HYDROGEOLOGY AND SALINITY ISSUES IN PUNJAB

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Introduction

Punjab State, one of the smallest states of India having geographical area of 50,362 sq km (Only 1.5 percent of the geographical area of the country), is per-dominantly an agrarian state contributing around two third of the food grains procured annually in the country and is devoid of any other mineral or natural resource except water. Agriculture in the State is highly intensive which needs heavy requirement of water. The economy of the State and well being of the farmers depend to a large extent on the availability of water. The hard work of the farmers has proudly earned the State the name of "Food Basket of Country".

In Punjab State, although a well-organized canal irrigation system has been developed, the available surface water resources of the State are unable to meet the demand of agriculture as such there is an increasing pressure on ground water resources. The ground water is being over-exploited to meet ever increasing demands of water for diverse purposes i.e. for intensive irrigation, drinking, industry, power generation etc. With the introduction of Green Revolution in the State in mid-sixties, the number of tube-wells increased from a meagre 50,000 in the early sixties to above 70,000 in early eighties, to about 10.70 lakhs in year 2001, 11.80 lakhs in the year 2005-06 to 14.06 lakhs in the year 2014-15 , same has increased to 14.76 Lakhs (2017-18) as per statistical abstract of Punjab.

Over development of groundwater has also brought in the problems of decline in ground water levels, increased salinity in groundwater, increasing incidences of Fluoride occurrences and Arsenic contamination in groundwater. On the other hand there are waterlogged areas in South-Western Punjab. In the present paper an attempt has been made to analyse effect of ground water development on ground water regime and ground water resources of Punjab through the decads.

General Features

Punjab is one of the North Western States of India and covers an area of 50,362 sq km falling between latitude 29°30' N to 32°32' N and longitude 73°55' E to 76°50'E. There are 22 Districts and 146 Blocks in the State. It is one of the most developed State of India where all villages are approachable by metalled roads and all the houses in villages have electricity.

The Punjab State is a flat alluvial plain except a thin belt along north eastern border, where it is

mountainous and in the south western parts, where stable sand dunes are seen dotting the landscape. The slope of the plain is towards South & South West which seldom exceeds 0.4 m/km.

There are 3 perennial rivers namely Sutlej, Beas and Ravi and one non- perennial river Ghaggar in the State. These rivers feed a vast network of canal system in the State and even provide water to Haryana, Rajasthan and Jammu & Kashmir.

Hydrometerology

The climate of the State is semi-humid to semi-arid in the North, arid in the South & southwest and semi-arid in the remaining part of the State. The state experiences four seasons in the year namely, cold season from November to March, hot season from April to June, southwest monsoon season from last week of June to mid of September and post monsoon season from September to beginning of November. During cold weather season, seasons of western disturbances affect the climate of the state and bring rainfall of light intensity.

The State has well-defined rainy period from July to September. There is about 80% rainfall during this period due to South-West Monsoon. Long dry spells are often experienced necessitating irrigation from man-made systems for agriculture. Another period of rainfall is winter rain from December to March is about 20% of total rainfall which is mostly absorbed into the soil hardly resulting into any groundwater recharge.

The rainfall distribution in Punjab State is erratic both in time and space. The annual rainfall in the state varies from about 1000 mm in the northeast to less than 300 mm in the southwest. The areas to the north of Pathankot and near the Shivalik hills receive maximum amount of rainfall while the areas situated in the southwestern side of Punjab (Fazilka) receive minimum amount of rainfall. In the central part of the state, average long term rainfall varies from 400mm to 600mm.

Hydrogeology

The alluvial deposits in the state comprise of sand, silt and clays often mixed with kankar. Sandy zones of varying grade constitute a vast ground water reservoir. The alluvial plain towards the hills is bordered by the piedmont deposits comprising Kandi and Sirowal. Immediately south-west of the hills, Kandi belt is 5 to 8 km wide followed by Sirowal which imperceptibly merges with the alluvial plain. Kandi deposit explored almost down to 450 m bgl show a gradation from boulders to clays, at places an admixture of various grades in different proportions. The Sirowal is essentially composed of finer sediments but occasional gravel beds are also encountered. The saturated sand, gravel or boulder beds constitute the aquifers. **(Fig 1)**

In major part of the state multiple aquifer system exists, the aquifers are formed by granular horizons present consisting of Sand/Gravel. These are separated by finer sediments in the form of thick clays.

In general three broad aquifers have been identifies in the state which diversify from single aquifer system near foothills.

