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A comprehensive study of Ground Water Resource and its Management in Kolkata Municipal Corporation, West Bengal, India

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Abstract

Groundwater contributes nearly 37% of total water supply in Kolkata Metropolis. Population pressure caused by migration and growth after independence along with limited surface water supply, coupled with the rapid expansion of the city has resulted in a tremendous increase in the demand of groundwater since the 1960s. It has significantly distorted the aquifer recharge-withdrawal equilibrium. The city is endowed with safe and huge groundwater reservoir underneath the impervious clay beds which gets recharged only during monsoon. Hence, a detailed and comprehensive evaluation of the availability of surface water and groundwater resources in space and time is essential for sustainable development of water management in Kolkata to cope with the rapid urbanization and metropolinization. Unfortunately, very little attention has been paid so far to preserve this valuable natural resource in Kolkata. The prime objective of this article is to present a comprehensive picture of the present surface water supply and groundwater condition with the help of gradient or trend analysis and risk zonations for Kolkata. It provides important input to the sustainable development of surface and groundwater resource and also for judicious future planning of water supply of the city.

Introduction

Groundwater, a dynamic resource plays an important role as it can be explored and used in situ or as potable water. It contributes nearly 37.5% of the total water supply in the Kolkata metropolis. (World Bank Report,2015). Population pressure caused by urbanization, migration and natural growth after independence has resulted in a tremendous increase in the demand for groundwater during the last three decades. As a result, the groundwater reserve is under tremendous stress and the aquifer recharge-withdrawal equilibrium is greatly disturbed.

Though the city of Kolkata is endowed with huge groundwater reservoir in its deltaic plain within its sandy aquifer, the local recharge is limited due to the presence of clay layers at the top and bottom of it. The continuous pumping of groundwater in excess of its replenishment has resulted in appreciable lowering of underground water table by about 7 - 11.5 m in the last 56 years since 1960, formation of an acute `groundwater trough' in the south-central and eastern part of KMC area (Sikdar, 1999) and the declining trend of water level to the tune of 0.33m/year at the core of this trough and 0.11 m/year at its periphery. Considering the current status of groundwater, future demand and long term change in the piezometric surface, it is observed that the southern and eastern parts of the city have less groundwater potential than that of the northern part. But, the southern and eastern parts depend more on the groundwater than the surface water (Basu, 2001). This situation not only jeopardizes the availability of groundwater in future but also has invited some adverse surface and subsurface environmental effects like land subsidence, degradation of groundwater quality and intrusion of saline water in sweet water aquifer, etc.

Objectives

This research tries to find out the zones or the areas of 'high, medium and low' risk zones of groundwater exploitation in the KMC and its proper management.

Methodology

The data base for a time span of sixteen years i.e. 2000-2016 has been considered in this study. The pre- and post-monsoon groundwater data in KMC have been obtained from SWID and Central Ground Water Board, Govt. of India. To determine the characteristics of the trend of groundwater level during pre-monsoon and post-monsoon period and its fluctuation, linear regression analysis has been done. The slope or gradient of the regression line indicates an effective resultant trend of the pre- and post-monsoon piezometric level of groundwater for the given period. A positive value of gradient indicates a rising trend of piezometric level with an increased input to the system and a negative value of gradient implies a falling or declining trend of piezometric level with over-exploitation of groundwater or in other words reduction in input to the system. Zero gradients represent a static situation where no change in piezometric level is observed for the considered period.

The Study Area

The study focuses on the city of Kolkata which is bounded by river Hugli in the northwest, South 24 Parganas district in the south and southwest, Salt Lake City in the east and North 24 Parganas district in the north. The area falls between 22°28′00″ - 22°37′30″N latitudes and 88°17′30″ - 88°25′00″E longitudes and covers an area of 187.33 sq.km and is divided into15 Boroughs and 141 Wards (Fig.1).

