# ASSESSING GROUND WATER RESOURCES AND THEIR SUSTAINABILITY: A STUDY OF CHANDERNAGORE MUNICIPAL CORPORATION AND HOOGHLY-CHINSURAH MUNICIPALITY, WEST BENGAL

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**ABSTRACT**

*The main source of fresh water is ground water over the world. This non-renewable resource (non-renewability in terms of time of replenishment of the resource with respect to time frame of human activity) is depleted at an alarming rate. Therefore, the term sustainability comes into account. Sustainability of ground water depends on proper and scientific management of all dimensions of the concerned resource. The present work is an attempt to assess the ground water of Chandernagore Municipal Corporation (CMC) and Hooghly-Chinsurah Municipality (HCM), two class-I towns of West Bengal. The work also critically examines the term sustainability to be applied over the area. The work is also in search of how diversification of sources for different uses can reduce the pressure on ground water. Ground water resource has been estimated based on the Ground Water Estimation Methodology-1997, Central Ground Water Board, Ministry of Water Resources,India. All the estimations have been done for the year of 2004. The stage of ground water development and the declining trend of static water table show that the area comes under semi-critical zone. The present scenario of the study area is critical which is far beyond sustainability.*

## INTRODUCTION

The main source of fresh water is ground water over the world. 90 percent of world's water is saline. Of the available freshwater, 71 percent is locked in ice and large portion is inaccessible as groundwater (1). Water is abundant naturally, however; freshwater is a rare natural resource. The amount of present fresh water available for human use is less than 0.08 per cent of all water on the planet (2). India is the largest user of groundwater resources in the world and it is estimated that approximately 230 $km^3$ per year is used annually; this is more than a quarter of the total world consumpsion from this resource (3). Overpopulation is the root cause of the problem of water scarcity. Inter Govermental Panel on Climate Changereport states that the gross per capita water availability in India is projected to decline from about 1,820 $m^3$/ yr in 2001to as little as 1,140 $m^3$/yr in 2050, as a result of population growth (4). India, with 20 per cent of the world's population, has to make do with 4 per cent of it's freshwater resource (5). More demand for water leads to the over exploitation of water. Over exploitation of ground water sometimes leads to deterioration of the environment as excessive rate of groundwater depletion triggers a series of environmental problems such as subsidence, drying up of aquifer, arsenic contamination, *etc*. The less recharge of groundwater due to the increasing proportion of built-up area along with urbanization aggravates the other problems. In India the problem of water availability with adequate quantity and quality is being observed in major urban units but due course of time the problem is also getting into the small urban units of the country.

This non-renewable fresh ground water resource (non-renewability in terms of time of replenishment of the resource with respect to time of human activity) is depleted at an alarming rate because of huge dependency and misuse of the resource. Therefore, the term sustainability comes into account. Before going to discuss sustainable management of water resource it is necessary to assess the resource properly.

**OBJECTIVES**

The objectives of the present work are as below-

- To assess the ground water resource of the study area,
- To find characteristics of aquifer system,
- To identify the picture of static water table and flow-net analysis,
- To examine users efficiency for sustainable management,
- To find out how the water resource of dug well (sub-surface water) can be used to reduce the pressure on ground water,

**MATERIALS & METHODS:**

Ground water resource has been estimated using static water table data (1995-2004) provided by State Water Investigation Directorate (SWID), Kolkata and the methods have been used to estimate ground water resource of the area as provided by Ground Water Estimation Methodology-1997 of Central Ground Water Board (6). Characteristics of aquifer have been found using lithological logs of the bore holes, provided by the municipalities. Hydraulic gradient and ground water velocity have been calculated using Henry Darcy's Law (1856).

v= -K (dh/dl), where, v= velocity of ground water, dh= difference in hydraulic head, dl= horizontal distance between two wells, K= hydraulic conductivity. Average hydraulic conductivity of clay has been taken from table value of R. Brassington (1988) (7). Demographic characteristics have been analyzed using population data, provided by the Census of India (1961-2001). Meteorological data has been collected from Rice Research Station, Chinsurah, 2008. Water diary approach has been used to examine user's efficiency. Another household-survey was conducted to find water resource and water uses from dug well over the area. All the maps have been prepared in Map-Info professional 7.0 GIS software and 21$^{st}$ Century GIS/ RS software. Statistical calculations have been done using Exel-2007 and manually.