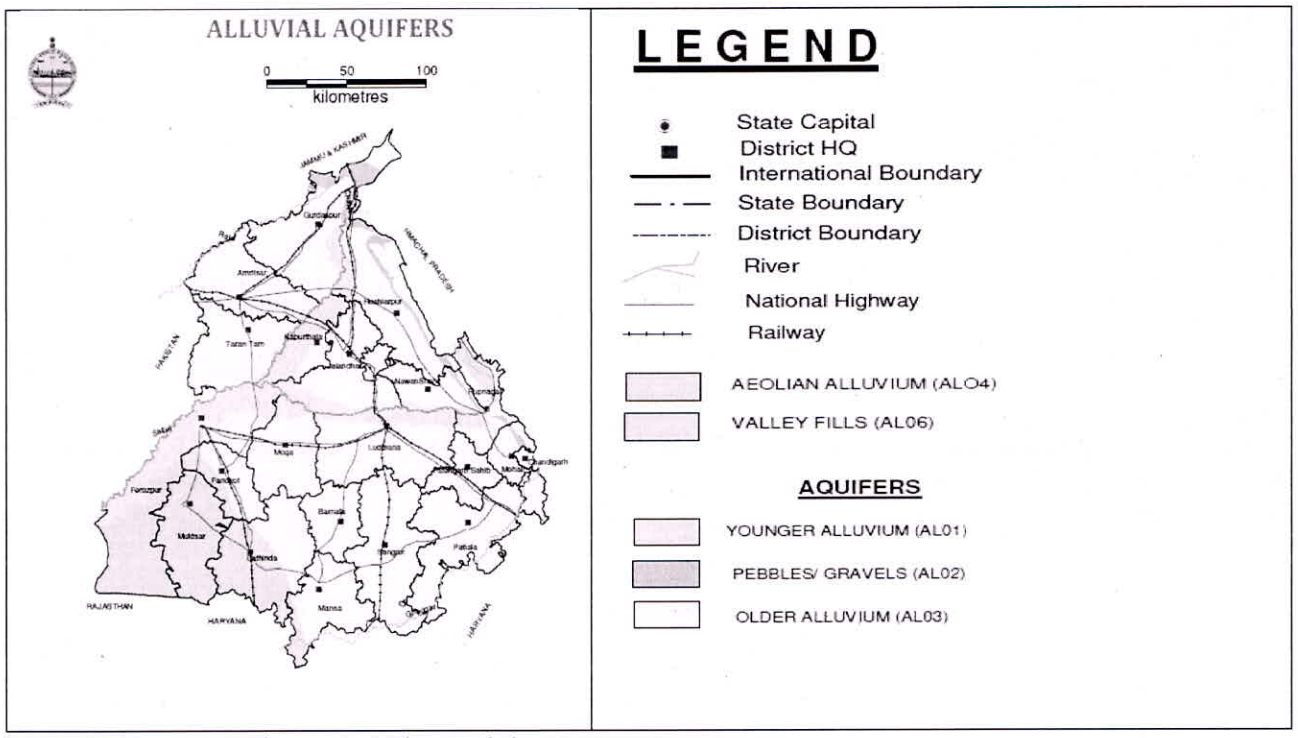


Fig 1: Major Aquifer System in Punjab

Aquifer system in Punjab can be suumerised as per following table.

Fresh Water AQ	Saline Water AQ	
Single Aquifer System Kandi Formation	Single Aquifer System	Single Aquifer with limited freshwater at shallow depth
Pathankot, Parts of Ropar, SAS Nagar and Hoshiarpur Districts.	Muktsar,Parts of Faridkot, Ferozpur, Sangrur, Bathinda, Moga, Mansa	NIL Water Logged Areas- Muktsar, Parts of Bathinda, Fazilka and Mansa.
Multiple Aquifer System (2-3)	Multiple Aquifer System (2-3)	

Amritsar, Barnala, Fatehgarh Sahib, Gurdaspur, Hoshiarpur, Jalandhar, Kapurthala, Ludhiana, SBS Nagar ,Patiala , Tarn Taran, Parts of Faridkot, Ferozpur, Sangrur, Bathinda, Moga, Mansa ,Ropar	NIL