Ground Water Resource in Kolkata

The occurrence of groundwater in Kolkata is controlled by its geological set-up. The subsurface geology of the area is completely blanketed by Quaternary sediments (Coulson, 1940). Both Recent and Pleistocene sediments have been deposited successively by the Ganga River as floodplain deposits (Biswas, 1959). In Kolkata, clay and silty clay with an average thickness of 40 m occur at the upper part of the sedimentary sequence. This is underlain by coarse clastics of 300 m thickness consisting of sands mixed with gravel. These coarse clastics form the aquifer material. Below this, there is again a clay bed whose thickness is over 300 m. Because of the presence of clay beds at the top and bottom, the groundwater in the Kolkata area occurs under a confined condition. But in Ballygunj, Dhakuria and Kasba area shallow aquifer occurs with 12 mbgl as think lenses and groundwater occurs hereunder unconfined condition. Potential freshwater aquifer occurs in the depth range of 40-100 m in the northern part, within 60-160 m in the central part and within 180-300 m in the south-western parts of KMC are (Biswas and Saha,1990).

Ultimate source of groundwater is the rainwater. The predominance of impervious clay in the near-surface strata of Kolkata area and its immediate neighbourhood signified that not much local recharge to deeper aquifers in Kolkata region is possible. Therefore, the major recharge area of Kolkata region must be lying in the north and western side of the Great Kolkata region. In the north, at Bhatijangla near Krishnanagar in Nadia district and the zone of Tarakeswar-Nalikul-Mogra to Pandua serves as the zone of prolific recharge to groundwater annually (Coulson,1940).

City water supply is dependent on both surface water source from the river Hugli and groundwater sources. Initially, the surface water supply was made from Palta pumping station (27mld in 1869). A quantity of 1161mld (258mgd) of treated surface water from river Hugli is being supplied in KMC area through four pumping stations at Palta, Garden Reach, Dhapa in 2006. They supply nearly 500 mgd of water. Withdrawal of groundwater in Kolkata Municipal Corporation area by Kolkata Municipal Corporation increased progressively from 121.5 million liters per day in 1986 to 209.7 million liters per day in 1998 and it continued till 2004. From 2005 Kolkata Municipal Corporation started replacing gradually the groundwater supply by surface water supply. As a result, there is a reduction in the quantum of groundwater withdrawal from 2005. In 2006 groundwater withdrawal by Kolkata Municipal Corporation owned tube wells come down to 144.30 million liters per day and in 2016 it is 400 million liters per day (KMC, 2016).

As a result of this development, there has been a noticeable change in the hydrological regime in the form of the recession of the piezometric surface. The overexploitation of groundwater in excess of natural recuperation has resulted in the development of a more or less north-south elongated basinal pattern of the piezometric surface in the south-central part of the study area (Sikdar,1999). The highest declining trend is observed in Borough VII and VIII mainly in Park Circus, TiljalaTopsia area and in Park Street area where declining trend is @ >0.30 m/yr. It has distorted not only the aquifer recharge withdrawal equilibrium but also results in the formation of an acute `groundwater trough' in this part of Kolkata city. Lowest is found in Borough XIII, XIV and XIV and the declining trend are 0.11 m/year (Table -1).

Discussions and Data Analysis

The water table represents the upper limit of the zone of saturation and the pressure on the water-table equals one atmosphere. Water occurring in the confined aquifers is held under pressure greater than one atmosphere and such levels are designated as piezometric surface or potentiometric surface that is an imaginary one and can be obtained only by punching the confined aquifers (Biswas, 1990). In the KMC, the lower availability of groundwater and greater exploitation mainly due to urbanization has resulted in the lowering of the piezometric level. The pre-monsoon depth to water-table for 2015 shows (fig.2) that the maximum groundwater level i.e. over 17m below mean sea level has been found in Northern Kolkata mainly in Sinthi-Bagbazar-Beniatala area in the north of Kolkata city. The deepest water level recorded is 20.5m below ground level at Beniatala Street in north Kolkata. This is followed by Harish Mukherjee Road (19.5mbgl), Keyatala Road (17.9mbgl), Park Circus(17.8mbgl), Hazra(17.8mbgl) Bagbazar (17.5mbgl), In Jorasanko, Rajabazar, Babughat, Beleghata, Bondel Road, Haltu, Kasba, Jadavpur, Kudghat, Bansdroni, Tollygunj, and Behala the depth to water table ranges between 15 to 17mbgl. The lowest depth below 12 m occurs at south-western and south-eastern parts of Kolkata city mainly in Sarsuna, Thakurpukur, Garia, Kalikapur and Mukundapur area.