Table-1: Data sources and their providing authority

| Data | Providing authority | Year |
|---|---|---|
| Static water table | State Water Investigation Directorate, Kolkata | 1995-2004 |
| Lithological logs | Municipalities | 2011 |
| Meteorological data | Rice Research Station, Chinsurah | 2008 |
| Demographic data | Census of India | 1961-2001 |
| Water diary | Household-survey | 2011 |
| Dug well data | Household-survey | 2011 |

**An Overview of the Study Area:**

The present work is done on two class-I towns of West Bengal namely, Chandernagore Municipal Corporation (CMC) and Hooghly-Chinsurah Municipality (HCM). The geographical location of the area is 22º46'50"N to 22º56'30"N and 88º21'20"E to 88º23'56"E. The area is a landmass between two rivers, Hooghly to the eastern portion and Saraswatiriver to the west. This is a part of the great Indo-Gangetic plain. This area is covered by a huge thickness of Quaternary alluvium underlain by Tertiary & Mesozoic formation (8). The area is composed with newer alluvium, therefore the materials are unconsolidated which gives a great importance to the area in terms of ground water reserve. The amount of normal annual rainfall is 1453.7 mm and maximum rainfall is occurred during the month of June to September, which is almost 74% of the total annual amount because of the effect of monsoon. The maximum amount is received in the month of August (302.6 mm) and the minimum amount is received in the month of December (4.2 mm). The mean annual normal temperature of the area is 25.7$^0$C. The maximum mean monthly normal temperature is found 30.7$^0$C in May and minimum mean monthly normal temperature is found 18.3$^0$C in December. The general identity of the study area is as follow (Table-2)-

Table-2: General information of the study area

| Attributes | Hooghly-Chinsurah Municipality | Chandernagore Municipal Corporation |
|---|---|---|
| Year of establishment | 1865 | 1955 |
| Geographical area (sq. km) | 17.27 | 22.03 |
| No. of wards | 30 | 33 |
| Population (Census of India, 2001) | 170201 | 162166 |
| Population density (person/ sq. km) | 9844 | 8108 |
| No. of slum pockets | 91 | 41 |
| Slum population (Census of India, 2001) | 17921 | 42894 |
| Percentage of slum population to the total population | 10.0 | 26.0 |

Source: Census of India, 2001 and Urban West Bengal, Institute of Local Government and Urban Studies, Calcutta, 2000-2002 (9)

The main source of water of CMC (95 per cent) and HCM (90 per cent) is the ground water. Rest of the per cent comes from surface water. There are 43 and 51 running pumps of CMC and HCM which are spaced in an unscientific manner. Many authorized and unauthorized submersible pumps have been found in the apartments of the study area though it is legally prohibited.

**DEMOGRAPHIC PROFILE**

The population size of Chandernagore Municipal Corporation was 67, 105 in 1961 and it increased to 1, 62,166 in 2001. The population density has also increased from 6, 947 in 1961 to 12, 462 in 1991 and then declined to 7, 361 in 2001 because of increase of geographical area of Chandernagore Municipal Corporation in 2001. Decadal population growth increased from 12.12 % (1961-1971) to 34.71 % during 1991-2001 (Table-3). The population size of Hooghly-Chinsurah Municipality was 83, 104 in 1961 which increased to 1, 70, 206 in 2001. The population density also increased from 5, 348 in 1961 to 9, 856 in 2001. Decadal population growth of the city decreased from 26.64 % (1961-1971) to 12.12 % (1991-2001) (Table-4).

