Report
Integrated Water Resources Management of Sohna Division, Gurgaon District, Haryana

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Foreword

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Gurugram, the millennium city has been struggling with water crisis. The geographical area of Gurugram district as per 2011 Census is 1258.00 square kilometers. With more than 77% of it's area as rural and under agriculture, yet no perennial river, the district is increasingly relying on the canal water from Western Yamuna Canal system for domestic use and groundwater for agricultural and commercial use.

Only about 10 percent of the agricultural area in the district is rainfed, a mighty 98.7% of the irrigated agriculture is through borewells dismally resulting in 100% of the area under the Gurugram district falling in the over-exploited zone.

There have been initiatives undertaken by various departments of the Administration be it in terms of Pond rejuvenation, rainwater harvesting structures, plantation etc. However, because of lack of adequate R&D and a holistic strategy it inevitably thus which led to failures inevitably, thus it raised the need for learning from past experiences and to understand the gravity of the situation with on-ground feedback and urgency with specifications owing to the Gurugram land and situation.

Thus, GuruJal was conceived an initiative with the objective of addressing the issues of water scarcity, ground-water depletion, flooding and stagnation of water in Gurugram. The focus is to work on improving the compliances of schemes and policies supporting water conservation, following up on better enforcement of rules and regulations, to mitigate water exploitation, extensive campaigning to sensitize people, come up with better design solutions for the current standing issues and work towards making a better policy framework for water management. It aims to collaborate with the different stakeholders of the district like corporates, civil society, and research organizations to address the issue using systems thinking approach.

Therefore, Under GuruJal, Research & Analysis was done starting with the Sohna Block as it is being planned under 'South Gurgaon' in future development & urban expansion. Therefore, it was very important to understand the hydrological factors of this region for a better planning and utilization of resources.

And in order to make the study holistic, varied regions were taken involving an urban area of Sohna town, Gairatpur Bas, a rural village located in the foothills of the Aravallis, an urbanized village, Ullhawas and a water stressed village Ghangrola, located in the region affected by salinization of soil and groundwater salinity were selected for the study.

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1 Physiography of Gurugram District

1.1 Introduction

Gurugram district lies in the South Eastern part of state of Haryana in India. It is adjacent to the Union Territory of Delhi and is surrounded by Jhajjar, Rewari, Mewat, Palwal and Faridabad districts (Figure 1). It lies between 27° 39' 00" North and 28° 32' 25" North latitudes and between 76° 39' 30" East and 77° 20' 45" East longitudes. The geographical area of Gurugram district as per 2011 Census is 1258.00 square kilometers. Out of this, 976.65 square kilometers is categorized as rural and 281.35 square kilometers as urban. The district has the Aravalli ranges offshoot along the western part and extending upto Delhi in the north-east. Physiographically, the district can be divided into two sub-parts – the Gurugram plain and the Sohna rolling plain with Aravalli offshoots. The Gurugram plain comprises the north and north western parts of Gurugram tehsil and the entire Pataudi tehsil and the Sohna rolling offshoot extends over parts of Sohna and Gurgaon Tehsils.

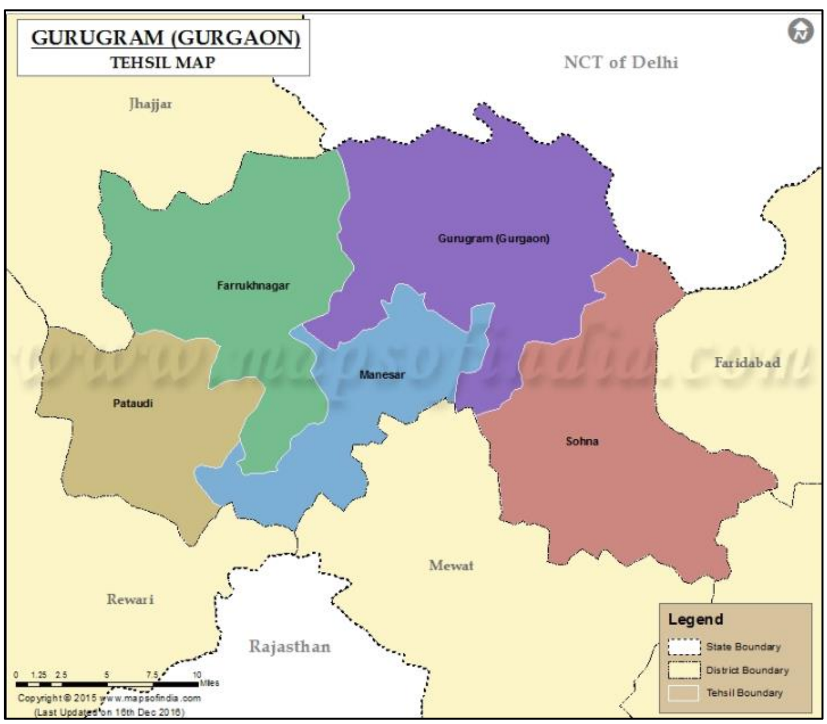

Figure 1: Map of Gurugram District (Source[1])

[1] https://www.mapsofindia.com/maps/haryana/tehsil/gurgaon.html

1.2 Drainage

The drainage of the district is arid to semi-arid type with no perennial river. There are a few seasonal streams and due to topographic diversity, they do not flow in any uniform direction. The Sahibi Nadi (River), which originates in the Sewar hills of Jaipur (Rajasthan), passes through Gurugram tehsil and culminates in the topographic depression of Jhajjar tehsil in Jhajjar district of Haryana. As the river traverses through the arid region, it is usually dry, and the strength of the stream flow can only be seen during the rainy season. The Indori Nadi which originates from the Aravalli hills in Rajasthan joins Sahibi Nadi near Pataudi. Many other tributaries emerging from the Aravalli hills also join the Sahibi River. The different paleochannels of the Sahibi river is shown in Figure 2. Apart from this various nullahs (drains) like the Badshahpur, Mehndwari, Kasan, Manesar and Landoha pass through the Gurugram district and often overflow during rainy season resulting in monsoon nightmare.

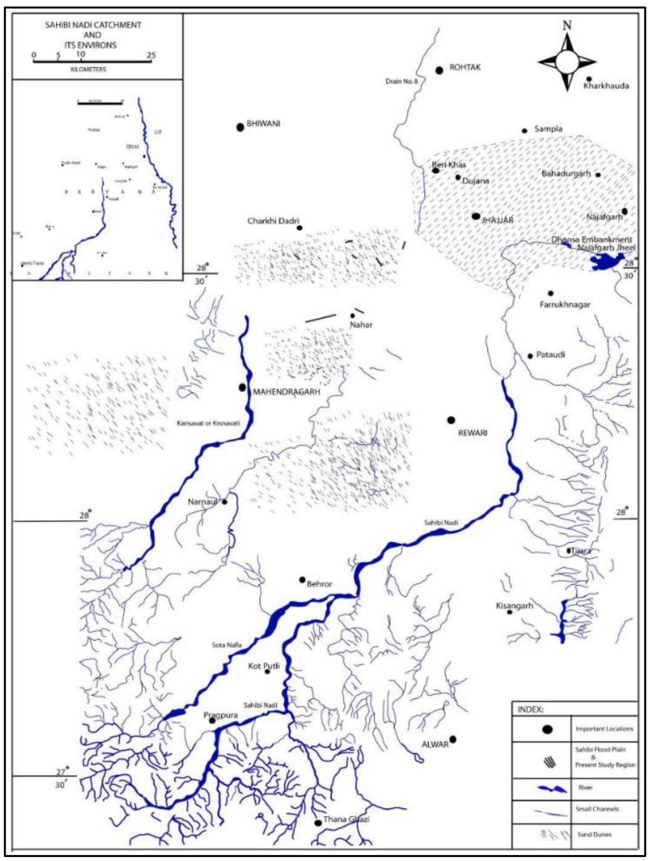

Figure 2: Location of different geographic units and Paleochannels of River Sahibi[2]

[2] https://shodhganga.inflibnet.ac.in/bitstream/10603/208307/7/4_chapter%201.pdf

As per the status report filed by the government officials, the revenue record of 1956, Survey of India maps of 1967 and satellite images of 2011-12 (Figures Figure 3 and Figure 4) have indicated respectively 641, 476 and 250 water bodies in Gurugram district respectively. The district is increasingly relying on the canal water imported from Western Yamuna Canal system for the domestic use.

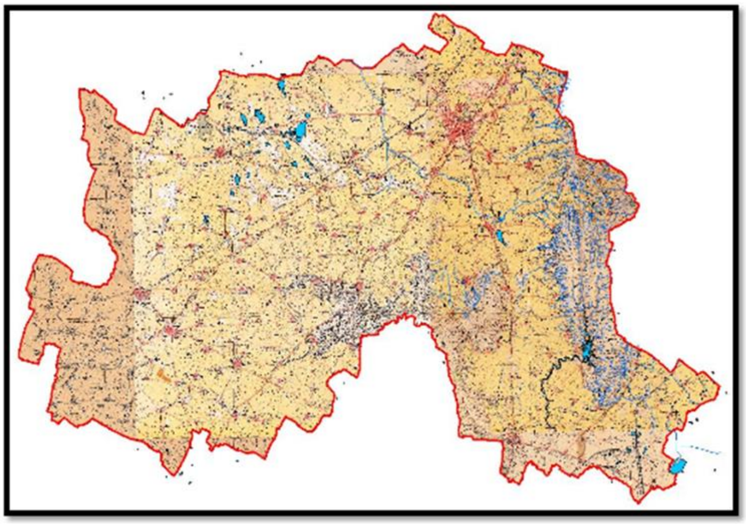

Figure 3: 476 Water Bodies in Gurugram District as per the Toposheet 1967 covering a total area of 8.88 sq km

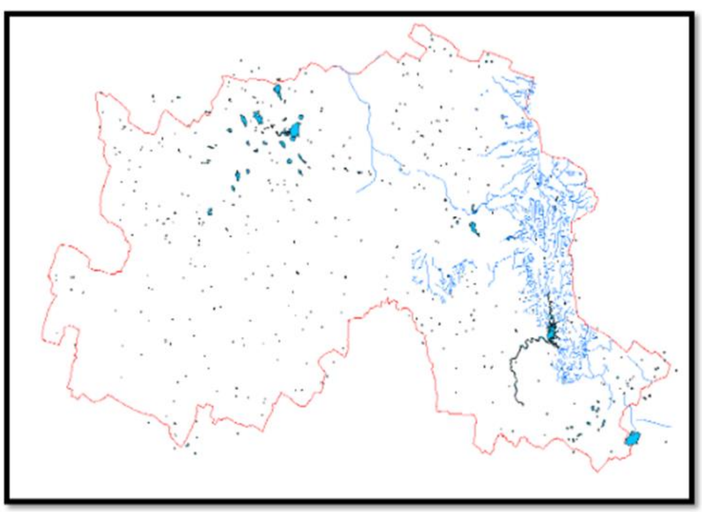

Figure 4: 275 Water Bodies in Gurugram District as per the Satellite Data 2012 covering a total area of 2.96 sq km

1.3 Climate

The climate of Gurugram district is characterized by monsoon-influenced humid subtropical and semi-arid. It has a high variation between summer and winter temperatures and precipitation. There is huge seasonal variation with hot summer combined with dust laden winds to cool winters with occasional dense fog. Summer season is usually from mid-March to end of June which is followed by the rainy season from July to mid-September. The winter season is usually from November to mid-March, though lately, the winter season has been getting delayed. The average temperature variation and rainfall in the district is shown in Figure 5.

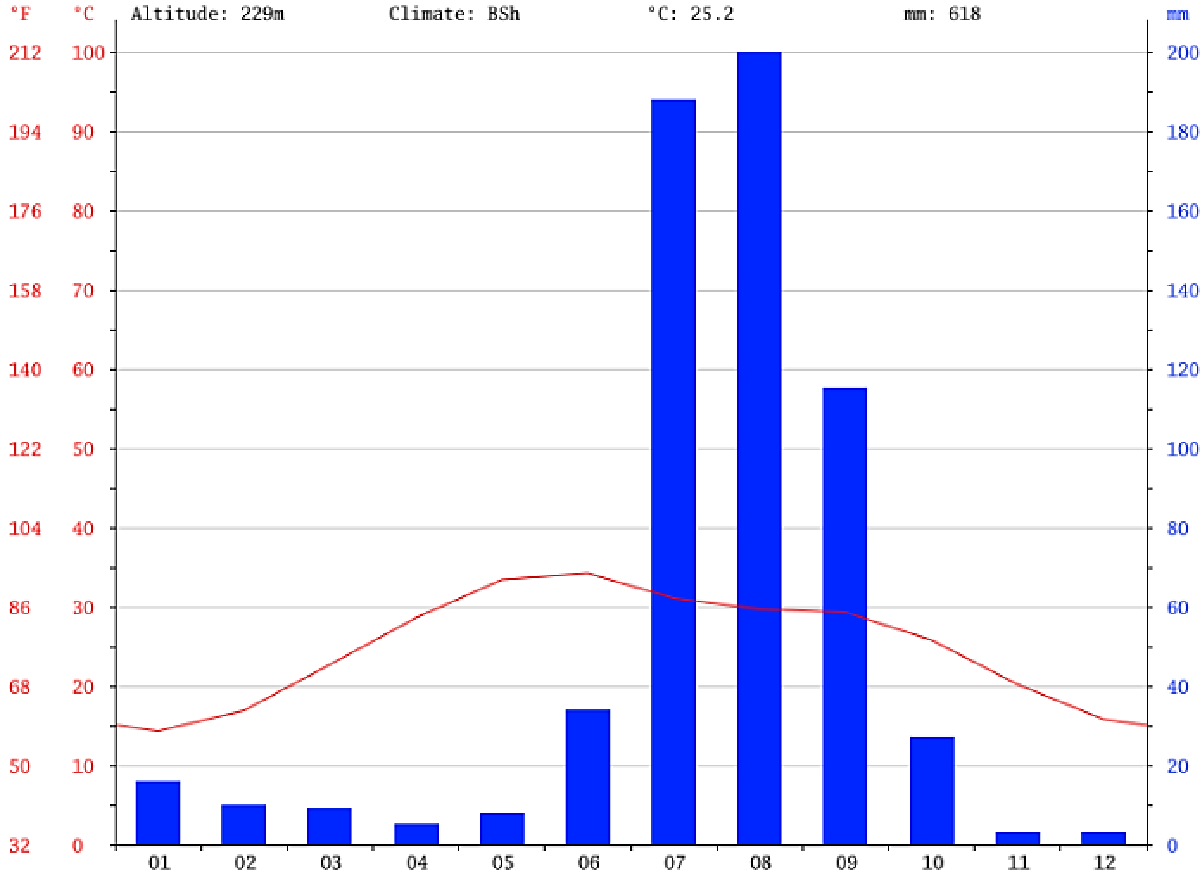

Figure 5: Average temperature and rainfall variation in Gurgaon District (Source[3])

[3] https://en.climate-data.org/asia/india/haryana/gurgaon-967597/

BSh- Köppen climate classification, Hot Semi-Arid Climate or Steppe Climate

1.4 Agriculture

The total cultivatable area in the district of Gurugram is 84000 hectares and the major soil type is loamy sand. The area that is sown more than once is approximately 37000 hectares. The net irrigated area in the district is 76000 hectares and only about 10 percent of the area is rainfed. 98.7% of the irrigated agriculture is through borewells resulted in 100% of the area under the Gurugram district falling in the over-exploited zone. The groundwater quality is alkaline in nature and moderately to highly saline. The major crops grown are wheat, mustard, bajra and rice. Among the horticulture crops – Chilli, Tomato, Radish, Guava etc are the main crops grown in the district.[4]

1.5 Forestry

The district did not have much forest area till about 1930 and it was after independence that special efforts were made to increase the forest cover. The forests in the district are classified based on the type of ownership into state owned forests and private forests. The State forests are categorized as reserved, protected and unclassed. The forest native species in the district are Khairi (Acacia Senegal), Dhouk (Anaogeisus pendula edgew), Dhak (Butea monosperma), Papri, (Holopetelea integrifolia planch), Rounj, (Acacia leucophloea) Inderjo (Wrightia tincloria), Chamror (Erhetia laevis), etc. While Sheesham and Neem trees are there both on the foothills and the plains, Kikar is found only on the plains. Lately, Eucalyptus trees have been planted along the canals, field boundaries and roads especially in areas where salinity is very high.

1.6 Minerals and mining

The geological structure of the district is formed of Alluvium (recent) and Delhi Super Group (Middle Proterozoic) rock formations. Sand, bajri and quartzites are mined from various localities from the hills of Manger-Harchandpar and Bhondsi-Sohna. Minor occurrences of saltpetre are reported from all tahsils of the district. Other minerals found in small quantities in the district are

[4] http://www.crida.in/CP-2012/statewiseplans/Haryana%20(Pdf)/CCSHAU,%20Hisar/HAR3-Gurgaon-30-06-11.pdf

arsenopyrite, china clay (kaoline) and other clays, graphite, farnet, iron, kyanite, silicons kankar, mica and quartz. Mica in large flakes is obtainable from Bhondsi. Sikanderpur, Alipur, Ghamroj and Ghausgarh have deposits of potter's clay. Graphite interbedded in the quartzite occurs in the hill west of Sohna town and in Hariahera. The deposit is very small one. It is also reported in a gorge on the eastern side of Sohna hill. Transparent quartz crystals occur near Bhondsi, Indri and Sohna. Hot springs of mineral water are located at the base of hill at Sohna near Sohna Municipal Council. The temperature of water is 46°C and is considered to have medicinal power for curing skin and liver ailments. Mining in Haryana State has been officially banned since March, 2010.[5]

1.7 Objectives of the Study

The overall objective of this study is to perform an assessment report for integrated water resources management for Sohna block, while the specific objectives are given below:

i. To review the current status of the water projects (existing and work in progress) within Sohna block and categorise them according to their usefulness in present context.
ii. To conduct a comprehensive mapping and qualitative and quantitative analysis of drinking water, surface water, groundwater and wastewater.
iii. To conduct geospatial analysis of cropping pattern and soil health along with recommendations on efficient water use for improved crop production.
iv. To assess the feasibility of various sustainable watershed management practices and recommendations for a conjunctive use of surface and groundwater.

1.8 Scope of the Study

The study is limited to the Sohna Block in the Gurugram district of Haryana. Detailed study was conducted in four identified locations within the block. The study looks into socio-economic profile, change in land use land cover, water quality and quantity and soil and crops in the region.

[5] http://censusindia.gov.in/2011census/dchb/DCHB_A/06/0618_PART_A_DCHB_GURGAON.pdf

2 Policy and Governance

2.1 National Water Governance Structure

The water governance in India is looked after by different ministries. While the drinking water supply in the Urban Sector comes under the ambit of the Ministry of Urban Development, the water provisioning in the Rural Sector is looked after by the Department of Drinking Water and Sanitation (DoDW&S) under the Jal Shakti Mantralaya[6]. Since, water is a state subject in India, the departments/ authorities looking after water distribution may vary from one state to the other. The water quality monitoring is generally looked after by the Central and State Pollution Control Boards which fall under the Ministry of Environment, Forest and Climate Change (MoEFCC) and the groundwater monitoring is done by the Central Ground Water Board.

The National Green Tribunal (NGT), which was established on 18.10.2010 under the National Green Tribunal Act 2010 and comes under the ambit of Ministry of Law and Justice, focusses on effective and expeditious disposal of cases relating to environmental protection and conservation of forests and other natural resources including enforcement of any legal right relating to environment and giving relief and compensation for damages to persons and property and for matters connected therewith or incidental thereto[7]. The main government bodies looking at the water resources management in India have been mapped in Figure 6.

[6] http://mowr.gov.in/

[7] https://ngtonline.nic.in/newsite/about-us

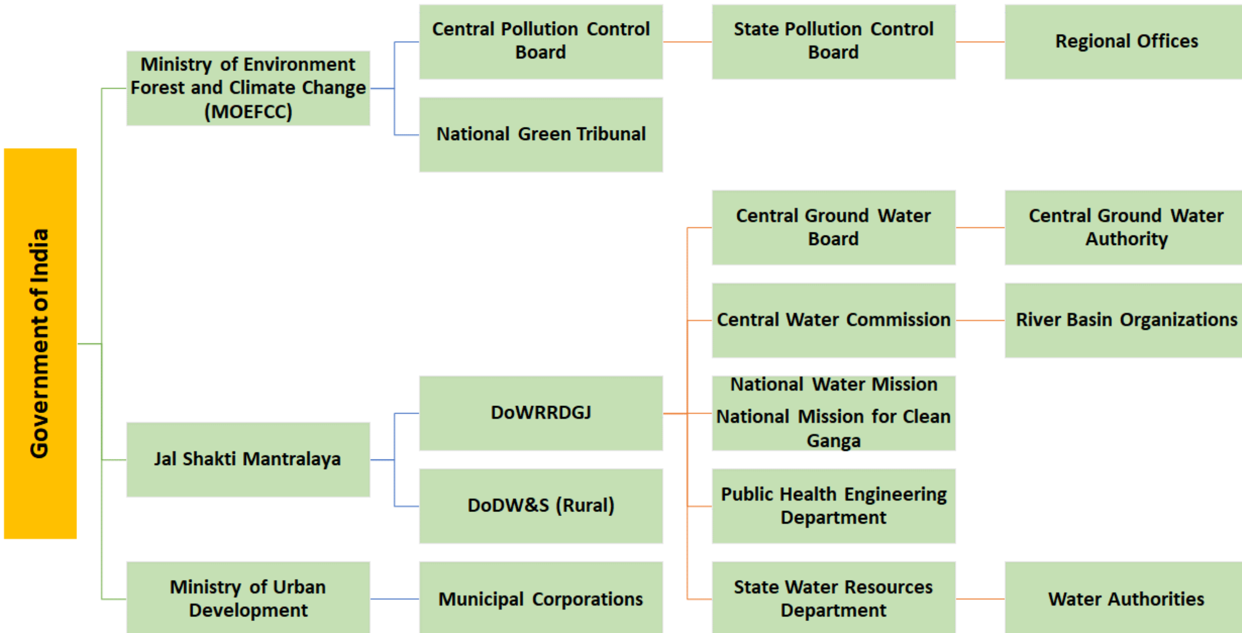

Figure 6: National Water Governance Structure, India

DoWRRDGJ – Department of Water Resources, River Development and Ganga Rejuvenation
DoDW&S- Department of Drinking Water and Sanitation

2.2 Water Policy - Roles and Regulations

	Water supply for domestic and industrial use	Water Supply for Irrigation	Water abstraction permits	Water use efficiency in Agriculture	Water conservation and reuse	Water pollution prevention and control
Key Actor	**PHED** **Village Panchayat**	**Irrigation Department**	**CGWB, MCG**	**Agriculture Department** **Irrigation Department**	**GMDA, MCG** **Pond Authority** **GuruJal Society**	**CPCB** **SPCB**
Roles	• To provision safe water for household purpose in both urban and rural Gurugram. • To allocate water use for the industry.	• To ensure uninterrupted water supply for irrigation by planning, implementing, monitoring and maintaining irrigation infrastructure. • Equitable water allocation to all farmers.	• To Issue No Objection Certificates (NOCs) before establishment of an industry, building or for initiating any process of withdrawal of groundwater.	• Crop Planning • Crop water use budgeting. • Training farmers in sustainable irrigation practices.	• Providing enabling environment to promote rainwater harvesting . • Ensuring reuse of wastewater for recharge, horticulture and use of water efficient technologies by industry	• To check the water quality from time to time. • To provide technical assistance to the State Boards. • To prepare guidelines, codes and set norms relating to treatment, disposal and reuse of wastewater.
Laws and Regulations	• National Water Policy 2012 • Jal Jeevan Mission	• The Haryana Canal and Drainage Act, 1974 • National Water Policy 2012	• Model Bill for Conservation Protection and Regulation of Ground Water, 2011 • Guidelines to regulate ground water by CGWA	• National mission for sustainable agriculture • Pradhan Mantri Krishi Sinchai Yojana • Micro Irrigation Fund • Agriculture Contingency Plan	• Haryana Building Code, 2017 • National Water Policy, 2012 • Jal Jeevan Mission	• The Water (Prevention and Control of Pollution) Act, 1974 • The Water (Prevention and Control of Pollution) Cess Act, 1977

Figure 7: Water Policy Chain

2.2.1 Haryana Building Code 2017[8]

The Haryana Building Code 2017 clearly lays down the following:

- Public Health Installations (Chapter 11 of the Building Bylaws)
    - Two pipe system in drainage -The drainage system of building shall be of two pipe system in which the soil and waste pipes are distinct and separate. The soil pipes being connected to the drain direct and waste pipes through a trapped gully. All traps of all appliances are completely ventilated in this system.
    - In Group housing, commercial complexes, commercial (other than plotted), institutional, industrial, other building specified by the competent authority in accordance with Code 8.4, the water from waste pipes shall be treated within the

[8] https://tcpharyana.gov.in/Notifications_Judgements/The_Haryana_Building_Code_2017.pdf

premises from appropriate treatment plant. The treated water shall be used for flushing, horticulture and cooling tower purposes. Further, no soil/ waste pipe shall be allowed in common wall.

- The requirements for fitments for drainage and sanitation, in case of buildings other than residences such as office buildings, factories, cinemas, concert halls, theatres, hospitals, hotels, restaurants, schools and hostels shall be in accordance with relevant Bureau of Indian Standards of "Basic Requirements for Water Supply, Drainage and Sanitation" with such modifications as may be made from time to time.
- Method of disposal -Every water borne drainage installation shall be connected with the public sewer, but in case no public sewer exists in the vicinity of the said premises the drainage system may as a temporary measure and subject to the previous written approval of the Competent Authority be connected to a septic tank from which the effluent shall be drained off –(i) into absorption pits; or (ii) by sub-soil drain. Provided that no absorption pit shall be allowed in the case of any premises or area in which domestic supply is taken from sub soil water.
- Effective arrangements shall be made to treat the effluents up to the parameters/ guidelines issued from time to time by Central Pollution Control Board (CPCB) or Haryana State Pollution Control Board from the sewer system to ensure that the untreated effluents do not enter any canal, river or water body.
- Septic tank - No septic tank shall be located –
    - at a distance of less than 25 metres from a dwelling unit or any other building used for human habitation or for work or recreation;
    - within a public through fare;
    - within 60 (sixty) metres from any percolation well, watercourse or stream used or likely to be used for drinking or domestic purposes or for manufacture or preparation of any article of food or drink for human consumption and it shall be readily accessible so as to permit cleaning

operation being carried out without interference with the operation of any water borne sanitary installation as a whole.

- Every septic tank intended to serve a population of 24 or more persons shall be constructed into two separate compartments so that one compartment when required can be put out of use for cleaning purposes. The capacity of every compartment of the septic tank shall be 2 1⁄2 (two and half) times the total water supply allowances for the total number of residents of the buildings in premises.
- Every inlet pipe into a septic tank shall be effectively trapped.
- The design of septic tank shall be in accordance with the National Building Code and guidelines issued by Public Works Department, Haryana.

- Absorption pit -In the matter of location, every absorption pit shall conform to same restrictions as are laid down for a septic tank in Code 11.4. No absorption pit shall have any outlet into, a means of communication with any sewer, storm water drains and surface drain. The walls of every absorption pit shall be at least 0.5 metres above ground level to exclude effectively the entry of storm water into the absorption pit. The absorption pits shall be constructed in duplicate so that one pit can be put out of use for cleaning purposes. The capacity of the absorption pit shall be as approved by the Competent Authority and other details shall conform to the National Building Code.
- Sub-soil irrigation for disposal of effluent- No Sub-soil irrigation work for disposal of effluent from a septic tank shall be laid out within a premise till a suitable area of open land, the situation and extent and sub-soil of which is previously approved by the Competent Authority, is set apart within the premises to be used as a farm or a garden. The area set apart shall be one hectare for every 25,000 liters of effluent per day. No part of any area reserved for sub soil irrigation, shall be within a distance of 25 metres from the nearest point of any dwelling unit or any other building used for human habitation or for work or for recreation and of any canal or irrigation well. No such works shall be laid out within a distance of 75 metres

from any percolation well, tube well, or water-course or stream used or likely to be used for drinking or domestic purposes or for the manufacture or preparation of any articles of food or drink for human consumption.

- Zero waste water discharge -The group housings, industries, commercial, institutions and any other building specified by the competent authority shall ensure zero waste water discharge to main sewer line and shall install suitable treatment plant for treatment of waste water. The applicant shall submit completion certificate of installation of treatment plant from independent expert agency along with the application of Occupation Certificate.
- For water conservation in the building, provision shall be made whereby the wastewater generated from the sources such as dishwashing or washing machines, is used for sub-surface irrigation, or if treated, for non-potable purposes e.g. to flush toilets and for washing cars.

2.2.1.1 Rain Water Harvesting

As per the Haryana building code 2017, Rainwater Harvesting Structure is mandatory for the following buildings and public spaces

- Area of Rooftop= 100 square meters or more.
- Mandatory for all type of buildings including Group Housing Societies having a plot area more than 500 square meter or above.
- Mandatory for open spaces like parks, parking, plazas, playgrounds etc.

The Rainwater harvesting structures need to be constructed by a Competent Authority with the involvement of community-based organizations like RWA's (Resident Welfare Associations).

Rain Water Harvesting Measures

- System of collection, conveyance and dispersion of rain water for harvesting shall be made that no contaminated wastewater from building or surrounding area finds its way in system.
- In normal days, entry point of systems should be covered. Arrangement of segregation of Rain Water from the first shower (containing wash water) shall also be made.

- Arrangement of quick filtration of rain water shall be made in Rain water harvesting tube well/wells.
- Rain Harvesting Structure need to be constructed within the plot area available with owner.
- Recharge well shall be located at a distance of not less than 10m away from any structure handling sewage.
- Detailed proposal of system has to be shown on building plan for approval.
- Architect/Engineer duly engaged for supervision and execution of construction of building shall submit certificate stating rain water harvesting system is functional at site.