Fig.3 shows the present status of the water level condition during the post-monsoon period of 2015. Bagbazar in the north, Commissariat Road and Khidirpur in the west and Beckbagan, Bondel Road, Kyd Street, and Park Street area of central Kolkata the depth to the water level in Post-monsoon lies at a depth of 15 mbgl, with highest 18.5mbgl at Beniatala street in North Kolkata. In Kalighat, Alipur, and Hazra in south Kolkata, the post-monsoon piezometric level ranges between 13 mbgl to 15 mbgl. While the lowest value of fewer than 13 mbgl occurs in south-western and south-eastern parts of the city area of KMC. On the basis of the present utilization, water demand, groundwater condition, long-term change in the piezometric surface in the past 50 years and pre-monsoon, post-monsoon groundwater analysis of the entire study are (KMC) may be divided into the following zones (fig.4):

Zone -1: High-Risk Zone

It covers the boroughs via, VIII and partly Borough I (mainly Sinthi areas i.e. Ward -1only). In this zone, the water level declining trend is over 0.20 m/year. Borough VII covers the central part of the KMC area mainly Beleghata, Kyd Street, Park Circus, Picnic Garden, Tiljala, and Topsia areas where the water level declining trend is over 0.30m/year. Borough VIII covers Kalighat, Hazra, Poddopukur areas where the declining trend is over 0.20m/year.

It is the `high-risk zone' in the Kolkata because the uncontrolled withdrawal of groundwater than that of its recuperation has resulted in lowering of underground piezometric level as below as 12 m. In 1958, the piezometric level was around 4 to 5 mbgl in Beleghata, Park Street, Tiljala, Topsia, and Picnic Garden areas, but due to over-exploitation of groundwater, the piezometric level has lowered to 16 to 17 mbgl in 2015. The entire area largely depends on groundwater resources that contributes nearly 40 to 50% of the total demand for water (CGWB, 2015).

It is not only characterized by a negative trend in both pre-monsoon and post-monsoon period but also a greater rate of declining of the piezometric level of the post-monsoon period than that of the pre-monsoon period implying an alarming situation. Moreover, the gap between pre- and post-monsoon period i.e. the fluctuation is alarmingly deteriorating which may generate stresses on groundwater regime in the near future in these areas. If the increasing fluctuation trend continues, the deficiency will cross the optimum level, causing disequilibrium. Thus, a worsening situation has been developing in this region. The situation goes beyond the normal limit where the yearly normal monsoon is incapable of recuperating the preceding cycle of water deficiency progressively and hence a negative post monsoon water table is evolved, only with the exceptions in Park Circus area (Dargah Road)(fig. 5a, b, and c). Within this zone, Beleghata, Picnic Garden and Kyd Street near Loreto College (fig. 5) are highly vulnerable to land subsidence problem. The maximum subsidence of 12 mm per year is recorded in Tiljala-Tangra area, Park Circus and Beleghata areas. This zone needs immediate attention for scientific management and planning of groundwater to preserve this valuable natural resource, arrest the possibility of land subsidence and prevent arsenic contamination in the future

Zone - 2: Medium Risk Zone

It is the `medium risk zone', where large withdrawal of groundwater has disturbed the natural equilibrium of input-output groundwater balance and also there is 8 10m of the drop in the piezometric surface during the past 50 years. This zone includes the Boroughs IX (New Alipur and Garden Reach areas) and Borough X (Jadavpur, Prince Anwarshah Road, Tollygunj Bansdroni -Ranikuthi in the south of the study area) where the groundwater declining trend lies between 0.15 - 0.20 m/year. Groundwater accounts 30 to 40% of the total demand for water in this zone. Here the gap between pre-monsoon water level and post-monsoon water level (fluctuation gradient) has been improving compared to Zone -1 (fig.6).

Zone -3: Low-Risk Zone

It includes Borough I, II, III, IV, V, XI, XII, XIII, XIV and XV. It covers Bagbazar, Hedua, Shyam Bazar, Maniktala, Beniatola Street in the north to Sarsuna, Thakurpukur, Garia and Sonarpur in the south-western and south-eastern parts of Kolkata city. In this zone, the groundwater declining trend is less than 0.15m/year. This zone is characterized by both pre- and post-monsoon negative gradient, with the exception in Garia and Harinavi areas where positive post-monsoon gradient has been observed (fig. 7). Pre-monsoon water table shows a declining trend but the post-monsoon trend is either rising or maintaining the equilibrium with that of the pre-monsoon period. This is indicative of no major harm that has occurred in the region until now. However, if the exploitation of groundwater increases considerably in near future (as is indirect evidence by the positive fluctuation trend or of increasing the pre- and post-monsoon water table gap), the situation may alter the existing equilibrium. Moreover, in this zone, there is no significant change in the piezometric surface in the last 50 years. Thus, this zone is safer and further development of a limited number of additional tube wells is possible for municipal use.

