

# Integrated Water Management Approach for Vulnerability Reduction in Delhi, India

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## Abstract—

**W**ater supply and demand gap is a potential crisis situation for any metro city like Delhi. This situation can escalate during the times of disaster events due to their cascading effects damaging the water storage and supply network infrastructure. Under this study, integrated water management has been emphasized as a comprehensive approach to address the crisis during extreme events. The process of integrated water management is described not only from water management perspective but also from perspectives of disaster management and Sustainable Development Goals. Emphasis on technological and institutional reforms for efficient and effective implementation during disaster event has been given. Along with this, the role of community participation is also considered as an integral component to make the proposed integrated approach sustainable. Results of an impact assessment study on human lives, economic and environmental conditions can be used to create holistic response plans which subsequently may result in disaster risk reduction and thus increased resilience towards vulnerability in disaster scenarios.

**Keywords—** *Integrated Water Management, Disaster Management, Vulnerability Reduction, Sustainable Development, Holistic Plan, Delhi*

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## I. INTRODUCTION

Disasters of different types could have similar cascading impacts in an urban environment due to dense and complex infrastructure development in a city. An earthquake can lead to destruction of buildings, utility networks and thus disrupting the essential supplies and services. Dependence of the society on the reliable functioning of critical infrastructures can be affected negatively in case of disruptions, although the society itself has its own coping capacities [17]. Delhi, a metro city and capital of India, is vulnerable to different natural and anthropogenic disasters such as earthquakes, floods, fire and terrorist acts etc. Any disaster can cause disruption of service by damaging supply networks such as water supply. Delhi, on the other hand, is looking forward to become a smart city [14]. The Indian mission on smart cities aims to develop cities with good quality infrastructure and environment while using smart solutions [25]. For the sustainability of urban areas, water is a prime factor [34]. To become a successful smart city, Delhi has to develop smart water management solutions which could ensure continuity of safe water supply even in case of disaster events. This would enhance the resilience of city in context of water availability for consumption.

In case of Delhi, the surge in population has continued over the years and thus demand for water exceeds its supply provided by Delhi Jal Board, the nodal agency for water supply [9], [21]. The gap is often visible during the peak season of summer. To meet this demand, water supply is augmented by abstracting groundwater by individual households and private suppliers, resulting in lowering the water table. In recent years, water security has become a major concern for Delhi [3], [5], [34].

The study tries to address the issue of minimizing the gap of water demand-supply and ensuring water availability during disaster event by formulating an integrated water management approach based on community participation. The conceptual framework developed identifies the key stakeholders and their roles in this interaction between water demand and supply. The process of integrated water management is described through application of technology to link water resources and distribution systems, current and near future demand and supply assessment in the form of population growth rate, commercial development, groundwater quantity and quality available and surface water storage in local water bodies.

## II. CONCEPT OF INTEGRATED WATER MANAGEMENT AND COMMUNITY PARTICIPATION

Many regions are continuously facing excess water demand over supply, which could be the result of extreme weather events or population growth and other demographic changes [29] [30] [31]. Integrated Water

Resources Management promotes the coordinated development and management of resources so as to achieve maximization of social and economic welfare in a sustainable manner [10].

The concept of “water governance” gained popularity in policy dialogues since its advent in 1970’s. It considers the processes and institutions involved in water related decision making [11] [35]. The importance of community participation for enhancing the access to basic civic amenities has been well acknowledged by civil groups and international organizations. In urban areas, struggle to avail water is a continuous process resulting in an inter-play of formal and informal groups with varying agencies. The diverse interests of such groups come up as an important challenge to form cohesive partnerships resulting in meaningful community empowerment [36]. Communities relying on mutual support systems and own resources, are able to reduce the impact of disaster events and to develop resilience for rapid recovery [27]. Using innovative means, such as citizen observatories enabled by information and communication technologies, have the potential to provide citizens with a substantially new role in decision-making [35]. Academic Institutions has pivotal role to play by providing customized training as per the specific requirements of different stakeholder groups under a perceived disaster scenario. Such institutions should take such customized and advanced technical trainings under their research umbrella. Center for Disaster Management Studies under Guru Gobind Singh Indraprastha University is contributing its part in capacity building of the society in crisis management relevant domains by imparting quality education under its Master’s programme on Disaster management.

