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Assessment Of Groundwater Depletion at Guwahati, Largest Metropolis in North East India and its consequences - A review

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Abstract:

Over past couple of decades, the problem of rapid depletion of groundwater volume has drawn significant attention of scientists worldwide. A large number of studies established the rapid reduction of ground water storing which happened as an aftereffect of increase in irrigation for higher yielding of crops as well as for development in urbanization. Groundwater depletion being a global problem, Guwahati does not escape from that. In this paper the importance of Ground water as an inescapable resource has been stressed upon and quite a few of the research papers published in this millennium focusing on depletion of Ground Water have been reviewed to arrive at possible recharge methods by regulating the extraction of ground water at Guwahati in periphery of Brahmaputra River and the encircled hilly terrains has been looked into and the necessity of thorough technical research has been stressed upon with relevant data. The authors attempted to reach a consensus as to how under favorable policies on groundwater management in India can change from scarcity to adequacy of water in the country, with particular focus at Guwahati has been presented. The socio-political requirements and sustainability with suitable measures for recharging Groundwater Storage at Guwahati has been narrated with due weightage to water budget equation and other relevant facts and figure in the region considering Hydrological Cycle.

Abbreviations Used:

ADB	: Asian Development Bank, Philippines
ICRISAT	: International Crops Research Institute for the Semi-Arid Tropics, Hyderabad
MCE	: Multi-criteria evaluation
FCC	: Geocoded False Colour Composite
CGWB	: Central Groundwater Board
ARSAC	: Assam Remote Sensing Application Centre
RMC	: Regional Meteorological Centre,
NIH	: National Institute of Hydrology
DGM	: Directorate of Geology and Mining
DPSIR	: Driver Pressure State Impact Responses Cycle
LULC	: Land Use Land Cover Maps
GWS	: Ground Water Storage
HYV	: High Yielding Variety
IGB	: Indus-Ganges-Brahmaputra
WHO	: World Health Organization
WtP	: Willing to Procure

1. Introduction

For fresh water requirement of the civilization Groundwater is an important resource that comes from rain and - ice melt. The obtained water soaks into the soil except in the impermeable covered surface and gets

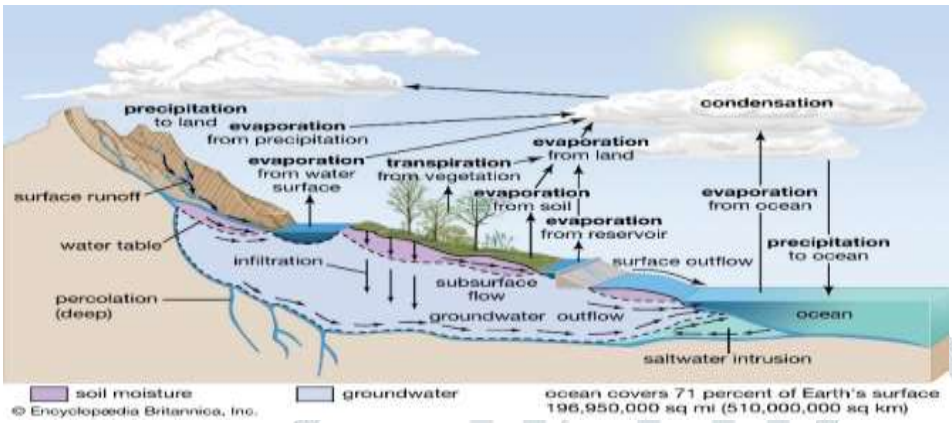

Figure 1: *water-hydrologic-cycle-land-surface-atmosphere-ocean (Source: Britannica)*

stored within the interstices within soil or rock particles under the ground. Humans and animals throughout the world need water in order to survive and water is also needed for wetting vast swathes of agricultural land and to support various industrial processes. Aquifers get water from precipitation (rain) or melting of snow).

Surface waters from rivers, lakes and other water bodies also contribute to Aquifers. Sometimes when water table touches the ground surface; water may come out in the form of a spring. At times water also comes through seepage to the surface from nearby higher grounds holding the Aquifer. India is at the top of the list of 10 highly groundwater extracting countries. As per statistics of CGWB India draws approximately 251 billion cubic meters annually, and is largest user of this precious liquid. Layers of coarse fine aggregates like loose sand holds more water than rock layers and at layers of different size of gravels aquifers are found to be formed. The cycle of movement of water in the system of Earth and surrounding troposphere is presented by Hydrology cycle (Figure 1), which shows the processes of disappearance, transpiration, concentration, rain, and overflow. The total amount of water remaining constant there always happens a change in the distribution system of water. World Resources Institute's reports say India lists in the 17 number countries abutting tremendous crisis in water and also needs attention in this field. Guwahati, the largest metropolis in North Eastern India is also facing groundwater depletion and land subsidence similar to different international cities like Singapore, Jakarta etc. and warrants thorough investigation and research into the reasons and find measures for sustainability.

