Study of Impact Assessment of Community Based Aquifer Level Groundwater Management Initiatives Jalswarajya-2 project, Satara, Maharashtra, India

Megha Shinde[1], Sayyed N.M[2]
[1]*Senior Geologist, Groundwater Surveys and Development Agency, Satara, Maharashtra, India*
[2]*Assistant Geologist, Groundwater Surveys and Development Agency, Satara, Maharashtra, India*

***Abstract*—This paper is intended to produce the impact of the supply and demand side measures implemented during the Jalswarajya Project work in Groundwater surveys and development Agency, water and Sanitation department, State government of Maharashtra, project period. Mainly, the comparison between pre-project and post-project scenario has been carried out. There are total 12 aquifers delineated in 7 districts under Jalswarajya-II program and each aquifer has been documented as a separate impact assessment report. The present impact assessment report pertains to aquifer from Satara district. This paper is a reference document for the participatory groundwater project implemented under Jalswarajya-II Program. The paper has been intended to bring out the impact of the activities implemented. Such impact assessment is a first of its kind endeavor by the department wherein various indicators have been set to evaluate the pre and post project scenarios. The present report relates to aquifer delineated in BM-85 watershed of Satara district. The report shall take the reader through the aims, objectives, methodology and analysis of indicators to show the tangible and intangible results. The report is also annexed with necessary data sheets to support the results and discussion.**

The study envisaged, participatory groundwater management activities based on water balance framework. Village Water and Sanitation Committee (VWSC) and aquifer level management organizations i.e. Groundwater Management Association (GWMA) prepared the Groundwater Management Action Plan (GWMAP) based on appraisal of local groundwater problems. They have identified various activities in consultation with the District Technical Committee (DTC); analyzed status of groundwater availability; its use for various purposes and have formulated suitable plans of groundwater management.

***Index Terms*—Jalswarajya, GSDA, Groundwater, water levels, impact assessment, groundwater management, geology**

I. INTRODUCTION

Groundwater has been the primary source of water supply for domestic, agricultural and industrial uses in Maharashtra. It is the single largest and most readily available source of irrigation. Nearly 80% of rural water supplies are based on groundwater. Groundwater availability for drinking water is directly linked to the overall groundwater usage in agriculture. It also depends upon its management by the farmers, industries and urban users. The desire of the farmers to have private irrigation sources has led to mushrooming of dug wells/bore wells/tube wells resulting in large declines in groundwater levels in many areas. Many watershed recordings show deficit water balance and large-scale deterioration in groundwater quality.

Moreover, the inherent heterogeneity and comparatively low water yielding capabilities of hard rock compared to alluvial aquifers pose the problem of sustainability of groundwater resources. The intensive agricultural practices of growing crops like sugarcane, fruit crops etc., which require large quantities of water are heavily depleting groundwater sources in the water scarce areas. As agriculture is the greatest consumer of water, the drinking water sector has become intricately linked to the happenings (water usage) in the irrigation sector. Many of such consequences have pronounced impact on the drinking water quantity and quality. Thus, it is incumbent to the rural drinking water sector to work closely with the Irrigation Department, Groundwater Department and other related agencies. The demand of groundwater is ever increasing. The necessity to evaluate and manage groundwater resources is getting increased attention. Now there is a global shift from Watershed Management to Aquifer Management. Maharashtra is one of the pioneering states in the country to adopt the unit of aquifer for groundwater development and management and decided to go for “Aquifer Mapping” and “Community based Groundwater Management”. Community based groundwater management component of Jalswarajya-II program has been implemented in seven districts of Maharashtra state viz. Pune, Satara, Ahmednagar, Jalgaon, Aurangabad, Buldhana and Amravati. There have been two phases of this component 1) Aquifer delineation and 2) Community based groundwater management. Total duration of the project implementation was 6 years i.e. from 2014 to 2020.

II. BASELINE SURVEY OF THE STUDY AREA

Out of 34 districts in the state of Maharashtra, Satara is one of the district selected under Jalswarajya -II programme for aquifer mapping and community based groundwater management. Satara district has 50 watersheds, out of that 1 is Over-exploited, 07 are Semi- critical and 42 are Safe as per the Groundwater Estimation of 2013-14. The aquifer based participatory groundwater management project has been implemented in BM-85 watershed (Figure 1) mini watershed 09/14, 12/14, 13/14, 14/14 of Satara district. The selected mini watershed was categorized as Over-exploited in the reassessment of the Groundwater Estimation during Mini GWE 2008-09, with stage of development 112% and long term pre and post-monsoon groundwater level trend as ‘Falling-Rising’. The villages under this mini-watershed were notified in 2010, as per the provisions of prevailing Maharashtra Groundwater (Regulation for Drinking water purposes) Act, 2009.