### III. DELHI WATER MANAGEMENT SCENARIO

Delhi receives its water from upstream areas of Yamuna river as well as from river Ganga [18], [19], [21]. Figure 1 shows the raw water sources availability.

#### A. Identified Key Stakeholders –

##### 1) Community of Delhi:

Delhi has an estimated Population- 1,67,87,941 comprising 89,87,326 males and 78,00,615 Females. The decadal growth of population for Delhi has declined from 51.45% in 1981-91 to 47.02% in 1991-2001 to 21.2 % in 2001-2011. The population density of Delhi was 9,340 persons per sq.km. in 2001 increasing to 11,320 persons per sq.km. in 2011 which is highest as compare to All India and other States/UTs. Total households in Delhi are 3,340,538 comprising 79,115 Rural and 32,61,423 Urban Households in 2011 as compared to the total households as per Census 2001 of 25,54,149 [26], [21].

##### 2) The Ministry of Drinking Water and Sanitation-(MDWS), Government of India:

The ministry has the prime objective to ensure access and usage of safe and sustainable drinking water and improved sanitation facilities for rural households. This is to be done by supporting the states for providing basic amenities. The ministry also gives inputs to other departments/ministry for policy formulation in context of water and sanitation issues [13].

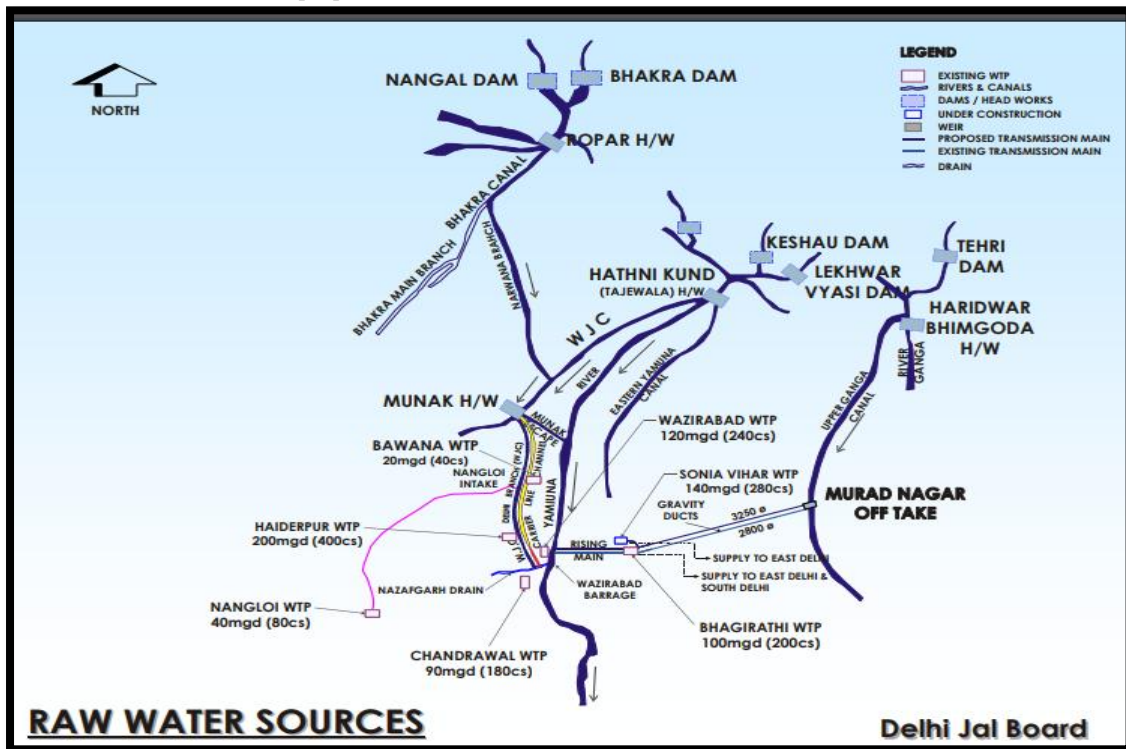


Figure 1: Raw Water Sources (Source: [15].)

