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Data Analysis for Characterization of Depleting Water Table and Water Quality in Central Punjab

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Abstract: In this paper, analysis of rainfall pattern, water quality and water table fluctuations locally as well as on regional scale in Central Punjab region is carried out. Spatial and district wise rainfall analysis on yearly basis is carried out using the rainfall data in general since 1980 and in particular from 1991 to 2002. Monthly average rainfall is also plotted with the observed discharge at the Harike gauge site and average groundwater table condition. Local level groundwater fluctuations are analyzed considering short term of ten years (1991-2002) and regional analysis for long term of thirty years (1972-2002). Quantitative spatial variation of annual rainfall does not show any appreciable change however, district wise annual variation depict a continuous fall in rainfall in recent times since 1997 in almost all the districts. This study has indicated that long term depletion in water table is noticed in Kapurthala and Jalandhar district, whereas all other places are facing short term depletion problem. Long term analysis showed that water table fluctuations, in Central Punjab region are governed by the river-aquifer interactions to large extent. Water level is observed deeper in the Kandy belt and almost water logging condition in the parts of southwestern districts. Short term as well as long term analysis show that base flow is converging towards the confluence point of Satluj and Beas Rivers and some share of it may be emerging as river flow at Harike gauge site. Moreover, Satluj river water levels are found sensitive to groundwater levels in the study area. At several places in the study area, the groundwater was not found suitable for drinking and other domestic purposes due to either high soluble salt contents or high nitrate or high fluoride present in the water. The groundwater was not found suitable for irrigation too at many places in all the districts.

Key words: Rainfall pattern, water quality, water table fluctuation, Local level and regional level analysis, spatial variation

INTRODUCTION

This state having a part of alluvial areas of Indo-Gangetic plains has vast potential of groundwater resources. In central Punjab water resources have been exploited for the last few decades to a large extent for agricultural production and domestic uses. The population growth in the study area has been recorded more than the normal state growth rate (Census 2001). The last decades or more has witnessed tremendous groundwater development by means of lot of private shallow tubewells. This increase in number of tubewells has caused over draft and lowering of water table. The percentage of groundwater utilization has become almost double that it was 50 years back as well as the surface water utilization itself has increased many fold. There are arguments that extensive rice and wheat crop production has encouraged the people to extract more and more groundwater and thereby caused depletion in water table. There may be depletion in the well water levels locally due to excessive draft whereas, on regional scale, water table of the region would get affected if sufficient recharge to the aquifer is not available. The depletion in the well water levels could be because of extensive groundwater withdrawals for a specific period, which gets rejuvenated after the recharge period. In this case impacts of over-draft would be in patches and may be seen only in certain periods.

In the study area, the groundwater withdrawals in the present state of water table condition have interrelated impacts on local and regional scale. The depleted groundwater table may be short term depletion and long term depletion. The short term depletion may be attributed to scanty rainfall or excessive draft for a particular period while, long term depletion may be because of long term excessive pumping violating the safe yield criteria (ITSAP, 2004). The objectives of the present study are to analyze the rainfall and water table data to characterize the depleting water table and to quantify the quality of groundwater in the study area.

STUDY AREA AND HYDROGEOLOGICAL FEATURES

The study area consists of catchments of Satluj and Beas rivers in central Punjab. The area is triangular in shape, constituted by Satluj and Beas rivers on two sides and Shivalik hills (Kandi belt) on the third side (WAPCOS, 1996). The catchment of Satluj River is considered from Nangal to Harike and that of Beas from Pong to Harike (Fig. 1). The total area of the catchment up to Harike is approximately equal to 21913 km^2. Hoshiarpur, Kapurthala, Jalandar and Nawan shahar are the districts falling under the study area, however for analysis, data of the adjoining districts like Ludhiana, Moga, Ferozpur, Amritsar, Gurdaspur and Ropar is also included. The Satluj originates in regions of Mansarover Lake beyond the border of India. Near the Nangal town, Satluj enters the Anandpur dun, a valley/plain area between the shivalik and the outer range of the Himalayas. The river flows along the valley up to Ropar. Besides perennial, some seasonal streams and man made drains also contribute their flow to the Satluj river. The Beas originates in the upper Himalayas near Rohtang Pass and enters Hoshiarpur district in Punjab at Talwara soon after debauching from the Himalayas and on meeting the Shivaliks curves northward. The Beas strikes the border of Gurdaspur district at Mirthal flowing in Northwest and it runs along the district boundary between Amritsar and Kapurthala districts in Southwest direction. Many small streams from local catchments and man-made drains drop in the Beas between Mirthal and Harike.

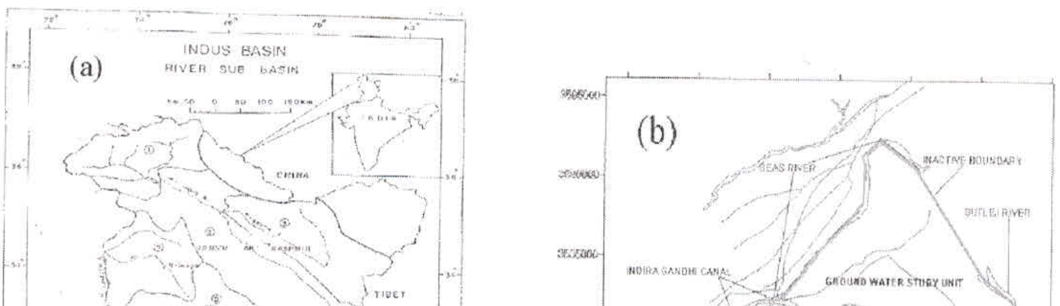

Fig. 1: Location map of the study area (a) Study area in Indus basin (b) Highlighted study area

In the study area, the alluvial deposits form good repositories of ground water. Water level is deeper in the Kandy belt and almost water logging condition in the parts of southwestern districts. Two types of aquifers are found in the study area namely, shallow and deep aquifer. The shallow aquifers are under unconfined state while the deeper aquifers forms confined conditions. In the study area, the recent observations indicate the declining trend in ground water table and decreasing runoff at the outlet. It may be attributed to the reduction in rainfall recharge and overexploitation of the ground water table in the region.