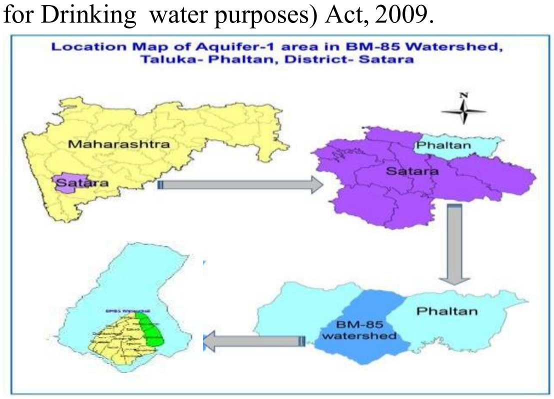


Figure 1: Loation map of project area

The Project area BAS/BM-85 is located at a distance of about 70 km from the Satara district headquarter in East direction and due SE direction of Phaltan tehsil headquarter, at a distance of about 14 km. The area falls in Survey of India, Toposheet No.47K/5 and quadrant A2, B2,B3, and C2 between 17°49’20” to 17° 56’10” N latitudes and 74°18’30” to 75°26’20” E longitudes. This watershed is spread over an area of 375.46 Sq.Km covering the fourteen notified villages as shown in Fig. 1. The highest elevation in the project area is 1048 m amsl & the lowest elevation noted toward north is 620m amsl. Since the aquifer is delineated in Basaltic hard rock terrain, the nomenclature of aquifer is given as: BAS/BM-85 where, BAS = Basalt; BM- Bhima river basin and aquifer delineated in watershed no.85.

Table 1: Salient features of the aquifer

No. of villages included	14		
Name of the villages	Bodakewadi, Jadhavnagar,	Dalvadi, KuravliKhurd,	Daryachiwadi, Mandavkhadak,

Manewadi, Miryachiwadi, Sawantwadi, Tardaf, Tathavda, Upalave, Veloshi, Zadakbaichiwadi.

No. of Village Water and Sanitation Committees in place: 14
Total population (Human / Cattle): 13656 / 5555
Groundwater Dependability: 100%
Normal Rainfall: 367.5 mm
Total area of aquifer: 86.86 Sq.Km
Formation: Deccan Basalt
Aquifer type: Phreatic / Water Table
Thickness of aquifers observed in the area : 8 m
Specific Yield: 0.02 (by dry season approach)
Transmissivity: 79.77sq. m/day

* Kh – Khurd, Bk – Budruk. These are the administrative designations used to denote smaller and greater segments of the town/village, Bk being the greater.

The entire catchment is a sub basin of Banganga River which is a tributary of Nira River that drains toward west and join Bhima river (Fig. 2a). The area is located on moderately sloping terrain. It is bounded by hilly ranges towards south, while rest of the area shows relatively plain surface. The elevation ranges from 620 to 1048 m above mean sea level that is indicative of dynamic groundwater system of the area. The drainage shows typically dendritic pattern of Deccan volcanic province. The groundwater flow, thus, is from upper regions in the south towards low lying area in the north (Fig 2b).

