INVESTIGATING ALLUVIAL AQUIFER FOR GROUNDWATER MANAGEMENT IN KHANEWAL DISTRICT, SOUTH PUNJAB, PAKISTAN

S. Iman[1], I. Ahmad[1], S. R. Ahmad[1], and M. Sanallah[2]

[1]College of Earth and Environmental Sciences, University of the Punjab, Lahore, Pakistan
[2]Institute of Geology, University of the Punjab, Lahore, Pakistan

ABSTRACT: Investigations are made to study the aquifer dynamics and ground water fluctuation trends in Khanewal district (29◦52'03"N to 30◦44'30"N and 71◦32'19"E to 72◦28'31"E) of Punjab province. Water table of 2006-2015 was used for ground water delineation and its flow direction assessment. The aquifer parameters; hydraulic conductivity (K), specific yield (Sy), maximum drawdown (Sw), specific capacity (Q/Sw) and discharge (Q) were assessed for sufficient groundwater yield. Stratigraphic Profiling was performed for seventeen boreholes by using Ground Water Modelling Systems (GMS). ArcGIS10.2 was introduced for mapping of irrigation channels, water table delineation and aquifer characteristics. Results of stratigraphic profiling demonstrate the presence of fine to medium sand with some gravel with few of clay lenses. Aquifer has postured hydraulic conductivity (40-70 m/day), specific yield (25-40), specific capacity (1300-2100 cumecs/m) and average depth of water table (12m). Maps of water table elevations, depth to water table, hydraulic parameters of aquifers, average annual rainfall and surface water channels were produced. Analysis of groundwater maps display a declining of water table at the rate of 0.09 m/year in the area. Low water table decline rate suggests of the installment feasibility of shallow wells (200-250 ft.). Surface water resources should be utilized more efficiently to enhance recharge of the groundwater.

Keywords: Ground Water Fluctuations, Specific Capacity, Ground Water Modelling Systems (GMS), Stratigraphic Profiling, Water Table Decline, Drawdown.

(Received 20.03.2021 Accepted 01.06.2021)

INTRODUCTION

Groundwater is one of the most abundant and widely available natural resource in Indus basin. Its importance is entitled to its accessibility and resiliency. Groundwater is a huge fresh water resource which is easy to access and develop as compared to any other natural water resource. Its ability to be replenished by precipitation and seepage from surface water storages makes it a reliable resource. This is the reason of extensive use of groundwater in agriculture, industry, domestic water supply and recreational purposes (Rani and Chaudhary, 2016). Groundwater becomes the only dependable resource for agricultural and domes- tic uses during non-rainy season. Growing population, industrial revolution, urbanization and many other uses are resulting in over exploitation of groundwater (Basharat and Tariq, 2012).

Difference between water demands and supplies is major cause of excessive use of groundwater for irrigation and domestic purposes. The expansion of this gap between demand and supply is forcing people to depend more on most vulnerable resource of water i.e. groundwater (Shakir *et al.*, 2011). Groundwater discharges are ever-increasing while recharge is not enough to meet the requirement of the aquifer to maintain water levels; consequently we are facing declining trends in groundwater levels. The study of groundwater distribution and behavior through time and space is very significant for its conservation and sustainability (Yeh *et al.*, 2016, Singh *et al.*, 2015).

Groundwater potential of any aquifer system depends on its stratigraphy and aquifer parameters. We are able to get point data of well logs through drilling or electrical resistivity surveying. This data can be interpolated from point-to-point for making a complete profile of the stratigraphic layers underlying the study area. Groundwater Modeling System (GMS) is a very useful tool for the said purpose. It helps in conceptualization of aquifer conditions for determining its characteristics (Whelan and Castleton, 2006).

Behavior of groundwater over time and space is of great significance for water resources management of any area (Kumar and Ahmed, 2003; Aslan and Gundogdu, 2006). Geographical Information System (GIS) is very convenient tool for getting a broad picture of the information by using only point observations (Igboekwe and Akankpo, 2011, Babu *et al.*, 2011). There are many innovative technologies and methods in a GIS environment to analyze the observed data for converting it into a meaningful illustration (Pachri *et al.*, 2013). Key importance of the GIS is in its ability to integrate the layers from various sources for making an effective analysis of all the features collectively. Integrated analysis helps in making wise management decisions (Ofosu *et al.*, 2014).

Important hydrogeological features of groundwater resources can be mapped by Geographical Information System (GIS) and it is a cost effective and productive way of gathering important information about groundwater resources of any area. Maps developed by using GIS are used for making strategies for controlled ground- water development and as an input for different hydrogeological models (Elbeih, 2015, Chenini, 2015, Baalousha, 2016).

Information about aquifer parameters and aquifer conditions are obtained from various sources and different techniques are employed for multiple type of information. The parameters obtained from various techniques are used to designate any aquifer as good, moderate or bad in accordance to its groundwater potential (Anomohanran, 2014, Senanayake *et al.,* 2016).

Kriging technique of geostatistical tool of ArcGIS is widely used for interpolation of groundwater levels to illustrate the groundwater fluctuations over time to identify the zones with declining water table trends and potential site for groundwater recharge (Nayak *et al.*, 2015, Peterson *et al*., 2011, Mini *et al*., 2014, Ahmadi and Sedghamiz, 2007).

Various thematic layers developed in GIS interface were prepared for groundwater by using different sources e.g., ground truth data and data available from secondary sources. These layers are overlaid in a GIS environment to correlate and integrate the information from all layers to demarcate recharge potential zones and identify the groundwater zones pertaining to water quantity (Ibrahim-Bathis and Ahmed, 2016).

Study Area: Study area is District Khanewal (4349 Km2), located in South of the Punjab. It consists of four tehsils; Khanewal, Jahanian, Kabirwala and Mian Channu. It is located between 29◦52’03”N to 30◦44’30”N and 71◦32’19”E to 72◦28’31”E at an altitude of 128 meters. (Fig. 1)

Climate: The climate of the District is hot and dry. The summer Season extends from April to October. Hottest month are May, June and July. Normal annual rainfall is 300 mm. (Fig. 2)

Hydrological Settings: Study area lies in Lower Bari Doab Canal Command area which is bounded by two rivers, namely Ravi and Sutlej. The district receives its share of irrigation supplies mainly from 10 R branch and disty (Fig. 3). General slope of the area is in southwest direction. Its land is fertile for the crops of sugarcane, wheat, and cotton. There is no drain for sewage disposal from industries but waste water in disposed of in rivers Chenab and Ravi.

Geology: The area is underlain by vast alluvial plains formed by deposits from river Ravi and Sutlej. The area being a part of lower Bari Doab represents the geology with the predominance of sands. Clay and silt is found in the form of thin lenses but the occurrence of clay lenses is also very low and scattered. Gravels and coarse sands are rare in the area. Fine sands are prevalent under the Khanewal district.