Table-3: Demographic profile of Chandernagore Municipal Corporation

| Year | No. of wards | Area (sq.km) | Population size | Population density (population/sq.km) | Decadal population growth rate (%) |
|---|---|---|---|---|---|
| 1961 | 5 | 9.66 | 67, 105 | 6947 | |
| 1971 | 22 | 9.66 | 75, 238 | 7789 | 12.12 |
| 1981 | 22 | 9.66 | 1, 01, 925 | 10551 | 35.47 |
| 1991 | 22 | 9.66 | 1, 20, 378 | 12462 | 18.1 |
| 2001 | 33 | 22.03 | 1, 62, 166 | 7361 | 34.71 |

Source: Author's calculation based on data of Census of India (1961-2001) (10)

Table-4: Demographic profile of Hooghly-Chinsurah Municipality

| Year | No. of wards | Area (sq.km) | Population size | Population density (population/sq.km) | Decadal population growth rate (%) |
|---|---|---|---|---|---|
| 1961 | 6 | 15.54 | 83, 104 | 5348 | |
| 1971 | 30 | 15.54 | 1, 05, 241 | 6772 | 26.64 |
| 1981 | 30 | 16.06 | 1, 25, 193 | 7795 | 15.11 |

| | | | | | |
|---|---|---|---|---|---|
| 1991 | 30 | 16.06 | 1, 51, 806 | 9452 | 21.26 |
| 2001 | 30 | 17.27 | 1, 70, 206 | 9856 | 12.12 |

Source: Author's calculation based on data of Census of India (1961-2001) (10)

**CHARACTERISTICS OF AQUIFER**

The characteristics of aquifer of the area have been found from the lithological logs of the area. The aquifer is dominantly consisted with fine sand, fine to moderate sand and coarse sand with gravels. Depending on the maximum depth of boring it is found that aquifer comes under the area horizontally continuous with different thickness and with two to three aquifer systems vertically separated with clay layers which acts as an aquitard. There are many sites have been found where only one aquifer system is tapped and Kalupukur ditch road site is an exceptional in the study area where four aquifer systems have been tapped. Thickness of aquifer varies from one sites to another, though depth of boring is not fixed for all sites (Fig.1). The maximum thickness of the aquifer (which situates in a succeeding manner with clay in between them) is found at Nabagram-1 which is 181.2 m (boring depth 208.3 m) with two aquifer systems. The minimum thickness is found at Mahadanga (boring depth 161.6 m) which is 85.4 m with two aquifer systems. The average thickness of the aquifer systems in the area is 120.97 m. The study area comes in the category of leaky aquifer system.

