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RAIN WATER HARVESTING- THE SUCCESSFUL TECHNOLOGY FOR PARTIAL SOLUTION TO WATER SCARCITY IN INDIA

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Abstract

The rain water harvesting and water scarcity are two opposite extreme end products of adequate management and un-scientific planning of ground water renewable resource in specific geographic area / river basin / hydrological unit, respectively. It has been influenced with potable nature of water under different water utilization categories namely: Potable, Semi-potable and Non-potable.

The potable water is being utilized for drinking, irrigation of food crop and cultivation of fruit / vegetables. The semi-potable water has utility in municipal supply, washing, bathing, cleaning, and sanitization of street / road and gardening / lawn maintenance. The non-potable water has industrial application, construction activity with BIS Code provision, fire fighting, vehicle washing cum cleaning and dilution of sewage.

The water scarcity is on account of excessive pumping out of ground water at alarming rate, leading to area as critical, semi-critical and over-exploitation category of ground water development stage [%]. It is required for meeting to the heavy demand under various water utilization categories [6].

The rain water harvesting has been common in developed to developing country including India. There is various rain water harvesting structures with proven capability for urban and rural area. These are discussed with quantification of rain water harvesting potential and cost estimate. The implementation of proper rainwater harvesting with holistic approach has great significance towards ground water conservation including mine water locked up in old workings of coal and lime-stone deposit.

Introduction

The 'Water Scarcity' refers to occurrence of water crisis in a region. The water crisis refers to a region possess any SLACKNESS among water security. The water security has similarity with Military security of a nation and defines as- "reliable availability of accepted quantity and quality of water as per statutory norms for human health, livelihood & food production along-with acceptable level of water related risks to bona-fide citizen and their dependants towards various water utilizations at right time". The unit of water security is cubic meter per person per year [5].

The water stressed condition refers to availability of water in a region, less than 1700 cubic meter per person per year as per global standard [1]. The Ministry of Jal Shakti [erstwhile Water Resources], Govt. of India has estimated 1500 cubic meter per person per year in 2011, which has been reduced to 1368 cubic meter per person per year in 2019 and likely to further decline as 1293 cubic meter per person in 2025. If present trend of decline is continued, it may come down to 1140 cubic meter per person per year in 2050 [10]. Gujarat state has already reached to 1000 cubic meter per person per year. There are 256 districts under water stressed condition in India, as on March 2020 vide minutes of tenth sitting of the standing committee on Water Resources.

The ground water has been extensively extracted in India; with extraction of 210 Billion cubic meter during the period of January to December 2017, alone- the highest in world [13]. It is harshly pumping out through 200 million bore-wells for all practical purposes in entire country [18].

The ground water has been marginally recharged through two processes namely-Natural Recharge and Artificial Recharge or Rain Water Harvesting. The natural recharge depends upon average annual precipitation [rainfall], which is about equivalent to 4000 Billion cubic meters per year in India. About 18% of it, equivalent to 690 Billion cubic meter percolates down into sub-surface for ground water storage. It travels in saturation zone with large residence time period of average horizontal velocity of 100 meter per year and average vertical velocity of 1 meter per year [9]. The remaining portion of required recharge depends upon Rain Water Harvesting/ Artificial Recharge.

The rain water harvesting technology is process for conservation of each drop of rain water, efficiently and safely during rainy period and mitigation of rain water from its wastage during rainy period [11]. It is carried out through four and eight rain water harvesting structures in urban and rural area respectively. Central Ground Water Board has published a manual for implementation of rain water harvesting structure in urban and rural area of India. [4]. The successful rainwater harvesting structure in urban area are-Roof top rain water collection cum recharge pit, Recharge trench, Use of abandoned bore well , Pumping- in recharge well. The successful rain water harvesting structure for rural area are-Gully plug, Contour bund, Percolation tank, Nalla bund / Check dam, Recharge shaft, Recharge well, Gabion, Ground water dam and Sub-surface dyke.