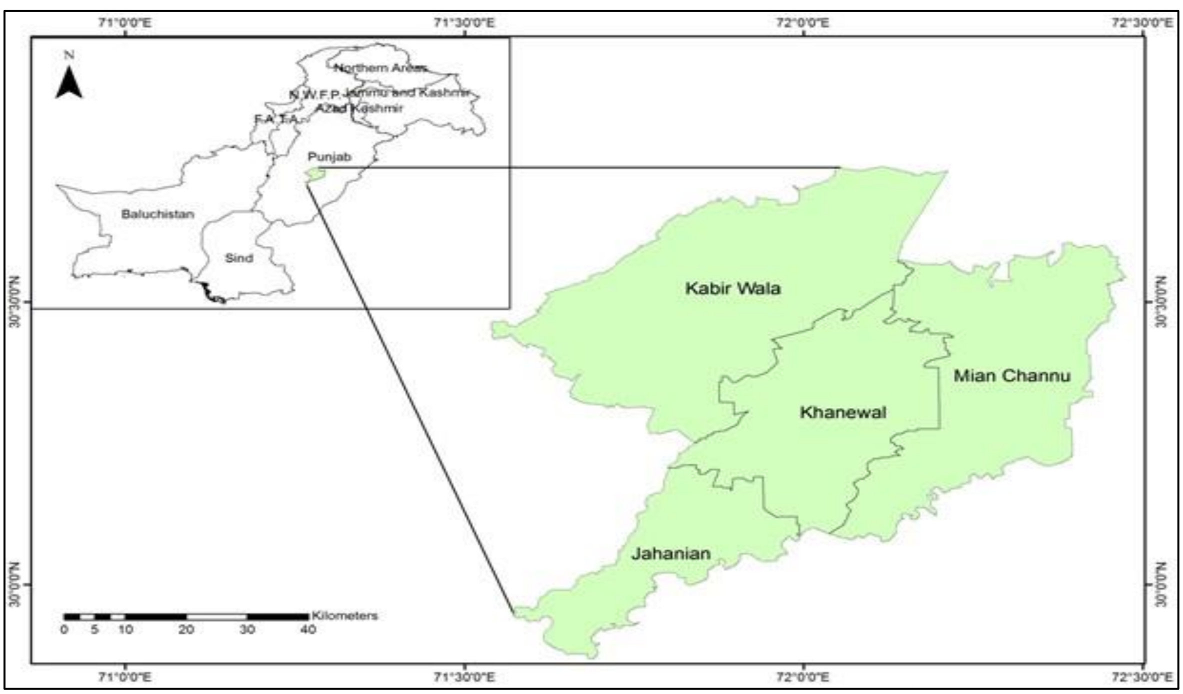

Fig. 1. Location Map of Khanewal District

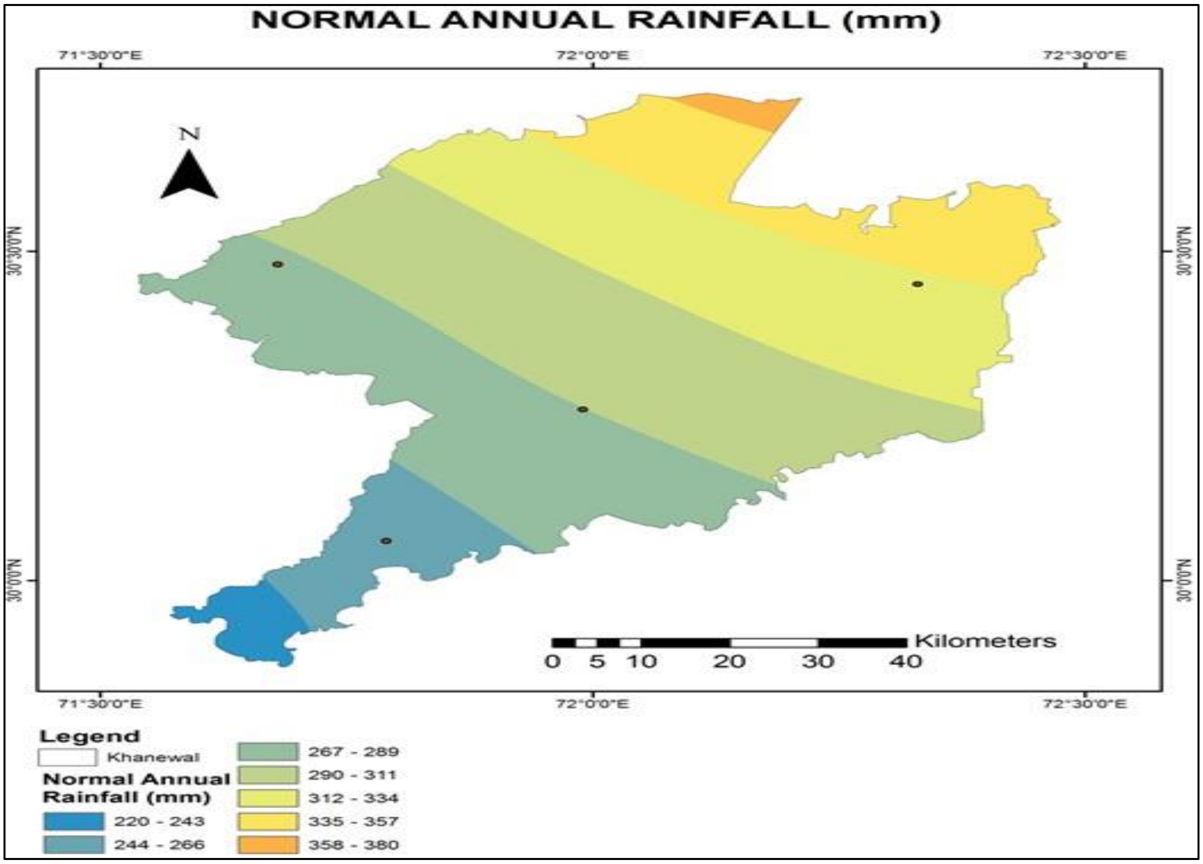

Fig. 2. Normal Annual Rainfall Map

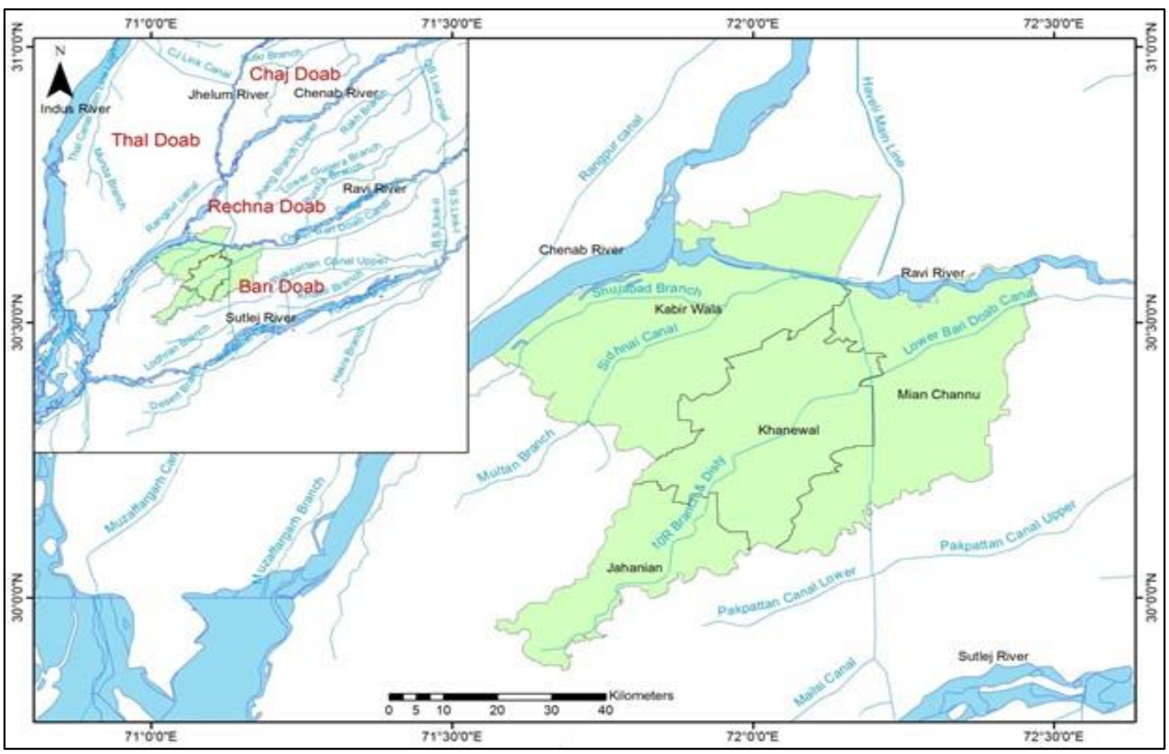

Fig. 3. Hydrological Map of Khanewal District

MATERIALS AND METHODS

Data required for this study is obtained from different government organizations and their published reports. Seasonal (pre and post monsoon) depths to groundwater table data were obtained from Directorate of Land Reclamation (DLR). Annual number of tubewells data was obtained from On Farm Water Management, Agriculture (OFWM), Directorate General Agriculture. Lithological logs data were obtained from Water and Power Development Authority (WAPDA). Aquifer parameters data were obtained from report on “Analysis of Aquifer Tests in the Punjab Region of West Pakistan” published by Water and Power Development Authority in 1967. Design Capacities of Canals were obtained from Punjab Irrigation Department (PID).

Groundwater Modeling System (GMS) is used for stratigraphic profiling of the aquifer underlying the study area. Cross sections are manually built in the software package to obtain the fence diagram for lithology of the area. A fence diagram is a network of three dimensional geological cross sections presented in a two dimensional perspective. Depth and thickness of permeable material is determined from these cross section.

Seasonal depths to water table data were mapped using Kriging technique of Geostatistical Analysis in ArcGIS for 10 years (2006 – 2015). Depths to water table were converted to water table elevations by subtracting the depths from NSL (Natural Surface Level). Water table elevation contour maps were generated using Kriging Technique of Geostatistical Analysis in ArcGIS for 4 years with 3 years interval (2006, 2009, 2012 and 2015). Rainfall and aquifer parameters were also mapped using Kriging.

Geostatistis is a set of models and tools for statistical analysis of continuous data. We use interpolation methods of geostatistical analysis for the estimation values for any location where observed data is not available. Interpolation is carried out by using sampled data which is limited. While using interpolation techniques we are able to get values at any location within the interpolation domain. Interpolation definitely underestimates the high and overestimates the lows as it is integral with the interpolation techniques. Kriging Technique is used in this study for interpolation purpose (Xiao *et al.,* 2016). Kriging is different from other interpolation techniques e.g., Inverse distance weightage, Spline and Natural Neighbor in the sense that it uses covariance and semivariogram for choosing a weight for any data point instead of using only distance between the locations to assign the weights. Kriging is an exact estimator for prediction of values (Bohling 2005).