3 Study Area-Sohna Block

3.1 Introduction

In the context of rapid urbanization and rising evidence of climate change in the recent decade, water has become a scarce resource across the globe. The situation is not different in peri-urban and rural regions of India which are heavily dependent on ground water with rapid decline in water table and the deteriorating quality of the existing water resources. ADB (2013) estimated the net annual ground water availability of the district to be 20215.12 ham and existing gross ground water draft for all users was 33055.33 ham. On the contrary, increase in urbanization has resulted in flood damages during monsoon season. Moreover, the district is yet to fully embrace a proper waste water management culture that is clear from its polluted waterbodies. Hence, this project aims at a holistic perspective of integrated water resources management that aims at addressing the issues of drought, flood and waste water management in a sustainable manner.

3.2 Site Description

Gurugram district recorded jurisdictional changes in the intercensal period of 1991-2001 wherein 72 villages and Sohna town was transferred from the Gurgaon tahsil to the newly created Sohna tahsil in July 1995. Major reshuffle of the Gurgaon district again took place during 2001-11 and 64 villages, Sohna Town and Bhondsi Census town has been reported under Sohna Tehsil in the Census 2011. A recent report published in the Times of India stated that the Haryana Government has included seven villages namely Maidawas, Palra, Aklimpur, Teekli, Gairatpur Bas, Hasanpur and Sakatpur of Sohna Block into Gurugram Block[9]. The Sohna Block Map showing the village boundaries is shown in Figure 8. The total area of Sohna tehsil as per Census 2011 is 320.15 sq km of which rural area is 283.85 sq km and urban area is 36.30 627 sq km. The female to male ratio was reported to be 0.86 i.e 1000 males to 860 females.[10]

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[9] https://timesofindia.indiatimes.com/city/gurgaon/7-villages-in-sohna-are-now-part-of-gurgaon/articleshow/70199608.cms
[10] http://censusindia.gov.in/2011census/dchb/0618_PART_B_DCHB_GURGAON.pdf

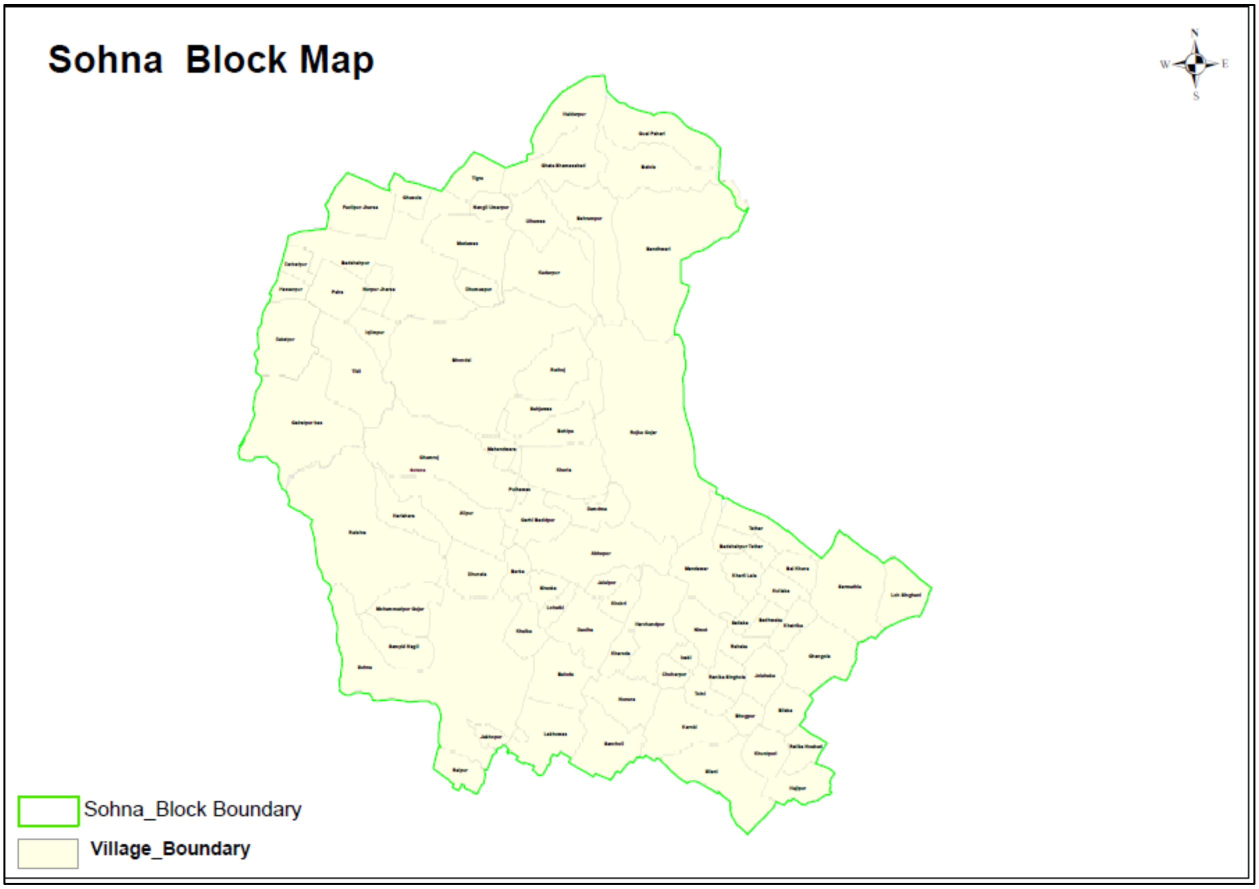


Figure 8: Sohna Block Map showing village boundaries (Source- Municipal Corporation of Gurugram)

In order to investigate the changing nature of the area of Sohna block, Haryana, and reflect on the different water demands, supply mechanisms and the status of the existing resources, an urban area of Sohna town, Gairatpur Bas, a rural village located in the foothills of the Aravallis, an urbanized village, Ullhawas and a water stressed village Ghangola, located in the region affected by salinization of soil and ground water salinity where selected for the study. The four study sites, Sohna Municipal Council and three villages are shown in map (Figure 9).

3.2.1 Sohna Municipal Council (Sohna M.C)

This is a hub of government offices and residential area and consists of both Old Sohna Town and New Sohna Town. Agriculture continues in some parts of the Sohna block though it is no longer the dominant occupation. The source of water in this area was from ground water originally but with progressive decline in ground water table in the area, the water is now supplied to the town by the Public Health and Engineering Department (PHED) from the 66 MGD ()water treatment

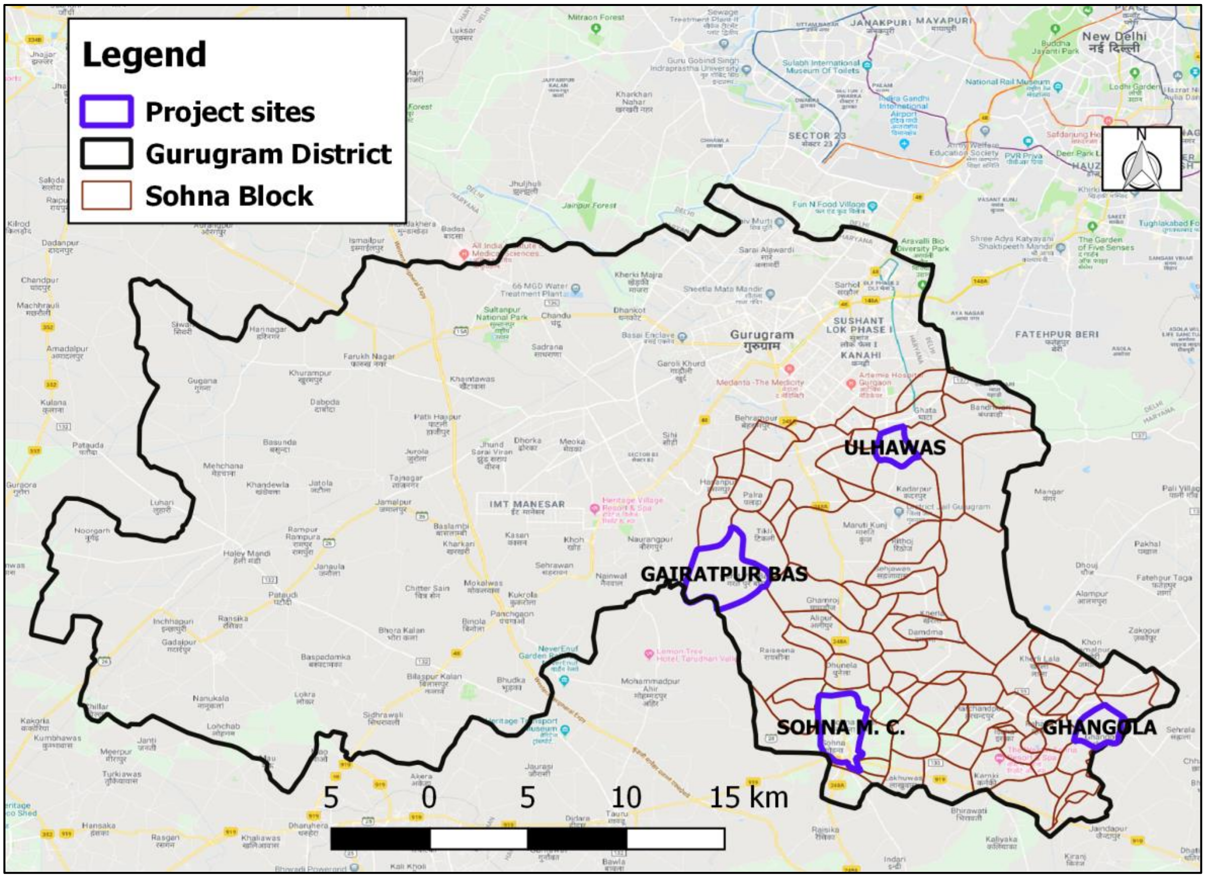


Figure 9: Study area within Gurgaon district

plant located at Chandu Budhera, which is almost 40 km away from Sohna M.C. area. The water supply to the region is through gravity system. Despite the use of booster pumps by the residents, the pressure of water supply is inadequate at various places. Notwithstanding the decline in the groundwater table by several metres in the past six years (as seen from recent water levels in Figure 17 referred in the Section on groundwater resources 4.1.3), it is still being used for agriculture and domestic purpose albeit to a limited extent, as most parts of the Sohna town have access to piped water supply by PHED.

The current groundwater table is reported to have fallen to a depth of 60-70m from 50-55m about a decade ago. The town also has a hot water spring popularly known as the “Shiv Kund”. The declining water table of the spring is a major cause of concern for the people in the town.

The unique geology of the area has led to the formation of the hot water spring. The hot spring is located adjacent to the foothills of the Aravallis. Geologically, it lies on the Sohna fault. A combination of presence of minerals in the metamorphic rocks and decay of naturally radioactive elements (like potassium or uranium) generates the heat which combines with the ground water to create the unique hot spring. As hot water holds more dissolved minerals and salts than cold water, it renders the therapeutic value to the water. The rock belt has numerous fissures as it is a metamorphic mountain and the groundwater recharge in the area is essentially due to the rainwater seeping in the rocks that are subject to weathering. The hot spring is a unique feature of the Sohna town, to which the residents attach a lot of cultural value and pride. However, heavy ground water use in the vicinity of the Sohna town has led to falling ground water levels in the Sohna town, which in turn has led to fall in the hot spring water levels. The spring discharge is not very high (approximately 0.5l/s during and after the monsoon) and is collected in pools by the Shiv Kund Authority for bathing purpose of regular visitors and pilgrims. The spring had dried up a few years back and the rejuvenation of the spring would require developing of a dedicated green corridor along the Aravallis. The intervention may significantly restore the groundwater level in the area.

3.2.2 Gairatpur Bas

Gairatpur Bas is a village located in Sohna Block of Gurgaon district in Haryana, on the foothills of the Aravalli Mountain Range, it is demarcated from the Sohna town by a smaller hill range. It is unique in its position on the foothills, surrounded by the protected forest, which makes it a popular destination for trekking and camping. It is one of the crucial parts of the protected forest land of Haryana (Haryana as a state has very little forest area). Agriculture is predominant occupation of the village residents and they use sprinkler systems for irrigation owing to the falling ground water levels. The groundwater table is reported to be in the range of 50-70m. The source of water for the sprinklers is groundwater and the number of operating hours, which is based on farmer’s personal assessment rather than scientific data, is adding to the water woes in the region. The residents reported depletion of the ground water table at the rate of 1.5-2.0m every year. Hydro-geologically this aquifer belongs to a different basin as the rainwater from this portion does not flow eastwards towards Sohna town but flows towards Gurgaon. It is a source of surface water and groundwater for the northeast part of Gurgaon. Hydrologically, this is a part of the seasonal tributary joining Sahibi River flowing from further down south. The falling groundwater is a cause of concern but the presence of check dams in the immediate vicinity of the foothills may be able to restore the groundwater levels in the future if the sprinkler flow rate is regulated. The village manages its own water resources through private borewells in the absence of any water supply from PHED. It also gets water through pipeline laid by the Panchayat Samiti from the temple which has a borewell in its premises.

3.2.3 Ulhawas Village

This is a peri-urban village in the vicinity of South Gurgaon City, which has rapidly urbanized in the past decade, leaving only a handful of village residents to practice agriculture. Because of its proximity to Gurgaon, it gets water supply through pipelines laid by PHED, which supplies water through submersible pumps. This points to the fact that ground water is used for water supply in the village. Some residents have their own borewell which they use for domestic purpose. The groundwater table is reported to be in the range of 60m-80m. The falling groundwater table may pose major problem for the residents, especially in the absence of any rainwater harvesting initiative except one in the government school.

3.2.4 Ghangola Village

Ghangola village is a gram panchayat and it is at the border of the Gurugram, Mewat and Faridabad districts. The total geographical area of village is 514 hectares. There are about 351 houses in Ghangola village and has a total population of 2,052 people (Census, 2011).

3.3 Land use pattern and trend

It is evident that a significant land use change has happened during the last decade. The change has been explained here using the land use maps between 2008 and 2016 prepared using IRS LISS-III satellite images. Figure 10 shows the elevation map (SRTM DEM) of the region. The elevation ranges between 190-310m where the highest elevation of 330 is the Aravalli hills and has the forest cover as well.

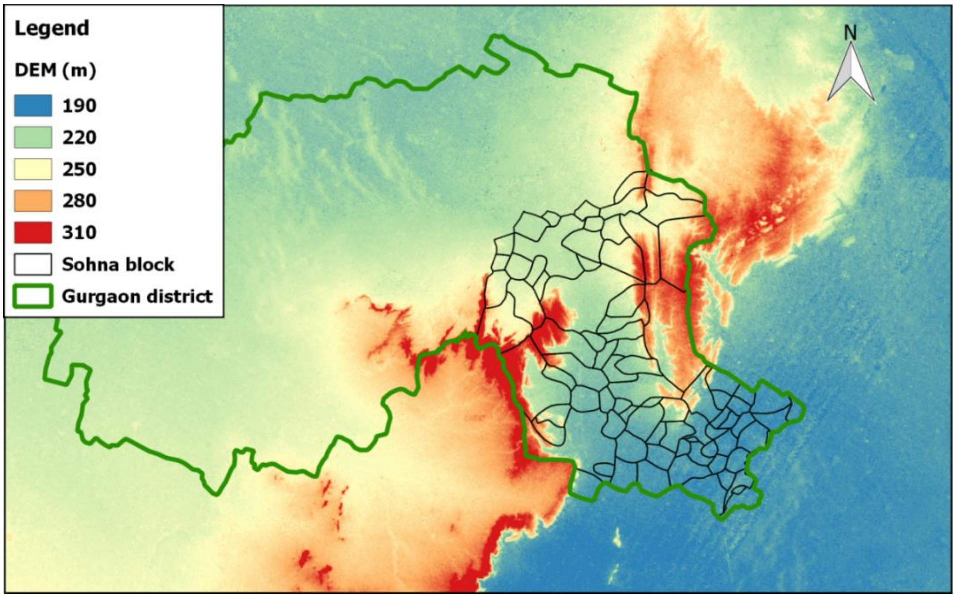


Figure 10: Elevation map of Sohna block

Figures Figure 11 and Figure 12 show the land use pattern of the Gurgaon district in 2008 and 2016. There has been a rapid urbanization in Gurgaon Tehsil and around Gurugram as shown by 'Built-up' class. Also, many waterbodies present in 2008 map are not seen in 2016 map, which depicts the drought pattern of the region (water stress condition) and overdraft of groundwater.

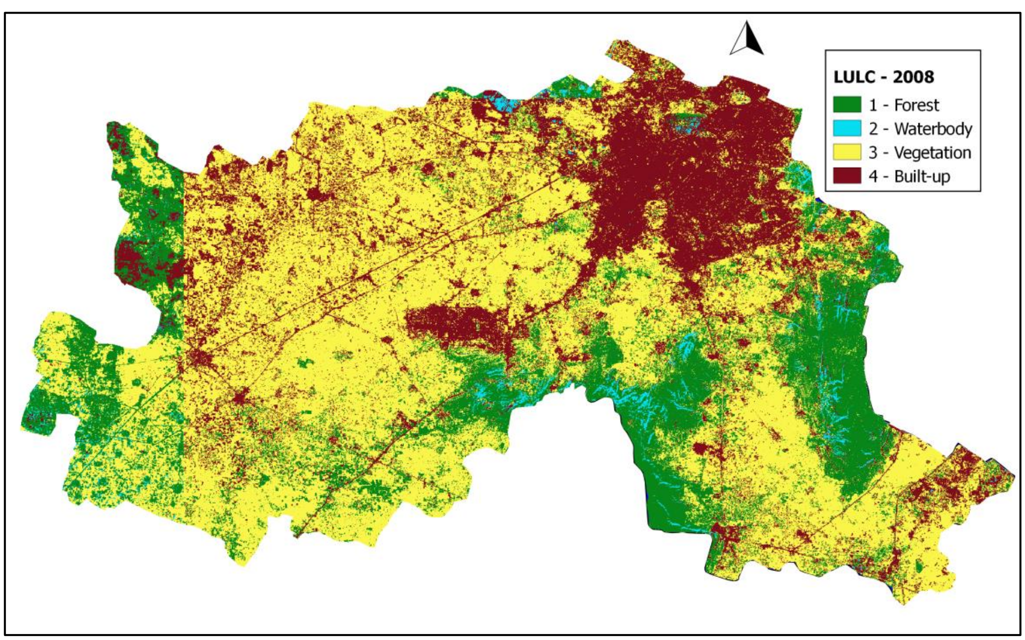


Figure 11: LULC map of Gurgaon district (2008)

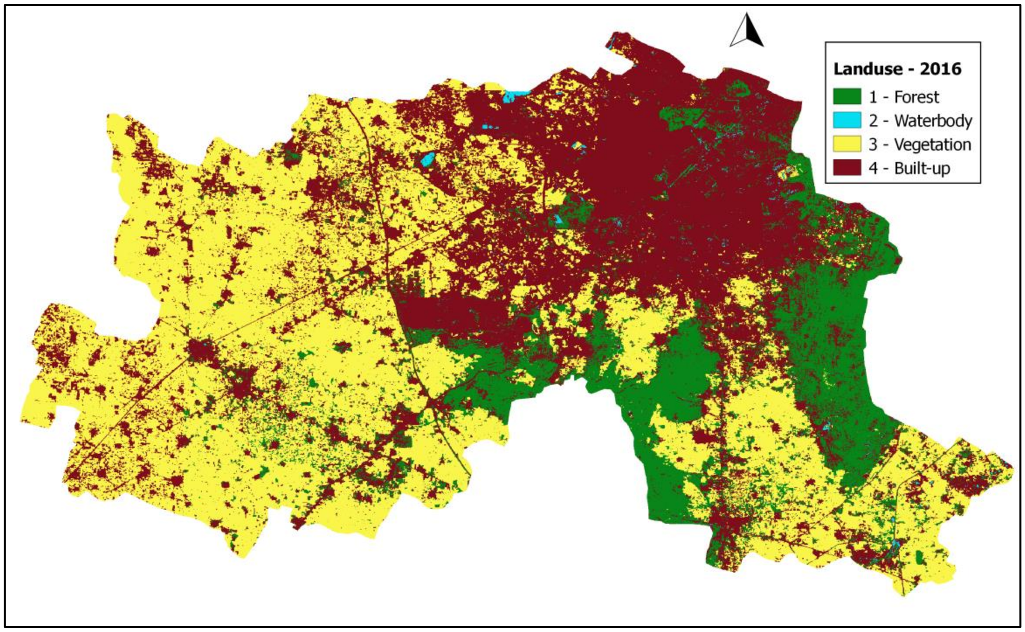


Figure 12: LULC map of Gurgaon district (2016)

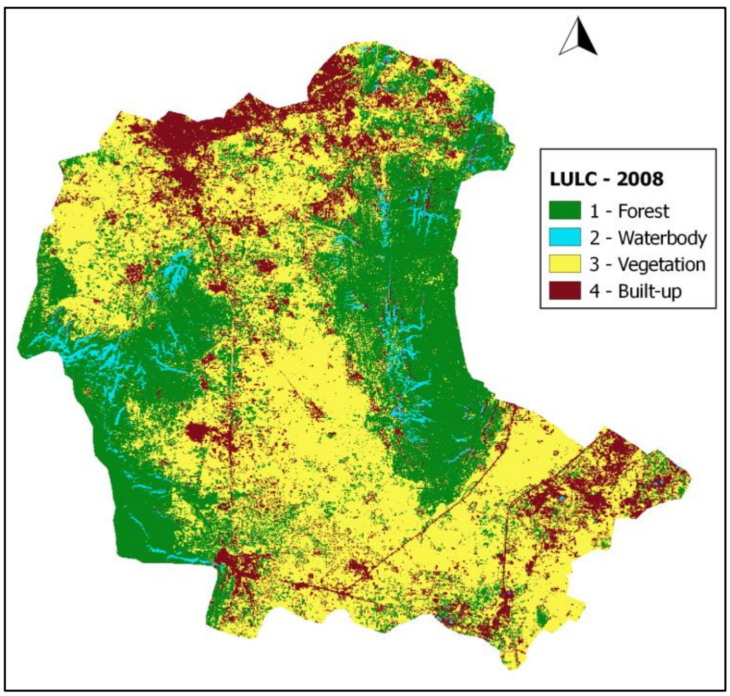


Figure 13: LULC map of Sohna block (2008)

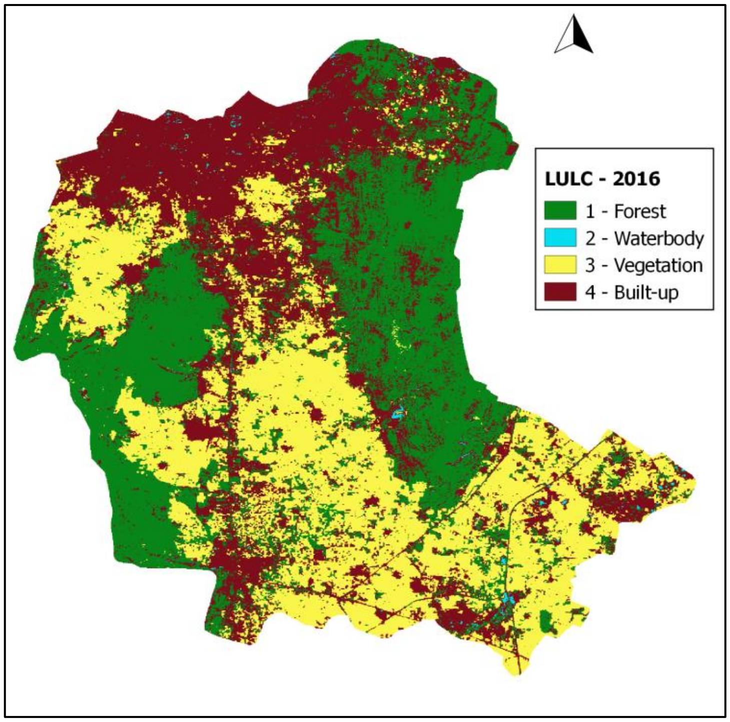


Figure 14: LULC map of Sohna block (2016)

Figures Figure 13 and Figure 14 show the land use during 2008-2016. It is evident from the figures that:

- Ulhawas village rapidly turned into urban region with agriculture plots converted into dense residential plots.
- Though Gairatpur Bas has not changed rapidly in terms of urbanization, many waterbodies present in 2008 are not seen in 2016 anymore.
- Sohna M. C. shows a rapid urbanization with agricultural lands getting converted into residential/commercial areas. This portion too shows reduction in water bodies.
- Ghangola also shows a trend of urbanization, however, relatively slower.
- Overall, it is observed that many small streams present in the forest areas of Aravalli hills have disappeared by 2016. These short streams, rivulets and water bodies would slowly recharge ground water in the past over the course of the year.

4 Hydrology and Water Resources

The surface and groundwater flow in the region and its interlinkages are explained in this chapter. The Sohna block and the Ullhawas village are in the piedmont plains (older alluvium region) between the Aravalli ranges. The groundwater stored in this area is because of the seepage at the surrounding hill ranges and foothills. The unique location of small ponds (johads) in each of the village indicates storage of rainwater in these structures which eventually would result in groundwater recharge and flow. The presence of these johads appear to allude to distinct flow lines, where sub surface water would flow from higher to lower potential due to the natural gradient which is because of elevation difference between the Aravallis and the valley (Figure 10) and the presence of soil which allows the water to flow through. This elevation difference and direction is from Sohna town from the west and Damdama lake from the east to the narrow valley below, where the scattered villages are located. The rapid urbanization in the area has led to the hydrological sub surface paths to be redundant and most of the water now flows only adjacent to roads rather than accumulating in the johads immediately after rainfall. Johads have now been converted to wastewater tanks and are used for discharging of grey water thus impacting the water quality in these johads and the groundwater.

The deep borewells in the area point at the presence of groundwater in deep aquifers. This fresh water reservoir is charged with rainwater seeping in through the numerous cracks and fissures of the Aravalli range, creating deep ground water reservoirs. The presence of phyllite-muscovite metamorphic rocks in the mountain range is the reason for presence of chlorides and sulphates in the ground water. However, annual monsoon freshwater recharge in the mountains allows fresh water to seep to the ground below and improves the quality of water and may be used by residents. The hill ranges in the region suffer from weathering and erosion during the rains. The water from the hills flows down rapidly and reaches the low-lying areas in a very little time. It will be worthwhile to have more detention structures near the foothills including small check dams and green belt in order to ensure ground water seepage.

4.1 Inventory of existing water resources and mapping

4.1.1 Existing sources of drinking water

Survey of study area reveals that the Sohna town gets PHED piped water supply from the Water Treatment Plant (WTP) located near Gurgaon from 2017. Prior to that they were heavily dependent on the groundwater resources (through borewells) for drinking water. However, the villages in Sohna Tehsil still use borewell water for drinking purposes; the quality of which varies from village to village. Though all villages in Sohna Tehsil have ponds, they are no longer used as drinking water source barring a few villages who use it for livestock, which are essentially cattle. Public stand posts are absent in the villages. However, the possibility of getting treated water from PHED could be explored through installation of common taps.

A few selected utility points are mentioned below:

a. **Government School, Ulhawas:** The source of drinking water is through jet pump installed at a depth of 180-200ft. Solar panels are installed on the roof the school to run the pump (**Error! Reference source not found.**).

Figure 15: Jet Pump in Government School Ullhawas

b. **Heritage School, Ulhawas:** Three jet pumps are available inside the school campus out of which two are being used on a regular basis to extract water and the third is installed to meet emergency requirement. The pumps are being run using solar power from the roof top solar panels in the school.

c. **Ward 7 (Sohna M. C.):** The locality has pipes laid down and is connected to the utility, but as the pressure is inadequate, they are dependent on borewell water. They have overhead storage tanks of capacity 500-1000L.

4.1.2 Surface water resources

The map shows the highest elevation points on the mountain ranges (310m) and the valleys located in between the mountains have elevation of 220-190m. The streams if present are ephemeral and flow only during the rainy season. However, streams are not seen on the Gurgaon- Sohna-Alwar highway anymore due to the dense built up area and construction and widening of highways. The storm drains located parallel to the highway are the major carriers of storm water in the absence of natural hydrological channels and through these storm water drains, recharge of ground water may be thought of at specific locations. As shown in Figure 16, while ponds are located in most of the villages, the marshy land is located further south in the area where palaeo channels exist (to the south east of Damdama lake hill range) near Ghangola and Sarmathla villages.

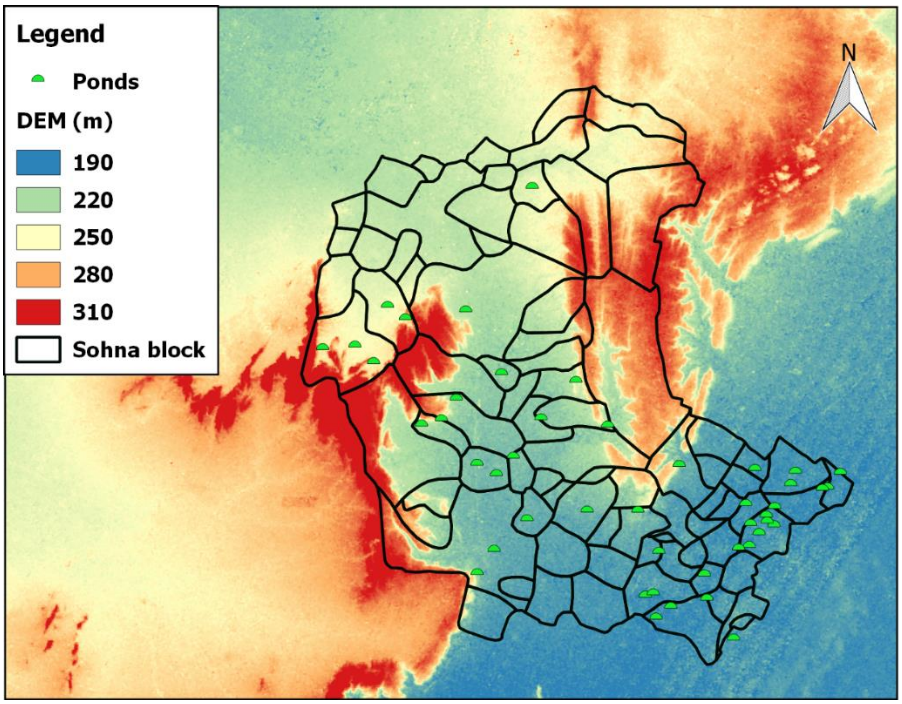


Figure 16: Location of ponds/lakes in Sohna block

Topographically, the Sohna Block forms a valley between the Aravalli Ranges on both sides. Hence, it is very clear that springshed management of the Aravallis can augment the groundwater recharge within the Sohna block due to natural gradient. This can also ensure better water quality due to natural cleaning mechanism through long distance travel beneath the ground.

