STUDY AND ANALYSIS OF GROUNDWATER LEVEL IN S.A.S NAGAR DISTRICT, PUNJAB

A Thesis Submitted in Partial Fulfillment of the Requirement for the Award of the Degree of

MASTER OF ENGINEERING
IN
INFRASTRUCTURE ENGINEERING

Submitted by

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JULY 2019

DECLARATION

I hereby declare that the work which is being presented in the thesis entitled **"Study and Analysis of Groundwater Level in S.A.S Nagar District, Punjab"** in partial fulfillment of the requirements for the award of the Master of Engineering in Civil Engineering(Infrastructure Engineering) and submitted to the Department of Civil Engineering of Thapar Institute of Engineering and Technology, Patiala-147004, Punjab is an authentic record of work carried under the guidance of **Dr. Sarbjit Singh,** Associate Professor, TIET Patiala, Punjab-147004.

The matter presented in this thesis has not been submitted by me for the award of any degree of this or any other institute.

Balp Sjh

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This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

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ABSTRACT

The study was carried out in Derabassi, Zirakpur, Landran, Sohana and Kharar blocks of S.A.S Nagar district to measure the level of the groundwater in various blocks of the district and to analyze reasons for the rapid decrease in the level andprovide remedial measures to prevent the depletion of groundwater level. Eight well locations were selected vizZirakpur, Derabassi, Issapur, Sarsini, Dheri, Landran, Sohana and Goga. These wells were open wells with impervious lining. The water depth was measured using a 30 m metallic tape with a heavy load attached at the lower end. The ground water levels of the neighbouring districts vizRoopnagar, Patiala and Fatehgarh Sahib and the five year data (2013-18) obtained from Punjab Irrigation Department was analyzed and compared with the data of the S.A.S Nagar District.

Month wise, Year wise and District wise comparison of the data was carried out to check the level of groundwater.The study revealed declining trends in level of groundwater with major decline in Zirakpur. Proper and immediate measures need to be adopted to control the depletion of groundwater otherwise the state will turn to a desert in the coming years.

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All deserve special compliments

July 2019 Balpreet Singh

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CHAPTER-1 INTRODUCTION

1.1 GENERAL

Groundwater is defined as the water available beneath the earth surface. It is the freshest water source available for carrying out daily activities/purposes. From years back people have been extracting water from below the ground with the help of wells, pumps etc. Groundwater is also considered helpful for carrying out irrigation practises all over the world.Figure 1.1 shows the groundwater system below the earth surface. The following features are explained in the figure:-

i. **Ground Surface**–The ground surface is the surface of the earth which comprises of soil, forests, rivers, buildings and roads.
ii. **Soil Water** – Soil Water is the water which is stored in the pores of the soil and it is this water which travels below the surface of earth and forms ground water.
iii. **Capillary Fringe** – A subsurface layer where the groundwater moves to fill the pores of the soil is capillary fringe. If the pore size is less, the soil becomes fully saturated while in other case the soil will be partially saturated.
iv. **Water table** – The upper surface of the saturation zone is called water table. It is the area where water pressure head becomes equal to the atmospheric pressure.
v. **Groundwater** – Groundwater is the water beneath the earth surface and is considered the freshest water source available on the earth.
vi. **Saturated Zone** – Saturated zone is the zone where the water content is maximum. It is the zone below the surface of the earth where the pores of the soil and rocks are filled with water. The moisture content of the zone is maximum as compared to the dry zone. This zone is also called phreatic zone.
vii. **Unsaturated Zone** – Unsaturated zone is the area between the earth surface and phreatic zone. It is the zone in which groundwater is at atmospheric pressure. The moisture content of the unsaturated zone is less as compared to the saturated zone.

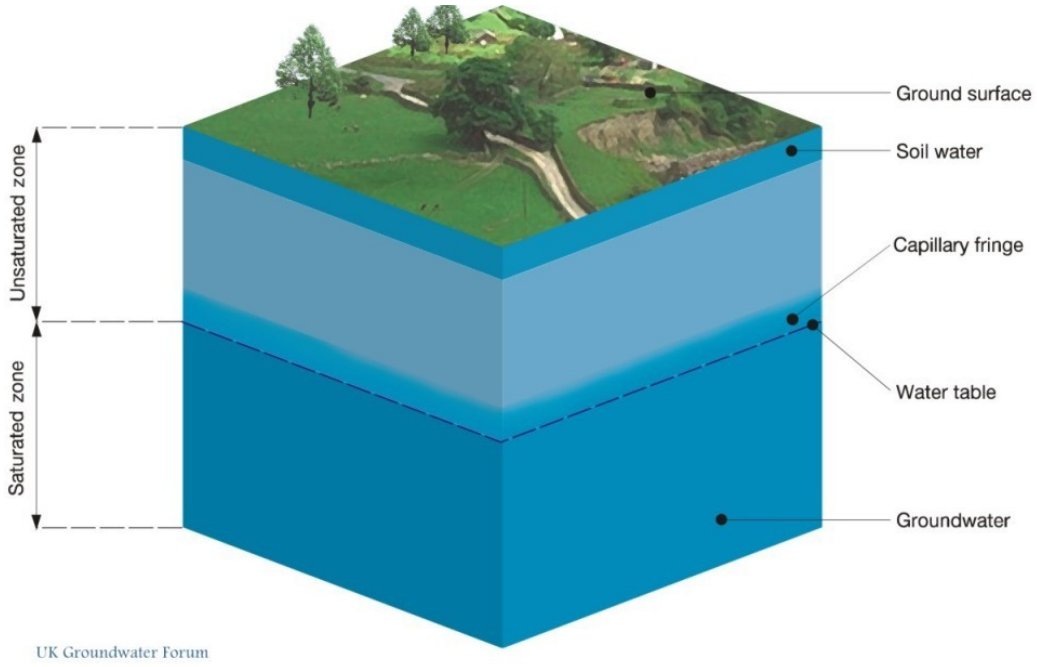

Figure-1.1 Groundwater below the earth surface

(https://www.bgs.ac.uk/research/groundwater/datainfo/levels/ngla.html)

1.2 HYDROLOGICAL CYCLE

The hydrological cycle is the cycle followed by the water starting from rivers and lakes to the clouds and to the surface of earth. The hydrological cycle best depicts the way how water from lakes and rivers get transformed to groundwater. Following steps are involved in the hydrological cycle depicted in figure 1.2.

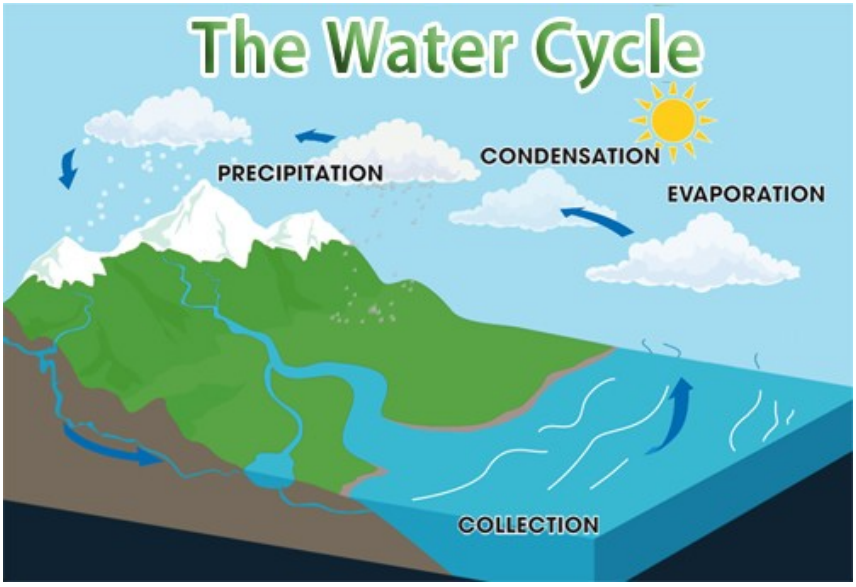

Figure -1.2 Hydrological cycle

(https://easyscienceforkids.com/all-about-the-water-cycle/)

1.2.1 Evaporation

Water from lakes, ponds and sea gets evaporated in the form of water vapor. The evaporation rate is directly proportional to the prevailing temperature of the area i.e. with the increase in temperature there will be an increase in the rate of evaporation. Figure 1.3 shows the process of evaporation. The scale below depicts that the process of evaporation is taking place under normal conditions

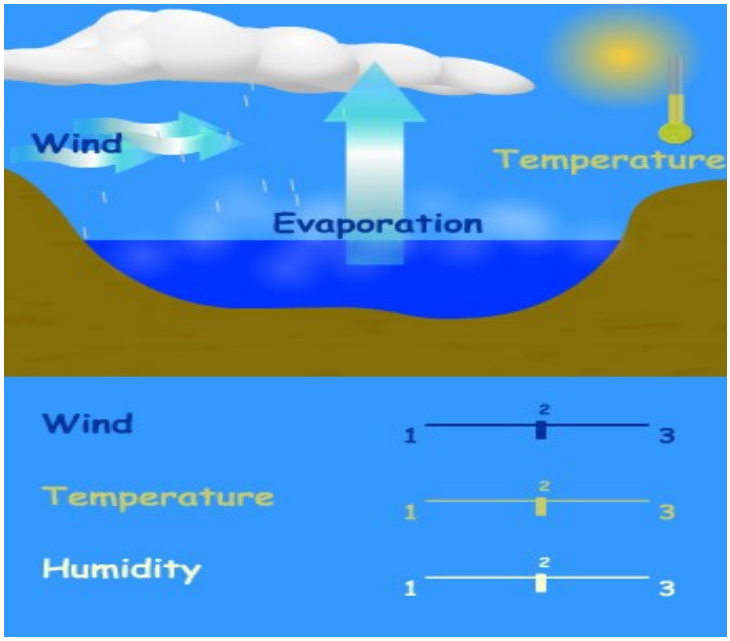

Figure 1.3 Evaporation process

(http://techalive.mtu.edu/meec/module01/EvaporationandTranspiration.htm)

1.2.2 Absorption

Once the water gets evaporated in the form of vapor it is absorbed by the atmosphere where the formation of clouds takes place. The rate of absorption is dependent on the rate of evaporation and the variation of temperature.

1.2.3 Precipitation

After the process of evaporation and absorption the next process is of precipitation in which the absorbed water reaches the earth surface either in the form of rain, snow and hail. The water droplets of diameter range 0.1-9mm is rain, 10µm is snow, 5mm is hail and water droplets with diameter smaller than snow is ice. Figure 1.4 shows the different forms of precipitation.

Figure-1.4 Different forms of precipitation

1.2.4 Transpiration

After precipitation the water through the earth surface gets transferred to the soil and from there it travels back to the ground surface completing the whole process.

1.3 INTERACTION OF SURFACE WATER AND GROUND WATER

The key element related to surface and ground water is the interaction between them. The groundwater travels beneath the surface of the earth and is considered one of the important source for rivers, streams, lakes and wetlands. The concept of groundwater interaction can be understood with the example of a piggy bank. Like the money is stored in piggy bank for emergency purposes so is the water stored below ground and is used during the times of drought when the surface water gets dried. Groundwater has the ability to stay underground for days, weeks, years and decades. The region where surface water and ground water interact is called hyporheic zone. Figure 1.5 shows the interaction between surface and ground water.

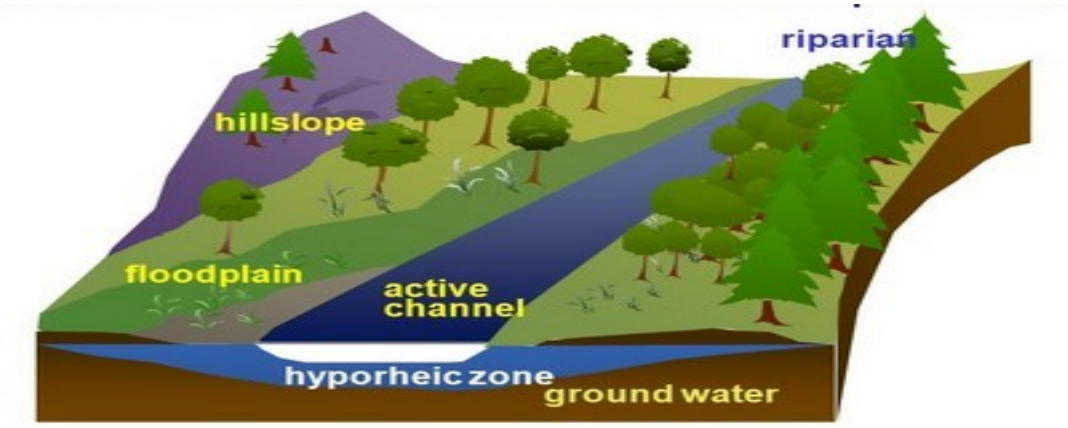

Figure – 1.5 Groundwater and surface water interaction (https://slideplayer.com/slide/8992771/)

The interaction of surface water and groundwater can be best understood by considering following processes:

(i) **Gaining stream**- In this the water source on surface like rivers, lakes, and ponds collects water from the ground. The flow of water is from bottom to top direction by capillary action.

(ii) **Loosing stream**- In this the water moves from surface sources like rivers, ponds and lakes below the surface of earth. In other words it is the movement of water from the top to bottom direction.

(iii) **Disconnected stream**- This process occurs when there is shortage of water in both cases. In this a gap occurs between the ground and surface due to which there is no movement of water in both cases.

Figure 1.6 depicts the different stages of interaction. Following features are shown in the figure

i. **Stream Flow** – The flow of the stream in the form of river or canal is the stream flow. It forms the surface water

ii. **Unsaturated Zone** – The zone between the ground surface and the ground water table is unsaturated zone.

iii. **Water Table** – The zone where groundwater is available is the water table.

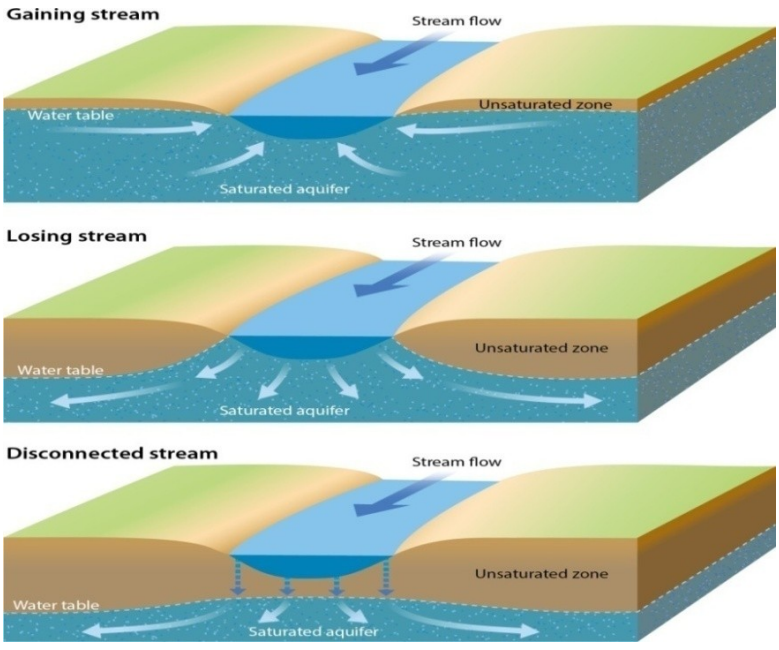

Figure-1.6 Different stages of groundwater and surface water interaction(https://serc.carleton.edu/teaching_materials/water_science_society/student_materials/938)

The groundwater and surface water interaction takes place in following ways:

(i) River and Groundwater Interaction- This is a complex interaction between rivers and groundwater. When a river travels from the mountains the water lost gets seeped in to the dry ground. This water turns into groundwater. This water flows to the low elevation areas. When the river and groundwater which was stored earlier meets with the river and flows downstream it forms surface water. The groundwater entering the river is base flow. Figure 1.7 shows the interaction between the river and the ground water. The arrow depicts the movement of the water.

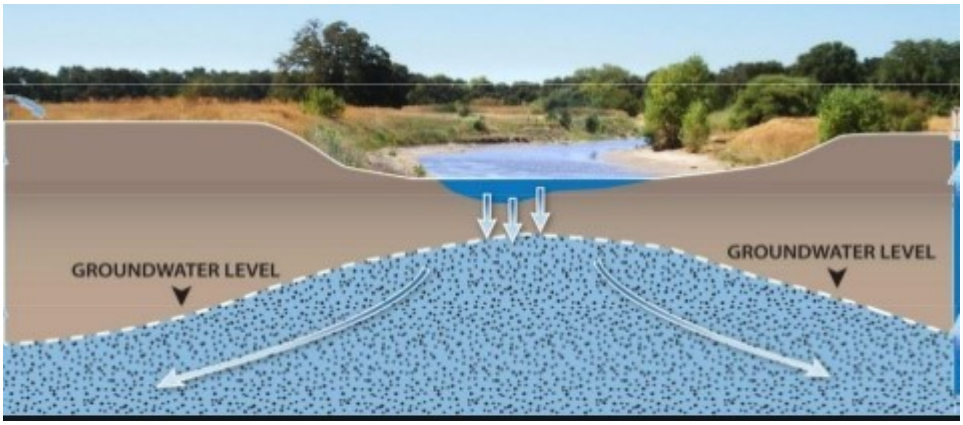

Figure -1.7River and Groundwater Interaction

(https://www.slideshare.net/cpkumar/surface-water-and-groundwater-interaction)

(ii) Base flow- Groundwater entering the river is base flow. In winters due to less rainfall as compared to summers the groundwater contributes more water to streams and rivers which lead to the formation of base flow which is considered to be base amount for rivers and streams during the period of base flow. This interaction may reverse for high flow period.

(iii) Groundwater flooding – It occurs when a large amount of water from the ground suddenly comes to the surface. When the level of water rises above ground surface, flooding occurs. It happens on its own and at times as surface water flooding, when river has high flow compared to water below ground surface. In other cases groundwater flooding occurs.

(iv) Wetlands and Groundwater- Groundwater is the main source for wetlands. It is essential for wetlands to have water to maintain ecosystem. Precipitation and runoff are also the key sources of groundwater. When the wetland is full it converts to recharge zone.

(v) Lakes and groundwater- These are also considered to be complex interactions. In some cases lake bed feeds groundwater and in other cases groundwater feeds the lake bed. For some cases direction of flow of water from lake to groundwater or vice versa does not change

while in others it may change depending on the amount of water in the lake. It is possible for lake to receive water from ground at one part and loose at the other part.Figure 1.8 shows interaction between lakes and groundwater in which aquifer is the area where groundwater pressure is maximum and confining layer is the layer after aquifer with space between particles for the flow of liquid through it.

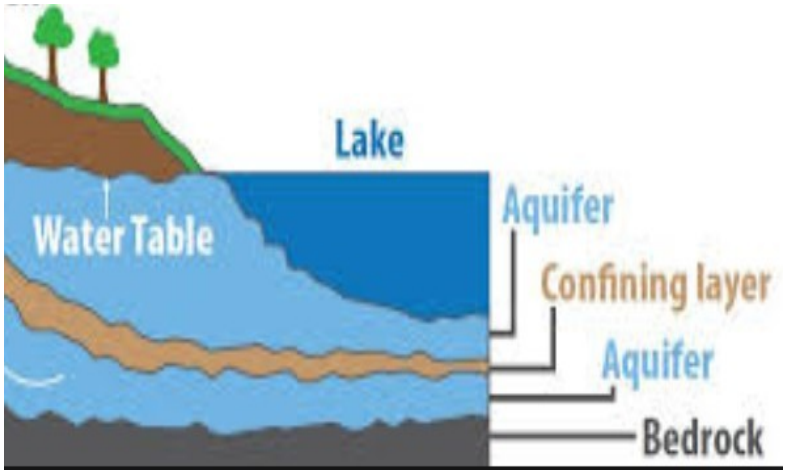

Figure – 1.8Lake and Groundwater Interaction

(vi) Impact of Human Activities- With the withdrawal of water from aquifer, the water migrates and is consumed again. As aquifer pumping occurs less water reaches the streams and in this way it can even reverse the direction of flow. Using groundwater instead of surface water can preserve water resources but it can have an impact on both of them.

1.4 WORLD WATER DISTRIBUTION

Water is not only important for life but it also helps in socio economic development. The quantity of water available in the world is plenty but not adequate for human use and benefit.Water available on the earth is 71% and rest is the land.

Table 1.1 shows the amount of water available in ocean and water bodies. Only one percent is available for human use. Proper measures need to be taken for the sustainable development and management of the groundwater.

William Edwards Deming, an American Engineer and Scientist once stated in 1975 that 'The wealth of a nation does not lie in the precious sources like groundwater and fossil fuel but the ability to use them and preserve for future generation'.

Table – 1.1 Water Resources Available on the Earth

S. No.	Resource	Volume (km^3)	Percentage
1	Atmosphere	13000	0.001
2	Oceans	1,32,20,00,000	97.20
3	Ice Caps and Glaciers	2,92,00,000	2.15
4	Saline lakes and inland water	1,04,000	0.008
5	Soil Moisture	67,000	0.005
6	Under Ground	41,70,000	0.625
7	Rivers and Streams	1,250	0.001
8	Fresh Water Lakes	1,25,000	0.009
	Total	1,35,56,80,250 km^3	100%

1.5 NEED FOR PROTECTED WATER SUPPLY

Water is a free gift nature has given to humankind and is the most essential source available for sustainability of life on the earth. Water is used for multi purposes. From the beginning of civilization the importance of water was felt for various purposes. During ancient India, the population was less and the demand for water was also not much. During ancient times, the water sources available were streams, lakes, ponds, rivers and wells.

As the living standards of the people improved so did the demand for water increase. Due to increase in industry and agriculture, the increased demand lead to depletion of water present below the earth surface. If this situation continues, a time may come when no fresh water will be available for the fulfillment of demands of humans.

There is an urgent need for a particular groundwater management model which will help in sustainable management and development of the groundwater for the benefit of the future generation.

Table 1.2 shows the status of groundwater development in India. According to the table, areas under the safe category decreased from 1995 to 2011 while the areas under semi critical, critical and over exploited category increased from 1995-2011. Safe category is one in which groundwater quantity is sufficient while semi critical, critical and over exploited are those in which depth of groundwater is below the required depth.

Table -1.2 Status of Groundwater level development in India for past 20 years

Groundwater level development	Explanation	% Districts 1995	% Districts 2004	% Districts 2009	% Districts 2011
0-70% Safe	Areas with groundwater potential for development	92	73	72	71
70-90% Semi Critical	Areas requiring urgent ground water management	4	9	10	10
90-100% Critical	Require intensive evaluation of groundwater development	1	4	4	4
>100% Over Exploited	Areas where future groundwater development linked with conservation of water	3	14	14	15

1.6STATE OF PUNJAB

Punjab state lies on the north western side of India. It is bordered by Jammu and Kashmir on the North, Himachal Pradesh to the East, Haryana to the South and South East, Rajasthan to South West and national boundary Pakistan to the West. Figure 1.9 shows the location of Punjab in the Map of India. Area covered by the state is 50,362km^2 which is 1.53% of the total geographic area of the country.Of all the largest states of India, it is at 20th number. In terms of population it is the 16th largest state and comprises of 22 districts. The language spoken is Punjabi which is the official language of the state. Sikhs are the dominating groups present with 58% of the total population followed by Hindus which are 38% of total population. Chandigarh, a Union Territory is the capital of Punjab. The five rivers Sutlej, Ravi, Beas, Chenab and Jhelum are known to bear this state the name Punjab which literally means five rivers.

