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Rising Demand for Rain Water Harvesting System in the World: A Case Study of Joda Town, India

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ABSTRACT

Worldwide, annual water demand has been increased for different uses. This can be attributed to population expansion and the accompanying need to satisfy their water needs for domestic, agricultural, and industrial purposes. The situation has been becoming worst due to vulnerable and inefficient water supply systems. Rainwater harvesting (RWH) has been proved to be a sustainable option in solving the on-ground water shortage to a great extent. India has been facing the wrath of a water crisis for about a decade or two. The potential of RWH in India is more due to its geographical location and landscape. This paper aims at studying the impact of adopting RWH techniques as an artificial recharge option to evaluate groundwater table in the Joda town of India by analyzing the difference in water levels of the township throughout the past decade (2009-19). The study revealed the increase in the underground water level of the study area and established that RWH systems are crucial in arid regions to a large extent.

***Keywords*:** Rainwater, Harvesting, Water Resources Management, Groundwater, Joda

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1. INTRODUCTION

Water is the very stepping stone of our existence and the basis of our everyday life. Nearly every activity in our day to day life involves water consumption. Drinking, washing, cooking, irrigation, industry consumption, hydro-power generation, etc. comprise of water utilization. Most of the consumed freshwater is derived from rainfall. Rainwater is naturally stored in lakes, streams, ponds, wetlands, rivers, and underground reservoirs (aquifers). Underground water reserves are the primary sources of freshwater consumption. According to NOAA (National Oceanic and Atmospheric Administration), nearly 30% of our freshwater consumption accounts from groundwater sources. Groundwater acts as the sole source of water in places of surface water unavailability. Pumping out of groundwater can solve numerous water-related problems but at the same time overdependence on it can lead to its exploitation. Overutilization of groundwater can have disastrous effects both on the economy and the lives of human beings. Some of the forthcoming threats include decreasing of the underground water table, degrading water quality, rise in water expense, land subsidence, etc.

According to UNESCO (United Nations Educational, Scientific and Cultural Organization) World Water Development Report 2015, India stands as one of the prime groundwater extractors in the whole world and several other facts regarding India's groundwater which states that over the past 7 years, 54% of India's groundwater wells have declined and 21 major cities are anticipated to run out of groundwater by 2020. Therefore, India faces a two-fold challenge of administering the rising groundwater demand while replenishing its sources at the same time. The world's surface temperatures during the most recent couple of decades have escalated at a phenomenal rate because of global warming. This has affected the worldwide hydrological cycle and rainfall patterns over the globe. Global warming has an adverse effect on rainfall and can be observed from its long and steady advancement. In India, annual rainfall to a great extent comes from the southwest and northeast monsoon rainfall. Indian rainfall is an exceptionally variable, complex framework that relies upon a few climatic and maritime processes.

Nair *et al.* studied the cautions against the substantial changes in Indian rainfall and introduced a novel method for evaluating variation and trends in Indian rainfall [1]. Further Puranik *et al.* analyzed the efficacy of North American Multi-Model Ensemble (NMME) models during the southwest monsoon throughout the Indian territory. Their observation revealed crucial information regarding all the nine models and their positive correlativity over the Indian sub-continent [2]. Various observations by Sinha *et al.* illustrated declining rainfall in large parts of India over the past few decades [3]. While, Paul *et al.*, discovered that deforestation brings about debilitating of the Indian Summer Monsoon Rainfall (ISMR) because of the reduction in evapotranspiration and consequent abatement in the recycled component of precipitation [4]. India is a country with a large growing population and water scarcity associated issues. Several case studies in India revealed crucial information related to water conservation and RWH systems [5, 6]. Several other researchers across the globe have aided by analyzing rainfall patterns, designing efficient RWH systems, analyzing runoff and underground water levels, etc., while being unanimous in tackling water scarcity and conservation [7-9]. Present synopsis of global rainwater harvesting has been highlighted in the paper.

