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*RESEARCH ARTICLE*

# BRIEF HYDROGEOLOGICAL STUDIES OF WATERSHED MR-21 IN CONTEXT OF GROUNDWATER ESTIMATION AND GROUNDWATER RECHARGE PLAN, OSMANABAD, MAHARASHTRA, INDIA

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## Abstract

The global population is increasing rapidly and expected to touch the 9.5 billion mark by 2050 from the current 7.2 billion. The management of the groundwater resources is a challenging task worldwide against the backdrop of the growing water demand for industrial, agricultural, and domestic uses and shrinking resources. Moreover, this task has been hampered significantly due to declining/rising groundwater levels and associated contamination. A broad range of solutions could be considered to address the aforementioned problems of groundwater management strategy. This paper presents a comprehensive review on the Water level, Rainfall, Groundwater estimation and cropping pattern of the studied area which can be useful for applications of the management of groundwater resources and recharge techniques.It would also be necessary to plan, recharge and control the use of groundwater under the prevailing conditions. Publication and distribution of annual reports and related programmes for creating awareness amongst the community and for educating them will have to be undertaken regularly. This will enable avoiding scarcity in the studies area, as well as the hectic activity and excessive expenditure that has become characteristic of summer months in the marathwada and adjacent area. The present study discussed about the optimum planning of GW recharge and need to control the irrigation draft less than the recharge for future use. Application of Regulatory measures for not drilling bore wells. Optimum use of water saving practices. There should be annual GW budgeting on regular basis, need to plan cropping as per GW availability.



## Introduction:-

Groundwater is a natural resource with both ecological and economic value and is of vital importance for sustaining life, health and integrity of ecosystems. This resource is increasingly threatened by over-extraction which has insidious long-term effects. Scarcity and misuse of groundwater pose a serious threat to sustainable development and livelihood. The availability of groundwater is extremely uneven, both in space, time and depth and so will be the case in future. The uneven distribution of groundwater in the district can be mainly attributed to highly heterogeneous lithology and regional variation of rainfall. Because of variations in their basic characteristics;

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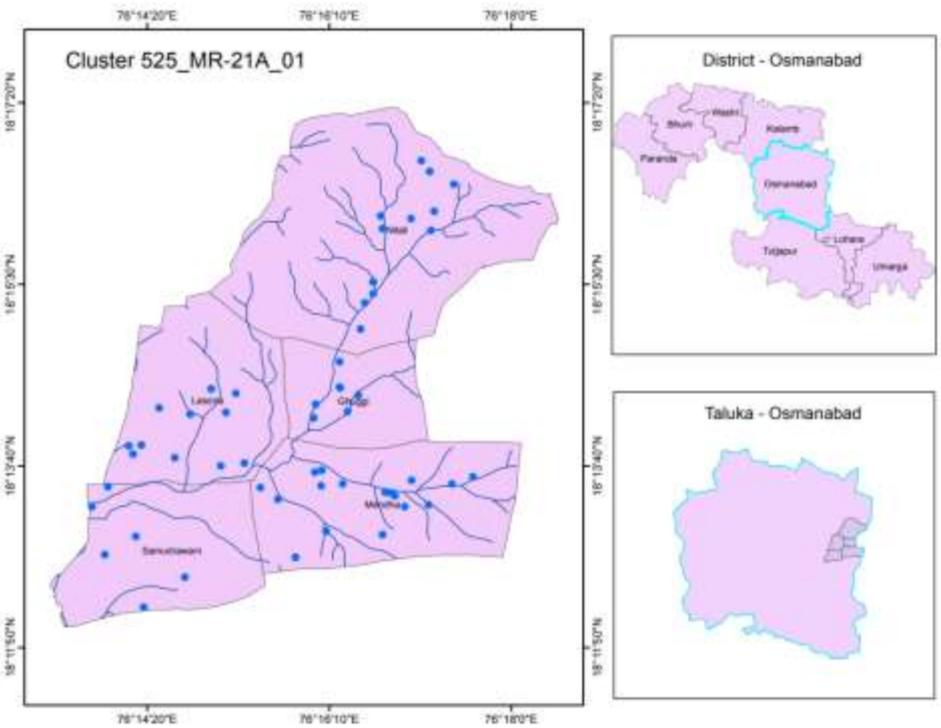
physiography and variability in the rainfall, there are limitations on the availability of groundwater. Though there is unanimity about this, there is still considerable difference of opinion among the scientists about the precise degree of these limitations. In order to assess the availability of groundwater and to ensure maximum accuracy in groundwater estimates, the Central Government and state government has, from time to time, appointed committees comprising groundwater experts and Geoscientist and has laid down guidelines for this purpose. The total demand for water from the groundwater domain is increasing day by day. The main reason for this is the self reliance being experienced by users of groundwater. But as this is leading to inexorable withdrawal, and as the status regarding total availability of groundwater is of uncertain nature, it is imperative to give more serious thought and a new direction to groundwater planning and management.

Groundwater is a major component of public water supply and water use in the Osmanabad district. The groundwater systems underlying present study area is phreatic and dynamic, thus responds to the balance between supply (precipitation) and demand (draft). Anthropogenic activities, such as excessive groundwater extraction for irrigation, domestic purposes are created a condition of lowering of water levels in an aquifer. These effects might manifest themselves locally, but can extend over larger areas limited to the area occupied by aquifer due to intensive extraction of groundwater. Moreover, changes to the landscape occurring from alteration of the land cover can also have a significant influence on aquifer water levels by changing the ability of precipitation to recharge the subsurface. Apart from anthropogenic activity, there is large-scale climatic effect that affects adversely on the groundwater regime of Osmanabad district. So the Groundwater estimation and recharge plan is needed in studied area.

**Background:**

The watershed **MR-21** in OsmanabadTaluka of Osmanabad district of Maharashtra is one of the studied area identified for to enhance the climate-resilience and profitability of smallholder farming systems in project area in NanajiDeshmukhKrushiSanjeevaniPrakalp, Mumbai and to frame the groundwater estimation and groundwater recharge plan for the study area. Groundwater being the main source of irrigation in the area for providing protective irrigation during dry spells of rainy season and for rabbi and perennial crops also, the study of groundwater system, its behavior, recharge and withdrawal, and possibilities of groundwater recharge is undertaken in this study area. The studied watershed **MR-21** consists of five villages namely, **Nitali, Mendha, Ghugi, Samudrawani, Lasona**having census number 561405, 561414, 561413, 561411 and 561412 respectively. The study area is located in quadrant A-3,A-1,C-1 of the Toposheet no. 56B/4, B/7 B/8 extending from N18$^0$ 15’ 50” to N18$^0$ 13’ 45” and 76$^0$ 16’ 50” E to 76$^0$ 15’ 00”E. The area is included in mini watershed no **MR 21 (1/2).** As per the Groundwater Resource Estimation (GWRE) 2018-19, the watershed is categorized as Semi-critical with Stage of extraction 88.90%.