3) *The Ministry of Water Resources (MoWR), Government of India:*

The ministry formulates policies and programmes regarding water resources of India. It provides infrastructural, technical and research support for sector development including state level activities in groundwater development, flood forecasting and warning on inter-state rivers and master plans preparation for flood control in Ganga and the Brahmaputra [16].

4) *Central Ground Water Board and Central Ground Water Authority:*

Central Ground Water Board, under Ministry of Water Resources, has a mandate to develop and manage the ground water resources in a scientific and sustainable manner. It includes exploration, assessment, conservation, augmentation, protection from pollution and distribution based on principles of economic and ecological efficiency and equity [2].

Central Ground Water Authority formed according to Section 3(3) of the Environment (Protection) Act, 1986 for developing and regulating ground water resources in the country [1].

5) *Delhi Jal Board:*

Delhi Jal Board (DJB) has a mandate of managing water resources, monitoring the water quality and supply of potable water. Wastewater collection, conveyance, treatment and disposal facilities are also the responsibility of DJB. NDMC and DCB, receives water from DJB, are responsible for the distribution of this water to their connection holders. The water supply infrastructure in these territories is not the responsibility of the DJB [9].

**B. Demand for Water in Delhi:**

Water demand projections by DJB for year 2021 are given in Table 1.

Table 1: Water Demand Projections for year 2021; Source: [9]

Population (million)	Net per Capita (gpcd)	Leakage (gpcd)	Gross Per Capita(gpcd)	Demand (mgd)
26.0	52	8(15%)	60	1,560

As per the 12th Five Year Plan Approach Paper of the DJB has a demand projection of 1140 MGD by 2017 taking rate of supply as 60 GPCD for 190 million population. In other papers, DJB is projecting a total demand of 1113 MGD in 2021. This is based on a supply norm of 50 GPCD [228 lpcd] for most planned areas, 75 GPCD [320 lpcd] for NDMC area, 35 GPCD for outer Delhi [160 lpcd] [22], [23], [24], [34].

**C. Supply of Water in Delhi**

Presently 900 MGD is being supplied by DJB which translates into about 220 lpcd. In Delhi, Zonal Distribution is highly variable with 509 LPCD Delhi Cantt. 440 LPCD is supply for NDMC area while for Outer Delhi, it is only 40 LPCD. As such there is a need for spatial equity in distribution. Groundwater augments the water supply in Delhi with DJB using 2,488 tubewells and 21 Ranney Wells amounting to 90 MGD [4], [19], [23], [34].

While close to 3<sup>rd</sup> decade of 21<sup>st</sup> century, Delhi needs to manage increasing demand for water while dealing with fast changing externalities such as extreme rainfall, decreasing flow in rivers, uncertainty of dam based resource augmentation, falling groundwater output, reduced water for environmental flows, rising differences with riparian states [12], [20], [34].

**IV. PROPOSED INTEGRATED WATER MANAGEMENT FOR DISASTER RISK REDUCTION**

The proposed integrated water management approach accepts the cascading impact of disaster in the form of damaged water supply network and other related assets like pumping station and electricity generation and distribution infrastructure. Disaster event can also impact the source of water such as tubewell. Using a community participatory approach, the proposed integrated water management can generate comprehensive solutions. The impact of these solutions shall help in disaster risk reduction and increasing the resilience of the city from water security point of view. The holistic responses will help to transform Delhi as a smart city.

The conceptual framework, refer to figure 2, presents a holistic approach for Delhi to reduce the impact on the city due to the damaging of water supply network. As described in the above sections, it first takes into account the current water demand and supply estimates along with the role of stakeholders involved. Disaster event could lead to damage to supply network and other related assets. Considering all these factors, an integrated water management plan shall be formulated which has to focus on required institutional reforms, upgradation of physical network, technological applications and community participation. This plan also aligns itself with the Sustainable Development Goals 6 and 11 focusing on water conservation and safe & resilient cities. While acknowledging the direct impact of institutional, physical and technological measures on increasing the resilience of the city water structures & water supply sources, it shall elaborate the role of

community participation in plans for response and reconstruction phases. Students and other young community members' role should be emphasized by channelizing their energy, skills and quality in the form of youth volunteer forums or groups. During a disaster event, communities take various shapes in the form of RWAs, volunteer groups and simple informal groups which offer technical knowhow along with required human resources in coordination with governmental and other organizations. For this, role of education institutions has to be highlighted so as to make people aware and trained in a professional manner.