Groundwater Management and Artificial Recharge

In most of the stations within the KMC area are having `negative' and `declining' trend in both the pre-monsoon and the post-monsoon period only with the exception in Garia, Harinavi and Park Circus, Dargah Road where the positive trend in the post-monsoon period has been observed (fig. 5, 6 and 7). This indicates, not only the increase of groundwater withdrawal because of high water demand in the entire study period in KMC area, but also, the persistence of the same in post-monsoon indicates inadequate recuperation of the aquifer. The trend values suggest that in Beleghata-Kyd Street-Park Circus-Picnic Garden-Tiljala-Topsia, Bansdroni-Naktala, Babughat-Commiserate Road-Chitpur areas are experiencing not only greater rate of declining of piezometric level (i.e, higher negative trend value) during the post-monsoon period than that during the pre-monsoon period, but also the fluctuations or pre-monsoon and post-monsoon gap is rapidly diminishing which implies an alarming situation. These are the `high-risk zone' with respect to groundwater utilization in Kolkata.Besides, Tollygunj-Jadavpur-Kalighat- Hazra areas are also affected by the lowering of piezometric level due to continuous over-pumping of the aquifer.

Thus, the eastern and southern part of the city is highly affected by the maximum withdrawal of groundwater and or inadequate recuperation of the aquifer than that of the northern part of the city. Thus, it results in a negative and declining trend of pre- and post-monsoon water table. Due to the unplanned pattern of utilization, heavy-duty tube wells and hand pumps have been installed haphazardly as per local requirement without giving any consideration to the potentiality of the aquifers. Thus, it is imperative to formulate a management plan with recommendations to maintain groundwater quality and quantity for Zone - 1 and Zone - 2 in the Kolkata metropolis. Only proper management and scientific utilization of groundwater can handle this alarming situation by:

1. stopping the over-exploitation either by enforcement of the

law or awareness campaign,

2. improving the quality and quantity of groundwater using artificial recharge techniques wherever applicable; it also helps regain the piezometric level and maintain recharge withdrawal equilibrium.

Therefore, multiple preventive and damage control measures are to be taken on a priority basis to conserve the precious natural resource of groundwater to avoid an impending disaster. Moreover, the presence of Lakes (Subhas Sarovar and Rabindra Sarovar) are of great advantage for artificial recharge in Kolkata city because the water of those lakes can be utilized for recharging after treatment. The lakes should be desilted to increase the storage capacity so that, more water can be stored during monsoon. Recently, in Baisnavghata-Patuli areas this type of artificial recharging has been done successfully to rejuvenate the piezometric level. Groundwater exploitation should be restricted in these high-risk areas (Zone -1 and Zone -2) by phasing out tubewell operations, introducing well construction permit programme, increasing public awareness and ensuring an abundant supply of surface water that can help reduce the overwhelming dependence of groundwater resource for domestic purposes. People must be made aware of this problem through mass media that in the localities where both surface and groundwater are available, total dependence on surface water should be invoked. Conservation of groundwater for the future is the best solution. People need to be made conscious that they are all groundwater users and all have a vested interest in preserving and maintaining its quality and quantity for everyone's use for years to come.

Conclusion

Due to critical groundwater condition in the KMC area indiscriminate withdrawal of groundwater is to be restricted. If necessary, the area is to be notified by legal means. Emphasis is to be given to lower the stress on groundwater development by covering more and more area under pipe water supply (treated surface water). Regular monitoring of both groundwater level and quality of groundwater is to be done. This will help to understand the change in piezometric surface consequent to withdrawal of groundwater and the change in the quality of groundwater and to identify the tube wells affected by arsenic or any other chemical and/ or biogenic contamination. The tube wells affected by any sort of pollution should be discarded. Groundwater from open wells wherever present may be used for domestic purposes after proper treatment.