WATER AVAILABILITY AND UTILIZATION

Monsoon rainfall accounts for the bulk of annual rainfall. About 70% of the annual rainfall is received during the monsoon season in the study area. The lower reaches of Beas river, which are plains, receive very low rainfall of less than 300 mm whereas the mountainous upstream region receives ten times the rainfall of downstream area. The upper reaches of Satluj receive low rainfall of about 600 mm only. From the isohyetal pattern, the spatial rainfall variation is seen to be quite high. The highest rainfall of about 3200 mm and lowest rainfall of 270 mm was recorded in the study area at Dharamsala and Abohar respectively. From the maximum precipitation in the region at Dharamsala, it reduces to a relatively very low rainfall of only 400 mm at Kulu within a short distance of 90 km. The coefficient of variation of monsoon rainfall is about 35% to 40% in the region. A considerable seasonal variation is observed in the rate of flow of both the rivers. The average rate of flow during monsoon months (July to September) and lean period (April to June) is respectively 4.7 and 1.4 times that of the winter flows.

In the study area, presently there will be hardly any area, which is solely irrigated by canal water. In most of the areas both canal and ground water are used, however, in Kandi belt solely ground water is used to irrigate an area of approximately equal to 3000 sq. km. The utilization from Satluj through Sirhind canal during monsoon (July-September) was 19883 MCM in 1998, which is 67.3% of the inflow at Ropar for the same period. The mean volume of flows of Satluj for 5 years (1998 to 2003) at Harike was observed as 170998 MCM. For the last five decades, well irrigation has been on the rise and increased to irrigate the area double that of which was there in 1952.

ANALYSIS OF DATA

Rainfall pattern

In this study, the analysis of rainfall pattern and water table fluctuation on local as well as regional scale over a period of time is carried out using the available data in general since 1980 and in particular from1991 to 2002. Spatial variation of rainfall for the years 1991 to 2002 is depicted in figures from 2 to 13. Spatial variation of annual rainfall does not show any appreciable change in the years of plot. District wise annual variation of rainfall for Jalandhar, Hoshiarpur, Kapurthala, Ropar, Ludhiana and Nawan shahar is shown in figures from 14 to 19, where in almost all the districts, a continuous fall in rainfall pattern was observed in recent years since year 1997. Monthly average rainfall in the study area is plotted along with the observed discharge at the Harike gauge site and average groundwater table condition is shown in figure 20. It is evident from the figure that the discharge peaks are following the rainfall peaks and to a large extent followed up by groundwater table. However, most of the wells considered are located along the river course only.