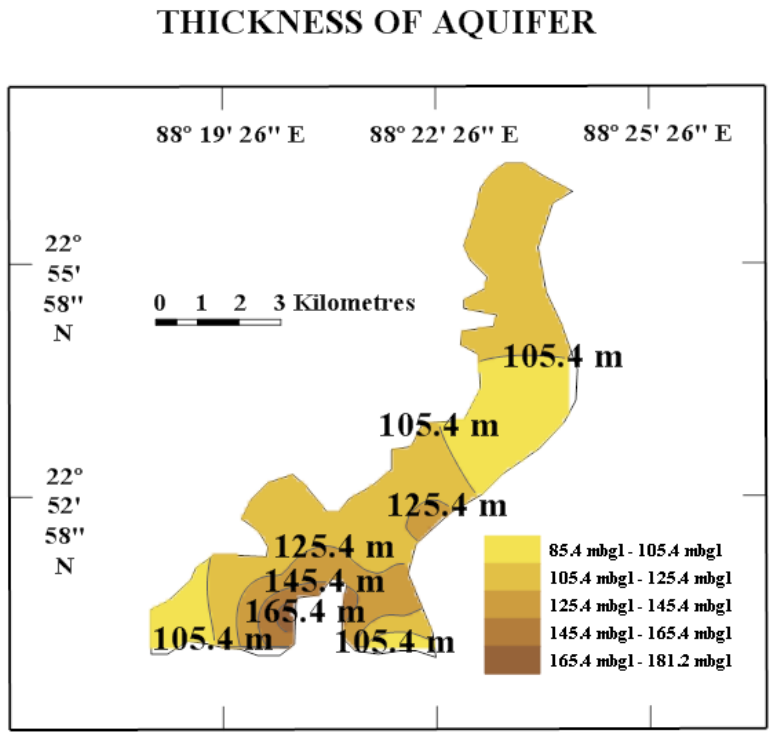


Fig.1

**Sand-Clay Ratio**

Sand-clay ratio has been calculated to show the thickness of sand proportion with respect to the thickness of clay proportion of a particular place (Fig. 2). This is a relative measurement and independent from boring depth. Higher value of sand-clay ratio indicates the greater chance of ground water reserve and vice-versa. Sand is an important geological material for good ground water storage in terms of quantity and quality; however clay is such type of geological material which helps to form aquitard. The maximum sand-clay ratio of 28.98 and the minimum ratio of 1.12 are observed in the area and both are located in Chandernagore Municipal Corporation.

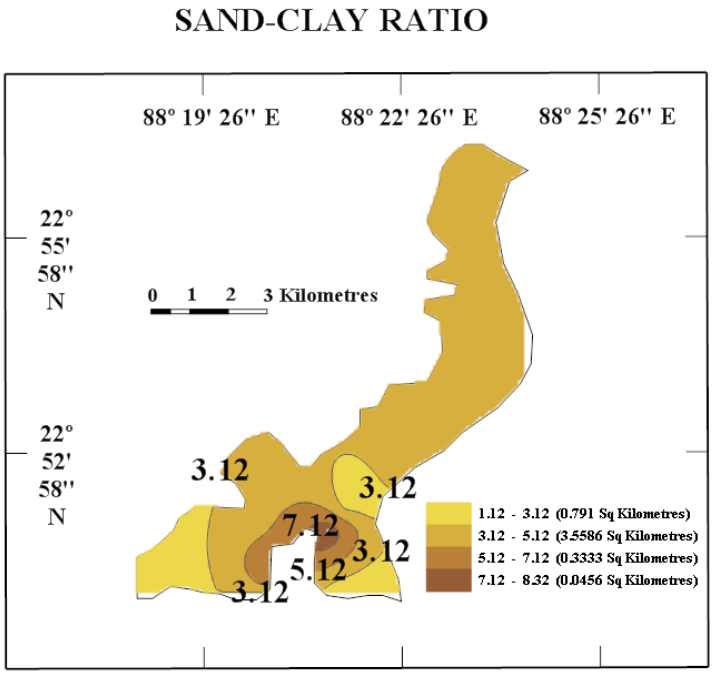


Fig.2

**Co-efficient of Storage**

Co-efficient of storage is defined as the volume of water that an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head (11). Co-efficient of storage has been calculated of four sites in the study area which are ChandernagoreO.S.Club, Bhadreswar P.S., Bandel Survey T. Centre, AdisaptagramB.S.F using Jacob's equation (1950). However, Bhadreswar P.S. is located at the outside of the study area though it is very nearest to the southern part of the area. The lithologs have been used to calculate co-efficient of storage of the nearest sites of the observation wells. These co-efficient values are different from place to place because of varying thickness of the main water bearing materials (sands with different gradation) which is controlled by the depth of the bore-hole. The average co-efficient of storage of the area is 0.014407997 (Table-5).