This study on the RWH system would be a significant endeavor in advocating the perks and exigency of water management, especially in India. The case study presented in this current research study demonstrates the water consumption demand in mining areas and reports the necessity of adequate water harvesting structures to meet the growing water demand. A typical Storage cum Percolation Pond based RWH system has been interpreted conjointly with its design and operation to provide better insights on water harvesting structures.

2. RWH SYSTEMS ADOPTED WORLDWIDE

Rainwater harvesting (RWH) is the process of accumulating incident rainfall droplets on rooftops, land surfaces, roads, or rocks with the help of tanks, pots, cistern, underground check dams, etc. [10]. RWH plays a crucial role in the efficient utilization of water for a sustainable urban future as it holds lots of opportunities [11]. It is highly important in areas where there are serious issues with the availability of water due to climatic conditions such as Jordan [10], south-eastern Europe [12], Kenya [7], Tanzania [13], Zimbabwe [14] and many other African drylands [15]. It is also important when the availability issue is due to urbanization such as Australia [7], India [16], and Lebanon [17].

If properly deployed and utilized, RWH at a domestic level can help supplement the demand from the municipal water supply [18]. Furthermore, the primary economic benefit of rainwater harvesting depends on the amount of water saved and the reduction in the price paid for it [7]. Areas, where rainwater is harvested and stored, would reduce the cost of sourcing water for farm irrigation as the water quality is suitable for the purpose. Biazin *et al* discussed that this reduced cost due to cheaper sourcing of water has led to greater profitability crop production [19]. However, the direct financial evaluation of rainwater harvesting shows widely varying results most of which involve large payback figures and long break-even times [20]. Dallman *et al.* were able to show that in the long run, despite the cost implementation and operation, the benefits of rainwater harvesting outstrip the costs [21]. Gabarrell *et al.* were able to establish the baseline levels of profitability for rainwater harvesting at the house scale and apartment building scale using plugrisost simulation modelling [22].

Less than 1% of all existing freshwater resources are available for human consumption. This small proportion of available freshwater resources is reducing due to the increasing negative effect of environmental pollution [23]. Global water consumption is also on the rice due to rising populations. These environmental considerations portray the need for more sustainable water management and utilization techniques, especially in the urban scenario. Rainwater harvesting holds great potential in this regard. In the lifecycle assessment by Ghimire *et al.*, it was revealed that the typical commercial rainwater harvesting system outperforms the municipal water supply system in Washington D. C. in all categories except Ozone Depletion [24].

Rainwater harvesting reduces the volumes of water discharged into the environment from rainfall run-off thereby reducing the risk of flooding [10]. This is a key environmental advantage of rainwater harvesting. The quality of the harvested water is dependent on the nature of the catchment surface, the storage materials, and the site environment [25]. Harvested rainwater from various regions in Australia has been shown to contain ionic contaminants such as heavy metals [18] and above regulatory limits. Furthermore, there have also been reports of microbial contamination in harvested rainwater from various regions in Australia [18]. These concerns of water quality are even more crucial in developing countries where it is a source of drinking water (sometimes without any secondary treatment) [26-34].

The quality of rainwater may not be high enough for certain applications such as drinking (without adequate purification technologies) but it is suitable for many agricultural purposes. There are different technologies for rainwater harvesting (both in the micro-catchment and macro-catchment domain) [27].

The micro-catchment systems are designed for small areas between 10-5000 m^2 and these include pitting, contouring, terracing, and micro-basins [19]. The macro-catchment is for areas larger than 50 m^2. In Jordan, the scarcity of water is due to the arid nature of the land and the climatic conditions without rainfall. Abdulla and Al-Shareef described a typical rooftop rainwater harvesting scenario in the urban communities in Jordan [10]. The roofs are preferably corrugated or tiled to give higher water quality. In Jordan, cemented and tile roofs are the most common. The conveying system is by gutters or pipes and it leads into a covered concrete tank serving as the cistern. More discussions on RWH technologies are revealed in the review by Gowing *et al.* [13].