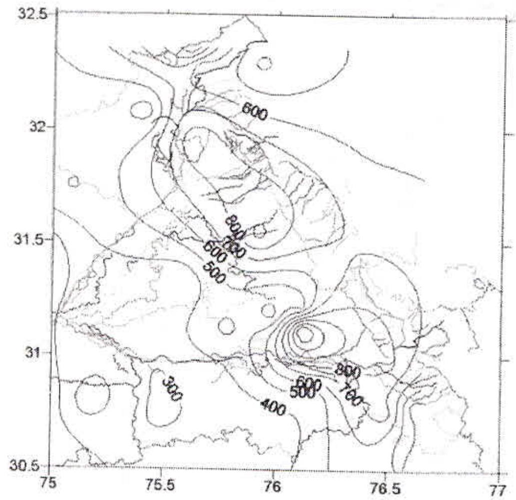

Fig. 2: Rainfall distribution in Year 1991

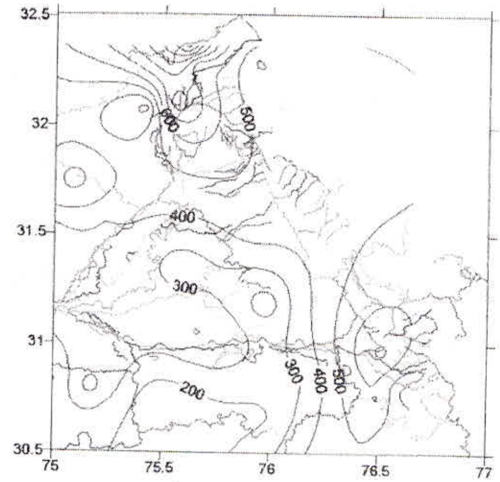

Fig. 3: Rainfall distribution in 1992

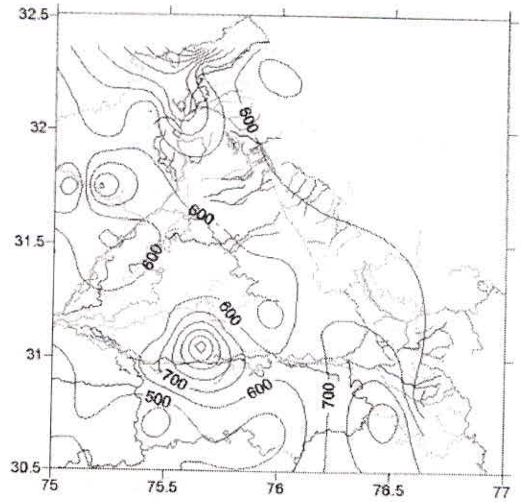

Fig. 4: Rainfall distribution in 1993

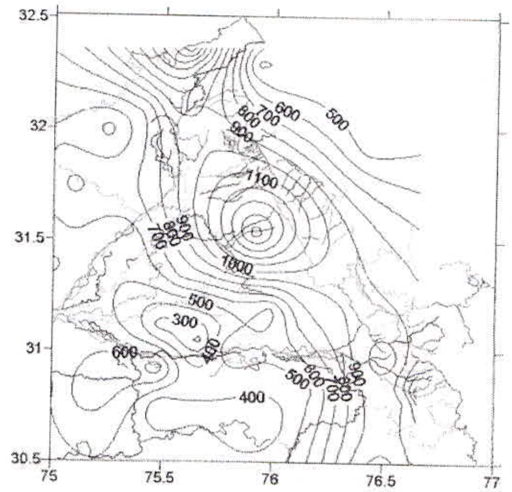

Fig. 5: Rainfall distribution in 1994

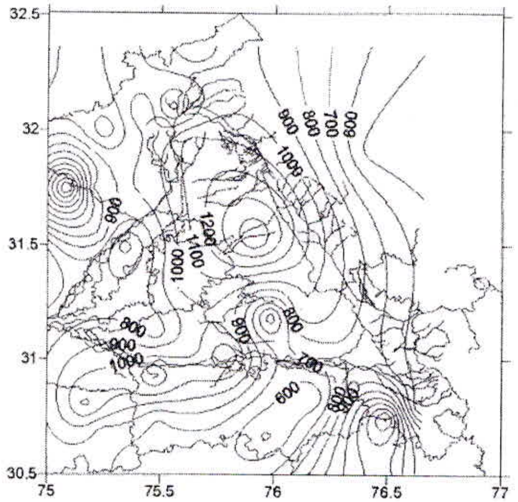

Fig. 6: Rainfall distribution in 1995

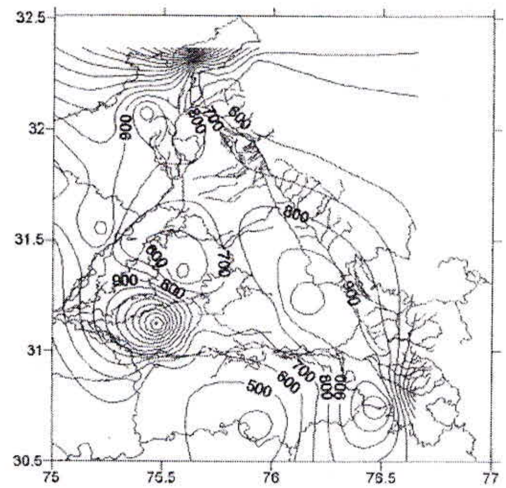

Fig. 7: Rainfall distribution in 1996

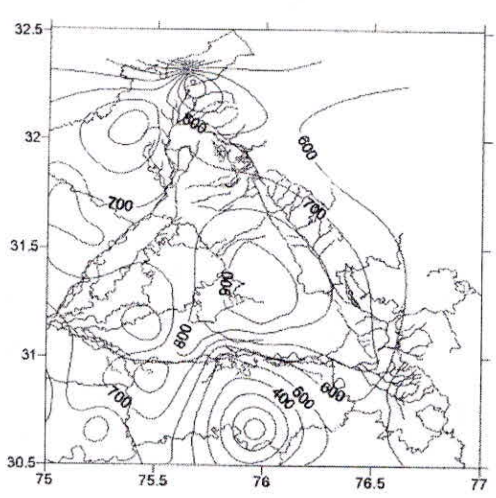

Fig. 8: Rainfall distribution in 1997

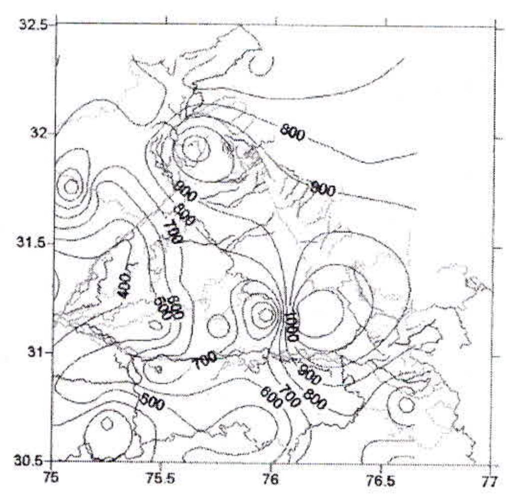