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References

1. "Calcutta Water Supply, Sewerage and Drainage Project, Final Report, Executive Summary World Bank Project' 2000: No. P.O. 50648, pp. 3-1 to 3-6.
2. "Hydrogeology and Groundwater Resources of Kolkata Municipal Corporation area Technical Report': Series `D' Central Groundwater Board, September 1999, Calcutta, West Bengal, pp. 5-13.
3. "Kolkata Water Supply, Sewerage and Drainage Project, Final Report, World Bank Project' 2015: No. P.O. 50648, pp. 13-18.
4. Basu, S.R. and Main, H.A.C (2001): Calcutta's Water Supply: demand, governance and environmental change', *Applied Geography*, 21, pp. 23-44.
5. Basu, S.R., (1999): Problems of Arsenic Contamination of Drinking Water Supply of Deltaic West Bengal and Calcutta", In R.L. Singh (ed.): *Impact of Man on Environment: Some cases of Concern*, Professor R.N. Dubey Foundation, Allahabad, 2001, pp. 30-37.
6. Biswas, A.B. (1990): Geology and Groundwater Resources of Calcutta Metropolitan District', *Geographical Review of India,* Geographical Society of India, Volume 52, No. 3, Kolkata, pp. 10-23.
7. Biswas, A.B. (1990): Water Supply in Calcutta,' In S. Chaudhuri, *Calcutta: The Living City, present and future,* Volume II, Oxford University Press, pp. 162-166.
8. Biswas, A.B.andSaha, A.K. (1986): Groundwater conditions of Calcutta Metropolitan area', unpublished, Project Report, CSME, pp. 13-17.
9. Chatterjee, G.C., Biswas, A.B., Basu, S. and Niyogi, B.N. (1964): Geology and Groundwater Resources of the Greater Calcutta Metropolitan Area, West Bengal', *Bulletin of Geological Survey of India,* series `B', 21, pp. 1-150.
10. Mukhopadhyay, A (2004): Geomorphology of Kolkata Municipal Corporation (KMC) - its impact on urban functions, Ph. D Thesis, University of Kolkata.
11. Sikdar, P.K. (1999): Development Dynamics and Management of Groundwater in and around Calcutta', *Indian Journal of Geology*, Vol. 71, No. 3, Kolkata, pp. 173-186.

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Table - 1: Boroughwise Groundwater Potential, Kolkata

Borough No	Depth to Ground water aquifer (mbgl)	Depth of Grooundwater level (mbgl), 2016		Trend of Decline of Groundwater level
		Pre-monsoon	Post- monsoon	
1	Within 170 except Kasipur (200)	15.0 – 17.0	11.0 – 13.0	@0.11m/yr
II	<=160	16.0 - 16.5	13.0 - 13.5	@0.11 - 0.12 m/yr
III	<=160	14.0 - 16.5	12.0 - 14.5	@0.11- 0.15m/yr
IV	<=160	16.5 – 17.0	13.5 - > 15.0	@0.11- 0.15m/yr
V	<=160	16.5 – 17.0	14.0 - >15.0	@0.11- 0.15m/yr
VI	<=160	16.0 - >17.0	12.0 - 13.75	@ 0.13 - 0.18m/yr
VII	<=160	13.0 - 16.8	11.0 - 13.5	@>0.30m/yr
VIII	<=160	14.5 – 15.0	12.0 – 13.0	@ 0.20m/yr
IX	< 160 & within 160 in the eastern part near Fort William	14.0 - 15.5	11.0 - 12.5	@ 0.13- 0.16m/yr
X	<=160	14.5 – 15.0	12.5 – 14.0	@ 0.13- 0.16 m/yr
XI	<=150	13.5-14.5	12.5 – 14.0	@0.11- 0.13 m/yr
XII	<=150	13.0 – 14.0	11.0 – 12.0	@0.11- 0.13 m/yr
XIII	<160	13.5 - 14.5	12.0 – 13.0	@0.11- 0.13 m/yr
XIV	< 160	12.5 - 13.5	11.5 – 12.0	@0.11m/yr
XV	<150	14.5 – 15.0	10.5 – 11.0	@0.11m/yr