3. RWH SYSTEMS ADOPTED IN INDIA

3. 1. TRADITIONAL APPROACHES/PRACTICES IN INDIA

Throughout history, Indians have been worshiping both water and rain due to religious beliefs. RWH occurred naturally without human intervention, till 3000 B.C., but were later improvised by humans to operate more efficiently. Indians have been harvesting rainwater through several ancient traditional methods, but since 1800 A.D. various unfavorable events and conditions triggered the deterioration of the methods. India has an extraordinary and long-established practice of water harvesting.

Water harvesting has been practiced in India from ancient times, as the predecessors specialized in water management. Water conservation is deeply rooted in ancient India and can be substantiated through archeological findings. Recent excavations of Indus Valley civilization provides ample evidence of exceptional water management systems and establishes the fact that the civilization was way ahead of their time in terms of water harvesting and drainage systems. Depending upon centuries of experience, Indians maintained a steady progress in constructing structures to reutilize rainwater in dry seasons.

Table 1, provides a brief description of some of the ancient/traditional rainwater harvesting systems practices in India. The groundwater accessibility in India is profoundly intricate because of differentiated geological formations, multifaceted nature of the tectonic arrangements, variable climatic conditions, etc.

Table 1. Traditional/Ancient approaches for Rain Water Harvesting in India.

Eco-Zone	Traditional RWH Systems	Description	Reference
Eastern Himalayas	Apatani	Valleys are terraced into plots isolated by 0.6 meters high earthen dams upheld by bamboo outlines, Arunachal Pradesh (Agarwal and Narain, 1997).	[16]

Western Himalayas	Ghul	Ranges long from 1-15 km and conveys a release of 15-100 liter of water/sec. Jammu, Himachal Pradesh, and Northern Uttaranchal (Clark et al. 2017).	[28]
	Khatri	These are rectangular, deep pits made on the hill slopes in hard rocks, where rainwater is collected through seepage from rocks, Himachal Pradesh (Sharma et al. 2009).	[29]
North-Eastern Hill Ranges	Zabo	It is an ingenious method of catching rainwater from running off the mountains. Preservation of the entire framework alongside the catchment zone is done each year, Nagaland (Agarwal and Narain, 1997).	[16]
Brahmaputra Valley	Garh and Dara	Garh is like a big nala and Dara are small embankments where rainwater is put away and used for irrigation development, Assam (Borthakur, 2008)	[30]
Thar Deserts & Western India	Kund/Kundis	It is an ingenious system of rainwater harvesting which appears as an upturned cup settling in a saucer and is built toharvestrainwater for drinking purposes, W. Rajasthan (Ministry of rural development, 2004).	[16]
	Kuis/Beris	These are 10-12 m profound pits burrowed close to tanks to gather the seepage which is utilized to harvest rainwater in zones with insufficient precipitation, W. Rajasthan (Dhiman and Gupta, 2011).	[16]
	Nadis	These are village lakes that store water from the connecting natural catchment zones, Jodhpur, Rajasthan (Ministry of rural development, 2004).	[16]
	Johads	These are tiny earthen check dams that catch and preserve rainwater, increasing permeation and groundwater recharge, Rajasthan (Borthakur, 2008).	[30]
Eastern Coastal Plains	Eri & Kulams	An arrangement of tanks (eri) made around 1500 years back to gather rainwater and deliver water for drinking, irrigation, human consumption, and recharging of the groundwater table. Kulams are small ponds usually produced by masonry, beside a temple primarily utilized for drinking purposes, TamilNadu (Agarwal and Narain, 1997).	[16]

3. 2. NECESSITY OF RWH IN INDIA IN RECENT TIMES

Because of its rainfall pattern, India has a history and a tradition of implementation of RWH systems as discussed in the earlier section. However, in contemporary times, the implementation of RWH has become a necessity more than ever. The technological advancements in the extraction of groundwater for civilization demands have greatly affected the groundwater table leading to severe aquifer depletion.

