CHAPTER V

PATTERN OF DRINKING WATER USE

There is considerable confusion in the global water literature about the terms for ‘use’, ‘need’, ‘withdrawal’, ‘requirement’, ‘demand’, ‘consumption’, ‘water supply’ and ‘available water’ and so on. Great care should therefore be taken in interpreting or comparing drinking water related studies. ‘Water withdrawal’ refers to water removed from a source and used for human needs. Some of this water may be returned to the original source with changes in the quantity and quality of the water. The term ‘consumptive use’ refers to water withdrawn from a source and made unusable for reuse in the same basin, such as through irrecoverable losses, including evaporation, seepage to a saline sink, contamination. Consumptive use is sometimes referred to as ‘irretrievable losses’. The term ‘water use’ is often used inconsistently, referring at times of consumptive use and at times to withdrawals.

The municipal water use is directly related to water withdrawal by population of cities, towns and housing estate, domestic and public service enterprises. The volume of public water use depends on the size of urban population and the status of the available services and utilities. It depends on the infrastructure created for the purpose. Also it depends to a considerable extent on climatic conditions. Water use by consumers is only a small part, 8% of total water use, in low and middle-income countries (European Environment Agency). In many large, equipped cities of the world the recent water withdrawal amounts to 300-600 ltr./ day per person. By the end of the current country, in industrially developed countries of Europe and North America, the specific per capita urban water withdrawal is expected to increase up to 500-800 ltr. /day. On the other hand, in developing agricultural countries of Asia, Africa and Latin
America, public water withdrawal is 50-100 ltr./day. In individual regions with insufficient water resources, it is not more than 10-40 ltr./day of fresh water per person.

A greater part of the water that has been withdrawn from the urban water supply system is returned back after being used (purified or not) as wastewater to the hydrologic network. This occurs if the urban drainage system operates effectively. The principal part of consumption consists of water losses for evaporation with leakage from water supply and sewerage systems, for watering plants, streets, recreation zones, and personal plots. Thus, to a large extent, it depends on climatic conditions. In dry hot regions, the losses are certainly larger than in cold and humid. The water consumption for personal human needs is insignificant as compared to water losses for evaporation and percolation. Relative values of consumption expressed usually in percentage of water intake depend to a considerable extent on the volume of specific water withdrawal for public supply. So, in modern cities equipped with centralized water supply and effective drainage systems, the specific water withdrawal is 400-600 ltr./day, and consumption is usually not above 5-10 percent of total water intake. Small cities with a great stock of individual buildings not fully provided with centralized system have a specific water withdrawal of 100-150 ltr./day. Consumption significantly grows and can reach 40-60 percent of water intake.

The modern tendency of public water supply development in all countries of the world is the construction in small and large cities of effective centralized water supply. Also it is connecting to these systems a greater number of buildings and populated areas. In this connection, in the future the specific per capita water withdrawal is expected to increase, and the values of water consumption expressed in percentage of water intake are expected to be considerably decreased.
The availability of water resources, geomorphically and temporally, the quality of these resources, the rates at which they are replenished and depleted, and the demands placed upon them by water users are determining factors in water management strategies. Estimates of future water uses, uncertain as they might be, are fundamental to efficient and/or equitable allocation of water resources. These estimates depend on an ability to forecast changes in population, agricultural and industrial activity, economic conditions, technology, and other related factors.

Relevant factors include water-use permitting, estimating water requirement; inventorying water supplies; defining new ‘reasonable beneficial uses’, infrastructure development, operation and maintenance and replacement; policies for allocating water among competing users; strategic planning, financing, education, conservation and reuse, research, coordinating water supply and water quality management programmes, and assessing risks tied to proposed causes of action.

**Water Use**

Decisions related to the allocation of water must be based on knowledge of both the availability of water and the types and rate of use. Otherwise inefficient allocations and undesirable levels of water-sources depletions are likely to be the outcomes. This is particularly true when the resource is scarce and/or it is subject to a spectrum of competing demands. Accordingly, the major water-using sectors must be recognized, and the demands they place on their source waters quantified.

In Guwahati city more than 12 lakhs people are residing in the municipal area. Approximately 68 percent people are not served by any supply agency and install their own domestic systems. The principal domestic and commercial water uses are for
drinking, cooking, meeting sanitary needs, lawn watering, swimming pool maintenance, fire fighting and various aspects of city and park maintenance.

**Pattern of Water Use by Source**

In Guwahati the main source of drinking water is groundwater followed by water supplied by various agencies; surface water and rainwater is also used by a small section of population. The household survey carried out in the course of this study reveals that out of the total households of the city, 59 percent households use groundwater installed by themselves, 25 percent use piped water supplied by various supply agencies viz Guwahati Municipal Corporation, Public Health and Engineering Department, Urban Water Supply and Sewerage Board, NF Railway and Guwahati Refinery, 11 percent use both supplied and Ground water, 3 percent use both groundwater and surface water and only 2 percent use both ground water and rain water (Fig. 45).

![Fig. 45: Pattern of Drinking Water Sources in Guwahati](image)

The multiplicity of water sources is shown in the figure 21 in chapter IV. In this figure it is found that 7 numbers of wards use single water sources. These are 5, 13, 15, 20, 21, 22 and 60. In these wards households use groundwater installed on their own. Further the study reveals that 30 numbers of wards use two sources of drinking water, both groundwater and piped water. These are 1, 2, 4, 6, 8, 9, 14, 16, 17, 18, 19, 23, 24,
25, 26, 27, 28, 29, 33, 43, 45, 46, 47, 48, 51, 52, 53, 54, 57and 58. All these wards use both ground water and piped water except ward numbers 16, 53 and 58. The ward number 16 uses both groundwater and surface water while ward 53 and 58 uses groundwater and rainwater. Again 17 numbers of wards use water for their household purposes from a combination of three sources. The ward nos. 3, 36, 40 and 50 use the combination of groundwater, piped water and surface water. The ward nos. 31, 32, 34, 35, 37, 38, 39, 41, 42, 55, 56 and 59 use the combination of ground water, piped water and rainwater. Only 5 numbers of ward use more than three sources of water namely ground water, piped water, surface water and rain water. The wards are 7, 10, 11, 12 and 49.

**Groundwater Use**

Rights in ground water belong to the landowner since it forms part of the dominant heritage and land ownership that is governed by the tenancy laws of the state. The Transfer of Property Act necessitates that rights to groundwater can be given to anyone else only if the land is transferred. The consequence of such a legal framework is that only the landowners can own ground water in India. There is no provision in the Guwahati Municipal Corporation Act or any other existing laws for regulating the use of ground water. Therefore, no permission from the corporation is required for installing deep tube wells by the residents and the real estate developers. Even judicial action at the level of the Supreme Court has not yet resulted in the formulation of uniform laws throughout the country for planned and judicious exploitation of ground water.

The city of Guwahati is presently served by piped water supply in limited quantity in specific areas. This facility neither covers the entire city nor fulfills the standard of per capita demand. Therefore, most of the city dweller use ground water
installed on their own. The household survey carried in course of this study shows that 59 percent of the households depend on ground water source and only and 11 percent households use both ground water and supplied water.

The central and western parts of the greater Guwahati are very much promising from ground water point of view, except some local variations. In case of eastern, southern and northern parts restriction of the alluvial thickness poses problem for large scale development of ground water (Srikantha and Devi, 1996).

The subsurface disposition of alluvial deposits has been deciphered from borehole litho logs drilled at different parts of the area (DGM Report, 1993). The lithological logs reveal the presence of moderately thick pile of unconsolidated sediments deposited over basement rocks. The formation materials consist of clay, sands of various grades, granules, pebbles and occasional gravels. Thickness of alluvium varies widely from one location to another. Hard rock basement is encountered at depths between 330 meters (Jyotinagar) and 119.00 meters (Fatasil Ambari) in the central region, between 340 meters (Beltola) and 220.00 meters (Paschim Boragaon) in the South Western region, between 30.00 meters to 47.00 meters in the eastern region (DGM Report, 1999), while in the South region, thickness of alluvium varies from 36.0 meters to 57.00 meters. Thickness of alluvium increases from east and south-east part of the area towards south-west. The thicknesses of alluvial deposits at several locations of Guwahati city are given in the table 22.

