WATER RESOURCES MANAGEMENT AND ARTIFICIAL GROUNDWATER RECHARGE MEASURES IN BIST- DOAB REGION, INDIA

P. Purushothaman, M. Someshwar Rao, Y.S. Rawat & C. P. Kumar
Hydrological Investigation Division, National Institue of Hydrology, Roorkee- 247667, India
Corresponding Author: purus26@gmail.com

KEYWORDS

ABTSRACT

The Beas-Satluj interfluves region of Punjab, popularly known as Bist- Doab is one of the groundwater stressed region in the country. The major rivers in this region are the two perennial R. Satluj and Beas. Other seasonal streams in this region are Kali/ West Bein and White/ East Bein. The region is also drained by canal network of River Beas in Northern part (Kandi Canal) and River Satluj in eastern and central part (Bist- Doab Canal). These canals are not perennial and operated during major agricultural period as it serves mainly for irrigation purposes. Over exploitation of groundwater has resulted due to increased agricultural activity resulting in decline of groundwater table with stage of groundwater development exceeding100% in almost all the blocks of Bist- Doab region. Taking this in view Sh. Gurjit Singh Rana M.L.A Kapurthala constituency of Punjab State, India consulted NIH Roorkee to look for possibility in improving groundwater/ surface water conditions in this part of Punjab. To overcome deteriorating water resources conditions in Bist- Doab region a systematic study has been carried out with following objectives: surface recharge sources and conditions, availability of groundwater, utilization of water resources and future demand and management measures. Study using stable isotopes shows recharge from Bist- Doab canal is very minimal and rain water act as a main source of groundwater recharge in this region. The tritium dating methods shows shallow groundwater gets recharge mainly in northern part of Bist- Doab region especially near in Kali Bein catchment. Kali Bein catchment, in northern part of Bist- Doab region, shows excess availability of groundwater where as White Bein catchment, in central and southern part of Bist-Daob region shows very old groundwater indicating very little recharge. Bist- Doab canal is not perennial as water from R. Satluj is also diverted for southern part through Sirhind canal at Ropar head works. Kandi canal transfers water from R. Beas to Kandi zone of Bist- Doab region. The water transferred is huge and covers little area when compared with Bist- Doab canal covering large area. Hence, with the assumption that this water can be additionally passed through Bist- Doab region, to decrease groundwater stress and increase recharge conditions in the region, following viable links are identified: R. Beas and head works (Origin point) of R. Kali Bein (Link 1) and R. Beas with Kali Bein in downstream (Link 3) can be linked to increase water in western parts. Water from Link 1 can be transported using Kali Bein and can be linked to Bist- Doab canal by constructing a joining canal and Bist- Doab canal be used for distributing water to the central and southern parts (Link 2), keeping Kandi canal perennial and joining Kandi canal with White Bein for distribution of water for central and southern region (Link 4) local and major dams can be judiciously used for keeping the Kandi canal perennial. This management measure will help to increase perennial conditions of surface water sources, and augmenting surface water condition without affecting local environment.

1. INTRODUCTION

Groundwater is an essential resource for drinking, irrigation and industrial purposes. However, groundwater resources are under stress due to rapid population growth, urbanization, industrialization and agriculture activities. Punjab State in the northwestern part of India is facing severe groundwater stress due to intensive agricultural and other activities. The economy of the state depends mainly on agriculture. The total geographic area used for agricultural purpose in the state is about 85% of the total area out of which 97% area is irrigated (Gupta, 2011). As surface water resources (river ad canal network) are very limited and used to its maximum extent dependency on groundwater has increased day by day to meet increasing water demand for agricultural, domestic and industrial purposes. The total demand for irrigation water in the state is estimated at 4.38 million-hectare meters with the existing technology and cropping pattern. But the total supply from both surface and annual recharge of ground water is only 3.13 million-hectare meters. The annual deficit turns out to be 1.25 million-hectare meters (Sondhi and Khepar, 1995) which is met through over explotation of groundwater reserves, resulting in

rapid decline in water table (Tiawana et al. 2007). As the shallow groundwater is not sufficient for excess draft, water from deep aquifer has been pumped by using tubewells. The area under irrigation by groundwater through tube wells had increased from 55 to 72 percent during 1970-2006 with the corresponding decrease in the area under irrigation by canals (Vashisht, 2008; Statistical Abstracts, 2009). This has resulted in fast decline in water table and use of ground water in excess of recharge is leading to a fall in water table. The annual average rainfall has also decreased from 739.1 mm in 1980 to 529.2 mm in 2008 (Statistical Abstracts, 2009), which is putting extra pressure on groundwater resources.

