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# INTEGRATED ANALYSIS OF RAINFALL, WATER SUPPLY SYSTEM AND HYDROGEOLOGY TO HIGHLIGHT GROUNDWATER RISING PROBLEM IN JODHPUR CITY

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## ABSTRACT

*The Rajasthan state is facing scarcity of groundwater and extraction of this resource from ground has reached to critical stage. In contrast Jodhpur city is facing anomalous problem of swift increase in groundwater level that has set out seeping into houses. This necessitated administration as well as many residents to withdraw large volume of water from wells and subsurface water from houses to live in safe environment. Groundwater level has been rising for more than a decade in at least 40 percent of the land area in the city, and in some areas it has approached to the surface.This study focused to find out the possible causes of groundwater level rise problem. Main objective of the study isto analysis trend of water level in the city, rainfall,water supply condition over a period of last 4 decades, Hydrogeology of the area and Hydrochemistry. Probable causesinclude seepage of water from higher elevation to lower elevation, combined effect of increased rainfall pattern in recent years, improper and old drainage system, unutilized water sources within jodhpur city, seepage of water from kaylana lake and peculiar hydrogeology of the area. Further scope includes establishment of the thickness of the impermeable layer in various zones to detect the possibility of water below the strata.*

***Keywords: Anomalous, Hydrogeology, Hydrochemistry, Impermeable layer,Seepage***

## I. INTRODUCTION

The groundwater existence, scattering and eventfulness is a subterranean happening, controlled by terrain attributes like physiography, drainage, lithology, geological structures and hydrogeology. The groundwater usually found in fractures, porous, cracks and permeable rock formations, whereas surface water occurs above the surface of the earth. If both surface and subsurface waters get linked to each other, then the groundwater get recharged with the surface water occurring in rise in the water level.

Jodhpur is the second largest city of Rajasthan State. The city had distinctive medieval rainwater harvesting and water management system which made city to get through in barren desertic climate with successive droughts.Jodhpur city is located between latitude 26°15' N to 26°20' N and longitude 73°0'E to 73°4'E (Figure 1). Within this, on the hill comprising of rhyolites and sandstone, stands the prominent Jodhpur fort, the famous 'Mehrangarh' overlooking the city. The fort hill is about 125 m. above the surrounding plains. The city expanded beyond old walls with growing population and urbanization. The standard urban area of Jodhpur town is 208.31

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Sq.km comprising 78.60 $Km^2$ area of urban component and 120.71 km sq. area of rural component. The city composed of a number of water confining formations. The Jodhpur Urban area covers Jodhpur, Mandore Industrial Area, Kuri Bhagtasani, Pal Village, Nandri and Sangariya. Jodhpur town has peculiar geomorphologic backdrop. Old walled city part is situated on hill slope area and in the base of the fort hill ridge. The sloping land gently turns to plain alluvial terrain towards south, east and south west. Streams and drains originating from the city area join Jojari river which is ephemeral.Water levels in the city area have started rising since early eighties. However, these have significantly risen in most of the area after 1996.It has been noticed that groundwater table has approached nearly to the ground surface and 40% of the land area has covered of the city. This has caused serious problem of appearance of water in the basements of buildings and dampening of walls in some parts of the city. Weakening of foundation of houses and decrease in life of buildings cannot be ruled out.

## II. STUDY AREA

### 2.1 Physiography And Drainage

Jodhpur City is situated partly along the foot of hills and partly in the plains formed by weathering of rhyolites and sandstone. Major part of the old city lies on the piedmont zone. City is bounded by the hills in the north and west directions (Figure 2). The hills of rhyolites rising to an elevation of 395 m above mean sea level mark the prominent elevated landmark feature in the western part of the area. Topographic lowering of the plain area to the extent of 180 m above msl occurs in the south-eastern part of the area. The area is devoid of perennial drainage. Jojari River is an ephemeral stream in the area which flow in response to monsoon rainfall. The city sewerage is directed to Jojari through various drains. Balsamand, Kaylana, Takhatsagar, Ummedsagar, Ranisar, Padamsar, Lalsagar, Gulabsagar and Fatehsagar are notable water reservoirs in and around the city.