Himalayas form an undulating belt along the north east part of the state. The elevation of hills is 300m above the sea level with the range 180m in South East to 500m along North East border. Characteristics of soil depend on the topography, vegetation and parent rock of the state. On the basis of soil, Punjab is divided into three regions – South Western, Central, and Eastern part. Of the four seismic zones, Punjab comes under Zone II, III, IV. Zone II is low damage Zone, Zone III is moderate while Zone IV is high damage zone.

Climate – The monthly variations of climate of the Punjab state are due to the geographical and latitudinal location of the state. Though limited area show 0°C temperature but still frost is in majority during the winter season in the state. High humidity is experienced with increased temperature while steep temperature rise is experienced when the sky is clear and humidity is low. During mid May and June maximum temperature is experienced with rise up to 40°C. In Ludhiana, the highest temperature is recorded followed by Patiala and Amritsar. In contrast these areas are cooler with lowest temperature during January.

Seasons – Punjab experiences the following seasons:

(i) Hot Season during the period mid April to June end

(ii) Rainy Season during early June to September end

(iii) Cold Season during the early December to February end

(iv) Pre Summer Season during the period March to Mid April which is the period of change of season from winter to summer

(v) Post Monsoon Season during the period September to November which is the period of change of season from monsoon to winter

Rainfall –

Monsoon Season -This season provides most of the rainfall. The rain winds travels from region of Bay of Bengal to Punjab and enters the state of Punjab during month of July

Winter Season – The cool Season of the state. Rainfall is considered a blessing for farmers as many crops depend on rain. Shiwalik area receives 100 mm rainfall during this season. Figure 1.10 shows movement of winds. Black arrows depict cyclone and blue depict winds.

Figure 1.9 India Map showing the state of Punjab

(https://www.mapsofindia.com/maps/india/hillranges.htm)

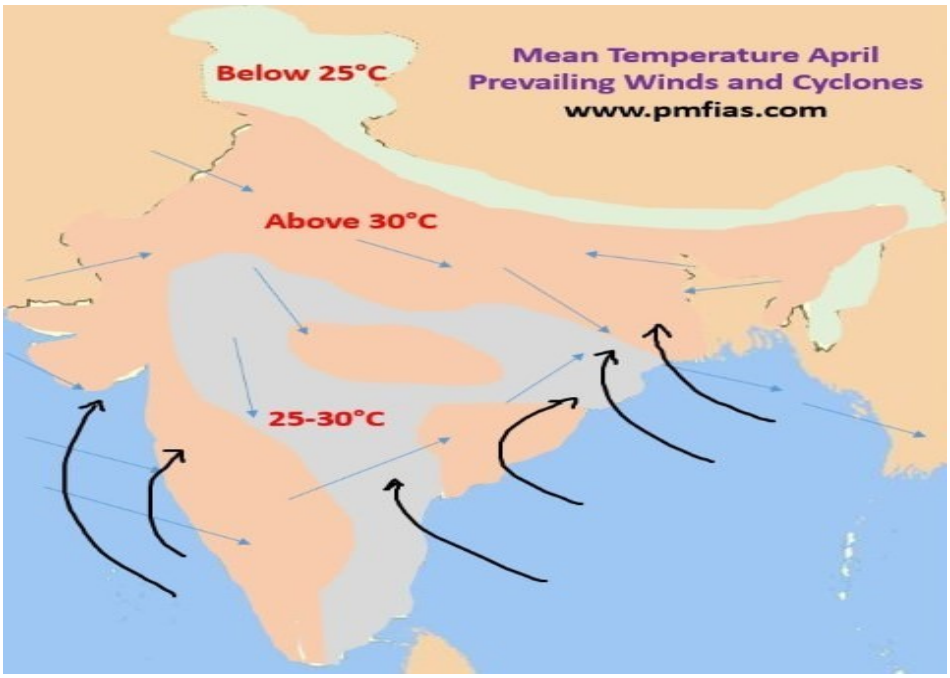

Figure 1.10 Movement of winds during Summer Season (https://www.pmfias.com/winter-season-summer-season-indian-climate-loo-andhis-norwesters/)

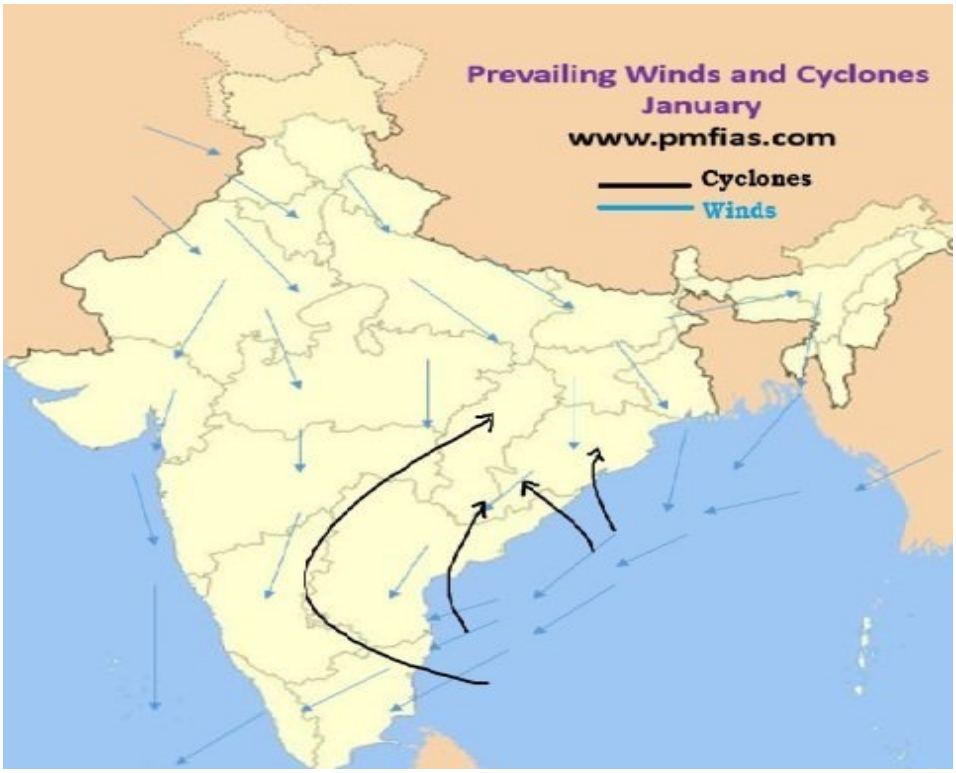

Figure 1.11 Map showing movement of winds during winter season (https://www.pmfias.com/winter-season-summer-season-indian-climate-loo-andhis-norwesters/)

1.7 S.A.S. NAGAR DISTRICT

S.A.S Nagar or SahibzaadaAjit Singh Nagar is located in the East side of the state of Punjab with area 1189 km^2. It lies on 30°21'00''&30°56'00'' North latitude and 76°30'00'' & 76°55'00'' East longitude. The boundary districts are Patiala and Fatehgarh Sahib which lie to the South West, District Ropar lies in the North West region and Chandigarh lies in the east side. Figure 1.12 shows various blocks of S.A.S Nagar district.

Table 1.3 gives the information about the various features of the S.A.S. Nagar district.

Table 1.3 S.A.S. NAGAR District at a glance

S No.	Items	Statistics
1.	General	
	Geographic Area	1189 km^2
	Administrative Divisions	
	Tehsils	3
	Blocks	3
	Towns	9
	Villages	384
	Population (As per 2011)	9,86,147
2.	Major Physiographic Units	Alluvial plains
3.	Major Drainage	Ghaggar and Sutlej
4.	Land use (km^2)	
	Forest	190
	Net Area Sown	750
	Gross Cropped Area	1180
	Cropping Intensity	157%
5.	Major Soil Types	Tropical Arid Brown
6.	Irrigation by tube wells	
	Shallow Tube wells	9050
	Deep Tube wells	2586

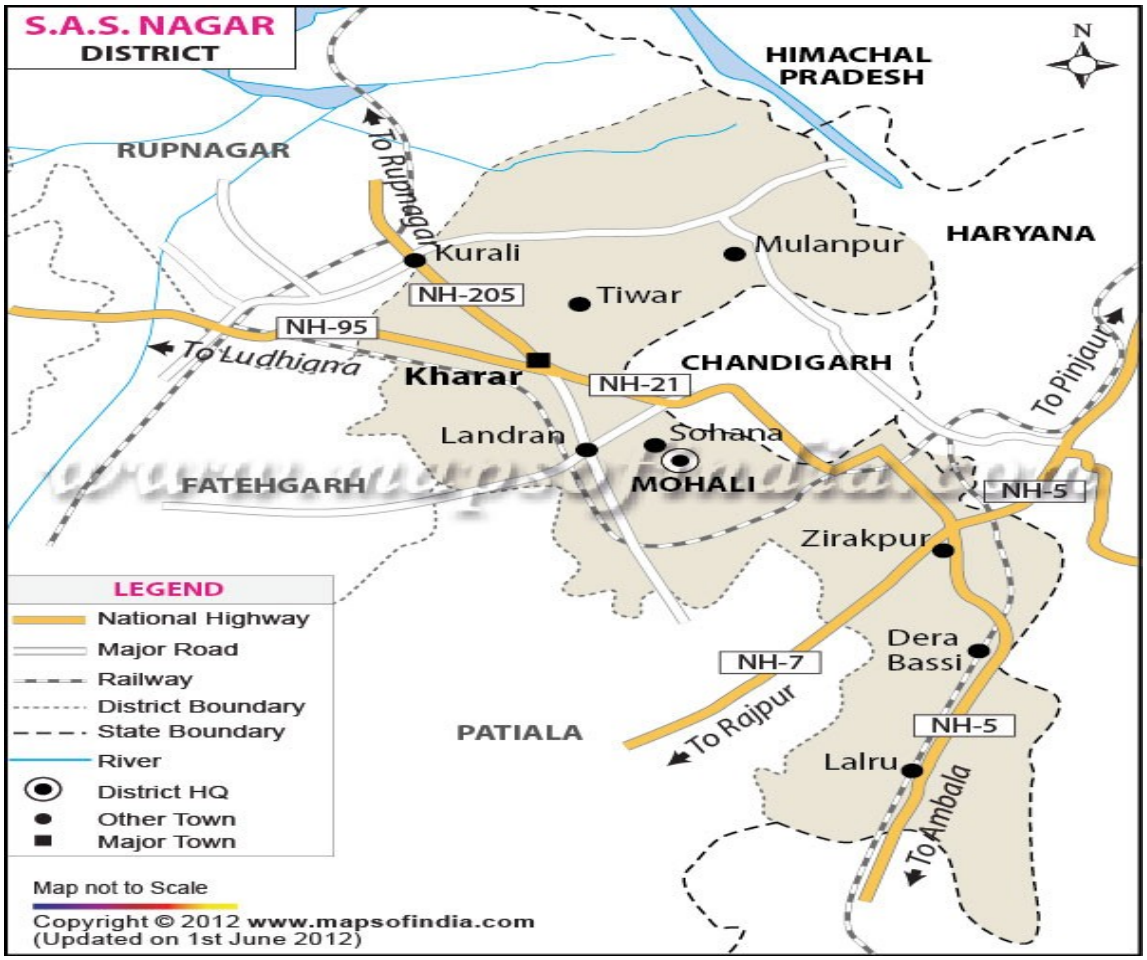

Figure 1.12 S.A.S Nagar Map showing major blocks

(https://www.mapsofindia.com/maps/punjab/districts/sas-nagar.html)

1.8 NEED AND OBJECTIVES OF STUDY

(i) At present the major issue faced by the district is scarcity of groundwater. With decreasing level of water, a day may come when there may be minimum or no water available for future generation.

(ii) The groundwater level in the District is depleting by 5-7 feet every year according to a study conducted by the Central Ground Water Board.

(iii) The rate at which groundwater is depleting every year is an alarming issue for the state and remedial steps need to be taken to control it.

(iv) With the decrease in level of water below the surface of ground, problems like salinity may occur.

Keeping in mind the above alarming issues, a study has been carried out to investigate level of groundwater, causes for depletion and to suggest measures to control it.

CHAPTER – 2 LITERATURE REVIEW

2.1 GENERAL

Earlier groundwater was considered as an important gift given by nature to mankind. At present the groundwater is not enough for the fulfillment of daily activities like drinking and irrigation.The level of groundwater is depleting during its movement through different stages of hydrological cycle. The level is decreasing due to increase in industrialization, urbanization and misuse by humans.The Tribune dated August 9, 2018 pointed out that in 1970-71 Punjab had 1.92 lakh tube wells which increased to 14.14 lakh by 2015-16 leading to decrease in level between 6 and 22 meters shown in Figure 2.1.

'Dry' Punjab draws 1.5 times the water that goes in ground

RUCHIKA M KHANNA
TRIBUNE NEWS SERVICE

CHANDIGARH, AUGUST 9

The Punjab Government may have put on hold the release of new tubewell connections, but the dramatic rate of fall in the ground water level is likely to continue unabated as the existing tubewells annually draw one and a half times the amount of recharge.

As much as 77 per cent of the cultivable area in the state is irrigated by tubewells, while the rest is from canals or dependent on rain.

These are the findings of a new study, published in the form of a book, "Emerging Water Insecurity in India: Lessons from an Agriculturally Advanced State", written by eminent agro-economist RS Ghuman and Rajeev Sharma.

The study has calculated that overall the state is drawing 49 per cent more water than is being recharged in the ground from rain or natural and manmade water bodies. The highest draft, of more than double the recharge, is happening in four districts — Sangrur, Jalandhar, Kapurthala and Moga, mainly in the central plain zone, where paddy is the main crop during the kharif season.

Among the other high-drawing districts are Barnala (94 per cent more than the recharge), Fatehgarh Sahib (91%), Patiala (89%), Ludhiana (62%), and Faridkot (60%).

CONTINUED ON PAGE 13

Top drawing districts

(% more than recharge)

Sangrur	111
Jalandhar	109
Moga	107
Kapurthala	105

TUBEWELL SWELL

- Study points out that in 1970-71, Punjab had 1.92 lakh tubewells, which increased to 14.14 lakh by 2015-16.
- The result was that between 1996 and 2016, the ground water level in different districts declined between 6 and 22 metres.

Figure-2.1 News clipping showing the state of wells in Punjab (The tribune dated August 10, 2018)

The Tribune dated 7 February, 2019 pointed out that the water table is going down at the rate of 0.37m every year. According to a report by central ground water board (CGWB), the overexploitation of groundwater has increased by 16 percent in past six years as shown in figure 2.2.

The Tribune
CHANDIGARH | THURSDAY | 7 FEBRUARY 2019
PUN

Water table decline alarming, govt steps go down the drain

Average fall 0.37 m/year; groundwater extraction increases to 165 %

VISHAV BHARTI
TRIBUNE NEWS SERVICE

CHANDIGARH, FEBRUARY 6

Various initiatives taken by the state government to stop over exploitation of groundwater resources seems to have gone down the drain as on an average, the water table is going down at the rate of 0.37 metre every year.

A recent report has found that the condition of groundwater resources have deteriorated further in the past five years.

A report 'Groundwater Resources of Punjab' by the Central Ground Water Board and the State's Water Resources and Environment Directorate has found that the over-exploitation of groundwater has increased by 16 per cent in the past six years.

The groundwater extraction has increased from 149 per cent of the total recharge in 2013 to 165 per cent in the present report. The outcome is that about 79 per cent area of the state is over-exploited. Out of 138 blocks, 109 blocks are 'over-exploited' two blocks are 'critical' five are 'semi-critical' and only 22 fall in the safe category.

The number of over-exploited blocks has increased from 105 in 2013 to 109. "There is an urgent need to recharge groundwater in the over-exploited blocks and develop available shallow groundwater in safe blocks to avoid waterlogging in future," the report observed.

In historical analysis of groundwater, the report noted that the groundwater level fell almost in 85 per cent of the area between 1984 and 2016. While in the remaining about 15 per cent area of the state it has risen during this period. It has been observed that the area, in which groundwater table is more than 10-metre deep, has been continuously increasing. It was 14.9 per cent in June 1989, 20 per cent in June 1992, 28 per cent in June 1997, and 44 per cent in June 2002 and 61 per cent in June 2008, 65 per cent area fell in that category in 2016.

It has been found that the average yearly rate of fall of water level in the past six years was approximately 0.37 metre a year.

However, in badly-hit areas, including Barnala, Bathinda, Fatehgarh Sahib, Hoshiarpur, Jalandhar, Moga, Mohali, Pathankot, Patiala and Sangrur, it was approximately 0.49 metre.

Parched Punjab

Manifold increase in tubewells has led to over exploitation of groundwater. In the past 30 years, the state witnessed almost 20 times increase in number of tubewells. Post Green Revolution in mid-60s, the number of tubewells increased from 50,000 in the early 60s to 70,000 in early 80s, and 10.70 lakh in 2001 to 11.80 lakh in 2005-06 and nearly 12 lakh in 2012-13.

Groundwater quality

- Nearly 50-60% of the groundwater up to 60 metre depth in the state is fresh and fit.
- Nearly 20-30% of the groundwater generally is moderately saline and of marginal quality.
- About 15-25% of the groundwater is saline/alkaline and not fit for even irrigation use.

Figure 2.2 News clipping showing the condition of water table (The Tribune dated 7 February 2019)

Thus, the problem of depletion of groundwater is a major issue the Punjab state is currently facing. It is the right time for the Government, Scientists, Engineers and Policy makers to propose ideas and to implement them for the sustainable management and development of the groundwater.

2.2 MEASUREMENT OF GROUND WATER LEVEL

For the measurement of groundwater level the following methods are adopted

Piezometer – A piezometer is designed to measure the static pressure by measuring the height to which water rises against gravity.

Bore well – A bore well is water well having a long 100-200 mm wide tube or a pipe bored into an underground aquifer. The lower end of the pipe is provided with a strainer and a pump is used to lift water for irrigation. The required depth of bore well is dependent on the depth of water table. Figure 2.3 shows a bore well with its component parts. The aquifer is the zone where groundwater pressure is maximum. Cone of depression is formed when the well is pumped.

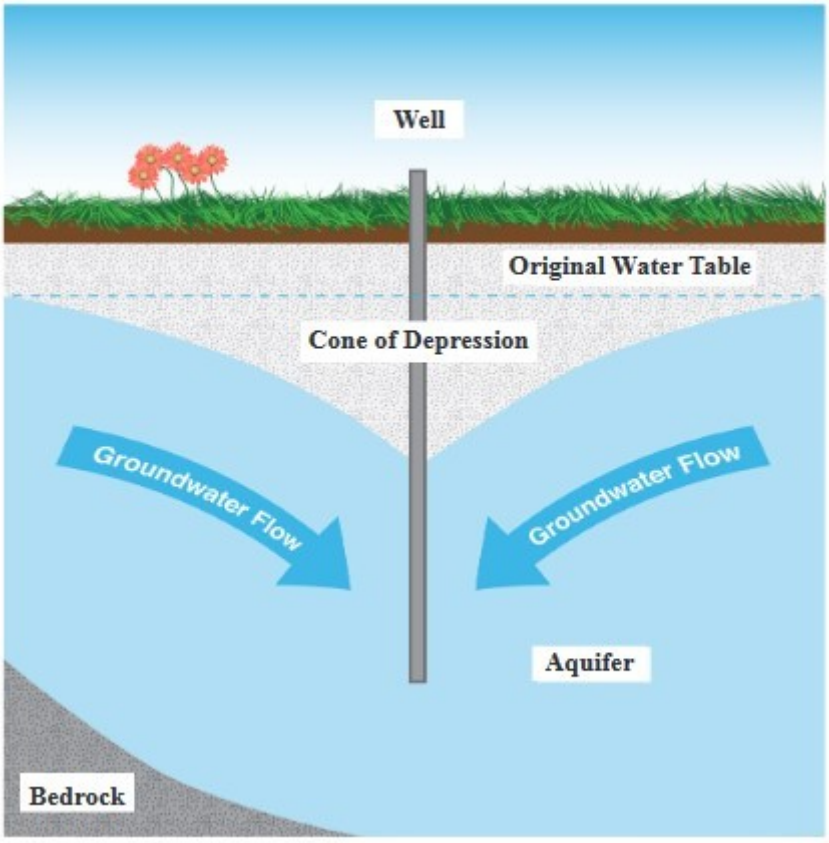

Figure – 2.3 Bore well (http://extensionpublications.unl.edu/assets/pdf/g2188.pdf)

Open Well – To tap storage of groundwater, a vertical hole of bigger diameter is dug in the rock. The hole is dug to a depth below groundwater table. The depth should be such that sufficient water is available in cases of dry conditions. Open wells are of two type's viz. wells with pervious lining and wells with impervious lining

Wells with pervious lining – In this case the lining of wells is done with the help of dry bricks or stone masonry. Contribution of wells takes place through the sides. It is adopted when subsoil formation is of gravel or coarse sand deposits. Figure 2.4 illustrates the same. The following components are shown in the figure

i. **Brick Lining** – The side walls of the well are constructed with brick as they prevent the well from damage due to caving.
ii. **Brick Ballast** – Brick ballast is provided along the sides of the well below the surface of earth so as to control any seepage of water from the well.
iii. **Unsaturated soil zone** – It is the zone which lies between the ground surface and the ground water table. The water content is minimum in this area.
iv. **Saturated Soil Zone** – It is the zone in which water or the moisture content is maximum.

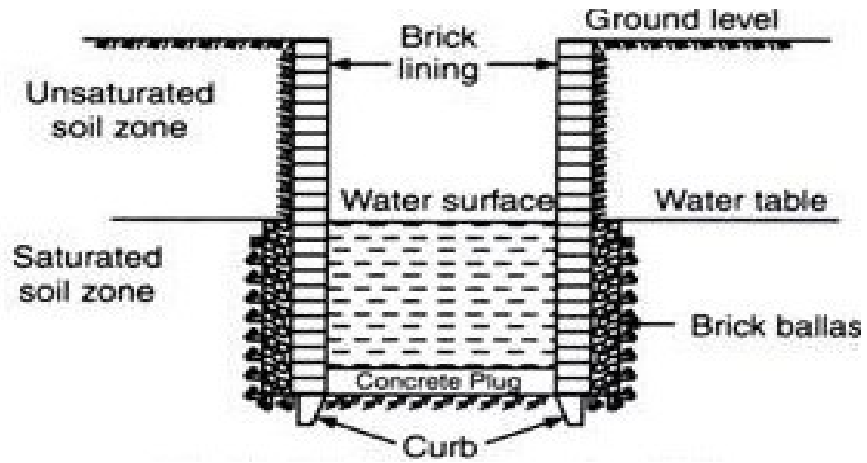

Figure – 2.4Well with pervious lining

(http://cdn.yourarticlelibrary.com/wp-content/uploads/2015/06/clip_image002188.jpg)

Wells with impervious lining – This type is adopted at areas with alluvial soil formation. It is best suited for irrigation purposes as it acts as a permanent source of water until groundwater conditions are favorable. The depth should be up to 30m but not more, as in that case water lifting may be difficult.Figure 2.5 illustrates the same

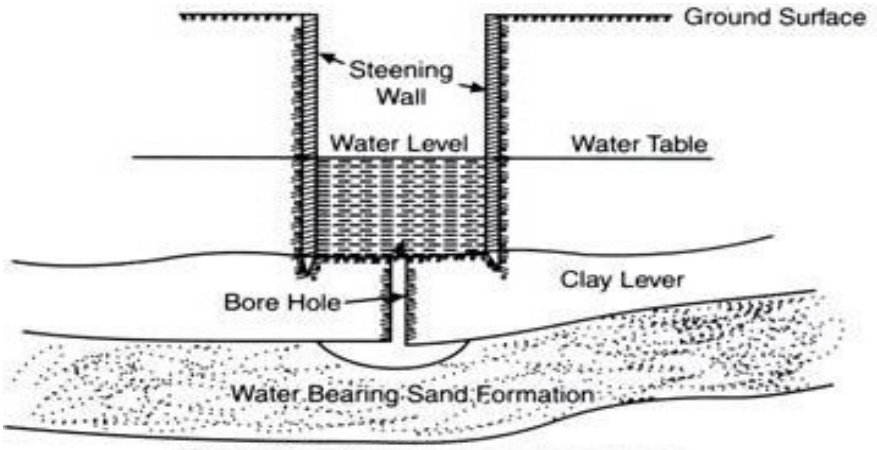

Figure – 2.5Well with impervious lining

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2.3 LITERATURE REVIEW ON ANALYSIS OF GROUNDWATER LEVEL

Kushwaha K. and Goyal R. (2016) conducted a study for estimating the flux of groundwater in Khushkhera-Bhiwadi-Namrana region of district Alwar, Rajasthan with the help of GIS. According to this study, the estimation of groundwater budget is dependent on the accurate estimation of flux across the boundary of the region. The study presented a method based on GIS for the estimation of groundwater flow rate and volume of water flux across the boundary.The study showed that maximum level of groundwater flux was found in the post monsoon season and minimum during the pre monsoon season. Figure 2.6 shows the graph.