Bist Doab region, the interfluves of Rivers Sutlaj and Beas, in Punjab is also experiencing severe groundwater depletion due to increasing agricultural activities and physiology of the region. In general, water levels are declining in region on a long term basis. The net groundwater availability in Bist-Doab region is much smaller than the total groundwater draft (CGWB, 2007 a-d). Thus, the pressure on groundwater resources is continuously increasing. Therefore, to maximize production per unit of resources, it is emphasized to utilize every drop of water available sensibly and carefully. Hence, it becomes imperative to understand the availability of water resources, water level behaviour and measures that can be adopted to improve groundwater resource in the region. Taking this in view Sh. Gurjit Singh Rana M.L.A Kapurthala constituency of Punjab State, India consulted NIH Roorkee to look for the possibility in improving groundwater/ surface water conditions in the Bist- Doab region of Punjab. To overcome the deteriorating water resources conditions in the Bist- Doab region a systematic study has been carried out with the following objectives: the surface recharge sources and conditions, availability of groundwater, utilization of water resources and future demand and management measures.

2. STUDY AREA

The Bist Doab is a triangular region and covers an area of 9060 km^2. The area lies between 30°51' and 30°04' N latitude and between 74°57' and 76°40' E longitude. The region comprises Hoshiarpur, Kapurthala, Jalandhar and Nawan Shahar districts of Punjab State, India (Fig. 1). The average rainfall in Bist- Doab region for the past century (1901- 2002) shows that the region receives maximum rainfall during monsoon period i.e. June to October with almost 80% of total rainfall in a year. The minimum rainfall is during November with the amount less than 10 mm. Long term rainfall patterns shows that maximum rainfall occurred during monsoon of 1980 and almost no rainfall in the winter of 1943. The rainfall pattern in late 90s and early 2000's shows a decreasing trend in the rainfall amount in entire Bist-Doab region.

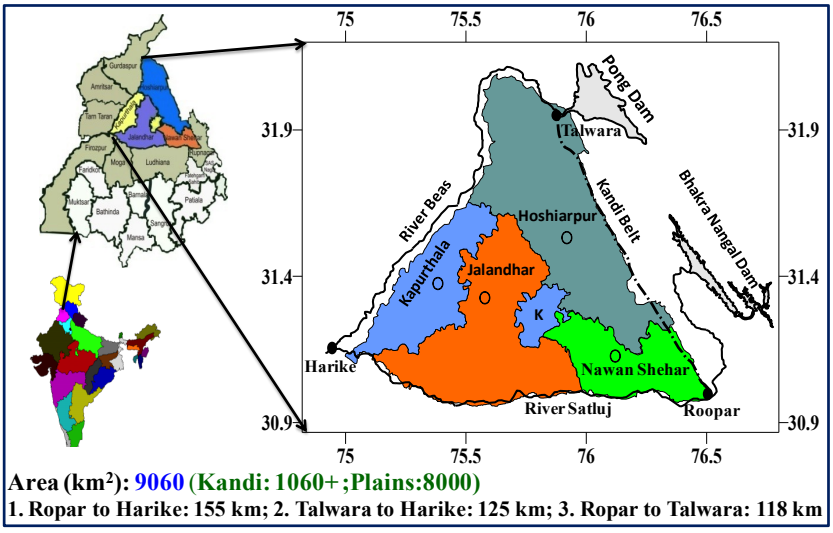


Figure 1 Bist-Doab region

The major rivers in this region are the two perennial R. Satluj and Beas. These two rivers are dammed before entering the region by Pong Dam (R. Beas) and Nangal Dam (R. Satluj). Other seasonal streams in this region are Kali/ West Bein and White/ East Bein. Besides these, the Kandi region is full of seasonal streams. The drainage density is high in the north east strip bordering the Siwaliks, but it is moderate to low in the rest of the area with sub-parallel and sub-dendritic patterns. The region is also drained by canal network of River Beas in the Northern part (Shah Nehar Canal/ Kandi Canal) and River Satluj in the eastern and central part (Bist- Doab Canal). A part of kandi canal which covers Kandi region is under construction. These canals are not perennial and the canal network is operated during the major agricultural period as it serves mainly for irrigation purposes. There are few small dams in the Kandi region which are used to store water from seasonal streams/ rivulets for irrigation and domestic purposes. The water table elevation is highest in the north-eastern part (Kandi area) and lowest in the south-western part, which in turn reflects the topographic gradient. The distribution of depth to water table in the region is non-uniform. In the southern and south-western region it is in the range 20-25 m bgl and at a few locations the depth extends down to 30 m bgl. In the northern part, the water table is within 4m bgl. In the canal network region, water table is usually within 10m reach. The stage of groundwater development in almost all the blocks of Bist- Doab region exceeds 100% making the region over exploited in groundwater. The block like Saroya, balachaur and Talwara shows less groundwater stage making them safe category. The Talwara block has least development of ground water i.e. 45% and Lohian block has maximum development of groundwater (418%) among all blocks.