Evolved Methodology & Objectives

The evolved methodology is based upon conventional approach- as reviewing eighteen relevant literatures along-with scrutiny of available Central Ground Water Board records at national, state level and field experience in mining area. The objectives of study are as follows:-

- Status of rain water harvesting technology at global, national, regional and local [Bilaspur-CG] level.
- Quantitative estimate of rain water harvesting potential.
- Cost estimate of rainwater harvesting structure in CG.

Result & Discussion

There must be proper balance in between recharge, discharge and storage of ground water in saturation zone as per principle of prevailing ecosystem of the mother- Earth from conservation point of view. It is similar to cash money withdrawal through A T M of finance bank, without exhibiting the details on slip. The geometry of aquifer disposition with its vertical and horizontal extent, ground water governing parameters are yet to be established for particular river basin / watershed as either representative hydrological unit or experimental hydrological unit under authentic manner in India. The varied degree of adverse impact due to human influence on watershed hydrology has been responsible for water stressed condition in geographic area. It requires the need for implementation of rain water harvesting at war level with more scientific data and its validation cum sincere responsibility.

Each objective has been discussed as follows with inferences.

- ✓ Status of rain water harvesting technology at global, national, regional and local [Bilaspur-CG] level

The significance of rain water technology has been recognized, globally even in developed countries like: Germany, Japan and Singapore. The Frankfurt airport in Germany collects rain water though roof top of new terminal building having catchment area of 26,800 square meter and fully utilized for ground water conservation through recharge pit. The Tokyo airport –Narita & Haneda in Japan collects rain water in the form of rain water harvesting for emergency purpose to meet critical water demand. The Singapore-JEWL CHANGI airport has average annual rainwater of 2400 mm. It has been fully utilized for ground water storage as rain water harvesting with marvelous structure, illustrated as Fig1.The catchment area of rain water is carried through roof top of three interconnected terminals with reverse dome shape cum vortex of water fall as scenic/aesthetical view with light and music sound system, before draining into underground recharge pit for economical utilization. The water is used for non-potable purpose as fire fighting mock drill and toilet flushing. Such collected and preliminary treated water accounts for 28 -33 % of total water used, resulting in saving of about Singapore dollar 3, 90,000 per year.

The developing country like- Malaysia has established at University of Saheb-Eco-campus with utilizing rain water harvesting for maintaining green infrastructure in concrete building as sustainable water management and reducing the dependence on treated water supply as well as saving substantial economy [9].

Fig.1 Rain water harvesting structure at JEWL CHANGI, Singapore airport

Rain water harvesting has been initiated in India since 2000, when most of states started to face water stressed condition. It has been carried out by Government agencies, NGO and Research Instititute / University as advisory body, implementation body & research body respectively and still continued in same manner. The artificial recharge of ground water by roof top at surroundings of coal mining area has been introduced by Central Mining Research Instititute, Dhanbad in 2002 [12]. The GIS products like- land-use, hydrology, soil, slope and DEM with water balance, temperature & rainfall have been analyzed for Soankhand watershed Ludhiana, Punjab through Integrated Mission for Sustainable development. Six percolation ponds along low lying land and fourteen check dams along sloppy land have been proposed for construction of rain water harvesting structure by Ludhiana Agricultural University in 2009 [17]. The rain water harvesting with pond structure has been carried out at Panipat Institute of Engineering Technology in 2017 [16]. Roof top rain water harvesting with recharge pit has been executed for hostel no. 12 & 13 at I I T Powai Bombay in 2018, The rain water harvesting at undulating land for ground water recharge is carried out at Gcoease campus [Maharashtra] in 2019 [9].

