RETHINKING URBAN WATER MANAGEMENT

LESSONS FROM BHUJ

October 2017

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Acronyms

ACT	Arid Communities and Technologies
AMRUT	Atal Mission for Rejuvenation and Urban Transformation
BHADA	Bhuj Area Development Authority
BNP	Bhuj NagarPalika
CBO	Community Based Organizations
CGWB	Central Ground Water Board
CPCB	Central Pollution Control Board
CPHEEO	Central Public Health and Environmental Engineering Organization
DCR	Development Control Regulations
DDWS	Decentralized Drinking Water Scheme
DEWATS	Decentralized Wastewater Treatment Systems
GDCR	General Development Control Regulations
GIDC	Gujarat Industrial Development Corporation
GPCB	Gujarat Pollution Control Board
GWSSB	Gujarat Water Supply and Sewerage Board
IUWM	Integrated Urban Water management
JSSS	Jalsrot Sneh Samvardhan Samiti
lpcd	litres per capita daily
MLD	Million litres daily
MoEF	Ministry of Environment and Forests
NGO	Non-Government Organization
NRW	Non-Revenue Water
PGWM	Participatory ground water management
RO	Reverse Osmosis
RRWH	Rooftop Rain Water Harvesting
SDG	Sustainable Development Goals
SLB	Service Level Benchmarking
SLIP	Service Level Improvement Plan
STP	Sewage Treatment Plant
TDS	Total Dissolved Solids
ULB	Urban Local Body
WASMO	Water and Sanitation Management Organization
WSUD	Water Sensitive Urban Design
WDS	Water Distribution Station

Acknowledgement

This report has been prepared by C-WAS at CEPT University under the project "Knowledge Management and Advocacy Partnership for Participatory Ground Water Management in Bhuj". CEPT as a knowledge partner of Arid Communities and Technologies (ACT) has documented their ground water management activities in Bhuj. This report is the second report prepared under this project.

The report describes the current water supply scenario of Bhuj, and its dependence on multiple sources. It identifies emerging challenges and opportunities of urban water management in Bhuj and highlights the measures required to make the city water secure.

We acknowledge support of Arghyam for this project. We thank the ACT team led by Dr. Yogesh Jadeja, for sharing information, supporting CEPT team during their visit to Bhuj and for their valuable feedback on the report.

At CEPT this work is carried out by a team that includes Dhruv Bhavsar, Upasana Yadav, Aditi Dwivedi and Jigisha Jaiswal.

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Executive Summary

Introduction

Water is a critical natural resource for the rapidly growing urban areas. In recent years, cities have become more susceptible to water scarcity. Climate change, leading to more frequent and extreme weather events, is expected to alter the quality, quantity, and seasonality of water available to cities.[1] In response to mitigate such threats, water practitioners are revisiting century-old practices in search of a sustainable solution for water security. Augmenting city's water resources through water shed management provides an opportunity to the city managers to focus on local water resources and reduce dependence on water brought from long distances.

This study focuses on Bhuj, a city located in the arid region of Kachchh district in Gujarat. It demonstrates how a city that had withstood water scarcity for centuries in the past, revived its traditional practices to work towards becoming water secure again. Its survival in the past was made possible due to the strategic water reserves created through a water management system of linking lakes and wells. The report provides an assessment of current water supply scenario of Bhuj. It describes city's dependence on multiple sources and identifies the challenges and opportunities of urban water management in Bhuj.

Opportunities and challenges of urban water management in Bhuj

Piped water supply system was introduced in Bhuj in 1968-69. Since then, there have been significant additions in sources of water supply for Bhuj. In exploring additional source of water, the municipality went 11 km east of Bhuj city in Kukma village. 26 borewells in Kukma and 4 bore wells within the city supplied 2 Million Litres per Day (MLD) of water to Bhuj city in 1970. From the same sources, nearly 12 MLD of water is currently drawn. In addition, since 2004 Bhuj Municipality receives water from Narmada canal. In 2004, it used to receive 4 MLD. This has increased to nearly 20 MLD in year 2016. Thus, Bhuj city receives a total of 32.5 MLD of water from different sources. The present dependency of Bhuj on different distant sources of water is illustrated in the table below:

[1] Bahri A., (2012),"Integrated Urban Water Management", GWP

Table 1: Municipal water supply in Bhuj: 2016

Sources	Quantity (MLD)
Narmada Main line	14.0
Kukma Borewells* (outside Bhuj municipal boundary)	2.5
Madhapar Borewells (outside Bhuj municipal boundary)	8.0
Narmada Air valves	4.0
Bharapar Tubewells (outside Bhuj municipal boundary)	1.0
Patwadi and Valdasnagar (local borewells)	3.0
Total	**32.5**

Source: As per discussion with Bhuj municipal council (water engineer and valve men) and GWSSB Bhuj office, 2016

**Exact value of extraction from 7borewells located in Kukma is not known*

At macro level the quantity of water supply seems to be adequate. However, despite this, the water delivery is very poor. The city supplies water every alternate day in most areas (and in some areas it is every third day). The water quality is poor, with high TDS. As a consequence, Bhuj residents depend on private bottled water suppliers. Those who can afford, also have their own private well. Groundwater is also used for industrial and agriculture uses. Thus ground water level in the aquifer has dropped considerably, leading to increased cost of pumping and also ingress of salinity.

Bhuj's dependence on Narmada is high, with nearly 20 MLD of water received every day. Given that Bhuj is at the tail end of Narmada canal, it is vulnerable to changes in supply of Narmada water. In order to assess whether this dependency on Narmada water can be reduced, a water balance study was conducted. The water balance study suggests that there is positive balance, i.e. the outflow of water is less than the inflow of water. However, water import constitutes a high percentage of inflow and without this import, groundwater extraction (from inside the system) will have to rise to match the water demand, leading to depletion of the water table. This suggests that the city needs more recharge or infiltration wells to increase its water reserve. The city needs to retain and revive all its water bodies, instead of using them for development projects. This will also improve groundwater quality, prevent surplus runoff from flowing out of city. The water distribution system has to be made more efficient by reducing losses and removing illegal pumping of water.

Alternative water systems in Bhuj

Realizing the deteriorating situation of water resources, a city based NGO, Arid Communities and Technologies (ACT), initiated activities for a revival of traditional water system by creating awareness among communities and other stakeholders. Various actions taken by ACT and its partners in the context of exploring local water resources in Bhuj city were based on the technical studies (i.e. understanding hydrogeology, aquifer systems, etc.). They demonstrated pilot projects on decentralized drinking water systems in slum areas, rainwater harvesting in residential and institutional buildings, groundwater recharge, revival of water bodies, revival of lakes etc. A key aspect of ACT's intervention was the participation of the community in every project.

With some success of its initiatives, ACT has been able to influence the policy makers in Bhuj to adopt these measures at a city-wide scale. The various activities demonstrated by ACT and other partners illustrate that there are plenty of opportunity in adopting alternative water supply systems in Bhuj. However scaling up the pilot projects at city level requires detailed assessment of technical and financial aspects. A feasibility analysis was carried out to build possible scenarios.

City-wide Water Management in Bhuj

In order to reduce its dependence on external sources, Bhuj needs to tap its own resource carefully and strategically. Given the emerging challenges, it is essential for the city to adopt a more sustainable and integrated approach. It is no longer suitable to build new pipelines or increase water produced without fixing leakages and losses in old pipelines. Water management in Bhuj can be supported by both measures of increasing efficiency of water systems as well as water conservation practices. One approach is to look at increasing efficiency of existing system and demand management through proper pricing policy, metering of water supply, reducing water losses, etc. Another is on supply side management - looking at alternative sources like rainwater harvesting, groundwater recharge, etc. Both these approaches can be implemented simultaneously.

Increasing efficiency of existing water systems

Review of existing water supply system suggested that the water supply in Bhuj could be augmented by increasing efficiency of existing systems. Simple measures of reducing NRW, appropriate pricing mechanism, metering of water supply, providing good quality water, etc. would help in improving the efficiency. Bhuj Nagar Palika provides 32 MLD of water. Yet, the dependency of the citizens on other sources suggests that what reaching the consumers is much less, probably due to losses during the transmission. The losses in the system are unknown as there has not been any water audit in the city. If such audit was conducted, it would suggest where the leakages and theft of water occur.

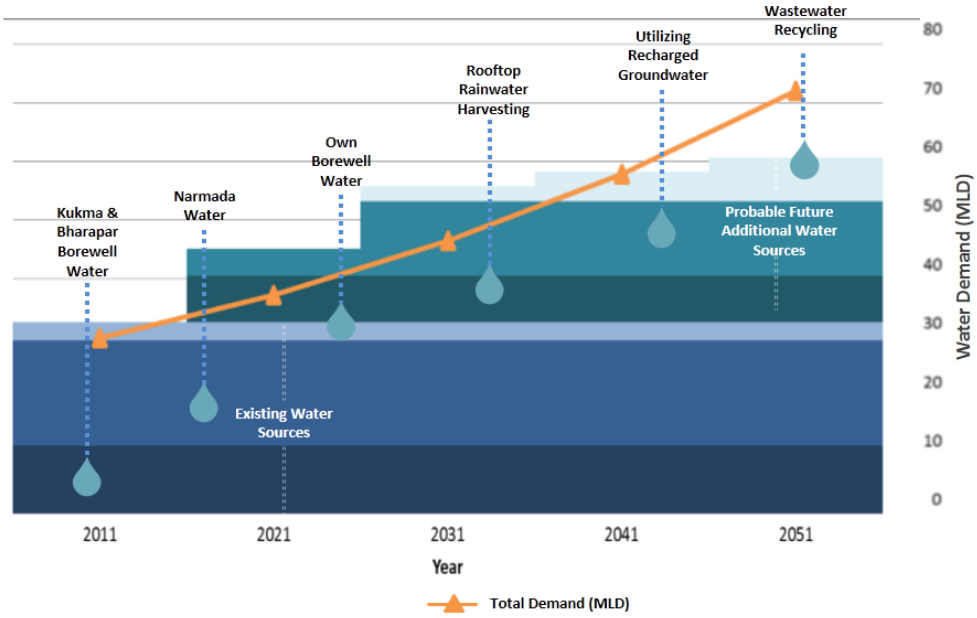
In absence of metering, Bhuj municipality is unable to prepare effective and equitable water distribution and management plan. Also, water is supplied at a very subsidized rate and is treated almost as a free commodity than a resource. Thus in order to improve the efficiency of the present system, tariff charges and its collection must be revised. User charges should be sufficient to meet at least the marginal cost of supply. Thus the idea of paying for water by meters must be adopted. Moreover, improving the quality of water would also satisfy the citizens of Bhuj and would reduce their dependence on private water sources.

Water conservation and demand management through other practices

Bhuj is characterized by low and highly variable rainfall pattern. But even in the years of low rainfall, the intensity period is high with a large amount of rain falling in a short period of times. Also paving of open areas has reduced water infiltration capacity. In Bhuj where the municipal water supply is not provided every day, and the groundwater table is declining, rainwater harvesting can certainly help. Schools and institutes having a large rooftop can sustain for a whole year by harvesting rainwater which falls on its roof. Along with this, if all the residential places also adopt Rooftop Rainwater Harvesting, 770 ML of water would be harvested every year. This would reduce pressure on Bhuj Nagar Palika to fetch water from distant sources. Proper policy regulations for compulsory installations and incentives are required for citizens to take up RWH in their houses.

The unique geo-hydrology of Bhuj has potential for groundwater recharge. A major potential for recharging groundwater is through existing water bodies. According to water balance analysis, the surface runoff of 14.6 MCM (14,599 ML) which largely goes unutilized can increase groundwater level by adopting artificial recharge practices. To capture 40% of this runoff, 5 recharge structures per sq. km. would be required. The structures must be located, based on topography, in vulnerable and/or potential zones of the city. At present in Bhuj, treatment of wastewater is done with the help of oxidation pond. With the upcoming treatment plant of 23.70 MLD sanctioned under AMRUT, the treated wastewater could be reused for different purposes. Treated wastewater could be reused for agriculture or for artificial recharge of groundwater.

Figure 1: Comprehensive urban water scenario for Bhuj



Analysis by CEPT University

With these alternative urban water management approaches, a comprehensive scenario for Bhuj is developed. It shows how the alternative practices can help in addressing the increasing water demand of the city in the future.

Table 2: Potential water availability and their costs

Sr No.	Activities	Potential water availability (MLD)	~Total investment required (crore)	~Private Cost (crore)	~Public Cost (Crore)
1	**Rainwater Harvesting**	8	125	100	25
2	**Groundwater recharge**	13	13		13
3	**Wastewater Recycling**	7.5	Depending on STP technology and purpose of reuse		
4	**Improving efficiency of existing system (reducing NRW)**	6.4			
4.a	Reducing NRW (Water audit and plugging leakages)				4
4.b	Metering (Consumer)		20.76	20.76	
4.c	Metering (bulk meters)		0.36		0.36

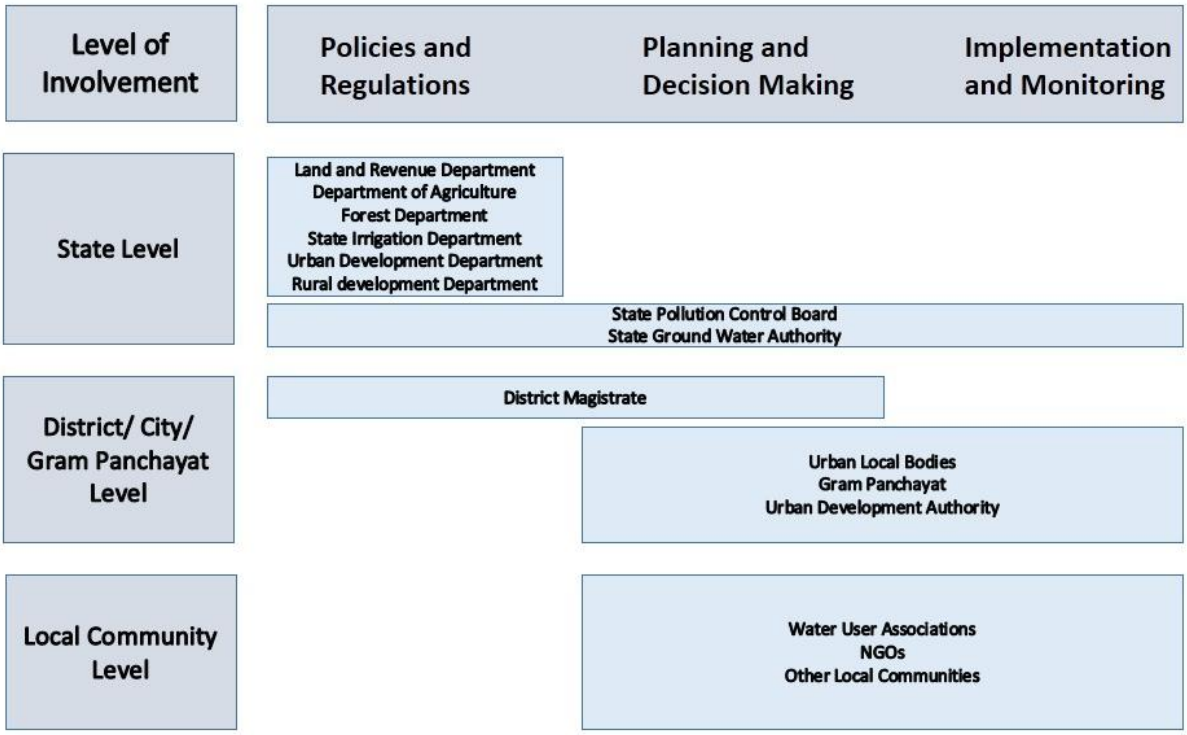
Analysis by CEPT University

Institution and Governance

In the case of Bhuj, water management involves various stakeholders – the local government, local NGO's, various water related associations and community based organisations. Bhuj watershed covers various jurisdictions. It includes Bhuj municipal area, Bhuj urban development authority area, Madhapar town area, Agriculture area, Forest area, Army area and village panchyat areas. A holistic approach needs to be taken to involve organizations at all level. A platform is needed where all organizations from various administrative levels can meet and coordinate their activities for effective watershed management.

Such a platform consisting of officials from various departments as well as the local community would aid in taking into consideration all the aspects for better water conservation and use. Such urban watershed level approach would set an example for other cities in India to adopt similar approach.

Figure 2: Proposed organizations involvement at Watershed Level



Prepared by CEPT University

Way forward

The most important aspect to ensure water security for Bhuj is to recognize that there is a net surplus of water in Bhuj. This suggests that water security can be achieved by adopting an integrated urban water management approach. In the case of Bhuj, focusing on improving the water network efficiency and harnessing local water sources will mitigate the future water challenges.

Planning of water resources should become a key component of urban planning exercise. Integrating and mimicking the hydro-geological aspects in land use planning and focusing on local water sources hold importance. Local water sources act as last oasis in water scarcity, a comprehensive framework can also be developed locally which aims to conserve and protect water sources.

Moreover the roles and responsibilities of all stakeholders must be defined, and an inclusive organization structure supporting integrated development must be designed. Various approaches for managing water like Integrated Urban Water Management (IUWM), Water Sensitive Urban Design (WSUD), and Participatory Ground Water Management (PGWM) must be examined and integrated in the urban planning to make a city water secure.

1 Introduction

Water is a critical natural resource for the world's growing urban areas. Cities have become more susceptible to water scarcity than ever before. At the same time, because of climate change, more frequent and extreme weather events are expected to alter the quality, quantity, and seasonality of water available to urban centers and their surroundings.[2] The global community has also recognized importance of this issue and has included it in 2030 Agenda for Sustainable Development as its goal-6 that sets out to "ensure availability and sustainable management of water and sanitation for all."[3]

Today, cities face many daunting challenges, but water management is one of the most serious.[4] In response to such threats, the water sector is revisiting conventional practices as it searches for sustainable solution to safeguard the integrity of the resource base. In comparison, an alternative approach for providing water services to urban areas based on Integrated Urban Water Management (IUWM) and Water Sensitive Urban Design (WSUD) principles helps in achieving the demand.

The level to which a given city depends on groundwater to meet its water demand depends on a variety of factors. The physical/geographic factors include: availability of sufficient groundwater either from natural recharge due to combination of good rainfall and receptive sub-surface geology or from other sources such as canals, good aquifers that can store and transmit groundwater, availability of good quality groundwater that is not subject to constraints such as saline water intrusion. However, such factors are usually not considered by urban planners and cities look for water to be brought from afar.

A better urban water management requires that we treat Urban Water Cycle as one system and understand the relationship between various components. Urban water cycle is closely linked to watershed. The city depends on and impacts the wider watershed. One can increase water security through diversity, i.e. by exploring diverse and flexible options for water sources. Good water management also recognizes that "Water should be fit for purpose", by matching water quality to its intended use, rather than using pure drinking quality water for factories and gardening[5].

Augmenting city's water resources through better water management, gives an opportunity to the city managers to focus on local water resources and culminate its search for new sources of water. It

[2] Bahri A., (2012),"Integrated Urban Water Management", GWP
[3] UNWater (2014),"Sustainable Development Goals 2030", retrieved from: http://www.unwater.org/sdgs/a-dedicated-water-goal/en/ on 10th October, 2016
[4] GWP (2013),"IUWM: Towards Diversification and Sustainability"
[5] Kala Varaivamoorthy (2014) Managing water for the city of the future, a presentation.

also creates a host of other benefits for communities, including building citizenship, revitalizing communities to work together, energy savings restoration of streams, aquifers, wetlands, and habitat.[6] It will be more adaptable to changing land-use as well. It also makes management boundary small enough for the people concerned to participate in the decision making process on risk-benefits of the community water system.[7] This allows active involvement of the citizens in taking decisions about water management, allocation and use.

Patel and Krishnan (2009) analyzed information of 300 cities in India to conclude that smaller towns are more dependent on local water resources (through open dug-wells, lakes, rivers etc.) in the initial period, then it is bore-wells and tube-wells for tapping groundwater from deeper aquifers as demand exceeds the prevalent supply[8]. However, as other studies have shown, both the quantity and quality of ground water has been decreasing over time. For example, Kulkarni et. al. (2015) states that "ground-water contamination has emerged as a threat to drinking water security in many parts of the country. Groundwater exploitation and contamination have emerged across a diverse range of agro-climatic and hydrogeological conditions in India, with nearly 60% of the districts in India showing evidence of either depletion or contamination or both[9].

This study focuses on Bhuj, a city located in the arid region of Kachchh in Gujarat. The city had successfully survived centuries of low rainfall and droughts through traditional water management system, linking watersheds, lakes and wells. However, over the years, this conventional wisdom appears to have been lost. With city's growth, many water bodies in the city have disappeared, and ground water quality as well as quantity is depleting at a fast rate. Moreover present water supply system in Bhuj is dependent on multiple sources of water yet not able to cater to its entire city's demand.

Realizing the challenges faced by the city, Arid Communities and Technologies (ACT), an NGO in Bhuj, decided to demonstrate a new approach. It took up the tool of decentralized system with citizen involvement and demonstrated pilot projects in the city. These services mainly include rainwater harvesting, groundwater recharge, revival of water bodies, wastewater reuse and

[6] Nelson, V. (2008), "New Approaches in Decentralized Water Infrastructure", NDWRCDP, Gloucester, MA
[7] Yamamoto, K.(2011), "Autonomous and decentralized water system for wise use of water and creating healthy and sound water environment" he University of Tokyo, Japan
[8] Patel, Ankit; Krishnan, Sunderrajan. 2009. Groundwater situation in urban India: overview, opportunities and challenges. In Amarasinghe, Upali A.; Shah, Tushaar; Malik, R. P. S. (Eds.). Strategic Analyses of the National River Linking Project (NRLP) of India, Series 1: India's water future: scenarios and issues. Colombo, Sri Lanka: International Water Management Institute (IWMI) pp.367-380
[9] Kulkarni, H., Mihir Shah, and Vijay Shankar (2015)., Shaping the contours of groundwater governance in India. J. Hydrology: Regional Studies (2015), http://dx.doi.org/10.1016/j.ejrh.2014.11.004

decentralized water supply in slum areas. For implementation of these projects, the major focus was on involving citizens and adapting mechanisms according to the context of the place.

This report is an attempt to describe the approach adopted by Bhuj to solve its water problems. It explains about the alternate systems implemented in the city to capture and revive its own sources.

This report represents an assessment of current water supply scenario of Bhuj. It describes city's dependence on multiple sources and identifies the emerging challenges and opportunities of urban water management in Bhuj. It highlights the measures taken by ACT to adopt decentralized systems as a measure to the emerging challenges in the city. In particular, the role of ACT working along with the citizens of Bhuj to implement these projects and its impact on the city is described. Based on this, the report showcases opportunities and limitations in scaling up these options. An assessment of municipal finance of Bhuj Municipality was done to identify possibilities of funding such projects.

2 Opportunities and Challenges of Urban Water Management in Bhuj

Assessment and in-depth understanding of current water supply scenario is a key first step in planning for a water secure city. This chapter describes the present water supply system in Bhuj and assesses reasons for its dependence on multiple sources. It outlines challenges and opportunities that Bhuj city will face in fulfilling future water demand.

In January 2001, a massive earthquake, with its epicentre at about 70 Kms from Bhuj, had devastating effect on Kachchh district. The earthquake killed nearly 20,000 people, injured 170,000 and destroyed over 4,00,000 houses. Bhuj suffered extensive damage. Its water supply system had to be retrofitted and reconstructed after the earthquake.

This disaster provided an opportunity to revamp the water supply distribution system in conjunction with revival of the lakes. However, this crisis provided Bhuj access to Narmada water. As described below, bringing water from far has not really resolved the water scarcity problems in Bhuj. Parts of the city are still dependent on private wells and water tankers. Bhuj had missed the opportunity, after the earthquake, to look at water management from integrated and inclusive perspective and consider a wide range of solutions.

2.1 Municipal water supply in Bhuj

Piped water supply system was introduced in Bhuj in 1968-69. Since then, there have been significant changes in sources of water supply for Bhuj municipal area. Bhuj municipality is responsible to ensure supply of drinking water to the residents. In exploring sources of water, the municipality went 11 km east of Bhuj boundary in Kukma village. Nearly 26 borewells in Kukma and 4 bore wells within the city supplied 2 Million Litres per Day (MLD) of water to Bhuj city in 1970. From these sources nearly 12 MLD of water is currently drawn. In addition, since 2004 Bhuj Municipality receives water from Narmada canal. In 2004, it used to receive 4 MLD. This has increased to nearly 20 MLD in year 2015.