Rivers are becoming dry and the country is facing floods and droughts in the same year as noticed in several states. Yes, the rainfall is abundant in a way but it is not evenly distributed amongst all states, therefore, implementation of modern RWH systems in the epicenters of rainfall is expected which will certainly improve the groundwater reserves of in and around regions. It has been reported that states of India such as Odisha, Gujarat, Rajasthan, Maharashtra, Tamil Nadu, Karnataka, Andhra Pradesh, Madhya Pradesh have taken up serious action plans/programs at a larger scale to implement RWH systems and recharge the groundwater table [31]. In 2019, India witnessed major rainfall with floods in its northern part in comparison to the issue of acute water shortage in the southern part at the same time. Chennai becomes the main significant city to confront intense water deficiency. The National Institution for Transforming India (NITI Aayog) states clearly that India has been suffering from a critical water emergency for which monetary development, employments, human prosperity just as environmental maintainability in question and 21 significant urban areas including New Delhi will come up short on groundwater by 2020. Moreover, the intensity of crop production in India has increased manifold and consequently affects the available groundwater reserves. Firstly, it consumes the share of runoff created by rainfall from that particular area. Secondly, the land used for crop production has to be cultivated and thus increases the overall water requirement thereby depleting groundwater table reserves. Hence, large regions of India are facing a serious issue of shortage of water to meet the existing agricultural demands. As per the 2007 Indian groundwater management reports, states which are facing over-exploitation of groundwater are Gujarat, Rajasthan, Madhya Pradesh, Karnataka, Tamil Nadu. Therefore, it has become necessary to recharge the groundwater table and revive the natural aquifers through the implementation of proper RWH systems in the present scenario, and this paper highlights this issue with a comprehensive case study discussed in the following sections.

4. CASE STUDY

This paper focuses on the exploitation of underground water reserves and growing needs & demands for underwater conservation in Joda, India. RWH is an efficient method for the conservation of water and is demonstrated through the concise case study. Various news and research articles and websites of government agencies provided most of the data, while some undisclosed information was collected through the Right to Information (RTI) Act of the Indian government.

4. 1. STUDY AREA

Joda township as indicated in Fig. 1 is surrounded by hills with steep slopes and is at a distance of 67 km from Keonjhar town, India. The total population of the area is around 1,50,000. The area is rich in hematite, goethite, pyrolusite, and psilomelane with traces of pyrites. Other associated rocks are dolerites, tuffites, and laterites. Being a mineral-rich area, water consumption is considerably more than any other place. 2 ponds in very bad conditions are located in the township. Sona Nadi and Baitrani river used to be the chief sources of water for the locals. Almost dried Sona Nadi and rapidly drying Baitrani river is leaving no choice but to completely rely upon underground water. According to the Bureau of Indian Standards, IS:1172-1993, per capita consumption of water in industrial and commercial towns with a full-flushing system stands around 280 liters. The township/municipality is spread over an area of about 26.40 km^2 (10.2 sq mi). Groundwater status of the entire Joda block (41 km^2/16 sq mi) has been illustrated in Table 2. An efficient water conservation system could present a more sustainable solution in addressing these growing issues.