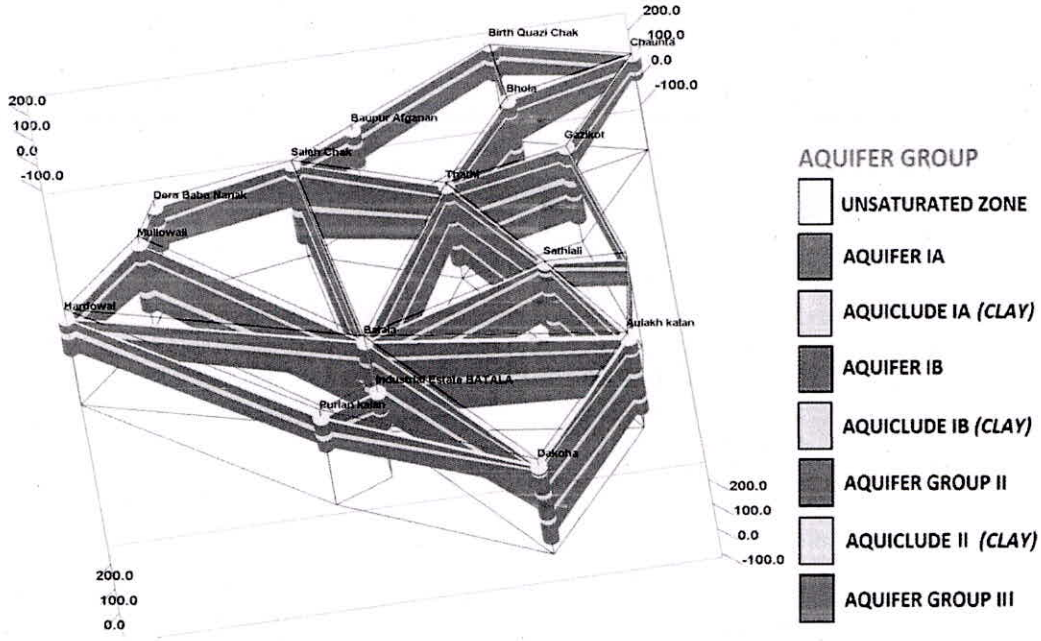


Fig 2: Aquifer disposition in Batala Area, Gurudaspur District, Punjab

Ground Water Regime Monitoring

The Central Ground Water Board, North Western Region, has established Ground water observation wells in Punjab State and Union Territory of Chandigarh for monitoring water level. As on 31.3.2017 there were 964 **Ground Water Observation Wells** in Punjab which include 170 dug wells and 737 piezometers for monitoring shallow aquifers and 57 deep Piezometers for monitoring the behaviour of deeper aquifers in Punjab.

About 80% of the Ground water observation wells fall in the canal command areas of various canal systems, the areas falling out of the major command is part of Pathankot, Hoshiarpur, Nawanshahr, Ropar and SAS Nagar districts, parts of Gurdaspur, Jalandhar and Ludhiana districts.

Behaviour of Water Level

In order to assess the quantitative change in ground water resources, water levels were monitored as a routine of four times in a year. The behaviour of water level in May 2017, August 2017, November

2017 and January 2018 is discussed in following paragraphs. The maximum and minimum water levels recorded in different season is given below in Table 1.

Table1. The maximum and minimum water levels during all four seasons

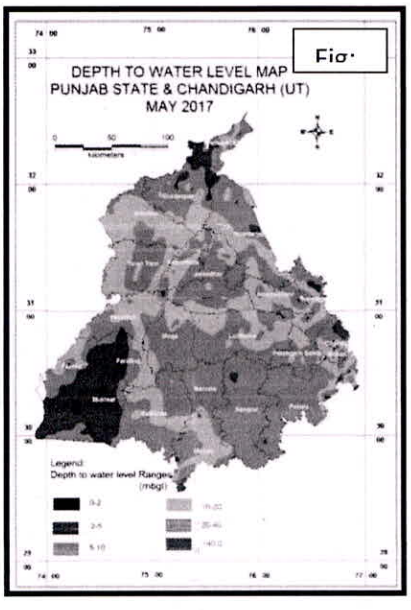
Range	May 2017	August 2017	November 2017	January 2018
Minimum	1.31m bgl Kondal (Fazilka district)	0.39 m bgl Burj Bhalai Ke (Mansa district)	0.70m bgl Aryan wala (Fazilka district)	0.45m bgl Mothian wala (Fazilka district)
Maximum	59.18m bgl Sangha (Mansa District)	41.68m bgl Chatamali (Rupnagar District)	50.20m bgl Pedol (SAS Nagar District)	50.40m bgl Pedol (SAS Nagar District)

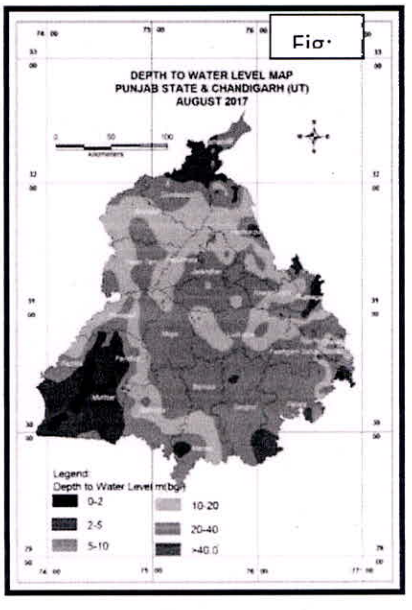
It is evident from the above table that shallowest water level conditions prevail in southwest parts mainly in Mansa, Fazilka and south west parts of. While deepest water level conditions exist in the central and north eastern parts of the state covering Fatehgarh Sahib, Ludhiana, Rupnagar, Sangrur, Mansa and Kandi areas of SAS Nagar district. The water level data of all four seasons is discussed below .

May 2017

The behavioral pattern of water level in May 2017 along with depth to water level map (Fig. 3) is discussed below.