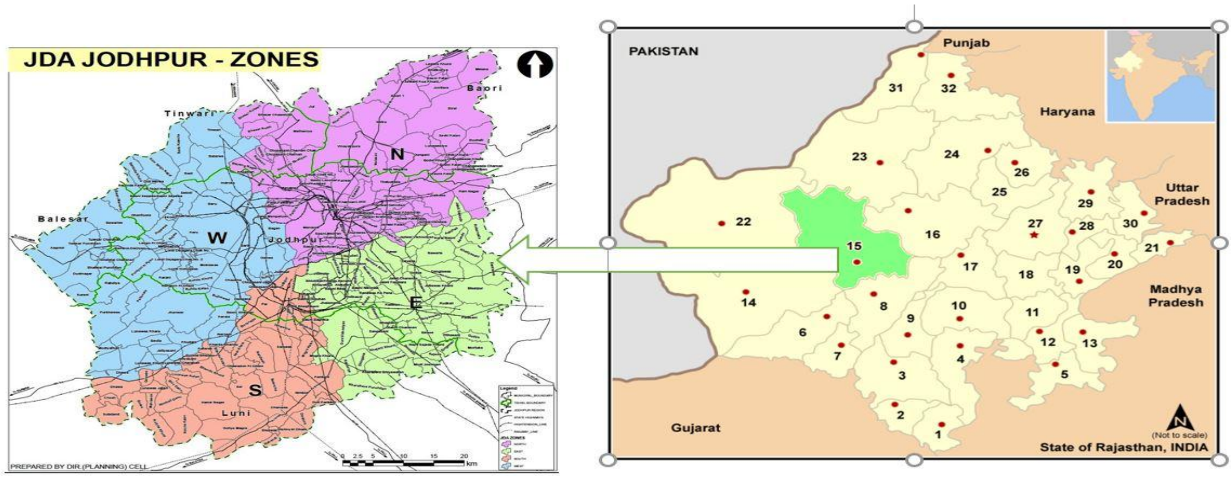


**figure1. Jodhpur City Location**

### 2.2 Climate

Climatic condition in is tropical and Mean daily maximum temperature is highest (41.6°C) in May. January is the coolest month with both daily maximum and minimum temperature being lowest at 24.6°C and 9.5°C respectively. The air is usually torridduring the most of the year. However, in monsoon period the climate becomes a little humid, relative humidity is highest in the month of August (81%).

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## III. METHODOLOGY

In this study all the factor which could affect the groundwater level in the city area has been incorporated and an integrated approach has been used to find out the cause for the rise of groundwater level in city. Methodology is shown here in diagram.

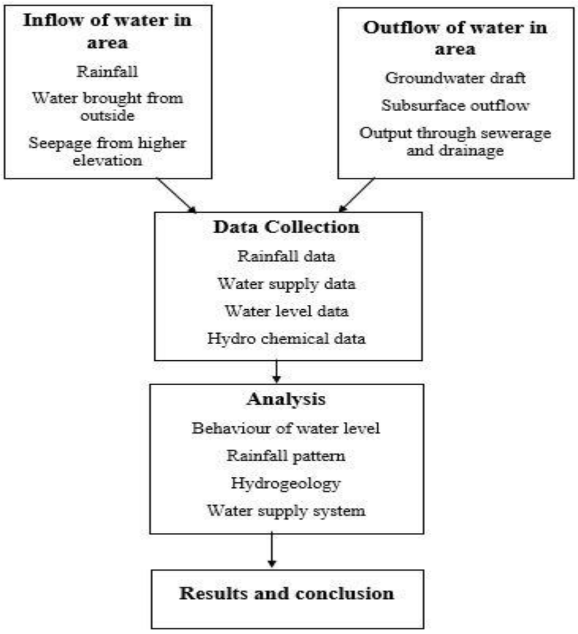


**Figure 2. Methodology**

## IV. INTEGRATED PERSPECTIVE FOR THE GROUNDWATER RISE PROBLEM

### 4.1 Rainfall pattern of the area

More than 85% of the total annual rainfall is by the southwest monsoon, extends from July to September. August is the moist month with normal monthly rainfall of 128.9 mm. Mean annual rainfall of the area is 377.65 mm (1969- 2014) whereas, the IMD Normal Annual Rainfall is 314mm. The Rainfall data, along with the departure from average rainfall is given in figure 3. It is observed that there are intervals of relatively high and low rainfall. In current time, 1994-1999 and 2010 to 2013 have been periods of relatively high rainfall.

