful basin recharge operations. These recommendations were slightly modified to form the required hydrogeological criteria for the selection of possible application locations.

A minimum of 18m depth to the groundwater was required to allow for geo-purification processes (i.e. filtration, adsorption, etc.) before the infiltrating water reaches the groundwater. This depth also allows for groundwater mounding during the recharge process without affecting the infiltration process. The unsaturated zone must realize an infiltration rate not less than 0.25 m/day.

High values of saturated zone transmissivity and porosity are recommended to prevent water mounding below the basin bottom that can cause a decrease in infiltration rate and recharge capacity (effective porosity > 0.1, and transmissivity > 500 m3/day).

Aquifer characteristics down stream the recharging sites must have good hydrogeological conditions to allow water recovery at the desired rates.

Planning considerations: Water resources plans in NCR are considering Waste water & sewerage water reuse as a source for irrigation water. Accordingly, replacement of Yamuna water by recharged sewage water for irrigating existing or planned reclamation lands is a main criterion for the selection of possible sites for Artificial recharge through wastewater.

Environmental and health safety considerations: Detailed environmental impact assessments will be carried out for each of the individual sites before the application that will include mitigation and monitoring plans. However, for the purpose of the general selection of sites, two factors were taken into considerations. Firstly, the site should not be within or upstream of a groundwater-drinking community, and secondly, no recharge should be considered where groundwater is flowing into the River.

- Artificial recharge through Waste water can be an added dimension for the reuse policies in NCR. The technique has far superior advantages over the direct application of treated wastewater. However, restrictions and precautions should be imposed to prevent a damaging impact on the groundwater.
- The framework included possible locations, amounts of available wastewater for these locations, general environment and health safety considerations, recharge method, and range of applications. Artificial recharge through waster water application in NCR, according to the proposed framework, should be restricted to basin recharge which to be used for irrigation purposes in the reclaimed areas.
- Due to the presence of thick clay cap and the dependence on groundwater for drinking hydro geologically unsuitable areas and regions should be excluded from the Artificial recharge through waster water plans.
- Columns experiments to be conducted to study the processes that take place during the infiltration of treated wastewater through the unsaturated zone and to estimate the attenuation capacity of the soil at the location selected for the experimental scale basin recharge.

7.8 Impact assessment of Rain Water Harvesting & Artificial Recharge to Ground Water

The Central Ground Water Board has implemented more than 200 rain water harvesting and recharge schemes and assessed the impact of recharging on ground water levels. The rise in ground water levels found to be in the range from 0.15 to 12 meters in various places in different States of the country. Details of impact assessment of rain water harvesting and recharge projects are given in table below.

Table: Impact Assessment of Artificial Recharge Projects Implemented by CGWB

S. No.	Name of State	No. of schemes for which impact assessment done	Artificial Recharge Structures	8. Impact assessment
1.	Andhra Pradesh	6	Percolation Tanks	4500-5900 Cubic meter runoff water recharged in one year
		3	Check dams	1000-1250 Cubic meter runoff water recharged in one year
		1	Combination of recharge pits and lateral shafts	370 Cubic meter runoff recharged in one year
2	Arunachal Pradesh	1	Roof Top Rain Water Harvesting	7000 cubic meter runoff water harvested in one year

3.	Assam	1	Roof Top Rain Water Harvesting	5500 Cubic meter runoff water harvested in one year
4.	Bihar	1	Roof Top Rain Water Harvesting	4700 cubic meter runoff water recharged in one year
5.	Chandigarh	6	Roof Top Rain Water Harvesting	1440-13,000 Cubic meter runoff water recharged in one year
		1	Rain Water Harvesting through Roof Top & Pavement catchments	34.50 lakh cubic meter runoff water recharged in one year
		1	Recharge Trenches	9.50 lakh cubic meter rainwater runoff recharged in one year
6.	Gujarat	3	Rain Water Harvesting through Roof Top & Pavement catchments	11000-45000 runoff water recharged in one year
7.	Haryana	1	Roof Top Rain Water Harvesting	2350 Cubic meter runoff water recharged in one year
		1	Combination of Recharge shafts and injection wells	3.50 lakh cubic meter runoff water recharged in one year. Declining rate reduced from 1.175 m/yr to 0.25 m/yr.
8.	Himachal Pradesh	3	Check dams	1.20-21.00 lakhs cubic meter runoff water recharged in one year.
9.	Jammu and Kashmir	2	Roof Top Rain Water Harvesting	300-1200 Cubic meter runoff water harvested in one year
10.	Jharkhand	1	Roof Top Rain Water Harvesting	4500 cubic meter runoff water recharged in one year.
11.	Karnataka	1	Combination of Percolation Tanks, Watershed Structures, Recharge wells, Roof Top Rain Water Harvesting	2-3.5 m. rise in water levels and 9-16 ha area benefited from percolation tanks 8.60 lakh cubic meter water recharged through recharge well. 3-5 m rise in ground water levels through watershed structures. 530 cubic meter recharged from Roof Top Rain Water Harvesting.

12.	Kerala	1	Sub-surface Dyke	Augmented 5000 Cubic meter of ground water in upstream side with 2 m rise in groundwater levels.
		1	Recharge wells	2800 Cubic meter runoff water recharged in one year
		3	Percolation tanks	2000-15000 Cubic meter runoff water recharged in one year
		1	Tidal regulator	4000 Cubic meter runoff water conserved and a difference of 1.5 m was observed in upstream and downstream water level.
		2	Check Dam	5,100 - 30,000 Cubic meter runoff water recharged in one year
13.	Lakshadweep	1	Roof Top Rain Water Harvesting	300 Cubic meter rainwater harvested in one year
14.	Madhya Pradesh	4	Sub-surface Dykes	Rise in water level in dugwells in the range of 0.80-3.80 m and 6-12 m in hand pumps has been observed.
		1	Percolation Tank	Rise in ground water levels by 1-4 m. in command area downstream of tank has been observed.
		1	Roof Top Rain Water Harvesting (1000 houses)	More than 2 lakh cubic meter runoff water recharged in one year.
		1	Combination of sub-surface dykes and check dam	Rise in water levels in existing tubewells in upstream area by 0.30 m to 2.00 m has been observed.
15.	Maharashtra	2	Roof Top Rain Water Harvesting System	196-280 cubic meter runoff water recharged in one year
		1	Combination of Percolation Tanks and Check Dams.	Benefited area – About 60 to 120 ha. per Percolation Tank, 3 to 15 hectare per Check Dam Water level rise – Upto 1.5 m.
		1	Percolation tanks, Recharge Shaft, Dugwell Recharge.	Benefited area – 400-500 hectare around the scheme.
16.	Meghalaya	1	Roof Top Rain Water Harvesting	6800 cubic meter runoff water harvested in one year

17.	Mizoram	1	Roof Top Rain Water Harvesting	50,000 cubic meter runoff water harvested in one year
18.	Nagaland	3	Roof Top Rain Water Harvesting	2,480 – 14,065 cubic meter runoff water harvested in one year
19.	NCT Delhi	2	Check dams	Water levels have risen upto 2.55 m in the vicinity of Check Dams and area benefited is upto 30 hectare from each check dam in JNU & IIT. 1.30-lakh cubic meter of rainwater was recharged in one year in Kushak Nala.
		7	Roof Top Rain Water Harvesting	800 – 5000 Cubic meter runoff water recharged in one year
		8	Rain water harvesting through Roof Top & Pavement catchments	8500 – 20,000 cubic meter runoff water recharged in one year
20.	Orissa	1	Rain water harvesting through Roof Top & Pavement catchments	1,200 cubic meter runoff water recharged in one year
		1	Renovation of creeks & sub - creeks, Construction of Control Sluices and recharge bore wells	Quantity of fresh water impounded in 798119 cubic metres and irrigation potential is 11000 has in a year.
21.	Punjab	1	Roof Top Rain Water Harvesting	500 cubic meter runoff water recharged in one year
		3	Recharge wells	9 – 15.50 lakhs cubic meter runoff water recharged in one year.
		1	Trenches	Average rise in water level upto 0.32-0.70 m has been observed.
			Combination of vertical shafts, injection wells & recharge trenches	Recharge of 1.70 lakh cubic meter runoff water caused average rise of 0.25 m. in ground water levels around the scheme area.
		1	Combination of recharge shafts and injection wells	14,400 Cubic meter runoff water recharged in one year.

22.	Rajasthan	1	Check dams	88,000 Cubic meter runoff water recharged in one year. Water level rise - 0.65 m.
		12	Roof Top Rain Water Harvesting	350-2800 Cubic meter runoff water recharged in one year.
		3	Sub-surface Barriers	2000-11500 Cubic meter runoff water recharged in one year. Water level rise from 0.25 to 0.60 m.
23.	Tamil Nadu	1	Sub-surface Dyke	39.25 ha. area benefited.
		7	Percolation Tanks	10,000-2,25,000 runoff water recharged in one year.
		1	Roof Top Rain Water Harvesting	3700 cubic meter runoff water recharged in one year
24.	Uttar Pradesh	7	Roof Top Rain Water Harvesting	350-23033 cubic meter runoff water recharged in one year
25.	West Bengal	1	Combination of Farm Ponds, Nala Bunds, Sub-surface Dykes	Water level rise of 0.15 m. observed.
		1	Sub-surface Dykes	Rise in water levels by 0.45 m. observed

8. Other Management Measures

Other than the water harvesting and augmentation measures, there are several management options as discussed below:

8.1 Unused Flood Water

The unused flood water from the from the canal network of Yamuna basin can be fruitfully utilized for ground water recharge during the monsoon period. The unused flood water can be taken from the barrages constructed on Yamuna and Ganga rivers falling in the different parts of sub regions. The statistics of unused flood water has already been discussed in section 4.1.2. **Fig. 8.1** gives the distribution of unused flood water in NCR.

8.2 Recycling and Reuse of water

Water recycling is an essential component of managing the water resources efficiently and making the most of a resource that is often wasted. Water recycling adopts the concept of using water that is 'fit for purpose'. In practice this means using high quality water for drinking and other personal uses, but not necessarily for purposes where alternative water sources can be safely used, such as toilet flushing, limited garden etc.

The world's population is expected to increase manifolds in the couple of decades -and with this growth will come an increased need for water to meet various needs, as well as an increased production of wastewater. Moreover, there has been significant decline in runoff in the surface water catchments and recharge to groundwater resources, in general. This has increased pressure on the water resources in the area.

Many areas throughout the world are approaching, or have already reached, the limits of their available water supplies. This subsection details out the recycle or reuse of wastewater with the sole objective to minimize the water demand during the operation phase of the project.

RECYCLING AND REUSE BENEFITS

The benefits of water reuse and recycling are:

- Lower use of drinking water resources
- Less fresh water extracted from rivers/groundwater for irrigation
- Less wastewater discharged into our rivers and stream channels
- Potential to release recycled water (instead of drinking water) to mimic natural environmental river/stream flow

REUSE APPLICATION

Quantity and quality requirements are considered for each reuse application, as well as any special considerations necessary when reclaimed water is substituted for more traditional sources of water. The common key elements of water reuse are supply and demand, treatment requirements, storage, and distribution. There are a number of practical options for using recycled water which is as listed below.