Fig. 9: Rainfall distribution in 1998

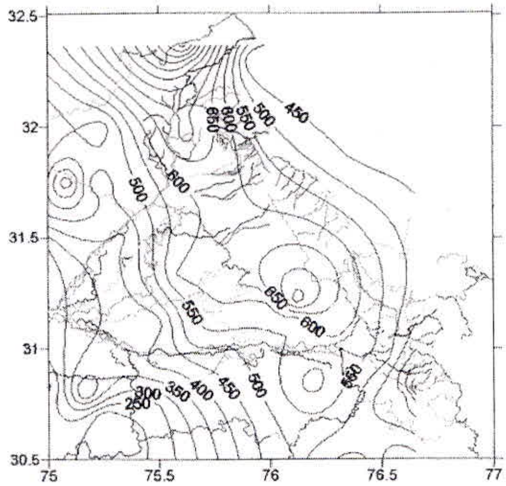

Fig.10: Rainfall distribution in 1999

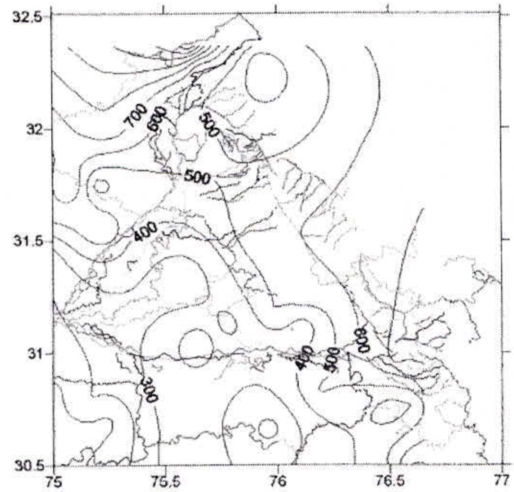

Fig.11: Rainfall distribution in 2000

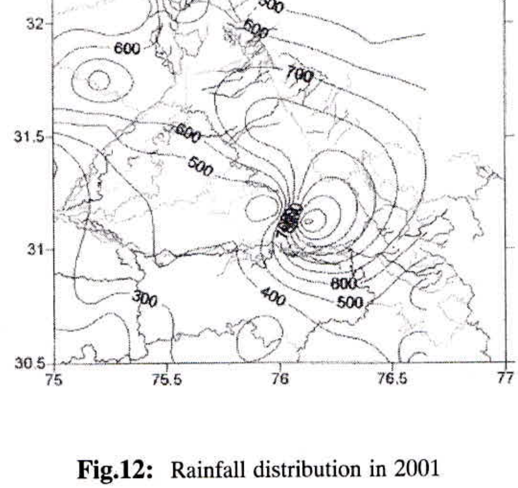

Fig.12: Rainfall distribution in 2001

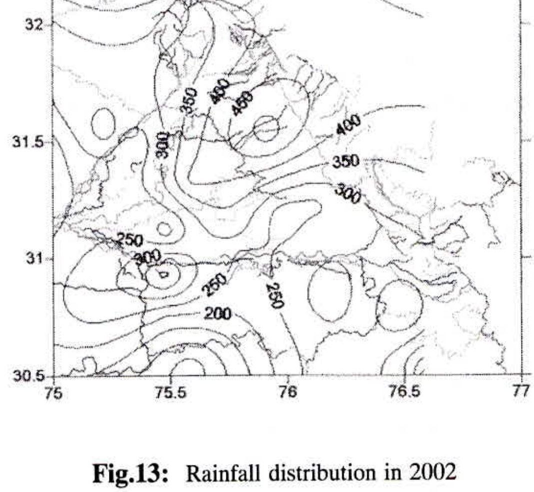

Fig.13: Rainfall distribution in 2002

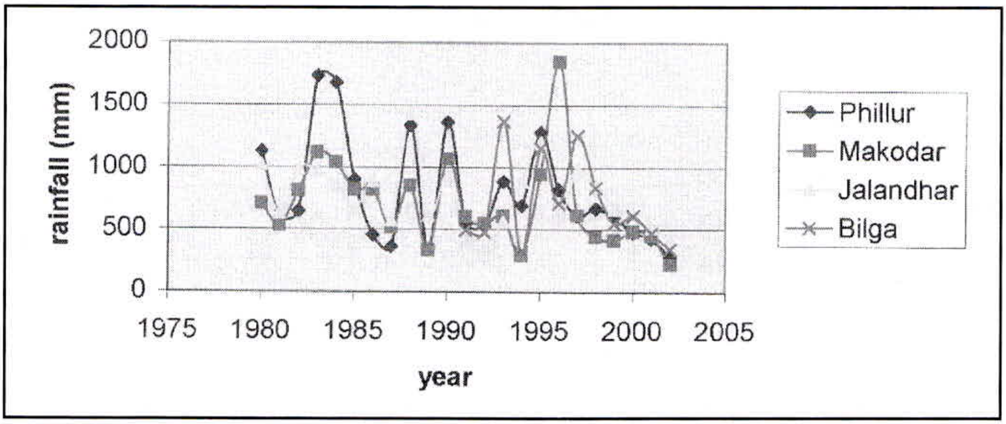

Fig.14: Annual Rainfall variations in Jalandhar District

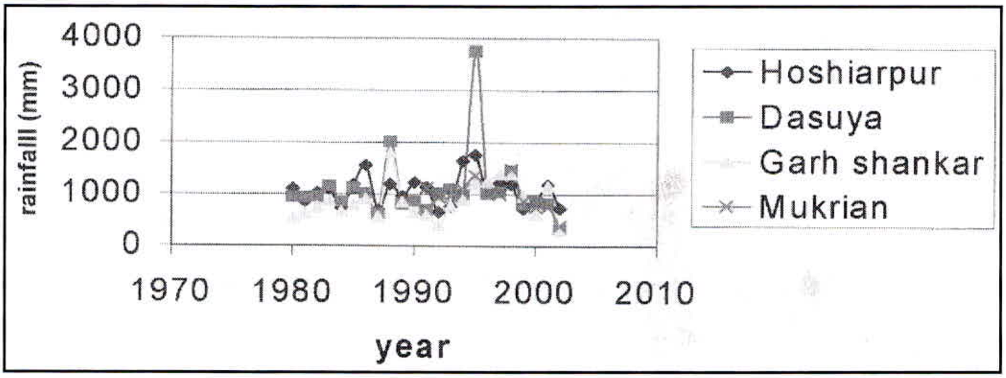

Fig.15: Annual Rainfall variations in Hoshiarpur District

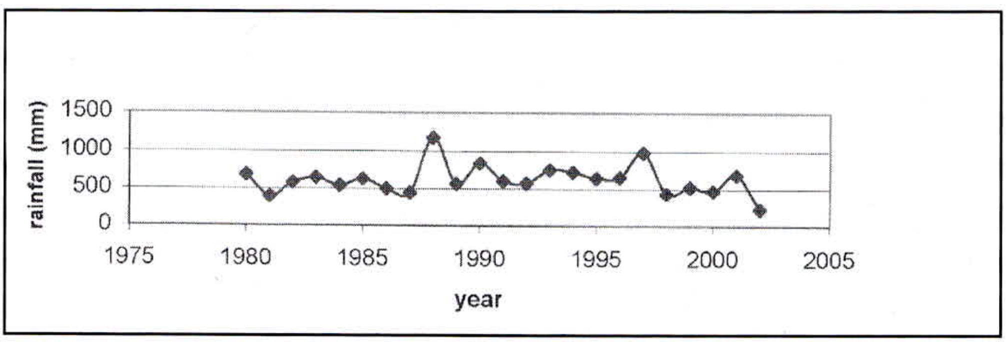