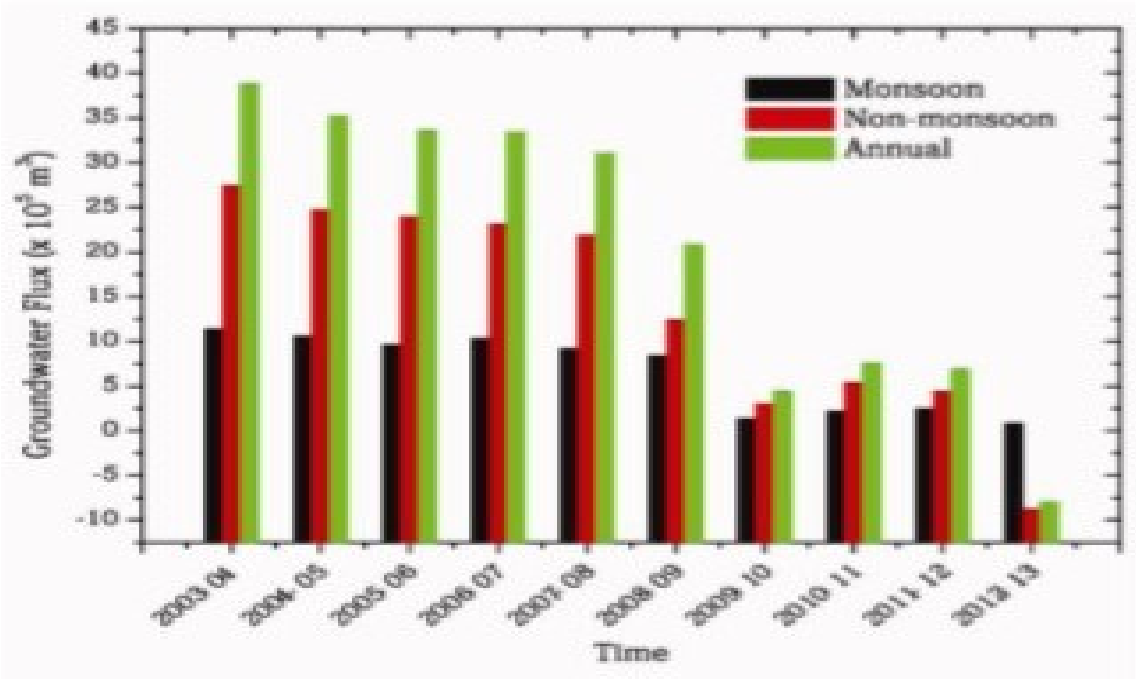


Figure – 2.6 Graph showing variation of Groundwater flux with time

Shekhar M. and et.al. (2017) conducted a study in Bangalore to study the behavior of groundwater system for the period 2015 and 2017. According to the study, on local scale behavior is non classic with valleys depicting deep groundwater than ridge tops. The major reason was less pumping activity. During the drought year of 2016, the depletion of groundwater was analyzed to be 27mm for the study area. According to study it is analyzed that rainfall has the ability to recharge the aquifer. With maximum rainfall during period August-September 2007 the mean recharge was 67mm. So there is an urgent need for continuous monitoring at study area.

Jadwiga R. and Reyes R. (2016) conducted a study to analyze the groundwater resources for agricultural, industrial and municipal uses for the period 2003-2014in major areas of U.S.A. According to the study, during the drought period of 2011-2014, 90% of Texas and 95% of Oklahoma were affected. $1.6 billion production of agriculture was lost due to drought in Oklahoma and $7.6 billion in Texas during the period of 2011. The drought period not only led to water scarcity but also forced the farmers to overuse groundwater for maintaining the production of crops.

Olumana M. and Furst J. (2013) conducted a study to analyze the spatial and temporal fluctuations in the depth of groundwater at Wonji – Shoa Sugar Estate. According to the study after 60 years of irrigation a serious problem of water logging is being faced by the area. Depth is found to be shallow in many piezometers as in Figure 2.7. Unless reasons for decline in level of groundwater table are known, measures cannot be adopted to control it.

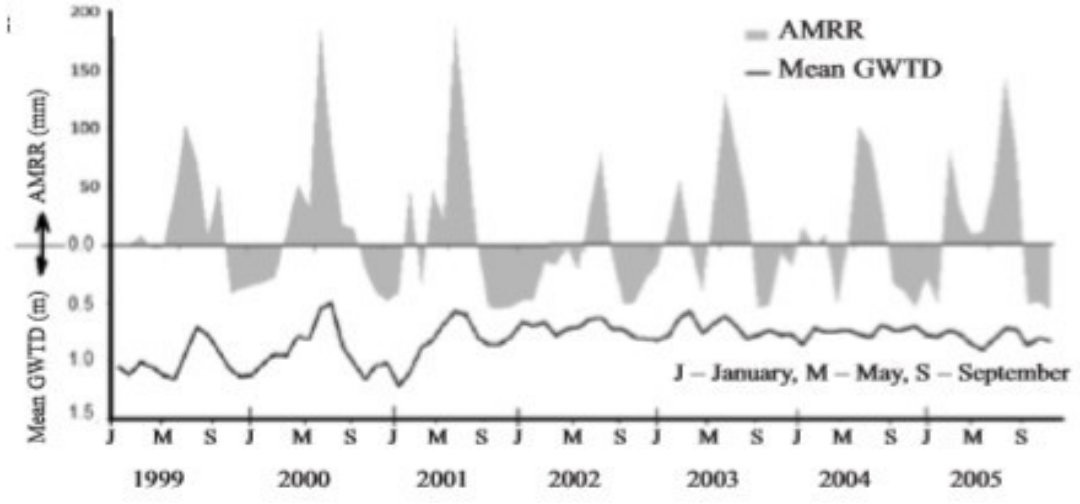


Figure – 2.7 Seasonal Variations in Groundwater due to Annual Mean Rainfall Runoff

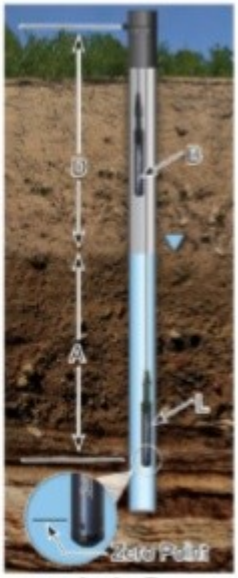
Goyal S.K and Chaudhary B.S (2010) conducted a study to analyze the variations in the depth of water level due to rainfall for the period of 1998 to 2007 in Kaithal district, Haryana as shown in Table 2.1. The depleting rates of groundwater during successive decades were compared with fall in level of groundwater. Further analysis was done to study the block wise change in the level of groundwater. The level of water table in the areas of Gulha, Pandri and Kaithal were found to be declining by magnitude of 10-23m as shown in Table 2.1. The rate of depletion was found to be greater in comparison to other decades for the period of 1999-2007. They recommended that change in pattern of cropping and methods of irrigation are necessary for sustainable management of resource in the study area.

Table -2.1 Block wise average depth to water level and groundwater depletion

Blocks	**Average Pre Monsoon Depth (m)**					**Decline in successive five years (m)**				**Decline 87-07**	**Average annual decline**
	1987	1992	1997	2002	2007	87-92	92-97	97-02	02-07		
Gulha	10.5	13.1	15.25	19.76	26.71	2.6	2.15	4.51	6.95	16.2	0.81
Kaithal	7.32	8.94	8.9	12.04	18.12	1.62	-0.4	3.74	5.48	10.8	0.54
Kalayat	4.79	5.92	4.42	4.55	6.58	1.13	-0.5	0.13	2.03	1.8	0.09
Pundri	8.6	10.36	8.83	10.88	16.13	1.76	-1.53	2.05	5.25	7.6	0.38
Rajaund	6.08	5.89	3.4	4.81	7.12	-0.19	-2.49	1.41	2.31	1	0.05
District Average	7.46	8.84	8.16	10.53	14.93	1.38	-0.68	2.37	4.4	7.47	0.37

Harun N. (2016) carried out a study to monitor the level of groundwater and analyze long term data on level of groundwater using a levelogger. Levelogger is a convenient method to measure level, temperature and conductivity all together. The Measurement of boreholes is the principal information about recharge, discharge and storage. The major advantage of this method is that the collection of data can be updated easily. These can boost the capacity to produce interactive data of level of water to potential users. Figure 2.8 a) and b) shows levelogger and its working.

(a)



(b)

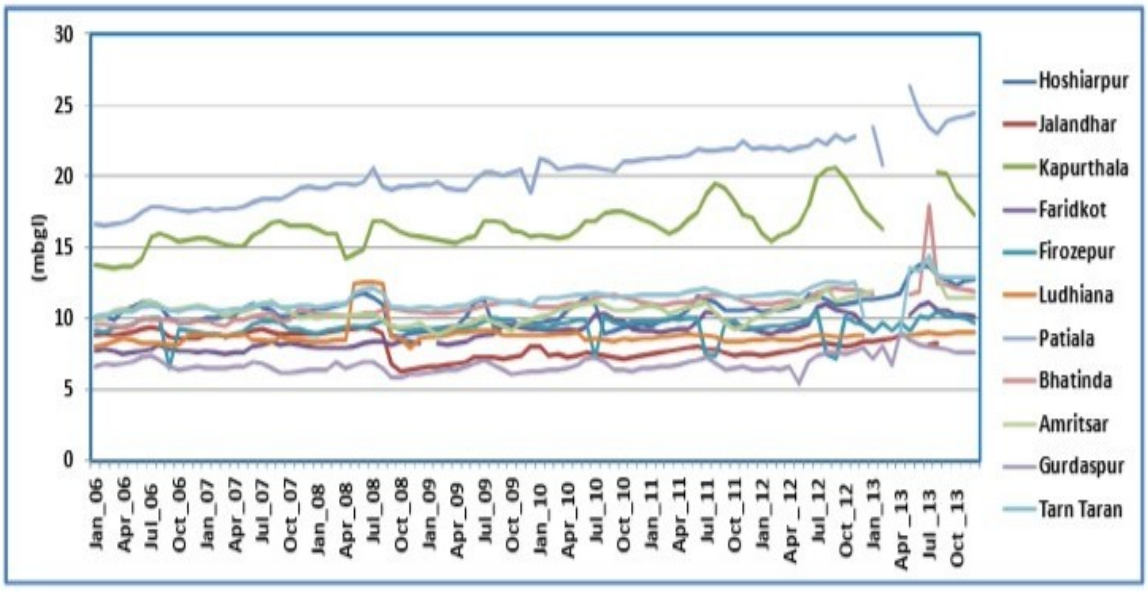
Figure 2.8 a) Levelogger b) Working of levelogger

Rajendra P. and Wendy D. (2015) conducted a study in three districts of South India to analyze the changes in the pattern of irrigation and rainfall. The study concluded that the main reason for the decline in the groundwater level was the increase in use of groundwater for irrigation and power subsidy policy. With the increase in drilling of wells this situation is going to get worst. The Reforms are thus needed to maintain the availability of groundwater for future generations.

Aneja R. (2017) conducted a study to analyze the issue of ground water depletion in the state of Haryana. The study was done to analyze the impact of annual rainfall and number of tubewells on the level of groundwater. According to the study more than 75% of rural, 50% of urban and 50% of irrigation requirements are fulfilled with the help of groundwater. With the passage of time the groundwater is depleting at a higher rate due to increase in the demand. The study revealed that the areas of Gurgaon, Kurukshetra, Kaithal, and Mahendergarh were the most affected areas with groundwater depth depletion getting doubled in the year 2014 compared to 1974. The state is currently facing major problems of water logging and water shortage. The major reason is growth of water intensive crops at areas where the depth is below average. According to study, the decline in level of the groundwater is a challenge for the sustainability of the state.

Saigal S.K. (2013) conducted a study at various areas or blocks of S.A.S Nagar by drilling 11 exploratory wells, 2 slim holes in the depth range of 295-590 m below ground level. In major part of the district the level of water ranges between 5-10m whereas in north western and eastern part the level ranged between 10-20m while in extreme western part it ranged around 30m. In southern part it ranged between 2-5m. According to the seasonal fluctuations there is decline in level of water. The study revealed that Derabassi and Kharar come under over exploited category and so there is no chance of groundwater development. The study concluded that to avoid decline in level of ground water, management of groundwater is necessary with the help of practices like roof top harvesting and construction of recharge systems. Also public awareness is most important for management of ground water.

Kishen G. and Loyal R.S. (2013) conducted a study in various districts of Punjab. According to the study the level of groundwater is decreasing at a high rate due to increasing number of tubewells. The level was monitored for the period of 2006-2013 in areas of Hoshiarpur, Jalandhar, and Kapurthala district of Bist Doab Area, Ferozpur, Ludhiana, Bathinda and Patiala of Malwa region and Amritsar, Gurdaspur and Tarn TaranDistrct of Majha region. Study found that decline in level was 9.75m in Patiala, 8.57m in Bathinda and 3.13m in Jalandhar. The areas showing decline in level of groundwater need to adopt artificial recharge practices. Immediate measures need to be taken to control the decline in the level of groundwater for future benefits. Figure 2.9 shows graph of variation in level of groundwater in various districts in Punjab.



Figure– 2.9 Groundwater level variation in Various Districts inPunjab

Mangalekar S.B and Samant J.S (2014) conducted a study in the Kolahpur District. According to, study apart from surface water; groundwater is also used for drinking and irrigation purposes.

With the increase in population and agriculture, there is an increase in the demand of water for daily activities which leads to depletion of groundwater level in the study area. The major causes for depletion are disturbance in sewage maintenance and uncontrolled runoff. The study recommends that there is an urgent need for strategy to implement sustainable development and management of groundwater in the study area.

Shao-Feng Yan and Yu-baiWu (2014) constructed nine shallow wells to study the level of groundwater in the coastal plain area of Tiangsu Province, China. According to the results precipitation and evaporation had a great impact on the ground water level in the study area. The results were found positive related to precipitation while negative results were found in terms of evaporation. During dry season salinity increased reaching to peak in December. Season had a great impact on changes in the ground water level. Fluctuations in level were observed during wet season while fluctuations in evaporation were found during the dry season as shown in Figures 2.10 a) and b).

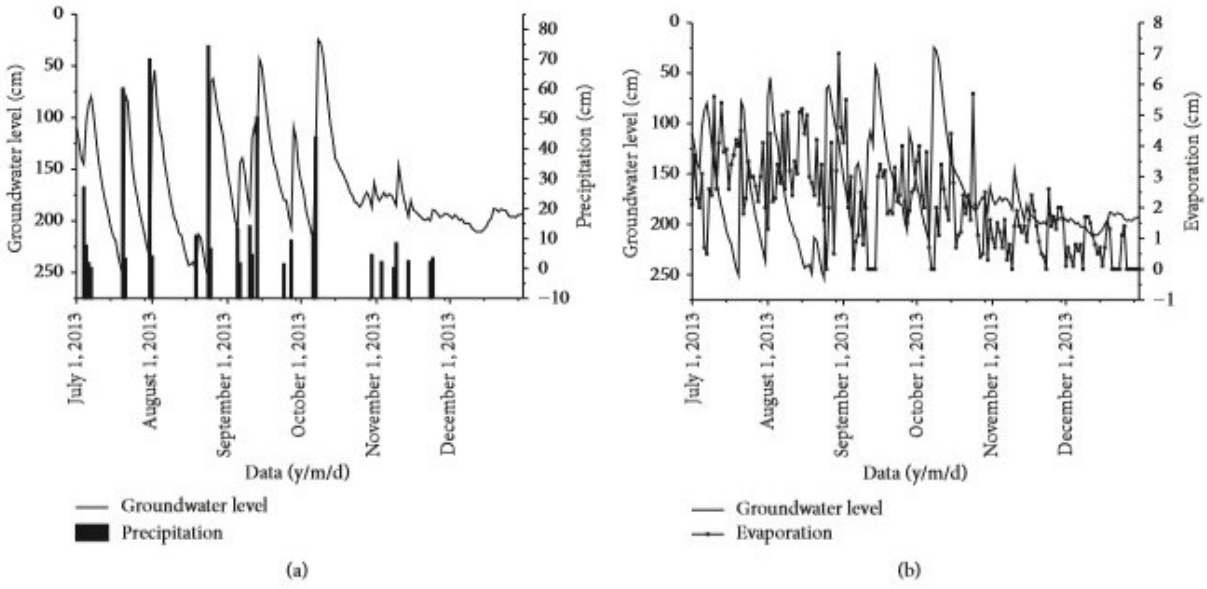


Figure 2.10 a) Groundwater level fluctuation due to precipitation and b) due to evaporation

Suhag R.(2016) conducted a study to analyze the trends of groundwater level all over the country India.The aim of the study was to increase management of groundwater resource by i) identifying and mapping the aquifers ii) analyzing the quantity of available ground water and iii) proposing plans accurate for scale of demand, characteristics of aquifers and methods for management. The groundwater level was found to be low in the states of Delhi, Punjab, Haryana, Punjab and Rajasthan with above 40 mbglwhereas in the states of Tamil Nadu the level was found to be 5-10 mbgl while in coastal areas it was found below 2 mbgl. According to study, the country is heading at a rapid rate towards crises of overuse of groundwater and contamination. Figure 2.11 depicts depth to water level in India.

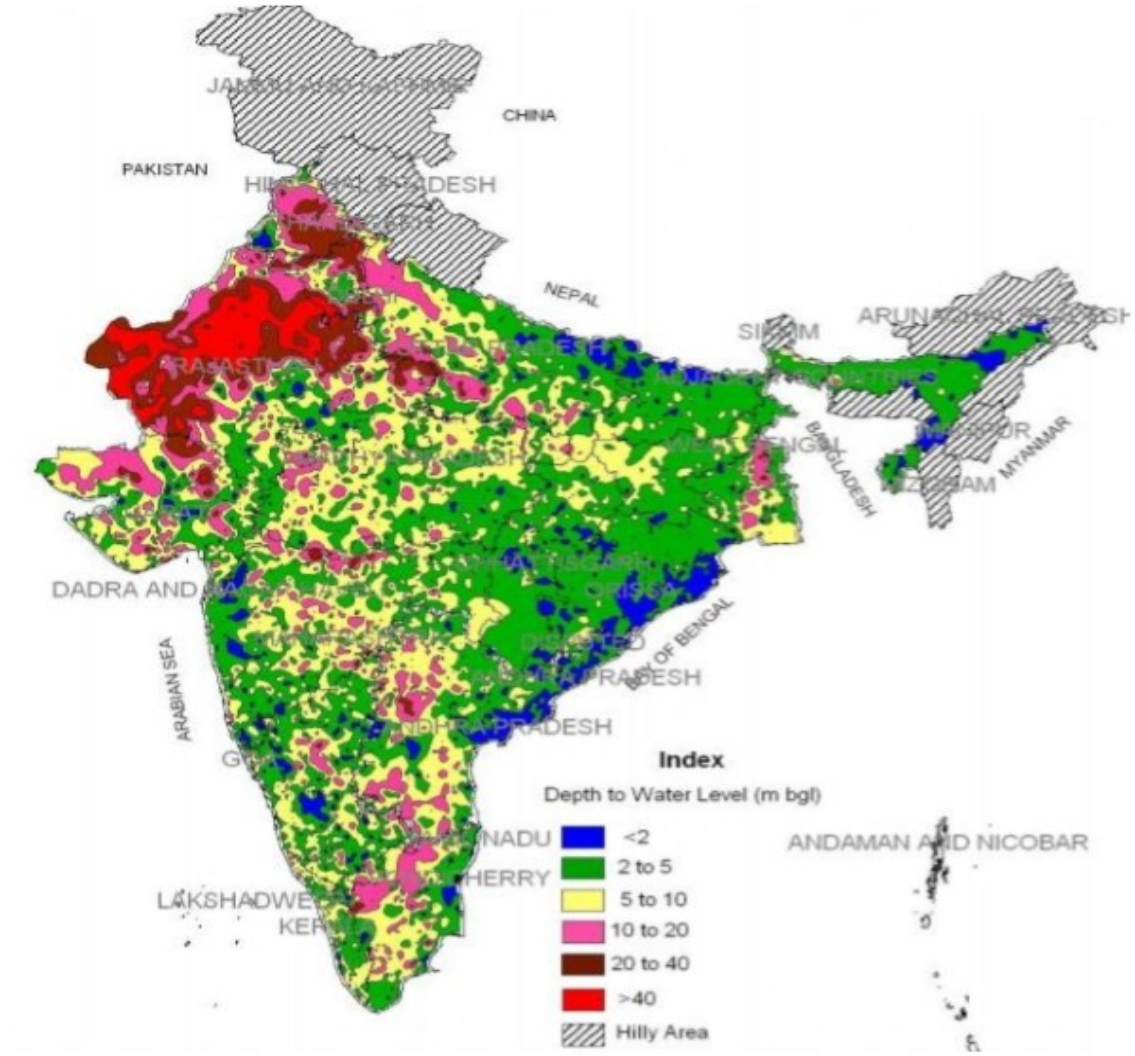


Figure – 2.11Map of India showing depths of groundwater level

Pandey V.P and Shrestha S. (2012) conducted a study to analyze the knowledge and facts related to development and management of groundwater in the Kathmandu valley, Nepal. The study discussed the importance of groundwater in the valley and its availability and positive and negative effects on the level of groundwater and measures to adopt sustainable management of groundwater in the area. The paper also suggested the need to invent methods to monitor groundwater and conservation under an effective leadership. Table 2.2 displays the results of these locations

Table – 2.2 Aquifer depletion at selected locations

Location	WID	Previous water level(mbgl)		Current water level(mbgl)		Depletion (metres)
Bansbari	Bal-La	2000	5.27	2008	10.89	5.58
	M8	2001	12.75	2008	14.52	1.77
Gokarna	GK-2a	1999	16.41	2008	23.91	7.50
	GK4	2000	16.60	2008	20.18	3.55
Dhobi Khola	DK 1	1999	28.90	2008	30.73	1.53
	DK 8	2000	3.89	2008	5.27	1.38
Manhora-Bhaktapur	BHK-1	1999	37.68	2006	42.00	4.32
	M5	2001	93.33	2008	92.87	5.54
Pharping	M1	2001	8.48	2008	8.85	0.37
Central Area	I 26	2000	7.37	2008	13.08	5.71
	G17	2000	10.68	2008	11.68	1.00

Soumendra N. and Mukherjee A. (2016) conducted a study to analyze the trends of level of groundwater in different states of India. According to the study the decreasing level of groundwater in India is a major issue in recent years.