Heavy-duty tube wells are thus feasible in the western and intensely populated central portion of greater Guwahati. In case of eastern, northern and southern parts, low duty tube wells and large diameter dug cum bore wells are feasible.
Table 22: Thickness of Alluvium at Different Localities in Guwahati City

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Location</th>
<th>Thickness in (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Beltola</td>
<td>34.00</td>
</tr>
<tr>
<td>2</td>
<td>Bhangagarah</td>
<td>64.05</td>
</tr>
<tr>
<td>3</td>
<td>Borjhar</td>
<td>94.56</td>
</tr>
<tr>
<td>4</td>
<td>Chandmari</td>
<td>75.33</td>
</tr>
<tr>
<td>5</td>
<td>Fatasil Ambari</td>
<td>110.03</td>
</tr>
<tr>
<td>6</td>
<td>Gopinath Nagar</td>
<td>93.75</td>
</tr>
<tr>
<td>7</td>
<td>Janakpur, Kahilipara</td>
<td>46.30</td>
</tr>
<tr>
<td>8</td>
<td>Jawahar Nagar</td>
<td>23.70</td>
</tr>
<tr>
<td>9</td>
<td>Khanapara</td>
<td>57.23</td>
</tr>
<tr>
<td>10</td>
<td>Narengi</td>
<td>47.78</td>
</tr>
<tr>
<td>11</td>
<td>New Guwahati</td>
<td>33.90</td>
</tr>
<tr>
<td>12</td>
<td>Panbazar</td>
<td>95.77</td>
</tr>
<tr>
<td>13</td>
<td>Pashim Baragaon</td>
<td>220.40</td>
</tr>
<tr>
<td>14</td>
<td>Rupnagar</td>
<td>41.90</td>
</tr>
<tr>
<td>15</td>
<td>Saokuchi</td>
<td>138.98</td>
</tr>
<tr>
<td>16</td>
<td>Sijubari</td>
<td>55.15</td>
</tr>
<tr>
<td>17</td>
<td>Tokobari</td>
<td>102.72</td>
</tr>
<tr>
<td>18</td>
<td>Ulubari</td>
<td>41.20</td>
</tr>
</tbody>
</table>

The Guwahati Municipal Corporation (GMC), other statutory bodies and various government departments fail to provide piped water to a large section of the city dwellers due to non-existence of necessary infrastructure. Therefore, 59 percent of households use ground water, 11 percent use both supplied and ground water. The figure 46 indicates 100 percent ground water use by the households in the ward nos. 5, 13, 15, 20, 21, 22 and 60, followed by 80-99 percent use in 16 wards, 60-79 percent use in 8 wards, 40-59 percent use in 7 wards, 20-39 percent use in 12 wards and below 20 percent use in 10 wards. The pattern of groundwater use in Guwahati city are presented in fig. 47.
Fig. 47: Pattern of Groundwater Use in Guwahati City
Based on the household survey, the percentage of various types of spot sources are indicated in figure 48. It shows that 55 percent of the households use pucca well, 25 percent use tube well, 10 percent use bore well (deep tube well), 7 percent use dug well and only 3 percent use both pucca well and tube well. The photograph nos. 1-4 are shows the groundwater scenario in some localities of the city.

According to a CGWB study, deep ground water structures are feasible to a larger extent in the western and central parts of the greater Guwahati like Ulubari, Uzanbazar, Fancybazar, parts of Bharalumukh etc. Shallow groundwater structures
with limited ground water potentiality are feasible in the eastern, northern, and southern parts of the city like Tetelia, Sodilapur, parts of Pandu, Ulubari, Paltan bazar, Bamunimaidam, Chandmari, Uzan bazaar, Japorigog, parts of Jatia, Dispur, Fatasil, Hatigaon, Rukminigaon, Jatikuchi, Pub Boragaon, Paschim Boragaon, Suakuchi, Teteliagaon etc.

Different types of ground water structures are feasible around Guwahati in different types of geological formations. On the basis of structure, there are two types of formation, namely, hard rock areas and alluvium areas. In the hard rock areas dug well and bore well are suitable, and in the alluvium areas shallow tube wells and deep tube wells are feasible.

(1) **Dug wells and Pucca well**

These are open surface wells, which differ in dimensions depending upon the thickness of the weathered horizon. These may be lined or unlined. These wells should be provided with deep holes from the starting of the aquifer zone at regular interval down to the bottom. Generally, depth of the well varies between 10-20m with diameter of 2m. Considering the pre monsoon water level of the area as 5m, the water holding capacity of such wells vary from $15m^3$ to $50m^3$. The approximate cost of these structures would be about Rs.25,000 to 35,000 per well.

(2) **Dug cum bore wells**

When the aquifer zone is deep-seated, this type of structure can be taken up. It involves a bore portion usually 7.5 cm in diameter or more in the dug portion. Instead of a large diameter hole, number of holes 4 to 5 cm diameter in various directions of the water bearing zones can be more beneficial. The yield of such well is generally much higher than the deep well. Such types of wells are much more economical as large quantity of water can be had and can be pumped by normal centrifugal pump. Boring
can be done down to a limit of 30 to 40m and it involves additional expenditure of Rs. 4000 to 15,000 which would be compensated due to heavy yield.

(3) Tube well

In the recent alluvium bordering the bank of the river Brahmaputra, tube wells with the depth range of 100 to 150m tapping 30 to 40m of aquifer in the central and western parts are feasible and may be deployed for large scale supply from definite pumping points, the discharge of which will be more than 100m$^3$/hr. for drawdown around 6 mts. The shallow tubewells with the depth range of 35 to 50m tapping 8 to 10 m of aquifer would be able to supply 40 to 45 m$^3$/hr with a limited drawdown of less than 5m. The cost of a shallow tube well with 3 to 4 inch diameter would range from Rs. 20,000 to Rs. 30,000 and the cost of a deep tube well would be about one lakhs. But utilizing the above structures at suitable places, it is expected that the additional requirement of 55,000 m$^3$/day can be met with.

Table 23: Summarised Salient Hydrological Parameters of Greater Guwahati

<table>
<thead>
<tr>
<th></th>
<th>Eastern</th>
<th>Western</th>
<th>Northern</th>
<th>Southern</th>
<th>Central</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness of aquifer in meters</td>
<td>6.00</td>
<td>43</td>
<td>20</td>
<td>10</td>
<td>55</td>
</tr>
<tr>
<td>Discharge m$^3$/hours</td>
<td>48.25</td>
<td>81</td>
<td>54</td>
<td>9.03</td>
<td>1620</td>
</tr>
<tr>
<td>Drawdown in meters</td>
<td>15.69</td>
<td>1.0</td>
<td>3.0</td>
<td>5.16</td>
<td>2.0</td>
</tr>
<tr>
<td>Static Water Level in m.b.g.l.</td>
<td>4.00</td>
<td>1.0</td>
<td>5.53</td>
<td>6.81</td>
<td>4.82</td>
</tr>
<tr>
<td>Tm$^2$/D</td>
<td>1.336</td>
<td>4500</td>
<td>1113</td>
<td>3.5</td>
<td>927</td>
</tr>
<tr>
<td>Pm/D</td>
<td>0.21</td>
<td>166</td>
<td>60</td>
<td>0.35</td>
<td>40</td>
</tr>
<tr>
<td>Specific Capacity lpm/m/d/d</td>
<td>3.075</td>
<td>1452</td>
<td>-</td>
<td>29</td>
<td>487</td>
</tr>
</tbody>
</table>

Source: Srikantha and Devi, 1996)

The household survey done in this study reveals that the average depth of ground water structure as shown in the figure 49 varies between less than 20m to more than 80m of depth. It indicates that 37 percent households use ground water from the depth of 20-40m, followed by 30 percent using from the depth of 20m and below, 18
percent from the depth of 40-60 m, 9 percent from the depth of 60 - 80 m and 6 percent from the depth of 80m and below.