Location Map of the Villages in the Watershed **MR-21** of Osmanabad

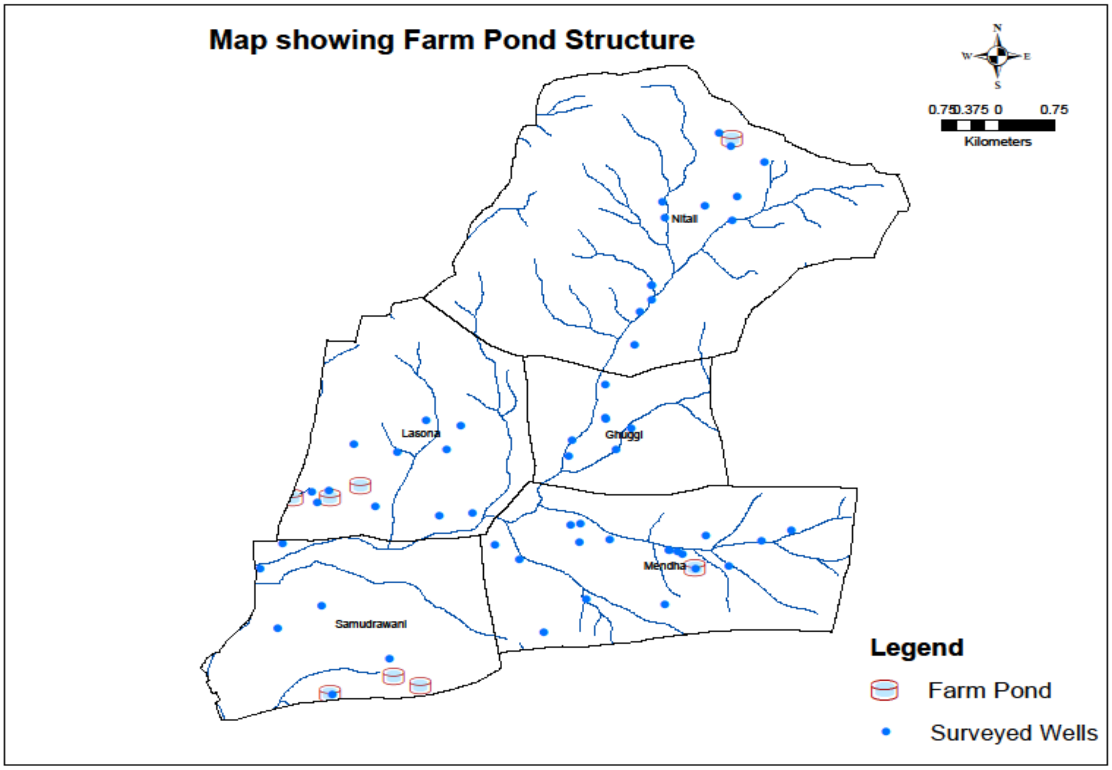
## Methods and Methodology:-

In order to study the area, detailed baseline data collected from different government departments. The detail hydrogeological field survey has been carried out in the month of May-Sept 2019, Geophysical (Electrical Resistivity) Survey has been carried out from experts of the organization. Aquifer based Groundwater Estimation and detailed groundwater recharge plan is also discussed in the said paper.

**Details of Existing Water conservation structures information**

| Sr. No. | Name of structure | No. | Total storage capacity in TCM | No. of Fillings | Total annual run off arrested (annual storage) in TCM |
|---|---|---|---|---|---|
| 1 | Cement Nala Bund | 14 | 042 | 2 | 084 |
| 2 | Nala deepening | 01 | 072 | 1 | 072 |
| 3 | Percolation Tank | 04 | 300 | 1 | 300 |
| 4 | K.T. weir | 12 | 103 | 2 | 206 |
| | Total | 31 | 517 | | 662 |

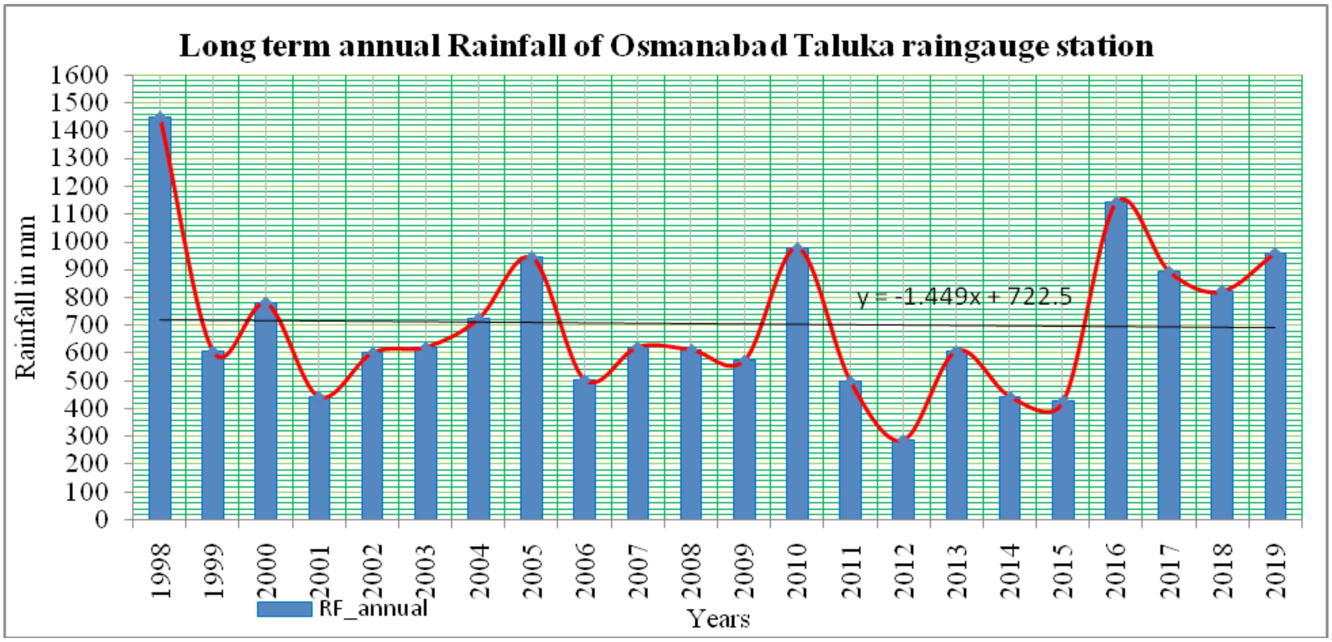
There are total 13 farm ponds existed in the study area. Most of the farm ponds are reported to be constructed during the last 3-4 years. Out of these farm ponds 1 (10%) is located along the bank of stream flowing through the study area and remaining 12 (90%) farm ponds are located in inside land away from the streams .It is reported that farm ponds located along the stream bank (10%) are filled partially by pumping run off water accumulated or drained through the streams during the rainy season and partially by groundwater pumped either from dug well or bore well; while the remaining 90% are filled by groundwater pumped either from dug well or bore well, as there is no scope of that much run off to be generated and accumulated in the field. Thus the farm ponds are mainly filled by groundwater which may be pumped either from dug well or bore well. Total storage capacity of these farm ponds is 41.722 TCM. These farm ponds are filled and refilled as per the availability of water and irrigation timings of the crops. Groundwater pumped from dug well or bore well is stored in farm pond and then supplied to the crop either by gravity flow or by pumping.