The depth to water level lies between 0.31m bgl at Kondal in Fazilkz district and 59.180m bgl at Sangha in Mansa district.





Very shallow water levels of 0-2 m (causing water logging) occur in more than 2% of wells and cover nearly 1% area of the state in south western parts in Muktsar and Fazilka districts. Shallow water levels of 2-5 m have been observed in 12% of the wells and more than 11% of the total area that lies in south western parts of Muktsar, Fazilka, Faridkot, and in northern parts of Gurdaspur & Pathankot districts, being the canal command areas, canal water is used for their agricultural needs. The water levels between 5-10 m are observed in the northern parts (Pathankot, Gurdaspur, and Hoshiarpur districts), south and south western parts (Fazilka, Ferozpur, Faridkot, Muktsar, Bathinda and Mansa districts). About 23% of wells and 20% of the area fall in this range.

Moderately Deep water levels (10-20 m) are predominant and observed in 28% wells covering about 31% area in central parts of the State. Deep water levels (20-40 m) are also observed covering parts of Amritsar, Tarntaran,Jalandhar, Kapurthala, SBS Nagar,Moga, Ludhiana, Fatehgarh, Patiala, Sangrur, Barnala and Baathinda districts and observed in 35% wells covering about 37% area of the State in central part. Very deep water levels (>40 m) are observed isolated patches in Sangrur and SBS Nagar districts and observed in 1% wells covering about 1% area of the State.

August 2017

The behavioral pattern of water level in August 2017 along with depth to water level map (Fig.4) is discussed below.

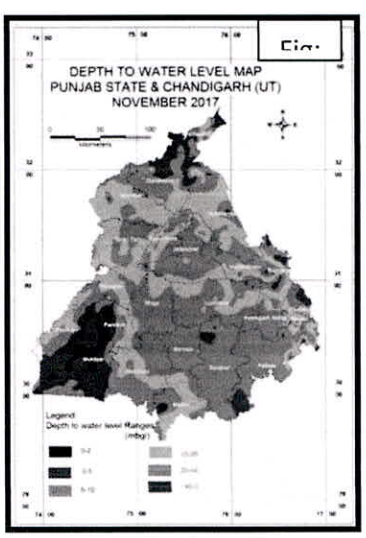
The depth to water level lies between 0.39m bgl at Burj Bhalaike in Mansa Mansa district and 41.68m bgl at Chatamali in Rupnagar district. Very shallow water levels of 0-2 m (causing water logging) occur in more than 5% of wells and cover nearly 2% area of the state covering parts of Muktsar and Fazilka districts. Shallow water levels of 2-5 m have been observed in 18% of the wells and more than 12% of the total area that lies in south and south western parts of the state in (Muktsar, Fazilka, Faridkot) and in northern parts (Hoshiarpur, Gurdaspur & Pathankot) districts and few isolated patches in north eastern parts. The water levels between 5-10 m are observed in about 22% of wells and 16% of the area of the state and are observed in the northern parts (Gurdaspur, Amritsar, and Hoshiarpur districts), south and south western parts (Fazilka, Ferozpur, Faridkot, Muktsar, Bathinda and Mansa districts), eastern parts of Ropar and SAS Nagar districts.. Moderately Deep water levels (10-20 m) are predominant and observed in 24% wells covering about 29% area of the State in parts Amritsar, Tarntaran, Kapurthala, Jalandhar, Hoshiarpur, Nawanshahr, Ludhiana, Fatehgarh Sahib, Rupnagar, Chandigarh, Patiala, Ferozpur, Faridkot, Bathinda and Mansa districts. Deep water levels (20-40 m) are also observed covering parts of Amritsar, Tarntaran, Jalandhar, Moga, Ludhiana, Fatehgarh Sahib, Patiala, Sangrur and Nawanshahr districts and observed in 27% wells covering about

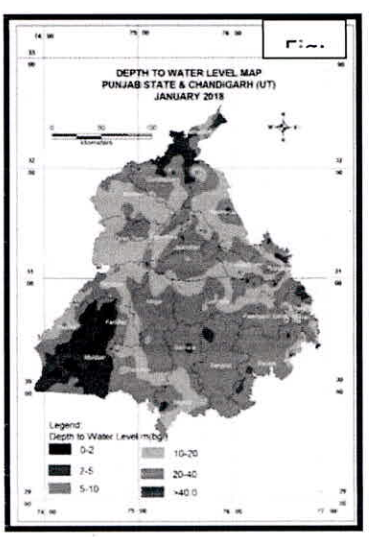
39% area of the State in central part. Very deep water levels (>40 m) are also observed in small patch in Sangrur and Patiala districts in 3% wells covering about 2% area of the State.

November 2017

The behavioral pattern of water level in November 2017 along with depth to water level map (Fig.5) is discussed below.