![Pie chart showing depth of different groundwater structures in Guwahati](image)

**Fig. 49: Depth of Different Groundwater Structures in Guwahati**

**Expenses for Procuring Water**

The costs of installation varies on the basis of area and economic condition of the household. The figure 50 indicates that a cost ranging from Rs. 5001- 10,000 is incurred by 31 percent of the households followed by 14.7 percent people incur installation cost ranging below Rs.5000, 31 percent between Rs. 5001-10,000, 16.1 percent between Rs.10,001-15,000, 11.9 percent between Rs.15001-20,000, 6.4 percent between Rs. 20,001-25,000, 6.7 percent between 25,001-30,000, 2.8 percent between Rs. 30,001- 35,000, 4.1 percent between 35,001-40,000 and 6.3 percent above Rs.40,001. Further, the study shows that almost half of the households use electric motor for procuring their drinking water (fig. 51). The figure 52 shows that, household with the monthly income ranging from of Rs. 3001 to 12000 are 58 percent in the city, followed by 23 percent households with income within the range of Rs.12001 to 30,000, 15 percent of households fall in the low income group below Rs.3000 and 4 percent within the range of above Rs. 30,000.
The perception about the water quality of supplied water is not satisfactory. Tests conducted on the samples of GMC water in the public Analysis Laboratory have revealed absence of residual chlorine up to the desired level in all the cases. According to the Laboratory, this is not at all a satisfactory position for the people using GMC
water for drinking purposes. However the drinking water supplied by the Municipal Corporation is found to be satisfactory so far as chemical contamination is concerned.

As per the World Health Organization (WHO) and Central Public Health and Environmental Engineering Organization (CPHEEO) norms, residual chlorine is a must if bleaching powder used as a disinfectant during the treatment of drinking water. Absence of residual chlorine has made it unsafe for the Guwahatians to use GMC water without proper boiling and particularly during the rainy season. The GMC water samples are also found to be turbid in most of the cases. This is due to inadequate treatment or problems like leaks in the water supply network.

According to household survey it is found that people are not satisfied in terms of supplied water quality. The figure 53 shows that 73 percent of the households rate the supplied water as not potable, 20 percent of the households think it is potable and other 7 percent households express their lack of knowledge.

![Pie Chart](image)

Fig. 53: Perception about Quality of Supplied Water in Guwahati Pipe Water Use

Urban water supply and sewerage services in Guwahati are characterized by inadequate access, low levels of service and low customer satisfaction. The present study reveals that piped water serves only 25 percent of the households in the city while 75 percent of the households do not have any access to piped water. The percentage of household covered by piped water are categorized into seven classes: fully covered
(100 %), very high (80-99 %), high (60-79%), moderate (40-59 %), less moderate (20-39 %), least (below 19 %) and not covered (10 %).

In an earlier study done by Kalita et. al. (2000), it was found that 70 percent of the households did not have provision for potable water, while only 30 percent were covered by piped water from Guwahati Municipal Corporation, Public Health Engineering Department and Urban Water Supply and Sewerage Board.

The figure 54 shows that the fully covered (100 %) wards are nil, followed by very high (80-99%) - 1, high (60-79%) - 8 wards, moderate (40-59%) - 8 wards, less moderate (20-39%) - 13 wards, least (< 19%) - 16 wards and not covered (0%) at all - 14 wards. The ward covered by supplied water in Guwahati city is presented in fig. 55.

The multiplicity of piped water (Fig.56) itself reveals the pattern of water supply by different water supply agencies. Only 37 number of wards are covered by two supply agencies, 2 numbers of ward covered by three supply agencies and 9 wards are not covered by any supply agencies in the city. The diagram 57 shows the percentage of households served by different water supply agencies. The GMC serves the highest number of households covering 54 percent of the city's total, followed by PHED 11 percent, Urban Water Supply & Sewerage Board 13 percent, NF Railway 18 percent and Guwahati Refinery only 4 percent.
WARDS COVERED BY SUPPLIED WATER IN GUWAHATI

Fig. 55: Ward Covered by Supplied Water in Guwahati
Fig. 56: Multiplicity of Piped Water Supply in Guwahati

Fig. 57: Present Status of Piped Water Supply in Guwahati

Again the figure 59 shows that the water supply system of Guwahati Municipal Corporation covers the highest number of wards (25) followed by Public Health and Engineering Department (15), Urban Water Supply and Sewerage Board (12), NF Railway (12) and Guwahati Refinery (4). The supplied water covered by different supply agency in Guwahati are presented in fig. 58.

Fig. 59: Piped Water Covered by Different Supply Agencies in Guwahati
Fig. 58: Status of Piped Water Supply in Guwahati by Various Supply Agencies
The study also shows in figure 60a the piped water coverage scenario of the GMC and other agencies. The ward nos. 37, 35, 23, 7 and 43 are covered with PHED, UWSSB and NF Railway. The figure 60b shows that only 6 wards are covered by the PHED. In these wards mostly government offices, colonies and other Govt. organizations are situated. The PHED not supplied to the household only a few households getting the service and a few nos. of stand post are available in the street. The Urban Water Supply and Sewage Board covers mainly both sides of the Zoo road. The figure 60c shows the wards covered by the agency. Further the study shows that the NF Railway water supply covers Maligaon, parts of Panbazar and parts Noonmati area. The agency covers railway employees’ quarters only. (Fig. 60d).

Fig. 60a: Piped Water Coverage of Guwahati by GMC and other Agencies

Fig. 60b: Supplied Water by PHED and other Agencies
The Guwahati Refinery covers only the Refinery complex and Satgaon Army Cantonment complex. The fig. 60e shows that ward nos. 48 and 45 are served by UWSSB and NF Railway. The Refinery connects the pipe water supply through some public stand post. But some households capture water by connecting rubber pipes illegally with the stand post.
Types of Connection

The supply water systems are connected to households through tap connection, public stand post and tanker truck. The GMC tap connections are provided from Panbazar and Satpukaneri plants; only street taps are provided from the Kamakhaya plant and the DT schemes, excepting in New Field, Santipur and certain areas of Bharalumukh. The Urban Water Supply and Sewerage Board connects the taps to the households. The Guwahati Refinery and NF Railways have their own water supply schemes which are connected with taps in their employees residences only. The Guwahati Refinery provides limited connection to the general public through public stand post (Photograph nos. 7 and 8). Our study reveals that in the city only 46 percent of households receive pipe water supply through house connection, followed by 26 percent that have both house connection and use public stand post, 23 percent that receives water through public stand post and only 5 percent of the households receiving water through tanker trucks (Fig. 61). The photograph nos. 9 and 10 shows piped water supply situation in slum areas of the city. Again the photograph nos. 11 and 12 are shown about the leakage of pipes in the city.

![Fig. 61: Types of Connection of Piped Water Supply in Guwahati](image)
Photograph 7: A View of Public Stand Post in Guwahati

Photograph 8: Unauthorized Multiple Connection from Public Stand Post

Photograph 9: Water Collected from Pipe Joints

Photograph 10: A Slum Boy Trying to Collect Water from Pipe by his Mouth

Photograph 11: Slum Dwellers Using Water from the Leakage

Photograph 12: Faulty Pipe Joints of Supplied Water in Guwahati
Timings of Supply

The supply timings vary from agency to agency and also depend on area. The figure 62 shows that 45 percent of the households receive water twice a day followed by 29.8 percent once in a day, 17.3 percent receives erratic supply, 5 percent receives water for the whole day and only 2.7 percent households receives water once after two days.

![Bar chart showing supply timings in Guwahati](image)

**Fig. 62: Timings of Water Supply in Guwahati**

Satisfaction Level

The satisfaction level of the people from various supply agency in Guwahati was found be very low. The fig. 63 indicates that only 39 percent of households say the supplied water fulfill their requirements, 42 percent remarked their requirement is partly fulfilled and 19 percent households claimed supplied water do not fulfill their requirement. Again from the fig. 64 it is clear that 73 percent of the households feel that the supply waters are not directly potable, only 20 percent of households think that the water are directly potable and 7 percent of the households have no concept at all about water quality.
Surface Water Use

Guwahati has one of the largest rivers of the world, the Brahmaputra, flowing along its northern boundary with an average daily mean flow of about 20,000 cumec at Pandu near Guwahati. It is unfortunate that this huge potential of the Brahmaputra has not yet being properly tapped for supplying the much needed domestic water for city dwellers. 102.60 MLD water is supplied by the supply agency in the city. Apart from the Brahmaputra river, there are several streams that flow from the hills located in the city or its surrounding areas. But these streams are not properly tapped. Among them, some are flowing around the year while others are seasonal. Some of the households use surface water from the streams located nearby their house. In the city only 2 percent of households use both groundwater as well as surface water (Photograph 5 and 6). Our
study reveals that in the city out of the total population using surface water, 78 percent of the households use spring water followed by 20 percent using river water, mainly those who live near the river Brahmaputra and are in low income group, and only 2 percent of households use pond water, maintained on their own, during the scarcity period (Fig. 65). In the city there are some public ponds which are large perennial water bodies but not properly maintained, namely Dighalipukhuri, Silpukhuri, Nagputapukhuri etc. The figure 66 shows the detailed scenario of surface water use in the city. The figure 67 shows the distances from different sources.