Table-5: Calculation of co-efficient of storage after Jacob (1950)

| Observation sites | Nearest site of litholog | Co-efficient of storage (fraction) |
|---|---|---|
| ChandernagoreO.S.Club | Halderpara | 0.015562194 |
| Bhadreswar P.S. | Dinemardanga | 0.01447284 |
| Bandel Survey T.Centre | Chowmatamore | 0.011866172 |
| Adisaptagram B.S.F. | Sahaganj | 0.015730784 |

Source: Author's calculation based on lithologs and table value

**GROUND WATER RESOURCE**

The assessment of ground water resource of Chandernagore Municipal Corporation and Hooghly-Chinsurah Municipality has been done following ground water estimation methodology-1997 of Central Ground Water Board. All the estimations have been done for the year of 2004. The projected population size of Chandernagore Municipal Corporation is 1, 74,705 and of Hooghly-Chinsurah Municipality is 1,75,726 in 2004 with an annual growth rate of 3.54 per cent and 2.62 per cent respectively. The estimated ground water recharge of CMC and HCM by rainfall is 972.8448ham and 1033.4368ham. The amount of ground water withdrawal of CMC and HCM is 645.32 ham/ year (12) and 725.985ham/ year (13) respectively. The unaccounted annual natural discharge is calculated for CMC is 48.64224ham and for HCM is 51.67184ham. Therefore, the total amount of ground water discharge amounts to 693.96224ham for CMC and 777.65684ham for HCM. The net annual ground water availability for CMC is 924.20256ham and for HCM is 981.76496ham. The available ground water resource is 52.90 cumec/ per capita/ year or 144.93 litres/ per capita/ day for CMC and 55.87 cumec/ per

capita/ year or 153.07 litres/ per capita/ day for HCM. The stage of ground water development for CMC is 75 per cent and for HCM is 79 per cent.

**Nature of Static Water Table**

From the linear regression analysis of pre-monsoon static water table of four observation sites it is found that the threshold value (a= distance between the point of origin and the point where trend line touches the Y-axis) is maximum at Chandernagore O.S. Club (a= 13.90) and minimum at Adisaptagram B.S.F. (a=8.14). The 'a' value shows that the depth of static water table is maximum at Chandannagore O.S. Club and minimum at Adisaptagram B.S.F. The co-efficient of 'X' or slope value (b) is maximum at Bhadreshwar P.S. (b=0.23) and minimum at Adisaptagram B.S.F. (b=0.12). The 'b' value shows the gradient of the falling water table from 1995 to 2004. The falling rate is maximum at Bhadreshwar P.S. and minimum at Adisaptagram B.S.F.

From the post-monsoon water table data (1995 to 2004) it is found that the threshold value is maximum at Chandernagore O.S. Club (a=10.14) and minimum at Adisaptagram B.S.F. (a=3.51). The 'a' value indicates that the depth of static water table is maximum at Chandernagore O.S. Club and minimum at Adisaptagram B.S.F. The co-efficient of 'X' or slope (b) is maximum at ChandernagoreO.S.Club (b=0.23) and minimum at Adisaptagram B.S.F. (b=0.10) which shows that the rate of falling of water table is maximum at Chandernagore O.S Club and minimum at Adisaptagram B.S.F. during the period (1995 to 2004).

From the slope analysis of pre-monsoon and post-monsoon static water table (1995 to 2004), it is found that the gap between the gradient of pre-monsoon and post-monsoon water table is maximum at Bandel Survey T. Centre (pre-monsoon: b=0.19, post-monsoon: b=0.14) and is minimum at Chandernagore O.S. Club (pre-monsoon: b= 0.21, post-monsoon: b=0.23) and Adisaptagram B.S.F. (pre-monsoon: b=0.12, post-monsoon: b=0.10). Irrespective of the same gap between the two sites, the falling rate of the static water table is higher at ChandernagoreO.S.Club.