2. Depletion of Ground Water

The beginning of the high yielding of crops since 1960s and applicability of HYV seeds and manures resulted into higher use of quantity of underground water sources leading to scarcity. It became a serious cause of apprehension that replenishment of the pumped-out water does not happen. As per 5th Minor Irrigation Census from 2007 and 2017, 61% declination of underground water has been observed, which happened at a rate of 10-25 mm each year from 2002 to 2016. It is feared that by 2030 approximately close to 40% of population of India may not have drinking water access. Undoubtedly such data is noted to be a serious cause of concern as well, because water is related with life. The soaking and infiltration rate of water into earth depends on the duration and intensity of rain and storm, type of soil, land use land cover (LULC) and other management factors. For paved areas infiltration of water to earth is minimum, practically nil. The transpiration from

plants along with evaporated moisture rises much above ground surface, which after condensation transforms as clouds.

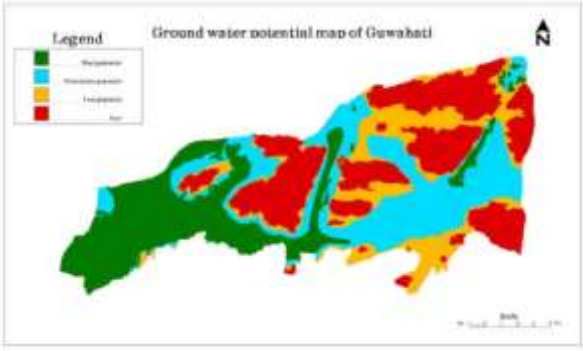

Figure 2 : Ground Water Potential Map Guwahati

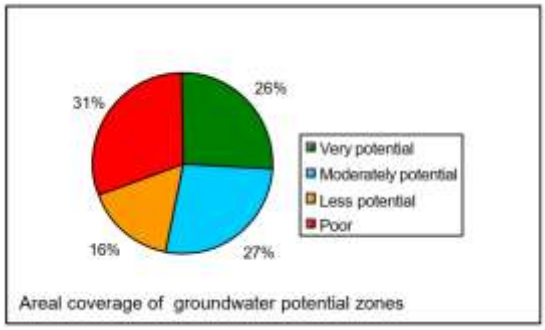

Figure 3. Pie Diagram - Zones of Groundwater

With a fast rise in population and its growing need for food led to unrestrained extraction of underground water in India. Causes from nature like irregular precipitation and change in climate are also impeding the procedure of revitalizing underground water. Lessening of underground water may decrease flow of water in rivulets. Underground water being a backing to the soil, the soil flops, pacts, and subsides leading to settling of land, when underground water is taken out.

3. Literature Review

Bekele A Shiferaw et al. first identified (2003), the reasons for Ground Water Depletion in this millennium and observed [ADB and ICRISAT] that growing populace, shortage of fertile land and diminishing sizes of farmhouses in our country have encouraged the augmentation of land uses by application of more quantities of composts, insect killer, improved hybrid quality fast growing seeds and plenty of irrigation. The so called 'Green Revolution' converted India from a deficit to surplus capacity country in terms of food but frequent droughts and water scarcity happened to be the critical barricades to augmenting agronomic production and source of revenue in India. This was one of the first such papers [1] providing some perceptions into the rural outwardness that exacerbate underground water exhaustion and suggested the diverse strategy to improve community water management. The results from an econometric land productivity model indicated that charges for using water can be introduced. Since 1995, increase in the quantity of tube-wells than open wells have been noted. In this paper through some empirical relations between several factors of crop productivity they came to a conclusion about the severity of groundwater depletion [1].

P. Phukon et al. pointed out (2004) that extraction of underground water in a geographically multifaceted topography necessitates contemplation of both natural and anthropogenic factors. MCE numerical algorithm was used by them to outline the appropriateness of a specific resolution as per criteria based on weightage assigned to a particular area. A paired comparison matrix showing geomorphology, slope, soil, geology and LULC for Guwahati city with weightage of individual class and mapping scores were worked out and presented in Figure 2 & Figure 3 [2].