![Fig. 65: Pattern of Surface Water use in Guwahati](image)

![Fig. 66: Types of Surface water Use in Guwahati](image)
Rain Water Use

The rainwater use in Guwahati is very less. Only 6.7 percent households use rainwater (Fig. 69). In the scarcity areas of Guwahati, people use rain water for washing and gardening purposes. However, no permanent storage structures are made by the households. People store rainwater using some vessels. The figure 70 shows that 74 percent of the households store rainwater while 26 percent of household do not store. Since there is immense potential for use of rain water in the city, Some NGOs
and individual households are taking up schemes to harvest rainwater, especially rooftop harvesting.

![Fig. 69: Rain Water Use in Guwahati](image1.png)

![Fig. 70: Storage of Rain Water in Households in Guwahati](image2.png)

**Storage Facility**

The service reservoirs provide a suitable reserve of treated water with minimum interruptions of supply due to failure of mains, pumps etc. They also enable meeting the widely fluctuating demands when the supply is by affected intermittent pumping. They are also helpful in reducing the size of the mains, which would otherwise be necessary to meet the peak rates of demand. They can serve as an alternative to partial duplication of an existing feeder main as the load on the main increase.

The capacity of the service reservoir to be provided depends upon the better economic alternatives amongst various options. A system supplied by pumps with 100 percent stand by will require less storage capacity than that with less standby provision.
Similarly a system divided in the interconnected zones will require less storage capacity for all zones except for the zones at higher elevations.

However, the minimum service or balancing capacity depends on the hour and rate of pumping in a day, the probable variation of demand or consumption over a day. The hours of supply can be calculated from a mass diagram or by a demand and pumping budget.

The ground level reservoir is generally preferred as storage reservoir, which is circular or square or rectangular in shape. If it is circular, it is usually constructed of RCC and in the case of other shapes it is constructed either of RCC or masonry. The elevated reservoirs are used principally as distributing reservoirs and can have shapes like circular, square, rectangular and conical or may be of Intze type. They are generally made of RCC or pre stressed concrete. Small capacity tanks can be fabricated with steel or PVC or HDPE. Circular shapes are generally preferably, as the length of the wall for a given capacity is minimum and further, the wall itself is self-supporting and does not require counter fort. Reservoirs of one compartment are generally square and those of two or three compartments may be rectangular with length equal to one and half times the breadth. The economical water depth for reservoirs with flat bottom upto 1000m$^3$ Capacity is between 3 and 5.5 m. The service reservoirs should be covered to avoid contamination and prevent algal growths. Suitable provision should be made for manholes, mosquito-proof ventilation, access ladders, scour and overflow arrangements, water level indicator, and if found necessary, lightening arresters.

According to the household survey done for this study in the city, only 41 percent of the households use motor for pumping purposes and they connect the pump with reservoir 50 percent of households do not have any reservoir or pumping facility. They use vessel for storage. Around 6 percent of the households do not store water
because they are getting water at any time from the source and they can not afford the money for installation of motor or pump. Others 3 percent households store water for drinking and cooking purpose using buckets etc. (Fig. 71).

![Pie chart showing the pattern of water storage facility of households in Guwahati.](image)

**Fig. 71: Pattern of Water Storage Facility of Households in Guwahati**

The figure 72 indicates that more than 80 percent households have facility of reservoir connected with pump in only one ward in the city. In 8 wards such facilities exist in 60-79 percent households, in 20 wards in 40-59 percent households, 19 wards in 20-39 percent households and in 12 wards below 20 percent households. The figure 73 shows that 93.4 percent of the households use more than 2000 litre-size of reservoir. The study further indicates that 50 percent of households in the city use different types of vessels for different purposes like, drinking, cooking, bathing, washing etc. The study reveals that more than 53 percent of households use metallic vessel followed by plastic in 38 percent households, earthen vessel uses in 5.8 percent and in 0.2 percent other types. (Fig. 74).

![Bar chart showing the distribution of households in wards with fitted pumps.](image)

**Fig. 72: Household Reservoirs Fitted with Pumps**
Losses of Water

Unfortunately, much of the water abstracted from surface and ground water sources for human activities is used very inefficiently. Losses also occur in the public water supply distribution system, particularly where the water mains are old and are not well maintained. Leakage of 50 percent or more of the water is not uncommon and there are losses due to illegal connections as well. There are also losses from public stand post. According to the household survey, more than 74 percent of households loss water at the source due to misuse, followed by 14.3 percent due to leakage of pipe and only 11.4 percent for other reasons (Fig-75). Further, the study reveals that more than 65 percent of households loss water daily below 5 litres, followed by 24 percent within the range of 5-10 litres (Fig. 76).
Causes of water loss

Fig. 75: Causes of Water loss in Guwahati

Fig. 76: Pattern of Water Losses in Guwahati

Leak Detection and Repair

Losses in drinking water and sewerage systems are due to evaporation and seepage in storage and regulation reservoirs, leaks in purification plants, distribution networks and home outlets, and inaccurate or nonexistent metering, leading to wrong estimates, unauthorized outlets and unrecorded volumes consumed by municipal services such as watering of public gardens or fire hydrants.

Leaks in the supply network may be visible or concealed; in visible cases water rise up through the soil or pavement, while the latter are not visible and flow into the drainage system or aquifer. In Guwahati city, such leakages are rather common due to inadequate maintenance of supply lines or other reasons.
Causes of leaks

The causes of leaks vary depending on the type of soil, quality of water and construction materials used, pressure, age of the network and operating and maintenance practices. Along the network, leaks can be the result of crosswise cracking, crushing or lengthwise cracking; surface vibrations cause the first, while the second is due to poor construction and the third to fatigue, manufacturing flaws or hydraulic ramming. Other causes include rusting, poor pipe joints or valve failure. In home outlets, faults can be due to fissures, perforations, cuts or loose fittings. The first type of fault is associated with poor quality materials or poor construction; the second and third with external loads, and the fourth with poor construction.

Pattern of Pipe use

Water supply system broadly involves transmission of water from the sources to the area of consumption, through free flow channels or conduits or pressure mains. Depending on topography and local conditions, conveyance may be in free flow and/or pressure conduits. Transmission of water accounts for an appreciable part of the capital outlay and hence careful consideration of the economics is called for, before deciding on the best mode of conveyance. While water is being conveyed, it is necessary to ensure that there is no possibility of pollution from surrounding areas. Pipelines are major investments in water-supply projects and as such constitute a major part of the assets of water authorities. Pipes represent a large proportion of the capital invested in water supply undertakings and therefore are of particular importance. Therefore, pipe materials shall have to be judiciously selected not only from the point of view of durability, life and over all cost which includes, besides the pipe cost, the installation and maintenance costs necessary to ensure the required function and performance of the pipeline throughout its designed life time.
**Choice of Pipe Materials**

The various types of pipe used are - (i) Unlined metallic pipes and (ii) Metallic pipes lined with cement or epoxy lining.

Depending on the soil environment and corrosiveness of ground water, protection against external corrosion is provided with cement mortar joining or hot applied coal tar asphaltic enamel reinforced with fiberglass fabric yarn (CPHED, Govt. of India, New Delhi, 1999). In Guwahati, there are five organizations for water supply but they hardly follow the specifications given by Central Public Health and Engineering Department, Government of India.