Location Map of farm ponds in **MR-21**, Osmanabad

**Hydrogeological data analysis: (historical data analysis and field survey):**

Name of nearest is rain gauge station is in **Padoli**Circle of Osmanabad,**Taluka where** Normal Rainfall is 705.85mm, Monsoon RF for **Taluka**station in year(2018-19) is 961 mm, 75% dependable rainfall for **Taluka** station is 574 mm, Monsoon RF for **Circle** station in (2018-19) is 541 mm ,Rainy days in (2018-19) for **Circle** station is 42.Long term monsoon rainfall over the area is very much fluctuating and shows DPAP signatures although the normal annual rainfall is nearly 764 mm. Long term monsoon rainfall over the area is very much fluctuating and shows Drought Prone Area Programme (DPAP) signatures although the average annual rainfall is nearly 705 mm. Long term monsoon rainfall shows falling trend (@1.45 mm/year) for the station shown in the figure.




Long term monsoon rainfall of Osmanabad rain gauge station

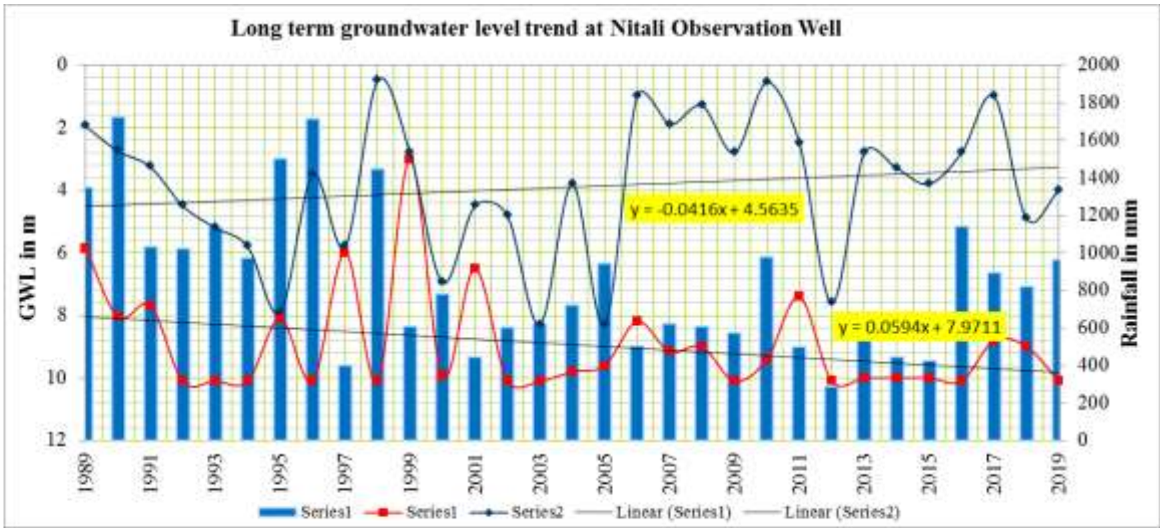
**Run off estimates for the area:**

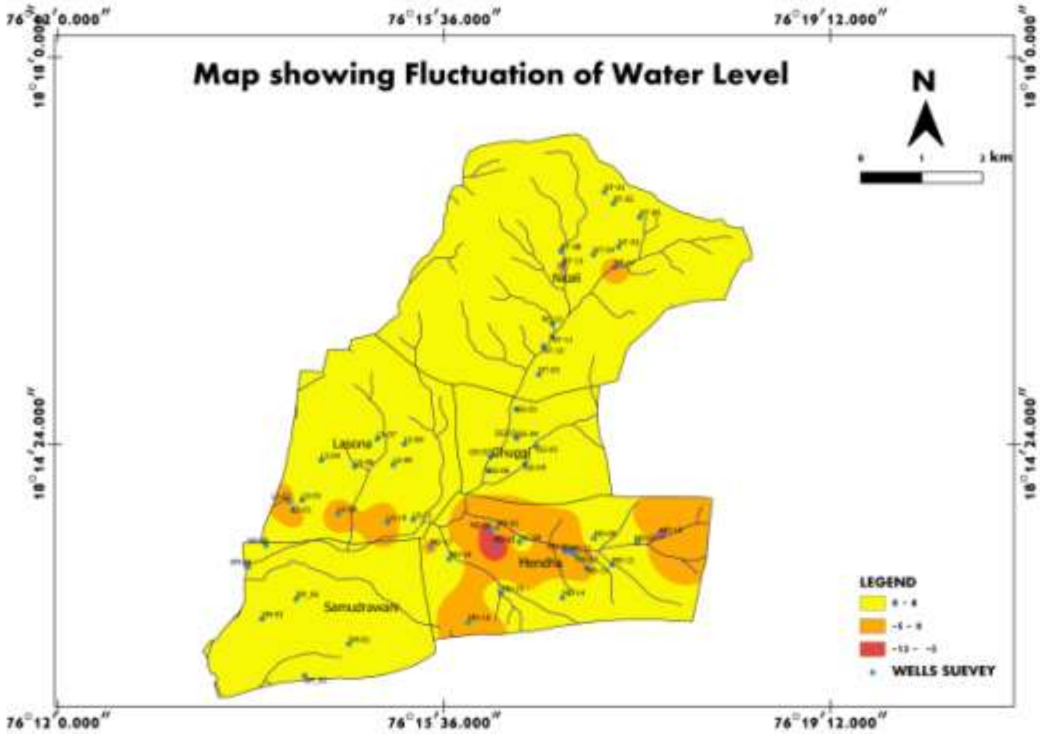
Run off for the study area is estimated by using run off coefficient obtained from Strange's table. The area is covered by black cotton soil (up to 0.30 to 0.50 mbgl) followed by highly weathered basalt up to 2 to 3 mbgl, with slope percent ranging from 0.50 to 2 % (gentle), thus as per Strange's categorization it comes under category of average catchment from run off point of view.Average annual rainfall for the area is 705.85 mm which has dependability of about 45%, while 75 % dependable rainfall for the area is 574 mm. As the annual rainfall is very fluctuating 75% dependable rainfall (return period of 1.32 years) which is the most reliable rainfall value, is considered for estimating the run off. As per the Strange's table run- off coefficient for average catchment with rainfall of 574 mm is 13% (0.12). Thus if WCS are planned by using this value, the probability of filling of all the structures will be more. Estimated value of run-off is as;