Urban Reuse

Urban reuse systems provide reclaimed water for various non-potable purposes including:

- Irrigation of parks and recreation centers, athletic fields, school yards and playing fields, highway medians and shoulders, and landscaped areas surrounding buildings and facilities
- Irrigation of landscaped areas surrounding residences, general wash down, and other maintenance activities.
- Irrigation of landscaped areas surrounding commercial, office, and industrial developments
- Ornamental landscape uses and decorative water features, such as fountains, reflecting pools, and waterfalls
- Dust control and concrete production for construction projects
- Fire protection through reclaimed water fire hydrants
- Toilet and urinal flushing in commercial and industrial buildings

Water reclamation facilities must provide the required treatment to meet appropriate water quality standards for the intended use. In addition to secondary treatment, filtration, and disinfection are generally required for reuse in an urban setting. Because urban reuse usually involves irrigation of properties with unrestricted public access or other types of reuse where human exposure to the reclaimed water is likely, reclaimed water must be of a higher quality than may be necessary for other reuse applications.

Recreational Reuse

Uses of reclaimed water for recreational purposes range from landscape impoundments, water hazards on golf courses, to full-scale development of water-based recreational impoundments, incidental contact (fishing and boating) and full body contact (swimming and wading). As with any form of reuse, the development of recreational water reuse will be a function of a water demand coupled with a cost-effective source of suitable quality reclaimed water.

Playing fields and parks

Recycled water can be used in playing fields, parks and golf courses where usually large quantities of water is required. Replacing this supply with recycled water can be practical and offers significant benefits.

Horticulture/Agriculture

Horticulture and agriculture can be significant user of water. Using recycled water for irrigation is possible and could provide significant reuse of the nutrients contained in recycled water. Recycled water is currently used to irrigate horticultural and orchard crops in some industrial setups.

Woodlots

Using recycled water to grow tree crops in the area can be one of the various forms of utilization.

Table 8.1: Appropriate uses of Recycled Water according to level of treatment

Treatment	**System verification / monitoring**	**Appropriate reuse application, if water sourced from and reused within single domestic premises**	**Appropriate reuse application, if water sourced from multi -dwelling /Commercial premises**
Temporary Diversion Systems:			
Untreated	None	Garden irrigation:	Garden irrigation:
		• manual surface • sub-soil trench	• sub-soil trench
Permanent Treatment Systems:			
Filtration	EPA Certificate of Approval for specific treatment system specifies ongoing maintenance and monitoring requirements.	Garden irrigation: sub-soil trench	Garden irrigation: sub-soil trench
Primary treatment	EPA Certificate of Approval for specific treatment system specifies ongoing maintenance and monitoring requirements.	Garden irrigation: sub-soil trench	Garden irrigation: sub-soil trench
Secondary treatment (20/30 standard)	EPA Certificate of Approval for specific treatment system specifies ongoing maintenance and monitoring requirements.	Garden irrigation: • sub-surface drip • sub-soil trench	Garden irrigation: sub-soil trench

Secondary treatment and disinfection (20/30/10 standard)3 (<5000L/day)	EPA Certificate of Approval for specific treatment system specifies ongoing maintenance and monitoring requirements.	Garden irrigation: • surface • sub-surface drip • sub-soil trench In-house use: • toilet flushing • washing machine	Garden irrigation: • surface • sub-surface drip • sub-soil trench
Treatment and disinfection (Class A standard) (>5000L/day)	As per reclaimed water guidelines.	Garden irrigation (any method) In-house use: • toilet flushing • washing machine	Garden irrigation (any method) In-house use: • toilet/urinal flushing • washing machine

Technical Issues in Planning Water Reuse Systems

The technical issues associated with planning the beneficial reuse of reclaimed water derived from wastewater facilities are given below:

- Identification and characterization of potential demands for reclaimed water
- Identification and characterization of sources of reclaimed water to determine their potential for reuse
- Treatment requirements for producing safe and reliable reclaimed water that is suitable for its intended applications
- Storage facilities required to balance seasonal fluctuations in supply with fluctuations in demand
- Supplemental facilities required to operate a water reuse system, such as conveyance and distribution networks, operational storage facilities, alternative supplies, and alternative disposal facilities
- Potential environmental impacts of implementing water reclamation
- Identification of knowledge, skills, and abilities necessary to operate and maintain the proposed system

Treatment Requirements for Water Reuse

One of the most critical objectives in any reuse program is to ensure that public health protection is not compromised through the use of reclaimed water. Protection of public health is achieved by: (1) reducing or eliminating concentrations of pathogenic bacteria, parasites, and enteric viruses in the reclaimed water, (2) controlling chemical constituents in reclaimed water, and/ or (3) limiting public exposure (contact, inhalation, ingestion) to reclaimed water. Reclaimed water methodology may vary significantly in the level of human exposure incurred, with a corresponding variation in the potential for health risks. Where human exposure is likely in a reuse application, reclaimed water should be treated to a high degree prior to its use. Conversely, where public access to a reuse site can be restricted so that exposure is unlikely, a lower level of treatment may be satisfactory, provided that worker safety is not compromised. Determining the necessary treatment for the intended reuse application requires an understanding of the constituents of concern in wastewater. Levels of treatment and processes applicable for reducing these constituents to levels that achieve the desired reclaimed water quality.

Additional Requirements for Reuse Applications

Different degrees of hazard are posed by process failures. From a public health standpoint, it is logical that a greater assurance of reliability should be required for a system producing reclaimed water for uses where direct or indirect human contact with the water is likely, than for water produced for uses where the possibility of contact is remote. Similarly, where specific constituents in reclaimed water may affect the acceptability of the water for any use (e.g., industrial process water), reliability directed at those constituents is important. Standby units or multiple units should be encouraged for the major treatment elements at all reclamation facilities. For small installations, the cost may be prohibitive and provision for emergency storage or disposal is a suitable alternative.

8.3 Conjunctive Management of Surface and Ground water

Water resources management strategy in which ground water and surface water are used in tandem, making use of the comparative advantages of both is termed conjunctive use. Conjunctive management of all the water resources available in the area be it ground water, surface water or recycled water can provide a sustainable solution to growing scarcity of water in an area. Some of the common examples practiced in different parts of the world include:

- Use of surface water for inefficient flood irrigation to enhance aquifer recharge in the wet season.
- Use of ground water in dry period for irrigation to replace the normal surface water supply

An active form of conjunctive management utilizes artificial recharge, where surface water is intentionally percolated or injected into aquifers for later exploitation thus, combating the dual problem of over exploitation of ground water and temporary water inundation in the canal command or low lying areas. Various studies in India have proven that irrigation channels can be transformed into recharge systems at minimum cost.

In the flood plain areas, there exists ample scope for conjunctive use of aquifer water and river water. In the NCT Delhi area especially in the flood plains such practices may be adopted for using the surplus and non committed river water for recharging the aquifer in the form of induced recharge. Various scenarios indicating different types of river – aquifer linkages are shown in **Fig. 8.2**

8.3.1 Ground Water Development in Waterlogged Areas/ Saline Areas

Water logging and soil salinity problems resulting from gradual rise of ground water levels due to various reasons has been observed in selected inland areas underlain by saline water and in many canal command areas due to the implementation of surface water irrigation schemes. As per the assessment made by the Working Group on Problem Identification with Suggested Remedial Measures (1991), about 2.46 million hectare of land under surface water irrigation projects in the country is either water-logged or under threat of it. Such areas offer good scope for further ground water development as the shallow water table in such areas can be lowered down to six meters or more without any undesirable environmental consequences. The problems related to inferior quality of water in such areas can be solved by mixing them with the canal waters. Judicious development through integrated use of surface and ground water can greatly reduce the menace of water-logging and salinity in canal irrigated areas. Various studies have been carried out in order to develop viable technologies for use of poor quality of ground water. These studies have established the need for conjunctive utilization of ground water and surface water in a judicious proportion to address the existing and emergent problems of water logging and salinity i. Based on these studies, sector wise planning for conjunctive use may be been devised including techno-economic feasibility of implementing these schemes. At the same time using saline or brackish water for other related use such as Fisheries, growing salt tolerant crops and other farm products.

9. Initiatives of Rain Water Harvesting and Artificial Recharge in NCR

9.1 Success stories

Artificial Recharge projects in New Delhi district of NCT Delhi:

The recharge projects implemented in Urban environments utilizing runoff generated from roof top, roads, paved area and bare ground are given below:

a. Artificial recharge to ground water in **Presidents Estate (Fig. 9.1)** .
b. Artificial Recharge to ground water in **Shram Shakti Bhawan (Fig. 9.2).**
c. Artificial Recharge to Ground water in **Lodhi garden.**
d. Artificial recharge to ground water in **Prime Ministers Office.**
e. Artificial recharge to ground water in **Safdarjung Hospital.**
f. Artificial recharge project at **Tughlak Lane** and Surrounding areas
g. Artificial recharge project at **Bunglow-5, Janpath Road,** New Delhi
h. Artificial Recharge project in **Sena Bhawan, New Delhi**
i. **Kushk Nala** Artificial Recharge Project

Under these projects runoff generated from urban environments like roof area, paved area, roads, parks and bare grounds has been utilized for recharging depleted aquifers. Under these projects different types of urban recharge structures were constructed. They are recharge shafts, recharge trenches, recharge through abandoned tube wells, recharge through abandoned dug wells. Two typical projects are briefly elaborated below:

In **President Estate Project** runoff generated from 1.3 sq. Km of area is recharged through two abandoned dug wells, one recharge shaft and two trenches with borewells. This has resulted in rise in water levels ranging from 0.66 to 4.10 meters.

The Kushak Nala Project is on a small nala originating from Birla Mandir and flowing west of Rashtrapati Bhawan. It has effective catchment area of 3.5 Sq.km. Under the artificial recharge scheme two gabion structuresand two nala bunds were constructed to recharge the 110000 Cu.mts of rainfall runoff generated in this watershed.

From all the above projects it is estimated that about 225670 Cu.mts of runoff water is recharged to ground water from about 3.678 Sq.Km. of catchment area. The total cost of the above eight schemes is Rs: 60.12 lakhs.

Artificial Recharge projects in South, South West and West districts of NCT Delhi:

The details of different projects under various hydrogeological setting is given below:

A. HARD ROCK TERRAIN:

JNU - IIT - Sanjay Van Project: Under this project four check dams and one roof top rain water harvesting structure was constructed with the cost of 43.58 lakhs. Total reservoir capacity created in four check dams is 49048 Cu. mts.

The total capacity utilization of the created storage capacity is about 368% by repeated filling of the check dams. The total recharge to ground water is about 75.72 TCM (Thousand cubic meter) which resulted in rise in water levels to the tune of about 13.70 m. Included in this project was the roof top rain water harvesting scheme taken up in Block-VI of IIT, Delhi campus. The rain water harvested was recharged to ground water through construction of injection wells and abandoned dugwell. It is seen that about 830 Cubic meters of rain water is recharged from 1660 Sq.m of roof area which has resulted in rise in water level to the tune of about 2.29 to 2.87 m in one hectare of area.

Sultan Garhi Tomb Artificial Recharge Project: This project was implemented around Sultan Garhi Tomb. Under this project, the three big quarries present in the tomb area were converted into recharge ponds by construction of proper bunds and diversion channel to divert runoff from Vasant Kunj-D block. Three recharge ponds were created. In order to increase the recharge rate, one recharge pit with tubewell and one recharge pit with borewell filled with gravel were constructed in these ponds **(Fig. 9.3)**. About 65000 Cubic meters of runoff is diverted to the recharge ponds from 0.99 Sq.km of catchment area. The total cost of the scheme was Rs. 6.0 Lakhs.