Our household survey showed that more than 76 percent of the households use GI (Galvanised Iron) pipes without knowing proper specification while 22 percent of households use plastic pipes – PVC, polyethylene, glass reinforced plastic etc. (Fig. 77).

![Fig. 77: Types of Water Pipes Used in Guwahati](image)

Several technical factors affect the final choice of pipe material such as internal pressures, co-efficient of roughness, hydraulic and operating conditions, maximum permissible diameter, internal and external corrosion problems, laying and joining, type of soil, special conditions, etc. The life and durability of the pipe depends on several factors including inherent strength of the pipe material, manufacturing process along with quality control, handling, transportation, laying and jointing of pipeline.
surrounding soil conditions and quality of water. Normally the design period of
pipelines is considered as 30 years (CPHED, Government. of India, New Delhi). The
pipelines installed by the GMC and PHED date back to 1962. So, the effective period
of utility is over for these pipes.

Pattern of Water Use

As a basic principle, cities of smaller size (as per population) do not need the
same level of service that a bigger urban centre will need. For example, major urban
centres use more water per head as compared to smaller cities and towns. In small
town, some of the non-essential uses such as washing clothes and utensils could be
from non-protected sources (wells, ponds, etc.), which in a big city have to be met only
by piped water sources. Water supply standards will also very from one region to
another, according to functional, climatic and other characteristics including habits of
the people. The Central Public Health and Environmental Engineering Organisation
(CPHEEO), Govt. of India has set minimum standard at 125 to 200 litres per capita per
day for cities with a population of 59,000 and above. The Zakaria Committee has,
however, suggested that a per capita supply of 157.5 to 270.0 litres per day per head
would be an ideal goal for cities with a population of 10,000 and above.

The National Master Plan of India has suggested a water standard of 70 to 250
liters per capita per day (lpcd) with an average supply of 140 lpcd irrespective of
population size. The Master Plan has also recommended, coverage, on an average, of
90 percent of urban population under protected water supply (Mathur, 1999)

Population coverage under piped water supply is an important indicator of
levels of water supply. According to the Census of India, 1991, an average of more than
81 percent of population is being served potable water.

194
Residential water use rates are continually fluctuating, from hour to hour, from day to day, and from season to season. Average daily winter consumption is only about 80 percent of the annual daily average, whereas summer consumption averages are about 25 percent greater than the annual daily average. The figure 78 shows that 41 percent of available domestic waters are used for bathing, followed by 37 percent for washing, 10 percent for toilet, 7 percent drinking and cooking, 2 percent for washing vehicles etc., 2 percent for watering gardens and 1 percent for domestic animals and pets.

![Fig. 78: Pattern of Daily Water Use by Household in Guwahati](image)

The consumption of water is the Guwahati city is found to be around 481 litres average per day per household in the summer, that is approximately 120 litres per head per day, which is lower than the WHO norms 135 litres per head per day, and 383 litres on average in the winter, that is approximately 95 liters per head per day (Fig.79). While implementing the urban water supply schemes for providing potable drinking water to the urban population, the Central Public Health and Environmental Engineering Organization follows the norm of 135 liters per capita per day. This calculation is done on the basis of household survey. For the sample survey, an average of 4 persons in a family was considered. As per CPHEEO norms the minimum need of water is 540 litres per day per household. The figure 80 shows that households in only
6 wards of the city use more than 540 liters, which fulfills the CPHEEO norms. But in the winter only 4 wards fulfill these norms.

**Fig. 79: Water Use by Household in Litres**

![Bar chart showing water use by season](image1)

**Fig. 80: Pattern of Daily Water Use in Households in Guwahati**

The figures 81a-c indicate the wardwise daily water use pattern in Guwahati. These clearly show the large variations in water use scenario across the metropolitan area.

**Fig. 81a: Pattern of Daily Water Use in Guwahati (wardwise)**

![Line graph showing ward-wise water use](image2)
The daily water use mainly depends upon standard of living of a family, availability of water and use of household amenities. In the city, only 6 wards use more than 540 liters per day per family. The figures 82 and figure 83 show that the water use in those wards basically depends upon income of the households. The figure 82 on household income shows that near about 75 percent of the households fall within the range of Rs.12001-30,000 (Upper middle income group), while the figure 83 on daily water use shows that household water use in those wards are well above the average figure for the city as a whole.
Fig. 82: Households’ Monthly Income in Selected Ward in Guwahati

![Households' Monthly Income in Selected Ward in Guwahati](image1)

Fig. 83: Pattern of Daily Water Use in Selected Ward in Guwahati

![Pattern of Daily Water Use in Selected Ward in Guwahati](image2)

The distribution of SC and ST dominated wards in Guwahati (Fig. 84 a-c) it shows that the ward nos. 12, 14, 34, 46 and 49 except ward no 34 used lesser amount of drinking water compared to the average of 432 litres for the city (Fig. 85) and depend monthly on ground water (Fig. 86).

The figure 87 shows the amenities used by the households in Guwahati. It indicates that 17 percent of the households have water pump, washing machine, shower, car and scooter. Only 4 percent of the households use shower in the bathroom and 2 percent use washing machine. Other equipments like dishwasher are used by
lesser number of the households. Most of household works are done manually. The amenities like shower, flush latrine, washing machine

Fig. 84a, b and c: Distribution of SC& ST Population in Guwahati

Fig. 85: Water use in the SC&ST Dominated Wards in Guwahati

Fig. 86: Water use by Source in SC& ST Dominated Wards in Guwahati
etc. consume more water than manual work. Already we have discussed in the chapter IV that only 29 percent households use flush toilet and 62 percent of household use pour latrine. The residential use mainly depends upon the nature and number of amenities used by the households.

![Pattern of Amenities used by Households in Guwahati](image)

**Fig. 87: Pattern of Amenities used by Households in Guwahati**

**Determinants of the Pattern of Drinking Water Use**

To understand the driving forces leading to scarce water situation in most part of Guwahati city, the hydrologic process needs to be analysed. The urbanization process that includes urban surface sealing and increase of built up area results in to a disturbed local hydrological cycle. With rapid urbanization and dramatic growth of population in urban areas, the city is experiencing increased pressure on their ground water sources. The natural water balance is a very delicate relationship where water leaves its meteoric form to fall as precipitation and thereafter flows as streams, recharges the aquifers, provides moisture to soil and so on. A little change in any part of the process affects the whole water flow system. Haphazard growth has been responsible for affecting the water balance in many ways, which in turn has affected the overall water availability.
Physical Factors

Within the physical forces that act as determinants of the pattern of water availability is the hydrogeomorphological, meteorological, land use and lithological constraints.

Hydrogeomorphological Constraints

The study of hydrogeomorphological condition of the area reveals that almost the entire western part of the study area is occupied by alluvial plain (both older alluvial plain as well as younger alluvial plain). Lithologically, these formations are comprised of intercalated beds of sand, silt and clay in varying proportions (Goswami and Goswami, 1996). However, the thickness of the upper clay layer is only a few meters while that of the sandy layer varies from 40 to 50 meters. Hence, the infiltration of surface water is higher in this zone as compared to others. This zone, which includes the Deepar Beel and Dharapur areas, therefore, forms a high recharge zone.

In the eastern part of the study area there is a fault trending NNE-SSW which gives rise to the formation of Silsako and Hahshora Beels. Another prominent fault is seen in the central part of the study area trending along NNE-SSW direction. This lies in the corridor between the Fatasil hills and the Narakashur hills. Weathered rocks or alluvial plain overlie these faults. This zone, which includes areas such as Garchuk, Betkuchi, Fatasil-Ambari, Birkuchi, Silsako beel and Hahsora beel, has negligible thickness of clay layer in their soil profile, while the thickness of the sandy layer varies from 50-60 meters, thus resulting in easy and convenient infiltration of surface water through them. This zone therefore serves as a high recharge zone.

The denudational hills, which include the Narengi hill, Japorigog hill and Narakashur hill consist mainly of highly metamorphosed quartzo-feldspathic gneisses. The rocks are highly dissected and deeply weathered (Goswami and Goswami, 1996).
The areas act mainly as run off zone. As the primary porosity and permeability is low in this unit because of the presence of hard rocks, the amount of recharge is very low.