Fig.16: Annual Rainfall variations in Kapurthala District

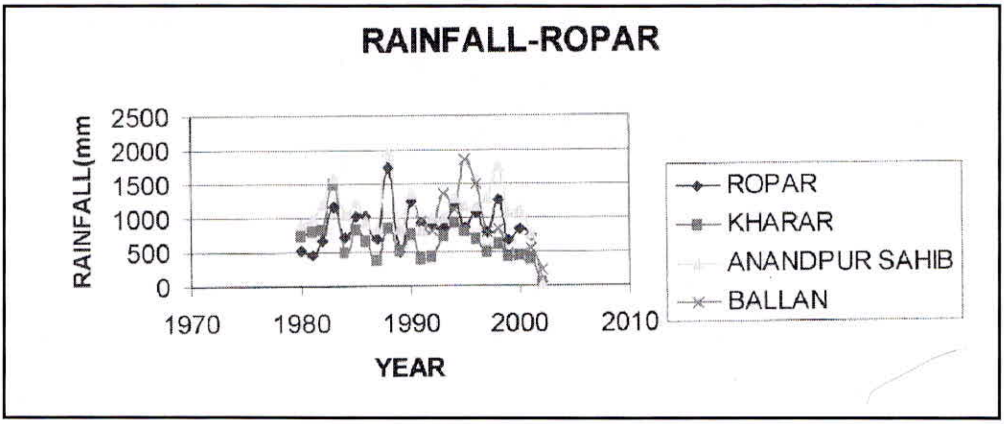

Fig.17: Annual Rainfall variations in Ropar District

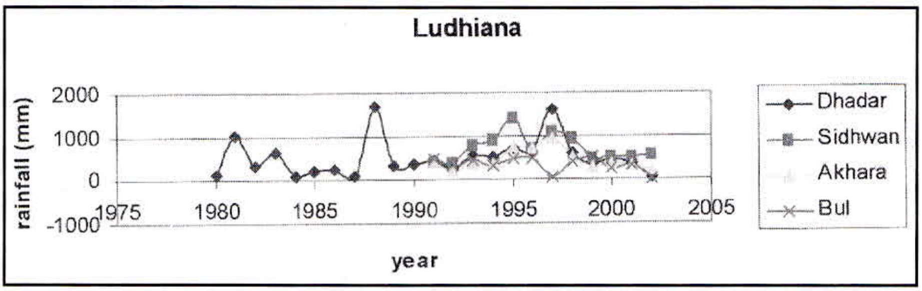

Fig.18: Annual Rainfall variations in Ludhiana District

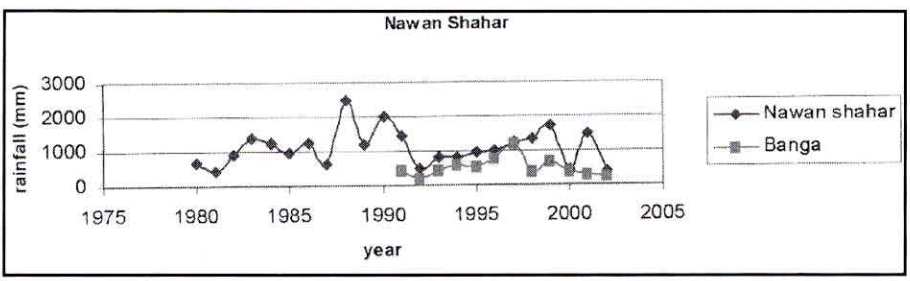

Fig.19: Annual Rainfall variations in Nawan Shahar District

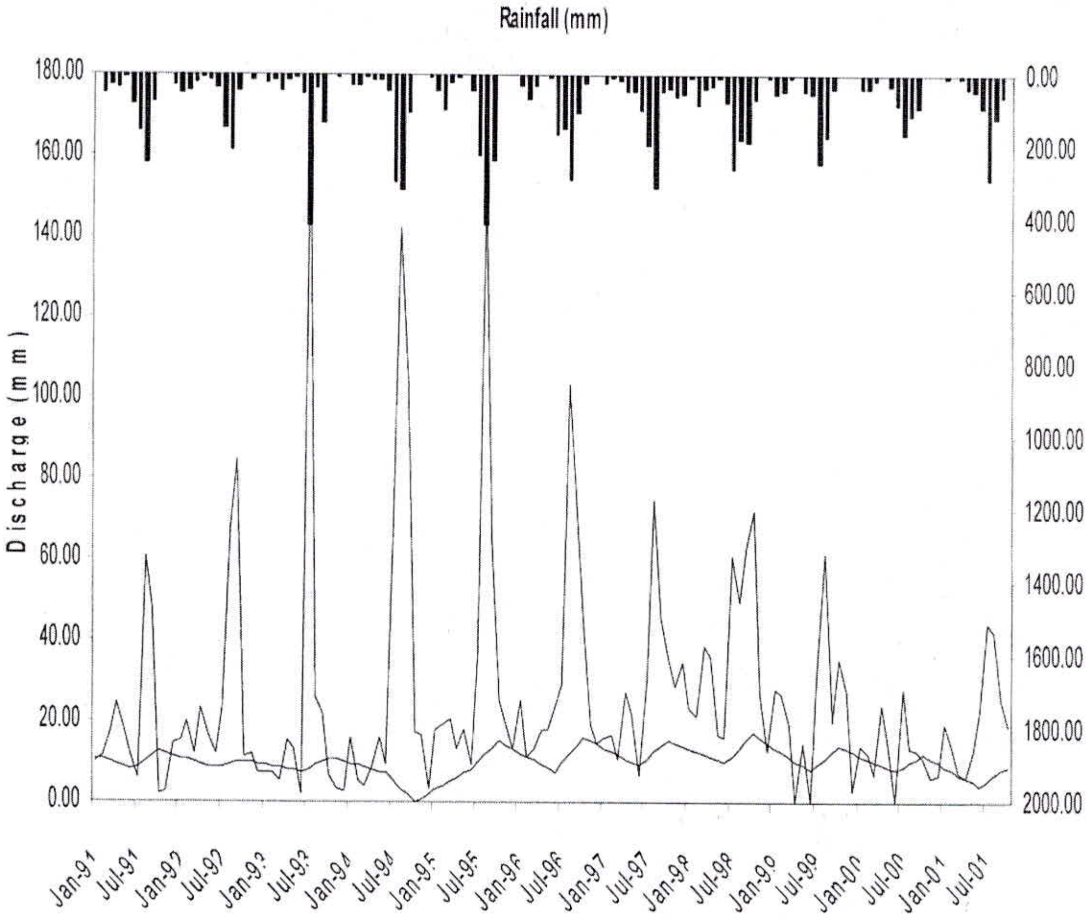

Fig.20: Monthly Average Rainfall, Discharge at Harike and Average depth to water table

Water table fluctuations

The groundwater fluctuations are analyzed on the basis of local level as well as regional level as described in the following sections.