| RUN OFF ESTIMATION (TCM) | | |
|---|---|---|
| 1 | Total catchment area (Cluster area) in Ha | 4714.29 |
| 2 | Average annual rainfall in mm | 705.85 |
| 3 | 75% dependable rainfall in mm | 574.00 |
| 4 | Average slope of area in % | 1 to 2 |
| 5 | Run off coefficient for the area in fraction | 0.13 |
| 6 | Run off yield from the area in TCM | 3517.80 |
| 7 | Utilizable Run off for harvesting in TCM = 65% of Row 6 (35% left as riparian rights of the downstream) | 2286.57 |
| 8 | Run off booked for existing WCS structures and farm ponds in TCM | 704.00 |
| 9 | Run off ultimately available for harvesting (7-8) | 1582.57 |
| 10 | No. of fillings assumed | 2.00 |
| 11 | Approximate water storage capacity that can additionaly be created (50% of 9) | 791.29 |

If the annual rainfall is more than the considered value with uniform temporal distribution, the runoff coefficient will be more. So the runoff will naturally be more, but dependability of such rainfall and hence the runoff is very less.

Nearby observation well (OBW) to the area is Nitali, which is located due south-west of the area at a distance of 12 Kms. Long term pre monsoon (summer) groundwater level shows the **falling** trend (@ 5.94cm/year) in the area, whereas post monsoon (winter) groundwater level shows the **rising** trend (@ 4.16 cm/year) in the area. This indicates that total groundwater recharge occurred by all means during the rainy season is being extracted during the non-monsoon season for all purposes; the main purpose is the irrigation.



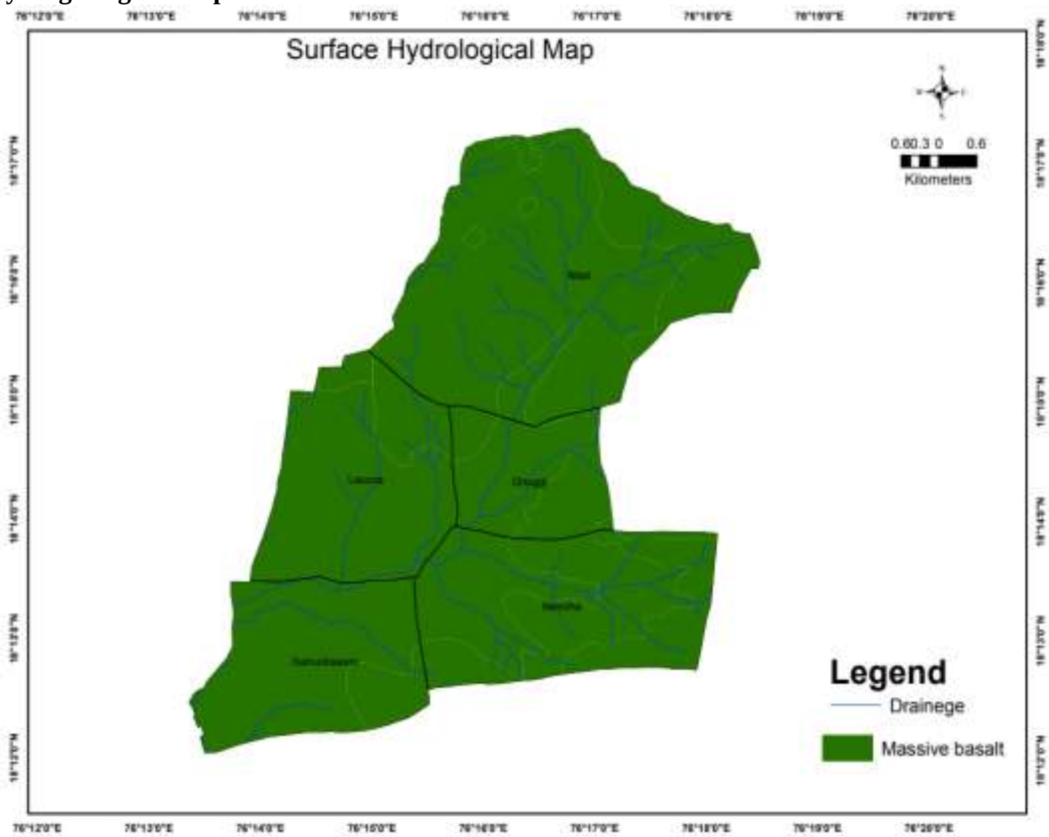




Depth to groundwater level in summer 2019 varies from 6 to 18 mbgl. However the depth to GW level between 8 to 12 mbgl is more common. Depth to groundwater level in winter 2019 varies from 3 to 13 mbgl. However the depth to GW level between 4 to 8 mbgl is more common. Annual GW level fluctuates between 3 to 11 m. But major part of the area shows the GW fluctuations between 3 to 9 m. Thus average Water table fluctuation for the study area is considered as 6 m.