The depth to water level lies between 0.70m bgl at Aryanwala in Fazilka district and 50.20m bgl at Pedol in SAS Nagar district. Very shallow water levels of 0-2 m (causing water logging) occur in more than 3% of wells and cover nearly 2% area of the state in south western parts in Faridkot, Muktsar and Fazilka districts. Shallow water levels of 2-5 m have been observed in 13% of the wells and 10% of the total area in south western parts of state covering Muktsar, Fazilka, Faridkot, and Ferozpur districts, in north, parts of Gurdaspur, Pathankot & Hoshiarpur districts and few isolated patches in north eastern parts. The water levels in range of 5-10m are observed in northern Punjab covering Pathankot, Gurdaspur, Amritsar, Kapurthala and Hoshiarpur districts, Fazilka, Ferozpur, Faridkot, Muktsar, Bathinda and Mansa districts in south and south western Punjab and Ropar and SAS Nagar districts in the east covering 19% of wells and 18% of the area of the state. Moderately Deep water levels (10-20 m) are predominant and observed in 27% wells covering about 30% area of the State in central parts covering Gurdaspur, Amritsar, Tarntaran, Kapurthala, Jalandhar, Hoshiarpur, Nawanshahr, Ropar, Fatehgarh Sahib, Ludhiana, Moga, Ferozpur, Bathinda, Barnala and Mansa Districts. Deep water levels (20-40 m) are also observed covering parts of Amritsar, Tarntaran, Jalandhar, Nawanshahr, Hoshiarpur, Moga, Barnala, Bathinda, Mansa, Sangrur, Ludhiana, Patiala, and Fatehgarh sahib, districts and observed in 37% wells covering about 39% area of the State. Very deep water levels (>40 m) are also observed in small patches in Sangrur, Patiala and SAS Nagar districts in 1% wells covering about 1% area of the State.





January 2018

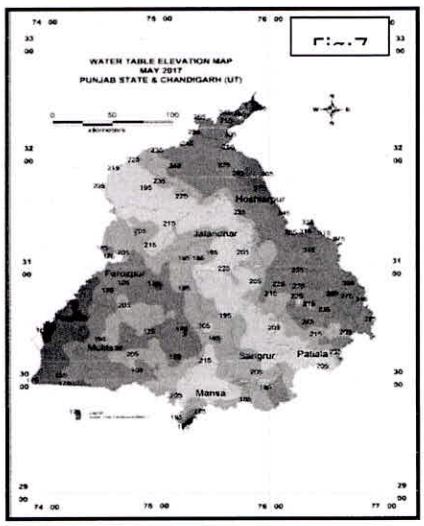
The behavioral pattern of water level in January 2018 along with depth to water level map (Fig.6) is discussed below

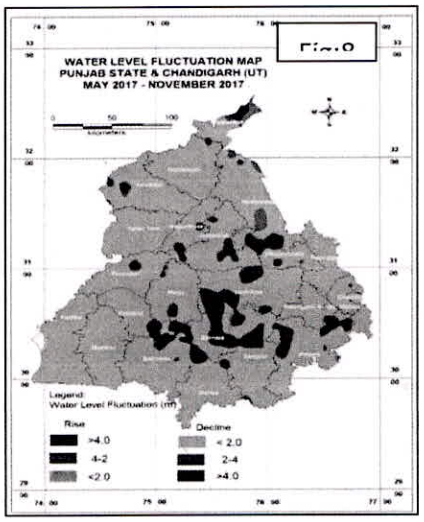
The depth to water level lies between 0.45m bgl at Mothianwala in Fazilka district and 50.40m bgl at Pedol in SAS Nagar district. Very shallow water levels of 0-2 m (causing water logging) occur in more than 3% of wells and cover nearly 4% area of the state in south western parts in Faridkot, Muktsar and Fazilka districts. Shallow water levels of 2-5 m have been observed in 13% of the wells and 10% of the total area that lies in south western parts of Muktsar, Fazilka, Faridkot, and in northern parts of Gurdaspur & Pathankot districts and few isolated patches in north eastern parts. These are mainly canal command areas and use canal water for their agricultural needs. The water levels between 5-10 m are observed in the northern parts (Pathankot, Gurdaspur, Amritsar, and Hoshiarpur districts), south and south western parts (Fazilka, Ferozpur, Faridkot, Muktsar, Bathinda and Mansa districts), eastern parts of Ropar and SAS Nagar districts. About 20% of wells and 19% of the area fall in this range. Moderately Deep water levels (10-20 m) are predominant and observed in 25% wells covering about 30% area of the State in parts of Gurdaspur, Amritsar, Tarntaran, kapurthala, Jalandhar, Hoshiarpur, Nawanshahr, Ropar, Fatehgarh Sahib, Ludhiana, Moga, Ferozpur, Bathinda and Mansa Districts. Deep water levels (20-40 m) are also observed covering parts of Jalandhar, Nawanshahr, Fatehgarh, Moga, Barnala, Ludhiana, Patiala and Sangrur districts and observed in 37% wells covering about 38% area of the State in central part. Very deep water levels (>40 m) are also observed covering parts of Kandi belt in Hoshiarpur and SAS Nagar districts and observed in 2% wells covering about 1% area of the State.