(a) Local level fluctuation

In the present study, local level fluctuations are analyzed considering short term of ten years from 1991 to 2002 and long term of thirty years from 1972 to 2002 for various districts.

In Jalandhar District, short term depletion was recorded from 1.0 to 1.5 m while an average long term depletion of 0.15 to 0.20 m was observed indicating more water table depletion in the short term analysis. This may be because of low rainfall in the area resulting in low monsoon flows in the river and more groundwater draft however, no depleting trend was observed in Nawan shahar district. In Kapurthala district, the short term depletion was observed from 1.0 to 1.5 m and average long term depletion ranged between 0.1 to 0.15 m. The short as well as long term analysis indicated water logging condition in Sultanpur Lodhi block showing that base flow is converging towards the confluence point of Satluj and Beas Rivers and some share of it may be emerging as river flow in Harike gauge site, the same observation is also reported by CGWB. The short term as well as long term analysis did not show any depletion in water table in Ludhiana district. In Hoshiarpur district, no long term depletion is observed, however short term analysis exhibit a small change in pre-monsoon water table condition. There was a temporal fall in water table due to scanty rainfall which gets recouped with subsequent good rainfall years. In Ropar district, the present analysis does not show any short or long term depletion in water table however, there was incidental fall which may gets recouped in subsequent years of good rainfall. It is also noticed that rainfall and Satluj River may be influencing the shallow groundwater table. The bordering districts such as Amritsar, Gurdaspur and Ferozpur were also included for short term analysis. In Amritsar district, a continuous depletion trend was observed during short term analysis however, Gurdaspur and Ferozpur districts did not depict any such trend in the analysis. A rise in water table had been noticed in some of the places in these two districts.

(b) Regional level fluctuation

In this study pre and post-monsoon water table contours are developed for the year 1991, 1995, 1998, 1999, 2000 and 2001. The water table contours revealed that pre-monsoon water table contours do not have much change however, the post monsoon water table contours changed according to the amount of rainfall occurred during that year. The pre and post-monsoon water table contours for the above years are shown in figures from 21 to 32. The analysis has indicated that the pre-monsoon water table condition reaches to steady state irrespective of the post monsoon water table condition of the previous year. Seasonal water table fluctuations for the year 1998, 1999 and 2000 shows that the fluctuations are more in the regions around Satluj and Beas river stretches in Jalandhar and Kapurthala districts resulting that water table fluctuations in the central Punjab region is governed by the river-aquifer interactions to large extent.

WATER QUALITY ANALYSIS

In the study area, low minerals were found in groundwater in some of the northern districts such as Gurdaspur, Ropar, Hoshiarpur and central districts consisting of Amritsar, Jalandar, Kapurthala, Ludhiana, Patiala, Mansa and Nawan shahar. The values of EC were observed high (>4000micromhos/cm) in some of the western districts such as Ferozpur, Faridkot, Bhatinda, Moga and Muktsar and varying from 4043 to 11017 micromhos/cm at 25^{0}C, which may be attributed to leaking and dissolution of salts. Nitrate concentration was observed more than 100 mg/l at several places in Bhatinda, Faridkot,