3. MATERIALS AND METHODS

Groundwater is under considerable stress since it is the most exploited source for irrigation and drinking purposes. To understand the groundwater conditions, the region is mapped with respect to the present day available of water resources, flow pattern, landuse, soil conditions, terrain elevation and changing water demand. The relevant data and literature has been collected from various state and central organizations and academic institutions.

3.1 Data Collected

Hydro meteorological data such as, rainfall is collected from Department of Agriculture, Punjab Government. Depth to water table for the period 1998-2008 and long term data at few locations has been collected from CGWB, NWR Chandigarh. For deriving DEM, elevation data at 30 m x30 m resolution was of open source ASTER data was downloaded. Landuse and soil details were procured from Punjab Remote Sensing Agency. For stratigraphic details, strata chart for 26 locations distributed uniformly in space was collected from CGWB and State Groundwater Department.

3.2 Samples Collected

For characterizing water types, all the three types of waters namely, precipitation, surface water (Ponds, rivers, canals etc.) & Groundwater were sampled. Groundwater samples were collected from aquifers at different depths (shallow < 30m, intermediate ~ 60 m and deep wells >120 m) using existing hand pumps and tube wells and peizometeres at both pre & post monsoon periods. Regular sampling of rainfall is collected from 13 locations from different part of Bist- Doab region. Surface water sampling (river/ Dam) is done from 13 locations on ten daily intervals. Groundwater (both shallow and deep) from 5 locations (Harike, Ropar, Maili, Dolbaha and Garhshankar) is collected on ten daily basis, 16 shallow groundwater samples are collected on ten daily bases to understand surface water- groundwater interaction. Apart from these sample seasonal groundwater (from deep and shallow) sampling were made from 26 location.

3.2.1 Sample Analysis

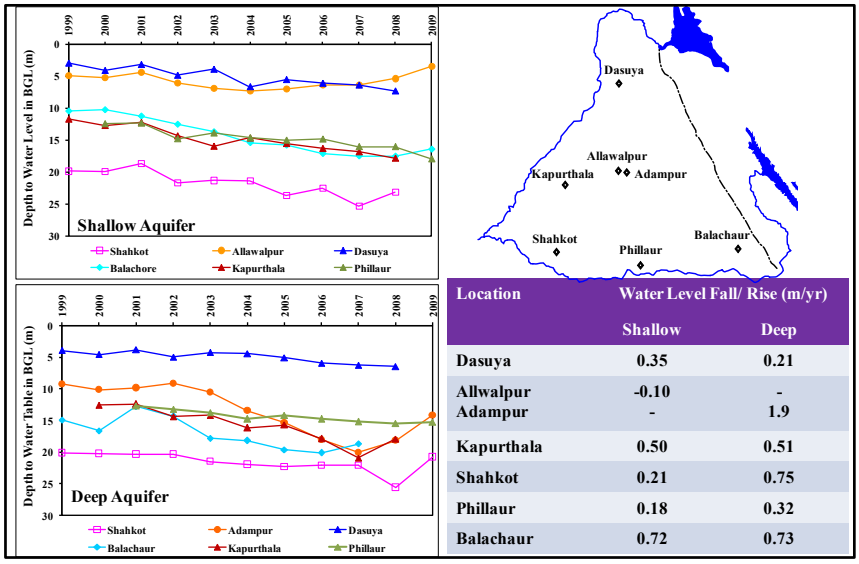
Collected water samples were analyzed for physical parameters such as pH, EC at field during sample collection. The samples were collected in 100ml polyethylene bottles for stable isotope and chemistry analysis and 500ml polyethylene bottles for environmental tritium analysis. The samples were analysed for major cation and anions using Dionex ICS 5000 ion chromatograph at National Institute of Hydrology,

Roorkee. The samples were also analysed for bicarbonate by titration techniques as described in APHA. The total ionic balance of the samples is within 15%.
Stable isotopes ($\delta^{18}O$, δD) were analysed on DI-IRMS and CF-IRMS and Tritium using electrolytic enrichment and Ultra Low Level Liquid Scintillation Counting facility of National Institute of Hydrology, Roorkee. The error limit for isotopic analysis is within 0.1‰ for $\delta^{18}O$ and 1‰ for δD.