4.1.3 Groundwater resources

The ground water table is noted to be at a depth of 50m and below in most of the areas surveyed in Sohna block. The locations of observation wells are shown in Figure 17. The fall in depth of the ground water in the last six years (2012-2018) is noted through Figure 18. The depth of current water table and the fall from previous years indicate that the aquifer band width is not very high. It could at best be 10-15m band width and it is available between 45-60 metres.

From the observations of groundwater table drop, it is very clear that majority of the locations have been facing drastic decline in groundwater table, while few low-lying flood-prone localities show no significant difference. It is alarming to note that Sohna M. C. has faced a drop of 16m during 2012-2018, whereas the remaining parts of Sohna block faced an average drop of 2-3 m.

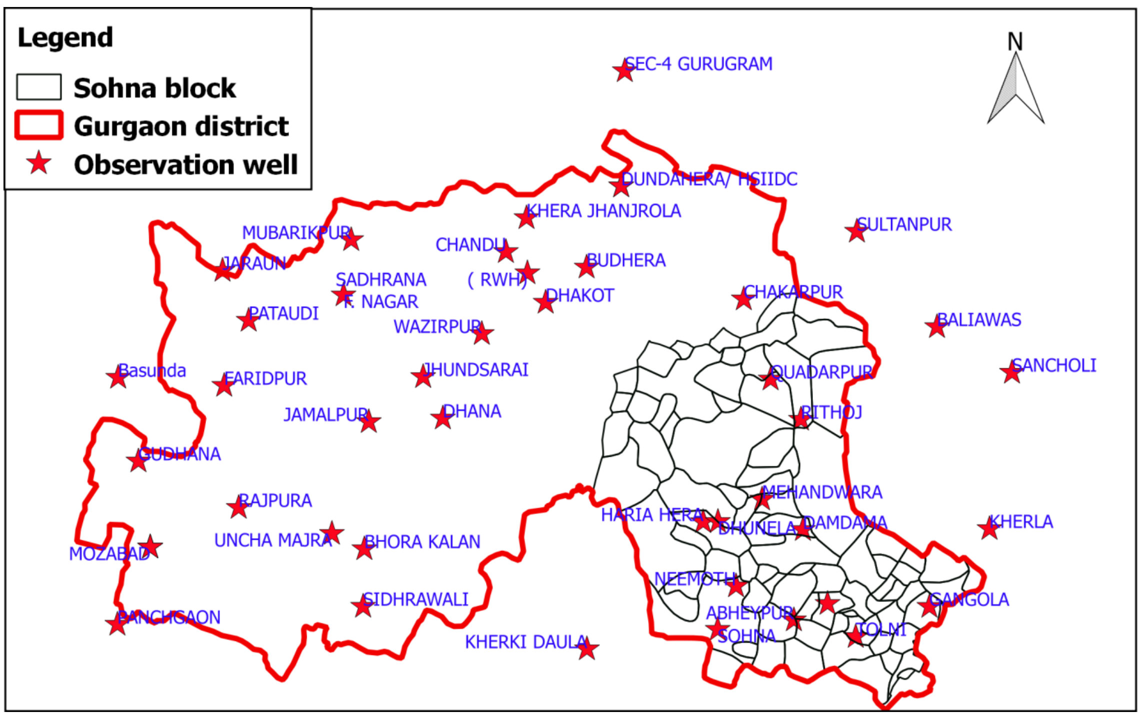


Figure 17: Locations of groundwater observation wells

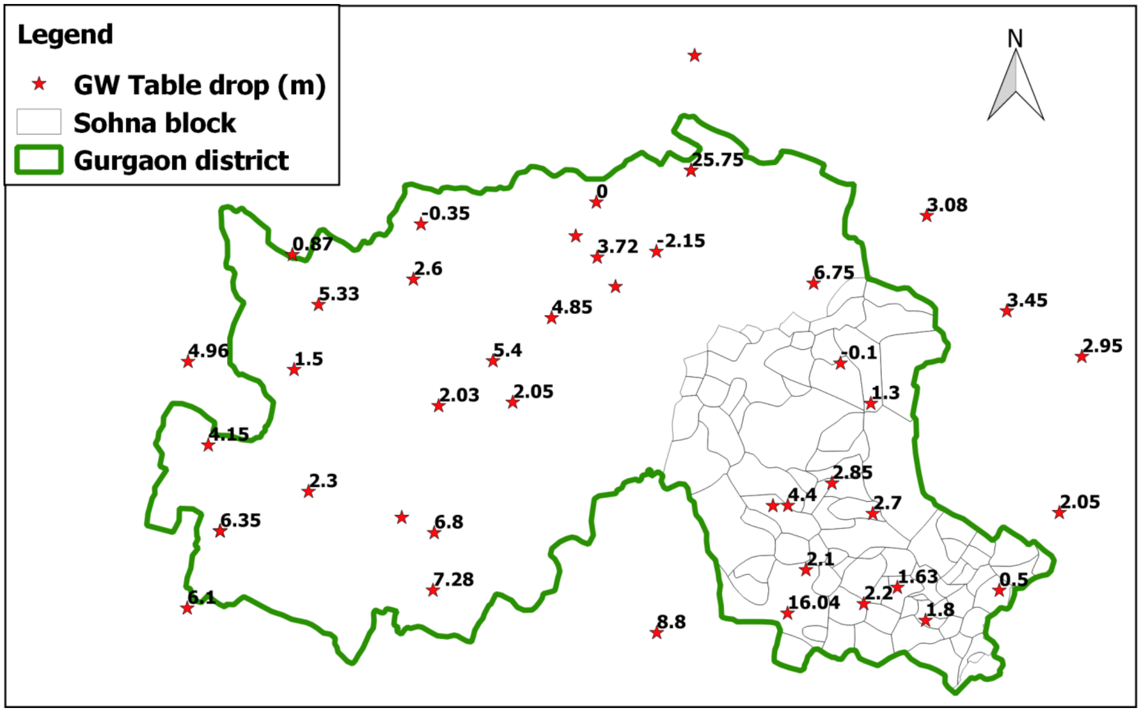


Figure 18: Drop of groundwater table across Gurgaon district during 2012-2018

In the semi-arid region of Gurugram district, where rain water is the only source of water to recharge the groundwater (no rivers are there in the vicinity) and borewells are being used for domestic and agricultural water needs, strategic locations for groundwater recharge is imperative. The geology, which confines the Sohna block between the mountain range with Sohna at one end and Damdama lake at the other, gives the block the advantage of using the water that is recharged in the region. Nevertheless, this shall only help in limited fresh water storage as groundwater and other avenues of water resources like grey water reuse in the villages, need to be explored.

4.1.4 Existing rainwater harvesting structures

Existing rainwater harvesting structures at some selected localities are explained.

a. **Government School, Ullhawas:** The records in the school show two structures. However, during the survey we found only one operational structure which was located within 10 metres of the septic tank in the front ground (Figure 19).

Figure 19: Rainwater Harvesting Structure, Government School, Ullhawas

b. **Heritage School, Ullhawas:** There were a total of six underground recharge structures within the school premises. The water from the roof as well as from the floor and the ground area gets collected in these structures.

Figure 20: Underground Rainwater Harvesting Structure at the Heritage School, Ullhawas

4.1.5 Wastewater disposal-Sewage Treatment Plants (STPs)

The existing wastewater management is explained for all three project sites of Sohna block.

a. Gairatpur Bas

Gairatpur Bas Panchayat is divided into three areas- 1) Bas Village, 2) Gairatpur Village and 3) Pandala Village (in the order of entrance from the board outside the village) and has a total population between 3500-4000.

Type of drainage: The panchayat has open drains, mostly unlined, while some households have borne the expense of lining the section adjacent to their houses. The drains are filled with household garbage. There are a few poor households who do not have drains. The image here shows the Bas Village with no sewer line. As per the residents, currently, the wastewater goes into a ditch in the nearby location. In Gairatpur, Sarpanch has built a wastewater drain but it is not connected to the main drain now, thus waste water does not drain out of the village ().

Disposal point of sewer: Gairatpur residents informed that the wastewater goes into the Johad. According to the Sarpanch, there is a municipal sewer that drains out of Gairatpur Bas. The Bas Village wastewater disposal is into a ditch.

Figure 21: Drains in Bas village in Gairatpur Bas

Septic tanks: As per our interview with the residents, the mentioned that they have lined septic tanks and they are clean once filled.

b. Ulhawas

Ulhawas village has a population of 4000 and the study also included the water and wastewater management in two schools of the village, namely Government School (300 students) and Heritage School (3300 students).

Type of drainage: The village has open drains which are mostly lined but are chocked due to indiscriminate disposal of household waste into the drains. However, a drain was spotted that according to the residents connects with the main sewer. Drains in some sections of the village are poorly maintained both during monsoon and non-monsoon period as shown in the photograph (Figure 22).

Figure 22: Drains in Ullhawas village

Disposal point of drainage: The disposal point of the drain is the STP nearby (HUDA line); however, Government School, Ulhawas dumps waste into a pit inside the school campus.

Septic tank: Locally called as "Haud", the presence of septic tanks was reported by all respondents. Even though the residents interviewed said that it has a concrete lining, a person whose household was at the boundary of the village mentioned that some of them are unlined and because of that the taste of borewell water of the village area is no longer sweet. The other findings of the study are that:

- The households pay for the cleaning of this haud twice in a year which costs them Rs. 600-650 per visit.
- In the Government School, septic tank is lined by cement plaster and is cleaned once in 3 months as reported by the Principal.
- In Heritage School, there is a composting pit and a solid waste storage facility where waste is recycled and reused. However, they do not have septic tank and sewage goes to main sewer line of PHED.

Figure 23: Waste recycling facility at the Heritage School, Ullhawas

c. Sohna M. C.

The study reports on the survey that was conducted at three locations, namely, Shiv Kund, Civil hospital and ward 7.

Shiv Kund: The colony surrounding the Shiv Kund (the hot water spring) is inhabited by the local people of Sohna. The houses located are more than 100 years old and the drains are clogged and ill-maintained. The Shiv Kund Temple has a separate drain from the ones that serve the residential houses. The two drains in due course connect with the main sewer near the municipal council office of Sohna.

Figure 24: Chocked drains in Sohna MC area

Civil Hospital: The civil hospital is near the local market area and the nearby residents complained of the blocked drains. The drain outside the Civil Hospital carries wastewater (WW) from the residential houses and the WW generated from the nearby market area but during heavy showers, the water from these drains enters the hospital park. There are three rainwater harvesting (RWH) structures in the hospital but all of them are dysfunctional now as the outside garbage has entered these channels preventing the water to go into these structures. There were open drains with standing water seen in the hospital. Few lanes had sewer lines, but others didn't have sewer system. The waste (other than the hazardous waste) was dumped within the hospital omplex.

Figure 25: Stormwater drain, solid waste disposal and rainwater harvesting structure at Civil Hospital, Sohna M.C

Ward 7: Ward 7 had open drains which were mostly chocked. The drains are cleaned by the municipal workers, but the solids were seen to be left on the roadside adjacent to the drains. All drains are connected to a main municipal drain and no septic tanks exist within the municipal council area. Some residents of this ward practiced agriculture. Areas with floating population and no access to toilets were also seen during the survey.

Figure 26: Open drains and slum area in Ward 7, Sohna Block

4.2 Qualitative Assessment and Mapping

Water samples were collected from various locations in the study area and the water quality analysis was carried out to understand any health risk associated from the water.

4.2.1 Water Quality Testing

Water quality analysis was carried out for drinking water, groundwater and surface water samples collected from various locations as shown in Table 1. The specific locations in Sohna Tehsil from where the samples were taken is shown in Figure 27. The drinking water quality was observed to be within acceptable limits in Sohna M.C, except for the borewell water taken from Ward 7. This borewell water had high chlorides and nitrates pointing to contamination in the water. The water quality of the Shiv Kund and Civil Hospital in Sohna M.C showed the presence of sulphates but within acceptable limits. While the water was found to be safe in the deep aquifers of the Shiv Kund and Civil Hospital, the presence of chloride and sulphate in the region is of geogenic origin (and presence of hot spring) and not due to anthropogenic activities.

Table 1: Locations of water sampling

S. No.	Village/M.C.	Location
1	Sohna M. C.	PHED office
2		Shiv Kund
3		Borewell Ward 7
4	Ullhawas	Borewell- Sarpanch's house
5		Govt. School's jet supply
6		Govt. School's PHED supply
7		Water ATM
8		Anganwadi
9	Gairatpur Bas	Borewell- Gairatpur Bas Household
10	Ghangola	Borewell -Sarpanch's house

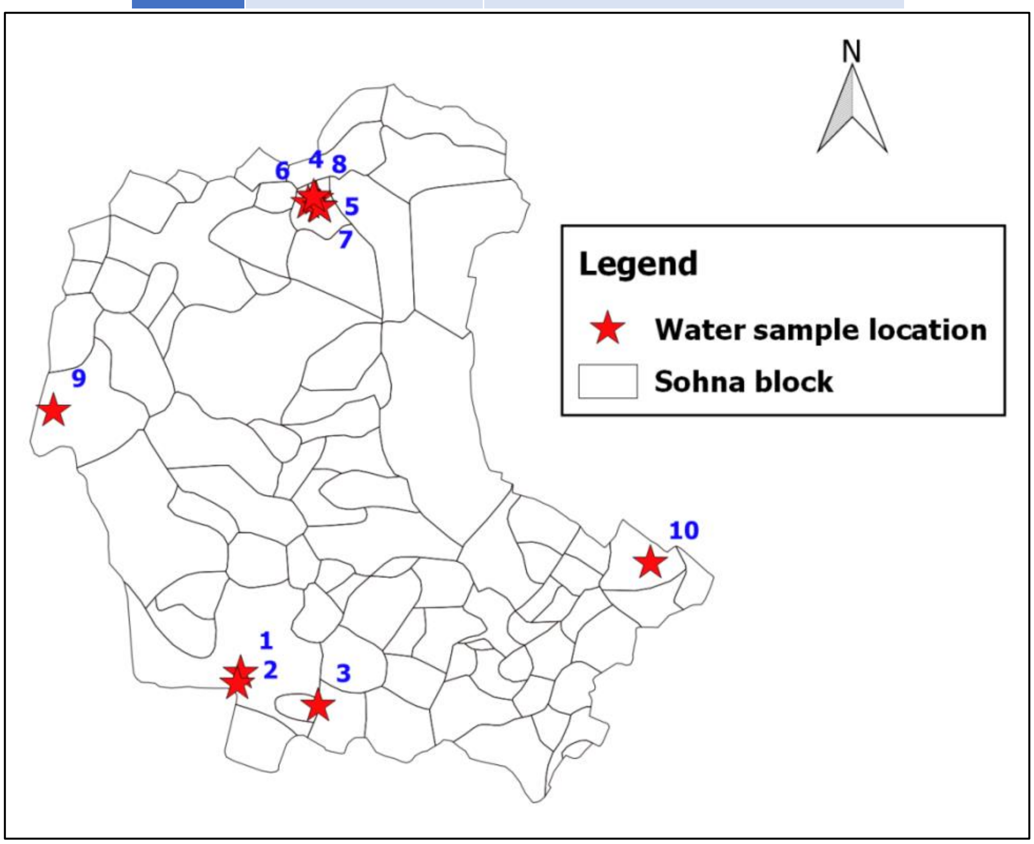


Figure 27: Locations of water samples

Table 2: Representative samples and analysis

Water Quality Parameter	PHED office	Shiv Kund	Ward 7, Sohna MC	Borewell, Ullhawas	Govt. School Ullhawas	PHED Supply, Ullhawas	Water ATM, Ullhawas	Anganwadi, Ullhawas	Ghairatpur Bas HH	Acceptable Limits	Permissible Limit **(in the absence of alternate source)**
Alkalinity **(mg/l as CaCO3)**	60	330	**640**	410	340	330	40	420	330	**200**	**600**
Hardness **(mg/l as CaCO3)**	140	270	**620**	500	260	280	40	500	250	**200**	**600**
Chloride **(mg/l)**	40	204.9	**1060**	140	24.49	49.98	45	120	95	**250**	**1000**
Fluoride **(mg/l)**	0.7	0.8	**1.6**	0.5	0.6	1	0.7	0.3	0.6	**1**	**1.5**
Nitrate **(mg/l)**	0	0	12.1	11.6	7.9	6.0	0.3	11.1	6.1	**45**	**No relaxation**
Sulphate **(mg/l)**	123.6	89.6	158	88	21	14	0	84	75	**200**	**400**
pH	8.16	6.5	6.9	7.1	6.71	6.8	5.4	6.6	6.5	**6.5-8.5**	**No relaxation**
Turbidity **(NTU)**	4.1	**5.7**	**9.8**	3.4	1.6	2.2	1.6	2.1	4	**1**	**5**
EC (dS/m)	0.146	**0.9**	**4.04**	**1.021**	0.706	0.645	0.035	1.308	0.663	**.8**	**2.5**
TDS (mg/l)	122	**607**	**2903**	**1000**	396	308	36	**840**	488	**500**	**2000**
WQI	**107.1**	**63.9**	**275.4**	**109**	**59.6**	**59.5**	**83.9**	**69.9**	**26.4**	**92.5**	**63.9**

*The water quality analysis of Ghangola is shown in chapter 6.

The high turbidity in the hot spring water is expected due to the presence of minerals in the dissolved state, which is also revealed by the high TDS present in the Shiv Kund sample that was tested. Ward 7 of the Sohna Municipal Council is widely covered by the agricultural land and residential accommodation on either side of the Palwal-Sohna Marg. When the respondents from the area were asked about the quality of the water, an elderly person offered us the water which they consume, and it was saline and hard in nature. This confirms the findings of the water sample tested from the area which shows higher value for Total Dissolved Solids (TDS), Chloride, Fluoride and Electrical Conductivity (EC). The high value of EC in the area indicates that the groundwater is saline. Few respondents complained of joint pain which can be attributed to the very high fluoride value. Excess amount of fluoride i.e. above 1.5 mg/l can cause fluorosis while long-term ingestion can cause skeletal fluorosis. Even though it is a worrying sign, people are forced to use borewell water for consumption as the authorities are unable to provide alternate option to the residents.

The groundwater quality of Ulhawas Village is also not very good since it is both hard and saline. The water infrastructure serves only a few parts of the village while others rely on private borewells for household needs. The Sarpanch of the village is aware of the presence of high TDS value in their borewell water and has installed Water ATM inside the PHED Office. Though no health issues were reported by the respondents, but persistent use of this groundwater can have negative health impact on the residents.

The water quality index map for the three locations is shown in Figures 28,29 and 30.

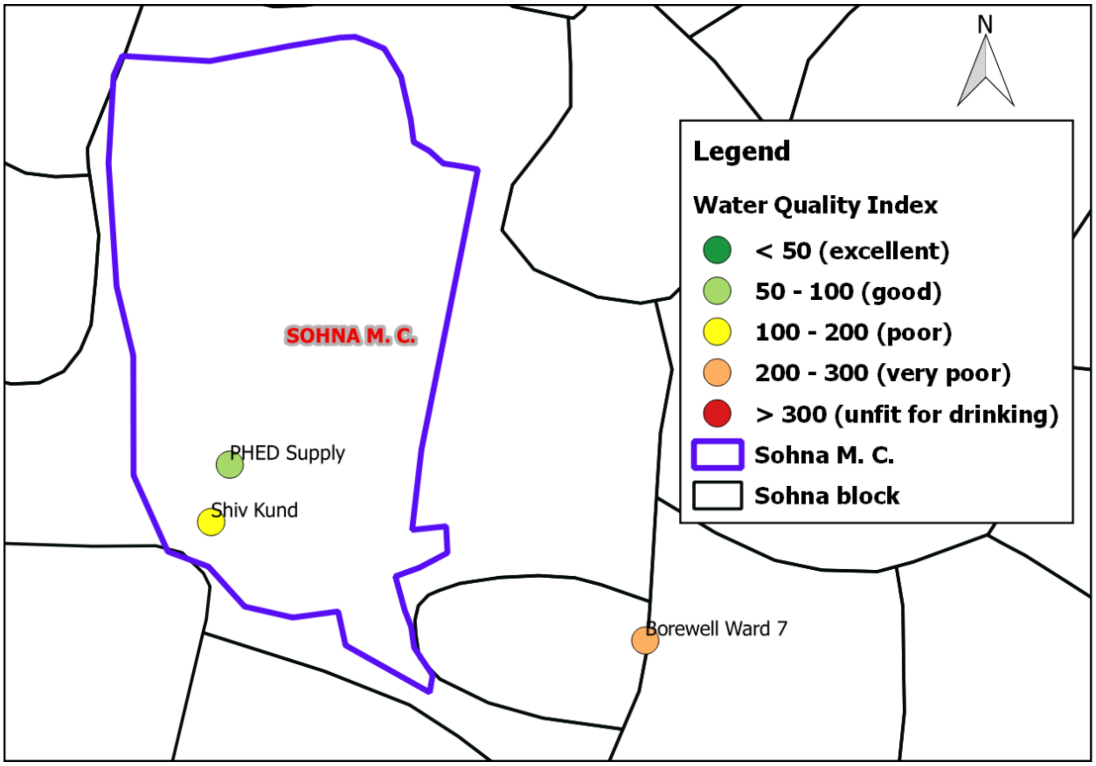


Figure 28: Water Quality Map for Sohna M. C.

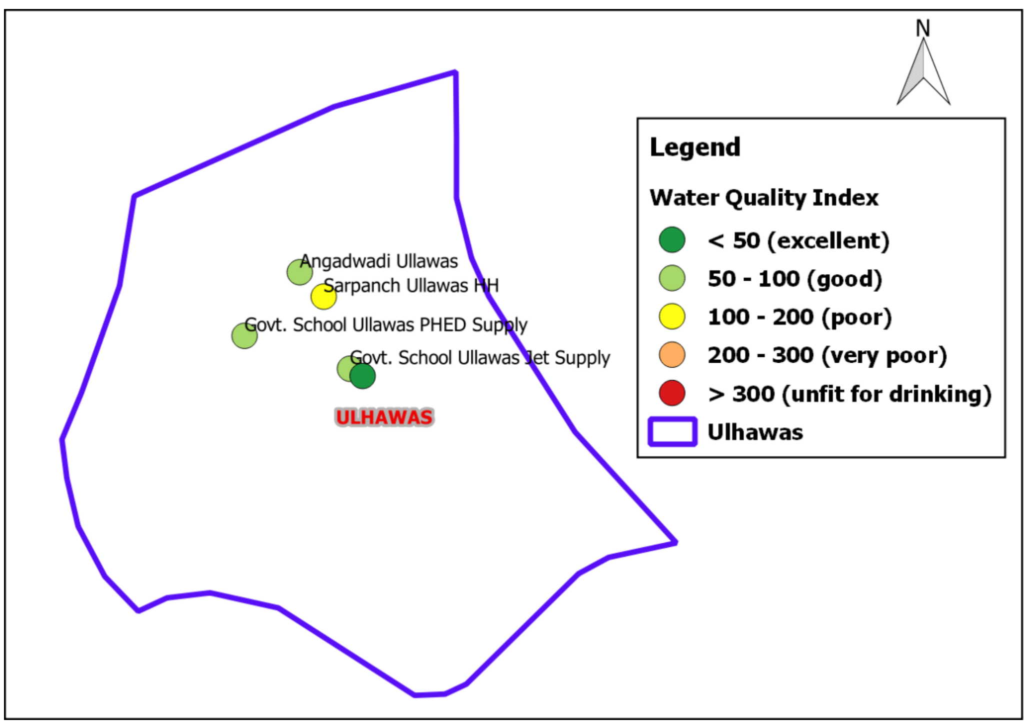


Figure 29: Water Quality Map for Ulhawas

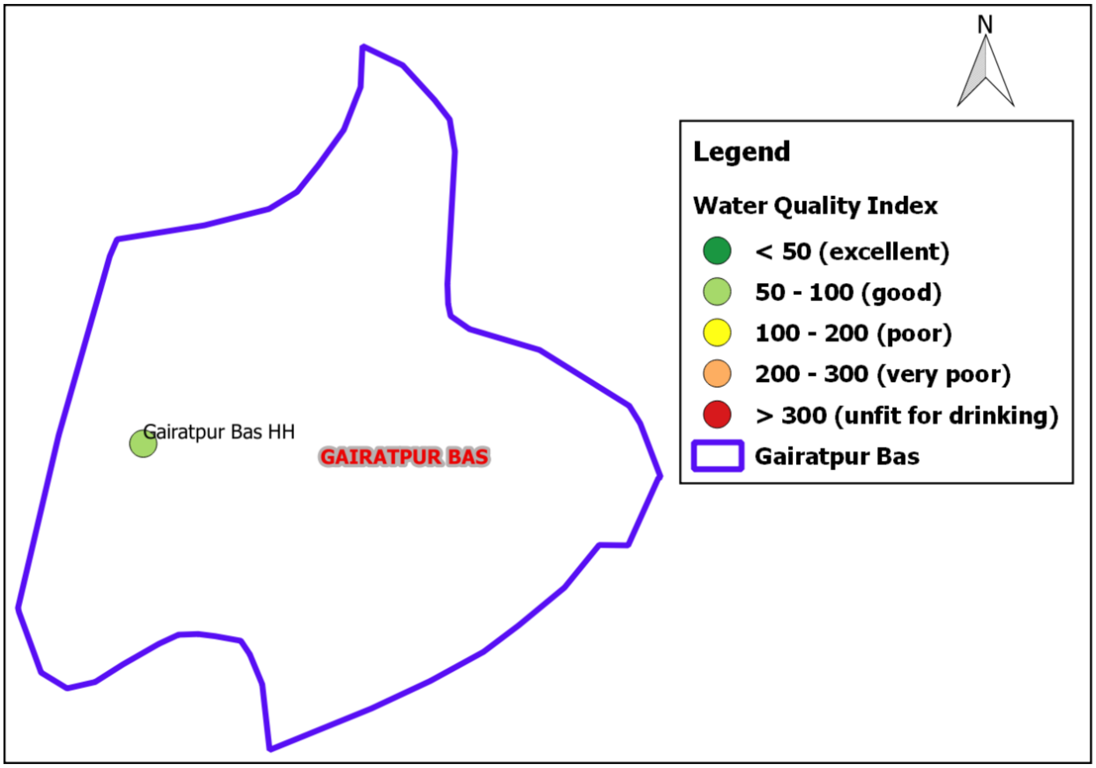


Figure 30: Water Quality Map for Gairatpur Bas

5 Case Study of Ghairatpur Bas Village

5.1 Gairatpur Bas

Located in the foothills of the Aravalli Hills, Gairatpur Bas is surrounded by natural forests as shown in Figure 31. The village is in the Sohna Tehsil of Gurugram District in Haryana. It is 13 km from the district headquarter in Gurugram. As per the Panchayati Raj Act of Indian Constitution (1993), the Panchayat manages three parts in the village namely, Bas Village, Gairatpur Village and Pandala Village. These three parts constitute Gairatpur Bas area.

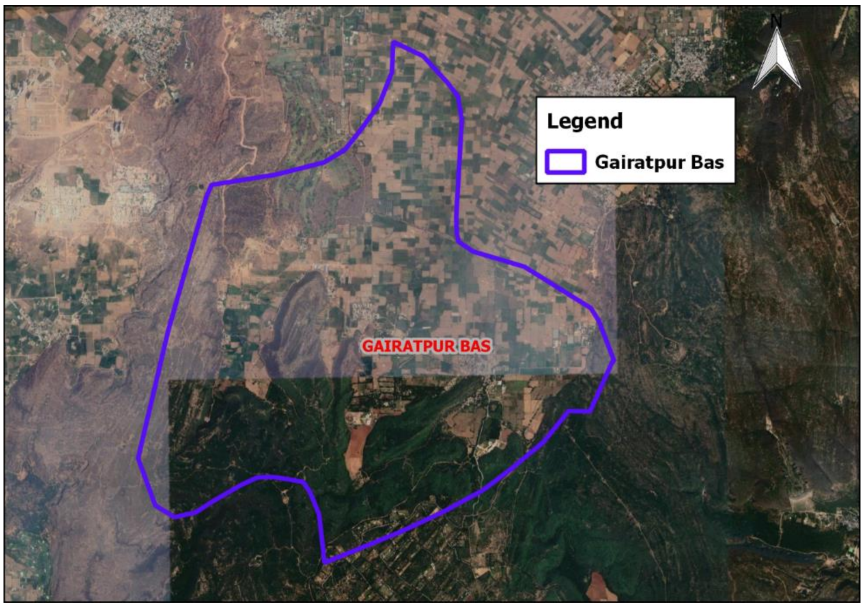


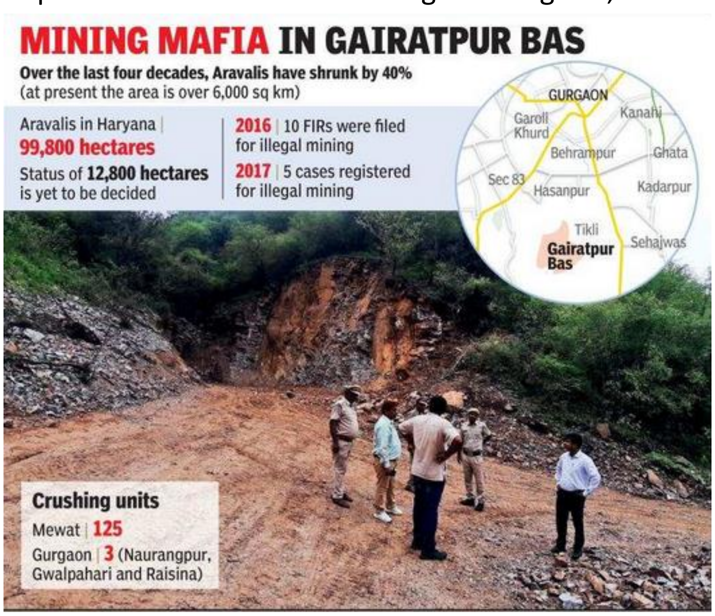
Figure 31: Gairatpur Bas Village (Source: Google Map)

Table 3: Attributes of Gairatpur Bas Village

Geographical Area	**750 hectares**
Total Number of Households	352 (Census, 2011)
	400 (Presently according to Sarpanch)
Total Population	2044 (Census, 2011)
	4000 (Presently according to Sarpanch)
Votes	1300
Communities	Gujjars, Valmiki, Muslims, Kumhar, Sahu

Agriculture is the main occupation of the villagers, though many of them are agricultural labourers and only a few own lands. Maximum size of land holdings is 5-7 kila (1 kila = 1acre). People maintain livestock like cows and buffalos and the milk is sold in the nearby areas. Till 2008, as seen from Figure 11 of Chapter 3, the Aravalli hills adjacent to the village had a wider green corridor, with presence of several water bodies in them. However, the land use map of 2016 shows lessening of the water bodies and increase in built up area.

