Aquifer modeling in and around Varanasi, India

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By

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CHAPTER-8

CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusion

1. The holistic hydrological modeling (SWAT) plays an important role in the entire study. By applying the SWAT model, we could comprehend the basic hydrological cycle existing in the study area with rainfall as a major source of groundwater recharge.
2. Rainfall calculated from the SWAT model is 967.5 mm. About 40.1 percent of evapotranspiration takes place in the entire study area, where return flow to the river Ganga is 15.63%. Total surface runoff is 35.12%, and only 8 % of rainwater is going to the deep aquifer. Evapotranspiration and recharge have been used as input for groundwater flow modeling (MODFLOW).
3. GMS MODFLOW gives an accuracy of 87 % in the observation of heads. There is a depletion of 1.2 to 4.6 m in terms of water level of Wells. The amount of water entering (Inflow) from the river is 44.75 % whereas, from the drains, it is found to be 45.47 % with respect to total flow. But, amount of water coming out from river is only 2.5% and around 90 % is from drains. This shows how groundwater plays an important role and from volumetric budget the study is comprehended.
4. Head variation of study area shows that the head is relatively lower near bank of river. So, flow of groundwater takes place towards river. The flow could be parallel to the river if a relatively much lower head is in the other direction.

5. The variation of head with time also gets affected due to phenomenon like the severe flood in the region. The variation of the head with time indicates that and can be utilized to understand the impact of a similar phenomenon.
6. The prediction of the head through MODFLOW is satisfactory for the Varanasi region. The R^2 value of the prediction model is found at around 0.8972.
7. More intensive and daily monitoring data of wells should be implemented for more accuracy and better prediction. In order to continue this study, a different optimisation technique has been adopted for a time series analysis of GW wells with GHAT with limited data sets.
8. This will also help to forecast the water level for the future in the existing condition through optimization techniques. Also, based upon the changed condition, future predictions can be done. This study will help to monitor the groundwater level with limited resource and with limited data for a larger area.
9. GHAT approach gives an accuracy of 96.2% compared with previous studies in a time series analysis, which can be used to predict GW level for the years 2030, 2040, and 2050.
10. Ponds need to be an important factor to increase the GW capacity of Varanasi City, its data should also be managed in the groundwater study for proper recharge.
11. The Subsurface distribution of the alluvial deposits in the area indicates that the ancestral Ganga River has been the principal agent of deposition during the development of the sedimentary sequence in the upper 150 meters of the deposit. There are two distinct sedimentary sub-surface horizons met within the area. First one is back–swamp clays containing kankar and lying at the average depth of 50 m from the surface. Second one is the underlying meander-belt deposit, comprising

fine to coarse-grained sand having an average thickness of about 60m. The thickness of back–swamp clays which are maximum in the central northern part, decreases towards the eastern and western part of the area with a consequent rise in thickness of meander belt deposits.

12. As far as the deposits to water in the well are concerned, the minimum depth–to–water recorded is in the northern part of the study area. The deepest water level recorded is in the southwestern part of this area.
13. Two types of groundwater bodies were found from the study. First one is a shallow groundwater body in the back swamp with clay deposit and second one is a deep groundwater body with the meander–belt sand deposits. The groundwater in the back- swamp deposit generally occurs under sub- surface head. In areas where the back – swamp deposits are thin; lie above the zone of saturation and the groundwater in the meander-belt deposits occur under water table condition.
14. The entire area is suitable for groundwater development. Tube wells may be constructed to tap deep groundwater bodies occurring in the meander belt deposit as these are more productive than the back–swamp deposits. The lowering of water level is found in the years when rainfall was below normal condition. For such cases, arrangement of groundwater recharge can be done by providing 50 m to 70 m hosing pipe in the tube wells depending upon the depth of water level.
15. The consumption of water in the city has increased manifold. As groundwater is a prominent source for quenching the thrust, it is assumed that in next decade , aquifers in the area would be assimilating a critical state. In order to understand the aquifer behaviours and its management concomitantly, the parameters of ground waters ought to be analysed broadways to access properly the level of

groundwater.No, doubt the aquifer system could be well and efficiently modeled by using numerical model. Based on the supply and demand analysis of water resources, the established model would finally provide a scientific basis to use the groundwater sustainability, in the area of study.

8.2 Recommendations

The following recommendation has been made to the government for the proper utilization and development of groundwater in the study area.

1. Measurements of discharge and pumping water level in each tube well might be taken at least once in 2 months. Specific capacities of the tube well can be determined and noted on a chart provided for this purpose.
2. Deep trial borings up to 300 meters should be made to find out the additional potential aquifers within the old alluvium and their water-bearing properties.
3. Preference should be given in the construction of tublewells to those area where the depth of water level in dug well ranges betwen 10 – 15 meters and also where the masonary well irrigation is difficult.
4. Wherever possible, boring should be made at the bottom of the masonary well to an order of 60 – 120 meters depending upon the thickness of the top clayey bed and deep groundwater body of the meander–belt sand deposits. This will increase the specific capacity of masonary wells to such an extent that it could even be pumped mechanically.