4. RESULTS AND DISCUSSIONS

4.1 Groundwater Depth to water table

The peizometric head of groundwater in the study region has been studied for both shallow and deep aquifers. For easy understanding of the groundwater depth in the region the study area have been divided into four parts: 1) North region; 2) Kali Bein region; 3) Central region and 4) Southern region. The northern region comprises of Mukerian, Talwara and Hazipur shows that the peizometric depth in this region is very shallow i.e. less than 10m below ground level (BGL). The depth to water table in pre monsoon period is almost constant from 1999 to 2009 but in post monsoon period the location Mukerian shows high fluctuation in groundwater depth indicating recharge of groundwater during monsoon periods in this location. In Kali Bein region shallow groundwater shows continues decline in groundwater table from 1999- 2009 in all the locations in this region except Durmiwal which is in the northern most part of the kali Bein catchment. The piezometric head of groundwater in the deep aquifer shows negligible amount of seasonal fluctuation with decreasing water table in the downstream of the Kali Bein region. The piezometric head of shallow and deep aquifer in the central region is very deep when compared with other regions of the study area with water table below 20m in locations like Jalandhar, Nakodar and Phagwara. The water table at deep aquifer in Kandi region is deeper which is evident from high depth of water table at Hoshiarpur. The southern region of the study area also shows similar characteristics to that of central region with negligible seasonal change in piezometric head both in shallow and deep groundwater. Shahkot which is situated in the downstream, towards Harike, in this region shows higher depth to water table.



Location	Water Level Fall/ Rise (m/yr)	
	Shallow	Deep
Dasuya	0.35	0.21
Allwalpur	-0.10	-
Adampur	-	1.9
Kapurthala	0.50	0.51
Shahkot	0.21	0.75
Phillaur	0.18	0.32
Balachaur	0.72	0.73

Figure 2 Variation in Depth to Water Table in Selected Deep and Shallow Aquifer

The groundwater draft has been continuously increasing in the Bist- Doab region. The groundwater availability (Fig. 3) shows maximum availability (>15000MCM) upto 5-20 km near the river Satluj and in Mukerian block near river Beas in this region. The groundwater availability decreases from central zone to central region of Kandi. The Jalandhar district shows maximum amount of groundwater draft with

maximum of 30,000MCM/yr. The groundwater stage (Fig. 3; Table 1) in the region shows that most of the area is over exploited (22 out of 30 blocks) with groundwater stage more than 100%.