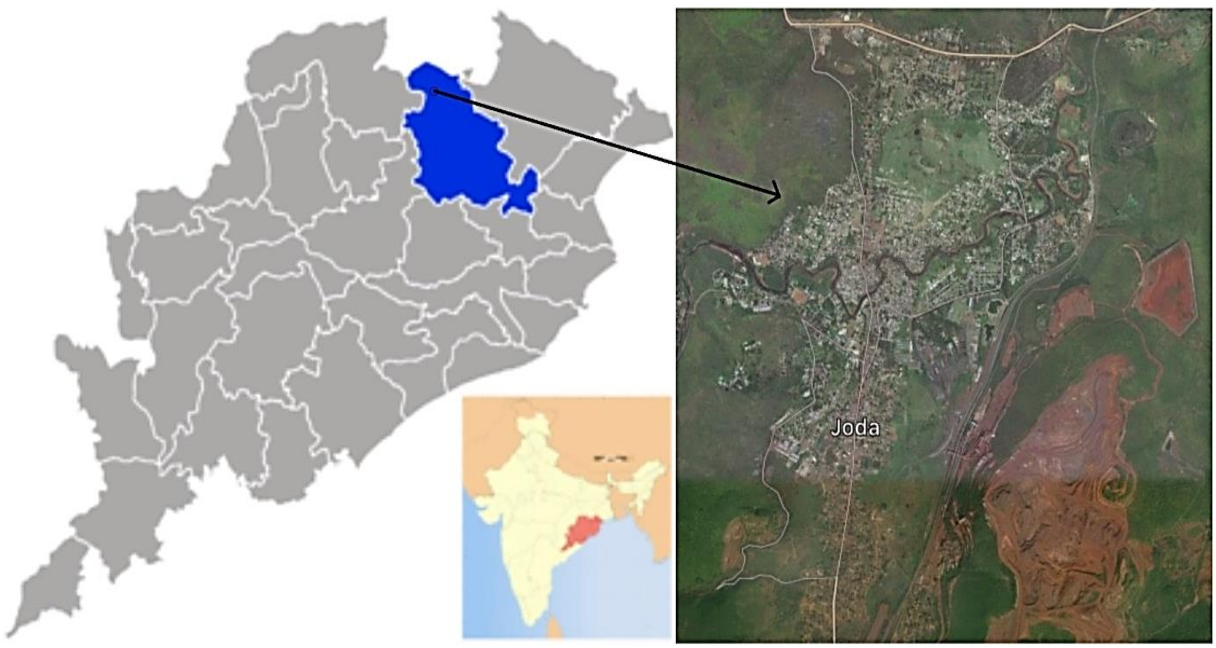

Figure 1. Illustration of the Joda township in India

Table 2. Ground Water (GW) resources of Joda block, 2013 (*ham*).

Evaluation Area	Net Annual Availability (GW)	Existing Gross GW draft for irrigation	Existing Gross GW draft for domestic and industrial consumption	Existing Gross GW draft for all uses	Allocation for domestic and industrial requirement supply up to the next 25 years	Net GW availability for future irrigation development	Stage of GW development (%)
Joda	3926	637	1824	2461	715	2574	62.68

4. 2. RAINFALL & CLIMATE

Joda is situated in the south-eastern part of India and comes under Keonjhar district. Its climate is distinguished by an onerously hot summer with elevated humidness. The temperature in the district commences ascending quickly in the spring with the highest temperatures recorded in May usually go up to 38 °C. The maximum recorded temperature, however, is 43.3 °C. The climate turns out to be progressively wonderful with the appearance of monsoon in June and stays all things considered up to the finish of October. The temperature in December is most minimal, i.e. it floats at around 11 °C. At times it even drops down to as low as 7 °C. The average annual precipitation is around 1910.1 mm and can be determined from table 3.

Table 3. Rainfall of Keonjhar District for the last 5 years.

Month	2014		2015		2016		2017		2018	
	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP	R/F	%DEP
JAN	0.0	-100	12.0	-26	3.3	-79	1.8	-89	0.0	-100
FEB	34.5	8	15.2	-52	61.2	92	0.0	-100	0.1	-99
MAR	33.9	-8	12.0	-68	24.7	-33	36.7	-1	1.7	-95
APR	22.6	-55	62.0	24	7.0	-86	14.9	-70	140.3	180
MAY	62.2	-39	54.3	-46	145.0	43	132.4	31	101.0	0
JUNE	137.7	-41	219.4	-6	151.9	-35	183.4	-21	198.8	-15
JULY	450.4	62	327.8	18	280.2	1	349.6	26	371.6	34
AUG	346.2	8	167.7	-48	355.1	11	266.5	-17	349.5	9
SEPT	146.2	-35	115.5	-49	180.5	-20	188.5	-16	363.3	61
OCT	102.1	-10	34.5	-70	60.9	-46	179.0	58	113.8	0
NOV	0.0	-100	0.0	-100	3.3	-87	24.9	1	0.3	-99
DEC	0.5	-91	28.6	401	0.0	-100	0.1	-98	61.3	976

*Source - Customized Rainfall Information System (CRIS)
Note: The district rainfall in millimeters (R/F) is the arithmetic averages of rainfall of stations under the district.
% Dep. indicates the departures of rainfall from the long period averages of rainfall for the district.