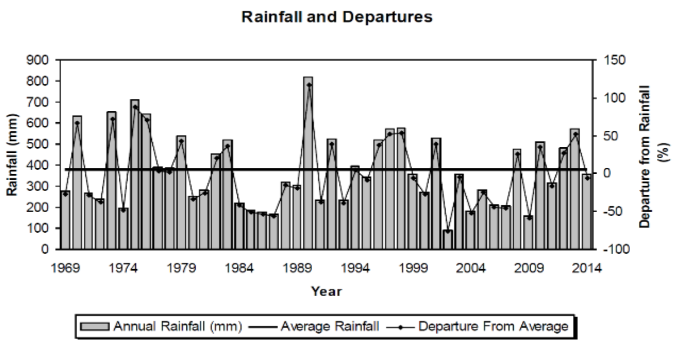


**Figure 3. Rainfall and Departure of Rainfall from Average**

### 4.2 Integrated Water Supply Scenario In Jodhpur City.

Jodhpur City has scarce and inferior quality of groundwater resources and the city has relied predominantly on surface water sources, for miscellaneous needs since past time. In the past, the city population used to meet their requirements of water from "Baories" (step wells) and surface water reservoirs like Umedsagar, Lalsagar,

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Takhatsagar, Kaylana, Baiji Ka Talab, and Balsamand. The abundance of old baories and surface water sources indicate such type of water supply. With time, the population of town increased and the water sources were not enough for the greater requirements of water supply.

Therefore, during British period Jawai reservoir located in Pali district, was constructed to meet the water supply demands of Jodhpur citythrough Jawai canal. Jawai canal was in addition to the supply from old sources of the city. To meet the increased household requirement of drinking water for Jodhpur City, PHED authorities constructed number of tube wells in Doli-Pal area which is located about 9 km south west of Jodhpur town. Due to excessive development of groundwater resources for irrigation and drinking, Doli-Pal area became overexploited. This resulted in continuous decline of water levels in the area.

Extreme drought situation experienced during 1986-89 in western Rajasthan.Due to this the supply from Jawai reservoir reduced considerably and became insufficient. Government implemented two new schemes to meet out the demand for city water supply (l) Rampura-manai, Teori-Balarwa scheme (ii) Ransigaon scheme. Heavy pumping from these areas for the increased demand of water for Jodhpur city together with the enhanced use of groundwater by the agricultural 7 sector led to overexploitation conditions, this resulted in considerable decline in groundwater levels in these areas and reduction in well yields. In Jodhpur city area about 1800 bored wells with hand pumps and pumps in some cases were constructed for various domestic purposes. The quality of groundwater in these was inferior in general. In major parts of walled city and Ratanada area salinity in groundwater is also associated with high nitrate concentration thereby making the groundwater unfit for drinking purpose.

Despite all above efforts the water supply to the city was far less than the requirement. In view of the above there was an imperative need for long term planning of water supply to Jodhpur town keeping in view the increasing population. Accordingly the state authorities implemented IGNP lift canal scheme for the town. The water received through the lift canal is stored in Kaylana Takhatsagar reservoir from where it is supplied to the city. Kaylana Lake has caused the reservoir water level to rise to a new high which is maintained almost throughout the year due to inflow of water from the lift canal. Water supply from Ransigaon area and Jawai canal has been stopped for Jodhpur city since 1998.Presently water supply to Jodhpur city is met mostly by IGNP lift canal and partly from groundwater sources from the area around Jodhpur city namely Rampura-Teori-Manai-Manklao and Doli-Pal area. At present water in lake Kailana is mainly supplied by lift canal. Input from lift canal to Kailana lake is 0.21 million cubic metre per day.The mean depth of lake is about 18 metre, which has capacity of about 5 million cubic metre of water. Present water expenditure from the lake is 0.18 million cubic metre per day while, it was about 0.08 million cubic metre before the feeding by lift canal. In 1997 supply of water to the city was 259 lac gallons/day.Present level of water supply to the city is 377.54 lac gallons/day, which is adequate considering the requirement.