As per Municipal council records, currently Bhuj Municipality supplies a total of 32.5 MLD of water from different sources as per given table:

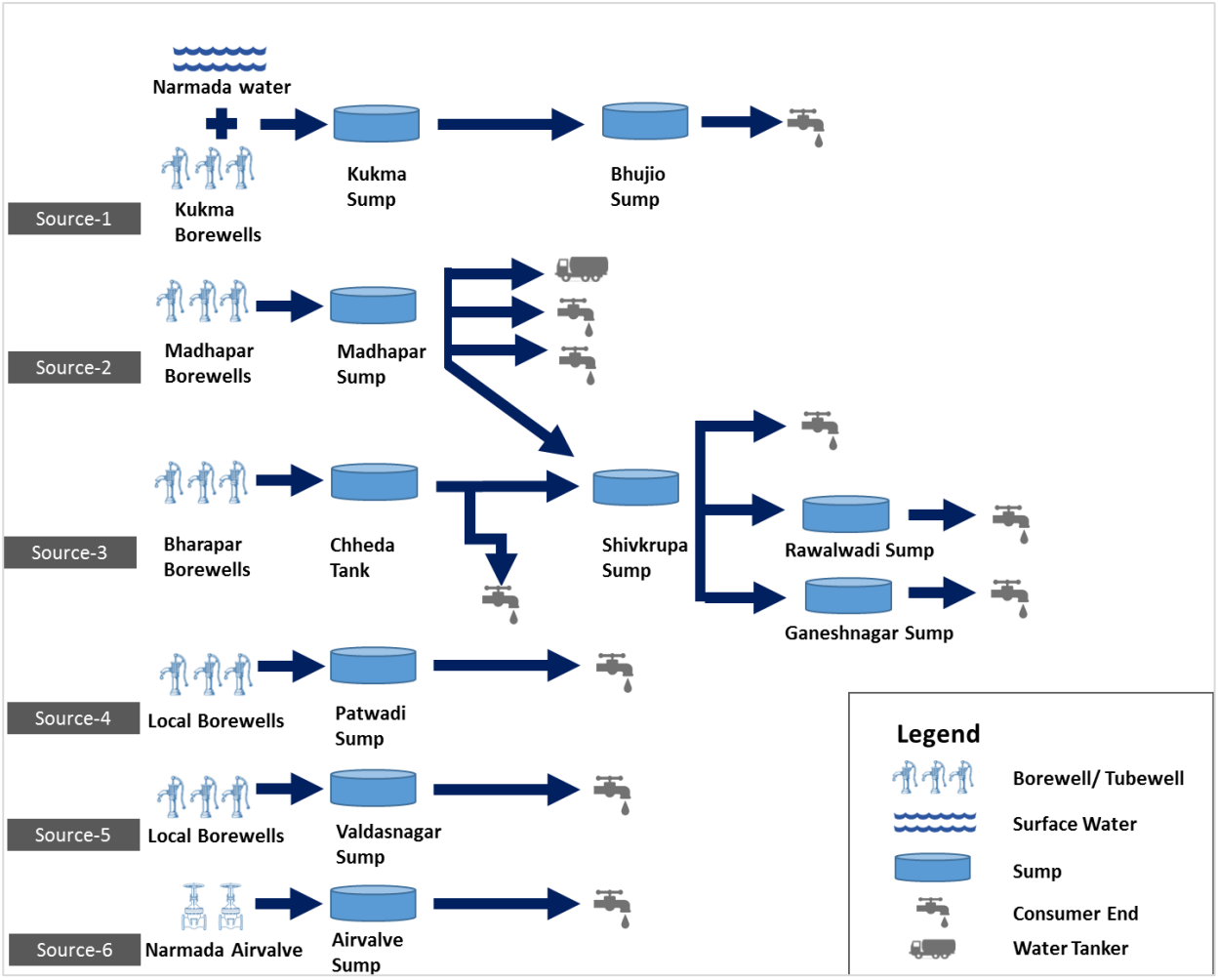
Table 2: Municipal water supply in Bhuj: 2016

Sources	Quantity (MLD)
Narmada Main line	14.0
Kukma Borewells*	2.5
Madhapar Borewells	8.0
Narmada Air valves	4.0
Bharapar Tubewells	1.0
Patwadi and Valdasnagar	3.0
Total	**32.5**

Source: As per discussion with Bhuj municipal council (water engineer) and GWSSB Bhuj office,2016

**Exact value of extraction from 7borewells located in Kukma is not known*

Figure 1: Schematic diagram of water distribution system in Bhuj



Source: Field survey at respective source

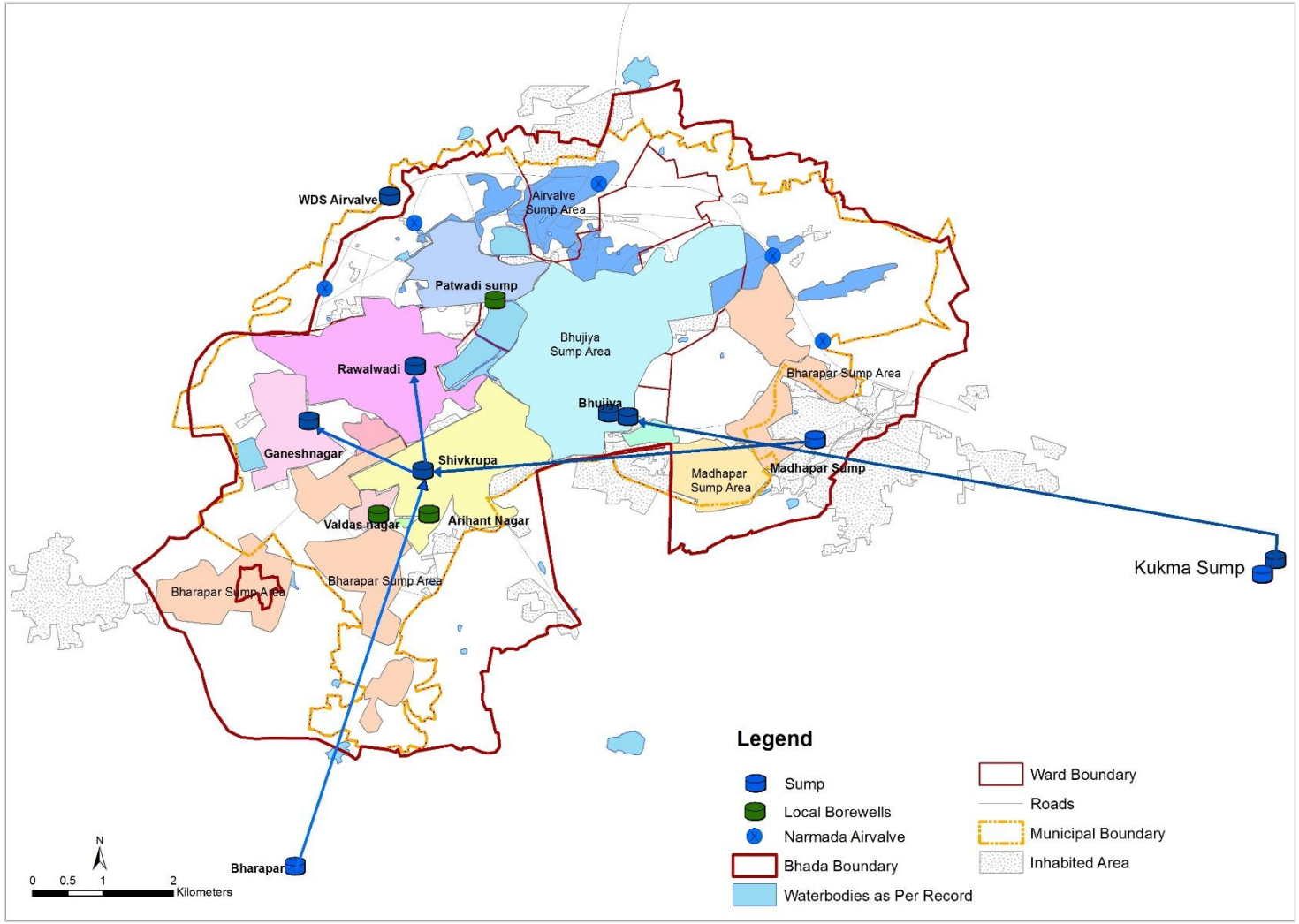
Water from Narmada canal is pumped at Malia and conveyed to Kukma sump having capacity of 15 Million litres. There are 7 borewells (~550 ft deep) around Kukma from which water is pumped 24

hrs to Kukma sump. Both groundwater and Narmada water is mixed in Kukma sump and then pumped to Bhujia hills sump from where water is distributed in city.

Ground Water from another 16 tube wells is pumped through rising main and collected in the Madhapar sump of capacity 8.5 lakh litres. Water from this storage sump is then conveyed to Shivkrupa Nagar WDS and other areas viz. Hiraninagar, Shivaninagar, Bhatnagar and Kutch-mitra areas. Water from tubewells located at Bharapar is pumped to reservoir storage at Shivkrupa Nagar. From Shivkrupa Nagar sump water is distributed to nearby areas and to Ganeshnagar and Rawalawadi sump. There are also Borewells located within Bhuj Municipal area which supplies water to Valdasnagar sump and Patwadi sump and from there it is distributed in different areas.

Apart from above distribution system, Narmada air valves supply around 4MLD of water in Northern peripheral areas through underground sump. Water Distribution pattern and zones are depicted in *Figure 2* below.

Figure 2: Distribution of Water in Bhuj



Source: Bhuj Municipal council, ACT

Issues in estimating quantity of water supply:

There is a lack of clarity as to how much water Bhuj actually receives from Narmada and extracts from borewells. Its reported bulk water purchase was only about 15 MLD in 2014-15 as per the information it supplied for the state government monitoring for Service level benchmarking (SLB).[10] However, as per the bulk water bills for Narmada collected from the municipality, in 2013-14, it seems to have received about 9 MLD, and has steadily increased each year reaching 29 MLD in 2015-16. This is contested by Bhuj municipality. They state that Bhuj gets around 14 MLD from Narmada water and around 4 MLD from Narmada Air Valves.[11] Lack of exact quantification of total water supply in city is one of major concern in formulation of water security plan for Bhuj city.

Table 3: Estimates of quantity of water sourced by Bhuj Municipality (in MLD)

Year	Average quantity of water sourced by the Bhuj Council for municipal water supply in Bhuj			Estimated per capita supply *(lpcd)*	Average hours of supply per day *(mins)*
	Ground water sources	Narmada bulk water source	Total		
2008-09	13.9	4.3	18.2	107	30
2009-10	13.9	2.5	16.4	84	37.5
2010-11	13.9	2.5	16.4	83	37.5
2011-12	13.9	2.5	16.4	91	37.5
2012-13	14.0	6.0	20.0	103	37.5
2013-14	14.0	6.0	20.0	104	45
2014-15	12.0	15.0	27.0	135	30

Sources: Based on data submitted by the Bhuj Council to the Government of Gujarat for Service level benchmarking measurement.

Table 4: Estimates of quantity of water sourced by Bhuj Municipality (in MLD)

Year	Average reported quantity of water sourced by the Bhuj Council from Narmada bulk water source as per SLB	Estimated quantity of daily water sourced from Narmada as per bills received by Bhuj Municipality
2011-12	2.5	8.6
2012-13	6.0	14.1
2013-14	6.0	18.2
2014-15	15.0	23.7
2015-16	16.0	29.1

Sources: Based on data submitted by the Bhuj Council to the Government of Gujarat for Service level benchmarking measurement.

At present, there are no functional bulk flow meters at either water source, WDS or consumer end to validate exact quantity of water supplied and water received. Water quantity supplied is based on

[10] As per information submitted by Bhuj city for Service level Benchmark for year 2014-15

[11] The bills suggest that Bhuj received 8.6 MLD in 2011-12, 14.1 MLD in 2012-13, 18.2MLD in 2013-14, 23.7 MLD in 2014-15 and till June-15 it had reached 29.1 MLD.

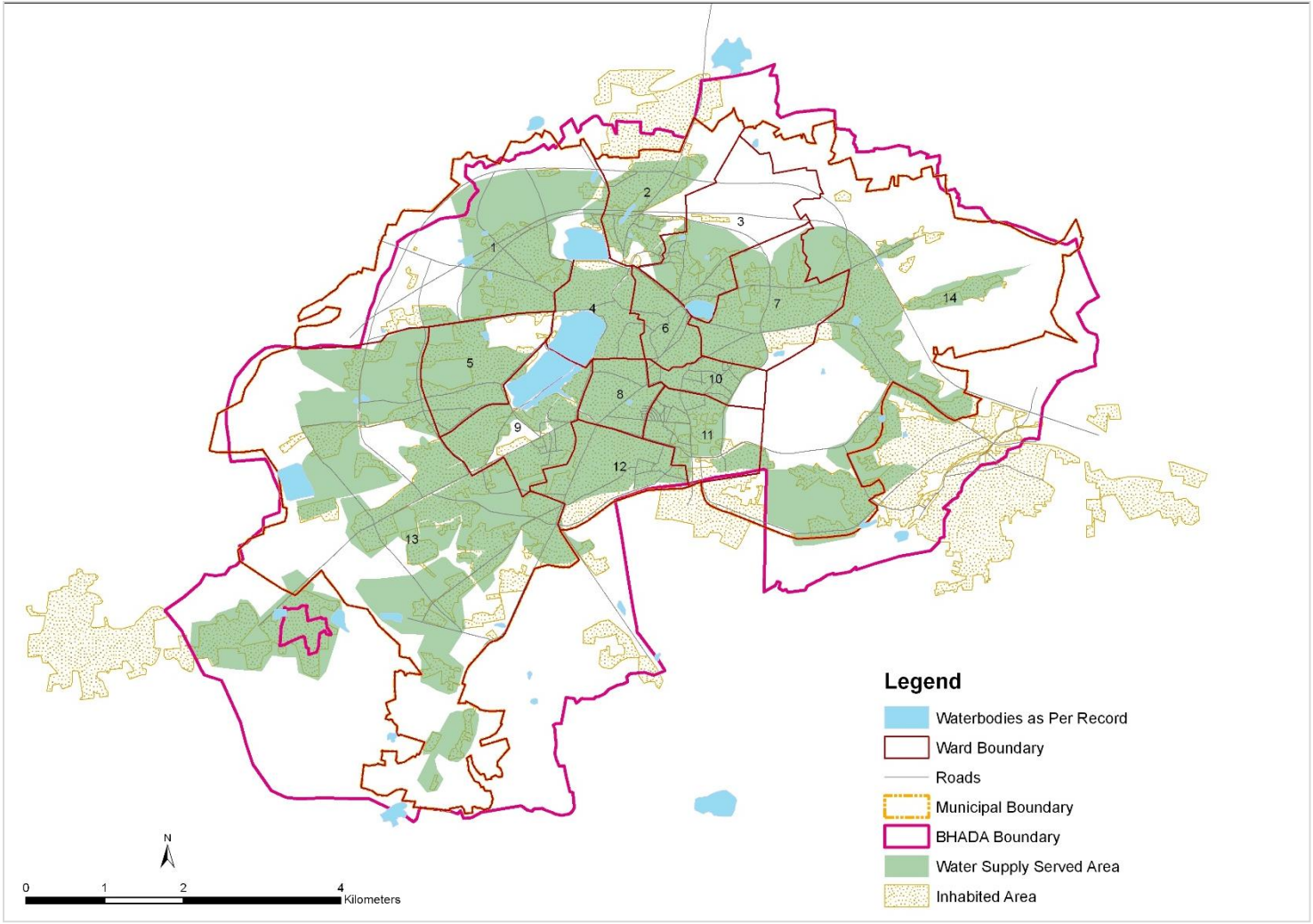
the estimation by municipal officials. It was also discovered that there are huge distribution losses both due to leakages in pipelines and because of water theft through Narmada Air valves.

Since this study began, it has been recommended that a preliminary water audit study must be carried out in Bhuj to provide correct estimates of the supply of water and determine losses in the system.

Spatial coverage of water supply network

Spatial analysis was carried out for understanding distribution of individual water connection and dependence on private wells for drinking purpose. At an aggregate level, it is seen that 90% of Bhuj area is covered with water supply network. This indicates that 10% of city area is completely dependent on groundwater or private tanker supply. Apart from uncovered areas, the peripheral area covered under Bharapar water supply zone receives very less quantity of water (0.5 MLD). This is because of the presence of silt and iron content in water which has lowered water quality and quantity. Households in this area depend heavily on private tubewells and tankers for their water needs.

Figure 3: Served and unserved area by water supply network



Source: Bhuj Municipality

Infrequent water supply

In Bhuj, piped water is not supplied every day. There are large variations in access to water supply in different areas. Few areas get water supply on alternate days while few get water once in three or four days. The main reasons for this as described by Bhuj Municipal officials are lack of adequate storage infrastructure. So the burden of creating adequate supply of water is shifted to households. Those households that can afford to build large sumps and overhead water tanks are water secure. However, the households that cannot build sumps (either due to lack of space or lack of funds) suffer the most.

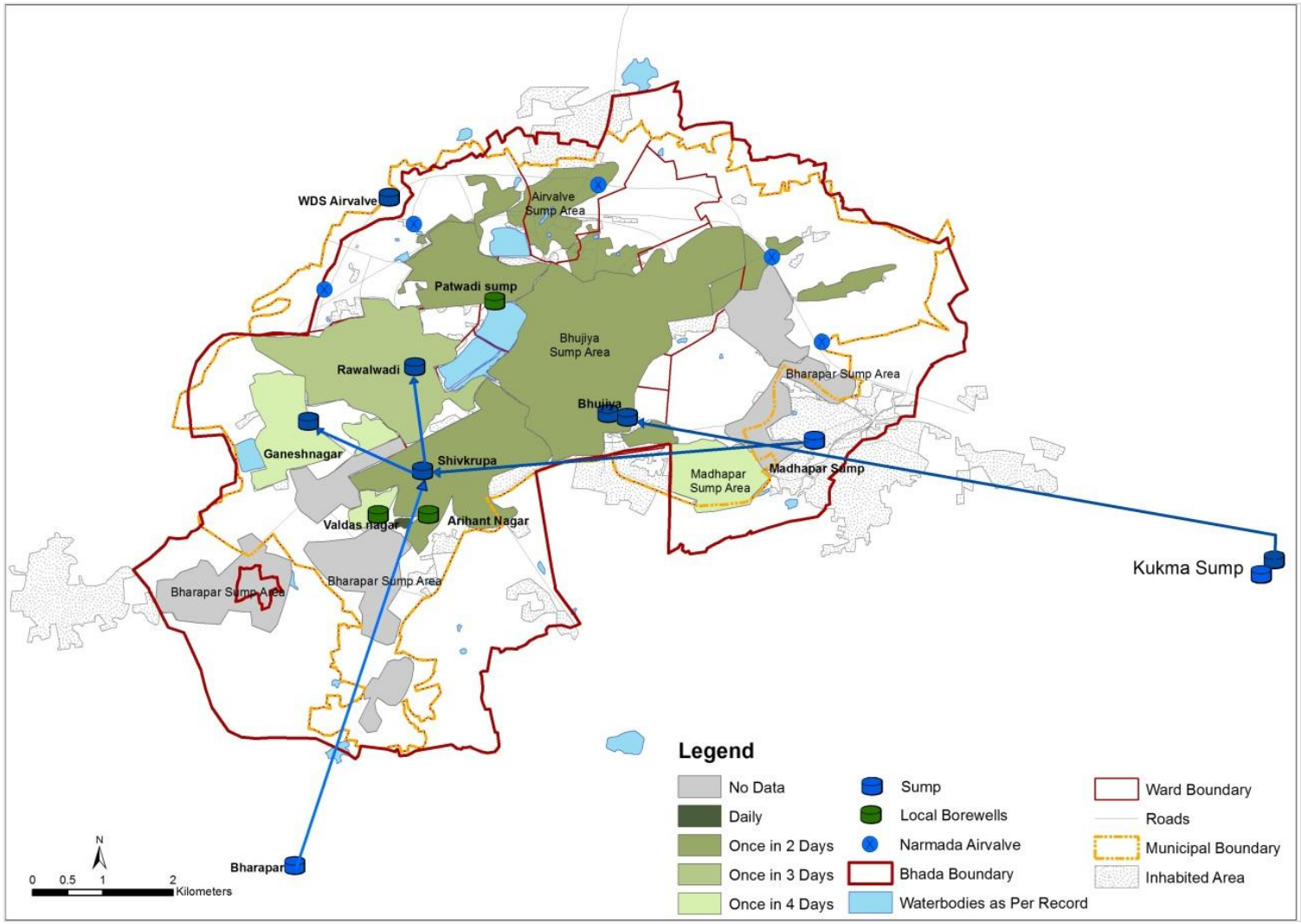
Various sump capacities and the variance in supply of water are shown in table below:

Table 5: Sump capacity and water supply duration in Bhuj

Sump area	Sump Capacity (ML)	Water Supply Duration	Source
Hirani Nagar	0.95	Once in 3 days	Kukma BW + Narmada
Bhujiyo no. 1	7.5	Once in 2 days	Kukma BW + Narmada
Bhujiyo no. 2	3.0	Once in 2 days	Kukma BW + Narmada
Bhujiyo no. 3	1.8	Once in 2 days	Kukma BW + Narmada
R.T.O	0.3	Once in 2 days	Kukma BW + Narmada
Shivkrupa Nagar	1.2	Once in 2 days	Madhapar BW+ Bharapar BW
Ganesh Nagar	1.0	Once in 4 days	Ganesh Nagar BW
Valdas Nagar	0.3	Once in 4 days	Valdasnagar BW
Rawalvadi	1.0	Once in 3 days	Madhapar BW + Bharapar BW
Paatvadi Naka	0.75	Once in 2 days	Paatvadi Naka BW
Arihantnagar	0.12	Daily	Arihantnagar BW
Total	17.92		

Source: Bhuj Municipal Council and ACT

Figure 4: Water supply duration in Bhuj



Source: Bhuj Municipality, 2015

Poor quality of water:

The quality of water supplied by the municipal council is a major concern for a citizen of Bhuj. Currently, there is no functional water treatment plant[12]. Groundwater extracted from Kukma is high in TDS content and its water quality is improved by mixing it with Narmada water. Water supplied from Bharapar also has silt and high iron content. Water extracted and supplied from municipal borewells located within BHADA area viz. Patwadi, Valdasnagar, Arihantnagar do not provide potable water for drinking and cooking purpose. Poor water quality imposes coping cost on households in terms of money spent on water treatment plants or purchasing of RO bottled water.

Inadequate water supply in slums

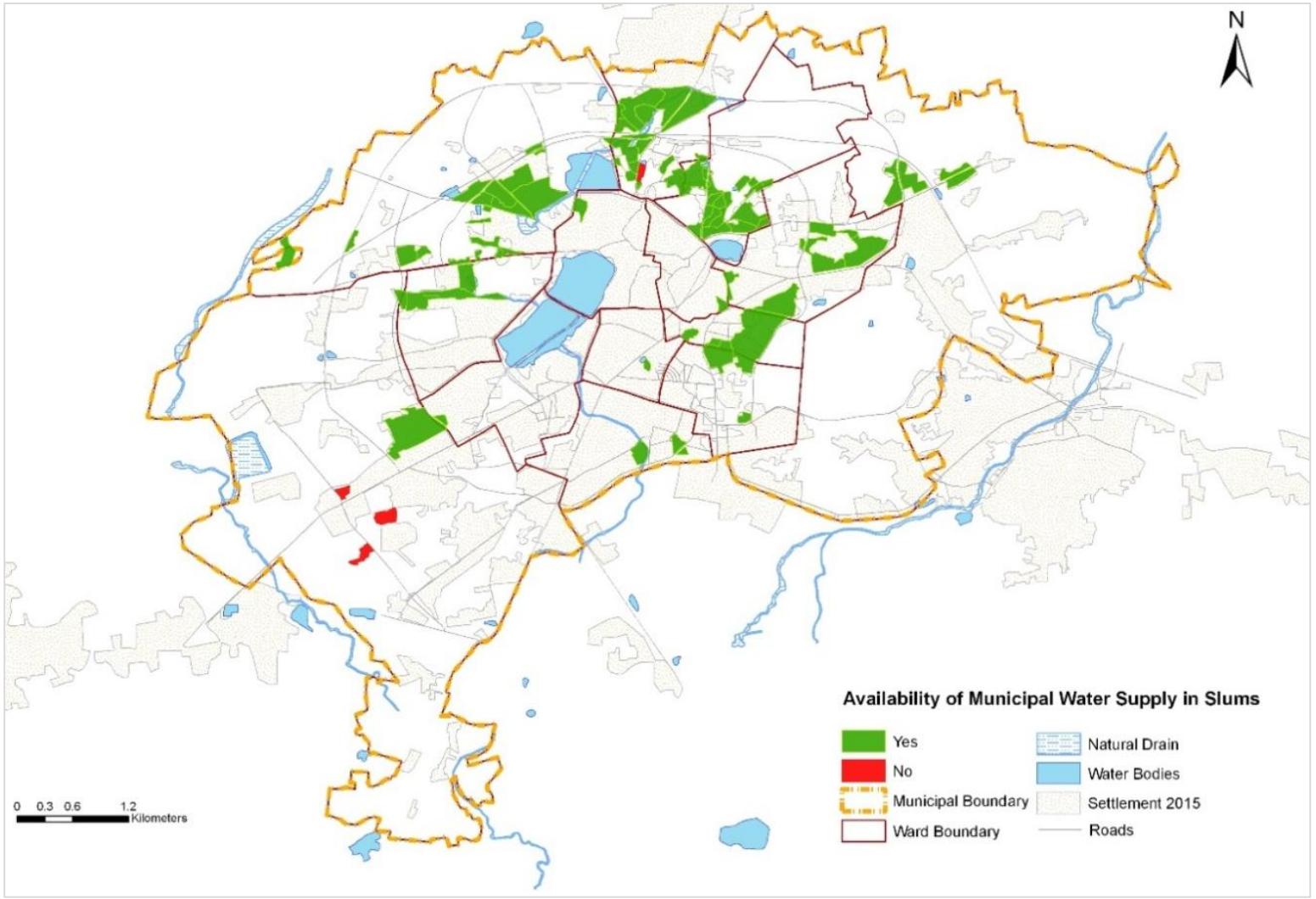
In Bhuj, there are 74 slums, covering nearly 40% of city population and spread across 6% of city's area. Almost all slums locations have municipal water supply except four slum locations.

However, the issue of access to water supply in slums is not resolved simply by laying municipal water lines. Despite high coverage, the supply of water is almost non-existent. In the slums of Bhuj, water is supplied once in three days and for a short duration of only 20 minutes (SLB data 2014-15). Slum dwellers have to depend on external sources like tankers or have to fetch water from neighbouring areas.

Most slums households lack water storage facilities. For Middle class households, though water may be supplied only for a few hours in two or three days, they can store water and use it as and when they require it. Hence, the non-poor households do not face major difficulties with intermittent and infrequent water supply, while the poor households suffer a great deal. (Meena Nair, Venugopal Reddy, & Sita Shekhar, 2005).

[12] This is despite the fact that under CPHEEO guidelines, it is recommended that all surface water sources have to be treated before using it as a drinking water.

Figure 5: Accessibility of Municipal water supply in Slums



Source: ACT, Bhuj, Hunnarshala

Increasing dependence on tanker supply

Despite the elaborate plan of bringing water from Narmada, there are a large number of households that do not have adequate access to municipal water supply. The households connected to piped water supply face the issues of intermittent and poor quality water supply. Because of these, most families supplement municipal water supply with water from private wells, tanker supply or RO bottled water supply.

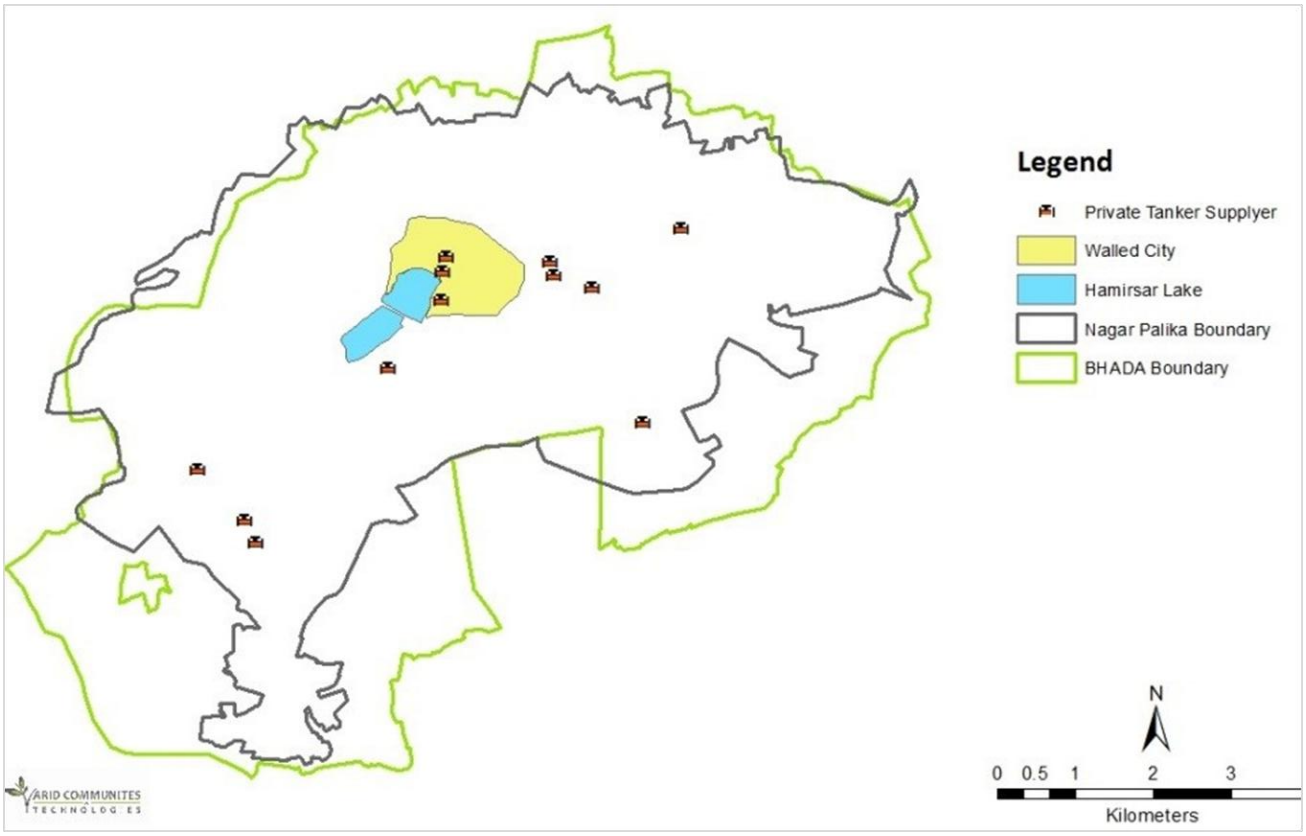
The Bhuj Municipal council supplies water through tankers in areas where piped water network has not reached. The municipal tanker makes an average of 44 trips per day; of which 75% are free trips and other 25% are chargeable trips (for marriage and other occasions). Total water supplied by municipal tankers is around 1.8 lakh litres per day.

Photograph 1: Tractor pulled tankers for water supply

Source: ACT, Bhuj

Apart from municipal tanker supply, there are many private water tanker suppliers in Bhuj. There are 12 suppliers who extract groundwater from borewells/open wells located in different parts of city. Groundwater level at these sources is found at a depth of 150-300 m and quality of water varies between 1000-2500 TDS. These 12 water tanker suppliers have a total of 75 tankers. These tankers make average of 400 trips every day. This suggests that around 2.1 MLD of water is supplied by private tankers in Bhuj City, which is about 6% of present municipal supply. Private water suppliers assume greater importance during hot summer months when the demand for water is the highest.