From water management perspective, which focus on managing the available water resources and repairing/reconstruction of water supply network and related assets, initiatives can be taken using the community participation as a reliable tool for managing the local water bodies, maintenance and reconstruction of water supply network, tube wells, electricity infrastructure maintenance and distribution of potable water brought from other regions using the rail network etc. For this purpose, technical and resource management training as part of capacity building programmes for the community members and employees of line departments can be initiated.

Simultaneously, results of an assessment of impact on human lives, economic and environmental conditions from disaster management and Sustainable Development Goals perspective can be used to create holistic response plans which will subsequently result in disaster risk reduction and increased resilience. This will be a concrete step for Delhi to become a smart city from disaster point of view.

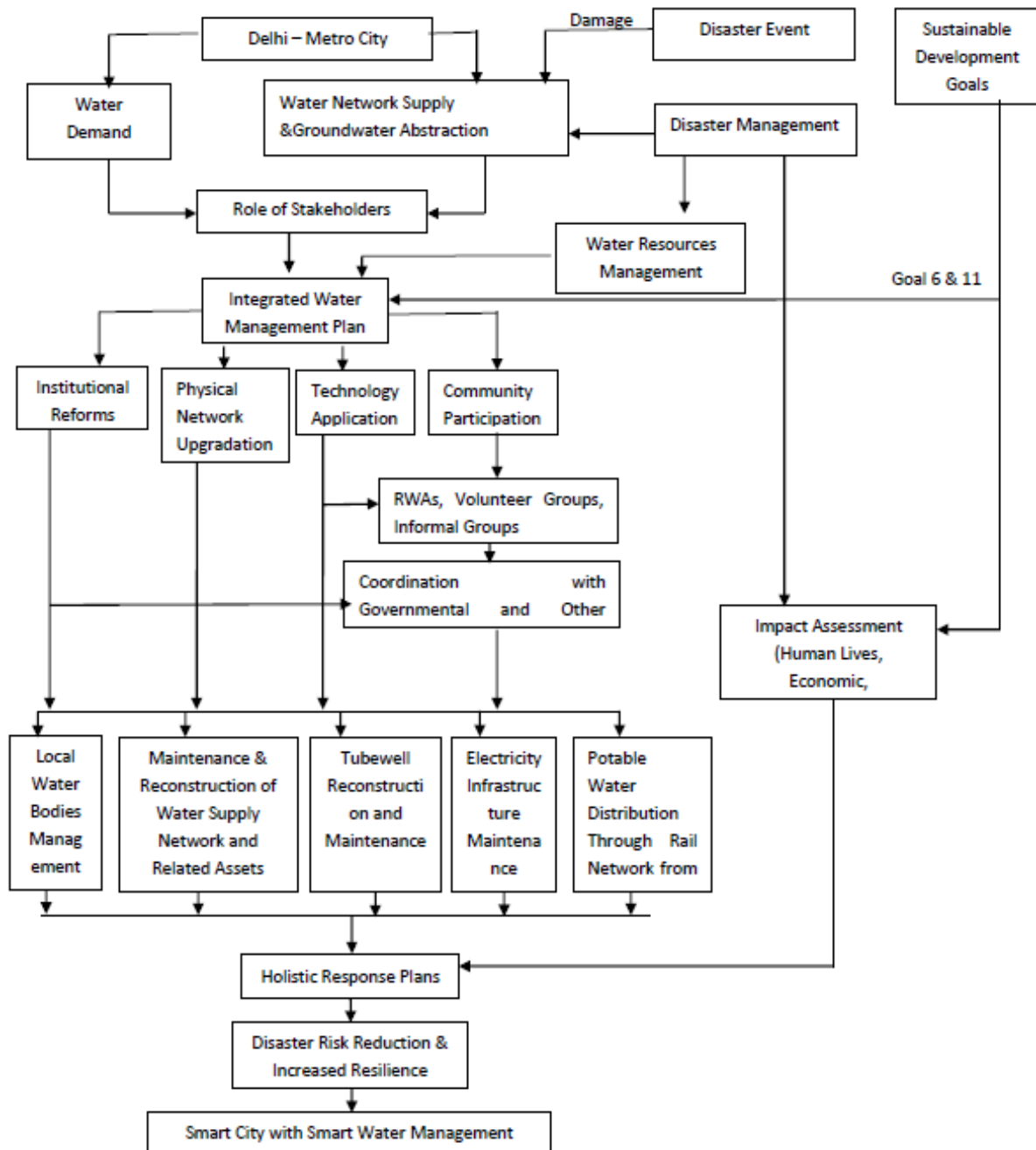


Figure 2: Conceptual Framework for Integrated Water Management with Community Participation