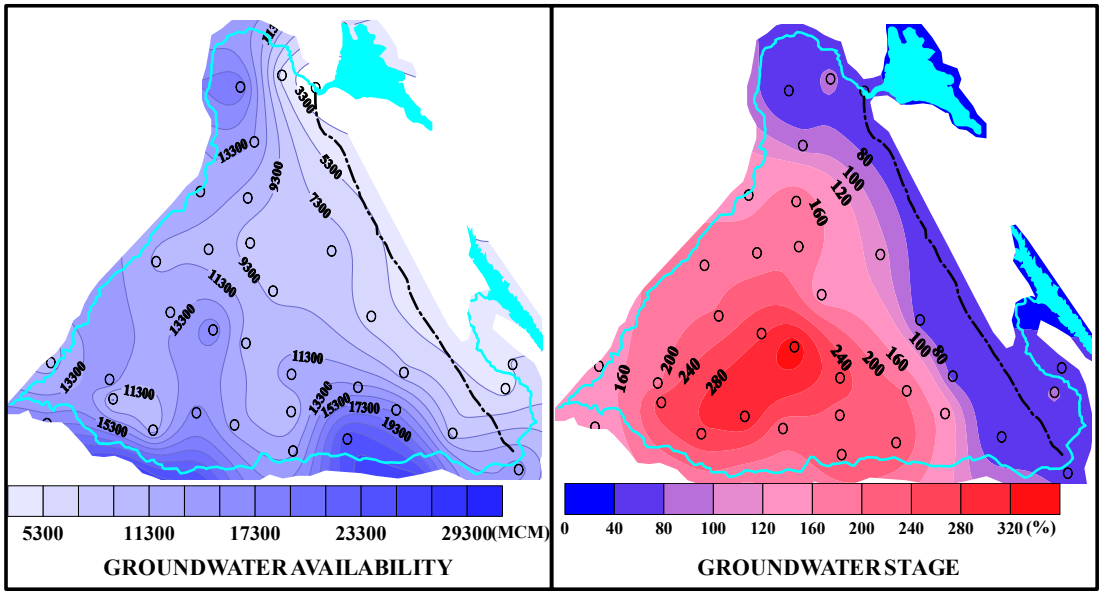


Figure 3 Groundwater Availability and Stage (2004) in Bist-Doab Region

Table 1 Categorization of groundwater stage in bist-doab region

S.No.	District	Semi-Critical	Critical	Over-Exploited
1.	Hoshiarpur (Total 10 blocks)	1 Garh Shankar 2 Hazipur	- -	1 Hoshiarpur-I 2 Tanda
2.	Jalandhar (Total 10 blocks)			1 Adampur 2 Bhogpur 3 Goraya 4 Jal-east 5 Jal-west 6 Lohian 7 Nakodar 8 Nurmahal 9 Phillaur 10 Shahkot
3.	Kapurthala (Total 5 blocks)			1 Bholath 2 Dhilwan 3 Kapurthala 4 Phagwara 5 Sultanpur
4	Nawan shahar (Total 5 blocks)			1 Aur 2 Banga 3 Nawanshahar

4.2 Cropping Pattern and Water Utilized for Irrigation

The groundwater over exploitation in the region is mainly due to the agricultural activities. To find out the water utilized by various crops for cultivation in the study area we used virtual water required for various crops (Table 3) (Kumar & Jain, 2007). The virtual water required for various crops in the study area have been calculated by multiplying the virtual water amount with the area of irrigated land for the crop of interest.

The study shows that although area used for irrigation of wheat is more than rice the water consumed by the latter is more than the former. The groundwater utilized per unit area (m/ha) is highest in Jalandhar district followed by Kapurthala district and least in Hoshiarpur district (Fig. 4). This is mainly because of the cropping pattern in these districts. It is evident from Fig. 5 that the rice is the major crop in Jalandhar and Kapurthala districts which requires more water than other crops. The amount of wheat grown in all the districts in Bist- Daob is similar (Fig. 5) hence the major water utilizing crops in this region are Rice and maize.

Table 3 Water Requirement for Various Crops (Kumar & Jain, 2007)

S. No	Product	Virtual Water (m^3/tonne)	Bist- Doab Region		
			Total Area		VWR
			(km^2)	(%)	(m^3)
1	Cotton Seed	8264	***5***	***0.04***	***16528***
2	Rice	2850	***3564***	***28.63***	***3602717***
3	Maize	1937	***1321***	***10.61***	***593368***
4	Wheat	1654	***4964***	***39.88***	***3367360***
5	Sugar Cane	159	***491***	***3.94***	***44096***
6	others		***2104***	***16.90***	