Figure 6: Location of groundwater sources of Private tankers in Bhuj



Source: ACT, Bhuj

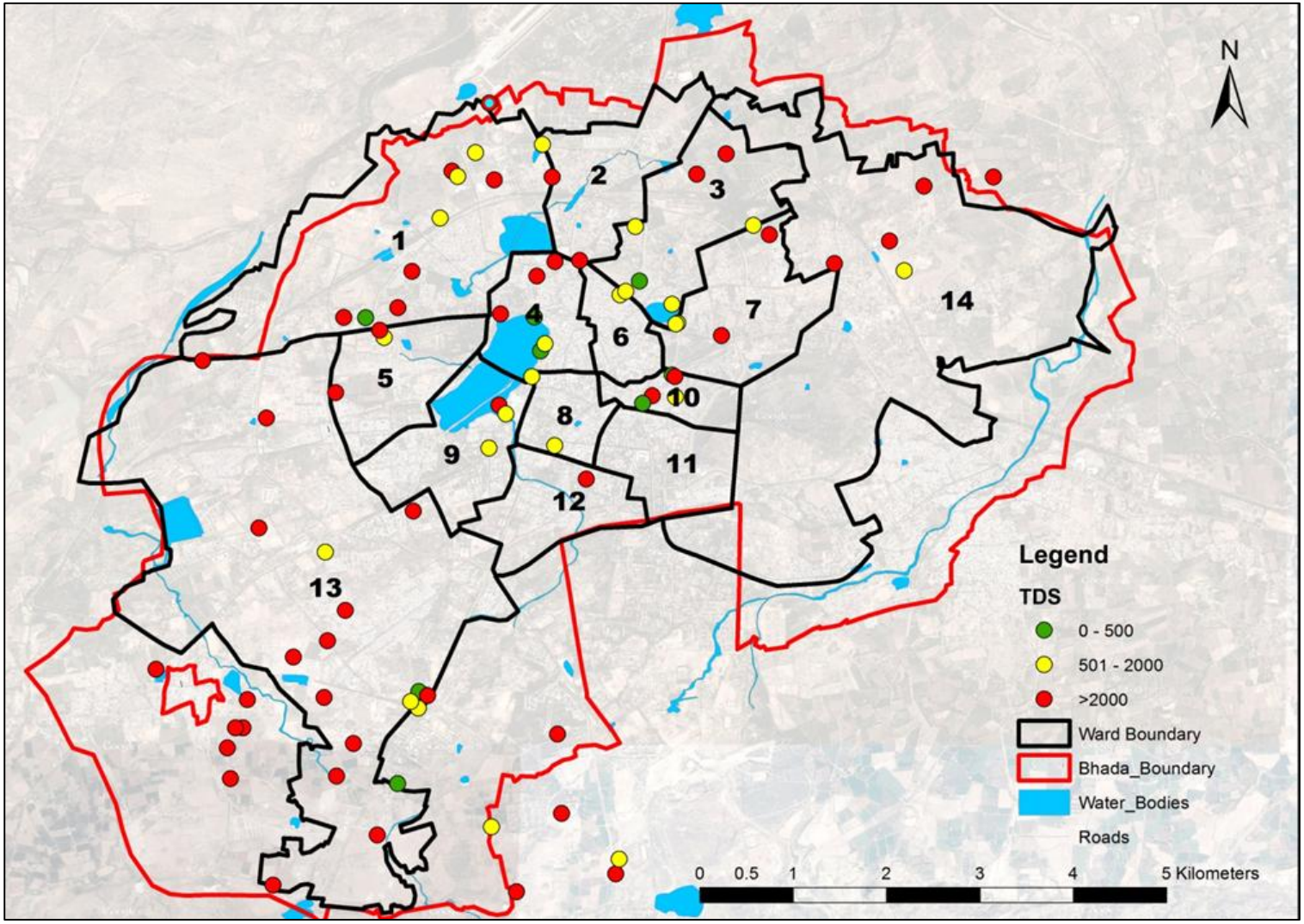
Use of private borewells

In Bhuj, almost every society has a private borewell or tubewell to augment municipal water supply. This phenomenon is more prominent in peripheral areas of the city where there is a lack of municipal water supply. There are a few societies that do not have municipal water supply and depend solely on ground water.

A large number of institutional and commercial properties are also dependent on groundwater. Even the GIDC industrial area located within Bhuj city is depended on groundwater and extract around 0.5 to 0.9 MLD of groundwater. In addition, groundwater abstraction by farmers around Bhuj is causing rapid depletion of groundwater in aquifers.

Lowering of groundwater levels has a compounding negative effect on its quality as it increases water salinity ingress. The water level in the aquifer is dropping unsustainably, causing not just decline of available water but also makes it non-potable. It was observed that groundwater in the peripheral areas has high Total Dissolved Solids (TDS). As there is no municipal water supply in this area, the residents have to use the poor quality ground water.

Figure 7: Monitoring wells: water quality information



Source: Developed by CEPT

Business of bottled water

There are 6 RO bottled water suppliers in the city. They supply around 3300 bottles (of 20 ltrs) daily. The residents of Bhuj prefer to use this bottled water for drinking purpose as they do not trust the quality of water delivered by the Bhuj Municipality[13]. The total amount of water supplied through these bottled water suppliers is approximately 66000 litres daily.

Demand for water in future

Pattern of demand for water in Bhuj has changed over the years. In the 1940s, Bhuj population was small and survived on water from wells and lakes. It is estimated that water usage did not exceed 40 lpcd[14]. This meant that the total water demand was in the range of 1 to 1.5 MLD, and this was largely met through the wells. In 1950s, as population started to grow, and as the availability of water from wells and lakes declined, there was a crisis. While the demand for water was nearly 2 MLD, the supply did not increase much, leading to shortages, particularly in newly growing areas.

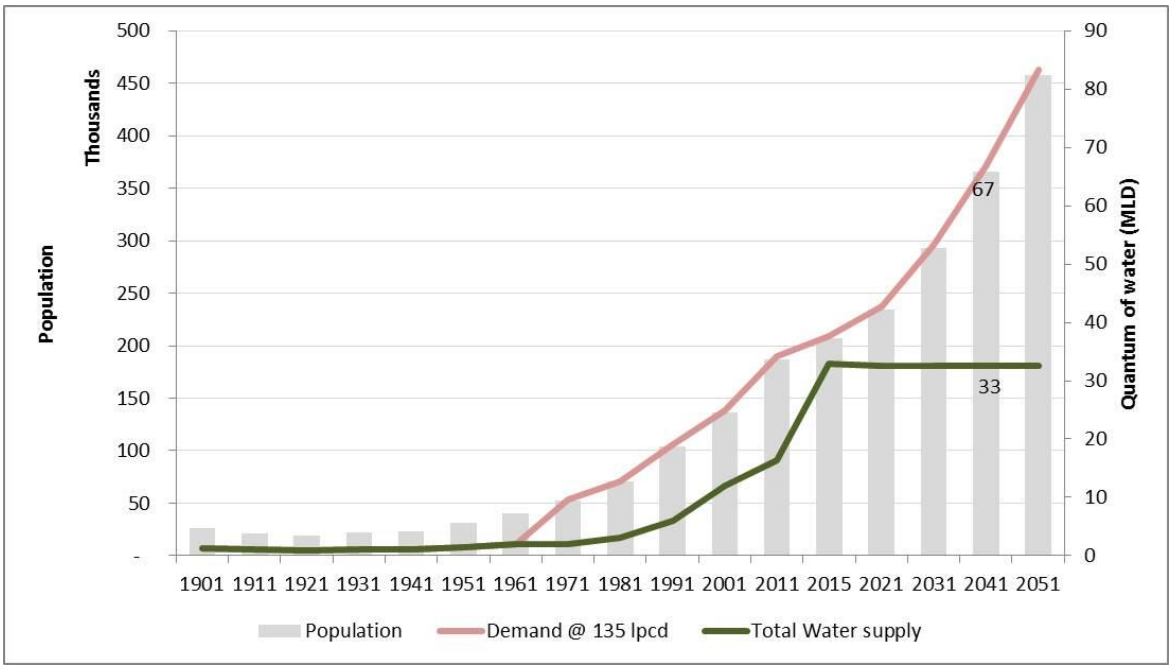
Demand for water increased dramatically with the introduction of piped water supply system in the late 1960s. In addition, sewerage system was also introduced in this period, which required a minimum level of water supply to remain functional. Thus, with these piped systems for water and sewerage, per capita water usage would have increased to about 135 lpcd. Thus, the total water demand increased to nearly 30 MLD – more than 10 times in 30 years since 1970.

Bhuj is expected to grow at a moderate growth of 25% per decade in future. At this rate, the population will double in next 40 years. With an increase in population and improvement in levels of living, demand for water will increase. The existing supply of water is likely to remain the same and will not be sufficient to meet the future demand. As shown in Figure 8, Bhuj population is expected to be around 450,000 in 2051. The demand for water will be around 80 MLD. At present, Bhuj municipality supplies around 32 MLD. In addition, the private borewells and tanker suppliers provide around 2.5 MLD of water. There is no likelihood of any significant increase in this quantity in the near future.

[13] Although it is not clear whether any RO water supplier in Bhuj provides in accordance with IS 10500 : 2012

[14] 40 lpcd is the norm for rural water supply and it is assumed that in 1940s, Bhuj residents received no more that this norm, as there was no piped water supply and no sewerage system.

Figure 8: Projected Bhuj population, water demand and supply



Source: CEPT Analysis

If the Business-as-usual scenario continues, an increase in demand for water will require Bhuj municipal council to tap more water from distant sources. At present, the dependence on Kukma and Bharapar may look sufficient to serve the city, but its future is uncertain. The rise in groundwater extraction from both Kukma and Bharapar will be subject of concern for BNP as quantity and quality of groundwater is constantly falling in these regions. Also, availability of increase in Narmada water supply is unlikely in future as there will be an increase in competing demands from agriculture, industries and other large urban centres.

To conclude, it can be stated that the supply of water in Bhuj is going to be a big challenge in future. The rapid increase in population, depleting groundwater resources and enhanced consumer needs are going to create a difficult situation. This emerging problem is not going to be solved by conventional approaches. It requires adoption of new approaches like "IUWM" – integrated urban water management".

2.2 Water resources perspective to enhance urban water system

Given the emerging challenges, it is essential for the city to adopt a more sustainable and integrated approach than the conventional one. There is a need that city officials look at urban water management from a different perspective and develop strategies that can respond to all these challenges simultaneously. In Bhuj, it will not be sufficient to build new infrastructure or bring water from long distances without considering long-term sustainability in terms of expanding own

resources, proper management of its watershed or wastewater reuse. It is no longer suitable to build new pipelines or increase water produced without fixing leakages and losses in old pipelines. Future strategies must be based on integrated and innovative solutions.

Approaches for water management of Bhuj city should also consist of utilizing existing available ground water along with increasing recharge or infiltration activities which will improve groundwater quality. Revival of lakes and watershed system, recharging of groundwater and rainwater harvesting have to be the focus of urban planning and decision-making processes as these water sources, if protected and managed properly, will create tremendous potential to augment the overall water resources of city.

Managing existing water supply system

Water supply in Bhuj city could be augmented by ensuring effective and efficient delivery of available water supply. As highlighted earlier, the city authorities do not have a clear idea of how much water is being supplied. All they know is that in some parts of the city, the water supply is adequate, while in other areas, it is insufficient. Ensuring that the city authorities know exactly how much water is being supplied, and where the leakages are there is extremely important. It is suggested that the following actions should be immediately taken by Bhuj Municipality:

- Detailed water audit study to estimate exact quantity of water supplied by municipality and water received at consumer end. The study will also determine losses, leakages or theft in present system at various points.
- Installation of bulk flow meters at source and Water Distribution Station (WDS) as well as meters at households level
- Increasing storage capacity (WDS) which will improve frequency of water supplied from once in two or three days to daily basis
- Improving quality of municipal water supply so that citizens can directly use it for drinking and cooking purpose. Bhuj Municipal council need to propose new water treatment plant for resolving quality issues.

Managing local water resources

An important aspect before planning any new projects to cater to future water demand is to assess the potential of its local water resources. A city can become self-sufficient in water if it tries to sustain, recharge and develop its local water resources. Bhuj city's local water resources are its groundwater and lakes. However, at present, one does not know the amount of groundwater that is

extracted in the city. Assessment and consideration of this important resource remain a missing link in existing water planning.

Water Balance

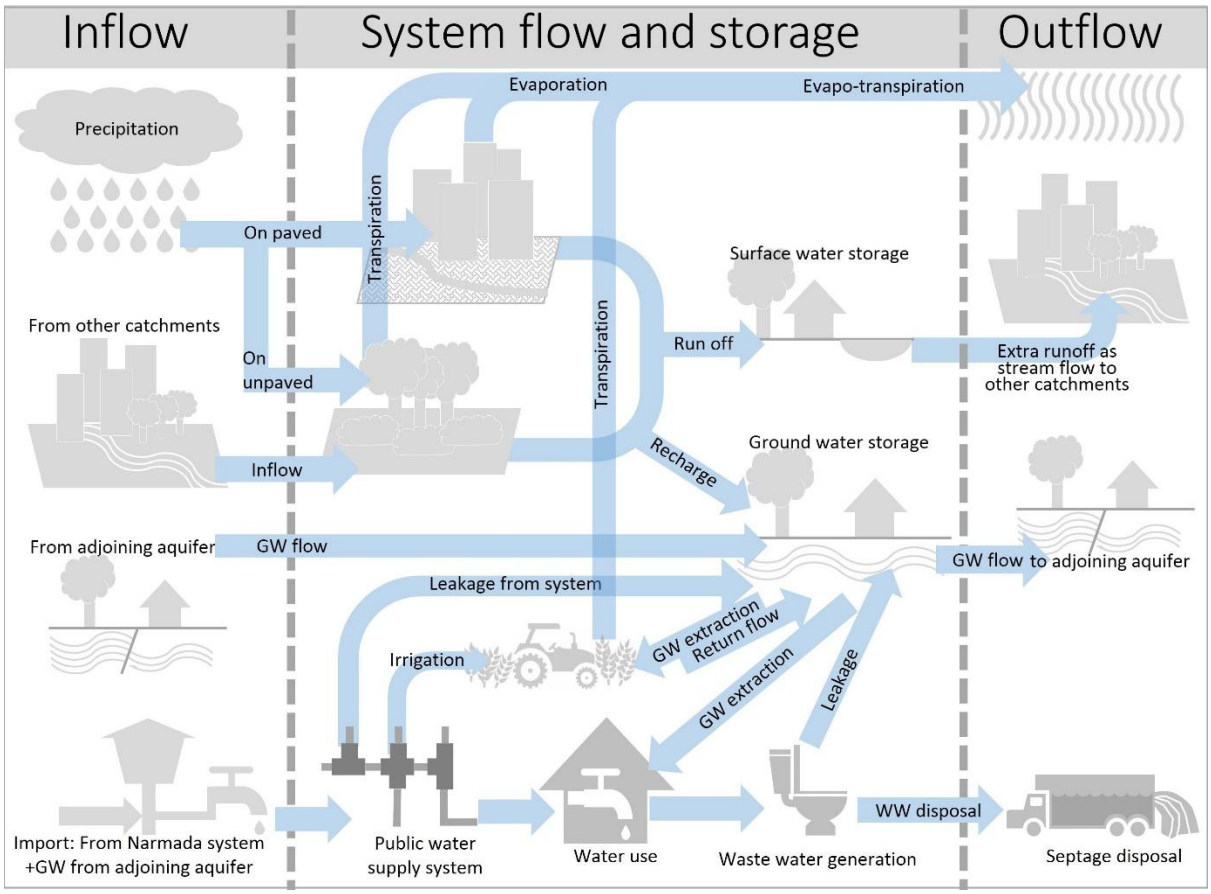
In hydrology, a water balance can be used to describe the flow of water in and out of a basin. It is an assessment of the various flow components of the hydrological cycle of a specific region, comparing precipitation and other inflows with outflows, and accumulation/storage changes over a certain time period. The water balance is a very fundamental concept in hydrology[15].

The hydrological cycle consists of various processes of inflow, outflow and storage- rainwater reaches the groundwater system through percolation; traps into soil as soil moisture; returns to atmosphere through evapotranspiration; some amount flows as surface runoff and gets stored into water impounding reservoirs; whereas remaining part flow out from the catchment as overland as well as sub-surface flow. Some amount of water also gets stored in aquifer while some amount of water is pumped out for usage and this balance is expressed as water balance. (Schicht and Walton, 1996)

The following diagram describes all possible water pathways –

[15] *International Water Management Institute, retrieved from* http://iwmi.dhigroup.com/hydrological_cycle/waterbalance.html *as on 4.5.16*

Figure 9: Water pathways in hydrological cycle



Source: Developed by CEPT

The processes of the hydrological cycle described above can be categorized in 4 categories, those that occur in i)the atmosphere, ii) land surface, iii) unsaturated zone and iv) deep aquifer. Since the model is being applied on an urban area, the effects of human activities in the form of groundwater withdrawal and wastewater disposal are also included in the analysis.

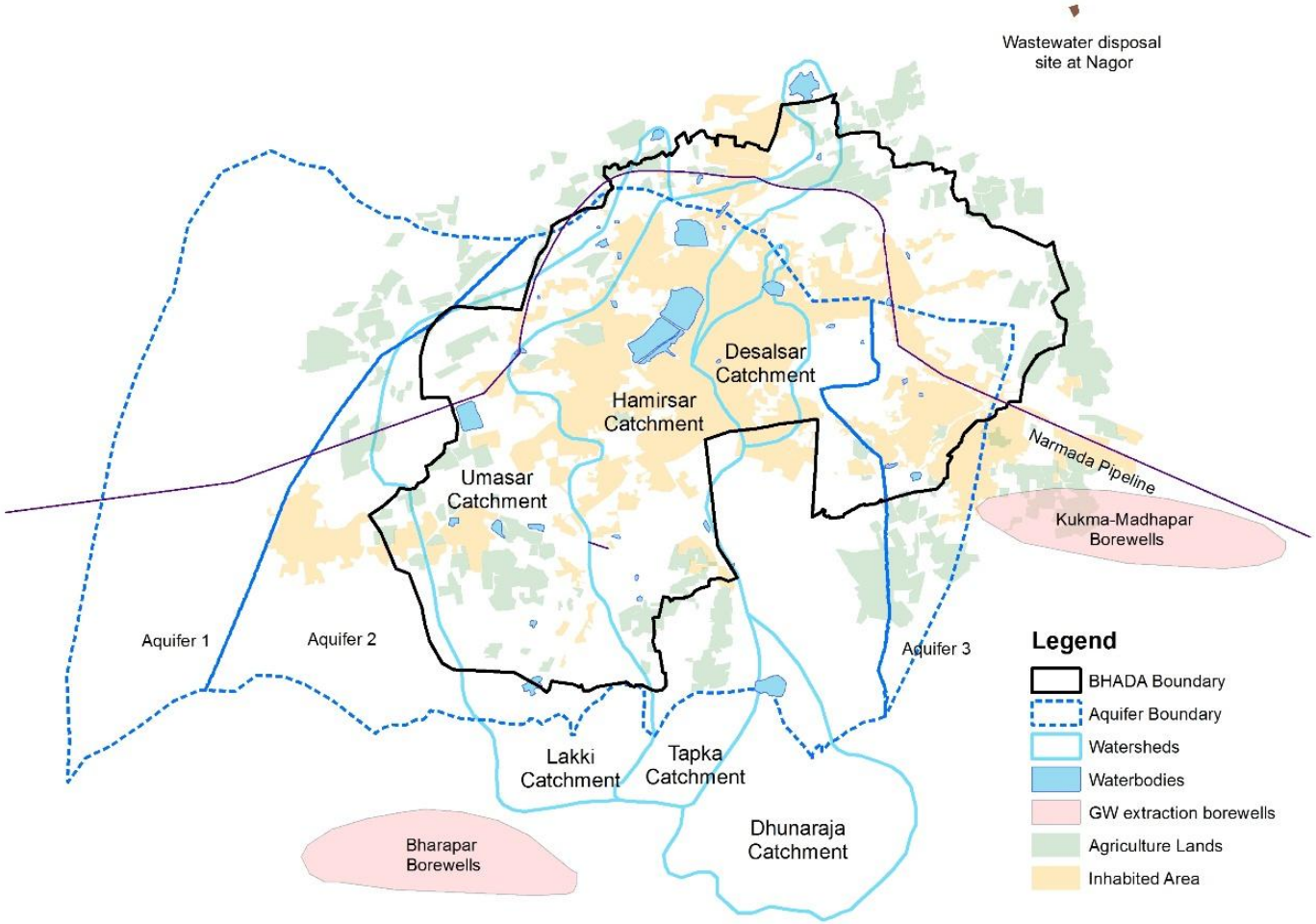
Applying the law of conservation of mass to water, the following equation can be used after defining a finite study area–

$$\text{Inflow} = \text{Outflow} + \text{storage}$$

Water balance estimates are often presented as being precise. However, there is always uncertainty, arising from inadequate data, measurement errors and the spatial and temporal complexity of hydrological processes. Consequently, arriving at an exact balance is next to impossible while it is possible to arrive at a simplified model of real life. Therefore, we add a constant to balance the equation-

$$\text{Inflow} = \text{Outflow} + \text{storage} + c$$

Figure 10: Water balance study area



Source: Developed by CEPT

Analysis of such an equation can be useful in assessing the current status and trends in water resource availability in an area over a specific period of time therefore strengthening water management decision-making by assessing and improving the validity of visions, scenarios and strategies.

Water Balance of Bhuj city was studied in detailed to assess the current status and trends in water resource availability in an area. BHADA boundary was defined as the study area for water balance of city for a period of one year.

Major parameters contributing inflows in the study area are Rainfall, Inflow/runoff into basin, Groundwater flow from adjoining aquifer and Water import by municipality. Water flows out of study area mainly in the form of Evapotranspiration losses, outflow to catchments outside basin, Groundwater flow to adjoining aquifer and Wastewater disposal to dumping site outside of study area.

Table 6: List of components considered for water balance

Inflow	**Storage**	**Outflow**
Rainfall	Surface	Evapo-transpiration
Inflow from outside catchments	GW storage	Outflow to other catchments
GW inflow		GW outflow
Water import		Wastewater disposal

Source: Developed by CEPT

Inflow:

1. Precipitation: Bhuj receives and annual average rainfall of 430 mm. This, over the BHADA area of 56.6 sq km gives us a total of 24.33 MCM rain annually.

Average annual rainfall (m)	=	0.43m
Study area	=	56.6 sq km
Annual rain received	=	**24.33 MCM**

2. Inflow from outside catchments: Water flows into our system from Dhunaraja, Lakki and Tapka catchments through the Haripar canal. We use Barlow's runoff factors to calculate runoff in these catchments assuming all to be average catchments in terms of terrain. For rainfall

intensity, even though Bhuj is an arid area, the third category is assumed, i.e. continuous downpour since all the rainfall in the year is received over a few days' time with heavy intensity.

Table 7: Barlow's table

Barlow's Factors for runoff %

Class	Description of catchment	1.Light rain	2.Average or varying rainfall	3.Continuous downpour
A	Flat, cultivated, and absorbent soil	7%	10%	15%
B	Flat, partly cultivated, and stiff soil	12%	15%	18%
C	Average catchment	16%	20%	32%
D	Hills and plains with little cultivation	28%	35%	60%
E	Very hilly, steep and no cultivation	36%	45%	81%

Table 8: Runoff calculation for Bhuj

Inflow points	Catchment area	Catchment type	Runoff %	Area (sq km)	Annual Rainfall (m)	Runoff	Inflow amount
Haripar canal	Dhunaraja - unpaved	C3	32	3.61	0.43	0.50	0.50
	Lakki and tapka - unpaved	C3	3	3.00	0.43	0.41	0.41
						MCM	**0.91**

Source: CEPT analysis based on ACT data

3. Ground water inflow: For level aquifers, we assume rate of inflow and outflow between adjoining aquifers of the same type are the same and thus GW inflow and outflow cancel each other out across the equation.
4. Water import: Bhuj imports water from Naramada. In addition to this, GW extraction for Bhuj municipal supply takes place at Kukma, Madhapar and Bharapar. All three borewell sites fall outside the influence of the aquifer covering our study area. Thus we calculate these in imports.

Table 9: Annual bulk water import to Bhuj from outside sources

Source	MLD	MCM
From Narmada (MLD)	18	6.57
From Kukma borewells (MLD)	2.5	0.9125
From Bharapar borewells (MLD)	0.5	0.1825
From Madhapar borewells (MLD)	8	2.92
total	29	**10.585**

Source: CEPT analysis based on ACT data

Storage

1. Surface storage: In an annual cycle we consider all surface storage inside study area fill up once. We assume the bigger and more permanent lakes (category 1) to have an average depth of 3.11 m and the smaller ones (category 2) to have 1.5 m.

Table 10: Annual estimated surface storage of Bhuj

	Coverage Area (sq km)	Avg depth (m)	Capacity (MCM)
Category 1	0.98	3.1	3.04
Category 2	0.28	1.5	0.41
			3.45

Source: CEPT analysis based on ACT data

2. Ground water storage: Although aquifer storage is difficult to determine, we can estimate the amount through change in water table and water holding capacity of aquifer. Through local tests specific yield of this aquifer is determined to be 9.5%.

Table 11: Estimated groundwater storage of Bhuj

Aquifer type	Area (Sq.km)	Specific Yield (%)	Annual water table change	Storage (MCM)
Sandstone	56.6	9.5%	0.44	**2.37**

Source: CEPT analysis based on ACT data

Outflow

1. Evapo-transpiration: This is a total of 2 processes.
    a. From Scrub/forests and crops: Calculated using Pan-evapotranspiration, and consumptive use coefficients. In our case the major crop is wheat and rest is scrub.

Table 12: Estimated evapotranspiration from vegetation in Bhuj

	Crop	**Scrub/Forest**		**Wheat**	
	Area (Km2)	**3.90**		**4.38**	
Consumptive use coefficient (k)		**0.45**		**0.61**	
Month	**Pan Evaporation (cm)**	**PET (cm) =k*PanEv**	**AET (MCM) =area*PET**	**PET (cm) =k*PanEv**	**AET (MCM) =area*PET**
January	11.4	5.1	0.2	7.0	0.3
February	12.7	5.7	0.2	7.7	0.3
March	19.3				
April	20.6				
May	25.4				
June	26.7				
July	22.9	10.3	0.4		
August	20.0	9.0	0.4		
September	23.9	10.8	0.4		
October	15.2	6.8	0.3		
November	15.2	6.8	0.3	9.3	0.4
December	11.4	5.1	0.2	7.0	0.3
Total		59.7	2.3	30.9	1.4
Total annual (MCM)					**3.7**

Source: CEPT analysis based on ACT data

b. From surface storage:

Table 13: Estimated evapotranspiration from surface water in Bhuj

Surface area of water bodies (sq km)	1.53
Annual Evap rate (m/yr)	2.25
Total Evaporation from water bodies	**3.4425**

Source: CEPT analysis based on ACT data

Total evapo-transpiration = **7.1 MCM**

2. Stream outflow: Hamirsar-Umasar and Desalsar catchments fall inside our study area and the only Outflow point is the stream flowing northwards from Pragsar Lake towards Khari River. Since these catchments contain a considerable amount of built up area, the highest runoff factor (from previous Barlow table) is applied to these areas.

Table 14: Estimated runoff and stream-flow in Bhuj

Outflow points	Catchment area	Catchment type	Runoff %	Area (sq km)	Annual Rainfall (m)	Runoff
To Khari river	Inflow from outside area					0.91
	Paved	EC	0.80	18.28	0.43	6.29
	Unpaved	CC	0.32	38.36	0.43	5.28
Subtracting surface storage						3.25
Outflow (MCM)						**9.23**

Source: CEPT analysis based on ACT data

3. Ground water outflow: as described in GW inflow, for level aquifers, we assume rate of inflow and outflow between adjoining aquifers of the same type are the same and thus GW inflow and outflow cancel each other out across the equation.
4. Wastewater disposal to outside areas: Wastewater is generated in the city through usage of the the Municipal water supply as well as private groundwater extraction inside the study area. This is disposed off outside BHADA limits in Naghor. As a thumbrule of UWSS, we assume wastewater generation o be 80% of water supply.

Table 15: Wastewater disposal to outside areas in Bhuj

	Water supply	Wastewater generation	
	MLD	**MLD**	**MCM**
Municipal water supply	32.5	26	9.49
Private GW draft		8.06	6.448
Total			**15.93**

Source: CEPT analysis based on ACT data

Water balance analysis

Table 16: Water balance analysis of Bhuj

Inflow		**Estimated Storage**		**Out-flow**	
Rainfall	24.34	Surface	3.247	Evapo-transpiration	7.126
Inflow from other catchments	0.91	Ground water	2.37	Stream-flow to other catchments	9.23
GW inflow	0			GW outflow	0
Water Import	10.59			WW disposal outside of area	15.94
Total	**35.83**	**Total**	**5.612**	**Total**	**32.29**
Balance (MCM)	**Storage+c= Outflow-Inflow=**				**3.53**

Source: CEPT analysis based on ACT data

Analysis of water balance:

Outflow – Inflow is a positive amount indicating that Bhuj has enough reserves of water. However, water import constitutes a high percentage of inflow and without this import, groundwater extraction (from inside the system) will rise to match the water demand of the population leading to depletion of the water table. Wastewater generation, although dependent on water supply, offset by this groundwater extraction will remain a constant amount that is removed outside the area. This will result in a system where more and more water is leaving the study area, upsetting the current balance. We can conclude that positive storage in the equation is highly dependent on water import. In addition, wastewater disposal and stream-flow (run-off) are high contributors to outflow which can be harnessed.