## V. OVERVIEW-HOLISTIC RESPONSE PLAN

Holistic Response Plan, refer to Figure 3, shall consider the central command authority in the form of a Integrated Command Centre. The Centre will be the focal point for linkages between the existing supply network and other assets, hydrogeological solutions and community participation along with governmental and NGOs support.

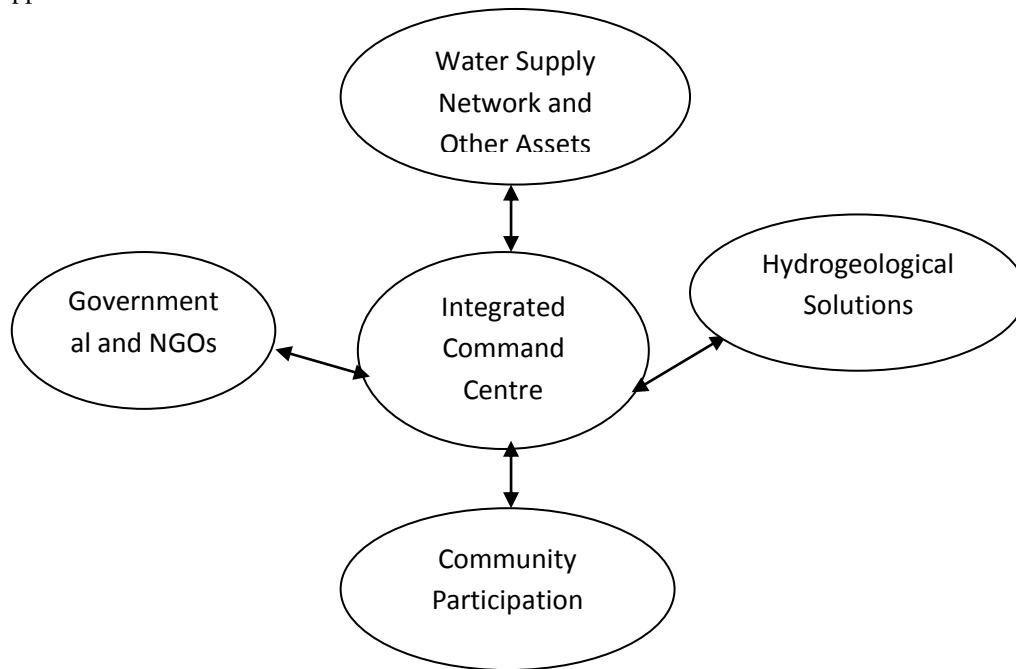


Figure 3: Schematic Diagram of Holistic Response Plan

There has to be a coordinated network between these entities and synchronization of the efforts to be made under such plan.

As a part of holistic response plan, water storage and supply assets need to be structured and distributed in the city in such a way that water availability and its supply get minimum disruption. Currently, to deal with water emergency situations, DJB has water emergency control rooms at strategic locations to cover all parts of the city. There is a provision of checks by enforcement department and other senior officers [28]. From a broader perspective, water conservation activities need to be emphasized with contingency measures also for disaster events. Some of the water conservation activities suggested by Central Ground Water Board [6] and Delhi Jal Board [32] are as follows:

### A. Rain Water Harvesting

Using rainwater collected from the rooftops of buildings, an estimated 2 MCM of groundwater can be recharged.