According to statistics India, is the largest user of groundwater. The decrease in level of groundwater is due to rapid and unmanaged ground water withdrawal. According to the study there has been decrease in level of groundwater at the rate of (-5.81±0.38 km^3/year) for the period of 1996-2001, (-0.92±0.21 km^3/year) for the period 1996-2002 while it was (2.04±0.20 km^3/year) for the period 2002-2014 and (0.76±0.08 km^3/year) for the period 2003-2014 in western and southern region. The study recommends that policies and reforms are needed to be made in order to refill the aquifers in west and southern regions of the country.

Sukumar S. and Sankar K.(2011) carried out a research work in the Theni District, Tamil Nadu. The depth to water level of the district was found to be fluctuating during the period of 2005-2007 and in some areas it was found to be 2-5 m below ground level. Of the 8 blocks, 5 blocks came under the over exploited category while 3 came under critical zone. The study recommends that there is a need for artificial recharge was must to control the depletion of the groundwater.

Anil M. and Bhushan R.(2014) carried out a study in the WR-2 Watershed area of the Deccan trap in the state of Maharashtra. The rich orange orchard belt utilizes huge amount of water which is met with the help of groundwater. With the increase in utility of the groundwater there is decline in the level of water below ground. With the decline in trends of the level a negative impact is being created on the quantity of the study area.
The trend was found to be decreasing at a rate of 0.003 to 0.004m per year for the period 1977-2010 whereas during the period 2007-2010 it was 0.03 to 0.67 m per year. There is an urgent need to provide measures to control the depletion of level in the study area. The major reason for the decline in the level of groundwater was due to the increased level of salinity in the water. The region of central and southern part of the study area show deep levels of groundwater compared to the other regions of the area. These regions are more compatible to contamination of water. The other major reason for the decline in the level of groundwater is due to growth of crops like orange at higher rate which requires more water for production and growth. There is an urgent need for the stakeholders, people and other government officials to come together and provide reforms to control the depletion of groundwater and implement these ideas. Although efforts have been taken but still much more is to be done to control the decline in the level of groundwater.

S.B Pan and Z.J Wang (2008) carried out a study to analyze the trend of groundwater level in the North West region of China. According to the study there is an urgent need for the development and utilization of groundwater management model in the study area. The level of groundwater needs to be shallow which means it should be at such a level so that water is easily available for the fulfillment of the present and the future generations.
The aim of the study was to develop information model of level of groundwater with the help of remotely sensed data i.e. data will be collected with the help of remote sensing technique. The results provided tools and methods for the sustainable development and management in the arid region of the study area. According to the study there is an urgent need for the

implementation of these methods so as to control the depletion of the level of the ground water in the North West region of China. Figure 2.12 shows the relation between soil moisture with depth of groundwater level. With decrease in soil moisture depth of groundwater decreases.

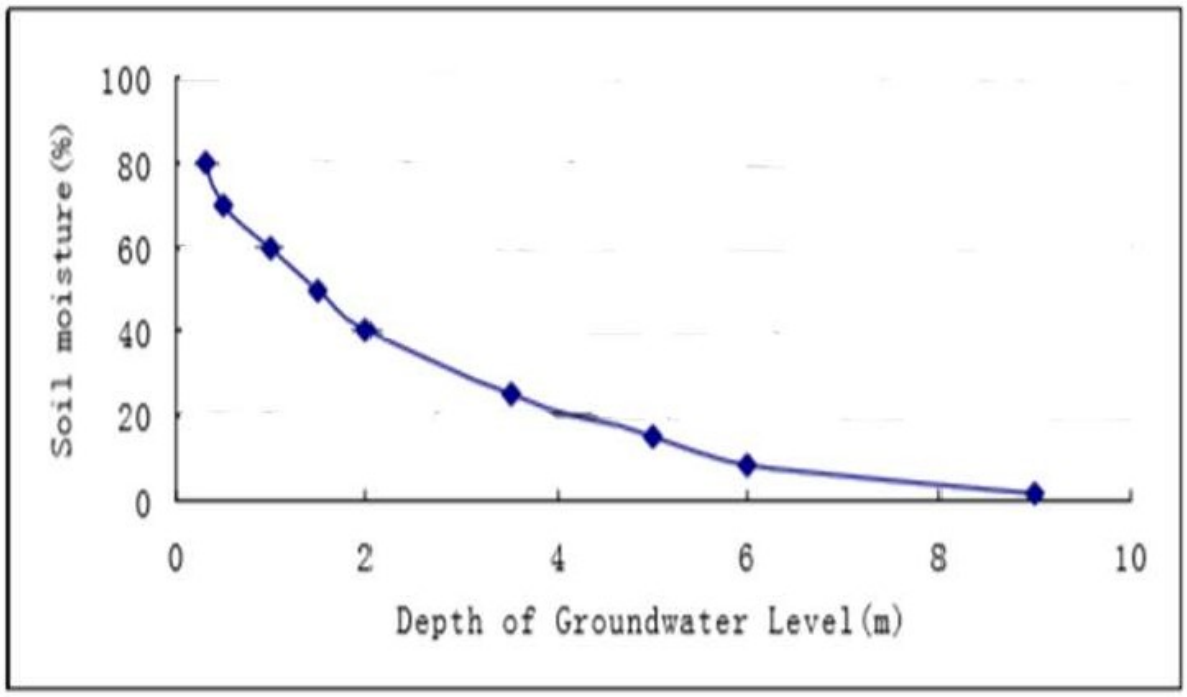


Figure-2.12 Graph showing relation between soil moisture and Depth of Groundwater Level

Chavanglin F. and Shaoping J. (2018) conducted a study to analyze the trend of the ground water level using regional Kendall test of correlated special data in the area of Beijing, Tianjim and Hebel areas of China for the years 1959, 1984, 2005 and 2013.
The results showed declining trend in ground water level indicating higher recharge rate than the withdrawal rate. The rise was due to supply driven water resource management whereas reverse was due to measures that implemented stresses in groundwater.

Sreenivasulu D. and Gumageri N. (2015) conducted a study in the coastal regions of India. The aim of the study was to evaluate the behavior of fluctuation of level of groundwater and study the changes due to parameters like temperature, humidity, rainfall, evaporation and soil type. In order to study the behavior, 42 open wells were analyzed keeping in mind weekly and seasonal variations.

According to the study most of the coastal regions are facing problems of shortage of water due to decline in the level of groundwater. With the increase in the demand of water, improper planning strategy, poor practice of agriculture the level of groundwater gets depleted.

Level was found to rise during monsoon season and decline during summer season for previous seven years. There was increase in level during the period 2004-2007 and 2008-2011 while it decreased during the period 2008-2011. Rainfall, stream flow and soil type have a great influence on the level of the ground water. Urgent steps need to be taken to control the depletion in level of groundwater.

Priyanka and Kishen G. (2016) conducted a study in the Mewat district of Haryana. According to the study due to low amount of rainfall and varying geological conditions there has been a decline in the level of groundwater. The data was collected for pre and post monsoon period for the year 2011-2015. 40 wells were monitored in the study area.
It was found that there was a gradual decline in the level of groundwater and immediate measures needed to be taken to control the depletion of groundwater in the study area. During the post monsoon season there is rise in the level of groundwater while during the pre monsoon season the level showed a declining trend due to non availability of rain and high extraction of water from the well by the people to meet their daily requirements.

Kumar P. and Kishen G. (2018) conducted a study to evaluate the level of groundwater using modified Mann Kendall method and Semi Slope Diameter method for the period of 1998-2012 for 13 locations in four districts of Lucknow i.e. Hardoi, Laxmipur, Luknow and Sitapur Uttar Pradesh.
The study showed negative results for seven areas covering 54% of the total area while positive results for six areas covering 46% of the total area for the pre monsoon period. During the post monsoon period four locations showed negative results covering 31% of the total area while nine locations showed positive trend covering 69% of the total area. The difference is due to the ability to recharge the groundwater of these areas.

2.4 CONCLUSIONS

The conclusions derived from the study of the previous research papers are that in many regions around the country the problem of depletion of ground water is a critical issue. The groundwater is considered to be the purest source of water available for the benefits of the humans and animals of the present and the future generations.

With the increase in the urbanization there has been an increase in the demand for fresh source of water to fulfill the daily needs. This leads to increase in extraction of the groundwater. This leads to depletion of the water available below ground surface leading to decline in its level.

The level of the groundwater depends on the temperature variations, average annual rainfall, agriculture and irrigation practices of the particular area. The studies also revealed that during the monsoon and post monsoon season there was an increase in the level of groundwater while it decreased gradually during the pre monsoon season. The major reason was that during monsoon season and post monsoon season rainfall occurs leading to increase in the level of groundwater while during the pre monsoon season due to high temperature evaporation is at a high rate leading to decreasing level of groundwater.

The other major reason for the declining level of groundwater was the growth of water intensity crops. For example in case of Punjab paddy crops require more water for their growth and are grown during the month of July-August. Due to the growth of these crops the extraction of groundwater increases leading to decline in the level of groundwater making it unavailable for the fulfillment of the future generations. So it’s high time we all come together and form policies and reforms and implement them in order to control the depletion of the groundwater.

Figure 2.13 reveals that India is the largest unmindful consumer of groundwater compared to other countries and Figure 2.14 shows the amount of groundwater available, demand of the people and the water utilized by the people for the period 1997-2050.

Figure – 2.13 Annual Groundwater with drawls of five different countries

(https://sandrp.in/2017/02/09/ground-water-2016-indias-water-lifeline-continues-to-bleed/)

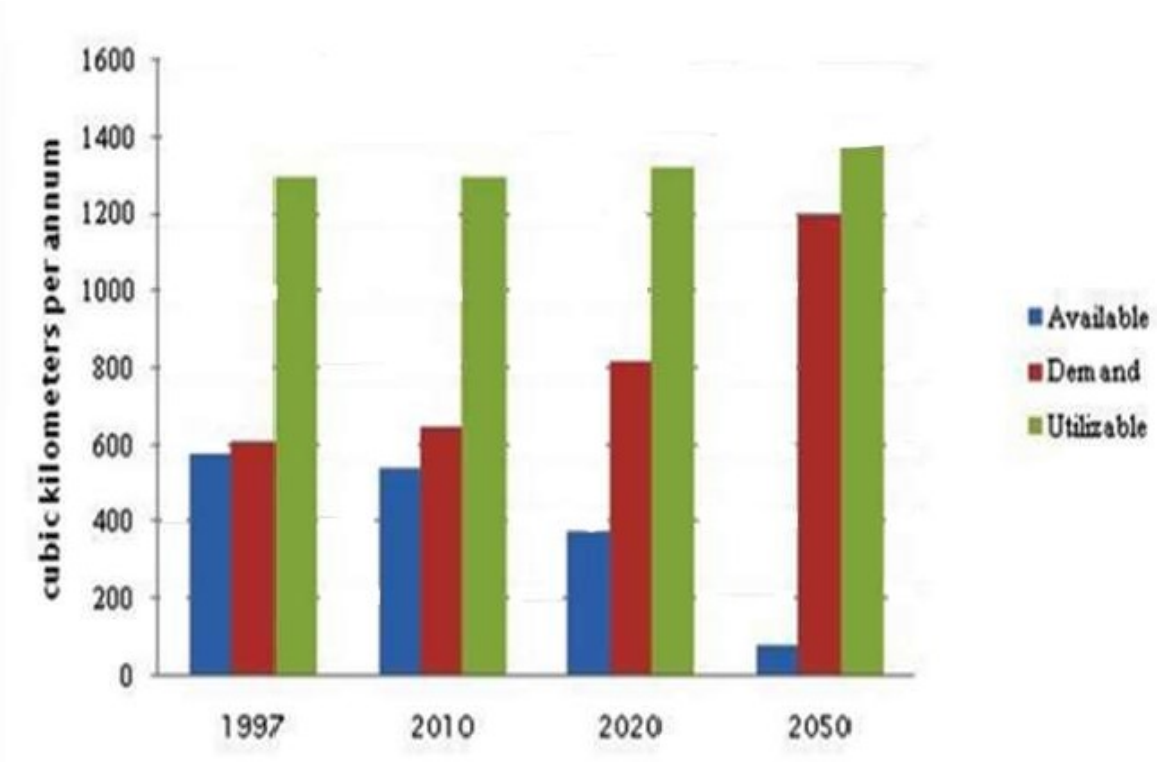


Figure -2.14 Groundwater availability, demand and utilizable in India

(http://www.futuredirections.org.au/publication/india-s-food-and-water-security/)

CHAPTER – 3 INSTRUMENTS AND METHODOLOGY

3.1 GENERAL

S.A.S. Nagar is a district of Punjab growing at a rapid rate having a population of 994,628. (https://www.census2011.co.in/census/district/605-mohali.html). The district is named in the memory of the eldest son of the Tenth Guru of Sikhs 'Sri Guru Gobind Singh' 'SahibzadaAjit Singh'. The annual growth rate of population in the district is found to be 33% during the year 2011 compared to 2001. Last census was conducted during the period of 2011 and the next census is scheduled to be held during the period of 2021. Figure 3.1 shows S.A.S Nagar district with different blocks and tehsils.

Figure – 3.1 S.A.S Nagar DistrictMap

The study conducted in the district gave unsatisfactory results with respect to the level of the ground water. Due to the unavailability of the water below ground surface, the wells are drying at a rapid rate forcing the people to use canal water. In this way both the surface and groundwater are depleting day by day and if it is not controlled, a time may come when there may be less or no water available for the future generation.

3.2 LOCATION OF STUDY AREA

The area of study i.e. S.A.S Nagar is one of the twenty two districts of Punjab and lies to the north of the tropical cancer and east to the state of Punjab. It lies on the 30.69° N and 76.72°E coordinates. The population of the S.A.S Nagar district is 986,147 with a growth rate of 32.02%. (https://en.wikipedia.org/wiki/Mohali_district). The district was formed in the year 14 April 2006.

To analyze the status of the groundwater level in the district the following parameters were considered.

i. **Monthly Variations** – Data was recorded on monthly basis for various sites of the district and analysis was done. The months of the recording were January, February, March, April, May and June.

ii. **Yearly Variations** – Data is analyzed for five consecutive years in order to monitor the changes in the trend of the level of the groundwater in the selected sites of the district.

iii. **District Wise Variations** – The level of groundwater in S.A.S Nagar is compared with the neighbouring districts of Patiala, Fatehgarh Sahib and Roopnagar to analyze the trends in the level of the ground water.

3.3 STUDY SOURCE

For the study, open wells were analyzed and those with impervious lining. These types of wells are best suited for areas having alluvial soil. The major advantage of these wells is that it acts as a permanent source of water till the period groundwater availability conditions are favorable. Depth is limited to 30m because excess may lead to difficulty in water lifting process. Table 3.1 shows thickness to be provided to wall of the well with respect to depth of well.

Table – 3.1 Thickness of well wall with respect to depth(http://cdn.yourarticlelibrary.com/wp-content/uploads/2015/06/clip_image00647.jpg)

Depth of well in meters	Wall Thicknessof well (cm)	
	Brick	Masonry
3	33	30
3-10	45	38
10-15	54	45
15-20	61	54
20-30	68	61

In the case of previous studies regarding the level of groundwater these wells were used. Figure 3.2 illustrates the same.

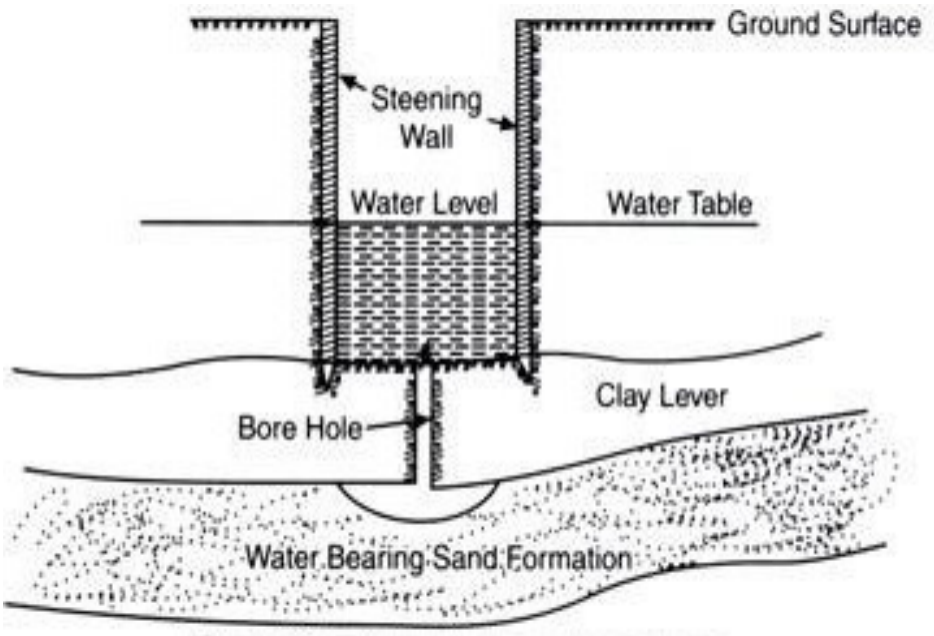


Figure – 3.2 Open well with impervious lining

(http://cdn.yourarticlelibrary.com/wp-content/uploads/2015/06/clip_image00468.jpg)

3.4 LOCATION OF STUDY SITES

For the study the following blocks were selected and the wells of these blocks were analyzed

a) Derabassi
b) Zirakpur
c) Mohali
d) Kharar
e) Landran

a) **Derabassi** – Derabassi lies to the South East of the S.A.S Nagar district on the Chandigarh – Delhi National Highway. Derabassi is located about 22 km from Mohali. It has an average elevation of 321 meters. The climate of Derabassi is humid sub tropical with very hot summers, unreliable rainfall pattern and great temperature variations. The study site is Issapur village which is about 3km from Derabassi and Derabassivillage. Figure 3.3 shows the Issapur area of Derabassi and figure 3.4 shows Derabassi area.

Figure – 3.3IssapurVillage, Derabassi

Figure – 3.4DerabassiVillage

b) **Zirakpur** – Zirakpur is a small town which is 17.1 km from Mohali towards North East side. It is on the foothills of the Shiwalik hills. It lies on the tri junction of the National Highways – Himalyan Expressway, National Highway 5 towards Shimla, Ambala – Chandigarh Highway towards Ambala and National Highway 7 towards Patiala. The study location is village Dhakoli about 4.7km from Zirakpur. Figure 3.5 shows Dhakoli village of Zirakpur

Figure – 3.5DhakoliVillage, Zirakpur

c) **Mohali** – Mohali is the main location and a major block of S.A.S Nagar district. Mohali along with Chandigarh and Panchkula forms the tricity. Climate here is sub tropical continental monsoon with hot summers and cold winters. Average annual rainfall in the area is 617mm. The study location selected is village Sohana which is about 4.2km from the district. Figure 3.6 shows Sohana village of Mohali.

Figure – 3.6Village Sohana, Mohali

d) **Kharar** – Kharar is a town and a municipal council which lies to the east of the district and is about 10km from the district. It is considered to be a tri junction of Kharar – Banur highway, Kharar – Chandigarh highway and Kharar – Roopnagar highway. The study was carried out at a village named Goga about 12km from Kharar.

e) **Landran**– Landran lies to the south of the district and is about 6 km from the district. The total population of the village is 2338. The study was carried out at areas of Landran and Dheri as shown in Figures 3.7 and 3.8.

Figure – 3.7LandranVillage

Figure – 3.8DheriVillage

3.5 METHODOLOGY

To measure the level of groundwater a heavy weight is tied to the end a steel tape which is 30m (100ft) in lengthas shown in Figure 3.9. The reason for using the heavy weight is to sense the ground surface below the well.

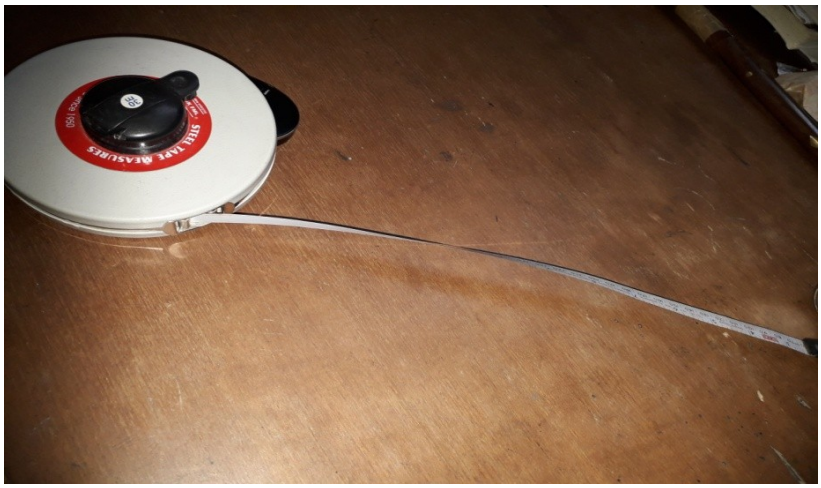


Figure – 3.9 Metallic Tape 30m in Length

The tape along with the weight is immersed into the well and made to touch the water surface. The dry portion and the wet portion of the tape are noted. The dry portion is subtracted from the wet portion to calculate the depth of the water below the ground level.

The well used were open well with impervious lining as in this case water easily enters the well through the hole bored below the well. One of the well of the study areas is shown in the Figure 3.10.

Figure – 3.10 Open well for the study of ground water depth

CHAPTER – 4

OBSERVATIONS, PRESENTATION AND DISCUSSION OF RESULTS

4.1 GENERAL

With the increase in urbanization, there is an increase in population and so there is an increase in demand of water to carry out the daily activities. In addition to the water extracted from canals people are extracting water from the ground to meet their day to day activities. This leads to depletion of groundwater leading to its shortage.

The scope of the study was to analyze the level of the groundwater on the basis of monthly, yearly and district wise and study the causes for depletion and to propose measures to control the depletion of the level of groundwater. For the yearly variations and comparison, data has been observed for five consecutive years 2013-18 for the neighboring districts vizRoopnagar, Patiala and Fatehgarh Sahib.

Although analysis of the level of the groundwater is done on the basis of collection of data during the pre and post monsoon season but due to time shortage the data was collected on the monthly basis for S.A.S Nagar District from January 2019 to June 2019. The pre monsoon season is the season which occurs before the arrival of rainfall. During this season the rainfall is low. The post monsoon season is the season which occurs after the arrival of monsoon season. During this period there is an increase in the level of groundwater.

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4.2 OBSERVATIONS

To analyze the results of the study, tables and graphs were prepared with the help of software Microsoft Excel. The following tables depict the value of level of groundwater whereas the figures depict the variation in the data of the level of groundwater of the selected areas.

4.3 RESULTS

4.3.1 Result – 1

Table 4.1 and Figure 4.1depicts the variations in groundwater level for the districts Roopnagar, Patiala, S.A.S Nagar and Fatehgarh Sahib for the post monsoon season. Figure 4.2 shows the line graph of the data.