Thus, in order to reduce its dependence on external distant sources, Bhuj needs to tap its own resource carefully and strategically. Strategy for water management based on water balance of Bhuj city should include preventing surplus runoff and “wastage” of wastewater as well as harnessing more and more rainwater for use as well as recharge.

2.3 Assessing options to improve security of water resources in Bhuj

This section describes efforts that need to be undertaken in Bhuj to improve water security. The water balance analysis suggests that such efforts should include preventing surplus runoff to flow out of city by building adequate infrastructure for storage (ponds/lakes), regulating abstraction of groundwater for domestic and other usages and reducing distribution losses. Revival of lakes and watershed system and integrated water resource planning should be accompanied by rainwater harvesting and recycling wastewater.

Revival of lakes and watershed system: Before introduction of the piped water in Bhuj, the entire urban water management system was dependent on the lakes. In such an arid and drought-prone area, the lakes served as a key source of water for storage and groundwater recharge, which has declined over the years. Historically, the Bhuj's lakes attract and sustain a variety of migratory birds including pelicans, flamingos, widgeons, mallards, and pintail ducks. The Lakes and reservoirs serve as a major recreational space for the city, providing the residents with rejuvenating places for relaxing. The traditional, religious and bathing rituals are still practiced when water fills the Hamirsar. This exhibits the water system's power to act as a social and religious binder (Revival of Hamirsar Lake and its catchment - wetland and urban rural relationships, 2012).

Bhuj needs to revive its lakes and its watershed. This will not only serve as an alternative water sources but eventually will also increase groundwater levels in aquifer and will act as a basis for community involvement.

Bhuj water supply system will depend on how city manages its water resource today and future perspective of its own resource.

Potential of rainwater harvesting: Bhuj is characterized by low and highly variable rainfall pattern. But even in the years of low rainfall, intensity is high with large amount of rain falling in short period of times. Hence most of water is wasted as runoff and very little is absorbed in the ground. Also concreting of roads and paved surface area have reduced water infiltration capacity.

One of the solutions for this is rainwater harvesting - capturing the runoff as it manages water at household or society scale. This method is effective in aquifer recharge by directing excess rain water into ground. Rainwater harvesting technique can also be adopted at city scale through storm water drains and infiltration trenches on roads or through recharge wells inside lakes. Water harvesting addresses issues of inadequacy of water supply, declining ground water level & groundwater quality.

For Bhuj, it is estimated that rain water harvesting potential is about 2000 million litres per annum, or 5.70 MLD. This is nearly one-fifth of the total water supply for Bhuj.

However, an enabling environment and governmental support are essential for spreading the concept and implementation of rainwater harvesting systems on a city level scale. Mainstreaming it in policy agendas, facilitating regulations, awareness raising, capacity building and technical know-how are all important for enhancing the use of rainwater harvesting systems.

DEWATS/ Wastewater treatment and recycling: Bhuj city must take into consideration wastewater treatment and recycling as additional water source, which could meet the increasing water demand. Recycled water can be used in agriculture and industries which requires large amount of water and which currently is extracted from groundwater. The use of recycled wastewater has been practised in many parts of the world for centuries. Whenever water of good quality is not available or is difficult to obtain, wastewater or drainage waters are spontaneously used, particularly for non-domestic usage like gardening, landscaping, washing, agricultural or industrial purposes. Hence, Bhuj should look at wastewater recycling as a long term option for meeting non-domestic water needs of city.

Watershed and aquifer management study for the catchment from which Bhuj draw its water: Bhuj city is currently dependent on water sources which are far from city and as population will grow and water demand will increase, this dependency will raise manifold in future posing more threat on these water resources. This has a huge effect on the catchment and aquifer of Kukma and Bharapar region from which they draw water. Hence it is crucial that city undertakes detailed study of Kukma and Bharapar catchment region and invest in recharge activities that will ensure sustainable and sufficient water resources in this region.

Thus, water security for future will depends on how Bhuj manages and revive local water resources today and reduces its dependence on external water sources. This will require a concerted effort by linking together traditional and centralized water system along with people's participation for better management and secured water resources.

3 Alternative Water Systems in Bhuj

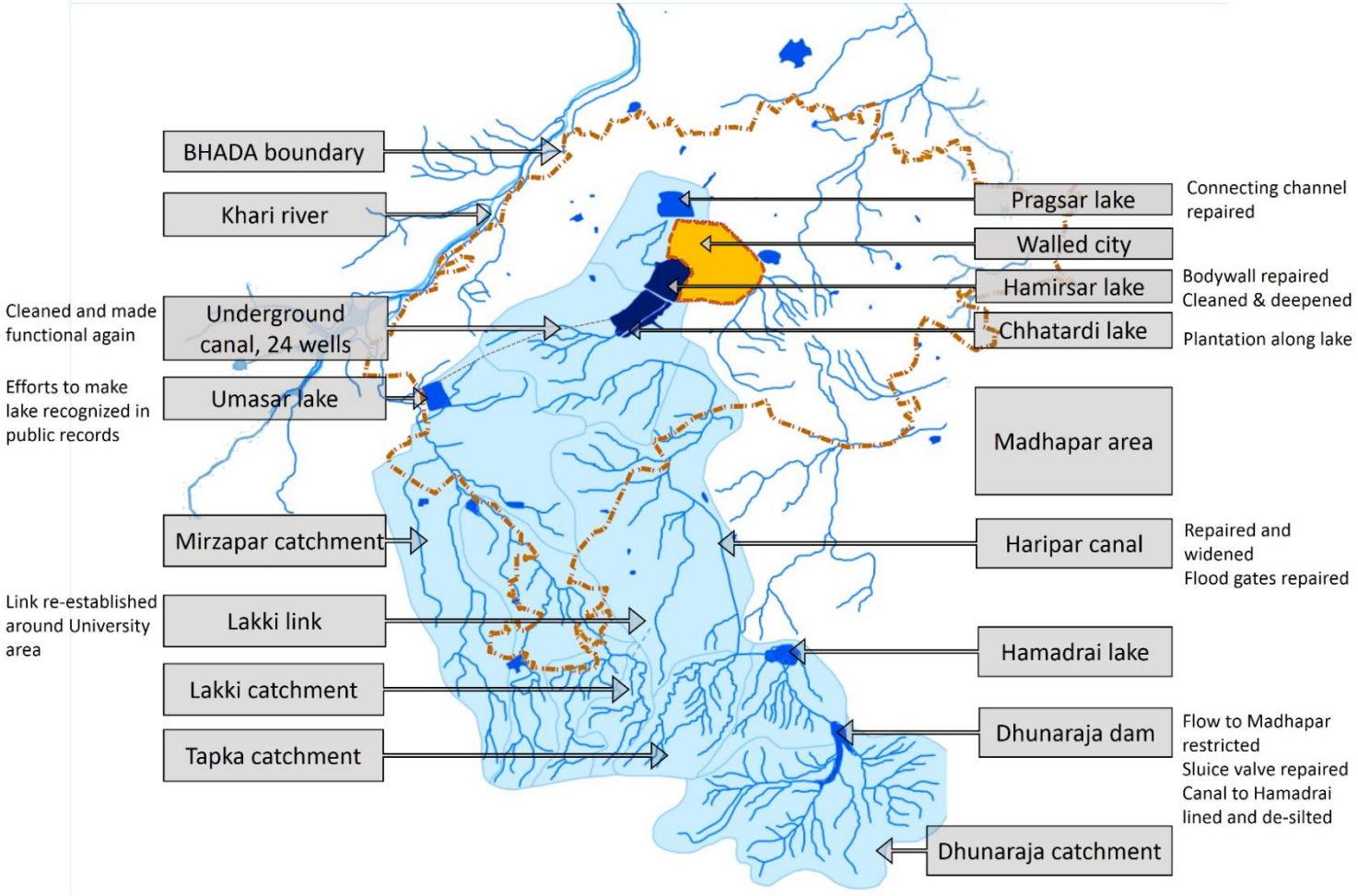
Most Indian cities have shifted focus from managing local water resources to look for 'perennial' water sources from afar. This dependence on water from distant sources has had cumulative negative effect on urban water management. First, with greater water availability, consumption (often wasteful consumption) of water increases. Second, since the local governments usually do not pay for the capital cost of bringing water to the city, its water tariffs do not reflect the costs. When water is provided at very low tariff, the real value of water is not recognized by both the local government and the consumers. This leads to neglect of basic water management practices viz. leakage management, pressure management, volumetric tariffs, replacement plan for assets etc.

This chapter describes various actions taken by Arid Community and Technology (ACT) and its partners in the context of exploring local water resources in Bhuj city. It highlights the measures taken by ACT to implement various projects, and assess its related impact. ACT decided to demonstrate alternative water supply approach in the city based on the technical studies carried out to understand hydrogeology of Bhuj. ACT demonstrated pilot projects in decentralized drinking water systems in slum areas, rainwater harvesting in residential and institutional buildings, groundwater recharge, revival of water bodies, revival of lakes etc. A key aspect of ACT's intervention has been the participation of the community in every project. With some success of its initiative, ACT has been able to influence the policy makers in Bhuj to adopt these measures at a city-wide scale.

3.1 Revival of lakes

In Bhuj, Hamisar Lake forms the largest and major water resource. Apart from this main lake, Bhuj has a network of another 43 lakes located in and around the city. These lakes are an important component of the water resource system of Bhuj city. These lakes formed an important part of natural watershed of Bhuj. However, over the years these lakes are forgotten and have become a victim of unplanned urban development.

Figure 11: Revival of Hamirsar catchment- summary



Source: Adapted from Raman (2013) and ACT interactions

ACT along with other stakeholders like JSSS, other civil society groups, local government, the District Collector office, State Irrigation department and Forest department worked towards revival of the lake system. In the summer of 2008, JSSS organized a programme of offering self-labour called "Swantah sukhay radiyamanu Hamirsar – Shram yagna" which resulted in a lake cleaning drive for Hamirsar. Around the same time, de-silting of Chhatardi & Dhobi lakes was undertaken leading to a complete revival of the 3 lake system of Bhuj. The forest department took up tree plantation along the boundary of Hamirsar and Chhatardi, which now serve as a wetland for migratory birds.

In 2009, the Bhuj municipality funded the repair and widening of the channel serving as overflow link between Hamirsar and Pragsar Lake thus fully re-establishing the old catchment system.

Between 2012 and 2014 a series of campaigns by ACT and its partners led to restoration, and in turn protection of 9 other, smaller lakes. Apart from this, ACT also carried out proper survey and mapping of all the 43 lakes in and around Bhuj and involvement of citizen group through formation of lakes conservation committee to protect, conserve, restore and develop lakes.

All these efforts in fixing the broken link and restoration of lake systems to revive the catchment system have met with great success.

3.2 Rainwater harvesting

"Rainwater harvesting, once seen as a quaint tradition of the rural poor, is growing in stature and scale, driven by urban demand, new mandates, economic incentives and the failures of centralised systems." – Vessela Monta[16]

Rainwater harvesting is one of the most effective manners for collecting and conserving rain water. In an urban setting, it forms a most fitting approach to manage water at a smaller scale. Advantage of installing rainwater harvesting system is that with this growing demand of water, partial demand of water can be met. Rainwater harvesting denotes the full spectrum of how we leverage rain to become water secure through retention, recharge or collection for direct use. Done well, it will slow down runoff, alleviate flood risks, reduce erosion, and mitigate droughts.[17] With an average rainfall of 430mm in Bhuj, conservation of this rain would aid in decreasing the dependency of the city on groundwater and distant water sources.

[16]Vessela Monta is a civil engineer, the author of the "Blue Schools" programme and since 2006, Executive Director of the International Rainwater Harvesting Alliance. Source: http://www.thesourcemagazine.org/heaven-sent-need-harvest-rainwater/ accessed on: 1.12.2016

[17]http://www.thesourcemagazine.org/heaven-sent-need-harvest-rainwater/ accessed on: 1.12.2016

a) Rooftop rainwater harvesting at campus level

In Bhuj, rooftop rainwater harvesting is done at two levels: campus level and household level. Many government schools in Bhuj lack access to drinking water. Based upon survey of municipal schools in Bhuj, ACT decided to take up pilot projects of rain water harvesting in these schools.

Another reason to take up rain water harvesting in the school was to make the children aware about the importance of conservation of water. As children are the leaders of the future, this project was important in itself for implementing water conservation plans, spreading awareness and carrying it forward at a same time.

After the initial survey, the Shiv Nagar Primary School was selected as a pilot project since it had severe water problems. Along with this, the principle of the school was also cooperative for the implementation of the rain water harvesting plan. The children and their parents were convinced to participate in the rain water harvesting project.

For making the students realize the importance of water and give them firsthand experience of the same, the school arranged a picnic with the help of JSSS[18] "Hamirsar Yatra". Along with this, meetings and film shows were arranged for parents. This approach of giving the students and parents information regarding water problem showing them how it can be solved, led to greater involvement of the students.

Figure 12: Field visit of students to understand importance of water

Source: ACT, Bhuj

The next step was to organize funding for the project. ACT found a donor "Sushil Trust". The staff of ACT also aided the project with some donation from their side. Apart from the donors, students were also involved in the project by collecting one rupee from each student as there donation towards the project. The parents also showed indirect support in executing the project. The table shows the amount of donation received by various stakeholders for RWH in the school:

[18] JSSS: A citizen led committee led by ACT

Table 17: Details of donor and donation for RWH in Shivranagar School

Name of Donor	Amount (Rs.)
Sushil Trust	32,000
School teachers and students	2,100
Nagarpalika	15,000
Contractor	5,000
Other donors	7,500
Total	61,600

Source: ACT, Bhuj

Figure 13: Students and teachers being a part of RWH implementation in campus

Source: ACT, Bhuj

Thus with the combined effort and support of the ACT, JSSS, Sushil Trust, staff of the school, Nagar seva sadan, students and their parents the project was successfully implemented and completed in year 2010. The project installed two water tanks of capacity 25000 liters and 10000 liters.

With installation of the rainwater harvesting system in the school, it solved the water problem. This resulted in many more students coming to this school for studies. With increasing number of students, the school started recharging the bore well through the rain water. For monitoring and maintaining the project, a student's committee was formed by the principle which takes care of the working of the system. Even during the non-working hours of the school, the people living around the school look after the system.

This project brought an end to the need of getting water through tankers in the school. Before the installation of the system, a tanker was needed every week to meet the water demand of the school.

The school administration spent over Rs 5000 each year for this. This amount is now saved and is used for student activities.[19] The implementation of this project led to many positive outcomes for the school. The school became a model for other schools for adopting rooftop rain water harvesting. Two of the school teachers also got inspired from such model and implemented it in their home as well.

During 2011-15, projects for rain water harvesting were implemented in 11 government schools and 2 private schools. These projects demonstrated roof based rain water harvesting, and storing nearly 1.15 lakh liters for use during the year. These projects also demonstrate support from large number of donors.

Table 18: Summary of School RRWH by ACT

School	Students	Total potential from Rain Water (L)	Work done		Expense Rs.			Public Contrib	Donation
			Water Tank (L)	Recharge Bore	Tank	Rechar. Bore	Total Rs.		
Shiv Nagar	445	80,000	35,000	80 ft	66,601	35,000	1,01,601	33,350	33,251
Bakali Colony	300	28,000	25,000	--	64,000		64,000	4,000	64,000
Chandra Jyotiba	368	28,000	25,000	--	64,000		64,000	1,500	64,000
Hiten Dholakia	505	80,000	30,000	80 ft	70,000	35,000	1,05,000	1501	70,000
Patwadi	310	90,000	40,000	--	1,00,000		1,00,000	3,600	1,00,000
Mundra Reloca.School	50	80000	25000	--	77191		77191	13650	63541
Mundra Reloca.School	50	80000	35000	100 ft	109987	40,000	149987	31000	78987
School No.7 Police Headquarters	425	84000	45000	100 ft	135000	40,000	175000	3300	132700
UmedNagar Primary School	322	82000	35000	100 ft	71788	40000	127888	10230	117888
Total	2775	632000	295000		658567	190000	658066	102131	624367

Source: ACT, Bhuj, 2015

[19] The total capital expenditure for the rainwater harvesting system is Rs 101,601. Purely in financial terms, the Rs 5000 savings of school suggests a long payback period of over 50 years (at 4 % interest which is savings bank interest). Thus RWH needs to be viewed in broader environmental dimension and not on financial parameters.

b) Rooftop rainwater harvesting at household level

Rainwater harvesting can be implemented at household level as well. In Bhuj, the implementation of rooftop rainwater harvesting in schools has been an inspiration to the residents around. Inspired by the efforts of school children, a few of the families have installed RWH at home.

Another reason for adopting RWH was poor quality of water supply. This made them dependent on tanker water suppliers. One household installed a tank with capacity of 20,000 liters for storing harvested rain water. This has helped the family reduce its dependence on water tankers.

It is recommended that RRWH should be made mandatory in Bhuj, as it has been successfully done in many cities – Chennai, Bangalore. CEPT has compiled the prevalent regulations related to RWH in cities of India. This has been discussed with Bhuj Municipality and Bhuj Area Development Authority (BHADA) officials.

3.3 Ground water recharge

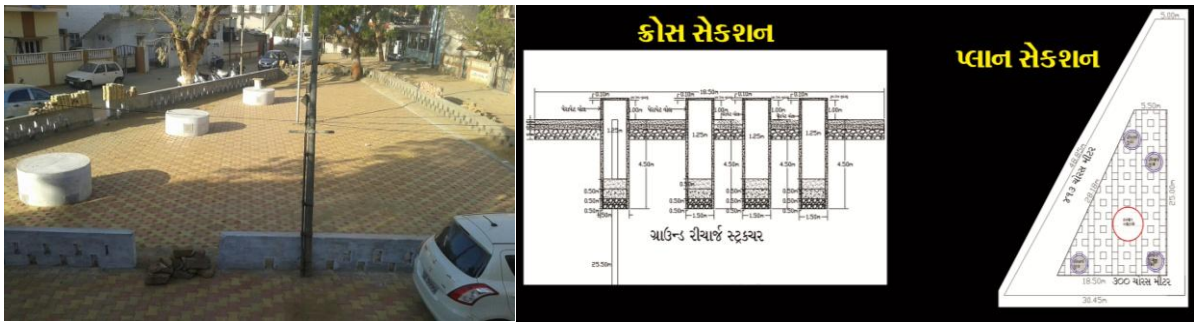
Increase in paved area and decreasing percolation zone is a major cause of water logging in the many parts of Bhuj. Unplanned urban expansion without taking into account the natural drainage pattern has blocked the channels that carried water to lakes. This break in the traditional catchment system is believed to be the main cause of water logging in Bhuj. Despite low average rainfall, and few rainy days, the rainfall is heavy. Heavy rainfall for a short duration leads to flooding as the natural drains are blocked.

To avoid flooding and water logging in the city, the surface runoff can be guided to the water body or to recharge pits. With this, the declining ground water level can be addressed. Thus it helps in addressing two issues simultaneously; reviving ground water levels and flood control.

a) Groundwater recharge at society level

Jubilee Colony of Bhuj made an attempt to recharge its groundwater with the help of recharge pits. It also stands as an example of citizen driven initiative for flood control measures. In September 2011, a heavy downpour led to a flood in Jubilee colony of Bhuj. Severe losses were incurred due to flood water entering the houses. This prompted the residents to take steps for preventing flooding in their area. JSSS volunteers took a transect walk of the area with the members of the colony and studied the flooding in the colony. The walk made it clear that the shape of the ground of the colony was like a saucer while the level of the surrounding roads was higher. This would make it impossible for the flood water to get an outlet.

Figure 14: Groundwater Recharge Plan at Jubilee Colony



Source: ACT, Bhuj

All the members of Jubilee colony came forward to join hands and implement the solution in the colony. The solution was very simple but innovative. It was decided to recharge the ground with recharge pits which would help the water to permeate in the ground as well as solve the problem of water logging. The cost incurred for recharge pits for Jubilee Colony:

Table 19: Cost incurred for recharge pits in Jubilee Colony

Items	**Total Cost (Rs.)**	Donors contribution (Rs.)		
		A.C.T	**Nagar Palika**	**Jubilee Colony**
Construction Cost	2,40,612	2,27,312	13,300	0
Recharging Borewells	54,100	54,100	0	0
Recharging Wells	70,205	34,205	0	36,000
Total	3,64,917	3,15,617	13,300	36,000

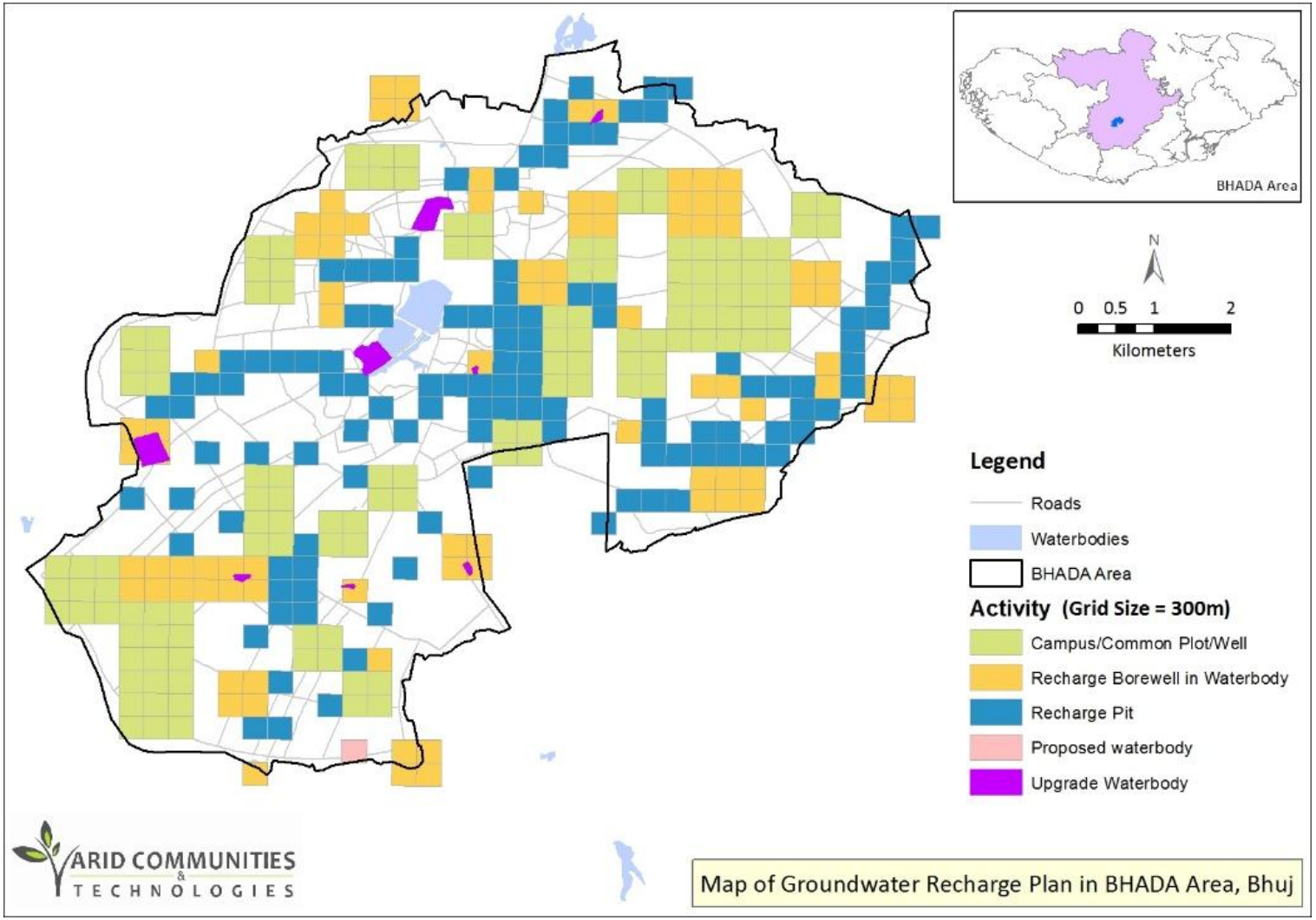
Source: ACT, Bhuj

Thus at a very low cost, ACT was able to demonstrate flood control and ground water recharge measure. Many other colonies have started to emulate the Jubilee Colony experience.

b) Groundwater recharge at city level

Bhuj Area Development Authority is in the process of preparing a new development plan. ACT's efforts and suggestions led to the Municipality paying special attention towards the subjects of ground water and storm water drainage. ACT compiled a set of suggestions and proposals which are now in the process of being incorporated into the Development Plan. ACT has suggested a recharge activity plan.

Figure 15: GW recharge plan proposal submitted as part of DP revision



Source: ACT, Bhuj, 2016

The plan proposes upgrading of several water bodies as well as the creation of a new lake with recharge borewells. Recharge pits are proposed at every 60 m in existing water channels. To support this, another plan to maintain the channels has been proposed. This is shown in figure 15. In addition to this, ACT suggested the use of common plots/ open grounds for collecting rainwater and using it for groundwater recharge.

3.4 Decentralized water supply schemes

In some sense, Bhuj already has a decentralized water supply scheme, with its WDS (water distribution station) spread over large area. However, there are parts of the city which are not served by municipal water supply network. ACT has made efforts to provide water in these areas.

a) Decentralized water supply schemes in slums

ACT and partners have demonstrated decentralized water planning in 6 slum areas. Four of these slums namely, Shivra Mandap Jagir Area (108 families), Bapa Dayalu Nagar Area (250 families), Ramdev Nagar Area (114 families), Kumbharvas Area (150 families), have their own drinking water schemes. Activities like installing hand pumps, de-silting and bund repair of existing ponds; construction of drinking water wells, storage tanks, pipeline distribution system, stand posts etc., were carried out by ACT and its partners.

For implementing decentralized water supply scheme in the slum, a reconnaissance survey was done. The ACT and JSSS team decided to carry out first pilot project in Shivramandap in the Madhavrai area. The area is located in ward no. 7 and was considered the worst in terms of water availability due to irregular supply by the Municipality. The slum has majority of the residents belonging to the Meena community who work as daily labourer, vegetable sellers, household help etc. Their average family income per month is around Rs. 3000/-.

Involvement of citizens for the project was the main aim of the team. The people of this community were mostly illiterate and were not convinced about the project. For them, awareness and motivation campaigns were organized to build up the trust of the residents. With support from Kutch Mahila Vikas Sangathan, the women in the area also formed a self- help group.

Figure 16: Community Participation for water supply in slum area

Source: ACT, Bhuj

After rigorous efforts of the team, the residents of the Shivramandap area gave their consent for the project. A water committee called the Madhavrai Pani Samiti was formed. The committee had office-bearers drawn from the community and included women as well. Initially the project had components of a new well, an overhead tank and five stand-posts. For the new well, location was finalized keeping in mind the area served and quality of water to be obtained. However, because of social barriers and opposition to the new well, it was not constructed. Instead, it was suggested by the community to use an old well within the community - "Vira Kuan". Moreover the "Vira Kuan" had sentimental value attached to it as it was a gift from the ancestors of the community. The water from the well was tested and considered safe to be a source of water for the community.

Since all the wells of Bhuj come under the governance of municipality of Bhuj, it became necessary to take permission for "Vira Kuan" as well. The municipality did not give permission in relation to ownership of the well for the community but allowed the usage of water from the well. Approval of the municipality was needed to lay pipes as well as construct the overhead tank.

Figure 17: Shivra Mandap public taps (left), Revitalized well (right)

Source: ACT, Bhuj

Work was taken up through a cost sharing arrangement, with residents of Shivra Mandap contributing their labor, Hunnarshala providing technical help and ACT provided financial help. An electric connection was taken out in the name of the committee which is responsible for paying the bills. Out of the 125 houses in the slum, only 40 houses opted to have taps installed in their homes. For a payment of Rs 150/- per month, which covers electricity charges, they get running water for one hour every alternate day. For those who could not afford tap water connections to their homes, 5 community stand-posts were constructed. The entire initiative is run, maintained and monitored by the community.

After the completion of the project, ACT made a presentation to the chief officer of Bhuj, head of nagar palika and councilors of various wards. A councilor of ward no. 11 decided to contribute towards the payment of electricity bill for a year.