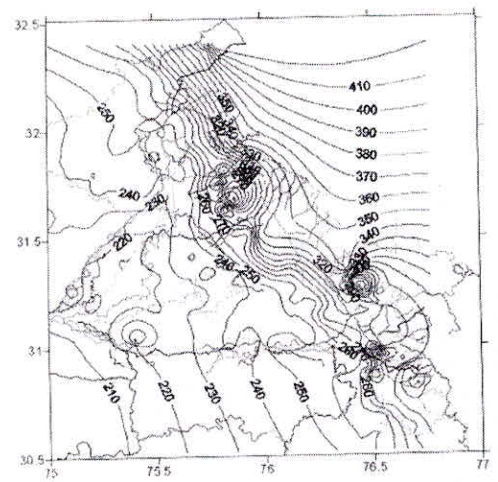

Fig. 21: Pre-monsoon WT Condition for year 1991

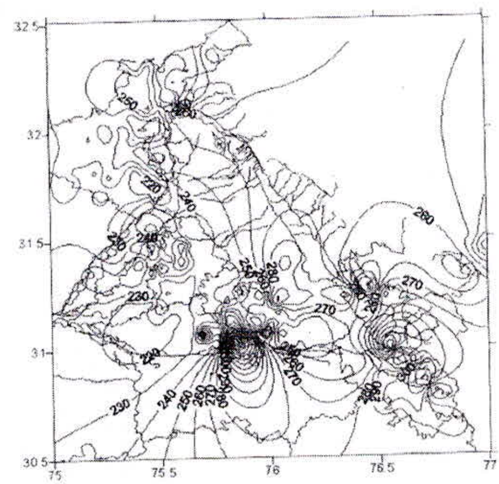

Fig. 22: Post-monsoon WT Condition for year 1991

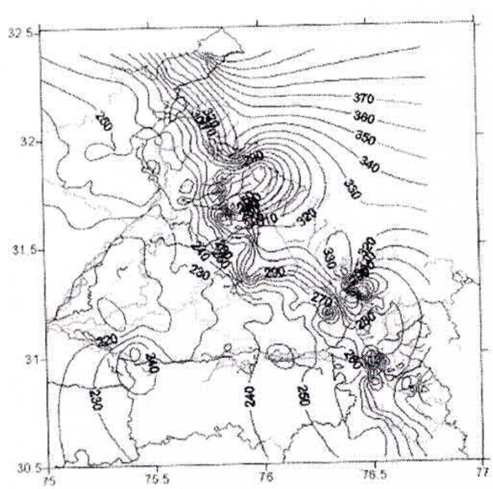

Fig. 23: Pre-monsoon WT Condition for year 1995

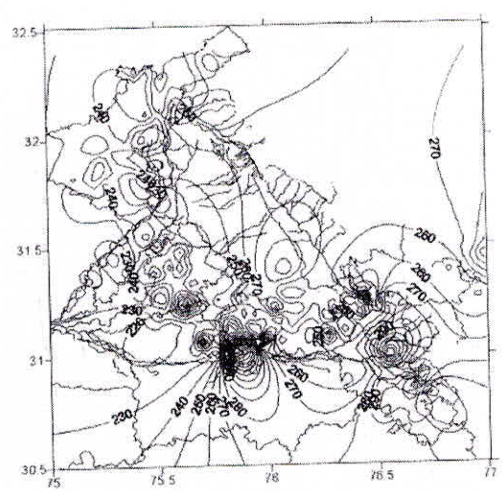

Fig. 24: Post-monsoon WT Condition for year 1995

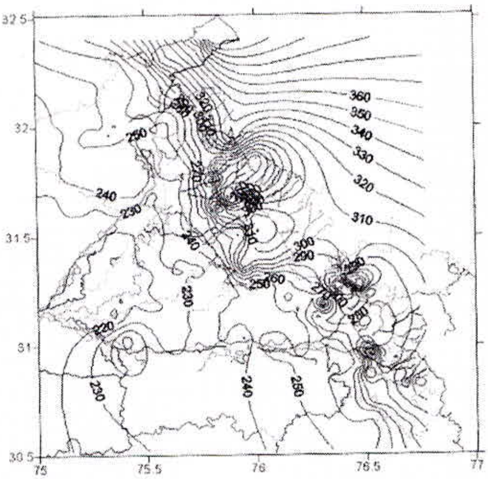

Fig. 25: Pre-monsoon WT Condition for year 1998

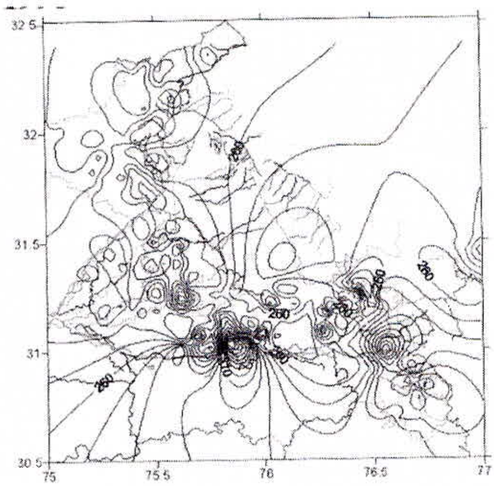

Fig. 26: Post-monsoon WT Condition for year 1998

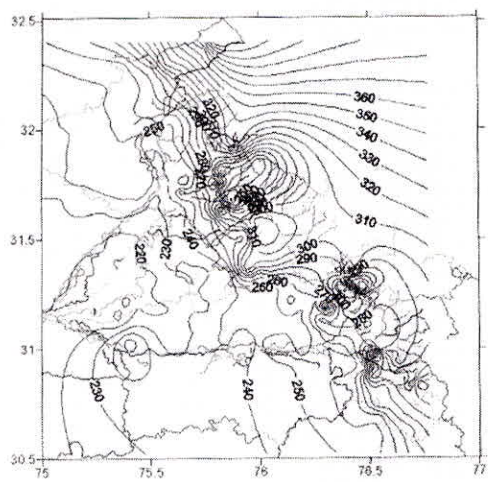

Fig. 27: Pre-monsoon WT Condition for year 1999

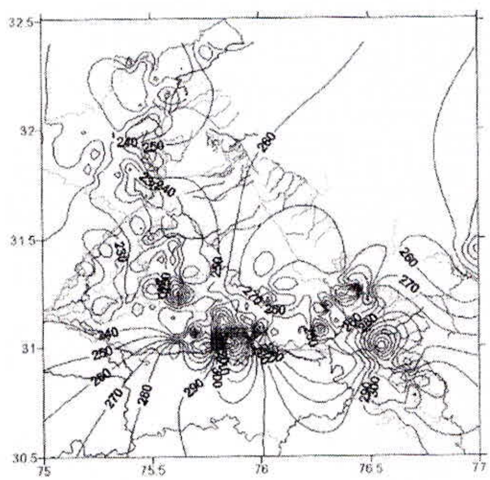

Fig. 28: Post-monsoon WT Condition for year 1999

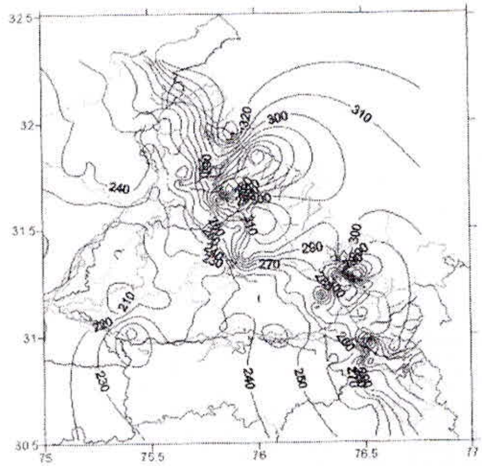

Fig. 29: Pre-monsoon WT Condition for year 2000

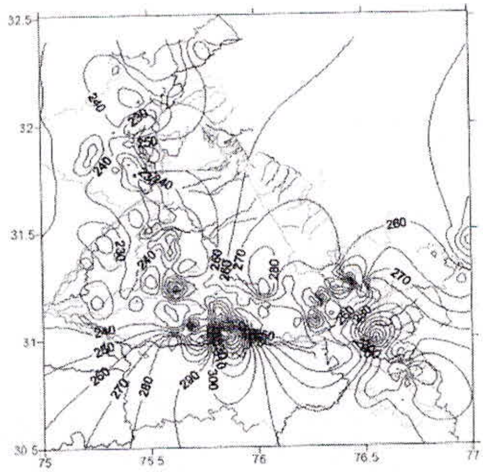

Fig. 30: Post-monsoon WT Condition for year 2000

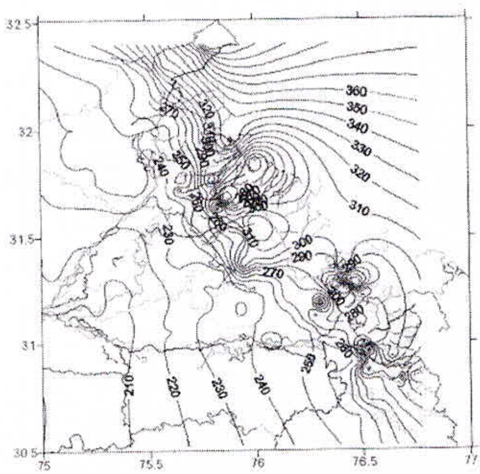

Fig. 31: Pre-monsoon WT Condition for year 2001

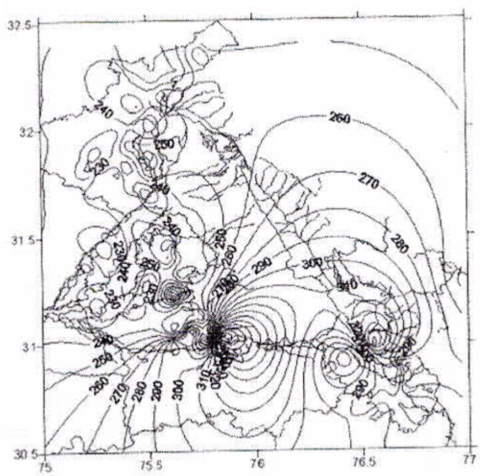

Fig. 32: Post-monsoon WT Condition for year 2001

Ferozpur, Hoshiarpur and Sangrur districts and at one or two locations in Jalandar, Ludhiana, Moga, Patiala, Muktsar and Nawan shahar. Also, the Nitrate concentration was observed more than the mandate limit of 45 mg/l in the entire districts except Amritsar, Gurdaspur, fatehgarh Sahib, Ropar Kapurthala and Mansa. The high concentration of nitrate in the groundwater of the area may be mainly due to leaching of nitrate from fertilizers and sewage from human and animal sources. The fluoride concentration in many districts of the study area was observed more than the desirable limits of 1.0 mg/l for drinking water. In the northern districts, it is comparatively low while in Amritsar, Bhatinda, Faridabad, Ferozpur, Jalandhar, Moga, Muktsar, and Sangrur districts the fluoride values were high varying up to 6.4 mg/l in Moga district. It was also observed that potassium concentrations were exceptionally high in groundwater at several places in districts of Faridkot, Bhatinda and Sangrur.

In districts such as Nawan shahar, Jalandhar, Kapurthala, Hoshiarpur, Ludhiana and Ropar the groundwater is mostly of CaHCO3 type and at few places either NaCl type or mixed type, while in other districts such as Gurdaspur, Amritsar, Ferozpur, Faridkot, Sangrur Bhatinda and Patiala, the groundwater is generally NaHCO3 type and at some places, it is either NaCl type or mixed type. At several places in the study area the groundwater was not found suitable for drinking and other domestic purposes due to either high soluble salt contents or high nitrate or high fluoride present in the water. The chemical data also reveals that at many places in all the districts, the groundwater was not found suitable for irrigation too.

RESULTS AND DISCUSSION