4. 3. NEED FOR RAINWATER HARVESTING

Underground water and public water supply have been the primary sources of water for Joda Township. Groundwater level data of Joda for the past 10 years indicates the emerging need for recharge of its aquifer. As from Fig. 2, we can observe the declining underground water levels from 2010-15. Unavailability of proper water management systems, unchecked mining activities, and over usage of groundwater has significantly contributed to the cause. Rising water demand has compelled local industries and authorities to adapt and install necessary water management systems to conserve water and check overutilization and runoff. However, the depletion of groundwater level affects the groundwater quality and increases pumping costs. Some after-effects include drying of wells, land subsidence, and water level reduction in streams and lakes. Disturbances in the hydrological cycle are caused by mining explorations. Estimation of groundwater level in mining areas is complex as the changes in excavation size change the dynamics of the groundwater. Increasing water level from 2017-19, with highest ever recorded in 2019 indicates the presence and impact of recently installed RWH structure in the study area.

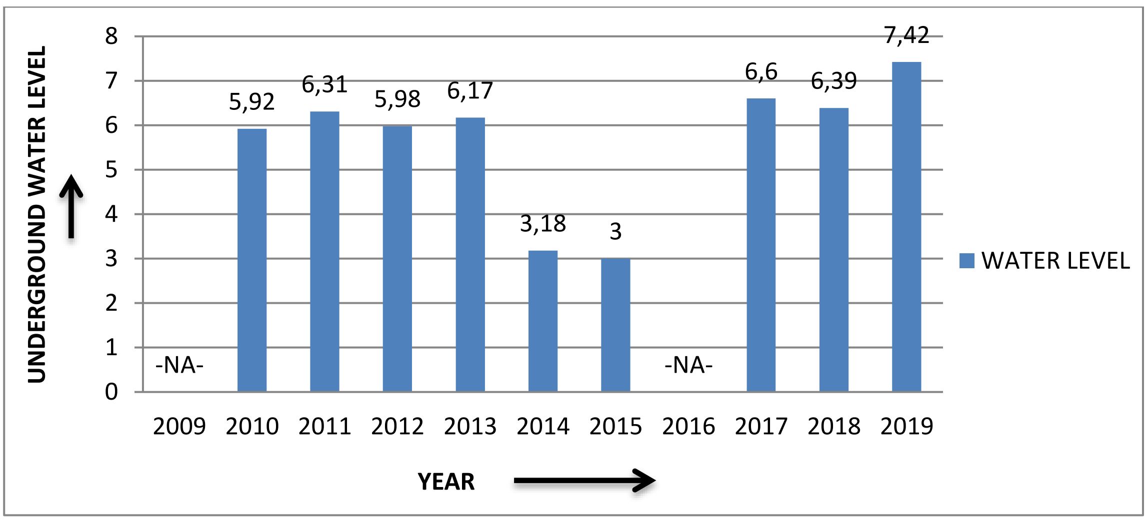

Figure 2. Ground water level of Joda for the past decade (2019-2009).

4. 4. RWH SYSTEM

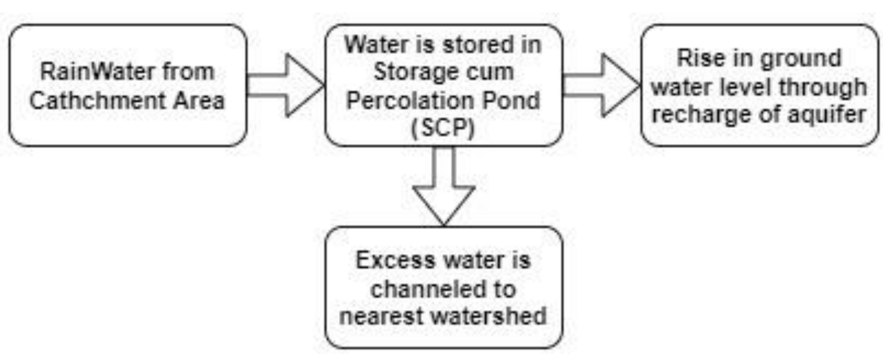

Figure 3. Block diagram of the RWH system

The first-ever scientific system in the area has been introduced by TATA Steel, after a detailed feasibility study by M/s KRG Rainwater Foundation, a Chennai based organization.