At present, all the slums have municipal water supply except for four slum areas. However, the issue of access to water supply in slums is not resolved simply by laying water network. Water supplied is infrequent and inadequate. Better water management in slum areas is required.

b) Decentralized water supply scheme in non-poor areas

There are few societies in Bhuj that have decentralized systems. These societies were built when water network was not available. They had their own well and overhead tank. These societies now have access to municipal network and are willing to shift to the centralized water system. This is due to high cost of operations and maintenance of decentralized water system. However, since there is an initial investment in building capital asset, the municipality should explore if it can be integrated with their existing system.

An example of this is the case of Arihantnagar in Bhuj. Arihantnagar society was built in 1997, outside Bhuj municipality in the Keshavnagar gram panchayat. For water supply in the society, the builder built a decentralized network with 2 borewells and an overhead tank. This system was managed by a valve man employed by the society. The 350 households in the society are supplied water every day; with one-half receiving water in the morning while the other receiving it in the evening. For the water service, each household pays Rs. 200-250 per month[20]. In 2002, the society was included in the Bhuj NagarPalika area. Overtime, the society administration faced difficulty in collecting water charges. It was decided to handover the management of water services to Bhuj municipality.

[20] It should be recognized that this is very high in comparison to Bhuj municipality's water charge of Rs 900 per year.

In 2005-06, the municipality took over the operations and maintenance of water supply services in this society. The supply system remained the same but the residents paid water tax to municipality instead of the monthly charges to the society. The salary to the valve-men, electricity bill payment and the other repairs and maintenance charges are now borne by the municipality. The quality of water is however not good and many households use bottled water for drinking and cooking purposes while the bore-well water is used for other domestic purpose.

3.5 Wastewater reuse

As its name implies, wastewater is grossly undervalued as a potential resource. All too frequently wastewater is ignored and left to drain away. [21] Sustained investment gives a possibility to generate multiple dividends in society and in its environment. Around 50% of the water supplied is used for non-potable uses such as gardening, flushing, etc.[22]These end uses are currently using fresh water for the purpose. Recycled water would stand as a much appropriate and suitable option for sustaining the urban water cycle.

Figure 18: DEWATS unit installed by Hunnarshala

In Bhuj, an initiative was taken to reuse the treated wastewater through decentralized treatment plant. Hunnarshala installed three DEWATS units in Bhuj to recycle 15,000 liters of sewerage. This recycled water is used to landscape 1km of a rivulet's banks. Municipal waste water is fed to the DEWATS treatment plant and the treated water is used to greening of rivulet's banks.

Source: ACT, Bhuj

The various activities demonstrated by ACT and other partners illustrate that there are plenty of opportunity in adopting alternative water supply systems in Bhuj. Such demonstrations are also essential to raise awareness and better understanding of local citizen about water as a precious resource. However scaling up the pilot projects at city level requires detailed assessment of technical and financial aspects. This is described in next chapter.

[21] UNEP (2009), "Sick Water Report"
[22] CSE (2011),"Building Earthscrappers: Environment Impact Assessment of Buildings"

4. Feasibility Assessment for Alternative Water Supply System

This chapter builds up possible scenarios for alternative water supply system in Bhuj and attempts to quantify various systems. It also assesses the feasibility of scaling up alternative water supply systems through detailed technical and financial analysis. Based on this, it tries to identify the type of institutional and regulatory framework that would be required for implementing integrated urban water management systems in Bhuj.

4.1 Alternative options for urban water management: Technical and financial viabilities and gaps

A resilient urban water management system makes cities water secure. By relying on a limited number of water sources, cities put themselves at risk of increased competition for water, climate variability, and political wrangling[23]. In response to the rapidly increasing urbanization, alternative options for urban water management must also be kept into consideration.

Urban water management in Bhuj can be supported by both measures of increasing efficiency of existing water systems as well as water conservation practices. One approach is on supply side management - looking at alternative sources like rainwater harvesting, groundwater recharge, etc. Another approach is looking at increasing efficiency of existing system and demand management through proper pricing policy, metering of water supply, reducing water losses, etc. Both these approaches can be implemented simultaneously. The feasibilities of these options need to be evaluated in the context of Bhuj city to achieve the larger goal of urban water security.

Increasing efficiency of existing water systems

Review of existing water supply system suggested that the water supply in Bhuj could be augmented by increasing efficiency of existing systems. The efficiency of the existing system can be increased through simple measures like leak detection, control and prevention of illegal connections, metering of water supply, appropriate pricing mechanism, etc.

Measures for reducing Non revenue water (NRW): Reducing physical losses will not only help postpone capital investments for developing new water sources, it will also help reduce electricity

[23] 2012 International Bank for Reconstruction and Development / International Development Association or The World Bank, The future of water in African cities: Why waste water? By Michael Jacobsen, Michael webster, Kalanithy Vairavamoorthy,

bill.[24] Reducing water losses can also help water utilities ensure their financial viability and avoid a spiral of financial decline: Reducing the apparent loss component of NRW to the economic level minimizes the volume of water supplied to customers that is not paid for, thereby maximizing revenues, whilst reducing the real loss component of NRW to the economic level minimizes overall operating costs.[25]

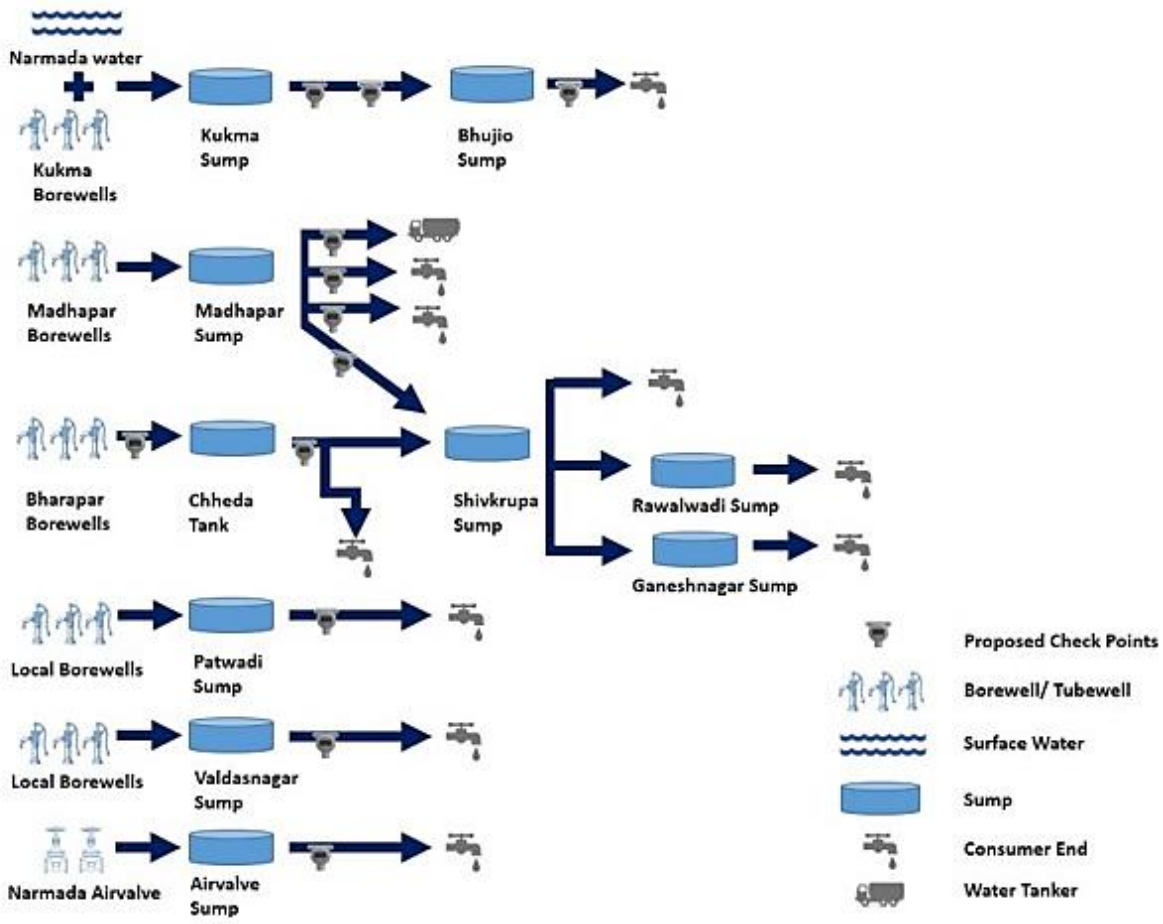
While there are no comprehensive studies undertaken in India, NRW is estimated to be in the range of 40% - 60% or even higher.[26] The Service Level Benchmark information on NRW (as reported by ULB) suggests that average NRW in Gujarat is 20%.[27] Bhuj Nagar Palika has reported 12% NRW in the service level benchmark[28] for the year 2014-15, however on the basis of the detailed field study carried out in Bhuj[29], NRW in Bhuj comes out to be around 40%. This largely consists of unbilled authorized consumption as well as real losses. However, these estimates are based on storage capacity and system inputs as recorded by ULB staff. It was observed that Bhuj city does not have any quantity measurement instruments at supply points nor at major distribution points. All quantities are estimated on the basis of system capacity rather than actual flows. To track these losses, the city must carry out water audit.

Water audits provide a decision making tool to ULB for quantification of water distribution system i.e. knowing where water is being supplied, where water is being loss, identify area of illegal extraction, leakages, which allows ULBs to take informed decisions about future investments to bring efficiency in water supply system[30]. It allows city to systematically reduce water losses, which will result in reduction of capital investments on augmenting new water sources. Moreover, the AMRUT mission also has a reform regarding water audit to be carried out by cities to understand the losses in its present network.

For the water audit to be carried out in Bhuj, 12 check points are identified where the water flow needs to be measured. With the existing water supply network the identified points where the checks would be appropriate to be carried out are marked in the figure below:

[24]Frauendorfer, R. and Liemberger, R. (2010),"The Issues and Challenges of Reducing Non-Revenue Water", ADB
[25] Fanner, P. (2008)," Non-Revenue Water reduction" Accadueo, Bologna
[26] PWC (2011)," Bringing water to your doorstep: Urban water reforms for the next decade"
[27] See pas.org.in for service level benchmarks of over 1800 cities in India
[28]Based on data submitted by the Bhuj Council to the Government of Gujarat for Service level benchmarking measurement; see pas.org.in
[29] Study carried out by students of Infrastructure Planning Studio 2016, CEPT University
[30] See Kalol water audit report (2011), and other presentations, PAS project, CEPT University

Figure 19: Schematic diagram of water supply in Bhuj with relevant check points



Source: Based on field visits and discussion with BNP

On the basis of findings from the water audit, the city can adopt further measures of tapping the leakages and also take decision to bill the other authorized consumptions.

Metering of water supply: Metering is an essential element of effective water management. In the absence of meters, urban local bodies (ULBs) are unable to prepare effective and equitable water distribution and management plan. Monitoring of water flow through meters is required to get a true picture of the operation of the utility distribution system as well as a city's actual water consumption.[31]Metering also enables ULBs to identify potential area of improvement and encourage taking up water conservation and efficiency measures. In Bhuj, metering was introduced at the time of inception of piped water supply system. The idea of paying for water by meters had deterred new connections. As a result in year 1972-73, meters were removed.

[31]AWA (2012),"Water Efficiency: The cases"

Currently, there is no provision for installation of water meters for consumers in the city. In Bhuj, water metering at consumer level as well as bulk meters at supply and distribution points is essential. In Bhuj, cost of installation of water meters will be Rs. 21crores. Proper regulations and awareness campaign is required to mandate installation of water meters at city level.

Table 20: Cost estimation for installation of meters in Bhuj

Sr. no.	Description	Units	Rs/unit	Total cost (Rs. in crores)
1	Consumer meters	34,608	6000	20.76
2	Bulk Meters	12	3,00,000	0.36
			Total Investment required	**21.12**

Source: CEPT Analysis

Pricing as a tool for water demand management: Currently, in Bhuj, water is supplied at a very subsidized rate. Water is treated as free commodity rather than a scarce resource. Pricing of water, as a tool for demand management, is expected to achieve the double benefits of reducing demand and improving financial sustainability of supply systems[32]. In Bhuj, water users are categorized into 3 main categories: residential, commercial and institutional. Of the total 34,608 number of connections; 33,291 are under residential category, 1031 are commercial and 236 are of Institution category.[33] Bhuj Municipality follows furrel based water tariff for different category of users. Following table depicts tariff structure for each user category:

Table 21: Existing water tariff structure in Bhuj

Category	Furrel Size	Tariff per Annum
Residential	15 mm	Rs. 900/-
	20 mm	Rs.1800/-
Commercial	15 mm	Rs. 3600/
	20 mm	Rs. 18000/-
Institutions	Meter Connection	Rs. 120/- per 5KL

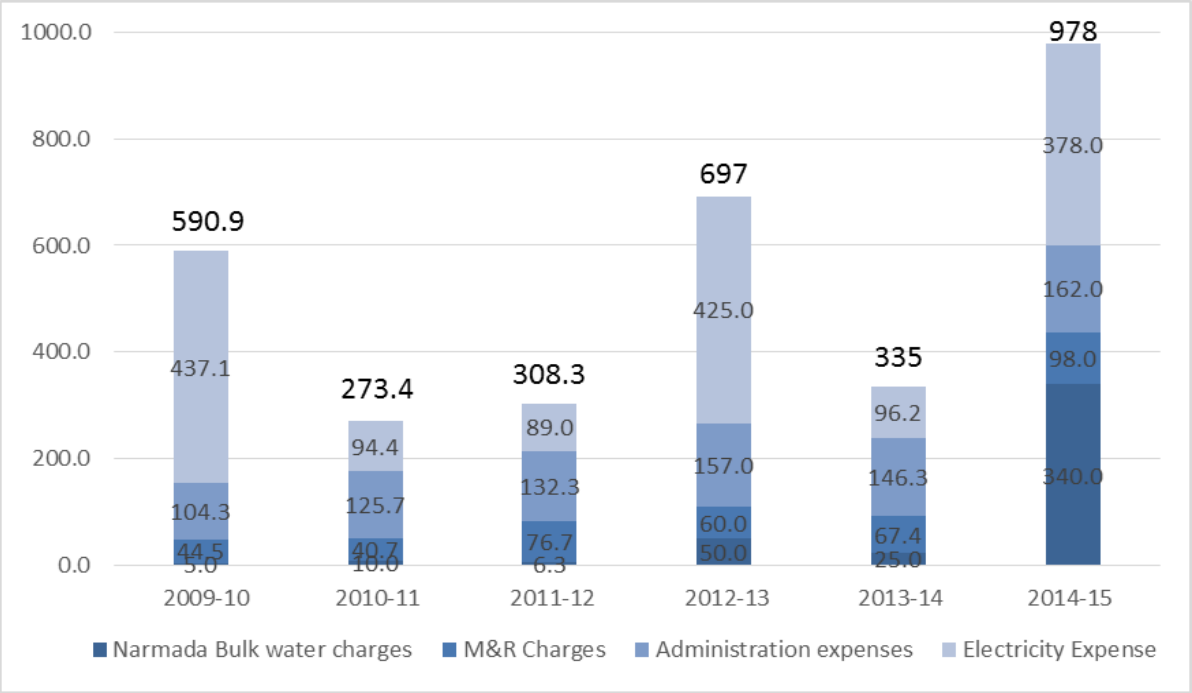
Source: Bhuj Nagar Palika

[32] EUSPP (2013), Report on" Regulating water demand and use in Rajasthan" by Surjit Singh V Ratna Reddy Charles Batchelor D.K. Marothia A.J. James M.S. Rathore

[33] ACT (2016),"Water economics of Bhuj"

Figure 20: Revenue expenditure for water supply in Bhuj

All values in lakhs

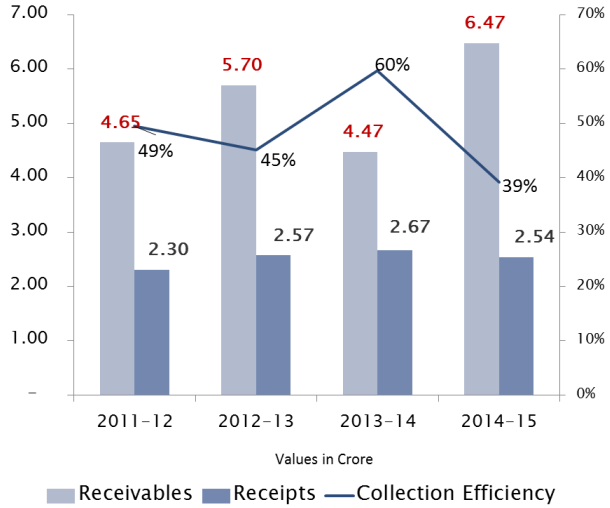


*Source: Bhuj Nagar Palika, Cash Based system**

The major heads involved in water supply revenue expenditure are of Narmada bulk water charges, maintenance and repair charges, administration expenses and electricity expenses. For the financial years 2009-10, 2012-13 and 2014-15, major contributor to the cost of delivery of municipal water supply is of the electricity charges. These costs are high due to the terrain of the city, as cost incurred in pumping of water is huge. The electricity charges presented in the graph do not include the dues of BNP towards PGVCL for electricity charges. With increase in the demand for water and one source being Narmada water, cost incurred in Narmada water charges has also increased. Although due to the dispute regarding the amount of Narmada water supply to BNP, the Narmada water charges claimed by GWIL are not paid by BNP. Thus the graph above does not include the pending dues for electricity charges to PGVCL and Narmada water supply charges to GWIL. If these were included, the expenditure would be doubled.

The BNP owes an amount of 10.3 crores for bulk water purchase for financial year 2014-15. Based on this, we can estimate that cost of water supply as 17.3 Rs per kl (excluding pending electricity charges). The present tariff structure, can recover only Rs. 3.98/- per KL against cost of Rs. 17.3 per KL. Which is only 16% of total cost that municipality incurs for water supply.

Figure 21: Collection efficiency of water charges in Bhuj



Source: Water Economics of Bhuj, 2015

Moreover the collection efficiency since the past four years has been in the range of 40-60%. However, looking at the recovery ratio against current year's receivables only for FY 2014-15 (Excludes receivables from previous years) it is slightly higher than overall recovery of that year. The current year's receivables for water tax in 2014-15 were Rs. 3.34 Crores against which the receipts of current year were Rs. 1.44 Crores which is 44%.[34]

Thus in order to improve the efficiency of the present system, tariff charges and its collection must be revised. User charges should be sufficient to meet at least the marginal cost of supply. Elasticity of tariffs is important: tariffs should be responsive to changes in population, household income, and inflation, which affect demand and production costs.[35]

As discussed above, Bhuj levies water tax on its residents at a fixed rate of 900 or 1800rs per annum which is insufficient to recover the cost incurred in daily operations and maintenance of the service. Thus revision of tariff becomes an important aspect as to recover it. If tariffs are not high enough, the municipality will remain financially weak and will not be able to provide appropriate service to its customers.[36]

One of the approaches for rational tariff revision would be of introducing water metering (domestic and commercial level and utility water mains) and adopt volumetric pricing system. The fixed pricing levied by Bhuj municipality will have to be replaced by volumetric or slab tariffs along with metered connections. Unless public funds are available to subsidize water supply operations, a utility's tariffs and connection fees are its only income to run the service.[37]In order to obtain 100% cost recovery of the operations and maintenance, volumetric pricing for Bhuj will be as follows:

[34]ACT (2016),"Report on Understanding Investments, Economics and Pricing Principles of Drinking Water in Bhuj City and Prospects of Local Water Resource Development: (Draft report)"

[35] WSP (2011)," Cost recovery in urban water services: Select experiences in Indian cities"

[36]Frauendorfer, R. and Liemberger, R. (2010),"The Issues and Challenges of Reducing Non-Revenue Water", ADB

[37] Berg, V. and Holt, L. (2002),"Pricing: The Most Dangerous and Most Important Decision" International Water Association

Table 22: Proposed volumetric water tariff for Bhuj

Particulars	Volumetric Water Tariff (Rs./ kl)*
Residential	21.4
Commercial	104
Institutional	125

*Source: Based on PAS Water Tariff Setting Model**

These tariffs are quite high in comparison to what is charged in other cities of India. (e.g. Mumbai charges Rs. 6/kl). So Bhuj will need to adopt a progressive water tariff.

Daily supply of water: In Bhuj, water is supplied on every alternate day. Key reasons attributed for the alternate day supply are less storage capacity and uneven topography. Detailed evaluation of existing storage capacity (ESR and OHT) was carried out to find out shortage in storage capacity if water is required to be supplied on daily basis.The CPHEEO Manual states that "A system supplied by pumps with 100% standby will require less storage capacity than that with less standby provision. Similarly a system divided into interconnected zones will require less storage capacity for all the zones except for the zones at higher elevations". However, on an average, according to CPHEEO, the storage capacity should be at least 30 percent of the total water supplied daily.

Table 23: Analysis of water storage capacity

Water Sumps	Water to be supplied daily (MLD)	Storage requirement (Lac litres) (30% of supply)	Existing storage capacity (Lac litres)	Extra storage capacity required (Lac litres)
Kukma	16.5	49.50	150	-
Madhapar sump	10.7	32.20	10	**22.20**
Bhujia Sump	32.3	97.04	60	**37.04**
Shivkrupa sump	10.2	30.53	12	**18.53**
Rawalwadi sump	5.5	16.44	20	-
Ganeshnagar sump	0.9	2.68	10	-
Patwadi	4.1	12.42	7.5	**4.92**
Valdasnagar	0.4	1.34	3	-
Narmada Airvalve	4.5	13.57	40	-
Cheda Tank (Bharapar)	4.3	13.00	25	-

Source: BNP and CEPT analysis

The result from above analysis shows that only four sumps required extra storage capacity. In that Madhapar, Bhujia and Shivkrupa are major sumps whose capacity needs to be augmented as they serves dual purpose of direct distribution for service area and source for other distribution sumps.

Bhuj Nagar Palika has already proposed project for construction of new 50 Lac litres and 40 lac litres sumps at Bhujia and Madhapar respectively under AMRUT scheme. Once this project gets implemented, extra storage capacity would be required for shivrkrupa and patwadi sump only.

Apart from increasing storage capacity, uneven topography is another reason for alternate day water supply in Bhuj. It was required for the people to get water at good pressure and for a longer time. Piped water supply in such areas could be augmented by either placing booster pumps or extra storage reservoir at suitable locations.

Improving quality of supplied water: Currently the municipal water supply in Bhuj does not have a proper treating mechanism before serving it to the households. Since the water treatment plant is not functional, chlorination process is only performed before water is supplied to them. Thus the quality of water received is a major concern for a citizen of Bhuj.

Figure 22: Narmada water storage tank at Kukma

Source: Primary survey

Surface water from Narmada and groundwater from kukma is mixed together before distribution. Groundwater extracted from Kukma is also high in TDS and is improved by mixing it with Narmada water. Thus there is a need for the city to focus on the quality of water served and not mere quantity. Water treatment plant must be operated to treat the Narmada water and Kukma groundwater before supplying. Bhuj Nagar Palika has already proposed project for repair and operations and maintenance of existing non-functional water treatment plant under AMRUT.

Another source for water supply in Bhuj is through borewells located at Madhapar, Bharapar, Patwadi, Valdasnagar and Arihantnagar. Major quality issues observed in this sources are the high content of iron (observed from the colour of water) and TDS. Poor water quality is also imposing indirect coping cost on households in terms of money spent on RO treatment or purchasing of RO bottle water.

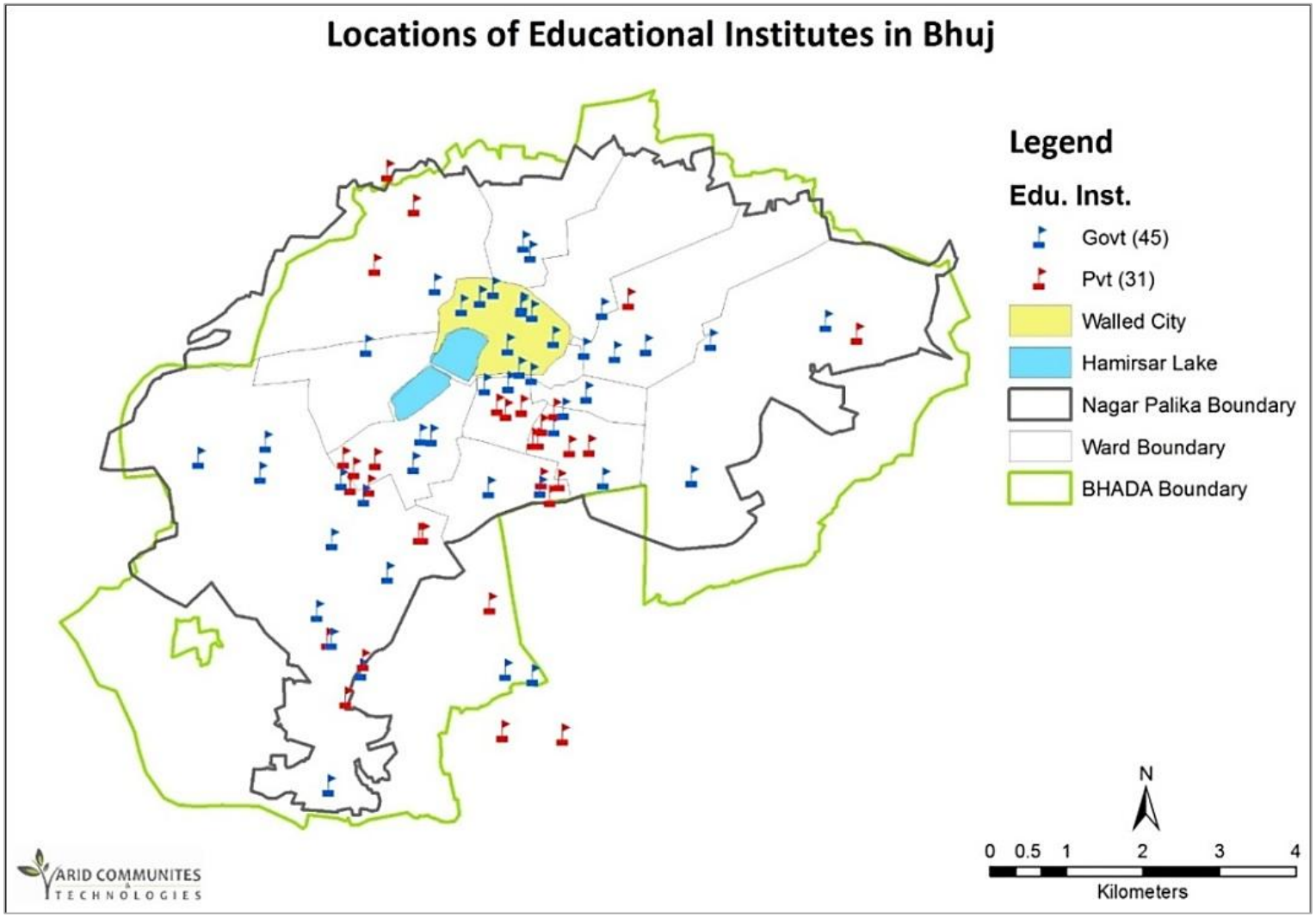
As these sources are at different locations adopting a centralized system for treating groundwater would not be a feasible option. With new evolving technologies, options for onsite groundwater treatment must be explored. Technologies are now driven according to the water quality issue. Fluoride removal systems, reverse osmosis system, iron removal systems, etc. can be adopted according to the quality of water available at different locations.

Water conservation and demand management through other practices

The other practices involve adaption and implementation of strategy to influence water demand by adopting a different approach than the conservative approach of centralized water supply system. These would mainly consist of adopting systems which reduces the dependency of the citizens on city's water supply and try to make areas self-sufficient. Few of the practices which can be adopted at city-scale are as follows:

Making all Educational Institutes 'Self-Sufficient': Majority of the educational institutes in Bhuj are dependent on the multiple sources of water: municipal water supply, tanker water supply or bottled water supply. The foremost source of water "rain" is unheeded by a few. If all the education institutes present in the city adopt the practice of rooftop rainwater harvesting, a large portion of rainwater can be captured**.** It stands as a potential approach for managing water demand at campus level. If all 45 government educational institutes and 31 private educational institutes take up this initiative, it would help in reducing its dependency on tanker water supply system and will make these institutes 'self-sufficient'.