The declining trend of static water table and the calculated value of stage of ground water development depict that both the area comes under **Semi-critical zone.**

**Flow-Net Analysis**

It is observed from the flow-net analysis of post-monsoon static water table (1996) that the whole area is divided with maximum isoline 9.67 mbgl (metre below ground level) and minimum isoline 3.67 mbgl with an interval of 1m. The ground water is flowing from north, south, south-west and north-west to central eastern part of the area. The maximum hydraulic gradient and ground water velocity is observed in d10 zone having a value of 4.00 mm/m and 0.02 mm/day; the minimum hydraulic gradient and ground water velocity is found in d1 zone with a value of 0.26 mm/m and 0.001 mm/day (Fig.3). The flow-net analysis of post-monsoon static water table (2004) shows higher hydraulic gradient in the area from the past and the flow direction is same as 1996. The maximum hydraulic gradient and ground water velocity is observed in d13 and d14 zones with a value of 5.00 mm/m and 0.025 mm/day. The minimum hydraulic gradient and ground water velocity is found in d1 zone with a value of 0.27 mm/m and 0.001 mm/day (Fig.4).

**FLOW-NET ANALYSIS OF POST-MONSOON STATIC WATER TABLE, 1996**

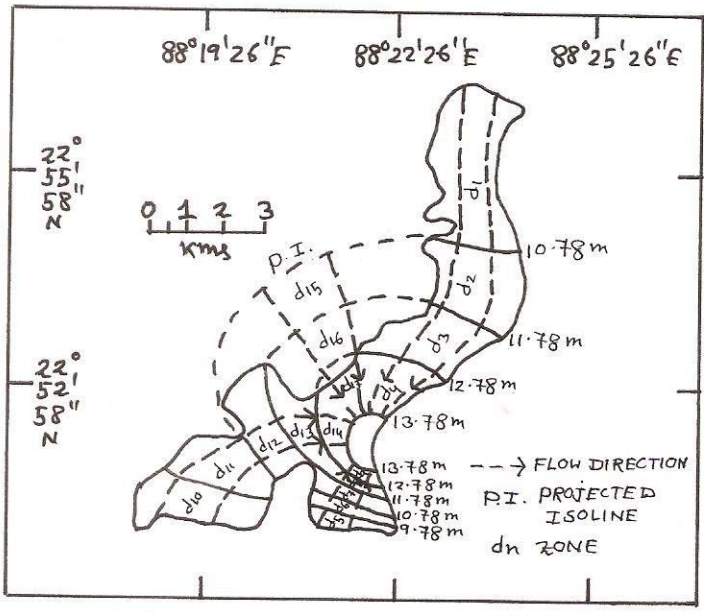


Fig-3

**FLOW-NET ANALYSIS OF POST-MONSOON STATIC WATER TABLE, 2004**

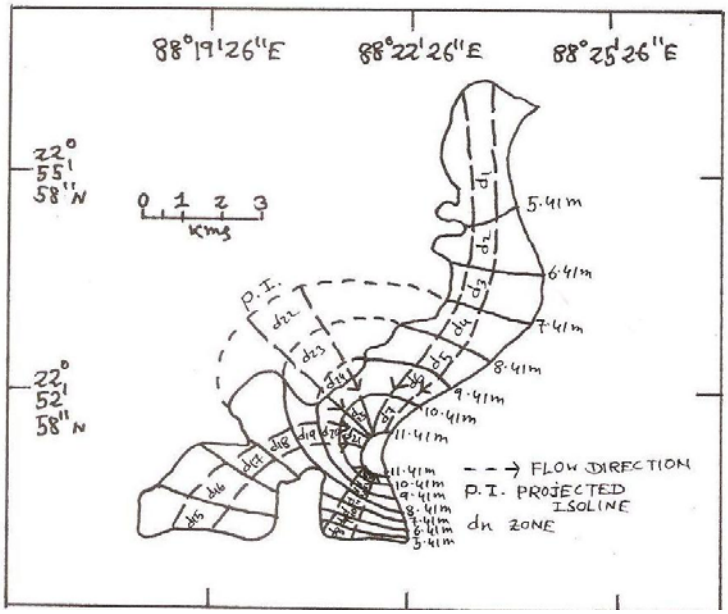


Fig-4

The flow-net analysis from pre-monsoon static water table (1996) shows that the maximum isoline 13.05 mbgl and minimum isoline 8.05 mbgl with an interval of 1 m cover the whole region. The maximum hydraulic gradient and ground water velocity is observed in d5 zone with a value of 3.33 mm/m and 0.01 mm/day. The minimum value of hydraulic gradient and ground water velocity is found in d1 zone with a value of 0.21 mm/m and 0.001 mm/day. The ground water is flowing in the area from north, south, south-west and north-west to central eastern part of the area (Fig.5). The flow-net analysis of pre-monsoon static water table (2004) demonstrates that the area is divided by minimum 8.78 mbgl and maximum 13.78 mbglisoline. The hydraulic gradient and ground water velocity is maximum in d8 and d9 zones with a value of 3.33 mm/m and 0.016 mm/day. The minimum value is observed in d1 zone having a value of 0.23 mm/m and 0.001 mm/day. The flow

direction of ground water is same as above (Fig.6). From the whole analysis it is found that the central eastern and southern part of the study area which is located in CMC is in most critical condition.