Ground Water Elevation and Flow Directions

Ground water flows from areas of high hydraulic head (high water-level elevation) to areas of low head (low water level elevation). Because hydraulic heads vary laterally and vertically in a ground-water system, ground-water movements generally have a vertical as well as a horizontal component. Contour maps of heads in aquifers are constructed to determine the horizontal direction of flow. A contour map of the water table represents the elevation of the top of the saturated part of the uppermost unconfined aquifer.

The horizontal direction of ground-water flow is generally perpendicular to the contour lines and water flows down the slope of the contours in a manner analogous to the flow of water down the slope of the land surface. Water-table maps are prepared from water levels measured in ground water observation wells the elevation of the water-table surface.





May 2017

The water table elevation (May, 2017) contours have a maximum value of 636.78m amsl at Kiari rising in the northeastern parts in Dhar Kalan Block of Pathankot district along the Himalayas to 147.82m AMSL in southwestern part in the Punjab plains (at Singha in Sardulgarh Block, district Mansa). The map helps in determining the hydraulic gradient and direction of ground water flow. The general ground water flow direction follows the natural slope. There is not much change in the ground water flow direction which still remains northeast to southwest, but the ground water troughs have been created in Jalandhar and Bathinda districts. Gradient between contour level 195 m and 165 m in Muktsar/Fazilka districts has become gentle indicating slowing of ground water movement resulting in spreading of water logged areas to adjoining areas of other districts. The water table elevation map for May 2017 is shown in Map (Fig. 7).

Seasonal fluctuations:

On comparing Water level data of current measurement with previous measurement data is termed as seasonal water level fluctuations. The water level data of all four measurements are compared to previous measurement and seasonal water level fluctuations are determined.

May 2017 - November 2017

Water level data of November 2017 is compared with Water level data of May 2017 to determine the seasonal water level fluctuation. The behavioral pattern of this seasonal fluctuation is discussed along with fluctuation map (Fig. 7) below.

The seasonal fluctuation shows a general decline of water levels in 59% of wells monitored and covering 67% area of the State. The decline has been observed in all districts. Water level decline in the range of 0-2 m is observed in 54% of wells and 53% of area. Water level decline in the range of 2-4 m is observed in 9% of wells and 5% of area in parts of Jalandhar, Fatehgarh Sahib, Ludhiana,

Sangrur, Moga, Barnala and Bathinda districts, whereas, water level decline of >4m is observed in 2% of wells and 1% of area during the period.

The water level rise has been recorded in 33% of wells monitored and covering 41% area of the State covering parts of Muktsar, Amritsar, Gurdaspur,Pathankot and Hoshiarpur districts. Water level rise in the range of 0-2 m is observed in 32% of wells and 38% of the area. Water level rise 2-4m is observed in 2% wells and 2% of area, whereas, water level decline of >4m is observed in more than 1% of wells and more than 1% of area during the period.

Ground Water Quality

Ground water is extensively used for drinking, irrigation and industrial activities in Punjab. Suitability of ground water for these uses depends on its ambient quality that is reflected in the concentrations of chemical constituents present in it at that time. There is a wide variation in concentration of various chemical constituents in ground water and 70% of ground water is fresh and potable in North and North Eastern part of the State (Fig 8). The ground water occurring in the southern and southwestern parts comprising of Bhatinda Faridkot Ferozepur, Ludhiana, Muktsar and Sangrur districts are affected with salinity, fluoride and nitrate contamination at several places and not suitable for drinking uses. A considerable area of the southern and southwestern part of the state have nitrate concentration exceeding 45 mg/L(>BIS Limit). Furthermore, quite a significant number water samples from, Bhatinda, Faridkot, Fatehgarh sahib, Ferozepur, Mansa, Muktsar and SAS nagar districts are found to have nitrate above 100 mg/L.