The current assessment of the study area is that though it is ecologically fragile with erosion in the hills during rainfall events, yet it may be preserved with minimal interventions and monitoring of activities in the green forest area. During the survey, it was also observed that the area is still very good in terms of ecology but due to mining activities, it may lose its ecosystem if it is not checked at the earliest. While doing the field survey in early August we found out that the stones were being transported from the foothills of the Aravallis and around the same time, the national daily, Times of India reported illegal mining in Gairatpur Bas even when Supreme Court has imposed a blanket ban on mining in Gurugram, Mewat and Faridabad Districts.



The Aravalli hills are very critical in this area for they are the only groundwater recharge zone and source of groundwater. The highly urbanized Ullhawas village north of Gairatpur Bas (as seen from figures 11 and 12 of chapter 3), has many borewells and the source of groundwater for these borewells are the recharge zone of Gairatpur Bas Aravalli Hills.

Figure 32: Problem of Mining Mafia in Gairatpur Bas (Source: Times of India, August 6, 2019[11])

[11] https://timesofindia.indiatimes.com/city/gurgaon/nine-booked-for-illegal-mining-in-aravalis/articleshow/70565252.cms

5.1.1 Rainfall

Since Gairatpur Bas comes under the semi-arid region, it receives an annual average rainfall of less than 500 mm. In the year 2010, the rainfall was around 425 mm but in the year 2018, the annual rainfall was around 190 mm *(Source: World Weather Online).* Though the fall in rainfall is a cause of concern, yet it may not be directly attributed to the change in land use. However, if the forest cover in the Aravalli Hills continue to deplete, the rainfall, even if it is normal will not result in ground water recharge. Since the ground water recharge only happens through the hills and at the foothills, the aquifer shall continue to deplete without immediate cordoning off the green forest cover and its rejuvenation.

Surface Runoff

Figure 33: Stormwater from Aravalli Mountains

The surface runoff from the hills is very high immediately after a rainfall episode of medium intensity. The soil is not densely compacted especially where the stream rivulets flow as can be seen from Figure 33. The water comes down rapidly from the hills and owing to soil erosion, it exhibits high turbidity. The picture was taken during one of our visits to the village on 25 July 2019. The slope of the mountain being steep, the water flows rapidly down the mountains. Only one check dam was visible. However, there were several pits below the hills where water was getting collected. Provisioning of check dams, gabions at the foothills would reduce the velocity of flow and store water in the rivulets for a longer period. This would allow the water to infiltrate through the soil and recharge the aquifer below.

5.2 Agriculture

There are only three crops which are sown here, wheat, pearl millet and mustard. While pearl millet is a Kharif crop, wheat and mustard are Rabi crops. The village of Gairatpur Bas has switched to a more sustainable practice of sprinkler irrigation system.

Figure 34: Sprinkler irrigation in Tikli Village in the foothills of the Aravallis

The shift to sustainable agriculture is a good move by the villagers but presently there is no limit to the number of hours for running the sprinkler. The crops that they grow do not have high evapotranspiration and as such the water consumption can be brought down by capacity building of the farmers.

Table 4: Soil quality parameters in Gairatpur Baas and Teekli

Sample Location	Nitrogen (kg/ha)	Phosphorous (kg/ha)	Potassium (kg/ha)	Electrical conductivity (dS/m)	pH Value	Organic Matter (%)	Total Organic Carbon (%)	Moisture Content (%)
Teekli Centre Soil	74.13	61.78	370.66	0.191	7.31	15.96	5.382	
Teekli Corner Soil	74.13	61.78	123.55	0.168	7.09	14.34	4.836	
Aravalli Soil	74.13	37.07	247.11	0.120	7.42	12.49	4.212	
Gairatpur Bas Centre	44.83	22.42	179.34			2.08	0.702	2.0119
Gairatpur Bas Corner	44.83	22.42	179.34			0.462	0.156	3.3099

5.3 Water Supply

The village as a whole is dependent upon the groundwater resource for their water consumption. Borewell water is supplied through pipelines in Bas Village and some parts of Gairatpur Village. There is a stand-post arrangement (locally called 'jet') in the village temple from where a few households carry water for domestic use. In Pandala Village, people have private borewells which are used for agriculture as well as for household consumption. Groundwater Table is at a level of 150-200 feet and according to the respondents of the survey, the water level is declining at an average rate of 5 feet every year. This could be attributed to the loss of forest cover, soil erosion immediately upstream of the village which disallows replenishment of adequate ground water during rainfall events.

5.3.1 Wastewater Discharge

There are open drains which are mostly unlined. A few households have taken the initiative to line the drain in front of their houses. The drains are chocked with household garbage. There are some households which do not even have drains.

Figure 35: Wastewater disposal in Bas Village

Figure 35 shows the Bas Village which does not have any sewer line. As per the residents, currently the wastewater goes into a nearby ditch.

In Gairatpur village, Sarpanch has built a wastewater drain to divert wastewater from households to the nearby Johad (village pond). However, the village has plans of connecting the current wastewater drain to the main sewer line, which shall then take the wastewater to a Sewage Treatment Plant (STP) to be built in due course of time.

Status of Johad

The village has a Johad which is close to Sarpanch's house (Figure 36). The Johad at the time of survey had a green cover because of algal growth. There is a definite need for grey water treatment prior to discharging it into the Johad. Root-zone technology may be adopted near the entry point of the Johad for the improvement in the water quality of the Johad. There is adequate space available for the installation of the constructed wetland system.

Figure 36: Village Johad in Gairatpur Bas

5.4 Recommendations

Gairatpur Bas is located at the foothills of the Aravalli Hills and the suggested remediation measures are construction of gabion check dams, revegetation for the stability of hill slope, creation of storage reservoirs immediately downstream of hills (already existing), and green corridor. These would help in augmenting groundwater recharge. Installation of smart meters and dynamic groundwater monitoring equipment shall help in water use efficiency and real time monitoring of water use and groundwater levels. The treatment of grey water prior to discharging in the Johads as proposed in the previous section can help in wastewater use for recharging groundwater.

5.4.1 Green Corridor for rejuvenation of groundwater in Gairatpur Bas

There is a rapid decline in groundwater table in the past decade; hence, efforts need to be taken to improve groundwater table. This shall require that Aravalli Hills have adequate forest cover to guide the rainwater through the faults and fissures in the metamorphic rocks. The recommended minimum width and length of the corridor (Figure 37) are 500m and 13Km, respectively.

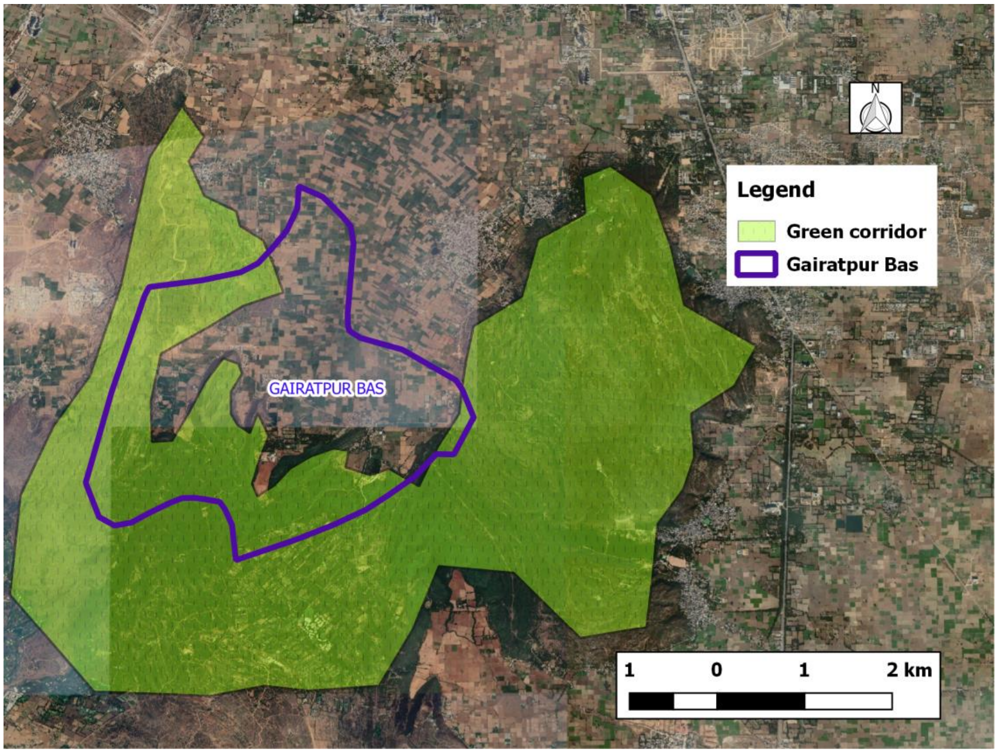


Figure 37: The proposed green corridor along Aravallis near Gairatpur Bas

5.4.2 Gabion Check Dam to control the flow from Aravallis at rivulets

A gabion is a rectangular shaped cage that is made up of galvanized wire, filled with rock or stones that are locally found and requires low capital investment (Table 5). A gabion check dam is made up of several gabions in both horizontal and vertical directions. Usually they are 1 m high and their length varies between 2 m to 6 m (Figure 38).

Characteristics of Gabions:

(a) ***Durability:*** High resistance to atmospheric corrosion and ability to support vegetation.

(b) ***Flexibility:*** Shapes itself according to stream bed even when this change is due to erosion, without losing its stability.

(c) ***Permeability:*** Provides easy drainage and slows down the velocity of water considerably.

(d) ***Strength:*** Quite strong and is capable of resisting flood force, etc.

Table 5 Typical Gabion Wire Mesh Properties

Technical Properties	Gabion Wire Mesh Properties		
	Unit	**Descriptions**	**Tolerance**
Mesh	Mm	50x70, 60x80, 80x100, 100x120	-
Max. Wire Thickness	Mm	2-5	0.05
Tensile Strength	MPa	350-2000	2
Elongation (25 cm)	-	10%	-
Zinc Coating Strength	Turns	5	Shall not break or crack

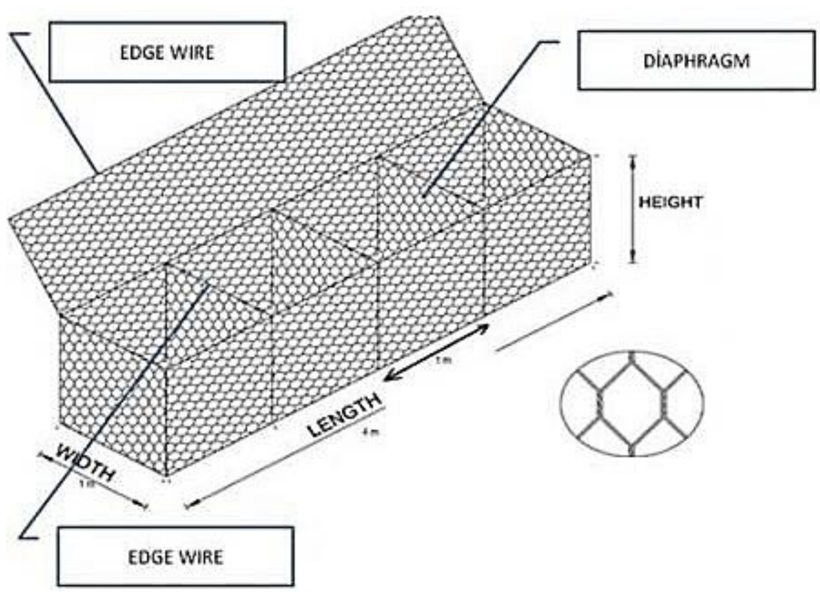


Figure 38: Layout of a Gabion Box (Source: theconstructor.org)

In Gairatpur Bas village, a single gabion may be anchored at the end of the rivulet, which can be complemented with a masonry bund with adequate free board below the gabion structure, as is seen in some locations built by the forest department. The structural design of gabion cross barrier on different channel gradients is shown in Figure 39. The estimation of one gabion structure of dimension 10mx2mx2m is shown in Table 6.

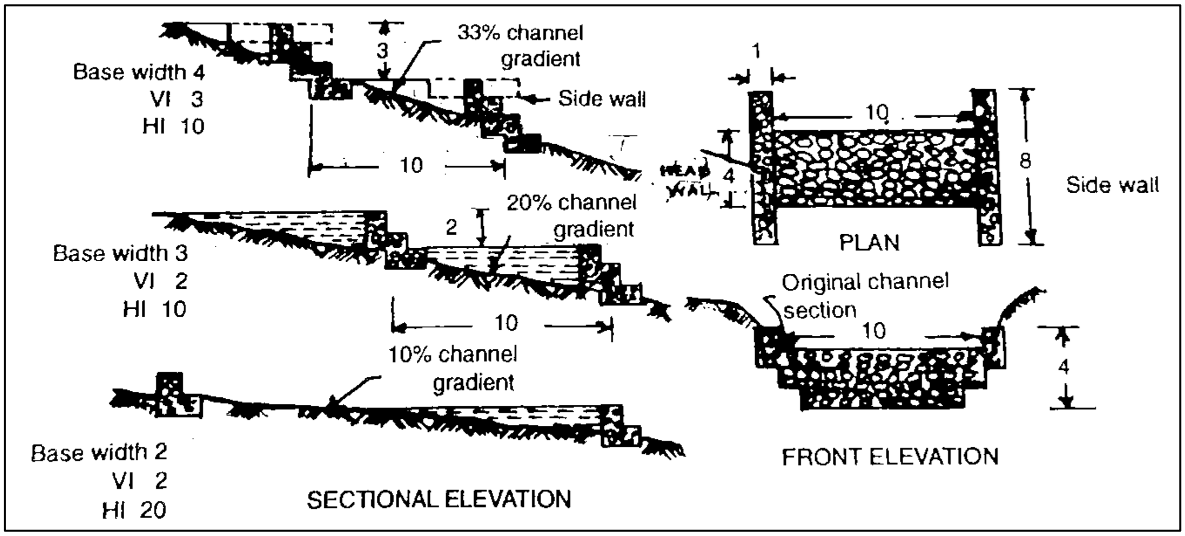


Figure 39: Structural design of gabion cross barrier on different channel gradients

Table 6 Calculation of Gabion Work[12]

Particulars of Works/Items	No.	Length (m)	Width (m)	Height (m)	Quantity (m^3)
(a) Bottom	1	10	2	2	40
(b) Top	1	10	2	2	40
(c) Side	1	8	1	2	16
Total Gabion Work					96
Total amount @ Rs. 905/unit = 96*905 = Rs. 86880					

***Note:** The cost specified here is only for the gabion material. The cost of stones, labour is not included.

[12] http://ecoursesonline.iasri.res.in/mod/page/view.php?id=125118

5.4.3 Jute or Coir Mat to prevent soil erosion in the Aravallis

It is a measure to protect the topsoil on slopes which are subjected to erosion. Erosion control mats (ECM) are used to control the erosion of the soil, by soil stabilization. It also facilitates plant germination (Figure 40). The ECM are made of Jute and Coir and are 100% natural bio-degradable, thus suitable for the forest environment. Jute and coir material are saltwater damage resistant as compared to other fibres. ECM can also be used on degraded land and waste land and to build landscape garden using construction debris and topsoil.

Advantages

- Easily available
- Quick execution time as it is available in rolls
- 100% biodegradable
- Reduces moisture loss

However, restoration of slopes will take a few monsoons.

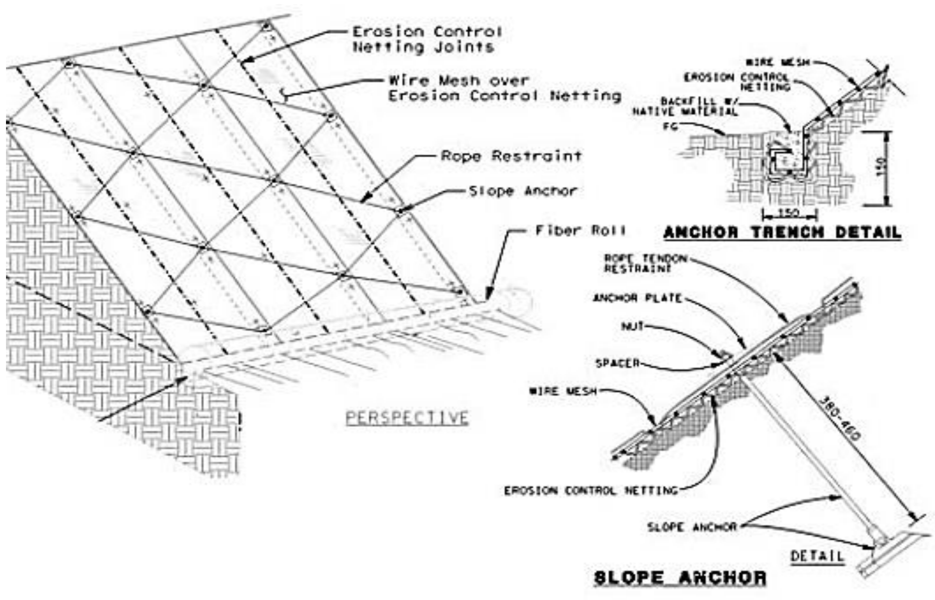


Figure 40: Layout of Jute/Coir Mat[13]

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13 https://web.mst.edu/~rogersda/umrcourses/ge441/online_lectures/slope_face_treatment/GE441-Lecture4-7.pdf)

Materials needed

- The wire mesh and coir netting (Figure 41) are fastened in place with slope anchors.
- The anchor is made of either ductile iron or aluminium and is designed to provide holding capacity and offers pull out resistance once locked in place.
- A 1/2-inch diameter threaded anchor rod, 30 inches in length, secures the anchor to a surface mounted plate.

Figure 41: Wire net over coir mats[14]

The wire blanket is composed of biodegradable coir netting sandwiched together with a welded wire mesh that is anchored in place with slope anchors.

- A vegetative cover is provided by a final hydro seeded application of fibre, seed, and fertilizer.

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14 https://web.mst.edu/~rogersda/umrcourses/ge441/online_lectures/slope_face_treatment/GE441-Lecture4-7.pdf

- Braided coir strand weave with 3/4 inch openings with 63-70% open area, sufficient to germinate hydro seeded material.
- This coir netting has an estimated life span of 4-6 years, sometimes 2” x 4” welded wire mesh placed over the coir netting to provide strength (Table 7 and Table 8).
- Vegetation is usually planted to help anchor the mats and provide a natural appearance.
- Open weave mats (Figure 42) perform better than stitched complete cover mats.

Figure 42 Open Weave Coir Mat[15]

Table 7 Specification of Coir Mat[16]

Particulars	Value/Dimension
Main Material	Coir
Roll Size Available	2 m × 50 m
Opening Size	35mm × 35 mm/ 55 mm × 55 mm
Rate	Rs. 55/ m^2

[15] https://www.geotrstgroup.com/coir-products-series/natural-coconut-fiber-net-and-erosion-control.html
[16] ibid

Table 8 Cost Calculation of Mat[17]

Particulars	Cost (Rs.)
Rate (in Rs.) per m^2	55
Cost per roll (100 m^2)	5500
Total cost incl. anchoring + other installation (+20%) per roll	6600

5.4.4 Smart Metering to tackle over-exploitation of groundwater

In places where there is no control over the groundwater extraction, water meters are essential in order to regulate the groundwater resource. Installation of water meter on borewells in Gairatpur Bas area would lead to optimum ground water use as shown in Figure 43. Since the village is experiencing approximately 5 feet of decline in the water table every year despite use of sprinkler irrigation, the water use must be curtailed. Smart metering will help in encouraging water conservation, restricting water use and allowing efficient allocation and redistribution of water. The reduction in consumption of groundwater would result in the increase of the ground water reservoir capacity. A multipronged approach can only result in restoring the groundwater levels.

[17] http://www.oceanglobal.co/ocean-erosion-control-mat

Figure 43 Irrigation Water Meter[18]

5.5 Water Budget Model

In the Gairatpur Bas, only Bas village gets supply through PHED borewell. The residents of Gairatpur and few in Bas village have their own borewell for daily water requirements that is for household as well as irrigation purposes which implies that groundwater is the major source of water in Gairatpur Bas. As per this water budget model, the ground water is divided into two categories, potable and non-potable. The potable water is required for drinking, household purposes where as Non-Potable water is required for irrigation, toilet and taking care of leakages. In the current scenario, grey water coming out of households is not treated as no treatment scheme is present in the village, thus cannot be reused. In the model, the wastewater comprising greywater, leaks are not re-used and directly account into **Losses**. The precipitation is directly accounted into loss as no Rain Water Harvesting structure is present at the buildings inside village like school etc.

[18] *AGwater Pumping and Irrigation Services*

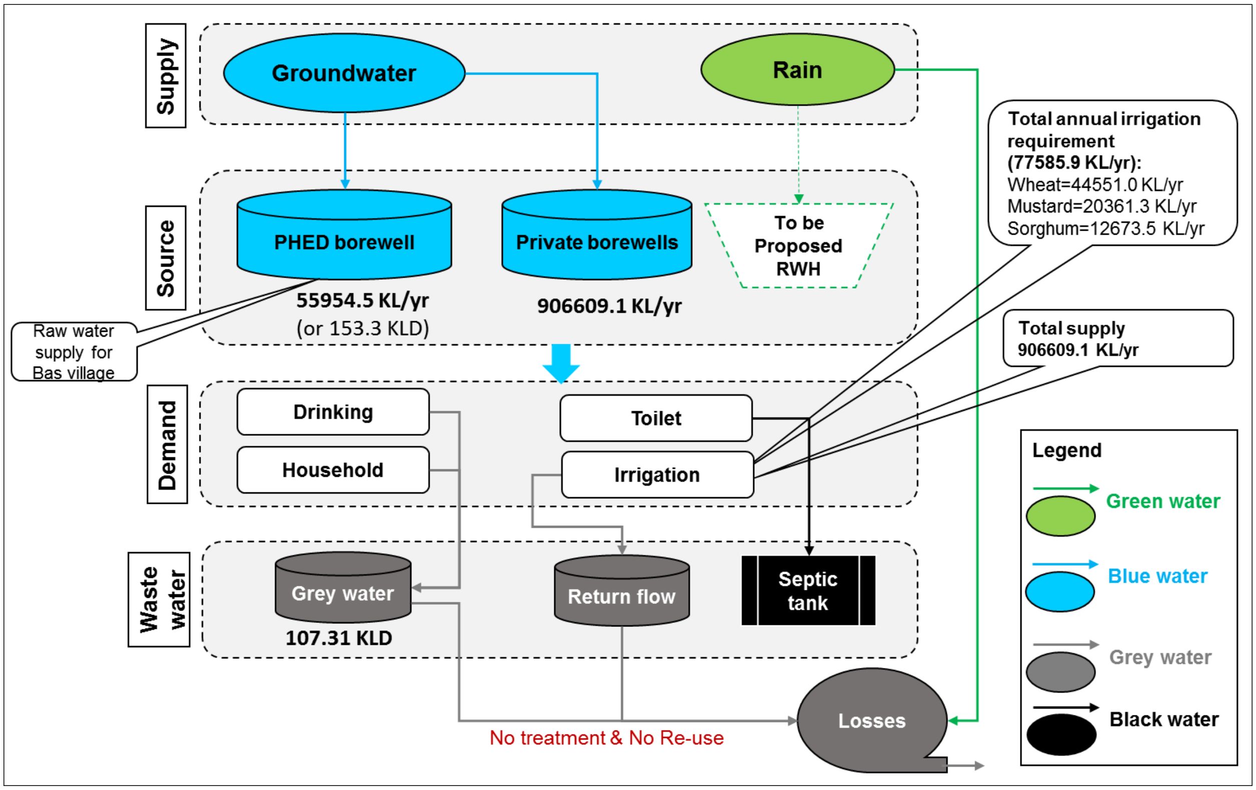


Figure 44 Gairatpur Bas Current Water Budget Model

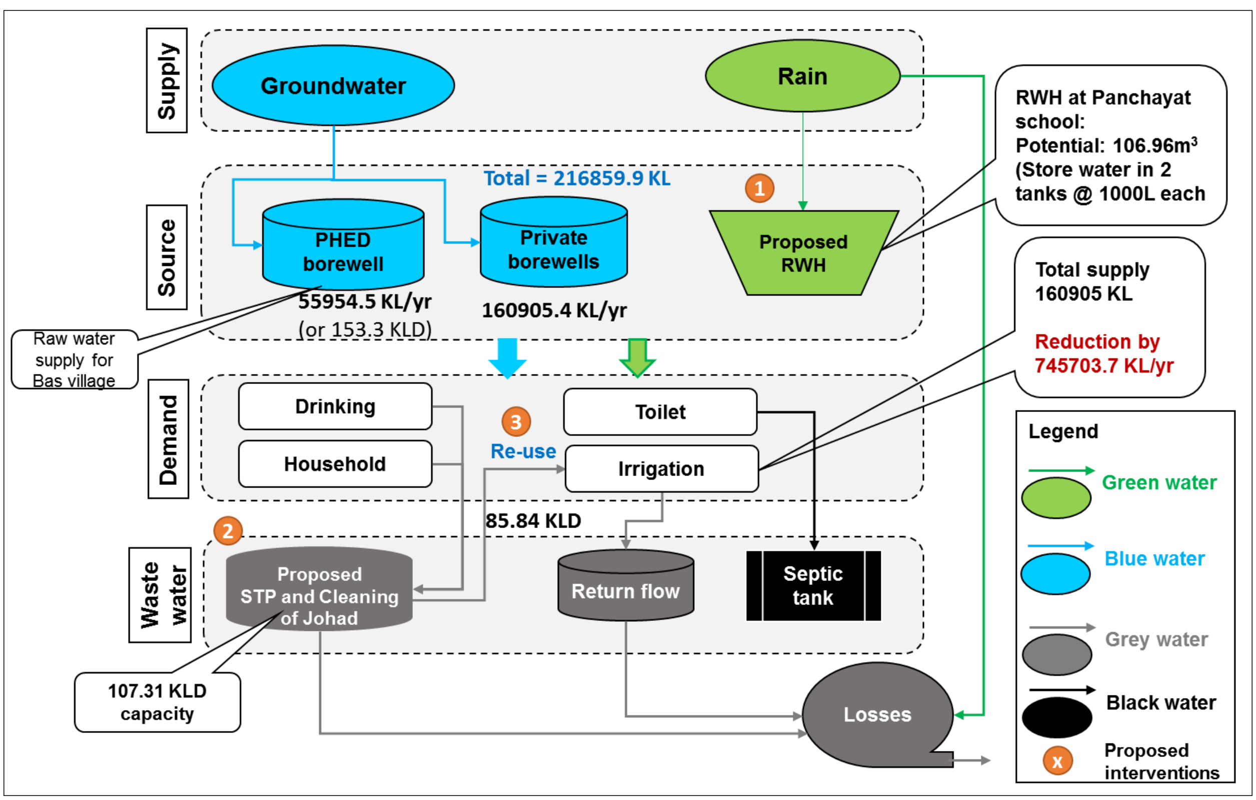


Figure 45 Gairatpur Bas Sustainable Water Budget Model

6 Case Study - Soil and Water Resources Management of Ghangola Village

6.1 Introduction

Ghangola village is located (28.2531439° N, 77.1831224° E) 15 km away towards the east of the Sohna sub district headquarters. The village is a gram panchayat and it is at the border of the Gurugram, Mewat and Faridabad districts. The total geographical area of village is 514 hectares. There are about 351 houses in Ghangola village and has a total population of 2,052 people (Census, 2011).

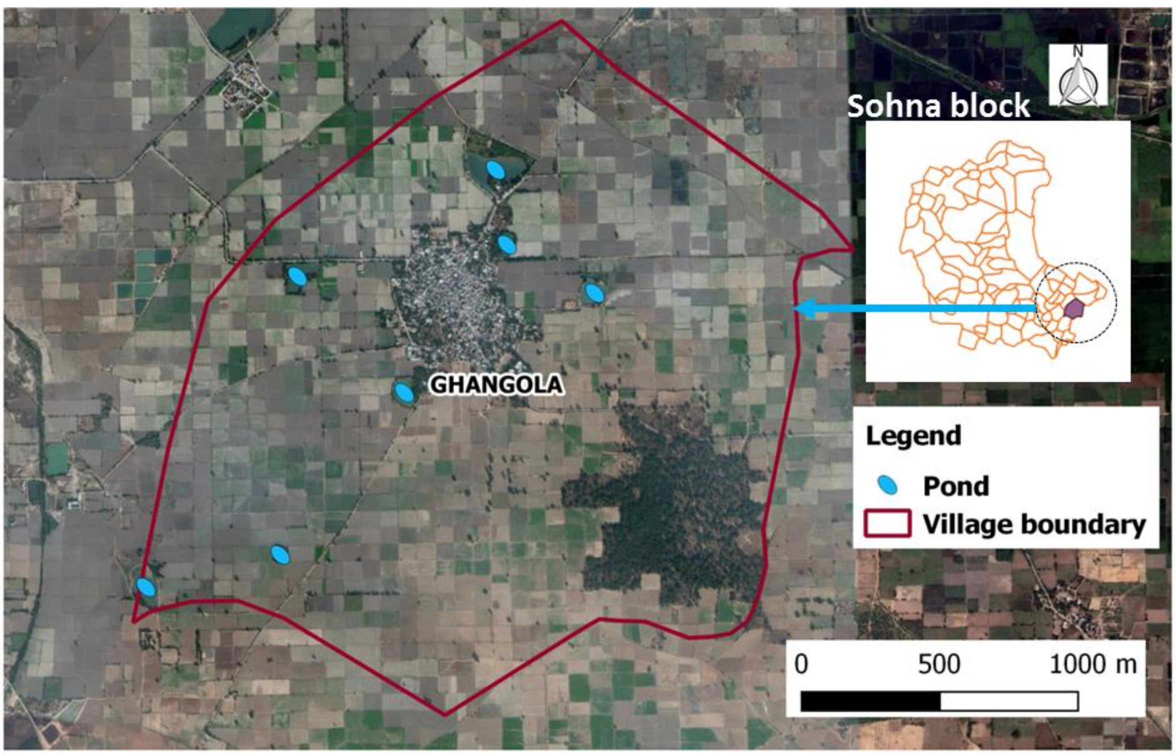


Figure 46 The location map of Ghangola village. The inset shows the location of Ghangola village within Sohna block (Background map courtesy: Google Inc.)