**FLOW-NET ANALYSIS OF PRE-MONSOON STATIC WATER TABLE, 1996**

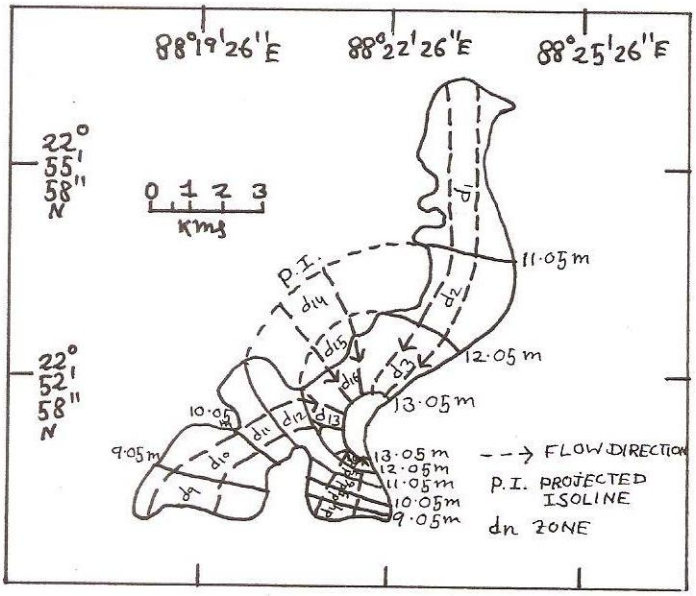


Fig-5

**FLOW-NET ANALYSIS OF PRE-MONSOON STATIC WATER TABLE, 2004**

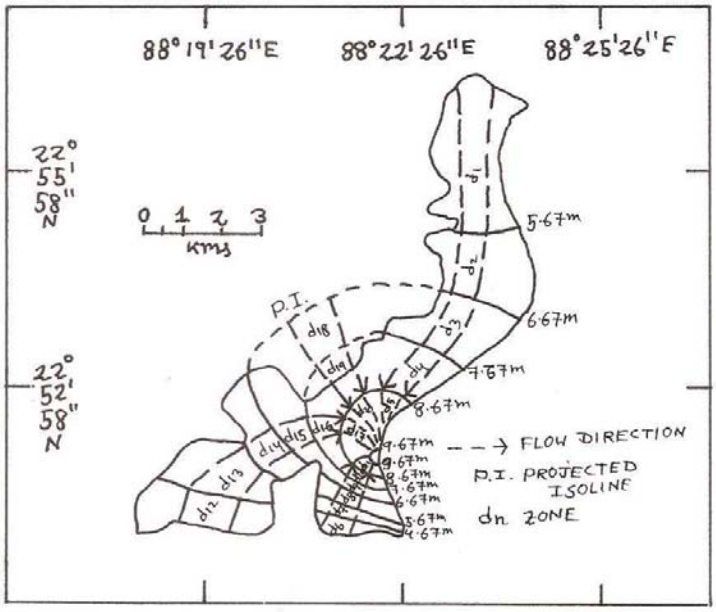


Fig-6

**WATER RESOURCE MANAGEMENT AT HOUSEHOLD LEVEL**

Water diary approach has been used to find how the users play an important role to sustain water resource at household level. It is found from the observation that higher income groups use more water for different purposes and they are mainly dependent on municipal supplied water. On the other hand lower income groups use less water and also they are dependent on diversified sources of water which reduces the pressure on ground water. Most of the household uses water more than their requirement and they are very much reluctant about the future of water supply. Female candidates play major role for management of water resource than male

candidates as they use water maximum. Consciously efficient uses of water at household level can sustain the water resource.

The use of water for different purposes from dug wells reduces the pressure on ground water. From the household survey of dug wells owner, it is found that the water has been using for different domestic purposes such as, bathing, house cleaning, washing utensils, washing clothes etc. The dependency on water of dug well is greater during power cut. It has also been observed that in the dry season the dug well is filled up with the municipal supply to bathe their pet cows and buffaloes as they do not have to pay any tax for water. Households are dependent on both, municipal supplied water and on dug well for their different uses. Some households have been found to have stopped the use of water from dug wells because of sufficient municipal supply which is a bad indicator in terms of increase of pressure on ground water resource. The average depth of water table in dry season is 1.98 m and is 0.82 m in wet season in the study area. The amount of withdrawal water ranges between 30 litres / day to 1000 litres /day round the year with a less amount in wet season in the area. The calculated net annual water availability from dug well (sub-surface water) is 27,35,280cumec for the two municipalities. This amount of water can provide 22.5 litres/per capita/day for the whole area which can reduce the pressure on ground water resource.