Apart from the above mentioned area, there are few other valley fill areas such as Chandmari, Dispur, Ulubari, Rupnagar, Machkhowa, Bhutnath and Maligaon that comprise soils with the thickness of the sandy layer varying between 40-60 meters, yet the surface water cannot easily infiltrate through them into the underground aquifer system. This is because these sandy layers are overlain by a thick layer of clay having thickness of the order of 10-20 meters, thus preventing the percolation of water through such impermeable layer. Hence these acts as medium to low recharge zones.

**Meteorological Factors**

Guwahati city is characterized by the prevalence of dominant monsoon rainfall regime. The southwest monsoon is the main cause of rainfall in Guwahati. However, due to modification brought about by local factors such as orography, periodic western disturbances, local mountain and valley wind etc., there are spatio-temporal variations in the local climate and weather system that further complicates the pattern. Guwahati has a mean annual rainfall of 165.3 cm and summer monsoon months of June, July, August and September experience highest rainfall accounting for more than 70 percent of the total. Distribution of rainfall is not uniform throughout the year in the city. The average rainfall in the city is less than the average annual rainfall of Assam i.e.220 cm. An analysis of rainfall data of the city covering the period 1868 to 2000 shows that there is no perceptible trend in the annual distribution of rainfall, although there are considerable annual, monthly and sesonal variations (Fig. 5).

The ratio of ground water recharge to rainfall in hard rock terrain is customarily between 9 percent to 13 percent. In the study area the denudational hills, which include Narengi hills, Japorigog hills, Fatasil hills, silapahar hills, Kamakhya hill, Narakashur
hill and Sonaiguli hill are composed of hard rugged topography, due to which most of the run off flows over the surface. Only the areas having thick forest cover or good number of faults and lineaments, which include the foot hills along the flanks of the Hengerabari-Japorigog hills and the Fatasil hill affect an appreciable amount of recharge into under ground reservoir. The basements of these denudational hills are composed of hard rocks like granite and gneisses (Goswami and Goswami, 1996). These rocks may not have any connected porosity but on macroscopic scale the storage co-efficient is about 0.03 percent to 0.3 percent.

In the alluvial plain, the ratio of recharge to rainfall is between 15 percent to 25 percent depending upon the nature of the top soil. In the study area, alluvial plain includes places like Gotanagar, Betkuchi, Gorchuk, Birkuchi and Garigaon. These areas consist mainly of unconsolidated materials like sand, gravel, pebble, silt and clay (Goswami and Goswami, 1996). Hence the rainwater can easily percolate through these materials and infiltrate into the under ground aquifer. Thus, these areas can be considered as most favorable sites for recharge. Moreover, it has been observed that the post- monsoon high water levels in the wells are gradually depleted to a lower position towards the end of the summer.

Rainfall is highly seasonal in the study area (Kalita and Sarmah, 1986). It comes under the Southwest monsoon regime. Based on the distribution of rainfall, the seasons experienced by the study area can be classified as to pre-monsoon, Monsoon and post monsoon.

From the hydrogeomorphological map of the city prepared based on satellite data, it has been observed that a few discontinuous structural lineaments are present in the denudational hills (Goswami and Goswami, 1996). These lineaments behave as channels for rainwater to percolate underground. The areas, which fall under this
category, are Hengrabari-Japorigog hills, Narengi hills, Fatasil hills, Silapahar hills, Kamakhya hills, Narakasur hills and Sonaighuli hills. Dug wells in the hills areas of the city dry up during lean period of the year because in these areas recharge of the storage and replenishment in the hilly areas are very limited. On the other hand, the alluvial plains in the northern and northwestern parts of the city, which cover areas like Garigaon, Azara, Dharapur and Kahikuchi, consists mostly sand gravel, pebble, silt and clay. These are considered as suitable areas for high recharge zone. In places like Gotanagar, Betkuchi, Gorchuk, older alluvium plains occur as isolated patches, which are located at a relatively higher level than the younger alluvial plains. Lithologically, this formation comprising unconsolidated sand, silt and clay in varying proportions act as a recharge zone (Goswami and Goswami, 1996). The entire alluvial plains of the city are densely populated and extensive construction of houses, roads and other concrete structures has reduced the percolation of rainwater and surface water through this potential recharge zone. Valley fill areas cover a major part of the city. These areas mainly consist of angular fragments, sands, gravels, pebble, boulder, silt and thick bed of clay deposited by run-off water and streams from surrounding hills areas (Goswami and Goswami, 1996). The thickness of alluvium varies from few meters to 100 meters and the cumulative thickness of granular zone varies from 4-28 meters. The depth of water table varies from 2.0 - 2.7 m below ground level in valley fill areas.

**Human Factors**

The human factors are a major determinant of the increase in water demand for domestic use. Population density can make water demand a serious constraint on water uses. The physical factors mentioned above are either caused directly by some of the anthropogenic activities or are aggravated due to the human activities as illustrated below.
Rising Population

The increasing population is one of the most important factors causing scarcity in water. It is significant because some of the other human factors depend directly on it. The increasing population has resulted in the increased number of dwelling and commercial units, which in turn increased the demand for water leading thereby to excessive water abstraction. It has been noticed that since 1940 the population growth has increased significantly. During the decade 1931-1951 the city recorded an increase of population of 35-78 percent. During 1951-1961 the population increase was 130.9 percent, while in 1991 the decadal growth was 188.25 percent. According to the 2001 census, the population of the city was 8,09,895. However, as indicated in recent studies by different researchers, the actual figure may exceed even 14 lakhs.

Table 24: Growth Profile of Guwahati in Relation to Urban Growth of Assam

<table>
<thead>
<tr>
<th>Year</th>
<th>Population in (000)</th>
<th>Gender Ratio</th>
<th>Decadal growth</th>
<th>Share (%) in urban population of Assam</th>
</tr>
</thead>
<tbody>
<tr>
<td>1901</td>
<td>11.6</td>
<td>500</td>
<td>-</td>
<td>15.13</td>
</tr>
<tr>
<td>1911</td>
<td>12.5</td>
<td>534</td>
<td>7.03</td>
<td>13.43</td>
</tr>
<tr>
<td>1921</td>
<td>16.5</td>
<td>528</td>
<td>32.04</td>
<td>12.97</td>
</tr>
<tr>
<td>1931</td>
<td>21.8</td>
<td>503</td>
<td>32.26</td>
<td>13.44</td>
</tr>
<tr>
<td>1941</td>
<td>29.6</td>
<td>567</td>
<td>35.79</td>
<td>14.22</td>
</tr>
<tr>
<td>1951</td>
<td>43.6</td>
<td>558</td>
<td>47.36</td>
<td>12.65</td>
</tr>
<tr>
<td>1961</td>
<td>100.7</td>
<td>497</td>
<td>130.90*</td>
<td>12.89</td>
</tr>
<tr>
<td>1971</td>
<td>123.7</td>
<td>638</td>
<td>22.90</td>
<td>9.60</td>
</tr>
<tr>
<td>1981</td>
<td>200.3</td>
<td>755</td>
<td>61.87</td>
<td>11.24</td>
</tr>
<tr>
<td>1991</td>
<td>557.6</td>
<td>783</td>
<td>188.25</td>
<td>23.22</td>
</tr>
<tr>
<td>2001</td>
<td>809.9</td>
<td>840</td>
<td>45.25</td>
<td>23.55</td>
</tr>
</tbody>
</table>

* Extension of municipal boundary

The demographic aspects as revealed by table 24 shows that Guwahati registered relatively faster growth in recent decades compared to the other cities and towns of Assam. The growing dominance of the city is reflected in its rising share (from 9.60% in 1971 to 23.22% in 1991) in the urban population of Assam. Further, the huge demographic growth over a relatively short period is attributed to migration of
families rather than lone male migration which is apparent from the rise in the gender ratio (measured as females per thousand males) from 638 in 1971 to 783 in 1991. One important fact is that the fast demographic growth of Guwahati has not been accompanied by an adequate economic prosperity.

The trend of population growth in Guwahati City as shown in (Fig.8) demonstrates an accelerated growth since the 1940’s, the present decadal growth being 45.25 as against 35.79 percent in 1941.