Table 4.1 Groundwater Variations for post monsoon season

Area	Groundwater depth variation (mbgl) (post monsoon)
Roopnagar	4.9
Patiala	5.79
S.A.S Nagar	1.7
Fatehgarh Sahib	22.55

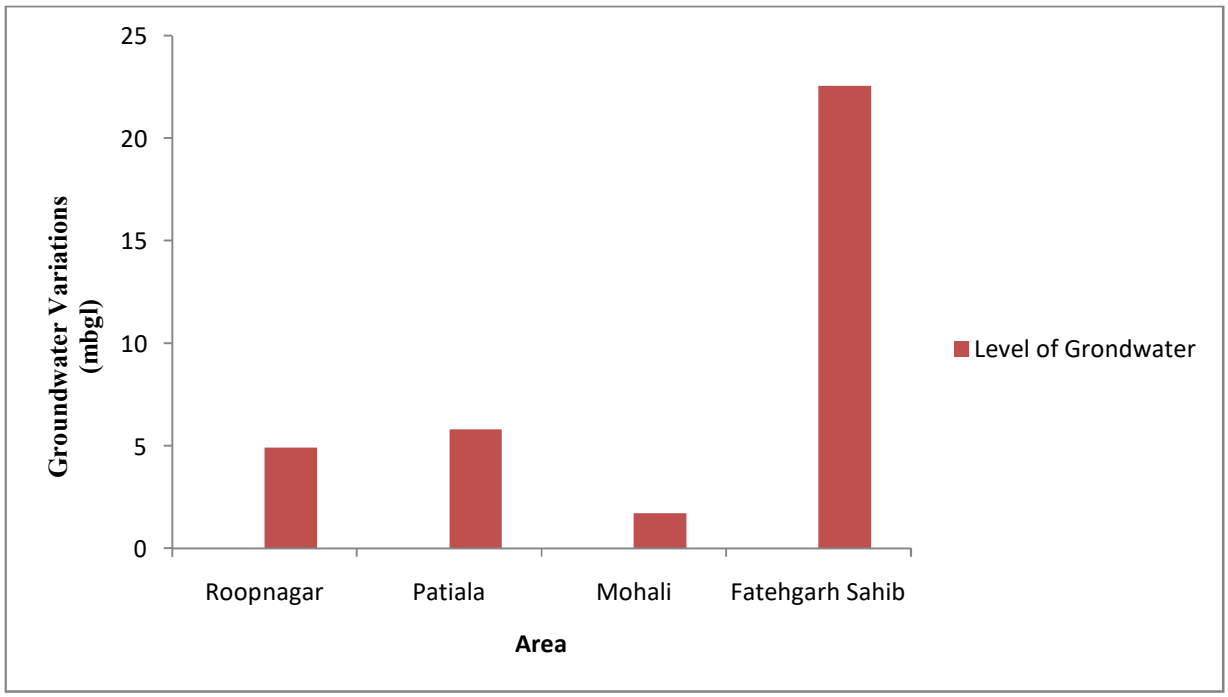


Figure - 4.1 Groundwater Level Variations (mbgl)

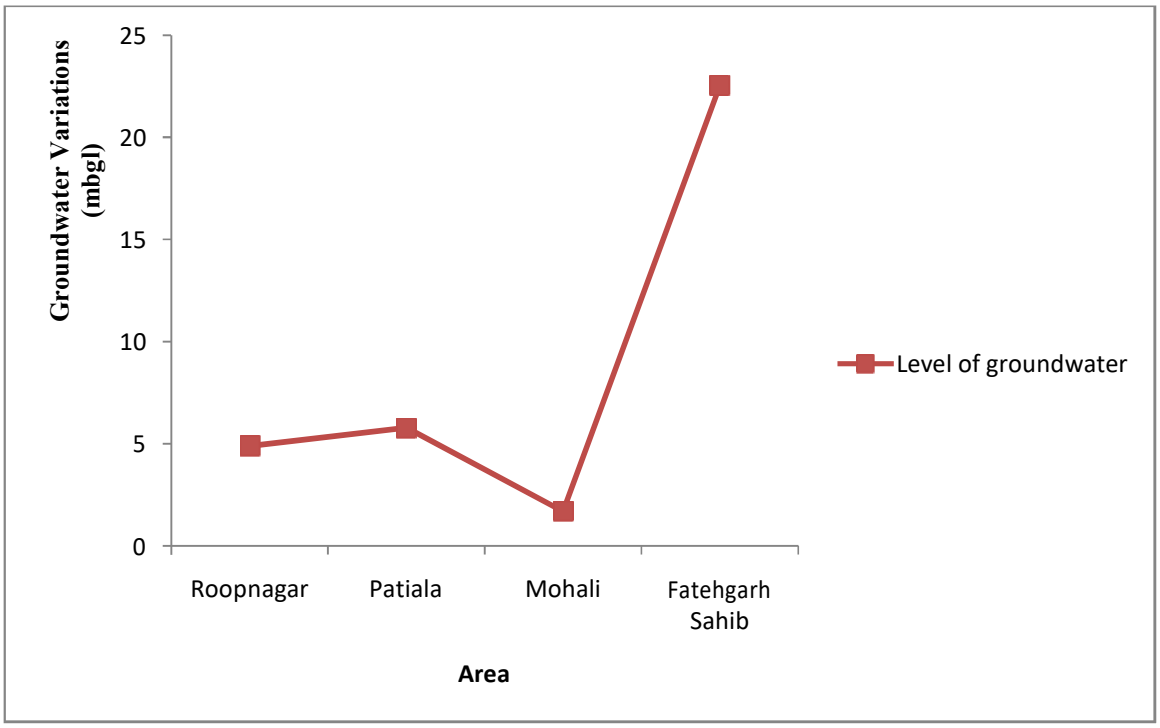


Figure – 4.2 Line graph showing the variations in level of groundwater

4.3.2 Result – 2

Table 4.2 and figure 4.3 depicts the variations in groundwater level for the districts Roopnagar, Patiala, S.A.S Nagarand Fatehgarh Sahib for the pre monsoon season (2018). Figure 4.4 shows the line graph of the data.

Table – 4.2 Groundwater Variation for pre monsoon season

AREA	**Groundwater depth variation (mbgl) (pre monsoon)**
Roopnagar	5.7
Patiala	7.79
S.A.S Nagar	3.4
Fatehgarh Sahib	21.55

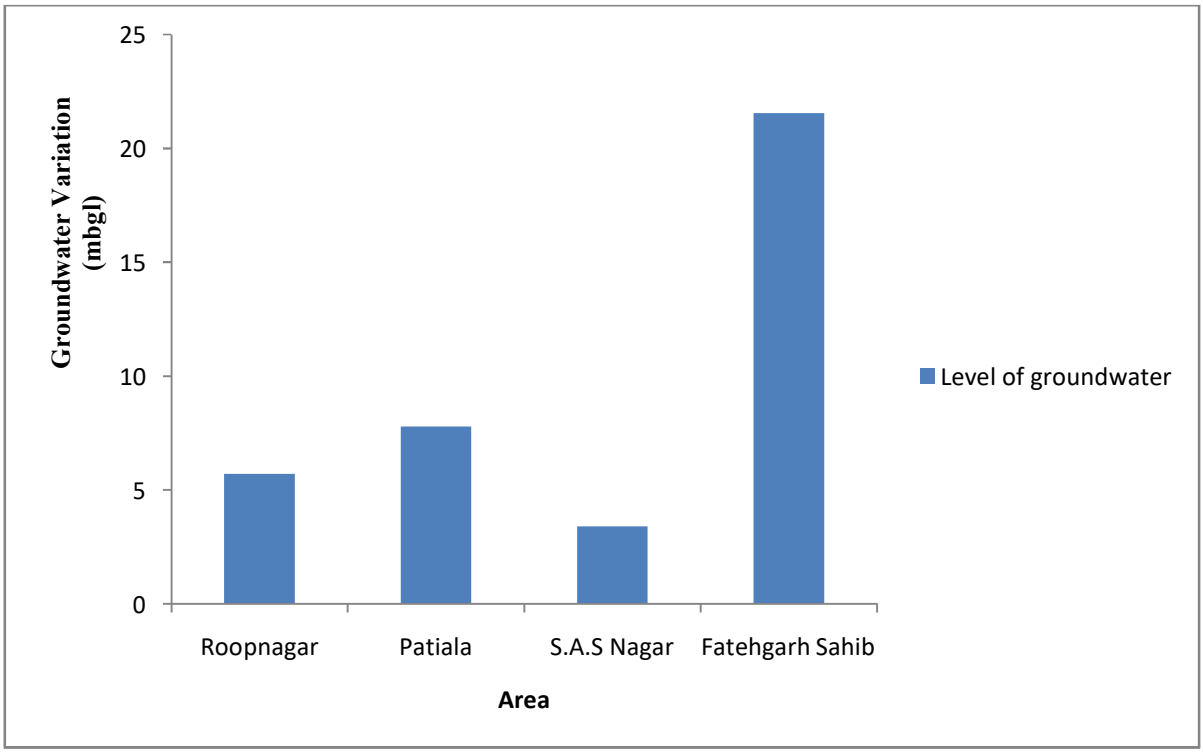


Figure – 4.3 Variations in Groundwaterdepth for pre monsoon season

Figure – 4.4 Line graph showing the variations in depth of groundwater level

Observations

The following observations are made for these districts in pre and post monsoon season for the period 2018. The level of the groundwater during this study was found to be maximum in S.A.S Nagar district while minimum in Fatehgarh Sahib district. All the reading of the figures and tables are expressed in terms of depth of water below ground level.

1) **Roopnagar** – In Roopnagar, the level of groundwater was found to be satisfactory during the pre and post monsoon season. The major reason was the presence of abundant water resources in this area. Roopnagar lies near to Himachal so the major rivers like Sutlej and canals like Sirhind canal and Bhakra main line canal pass through this area. The people of this area prefer to use surface water instead of groundwater for their daily requirements.

2) **Patiala** – In Patiala, the level of groundwater was found to be at the critical zone during the pre and the post monsoon season. The major reason is that the consumption of groundwater is more in this area as compared to recharge rate.

3) **S.A.S Nagar** – In S.A.S Nagar, the level of groundwater was found to be satisfactory compared to other districts during the pre and post monsoon season. The major reason is that S.A.S Nagar lies near to Chandigarh and forms the tri city region. The people here use water supplied by Municipal Corporation to meet their daily requirements leading to less consumption of groundwater. The nearest available source is Kajauliheadworks at Morindaconstructed on the Bhakra main line canal.

4) **Fatehgarh Sahib**– In Fatehgarh Sahib district the level of groundwater was found to be least compared to other districts during the pre and post monsoon season. The major reason is that in this district, the groundwater is much more pure as compared to other water sources. So the people prefer to utilize groundwater at a higher rate compared to other districts.

4.3.3 Result – 3

Table 4.3 and Figure4.5 depict the yearly comparison of groundwater level from 2013-18 in the districts Roopnagar, Patiala, S.A.S Nagar and Fatehgarh Sahib for the pre monsoon season

Table – 4.3 Yearly Groundwater Variations for Pre Monsoon Season

DISTRICT	**Groundwater Depth Variation (mbgl) (Pre-Monsoon Season)**					
YEAR	2013	2014	2015	2016	2017	2018
Roop Nagar	4.85	5.43	5.55	5.75	6.15	5.7
Patiala	7.79	7.29	7.19	6.79	7.59	7.79
S.A.S Nagar	2.7	1.75	3.2	2.95	3.2	3.4
Fatehgarh Sahib	17.85	17.8	18.35	19.35	20.55	21.55

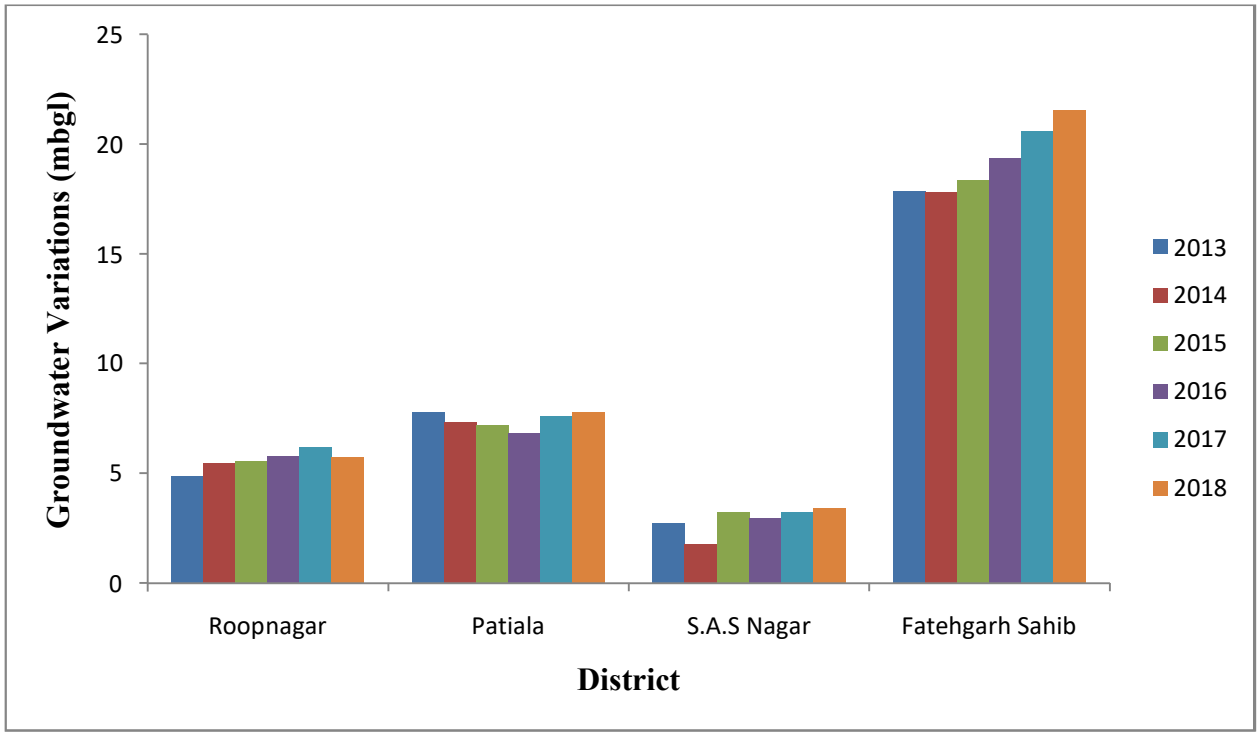


Figure – 4.5 Yearly Groundwater variations for Pre Monsoon season

4.3.4 ,4 Result – 4

Table 4.4 and Figure 4.6 depict the yearly comparison of groundwater level from 2013-18 in the districts Roopnagar, Patiala, S.A.S Nagar and Fatehgarh Sahib for the post monsoon season

Table –4.4 Yearly Variations for post Monsoon Season

DISTRICT	Groundwater Depth Variation (mbgl) (Post Monsoon Season)					
YEAR	2013	2014	2015	2016	2017	2018
Roop Nagar	3.75	4.7	4.65	5.15	4.85	4.9
Patiala	4.04	5.29	3.09	4.29	5.59	5.79
Mohali	0.8	1.3	2.25	1.2	2.4	1.7
Fatehgarh Sahib	18.05	19.45	19.1	19.6	21.5	22.55

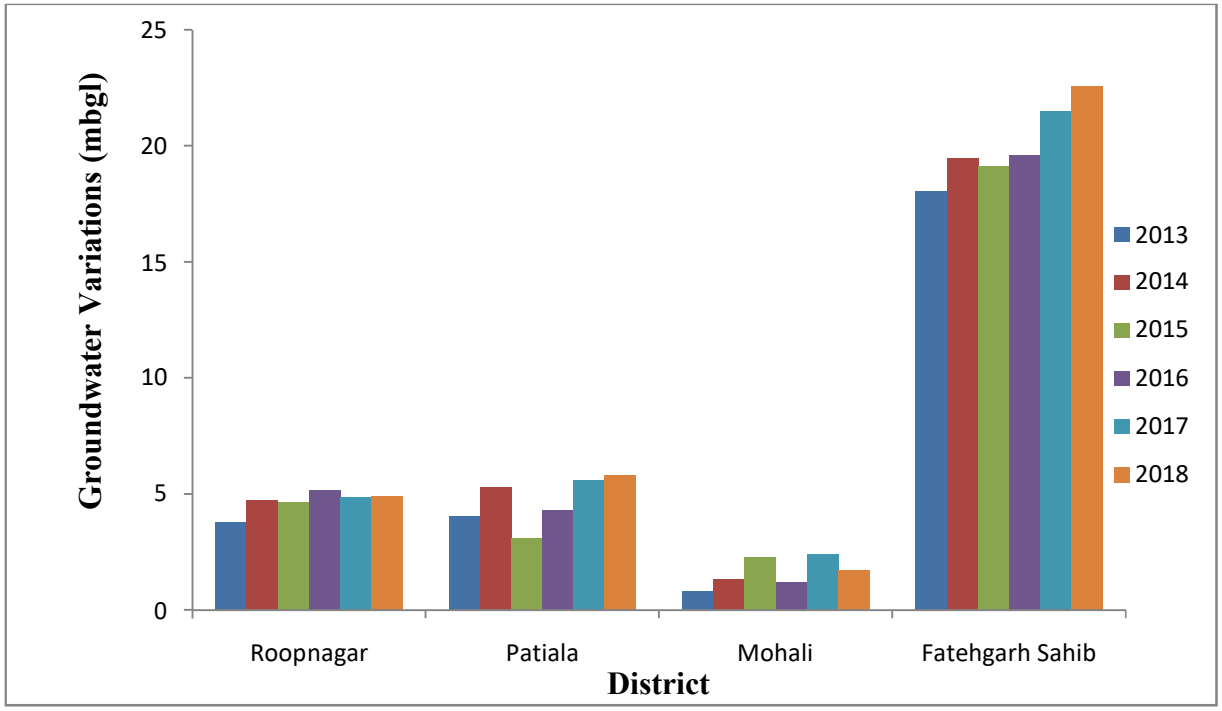


Figure – 4.6 Yearly Groundwater Variations for post monsoon season

Observations

The following observations were made from the tables and figures during the pre and the post monsoon. The level of the groundwater was found to be maximum in the S.A.S Nagar district while it was found to be minimum in the Fatehgarh Sahib during the five consecutive years i.e. 2013-17.

1) **Roopnagar** – According to the graph it is clear that the level of groundwater decreased during the period 2013-17. While in the year 2018 the level of groundwater increased suddenly. The major reason may be the change in the pattern of rainfall and temperature variation.

2) **Patiala** – According to the graph during the pre and post monsoon season the level of groundwater increased during the period 2013-16 while in the period 2017-18 there was decrease in the level of groundwater. The reason is the increase in population, temperature and rainfall variation in this area.

3) **S.A.S Nagar** – According to the study the groundwater level in the S.A.S Nagar showed a varying trend during the pre and post monsoon season. The major reason is increase in population. With increase in population and urbanization the development in the district is increasing leading to construction of malls and multi level residential flats which leads to depletion of groundwater. Also with increase in population the demand for groundwater increases.

4) **Fatehgarh Sahib** – According to the graph the trend of groundwater level in Fatehgarh Sahib showed a similar trend for pre and post monsoon season. It gradually decreased from 2013 to 2018. As discussed earlier the major reason is that in Fatehgarh sahib the only fresh water source available is the groundwater due to which the demand for groundwater is more in this district. So it is the only district which showed the least level of groundwater in the five consecutive years.

4.3.5 ,5 Result – 5

Figure 4.7 and table 4.5 depict the trend in the level of groundwater during five consecutive years (2013-18) in the areas Derabassi, Sohana, Landran and Zirakpur blocks of the S.A.S Nagar district for Pre Monsoon Season.

Table -4.5 Yearly Groundwater Variations for different blocks

Yearly Groundwater Depth Variation (mbgl) (Pre Monsoon Season)						
AREA	2013	2014	2015	2016	2017	2018
Derabassi	12.45	11.6	11.55	11	12.65	13
Sohana	2.7	1.75	3.2	2.95	3.2	3.4
Landran	4.3	3.75	3.7	4.1	3	6
Zirakpur	12	11.5	10.2	13.1	11	10.8

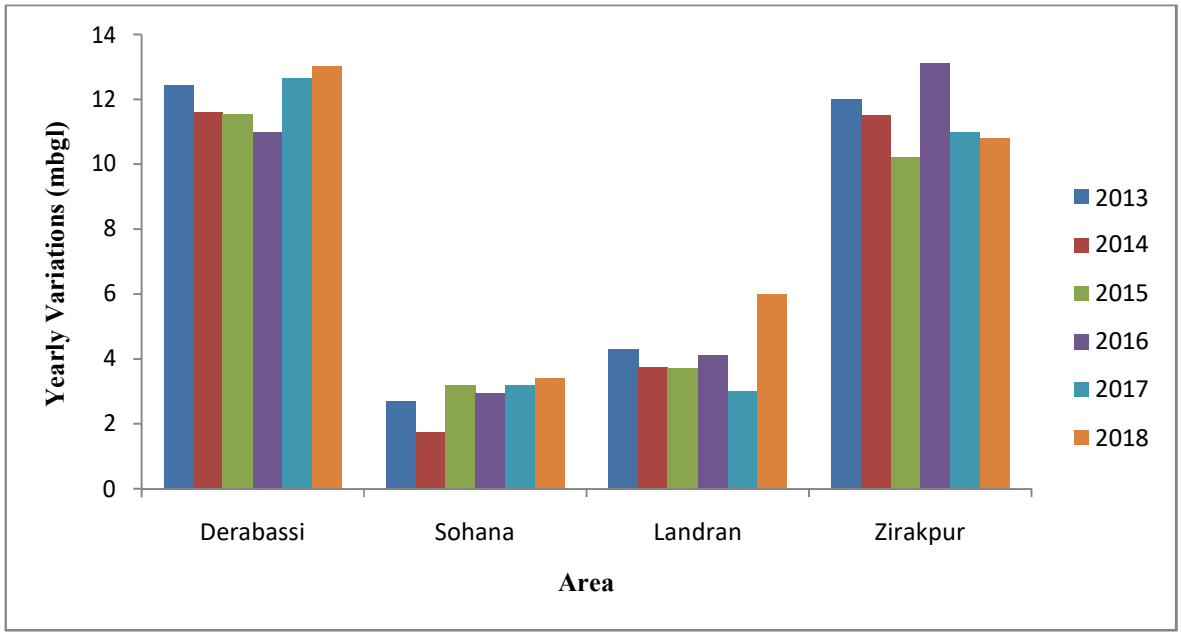


Figure – 4.7 Yearly Variations for different blocks in Pre Monsoon Season

4.3.6 ,6 Result – 6

Figure 4.8 and Table 4.6 depict the trend in the level of groundwater during five consecutive years in the areas Derabassi, Sohana, Landran and Zirakpur. This analysis has been made in different blocks of the S.A.S Nagar district for Post Monsoon Season.