## CONCLUSION

Ground water is the vital natural resource for supplying fresh water to sustain life on the earth. Rational utilization of ground water is necessary for sustainability of the resource. Before going to sustainable management of ground water resource of an area it is essential to assess the resource very scientifically; without having the background picture of the resource, sustainability can never be reached. Sustainability of ground water depends on proper and scientific management of all dimensions of the concerned resource, such as supply side management where the water is treated as natural resource, demand side management where the importance goes to user's efficiency. Sustainable management of a resource encompasses economic value of that resource. Economic value is added to a resource when scarcity comes into account either in terms of physical availability or equally distributed over the area. With the increase of population and development, the time has come to treat ground water resource as an economic good to make it sustainable as the resource is no longer abundant.

Chandernagore Municipal Corporation and Hooghly-Chinsurah Municipality both the area comes under semi-critical zone. The present condition of the study area is very much fragile in terms of ground water management and also it puts a great question mark before the term 'sustainability'. The spacing of bore holes do not follow scientific manner which ought to be. Submersible pump should be strictly prohibited. It should be mandatory for all the apartments to have their own rain water harvesting structure. Diversification of water sources for different uses after testing their quality is necessary such as, water from pond, dug well etc. to reduce the pressure on ground water. Taxation makes water as an economic good which help to reduce misuse of water and to save it for future.

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Malay Ganguli has completed his M.Sc. in Geography from Benaras Hindu University in 2009. At present he is working on *Urban Water Management and the Question ofSustainability* of two class-I towns of West Bengal as a Research Scholar (SRF-CSIR) in the Department of Geography, The University of Burdwan. His research focuses on how sustainability of water supply can be achieved in the region through the change of use and management at both domestic and ULB level. He has two published papers one on *Water Balance* in Chandernagore and Hooghly-Chinsurah cities and the other is on LandSubsidence related to ground water use in Singur region, West Bengal.