Declination of Spatial and Temporal Variation in Water table Depth Using GIS

Accepted 13th January, 2016

ABSTRACT

In Pakistan, groundwater is the major source of all activities like domestic, agricultural and industrial production. Agricultural requirements cannot be fulfilled through rainfall only; as such it is necessary to pump groundwater to meet the crop water requirements so as to ensure food security by increasing crop production with respect to increasing population. With increasing population and water consumption, the depth of water table is decreasing day by day and its availability is becoming rare. Water table depth prediction is essential for its extraction and research purposes. This Research was carried out at District Jhang to analyze the variation in water table depth. Water table depth data for the months of June and October for the years 2003 to 2011 were collected from Punjab Irrigation and Power Department. Spatial and temporal situations of groundwater level were delineated using GIS model. Maps were prepared on the basis of changes that have taken place in water table depth with respect to time and space. It was concluded that water table depth was between 6 to 15 m below from the ground surface respectively. The result of water table depth observed in the study area was high and in some places deep from ground surface. It showed low temporal variability due to recharge from link canals.

Key words: Groundwater, water table depth, spatial and temporal variations, GIS model.

INTRODUCTION

Groundwater is consisting of a large portion under the earth crust and it is estimated that the amount of groundwater in the world is about 615000 Billion Cubic Meter (BCM). About 1/5th of which consist of the active zone, at a depth of 763 m from surface. Its amount is thirty times greater than that of water present in lakes and three thousand times greater than that of water contained in ponds and rivers (Nazir, 1995).

Water in all forms is very important for sustainability of life but groundwater is very essential for many activities. All human beings have been using groundwater to accomplish their many activities. Groundwater is clean and pure with respect to other forms of water. The groundwater is a big source for all activities like industrial, domestic and agricultural operations in Pakistan. It is used for irrigation purposes; groundwater is also of vital importance for increasing production and helps the farmers to overcome their difficulties against seasonal changes. Water shortage is a serious problem for farmers. In such conditions, when farmers are facing water shortage groundwater is only the source to meet the irrigational needs of crops.

Groundwater level fluctuation depends on recharge from rainfall or some other sources. Groundwater level fluctuations are due to meteorological, tidal phenomena, urbanization, earthquakes and external loads stress and strain in water level groundwater recharge, discharge and intensity of rainfall are reflected in groundwater level
fluctuation with time (Gopinath and Seralathan, 2008).

In Pakistan, groundwater is used to fulfill agricultural as well as, the drinking requirements. Most of the population of Punjab province is fully dependent on groundwater to fulfill their needs. Groundwater is pumped through different types of pumps to meet the agricultural requirements (Qureshi et al., 2009).

Groundwater depletion occurs due to regular groundwater pumping. Most areas in Pakistan are experiencing depletion in groundwater. Groundwater depletion results in sea level rise due to transmit of accumulation from earth to oceans. Depletion can be calculated using models of calibrated groundwater, analytical approaches or by using volumetric budget analysis (Konikow, 2011).

This study was conducted to analyze the present status of groundwater table depth in District Jhang. The objective of research is to identify the changes with time and space using GIS maps to suggest the ground water management in the study area for future purpose.

MATERIALS AND METHODS

Study area

This study was conducted in District Jhang, Punjab, Pakistan. It is located in at 31°N latitude and 72°E longitude (Figure 1). It is located on the left bank of the Chenab River. In 2010, the population of the district was 3.4 million approximately. Its area is about 8809 km² and average elevation 159 m from Mean Sea Level. It occupies flat topography. There is frequent rainfall occurrence in the months of July and August. The average annual rainfall of the area is about 250 mm (Merriam, 2007).

In summer, hot and dry climate exists in District Jhang and in winter there is cold and dry climate. With respect to surface, it has three individual levels, one is sandy area
where big sand dunes is situated known as Thal in the West, second area is river valley and third is old Sandal Bar in the East. Trimmu Head-works is the spot where two rivers, Jhelum and Chenab join together. The hottest place of Jhang is Mari Shah Sakhira which is sandy area in Thal. Its temperature sometimes approaches 50°C during July and August (Government of Pakistan, 2000).