Table – 4.6 Yearly Groundwater Variations in different blocks for Post Monsoon Season

Yearly Groundwater Depth Variations (mbgl) (Post Monsoon Season)						
AREA	2013	2014	2015	2016	2017	2018
Derabassi	10.9	11.7	11.6	11.45	12.08	12.5
Sohana	0.8	1.3	2.25	1.2	2.4	1.7
Landran	1.95	2.7	3.1	2.1	1.9	1.58
Zirakpur	10.91	11.2	10.3	12.2	11.5	9.27

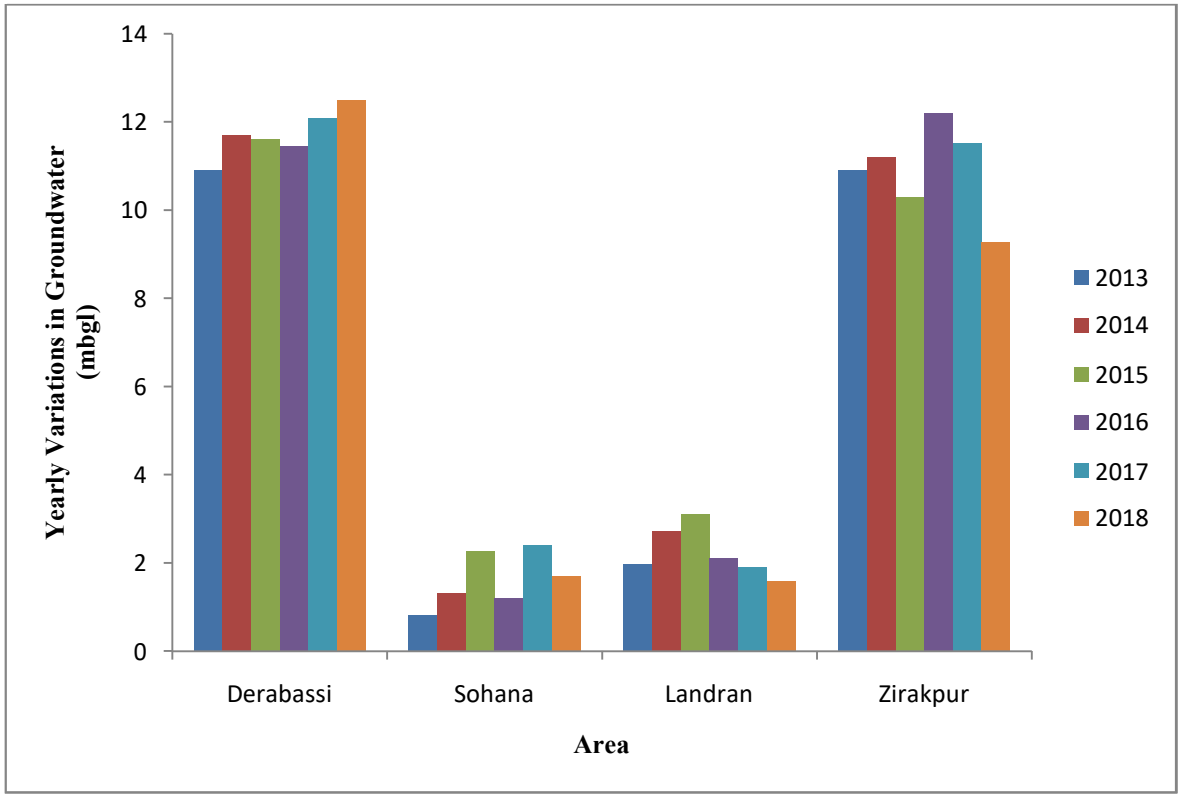


Figure – 4.8 Yearly Variation in different blocks for post monsoon season

Observations

The following observations were made from the figures and tables for the analysis of groundwater level in different blocks of the S.A.S Nagar during the pre and the post monsoon season. The level of groundwater was found to beminimum inZirakpur while it was found to be maximum in Sohana Block of the S.A.S Nagar district. The data of the figures and the tables has been expressed in terms of the level of water below the ground surface.

1) **Derabassi** – In Derabassi the level of groundwater increased during the period 2013-16 and then it increased during the period 2017-18. The major reason is the temperature variations and increase in population and industrialization which leads to increase in the demand of the water causing variations in the level.

2) **Sohana** – In Sohana the level of groundwater showed a varying trend during the period 2013-18. At some points it decreased and at some it increased. The reason behind the fluctuations is the variation in rainfall pattern, increase in population and temperature changes.

3) **Landran** – In Landran also the level of groundwater showed a varying trend during the period 2013-18. The major reason behind the variations in the level is the construction of buildings like Colleges and Residential Flats etc. which leads to increase in demand for groundwater.

4) **Zirakpur** – In Zirakpur also there was a varying trend in the level of groundwater during the period 2013-18. The major reason is the construction of flats, shopping malls, industries, variation in the temperature and the rainfall pattern of these areas. Zirakpur has the minimum level of groundwater compared to other blocks

4.3.7 ,7 Result – 7

Figure 4.9 and Table 4.7 displays the level of groundwater in different blocks of the S.A.S Nagar for the months of Jaunary to June in the year 2019. According to the study,Sarsini had the maximum level of groundwater while the minimum was found in Zirakpur.

The results of the figures and the tables have been expressed in terms of the depth of the level of water below the ground level (dbgl).

Table – 4.7 Monthly Variations in Groundwater level in different blocks

Monthly Variations in Depth of Groundwater level (mbgl)						
AREA	January	February	March	April	May	June
Zirakpur	9.5	9.97	10.47	11.27	13.972	15.4
Derabassi	4.6	4.57	4.92	5.54	5.84	5.6
Issapur	5.18	2.43	1.32	2	3.58	3.25
Sirsaini	1.02	1.1	1.03	1.11	1.49	2.9
Dheri	3.79	5.89	5.48	5.64	6.4	6.7
Landran	2.3	2.08	2.716	2.86	3.27	3.82
Goga	3.3	3.96	4.57	6.57	6.97	7.37
Sohana	3.749	4.359	4.511	4.587	4.94	4.93

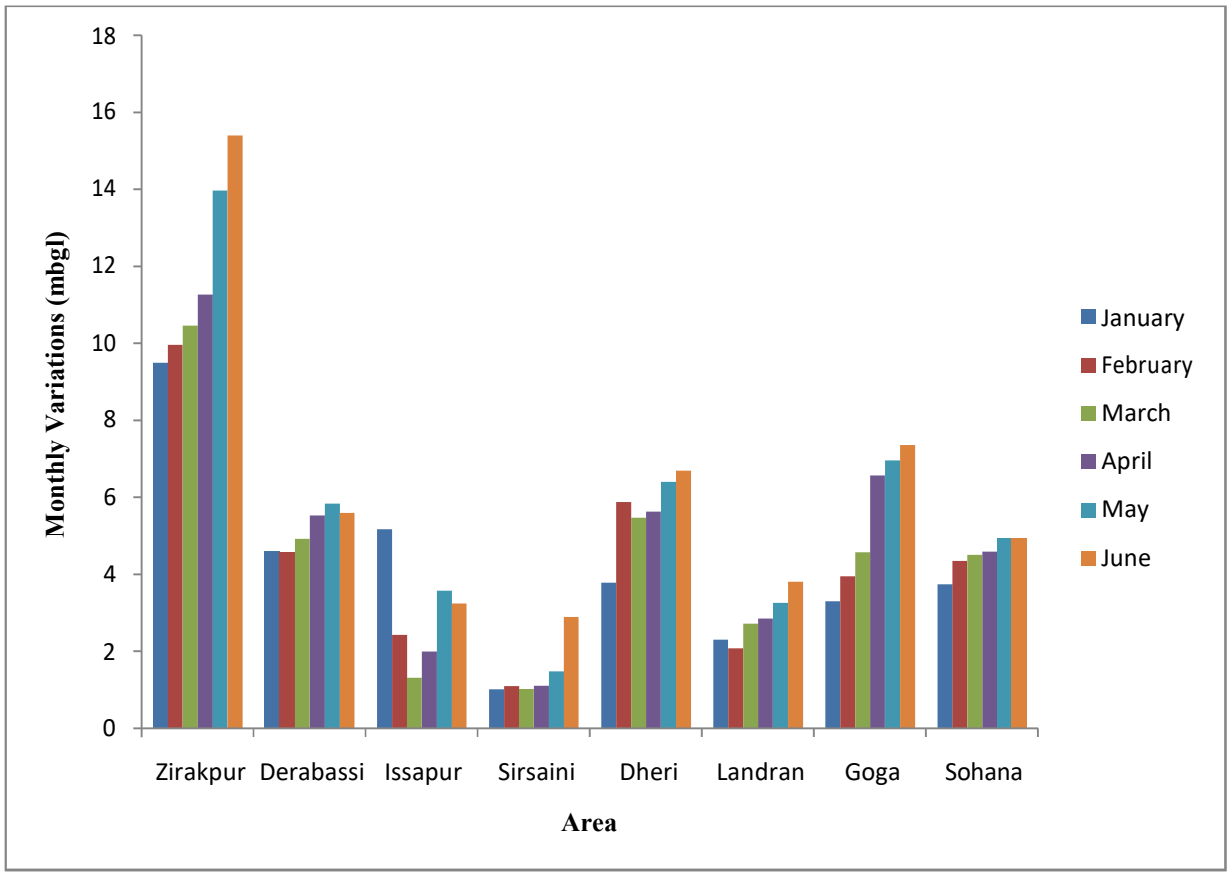


Figure – 4.9 Monthly Variation in groundwater level in different blocks of S.A.S Nagar

Observations

The following observations were made from the study of groundwater level in different blocks of the S.A.S Nagar district. All the readings of the tables and the figures have been expressed in terms of depth of water below ground level.

1) **Zirakpur** – In Zirakpur the depth of groundwater was found to be maximum compared to other blocks of the district. The level of groundwater decreased gradually from January to June. The major reason is the construction of multi level buildings in this area

2) **Derabassi** – In Derabassi the level of groundwater was found to be satisfactory as compared to the other blocks. The major reason is that Derabassi is a low lying area and so groundwater is easily available in this block.

3) **Issapur** – In Issapur the level of groundwater is found to be sufficient as compared to other blocks. The major reason is that Issapur is a agricultural land with lots of farms available. So the water which is supplied to the farms gets transferred back to the ground thus balancing the level of groundwater.

4) **Sarsini** – In Sarsini the level of groundwater was found to be more than sufficient and it is in this block only that the groundwater is maximum as compared to all the blocks of the S.A.S Nagar district. As in case of Issapur, Sarsini is also a agricultural land with less population. So the recharge rate of the groundwater is more than the consumption rate of the groundwater.

5) **Dheri** – In Dheri the level of groundwater was found to be varying during the study period. The reason is that in Dheri the temperature is high and so evaporation rate is more in this area leading to decrease in level of groundwater.

6) **Landran**–In Landran the groundwater was found to be satisfactory. The reason is the presence of agricultural farms in Landran which provide a balance to the level ofgroundwater. Somewhat variations are due to construction of residential flats and educational institutions in this area.

7) **Goga** – Goga is a region which lies near to Kharar. In this area the level of groundwater was found to be satisfactory compared to other districts. The reason for variation in the level of groundwater is increase in population and increase in construction of new bridges and buildings.

8) **Sohana** – In Sohana the level of groundwater was found to be satisfactory for the fulfilment of the daily activities. The major reason is that Sohana lies near to Mohali and so the water is supplied by Municipal Corporation through canals reducing the use of the groundwater thus maintaining the groundwater level.

CHAPTER – 5

CONCLUSIONS, RECOMMENDATIONS AND FUTURE SCOPE

5.1 CONCLUSIONS

On the basis of the study it is found that the level of the groundwater in the S.A.S Nagar district is decreasing at a rapid rate which is an alarming issue. Though the level of groundwater was found to be satisfactory as compared to other districts of Roopnagar, Patiala, Fatehgarh Sahib but still it is not enough to fulfill the demands of the future generations.

The level of the groundwater was found to decrease during the pre monsoon season. The reason was that in this period there was less rainfall and due to increase in temperature the evaporation was more. Also for the period from January to March the evaporation rate is less and so the variation in the level of groundwater was less. During the month of March to June there was increase in temperature leading to decrease in the level of groundwater.

While during the post monsoon season(July-August) the level of groundwater was found to increase. The reason is that during this period with abundant rainfall the level increases. Also after the post monsoon season the weather changes from summer to winter and the temperature changes and the demand for water also decreases due to which the variation in the level of groundwater decreases.

The fluctuations in the level of groundwater in the district were due to the following reasons:

a) Temperature variation
b) Change in rainfall Pattern
c) Increase in population
d) Recharge rate
e) Growth of paddy crop
f) Negligence of the public
g) Policy of free power for agriculture
h) Boring of wells

All the reasons have been explained in the following sections. If these reasons are analyzed properly and proper measures are adopted to control these measures then the depletion of the groundwater can be controlled easily in the district.

a) **Temperature variation** – With increase in pollution, there is increase in temperature which further leads to increase in the rate of evaporation and consumption rate also increases. With the increase in evaporation rate there is decrease in the level of groundwater. Figure 5.1 shows the variation in temperature in °c. As shown in figure temperature is maximum in the month of June in Mohali.

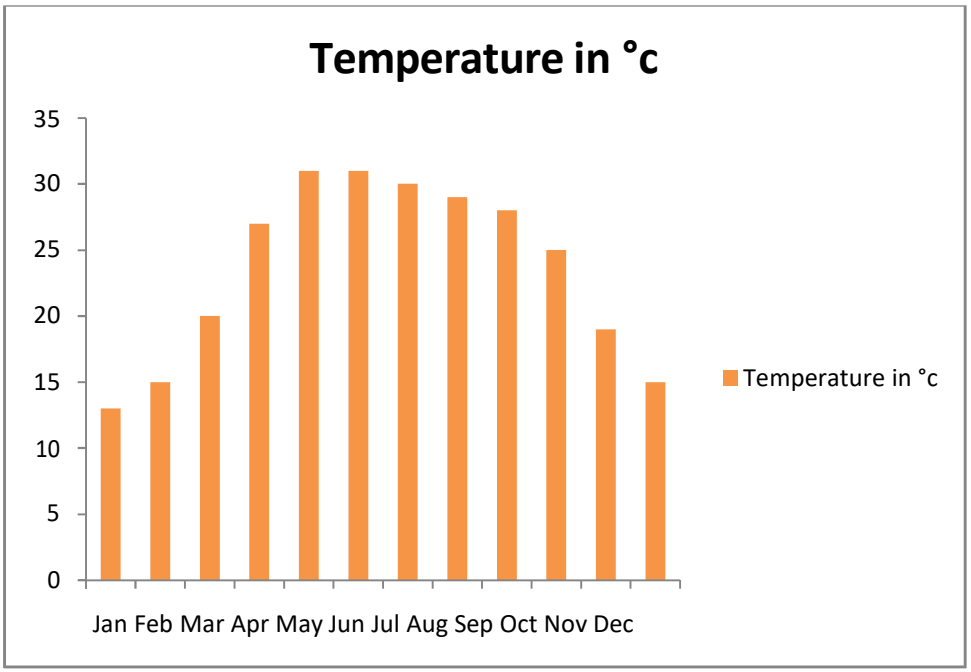


Figure – 5.1 Temperature variations in the district

a) **Rainfall Pattern** – The normal annual rainfall of the district is 1061mm which occurs for a period of 49 days. S.A.S Nagar district receives sufficient amount of rainfall during the monsoon season while during the pre monsoon season there is less amount of rainfall and so there is variation in the level of groundwater.

In the year 2017 a study was conducted to record the rainfall in Mohali district. As per study occurrence of low level winds with western disturbance is the reason for scattered monsoons. According to reports Mohali is termed as the second wettest district followed by Roopnagar.

Figure 5.2 depicts the rainfall pattern in the year 2018 for the S.A.S Nagar district.As shown in figure in rainfall is maximum in the month of August.

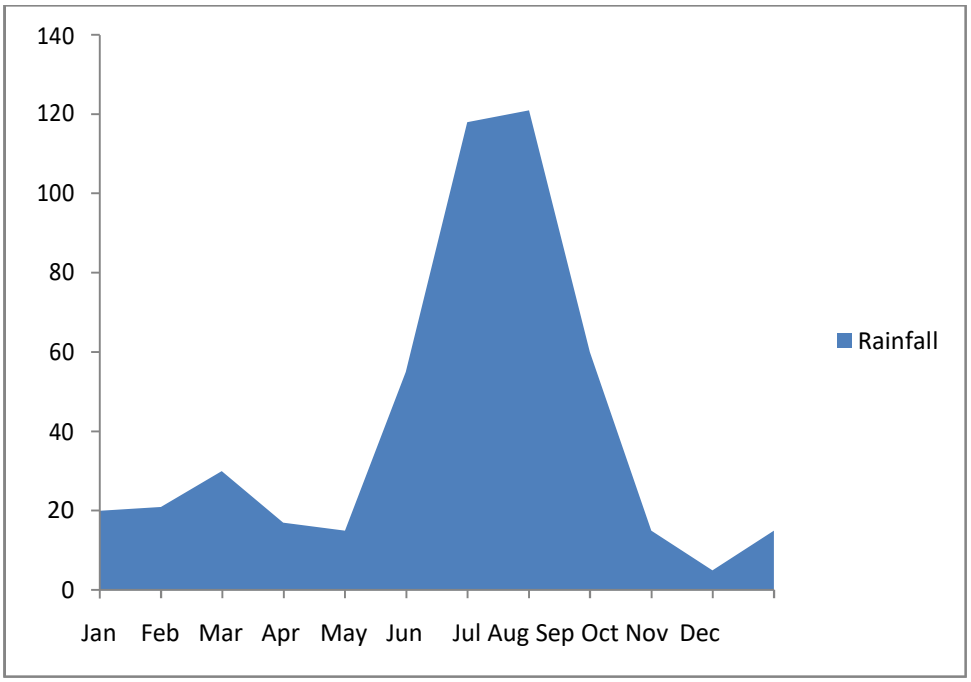


Figure – 5.2 Monthly Rainfall Variation in S.A.S Nagar district (2018)

b) **Recharge Rate** – Groundwater recharge is defined as the process in which groundwater enters back into the aquifer after its utilization. It mostly occurs below plant roots and is expressed as flux of groundwater table. Groundwater recharge occurs both naturally and through artificial methods. According to study the consumption rate of groundwater in the district is more than the recharge rate. It is very important to ensure a balance between recharge rate and consumption in order to ensure sufficient level of groundwater. Figure 5.3 shows groundwater recharge process.

The major factors which affect the groundwater recharging are

i. Change in Temperature
ii. Urbanization
iii. Drainage

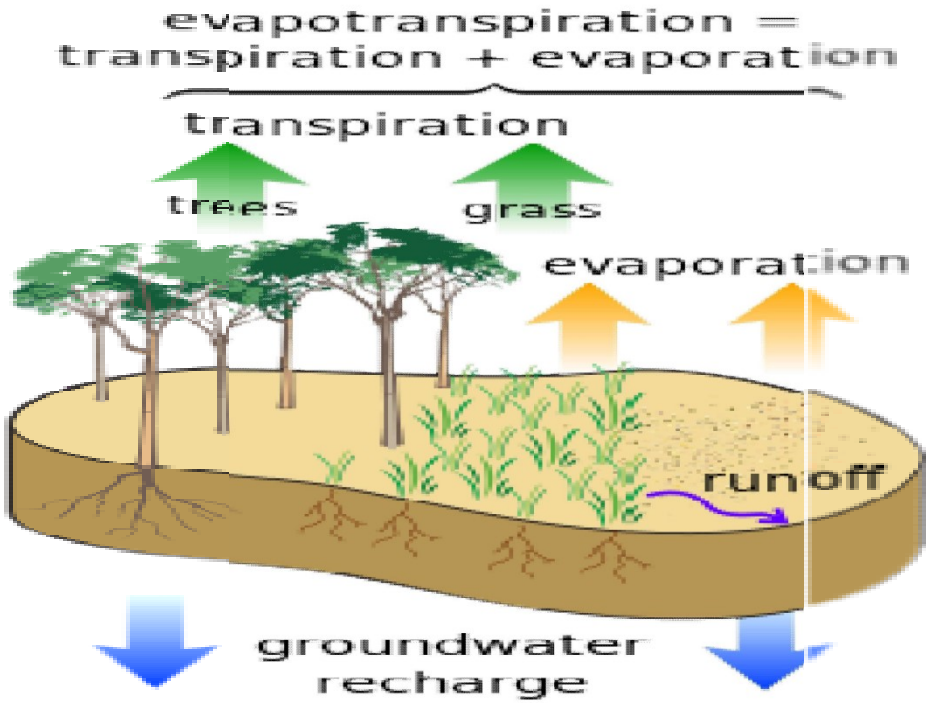


Figure – 5.3 Groundwater recharge (https://en.wikipedia.org/wiki/Groundwater_recharge)

i. **Change in temperature** – With the increase in temperature there is increase in recharge rate. The major reason is that with increase in temperature there is increase in global warming leading to increase in precipitation causing increase in level of groundwater. This is explained with the help of physical attributes of vegetation. With the increase in the temperature due to global warming the leaf area index decreases. Leaf area index is defined as the ratio of the one sided green area of leaf to the area of the ground surface. With the decrease in leaf area index there is increase in rate of infiltration of water to the soil and less interception within the tree itself.

But with the increase in temperature the demand for water also increases for agricultural and human needs. This leads to increase in pumping of water from

below the ground surface. The decrease in level of the groundwater is the result of the excessive pumping of groundwater.

ii. **Urbanization** – With the increase in urbanization there is an increase in the construction of buildings and bridges resulting in depletion of groundwater level. This is explained below.

When a multipurpose building like shopping mall and residential flats are constructed, basements are also constructed which are used for the parking of vehicles or other purposes. In some buildings especially shopping malls two to three basements are constructed. When a basement is constructed a major problem that arises is the appearance of dampness due to presence of groundwater.

In order to remove the moisture a sump is created below the building. A sump is a small hole or pit which is constructed so as to remove extra water below the building. Sump can also be considered as an area in the cave where an underground water flow occurs into the cave.

The water from the sump is lifted with the help of a sump pump which ejects the water from the sump to the collecting point. The following figure depicts the working of sump pump. Figure 5.4 shows how water is removed from below the foundation.

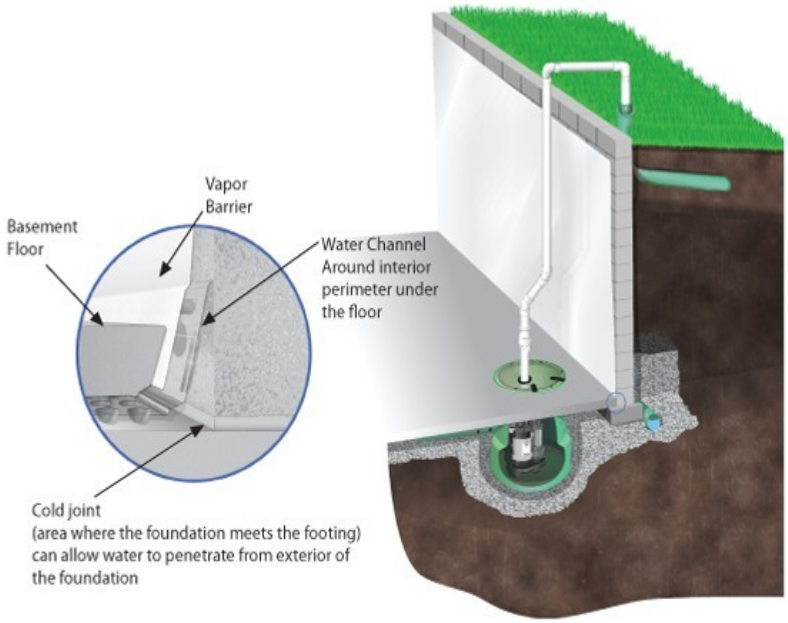


Figure – 5.4 Removal of water with the creation of sump (https://www.myfoundationrepairs.com/interior-basement-drainage-systems/)

With this process the level of groundwater gets lowered. With more and more construction of basements below the building the level of groundwater keeps on going decreasing leading to depletion in the level of the groundwater.

iii. **Drainage** – Drainage also has an adverse effect on the recharge rate of the groundwater. Drainage is defined as the process of removal of water from the soil to prevent water logging. It can be natural or artificial. Just like removal of water through sumps in this method, water is removed with the help of pumps. Once the water is drained from the soil it will not reach the ground water table leading to scarcity of groundwater level.

c) **Growth of paddy crops**–Paddy crop is basically unmilled rice which is grown when the crop has 25% moisture content. Paddy crop is mostly sown during the period of June-July when the temperature is above 20°c and harvested in the month of November-December. Figure 5.6 shows the various rice producing states of India. Figure 5.5shows crop production in various districts of Punjab with majority production in east side.