It is a unique method of interpolation used to drive predicted values by weighing surrounded measured values for an unmeasured location. In this technique, weights are based on distance between measured points, prediction location and the overall spatial arrangements among the measured points. It provides an easy method for characterizing the variance or the precision of predicted values and the theory assumes that the spatial variation in the modeled data is homogenous entirely across the surface. The kriging weights of simple kriging have no unbiasedness condition and are given by the simple kriging equation system.

$$\begin{pmatrix} w_1 \\ \vdots \\ w_n \end{pmatrix} = \begin{pmatrix} c(x_{1,} x_1) & \cdots & c(x_{1,} x_{n1}) \\ \vdots & \ddots & \vdots \\ c(x_{n,} x_1) & \cdots & c(x_{n,} x_{n1}) \end{pmatrix}^{-1} \begin{pmatrix} c(x_{1,} x_0) \\ \vdots \\ c(x_{n,} x_0) \end{pmatrix}$$

It can be used where spatially-related data has been collected (in 2-D or 3-D) and estimates of "fill-in" data are desired in the locations (spatial gaps) between the actual measurements.

RESULTS AND DISCUSSIONS

a) Aquifer Characteristics: Khanewal district is underlained by the vast alluvial plain worked out by rivers of Punjab, Pakistan. Borehole logs have been studied for the investigation of aquifer for groundwater potential. (Fig. 4). Aquifer consists of unconsolidated alluvium with predominance of sands and concretions (Kankers). The amount of clay is very low in the aquifer underlying Khanewal district. Clay layers are not continuous and are present in the form of thin clay lenses. These clay lenses are also very scattered and fewer (Fig. 5). Cross sections show that there is not any continuous impervious layer found in the aquifer, so we can conclude that the aquifer is unconfined. Presence of sand makes it a good aquifer with a fair chance of availability of fresh groundwater for multiple uses.

Cross sections also revealed that topsoil (clay) layer is only a few meters (approx. 3 – 5meters) thick. There is mostly sands and gravels present upto 150 – 200 meters depth. Impervious clays and silts are very rare and mostly below the aforementioned depth range. (Fig. 6(a, b, c, d)).