The new rainwater harvesting system has been installed in TATA Aquatica - Rain Water Harvesting Park to facilitate the rising water demand and is open for the public at all times in all days. It lies between latitude 22° 1' 18.5916" N and longitude 85° 25' 53.1588" E. The system was a part of TATA's Rain Water Harvesting Project Phase-II and was inaugurated towards the end of December 2018. The investigation included the reception of different scientific approaches, for example, geomorphologic, hydro-geological, traditional water divining surveys, and so forth to distinguish the potential revive zones. The park is spread across 3.5 acres and the catchment area for collecting rainwater is about 2500m × 1000m (2.5 Lakh sq.m). A massive Storage cum Percolation Pond (SCP) of 29000 KL has been fabricated in the park. Area of the lined RWH pond is almost 8567 sq.m and the park houses several other features such as 8 Nos. of attractive statues, 2 Nos of artificial waterfall, 3 Nos of colorful floating fountains, an artificial hill, mini butterfly park, yoga center (65 sq.m), exercise area (50 sq.m), children's park (95 sq.m), walking track (600 m) and green lawns (1200 sq.m). The average depth of the pond is about 3.5 m. The pond annually recharges 87000 KL of water to the aquifer. 5 of Nos imploders are attached to the pond. The pond can discharge (available discharge) 50-70 KL per hour at all times, while the recuperation time/water recovery time is about 10-15 hr. A huge recuperation well with a broader diameter and scientifically configured weep holes are developed on the northeastern corner of SCP where the groundwater flow line unites. The diameter and depth of the recharge well is 6 m and 8 m respectively.

The run-off water from different courses has been coordinated to the SCP through reasonable detour measures. The accumulated water from the SCP would be recuperated through the recuperation structure. Recharge zones have been spotted on the southern side of the SCP and the percolation pond has been developed with a fabulous park contiguous it. The catchment territory for the SCP is extremely immense, reaching out up to Banspani Lake on the southwestern side. The geomorphological study and investigation of seepage design indicated that the run-off water acquired from the Western side of Joda East Iron Mine and open region on the southern side streams towards the SCP. The excess overflowed water from the SCP is channeled towards Sona Nadi on the northern side. Sona Nadi passes through the whole township and acts as an urban watershed area; thus providing smooth access to all the runoff water of the area. The enduring seizing of rainwater both in the percolation pond and the SCP has been ascending the revive exercises at the task site, yet in addition to the downstream side incorporating Joda Township bringing about boosting groundwater table conditions. The RWH system, as illustrated in Fig. 3 has certainly contributed to the overall groundwater table of Joda Township which can be observed from Fig. 1.

5. SUMMARY AND CONCLUSION

Water scarcity is a global phenomenon with never-ending challenges. Therefore, water should be used in a watchful manner to avoid wastage and under-utilization. The study has provided insights on various problems associated with water scarcity and its management. RWH systems have been influential in water conservation for a long time. Modern RWH systems in the past decade or two have been successful in conserving rainwater and help meet water demands by recharging the underground water (aquifer). Emphasis on conserving rainwater should be given more due to its importance in shaping a more sustainable future. The observation of underground water levels from the study explicitly demonstrates the value of

RWH systems in water deficit areas and helps comprehend the beneficial applications of RWH systems while utilizing them to their maximum potential to help fight water scarcity. Insights from the case study have assisted in interpreting the functioning of SCP type RWH systems and its impact on the groundwater table of the surrounding area. The necessity of RWH systems in rural India is much more than it is anticipated. Therefore, implementations of similar systems are encouraged throughout water-scarce habitat/arid locations of India and should be our primary focus in the development of society.

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