Leonard F. Konikow et al. (2005) globally quantified 750–800 km^3/year groundwater withdrawals and opined depletion from aquifer as an inevitable natural consequence. They recommended that the utmost straight method to evaluate the volume of water exhausted from an aquifer is to assimilate maps of changes in head over the area of an aquifer. Optimization methods were suggested to place pumps with the objective of maximizing extractions while diminishing harmful effects. It is stated that in the coming range of decades, underground water exhaustion will linger to happen, but at a slower pace. Hydro-geologists are faced with a happenstance for developing and applying advanced means based on state-of-the-art technical sound methods, that believably notify society about the influences and substitutes to underground water exhaustion [3].

Matthew Rodell et al. (2009) mentioned about groundwater depletion (GRACE satellite of NASA) mentioning global

observations on changes in groundwater storage and simulation of differences in data in the model of hydrological system, which showed cumulative underground water exhaustion at some Indian states is equal to a clear loss of 109 Cubic Kilometer of water within 6 years (2002 to 2006). India was noted to be having serious water scarcity (World Bank's Report No. 34750-IN, 2005). The reason is stated to be dissimilarity in respective aquifer boundaries although aquifers are sometimes connected beyond the political boundaries of states. As a consequence, underground water managing culture are different within various states which can influence neighbouring states. They also mentioned about India Government's concerns about the withdrawal of groundwater resources and establishment of CGWB in 1986.[4].

Das Neel Kamal et al. (2013) studied groundwater recharge management in Guwahati and presented [5] that the city even being located at the lap of large and big river Brahmaputra face shortage of water in dry seasons. They highlighted basic reason of crisis of domestic water at Guwahati as the advantage from India's common law that landowners become the owner of the groundwater, although logically and factually Groundwater is a natural and national resource being shared from the available pool of aquifers. Primary data was collected from various sources like satellite images, Government Departments, CGWB, Research papers and also from field including from ARSAC, RMC, NIH, DGM etc. Considering that the water bodies are very important sources of recharging groundwater, the authors suggested that initiatives are required to be taken for reviving and maintaining ponds, lakes and other water bodies and wetlands within the city. The concept holds good for all cities as the wetlands sustains the micro-climate scenario in the surrounding areas of the city [5].

Hazarika Natasha et al. (2016) reviewed the sociopolitical issues and their relationships with underground water using DPSIR framework. LULC maps of Municipality's area at bank of Brahmaputra in Guwahati was studied and also questionnaire survey carried out from residents of supplied water system deprived wards who were primarily dependent on groundwater. The city was noted to practice drawing out underground water as if beneath the ground level there is a mine (because the huge Riverine body is under-used and groundwater resource is over-used). Therefore, for creating one umbrella for all households the researchers recommended taking fees for use of water so that people can use extracted groundwater in a rational manner. They also insisted for introducing tariffs for price of energy (electricity or diesel fuel) used for extraction of groundwater which according to them can be a powerful tool to influence groundwater pumping trends, as the price will directly hinge on the amount of water removed By this process, the unnecessary depletion of water can reduce and the reserve water can be handled in a more cost-effective way [6]

Bhanja S. N. et al. (2017) studied the changes in water-policy and its influence on underground water upgrading in various places of India. They recognized groundwater depletion in India out of fast and poorly managed withdrawal of groundwater. The satellite-based measurements on storage of groundwater after observing data for a decade's time and suggested for replenishment of GWS at regional-scale in several parts of India was firstly done by these authors. The authors commented that because of variations in hydro-geologic set-up and diversity in climatic conditions, both the availability of groundwater in nature and the possible processes of recharge in different places are not similar or homogeneous. While, aquifers of IGB regions are porous, northern India is rich in ground water and crystalline low-yielding aquifers are present in most of the areas of peninsular India [7].