**Geological traverses and well inventories:**

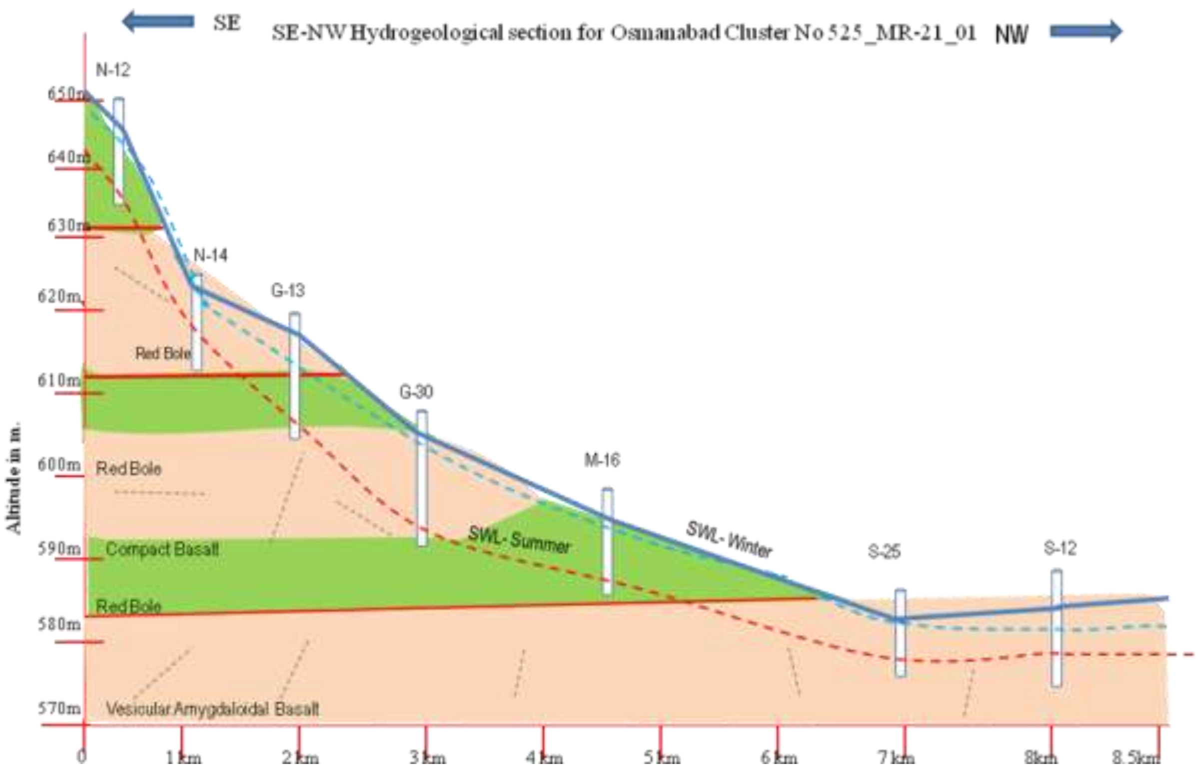
The complete area is divided into the grid (800x600) for observations of surface and sub-surface hydro geology and groundwater level measurements as shown in the figure. There are 648 dug wells and 307 bore wells in the study area as per revenue record. Each grid is surveyed and observed so as to cover the complete representation of the area. Accordingly 95 dug wells and 19 bore wells were observed during the field survey. Drainages were also traversed simultaneously for mapping of surface geology and water conservation structures.

**Surface hydrogeological map**




**Sub-surface hydrogeological section**

There are two aquifers are encountered in the area, one is shallow phreatic, depth ranging from 7-16m, which shows Altitude range in between 705- 725 mbgl, thickness of aquifers observed in the area average 8 m, Saturated thickness of shallow aquifer in winter 8-10m and in summer 1-2,which shows three Basalt flows having average thickness of 13 to 15 m. The flows are of simple nature as the boundaries are clearly differentiated at some depths and locations by means of Red bole. Each flow has two sub units as, the vesicular amygdaloidal basalt (VAB) and the compact basalt (CB). Red bole layer or chilled margins separate the flow from each other. (Fig 8&9). Weathered and sheet jointed vesicular amygdaloidal basalt (VAB) and compact basalt acts as an aquifer in the area. Vertical and sub vertical joints are also observed in the VAB and CB sub units but are not prominent enough to provide potential specific yield to the aquifer. Therefore average specific yield of the shallow aquifer in the study area is around 1.3 % (0.013) as obtained by dry season specific yield method.