**4.3 Hydrogeology of the area**

Geomorphologically, the city is located on a concealed pediment starting from the foothillsand hills surrounding the city along northern and western periphery. Jodhpur city area thatcovers areas affected by seepage consists of chiefly alluvium and rhyolite whereas Kaylanalake area, located about 10 Km on the western side of the city made up of fractured rhyolite.An extensive rhyolite ridge is running from northeast to southwest between Kaylana lake andcity area. Northern and eastern periphery of the Jodhpur city consists of alluvium and sandstone. Malani Rhyolites forms aquifer in inner city area from Tilwaria, Chopasani through Chandpol, Lal

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Sagar to Punjla. These are compact, hard, impervious, weakly jointed and form poor aquifer yielding meagre quantity of fresh to saline groundwater. Groundwater is limited to fractured, joints and weathered zone. In the northern and central part of the city sandstone forms aquifer. It is fine to medium grained hard compact; due tointercalations of shale in this formation that decreases the water potentiality. The discharge of wells in this sandstone generally varies from 10 to 50 $m^3$/day. Quaternary formation which comprises clay with kankars, sand, silt, pebbles, gravel and rock fragments makes aquifer in the easternand southern parts. Because of presence of calcareousmaterial, it is semi consolidated. The saturated thickness of the alluvium varies from 3 to 9 m in the area. Yield of the wells within this aquifer varies from 50 to 120 $m^3$/day. In Pal area due to excess development of groundwater for irrigation and drinking, the area has become over exploited.

Reduced level of Kailana lake and seepage locations is about 280 and 250 m above the mean sea levelrespectively. The affected area is sloping from north to east and southeast. The hills on which the fort is located have higher elevation and the relief is fairly steep. A number of surface water impounding structures was constructed in the immediate foot hills zone and also at suitable location within the city to receive monsoon flows.

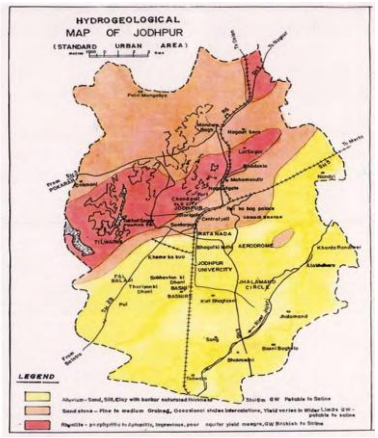


**Figure 4. Hydrogeology of Jodhpur City**

### 4.4 Water Level Behaviour

The water level data for last 20 years (1994 to 2014) for 6 wells is shown in figure 6 a-f. The trend of long term behaviour of water level at these 6 monitoring wells is shown in table below. It is seen that the water level has been rising consistently in 4 wells situated with the urban area.

| S. No | Monitoring Station | Type of Well | Trend m/year | Remark |
|---|---|---|---|---|
| 1 | Jodhpur | Dug Well | -0.87 | Rise |
| 2 | CAZRI | Pz | -1.06 | Rise |
| 3 | Chopasni Nath | Dug Well | -0.21 | Rise |
| 4 | Thorion Ki Dhani | Pz | -2.25 | Rise |
| 5 | Mandore | Dug Well | -0.07 | Rise |
| 6 | Bujawar | Dug Well | 0.12 | Decline |

**Figure 5. Long term trend of water level in jodhpur city**

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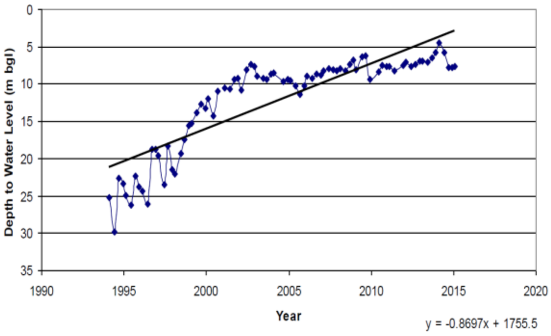