8.3 Suggestion for augmenting the water table in the city

A permanent decline in the water table has been observed due to excessive groundwater withdrawals. In the city of Varanasi, the lowering of groundwater has been

7 feet (213 cm approximately) in the preceding years. Excessive removal of groundwater to cater the need of ever-growing population in the city has resulted in land subsidence in past causing a decline of water head. In 1986, report of subsidence from Varanasi snatched press line and suddenly very alarming situation cropped up, truck weighing 12 tons suddenly went underground making hollows in busy thoroughfares of the city. The frequency of occurrence of land subsidence during the last years made the city as "city of subsidence". The aquifer sands in the city are overlain by a layer of clay often mixed with fine sand and kankars in a good amount which makes it leaky.

Undoubtedly, groundwater is a valuable economic commodity. Its significance would be increasingly felt in near future throughout the country, including the study area. In order to overcome this depletion, measures to recharge the aquifers should be extensively practiced in the area under study. This will be more effective to other place where, there is shortage of water in the city. The city obtains a total of 270 million litter's water from the river Ganga and tube wells, yet every fifth citizen lacks drinking water.

In places where there is an acute scarcity of drinking water (i.e., Gaighat, Rajghat and upstream side of the river), there is an increasing need to adopt rainwater harvesting method to adequately recharge the aquifers. In the water-starved city of Chennai, people resorted the rain water harvesting in a big way during the N-E monsoon in 1993 following acute scarcity preceding the monsoon. The rain water was collected in a ground level sumps, which are subsequently used after filtering and boiling. A number of voluntary organizations took the care for wider adoption and today incorporation of provisions for rain water harvesting and aquifer recharge in the building plans in Chennai is mandatory for approval, as the Chennai Metropolitan development authority has incorporated a regulation for conservation of rain water in its building guideline in the area of Chennai in the view of acute scarcity of water in the region.

For ordinary buildings at ground plans are floor requisite porcelain pits filled with broken bricks and sand on top have been prescribed. The rain water collected in the open terrace is led into these percolation pith for use subsequently. For larger buildings, pebble beds filled with rounded pebble are to be constructed all-round the buildings, and the concrete paving around the building is given necessary slope, so that the rain water from the terrace and other open space flow over there pavements and get collected in the pebble bed around. It has also been prescribed for all air-conditioned buildings to have their own water reclamation plan and for using the reclaimed water for the cooling purposes, replication of such exercise in a number of towns is already on.

A substantial emphasis is being laid towards promotion of local / localized initiative both by NGOs and individuals. The scheme primarily envisage collecting rain water in a existing rocky pit and providing primary treatment before further distribution, in a localized environment. This innovative scheme, envisage harvesting about a million liters of rain water every year .The state government in 2002 had made "rain water harvesting and groundwater recharging" compulsory for the government offices, hospital, shopping complexes and buildings having an area more than 300 square meters. But the scheme has not taken off. Concomitantly, there is an urgent need to look for an alternate water source or develop and manage the numerous ponds and water bodies in the city, which have been an important source of groundwater recharging in earlier times.

Varanasi was at one time famous for its 'Eight wells' and 'Nine Vapis' (large well) in addition to a large number of ponds which formed part of its cultural fabric. These water bodies supplied the city with water, recharged the groundwater and played an important role in city with water recharged the groundwater and played an important role in maintaining ecological balance. The rapid expansion of the city has led to these water bodies completely vanishing form the scene. Out of the Nine Vapis, only two exits today. The city boasted of around 118 ponds and tanks at one time, of which the Varanasi Nagar Nigam does not have in its revenue register. Land Mafia has converted many of these ponds into buildings, and government did not prevent this. Whilst most of these water bodies are beyond repair and re-development, the city authorities at the behest of an avid environmentalists. have drawn up a list of 54 water bodies that could be redeveloped and conserved, provided immediate steps in this direction. Out of there 54 water, only above 12, like Ram-Kund, Pishachmochan-Kund, Shankul-dhara, Durga-Kund and Puskar Talab (Srivastava, 2015) have water throughout the year. Likewise the Nagar Nigam listed around 5000 well in the city for its development . Historically, important as a source of water for the local people, these ponds and water bodies are on the verge of extinction due to diminishing groundwater level. The solution to Varanasi water problems is hot too difficult or farfetched.

It only requires re- development and conservation of the water bodies that city already has, capturing rainfall runoff and directing it to these water bodies and recharging the groundwater in this process. This could help bridge the gap between demand and supply of drinking water in the city. Besides, restoration of the ponds and water bodies can help tackle the problem of subsidence as usually occurring in the city throughout the year. Last but not the least to overcome the problem of availability of safe drinking water in the study area, we should opt three ways in an integrated ways .One is identification of new water bearing zones in the sectors for groundwater availability. This involves a determination of textural properties of aquifer sands through grain size analysis and identification of the hydrological properties of water-bearing zone with standard graphs (Mohan et al. 2011) . The identified horizon characterized by relatively low concentration of dissolved solids would be recommended for utilizing the water resource for the new township, which might be developed in the proposed 'SMART CITY'. The identified horizon characterized by relatively low concentration of dissolved solids would be recommended for utilizing the water resource for the new township. Second is the proper utilization of available groundwater resources. Third is the social aspect viz. community mobilization in several area where conflict and clashes over water supply are occurring profusely. Social awareness to save and manage groundwater is the need of the hour.

Though the task is very arduous but it is achievable, Effort should be made at all level to tackle the problem of depleting the groundwater levels and drinking water crisis. The rapid expansion of the urban areas has made the situation worst. The problem calls for a coordinated and integrated effort on the part of the government as well as local people.