| Groundwater Draft for Agriculture (2019-20) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Village | | Samudravani | | Lasona | | Mendha | | Ghugi | | Nitali | |
| Sr. | Well Type | | DW | BW | DW | BW | DW | BW | DW | BW | DW | BW |
| 1 | Total no. of irrigation wells in the area | | 118 | 29 | 154 | 39 | 144 | 45 | 95 | 96 | 137 | 98 |
| 2 | Total no. of wells in use | | 118 | 29 | 154 | 39 | 144 | 45 | 95 | 96 | 137 | 98 |
| 3 | Total no. of wells surveyed | | 13 | 7 | 11 | 1 | 16 | 2 | 42 | 2 | 13 | 7 |
| 4 | No of perrennial wells (perrenial pumping) | | 20 | 7 | 102 | 30 | 98 | 22 | 90 | 90.00 | 98.00 | 60.00 |
| 5 | % of perrennial wells (perrenial pumping) | | 16.95 | 24.14 | 66.23 | 76.92 | 68.06 | 48.89 | 94.74 | 93.75 | 71.53 | 61.22 |
| 6 | Average depth of wells in the area in m | | 15 | 134 | 13 | 121 | 17 | 150 | 16 | 110 | 18 | 162 |
| 7 | Average pump discharge/well /per hour (cum/hr) | | 22 | 15 | 22 | 15 | 22 | 15 | 22 | 15 | 22 | 15 |
| 8 | Average pumping hours a day | June-Sept | 4 | 4 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| | | Oct-Dec | 6 | 6 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 |
| | | Jan-March | 4 | 4 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| | | April -May | 3 | 3 | 4 | 4 | 2 | 2 | 3 | 4 | 4 | 4 |
| 9 | Average pump operation days | June-Sept | 12 | 12 | 16 | 16 | 14 | 15 | 11 | 11 | 14 | 14 |
| | | Oct-Dec | 20 | 20 | 24 | 24 | 21 | 21 | 20 | 20 | 28 | 28 |
| | | Jan-March | 30 | 30 | 35 | 36 | 31 | 31 | 30 | 31 | 38 | 38 |
| | | April -May | 22 | 22 | 24 | 24 | 20 | 20 | 25 | 26 | 25 | 25 |
| 10 | Average annual draft of a well (unit draft) in Ham | June-Sept | 0.11 | 0.07 | 0.11 | 0.07 | 0.09 | 0.07 | 0.07 | 0.05 | 0.09 | 0.06 |
| | | Oct-Dec | 0.26 | 0.18 | 0.37 | 0.25 | 0.32 | 0.22 | 0.31 | 0.21 | 0.43 | 0.29 |
| | | Jan-March | 0.26 | 0.18 | 0.39 | 0.27 | 0.34 | 0.23 | 0.35 | 0.23 | 0.42 | 0.29 |
| | | April -May | 0.15 | 0.10 | 0.21 | 0.14 | 0.09 | 0.06 | 0.17 | 0.16 | 0.22 | 0.15 |
| | | **Total** | **0.78** | **0.53** | **1.07** | **0.74** | **0.84** | **0.58** | **0.89** | **0.65** | **1.16** | **0.79** |
| 11 | Total groundwater draft in the area in Ham | June-Sept | 12.46 | 2.09 | 16.26 | 2.81 | 13.31 | 3.04 | 6.90 | 4.75 | 12.66 | 6.17 |
| | | Oct-Dec | 31.15 | 5.22 | 56.92 | 9.83 | 46.57 | 9.92 | 29.26 | 20.16 | 59.07 | 28.81 |
| | | Jan-March | 31.15 | 5.22 | 59.29 | 10.53 | 49.10 | 10.46 | 33.07 | 22.32 | 57.27 | 27.93 |
| | | April -May | 2.90 | 0.69 | 21.54 | 4.32 | 8.62 | 1.32 | 14.85 | 14.04 | 21.56 | 9.00 |
| | | Total | 77.67 | 13.22 | 154.01 | 27.49 | 117.60 | 24.74 | 84.07 | 61.27 | 150.56 | 71.92 |
| | | Total | **90.89** | | **181.50** | | **142.35** | | **145.35** | | **222.48** | |
| 12 | Total groundwater draft in the area in **TCM** | **Total** | **908.90** | | **1814.99** | | **1423.46** | | **1453.46** | | **2224.75** | |

| Groundwater Estimation (2019-20) | | |
|---|---|---|
| **Monsoon Recharge** | | **TCM** |
| 1 | Rainfall recharge during monsoon (by WTF) in TCM =(area × wtf × sy) (4714.29*7*0.0194*10) | 6402.01 |
| 2 | Recharge from groundwater irrigation during monsoon in TCM (considered 10% of water applied) | 80.44 |
| 3 | Groundwater Draft during monsoon in TCM | 804.40 |
| 4 | Recharge from Surface water irrigation during monsoon in TCM | 0 |
| 5 | Total groundwater recharge during monsoon in TCM =(1+(3-2)+4 | **7125.97** |
| **Non-Monsoon Recharge** | | |
| 6 | Recharge from WCS during non-monsoon in TCM (considered 40% of total storage capacity) | 264.80 |
| 7 | Recharge from canal in TCM | 0 |
| 8 | Recharge from Surface water irrigation during non-monsoon in TCM (10% of SW applied) | 0.00 |
| 9 | Recharge from Groundwater irrigation during non-monsoon in TCM (considered 10% of water applied) | 702.11 |
| 10 | Recharge from Tanks and ponds in TCM (as per GEC norms) | 0 |
| 11 | Total groundwater recharge during non-monsoon in TCM (6+7+8+9+10) | **966.91** |
| 12 | Gross groundwater recharge (5+11) in TCM | 8092.88 |
| 13 | Net groundwater availability in TCM - No Base flow | 8092.88 |
| 14 | Gross groundwater draft for all uses (from earlier sections) in TCM (Domestic+ Irrigation) = 119.39 +756.07= 875.46 TCM | 8157.90 |
| 15 | Stage of groundwater extraction (15/14) × 100 in % | 100.80 |
| 16 | **Groundwater surplus (+)/deficit(-) = 13-14 in TCM** | **-65.02** |

With this estimation it is estimated that the **category** of the study area is **Over Exploited.** It is also inferred that GW recharge percent w.r.t. rainfall of the current year is almost 14 %.This estimate gives a fair idea about the groundwater balance for the year 2019-20.

## Discussion:-

In the study area, Rainfall pattern is fluctuating and 2-3 dry spells in rainy season is very common.GW use exceeds the GW recharge thereby causing to deplete GW level in the area.Average well density in the area is 20 wells per square Km, which is much higher than the safe limit of 8 wells per sq.km.With the falling GW level, depth of wells is consistently increasing years after years. Yield of wells reduced to 0.80 Ham (8 TCM) per well, thereby reduction in area irrigated per well.GW is used for filling up of Farm ponds, thereby increasing GW loss by evaporation rather than to use it for irrigation. Dug Cum bore well and bore wells are very common, but does not have substantial yield. 30 to 40 % wells are dry in summer.High well density and large no. of bore wells could be the main reason of GW level depletion. It would also be necessary to plan and control the use of groundwater under the prevailing conditions. Publication and distribution of annual reports and related programmes for creating awareness amongst the community and for educating them will have to be undertaken regularly. This will enable avoiding scarcity, as well as the hectic activity and excessive expenditure that has become characteristic of summer months. It is necessary to formulate and adopt a long-term policy to protect groundwater by preventing pollution and overuse. This policy should be comprehensive and implemented at all appropriate levels. It should be consistent with other water management policies and be duly taken into account in other sectoral policies. Priority is to be given for demand management measures supported by artificial groundwater recharge in all the over developed (over-exploited/critical/semi-critical) watersheds. Similarly the convergence of the Government of India (GoI) and Government of Maharashtra (GoM) schemes of watershed development or artificial groundwater recharge need to be promoted in these areas. Unlike the land resource, groundwater is a dynamic resource. The groundwater flow cannot be measured like the flow through canals or pipe lines. The groundwater flows downward and spreads according to natural gradient and the permeability of the formations. Therefore, management of groundwater in fact, involves management of a dynamic, immeasurable and uncontrollable entity. While managing the groundwater resource, it is necessary to consider it to be a common property resource and is required to be controlled appropriately with the assistance of the community. Concepts like Village level Watershed Water Account, Village level Water Safety and Security, Basin/ Sub-basin Water Auditing, Aquifer delineation and its management etc, will have to be popularized and made a basis for equitable distribution of ground water