B. OLDER ALLUVIUM, WEATHERED AND FRACTURED HARD ROCK TERRAIN:

Four Artificial recharge projects were implemented in this hydrogeological environment. They are:

- Artificial Recharge to ground water in Vayusenabad-Residential area of Tughlkabad Air Force Station.
- Artificial Recharge to ground water in Meera Bai Politechnic, Maharani Bagh, New Delhi.
- Artificial Recharge to ground water in Central Park, D-Block Vasant Vihar, New Delhi.
- Artificial Recharge to ground water DTC Central Workshop-II, Okhla, New Delhi.

Under these projects also runoff generated from the urban environments like roof area, paved area, roads, parks and bare grounds present in these projects areas has been utilized for recharging the depleted aquifers. Recharge shafts with tubewells, recharge trenches with tubewells, lateral shafts with tubewells were constructed. It is estimated that about 42410 Cu.mts of runoff water is recharged to ground water from about 321325 Sq.mts of catchment area. The total cost of the above four schemes is Rs: 17.11 lakhs.

C. OLDER ALLUVIUM :

Two artificial recharge projects are implemented in this hydrogoelogical environments. They are located at:

- Artificial Recharge Project at Deen Dayal Upadhyaya Hospital, West district, Delhi.
- Artificial Recharge Project at Abhiyan Co-operative Group Housing Society Ltd., Plot No.15, Sector-12, Dwarka , South West district, Delhi.

In these two projects runoff generated from the complete campus i.e roof area, paved area, roads and other areas has been utilized for recharge purpose. It is estimated that about 8270 Cu.mts of runoff is being recharged from the 21970 Sq.mts of area. The total cost of these two schemes is Rs. 5.535 lakhs.

About 450 schemes were prepared and submitted for implementation in NCT-Delhi. In all these schemes runoff generated from complete urban areas like roof tops, roads, parks, paved areas and bare grounds is utilized for recharging to the ground water scheme. Recharge schemes implemented in governmental residential colonies like Pushp Vihar, RBI Colony located in R.K.Puram, Vasant Vihar, Hazkhas and SBI colonies in different parts of NCT-Delhi are some more examples for effective artificial recharge & rain water harvesting projects. Recharge schemes implemented for 33 flyovers located in NCT-Delhi were in different hydrogoelogical environments and are working efficiently. Details of few of the Important projects located in different hydrogoelogical environments are as follows:

a. Artificial Recharge to ground water in Indira Gandhi International Airport:

The area is underlain by alluvium of varying depths consists of clay, silt and silty sand mixed with kankar. Depth to water level is about 20 to 25 m bgl. In a catchment area of 5.59 Sq.km, the available runoff of 6144125 Cu.m. of water was utilized for recharging the ground water. 24 trenches with recharge tubewells are constructed at different locations in different drains which enabled no surface ponding of water **(Fig. 9.4)**. A rise of water level up to 1 m was recorded after the monsoon spell.

b. Artificial Recharge to ground water at Link Road connecting NH-8 to Dwarka:

DDA has constructed 60 m wide road to connect Dwarka with N.H.-8. The runoff generated from the road is being collected in a drain constructed adjacent to the road. A series of shafts were constructed to recharge the runoff generated from the road. The shafts were constructed at an interval of 250 to 300 m on both sides of the road.

c. Artificial Recharge to ground water at Rajiv Gandhi Setu(AIIMS Crossing Flyover) New Delhi:

Central Ground Water Board in NCT-Delhi, has provided technical designs for 33 flyovers. Intersection of Ring road and Aurobindo marg at AIIMS crossing is one of the most important flyovers in NCT-Delhi. Runoff from this green flyover is utilized for recharging to the aquifers. The total runoff available in this flyover is about 35000 cu.m., which is recharged to the aquifers through 10 recharge shafts constructed at different locations of the flyover **(Fig. 9.5).** The shafts are associated with recharge tubewells of depth 25 m to recharge the ground water aquifers.

A number of artificial recharge to ground water schemes are being implemented by different agencies in NCT, Delhi. NDMC has implemented the scheme in different buildings and parks like Talkatora garden and Nehru Park etc. MES has implemented the scheme in Delhi cantt. area, Subroto park area and in its establishment in Gurgaon (Air Force Station Gurgaon, Mohammdpur Air Force Station etc). Thus a good number of artificial recharge schemes are being implemented as per guidance of Central Ground water Board in NCT, Delhi.

d. Rain Water Harvesting and Artificial Recharge to Ground Water at 12 Akbar Road, New Delhi

The main objective of the study was solving water logging problems in the premises. Further, it would help in increasing the soil moisture and help in sustaining the green areas, arrest the declining ground water level and sustain the existing nearby ground water abstraction structures. The total area of the bungalow as per the plan is about 9521 sq km and about 6555 sq km of area was considered for estimating run-off from rooftop, paved and green area available for recharging. Two recharge pits are constructed. First structure is being constructed in front lawn of the premises having dimension 2mx2mx4m filled with 2.25 m of graded material along with two number of filter chambers. Second structure is having dimension 5mx2mx4m filled with 2.25 m of graded bedding along with four numbers of filter chambers.

e. Rain Water Harvesting and Artificial Recharge to Ground Water at Gandhi Smriti Bhawan, Tees January Marg, New Delhi

The main purpose of this project was to solve the twin problems of declining water level and limited water logging in the area. The total catchment area providing runoff for rain water harvesting is 20400 sq. m. The total roof top area considered for surface runoff calculation is 4650 sq m, the total paved area considered for surface runoff calculation is 8700 sq m and the total green area considered for surface runoff calculation is 7050 sq m. The annual water harvesting capacity calculated as 6895 cum. The recharge structures constructed are trenches with recharge wells-5.

f. Rain Water Harvesting and Artificial Recharge to Ground Water at Bungalow No. 78, Lodhi Estate, New Delhi

The main objective of this particular project is to propagate the concept of rainwater harvesting through a live demonstration project. The total area of the bungalow is 2810 sq m. The complex consists of main building, guesthouse, servant quarters, paved areas, roads and green lawns. Out of the total area of 2810 sq m, 2500 sq.m has been considered for effective rainwater harvesting through artificial recharge to ground water.

Rain Water Harvesting in other Urban Areas

Central Park, D-Block, Vasant Vihar, Southwest district

Vasant Vihar is a residential Posh colony consisting of six blocks with utility services including shopping complex, parks, etc. Water supply in this colony is mainly based on ground water resulting into alarming rate of decline in ground water levels. To arrest the decline ground water levels, CGWB has taken up Artificial recharge to Ground water in 'D'block. Rainfall Runoff generated i.e. 9400 cum. from the catchment area of 36375 sq. m. comprising of houses and roads in the vicinity of central park is utilized to recharge the ground water by constructing two trenches with recharge wells and one trench with abandoned tubewell. This scheme is implemented by CGWB and system is tested in the current monsoon and working very effectively.

Rain Water Harvesting in a Watershed

Sultan Garhi Tomb, South of Vasant Kunj

Sultan Garhi Tomb, a monument is located near Rangpuri, South of Vasantkunj area having rugged topography and is underlain by hard rock. Depth to water level is ranging between 20-40 meter below ground level. Whole area is considered as a watershed having catchment area of 0.99 sq.km which generates 64925 cum. runoff in a normal rainfall year. The runoff generated is diverted to the ground water system through three existing quarries with two recharge pits with tubewell/borewell. This scheme is jointly implemented by CGWB and DDA. This type of projects are also implemented in other colonies like Jorbagh colony and Pushp Vihar colony.

10. Functional Recharge Plan of NCR

In the present report an attempt has been made to analyze the various inputs required for planning rain water harvesting and artificial recharge measures along with the constraints and present the viable options. In the following paragraphs the Functional Recharge Plan for the entire NCR area has been discussed.

10.1 Sub Region

As discussed earlier the entire NCR has been divided in to four Sub regions , in view of the varying hydrogeological and geo-morphological conditions as well as availability of source water the recharge plan has been discussed Sub Region wise. The Sub Region wise most viable methods of recharge , type /types of structure suitable for these areas and their numbers along with tentative volume of water which can be recharged and cost is given in Table 10.1.

10.1.1 Haryana Sub-Region

In the Haryana Sub Region of NCR, the entire geographical area has been broadly divided into seven typical units in order to suggest area specific water harvesting and artificial recharge measures. The major area types are rural, urban, abandoned queries , agricultural fields and river flood plains other than major buildings in urban areas for which roof top rain water harvesting has been proposed.

In the region major portion fall under the Rural areas in which the most viable option for water harvesting and recharge suggested is through ponds , the existing ponds may be desilted with provision of vertical shafts driven up to water level. Nearly 5000 such structures have been recommended to be institutionalized which may be able to recharge to the tune of 100 MCM of water in to the ground . Similarly, in the Urban areas , the park type recharge structures have been proposed . As per the existing information about existing number of park, nearly 3000 such structures have been recommended to be constructed , which may recharge to the tune of 150 MCM of water in to the ground. The Yamuna flood plain areas offer good potential for recharge adopting the basin and pit method. The basic idea is to conserve the flood water in the loose sands to allow more and more percolation. In this context around 150 Basin recharge structures and about 150 river recharge pits have been suggested to be constructed, the feasible areas within the flood plain has also been demarcated as shown in **Fig.7.5 to 7.7**. This would augment the ground water reservoir, the tentative volume arrived based on average rate is about 60 MCM. Similarly, other harvesting measures has also been suggested for different geomorphic units based on the hydrogeological understanding of the area. It has been envisaged that by implementing the proposed plan , nearly a volume of 420 MCM can be augmented to ground water storage which can be suitably developed at the time of requirement.

Water Recharge Initiatives of Government

The Haryana government has constituted a water recharge mission under the chairmanship of principal secretary to the chief minister, to promote a holistic approach to water recharge by creating awareness among various stake-holders and the general public. The decision to constitute the mission has been taken to evolve a ‘‘collective action for water management’’ in the light of dwindling water resources. The mission has been assigned the task of devising a policy frame-work on water recharge and bringing all stake-holders on one platform for collective action on water management. It would coordinate, harmonies and synergize roles and functions of various stake-holders and approve plans for the recharge of ground water resources. It would also suggest steps for optimum utilisation of water and promote a balanced utilisation of surface and ground water. The mission would allocate periodical priorities among water users, devise methods for effective regulation, fair distribution and utilisation of water resources by different groups, and also under-take specialized studies as may be necessary for preparation of any plan or project relating to water recharge in the state. The other members of the mission include financial commissioners and secretaries of health, power, rural development, public health, fisheries, public works (building and roads), public relations, women and child development, and agriculture departments besides commissioners and secretaries of town and country planning, forests, animal husbandry, education, urban development and environment departments; chairman, Pcb, managing director of minor irrigation and tubewell corporation, director, public relations. The commissioner and secretary of irrigation department would act as its convener.

The government has also constituted a special water conservation cell in the irrigation department under the chairmanship of commissioner, irrigation, to assist the mission. The cell would also take stock of the existing water conservation practices adopted by various groups of water users in the state. It may be mentioned here that the southern districts of the state are highly deficient both in rain and canal water and this is one reason why the state government has been pressing for an early completion of satluj-yamuna link canal (syl) which is meant to bring surplus ravi-beas waters to these districts from punjab. In fact, this canal is considered as the life-line of agriculture in southern haryana. Haryana officials point out that non-completion of SYL canal has adversely hit irrigation in over three lakh hectares of land in the state. it is a national loss for the simple reason that once this land is provided adequate irrigation facilities through SYL, not only the agricultural production in the region will almost double, but the ground water level will also considerably rise.