The NGO have executed implementation of rain water harvesting work at Chennai, Bangalore and New Delhi. The rain water has been collected along pillars of Fly-over into enclosed lid recharge pit for ground water recharge with better quality than treated water at Chennai. There was good natural recharge arrangement through 10,000 ponds around surrounding of Bangalore about fifty years ago, which has been reduced to 50 ponds presently with development of concrete buildings. The NGO like- Escort, Rain water club & Mehto Glotze have engaged in good work for rain water harvesting at Bangalore presently. The Center for Science & Environment of Tata Steel has designed 16 rain water harvesting models and installed at different locations at Delhi, including Rashtrapati Bhawan. It is estimated that 150 sq. km. catchment area is available for rain water collection in the form of roof top at official, commercial and residential building in urban area of New Delhi having ample scope for rain water harvesting. Similarly, the semi- urban cum rural area of Delhi, need the renovation of two lakes namely Najafgarh and Tuglakabad have good scope for natural recharge for local aquifer. The Najafgarh lake earlier was spread in 220 sq km area, with storage capacity of 1550 million cubic water, has been reduced to 6 sq. km. spread area presently. The Tuglakabad lake was having spread area of 1,

20,000 sq. meters earlier and was used to care the water supply of whole fort area, but has been dried now. The ground water recharge work along sloppy land of Aravali hill through contour bund, gully plug has been done in excellent way by NGO team of Shri Rajendra Singh in eastern Rajasthan. Jubilant Life Sciences Limited-NGO has developed 60 village ponds within 10 km radius in Chuchela kala village around Gajraula town of district Amroha [U P] – over- exploited area for augmentation of ground water through rain water harvesting structure during 2018. It has recharged 21 lakh cubic meter of rain water into pheratic aquifer. It has improved the quality and quantity of available ground water for domestic and irrigation utilization purpose and reduced the electricity required for ground water extraction- over a period of time. It has also further improved the ecological flow in nearby flowing Ganga river during lean flow season through up-gradation of ground water table, since river has recharge pattern through pheratic aquifer [gaining river]-thus making "Aviral Ganga" The work has been executed for each village pond through following four stages and illustrated as Fig.2.

- Site selection for original old village pond
- Construction of recharge well with brick lining and bore-well pipe.
- Filling of layers through filter-composed of pebbles, gravels and Nylon filter cloth.
- Filling of coarse sand layers.

The Central Government agencies like ISRO & CGWB have done rain water harvesting work at Ahmadabad and Faridabad respectively. ISRO has executed large size open well like structure near front gate of Space Application Center [SAC], Ahmadabad for rain water harvesting of rain water collected at SAC campus. CGWB has identified 4.5 lakh Sq.km area of entire nation, where artificial ground water recharge is needed. It has estimated that annually 36 billion cubic meter of surplus water can be artificially recharged. CGWB has executed roof top rain water harvesting cum recharge pit at its Head Quarter Bhujal Bhawan, Faridabad and illustrated as Fig.3 [7].