**Expansion of Built up Area**

With the rising population, the built up area has increased in the city. The settlements have spread out between 1951-1961, due to establishment of High Court, the Railway Headquarters, the University Campus, the Engineering College, the Medical College, the construction of Saraighat Bridge, Oil Refinery, Military Catonment at Satgaon, the industrial estate, many Central and State Government Offices and Institution etc. In 1972, about 20,000 people including their families come to Guwahati from Shillong due to shifting of Capital. Increase in the network of roads, lanes and bylanes have increased the area of built up surface. The increase in concrete surface has increased the runoff, as the water fails to penetrate the surface and thus the natural recharge of groundwater has markedly reduced.

The growth and extension of the city of Guwahati is governed to a great extent by its variegated physical features like hills, hillocks, the Brahmaputra River, marshes and other water bodies, cultural features like road, networks, railways and service centers. Civic amenities also act as a controlling factor in this respect.

Early settlements established along the southern bank of the Brahmaputra were confined between the river Brahmaputra in the north and the railway line in the south. Later, the city expanded beyond the railway line and all low laying areas came under
human habitation and other uses. The city has witnessed a rapid expansion in the southern direction during the last decade. However, expansion in this direction beyond Khanapara- Beltola is restricted due to the existence of the Khasi hills of Meghalaya (Kakati, 1991)

Guwahati Master Plan covers an area of about 262 square km of which only 61.8 percent land is developable. The unusable land mainly constitutes hills, scrublands, water bodies and pockets of low laying areas. However, in the last decade due to huge influx of migrant population, residential development has taken place on hills as well as low lying areas. The Assam Remote Sensing Application Centre (ARSAC), Guwahati has carried out a detailed land-use survey based on the satellite imagery.

Guwahati city has witnessed phenomenal change in its built up area since 1911. The analysis was carried out by ARSAC with the help of SOI Topographical Sheet (1967-68) and satellite data of 2002 (SPOT PLA, &MLA). The figure 88 shows that the growth from 7.00 square km. in 1911-12 has increased to about 76.80 square km. area in 1968 and to 135.48 square km in 2002.

![Fig. 88: Expansion of Builtup Land in Guwahati](image)

The builtup area has increased at the cost of open, vegetated and wetland areas. These areas had water retention capacity that recharges the aquifers.
Unplanned Urban Development

One of the causes responsible for the water crisis in Guwahati is the blatant disregard of the statutory master plan for Guwahati. The master plan constituted of excellent provisions for protecting the open space and wetlands as a green belt. During the past four decades, increased ground water withdrawals have led to the decline of ground water table in many areas. The variation in settlement density within residential areas has significantly changed in recent decades. There was no area under highly dense residential category in 1968 and 1990. But over the decade ending in 2002, highly dense residential areas have emerged (14.76 percent). There is an increase of medium density area (8.56%) and decrease (6.56%) in low density area. This may be due to conversion of low density residential areas to medium density areas and further to high density areas (Fig. 89).

Fig. 89: Changes in Density of Residential Areas of Guwahati

The area covered by Guwahati Master Plan is 216.09 Sq. km. The comparison of area statistics as per master plan of Guwahati Municipality area (2001) prepared by Department of Town and Country Planning, Govt. of Assam with the satellite databased land use map prepared by ARSAC (2002) is made in this study as shown in figure 90. The figures reveal a non-parity scenario of residential, industrial, public/semi
public and transportation growth of the city as proposed in the Master plan (2001) vis-a-vis the ARSAC data based on satellite. The table shows that the built up areas cover 51.71% while water bodies and hills cover 25.97%. The existing residential areas cover a significant part of the city (40.02%) compared to the proposed (27.71%) area. This might have led to undergrowth of industrial, public and semi-public and area under transportation. Some portion of the proposed areas for industries, public institutions and transportation and green belt have already been used for residential purposes. The study reveals a non corroborative use of land as per proposed Master plan.

![Fig. 90: Comparision Land Use from Conventional (2001) and Satellite based Data (2002) in Guwahati City](image)

**Economic Perspective, Water Pricing and Equity**

Historically, governments have largely subsidized water costs in most countries, but it has become increasingly difficult to continue with such financing schedules, and it is now a question of establishing rate policies that emphasize greater user involvement. Rates are essential to efficient water use programs. According to Grisham and Flemming (1989), rates can help save water if their structure meets the following conditions: rates must reflect real costs, they must be linked to consumption levels, differential increases must be large enough to encourage water savings, and any change
in the rates must be accompanied by information and education programs. In short, if users are charged appropriately for water services, consumption becomes more efficient, since the amount of water used tends to diminish and there is less waste (Saavedra, 1991). In urban areas there are basically four kinds of use; domestic, public, industrial and special. Each of these categories reacts differently to the same financial spur in charging for the service, so it is important for the rate structure to be properly designed. This involves having detailed information on past costs and projected costs, knowledge of the consumer market and its seasonal variations, and information on users' ability to pay.

The costs of water supply and sanitation include the initial cost of the infrastructure, the ongoing operation and maintenance costs and provisions for replacement, upgrading and extensions. The initial capital cost is high and either has to be subsidized or recovered over a long period. Through tariffs sustainability costs include operation and maintenance and perhaps provisions for later installation, refurbishment. Whenever investment is provided, there needs to be sound financial management.

Public participation is important to strengthen transparency in setting prices, and in stimulating sound financial management and demands for greater efficiency. There is a need for a particular regulatory framework to bring in the private sector.

Provision of safe drinking water must ensure both continuous availability and equitable access. An important study by the World Bank (1999) recommended a variety of ways and means through which user cost recovery and private participation are possible, gradually though surely. The major obstacles to achieving equity, efficiency and sustainability remain quality degradation due to uneconomical exploitation as also overcrowding on the resources. This underscores the need for optimum utilization of
water. A comprehensive water policy, to be effective and to have a semblance of concern for equity, must take into account such issues as overdraw, wastage, and polluting acts by competing sectors and or individuals.

In the Guwahati municipal area, there are five agencies that supply the piped water. Among them, the NF Railway, Guwahati Refinery, and Public Health & Engineering Department are supplying piped water free of cost to the respective employees only. The Guwahati Municipal Corporation supplies water to the general public and they have not a policy for water pricing. The prices for supplied water are included in the property tax. Municipal taxes are never popular in Guwahati. Houses are invariably under-rated, defaulters of payment of taxes are numerous, the have and the have-nots alike are shy to clear their dues.

From a quick look at the history of water supply scheme in Guwahati it appears that the municipal authority in Guwahati has been suffering for long from fiscal disabilities in providing protected water to the residents; therefore, the provincial (State) and the Union government are involved in funding the water works, and at times in managing the service and distribution of water.

**Metering**

Metering in cities is necessary at both source and user levels. Metering at source level involves measuring the water flows impounded, conveyed and distributed. This activity is vital to the planning, design, construction, operation, maintenance and management of drinking water and sewerage systems. The object of metering at user level is to measure each user's consumption periodically in order to charge for the service, ensure reasonable consumption rates and maintain a proper balance between water supply and demand.
The Urban Water Supply & Sewage Board of Guwahati are a statutory body of Government. The board collects water tax from their subscribers on the basis of water meter.

Our survey reveals that out of the total number of households 62.8% of the households pay for supply water received from different service agencies (Fig. 91). Again the figure 92 shows that only 4.6% of the households use water meter in the selected wards.

**Fig. 91: Paying for Supplied Water in Selected Wards in Guwahati**

**Fig. 92: Use of Water Meter in Guwahati in Selected Wards**

**Willingness to Pay**

The major wave of urbanization is taking place in small and medium-size cities in developing countries, where human and institutional capacities are needed to provide livable and sustainable conditions. Water service coverage and quality are often...
detoriating due to inadequate water governance systems and population growth. Studies show that poor people living in unregulated areas are those most severely hit by floods and lack of water related services. The competition for water and related services is increasing both within the urban center itself and between urban and rural water uses- a competition that can trigger off tensions and conflict but also inspire cooperation. A low level of water provision services is reflected in intermittent water supply. While this tends to affect poor people most, all consumers have to take the necessary steps to cope with such condition, either by investing in storage tanks and/or alternative supplies, or by spending time in queuing. Consumers’ coping costs tend to be higher than payment to the water utility (often heavily subsidized) and can be used as a proxy to willingness to pay for more effective water services.