Aquifer parameters (hydraulic conductivity and specific capacity) are also mapped for the determination of potential for groundwater extraction from the aquifer. There is a relation between an aquifer’s transmissibility and specific capacity of the well. The ease with which an aquifer transmits water has an impact on the discharge from a groundwater well per unit drawdown. The hydraulic conductivity of the study area varies between 40 to 120 meters per day which is the characteristics of fine to coarse sands. (Fig. 7). This shows that aquifer is sandy and can be a good aquifer. Specific capacity of the study area varies from 1000 to 1500 (m3/day/m). Aquifer characteristics are compromising with well yielding sandy aquifer.

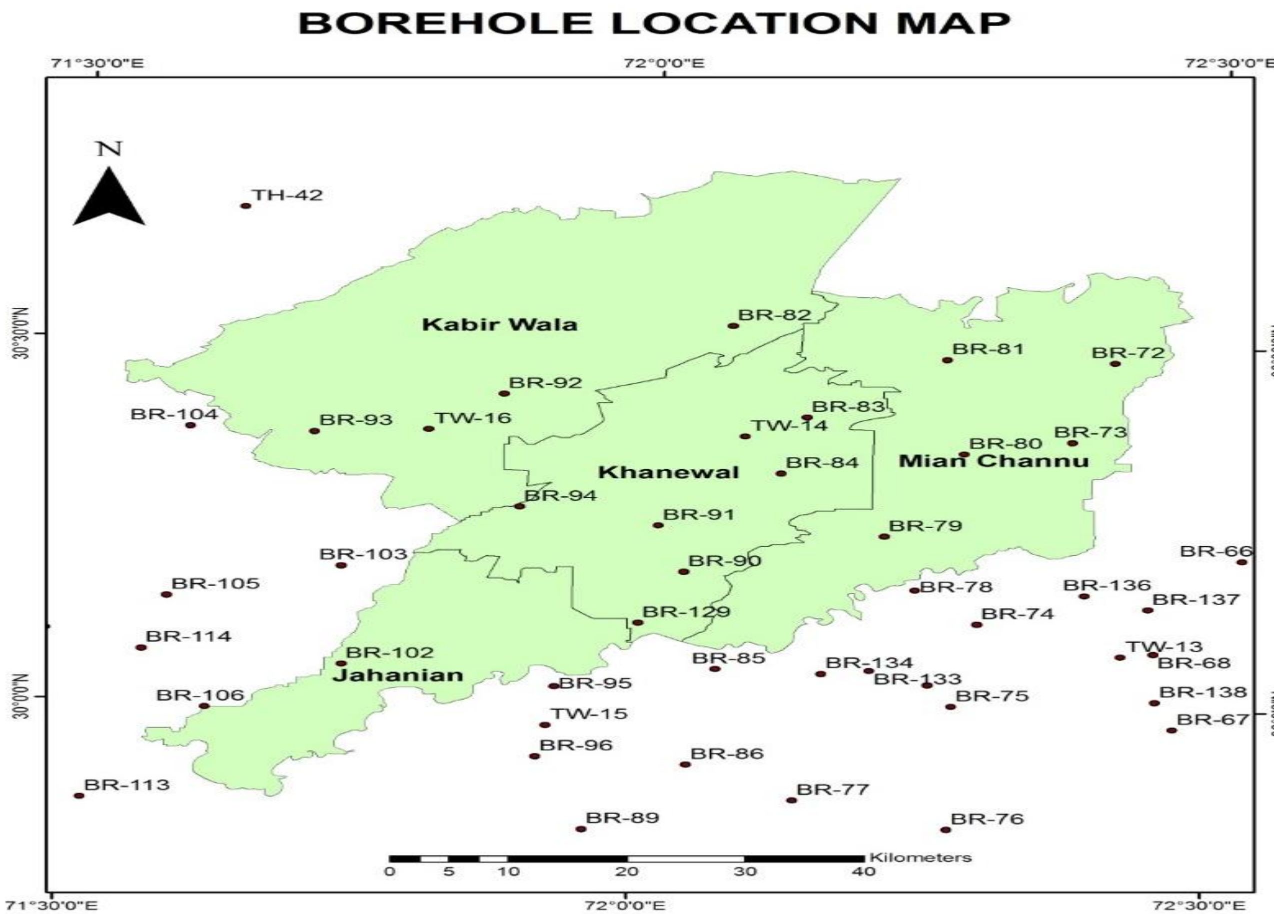

Fig. 4 Borehole Location Map

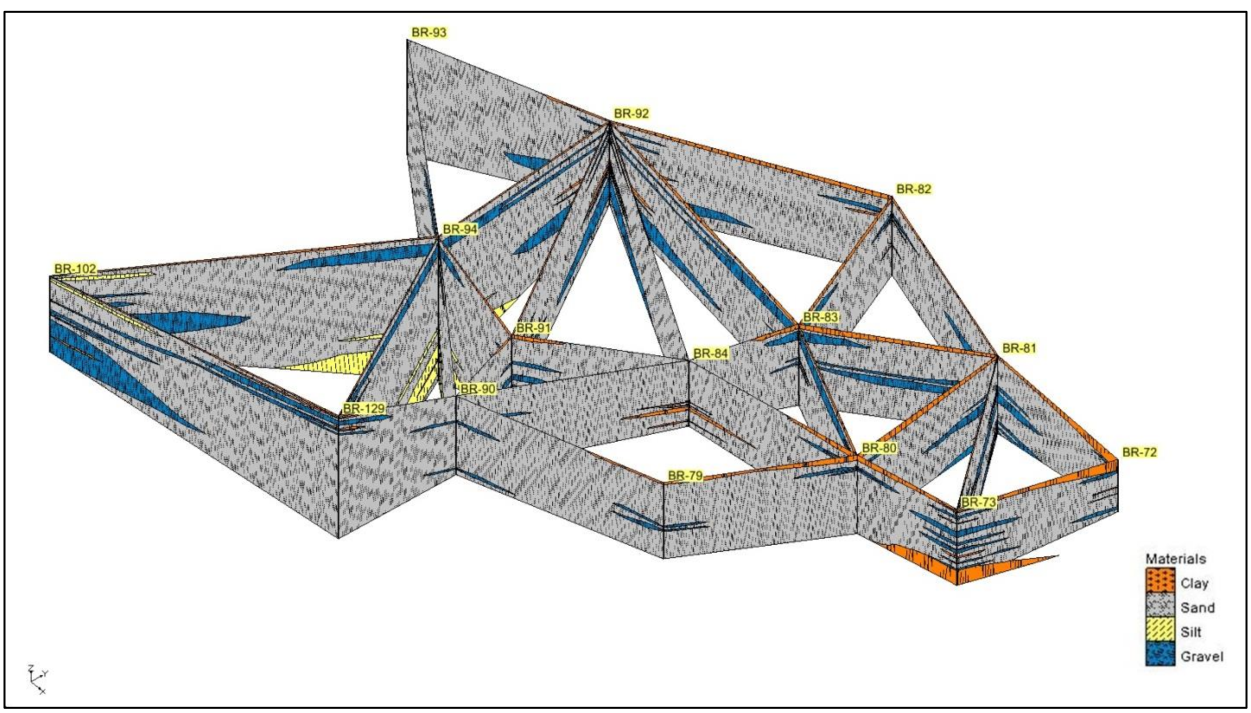

Fig. 5 Fence Diagram

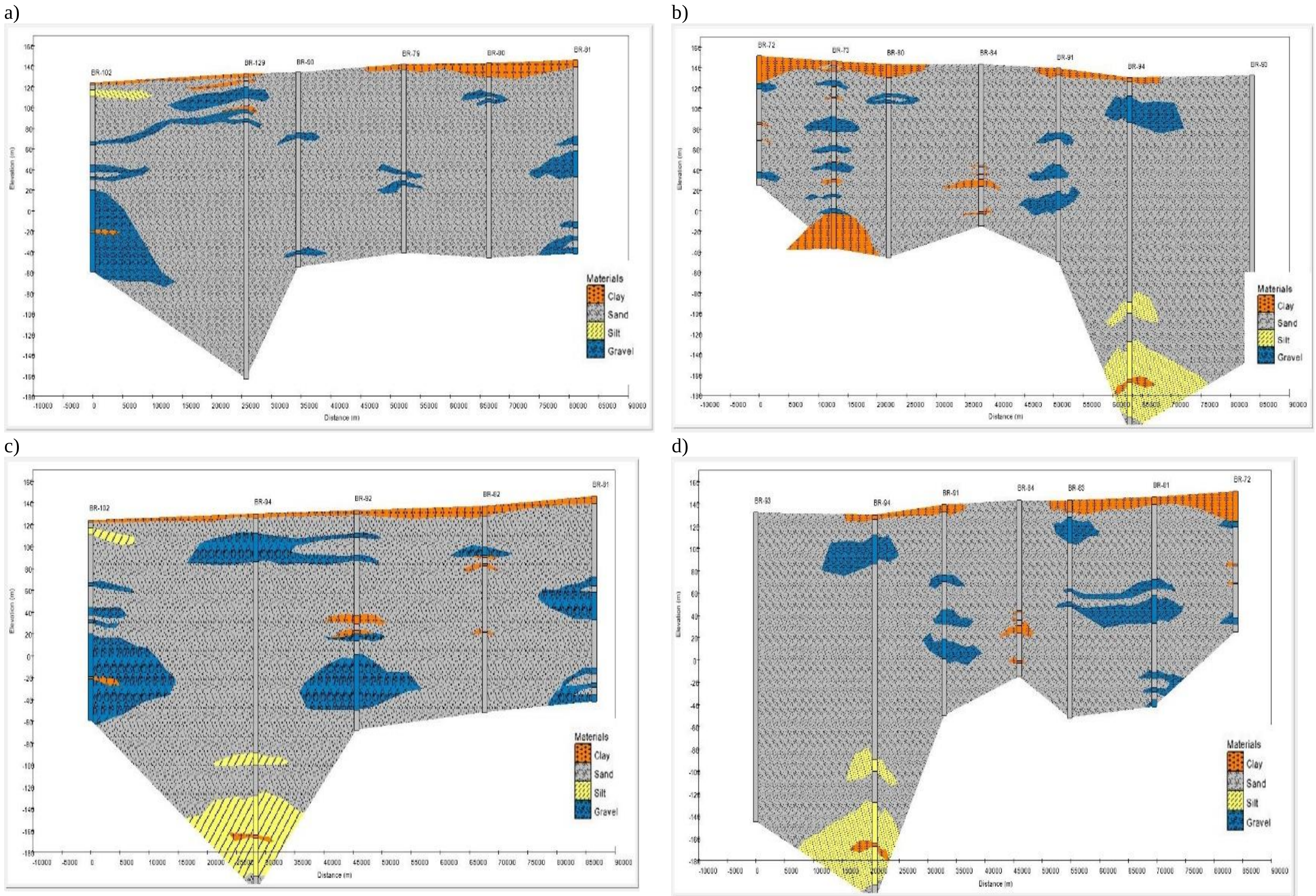

Fig. 6(a, b, c, and d) Lithological Cross Sections

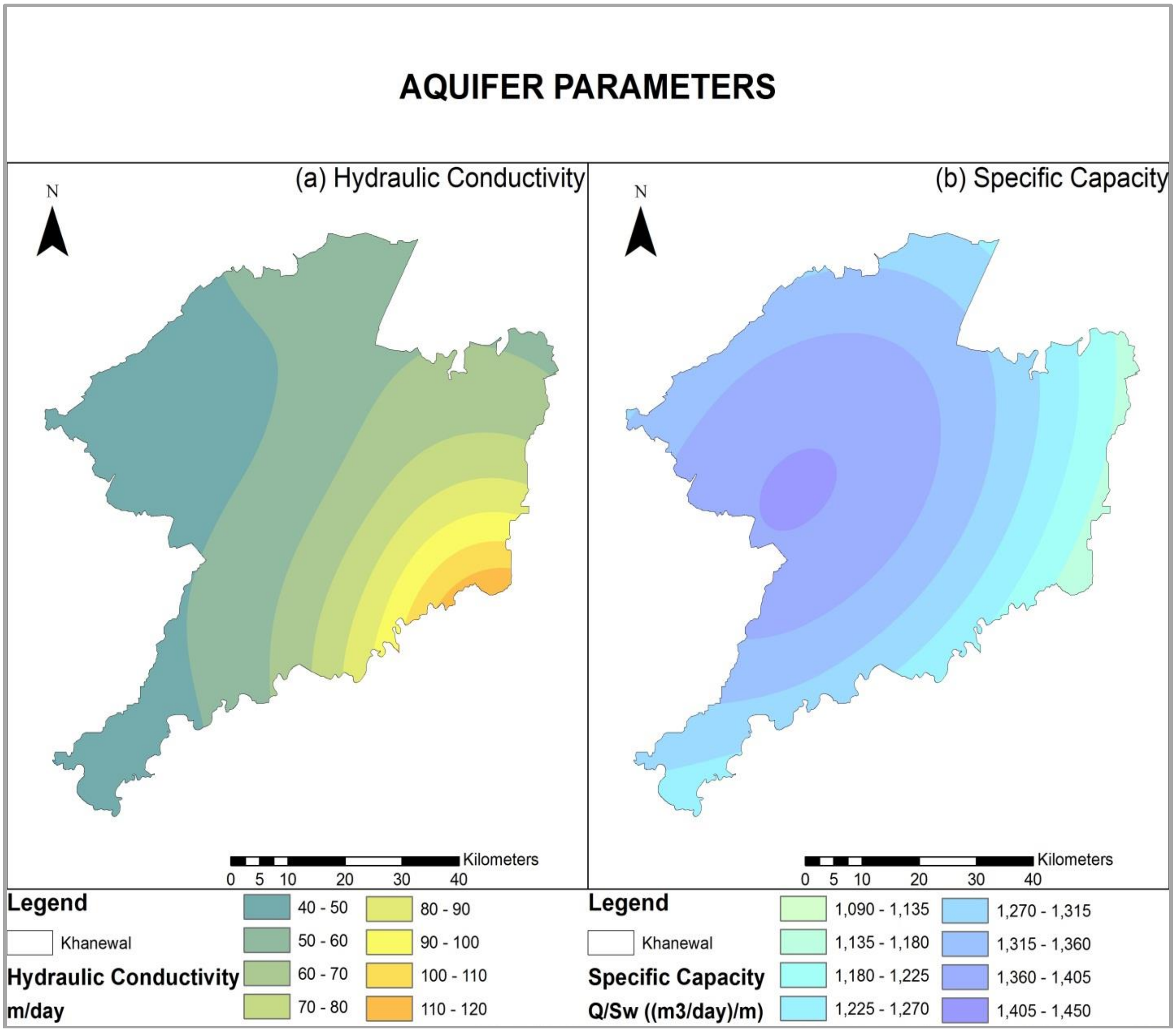

Fig. 7(a, b) Aquifer Parameters Map

b) Depth to Water Table and Water Table Elevation: Depth to water table is mapped for ten years (2006 – 2015) to see the change in depth over time. Depth to water table in Khanewal district varies between 3 to 25 meters. Depth to water table is lowest in the north part of the district while depth to water table is more in northeastern and south western part of the district. There is no significant change in depth to water table during these ten years. Maps showed that most of the area is under 10 – 20 m depth. (Fig. 8a – t).

Average depth to water table has also been plotted against years of observation to see the trend of water table. The plot showed that there is a declining trend in water table i.e. depth to water table is increasing with time. Water table has declined 0.9 meter in ten years with the rate of 0.09/yr. Graph showed that water table has a declining trend from 2006 to 2009, while depth to water table has been decreased during 2010 to 2012 due to flood period. There is again an increase in depth to water table from 2013 to 2015. (Fig. 9)