Source: KMC Report,2015

Fig. 1: Borough Map of Kolkata Municipal Corporation Area

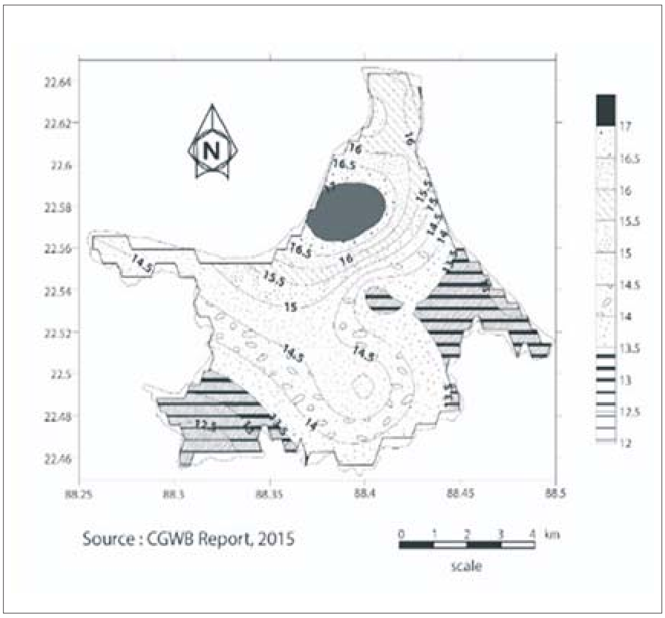

Fig. 2: Depth of Pre-monsoon Groundwater Table, 2015

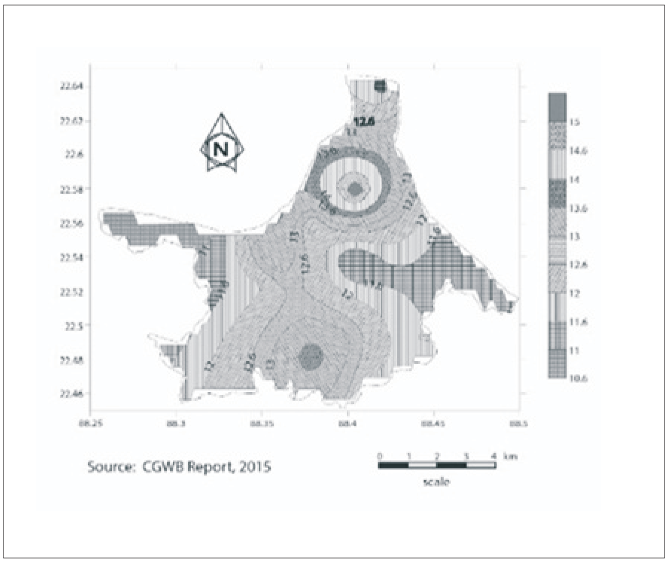

Fig. 3: Depth of Post-monsoon Groundwater Table, 2015

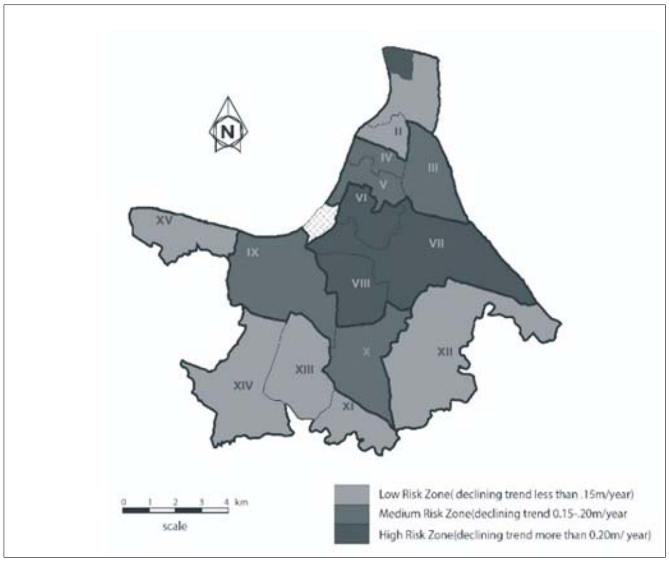