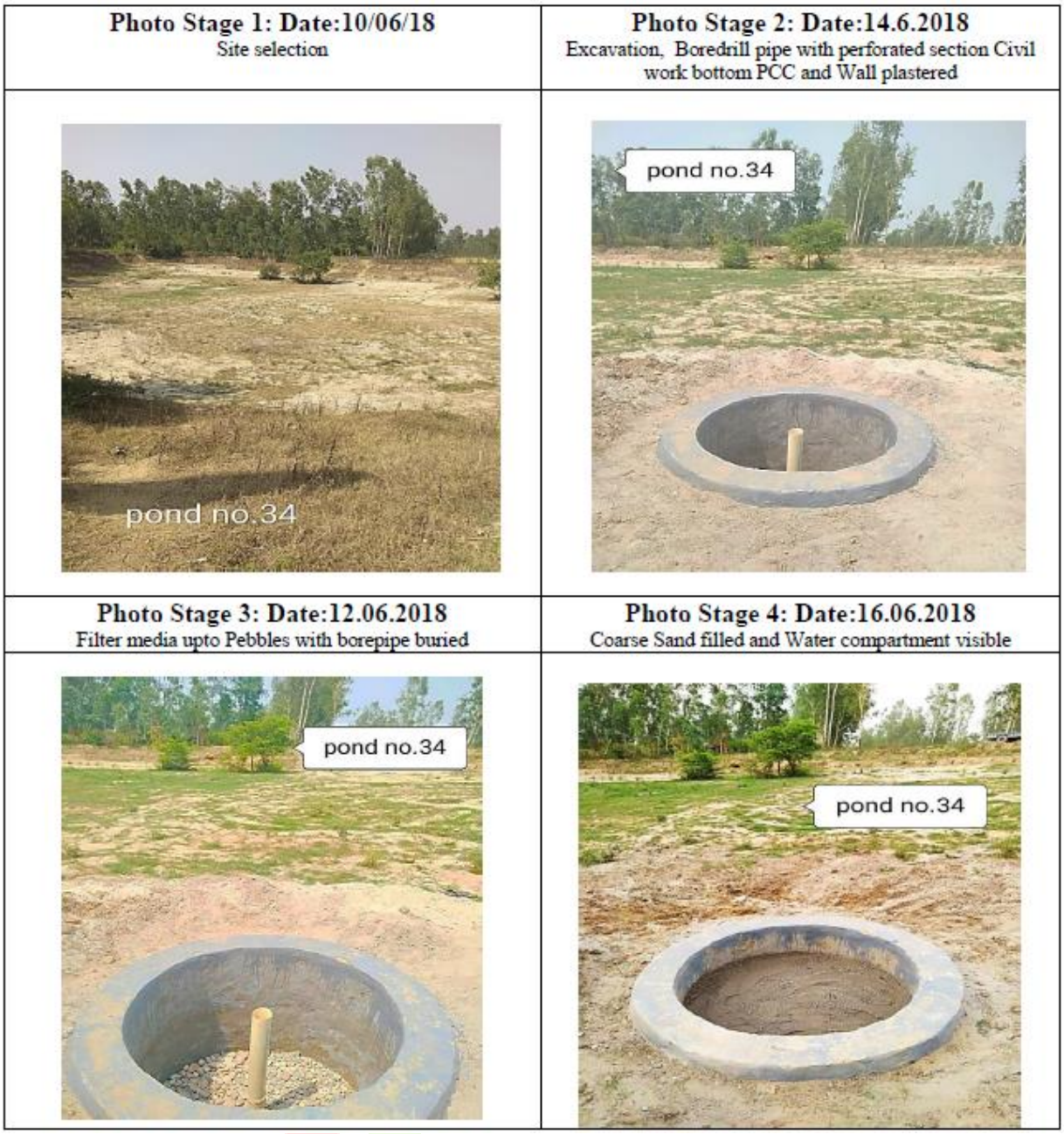

Fig.2 Execution of recharge well in abandoned village pond as rain water harvesting structure at Amroha [U P]