10.1.2 Delhi Sub-Region

National Capital Territory, Delhi occupies an area of 1483 Sq. Km. Out of this, about 145 Sq. km area comprising of weathered quartzite rock in the ridge. There are 6 blocks namely Alipur block, City block, Mehrauli Block, Najafgarh block, Kanjhawala block & Shahdara block. In Alipur block, Kanjhawala block, Najafgarh block & part of Mehrauli block in which substantial area is under cultivation.

In view of the increasing stress on ground water in NCR area, several small and medium schemes are under progress for roof top rain water harvesting by various agencies including DJB and CGWB. In an earlier attempt by CGWB, feasible areas for artificial recharge to ground water have been identified on the basis of depth to water level (> 3 m.bgl) and areas showing long term declining trend of water levels. The availability of surplus surface water for recharge has also been considered in this exercise. The area identified for artificial recharge to ground water is to the tune of 692.9 Sq. Km in NCT Delhi.

Since the NCT area represents three broad geomporphic units namely ridge areas, older alluvial plains and flood plains, the suitability of water harvesting structures are also different. In southern & western part of Mehrauli block there are lots of quarries & depressions and many bunds have already been constructed to harness the available surplus water from the area in these quarries, depressions & bunds and recharging the ground water. In other areas of Delhi state such as JNU, IIT, Sanjay Van, Vasant Kunj, Kushak nala area, Lodi Garden, Nehru Park, Talkatora Garden, Presidents Estate & Shram Shakti Bhawan etc. many artificial recharge structures have been constructed. As per the estimates of CGWB, the expected recharge from these recharge structures is 0.4 MCM.

In the present proposal, an attempt has been made to further assess the potentiality of these areas for water harvesting and recharge to ground water. The Aravali ridge areas offer a scope for ground water recharge through construction of check dams and gabion structures adopting the watershed approach. It has been assessed that approximately 250 such structures can be constructed in the NCT-Delhi area along the ridges through which the rain water can be harvested, which may add to ground water to the tune of 2.5 MCM. Village Ponds are the most common and prevalent structures available in the area which can be used for water harvesting and artificial recharge to ground water by de-silting, at places by constructing additional vertical shafts. The depth of the shafts would depend upon the depth to water level in the area. Nearly 200 ponds with vertical shafts and 500 de-silting of ponds have been proposed in the area . Yamuna flood plain of NCT-Delhi area is the most suitable area for water harvesting and recharge to ground water. The flood plain aquifers are most suitable areas for recharge , heavy withdrawal of ground water from the flood plain aquifer in the pre monsoon period may create enough space for induced recharge from the river during the flood period. Basin and Pit method is the most prevalent technique for flood plain recharge. In an area of about 95 sq. km of flood plain within the NCT-Delhi area about 100 basin recharge structures and 100 River recharge Pits have been proposed in the flood plain area. CGWB has estimated that about 95 MCM of water can be recharged in the flood plain area of NCT.

A total of 300 abandoned quarries have been proposed to be restored and revitalized for channelizing the runoff in the Abandoned queries which will able to recharge nearly 6 MCM to ground water . The urban areas forms major part of NCT-Delhi, in the urban areas broadly two types of recharge structures have been proposed, a substantial quantity of rain water goes as storm runoff from the paved areas and roads , which can be harvested by constructing trenches with shafts , around 4000 such structures have been proposed in the entire NCT area. Similarly, the existing parks offers good scope for water harvesting , a total of 2000 Park Type recharge structures have been proposed in NCT-Delhi, combined together, about 140 MCM of water can be recharge to ground water after successful completion of these structures. The other important scope for water harvesting exists from the roof top of major Institutional buildings, schools, Industries and Govt. office buildings , if the roof top rain water harvesting is strictly implemented through suitable structures , a volume of about 30 MCM of water may be recharged to ground water.

10.1.3 UP Sub Region :

The Uttar Pradesh sub Region forms the western portion of the NCR and lies in the doab area of river Yamuna in the west and river Ganga in the east. The entire sub region is represented by thick alluvial plain which is highly fertile in nature. Major portion of the area fall under the category of Rural area, where small to medium ponds are common. Relatively the urban settlements are less, whereas the Ganga and Hindon flood plains cover significant area.

In the rural areas , the most suitable water harvesting technique is through ponds, which can be used as recharge structure either by desilting so as to provide sufficient scope for infiltration or through construction of vertical shafts . Desilting of about 500 ponds and construction of about 2000 vertical shafts has been proposed in the region which will be able to recharge ground water to the tune of 70 MCM . In the cultivated areas , it has been recommended to utilize about 2000 for ground water recharge by putting suitable filtration media. The flood plain area of river Ganga and Hindon offers good scope for recharge to ground water by Basin and Pit method. It is proposed to construct 75 each of Basin Recharge structures and River recharge pits in the flood plain area , an attempt has been made identify the feasible areas for construction of these structures as shown in **Fig. 7.3 & 7.4.** The area identified for recharge measures in Ganga flood plain In the Urban areas Parks can be utilized for water harvesting and by suitable modifications and constructing Park type recharge structures as discussed in previous chapters. A total of 1000 such structures have been proposed in the regions which will be able to recharge ground water to the tune of 50 MCM. Similarly, in the urban areas the Institutions, school buildings, hospitals and Industries can be used for roof top rain water harvesting.

10.1.4 Alwar Sub Region, Rajasthan

Alwar Sub Region form the southernmost portion of NCR. The Region is devoid of major drainage except river Sahibi, which is an ephemeral river. As such the entire region is occupied by Aeolian and alluvial sand dotted with hills of Aravali range. Generally the rainfall in the area, specially in the hilly terrain flows out as runoff , this water can be very well conserved in the area by constructing suitable structures , which will in turn infiltrate in to ground water. The first and second order streams draining down the Aravali hills can be harnessed by suitable watershed management interventions. Similarly, there is scope for utilizing the flood plain of river Sahibi . The abandoned quarries, village ponds etc. have also been recommended to be utilized for recharging the aquifers.

The recommended Functional Recharge Plan in the Alwar region includes construction of trenches all along the 75 kms of fringe areas of Aravalis as well as in the upper slope segments, with a provision of backfilling with local boulders and pebbles. The **Fig.7.9** indicates the areas suitable for construction of these trenches which has the capacity to recharge the ground water to the tune of 37. 5 MCM. The lower order streams originating from the hills can be suitably trained and harnessed by constructing Check dams and gabion structures, a total of 600 such structures have been recommended to be constructed at suitable locations as identified in **Fig. 7.9.** The flood plain area is generally less developed and narrow in Sahibi river and hence may not be very potential area for recharge purpose, however, around 80 basin recharge structures and pits have been recommended, the feasible areas are shown in **Fig. 7.8.** Village ponds are extremely useful in this region, which can be utilized for recharge either by simple desilting or by constructing vertical shafts. A total of 1250 such provisions has been recommended for the region with a capacity to recharge 35 MCM of water to underground reservoir. In addition, the existing dug wells and abandoned quarries offer good scope for eater harvesting and recharge to ground water other than roof top rain water harvesting in urban areas. It has been estimated that an additional volume of about 181.5 MCM of water can be recharged in the sub region with the recommended structures.

Conclusively, the proposed functional recharge plan envisages construction of about 45,755 recharge structures in the NCR area which will be able to additionally recharge a volume of 1051 MCM of ground water in the aquifer with a cost of approximately 1823.48 crores.

Review of various Ground Water Recharge & Conservation measures Studies taken up in the Area

In the early part of nineties, the Alwar area has been opened to miners and loggers, who decimated its forests and damaged its watershed. Its streams and rivers dried up, then its farms. Dangerous floods now accompanied the monsoon rains. Overwhelmed by these calamities, villagers abandoned their Johads. As men shifted to the cities for work, women spirited frail crops from dry grounds and walked several kilometers a day to find water. Thus was Alwar when Rajendra Singh first arrived in 1985. Before that he worked with nomadic tribes and tried to understand issues in natural resources management in rural areas.

Guided by Gandhi's teachings of local autonomy and self-reliance, Singh has introduced community led institutions to each village, i.e. Gram Sabhas, Mahila Banks, River Parliament etc. He initiated an awareness campaign for Gram Swawlamban, which is organised every year during the summer months for forty days in different hundreds of villages. In this campaign discussion on Gram Swawlamban, soil conservation, improved seeds, collection of herbal medicine and shramdan were the activities undertaken. Singh coordinated all these activities to mesh with the villager's traditional cycle of rituals. Meanwhile, with others he waged a long and ultimately successful campaign to persuade India 's Supreme Court to close hundreds of mines and quarries that were destroying the ecology of Sariska National Park .

With a view to fulfill the needs of the villagers, Shri Rajendra Singh started rural development and employment generation in 1985 at Gopalpura village by Water Conservation. He played a catalyzing role in the building of 8600 johads (water harvesting structures) in 1058 villages spread over 6500 sq.km. Out of these 3500 were built by TBS and as an after effect of these the community was motivated to build the remaining 5100 structures. For these 5100 structures only technical help was provided. The area covers parts of the contiguous districts of Alwar, Dausa, Sawai Madhopur, Karoli and Jaipur districts. Johads and the other appropriate water structures have also been built in the districts of Jaisalmer, Ajmer , Udaipur and Bharatpur. As a result of these efforts five seasonal rivers in the northeastern Rajasthan area, that had nearly dried up have now become perennial. These rivers are Ruparel, Arvari, Sarsa, Bhagani and Jahajwali. After the regeneration of these rivers, the Govt. of Rajasthan gave contracts for fishing in certain stretches of Arvari River . To oppose this policy and to protect fish and other riverine life forms, a three-month long Satyagraha was organized for not allowing any fishing. This Satyagraha resulted in reversal of govt. policy. To sustain this unity and the river in future a decentralized power model has been structured among the 70 villages of Arvari River , and named ARVARI PARLIAMENT.

The efforts towards water conservation have had numerous positive impacts on the communities inhabiting the area. Employment opportunities have increased and migration has reduced substantially. Studies have shown manifold increase in the enrollment of students in school and output of food grains and milk production.

In 1995 he led a "Nadi Pahar Bachao Yatra" from Galta in Jaipur to Gangotri in Uttarkashi. The aim of this yatra, carried out between June 5 (World Environment day] and June 27 was to create mass awareness to preserve the sanctity and purity of rivers and the green cover of the mountains. Since 1996, he initiated Jal Bachao Johad Banoa, which is organised from Dev Uthani Gyaras in the first week of November to December for forty days. Shri Rajendra Singh also initiated several activities in association with Government. The Govt of Rajasthan which has now recognised and acknowledged the work done by TBS in the conservation of water and forests based on the knowledge and efforts of communities, and as part of this recognition has sought its co-operation and help. Similarly, the Minor Irrigation Dept of Govt. of Rajasthan has also sought Shri Rajendra Singh's help. During the last few years, the State Govts of Madhya Pradesh, Haryana, Uttar Pradesh, Maharashtra and Karnataka have sent their forest and watershed officials and community and Panchyat Raj representatives to TBS for an orientation on community based watershed development efforts.