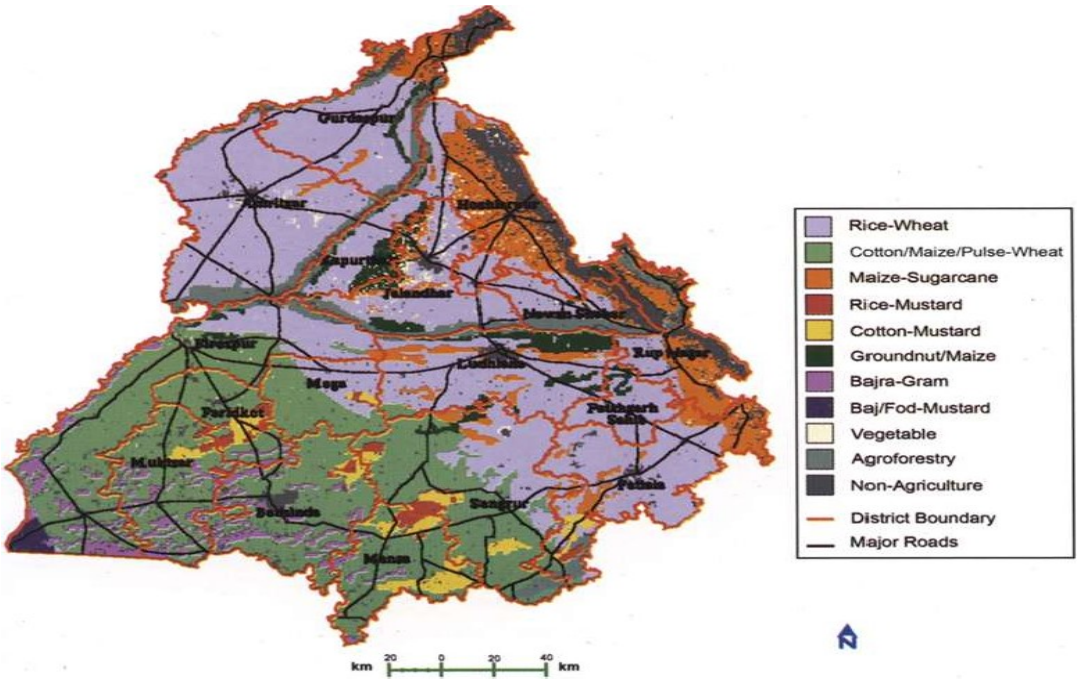


Figure – 5.5 Crop Productions in Punjab

(https://www.researchgate.net/figure/Crop-diversification-plan-for-Punjab_fig2_226382093)

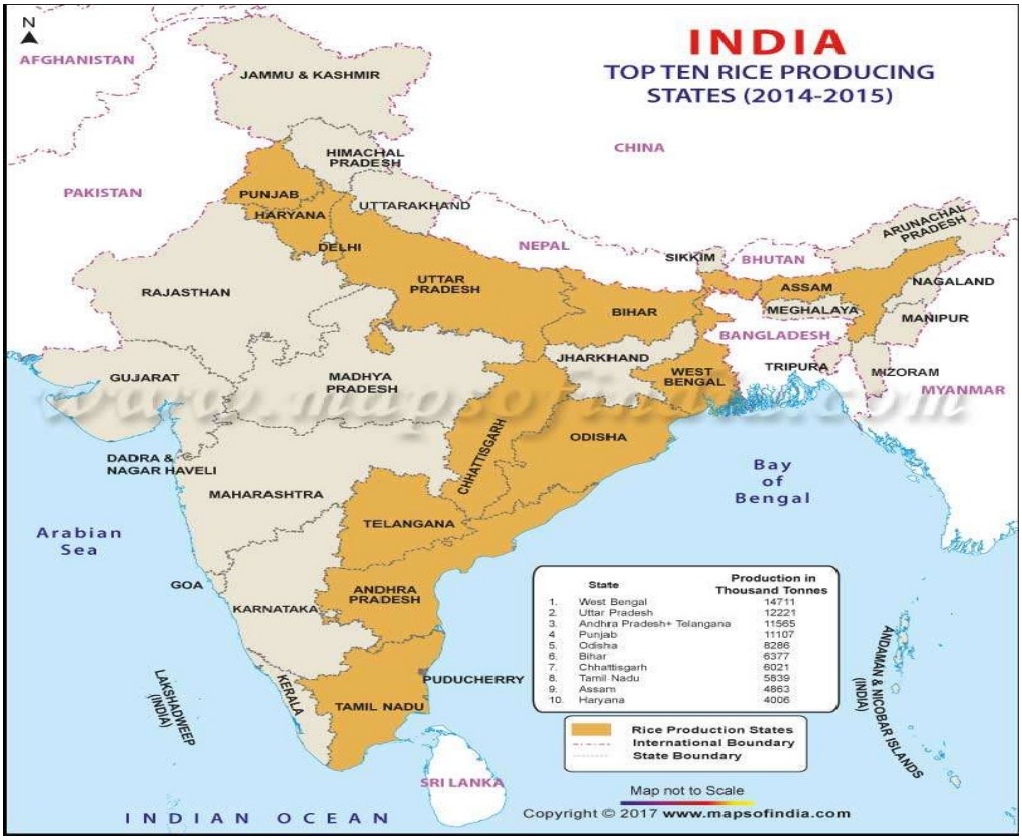


Figure – 5.6 Rice Producing states

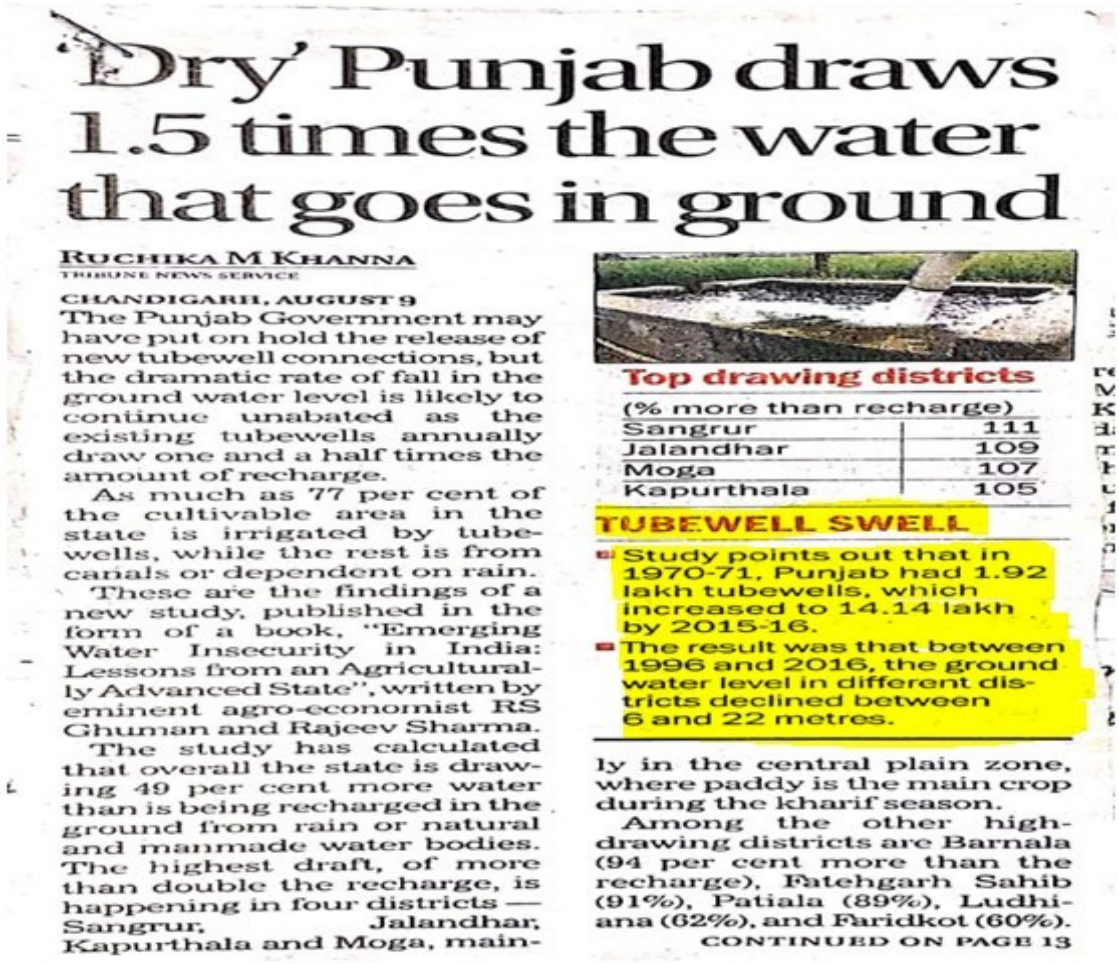
(https://www.mapsofindia.com/top-ten/india-crops/rice.html)

As shown in figure 5.6 the production of rice is maximum in North West region including Punjab. At the time of sowing of paddy there is increase in temperature which also leads to increase in demand of water for paddy cultivation leading to increase in extraction of groundwater causing its depletion.

d) **Negligence of public** – The nature of public plays an important role in the fluctuation in the level of groundwater. With excessive use of groundwater by the public the wells start drying and due to this reason people start dumping waste into the wells. In this way the wells gets filled with waste or silting takes place leading to blockage of bores below the wells. In this way the recharging of wells and groundwater becomes difficult which further leads to depletion of the level of the groundwater.

e) **Policy of free power for agriculture** – A policy was passed to provide free power to the farmers to carry out agriculture in Punjab. But with free power the farmers have started misusing the power and are operating huge pumps and machines which can extract huge amount of water from the ground. With the increase in the extraction of groundwater the level started declining leading to the depletion in the level of groundwater. S.A.S Nagar has less agricultural area compared to other districts of Punjab so the variation in level of groundwater is less.

f) **Boring of wells** – With the increase in demand for groundwater more and more tube wells are bored to meet the daily requirements of agriculture and other purposes. This lead to decrease in the level of groundwater. According to study Punjab had 1.90 lakh tube wells in 1970-71 which increased to 14.14 lakh in 2015-2016. Highlighted area of Figure 5.7 shows the exact information.



'Dry' Punjab draws 1.5 times the water that goes in ground

RUCHIKA M KHANNA
TRIBUNE NEWS SERVICE

CHANDIGARH, AUGUST 9

The Punjab Government may have put on hold the release of new tubewell connections, but the dramatic rate of fall in the ground water level is likely to continue unabated as the existing tubewells annually draw one and a half times the amount of recharge.

As much as 77 per cent of the cultivable area in the state is irrigated by tubewells, while the rest is from canals or dependent on rain.

These are the findings of a new study, published in the form of a book, "Emerging Water Insecurity in India: Lessons from an Agriculturally Advanced State", written by eminent agro-economist RS Ghuman and Rajeev Sharma.

The study has calculated that overall the state is drawing 49 per cent more water than is being recharged in the ground from rain or natural and manmade water bodies. The highest draft, of more than double the recharge, is happening in four districts — Sangrur, Jalandhar, Kapurthala and Moga, mainly in the central plain zone, where paddy is the main crop during the kharif season.

Among the other high-drawing districts are Barnala (94 per cent more than the recharge), Fatehgarh Sahib (91%), Patiala (89%), Ludhiana (62%), and Faridkot (60%).

CONTINUED ON PAGE 13

Top drawing districts

(% more than recharge)

Sangrur	111
Jalandhar	109
Moga	107
Kapurthala	105

TUBEWELL SWELL

- Study points out that in 1970-71, Punjab had 1.92 lakh tubewells, which increased to 14.14 lakh by 2015-16.
- The result was that between 1996 and 2016, the ground water level in different districts declined between 6 and 22 metres.

Figure – 5.7 News clipping showing the number of bore wells in Punjab

5.2 Remedial Measures

To prevent the decrease in the level of groundwater following measures need to adopted

a) Provide water storage structures
b) Provide canal outlets
c) Cleaning of chaos
d) Tariff on usage of power for agriculture
e) Recycling waste water for irrigation
f) Rainwater Harvesting

a) **Construction of water storage structures** – Water storage is defined as preserving both the potable and non potable water for use in future. Water storage structures are the structures which help in storing the water. Theare following types of water storage structures are

i. **Groundwater aquifers** – Groundwater is the water source which is available beneath the surface of the earth. Aquifers are the rock formations which lie beneath the earth surface. These are very helpful in storing the water below the ground.

Many natural and artificial methods are used to store water in the aquifers. The depth at which the pores of the soil become completely saturated by water is called water table. There are two types of aquifersviz confined and unconfined. Unconfined aquifer is the one which is not restricted by impervious rock formations at the top while confined aquifer are the one which are restricted by impervious rock formations at the top.

Quaternary alluvial deposits which belong to Indo – Gangetic alluvial plains are present in the S.A.S Nagar district which forms the main aquifer system as per report by Central Ground Water Board. There are two types of aquifers shallow and deep aquifers which help in storing ground water of the district.

ii. **Soil Moisture** – Groundwater can also be stored by soil moisture technique. Soil moisture is defined as the presence of waster in the pores of the soil. It is the water is which is held between the root zones of the plants generally in the top 200cm depth of the soil.

When there is increase in temperature this water from the pores of soil gets evaporated and returns to the earth in the form of precipitation. Water stored in the soil is most important to carry out the agricultural practises. The best example is in Africa where rain fed agriculture accounts for 95% of the farmed land.

iii. **Wetlands** – Wetland is defined as the area which is created either by the collection of rainwater or by providing a barrier to the flow of a river. They help in promoting wildlife in the area and also help in preservation of the ground water and surface water. Wetlands are sponges which have the capacity to easily store and release the rainwater, groundwater and surface water. With the increase in growth of vegetation cover, the wetland water is controlled and so there is

increase in the amount of water in the wetland. The best examples of wetlands of Punjab areRopar Wetland, Nangal Wetland and Harike Wetland.

iv. **Ponds and Tanks** – Ponds can be constructed in areas like villages in which the rainwater can be stored. This stored water can be used for agriculture and irrigation. In this way there will be decrease in the usage of groundwater and the water from the ponds can be allowed to penetrate below the groundwater which will further help in recharging of the groundwater. Figure 5.8 shows a water storage pond in Maharashtra state of Punjab.

Figure 5.8 Water Storage Pond

(http://manatelangana.news/maharastra-farmers-plans-for-rain-water-storage-in-ponds-with-plastic-covers/

Storage tanks can also be constructed in cities which can help in preserving the water from the canals and the rivers. The water from these tanks can be used in case of emergency as water from canals is not uniformly available throughout the year. Figure 5.9 shows the tank for storage of water.

Figure – 5.9 Tanks for storage of Water(https://www.butylproducts.co.uk/2016/08/25/steel-water-storage-tanks/)

b) **Providing Canal Channels** – Canal channels are the structures constructed along the flow of the canal to take water from canal to fields for irrigation. These are the structures through which water is transferred from the main canal to the branch canal and then to distributing channel and from there a minor canal is constructed and water from this canal is utilized for irrigation. This can be done by constructing of channels from the main canal.

The water from the canal can be used for irrigation and agricultural purposes and once the water reaches the field it will transfer to the ground surface leading to increase in level of groundwater.

The canal outlets are of the following types

1) **Non Modular Outlet** – These operate in such a manner that the flow of water is the difference of the level of water in distributing channel and the main canal.
2) **Semi Modular Outlet** – The discharge through these channels is dependent on the level of water in the distributing channel but independent of the level in the main canal.
3) **Modular Outlet** – The discharge through these channels is independent of both the distributing and the main channel.

Figure 5.10 shows the canal outlet being used in fields. The various components are

i. **River –** The natural flow of water from mountains is the river.
ii. **Canal** – Water from river is diverted to channel with the help of construction of head works.

iii. **Branch Canal** –A canal diverted from the main canal is branch canal. The discharge of these canals should be more than $30m^3/s$.

iv. **Distributary Channel** – A channel diverted from branch canal is distributary channel having discharge less than $30m^3/s$ and from this a minor canal is diverted and water is used for irrigation in fields.

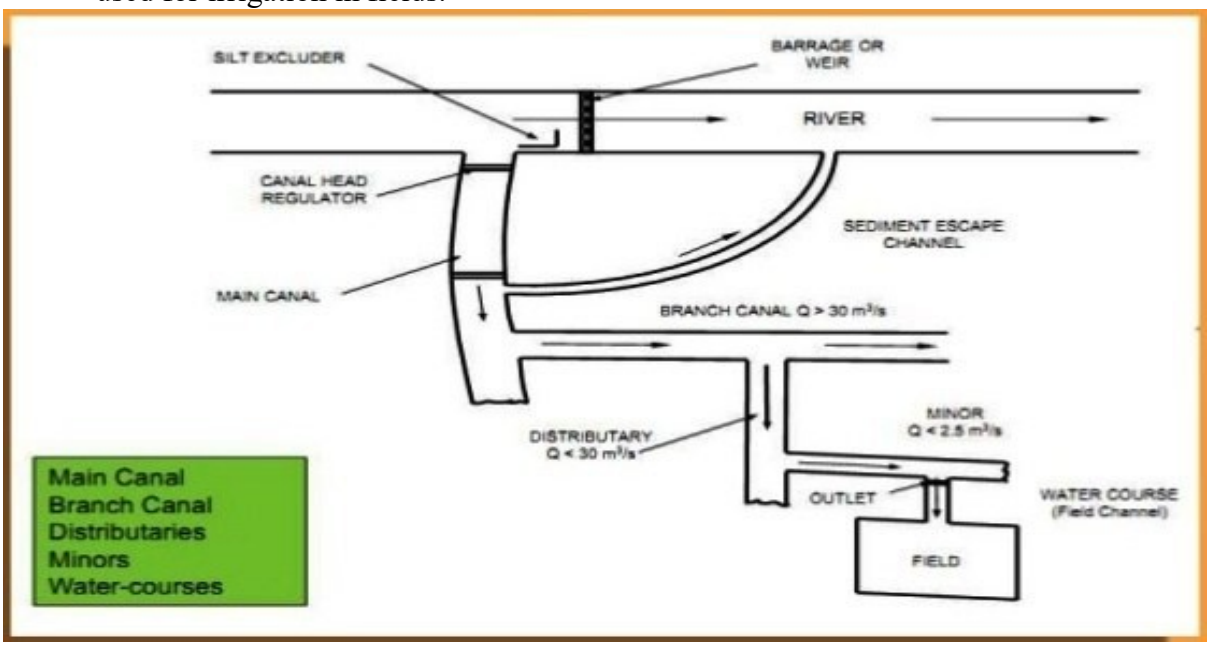


Figure – 5.10 Typical Canal Outlet used in fields(https://www.slideshare.net/YashPatel61/canal-regulation-work)

c) **Cleaning of Chaos**–In S.A.S Nagar there are three chaos namely SiswanNadi, Jainti Devi ki Rao and Patialirao which help in draining the flood water during excessive rains. These are explained below

i. The Ghaggar river along with its tributaries form the natural drainage system for the Derabassi block

ii. SiswanNadi drains the northern part of the S.A.S Nagar district and finally converges with the Sutlej river in the Ropar district

iii. Jainti Devi ki Rao and Patiali Rao drain the North Eastern and South Western region of the district and joins the Ghaggarriver at the end.

Figure 5.11shows the location of these drains in S.A.S Nagar and Figure 5.12 shows Patiali Rao drain of S.A.S Nagar district. In the figure it is clear that drain is chocked with wild grass and so any drained water is consumed by grass instead of percolating to the ground water table.The same is the case for other two chaos.

Figure – 5.11 Drainage system of the S.A.S Nagar District(http://cgwb.gov.in/District_Profile/Punjab/SAS%20Nagar.pdf)

If these chaos are cleaned and again brought in working condition as shown in figure 5.13 then these can prove to be beneficial in recharging the level of the groundwater.

Figure – 5.12Patiali Rao Drain S.A.S nagar District

Figure 5.13 Drainage Chao flowing at full supply

d) **Providing tarrif on usage of power** – In order to control the wastage of groundwater tarrif should be imposed on the use of power by the farmers for agriculture. In this way the farmers will have to pay money for use of power. Tarrif should be imposed either according to time or according to quantity of power utilized.

With this way, there will be decrease in the extraction of water as the farmers will restrict themselves from using heavy machines which will reduce the quantity of extraction leading to balance in the level of the groundwater.

e) **Recycling waste water**–Instead of releasing the waste water into the surface of ground directly, one can reuse the water to carry out daily activities like agriculture, irrigation, watering of plants and washing of cars. There are many processes by which waste water can be recycled. Out of these the most important is the reverse osmosis. This technique can be efficiently used at areas with scarcity of water.

Waste water is not only the water which has been affected by human use. Even the water which remains unused for some days and becomes unfit for drinking is also waste water. If we instead of throwing the water which becomes unfit for drinking

utilize it for cleaning of utensils and washing of cars and clothes then we can prevent wastage of huge amount of water.

Recycling of wastewater has following advantages and disadvantages

Advantages

i. Best use in regions which face the problem of water shortage
ii. A reliable water source for farmers as the nutrients of wastewater reduce cost of fertilization
iii. Impact on environment is reduced as direct release of effluents to atmosphere is decreased

Disadvantages

i. The treatment plants need to be modified properly so as to ensure better quality of water for irrigation
ii. Public health is a major issue in utilization of recycled waste water for irrigation. If the quality of water used for irrigation is not satisfactory then crops may get damaged leading to health issues
iii. Most irrigation projects which utilize recycled waste water are not always profitable.

f) **Rainwater Harvesting** – Rainwater harvesting is the best available method used in areas facing water shortage. Rainwater harvesting is defined as the process of storing the water from the rain and utilizing it later.

The common method of rainwater harvesting is the rooftop harvesting. In this method rainwater which falls on the roof of the building is collected either in a pit constructed in the lawn of the building or in a tank. In some cases, rainwater is directly made to travel below the surface of ground. This acts as a best method for recharging of groundwater as depicted in the figure 5.14.

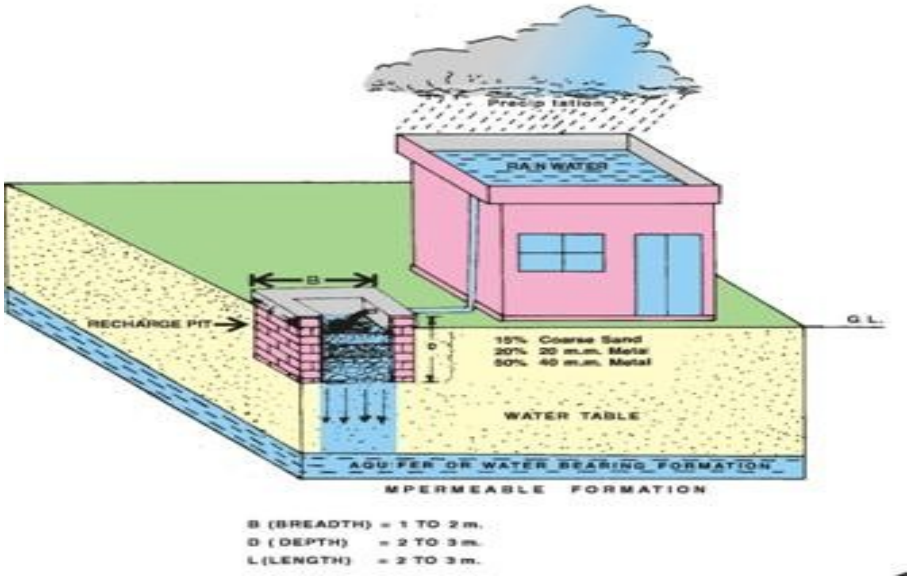


Figure – 5.14 Rainwater Harvesting(https://www.braingroom.com/Posts/detailPost/MjQyMg==/Rainwater+Harvesting)

Now-a-days a new approach is started to carry out rainwater harvesting. It is the rainwater saucer. In this a funnel in the form of tilted umbrella is used for the collection of water. These saucers are more efficient in collection of rainwater. The water from these saucers can be collected in storage tanks and can be utilized for household activities. Figure 5.15shows the rainwater saucer.