The neighbouring village, Khatrika, has recently introduced fish farming in the fields which are adjacent to the state highway and it is expected that the first harvest will be by the winter of 2019-20.

6.2 Need and Scope of the Study

The study area has high ground water table, unlike the rest of Sohna Block; however, it is saline and hence unsuitable for irrigation and drinking water. The use of saline ground water and presence of salts in the soil has led to salt crusts developing on the soil. The physical and chemical degradation of the soil has led to irreversible loss in soil quality. The study has been carried out to understand the status of agriculture in the region and propose a way forward for the area.

6.2.1 Socio-economic status

Based on the interview conducted with the Sarpanch, the village does not have enough Panchayat Funds to take care of the saline ground water conditions. The houses in the village are both kutcha and pucca but does not meet the construction standards as reflected from the materials used for construction. People have livestock in their houses and dairy is one of the prime occupations. Many villagers work in the neighbouring Ballabhgarh industrial area and Faridabad.

6.2.2 Physiography and palaeo channels

Palaeo channels are formed when a river dries up because of various geological and climatological factors in the past. They might be partially or completely buried, which has now witnessed the changes in the land-use pattern, weathering, amongst other things. Palaeo channels are important sites for mineral deposits, and they have a huge potential of groundwater recharge. The blue region in Figure 45 between Gurgaon and Faridabad districts signifies the palaeo channels. The villages namely, Ghangola, Sarmathla Silani, and Khatrika are located on these palaeo channels.

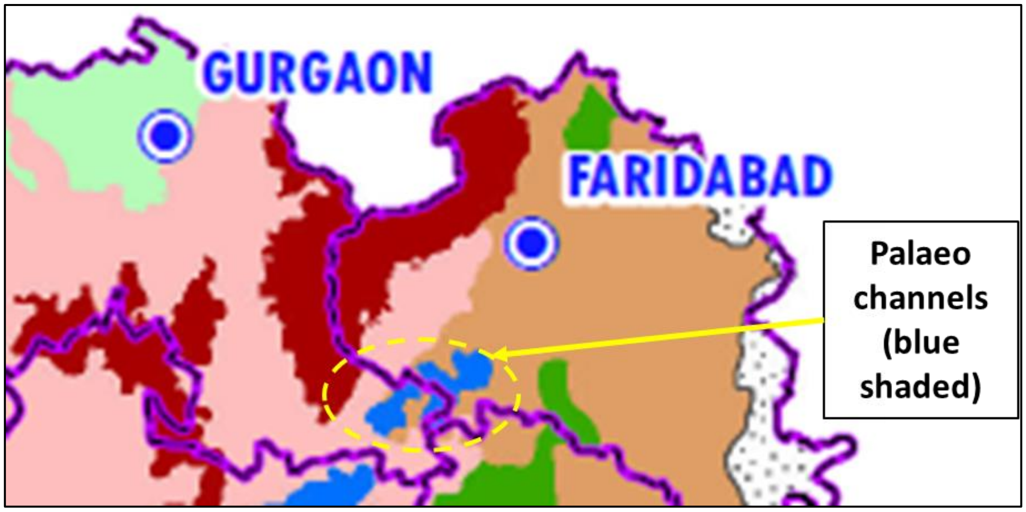


Figure 47 Physiography map showing paleo channels (blue shaded region) of Sohna block (Source: HARSAC)

However, in the border region of Gurugram and Faridabad district, where these clusters of villages are situated, the paleo channels have saline water and widespread use of this water has also led to salinity in the fields. Since the ground water table is high, the salt accumulation in the soil includes capillary rise from the subsoil palaeo channels which gets further aggravated by the irrigation through brackish ground water. These are low lying areas and the clay, sandy loam nature of the soil does not allow the water to move away from the fields (poor drainage conditions), resulting in persistent waterlogged conditions. The water evaporates and leaves behind salt crusts and poor soil quality.

6.2.3 Salinity in soils- areal extent from Sohna to Ballabhgarh

Electrical Conductivity (EC) is a measure of salinity and soil test results carried out during the course of the study reveals that the EC of the soil of Ghangola varies from 0.184 dS/m to 2.40 dS/m towards Sarmathla village. Ideally, the permissible limit of EC in soil is 0.8 dS/m for agriculture to flourish. The Sarpanch stated that the water from the branch of Sarmathla drain can also be used in agriculture for fields in other salinity affected area. Figure 46 shows the location of the soil sample taken for analysis.

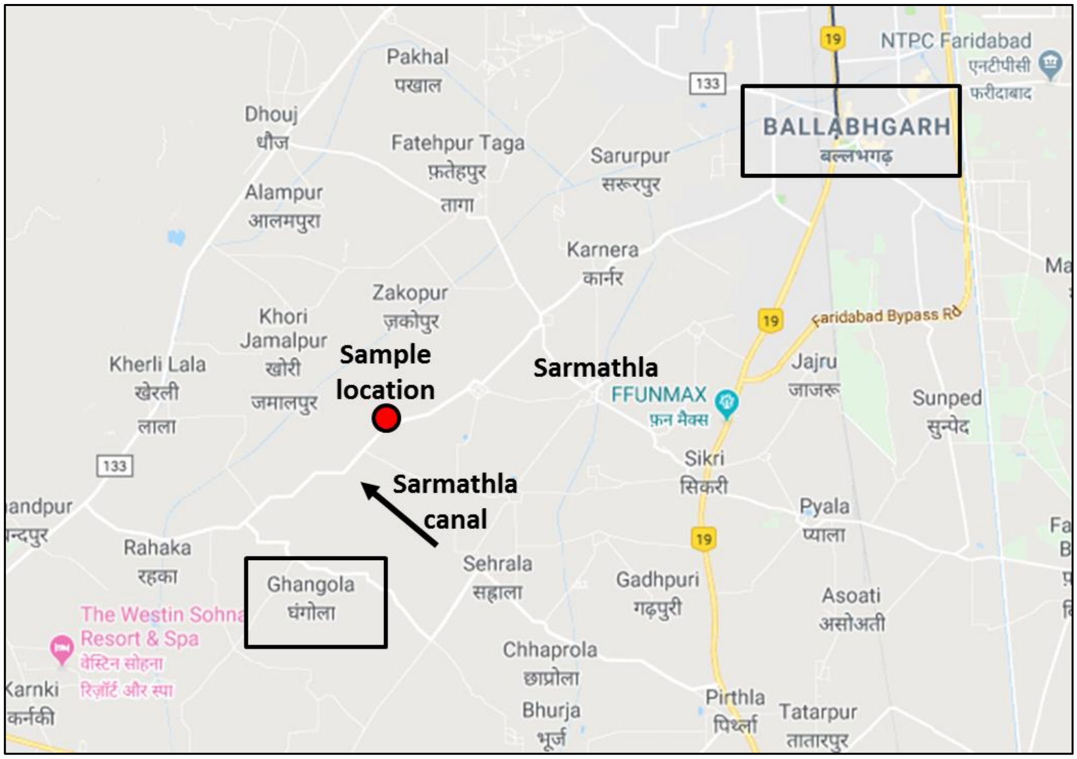


Figure 48: Location map of soil sample within the study area

6.2.4 Ground water salinity

Ground water sample was collected from Ghangola village Sarpanch's house (28.284126 N, 77.218483 E). The Electrical Conductivity (EC) from the borewell has a value of 3.140 dS/m. The corresponding Total Dissolved Solids (TDS) value is high, signifying greater amount of salt present in water in the form of sodium chloride or salts of magnesium, calcium, etc.

Table 9: Electrical Conductivity and TDS of water and soil samples in Ghangola Village

Parameters	Soil	Water	Acceptable Limits
Electrical Conductivity (dS/m)	2.40	3.140	0.8
Total Dissolved Solids (mg/L)	N.A.	1429	500

The drinking water supplied in the village is through the community (industrial) RO system which has been set up at the Panchayat Ghar recently. Sometimes the villagers receive RO water through tankers which supply water to households at their doorstep on payment of INR 10 for

20 liters. Sometimes tanker water is supplied from Nimmoth village where the aquifer has fresh ground water, since it is adjacent to the Aravallis.

6.2.5 Cropping pattern

The crops grown are Moong, Rice, Jowar, Bajra and Wheat. Rice, Jowar, Bajra and Moong are Kharif crops and require more water as compared to Wheat which is a Rabi crop. Since the salinity in soil varies even within a radius of five kilometres, those fields which receive irrigation water from Sarmathla drain and are not completely degraded attempt to grow moong, rice and bajra.

6.2.5.1 Water supply for agriculture

Figure 47 shows the Sarmathla canal that provides water to Sarmathla, Ghangola and neighbouring villages for irrigation and farmers grow paddy adjacent to the canal in Kharif season.

Figure 49: Samarthla canal used for irrigation

This water is shared with Mewat region too and sometimes these villages do not get an adequate share of the drain water (this is a distributary canal from the Agra canal coming from down-stream of Okhla barrage on river Yamuna. It gets further diverted at Delhi-Haryana Border near Badarpur, after which it is known as the Gurgaon Canal). Though there are 5 Johads in the Ghangola Village, almost all of them are filled with greywater with only the Temple Johad being clean.

6.3 Recommendations

The recommendations proposed for the soil and water management interventions are aligned with the recent agricultural policies of Haryana: (a) Subsidies for polyhouse (See Annexure A1) and (b) Subsidies on solar panels. Haryana has 330 sunny days on an average in a year and there is a great potential for harnessing solar energy in the state and hence, Haryana government offers 90% subsidy to promote solar water pumps of 2 Horse-Power (HP), 5 HP and 10 HP. Under the initiative, farmers bear just 10% cost while the rest is shared between the central and state governments. In addition to the policy initiatives of solar power, subsidy on polyhouses for growing vegetables may be complemented and a sustainable agricultural solution can be adopted by Ghangola village.

The various recommendations are explained below:

6.3.1 Salt tolerant crops

Various crops that are feasible to grow in the saline soil environment or can be grown as creepers using saline water and drip irrigation system are suggested as alternatives for these villages. Some of these are tomato, cucumber, guava, melons. These crops can tolerate EC upto 3-5 dS/m. Figure 48 shows the saline tolerance levels of crops like tomato.

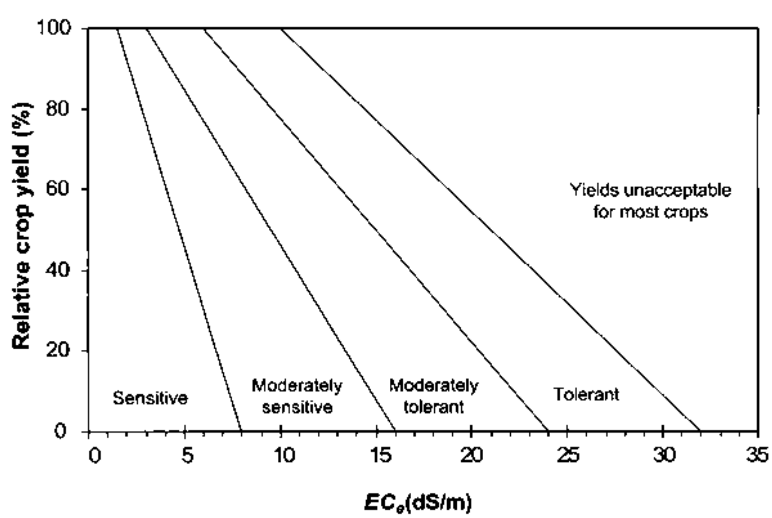


Figure 50: Saline tolerance of crops like tomato

6.3.2 Pisci culture

Pisci culture is an alternative if it is practiced on a large scale. Currently, there are newly dug fish ponds in Khatrika village (Figure 49). Both prawn farming and fresh water fish farming are being carried out, albeit it is at a pilot stage at present. The proprietor of the fish pond however was quite positive about getting a good yield.

Figure 51: Fish farming being practiced in Khatrika village

6.3.3 Solar pumps and drip irrigation using saline water

The solar pumps are installed largely by State Nodal Agencies (SNAs) with capital subsidy assistance from the Ministry of New and Renewable Energy (MNRE) as shown in Table 10. MNRE's 30 per cent capital subsidy assistance is coupled with state subsidy assistance that has historically ranged between 50 and 55 per cent to offer subsidized pumps to farmers at 15–20 per cent of their total cost.

Table 10 Subsidy framework for solar (SPV) Pumps in Haryana

Capacity of SPV Pump	Total Head (Suction & Delivery)	Solar PV (Watt)	Cost (INR)	Total Government Subsidy (INR)	Beneficiary Farmer Share (INR)
2 HP (DC Surface Mounted Monoblock Pump)	10 m	1,800	250,000	150,000	100,000
2 HP (DC Submersible Pump	30 m	1,800	260,000	156,000	104,000
5 HP (DC Submersible Pump)	50 m	4,800	550,000	333,000	220,000

Source: Haryana Renewable Energy Development Agency

Currently, for the year 2019-2020, the guidelines have been released by the Haryana Government regarding the implementation of Solar Water Pumping Scheme in which small and medium farmers are encouraged to switch to a totally pollution free alternative for irrigation instead of existing diesel agricultural pumps.

The selection of beneficiaries will be based on the criteria that the farmers should opt for micro irrigation techniques such as drip, sprinklers and/or underground pipe lines (UGPL) in their field. There will be a 75% (State + MNRE) subsidy and users have to bear only 25% of the cost.

6.3.4 Smart Agriculture

6.3.4.1 Poly houses with Drip Irrigation

Since both soil and water are saline in the area, it is proposed that poly house structure with drip system is to be followed for fruit and vegetable crops such as tomato and melon which has the capability of good yield even if saline water is used. It is suggested that the poly house be constructed on 500 sqm land first as a pilot project. The subsidy offered by the government is good (Annexure), especially for scheduled caste and may be adopted on an immediate basis. Figure 50 shows the layout of a drip system and that along with a polyhouse structure should be practiced in Ghangola Village. We can also provide drip along with vegetable compost/mulch (from the villages). The drip system is available in the market and comes with a whole set.

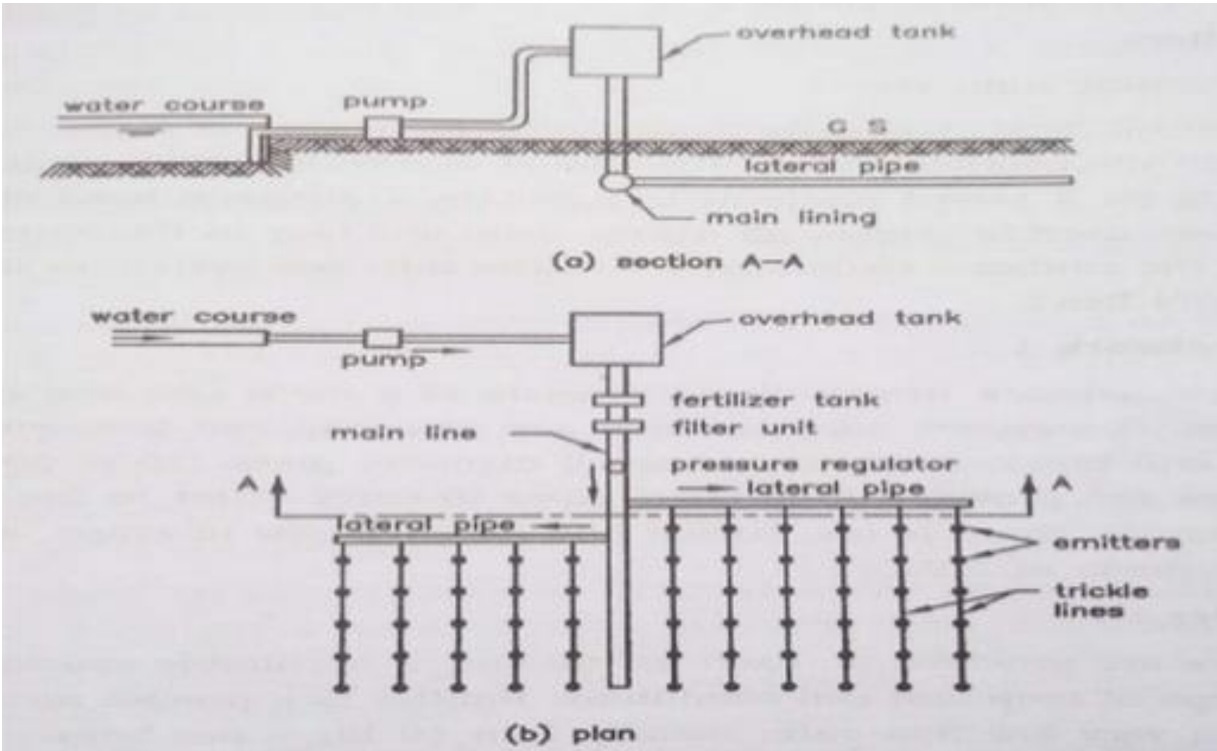


Figure 52 Layout of a Drip Irrigation System[19]

Major Components of Drip Irrigation System: 1) Pump, 2) Control Valves, 3) Water Tank, 4) Fertilizer Tank (Rather than adding fertilizer here, we would recommend adopting organic options), 5) Pressure Gauge, 6) Mains/Sub-mains, 7) Laterals, 8) Emitting Devices, 9) Micro Tubes. Figure 51 shows a polyhouse of tomato cultivation practiced using drip irrigation.

[19] Irrigation Theory and Practice, AM Michael

Figure 53 Tomato cultivation in a polyhouse using drip irrigation

A sample calculation of a drip irrigation system for tomato cultivation

Suppose the dimension of a polyhouse is 30m*30m (as per the norms mentioned in **Annexure A2**), hence we can have 10 laterals of 30 m each, which are 3m apart. Each lateral will then have 30 emitters and in total we would have 300 emitters which will be supplying water drop by drop to the tomato crop.

ET Requirement of Tomato= **228.64 mm** (obtained through CropWat Software)

Estimating the total volume of water required by the samples for the whole base period,

V= 0.22864*900= 205.776 m^3 = **205776 L**

Total number of days required for irrigation by tomato crop = **24 days**

Capacity of the water storage tank for one day of irrigation = 205776 / 24 = **8574 L**

Each lateral will get a quota of 857.4 L water and if we convert it into discharge required then,

Each lateral has 30 emitters; therefore, each emitter shall get 857.4/30 = **28.58L (approx. 30L)**

Emitter Discharge Rate, q = 30/ 24 = **1.25 L/h**

6.3.5 Water conservation through rainwater harvesting combined with smart metering

Rainwater harvesting storage in an underground cistern needs to be built and it should be connected through a common outlet from the rooftop of the houses and be stored at a place locally known as 'Tanka' (See Figure 52). Since water in Ghangola Village contains salinity, hence, the rainwater will be quite beneficial for the village needs and it need not be used to recharge ground water. Like in Rajasthan, rainfall can be collected from roof tops and taken to one common area located at a lower elevation (may be one of the johads which is in a state of disuse, may be repaired, walls may be plastered and clay lining at the bottom may be used to prevent ground water seepage). The sequence of rainwater collection and storage is shown in Figure 52.

Figure 54: Rooftop rainwater harvesting installed at Central Arid Research Institute, Jodhpur (Subfigures 1-4). Smart water meter and tank (Subfigure 5) [Courtesy: Google images]

There are various types of 'Tanka' ranging from circular to rectangular shape with a capacity as low as 1000L to as high as 300000L. These 'Tanka' are generally maintained by the Panchayat in most of the places and are cleaned before monsoons. Same concept can be applied in Ghangola Village also. Since immediate drinking water needs may be satisfied through the industrial RO already installed, these tanks may be used along with poly house to grow fruit and vegetable crops which have good yield and fetch good prices from the market. Since the village is located between Gurgaon and Faridabad, they shall have a ready market for delivery (a prerequisite for subsidiary as provided by the government of Haryana). However, additionally smart metering system must be installed with these rainwater harvesting tanks to restrict the use of excess water and thereby ensure a sustainable water use model.

Moreover, solar pumps and drip irrigation together with poly house would be a smart intervention in the region.

7 Case Study – Water Management in Sohna MC

7.1 Introduction

Sohna Municipal Committee became Sohna Municipal Council (MC) on 05 September 2014. Sohna MC has an area of 5 Sq km and the population of the town as per 2011 Census is 36552 out of which there are 17237 females and 19315 males. The council is divided into 15 wards of which six are general wards, three are reserved for Scheduled Caste, two for Backward Class and four for women [20]. Population density of the city is approximately 3768 per km^2 with ward 8 being the most populous and ward 9 being the least populated areas [21]. According to the interview with the Municipal Council official the population now has gone up to 100000. He stated that the increase in the population is primarily because of the construction of high-rise buildings. The nearest railway station is Gurgaon which is around 24 km away from the Council office.

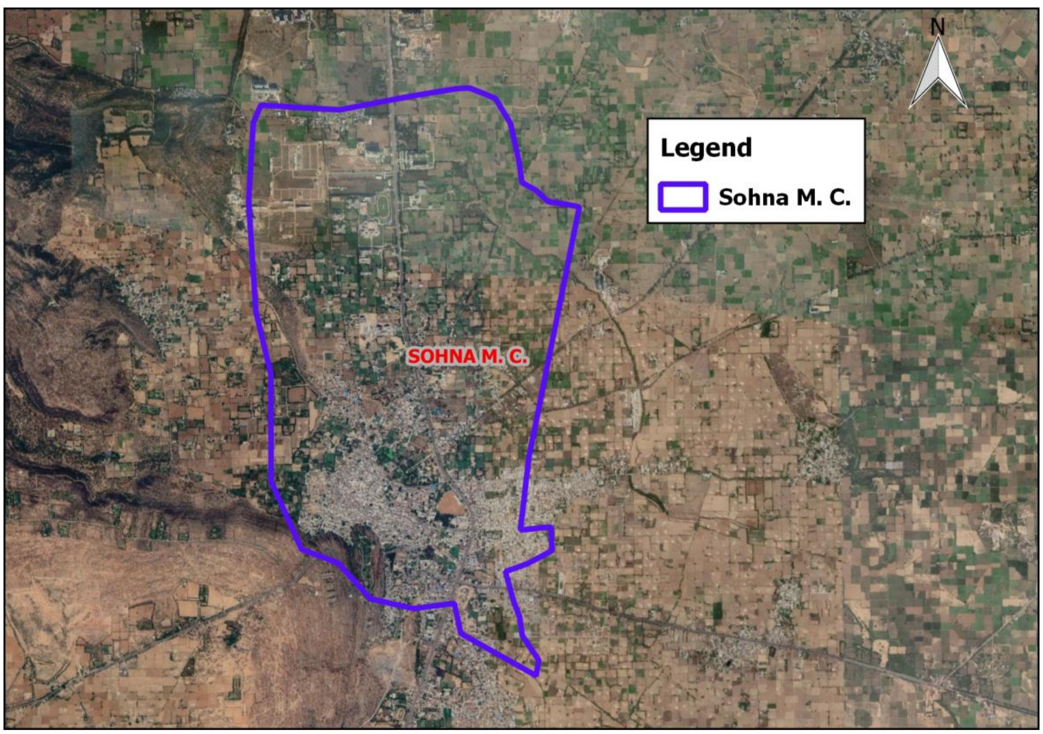


Figure 55: Map of Sohna Municipal Council)

[20] https://ulbharyana.gov.in/municipal-council-sohna.html

[21] https://www.censusindia.co.in/towns/sohna-population-gurgaon-hariyana-800431

7.2 Water Management in Sohna M.C

The drinking water supply and the sewerage network in the Sohna M.C is managed by the Public Health Engineering Department (PHED). The management of the storm water drains and the solid waste falls under the ambit of Municipal Council. Whereas, water for agriculture is the responsibility of Irrigation Department. The council also has a hot water spring called Shiv Kund, which is managed by the Shiv Kund Authority. A semi structured interview was conducted with each of these authorities to gain an in depth understanding of the functioning of each of these departments. A residents' perception survey was also conducted to understand how they view the water management in their town.

7.2.1 Public Health and Engineering Department

PHED Department is the nodal agency to supply water in the Sohna M.C, industrial area and four other villages. The officials during the interview stated that the Water Treatment Plant (WTP) is situated at Budhera. The capacity of this plant is 27 MLD and the efficiency is approximately 60 percent. The water in the WTP comes from the NCR Canal which became operational in 2016. Prior to that, water was sourced from borewells installed in the PHED premises. An abandoned borewell having pump capacity of 10 HP and pipe of 2-inch diameter was seen in the PHED office. Two overhead water tanks which are currently dysfunctional were also spotted in the Sohna M.C area.

Figure 56: Defunct borewell in PHED office, Sohna

According to the information provided by the officials, the number of metered connections in the town are 5091 and the total number of households connected to the sewer are 3301. People are charged for water at a flat rate -INR 360 for six months for metered connection and INR 750 for six months for un-metered connections. The approximate revenue that is generated per month is INR 5,33,000/- (A total of Rs 32 lakhs in 6 months) through the metered connections. The PHED official also informed that around 42 tube wells which were earlier present in the area have been closed. However, these could be utilized as potential locations for groundwater recharge.

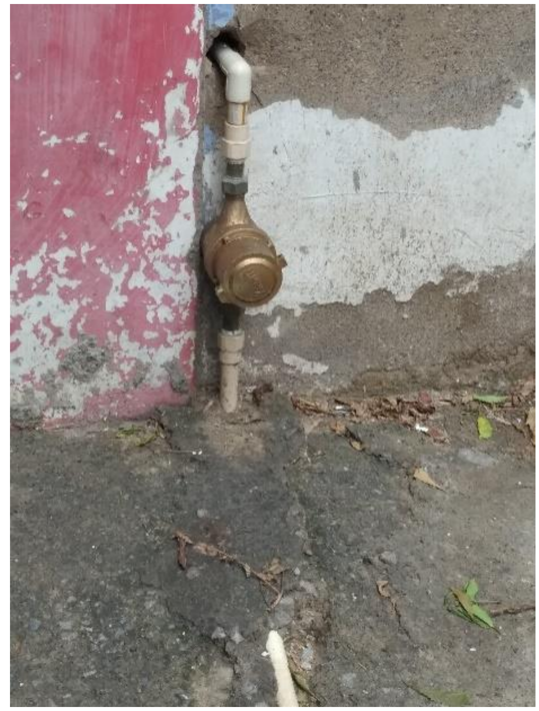


Figure 57: Figure 57 Installed water meter in Sohna M.C

The officials also mentioned that around 23 villages within the MC area are fluoride affected. The wastewater generated in the town is conveyed to a 6 MLD Sewage Treatment Plant (STP), situated at the Indri Road through gravity flow system. The challenges faced by the officials are as follows:

- Low availability of water when NCR channel is getting cleaned
- Challenge of pumping water from the boosting station in the event of failure in the electricity supply

The officials suggested that the stricter groundwater law should be introduced and enforced to address the problem of water stress in the region. They also proposed that the abandoned borewell in the premise of PHED and the rooftop area of 1100sqft can be used for rainwater harvesting. 100% metering and levying charges on volumetric basis rather than flat rate would help in optimizing water use. Also, there appeared an evident need for strengthening of the wastewater network.

7.2.2 Irrigation Department

The irrigation water in the Sohna Block usually comes from the Gurgaon Canal which flows adjacent to the Sohna City. Gurgaon Canal has running capacity of 800-900 cusecs and according the irrigation officials this water is insufficient to meet the irrigated agriculture in the block. The canal is lined and the drains connecting to it are unlined. They also mentioned that the farmers who use canal water do not use fertilizers for the crop due to natural characteristics of the water. The crops grown in the Sohna Municipal Council Area mentioned by the officials were Wheat, Bajra, Jowar, Vegetables like Brinjal, Radish, Paddy and Sugarcane (In some areas which are near to the canal). In ward 7, a landlord was seen practicing drip irrigation in his field though the water that he was using was through the borewell. He mentioned that he is not only able to save water but also the yield of the crop is much better. He has three polyhouses in which he grows vegetables.

Figure 58: Vegetables grown in Polyhouses in Ward 7, Sohna M.C

The officials stated that irrigation techniques such as drip and sprinkler are not popular in areas which are nearer to the canal but farmers who are far from the canal have adopted sustainable irrigation practices. The farmers do not follow the practice of traditional water distribution technique, ‘Warabandi’, because insufficient water supply. Instead, at outlet of each distributary of the canal, a Water User Association (WUA) has been made in which the Junior Engineer and the Patwari are the members on behalf of the government. They further mentioned that the permission for sinking new borewells for irrigation purposes must be taken from the Block Development Office (BDO).