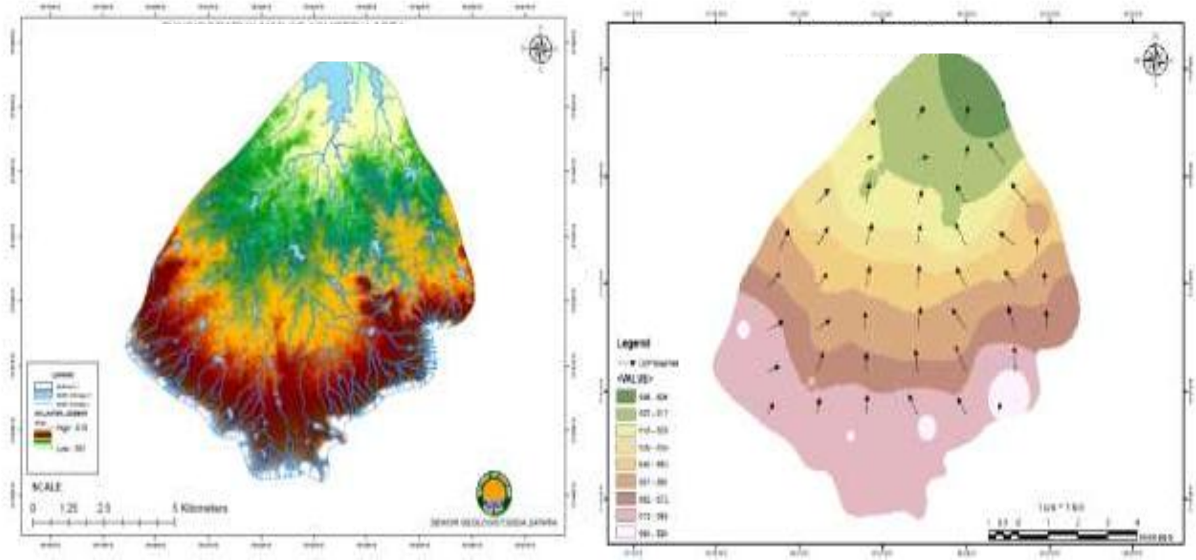


Figure 2: (a) Drainage system (b) Topographical elevation and groundwater flow direction

III. OBJECTIVES

The objectives of Community based Aquifer Level Groundwater Management projects were laid down as to enhance the sustainability of groundwater based drinking water sources, to manage the groundwater through community within the aquifer and make the drinking water sources sustainable even during the acute water scarcity years. To make the villages tanker free by using the community-based groundwater management tools. To evolve the region-specific approaches to determine reasons of water level fluctuation. To provide insight to key issues of control on deep irrigation bore wells, excessive use of groundwater for the water intensive crops, initiatives for sustainable groundwater management. To develop scientific micro level data base and analytical skills essential to monitor the groundwater conditions and understand the actual viability of potential management options. To demark regions where water level fluctuations are very high in pre-monsoon and post-monsoon periods.

IV. METHODOLOGY

Since the overall aim of this study is to assess the impact of various supply and demand side interventions carried out during the project tenure, following eight key indicators have been formulated for the qualitative and quantitative evaluation. As the Fig.3 depicts the proposed methodology for the evaluation of impact of the project.

1. Change in groundwater level (m)
2. Groundwater Drought Index
3. Decrease in Groundwater Draft (%)
4. Reduction in Water Supply by Tankers (%)
5. Community Awareness on GW Management
6. Changes in Micro Irrigation
7. Stage of Groundwater Development
8. Groundwater Quality Index of the Aquifer

The rationale behind selecting these indicators is the aspect that reversing the decline of water, changing the overexploitation status to safe and elevating the socio-economic status requires substantial time span to produce desired results. Therefore, the framework of above eight vital indicators is designed to assess the extent of impact of the supply and demand side interventions in the aquifer water management initiative. In the present impact assessment study, the dataset collected from various inventories have been analysed using standard techniques/procedures/guidelines. Various graphical, statistical, RS-GIS tools and techniques have been used for depiction.

V. BASELINE INDICATOR

Baseline hydrogeological survey for the study area was conducted with a view to demarcate the aquifer boundaries for managing the groundwater resources in watershed BM-85. A network of observation wells was established to periodically monitor the groundwater levels (Fig. 4). Also, the villages were provided with rain gauges to measure rainfall. The dataset thus generated has been used in the analysis of various indicators. The field survey data was used to produce hydrogeological maps, which were used to analyze change in the baseline indicators and evaluate aquifer related controls. In all, 172 groundwater recharge structures have been constructed in the study area. Out of these 66 are recharge trenches with recharge shafts, 4 are cement nala bunds and 102 are recharge shafts. The construction of these recharge structures commenced in June 2018 and completed by May 2019 i.e. just before the onset of monsoon. The geo tagged location of these recharge structures constructed under Jalswarajya-II program is depicted in Annexure 1. The computation of groundwater recharge and draft for the year 2014-15 and 2019-20 has been carried based on the Groundwater estimation Committee, 2015 Guidelines, The total annual (Gross) groundwater recharge is computed by adding recharge/accumulations during monsoon and non-monsoon seasons. Since the study area is non-command sub unit, the rainfall recharge is computed with the following components of water balance equation of GEC, 2015 methodology: (1)

$$R_{RF} = h \times Sy \times A - R_{GWI} - R_{WCS} + GE$$

Where,

RRF - Rainfall Recharge, h - rise in water level in the monsoon season, A - area for computation of recharge, Sy - Specific Yield, RGWI- Recharge from ground water irrigation, RWCS – Recharge from water conservation structures, GE-Ground water Extraction. As the study area is devoid of tanks and ponds, recharge from "other sources" (other than rainfall) mainly constitutes recharge due to groundwater irrigation and water conservation structures. The annual extractable groundwater resource is computed by deducting 5% annual natural discharge from total annual groundwater recharge as water table fluctuation is used.