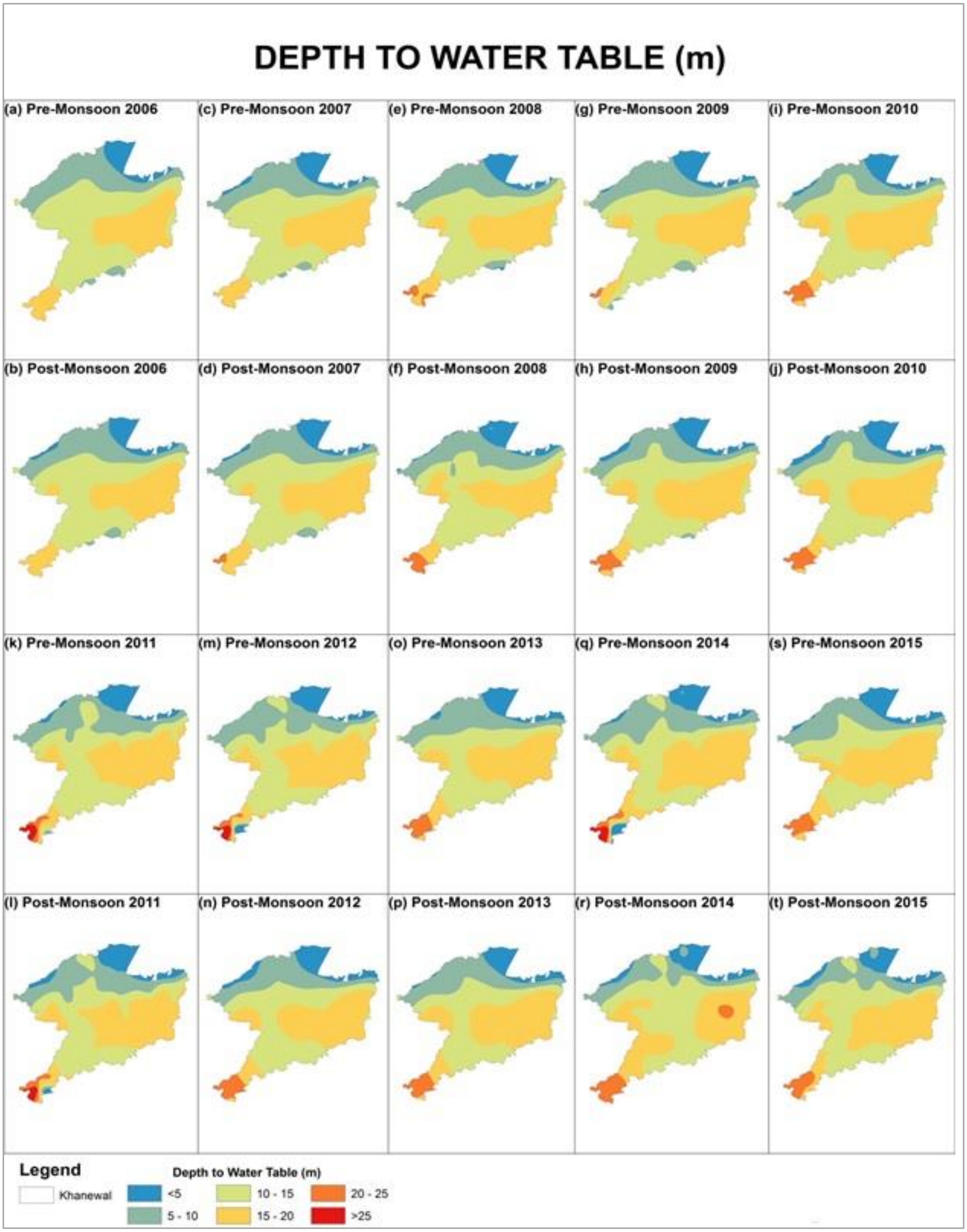

Fig. 8(a – t) Depth to Water Table Maps

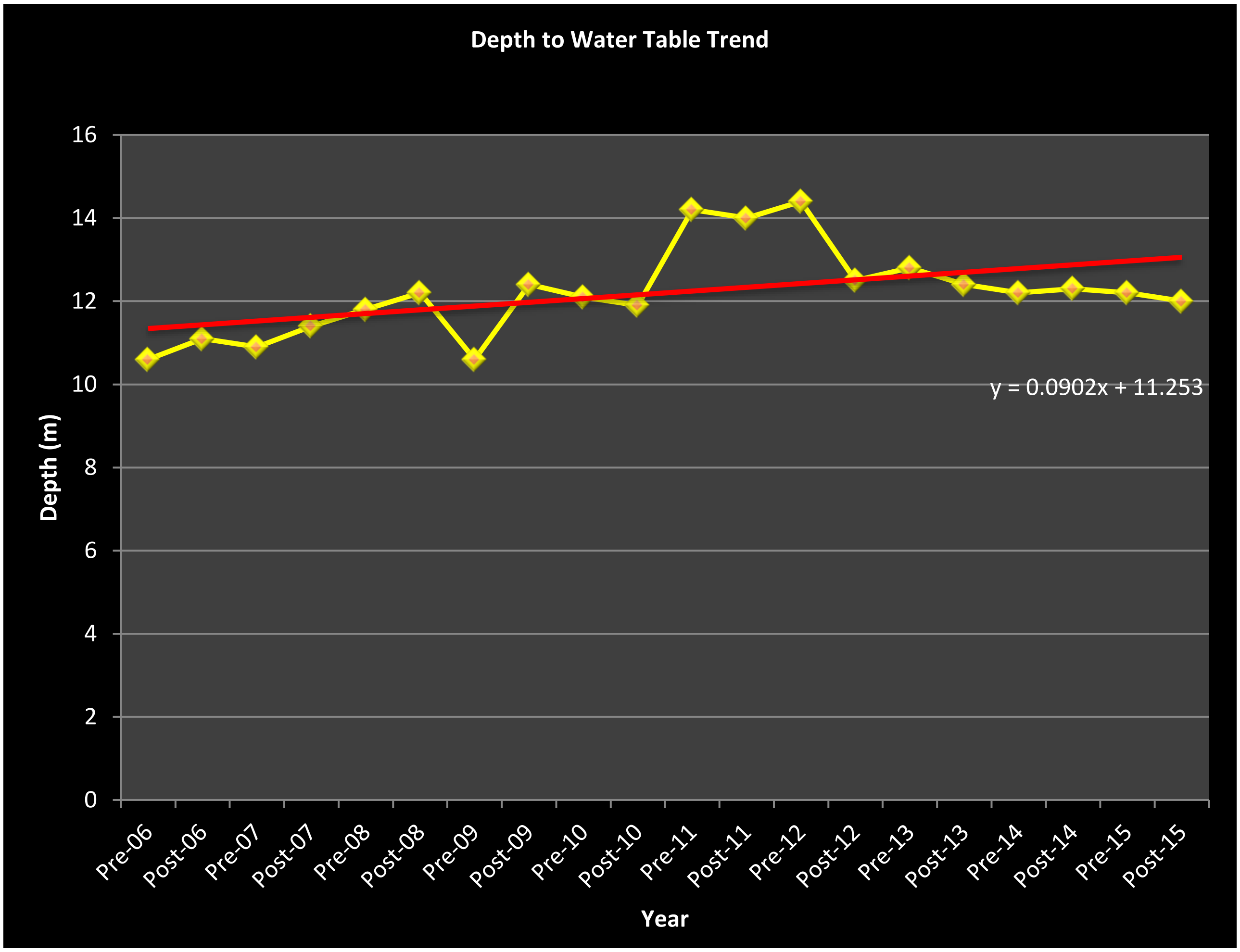

Fig. 9 Graph of Depth to Water Table vs Years of Obs.

Groundwater table elevations are mapped for delineation of groundwater flow direction and identification of stressed area due to overexploitation of groundwater. Water table elevations are mapped with three years interval to illustrate the change in elevations over time. There is not any significant change in water table elevation contours over the years. (Fig. 10(a – h)) Groundwater flow direction is in southern direction. (Fig. 10(i - l)). The lowering of elevation has a connection with surface water supplies and rainfall pattern. Rainfall amount decreases towards south direction which results in less recharge availability from north to south direction. (Fig. 2) Canal water supplies affect the groundwater recharge and groundwater use of the area.

Canal water discharges are more at head end of streams and less at tail end. That is why groundwater is extracted more in tail end areas to meet the needs of crop water requirements resulting in over-exploitation of the aquifer. This is the reason that water table elevation drops towards south direction. (Shakir *et al.*, 2011). Due to ever increasing water demands and canal water supply shortages there has been an increase of groundwater abstraction by irrigation tubwells from 4360 to 4550 MCM per year in 6 years i.e., 2010 – 2015 in Khanewal district (Fig. 11). This gap between water demands and supplies when filled with groundwater supplies, results in lowering of water table (Basharat 2013).