Figure 23: Locations of Educational Institutes in Bhuj



Source: ACT, Bhuj

A study done by ACT shows that all education institutions (schools and colleges) can manage their water demand by harvesting and recharging through only 61 % of rainfall received by their own campus.[38]Priority should be given to all institutes which have large campuses to take up rainwater harvesting system. Considering all the educational institutes taking up rainwater harvesting and capturing a minimum of 50% of the rainfall, the amount of total water harvested is as follows:

Table 24: Rain water harvesting potential for educational institutes

Feasibility of Rain Water Harvesting and GW Recharge in Educational institutes of Bhuj	
Education Units (Government and Private)	76
Student Population	38,000
Drinking Water Demand* (KL)	16,720
Other Domestic Demand** (KL)	83,600
Total Water Requirement (kilo litre)	**100,320**
Available Campus Area (sqm)	760,000
Gross Available Annual Rainfall @430 mm (kilo litre)	326,800
Dependable Rainfall (50 %)	163,400
Water Demand % against available Rainwater	**61%**

*2litres/student/ day ;**10 litres/student/day

Source: CEPT Analysis

From above analysis it can be observed that rainwater harvesting structures in educational institutes not only help them in fulfilling their water requirements but also improve groundwater level through proper recharge activities. Apart from this, educational institutes and students can play crucial role to encourage local citizens to adopt rain water harvesting system in their premises. By keeping a small rain gauge, a school can involve students in monitoring rainfall in a year; water collected in the rainwater tank and teaches them to ensure good maintenance of the system. Some of them could become model rain-center to spread awareness about the need to manage water resources efficiently and harness rainwater. Thus rainwater harvesting in educational institutes will not only help conserve water but also help students understand the concept of sustainable use of natural resources.

From economic perspective, the major investment is required for the capital works to set up the rain water harvesting structures at these institutes. Most of the rain water harvesting structure are made with a combination of tank and recharge wells. Thus a one-time investment is required for making

[38] AMRUT SLIP of water supply for Bhuj city

an educational institute self-sufficient in regards to its water demand, since operations and maintenance cost of these structures is also not ample. There are other maintenance requirement like cleaning of roof, removing the first flush and cleaning the filter unit, but these are only one time operations and can be undertaken by involving students volunteer.

To determine the benefits of these investments, it would be beneficial to calculate how soon the investment will pay for itself. Payback period for RRWH structures would be: amount invested in rainwater harvesting to annual savings made from this investment. Considering a working example, before the installation of RRWH a school was dependent on the water tankers with an expenditure of Rs. 5000 a year. A RRWH structure costing around Rs. 66,000, the payback period turns out to be of 13 years as the rain water harvesting structure would act as savings on the annual expenditure for water tankers[39]. Assuming 2% annual increase in the price of water tankers, the payback period would reduce to 11 years.

Potential for scaling up RRWH at residential places: Similar to the above case, if all the residential places are imposed to adopt compulsory rooftop rainwater harvesting it would help in capturing a large amount of rainwater. If 70% of the rainwater which falls on the roof is captured effectively, then also a major amount of water would be conserved in short time. The following table shows the amount of rainwater which would be harvested according to the available roof area:

Table 25: Potential of rainwater harvesting at household level according to rooftop area

Roof Area (Sq. m)	Potential of Water Harvested at each Rooftop (Liters)	Roof Area (Sq. m)	Potential of Water Harvested at each Rooftop (Liters)
40	12,040	100	30,100
45	13,545	125	37,625
50	15,050	150	45,150
60	18,060	175	40,515
70	21,070	200	60,200
80	24,080	250	75,250
90	27,090	300	90,300

Source: CEPT analysis

Keeping into consideration the size of the rooftops, rainwater harvesting must be made mandatory. For the smaller rooftop areas, storing rainwater does not hold as a solution since the capturing area

[39] This is calculated assuming zero interest on 66,000. While proper financial analysis would need to be done on market interest rate, in this case bulk of the investment is from donations/charity and hence the opportunity cost of these funds is zero and hence a zero interest assumption is valid.

becomes very small as well as there could be possibility of unavailability of space for creating such structures. Therefore there must be consideration in regards with the plot size. Based on the efforts of ACT and partners, the new development plan of Bhuj has included this in its regulations. As per Bhuj GDCR (General Development control Regulation), rainwater harvesting will be mandatory for all buildings with ground coverage 80 sq.mt. and above. However, implementing this regulation will be a major challenge.

Regulations for Rainwater Harvesting as per Bhuj GDCR:

Rain water harvesting is mandatory for all buildings with ground coverage 80 sq.mt. and above. The system of storm water drainage and storage in reservoirs and recharge should conform to one of the following specifications:

a. For Buildings with ground coverage above 80 sq.mt. and below 500 sq.mt: Percolation Pit or Bore Recharge shall be provided in the marginal space around the building. Such pits shall be filled with small pebbles, brick jelly or river sand and covered with perforated concrete slabs.
b. For Buildings with building-unit area above 500sq.mt. and up to 1500 sq.mt.:Percolating Well with Rain Water Harvesting System shall be provided (up to ground First River)
c. For Buildings with building-unit area above 1500 sq.mt. and up to 4000 sq.mt.: Percolating Well with Rain Water Harvesting System shall be provided for every 4000sq.mt. (up to ground Second River).
d. For Buildings with building-unit area above 4000 sq.mt.: One Percolating Well shall be provided for every 4000 sq.mt. land area. As an alternative to providing multiple percolating wells, a Water Retention Pond with minimum capacity of 300,000 liters with a percolating well for every five percolating wells or part thereof shall be permitted as an alternative.

For all building-units with area more than 1000 sq.mt., Rain water storage tank shall be mandatory with adequate storage capacity.

Source: Draft Bhuj GDCR, 2025

Considering the use of harvested rainwater for portable uses only, the availability of water harvested can be consumed for the whole year. Maximum storage capacity required would be 10-15 KL according to the household size. This captured water can cater to the household demand of potable uses. This storage of rainwater would ensure good quality of water. Moreover there will be annual savings for the houses which are dependent on bottled water supply.

Rooftop rainwater harvesting has number of advantages including reduction in overall quantity of municipal water to be supplied to the households. In Bhuj there are total 40,000 households. As per DCR, RWH is compulsory for building with ground coverage of 80 sqmt. Considering nearly 80% of households having ground coverage above 80 Sqmt, total 32,000 households would be required to have RWH structures.

Table 26: Rain water Harvesting potential for residential structures

Sr. No.	Description	Value
1	Total households with RWH structures (No.)	32,000
2	Min roof area (Sqmt)	80
3	Average rainfall (mm)	430
4	Total rainwater harvested (lit)	34,400
5	Assuming 70% of water falling on roof to be collected, total rainwater harvested (lit)	24,080
6	**Total water to be collected from all households(ML)**	**770**
7	Total number of water supply days in a year which municipal authority could save through RWH, Considering 32.5 MLD of daily water supplied by Bhuj Nagar Palika	24 days

Source: CEPT analysis

From above analysis, it can be seen that total 770 Million litres of rain water could be harvested in a year through installation of RRWH structures, which will ultimately reduce pressure on Bhuj Nagar Palika to fetch water from distant sources.

The basic cost estimate of rainwater harvesting structure at household level depends on the quantity of rainwater one wants to store or recharge and the type of material used. Cost estimate for installation of rainwater harvesting in existing building is as per below table. The costs would be comparatively less if the system were incorporated during the construction of the building itself.

Table 27: Cost estimate for installation of Rooftop rainwater harvesting structure in one household

Sr. No.	Items	Block cost (INR)
1	Plastic Water tanks (Rs/litre)	4-6
2	Ferro cement tanks (Rs/litre)	2.5-1.5
3	Plumbing work (Rs.)	5000-20000
4	Recharge borewell	45000

Source: Based on RRWH projects implemented in Bhuj

Rainfall is hard to predict and it becomes one of the limiting factor in RWH systems. Thus total dependency on the rainwater for all the daily needs would not stand as a viable option. Moreover collection and storage facilities would also impose a challenge as the short time storage won't be

able to serve for the entire year. The dependency on this captured water can be kept only for a short period depending on the capacity of the storage facilities.

Thus, Rainwater harvesting could contribute to improve the urban water management in the Bhuj city. Another benefit of rainwater harvesting at the household level is less dependence on municipal water supply. In the Bhuj environment where the municipal water supply is not on daily basis and the groundwater table is declining, an alternative water source in form of harvested rainwater would help to level out supply gaps and ensure higher water security. It could provide safe drinking water during the monsoon, reduce the risks of urban floods, refill the declining groundwater levels and take pressure off the overloaded municipal supply system. The economic benefits are probably not high enough to be an incentive for the people to invest in RWH structures against subsidies cost of municipal water supply. Hence proper policy regulations for compulsory installations and incentives are required, which would trigger citizens to take up RWH in their households. Simultaneously, appropriate tariff structure for water will need to be implemented.

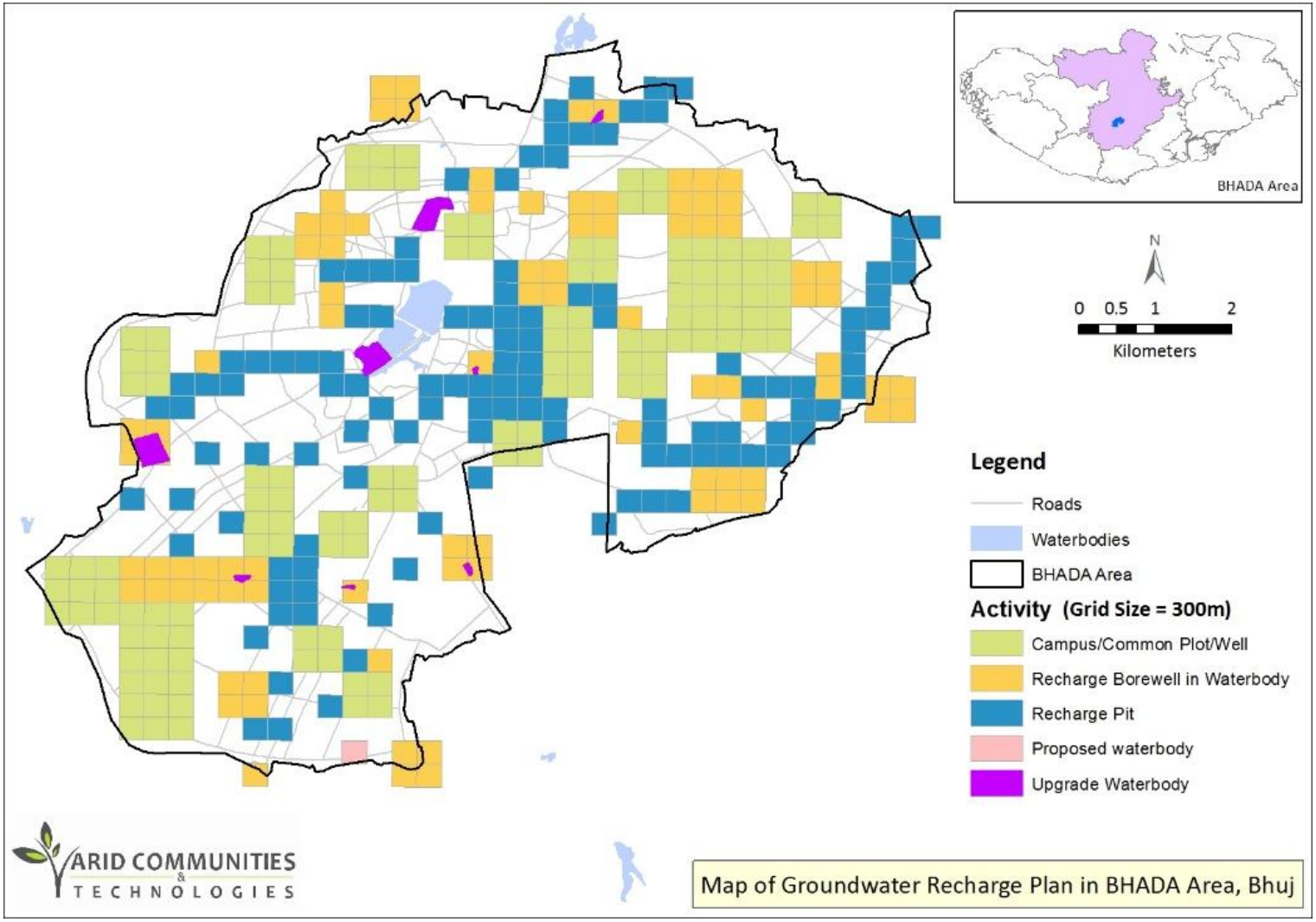
Groundwater recharge potential and revival of lakes: Groundwater recharge potential of any region is determined by its geology and aquifer system. Bhuj falls in one of the most arid regions of India receiving around 430 mm of annual rainfall in comparison to the national average of 1152 mm. Despite this, Bhuj has survived several years of droughts and low rainfall because of its unique geo-hydrology and aquifer system. Bhuj has relied on groundwater for centuries. This was possible due to its placement on a porous sandstone aquifer and an ingenious lake system. The main rock formations of the area are sandstone and shale with a few basaltic intrusions. This formation is divided into two parts known as lower Bhuj formations and upper Bhuj formations. This cretaceous sandstone belt is one of the few in Kachchh, and has enormous capacity to hold water for year-round municipal and agricultural use. With fault lines on south, east and west, it forms a confined aquifer which is an added advantage for the Bhuj.

Hydrogeological scenario and history of urban water management in Bhuj confirms that city has high potential for groundwater recharge, which if managed and utilized suitably may help to achieve urban water security in the city. In this regard, ACT has already pilot tested groundwater recharge activities in jubilee colony and Kachchh University. ACT's efforts and suggestions led to the municipality paying more attention towards the subjects of ground water and storm water drainage. ACT has proposed city level recharge plan to local government for further incorporation in AMRUT scheme and Development Plan. Under this, two types of interventions are proposed. First is the

revival/upgradation of lakes to maintain rainwater inflow by managing natural channel width based on runoff calculation and proposal for development of new water bodies.

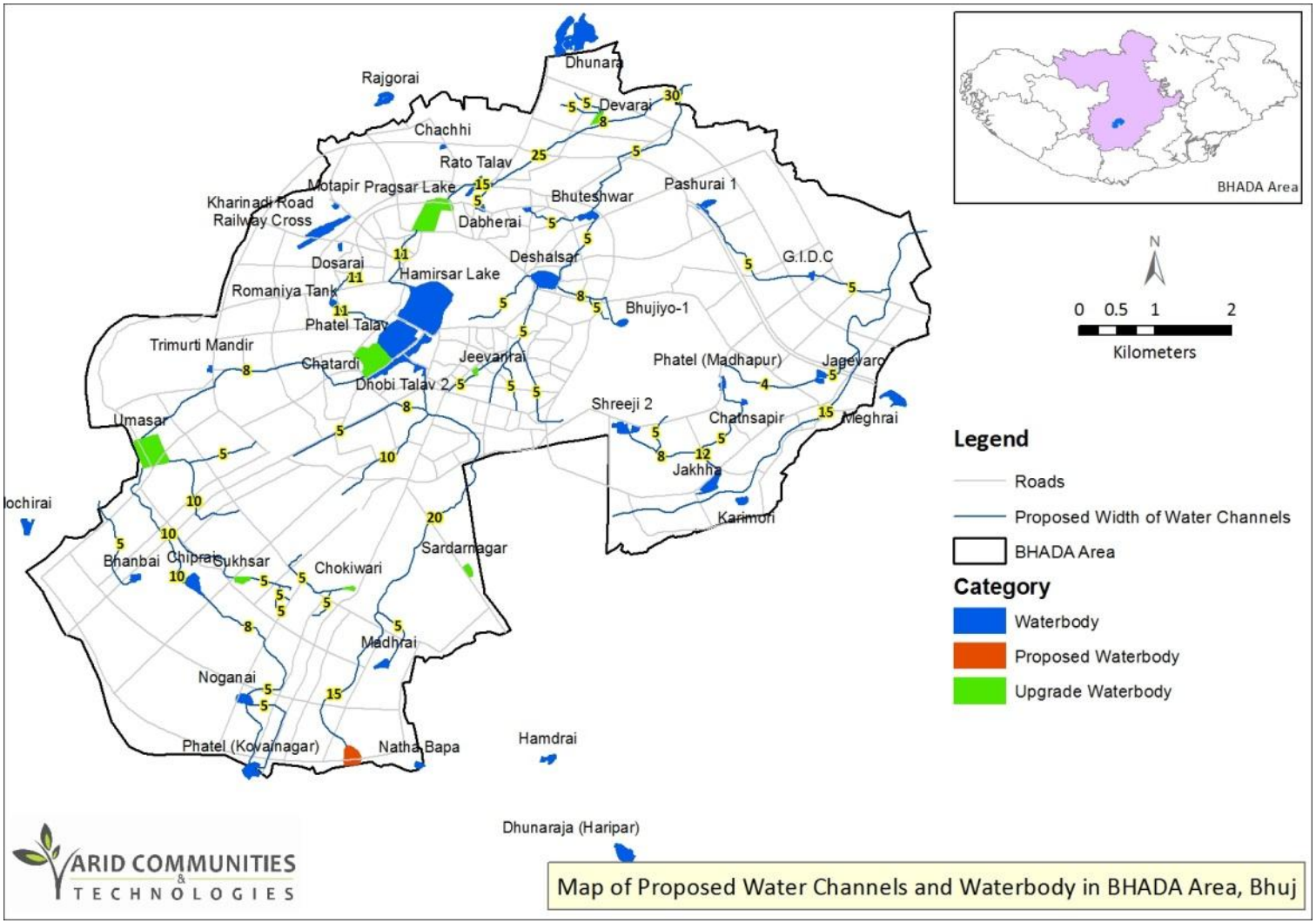
In the second intervention emphasis is on groundwater recharge activities. In this, ACT suggested the use of common plots/ open grounds for collection of rainwater, recharge pits at every 60 m in existing water channels and promotion of campus water recharge.

Figure 24: GW recharge plan proposal submitted as part of DP revision



Source: ACT, Bhuj, 2016

Figure 25: Water channel and water body revival plan proposal submitted as part of DP revision



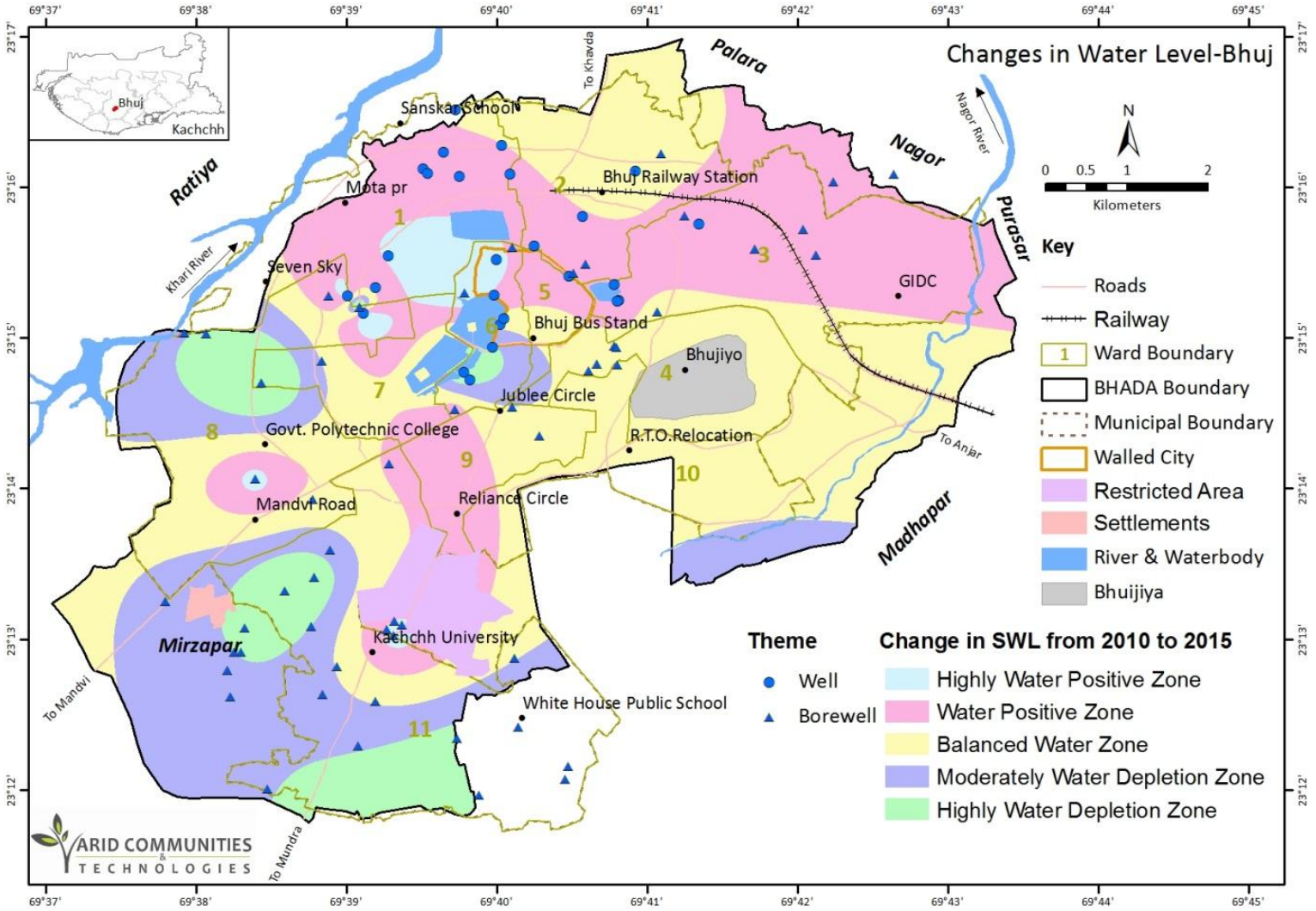
Source: ACT, Bhuj, 2016

Apart from above, ACT also carried out study on feasibility analysis of groundwater augmentation. ACT has been regularly monitoring pre and post monsoon ground water level and its quality through 79 observation wells. These observation wells are equally distributed within the BHADA area including borewells of ULB and private households. For the feasibility analysis study, observation well data from the year 2010 to year 2015 was analyzed. In this study, recharge potential areas was determined based on two criteria's:

1. Changes in water level over years
2. Changes in water quality over years

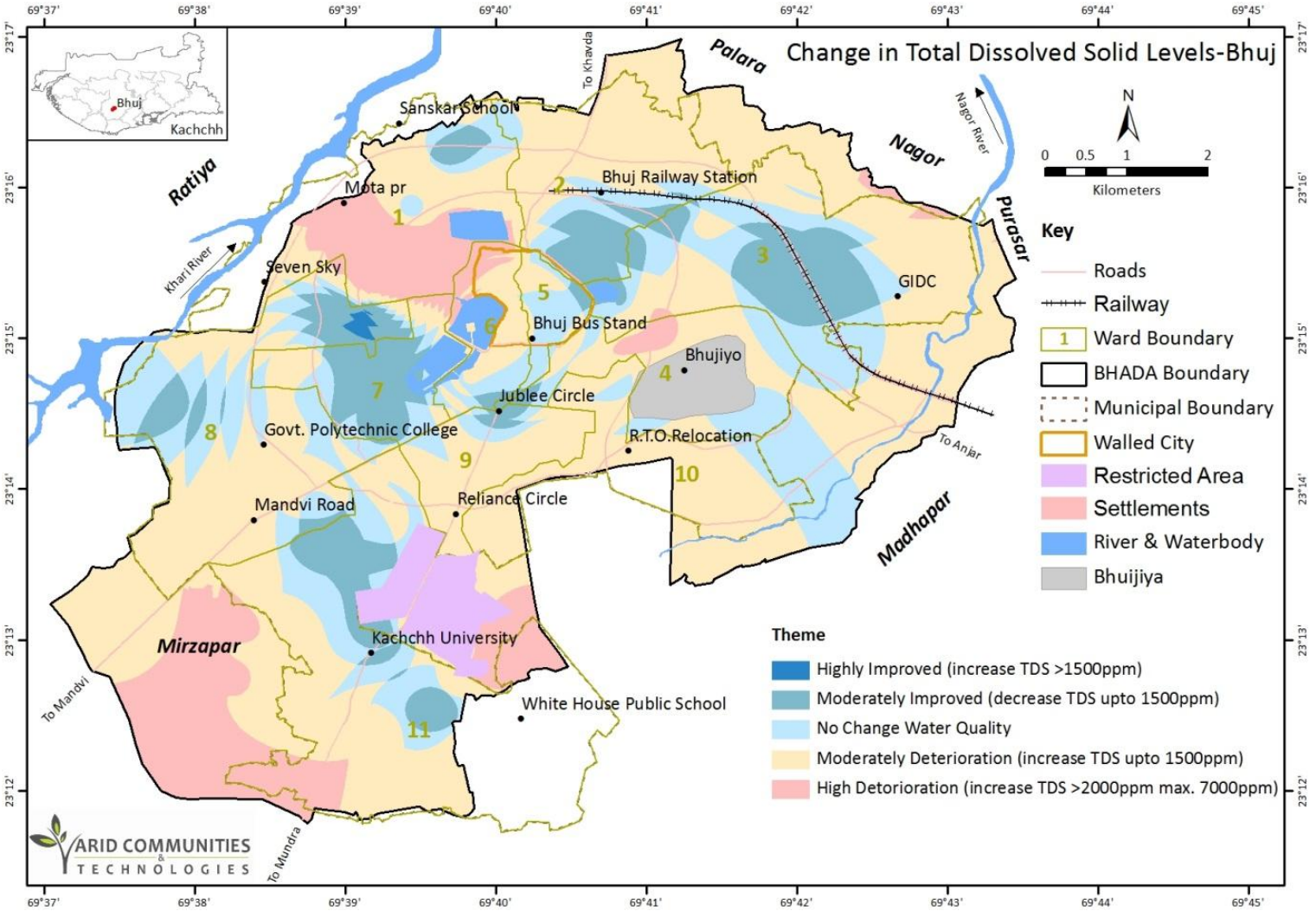
BHADA area is categorized into 5 zones, as seen in below map: Highly water positive zone (rise in water level >3m), Water positive zone (rise in water level upto 3m), Balanced water zone (no change in water level), moderately water depletion zone (fall in water level upto 3m) and highly water depletion zone (fall in water level >3m). It can be observed that ground water level is falling in southern and south-western areas. These areas are currently covered under Bharapar scheme. As water supplied from Bharapar is not sufficient, households are mostly dependent on their private borewells. Apart from this, there are few patches of agriculture fields which are drawing groundwater. Thus more artificial recharge activities are required in the water depletion areas to increase groundwater levels. Water positive zones are areas from which groundwater could be tap easily. Strategies for continuous groundwater monitoring and management intervention to regulate groundwater extraction are required in these areas.