Functional Recharge Plan for National Capital Region

A: Alwar Sub- Region								
Sl no	**Geographic Location**	**Water Recharge Methods**	**Type of Recharge Structure**	**Nos of Recharging Structure**	**Unit Recharge capacity (in TCM)**	**Total Recharge (in TCM)**	**Unit Cost (Rs in Lakhs)**	**Total Cost (Rs in Lakhs)**
1	Area Fringing Aravali Hills - Upper Slopes Segments	Trench	Trench Backfilled with boulders and pebbles(length in KM)	75	500	37500	75	5625
2	Micro-Watershed	Watershed management interventions	Check Dams (CD)	100	30	3000	7.5	750
	- Stream Draining down the Aravali Hills		Gabion (G)	500	5	2500	2	1000
3	Abandoned Quarry	RRR of Quarries Channelizing runoff to them	Revival and channelization	50	300	15000	4	200
4	Village Ponds	Desilting of ponds with four vertical shaft driven up to water level	Ponds Desilting	250	100	25000	5	1250
			Vertical shafts	1000	10	10000	3	3000
5	Farm Lands	Dug well	Dug wells with filtration system	5,000	5	25000	0.2	1000
6	Institutions/ Institutional Plots/Schools and colleges	Trench cum Recharge shaft	Well Recharge/Shaft driven trenches	5000	10	50000	5	25000
7	Flood Plain Rivers (Sahibi)	Basin and Pit Method	Basin Recharge structure	30	300	9000	7.5	225
			River Recharge Pit	30	150	4500	10	300
	Total			**12035**		**181500**		**38350**

B: NCT Sub- Region								
Sl no	**Geographic Location**	**Water Recharge Methods**	**Type of Recharge Structure**	**Nos of Recharging Structure**	**Unit Recharge capacity (in TCM)**	**Total Recharge (in TCM)**	**Unit Cost (Rs in Lakhs)**	**Total Cost (Rs in Lakhs)**
1	Aravali Ridge Area	Watershed method	Check Dams (CD)	50	30	1500	7.5	375
			Gabion (G)	200	5	1000	2	400
2	Village Ponds	Desilting of ponds with four vertical shaft driven up to water level	Ponds Desilting	500	100	50000	5	2500
			Vertical shafts	2000	10	20000	3	6000
3	Urban Area	Park Type	Park Type Recharge Structure	2000	50	100000	7.5	15000
		Urban Storm along Roads	Trenches with shafts	4000	10	40000	5	20000
4	Institutions/ Institutional Plots/Schools & colleges, Industries, Govt Buildings	Rain Water Harvesting and recharging	Well Recharge/Shaft driven trenches	3000	10	30000	5	15000
5	Flood Plain of Yamuna	Basin and Pit Method	Basin Recharge structure	100	300	30000	7.5	750
			River Recharge Pit	100	150	15000	10	1000
6	Abandoned querries	RRR of Quarries Channelizing runoff to them	Revival and channelization	20	300	6000	4	80
	Total			**11970**		**293500**		**61105**

C: Haryana Sub- Region

Sl no	Geographic Location	Water Recharge Methods	Type of Recharge Structure	Nos of Recharging Structure	Unit Recharge capacity (in TCM)	Total Recharge (in TCM)	Unit Cost (Rs in Lakhs)	Total Cost (Rs in Lakhs)
1	Rural Area	Desilting of ponds with four vertical shaft driven up to water level	Ponds Desilting	1000	100	100000	5	5000
			Vertical shafts	4000	10	40000	3	12000
2	Institutions/ Institutional Plots/Schools & colleges, Industries, Govt Buildings	Rain Water Harvesting and recharging	Well Recharge/Shaft driven trenches	3000	10	30000	5	15000
3	Urban Area	Park Type	Park Type Recharge Structure	3000	50	150000	7.5	22500
4	Yamuna Flood Plain	Basin and Pit Method	Basin Recharge structure	150	300	45000	7.5	1125
			River recharge Pit	150	150	22500	10	1500
5	Abandoned querries	RRR of Quarries Channelizing runoff to them	Revival and channelization	50	300	15000	4	200
6	Farmers Field	Dug well	Dug wells with filtration system	3,000	5	15000	0.2	600
	Total			**14350**		**417500**		**57925**

D: UP Sub- Region

Sl no	Geographic Location	Water Recharge Methods	Type of Recharge Structure	Nos of Recharging Structure	Unit Recharge capacity (in TCM)	Total Recharge (in TCM)	Unit Cost (Rs in Lakhs)	Total Cost (Rs in Lakhs)
1	Rural Area	Desilting of ponds with four vertical shaft driven up to water level	Ponds Desilting	500	100	50000	5	2500
			Vertical shafts	2000	10	20000	3	6000
2	Institutions/ Institutional Plots/Schools & colleges, Industries, Govt Buildings	Rain Water Harvesting and recharging	Well Recharge/Shaft driven trenches	1000	10	10000	5	5000
3	Urban Area	Park Type	Park Type Recharge Structure	1000	50	50000	7.5	7500
4	Ganga and Hindon Flood Plain	Basin and Pit Method	Basin Recharge structure	75	300	22500	7.5	562.5
			River Recharge Pit	75	150	11250	10	750
5	Farmers Field	Dug well	Dug wells with filtration system	2,000	5	10000	0.2	400
	Total			**6650**		**173750**		**22712.5**

SUMMARY					
	Number of Recharging Structure		Total Recharge (in TCM)		Total Cost (Rs in Lakhs)
Grand Total	45005		1066250		180092.50
	Total Number of Recharging Structure		Total Recharge (in MCM)		Total Cost (Rs in Crores)
Grand Total	45005		1066.25		1800.93

10.2 Convergence of Ground Water Recharge Measures

Water has been at the core of various development schemes initiated by different Ministries of the Government of India. There has been increasing recognition over the years of the need for water conservation and efficient water management. Ground water is a common pool resource and mostly being developed through private entrepreneurship. Due to ubiquous nature of ground water, it is the most preferred source; hence very often it is being developed in an unscientific way leading to over-exploitation, decline in water level and other environmental problems. Judicious development of ground water with suitable conservation measures is the need of the time. Several efforts are being made in this direction by different Govt. departments as well as stakeholders who have as their critical components, water conservation and water management issues. The key to success of such initiatives lies in convergence of these efforts so as to achieve the common goal of better governance of ground water. Truly speaking, the convergence is an evolving process which combines and pools up all resources and delivers at the place of requirement under combinatorial theory of maximizing the return.

The NCR area has a chronic problem of water scarcity. Number of Governmental and Non Governmental Organizations are striving to push forward various initiatives for water recharge and rain water harvesting through suitable means and recharging the already depleted aquifers so as to provide sustainability to ground water sources. The proposed measures for water recharge and rain water harvesting for the NCR area can be well converged and dovetailed with other initiatives of the Government such as , NREGS & Watershed Development, which is one of the flagship programmes of Govt. of India already undergoing in several states. There is s considerable scope to take up recharging of aquifers in Coordination with the above programme which will also avoid duplication of endeavor particularly at micro level.

Ministry of Rural Development has already worked out the convergence modalities on water recharge measures such as construction of check dams, recharge shafts under NREGA and running maintenance under watershed programme / RRR of Water Bodies; creation of ponds under NREGS and linking under RKVY programme of Ministry of Agriculture (MOA), etc. The artificial recharge activities in most cases cannot be taken up by individuals. It would require group action at community level or even by farmers level with financial assistance by the Government and financial institutions. There is also a need to work out the viable model under Public – private partnership mode . Further, the success of the programme would also depend upon inter-agency cooperation for joint programming, planning and implementation.

It is recommended that all the initiatives being taken up in NCR area related to water resources development which also include water conservation, rain water harvesting and artificial recharge may be converged and an integrated approach should be adopted by leveraging the advantages of each others so as to achieve the desired objective in the best possible and efficient manner. Following are the excerpts of various sustainability schemes of the Government which have water recharge as one of the critical components.

1. **National Afforestation Programme** : The overall objective of the scheme is to develop the forest resources with peoples participation. Financial support under the scheme is also provided for soil and water conservation.

2. **National Project for Repair , Restoration and Renovation of Water Bodies (RRR):** Under the scheme the states are to take up restoration of water bodies having original irrigation cultivable command area of 40 ha to 2000 ha to revive , augment and utilize their storage and irrigation potential. Similar measures already suggested for NCR area may be taken up under the scheme.
3. **National Rural Employment Guarantee Scheme (NREGS)** : One of the most successful programmes of Govt. of India, among the works undertaken under NREGS, water conservation, ground water recharge and water harvesting has high priority which culminates with creating durable assets in rural areas through legal guarantee of 100 days of employment. Various measures suggested for NCR area may be coupled with this scheme.
4. **HARYALI** : The objective of the project is to harvest every drop of water other than employment generation, poverty alleviation community empowerment etc. In the NCR area this scheme is already in vogue, various water conservation measures suggested for NCR area need to be integrated with this scheme.

Relevant components of the recommended measures for water conservation and artificial recharge to ground water for the NCR area may be dovetailed with the above schemes which would enable effective implementation.

10.3 Shelf Projects

Few Shelf projects available for implementation are discussed below:

10.3.1 Haryana State Proposal for Water Conservation & Augmentation

10.3.2 Management of Declining Water Levels In Western Uttar Pradesh.

10.3.3 Najafgarh Lake, NCT-Delhi

10.3.4 Sanjay Lake, NCT-Delhi

10.3.1 Haryana State Proposal for Water Conservation & Augmentation

Government of Haryana has formulated a proposal and the salient features of the proposal along with cost are indicated in the Table below.

Sl.No.	SCHEMES	ESTIMATED COST (IN CRORES)	TIME PERIOD FOR COMPLETION OF ACTIVITIES
1.	Action plan for augmenting ground water aquifers utilizing surplus rain water runoff and flood waters.		
	1-a. Artificial recharge through bores in nallahs, drains, depressions, escapes in canals and roof top harvesting in canal colonies & offices of Irrigation Department.	110.00	5 yr.
	1-b. Construction of humps in drain beds.	9.00	3 yr.
	1-c. Renovation, repair and rejuvenation of water bodies	200.00	5 yr.
	1-d. Allowing rain water to stand in fields for longer duration by compensating farmers	150.00	10 yr.
2.	Conjunctive use of surface and ground water.		
	2-a. digging of shallow wells along canals where area is water logged	20.00	5 yr.
	2-b. Rehabilitation of canals and distributaries	10.00	5 yr.
	2-c. Rehabilitation of existing water courses and their extension	996.00	10 yr.
	TOTAL	**1495.00**	

10.3.2 Management of Declining Water Levels in Western Uttar Pradesh

Introduction

In the state of Uttar Pradesh about 76% irrigated area is attributed to be private minor irrigation work, which are mainly ground water based structures. Uttar Pradesh, particularly western Uttar Pradesh is the centre of tubewell revolution in the state. In Western Uttar Pradesh 92.4% net area is irrigated by ground water resources. Out of about 39 lakhs tubewells in the STATE 16.60 lakh tubewells are located in western Uttar Pradesh.

Over dependence on the ground water in western Uttar Pradesh has resulted in over drawls of ground water and steep decline in ground water level in western Uttar Pradesh has been observed. Out of declared 50 over exploited/critical blocks in state of Uttar Pradesh 45 blocks are located in western U.P., Budaun being the worst effected district.

Thus there is an Urgent need to give more emphasis on surface water based structures and to promote rain water harvesting/recharging in a big way to improve ground water supplies and arrest ground water decline in this region.

Project Details

Declining trend of ground water level in western U.P. has created a very big problem. Farmers are deepening their shallow tubewell borings and replacing centrifugal pumps by electric submersible pumps. Cost of irrigation by private minor irrigation works like shallow tubewells and medium tubewells has gone as high as Rs, 60/- to Rs. 100/- per hour. Even in some areas the discharge of shallow tubewells has gone down and is some areas shallow tube wells has failed due to lowering of water levels.