Fig. 4: Boroughwise Groundwater Zonations in KMC, 2015

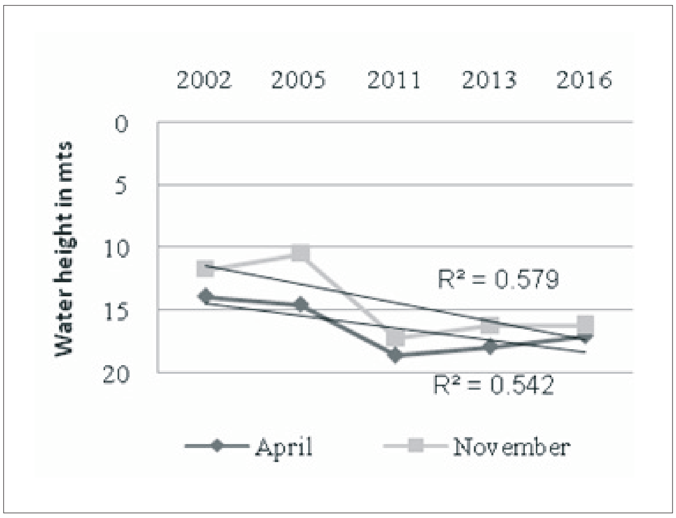

Fig. 5a: High Risk Area - Picnic Garden, KMC

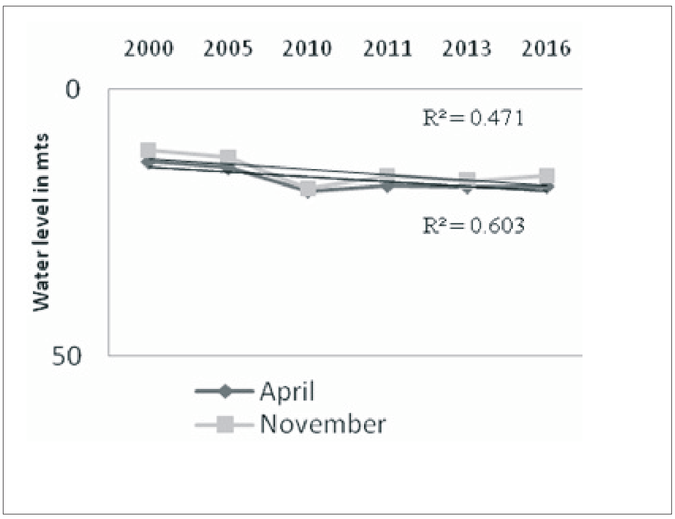

Fig. 5b: High Risk Area - Sinthi, KMC

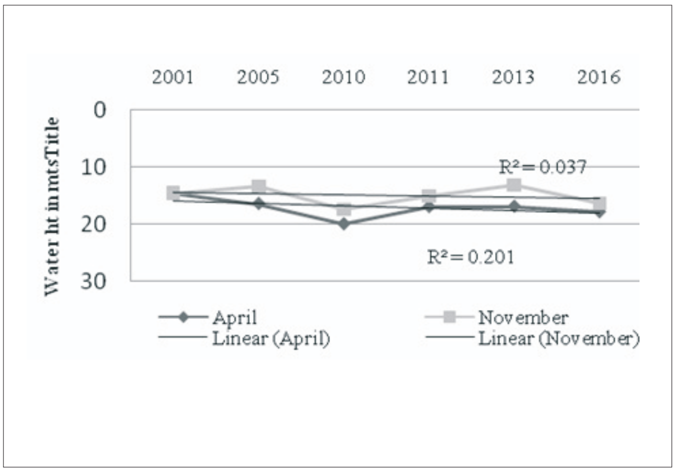

Fig. 5c: High Risk Area - Loreto College, KMC

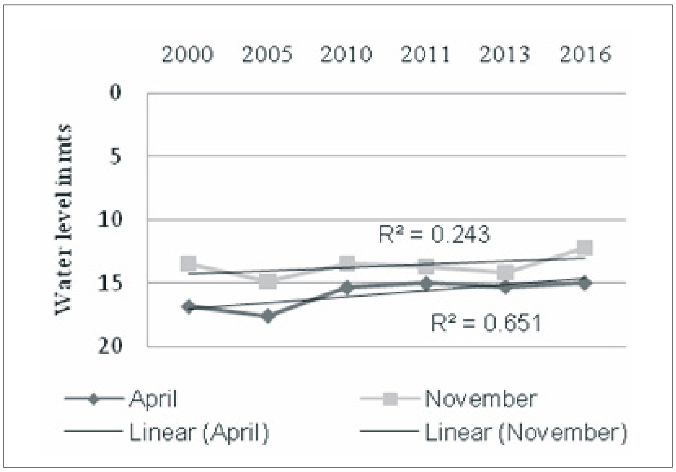