**Figure 6a Monitoring station Jodhpur**

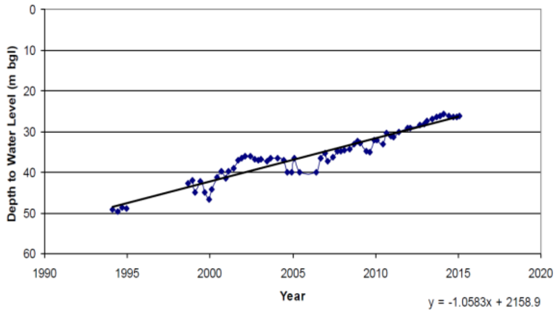


**Figure 6b Monitoring station CAZRI Pz**

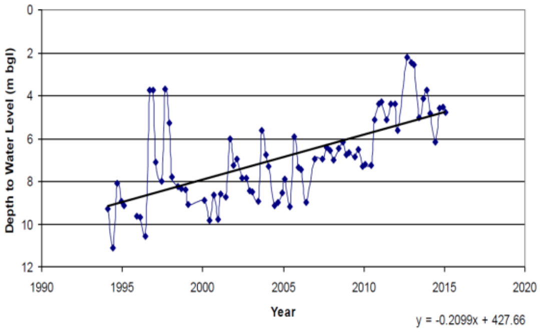


**Figure 6c Monitoring station Chopasani Nath**

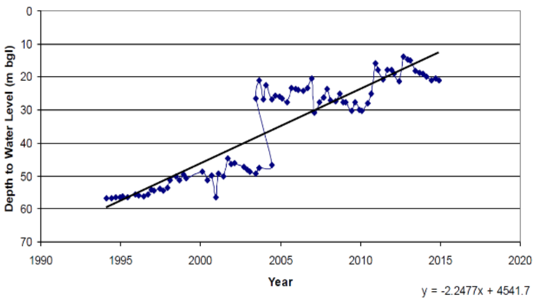


**Figure 6d Monitoring station Thorion Ki Dhani Pz**

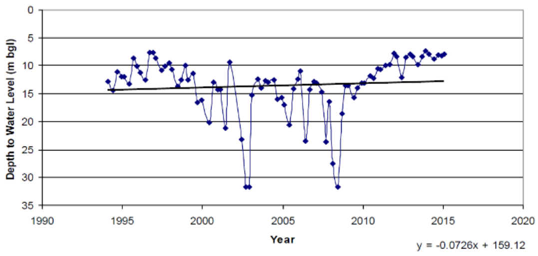


**Figure 6e Monitoring station Mandore**

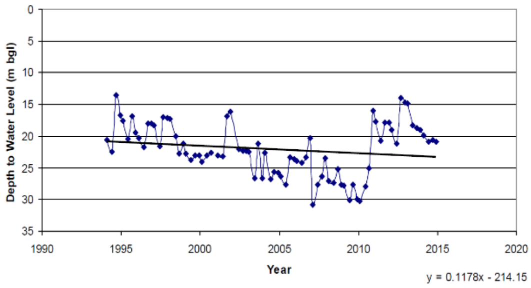


**Figure 6f Monitoring station Bujawar**

### 4.5 Hydrochemistry

Groundwater samples were collected from city borewells and tested for different hydrochemical parameters by central groundwater board jodhpur which is shown in figure 7 below. Quality of the groundwater is not acceptable for drinking purpose. More than 80% of water samples have electrical conductivity above 750 µS/cm.

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| S. No. | Constituent | Min. Value | Max. Value | Number of samples | | |
|---|---|---|---|---|---|---|
| | | | | Below Desirable Limit | Between Desirable and Permissible Limits | Beyond Maximum Permissible Limit |
| 1. | Electrical Conductivity (µS/cm) | 370 | 15320 | - | - | |
| 2. | Total Dissolved Solids | 182 | 5506 | - | - | - |
| 3. | Chloride (mg/l) | 21 | 4857 | 42 | 40 | 20 |
| 4. | Sulphate (mg/l) | 2 | 1112 | 34 | 52 | 13 |
| 5. | Nitrate (mg/l) | 0 | 1105 | 22 | | 80 |
| 6. | Total Hardness (mg/l) | 80 | 3445 | 33 | 39 | 27 |
| 7. | Calcium (mg/l) | 28 | 215 | 49 | 36 | 14 |
| 8. | Magnesium (mg/l) | 4 | 302 | 33 | 54 | 12 |

**Figure 7. Hydrochemical analysis of water samples**

## V. RESULTS AND DISCUSSION

Jodhpur town has anomalous geomorphologic location. Old city part is located on hill slope area and in the base of the fort hill ridge. The sloping land gradually turns to plain alluvial terrain towards east, south and southwest. Figures 8 show a typical cross section wherein it becomes evident that a bowl like situation is formed.