State Govt. has taken very serious view of it and state ground water deptt. has identified 71 blocks as problematic area. The present project proposal has been prepared to control the decline of ground water level by constructing ground water recharge structures as Roof top Rain water Harvesting, Construction of recharging tube wells, Construction and Renovation of ponds, Pumping Test for evaluation of aquifer parameter test, Public awareness programmes through I.E.C., procurement of rig machine with allied equipment and accessories, Impact assessment of rain water harvesting / recharging activities and vehicle for survey & investigation works.

An action plan for Rain Water Harvesting & Ground Water Recharge amounting about Rs. 3228 lakhs has been prepared and activity wise details are shown in table below.

PROPOSAL FOR MANAGEMENT OF DECLINING GROUND WATER TABLE IN WESTERN UTTAR PRADESH

PROPOSED WORKS FOR RAINWATER HARVESTING AND GROUND WATER RECHARGE IN PROBLEMATIC AREA OF WESTERN U.P.

NO. OF PROBLEMATIC BLOCKS IN WESTERN U.P. (RS. IN LAKHS)					
SL.NO.	**TYPE OF ACTIVITIES**	**UNITS**	**NOS.**	**RATES**	**COSTS**
1	2	3	4	5	6
1	ROOF TOP RAIN WATER HARVESTING	NOS.	355	5.00	1775.00
2	CONSTRUCTION OF RECHARGING TUBE WELLS	NOS.	30	2.50	75.00
3	CONSTRUCTION AND RENOVATION OF PONDS	BLOCKS	71	2.50	177.50
4	PUMPING TEST FOR EVALUATION OF EQUIFER PARAMETER TEST	BLOCKS	71	2.50	177.50
5	PUBLIC AWARENESS PROGRAMMES THROUGH I.E.C.	DISTRICTS	26	19.23	500.00
6	D.C. RIG MACHINE WITH ALLIED EQUIPMENT AND ACCESSORIES(MOUNTED ON VEHICLE)	NOS.	2	205.00	410.00
7	VEHICLE FOR SURVEY AND INVESTIGATION WORKS	NOS.	6	7.00	42.00
8	IMPACT ASSESMENT OF RAIN WATER HARVESTING/ RECHARGING ACTIVITIES	BLOCKS	71	1.00	71.00
	TOTAL				**3228.00**
		SAY RS. 3228.00 LAKHS			

Projects for Lakes and ponds in NCT-Delhi

Ecologically lakes are absolutely dependent on their surroundings. Lakes are water bodies that receive water from the surrounding catchment areas and lose water to either stream or to underground aquifers. With the waters received come organic and inorganic substances which define the nutrient status of the lake. The substances follow a biogeochemical cycle, through which cycle they are either deposited as sediments in the lake bottom, are absorbed by the biotica or held in the water column.

Lakes in Delhi are polluted with sewage disposal being the most common reason. Sewage pollution tenders natural surface waters unfit for any kind of use. The lakes become a breeding ground for many pathogens and the nutrient rich waters give rise to weeds which leads to eutrophication and ultimate death of the lake. Settlement of suspended solids reduces the depth and also the surface area under water. Further, it results in unhygienic conditions around the water body.

Existing proposal for two lakes prepared during 2005 – 06 by INTAC have been included namely Najafgarh Jheel (Lake) and Sanjay Lake located in NCT-Delhi.

10.3.3 Shelf Project of Najafgarh Jheel, NCT-Delhi

The Najafgarh Jheel is located in South Western part of the NCT-Delhi located adjacent to Najafgarh Drain. The water resources contributed to the Jheel is from Mahara Head – Drain No.8 – Bhindawas Lake-Outfall Drain No.8 – Dhansa Head and Tajewala – JLN Escape – Bhindawas Lake – Outfall Drain No.8-Dhansa Head. The major issues of concern for this lake are mainly severe reduction of environmental assets due to loss of 50% of water spread in last 5 decades. The groundwater depletion in and around the lake has also taken place resulting in to water scarcity. Current development pressures are resulting in further harsh concretization of Delhi Metropolitan area e.g. RIL SEZ which is coming up in this area. The Jheel Spread as per the Gazetteer was to the tune of 88 Sq. Miles initially. Later on during 1836 Najafgarh Drain was made to drain out the Jheel. The left embankment on the lake was created after 1964 floods. Records sates that during 1958 Floods the spread of the lake was about 14500 ha. This is indicative of the spread and connectivity with the surrounding catchment to contribute the water into the lake. In due course of time, developmental activities and urbanisation in the catchment of the lake has reduced the catchment to larger extent and now it is 700 hac. There is and urgent need to address following issues for revival and restoration of the Najafgarh Jheel.

- Environmental layer of map needs strengthening by introduction/restoration of counterbalancing blue & green Assets.
- Create a groundwater recharge zone, a raw water source based on conjunctive recharge methods which may yield up to 30 MGD for Delhi & Gurgaon areas of NCR.
- A major biodiversity habitat should be developed to have and prevent ecological deterioration and development of water resources in and around the lake.

A shelf project prepared by INTACH has been made during 2006. The salient features of the project and cost components are given here below.

Water Availability for Najafgarh Jheel

The water availability for restoration of the lake is given below:

i) Yamuna Allocation [Delhi & Gurgaon] [580 MCM + 4107MCM]

ii) Treated Effluent from Gurgaon STP [20 MGD]

iii) Local Flood Waters from rainfall

From Yamuna river unutilized allocation of flood water during July – October is required to be integrated with flood early warning system so as the flood water can be made available for the lake. The intake of water to the lake should commence during late September.

Gurgaon STP effluent quality to be improved and maintained which will provide 30 MCM of additional water. Local runoff generated during the monsoon period estimated to 2.2 MCM at 90 % Dependability can be utilize to enhance the water storage ion to the lake. Efforts have been made for estimation of Delhi catchment flood waters which is of the tune of 44 MCM at 90% dependability.

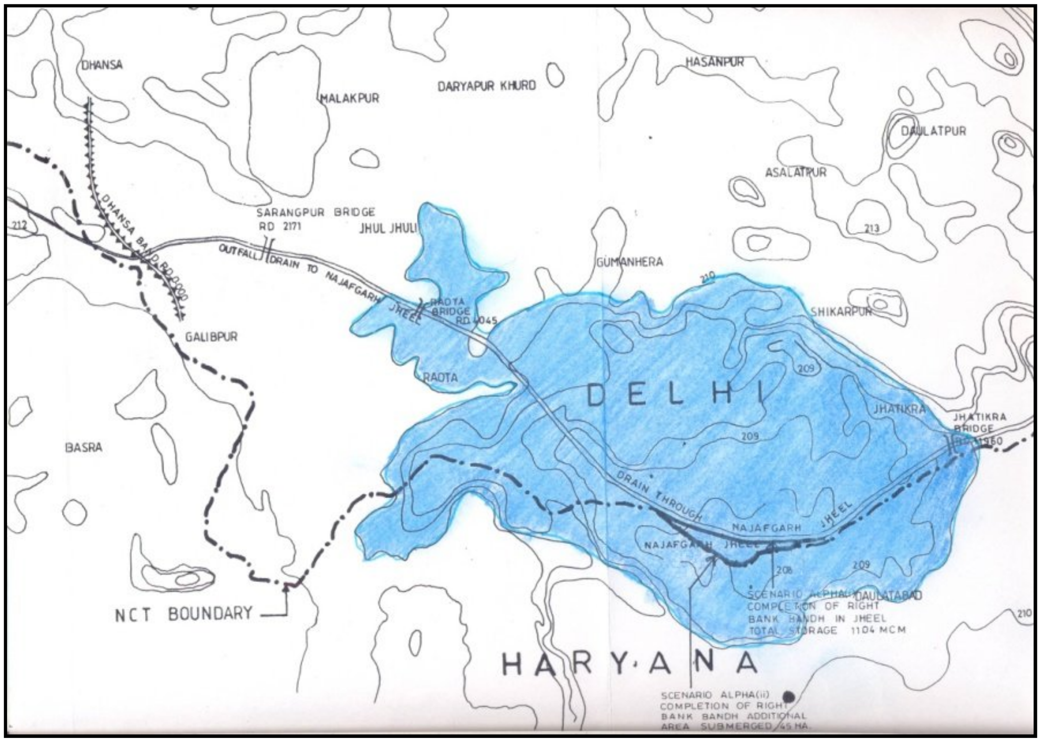
All the above source water can be diverted to lake for enhancing its spread and restoration of the environment of Lake including the recharge to ground water and raising the ground water levels in the surrounding areas.

Design Features

The design features of the project states that presently the Jheel is having and spread of 356 hac in Delhi State and 344 hac in Haryana(Gurgaon). The storage will be from najafgarh Drain from Dhansa To Kakraula which is about 30 Km long streach. Additionally, Mundela depression, Off-Channel Reservoir in Dwarka, Mungeshpur drain and other supplementary drain will act as storage.

The enhancement in storage will require additional land which is required to be acquire for the said purpose. At Highest flood Level of 209 meter above mean sea level it require land of 890 Acres in Delhi area and 850 Acres in Gurgaon area. The DDA has already identified 2210 acres of land in the 5 villages namely Raota, Jonpour, Ghummanhera, Shikarpur, Jhatikra of Delhi in this regard. The proposed Jheel spread after the project is indicated in the picture below:

Recharge shafts as per the given designs for recharge to ground water should be constructed all along the peripheral of the Jheel. It is proposed to construct at least 50 recharge shafts which will acts as conduit to ground water aquifers and arrest the declining water levels. It is also proposed to excavate the bottom of the existing lake to remove the silt which is presently acting as an impermeable layer, so as to enhance the natural recharge to ground water aquifers from the storage of the lake.



Water Balance:

The water balance of the lake is for the project is given in table below

Total Annual Inflows	75 MCM
Total Evaporation Losses	13 MCM
Total Percolation that may take place including 25 MGD of natural recharge	38 MCM
Induced Recharge including of natural recharge of 33 MGD	50 MCM

However to establish the statistics given above a detailed Hydrological Modelling should be carried out for actual quantifications of the water balance.

Capital Costs

- Land Acquisition : Delhi [890 acres] Rs. 270.0 Cr
- Land Acquisition : Gurgaon [850acres] Rs. 170.0 Cr
- Gated Regulator at Jhatikra Rs. 2.0 Cr
- Renovation of Inflow Channels Rs. 15.0 Cr
- Battery of Shallow Tubewells [400 No.] Rs. 11.0 Cr
- Pipeline Costs Rs. 25.0 Cr
- Power Supply Feeder Lines Rs. 12.0 Cr

Total Rs. 505.0 Cr

Annual Operational Costs is required to be established at DPR stage.

Revenue Elements

- Water Supply [RIL SEZ]
- Premium Low Density Residential Development on Shoreline
- Island Hotels
- Residential Islands
- Recreational Elements
- Fisheries
- Navigation Waterway from Gurgaon to Kakraula [later upto Yamuna]

Stakeholders

- DDA
- GNCTD {Dev. Dept. and I & FC]
- Govt. of Haryana [Gurgaon Distt. Admn.]
- CWC
- Irrigation Dept. Haryana
- CGWB
- Others

10.3.4 Shelf Project of Sanjay Lake, NCT-Delhi

Sanjay Lake is an old depression in low lying area of the old floodplain in East Delhi which was the receptacle of rainwater drainage from a localized catchment not having any natural outlet. The depression is shown on various survey maps from 1911 onwards. The lake was recipient of untreated sewage through a number of small nallahs which reduced the water quality status to a very low level of dissolved oxygen effectively killing all aquatic life and emitting a foul smell [owing to inadequate oxidation of contaminants]. This problem has been curtailed to a great extent with the diversion of most nallahs (except for some minor inflows).