District wise annual variation of rainfall shows that in almost all the districts, a continuous fall in rainfall pattern was observed in recent years, since year 1997. The water table contours revealed that pre-monsoon water table contours do not have much change however, the post monsoon water table contours changed according to the amount of rainfall occurred during that year. In this study, the recent observations indicate the declining trend in ground water table and decreasing runoff at the outlet. It may be attributed to the reduction in rainfall recharge and overexploitation of the ground water table in the region. Long term analysis shows that more water table fluctuations are observed in the regions around Satluj and Beas river stretches in Jalandhar and Kapurthala district. Long term depletion in water table is noticed in Kapurthala and Jalandhar district, whereas all other places are facing short term depletion problem. Moreover, Satluj river water levels are sensitive to groundwater levels in the study area but need to be studied further in conjunction with Ghaggar river basin. The short as well as long term analysis indicated water logging condition in Sultanpur Lodhi block showing that base flow is converging towards the confluence point of Satluj and Beas Rivers and some share of it may be emerging as river flow at Harike gauge site, the same observation is reported by CGWB. The depth to water table varies spatially from almost near surface to about 50 m below the land surface in alluvial deposits of the study area. Water table is deeper in Kandi belt and near logging condition in parts of southwestern districts, whereas in remaining parts of the state, the water table remains between 3 to 10 m. below the land surface. The general ground water slope is towards southwest. The water table is deep along the eastern fringe of Hoshiarpur and Ropar districts underlain by Kandi formations. At several places in the study area the groundwater was not found suitable for drinking and other domestic purposes due to either high soluble salt contents or high nitrate or high fluoride present in the water, moreover the groundwater also was not found suitable for irrigation

CONCLUSIONS

The following conclusions are drawn from the above discussion.

A continuous fall in rainfall pattern was observed in all the districts in recent years, since year 1997. Long term depletion in water table is noticed in Kapurthala and Jalandhar district, whereas all other places in the study area are facing short term depletion problem. The pre-monsoon water table does not have much variation however, the post monsoon water table changes according to the amount of rainfall occurred during that year. Water table fluctuations in the central Punjab region are governed by the river-aquifer interactions to large extent. In this study, the recent observations indicate the declining trend in ground water table and decreasing runoff at the outlet, moreover, Satluj river water levels are sensitive to groundwater fluctuations in the study area. The groundwater was not found suitable for drinking and other domestic purposes at several places in the study area moreover, the groundwater also was not found suitable for irrigation

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