### B. Lakes and Depressions

Lakes and Depressions can be used to store water at local level. The storage capacity and quality can be increased by physical measures and natural processes following the principles of wetlands. This process will positively impact the quantity or quality of groundwater recharge.

### C. Floodplain Reservoirs

Yamuna flood plain can be used for the development of groundwater resources subsequent to the storage of monsoon water. Out of 580 MCM of monsoon season flow allocated to Delhi, about 280 MCM goes unutilized due to lack of storages.

### D. Quarry Reservoirs

Nearby abandoned quarries can be used for storage of runoff water in their catchment area and can be linked with channels in vicinity. Tajpur and Bhatti are two most promising projects.

### E. Historical Water Bodies

Reservoirs, locally known as “Baolis”, refer to figure 4, can be reused as small recharge points. Large reservoirs can be used for large storages.



**F. Paleo-Channels**

Division of some of the monsoon flows into abandoned channels of river can greatly replenish the declining water table for subsequent use.

**G. Check Dams**

Regional topographic features of Delhi, allow having large and small check dams construction which can be mainly used for groundwater recharging. With micro watersheds presence in ridge area, monsoon runoff could be conserved through simple recharge structures. Artificial recharge through check dams have been already experimented in Jawahar Lal University and Indian Institute of Delhi. Small check dams raise the contact period of the rainwater with underlying formations [6].

**H. Ecoparks**

In such parks, artificial wetlands use aquatic plants for sewage treatment for reuse by irrigation and horticultural sector and possibly some industrial estates while having expected effluent quality of 5-10mg/l of suspended solids. A total of 495 MGD of recycled water can be made available for irrigation, horticulture and industrial needs and for domestic non-drinking supply.

**IN ADDITION, IT MAY BE SUGGESTED THAT:**

**A. Natural Drains and Water Bodies**

In National Capital Territory of Delhi, as shown in Figure 5, natural drains and water bodies shall be used to recharge the drier regions of Delhi with low water depth or having saline groundwater such as Dwarka and Rohini.