Similarly, the groundwater draft is computed by:

$$GE_{ALL} = GE_{IRR} + GE_{DOM} + GE_{IND}$$

Where,

GE - Groundwater extraction for all uses, GE ALL - Groundwater extraction for irrigation, IRR GE- Groundwater extraction for domestic uses, GE- Groundwater extraction for industrial DOMIND uses. As there are no industries in the study area, the computations of gross groundwater extraction mainly constitute draft for irrigation and domestic uses. Season-wise unit draft is taken into consideration and multiplied with the number of wells for attaining the extraction for irrigation purpose. Whereas, consumptive use of total population (human and cattle) is considered while computing extraction for domestic uses. Change Detection in Groundwater Levels A network of 42 observation wells and 14 rain gauge stations has been monitored with the help of community. Each observation well represents the hydrogeological conditions of the respective village. The groundwater levels of every month (measured in the last week) have been recorded by measuring it from the reference point fixed on circumference of well. As the groundwater levels are measured from the ground surface below, all computations of groundwater level are carried out in 'm bgl' i.e. meters below ground level. The hydrological year in the state starts with the beginning of monsoon i.e. June and ends by May of the next calendar year. Since the aquifer saturation is maximum in October (the post-monsoon month) and minimum in May (the pre-monsoon month), often resulting into drying up of wells, the present analysis is based on the water level fluctuation between October and May for each hydrological year (Groundwater Estimation Committee, 2015). Further, a consistent series of water table statistics is produced which enabled spatio-temporal comparisons across the study area. For this, data from 2014 to 2020 has been integrated from the inventory collected by GSDA office with the help of community. The groundwater level data has been converted to a GIS database, so that the spatial analysis of the groundwater level and its fluctuation over time can be carried out.

VI. GROUNDWATER QUALITY EVALUATION

Analyzing groundwater samples collected from the villages helped in generating groundwater quality data. As Groundwater Quality Index (GWQI) is one of the most effective tools to communicate information on quality of groundwater to the community and policy makers, the analysis is taken further to derive the GWQI of every village. It is considered to be an important parameter for the impact assessment and management of groundwater. GWQI was calculated from the point of view of suitability of groundwater for drinking considering 9 important parameters. This analysis has been carried out following the standard method of APHA (2015). The GWQI computation is derived in three steps as follows: In the first step, each of the 9 parameters has been assigned a weight (wi) according to its relative importance in the overall quality of water for drinking purposes (Table 1). The maximum weight of 5 has been assigned to the parameter nitrate due to its major bearing in water quality assessment

Table 2: Relative weight of chemical parameters

Chemical parameters	Indian Standards	Weight (w_i)	Relative weight (Wi)
pH	6.5-8.5	3	0.09
Total Dissolved Solids, mg/L	500-2000	5	0.16
Sodium	……	3	0.09
Potassium	…..	2	0.06
Calcium	75-200	2	0.06
Magnesium	30-100	2	0.06
HCO3	.....	2	0.06
Sulphate, mg/L	200-400	3	0.09
Nitrate, mg/L	45	5	0.16
Iron, mg/L	0.1-1	3	0.09
Fluoride, mg/L	1-1.5	2	0.06
		$\sum w_i = 32$	$\sum W_i = 1.00$

* All parameters are in (mg/L) except pH.

In the second step, the relative weight (Wi) is computed from the equation (3):

$$Wi = \frac{w_i}{\sum_{i-1}^{n} w_i}$$

Where, Wi is the relative weight, wi is the weight of each parameter and n is the number of parameters.

In the third step, a quality rating scale (qi) for each parameter is assigned by dividing its concentration in each water sample by its respective standard according to the guidelines laid down in the BIS and the result multiplied by 100:

$$qi = (Ci / SI) \times 100 \qquad (4)$$

where qi is the quality rating, Ci is the concentration of each chemical parameter in each water sample in mg/L, and SI is the Indian drinking water standard for each chemical parameter in mg/L according to the guidelines of the BIS 10500, 2012. While computing, the acceptable limit of the BIS standard i.e. the lower limit of range given in Table 2 is considered for SI.