7.2.3 Shiv Kund Authority

The ancient Shiva Temple also known as Shiv Kund is more than 500 years old. It has a hot spring which was built in 1576 BC. Kund water was used for supply to old city area of Sohna before 2016. People visit this holy place since it is believed that the water has healing power. Kund no longer gets naturally recharged and has to be filled using water drawn from the borewell. During winter, which is also the peak season (November-March), the worshippers are permitted to take bath in the Kund. Cleaning of the Kund is undertaken on a regular basis. The Pradhan, Shiv Kund Raksha Committee mentioned that the hot water is spread over a radius of 1 km around the Kund. The Kund is divided into two sections- the Thanda (Cold) Kund and the Garam (Warm) Kund. In the Garam Kund, water comes from a storage (original Kund) having Sulphur water. In winters, the water from borewell connected to the Kund is used to meet the excess demand of the worshippers.

Figure 59: Shiv Kund, Sohna M.C

7.2.4 Municipal Council

The storm water drains in Sohna M.C as stated by the officials are cleaned on contractual basis. The cleaning of drains is done both manually as well as mechanically. The drains were found to be in bad condition and few of them were chocked in different sections. Also, it was found that drains near Friends Colony were overflowing on the roads. In ward no.7, residents complained that the solid wastes removed from drains were left on the sides of the road.

There is no waste segregation at source and the solid waste separation is done at the dumping site. The waste collection is done by 8 trucks out of which Sohna M.C owns 1 and 7 are owned by private contractors. It was found that the trucks ply on the main roads and do not collect garbage from the lanes. In areas like New Friends Colony, Baruda Road it was quite evident that people are dumping their household wastes on nearby vacant plots. The officials mentioned that Sohna M.C is planning to keep big size dustbins on main roads where people can dump the waste and thereafter collection can be done by trucks. Institutions like schools and colleges are responsible for dumping their own wastes. The dumping site is on Sohna-Alwal road which is a temporary dumping station. Waste recycling at any point is not happening at the moment.

Figure 60: Solid waste from the drain after cleaning is left on the road near Shiv Kund

7.3 Public perception of water management in Sohna M.C

An in-depth questionnaire survey on water and wastewater management including public perception of rainwater harvesting was carried out with 50 respondents in three main locations namely Shiv Kund Area, Civil Hospital Area and Ward 7 of the Sohna M.C. The respondents mentioned that the water is supplied twice in a day for one hour in the morning and one hour in the evening. The water is stored in the private overhead tanks. Only a few households stated that the quality of the water is good but often has a peculiar smell. Others said that it is not potable. Most houses meet their drinking water requirement either through treating the PHED supplied water using Reverse Osmosis (RO) filters or buy water. No private rainwater harvesting structures were seen in the village.

7.3.1 Water and wastewater

About 77 percent of the respondents mentioned that they are connected to the utility and get water from the PHED on tap. However, 13 percent of the respondents did acknowledge having private borewells in their house. The domestic water source details are shown in Figure 59.

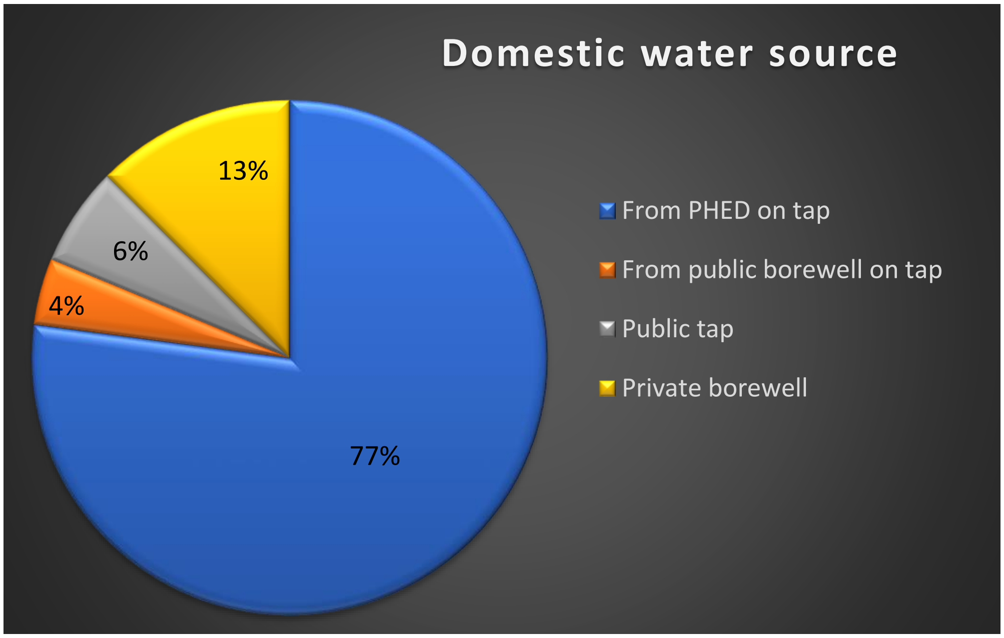


Figure 61: Domestic water source in Sohna M.C

The satisfaction of the water supply by the PHED was assessed by asking the respondents to rate the quality of water, pressure, billing system, maintenance services and reliability on a scale of 0 to 5 with '0' being poor and '5' being excellent. Majority of the respondents rated the service between poor to average. They especially were concerned about the pressure as not everyone could afford a private pump to fill their overhead tanks.

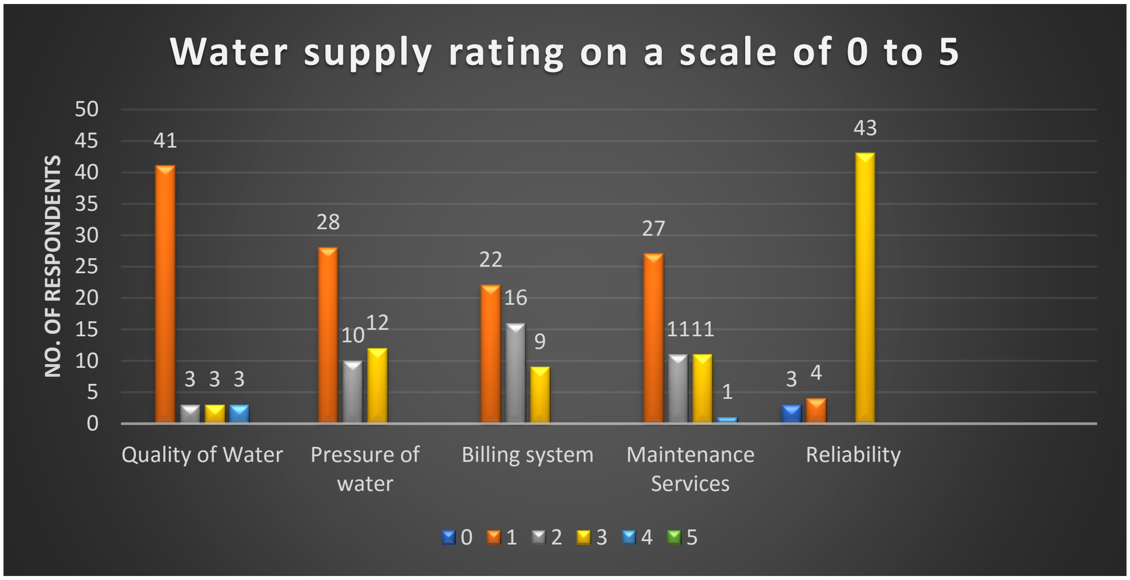


Figure 62: Water supply rating by residents in Sohna M.C

The views of the residents were also collected on the water tariff system. 70% of the respondents mentioned that they pay the water bills regularly. However almost the same percentage of people mentioned that they do not have water meter installed in their houses. Close to 30% of the respondents were unaware of the prevailing tariff system.

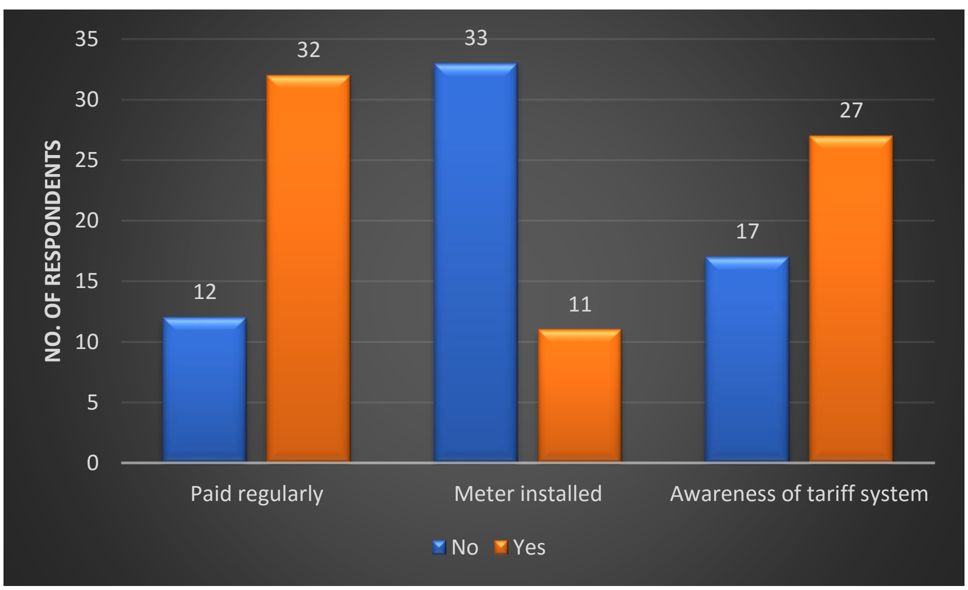


Figure 63 Residents' opinion on water billing, Sohna M.C

Most houses in Sohna M.C had toilets. Only a meagre 4% of the floating populating living in the slum area mentioned that they do not have access to functional toilets.

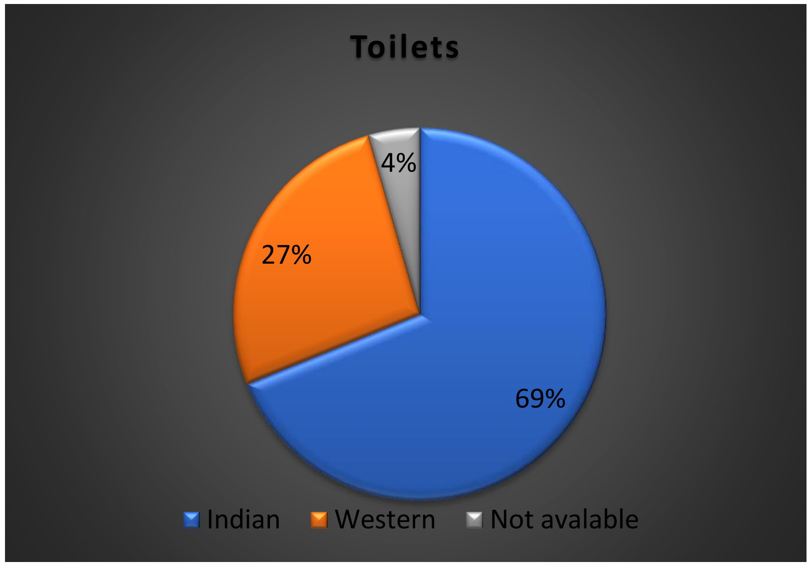


Figure 64 Access to toilet, Sohna M.C

Almost 75% of the respondents mentioned that their wastewater goes into the central sewer network. The houses do not have dual pipeline system and currently, the wastewater is not being reused.

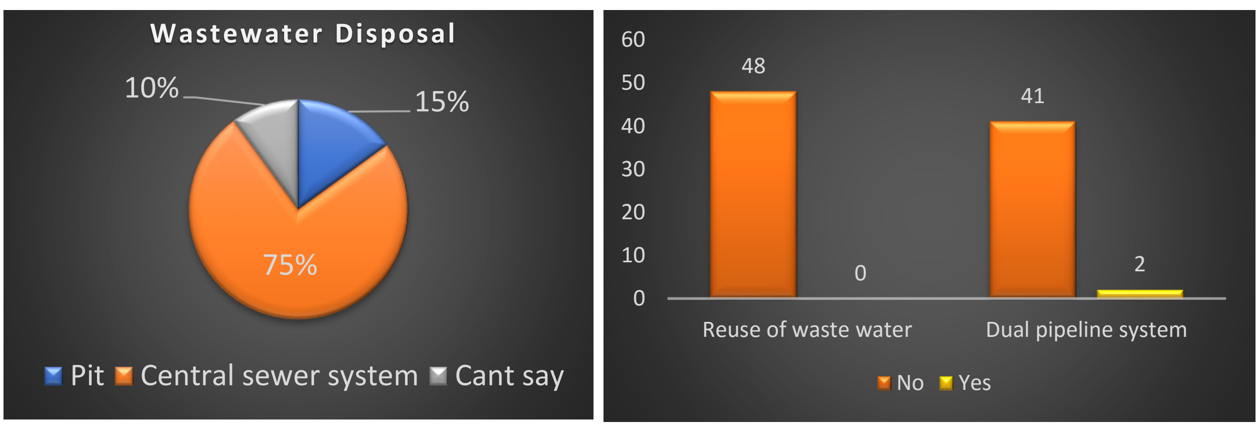


Figure 65 Wastewater disposal and reuse

7.3.2 Solid waste

Only 20% of the respondents mentioned that there is home collection for the solid waste. Almost 40% of the respondents said that there is no waste disposal facility and they throw the waste in the nearby open space (Figure 64). 67% of the respondents mentioned that the waste collection is done by the government (Figure 65). Only 10% of the respondents mentioned that they segregate waste prior to disposal (Figure 66).

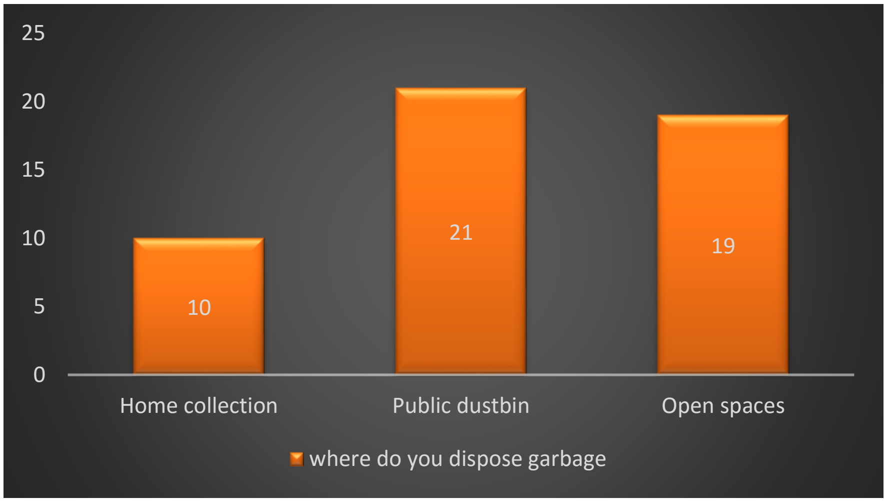


Figure 66 Waste disposal, Sohna M.C

Figure 67 Waste collection in Sohna M.C

Figure 68 Waste segregation at source, Sohna M.C

7.4 Recommendations

7.4.1 Rainwater Harvesting System

The proposed rainwater harvesting consists of a system of rain chains[22] connected to rooftop and rain channels. The rain channel will be levelled such that it shall collect water from floor area and reservoirs of PHED compound. The rain channels will be connected and will have the outlet at a sand gravel filter surrounding the current bore well. The sand filter will help in removing the impurities and dirt from the rainwater. Rainwater will then be injected in the borewell for groundwater recharge.

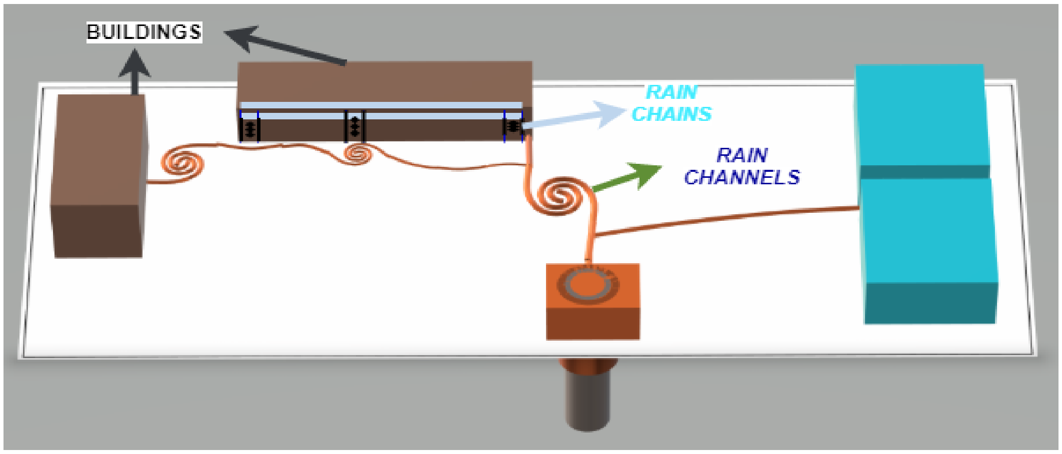


Figure 69 3D view of plan of rainwater harvesting system

7.4.2 PHED

The PHED office in Sohna has two reservoirs and a large green space area with high potential for rainwater harvesting with area of 1100sq ft. There is also an abandoned borewell in PHED compound, and PHED has 2 underground tanks of 1 Million litres capacity each.

[22] ***Rain chains***- they are widely used in japan and locally known as Kusaru-toi. They are used as an alternative to downspout.

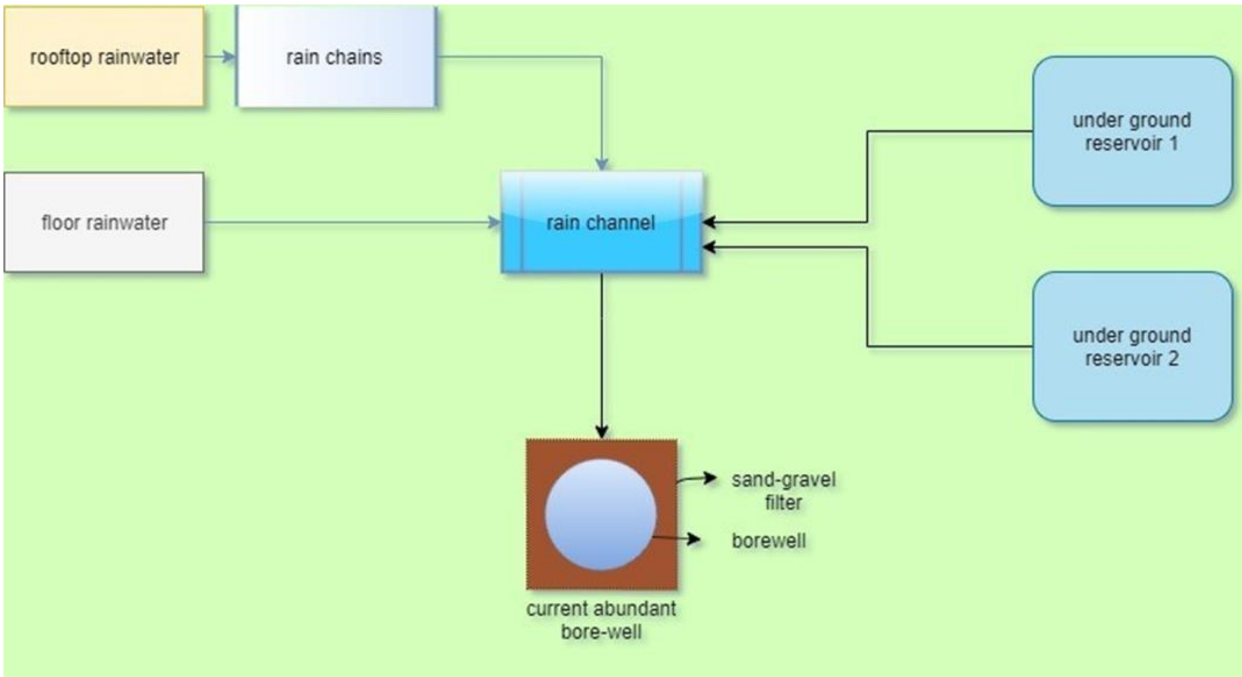


Figure 70 Proposed floor plan for PHED

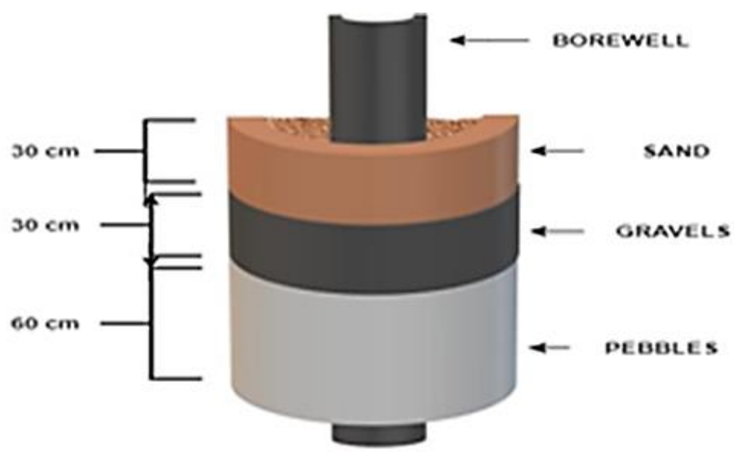


Figure 71 Design of sand filter for borewell

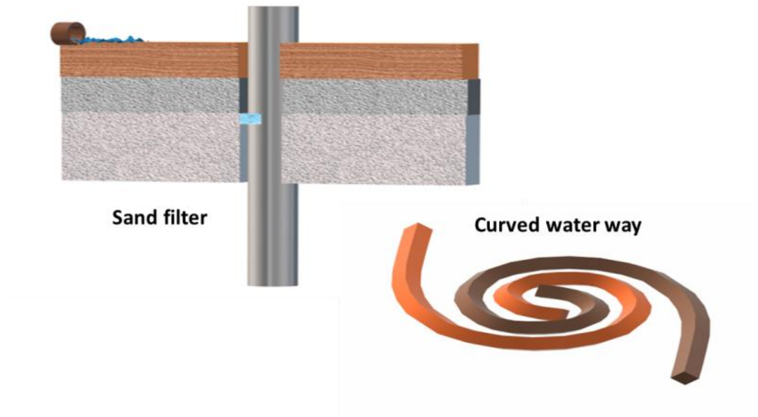


Figure 72 Components of RWH for groundwater recharge

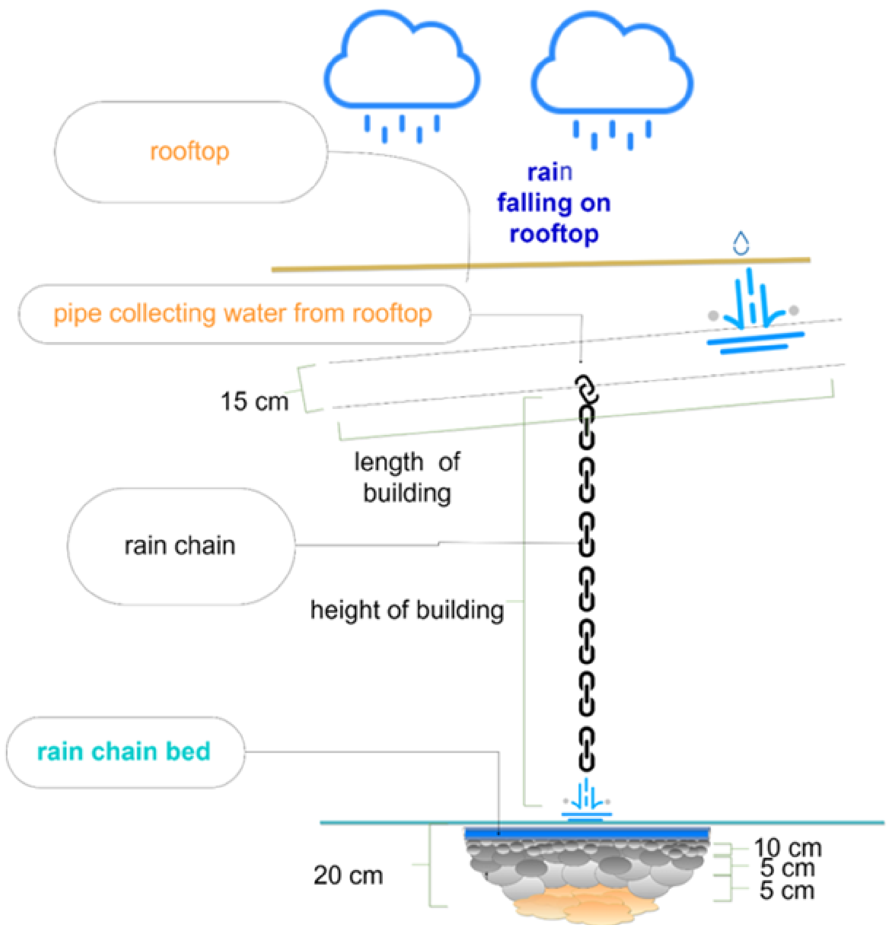


Figure 73 Components of a rain chain system

7.4.3 Civil hospital, Sohna M. C.

Civil hospital lies in the middle of Sohna MC. They have three RWH structures but official records in the MC office shows only two. The outside storm water drain comes into the hospital park where the RWH structures are made. But due to poor design and maintenance of these structures, they are ineffective now. In addition to that, outside water also brings in solid waste into the premises of Civil Hospital. In order to deal with this issue a system of rain garden is proposed.

The rain garden will be 125m long along the boundary of civil hospital and the road adjacent to it. The concept of rain gardens was engineered to mimic the original process for water movement. They originated in 1990 in Prince George's County, Maryland, where developer Dick Brinker had an idea to use them in place of traditional retention and drainage systems in a new subdivision. A gravel path will be provided at the opening of the storm water drain. The gravel path will reduce the velocity of the water and also help in filtering out the plastic waste, leaves etc. Then a depressed garden will be made to retain water for longer period of time which will also help in ground water recharge. For the excess water from the rain garden, a levelled path will be provided to the existing rainwater harvesting structure. On the sides of the channel bed *Tulsi* plantation is recommended to add a cultural context to the system (Figure 72 and Figure 73).

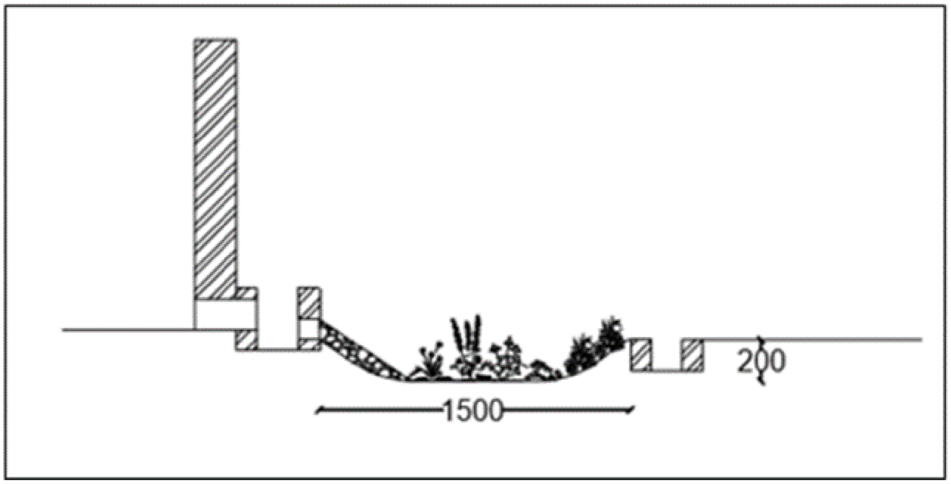


Figure 74 Proposed rain garden (View 1)

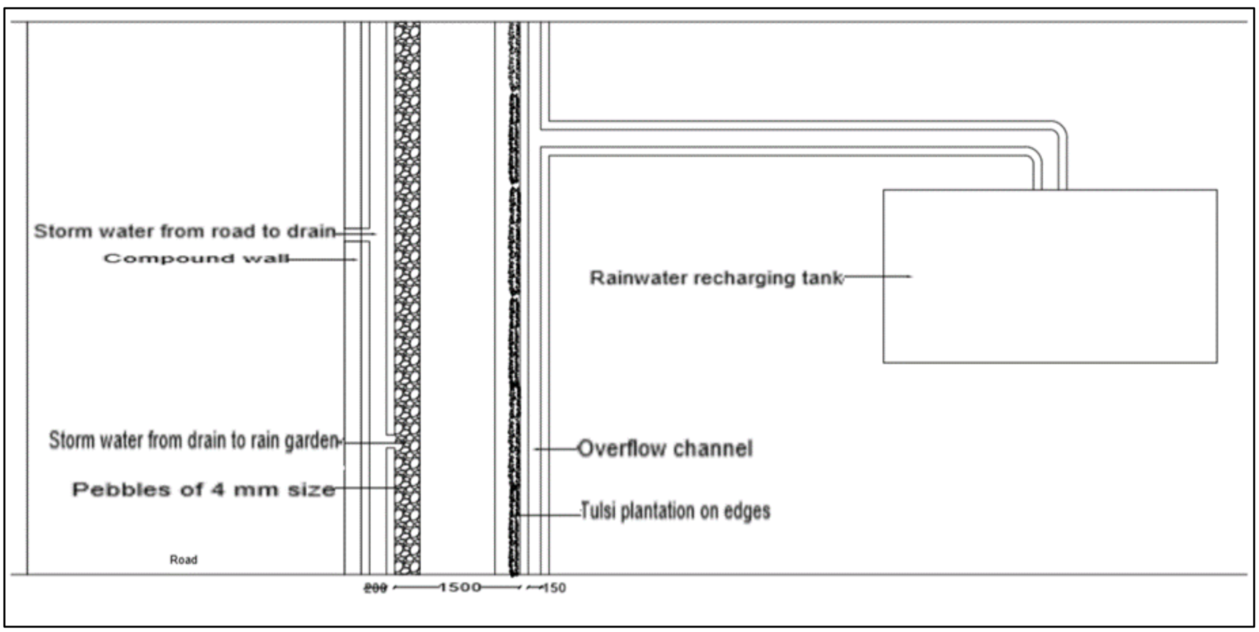


Figure 75 Proposed rain garden (View 2)

7.4.4 Pre-paid electric water meter

Conventional water metering has a tendency of being unreliable, inaccurate, and a source of dispute and disquiet among customers, and hence it is considered to be one primary reason why water service providers perform poorly and have very low revenue collection figures. The result of this poor performance spirals into poor management, ineffective maintenance, inaccurate billing and high non-revenue water. The current water metering systems are post-paid. Water authority sends its workers to customer's locations to read water meter units. The system is time consuming to the corporate workers. The system does not give the accountability to customers. Various studies showed that although communal prepaid metering can potentially improve the quality of water service provision and also enforces a sense of water use efficiency on the part of consumers because the water user must settle their water bills in advance. As outlined by Schnitzler (2012), the first prepaid meter was developed in the 1980s by South African electrical engineer Peter Clark, due to the widespread anti-apartheid rent boycotts that were prevailing in the South African townships. The financial problems that were caused by the non-payment of municipal services necessitated a technical solution to the problem. This led to the invention of the prepaid meter. In India the cost for these digital meter ranges from 5000 to 6000 rupees and are available in the market.