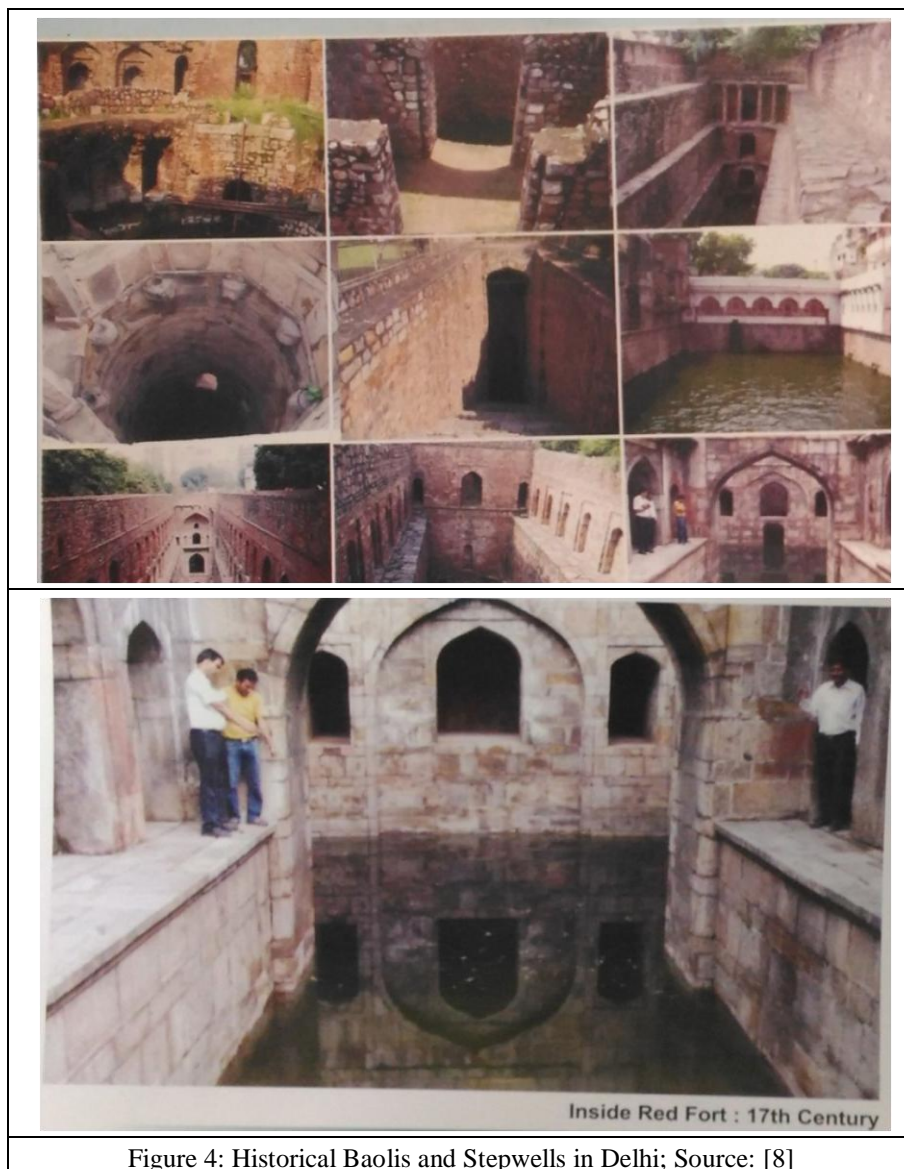


Figure 4: Historical Baolis and Stepwells in Delhi; Source: [8]

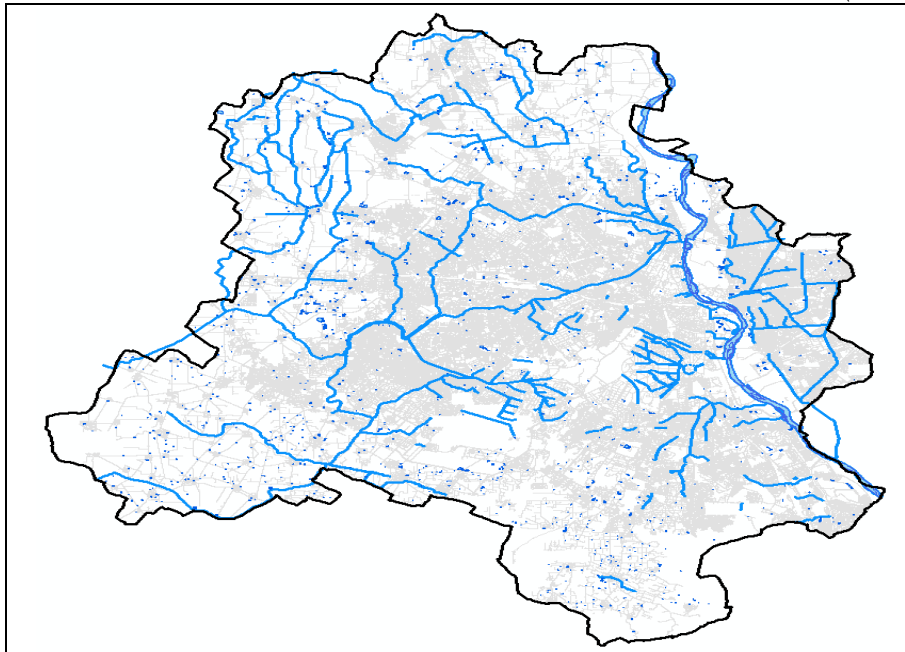


Figure 5: Natural drains and Water bodies in command of Yamuna River in Delhi;  
Source: [33]

**B. In drier regions, construction of scavenger wells should be promoted for mixing freshwater with saline water so as to dilute the salinity levels in groundwater.**

As shown in Figure 6, Yamuna alluvial plain is dissected by deep seated fault lines which can impact groundwater recharge or abstraction possibilities in context of water security. This makes it imperative to have good understanding of hydrogeology of Yamuna river before initiating any contingency measures in Yamuna floodplain.