For computing the GWQI, the SI is first determined for each chemical parameter, which is then used to determine the GWQI as per the following equation;

$$SIi = Wi \times qi \qquad (5)$$

$$GWQI = \Sigma\ SIi \qquad (6)$$

SIi is the sub-index of "i"th parameter; qi is the rating based on concentration of ith parameter and n is the number of parameters. The computed GWQI values are classified into five types, "excellent water" to "water unsuitable for drinking".

The computed GWQI values were classified according to the categorization proposed by Ramakrishnaiah et al. (2009) as: Excellent (<50) follows good water (50-

100), poor water (100-200), very poor water (200-300), water unsuitable for drinking (>300).

Change in Land Use Pattern

Various Land Use Land Cover (LULC) indicators have been derived using LISS IV FCC satellite imagery for improved understanding of impacts. A supervised classification technique has been used to prepare LULC map from these satellite imageries. Total seven classes have been derived for better understanding of land dynamics. Further, the Normalised Difference Vegetation Index (NDVI) has been derived using equation (5). The NDVI is used as an important supporting parameter for assessing drought in the study area.

$$NDVI = \frac{(NIR-R)}{(NIR+R)}$$

where, NIR = pixel values from the Near Infrared band; R = pixel values from the Red band.

DROUGHT ASSESSMENT

The Government of India (GoI) has provided guidelines for determining Groundwater Drought Index (GWDI). Monthly groundwater table records for a minimum period of 10 years are recommended for the computation of mean groundwater table. However, as the observations wells in the study area are established only 5 years before, the computations using 5 years dataset i.e. from year 2014 onwards for the month October, January, March and May have been carried out. The class and categories as per the GoI guidelines are given in Table 3. The higher rate of depletion of groundwater table in a given month/period than its corresponding mean value indicates water deficit conditions. The computation procedure, as derived in the Manual for Drought Management (2016) is as follows:

$$GWDI_{ij} = \frac{MGWD_j - GWD_{ij}}{GWD_{iMax}}$$

Where,

GWDIij = Groundwater Drought Index for its month and its year;

MGWDj= Mean depth to groundwater table below surface (in meter);

GWDij = Depth to groundwater table in its month and its year (in meter);

GWDimax = Maximum depth to groundwater table in its month in available data set for nnumber of years (in meter);

i = 1, 2, 3, 4, ..., 12;

j = 1, 2, 3, ... , n;

n = total numbers of years for which monthly groundwater records are used.

VII. ASSESSMENT OF COMMUNITY AWARENESS

The impact assessment without assessing the extent of community involvement cannot bring holistic meaning to the participatory groundwater management project study . In light of this, various efforts of community mobilization have been assessed. Efforts of Project Management Consultant (PMC) and Support Organization (SO) in consultation with Technical Support Group (TSG) led by Senior Geologist, GSDA, Satara for community mobilization and awareness on aquifer management in each village have been considered while assessing the indicator on community awareness on groundwater management. Mobilization activities such as formulation of Gram Panchayat Level Committee (GPLC) and Banganga Bhujal Vyavsthapan Sanstha (GWMA), corner meetings and Self-Help Group (SHG) meetings organized at village level, various training programs for water budgeting and management and regulation held at village level have been taken into account.

VIII. EVALUATION AND RANKING

A novel “ranking framework” based on multi-criteria indicator system has been designed to finally assign score and scale to the impact of the study of the project. The qualitative and quantitative impact of the aquifer water management initiative in the present study has been assessed through eight key indicators namely: change in groundwater level, GWDI, decrease in groundwater draft, reduction in water supply by tankers, community awareness on groundwater management, changes in micro-irrigation, stage of groundwater development and GWQI of the Aquifer. Considering the value obtained in each of these indicators, an “Impact Evaluation Index” has been computed where maximum rank 5 is assigned for excellent results and minimum rank 1 is assigned for poor results. The range for each parameter from 1 to 5 is set according to its relevant categories (Annexure 2). Total ranks of eight parameters are added to attain a score out of 40. The final score obtained is categorized into five classes based on equal intervals.

DATA INTEGRATION

Apart from primary data collection, data collected by other government line departments and agencies has also been incorporated in the present impact assessment study. The kind of data used, its scope and source of collection has been tabulated in Table 4.