Das Rakhi et al. (2019) stressed upon Groundwater Quality and Health Effects in their case study reported for a newly planned arrangement related to supply of water in Guwahati. They did a review by asking questions to people, collecting sample of underground water and analyzed the samples. It revealed from the analyses done in laboratory analysis that groundwater samples surpassed WHO guidelines for fluoride, iron and arsenic by 12, 55 and 9 % correspondingly. Cognizance on quality of underground water and related and its adversative effects on healthiness being the most important manipulating issues affecting public was found amongst only 3-4% people, which after knowing the effects improved from 58% to 74%. This exposed thought-provoking trend of reluctance amongst people in general. The awareness clearly threw consciousness amongst some people found their income sufficient to bear the expenses (tariffs related to pumping cost and treatment of water). The collected data on WtP was analyzed through a logistic regression model using STATA 9.0 software

(USA) for identifying the likely factors prompting willingness to proceed (WtP) within the people. Awareness programs on educating people on contamination of underground water and the paybacks from the new scheme on supply of water was advocated to upsurge public acquaintance for acceptance of the new scheme [8].

Lashkar Manasi et al. (2019) assessed heavy metal contamination of the groundwater in Guwahati city for their Cd (Cadmium), Pb (Lead), Fe (Iron) and As (Arsenic). It was found that out of the 81.48 samples where Cd was present, all of them had Cd content above MCL (Maximum Contaminant Level) recommended by WHO. Groundwater being the most widely and reliably trusted source of water, contaminations are of major concern. The results obtained from this study indicate a huge risk to the population. Exposure to these metals in small quantities even can affect the health of people, and in long-term can cause serious incurable diseases for majority of people, which portrays a dangerous situation. Out of the 81.48% samples where Cd was present, all of them had Cd content above MCL with marked variations in values in the different sites. Pb was present in all of the samples, out of which only 22.22 % samples had Pb content just within MCL in the wet season, and only 7.4 within MCL in the dry season. 62.96 samples had Fe content above the permissible limit in the wet season, while 92.59 had it above the limit in the dry season, with wide variations observed among the sites in both seasons. For the samples where As was present, all of the values were found to be below MCL in both seasons [9].

Singh Ashwin et al. (2019) studied a united modeled method relating data from satellite, changes in LULC and As (Arsenic) poisonousness for evaluating the susceptibility of As (Arsenic) in the groundwater at Guwahati. 10% upsurge in number of buildings was detected within 2013 to 2016 from the images obtained from satellite. LULC study detected that due to expansion of urbanization there took place reduction in plants (6%), unfertile areas (4%) and surface water sources (0.5%) respectively. The study recommends that planning for habitation should be done considering the presence of any toxic component in source of potable water [10].

Das, M et al. (2020) examined water in river Bharalu and underground water below city of Guwahati to find fluoride contents, with an objective to assess the impact of transfer of fluoride to groundwater aquifer which are nearer to the river. The intensity of fluoride in water of river was 0.02 to 3.73 mg/l and in underground water was 0.04 to 4.7 mg/l. In many places usually the groundwater table remains at higher than the river level, allowing groundwater to flow towards the river naturally. At the city of Guwahati, year after year the groundwater table has exhausted (Figure 4). Regression-Based Analysis established a high relationship was found within the fluoride contents in water of the river and that in the underground water and possibility of contamination of groundwater by the polluted river water has not been ruled out. [11]

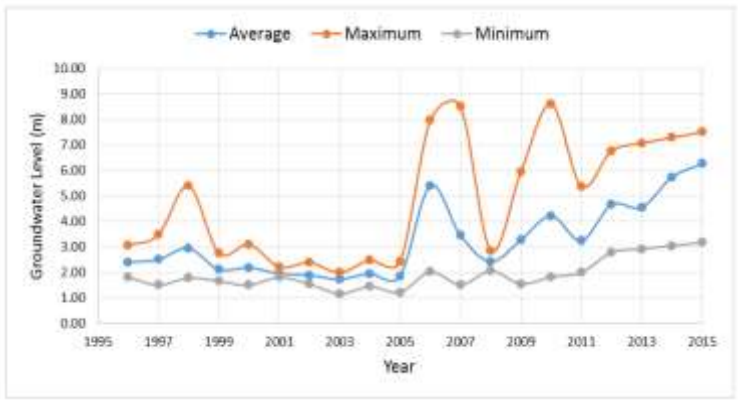

Figure 4. *Variation of Groundwater Level at a particular location at Guwahati [11]*

Jain Meha et al. recently (2021) expressed the concern of Groundwater depletion and resultant reduction of cropping intensity in India. As a strategy by the Indian government for adaptation of supply, in case surface irrigation delivery is

enhanced, intensity of cropping may even decrease, which will depend on inter annual variability of rainfall, and will be uneven at places. They found that irrigation through canals cannot be a substitute of groundwater and recommended that in the face of depletion of groundwater further different adaptation strategies will be required to be implemented for maintaining the similar levels of production [12].