Data collection
The data regarding the changes in water table depth from 2003 to 2011 were collected from Punjab Irrigation and Power Department Faisalabad. The data was processed to GIS for preparing maps in Arc GIS 9 (version 9.3, Figure 1).

Spatial variability
To view the variability in groundwater depth with respect to space, maps showed the visualization in spatially data distributed quantitatively. This was a very useful method for presentation of ranked data. Different places showed with different colors and proper legends.

Temporal variability
To view the variability of groundwater depth with respect to time, line graphs were used in MS Excel. These graphs showed the variability on the basis of time and different lines showed comparison of readings. These had multiple attributes classified on the basis of time.

RESULTS AND DISCUSSION
Spatial and temporal situation of groundwater level was analyzed with the aid of data were entered in the software. The spatial variability in water table depth at different sites in one year and temporal variability with respect to different years was also carried out. At the end, temporal variability in water table depth was presented in a graph.

Spatial variability in water table depth during June, 2003
Figure 2 shows variation in water table depth at 61 different locations in the District Jhang area. It showed the
depth to water level from ground surface. As observed in the regions of Jhang Sadar, Ahmad Por Sial and in some areas of Shorkot, water level was high during 2003, as indicated by pink and red colors, it ranged from 0.07 to 1.76 m and 1.77 to 3.42 m, respectively. In some places water level was deep from surface, depth to water level was high (as indicated by blue, and dark green colors) with respect to ranges in the regions of Jhang Sadar, Chiniot and Chenab Nagar. The areas where recharge sources like rainfall occurred in the water level was high and where there were water shortages, drought condition prevailed and water table was deep from the surface. For pumping water, deep boring had been done in such areas.

**Spatial variability in water table depth during October, 2003**

Figure 3 shows that the groundwater variation in different places in District Jhang. The places where recharge condition through canals and rainfall happened, water table level was high (as indicated by pink and red colors in the map) which were in regions of Jhang Sadar and Ahmad Por Sial and some areas of Shorkot. The places of deep water table areas (as indicated by blue, light green and dark green colors) ranging from 8.27 to 10.46 m, 10.47 to 12.76 m and 12.76 to 15.69 m, are regions of Chenab Nagar, Chiniot, and Jhang Sadar respectively.

**Spatial variability in water table depth during June 2011**

Figure 4 shows spatial variability in water table depth during June, 2011 of different areas in the District Jhang. Map shows the variability in different ranges. In areas of Ahmad Por Sial, Jhang Sadar and Shorkot water level was high, nearest to the surface which ranged from 0.86 to 5.92 m and 5.93 to 951 m respectively (as indicated by pink and red colors in the map). It covered South-west sides, lower part of the map. Jhang City, Chenab Nagar covers an area that ranges from 15.26 to 23.00 m (as indicated by dark yellow color in the map).

**Spatial variability in water table depth during October, 2011**

Figure 5 shows spatial variability in water table depth in October, 2011. It shows ranges from 0.06 to 2.13 m and 2.14 to 3.79 m respectively (as indicated by pink and red colors in the map) covering South West sides of the map in

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**Figure 3.** Spatial variability in October, 2003.
Figure 4. Spatial variability in June, 2011.

Figure 5. Spatial variability in October, 2011.
the Ahmad Por Sial, Jhang Sadar and Shorkot, where depth of water table to the surface was high in Chiniot, and Chenab Nagar (as indicated by parrot and dark green colors in the map) which ranges from 12.31 to 14.32 m and 14.33 to 16.47 m respectively.

**Temporal variability of water table depth in piezometer no (1 to 5)**

Figure 6 shows temporal variability of water table depth in piezometer number (1 to 5) during 2003 to 2011. Pizometer number 1, 3 installed in Shorkot, 2 installed in Hassuwal, and 4 and 5 installed in Haveli areas of District Jhang. It is clear from Figure 4 that piezometer number 2 and 4 have shallow water table and piezometer number 5 and 3 have deep water table from the ground surface.