IX. ANALYSIS AND RESULTS

In all, eight indicators have been considered to evaluate the impact of groundwater management interventions. Each of these indicators have been assessed using standard procedures and guidelines laid down by various committees of the Government of India and Government of Maharashtra from time to time. The detailed analysis and results have been described one by one in the following paragraphs. Moreover, suitable tables and pictorial depiction have been incorporated wherever required along with the data sheets in the respective annexures from 1 to 6. There is change in Groundwater Levels. Groundwater levels of each month are given in Annexure 3. The pre-monsoon depth to water table in 2014-15 and 2019-20 shows a substantial change from 9.26 to 8.50 m respectively. Similarly, the post- monsoon depth to water table in 2014-15 and 2019-20 varies from 4.80 to 4.42 m respectively. A significant difference in mean annual groundwater level is also observed as groundwater level goes up from 7.56 m to 6.54 m. The time series plot of mean pre-monsoon and post-monsoon groundwater levels in Fig. 5 shows the highest recordings in the year 2019-20. The pre-monsoon groundwater levels which used to reach to the depth of the wells, for example 9.26 m in 2014-15, has retained more water column in the wells even in the late summer due to supply side interventions as 8.50 m of groundwater level has been recorded in the year 2019-20. Similarly, the post-monsoon depth to groundwater table has been recorded closer to the ground surface i.e. upto 4.42 m. Moreover, the slope of a line of both the pre- monsoon and post-monsoon seasons clearly shows rising trends.

Table 5: Data collection and integration

1	Rainfall Water Balance Study Village community in project area
2	Hydrogeological Historical data analysis, pre-monsoon and post-monsoon groundwater level change; groundwater level fluctuation and computing recharge and groundwater availability.
3	Agriculture Water balance study and change in crop pattern; adoption of micro-irrigation practices.
4	Land use Change detection in land use pattern after project implementation.
5	Demography Computing water requirement Groundwater Surveys and Development Agency; Village community.
6	Agriculture Department and Revenue Department; NRSC satellite image, NRSC satellite image, Census Commissioner of India; Gram Panchayat data; Support Organization survey; Zilla Parishad.
7	Water Conservation Structures, Computing groundwater recharge before and after implementation of supply side measures, Agriculture Department; Minor Irrigation Department; Groundwater Surveys and Development Agency.
8	Geochemical, Change detection in water, quality before and after project; determining groundwater quality index. Groundwater Surveys and Development Agency, Irrigation Practices, Use of modern techniques to minimize water requirement. Agriculture Department.
9	Water Scarcity, To find change in drinking, water availability before and after project, Revenue Department.
10	Community Awareness Information, Community participation for groundwater management, Groundwater Surveys and Development Agency ; Support Organization; Zilla Parishad.

monsoon seasons. Though there is a definite rise in groundwater levels in the 6 years span, it is observed that the mean fluctuation in the aquifer remains in the range of 3 to 5 m. This infers that peripheral spatio-temporal variability of rise and fall has occurred in the aquifer as a whole.

The pre-monsoon season of 2014-15 (see Fig. 3a) shows groundwater levels >12 m in the southern part of the project area, whereas, the northern part of project area shows groundwater levels < 8m. South-eastern part of the project area shows pre-monsoon groundwater levels between 9 to 10 m, while, the remaining central part shows groundwater levels between 7 to 8 m. Impact after implementation of groundwater recharge structures, in 2019-2020 (see Fig. 3b), remarkably shows raised pre-monsoon groundwater levels from 5 to 7 m in 70% of the area and between 8 to 10 m in 25% area in the northern part and only 2% area shows groundwater levels > 10 m in the village Manewadi located in south-western part.