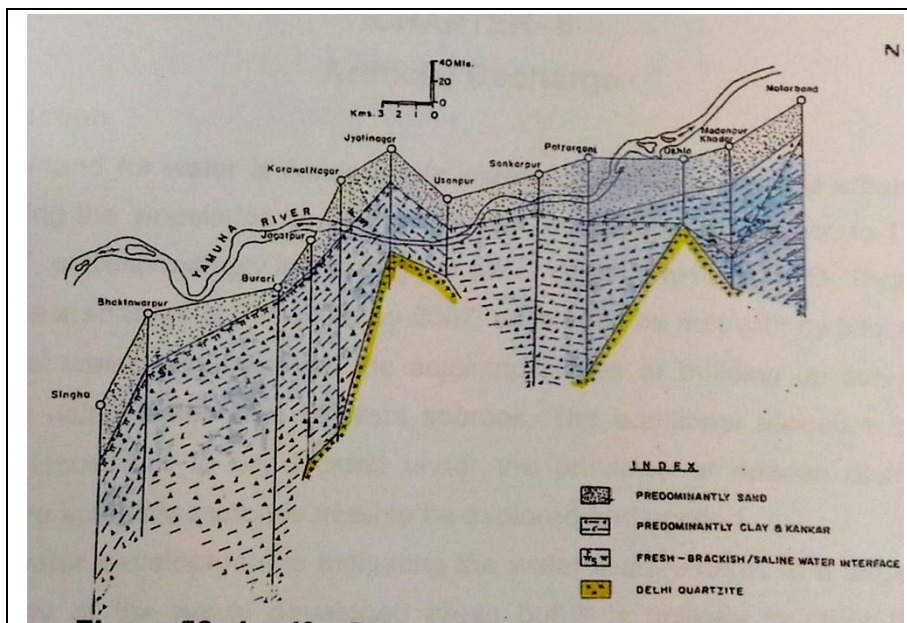


Figure 6: Aquifer Disposition along River Yamuna, Delhi; Source: [7]

Community has to be involved into this exercise as an active stakeholder. It has to play a larger role in preparing and implementing such holistic plans for its own benefit during extreme events. Sustainability aspect has a direct linkage with resilience development using community participation which will reduce the risk of water scarcity.

## VI. DISCUSSION

Delhi metro city, which is expanding in terms of population growth and infrastructure development, has been continuously facing the situation of gap between water demand and supply. In case of disaster events such

as earthquake and flood, the destruction or damage to the water supply structures and network, a critical situation can arise for the concerned agencies. The proposed integrated water management plan comprises of institutional mechanisms, physical network, technological applications and community participation. With emphasis on community participation, sustainability of designed alternatives can be maintained.

During the water crisis situation in a smart city, the water management and its distribution is the key criteria for providing a smart response. In order to achieve this, it is imperative to understand fully, the total water demand and supply of the city.

About 20 deep water tubewells should be constructed in Delhi to be used only in case of disaster events. Further, to ensure the effectiveness of these tubewells, groundwater movement needs to be assessed for complete understanding of total aquifer system.

Geological mapping also is another important aspect for Delhi as it has number of fault lines which may become activated during earthquake. The prior information about such faults is very important for construction of these tubewells.

## VII. CONCLUSION

It can be concluded that integrated water management using technological applications for efficiency along with institutional reforms and community participation is a sustainable solution for ending the woes of Delhi regarding water demand and supply. Institutional reforms can generate systemic changes while the technology applications such as geospatial technologies can help in implementation of the proposed reforms more effectively.

During disaster events, the community participation along with formal mechanism of governmental support would ensure the rapid recovery while minimizing the time to restore basic infrastructure for water generation, storage and supply.

With proper training by higher educational institutions for technical and management aspects, community groups will be better prepared to respond back and recover quickly.

Such comprehensive measures shall enable sustainability of water generation, storage and supply even in case of catastrophic events and thus reduce vulnerability at the system level.

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