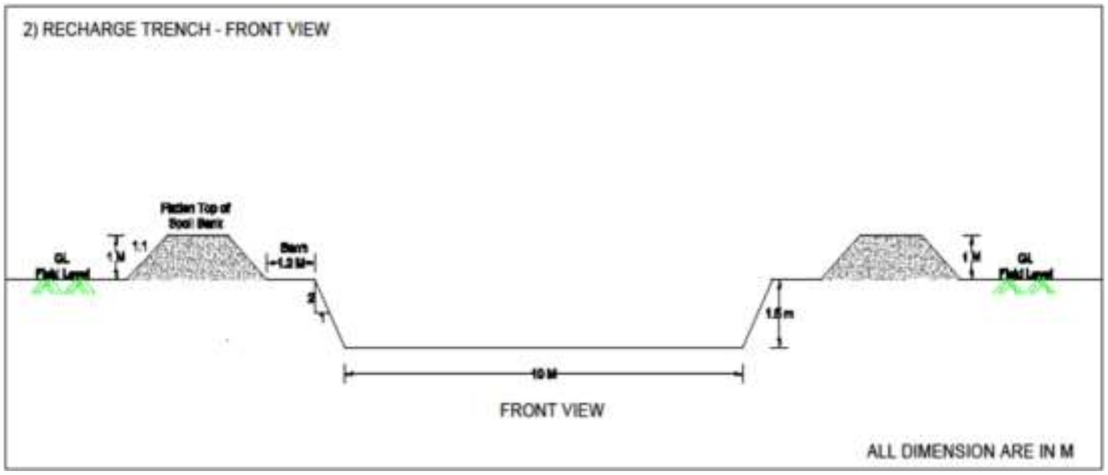
## Conclusion:-

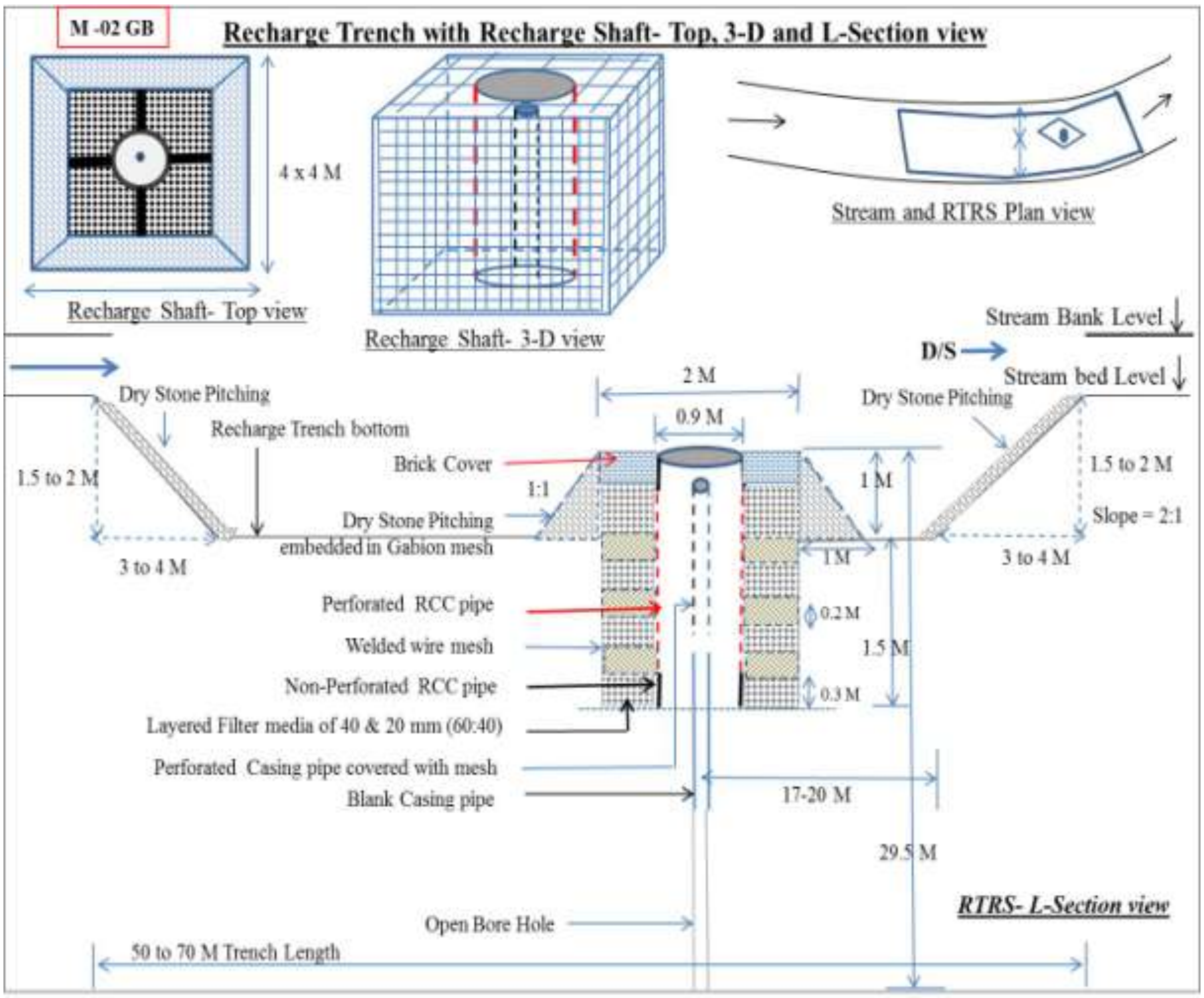
Optimum planning of GW recharge and need to control the irrigation draft less than the recharge. Application of Regulatory measures for not drilling bore wells. Optimum use of water saving practices. There should be annual GW budgeting on regular basis. Need to plan cropping as per GW availability. Need to discourage groundwater use for filling farm ponds. Groundwater Management action Plan should be implemented by supply and demand side. In the watershed proposed No. of structures for water conservation and groundwater recharge Un-utilized available run off is 1582.57 TCM. With assumption of 2 fillings, additional Storage that can be created is 791.29 TCM. There is no scope for new wells is found from the studies.