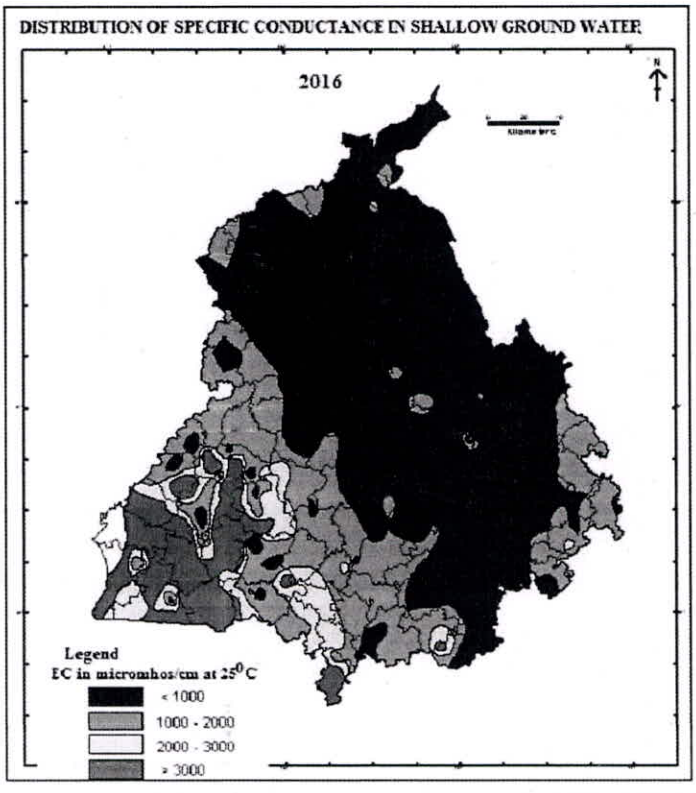


Fig:8

10.7% samples have fluoride above 1.5 mg/l round waters with fluoride above 1.5 mg/L are found mainly in Bathinda, Faridkot, Fatehgarh Sahib, Ferozepur, Mansa, Muktsar, Patiala, Sangrur, SAS Nagar and Tarantaran districts of the State. It is worth mentioning that high fluoride waters are encountered in areas where agriculture activities are predominant. It indicates the possibility that fluoride has come from the phosphatic fertilizers, which have fluoride as impurity. Most of ground waters from Amritsar, Fatehgarh Sahib, Gurdaspur, Hoshiarpur,

Jallandhar, Kapurthala and Ropar are suitable for irrigation for semi-salt tolerant crops on adequately drained soils. The waters from districts of Bhatinda, Faridkot, Ferozepur, Mansa, Muktsar, Patiala and Sangrur show wide variability in irrigation rating.

Occurrence of Heavy metals in ground water is also periodically monitored by CGWB and as per studies carried out during 2017, cadmium above permissible BIS Drinking Water limits has been recorded in 16.1% samples The affected districts are namely Bathinda, Faridkot, Firozepur, Ludhiana, Mansa, Muktsar,Sangrur SAS Nagar. 6.3% samples have Manganese above 0.3mg/l with higher concentration being reported from Bhatinda, Gurdaspur, Hoshiarpur Jallandhar,Pathankot . Sporadic cases of high manganese have been reported from in Hoshiarpur, Jalandhar, Kapurtahala, Patiala and sangrur districts. Copper concentration is generally below 1.5mg/l in groundwater of the State. Low concentration of Lead has been reported in Faridkot Gurdaspur Kapurthala, Nawanshhar districts but 23.8% samples of shallow aquifers from rest of the districts have Lead above 0.01mg/l.

Recognizing the enormity and severity of the problem of contamination of ground water by Arsenic, CGWB North Western Region, Chandigarh, under the quality-monitoring program, collected water samples in month of May-June 2015. It is observed that isolated cases from eight districts namely, Amritsar, Faridkot, Gurdaspur, Hoshiarpur, Nawanshahr, Ropar, Sangrur and Taran Taran have Arsenic concentration more than the desirable limit of >0.01mg/l.Highest concentration was recorded in water drawn from hsndpump at Harike(0.200mg/l). During 2017 the highest concentration of arsenic has been recorded in groundwater of Bara chaunta (0.0375 mg/l) village in Roopnagar district. 16% of the groundwater samples have high Iron with highest value recorded of 25.825mg/l at village Issarpur in SAS nagar.

Ground Water Resources

The fact is depicted in groundwater resources which is computed during different years. As per the ground water resources estimation in 1984which was the first year of ground water resource estimation, 54 blocks were over exploited out of 118 blocks, whereas during 2013 groundwater resources 113 blocks were found to be over-exploited out of 138 blocks. As per the various previous studies conducted by the state of Punjab for estimation of the Dynamic ground water scenario of the Punjab depicting the categorization of various blocks was as under :

Table Showing Categorisation of Blocks during different years as per Ground Water Resources assessments.

Category of Blocks / Study Year	1984	1986	1989	1992	1999	2004	2009	2011	2013	2017
Over-exploited	53	55	62	63	73	103	110	110	105	109

Critical	7	9	7	7	11	5	3	4	4	2
Semi Critical	22	18	20	15	16	4	2	2	3	5
Safe	36	36	29	33	38	25	23	22	26	22
Total	118	118	118	118	138	138	138	138	138	138