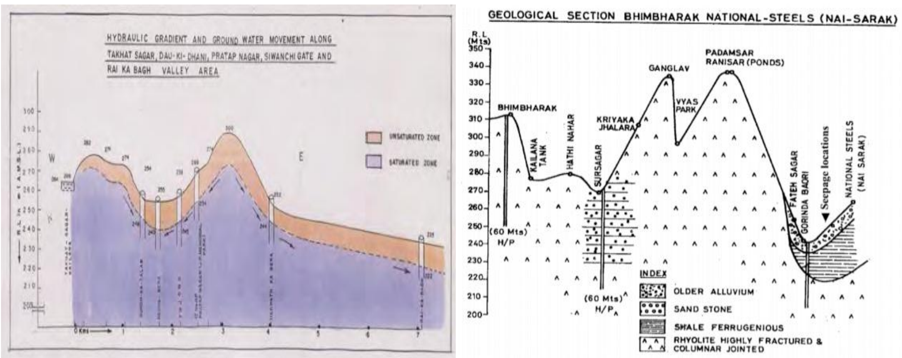


**Figure8 Typical cross sections across the urban area Geology**

The formations have in general poor yields and inferior quality of groundwater over the major area. Except in the upper weathered part both the rhyolites and sandstones are quite compact from shallow depth. Thus these formations do not allow the seepage water to percolate to deeper levels as such the transmissivity of the water bearing formations is very low.The draft from the area is less compared to the recharge, as a result of which water table in and around the city area was found to be rising gradually.

Based on the studies carried out, the main causes of water level rise in the Jodhpur city area are as below.

- Increased rainfall in recent years caused the increase runoff and it feed the unutilized open water bodiesin city which causes the seepage of water from that also groundwater table rises.
- Drainage and Sewerage system in the walled city area is somewhat old. The seepage from these opendrains and sewerage lines is a process, which continues throughout the year. The flow becomes sluggish due to regular

chocking of drains due to polythene etc. Also there is frequent leakage of water from waste water pipes. This seepage directly joins the groundwater in shallow water table area and causes rise.

- The water supply level to the city was 183.46 lac gallons per day in 1994.This has been almost doubled and increased to 377.54 lac gallons per day presently. Increased water supply causes increase in this seepage and therefore the rise.
- Many open water bodies lie in and around the city idle. These were utilized in the past for water supply. Presently these stand filled up with water throughout the year. The water bodies located on higher elevation causes continuous seepage. However, the water bodies located in the lower levels are being fed by the Groundwater.
- Due to abundant availability of fresh surface water, effective use of prevailinggroundwater structures in the city area has been discontinued both by the Government and private users. The groundwater sources here have inferior quality of groundwater and as such due to adequate supply of water met from IGNP lift canal the existing hand pumps, dug and bore wells are not been utilized causing rise in water levels.
- Presence of rhyolite which is poor conduit of groundwater due to massive nature from shallow depth does not allow the seepage water to percolate to deep levels. The stagnation of this seepage water causes rise in water level.
- In sandstone due to presence of fragmentary shale layers also hinders percolation of seepage water to deep levels.

## VI. CONCLUSION

Considering all the aspect for the possible causes of groundwater table rise in city it can be concluded that this problem is due to the combined effect of increased rainfall pattern in recent years, improper and old drainage system, unutilized water sources within jodhpur city, seepage of water from kaylana lake and peculiar hydrogeology of the area.The most probable cause could be seepage of water from higher elevation to lower elevation where the city is located. The larger part of seepage which add into the groundwater level is from the lake and could be either due to direct seepage from kaylana lake or seepage from water supply lines and drainage percolating to subsurface.In further scope of study exact measurement of the thickness of the impermeable layer in various zones needs to be established in order to detect the possibility of groundwater below and to detect the possibility of water below the strata.

## VII. ACKNOWLEDGMENTS

The data generated by Central ground water board jodhpur is used in this study. We are also thankful to the whole CGWB Jodhpur staff for the help they provided in this study.

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