The rapid urbanization of East Delhi was not accompanied by a sewerage system and thus the sewage generated was allowed to flow untreated into the Lake through eleven drains of which eight are now diverted. The regular drainage from two of the remaining drains and irregular inflow from the third one constitutes the daily intake of waters into the lake. The outflow of water from the lake is through mainly by evaporation to the atmosphere and a small component is from percolation to the underground aquifer.

Objectives

To enable Lake to serve its primary functions of:

- Acting as a recreational water body throughout year including in the summer months
- Acting as biodiversity habitat for birds
- Recharge and augmenting the ground water aquifers

Sanjay Lake needs to function as a healthy aquatic eco-system having high water quality with a minimum of 4-5 mg/1 of dissolved oxygen and a sustained water level through regular [daily] water augmentation to neutralize the water losses. This would enable it to support aquatic and avian biodiversity which in turn would keep the water clean for human purposes.

With no natural inflows and there being substantial evaporation losses during summers [percolation losses are low as the bed is fairly impermeable on account of its sealing with fine sediments and settled organic substrates as well as a high water table ranging from 1.4 m -2.5 m below ground level] the water level declines and in the shallow part of the lake comes down to as low as 15 cm] leaving the lake unfit for any recreational activity, increasing the concentration of dissolved solids and encouraging growth of floating weeds mainly hyacinth.

Sanjay Lake is a scour depression in the low lying areas of East Delhi originally washed by the Yamuna River when in spate. Now in the midst of urbanized area it has a very limited catchment. As a result the natural inflow to the lake is insignificant. The sources of water are rainfall that directly fall over the lake and the immediate surrounding area.

- The water spread is approximately 17 ha in extent.
- The water volume is approximately 120,000 cu.m.
- The elongated lake is 30 m wide at its narrowest point and 270m at its widest point.
- The water depth in the lake ranges from 0.7m to 1.10m.

The immediate surroundings of the lake consist of a partially landscaped area of some 52 ha. The lake is surrounded by plantations mostly comprising of Eucalyptus.The area is water logged with the overflow from the lake and rain water as there is no overflow point. The aquifer is being mined for human use at an unsustainable level and the good water sourced from the ground at one location, soiled by human usage, is disposed of with or without treatment into natural water courses.

Since there is no regular inflow into the lake except for rainwater addition from a very localized catchment, the lake looses water round the year through evaporative and percolation losses. The latter losses are not significant partly as a result of the lakebed having been lined by fine sediments and partly as a result of a high water table(Although, this table is declining due to over withdrawal from an increasing number of tube wells).

Thus the main losses are through evaporation which in turn varies on a seasonal basis. The highest evaporative losses are in the months of May and June. It is estimated that the evaporation losses on a daily basis are as follows:

Evaporation Losses From Open Reservoirs In Delhi (in mm/day)

Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
2	3	5	10	12	9	5	5	5	4	3	2

Source: 'Evaporation Control in Reservoirs'' — CWC

Proposal

- Measure to be undertaken is to reduce the loading of organic nutrients into the lake applying suitable technology.
- To prevent the lake from raw sewage and accord it tertiary treatment at suitable locations.
- Excavation of the bottom of lake and construct recharge shafts for augmenting the ground water from monsoon surplus runoff from the storage of the lake.

Cost Estimates

The cost estimates for implementation of the project are :

S No.	Item	Amount (Rs.)
1	Settling Tank of 350 cu.m. capacity with cement concrete lining	2,00,000/-
2	Mechanized Treatment Plant including Civil Works, Supply & Commissioning for 1800 MLD Capacity	1,75,00,000/-
3	Lime Dosing	6,00,000/-
4	Floating Aerators with 20 HP Pumps x 2 no.	10,00,000/-
5	Fish fingerlings x 120,000 no.s	1,00,000/-
6	Plant floatellas x 4 no.	20,000/-
7	Total	1.94,20,000/-

O & M Costs

The O & M costs AR mainly of the STP and are assumed at 10 %. Thus annual O & M cost should range around Rs. 20.0 lakhs annually.

ANNEXURE - I

Bill No. 1 of 2002

THE DELHI WATER BOARD (AMENDMENT) BILL, 2002

A

BILL

To amend the Delhi Water Board Act, 1998

Bill enacted by the Legislative assembly of the National Capital Territory of Delhi in the Fifty-second Year of the Republic of India as follows:-

Short title, extent and Commencement

(1) This Act may be called the Delhi Water Board (Amendment) Act, 2002

(2) It shall extend to the entire area of the National Capital territory of Delhi excluding area under New Delhi Municipal Council and Cantonment Area.

(3) It shall come into force on such date as the Government may, by notification in the official Gazette, appoint; and different dates may be appointed for different provisions of this Act and any reference in any such provisions to the commencement of this Act shall be construed as a reference to the coming into force of that provision..

Amendment of Long title Delhi Act of 1998

2. In the long title to the Delhi Water Board Act, 1998 (hereinafter referred to as the principal Act), after the words "water supply,"the words "regularisation, control and development of groundwater," shall be inserted.

Amendment of Section 2

3. In section 2 of the principal Act.

(a) after clause (O) the following clause shall be inserted, namely:-

"(oo) 'ground water' means the water which exists below the surface of the ground at any particular location;";

(b) after clause (aj), the following clauses shall be inserted, namely:-

"(ajj) 'sink' with all its grammatical variations and cognate expression in relation to a well include any digging, drilling or boring of a new well or deepening carried to the existing well;

(ajk) 'specified' means specified by regulations framed by the Board under section 109,",

© after clause (an) the following clause shall be inserted, namely:-

"(ann) ' 'well' means a well sunk for search or extraction of ground water by person or persons except by the authorised officials of the State or Central Government for carrying out scientific investigations, explorations, development or management work for the survey and assessment of ground water for irrigation and includes open well, bore well, dugcum-bore well, tube well, filter point, collector well and infiltration gallery;

Provided that it will exclude the person or persons who use ground water drawn from a well by manual devices such as hand pump or rope and bucket."

Amendment of clause Section 9

4. In section 9 of the principal Act, ion sub-section (1), for

(b), the following clause shall be substituted, namely:-

"plan for, regulate, control and development of ground water in Delhi and also give advice in this respect to the New Delhi Municipal Council and Delhi Cantonment Board:

Provided that the Board shall not licence and levy user charges for regulation, control and development of ground water in any area for the time being falling within the jurisdiction of the New Delhi Municipal Council and Delhi cantonment Board, except with the prior approval of the Central Government".

5. In the principal Act, after Chapter III, the following Chapter shall be inserted, namely:-

"CHAPTER III-A : REGULATION, CONTROL AND DEVELOPMENT OF GROUND WATER

Power to notify area for regulation and control of ground water

35-A (1) If the Board is of the opinion that it is necessary or expedient in the public interest to control and regulate the extraction or the use of ground water in any form in any area, it shall by notification in the Official Gazette, declare any such area to be a notified area for the purposes of this Chapter with effect from such date as may be specified therein:

Provided that the date so specified in the notification shall not be earlier than thirty days from the date of publication of the said notification.

(2) Every such notification shall, in addition to its publication in the Official Gazette, be published in not less than one daily region language newspaper having wide circulation, and also in such other manner laid down in sub-section (2).

Permission for use of ground water in notified area

35-B (1) Any user of groundwater desiring to sink a well in notified area for any purpose shall apply to the Board for grant of a permit for this purpose, and shall not proceed with any activity connected with such sinking unless a permit has been granted by the Board.

Provided that the person will not have to obtain a permit if the well is proposed to befitted with hand operated manual pump or water is proposed to be withdrawn by manual devices.

(2) Every application under sub-section (1) shall be made in such form, shall contain such particulars and in such manner as may be specified.

(3) On receipt of an application under sub-section (1), if the Board is satisfied that it will not be against public interest to do so, it may grant, subject to such conditions and restrictions as may be specified, a permit authorising the extraction and use of the water:

Provided that no person shall be refused a permit unless he has been given an opportunity of being heard.

(4) The decision regarding the grant or refusal of the permit shall be intimated by the Board to the applicant within a period of thirty days, 60 days from the receipt of the application.

(5) In granting or refusing a permit under sub-section (3), the Board shall have regard to:

(a) the purpose or purposes for which water is to be used;

(b) the existence of other competitive users;

(c) the availability of water;

(d) quality of ground water with reference to use;

(e) spacing of groundwater structures keeping in consideration the purpose for which waster is to be used;

(f) long term ground water level behaviour;

(g) any other factor relevant there.

(6) The permit shall be in such form as may be specified.

Registration of existing users in notified areas

35-C (1) Every existing user of groundwater is notified area shall, within a period of thirty days from the date of notification of notified area under section 35-A will apply to the Board for the grant of a certificate of registration recognising its existing use in such form and in such manner as may be specified:

Provided that the Board may entertain any such application after the expiry of the said period of thirty days, if it is satisfied that the user was prevented by sufficient cause from filing of application in time.

(2) The details to be furnished in any application under subsection (1) shall include the following, namely:-

(i) the description of the source of water, such as, type of well, its exact location;

(ii) the lifting device used;

(iii) the quantity of groundwater and hours of operation per day;

(iv) the purpose or purposes for which groundwater is being extracted;

(v) in case of irrigation well, the location and extent of area irrigated.

(3) On receipt of an application under sub-section (1), if the Board is satisfied that it shall not be against the public interest to do so, it may grant, subject to such conditions and restrictions as may be laid down, a certificate of registration authorising the continued use of the water. Provided that no person shall be refused a certificate of registration unless he has been given an opportunity of being heard.

(4) The decision regarding the grant or refusal of the certificate of registration shall be intimated by the Board to the applicant within a period of thirty days from the date of receipt of the application.

(5) In granting or refusing a permit under sub-section (3), the Board shall have regard to:-

(a) The purpose or purposes for which water is to be used;

(b) The existence of other competitive users;

(c) The availability of water;

(d) Quality of ground water with reference to use;

(e) Spacing of groundwater structures keeping in consideration the purpose for which water is to be used;

(f) Long term ground water level behaviour;

(g) Any other factor relevant thereto.

(6) The certificate of registration shall be in such form as may be specified.

(7) Pending the communication of the decision under subsection (1) every existing user of groundwater in the notified area shall be entitled to the continued use of the groundwater in the same manner and to the same quantity as he was entitled prior to the date of his application.

(8) If a registered well becomes defunct, the user of Groundwater shall immediately bring this fact to the notice of the Board.

Power to alter, amend or vary terms of permit

35-D At any time after a permit or certificate of registration, as the case maybe, has been granted, the Board may for technical reason alter, amend or vary the terms of the permit or certificate of Registration.

Provided the user of ground water has been given an opportunity of being heard:

Provided further that before taking such action, the Board shall ensure that the standing crop(s) are not damaged.

Cancellation of Permit or certificate of registration

35-E. If the Board is satisfied either on a reference made to in this behalf or otherwise that:-

(a)the permit or certificate of registration granted, under subsection (3) of section 35-B, or sub-section (3) of section 35-C, as the case may be, is not based on facts;

(c) the holder of the permit or certificate of registration has without reasonable cause failed to comply with the conditions subject to which the permit or certificate of registration has been granted or has contravened any of the provisions of this Chapter or regulations made hereunder: or

a situation has arisen which warrants limiting of the use or extraction of groundwater.