Dangar Swarup et al. reviewed (2021) the causes related to groundwater depletion and its implications in India. They recommended that groundwater management has to be sustainable to combat crisis of water availability. They also evaluated the challenges and opportunities for groundwater measurements, groundwater modeling, recharge of groundwater, cropping patterns and efficiency of irrigation, including suggestions for socio-political reforms for sustainability in management of groundwater. It has been recorded that mostly Diesel pumps are utilized in Assam. Estimating recharge of groundwater is stated to be very seriously important for the maintaining balance within the environment, and economy related to the quantity of water. Recharge can be assessed by WTF (water table fluctuation) or WB (water balance) approaches. Following law of conservation of mass of water and water balance method they suggested R (groundwater recharge rate) can be valued as:

$$R = P - ET - \Delta SM - SR$$ ……*This is termed as* Water Budget Equation& the parameters

P, ET, ΔSM and SR stand for precipitation, evapo-transpiration, soil moisture change, and surface runoff [13].

Bekele Shiferaw Senior Evaluation Specialist at the Independent Evaluation Group of World Bank in his report (2021) opined extraction of groundwater has been rising for decades, which is responsible for scarcity of water in India. The demand for additional groundwater for agriculture increased due to so called green revolution from 1960 onwards and Govt.'s support to ensure food security. Ongoing fast electrification in rural areas and availability of modern technologies for pumping has led to increased number of bore wells for meeting the demand. According to CGWB approximately about 17% of groundwater sources are desecrated (the rate of extraction of water exceeds the rate recharge) and is critical. For sustainability, integration of supply with demand is stated to be a very good option. Studies by IEG indicated aquifer recharging, watershed management, rehabilitation of tank cannot stand as sustainable without balancing demand-side action [14].

4. Conclusions

From the foregoing facts found in literature the importance of Groundwater resources for civilization is amply clear, however balance between consumption and extraction needs to be regulated to facilitate sustainability, failing which serious shortage of groundwater at many places including at Guwahati may lead to crisis in requirement of necessary quantity of water. The cause of over-extraction of underground water primarily is noted to be the ever-increasing demand from cultivation. It is also felt that awareness amongst people for quality of water, possibilities of contamination in water and its impact on health and agriculture needs to be enhanced. For regulating controlled use of water, Government should attempt to impose levy to the users, which automatically will help in conservation of Ground Water. It is important to find a balance amid the requirements of agriculturalists and to safeguard the bearable consumption of underground water. There is a scarcity of data for estimation of groundwater sources and sometimes not exhaustive, which inter-alia warrants for thorough research in groundwater. There should be consistent monitoring and evaluation of underground water levels to avail adequate data to help formulating strategies and finding innovative techniques for resolving the problem. Strategies for monitoring over extraction of underground sources of water is very important for maintainability of the resource. Installation of water meters is a good step to reduce misuse. Innovations in methods for artificial recharge of groundwater are also welcome. Steps to minimize and control the dumping of industrial waste into surface water and underground aquifers should also be taken to prevent groundwater from getting polluted. The groundwater replenishment appears to be caused by a combination of efforts of local communities at grass-root level as well as changes in government policy. New changes in Indian government's

strategies on underground water management, such as fees for electricity for irrigation, dedicated distribution of energy only for cultivation, large-scale recharging by interlinking of rivers are worth noting. Groundwater exhaustion has become an upsetting issue day by day. Attention requires to be paid to the causes and suitable measures are required to be taken to combat with future water crisis in future. Attention of local bodies alongwith Government is required. to reduce depletion. A multi-sectoral tactic is required to be dealt with. Studies on LULC is required to apportion cultivable land and other type of lands falling under the heavily vulnerable regions. Determining suitable crop pattern in water-stressed areas are required. Severe after-effect of lifting huge quantity of groundwater by pumping is lowering of the water table. When groundwater levels go down deep too far, then owner will intend to lower the pump and gradually the yield of the well will come down. Lowering of underground water level will force people to go deeper Land subsidence also is happening in many places including at Guwahati due to excessive extraction of groundwater.

It is felt that a thorough research on depletion of groundwater at Guwahati is warranted in the interest of people of the city, by taking data continuously and applying mathematical and stochastically determined approaches for regulating the extraction on a demand-based extraction, such that in the long run life does not become dry.

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