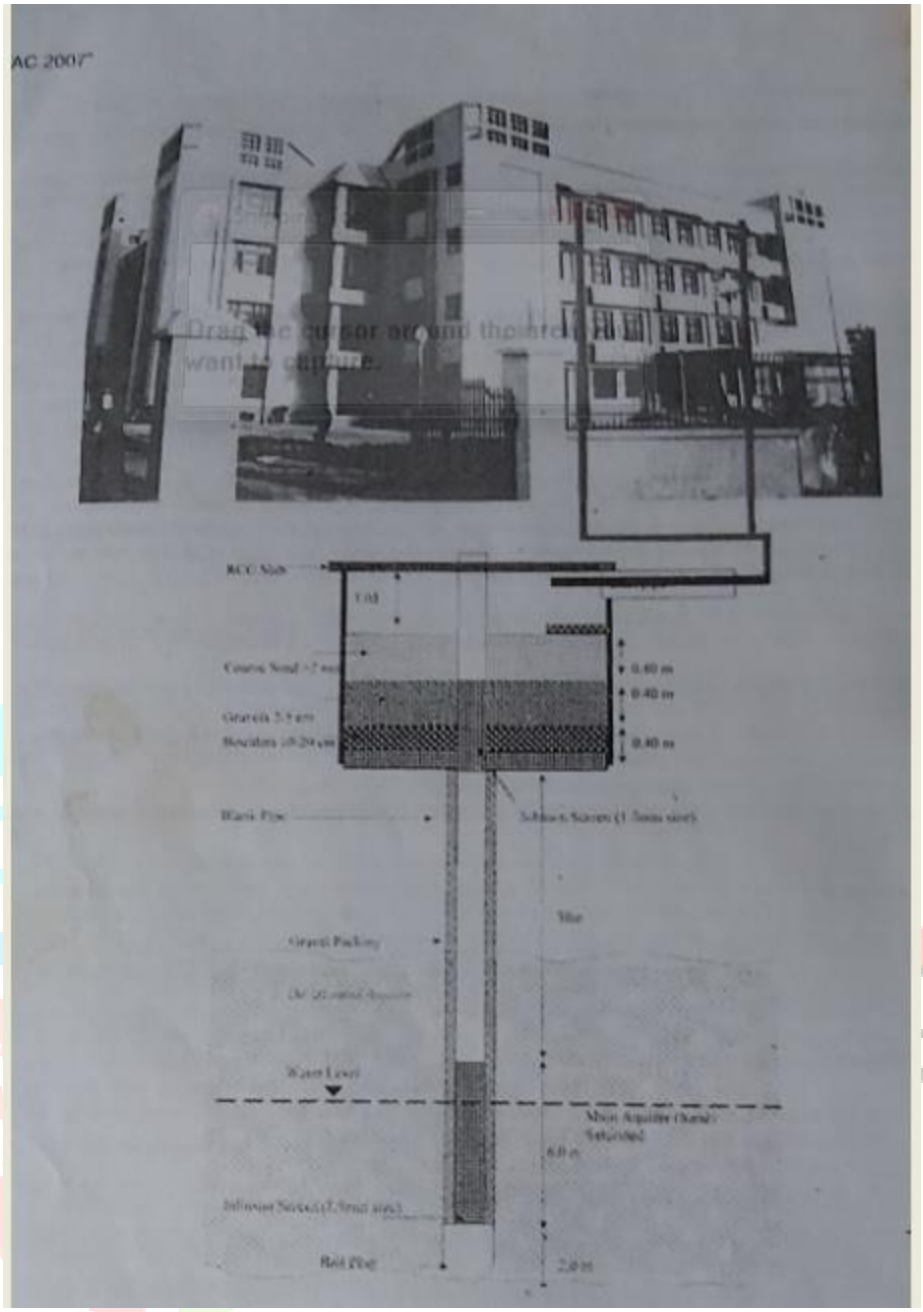

Fig.3 Rain water harvesting and artificial recharge to ground water in Bhu- jal Bhawan, CGWB Head Quarter, Faridabad

Regionally, Indore municipal corporation [M P] has allowanced a rebate of 6 % on property tax for those, who have implanted rain water harvesting structure in their houses/bungalow/building. Mahindra & Mahindra-NGO has constructed rain water harvesting structures namely-Gully plug-5, Gabion-47, Recharge shaft-3 & Percolation tank-1 in 50 hectare area in Phande block of Bhopal [M P] through Integrated Watershed Management Program in 2015. It has assisted in conservation of 7,06,838 cubic meter water as direct benefit to local 130 families. In Chhattisgarh, NCCR, CGWB Raipur has identified 23 prioritized watersheds for rain water harvesting through GIS approach [2]. The suitable rain water harvesting structures for rural area are Gully bund, Gabion, Contour bund & Nalla bund. The rain water harvesting structure for urban area are Percolation tank, Recharge pit, Recharge shaft, Gravity head well & Roof top [11]. The urban area of Raipur having catchment area in the form of roof top in the range of 100-10,000 Sq. meter have suitable rain water harvesting

structure namely-recharge pit, recharge soak trench, recharge shaft, recharge well and recharge borehole [15]. The limestone mining area of Dhamdha block in District Durg [CG] has several working to abandoned quarry sites and proposed for installation of Recharge shaft, check dam per 1.5 Sq. Km area and percolation tank per 15 Sq. Km by NCCR,CGWB [3] respectively and is illustrated as Fig. 4 .