Figure 26: Recharge potential area based on rise and fall in GW levels



Source: ACT, Bhuj, 2016

Figure 27: Recharge potential area based on increase or decrease in TDS concentration in GW

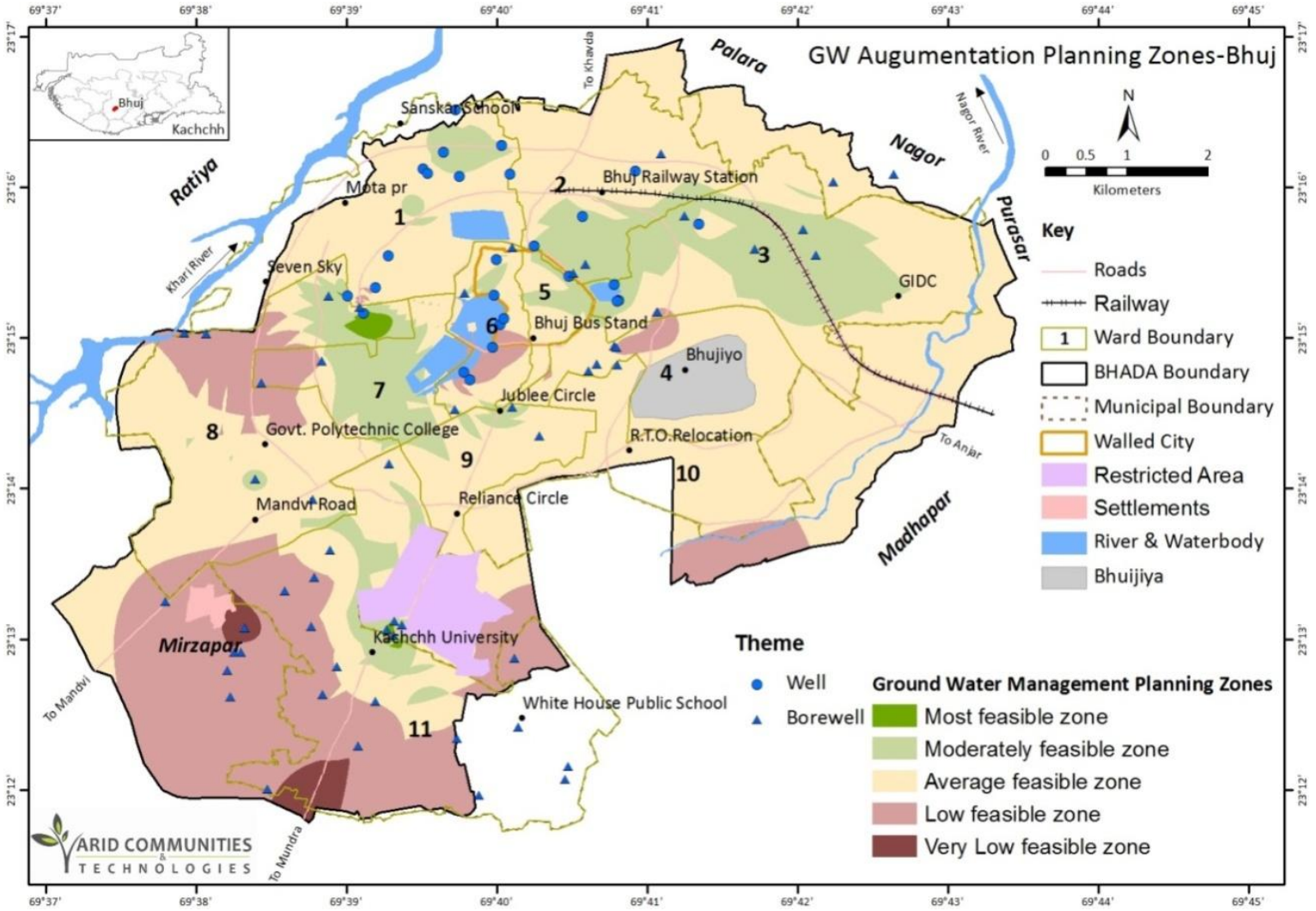


Source: ACT, Bhuj, 2016

In Bhuj, there is large dependency on groundwater and hence measurement of its quality becomes key area of concern. It was observed that in many places within BHADA area the Total Dissolved Solids (TDS) has increased over the years. On the basis of changes in water quality over the years, study area was divided into 5 zones: Highly improved zone (decrease in TDS more than 2000 ppm); Improved zone (Decreased up to 2000 ppm); Average zone (no change or negligible change in TDS); Slightly deteriorated zone (Increase in TDS up to 2500 ppm) and Highly deteriorated zone (rise in TDS > 2500 ppm).In some areas, natural salinity of the rocks is one of the reasons for high TDS in groundwater. Over-exploitation is another reason which is resulting in the increase in TDS over time.

Groundwater recharge zones were further finalize after amalgamating changes in groundwater levels over years along with present groundwater quality and then categorizing them based on the scoring system as per their recharge potential. Entire area was divided into 5 zones: Most feasible zone (Water level rise> 3m, TDS<1500ppm), moderately feasible zone (Water level rise upto 3m, TDS: 1500-2000 ppm), Average feasible zone (Water level rise: 0, TDS: 2000-3000 ppm), low feasible zone (Water level fall upto 3m, TDS: 3000-4000 ppm), and very low feasible zone(Water level fall > 3m, TDS >4000 ppm).

Figure 28: Groundwater recharge zones in Bhuj



Source: ACT, Bhuj, 2016

From the above map, it can be observed that most feasible, moderately feasible and average feasible zones should be taken up in priority for various recharge interventions. These zones have the most favorable hydrogeological conditions for the groundwater recharge and capability to augment groundwater source, if it is well planned and properly managed. Whereas low feasible and very low feasible zones may have some limiting factors and recharge structures should be design and planned to mitigate that limiting factors.

Best options for groundwater recharge (Parks, religious institutions, water bodies and streams): One of the approaches for promoting artificial groundwater recharge can be done at public parks and open plots. In urban areas, parks are very common feature and can be fruitfully utilized for recharge of groundwater. There are 19-20 identified parks in the Bhuj city. Rainwater from the catchment of park as well as surrounding area is diverted towards the park which is excavated in a basin type depression to accommodate the rainwater from the elevated surrounding area[40]. Considering 70% of the rainfall being captured by the recharge pits and recharging the ground, the amount of water recharged is estimated to be around 57 ML per year. The following table shows the amount of water recharged at parks:

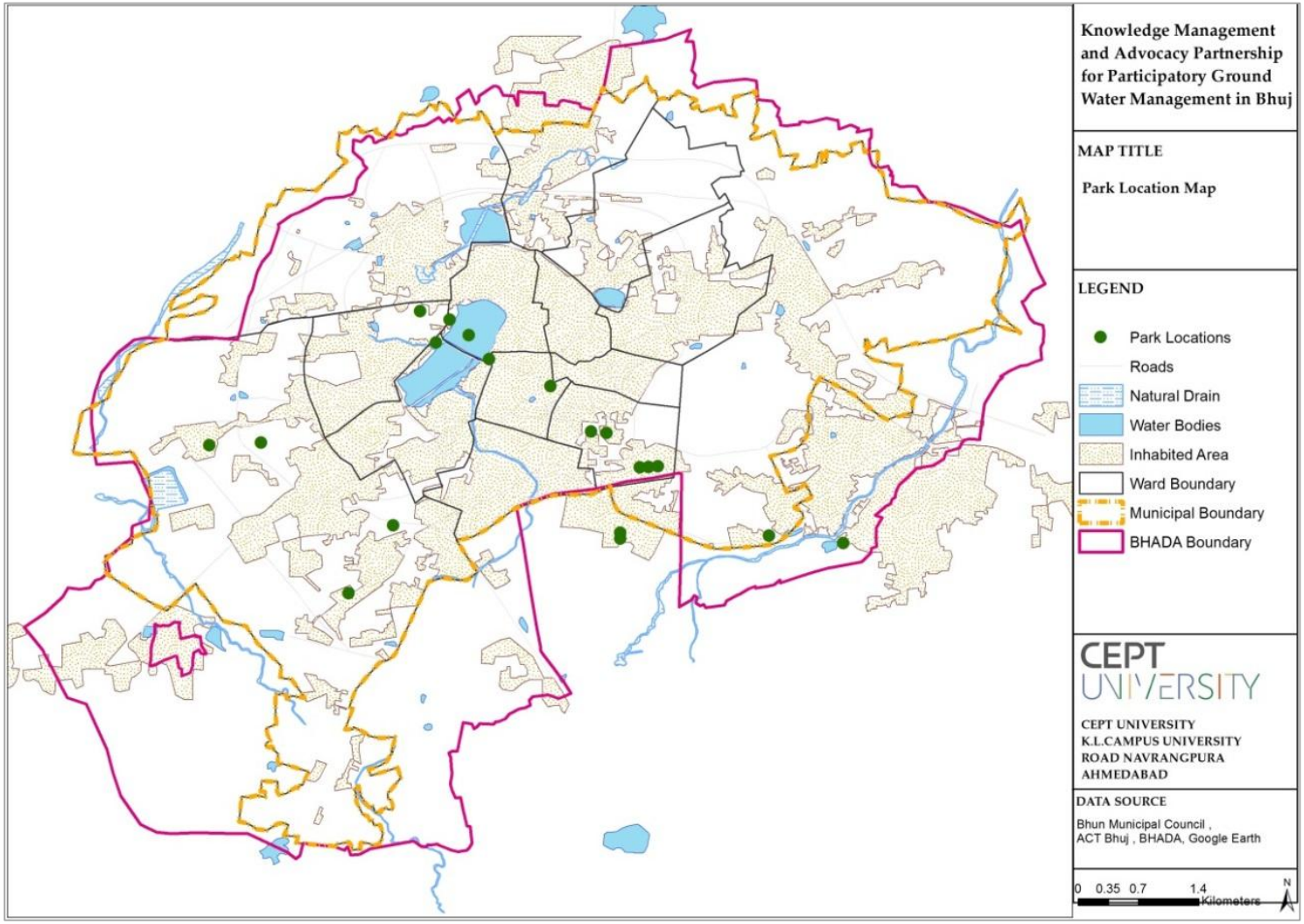
Table 28: Amount of water recharged at parks

	Area (sq. m)	**Water recharged at parks (KL)**	**ML/year**
All Parks	1,90,925	57,468	57

Source: CEPT analysis

[40] Proposal for groundwater recharge in NCR by Dr S K Sharma, 2009

Figure 29: Location of Parks in Bhuj



Source: Compiled by CEPT

Moreover recharge practices can also be adopted at the public places of Bhuj like large religious institutes, temples, etc. Take an example of Swaminarayan temple of Bhuj. With total area of 43,788 sq. m. and capturing 50% of the rainfall, it tends to captivate almost 9.4 ML of water annually. This treasured water can be used for the various purposes or even can be of environmental assistance by recharging groundwater. Such interventions would help in improving ground water quality and water level.

Another major potential for recharging ground water is through the medium of existing water bodies. Surface water and groundwater are closely linked in hydrological cycle. Hence, protection and management of these water bodies is of crucial importance as they are means to recharge the groundwater. It would also require proper demarcation of Lake Boundary (during flooding period) so that the lake area does not get encroached during the dry periods of the year. Installing recharge wells in the water bodies would act as one of the best medium for artificial groundwater recharge. The recharge shafts should be constructed in a way that only excess water is being recharged to ground water and minimum water level is maintained in water bodies for their sustenance and environment.

Apart from this, during rainy season, water channels containing rain water can be used for recharging groundwater. The natural drainage/ water streams must thus be considered during land-use planning of a city. Blockage of streams and water channel by dumping of waste and debris must be avoided. To harness the available runoff, trenches with recharge tube wells are to be constructed inside the drain bed. As observed in water balance analysis, the surface runoff of 14.6 MCM (14,599 ML) which majorly goes unutilized can be used to increase groundwater level by adopting artificial recharge practices. Considering utilizing 40% of the surface runoff, requirement of recharge structures and its cost is as follows:

Table 29: Quantifying groundwater recharge structures

Enumerating Groundwater Recharge Structures in Bhuj	
Surface runoff (ML)	14599.0
Amount of water to be recharge (40% of surface runoff) (ML)	5839.6
Recharge rate of one structure (L/s)	18.0
Considering 15 days rainfall period of Bhuj[41]	

[41] http://www.imd.gov.in/section/climate/extreme/bhuj2.htm retrieved on: 29.12.2016

Recharge by one structure (ML)	23.3
Recharge structure required	250
Area of Bhuj (sq. km)	56.0
Recharge Structures per sq km	5
Cost per structure (in lakhs)	5
Total Cost (in lakhs)	1250

Source: CEPT analysis

The major challenge to groundwater recharge persuaded in the city is solely on the quality of water received at the recharge pit end. There is a potential of contamination in the runoff water which would affect the quality of water injected. Thus intensive care must be taken to select the location of these recharge structures. Moreover dedicated staff for maintaining these structures is a major requirement. Because cleaning of these structures would be required before the onset of monsoon as it would affect the quality of water percolating to the ground. Local geology and aquifer characteristics exert strong influence in the recharge of Groundwater. Hence precise care is required while deciding depth of the recharge structure. At present, groundwater is being exploited from the confined aquifers of Bhuj. Thus, recharge well that reach upto the confined aquifer level could augment the groundwater level.

Potential of scaling up decentralized water supply scheme: Areas lacking water supply service provision in Bhuj city are mainly the peripheral areas with new upcoming developments. To circumvent investment in these areas, steps can be taken in such a way that these areas can adopt the decentralized water supply schemes with proper incentives from ULB. Such areas/societies should also be recommended to undertake recharge activities to improve groundwater level. This would indeed help in providing efficient and sustainable services. The distribution of the decentralized services based on suitable areas would help in making the water distribution plan more effective. These areas must be selected based on the geography, terrain and must be studied initially to see if extraction from the decentralized source does not deteriorate the environment.

The decentralized water supply services would be using the local water resources. The limiting factor for using the local water source would mainly be the quality of groundwater in that area. These decentralized services can only be adopted if the quality of the source of water is suitable for domestic purposes. In absence of any monitoring mechanisms over-exploitation of groundwater sources is also possible. Thus for area/society to adopt decentralized water supply service, monitoring of the quality and quantity of the local sources would be a major requirement.

Wastewater reuse for irrigation and landscaping: At present in Bhuj, treatment of wastewater is done with the help of oxidation pond only. With the upcoming treatment plant of 23.70 MLD sanctioned under AMRUT, the treated wastewater could be reused for different purposes. Recycled water can satisfy many demands, as long as it is adequately treated for its relevant use.[42] Reuse of treated wastewater for industrial use is not a viable option in Bhuj city as industries present in Bhuj GIDC are not water intensive. However, treated wastewater could be reused for landscaping or irrigation purposes. Another possibility which could be explored is artificial recharge of groundwater using treated wastewater. Currently CGWB and MOEF/CPCB has no guideline regarding the quality criteria for recharging aquifer with treated wastewater. Hence proper policy and guidance would be required for reusing treated wastewater by recharging.

Box 1.Wastewater reuse in Ahmedabad gardens

Ahmedabad Municipal Corporation is currently running seven STPs with total installed capacity of 817 MLD, which is enough for current sewage generation of the city but in a view to promote re-use and recycle of wastewater; AMC is envisaging to reuse sewage water for various purposes like gardening, lake filling, selling recycled water to industries etc.

One of the initial steps towards this practice was implementing decentralized STP at Navrang garden in Ahmedabad. The sewage is tapped from the nearby sewage pumping station. The untreated water will be brought in the tank and will be treated in three different tanks. The treated water is stored in a storage tank and is used whenever necessary. The plant capacity is of 10KLD. The quality standards achieved would be that the biological oxygen demand in the water will be less than 10 milligrams per litre. AMC is presently using majorly groundwater for watering garden, which will be saved by this alternate supply of water. Moreover it will also save 40 units of power daily which will help save ₨ 73,000 annually per garden.[43] With the successful implementation of this project, AMC will implement the same project in the other 200 AMC gardens of the city.

Figure 30: Installing STP in Navrang garden, Ahmedabad

Source: Primary Survey

Currently in the parks of Bhuj, ground water is extracted to landscape the green spaces. Hence feasibility of reuse of treated wastewater for gardening and landscaping purpose should be explored

[42] USEPA, retrieved from: https://www3.epa.gov/region9/water/recycling/#benefits
[43] http://www.urbannewsdigest.in/?p=7563 retrieved on: 30.12.2016

in Bhuj. As per new GDCR of BHADA, grey water recycling and reuse is compulsory for newly constructed large institutional and commercials building.

Table 30: Applicability of reuse of recycled water as per category of building use

No.	Building Use	Built-up Area (sq.mt.)
1	Hospitals and Nursing Homes	More than 5,000
2	Hotels, Lodges, Guest houses	
3	Hostels for Schools, Colleges, Training Centers	More than 10,000
4	Community Centre, Banquet Halls, and similar uses	
5	Commercial	
6	All hazardous, water-polluting, chemical industries	

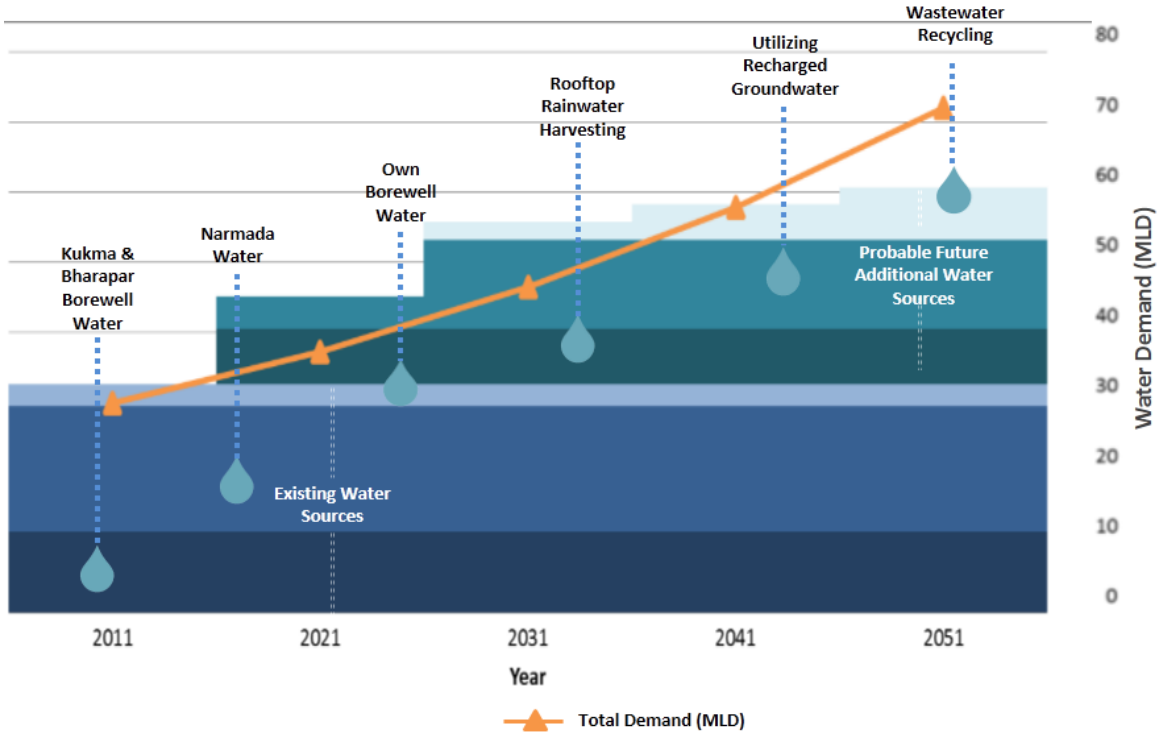
Source: Draft Bhuj GDCR- 2025

A major challenge for reuse of wastewater would be investment requirement for laying separate treated wastewater network for provision of it. Therefore selected reuse options which are feasible for a city must be adopted. Another challenge for reuse of treated wastewater is public perception towards it. Apart from above, the level of treatment also defines the reuse which can be adopted.

With the assistance of these alternative urban water management approaches, a comprehensive scenario for Bhuj is developed as shown below. The diagram shows how the alternative practices can help in addressing the increasing water demand of the city in the future. At present, major dependence is on the distant water sources such as Kukma, Madhapar and Bharapar borewell water and Narmada water. By incorporating these practices, it mitigates the efforts to search for a new distant water resource and lets a city focus on its own sources. It shows how these approaches promote local source diversification and helps in managing urban water demand. Moreover they are more flexible as it is easier to adapt the design to local conditions.[44]

[44] S. Muktaet. al (2015),"An overview of hybrid water supply systems in the context of urban water management: Challenges and opportunities" retrieved from: www.mdpi.com/journal/water on 30.12.2016

Figure 31: Comprehensive urban water scenario for Bhuj



Source: CEPT analysis

Table 31: Potential water availability and their unit costs

Sr No.	Activities	Potential water availability (MLD)	~Total investment required (crore)	~Private Cost (crore)	~Public Cost (Crore)
1	**Rainwater Harvesting**	8	125	100	25
2	**Groundwater recharge**	13	13		13
3	**Wastewater Recycling**	7.5	Depending on STP technology and purpose of reuse		
4	**Improving efficiency of existing system (reducing NRW)**	6.4			
4.a	Reducing NRW (Water audit and plugging leakages)				4
4.b	Metering (Consumer)		20.76	20.76	
4.c	Metering (bulk meters)		0.36		0.36

Source: CEPT analysis

Appropriate measure for sustaining urban water management must be taken by Bhuj city. It need not be necessary for a city to adopt all the mentioned practices in its area. Recognition of alternative solutions based on technical, economic and financial feasibility must be considered.

A supporting environment for implementing such projects should be available. Since these systems are relatively new in comparison with the conventional systems, understanding of ongoing management requirements is essential. Appropriate organization structure along with supportive policies and regulations can make it more likely to implement these projects on ground. Thus a co-governing mechanism to incorporate these practices must be looked upon.

4.2 Institutional and regulatory framework for integrated urban water management

The term "institutional framework" refers to a set of formal organizational structures, rules and *informal norms* for service provision. Such a framework is the precondition for the successful implementation of sanitation and water management.[45] This section captures the existing organizational structure present in Bhuj and the influence of various regulations and policies on alternative water supply projects. It also throws few ideas for integrated organizational structure along with its opportunities and limitations.

There is a challenge in describing the roles and responsibilities of all players. While general responsibility of provision of water services in a city is that of municipality, there are various other agencies – e.g. collector's office, GWSSB, GWIL, GPCB, that have a role in water management. From operational perspective, the responsibilities for centralized services are with ULB, but it shifts to who may invest in decentralized services, what technology to be adopted and who would operate and maintain these systems.[46] It thus follows that for co-governing alternative services, accountability and responsibilities given to be clearly defined. Moreover this approach involves citizens participation to a great extent, thus having a proper organizational structure would cater to the needs of these services. In the case of Bhuj, water management deals with the involvement of service providers, local NGO's, various water related associations and community.

Service Providers:

Urban water supply is a responsibility of urban local government. While the Central Government formulates overall policies for the development of the water sector in urban areas, the State Governments lays down detailed policies and sets up institutions for the proper development and

[45] Peters, D., "Building on Institutional Framework", SSWM, retrieved from: http://www.sswm.info/category/implementation-tools/water-distribution/software/creating-enabling-environment/building-ins on 14.11.2016

[46] OECD (2007-08), "Alternative Ways of Providing Water: Emerging options and their policy implications"

management of water systems in their areas (e.g. Gujarat Water Supply and Sewerage Board (GWSSB), Gujarat Drinking Water Company Ltd (GWCL)).

In Bhuj, multiple agencies are involved in managing supply of municipal water. The existing setup has institutions at the state level that allocate resources and provide major infrastructure, while local instituted in distribution of water resources to consumers.

Table 32: Institutional set-up of water supply in Bhuj

Agency/ Authority	Jurisdiction	Category	Roles and responsibilities
Department of Narmada, Water Resources, & Water Supplies	State level	Administration and regulation	Regulatory oversight of the water sector in the State Oversight of State government owned corporations involved in the implementation and operation of water schemes.
Gujarat Industrial Development Corporation (GIDC)	State level	Administration and regulation	Provision of retail water supply services in industrial estates owned by GIDC.
Gujarat Water Supply and Sewerage Board (GWSSB)	State level	Implementation and capital works	Mainly Implementing water supply and sewerage schemes for urban local bodies. Inspection of schemes where State government fund is provided.
Gujarat State Drinking Water Company Limited	-	Implementation and capital works	Bulk transmission and bulk supply of drinking water to local bodies, GWSSB, and Industrial estates
SardarSarovar Narmada Nigam Ltd.	State level	Implementation and capital works	Wholesale supply of Narmada water
Bhuj Municipal corporation	Local level	Operation and maintenance	Provision of water supply services for domestic purposes in the area of their jurisdiction
Bhuj Urban Development Authority	Local level	Operation and maintenance	Provision of water supply services for domestic purposes in the area of their jurisdiction

Source: Compiled by CEPT

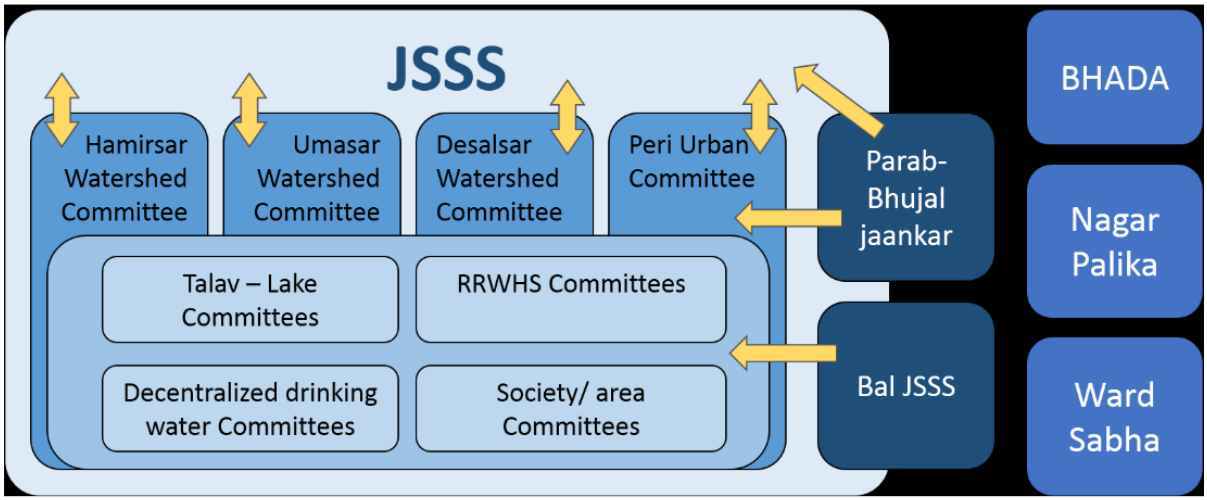
Citizen led groups:

A recent trend in managing water services is of involving the water users itself. Since the management boundary of the decentralized services is limited, it makes it possible to involve the citizens for the same. This kind of user participation helps to promote and sustain the project. Inclusion of such citizen led committees and NGO's ensures that the design choices, operation

practices are in context of the local conditions as well as they are more likely to be valued and maintained by the local citizens.

In the process of implementation of these projects, ACT strongly worked with citizens. To coordinate various activities with the citizens, it formed a citizen led committee namely "Jalsrot Sneh Samvardhan Samiti" (JSSS). It acted as a bridge between the CBOs, administration and the community. JSSS now functions as an umbrella organization in all activities related to community led urban water management in Bhuj.

Figure 32: Organization structure of JSSS



Source: ACT, JSSS

The JSSS committee is an amalgamation of retired bureaucrats, senior citizens, elected representatives and other similar stakeholders. This formed the core group of the committee. The second level of JSSS is made up of professionals and salaried staff, who bring focus to concepts and convert them into action with definite deliverables and visible impact. A third, invaluable layer is comprised of advocacy groups, funders and pro-active and dynamic officials who can push change through vital support such as funds, and official sanctions and permissions.[47]

Bhuj is spread over a large area and comprises of various economic groups. Thus JSSS was developed in a flexible, multi-layered organizational structure that would come into play for particular interventions. JSSS subdivided its committee according to the watershed boundaries in the city. Thus under JSSS committee there were mainly 3 watershed committees: Hamirsar watershed, Umasar watershed and Desalsar watershed. Under these watershed committees, RRWHS committees, decentralized drinking water committees, pani-samiti, society/area committees and lake committees

[47]Ghanashyam B., Jatkar U., "JalstrotSnehSamvardhanSamiti: Collective Strength for Collective Resource"

are operational. Talav (Lake) committees for all other smaller lakes are envisioned out of which several have been formed and have active members.

These smaller committees are comprised of local people from within the localities where intervention is proposed. They take charge of the planning, implementation and monitoring of the planned intervention. The aim in making this a part of the larger process is to enhance the sense of ownership of the community members, ensure their accountability and commitment and enhance their confidence to question any act that deviates from planned activities. JSSS act as the facilitator and is at hand to help when required.[48]

When these committees requires expertise which are rarely found with the agency, JSSS thus locates the agency, governmental or non-governmental that has specific competencies and links them with these committees. For example, JSSS calls for technical advice from ACT and also connects the pani samiti with the municipality, Zilla Parishad officials, funding organizations and organizations that provide advice in design / civil work as per the demands of the solution. JSSS has also worked with government agencies in getting various approvals, registering the lakes and other water resources and leveraging financial support for restoration work of lakes from corporate agencies. JSSS formed another small committee “Parabs”, which provide appropriate and timely technical services to panchayats, Pani Samitis, NGOs, CBOs and individual. They were identified as the para water technicians, and looked at as people who could give advice on the various issues related with augmentation and management of drinking water.