**Temporal variability of water table depth in piezometer no (21 to 25)**

Figure 7 shows temporal variability of water table depth in piezometer number (21 to 25) during 2003 to 2011. Pizometer number 21 installed in Lak Bdhar, 22 installed in Dholar, no 23 installed in Ghunwoan, no 24 installed in Mangani and no 25 installed in Mochiwala areas of District Jhang. It is clear from Figure 4.13 that piezometer no 21, 23 have shallow water table depth and piezometer no 24. 25 have deep water table depth from ground surface in this graph.

**Temporal variability of water table depth in piezometer no (56 to 61)**

Figure 8 shows the temporal variability of water table depth in piezometer number (56 to 61) during 2003 to 2011. Pizometer number 56 installed in Bhangu, 57 installed in Farid Mahmood, 58 and 59 installed in Ghagh, 60 installed in Bhangu and 61 installed in Mochiwala areas of District Jhang. Piezometer number 57 and 59 have shallow water table and piezometer number 61 have deep water table from ground surface.

**Groundwater in Jhang**

Major sources of groundwater in the Punjab are found in four zones of hydrogeological, which are known as Piedmont areas, alluvial plains, Potohar plateau and salt range, and Cholistan desert. Drainage of this province was caused by Indus River with its tributaries. With the irrigation system, most of the work was carried out by seepage and a lot of recharge in groundwater in the Punjab. Total potential of groundwater were dependent on recharge of rainfall, irrigation system recharge and recharge of groundwater. The importance of groundwater in Punjab is determined by the amount (50%) of water supplies provided from canals at farm-gate. It contributes 67.65 BCM water from canal system to the Punjab. About this quantity nearly 40% recharge are contributed in groundwater. All recharge and water resources of irrigation
were contributed by withdrawal of groundwater (Amin, 2005). In private sector, due to lack of groundwater management, farmers installed the tube wells anywhere in their field and can pump the desired quantity of water in any duration, without thinking about the effect of recharge sources. If there was balance between recharge rate and pumping in certain duration, the water table depth may remain constant under the ground surface.
Shah (2009) reported that large scale pumping in the private sector had introduced some groundwater management problems such as continuous decline of water levels and deterioration of groundwater quality. One major problem with the large scale pumping in the private sector (about 90% for irrigated agriculture) was that the farmers pumped groundwater in accordance with their crop water requirements irrespective of the groundwater recharge during a particular year. That meant that more pumping in dry years (as there was shortage of canal water) in spite of the fact that there was less groundwater recharge, and less pumping in wet years in spite of the fact that there was more groundwater recharge. This fact warrants necessary measures for groundwater management for the sustainability of this precious resource and agriculture, the life line of the 90 million people. Monitoring was the first step for any management. Cognizant of the ground condition, IPD implemented a project in collaboration with the World Bank, titled Punjab Private Sector Groundwater Development Project (PPSGDP), 1997 to 2001 which involved detailed studies on groundwater management and regulation. That led to the establishment of “Groundwater Monitoring Cell” in Directorate of Land Reclamation in IPD for systematic groundwater monitoring in the Province. Starting from the modest network adopted from SMO (WAPDA) the existing DLR network had gradually expanded and planned to extend it to Postwar Plateau so as to cover the non-irrigated areas also which are more prone to disaster in any drought period. There were 81 WL monitoring points in the District Jhang, out of which data for the year 2008 are available for 60 points. Groundwater level ranges from less than 20 feet to more than 40 feet below the ground surface; and water levels have shown mixed trends, generally rising and decline in some cases. The mean water table stage shows a more or less flat trend.

District Jhang lies in the Faisalabad irrigation zone. After study, it was observed that water table depth in some places was high and deep in some places was from the ground surface. It is therefore evident that spatial variability existed in this area and there was a shallow water table.

Conclusions

There was minute temporal variability in water table depth in District Jhang based from 2003 to 2011. There was spatial variability in water table depth due to recharge and discharge in different places. Groundwater level ranged from 4 to 15 m below the ground surface. There was shallow groundwater in 80% areas of District Jhang. There was no depletion due to recharge from the link canals. Groundwater management and regulatory infrastructure should be brought up in working for judicious utility of groundwater resources. Suitable irrigation methods should be applied for efficient use of groundwater. Research should be done for groundwater recharge. More tube wells should be installed by Government sector to avoid water logging.

REFERENCES


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