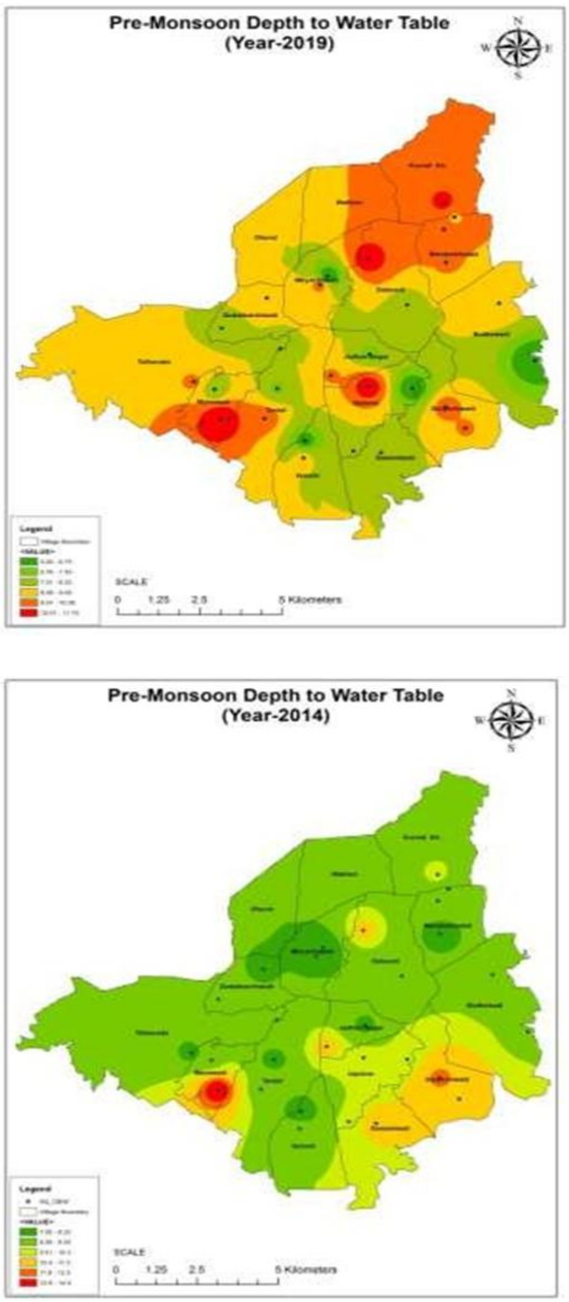


Figure 3: Comparison of pre-monsoon depth to water table (a) 2014-15 (b) 2019-20

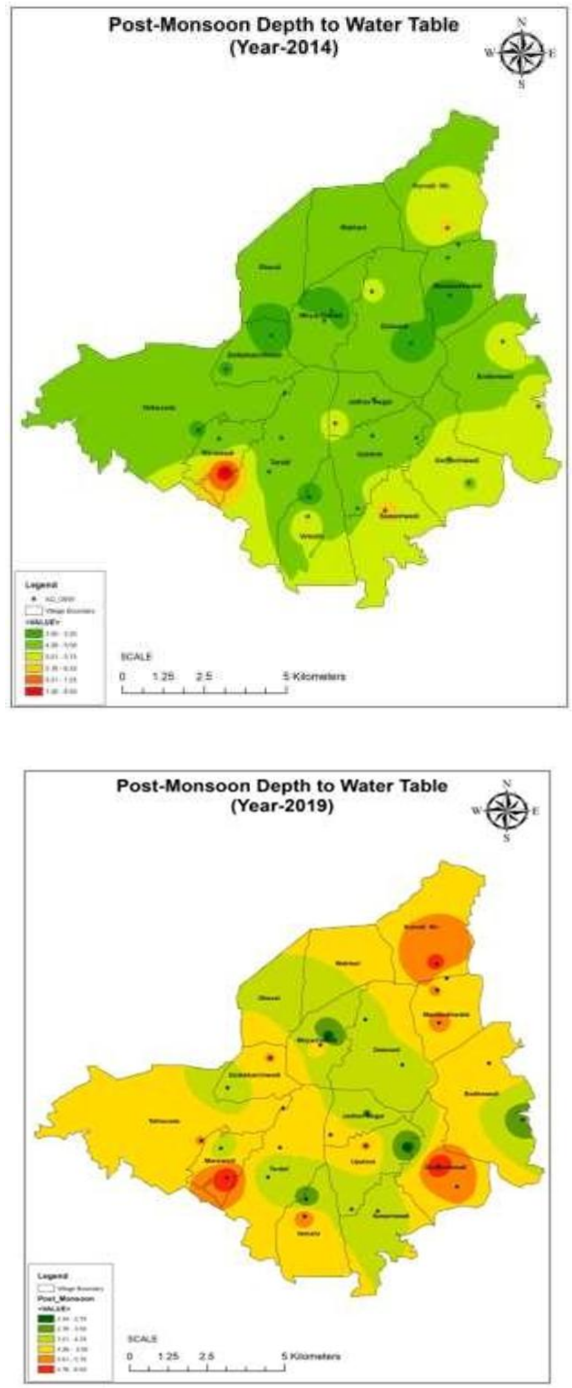
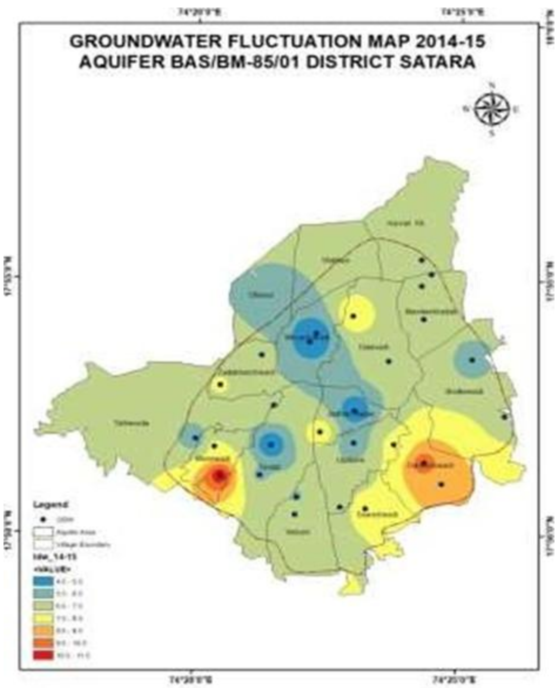