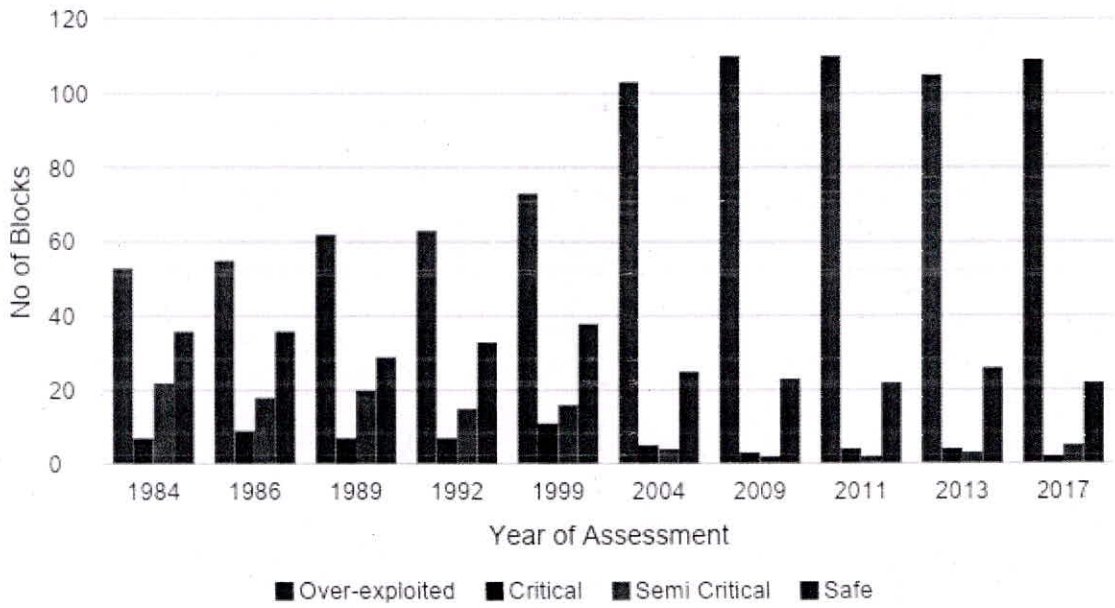
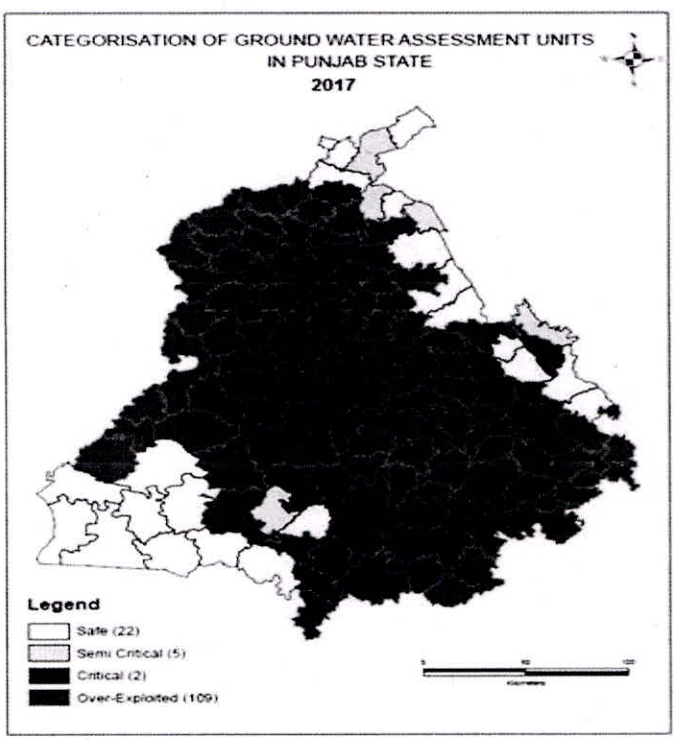


Fig 9: Categorization of blocks as per Ground Water Resources Estimations



The recent Ground Water Resource assessment following Ground Water Resources Estimation Committee Report, 2015 has revealed that for the year 2017 the net annual ground water availability (net annual replenishable ground water resources) is 21650 MCM/yr against which the ground water draft for all uses is 35812 MCM/yr which is 165% of ground. Out of 144 blocks 109 blocks are over exploited and two are critical, whereas only 22 blocks are safe and 5 are semi critical.

Fig:10 : Catorisation of Blocks as per Ground Water Resources Estimations, 2017

Table showing comparison of Ground Water Resources Estimates

Item	Year of GWR estimation				
	2004	**2009**	**2011**	**2013**	**2017**
Net Ground Water Availability(MCM)	21443	20349	20321	23390	21584
Gross Ground Water Draft(MCM)	31162	34661	34881	34810	35782
Net GW Availability for Future Irrigation Development (MCM)	--	--	--	--	-
Stage of Ground water development in %	145	170	172	149	166
No. of Blocks	137	138	138	138	138
No. of OE Blocks	103	110	110	105	109
No. of Critical Blocks	05	03	04	04	02
No. of Semi-Critical Blocks	04	02	02	03	05
No. of Safe blocks	25	23	22	26	22