Fig. 6a: Medium Risk Area - Kalighat, KMC

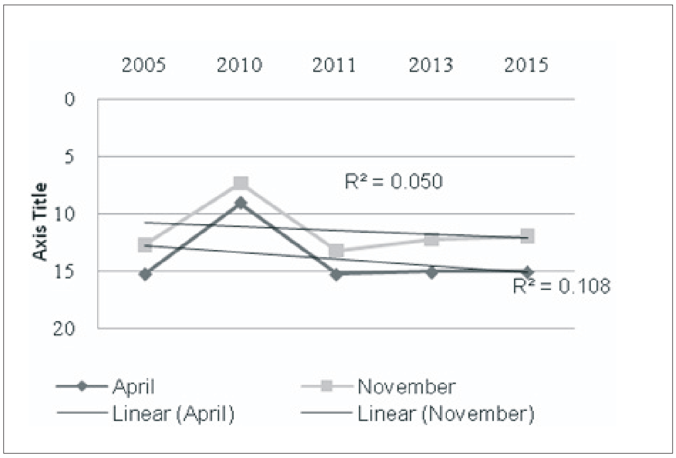

Fig. 6b: Medium Risk Area - Behala, KMC

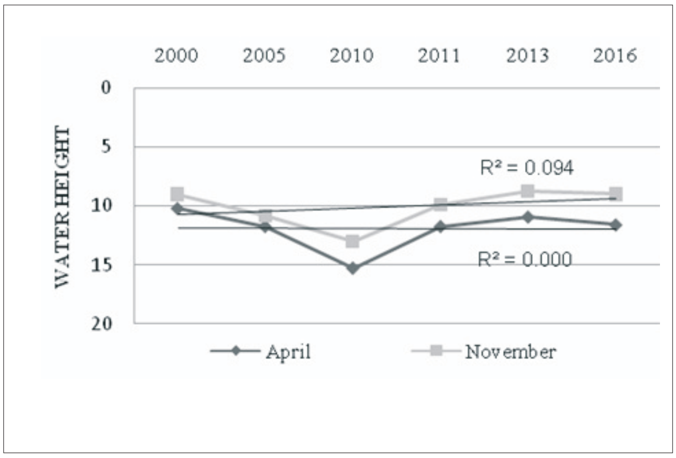

Fig. 7: Low Risk Area - Thakurpukur, KMC

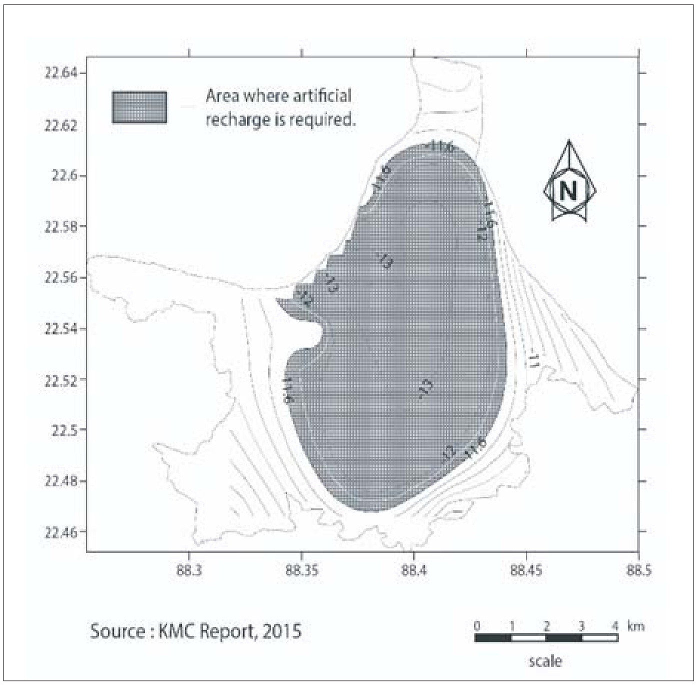

Fig. 8: Area for Artificial Recharge in KMC Area

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