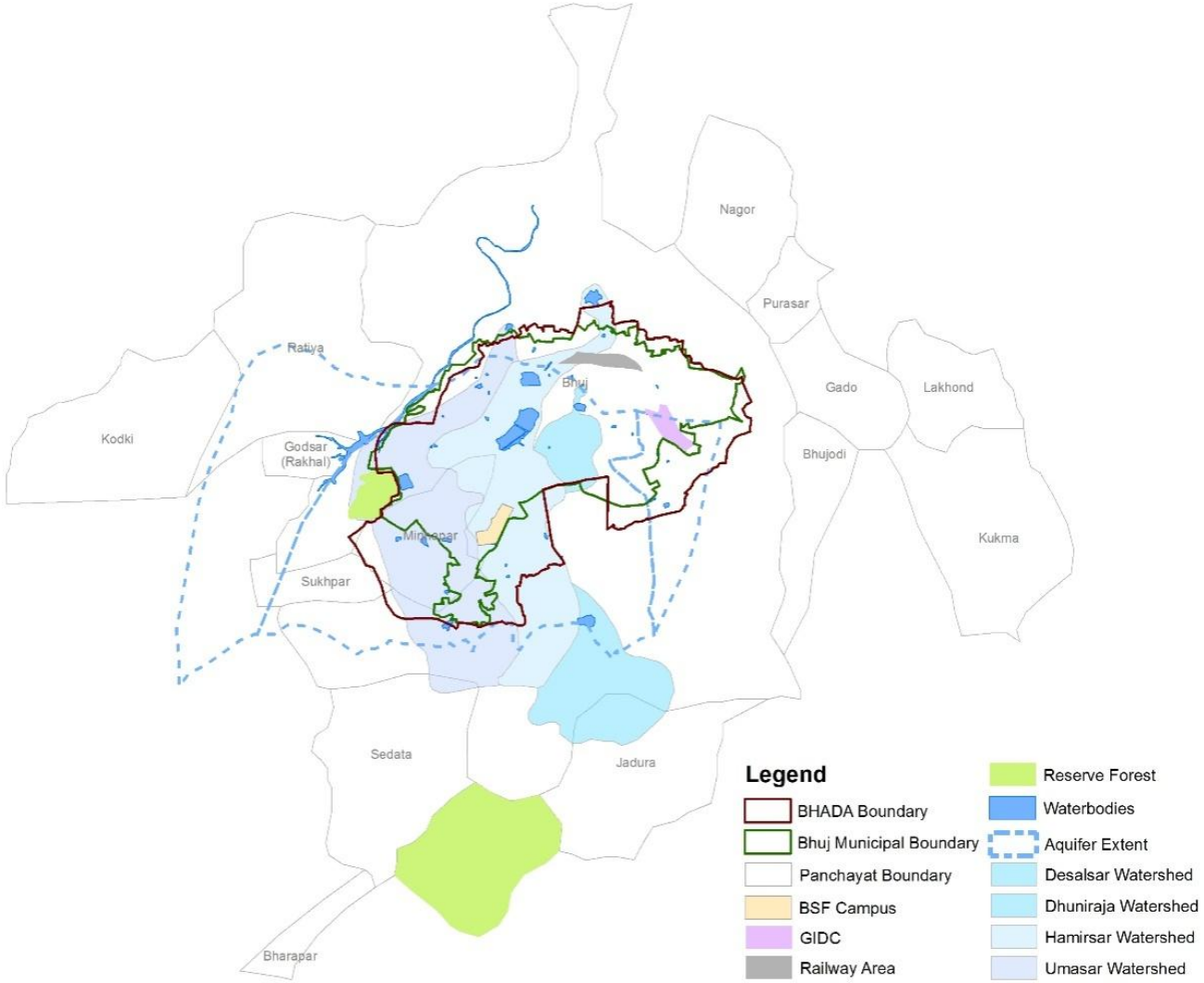
Thus these native committees have firsthand experience and knowledge regarding the functioning of local water resources. Thus involving such institutions would bring actual challenges faced in local context in the planning prospect of the city. It would also bring an emotional connect and citizens involvement in city planning practice. Monitoring with the help of the citizens would make the projects more sustainable.

Watershed committee:

Bhuj watershed system is spread over an area of 56 sq km. This watershed is covering diversified jurisdiction. It includes Bhuj municipal area, Bhuj urban development authority area, Madhapar town area, Agriculture area, Forest area, Army area and other rural areas.

[48]Ghanashyam B., Jatkar U., “JalstrotSnehSamvardhanSamiti: Collective Strength for Collective Resource”

Figure 33: Multiple government entities over Bhuj watersheds



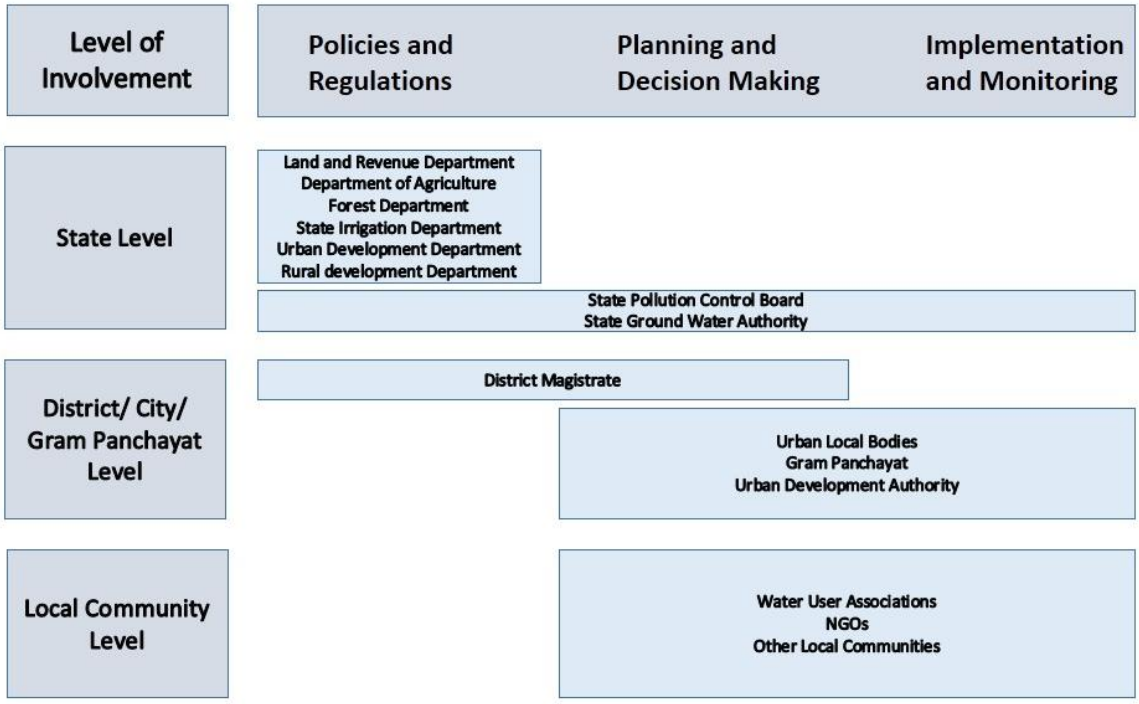
Source: Compiled by CEPT

Since watershed system and associated lakes are located under different jurisdictions various political issues are arising to manage a particular water body or watershed. These political boundaries of various regions such as Urban area (municipality, Urban Development Authority, Revenue), Rural area (Gram Panchayat), various departmental controls over catchment areas such as irrigation department, forest department, BSF areas etc. increases complexity for management of such natural resources.

Moreover, at present, the service providers and local level community associations show lack of coordination for the various water supply measures taken in the city. Also many local level committees need expertise which is rarely found amongst them. A common platform is required where these organizations can interact. Moreover land and water resource management often are covered by different organizations. The intra organization strengthening is also required. Many implications made on land use changes affect the water resources as well as the water supply system in a region. Thus a vertical and horizontal coordinating unit like a watershed management committee would be assistive as it can act as a facilitator. This committee can help to co-ordinate amongst relevant organizations.

Many organizations would be a part of this committee as the watershed boundary would cover different jurisdictions (administration boundary) as well as different aspects of a region (e.g. Land, water, forest, etc.). The level could vary from a district level, taluka level to local level. According to the common guidelines provided by Department of Land resources India for watershed management projects, each of the District Watershed Development Unit (DWDU) must consist of specialists on agriculture/ water management/ social mobilization/ management and accounts. Thus a watershed committee for Bhuj can involve following organizations:

Figure 34: Proposed organizations involvement at Watershed Level



Source: Prepared by CEPT

The participation of grass root organizations has been recognized as an essential attribute of watershed management projects.[49] Coordination between local administration and various associations can be managed by this committee. These various associations would involve other local actors' than water associations such as forest user groups or association of land developers, NGOs etc.[50]With the help of this committee, local level communities could also be involved in the planning and decision making process. Since the watershed boundary could cover different jurisdictions, presence of more than one local body is a possibility. This committee would help in scrutinizing the projects affecting at a watershed scale. For example: managing and maintaining the natural drains of an area, as natural drainage pattern can cover more than one administration boundary. In reference to this, the land-use can be proposed and other relevant projects can be managed.

To implement these aspects on ground, policy and regulations support is a must. The state level institutions are responsible for permits, standards and enforcement of rules and managing land use planning. Thus provincial organizations can support this formed committee. The district magistrate can act as a mediator and be involved in both the aspects of policies and regulations as well as

[49] MRC-GTZ (2009),"Institutional arrangements for integrated land and water management"
[50] MRC-GTZ (2009),"Institutional arrangements for integrated land and water management"

planning and decision making of projects at watershed level. This would aid in observing the legal framework and fast-track the decision making process.

Thus a committee consisting of officials from various departments as well as the local community would aid in taking into consideration all the aspects which would be affected by a project. The new urban watershed level approach would also be beneficial in accelerating the decision making. To support integrated organization approach, appropriate policy and regulations framework would be required.

Policies and Regulations

Implementing integrated approach for water services requires a favorable institutional context supported with coherent legislative and policy frameworks. Managing urban water all together, it would require strong policies and/or regulations support which would provide a framework to a city to carry out relevant actions. The National water policy, 2012 envisages the planning, development and management of water resources to be governed by common integrated perspective considering local, regional, state and national context. For integrated water resource management, it states of restructuring institutions and taking a multi-disciplinary approach. Because of the cross-cutting nature of water, many policies and guidelines other than National Water Policy have an impact on the development and management of urban water.

For the conservation and management of urban water bodies, acts and policies like: The Water (Prevention & Control of Pollution) Act, 1974, The Forest Conservation Act, 1980, The Wildlife Act, 1972, and the Environment (Protection) Act, 1986 also have a fair influence on it. Many other guidelines and policies such as guidelines for lake conservation, water bodies' protection norms by CPCB are also present which would address to the protection of water bodies. Along with these, the guidelines for repair, renovation and restoration of water bodies with domestic support, 2009 also provides an outline to help revival of local water bodies. The National Environment Policy (NEP), 2006 also seeks for setting up of a legally enforceable regulatory mechanism for lakes & wetlands to prevent their degradation and enhance their conservation.[51]

For the management and monitoring of groundwater, first ground water model bill was circulated in the year 1970 to all the states. At present a draft of model bill for the conservation, protection, regulation and management of groundwater, 2016 is available. The model bill, 2016 states the basic principles for using groundwater and also defines the legal status of groundwater and makes state

[51]MoEF (2008),"Guidelines for National Lake Conservation Plan" GOI

the public trustee for groundwater. It also promotes the preparation of groundwater security plans with inclusion of the lowest possible administrative level (local authorities and other monitoring and consulting institutes). But water being a state subject, its adoption by the state becomes more relevant. Although very few states have adopted the model bill aspects in reference to their state. Gujarat has initiated the legislations for groundwater development.[52] Gujarat irrigation and drainage act, 2013 have adopted highly specialized formal groundwater law that regulates irrigation sector.[53]

As a comprehensive measure for groundwater condition of the state, the draft Gujarat state water policy, 2015 states "Care shall be taken for utilization of groundwater recharged through storage of water due to rainfall through works like check dams, increased storage capacity of tanks and watersheds carried out with people's participation."[54] Thus the projects implemented in Bhuj for capturing rainwater and recharging groundwater would reflect the influence of these policies and would be support from these whenever required.

Despite of various acts, policies and organizations there are many gaps and challenges in developing and managing of urban water.

Lack of involvement of local organizations for monitoring*:* Monitoring in relation to water is mainly observed by central and state level organizations. The Central Pollution Control Board (CPCB), Central Ground Water Board (CGWB), State Pollution Control Board (SPCB), State Ground Water Board (SGWB), etc are the main authorities responsible for monitoring of water quality, groundwater exploitation, discharging effluent quality, etc. Involvement of grass-root level organizations is not observed while the major knowledge about a regions water condition would be with these organizations itself.

Lack of cross-sectoral linkages*:* Water sector development does not depend just on focusing on water resources management. Many other sectors' implications show it effects on it. Decisions regarding the existing and proposed land-use make huge effects on water resources and water supply. Local water resources are generally not considered by planners while making an Urban Development Plan. Urban planning needs better integration of hydro-geological aspects in land-use planning. Even there is absence of a category of urban water body in land-use planning. Moreover

[52] Kaushik, Y.B., (2016) "Model bill for regulation of groundwater development" CGWB retrieved from: http://wrmin.nic.in/writereaddata/2-1-1_Model%20Bill%20to%20Regulate%20GWDevelopment.pdf on 7.12.2016

[53] Water Governance Facility (2013) "Groundwater Governance in India: Stumbling Blocks for Law and Compliance." WGF Report No. 3, SIWI, Stockholm.

[54] Gujarat State Water Policy, 2014

intra-sectoral coordination is also not promoted in these policies, thus different departments of water supply, sewerage, storm water plans in silos.

Lack of participatory approach: Government policies often lack the efforts to build bridges between people and their local water sources. It is observed that the policies mention about having a participatory approach but lack in providing tools and framework for the same. For example: in the case of declining ground water levels in overexploited areas need to be arrested by encouraging community-based management of aquifers, and providing a regulatory role for PRIs at the appropriate level.[55]Projects can be developed by involvement of local communities. But there is no framework present which a city can adopt to implement such practices.

Rural focused approach for watershed level management: A common theme in urban water security is the importance of watershed based approach. While the basic definition and approach to watershed remains the same, there is lack of consideration/ recognition of the effects of development and construction that often takes place on natural drains in urban areas. In any city that takes up planning and PGWM approach, one of the first steps would be to delineate watershed boundaries however the importance of watershed development for the urban links is not yet considered.

Water pricing and water metering: A current level of water pricing is deficient in many aspects in the cities. Considering the cost of production, domestic water supply is highly subsidized in several Indian cities.[56]Majority of the cities in India observe fixed water charges and the charges are seldom revised in comparison to the costs incurred in its provision. The policy of supply augmentation overlooks the role of pricing in regulating demand for water.[57]Moreover the aspect of water metering is also not considered by many cities to administer its water supply. Regulatory and tariff based measures have to jointly address this issue.[58]

Brief approach towards conservation practices and lack of incentives for it: Many policies mention about the conservation practices such as rainwater harvesting, groundwater recharge. The part lagging in this take is the absence of frameworks or guidelines which a city can adopt. There is no specific legislation in India to protect water bodies – urban or rural.[59] Thus protection and prioritization of local water bodies is not observed amongst the urban local bodies. Moreover to

[55] Kumar, V. and Bharat, G. (2014),"Perspectives on a Water Resource Policy for India", TERI, New Delhi
[56] Kumar, D. M. et al.," Institutional change needs for Sustainable Urban Water Management in India"
[57] Padwal, R.," Issues of Pricing Urban Water", Dept. of Economics, University of Mumbai
[58] Kumar, V. S. (2014)," Perspectives on a water resource policy for India", TERI
[59] Shah, M. (2016)," Urban water systems in India: A way forward" ICRIER

adopt these practices the citizens are not provided with appropriate incentives which would encourage them.

Less emphasis on improving efficiency of existing water supply network and focusing on local water resources: The important aspect impacting urban water resources is the unaccounted for water. In Indian urban cities, distribution losses alone are in the order of 30-50 per cent and the total unaccounted for water (UFW) losses accounts to 45 per cent of the total water supplied.[60] The reasons for these losses are unmaintained water network, illegal consumption, etc. Tapping these faulting parts in the network can also help sustain the urban water supply. Moreover there is no consideration on limiting the quantity of water transfer from long distance. Supplying unlimited water to the cities and trying to augment it with the help of external resources merely leads to the negligence of local resources.

Thus a common eye for developing an urban water regime is required which considers all these aspects for urban water. An integrated perspective for planning, development and management of urban water backed by policy and regulations would help in sustaining urban water management. As discussed earlier, the policies and regulatory framework could be formed by the state level organizations with the involvement of local community. Profiling of stakeholders, from users to decision makers and policy makers could be undertaken as a part of the database on urban water development.

In the case for groundwater management, the Government should transfer the authority for regulating groundwater use to the lowest level. To give teeth to their actions the Central and State governments should enact suitable legislation and notify the permissible water depths to which ground water depletion will be permitted for each region/ block/ gram sabha/ watershed after identifying the special problems of each area.[61]

Policies can be formed with the objectives intended to be accomplished and accordingly the policy actions can be formed. Such as policies governing storm water management have to take into account the hydrological regime of the area.[62] Thus policies for sustaining urban water management must keep into consideration different aspects. Urban water policy should be integrated with the urban development policy; these policies will change across cities depending on physical, socio-economic, and administrative set-ups. Local water resources are generally not considered by planners while making an Urban Development Plan. Urban planning needs better integration of

[60] Kumar, D. M. et al.," Institutional change needs for Sustainable Urban Water Management in India"
[61] Water Supply and Reforms for India 2020

hydro-geological aspects in land-use planning. This would require a better understanding of geo-hydrology and micro aquifers, delineation of local watersheds and a history of water resources planning in the city. Urban planning needs to be based on an analysis of local watersheds and channels in planning of landuse and road systems.

It is also suggested that the new Government of India programmes such as AMRUT and smart cities need to incorporate the concept of urban water security and watershed based planning. There should also be a policy at a national level to limit the transfer of water from a long distance and between watersheds. The government should provide funds for water supply to only those cities that have brought their own water resources under security. The cities must augment their own local water resource before demanding access to water from far away sources.

For implementing conservation practices in a city, incorporation of such norms in general development control regulations and building bye-laws can also help. Moreover the ULBs can introduce few incentives to its citizens to adopt such practices. Another approach could also be a fine based system which would enforce the citizens to adopt it. This measure helps in implementing these projects at a wider base.

Box 1 Incentives or fines based system by various ULBs for implementing rainwater harvesting[63]

- Chennai Metropolitan Development Authority, all MCs, Municipalities, etc to sanction building plans only after implementation of RWH. Water and sewer connection would not be given to new buildings without RWH.
- Surat Municipal Corporation has made Rain water harvesting mandatory for all new buildings with the provision of 50 % subsidy maximum amount up to Rs. 2000/- is given to the citizens.
- Nagpur Municipal Corporation would levy a fine of up to Rs.1000 per annum per 100 sq. m. of built-up area if RWH not found in the new buildings.
- INDORE Municipal Corporation to give a rebate of 6 per cent on property tax has been offered as an incentive for implementing rainwater harvesting systems.
- The State Government of Meghalaya has instructed the concerned Department to provide funds under their respective annual plans for construction of roof top rainwater harvesting structures in the Govt. buildings.
- Gwalior Municipal Corporation imposes a penalty of Rs.7000 in case of non-compliance. A rebate of 6 % in property tax in the year in which the construction of rainwater harvesting facility has been completed will be provided for the owner of the building as an incentive.

[63] Source: http://cseindia.org/node/1161

The other area of focus for sustaining urban water would be increasing water services efficiency. Water pricing and metering plays an important role in it. Information, measurement and monitoring are needed for planning and management of urban water services in a number of ways. Lack of information about quantity of water supplied leads to unaccountability and water losses. Measurement of consumption and losses, when combined with proper pricing, it would make people better understand the “value” of water. Besides this measurement, local level regulations are needed to regularly monitor ground water for both quantity and quality. This will help to better understand local resources on an ongoing basis. Setting appropriate prices is indispensable to providing adequate water to growing urban population.

Institutional framework for urban water governance requires a new perspective to be looked into. Capacity building in urban water sector should go beyond institutional reforms. The ULBs are not equipped with the organizational, managerial, and technical resources to deal with the growing urban challenges. Strengthening of ULB with the support through policies and regulations as well as from the local community would aid in running them efficiently. Moreover creating a right kind of regulatory framework is essential to ensure responsibilities of different agencies.

Cognizance of regional water sources must be a mandatory exercise before developing of water plans or urban development plans for a city. Urban water development along with other urban development projects must be a take for all the urban local bodies. It would have an impact on physical performance of water systems and on urban water utilities efficiency. For preparing the plans, participatory approach would be a vital tool for the involvement of citizens for various urban water projects as well also provide an emotional connect to it.

5. Way Forward

Urban Population growth and expansion of city's footprint is inevitable. Its effect on the water resources is a major area of concern for many urban centres in India. Most of the current strategies about water management are blindly focus on developing new sources to meet the constantly increasing demand of water.[64] A paradigm shift is necessary for cities to manage their local water sources sustainably.

With growing population and water demand, Bhuj municipality sought additional water resources from far away rather than adopting any innovative approach. Poor pricing policy for municipal water supply and absence of regulation for ground water abstraction did not provide any penalty or incentive to citizen to protect and conserve local water resources. This has resulted in decline of the focus on local water sources and shifted focus on distant sources of water supply.

The most important aspect to ensure water security for Bhuj in next decades is to recognize that there is a net surplus of water in the water balance of Bhuj. This suggests that water security can be achieved by adopting an integrated urban water management approach, described in earlier chapters.

One low hanging fruit is in the approach of increasing efficiency of the existing water supply system. As we have shown, the total investments for this approach are not very high, but the gains in terms of 'additional' water available for supply are enormous.

The second and important approach is to harness local resources. This will mitigate the future challenges of growing demand for water and increasing competition for water resources between different sectors. Both these approaches aid to achieve the goal of making city water secure. These approaches require support on various fronts – administrative, financial and above all participation of people.

Water resources should become a key component of urban planning. Urban planning needs better integration of hydro-geological aspects in land-use planning. Focus on local water sources along with monitoring of the water resources in the city holds importance.

[64] 2012,Sustainable Urban Water Management, Dr. Fabino Masi

5.1 Inclusion of hydrogeology in land-use planning

At present in urban planning, the natural water resources are relegated to the background. Moreover, water, sanitation and storm water sectors are often planned in isolation from each other. With population rising in cities and increasing demand for land, the dry lakes are seen as potential land available, and in Bhuj, these were even filled up with debris to make way for housing. This disturbed the natural urban watershed and catchment system. Thus the manner in which a city develops will have a strong influence on its future water resources.

In this context, inclusion of the hydrogeology is a must in land use planning. Assessment of geo-hydrological conditions of urban area must be taken into consideration. Geological profile of a city, rainfall patterns, and water bodies in the city, their catchments and drainage patterns as well as inventory of natural water resources must be considered. Water cycle under the urbanized conditions gets affected as the porous land is paved at many places. By mimicking the natural hydrology, integrated urban planning can be achieved. For developing and protecting groundwater following measures can also be taken:

Delineation of "sensitive" zone to protect water sources: Delineation of certain area around the water sources must be considered. Even the areas from where groundwater is extracted, appropriate demarcation must be done and the relevant area can be defined as sensitive area. In this area, sources for water source pollution must be enlisted and monitored strictly. Thus areas susceptible to groundwater or surface water pollution must be identified and made a part of land-use plan as a sensitive zone.

Developing "Zero runoff zone": This concept basically deals with implementation of building plans in a way to utilize all of the surface run-off generated in any plot/building for domestic purpose or for groundwater recharging in the same premises.[65] There are guidelines available such as WSUD to develop such areas. This would help in decreasing the load on the urban local bodies for providing water for some of the usages.

5.2 Local water sources: Last oasis in water scarcity

Bhuj has become highly dependent on water coming from distant sources. . The issue is even more aggravated as Bhuj is located in arid zone and has a history of erratic rainfall patterns and severe droughts. Bhuj's local source is mainly groundwater. Hence conservation, management and recharge

[65] Joshi, A. (2006)" Groundwater conservation: A perspective plan for Ahmedabad Urban Complex Area" CEPT University, Ahmedabad

of Groundwater is essential in Bhuj. Protection and focus on local water sources through various measures must be of prime importance to a city. The urban local bodies can take these initiatives to conserve and protect local water sources.

Rainwater being the main source of water can be utilized by harvesting it and reviving the local sources annually. Rooftop rainwater harvesting, groundwater recharge, reviving water bodies, etc. are the supporting options for managing the water in a city. Saving every drop of water would lead to a better water secure world.

5.3 Monitoring groundwater and lakes

Information, measurement and monitoring are needed for planning and management of water in a number of ways. Monitoring groundwater levels and its quality is a must where it acts as source of supply for an area; else over-exploitation of the same is highly probable. The surviving lakes often became places for discharge of waste water. Seeking drying lakes in Bhuj and degrading quality of groundwater, the monitoring aspect becomes of vital importance.

The monitoring activities can be initiated by properly demarcating the water sources. Demarcation of a lake boundary during flood period must be done which will help in stopping encroachment of these properties as well as protecting these spaces. The unplanned construction around these water bodies leads to deterioration of them as many a times these constructions damage the natural drainage pattern of a city.

Few areas where the groundwater is over-exploited must be identified so that further exploitation is avoided and proper conservation measures can be taken. An inventory of activities after studying the land use in that area can be prepared and further delineation of the area can be done (Varaivamoorthy, 2014) (Patel & Sunderrajan, 2009) (Amarasinghe, Shah, & Malik, 2009) (Kulkarni, Shah, & Shankar, 2015) (project, 2011). Special attention must be given to the areas comprising of industrial estate, as some of the industries produce hazardous waste whose disposal must be strictly monitored. Else it may also lead to stormwater pollution and groundwater contamination.

Post implementation of the recharge structure also needs attention. Periodic maintenance and repairs of water harvesting and recharge structures must be done. Even the rise in water level due to the impact of these constructed recharge structures must be monitored.

5.4 Awareness activities and involvement of citizen

Participatory approach in a city can serve as a background for developing urban water security in a city. Community engagement in water service is key for ensuring project sustainability and accountability.[66]The citizens must be involved as it would help in accelerating related activities.

Traditional wisdom around water security based on ground water and lakes has been lost. A local history of water resources can be documented for cities in order to plan for water security. One of the approaches which can be developed is to understand aquifers and ground water with the help of the local people. Monitoring systems can be developed in a way where a citizen also has a role to play. This would help in having an emotional connect of the citizens to the water management practices in the city. As seen in Bhuj, learning activities can be developed at school level so that it is incorporated amongst the students.

Awareness regarding the importance of alternative systems and its impacts must also be described to the citizens. Individuals can be made aware that few actions by them could help in conserving and protecting water sources:

- Getting involved in local water source protection
- Constructing water harvesting structures at ones place
- Reducing individual use of water and stopping wastage
- Ensuring cleaning of their septic tanks, etc.
- Dumping of solid waste at designated places.

These activities could be backed by various pilot demonstration, awareness and capacity building programme, etc. It would help to accelerate the activities related in reviving water bodies of a city. Whole process of integrated urban planning and renewal water management system should be backed by a governance system that ensures sustainable water management.

A comprehensive framework can also be developed locally which aims to conserve and protect water sources. Even the existing regulations must be enforced in an appropriate manner. Regulations in relation of development around water sources, extraction of groundwater, disposal of sewage and industrial effluents, dumping of solid waste, etc. must be developed.

[66]http://www.sswm.info/sites/default/files/reference_attachments/WSUP%202013%20Getting%20communities%20engaged%20in%20water%20and%20sanitation%20projects.pdf

Under JNNURM and as a condition of the 13th Finance Commission, cities were required to prepare disaster management plan. Likewise, it must become obligatory for cities to prepare a water security plan. Such a plan should be prepared through participatory IUWM approach. (A toolkit for this is under preparation).

A water security plan would aid in understanding the need for present and future water management. For managing water sources, integrating both supply side and demand side approach must be taken. Moreover the roles and responsibilities of all stakeholders must be defined, and an inclusive organization structure supporting integrated development must be designed. Various approaches for managing water like Integrated Urban Water Management (IUWM), Water Sensitive Urban Design (WSUD), and Participatory Ground Water Management (PGWM) must be examined and integrated in the urban planning to make a city water secure.

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Knowledge Management and Advocacy Partnership for Participatory Ground Water Management in Bhuj

The Centre for Water and Sanitation (CWAS) at CEPT University has been established to focus on improving water and sanitation services in India. The Centre carries out various activities – research, training, advocacy to improve delivery of urban services.

CEPT University is the Knowledge Partner to Arid Communities and Technologies (ACT) for ground water management activities in the city of Bhuj, Gujarat. Through CWAS, CEPT is supporting ACT in documentation of processes related to Participatory Ground Water Management (PGWM) in Bhuj. Based on this study, CWAS plans to develop guidelines to promote Participatory Ground Water Management in Indian cities.

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