Figure – 5.15 Rainwater Saucers
(http://www.rainharvest.co.za/2013/11/the-rainsaucer-a-novel-approach-to-rainwater-harvesting/)

Another method is the formation of free forest swamp areas. These are constructed by storing the river water at a larger stretch. These forests can be helpful for carrying out rainwater harvesting technique and will help to control the depletion of groundwater as water through these forests will easily sweep to the ground. Figure 5.16 shows the free forest swamp area at Neyyar River, Thiruvanthampuram.

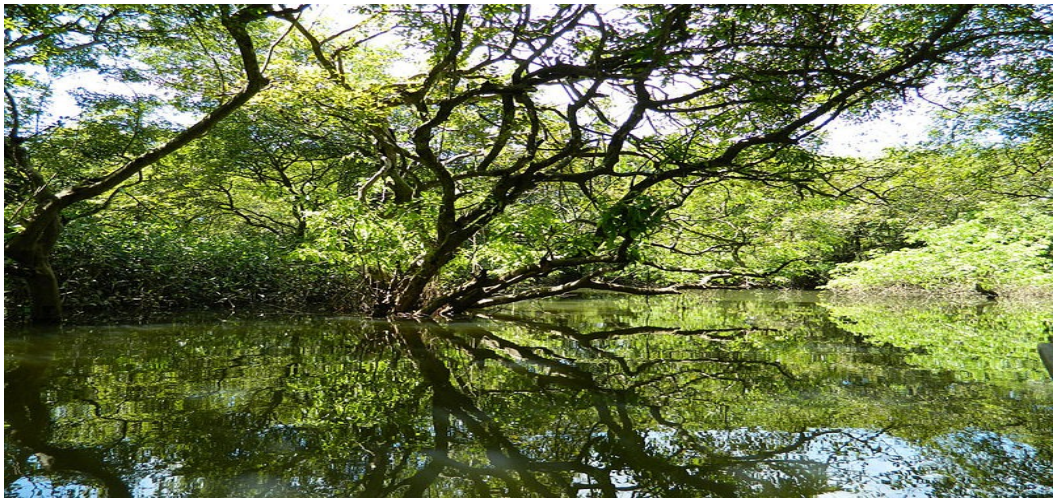


Figure 5.16 Free Forest Swamp Area in Neyyar River, Thiruvanthampuram

Advantages of rainwater harvesting

i. Independent water supply – Rainwater harvesting provides independent supply of water to the areas which suffer water storage. Those areas which have costly supply of water or it is not possible to supply water easily can practise rainwater harvesting to carry out daily activities.

ii. Supplement to Drought – During the period of drought when there is water shortage the water collected by rainwater harvesting can be utilized. In this way there will be decrease in utilization of groundwater for day to day activities.

5.3 Scope for Future Work – S.A.S Nagar is a rapidly growing and a fast developing district. There are many areas which suffer with the problem of water shortage. People use groundwater and surface water simultaneously. The following work can be carried out in future to control depletion of groundwater.

a) Analyze the variation in level by preparing profile of the areas
b) Prepare groundwater level maps and mark areas with low groundwater level

c) Identify causes for the depletion of groundwater and also to study the relationship between surface and groundwater.

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ANNEXURES

Annexure – 1 News Clipping showing condition of Groundwater in Punjab by 2039

Why Punjab's groundwater might run dry by 2039

EXPLAINED

After ushering in the era of Green Revolution and filling granaries of the Union government by over-exploiting its water for irrigation, Punjab is faced with the challenge of saving its underground water aquifers. **KANCHAN VASDEV** explains:

What is the situation vis-a-vis underground water in Punjab?

According to the state's own report on the underground water situation, there is over-exploitation of ground water to meet the agriculture requirements of the state. It says that about 79 per cent area of the state is over-exploited. Of 138 blocks, 109 blocks are "over-exploited", two blocks are "critical" five blocks are "semi-critical" while only 22 blocks are in "safe" category.

What amounts to the major drain on water resources?

The agriculture tubewells are a major factor. While ground water is being over-exploited to meet the ever-increasing demands of water for diverse purposes – intensive irrigation, drinking, industry, power generation – tubewells get the blame for the situation. At the time of the introduction of the Green Revolution in the mid-sixties, the number of tubewells increased from 50,000 to above 70,000 in the early eighties. It went up to about 10.70 lakh in 2001 and then 11.80 lakh in the year 2005-06. In the year 2012-13 there were approximately 12 lakh tubewells according to the 5th Minor Irrigation Census Report. The state now puts the number at 14 lakh.

Why is free power supply to farmers being blamed for indiscriminate use of ground water?

It is often argued that tubewells have an auto-start switch. They turn on as soon as power is supplied and pump water even if it is not required. Various agriculture experts scoff at the free power supply saying it is making the state lose its precious resource.

How is paddy to blame?

On an average, there are 34 tubewells per sq. km of net sown area in Punjab. The state policy of power for agriculture in combination with central policy favourable to paddy cultivation has ended up in indiscriminate use of ground water. The situation has reached a critical stage and a shift from existing practices is necessary to ensure that the next generation has adequate natural resources for its use. Experts suggest a dire need to diversify.

By when Punjab is feared to face water crisis?

As per a government report, ground water resources are likely to be used up by the year 2039. Thereafter, only annual replenishable resources will be available.

Which are the districts affected mainly due to lowering of underground water table?

The water levels have gone down in most parts of the state. The average yearly rate of fall in water levels, in the areas of significant fall in water level (more than 5 m) was worked out to be approximately 0.49 m per year. Districts like Baranala, Bathinda, Fatehgarh Sahib, Hoshiarpur, Jalandhar, Moga, Mohali, Pathankot, Patiala and Sangrur are worst affected. Moreover, taking the entire area of fall in water level into consideration, the average yearly rate of fall is worked out to be approximately 0.37 m every year for this area.

Does it affect water quality?

Lowering of water table coupled with increased use of fertilisers and pesticides is causing water quality deterioration in surface and groundwater resources. Groundwater at shallow depth is largely contaminated due to surface water pollution. Nearly 50-60 per cent of the groundwater up to 60 metres depth in the state is fresh and fit and generally found in the northern, northeastern and central parts of the state comprising Amritsar, Gurdaspur, Hoshiarpur, Jalandhar, Kapurthala, Nawanshahar, Ropar, Ludhiana, Fatehgarh Sahib and Mohali districts. Nearly 20-30 per cent of the groundwater generally found in northwestern and central parts comprising Tarn Taran, Patiala, Sangrur, Barnala and Moga is moderately saline and of marginal quality. Around 15-25%

Annexure – 2 News clipping showing effect of Canal system on the level of groundwater in Punjab.

Crumbling canal system takes toll on groundwater

Farmers encroach upon defunct irrigation channels, grow crops

MANMEET SINGH GILL
TRIBUNE NEWS SERVICE

AMRITSAR, JUNE 19

The collapse of canal irrigation system in most parts of Amritsar and Tarn Taran districts has increased the dependence of farmers on groundwater (tubewells).

As no water was released in many areas for years, the land under redundant canal minors (suwas) and irrigation channels (khaals) has been occupied by farmers and brought under cultivation.

The canal system in villages near Neshta, Daoke, Naushera, Kakkar, Kasel and many other areas has totally collapsed. At most of these places, land under canal minors has been brought under cultivation. In other areas, the water holding capacity of channels has withered due to the lack of maintenance and the volume of water released is very low.

On the other hand, farmers blame the government for the collapse of irrigation system as it allegedly stopped paying attention towards biannual maintenance exercise. Rattan Singh Randhawa of Jamhoori Kisan Sabha said, "The collapse of the canal irrigation system has increased the dependency of farmers on tubewells. If the government makes water available for irrigation, why would farmers spend lakhs on digging tubewells?"

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>
> Rattan Singh Randhawa,
> JAMHOORI KISAN SABHA LEADER

The number of tubewells in Punjab has increased from just 2,80,000 in 1980-81 to 13,66,160 in 2017-18. The figure has now touched 14.5 lakh. This has taken toll on already depleting groundwater. The farmers claimed that the canal system initiated by the British continued to work well till 1980s after which it started deteriorating.

The farmers allege that instead of strengthening the system and digging more canal minors to connect more villages, the government let it collapse.

Chief Engineer-cum-Director, Irrigation and Power Research Institute Jasbir Singh Sandhu said the process to reclaim land belonging to the Irrigation Department had been started. "We are demarcating the land and the system will be revived."

He said a proposal for overhauling the canal irrigation system had already been sent to the Union government. Sandhu said they had cleaned many minors under MGNREGA which were lying unused for many years.

Annexure – 3 News clipping shows the approval of administration for the construction of basements which can leads to declining groundwater levels.

Admn allows 3 basements to battle parking pangs

Societies, commercial & industrial plot owners to benefit

RAMKRISHAN UPADHYAY
TRIBUNE NEWS SERVICE

CHANDIGARH, JULY 11

In a major step to solve the parking problem in the city, the Chandigarh Administration has allowed a three-level basement in all commercial and industrial buildings, besides residential group housing societies and bigger residential plots.

The Administration has amended the Chandigarh Building Rules (Urban)-2017 to incorporate the provision for basements in Chandigarh. The relaxation will be allowed to all hotels, multiplexes, malls, commercial and industrial plots, banquet halls/marriage palaces, cultural and non-academic institutions, religious buildings, educational institutes, IT Park, and residential and government housing and integrated projects.

Earlier, a single-level basement was mandatory for all such buildings. Now, a three-level basement in all plots having an area of 4 kanal and above except residential (marla and kanal) houses shall be permissible beyond the zoned area in setbacks up to the plot boundary, subject to technical feasibility. A minimum of 80 per cent space shall be used for parking and a maximum of 20 per cent for services/storage purposes. All other safety norms and bylaws regarding construction of basement will be in line with the Chandigarh Building Rules (Urban)-2017.

An UT officer said more than three basements for parking shall be considered on a case-to-case basis. With the relaxation, plot owners can now make parking for commercial purposes. Traffic chaos in the city is routine due to the ever-increasing number of vehicles.

Annexure – 4

'Dry' Punjab draws 1.5 times the water that goes in ground

RUCHIKA M KHANNA
TRIBUNE NEWS SERVICE

CHANDIGARH, AUGUST 9

The Punjab Government may have put on hold the release of new tubewell connections, but the dramatic rate of fall in the ground water level is likely to continue unabated as the existing tubewells annually draw one and a half times the amount of recharge.

As much as 77 per cent of the cultivable area in the state is irrigated by tubewells, while the rest is from canals or dependent on rain.

These are the findings of a new study, published in the form of a book, "Emerging Water Insecurity in India: Lessons from an Agriculturally Advanced State", written by eminent agro-economist RS Ghuman and Rajeev Sharma.

The study has calculated that overall the state is drawing 49 per cent more water than is being recharged in the ground from rain or natural and manmade water bodies. The highest draft, of more than double the recharge, is happening in four districts — Sangrur, Jalandhar, Kapurthala and Moga, mainly in the central plain zone, where paddy is the main crop during the kharif season.

Among the other high-drawing districts are Barnala (94 per cent more than the recharge), Fatehgarh Sahib (91%), Patiala (89%), Ludhiana (62%), and Faridkot (60%).

CONTINUED ON PAGE 13

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(% more than recharge)

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TUBEWELL SWELL

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- The result was that between 1996 and 2016, the ground water level in different districts declined between 6 and 22 metres.

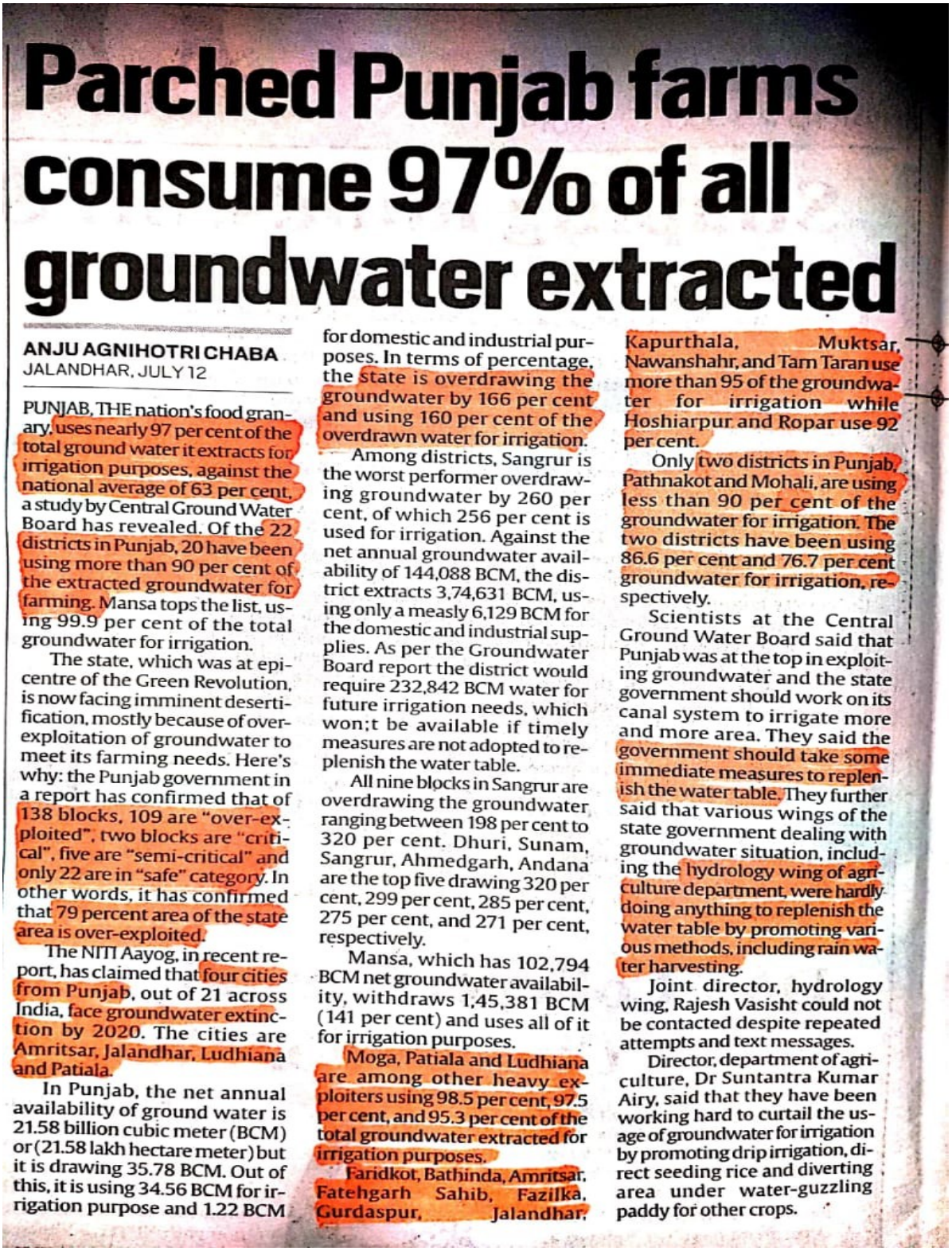
FROM PAGE 1

Only two districts, Pathankot and Hoshiarpur, have a draft less than the recharge, thus ensuring the ground level is maintained. Around 80 per cent of the water consumption in Punjab is for rice production, which is largely meant for the Central grain pool.

"This is a classic case of water export from Punjab to the rest of India," says Ghuman. "Ninety per cent of the draft is for irrigation purposes, though industrial and domestic draft of ground water is also high." Despite the alarming situation, Punjab has failed to evolve a water policy, which most states have, or are drawing up. Even the water use associations of consumers in Punjab are virtually non-existent, unlike other states. "Merely stopping new tubewell connections will not help. We need a water use policy, which includes irrigation, along with crop diversification to shift area away from paddy, to stop the state from turning into a desert," says Ghuman.

Citing depleting water resources, Punjab Power Minister Gurpreet Singh Kangar had announced two days back that the government was putting on hold the release of almost 1.5 lakh tubewell connections offered to farmers by the previous SAD-BJP government as a pre-poll bonanza.

Annexure – 5 Clipping shows the unmindful extraction of groundwater in various districts of Punjab.



Parched Punjab farms consume 97% of all groundwater extracted

ANJU AGNIHOTRI CHABA
JALANDHAR, JULY 12

PUNJAB, THE nation's food granary, uses nearly 97 per cent of the total ground water it extracts for irrigation purposes, against the national average of 63 per cent, a study by Central Ground Water Board has revealed. Of the 22 districts in Punjab, 20 have been using more than 90 per cent of the extracted groundwater for farming. Mansa tops the list, using 99.9 per cent of the total groundwater for irrigation.

The state, which was at epicentre of the Green Revolution, is now facing imminent desertification, mostly because of over-exploitation of groundwater to meet its farming needs. Here's why: the Punjab government in a report has confirmed that of 138 blocks, 109 are "over-exploited", two blocks are "critical", five are "semi-critical" and only 22 are in "safe" category. In other words, it has confirmed that 79 percent area of the state area is over-exploited.

The NITI Aayog, in recent report, has claimed that four cities from Punjab, out of 21 across India, face groundwater extinction by 2020. The cities are Amritsar, Jalandhar, Ludhiana and Patiala.

In Punjab, the net annual availability of ground water is 21.58 billion cubic meter (BCM) or (21.58 lakh hectare meter) but it is drawing 35.78 BCM. Out of this, it is using 34.56 BCM for irrigation purpose and 1.22 BCM for domestic and industrial purposes. In terms of percentage, the state is overdrawing the groundwater by 166 per cent and using 160 per cent of the overdrawn water for irrigation.

Among districts, Sangrur is the worst performer overdrawing groundwater by 260 per cent, of which 256 per cent is used for irrigation. Against the net annual groundwater availability of 144,088 BCM, the district extracts 3,74,631 BCM, using only a measly 6,129 BCM for the domestic and industrial supplies. As per the Groundwater Board report the district would require 232,842 BCM water for future irrigation needs, which won;t be available if timely measures are not adopted to replenish the water table.

All nine blocks in Sangrur are overdrawing the groundwater ranging between 198 per cent to 320 per cent. Dhuri, Sunam, Sangrur, Ahmedgarh, Andana are the top five drawing 320 per cent, 299 per cent, 285 per cent, 275 per cent, and 271 per cent, respectively.

Mansa, which has 102,794 BCM net groundwater availability, withdraws 1,45,381 BCM (141 per cent) and uses all of it for irrigation purposes.

Moga, Patiala and Ludhiana are among other heavy exploiters using 98.5 per cent, 97.5 per cent, and 95.3 per cent of the total groundwater extracted for irrigation purposes.

Faridkot, Bathinda, Amritsar, Fatehgarh Sahib, Fazilka, Gurdaspur, Jalandhar, Kapurthala, Muktsar, Nawanshahr, and Tarn Taran use more than 95 of the groundwater for irrigation while Hoshiarpur and Ropar use 92 per cent.

Only two districts in Punjab, Pathnakot and Mohali, are using less than 90 per cent of the groundwater for irrigation. The two districts have been using 86.6 per cent and 76.7 per cent groundwater for irrigation, respectively.

Scientists at the Central Ground Water Board said that Punjab was at the top in exploiting groundwater and the state government should work on its canal system to irrigate more and more area. They said the government should take some immediate measures to replenish the water table. They further said that various wings of the state government dealing with groundwater situation, including the hydrology wing of agriculture department, were hardly doing anything to replenish the water table by promoting various methods, including rain water harvesting.

Joint director, hydrology wing, Rajesh Vasisht could not be contacted despite repeated attempts and text messages.

Director, department of agriculture, Dr Suntantra Kumar Airy, said that they have been working hard to curtail the usage of groundwater for irrigation by promoting drip irrigation, direct seeding rice and diverting area under water-guzzling paddy for other crops.

Annexure – 6 - My article published in Daily Post dated 14 July 2019

OPINION

Punjab's major worry

Depleting GROUNDWATER

BALPREET SINGH

Although the Punjab Government is working on methods to curb the problem of depletion of groundwater and Punjab Chief Minister Capt Amarinder Singh has given the approval to set up Punjab Water Regulation and Development Authority (PWRDA) to regulate indiscriminate usage of water, still, the groundwater of the state is depleting day by day at a rapid rate. If proper measures are not adopted then a day may come when there will be less or no groundwater available in the state virtually turning it into a desert. Lowering of water table results in water quality deterioration as the groundwater is more contaminated in the shallow depth and not fit for drinking/irrigation.

According to a study conducted in S.A.S Nagar, the groundwater is depleting at a high rate in parts of Derabassi, Landran and Zirakpur. In Zirakpur the groundwater was found to be lowest. The other districts are also facing the same problem. Even Mohali area experienced declining trends in groundwater level. All results have been tabulated in the table shown below. The areas Issapur, Sirsaini are parts of Dera Bassi block, Dheri is a village in Landran block, Goga lies in Kharar block and Sohana lies in Mohali. The neighbouring districts of S.A.S Nagar i.e. Patiala, Rupnagar and Fatehgarh Sahib also showed the declining level of groundwater with a maximum decline in Fatehgarh Sahib. In Fatehgarh Sahib, the groundwater is the purest source available as compared to other water resources due to which the consumption rate is more than the recharge rate.

Monthly Variations in Depth of Groundwater level in meters

AREA	January	February	March	April	May	June
Zirakpur	9.5	9.97	10.47	11.27	13.972	15.4
Derabassi	4.6	4.57	4.92	5.54	5.84	5.6
Issapur	5.18	2.43	1.32	2	3.58	3.25
Sirsaini	1.02	1.1	1.03	1.11	1.49	2.9
Dheri	3.79	5.89	5.48	5.64	6.4	6.7
Landran	2.3	2.08	2.716	2.86	3.27	3.82
Goga	3.3	3.96	4.57	6.57	6.97	7.37
Sohana	3.749	4.359	4.511	4.587	4.94	4.93

The major reason is the atmospheric pollution which leads to an increase in temperature leading to an increase in evaporation rate. The other reason is industrialization, urbanization and construction of flats and malls at a high rate. When basements are constructed in these buildings, a sump is created for the removal of groundwater as it can cause dampness. In this way, the groundwater further keeps going down with the increase in basements.

About two third of the water used for irrigation comes from groundwater which leads to an increase in the consumption rate of groundwater and decrease in recharge rate. So proper measures like huge power subsidy for farmers to pump groundwater has to be done away. Also, the supply of metered water should be limited instead of providing 24x7 water supply which causes more wastage.

Cleaning of draining chaos in the districts, practising rainwater harvesting, construction of water storage structures like ponds and tanks and providing outlets in canals and utilizing the canal water for irrigation needs to be adopted so as to control the depletion of groundwater.

Rainwater Saucer

There are many drainage choos which are chocked due to the unwanted growth of grass. In this way, the water drained from floods gets consumed by the grass. Instead, the chaos should be cleaned so that the drained water can be easily transferred to the groundwater table. Rainwater can be collected in water storage structures like tanks and ponds which can be utilized for carrying out domestic purposes. The government should control the indiscriminate release of new tube well connections as with an increase in the number of bore wells the groundwater level will further go down. But merely this will not help. Cropping pattern should be changed time to time according to crop diversification programme instead of promoting the growth of paddy alone as it consumes more water for growth and the farmers should be motivated to switch to crops like pulses, maize, vegetables etc.

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