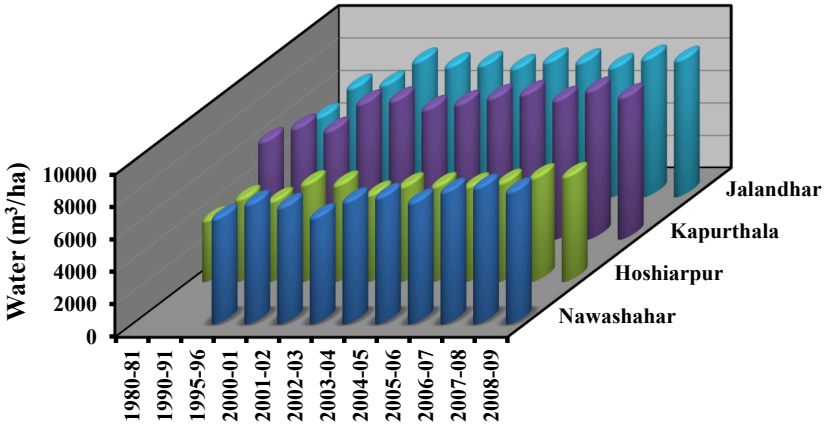


Figure 4 Water Utilized/ Unit Area for Irrigation in Bist- Doab Region

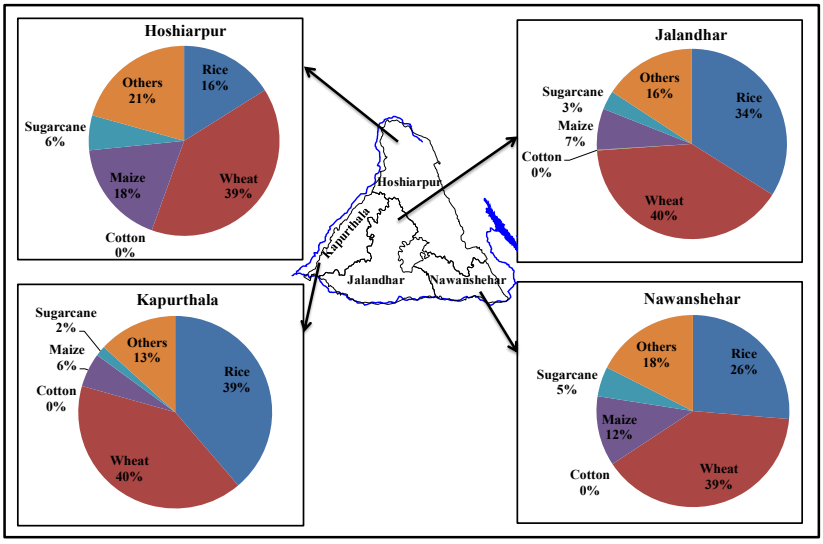


Figure 5 Crop Area Distribution in Bist-Doab Region (2000-09)

4.3 Isotopic Characterization of Waters & Identification of Recharge Sources

To characterise the isotopic composition of groundwater and understand recharge source the local meteoric water line and river water lines (for both R. Satluj and R. Beas) were made using the isotopic composition of precipitation in the study area and river water samples (Rao et al., 2010). The spatial distribution of stable isotopic composition ($\delta^{18}O$) of shallow and deep groundwater in the study area shows enriched character in northwestern region of the study area compared to that of the other parts of the region. The stable isotopic composition of deep groundwater shows that groundwater in study area flows from Kandi belt to towards the confluence of Rivers at Harike. Shallow groundwater isotopic composition indicates recharge mainly (approx. 90%) through precipitation. Possible recharge from rivers is limited to river banks and is evident from river- groundwater interaction with maximum recharge of 9% of total study area. Groundwater recharge through Bist- Doab canal is approx. 1% of total study area (Purushothaman et al 2011).

4.4 Environmental Tritium

To clearly understand the residence time of the groundwater in different aquifers the environmental tritium was analysed in rain, river and groundwater samples. The study shows that average environmental tritium activity in the rain water was 9.2TU and the River water (both R. Satluj and R. Beas) was 8TU. The environmental tritium in shallow groundwater ranges between 8TU to 2TU with average of 5TU and in deep groundwater ranges between 7.6TU to 0TU with average of 1TU (Purushothaman et al. 2012). The study shows that the groundwater in shallow aquifer younger in northern part, in eastern part (at Ropar region) and also at Harike where the rivers the confluence. The shallow aquifer is being recharged by the Kandi canal at north and and R. Satluj at Ropar and Bist Doab canal at Nakodar and Nawanshahar and Balachaur region. Older nature of shallow groundwater at central part of southern region is due to presence of clayey layer. Both Shallow and deeper aquifers are younger at Kandi region. The presence of dams in this region act as recharge sources for deep aquifer. The central region of study area is connected with the Kandi region. The groundwater age is modern in the northern part due to the presence of Kandi canal and in Ropar region where canals of the River Satluj debouches to its northern and southern sides of the river. The groundwater is sub-modern in the central region. The groundwater in the West kali Bein region shows that the groundwater is flushed out fast from the recharge area, i.e. northern part, to the downstream. The lower groundwater age at Nakodar and at Nawanshahar and Balachaur region indicates probable recharge from Bist Doab canal (Fig. 6). The shallow aquifer at the central part of southern region (Fig. 6) is older despite the presence of the River Satluj and Bist Doab canal shows that there is no recharge being done from the surface waters. The deeper aquifer is much older with all the locations showing very lower TU values except at the confluence of rivers and at Ropar where the groundwater is modern. The groundwater adjacent to the Kandi region shows age less than <30yrs, indicating contribution/ recharge of deep aquifer from the Kandi region (Fig. 6). The deep groundwater shows presence of a narrow connectivity between Kandi region and at the central part of study region (Fig. 6).