7.4.5 Green Corridor for rejuvenation of Shiv Kund spring, Sohna M. C.

Shiv Kund is a historical hot spring in the Sohna M. C. (Figure 8) and efforts needs to be taken to restore and rejuvenate the spring. This measure in turn requires that Aravallis have forest cover so that it may guide the rainwater through the faults and fissures in the metamorphic rocks.

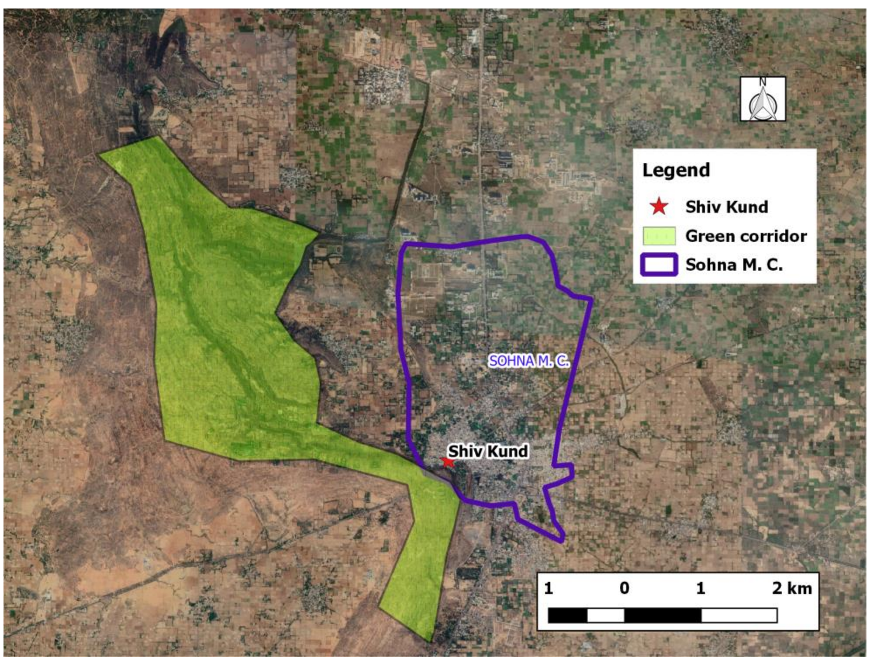


Figure 76 The proposed green corridor along Aravallis near Shiv Kund

The current status of the hot spring is such that it yields very little discharge from the month of November onwards and it almost dries up during the summer. Typically, as per Meinzer's classification of springs as shown in Table 11), the hot spring may be classified to have an order of magnitude 5th originally; however, currently, it may be restored into at the most of the order of magnitude 6th and efforts may be made to restore its properties as a perennial spring from its current status as seasonal spring.

Table 11 Classification of Springs by Discharge (after Meinzer)

Magnitude	Mean Discharge
First	>10 m^3/s
Second	1-10 m^3/s
Third	0.1-1 m^3/s
Fourth	10-100 l/s
Fifth	1-10 l/s
Sixth	0.1-1 l/s
Seventh	10-100 ml/s
Eighth	<10 ml/s

(Source: Groundwater Hydrology, Todd)

The Pradhan of Shiv Kund Committee reports that in the past, water from the hot spring would naturally come to the Kund area on its own; however, gradually the spring dried up, hence, recently, they have installed borewell to pump out this water. It concludes that the discharge is very low, and the spring is on the verge of depletion (A few years back, the spring had dried up fully in the absence of borewell).

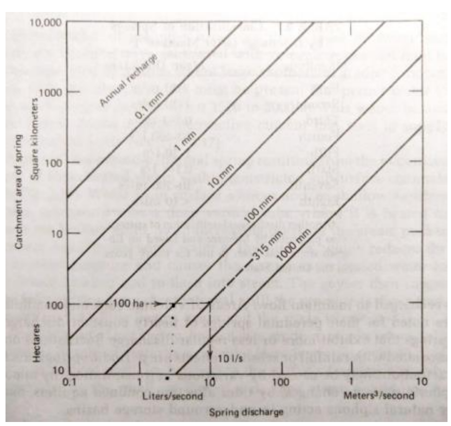


Figure 77 Relation of catchment area and annual recharge to average spring discharge
(Source: Groundwater Hydrology, Todd)

Following Meinzer's method as shown in Figure 77 of estimating spring discharge from the annual rainfall and catchment area of the spring necessary to restore spring discharge of 0.9 lps, the catchment area that needs to be maintained with sufficient green cover is shown below.

For estimation of mean spring discharge, Q=**0.9 l/s**

Rainwater available on annual basis for recharge in a semi-arid area like Sohna M. C. may be assumed as r=**225 mm.**

Accordingly, the spring catchment area required will be A=**33.5 hectares (335000 m^2)**

In order to achieve this, the green corridor width of 200m must be maintained upstream of the spring (**b =200m).** At many places, it is no possible to maintain 200m width as severe erosion has taken place. Thus, the length of the protected forest to be maintained in the Aravalli ranges would need to be 9 Km (**l = 9.0 Km**).

Needless to mention, more the hill area that is preserved, more will be the groundwater recharge which will help the entire Sohna Block as a whole. Hence, around **9 km** of Aravalli hill near Shiv Kund must be declared as green corridor where no construction activity should be allowed.

7.5 Water Budget Model

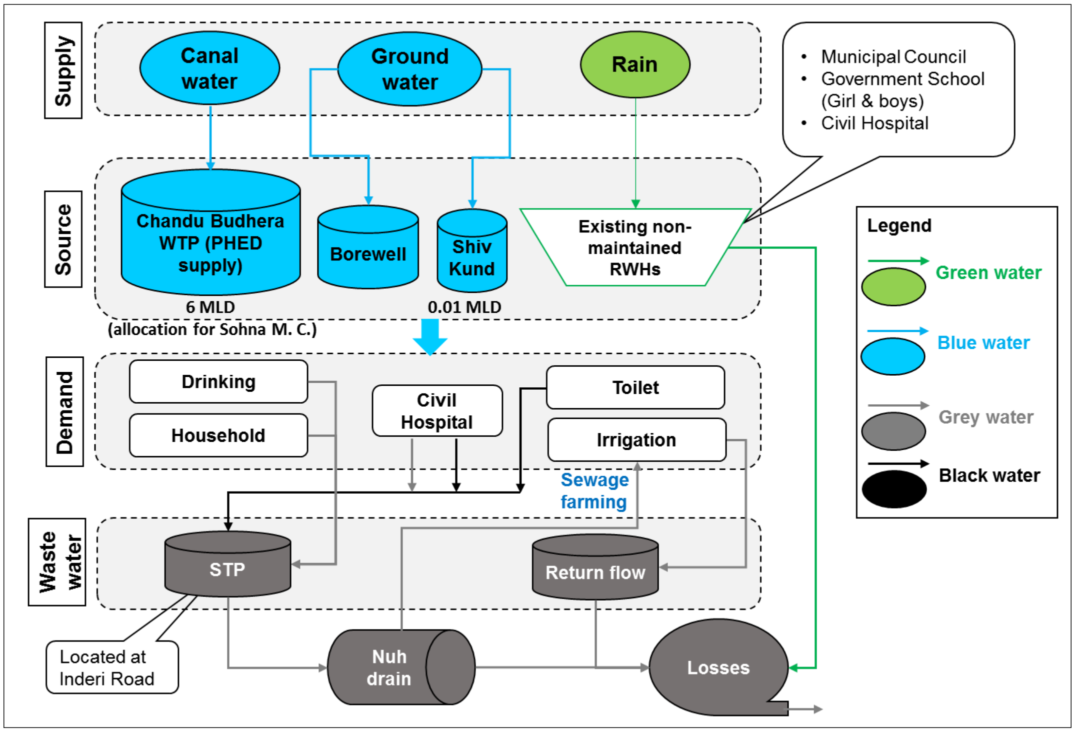


Figure 78 Current Water Budget Model, Sohna M C

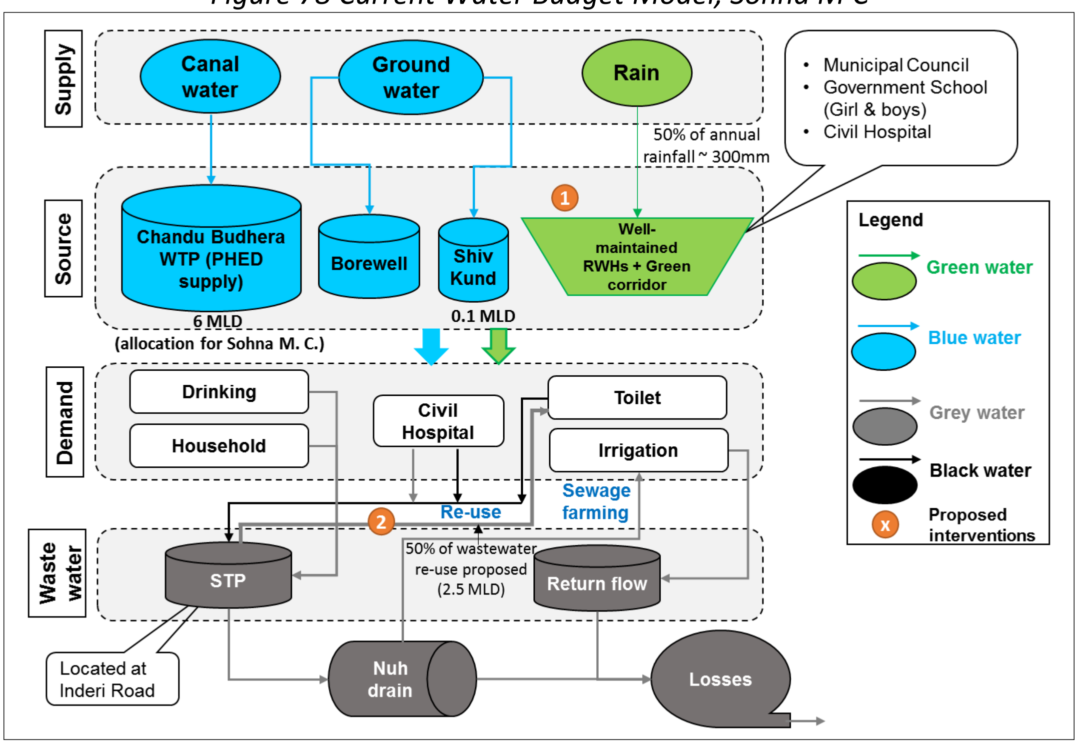


Figure 79 Sustainable Water Budget Model, Sohna M.C

8 Case Study of an Urban Village- Ullhawas

8.1 About Ullhawas

Ullhawas is located in Sohna Tehsil in peri urban Gurugram (Figure 80). According to the Census 2011, Ulhawas village had a population of 2284 in 329 families. However, as per the information provided by the Sarpanch the village now has 350-400 households and a population of approximately 4000[23]. The village has seen a surge in the population in the last decade due to rapid urbanization as shown in the change in the land use in Figures 13 and 14 (Landuse 2008/2016) in Chapter 3. The average sex ratio of Ullhawas village in 2011 was 854 which was lower than Haryana state average of 879. Ulhawas village has higher literacy rate compared to Haryana. In 2011, literacy rate of Ulhawas village was 81.43 % compared to 75.55 % of Haryana. In Ulhawas Male literacy stood at 90.42 % while female literacy rate was 71.02 % as per the 2011 census. The major castes in the village are Gujjar, Harijan, Chamar, Valmiki and Chooda. The village has about 15-20 farmers there is very little farmland available. Income generation is mainly through rental though there are a few carpenters, milkmen, drivers, shopkeepers and advocate.

Figure 80 Location map of Ulhawas (Source: Google Map)

[23] Data as shared by the Sarpanch of Ullahawas

8.2 Water and Sanitation

The major source of household water continues to be from private borewells though PHED supply through four government borewells, installed one each in Anganwadi and temple and two in the PHED premises, is also there in the village.

Figure 81: PHED Water Supply Premise in Ullhawas Village

Rainwater harvesting (RWH) and groundwater recharge structures are constructed only in the two schools - the Government school and the Heritage School. There is no evidence of RWH being practiced in the village.

Figure 82: Rainwater Harvesting Structure in Government School, Ullhawas

The livestock would earlier drink water from the Johad near to the temple but now as it is polluted, household water is used for them as well. The village has drains which are blocked at various places due to indiscriminate disposal of waste. The sewer line from the village is connected to the main HUDA sewer network. All houses in the village have toilets. There is no proper system for solid waste disposal and no penalty for littering. The sarpanch has employed six people to help in waste collection from pits and for transferring it to Bandhwari. Dengue, Cancer, Diarrhea, Typhoid, and Kidney Stones are the major diseases. The number of cases of Kidney stone has risen due to high TDS in the water.

Figure 83: Clogged drain and garbage disposal in Ullhawas Village

8.3 Public perception of water and sanitation

A public perception survey was conducted with 31 households of Ullhawas village. Purposive sampling was done in order to capture the views of all castes living in the village. It was found that only 13% of the respondents used water from the PHED supply for domestic needs. 83% of the respondents had private borewells. There were no public tap/stand posts in the village (Figure 78).

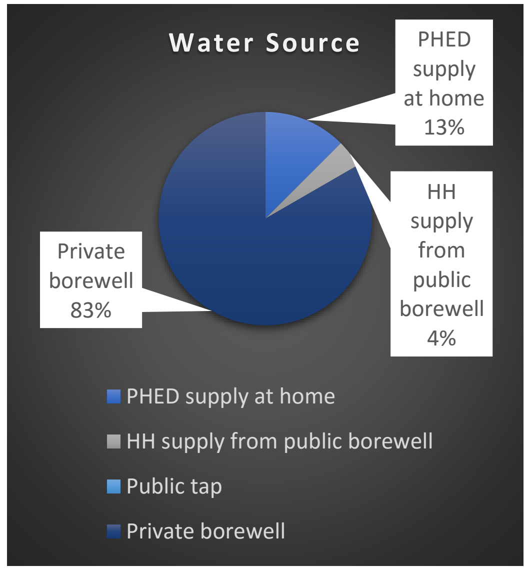


Figure 84 Source of water, Ullhawas

Public opinion was also taken on their satisfaction with the borewell water. People were generally found to be satisfied with the water they use from the borewell. A few of them complained about foul smell from the water. However, 61% of the respondents mentioned that the water is saline (Figure 79). Most households have RO installed and treat water before consumption.

The household water consumption was estimated by asking the total number of buckets of water being consumed in the house, assuming that a bucket has a capacity of 20 litres. The average consumption per household per day found in the survey was 22 buckets or 440 litres. However, this ranged from 1000 litres in bigger households to about 100 litres among migrant population. Assuming average number of members in a household to be 5-6, the approximate consumption per capita per day is 75-80 litres. The depth of borewell ranged from 200 feet to 300 feet.

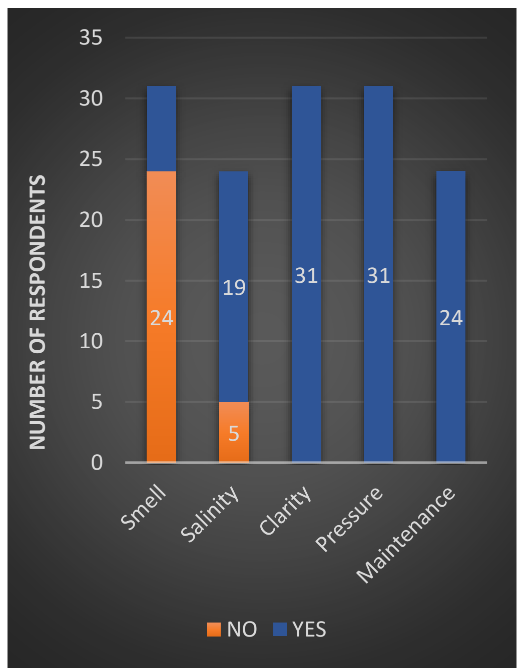


Figure 85 Household satisfaction with borewell water

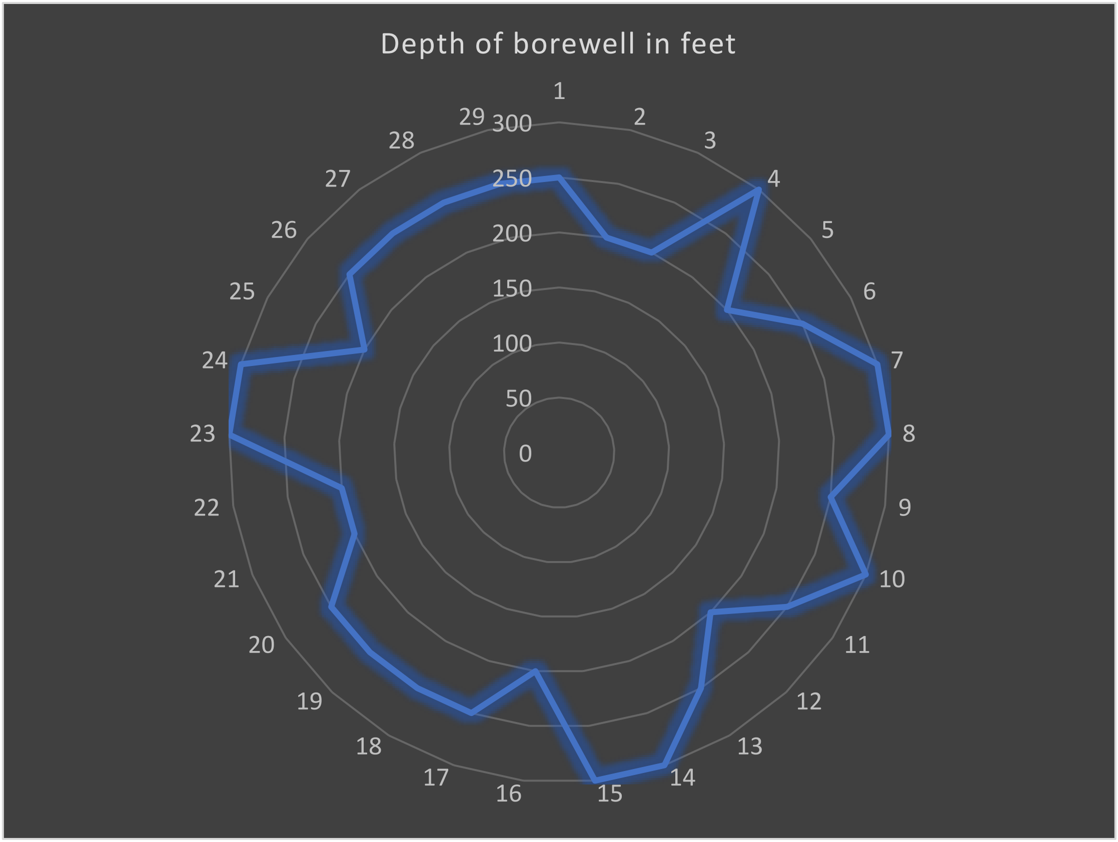


Figure 86 Depth of borewells in feet, Ullhawas

Awareness about rainwater harvesting was also assessed during the survey. There were no residential RWH system installed in the village and 66% of the respondents were not aware of rainwater harvesting. Only two respondents out of the total of 31 mentioned that they have been deliberating on installation of RWH system.

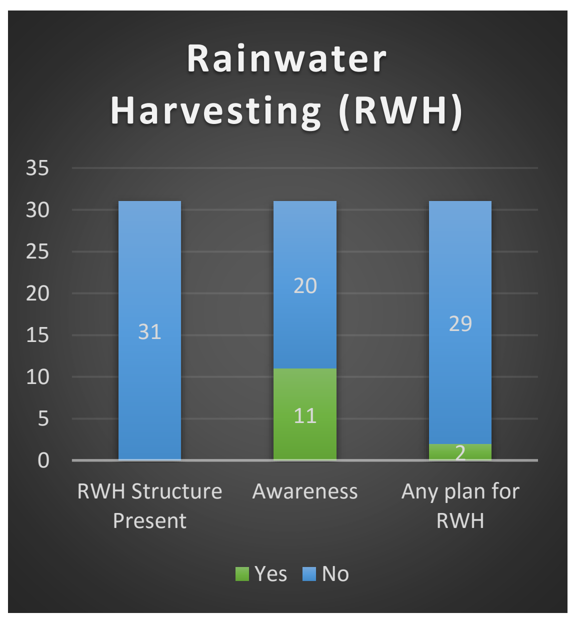


Figure 87 Perception about rainwater harvesting

70% of the households interviewed mentioned that the household sewage line is connected to the central sewer.

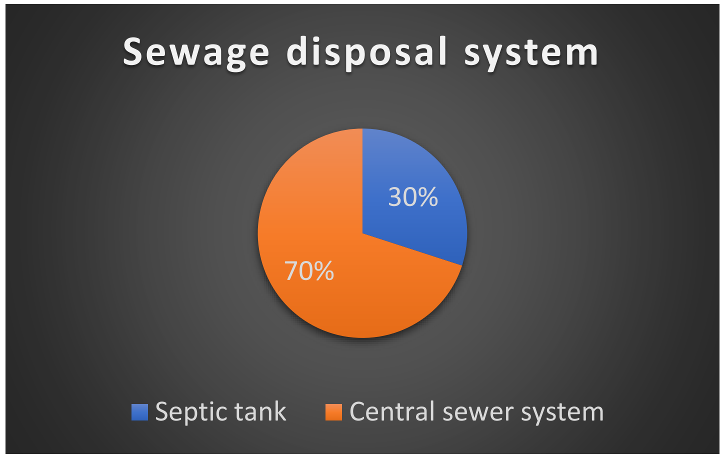


Figure 88 Sewage disposal system, Ullhawas

People were also asked about their perception of water stress in the region. The stated that the problem of water has started in recent years. However, when asked about their willingness to invest in the rainwater harvesting system to address water scarcity, 100 % of the respondents were unwilling if it required monetary investment.

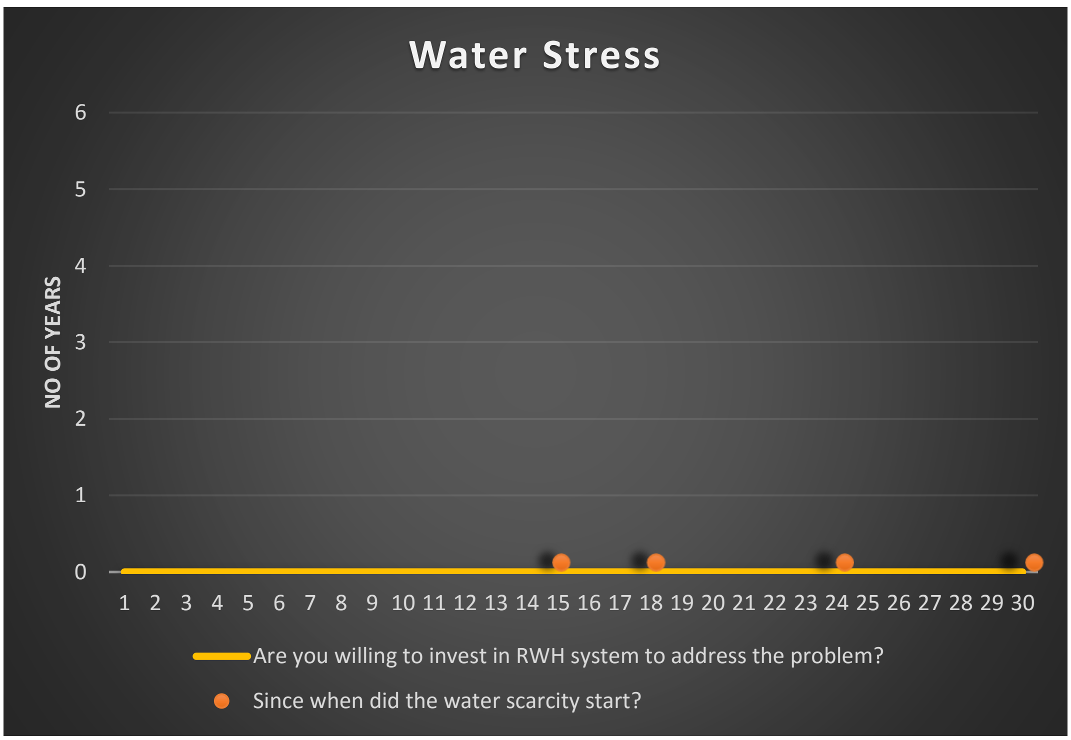


Figure 89 Resident perception of water stress

It is suggested that RWH structure be installed in the local Anganwadi through the rain chain system and the same may be used to recharge the groundwater through the abandoned well located within the premises of the Anganwadi. The reason behind this recommendation is that it shall be possible to monitor the level on regular basis by the authorities. The recharge of in-use borewells is also suggested as there are quite a few of them in the village.

8.4 Rainwater Harvesting & Groundwater recharge

There can be 2 types of recharge mechanism depending on the status of wells (in-use or abandoned). The well which is still functional will be having a more complex structure for more filtration then the well which is abandoned with a minimal level of filtration system. For abandoned bore well, the same model for recharge can be applicable as we proposed in PHED in Sohna M. C. The system has three stages as explained in Figure 84.

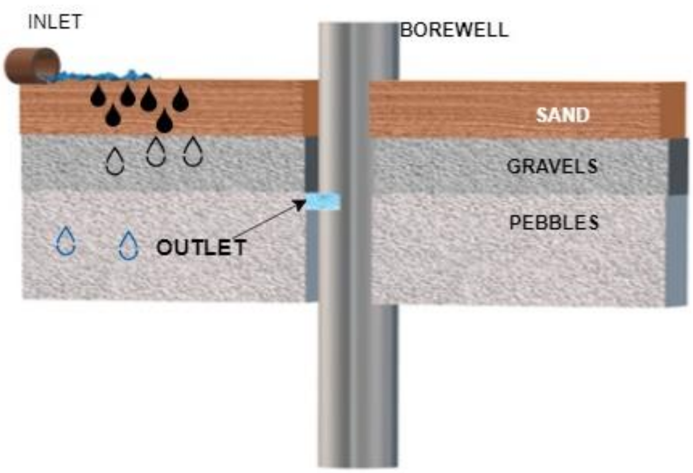


Figure 90 Abandoned bore well system

A representative flow diagram is shown in Figure 85 for Anganwadi compound in Ullhawas.

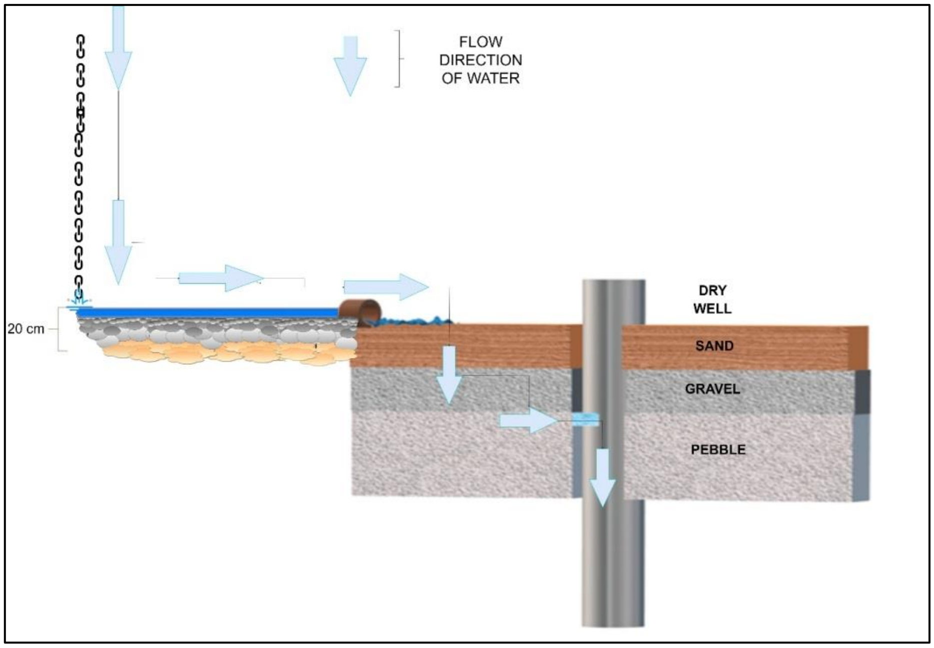


Figure 91 Proposed groundwater recharge system for Anganwadi (rooftop area: 100sq.ft), Ullhawas

For any in-use borewell, a more complex system of filtration needs to be adopted to achieve maximum level of filtration. Figure 86 shows a detailed sketch of filtration system for recharging of any existing borewell in-use.