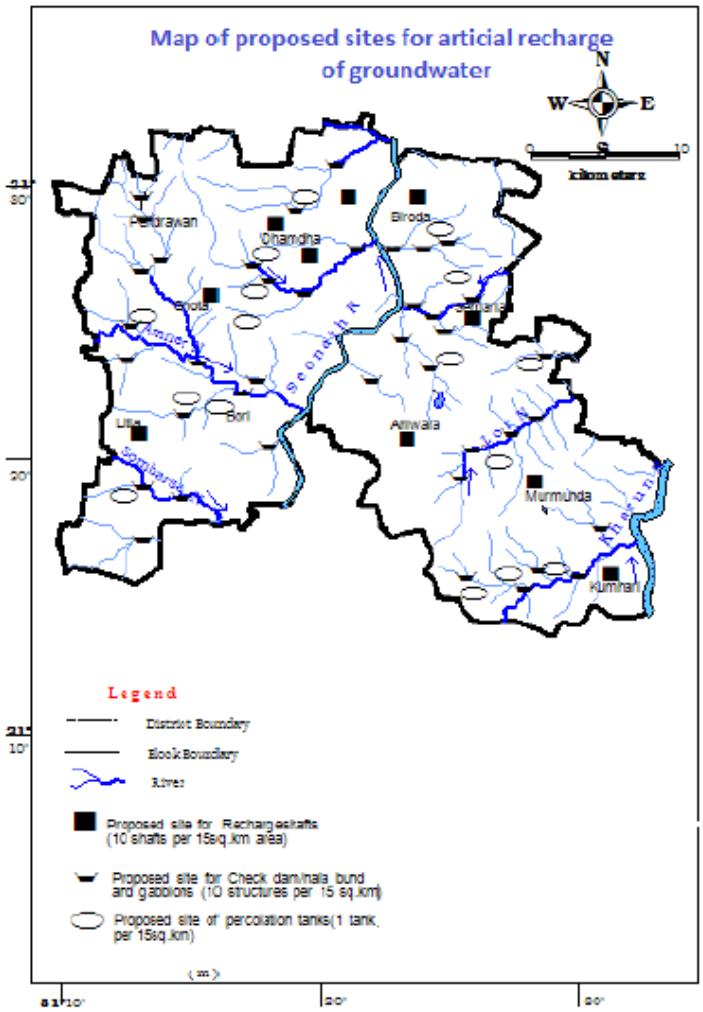

Fig. 4 Proposed rain water harvesting structure sites in Dhamdha block of Limestone mining area in District Durg [CG]

Locally, in Bilaspur [CG] South East Central Railway [SECR] has carried out rain water harvesting with roof top rain water collection through 210 buildings in railway premises during the period Jan-Dec 2017 [13]. The collected rain water has been used for cleaning cum washing of railway coach and laundry towards cleaning pillow cover, bed sheet, supplied to passengers of AC class. Bilaspur Nagar Nigam in association with Bilaspur Smart City Limited has been completed 2410 roof top, having area 150 Sq.meter each, at buildings as catchment area for rain water harvesting system in June 2021[8].

Quantitative estimate of rain water harvesting potential

The computation of rain water harvesting potential is based upon modified Darcy's law and is as follows:-

Rain water harvesting potential [cubic meter] = Area of catchment [Sq.mt] X Rainfall [mm] X K,

Where K = Run-off coefficient. It accounts for losses due to leakage, spillage and infiltration. It varies in the range of 0.5-1.0 and its variation is summarized as Table1 [9].