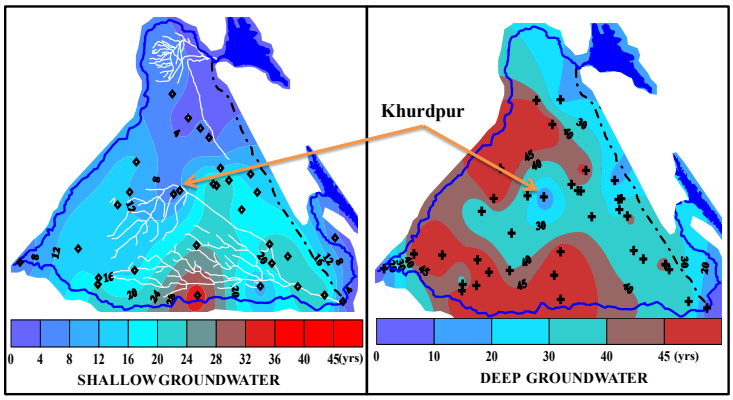


Figure 6 Spatial Distribution of Groundwater age in shallow and deep groundwater in Bist- Doab region

5. MANAGEMENT MEASURES AND ARTIFICIAL RECHARGE OF SHALLOW GROUNDWATER

The stable isotopic study (Section 4.3) shows recharge from Bist- Doab canal is very minimal and the rain water act as a main source of groundwater recharge in this region. The tritium dating methods (Section 4.4) shows the shallow groundwater gets recharge mainly in the northern part of Bist- Doab region especially near in the Kali Bein catchment. The Kali Bein catchment, in the northern part of Bist- Doab region, shows excess availability of groundwater where as the White Bein catchment, in the central and southern part of Bist-Daob region shows very old groundwater indicating very little recharge. The Bist-Doab canal is not perennial as water from R. Satluj is also diverted for the southern part through Sirhind canal at Ropar head works. The water diverted from R. Satluj is maximum for Sirhind canal (12622Cs) where as Bist- Doab canal is (1408Cs). In case of R. Beas, it is acting as a natural conduit to transfer water from Pong dam to Harike. The only canal which diverts water is Shah Nehar/ Kandi canal which transfers water (11500Cs) from R. Beas to Kandi zone of Bist- Doab region. The water transferred is huge and covers little area when compared with the Bist- Doab canal which covers large area. Hence, this water can be additionally passed through Bist- Doab region to decrease groundwater stress and to make the canal and local streams perennial and increase recharge conditions in the region. With the assumption that water for the Bist- Doab region can be taken only from R. Beas four viable links are identified (Figure 8):

Link1&3: for increase water in western parts
Link 2: between Kali bein and White Bein rivers
Link 4: Central & Southern part (to make white Bein perennial)

1) R. Beas and head works (Origin point) of R. Kali Bein and using the Kali Bein to transport water, then the water from Kali Bein can be linked to Bist- Doab canal by constructing a joining canal and Bist- Doab canal be used for distributing water to the central and southern parts.
2) Keeping Kandi canal perennial and joining Kandi canal with White Bein for distribution of water for central and southern region, as the Kandi canal is in lower level when compared with the level of Satluj canal a direct link can be made. Or the aqueduct (Kandi canal and the seasonal streams/ White bein) can be connected with Kandi canal and seasonal stream/ White Bein.
3) The local and major dams (like Maili, Dolbaha, Pong dam etc.) can be judiciously used for keeping the Kandi canal perennial.