Then, without prejudice to any other penalty to which the holder of the permit or of the certificate of registration may be liable under this Chapter, the Board may after giving the holder of the permit, or certificate of registration, an opportunity to show cause, cancel the permit, or certificate of registration, as the case may be.

Powers of Board In respect of Regulation and Control of ground water

35-F. (1) The Board or any person authorised by it in writing in this behalf shall have power to-

(a) enter on any property (private or Government owned) with the right to investigate and make any measurements concerning the land or the water located on the surface or underground;

(b) inspect the well which has been or is being sunk and the soils and any other material or of water extracted from such well;

(d) require by order in writing the persons sinking a well to keep and preserve in the specified manner specimens of soils or any material excavated there from for such period not exceeding the three months from the date of completion or and thereupon such persons shall comply with such requisition.

(e) inspect and take copies of the relevant record or documents and ask any question necessary for obtaining any information (including diameter or depth of the well which is being or has been sunk; the level at which the water is or was struck and subsequently restored or rested, the types of strata encountered in the sinking of the well and quality of the water struck) required for carrying out the purposes of its chapter.

(f) require the user of groundwater to install water measuring device or any water supplies when necessary to properly administer the water or where there is reason to believe that the user does not comply with the provisions contained in this chapter or any other sufficient reason for defending the public interest.

Provided that where the user of groundwater does not comply with the requisition issued to him within a period of thirty days, the Board itself may install such water measuring device and recover the cost from the defaulting user of groundwater;

(g) seize any equipment or device utilised for illegal sinking and destroy the work executed fully or partly;

(h) require any user of groundwater to close down any water supply or destroy any hydraulic work found to be illegal according to the provisions of this chapter and the regulations framed hereunder:

Provided that where the user of groundwater does not comply with the requisition issued to him within a period of thirty days, the Board itself may carry out the necessary work and recover the cost from the illegal user of groundwater;

(i) enter and search with such assistance, if any, as it considers necessary, any place in which it has reason to believe that offence under this Chapter has been or is being committed and order in writing the person who has been or is committing the offence not to extract or use the groundwater for a specified period not exceeding thirty days;

(2) The power conferred by this section includes the power to break open the door of any premise where sinking extraction and use of groundwater may be going on:

Provided that the power to break open the door shall be exercised only after the owner or any other person in occupation of the premises, if he is present therein, refuse to open the door on being called to do so.

2 of 1974

(3) Where the Board is of the opinion that water supply or hydraulic work ordered to be closed down under clause (h) of sub-section (1) needs to be closed down forthwith and user of it does not comply with such direction, it may direct such water supply or hydraulic work to be sealed in the manner specified by regulations.

(4) The provisions of the Code of Criminal Procedure, 1973 shall so far as may be, apply to any search or seizure under this section as they apply to any search or seizure made under the authority of a warrant issue under section 93 of the said Code.

(5) Where the Board seizes any mechanical equipment or Device under clause (h) of sub-section (1), it shall, as soon as may be, inform a magistrate and take his orders as to the custody thereof.

***Service orders etc*.**

35-G (1) Every order under clause (d) of sub-section (1) of section 35-F shall be served:

(a)by giving or tendering the order of notice or by sending it by post to the user for whom it is intended, or

(b) if such user cannot be found, by affixing the order of notice on some conspicuous part of his last known abode or place of business or by giving or tendering the order of notice to some adult male member or servant of his family or by causing it to be affixed on some conspicuous part of the land or building in which the well is being sunk.

(2) Where the person on whom the order or a notice is to be served is a minor, service upon his guardian in the manner provided in sub-section (1) shall be deemed t o be served upon the minor."

Levy of user charges For use of ground water

35-H (1) The Board may, for the purpose of this Chapter levy usercharges for the use of ground water in a notified area at such rates as may be specified by regulations.

(2) All money received or collected under sub-section (1) shall be credited to the Delhi Water Board Fund."

Amendment of Section 109

6. In section 106 of the principal Act, in sub-section (1), after clause (m) the following clauses shall be added, namely:-

"(n) the form of application under sub-section (2) of section 35-B and the particulars that may be furnished therewith.

(o) the form of application under section 35-C

(p) the form of the permit and certificate of registration under sub-section (6) of section 35-B and sub-section (6) of section 35-C;

(q) the manner in which specimens of soil or other material shall be kept and presented under clause (d) of sub-section (1) of section 35-F;

® *rates of charges to be levied for the use of ground water under sub-section (1) of section 35-H*

(s) any other matter which is to be or may be specified by regulations."

Amendment of Fourth Schedule

1. In the principal Act, in the Fourth Schedule, after the entry relating to section 35, the following entry shall be inserted, namely:-

1	2	3	4

Chapter III-A Regulation, Control 1000 200 Development of Groundwater

ANNEXURE - II

HARYANA GOVERNMENT
HARYANA URBAN DEVELOPMENT AUTHORITY
Notification
The 31st October, 2001

No. Auth. 2001/29449-In exercise of the powers conferred by Clause… (d) of Section 54 of the Haryana Urban Development Authority Act, 1977 (Act 13 of 1977) and all other powers enabling him in this behalf, and with the previous approval of the State Government conveyed vide their memo No. 10/1/98-2TCP, dated the 31st October, 2001 Haryana Urban Development Authority hereby makes the following regulations further to amend the Haryana Urban Development Authority (Erection of Buildings) Regulations, 1979, namely:

1. These regulation may be called the Haryana Urban Development Authority (Erection of Buildings) Amendment-Regulations, 2001. They shall come into force with immediate effect.

2. In the Haryana Urban Development Authority (Erection of Buildings) Regulation, 1979 (hereinafter called the said regulations), in regulation-II, after Sub regulation (3), the following regulation shall be added, namely : "(4) Construction of the works as laid down in regulations 81A shallpart of the occupation certificate. Unless such works are completed as per the approved drawings, no occupation certificate shall be issued."

3. In the said regulation 81, the following regulation be inserted, namely : "81 A Rain Water Harvesting :

1. Arrangement of roof top rain water harvesting will have to be made by the plot owner, constructing the building on the plot allotted by Haryana Urban Development Authority where the area of the roof is 100 square meter or more.

2. The system of collection, conveyance and dispersion of rain water for harvesting shall be made in such a manner that only clear water is able to enter. No contaminated/waste water from the building or surrounding area should find its way in this system.

3. The entry points of the rain water for harvesting shall be designed in such a manner that in normal days, these remain covered. Arrangement of segregation of the rain water from the first shower (containing wash water) shall also be there.

4. The arrangement of quick filtration of rainwater also be made in the rain water harvesting well/tube well so that rain water does not pollute or choke the strata.

5. The complete system of rain water harvesting will be constructed within the plot area allotted to the allottee as per allotment letter.

6. The recharge well shall be located at a distance of not less than 10 meters away from any structure handling sewage or industrial waste water (such as septic tank or effluent treatment plant etc.) this minimum distance of 10 meter will not be applicable to manholes or sewer lines although it will be ensured that they are leak proof.

7. The detail proposal of the system comprising of collections, conveyance and dispersion of rain water from the roof top to rain water harvesting well/tubewell will have to be shown on the building plan submitted for approval to the building plan approval committee. The committee after scrutiny will approved the drawing for implementation at site.

8. Any Engineer not below the rank of Executive Engineer, HUDA so authorized by Chief Administrator, Haryana Urban Development Authority/Director Town & Country Planning, Haryana will have the powers to inspect the system whenever considered necessary and direct the owner of the building to affect any changes/improvement as deemed necessary and the owner of the building will ensure compliance.

9. Haryana Urban Development Authority shall notify the area where such rain water harvesting system is to be provided. Broad guide lines about the approximate depth of the recharge well and the sample starta chart will also be made available.

10. The water (prevention and Control of Pollution) Act 1974 (Act 6 of 1974) with all amendments made from time to time shall be applicable.

ANNEXURE -III

संख्या-1703 A /9-आ-1-29-विविध/98

प्रेषक,

भोला नाथ तिवारी,
मुख्य सचिव,
उत्तर प्रदेश शासन।

सेवा में,

1. समस्त प्रमुख सचिव/सचिव
उत्तर प्रदेश शासन।

2. समस्त मण्डलायुक्त,
उत्तर प्रदेश।

3. समस्त जिलाधिकारी,
उत्तर प्रदेश।

4. समस्त विभागाध्यक्ष,
उत्तर प्रदेश।

आवास अनुभाग-1 लखनऊ : दिनांक 12 अप्रैल,

विषय: ग्राउण्ड वाटर के संरक्षण तथा रिचार्जिंग हेतु रेन वाटर हार्वेस्टिंग पद्धतियों को अपनाए जाने के सम्बन्ध

महोदय,

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

2. इस सम्बन्ध मे मुझे यह कहने का निदेश हुआ है कि रेन वाटर हार्वेस्टिंग एवं ग्राउण्ड वाटर के समुचित प्रबन्धन हेतु योज की संरचना तथा विकास एवं निर्माण के समय शासन द्वारा विचारोपरान्त निम्न व्यवस्थाएं सुनिश्चित किए जाने का निर्णय लिया गया

2.1 **महायोजना/जोनल प्लान स्तर पर कार्यवाही :**

नगरीय क्षेत्रो मे प्राकृतिक जलाशयो, तालाबो झीलो को चिन्हित कर महायोजना/जोनल डेवलपमेंट प्लान मे उनके अ संरक्षण हेतु प्राविधान किए जाएं एवं इनके अन्तर्गत आने वाली भूमि को किसी अन्य उपयोग मे प्रस्तावित न किया, साथ ही जलाशयो, तालाबो को प्रभावी रूप से रेन वाटर हार्वेस्टिंग के उपयोग मे लाने हेतु चारों ओर के क्षेत्र का यथासम्भव इन्ही जलाशयो मे निस्तारित करने हेतु प्राविधान किए जाएं, परन्तु औद्योगिक क्षेत्रो का प्रवाह उचित उपचा उपरान्त ही इनमे मिलाया जाए।

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

(i) 20 एकड़ एवं अधिक क्षेत्रफल की विभिन्न योजनाओ के ले-आउट प्लान्स मे पार्क एवं खुले क्षेत्रो के अ कुल योजना क्षेत्र के लगभग 5 प्रतिशत भूमि पर तालाब/जलाशय (Water Bodies) बनाई जाएं जिनसे ग्राउण्ड चार्ज हो सके। ऐसे जलाशय/तालाब का न्यूनतम क्षेत्रफल एक एकड़ होगा और उसकी गहराई 6 मीटर

(ii) 20 एकड़ से कम क्षेत्रफल की योजनाओ मे उपरोक्तानुसार तालाब/जलाशय बनाए जाएं अथवा पार्क/ग्रीन बेल्ट अन्तर्गत निर्धारित मानक के अनुसार एक कोने मे रिचार्ज-वैल/रिचार्ज टैंक बनाए जाएं।

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

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

3 भवन निर्माण स्तर पर कार्यवाही

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

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

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

4 अन्य कार्यवाही

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

(ii) यदि सम्भव हो तो सड़कों के किनारे कच्चे रखे जाएं जिनमें "ब्रिक-ऑन-एज"/"लूज-स्टोन पेवमेन्ट" का प्राविधान किया जाए ताकि ग्राउण्ड वाटर की चार्जिंग सम्भव हो सके।

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

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

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मुख्य सचिव

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प्रतिलिपि निम्नलिखित को सूचनार्थ एवं आवश्यक कार्यवाही हेतु प्रेषित,

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सचिव