The figure 93 shows that more that 70 percent of the households in the city are willing to pay more for drinking water if any organization/agency offers to supply purified water with improved water supply system.

Fig. 93: Willingness to Pay for Improved Water Supply

Determinants of Water use efficiency

The term ‘water use efficiency’ originates in the economic concept of productivity. Productivity measures the amount of any given resource that must be
expended to produce one unit of any good or service. In general, the lower the resource input requirement per unit, the higher the efficiency.

In an environmental resource context, however, the efficiency concept must be extended to include considerations of quality. Any effort to improve water use efficiency should be consistent with maintaining or improving water quality. Taking both quantity and quality into account, therefore, the following definition applies. Water use efficiency includes any measure that reduces the amount of water used per unit of any given activity, consistent with the maintenance or enhancement of water quality.

Water use efficiency is closely related to, and in several cases overlaps, other basic concepts of current environmental resource management. The best concept in this regard, perhaps, is water conservation. Although this term has received many definitions in the past, perhaps the definition used by Baumann et al. (1979), is the most useful here, namely, that water conservation is only socially beneficial reduction in water use or water loss. Put in this manner, water use efficiency is of central importance to conservation. At the same time, the conservation definition suggests that efficiency measures should, in addition to reducing water use per unit of activity, make sense economically and socially. Water use efficiency requires a multi-dimensional approach. In addition to the physical elements, social, economic and environmental factors are also important.

**Economic Dimensions**

Many of the variables affecting water use are economic in nature. Economic factors number among the most important determinants of water use and water use efficiency.
Throughout history, in the vast majority of cases, water has belonged to a class of materials called ‘common property resources’, to which access is non exclusive, ownership is held in common by ‘the public’ and prices are very low, or zero. The latter fact is the one of most interest here, for it is central in determining water use patterns, and consequently, water use efficiency. However, when the price of an input such as water is very low relative to other productive inputs, it is used without regard for quantity or conservation. This basis factor plays a major role in explaining why water usage per unit of production is high and why per capita use is higher in some areas / regions than in others. Stated simply, when water prices are low relative to the costs of other inputs and in relation to the costs of developing supplies, the resource will be overused and efficiency of use will be correspondingly low.

Basic pricing considerations also play a major role in explaining why pollution occurs. Most socio-economic activities require that waste by-products be removed. Waste removal, in the majority of cases requires the use of environmental resources such as water. In terms of the factors of production ‘model’, the ‘productive input’ is the waste-bearing- capability of water. When this input is available free of charge, it is invariably cheaper than any other option for waste disposal. The resulting overuse leads directly to water pollution problems. It is apparent that unreasonably low water prices are the enemy of water use efficiency. Free water at plant intakes is undoubtedly a cheaper solution for water supply than the installation of recirculation systems, assuming that basic quality needs can be met cheaply as well. High intake and low use rates are the logical outcome of low intake prices. Low Municipal water prices invariably lead to high per capita usage and wastage.
Social Dimensions

Social and political realities in a given area, locality or region play important roles in the use of water, and therefore, in efficiency considerations. The issue of social tastes and preferences is deeply embedded in societies, and may be a major influence on the ways in which individuals and groups view the need for water use efficiency. An example relates to a characteristic commonly termed ‘green lawn syndrome’. This term refers simply to the attitudes commonly held, at least in the developed world, that residential landscaping should be green, with healthy lawns, trees and shrubbery. These attitudes have led in the past to excessive water demands, particularly in drier areas, with subsequent overcapitalization of water infrastructure. In drier areas, xeriscaping, the use of water efficient landscaping, is gradually being accepted as an alternative to the green lawn syndrome. The point here is that deeply ingrained attitudes, tastes and preferences are important considerations in moving towards increased water use efficiency. The improper use of water in the urban centres, especially by the affluent sections, has already become visible in some parts of the city under review.

One fundamental key to gaining acceptance of water efficiency involves public education. In particular, public education holds the key to changing basic attitudes towards water use. The term refers to a wide range of activities, from incorporating water resource considerations in formal school curricula to the preparation of information brochures for widespread public dissemination. Particularly in times of water shortage, countless communities employ public information/education techniques to avoid or alleviate shortages. Often, the fact of pointing out the economic benefits to be gained from water conservation will initiate action toward water use efficiency. It appears also that moves to change water rate structures or to install water meters will prove more successful if accompanied by concerted public information campaigns. The
converse also applies i.e. in the absence of good information and education, attempts to improve water use efficiency by economic means are likely to prove unfeasible.

The legal systems of societies are endlessly complex; nonetheless, a few characteristics can be pointed out which clearly affect water efficiency decisions. Most urban centres in developed countries and some in developing countries employ systems of building codes, which specify minimum standards that must be met in new or renovation construction. However, the matter of water efficiency has rarely formed part of these codes in our country. Until codes and standards are modified, improved water efficiency will be very difficult to achieve. Municipal by-laws underlie efficiency-related issues such as water rates and sewer surcharges. Any movement towards improving water efficiency requires modification of such by-laws. Similarly, the ability to charge self-supplied water users royalties for the use of water constitutes formal legal arrangements. In the case of Guwahati, these systems are completely missing.

The last point leads directly into a fundamental legal issue underlying water use - that of property rights. The rights to natural resources are of any kind display varying degrees of ownership on the spectrum from public to private. At the public end of the scale, access is completely open to all citizens. The resource is essentially free for the taking. With open access, no incentive exists to manage the resource in a conserving, efficient manner, except through moral suasion, which is difficult to invoke in most circumstances. At the other end of the spectrum, where private ownership pertains, access to the resource belongs exclusively to its owner, is enforceable under law and is both divisible and transferable. Under such conditions, positive incentives do exist for effective management and efficient use.
Technological Dimensions

The rapid march of technology has driven the development of many world economies for over two centuries. While this march has been uneven in its effects, and has often led to environmental problems, there can be little doubt that technological progress holds one of the keys to the increased well-being of almost all societies. It is not the intention here to assess technological impacts on societies, or to prescribe unfettered development as a universally positive benefit. Rather, the aim here is limited to briefly discussing the processes that underlie technological change and their application to water use efficiency.

Technological change is a response to very specific socioeconomic conditions. The apparent triumph over scarcity of land and natural resource materials in many parts of the world is instructive in the search for means of achieving water use efficiency. The key has been technological advance. On the supply side, the progression of technology has vastly increased the resources available, through the discovery of new reserves and stocks of everything from petroleum to fish. Advances enabling the use of less accessible resources, of lower quality, and lesser concentrations, have expanded supplies even more. Even land, though limited in the spatial sense, has been augmented enormously in its capacity to produce crops.

On the demand side, technology has progressively reduced and eliminated our dependence on particular resources for particular purposes, broadening the range and improving the suitability of materials available to producers.

The lessons for water use and its efficiency is clear. When resources are correctly valued, commensurate with their contribution to productivity, the incentive exists, through the forces of supply and demand, to use those resources efficiently though the introduction of technological change. This principle relates back to earlier
points made about the economic forces underlying water use efficiency. It is separated here for separate discussion because technological change holds an important key to efficient water use in the future.

In the case of Guwahati city, technological change has been very tardy and the water use efficiency is quite low.

Environmental Dimensions

In contrast, the environmental aspect encourages us to take a somewhat broader view of the issue, and to realize the need for integrated approaches to management. This is where water quality considerations, become important.

An environmental view, in contrast, highlights the often-ignored fact that water quantity and quality are tightly interlinked, such that actions that affect one dimension have inevitable effects on the other. This is well illustrated in the case of groundwater. For example, over pumping an aquifer in an area may cause problem in contamination of the aquifer thereby creating health hazard. This type of sanitation has been reported from several wards of the city as a result of incidence of fluorosis due to overextraction of ground water. Similarly, a reduction in water use without an accompanying decline in waste generation may cause wastes to increase in concentration. The consequences of the latter can vary in their effect on quality. Since water quantity and quality are closely interlinked, increasing water use efficiency may have an impact on water quality, and vice versa. Indeed, it is essential that water use efficiency measures should only be considered when they maintain or enhance water quality.