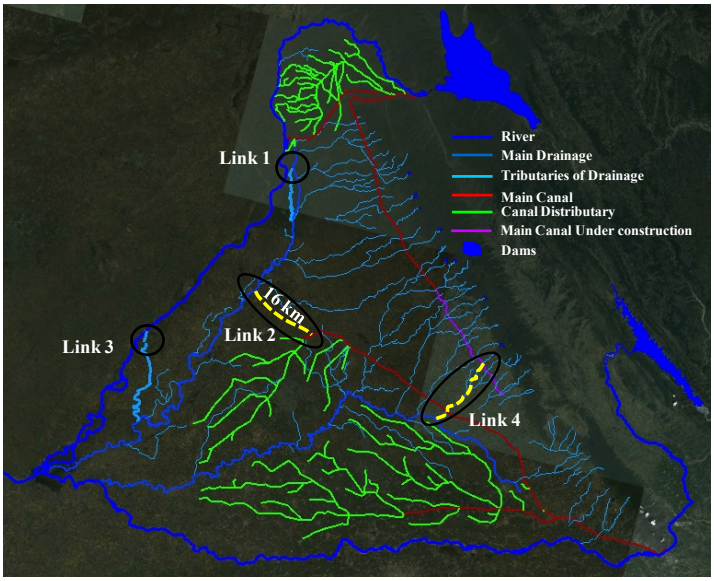


Figure 8 Proposed Links from River Beas to Central part of Bist- Doab Region

This was based on the minimum distance between two stream/ stream and canal/ canal – canal which are to be connected with minimal disturbance to the existing network. This has also taken construction

cost of these links into account. This management measure will help to increase the perennial conditions of surface water sources, and augmenting the surface water condition without affecting the local environment. Maintaining the required water discharge in R Beas will help to maintain the local ecololgy. As water from all these streams, canals confluve at Harike through well controlled nework of streams and canals the water logging problem at harike can be made more eco friendly. The proposed links fulfills water requirement for the entire bistdoab region and reduces the stress on R Satluj by inter linking R. Beas with Staluj canal network. As suggested by Sh. GS Rana, the detailed project report and implementation of this study can be taken up jointly with BBMB & Department of irrigation Punjab with help of planning commission.

REFERENCES

Aggarwal, R., S. Kaur, & P. Miglani (2009) Blockwise assessment of water resources in Jalandhar district of Indian Punjab. *Journal of Soil and Water Conservation* 8(3): 69-73.

Aggarwal, R., S. Kaur, & P. Miglani (2010) Assessment of water resources in Shaheed Bhagat Singh Nagar- A case study. *Journal of Soil and Water Conservation* 9(4): 288-300

CGWB (2007 a) Ground water scenario of Jalandhar District, Punjab. Central Ground Water Board North Western Region, Chandigarh, 2007, pp- 15.

CGWB (2007b) Groundwater Information Booklet Kapurthala District Punjab. Central Ground Water Board, North Western Region, Chandigarh, 2007, pp- 20.

CGWB (2007c) Ground Information Booklet Hoshiarpur District, Punjab. Central Ground Water Board North Western Region, Chandigarh, 2007, pp- 15.

CGWB (2007d) Groundwater Information Booklet Nawan Shahar District, Punjab. Central Ground Water Board North Western Region, Chandigarh, 2007, pp- 20.

Gupta, S (2011) Ground Water Management in Alluvial Areas. Available at: www.nass.usda.gov.http://cgwb.gov.in/documents/papers/incidpapers/Paper%2011-%20sushil%20gupta.pdf. Accessed 4 December 2011.

Kumar, V & S.K. Jain (2007) Status of virtual water trade from India. Curent Science, 93: 1093-1099.

Purushothaman, P., M.S. Rao, Bhishm Kumar, Y.S. Rawat, Gopal Krishan, 2011, Stable Isotopic Characterisation of Groundwaters in Bist- Doab Region, Punjab. Proceedings of National Conference in Recent Advanced Techniques in Civil Engineering “RACE-2011”, 14-16 Oct 2011, Banaras Hindu University, India

Purushothaman, P., M.S. Rao, Y.S. Rawat, 2012, mapping the groundwater flow regime in bist daob region, punjab, india using environmental tritium. National Seminar on Applications of Isotopes and Radiation Technology for Societal Benefits (AIRTS- 2012), during 21- 23 June, 2012, Department of Environmental Science, Bangalore University, Bangalore

Rao, M.S., P. Purushothaman, Bhishm Kumar, Gopal Krishan, Y.S. Rawat, Vishal Gupta and P. Garg, 2010, Isotopic Characteristics of waters of Bist- Doab and their Hydrological Significance. Regional Workshop in Proceedings Water Availability and Management in Punjab- 2010, 13-15 Dec. 2010, Chandigarh, India

Statistical Abstract of Punjab (2009) Economic & Statistical Organisation, Government of Punjab

Tiwana, N. S., Jeerat, N., Ladhar, S. S., Singh, G., Paul, R., Dua, D. K. and Parwana, H. K (2007) State of Environment: Punjab- 2007. Punjab state council for science and technology, pp. 243.

Vashisht A. K. 2008. Status of water resources in Punjab and its management strategies. *Journal of Indian Water Resources* 28(3): 1-8.