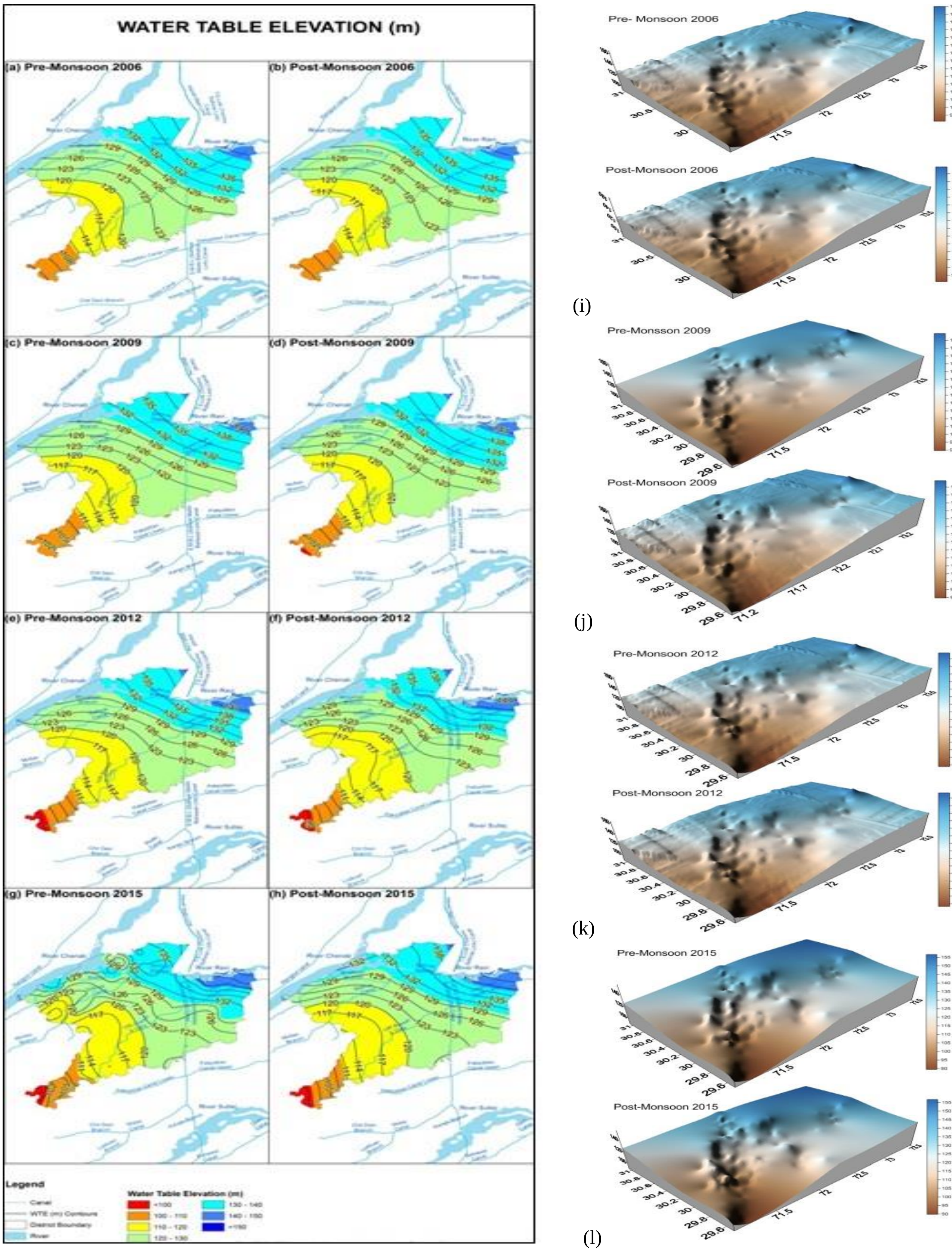

Fig. 10 (a – h) Water Table Elevation Contour Maps, (i – l) Water Table Elevation 3D Maps

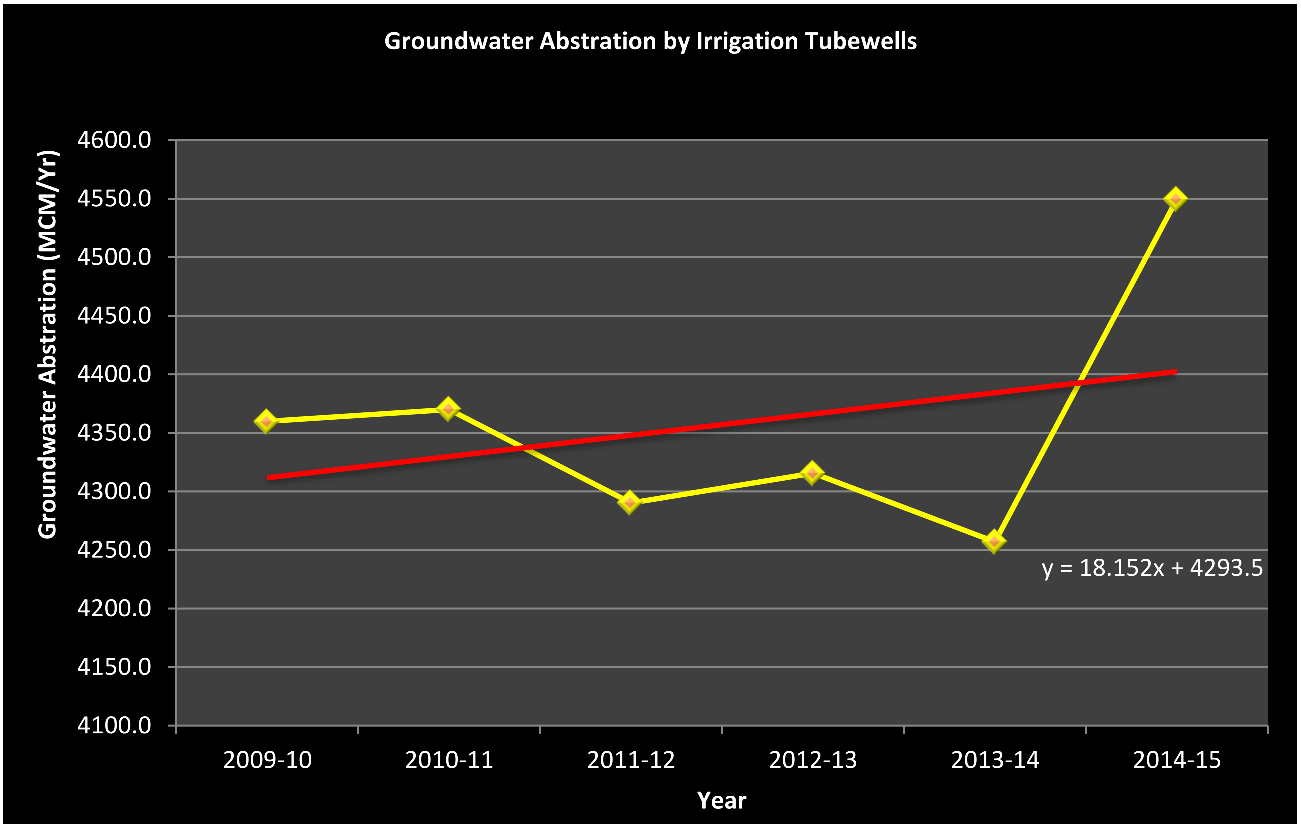

Fig. 11 Graph of Groundwater Abstraction Vs Year

Conclusions and Recommendations: Lowering of groundwater table is caused by over-exploitation of groundwater for meeting the crops requirements. Shortage of canal water supplies is the main reason of stress upon groundwater resources. A management policy is needed for sustainable and conjunctive use of surface water and groundwater. Maps of water table elevations, depth to water table, hydraulic parameters of aquifers, average annual rainfall and surface water channels were produced. Analysis of groundwater maps display declining of water table at the rate of 0.09 m/year in the area.

Aquifer is of unconfined alluvial nature. Sand is predominant in the area. Aquifer characteristics are favorable for appreciable amount of fresh groundwater availability at a shallow depth. Low water table decline rate and shallow water table depth suggests of the installment feasibility of shallow wells (200-250 ft.). Surface water resources should be utilized more efficiently to enhance groundwater recharge. Monitoring of private tube wells should be ensured to manage the groundwater resources accordingly. Common man should be provided with awareness and importance of groundwater monitoring and management. All the installed tube wells should be registered and a limit should be put on the withdrawal of groundwater.

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