S N	Type of Area	Flat Land [Slope < 5 %]	Rolling Land [Slope = 5-10 %]	Hilly Land [Slope > 10 %]
1	Urban	0.55	0.65	-
2	Rural	0.50	0.60	0.72
3	Pasture	0.30	0.36	0.42
4	Forest	0.30	0.35	0.50

Table 1: Variation in Run -off Coefficient [K]

The calculation for rain water harvesting potential has been explained with following example:-

If an urban area has annual average rainfall =1000 mm. The effective catchment area as roof top of building =100 Sq. meter and K=0.5

Rain water harvesting potential [cubic meter] = 100 X 1000 X 0.55 =1100. If this amount percolates into subsurface through recharge pit- depending upon favorable local hydro-geological condition, and land-use pattern through suitable rain water harvesting structure. The available ground water will be sufficient for 200 days in year towards family of 5 members and augment / raise ground water table by 1 meter with saving electricity of 0.4 KW for pumping out ground water [17].

The performance of rain water harvesting potential has to be cross checked with monitoring of ground water level in surrounding ten observation wells along all possible directions, within 500 meter radius of rainfall collection / catchment area, including surface water inventory for performance evaluation with analysis of positive cone of depression.

✓ Cost estimate of rainwater harvesting structure in CG.

The common rain water harvesting structures in rural CG area are- Percolation tank [retention pond] for plain portion, Nalla Bund / Cement plug along rolling land and contour bund at moderate sloppy land. The favorable rain water harvesting structure in urban area of CG are-recharge pit with roof top, recharge shaft, gravity head well. The cost estimate for such rain water harvesting was made in 2010 by NCCR, CGWB Raipur and summarized in Table 2 [10].

S N	Rain water harvesting Structure	Specification	Cost in Rs	Remark
		URBAN	AREA	
1	Roof Top with Recharge pit	100 Sq. meter catchment area	1.0 Lakh	Recharge pit as per CGWB Design
2	Recharge Shaft	As per local hydro-geology	2.5 Lakh	Attached with operational pump & ground water table monitoring arrangement
3	Gravity Head well	As per local watershed	2.5 Lakh	
		RURAL	AREA	
4	Percolation tank	0.1 M cubic meter	2.0 Lakh	Operational with 200% of capacity during rainy days
5	Nalla bund/Cement plug/Check dam	0.3 M cubic meter	1.0 Lakh	
6	Gabion	0.05 M cubic meter	10,000	

Table 2 Cost estimate for major rain water harvesting structure as CGWB in CG [2010]

The normal life of individual rain water harvesting structure is about 15-20 years with serving various water utilization aspects. The rain water harvesting structure requires regular maintenance and poorly construction with improper design has no use as well as birth place for several water born diseases and awkward situation.

Conclusion

Scientifically, the ideal condition for implementation of rain water harvesting is watershed in hydrological unit with known hydro-geological parameters and related boundary conditions for favorable deliverables to water scarcity. The recharge of ground water is governed by [a] natural rainfall, [b] rain water harvesting, [c] inherent palaeo-channels in sedimentary terrain. Similarly, the discharge of ground water is governed by [i] number and type of operating bore wells with density, [ii] type of pump with availability of electricity for execution, [iii] ground water table fluctuation with non-recoverable draw down / area under zero draw down [1].

The Coal & Limestone mining area of sedimentary terrain in CG have been locked up with huge quantity of mine water along old, abandoned and unused workings, left idle since more than thirty years [13]. The preliminary qualitative analysis of such mine water has good scope for various water utilization aspects including artificial recharge of ground water.

The prominent advantages of rain water harvesting through carefully collection cum conservation of rain water with avoiding the wastage during rainy period for tackling water scarcity are as follows:-

- Economically cheaper cost than in construction of dam, diversion and other similar hydraulic structures with threat to environment.
- Ideal for such area, having inadequate municipal water supply including surface water sources.
- Assists in conservation of primary source of water and dilution of sewer through non-potable water with reducing load on sewage treatment plant.
- Improving the storage and quality of local aquifer.
- Government encourages it through several incentive schemes and rebates.

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