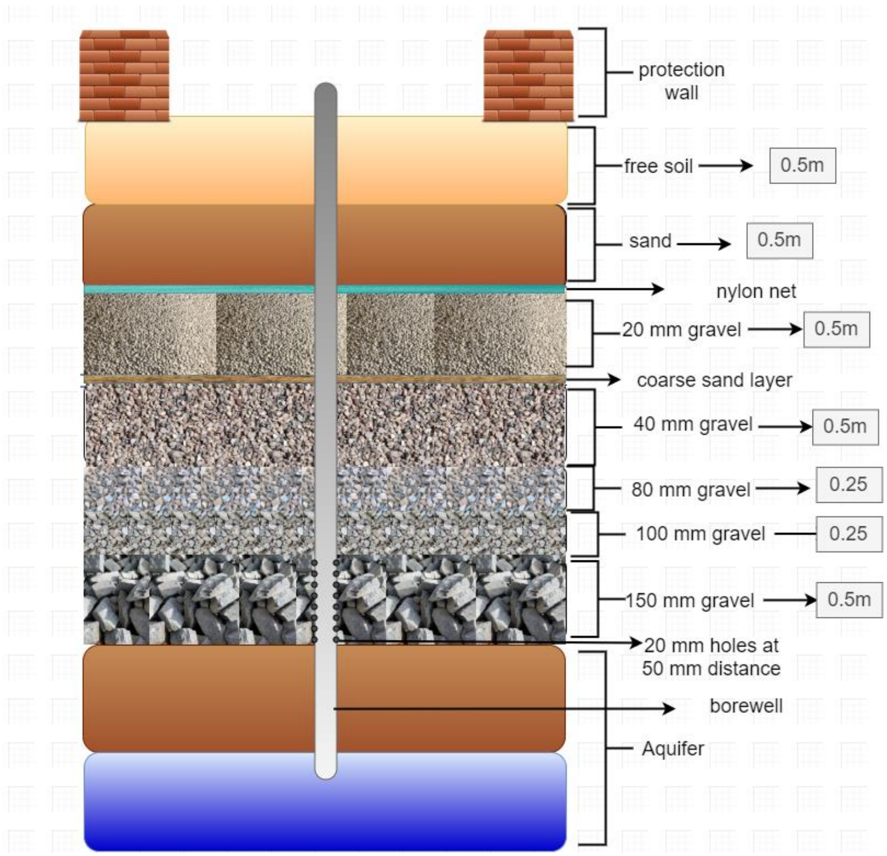


Figure 92 Detailed cross-section sketch of a filtration system for recharging in-use borewell

8.5 Water Budget Model

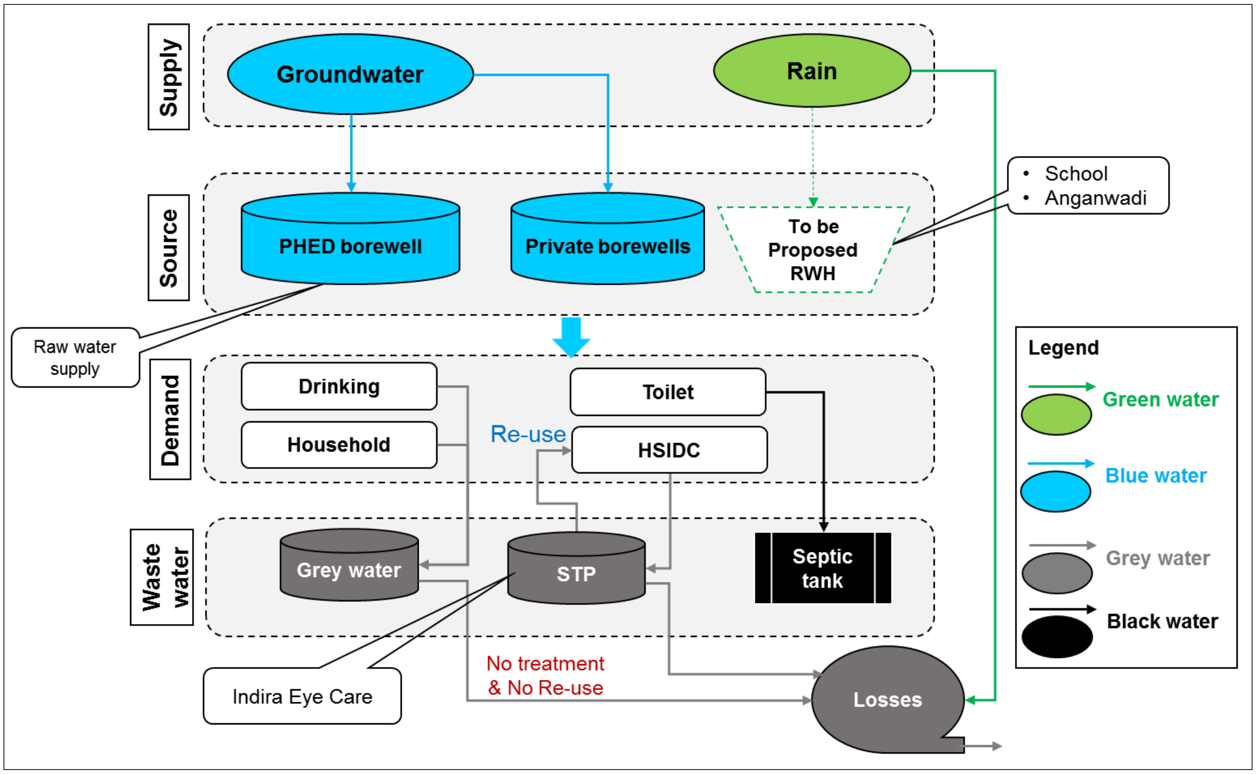


Figure 93 Current Water Budget Model, Ullhawas

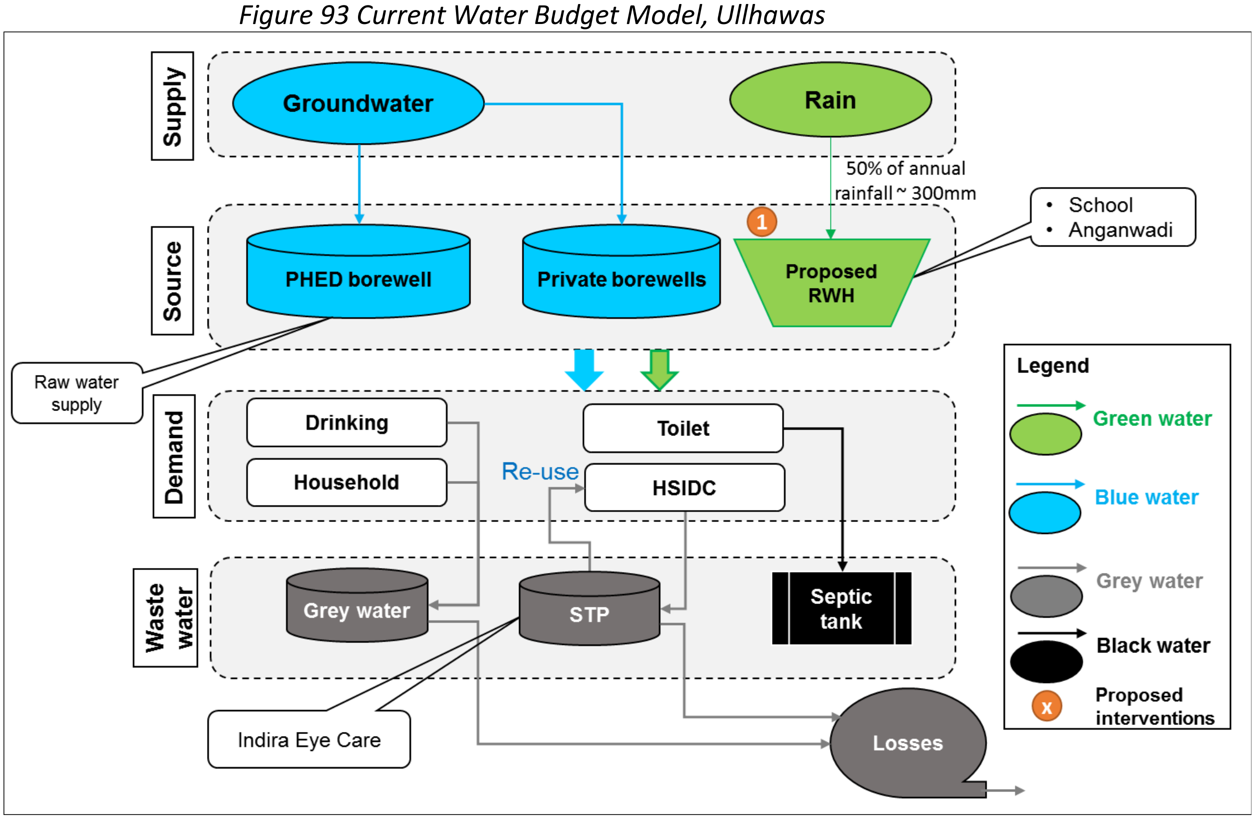


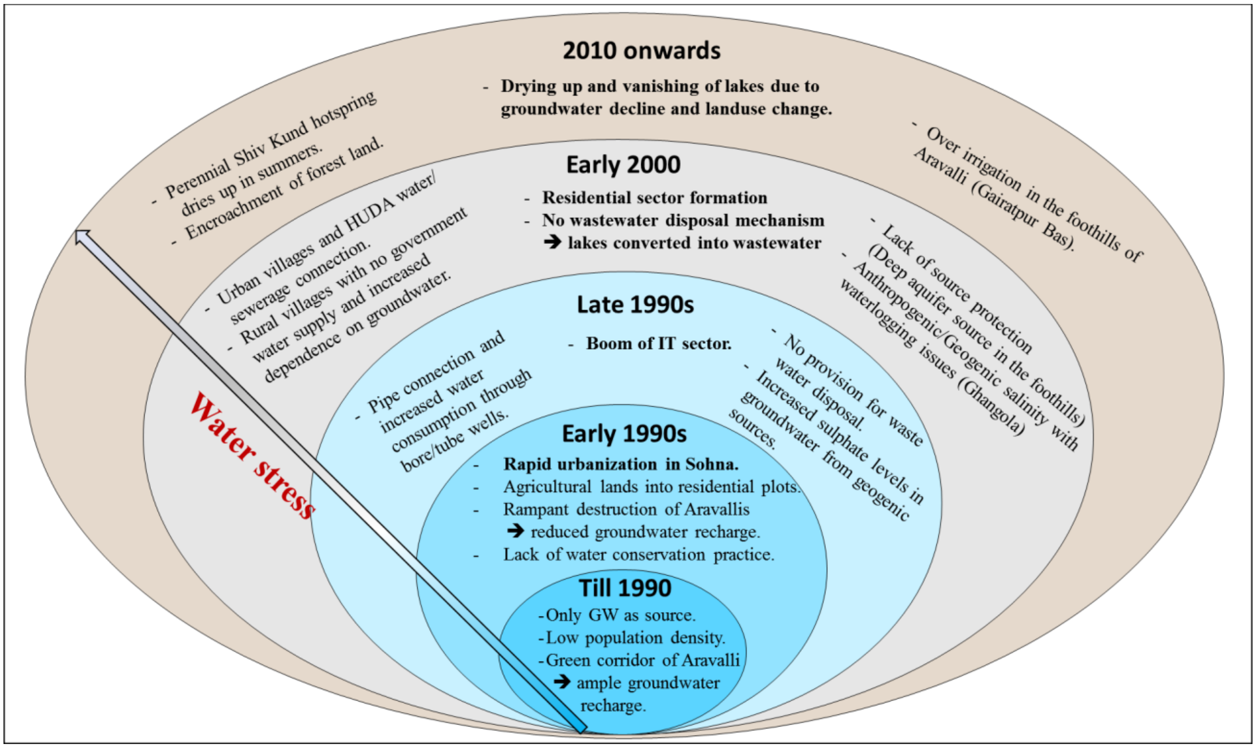
Figure 94 Sustainable Water Budget Model, Ullhawas

9 Conclusion

The water footprint of urban areas is increasing and Sohna block is no exception. Large volume of water is being consumed in urban areas which have high population density which leads to generation of large volume of sewage and grey water within a small area which is not being treated effectively. The Sohna block lies in the semi arid region of India which has less than 30 rain days and is naturally water stressed[24]. The area was always dependent on ground water but increasing population has reduced the quantity of water available in shallow and deep aquifers even further. Besides, the ground water quality is compromised because the deeper parts of the aquifer contain sulphates being added by the metamorphic rocks of the Aravallis. Hence, drawing water from depths greater than 60 m yields water with high total solids (TSS/TDS). The shallow aquifers in some areas are contaminated by untreated wastewater.

Gurugram is a rapidly urbanizing city and an emerging IT hub with good transport connections with other cities within the NCR region. The continuous aquiring of agricultural land for real estate development has led to rapid change in land use pattern. The severe loss of green forest cover of the Aravallis is also a result of this real estate development.This has led to decrease in ground water storage and recharge as the catchment area which replenishes it has been urbanising. The issue gets exacerbated with the shrinking of green cover, degradation of the Aravallis and soil erosion on the hills.

[24] India Meteorological Department



The River Yamuna, the primary source of water supply in the Gurgaon district has also been overexploited and sourcing water from it may not be a sustainable option in the long run. Ground water replenishment is recommended in the suggested locations with minimal technical innovations so that rejuvenation can happen naturally and effectively. Besides, treatment of grey water prior to discharging into Johads is also recommended so as to reduce the pressure on groundwater usage. In the areas affected with soil and ground water salinity issues, there is a need for paradigm shift in the cropping pattern. There are multiple government schemes and subsidies for promoting technological interventions in that effect (Appendix A1). Further, sustainable water budget models have been proposed for all the three regions under study.

Summary of Interventions

Figure 95: Proposed recommendations within Sohna Block portrays the spatial pattern of suggested recommendations for Sohna block. The recommendations are categorized mainly into: a) Urban/peri-urban villages; b) Foothills of Aravalli; and c) Saline affected villages.

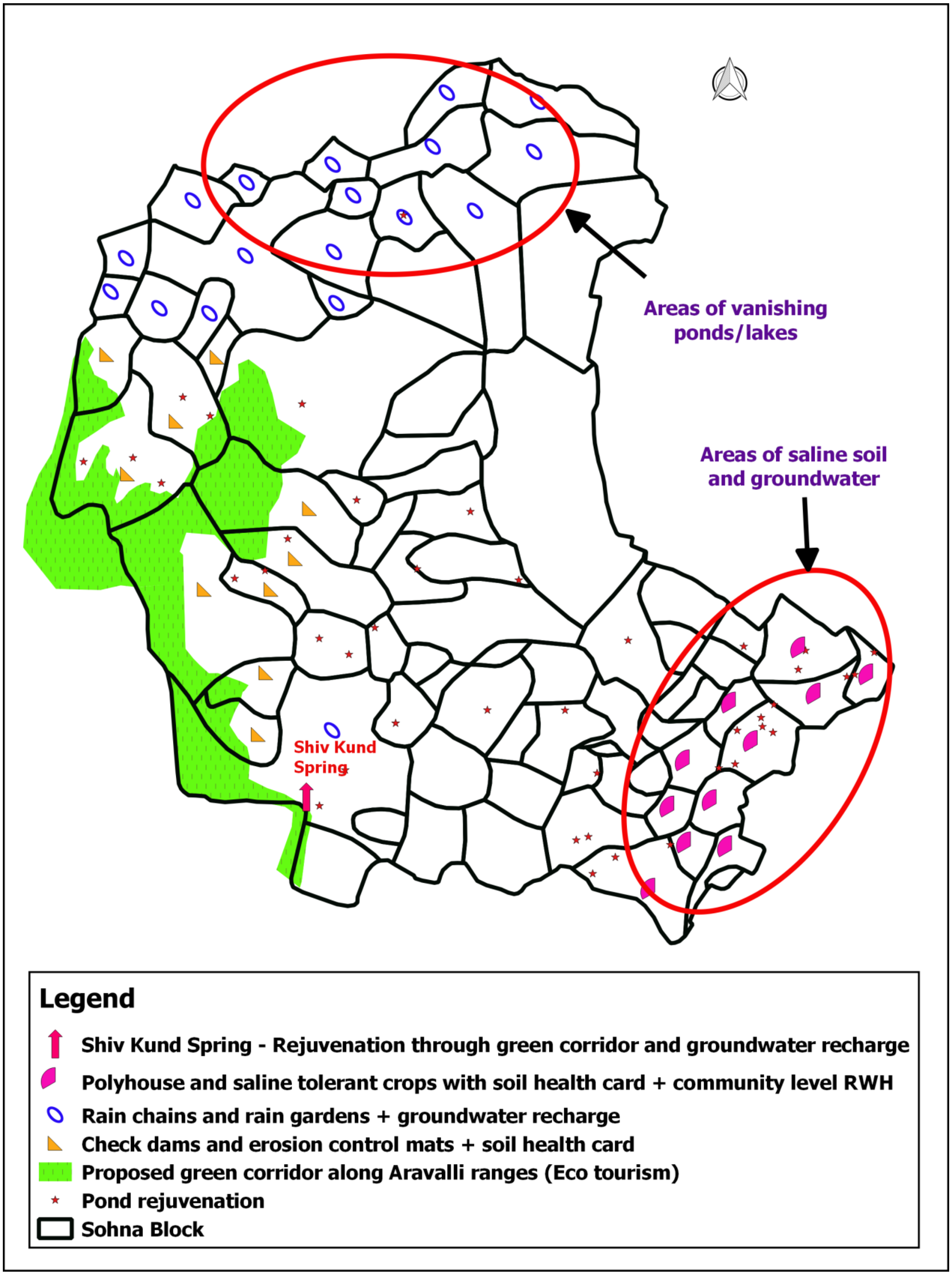


Figure 95: Proposed recommendations within Sohna Block

Table 12: Categorisation of villages based on recommendations

Foothills of Aravalli	Urban Villages	Saline affected villages
1. Gairatpur Bas	1. Hassanpur	1. Bhogpur
2. Tikli	2. Darbaripur	2. Khuntpuri
3. Raisena	3. Palra	3. Ratika Noabad
4. Alipur	4. Nurpur Jharsa	4. Bilaka
5. Hariahera	5. Badshahpur	5. Jolahaka
6. Sampki Nagli	6. Fazilpur Jharsa	6. Ghangola
7. Muhammadpur Gujar	7. Ghasula	7. Khatrika
8. Ghamroj	8. Dhumaspur	8. Saramathla
9. Sakatpur	9. Nangli Umarpur	9. Badshahpur Thethar
10. Aklimpur	10. Brehmpur	10. Low Singhani
	11. Gual Pahari	11. Silani
	12. Ulhawas	
	13. Ghata	
	14. Balola	
	15. Haiderpur	
	16. Tigra	
	17. Medawas	
	18. Sohna M. C.	

a) Urban/peri-urban villages

The LULC change analysis of the region suggests that different parts of the region have gone through different transitions which have had a significant effect on the water resource. In **the Sohna M.C**. (the original urban local town in the study region) located at the foothills of the Aravalli, there has been a decline in the groundwater due to decline in forest cover and increase in built up area. This had led to a decline in the availability of water at the hot spring. The perennial hot spring does not have any water in the summers now, even after monsoon the availability of spring water is quite low. It is a significant local heritage site and effort needs to be put to develop a green corridor in the Aravalli for its restoration. Since 2017 the water utility provider (PHED department) supplies water from the water treatment plant (WTP) at Budhera instead of groundwater from bore wells which was the earlier source of supply (withdrawals are now minimal in the town except for the hot spring). Thus, recharge through re-establishment of natural greens and channelized flow to existing and nonfunctional borewells for recharge is suggested.

More specifically for the Sohna MC area rain garden (with rain chains from roof top) has been suggested for the PHED compound and the civil hospital so that rain water collected from the rooftops may be taken to the existing borewell with the PHED complex for recharge of ground water. A maintenance schedule needs to be developed for the upkeep of the existing rainwater harvesting structures in the government schools and the Sohna M. C. office. The 9Km green corridor of at least 200m in the nearby villages all along the foothills is suggested as the potential recharge zone for the deep aquifer is at the foothills where there is an overall degradation of the green cover. Continuous effort towards development of such facilities will need minimum three years to show results and rejuvenation of the hot spring. In the meanwhile, withdrawal of groundwater must be reduced to a minimum.

Sohna MC has sewerage network through which the domestic wastewater is transported to the sewage treatment plant (STP). The water balance in the Sohna MC is negative as it draws on groundwater and water from outside its watershed limits in the absence of efficient groundwater management and adequate rainwater harvesting through green corridor and rain gardens.

Urban village- Ulhawas

The LULC analysis reveals that this part of the Sohna region has urbanized the rapidly, and the lakes and ponds have dried up. Besides, this region is completely dependent on groundwater and the decline is rapid. The groundwater quality is good, but groundwater recharge structures were found only in the local government school and private school, though the functionality of such structures is not monitored. The monitoring of the existing RWH within the new multistoried apartment buildings need to be ensured for its effectiveness. For the urbanized village, there are very few open areas left, so rainwater harvesting is suggested in the local anganwadi complex. The collected rainwater may then be diverted into the abandoned dug well in the vicinity. The dug well needs to be cleaned and its screens would need to be replaced to maximize recharge through this mechanism. The wastewater emerging from households goes to the nearby HUDA main sewer while some also flow through open drains outside the houses.

b) Foothills of Aravalli

There is large scale erosion in the foothills due to decline in the forest cover and mining in the area. During rainfall events, there has been an increase in surface runoff and decline in groundwater recharge. The increase in surface runoff is a cause of concern as it flows with high velocity owing to steep slopes resulting in soil erosion and quick accumulation of runoff at the foothills. There are a few check dams constructed by the forest department at the foothills to reduce the stream flow velocity and recharge groundwater. Specific recommendation for protection of the hillslopes includes laying of natural jute and coir erosion control mats for rejuvenation of slopes and gabion check dams at the bottom hill streams to reduce the runoff velocity. These gabion structures shall also function as minor water retention structures which will allow ground water recharge. The sandy soil in the area allows rapid recharge to the ground below. These foothills are the primary source of groundwater recharge for the deep aquifer for the entire region and source protection is of utmost importance. Accordingly, 13Km green corridor of 500m all along the foothills is suggested. Though the villages in the foothills of Aravalli use sprinkler irrigation, there is no regulation on the duration of pumping resulting in over irrigation. This has led to decline in the ground water levels in the region and downstream. The water quality of groundwater is found to be good.

The soil test results show that there is no overuse of fertilizers and the potassium content of soil is naturally high as the soil is formed from weathering of the nearby metamorphic rocks. Thus, the soil is healthy with low electrical conductivity. An intervention like smart metering will help reduce irrigation water usage and allow groundwater levels to rise in the aquifer. The villagers use groundwater drawn through the borewells for various water demands including irrigation, drinking water and other domestic uses. The ponds in the region are either polluted (due to disposal of grey water) or have diminished in size due to declining groundwater. Interventions have been suggested for treatment of grey water so that the johad remains clean and this water may be reused for irrigation. Promotion of eco-tourism is recommended to enhance community connect with the forest.

c) Saline affected villages

The salinity affected villages are located in Southeast Sohna and belong to a different geological profile. The area has high water table due to the presence of paleochannels, however, these paleochannels contain water with high salinity. Ground water test results show high TDS levels in the water. In addition, the soil is also saline as seen from the high electrical conductivity (Refer soil test report in Table 9). The soil heath is poor as seen from the low soil organic content that impacts the crop productivity. In order to address the socio-economic complexities of these vulnerable areas, the interventions suggested are based on the existing agricultural schemes. These schemes provide subsidy to farmers for construction of poly houses and use of drip irrigation for growing crops. Drip irrigation allows less amount of saline water to be used, so salt-tolerant crops like tomato may be grown in the poly houses. Besides rainwater harvesting is suggested from rooftops that can be stored in underground tanks which may be maintained by the community. Fresh water stored in these tanks may be used by the community for growing crops using fresh water but as trellis (climber plants) so that contact with the saline soil is minimal and more crop per drop may be achieved. Water ATMs are provided by the government for drinking water supply in the village, and in the absence of any other access to fresh water, this is the best possible option.

The overall scenario suggests that ground water resource and surface water structures like lakes and ponds need governance interventions. It is recommended that a holistic approach be adopted by the District Administration to rejuvenate the water bodies and groundwater. It is also recommended that the urban greens be restored in the area along with increase in forest cover for there exists clear linkages between the greens and the water resource of the area. More specific issues like efficiency of recharge structures to recharge ground water and rejuvenate ponds will need clear monitoring guidelines and impact assessment framework. The role of Guru-Jal will be crucial in meeting the Jal-Shakti goals. Creation of buffer zones and green corridors is recommended on an urgent basis.

In the areas vulnerable from severe soil and ground water salinity, the sustainable cropping pattern needs to change with technological interventions for which the government is willing to contribute. The practice of sustaianble water budget model is proposed at village level and the Sohna MC. Earlier in times of drought the villagers would migrate to cities, however, with rising water stress in cities, during times of drought the cities would be equally vulnerable.

10 Annexures

A1: Subsidies for Solar Pumps in Haryana

S. No.	Capacity	Type	Tentative Quantity (Nos.)	Estimated Cost (Rs.)	User Share @ 25% of the cost (Rs.)
1.	3 HP	DC, Surface	1065	2,35,000	58,750
2.	3 HP	DC, Submersible	1065	2,35,000	58,750
3.	3 HP	AC, Submersible	1070	2,35,000	58,750
4.	5 HP	AC, Submersible	4150	3,33,000	83,250
5.	5 HP	DC, Submersible	4150	3,33,000	83,250
6.	7.5 HP	AC, Submersible	1250	4,78,000	1,19,500
7.	7.5 HP	DC, Submersible	1250	4,78,000	1,19,500
8.	10 HP	AC, Submersible	500	6,10,000	1,52,500
9.	10 HP	DC, Submersible	500	6,10,000	1,52,500

Source: Scheme Guidelines Solar Pumps 2019-2020, Haryana Government

A2: Technical Specifications of a Naturally Ventilated Greenhouse

S. No.	Items	Description/Specification
1.	Structure	Naturally Ventilated Greenhouse
2.	Size	500 m^2 to 4000 m^2
3.	Bay Size	8 m x 4 m, with 4 side hockey 2 m
4.	Ridge height	6.5 m to 7 m
5.	Ridge Vent/Top Vent	80-90 cm opening fixed with 40 mesh nylon insect screen
6.	Gutter height	4-4.5 m from floor area
7.	Gutter slope	2% slope need to be provided in civil foundation work/structure
8.	Gutter material	2 mm thick GI with 220 GSM Galvanization
9.	Structural design	The structural design need to be sound enough to withstand wind speed minimum 120 km/hr minimum load of 25 kg/m^2. There should be provision for opening one portion at either side for entry of small tractor/power tiller for intercultural practices. The firm needs highlight design features and list of greenhouse clients.
10.	Structural	Complete structure made of galvanized steel tubular pipes of equivalent section confirming Indian Standards having wall thickness 2mm, structural member should be joined with fasteners properly.
	Columns	76 mm OD, 2 mm thick
	Trusses	Bottom cord 60 mm OD, 2 mm thick
	Trusses	Top cord 48 mm OD, 2 mm thick
	Purlin	48 mm OD, 2 mm thick
	Truss member & others	33/25 mm, 2 mm thick

	Hockey	60 mm OD, 2mm thick
	Foundations	Telescopic type. The column size to be 45 cm x 45 cm x 90 cm depth of CC 1:2:4 ratio properly compacted over 10 cm layer of 1:8:16. The holdfast to be used in perpendicular direction at 20 cm apart in concrete starting from 20 cm from base.
	Fasteners	All nuts & bolts must be high tensile strength and galvanized.
11.	Entrance room & door	One entrance room of size 3 m x 3 m x 3 m (L x W x H) need to be provided and covered with 200 micron UV stabilized transparent plastic film. Two hinge doors of 2 m width & 2.5 m height double leaf made in plastic/FRP sheets mounted in suitable strong frame.
12.	Cladding material	UV stabilized 200 micron transparent plastic films. Confirming Indian Standards (IS 15827:2009), multilayered, anti-drip, anti-fog, anti-sulphur, diffused, clear and having minimum 85% level of light transmittance
13.	Fixing of cladding materials	All ends/joints of plastic film need to be fixed with two way GI profiles with suitable locking arrangement along with curtain top. Wooden batons or PVC grippers need not used.
14.	Spring Insert	Zigzag high carbon steel with spring action wire of 2-3 mm diameter must be inserted to fix sheet into Aluminum Profile
15.	Curtains and insect screen	Roll up UV stabilized 200 micron transparent plastic film as curtains need be provided up to 3.0 m height on all sides with manual roll up system. 40 mesh nylon insect proof nets (UV stabilized) of equivalent size need to be fixed inside the curtains. Anti-flapping strips is suggested to ensure smooth functioning of the curtain.
16.	Shade net	UV stabilized 50% shading net with manually operated mechanism for expanding and retracting. Size of net should be equal to the floor area of greenhouse.
17.	Shade net operations	Non-motorized for all sizes with manual operation system.

18.	Drip Irrigation System with fogging & misting facility	Drip irrigation system under greenhouse need to be selected on the basis of crop spacing design on spacing 30 cm dripper to dripper (two rows per bed) 30 cm x 40 cm along with fogging and misting facilities. The spacing considered for calculation. The suggested bill of materials are Sand Filter 10 m^3/hr, Hydrocyclone filter 25 m^3/hr, Screen Filter/Disc Filter 10 m^3/hr, Control Valve 63 mm, Control Valve 50 mm, By-pass Assembly 1.5”, Air Release Valve 1”, Non Return Valve 1.5”, Throttle Valve 1.5”, Flush Valve 50 mm, Venturi 1.5” Assembly with manifold, PVC pipe 63 mm/6 kg/cm^2, PVC pipe 50 mm/6 kg/cm^2, PE plane lateral 16 mm, emitting pipe lateral 16 mm - @ 0.30 m to 0.40 m spacing, hanging type micro sprinkler nozzle (four way take off assembly) for very fine water particles (foggers & mister) to be fixed in PE pipe of diameter 16 mm and fittings & accessories @ 5%. Note: The above list of material is indicative list for 500 sqm structure area. The material may increase/decrease based on the size of structure.
19.	Bottom apron	UV stabilized woven fabric 160 GSM/200 micron poly film and a height of 1 m above ground and 50 cm buried below ground (Total width 1.5 m).
20.	Trellising system	i) Base wire 8 mm or GI Pipe 60 mm OD, 2 mm thick ii) Trellising wire 3 mm steel or 2 mm gear wire iii) Supporting wire 4 mm steel or 3 mm gear wire

Source: Norms & Guidelines for Protected Cultivation for the year 2018-19, Horticulture Department, Haryana