Demand side control interventions are regulatory measures like Drilling of new bore wells shall be discouraged and encouraging the use of surface water for filling up of farm ponds rather than GW. Water Saving practices should be done ,there is need to bring 66 Ha of GW irrigated sugarcane and 23.5 Ha of Horticulture crops, under drip irrigation so that GW draft will be reduced by 553 TCM ( 35% saving) All the perennial crops shall compulsorily be taken on drip irrigation without increasing the current area under cultivation of perennial crops especially sugarcane.Participatory Groundwater management done by Rainfall measurement, Groundwater monitoring, Regular water budgeting at the end of monsoon, Crop planning and water use planning these activites done by community.Drawing of GW recharge structures in the studies area is given below.

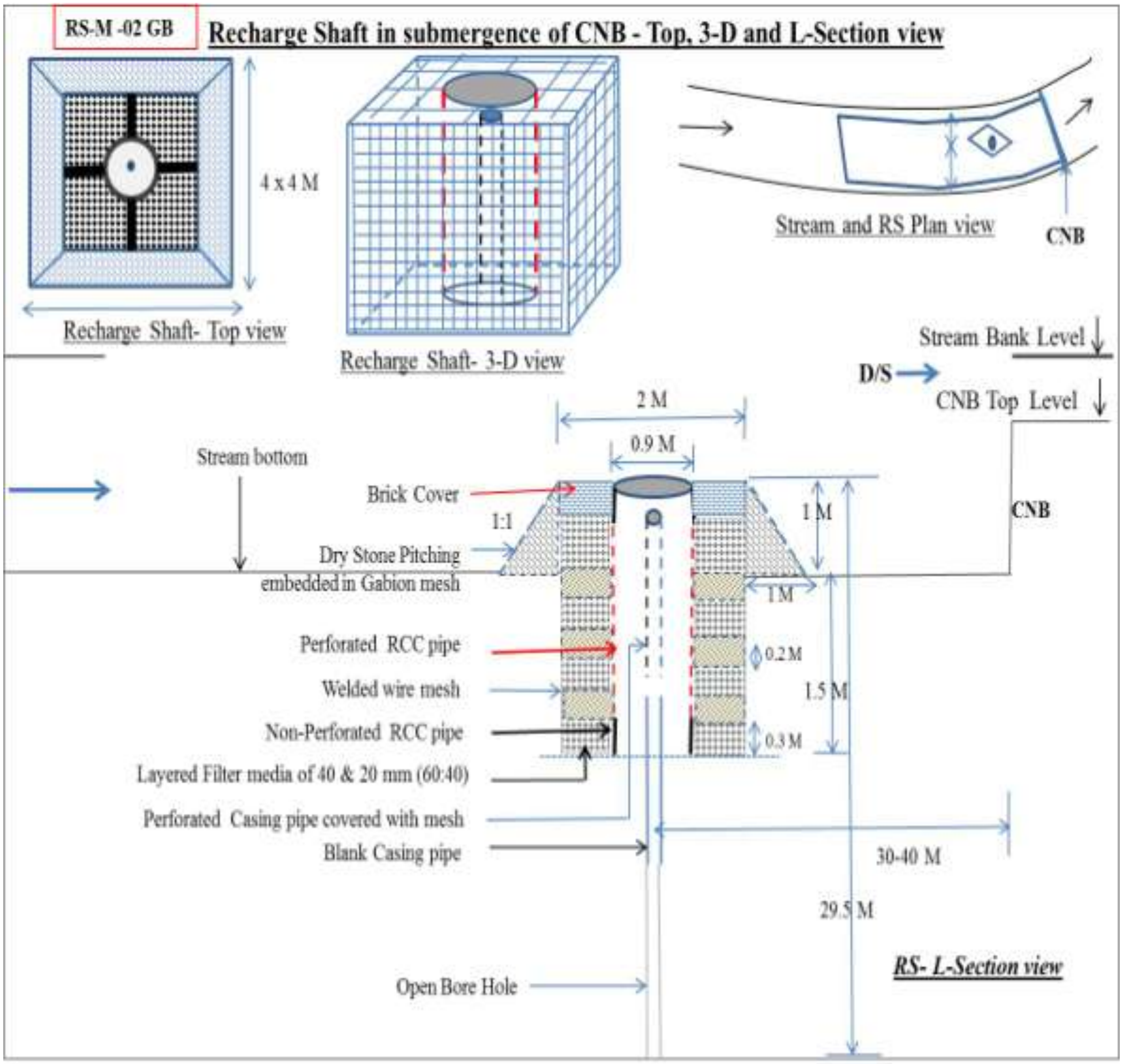
**Proposed Recharge Structures in Cluster-05_525_MR-21_01_Osmanabad**

| Sr.No. | Village | Recharge Trenches with Recharge Shafts ***(RTRS)*** | Recharge Shafts ***(RS)*** | Construction of ***New*** Hybrid Gabbion | Total Structures proposed |
|---|---|---|---|---|---|
| 1 | Samudrawani | 7 | 1 | 0 | 8 |
| 2 | Lasona | 10 | 4 | 0 | 14 |
| 3 | Mendha | 10 | 0 | 1 | 11 |
| 4 | Ghuggi | 1 | 15 | 4 | 20 |
| 5 | Nitali | 0 | 12 | 0 | 12 |
| **TOTAL** | | **28** | **32** | **5** | **65** |




Design of proposed new Recharge Shaft and Recharge Trench cum Recharge Saft in the Study area




Field Photgraphs of Studied Area

| | |
|---|---|
|  |  |
| Existing K.T. weir, Village- Ghugi | Existing Nala, Village- Lasona |

| | |
|---|---|
|  |  |
| Dug well section,Village- Mendha | Deep Groundwater Level-unlined well, village- Nitali |
|  |  |
| Lined Farm Pond, Village- Samudravani | Dug well Section,Village- Lasona |

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