Figure 4: Comparison of post-monsoon depth to water table (a) 2014-15 (b) 2019-20

The post-monsoon season of 2014-15 (see Fig. 4a) shows groundwater levels < 4 m in west and north-western region, whereas, remaining south eastern part of the project area shows groundwater levels between 5 to 6 m and in the village Manewadi it has gone further > 7 m. Impact of recharge structures in 2019-20 (see Fig. 4b) shows 80% of the project area having post- monsoon groundwater levels < 4 m. Only 10% of the area falls between 5 to 6 m.The groundwater level fluctuation (from post to pre-monsoon) in 2014-15 is shown in Fig. 5a. The range of groundwater level fluctuation is observed between 5 to 9 m in about 90% of the area. A central portion of the project area shows groundwater fluctuation between 4 to 6.5 m. Fig. 5b depicts groundwater level fluctuation during year 2019- 2020 i.e. after implementation of recharge structures. It distinctly shows the fluctuation in most part of the project area between 5 to 6 m. The eastern & central part shows less than 5 m fluctuation and a very small patch in the southern region, in village Manewadi, the groundwater level fluctuation is between 9 to 10 m. It is apparent that the spatio-temporal variability is almost consistent. The raised groundwater levels, after the implementation of the recharge structures, did not much affect the groundwater fluctuation which is a positive impact. It implies that community awareness was successful in regulating the additional extraction on account of greater groundwater availability. It helped in retaining groundwater availability for a longer period of time.



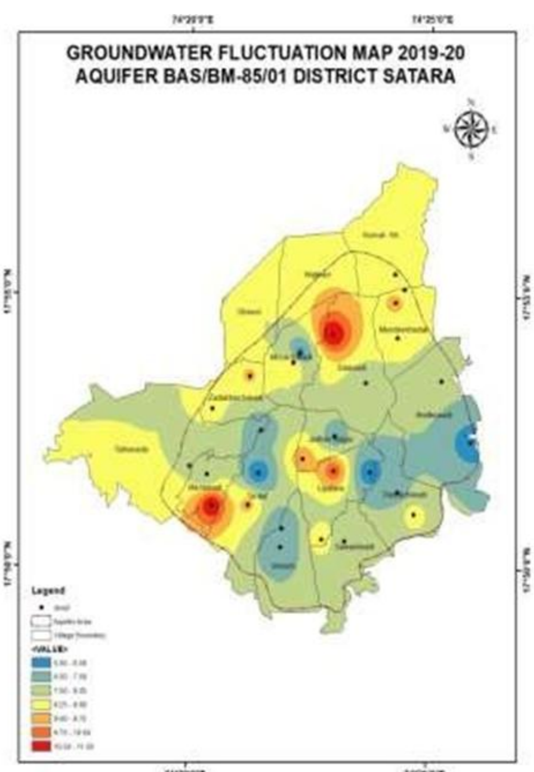


Figure 5: Comparison of groundwater level fluctuation (a) 2014-15 (b) 2019-20

The average annual rainfall of the area is 367.5 mm. Analysis of data indicates that there is no pattern in the rainfall during last five years characterizing its occurrence as highly random (Fig. 6). The lowest rainfall recorded in 2014-15 is 269 mm, whereas, the highest rainfall of 781.9 mm has been recorded during 2019-20. Rainfall is the major source of groundwater recharge as recuperation of shallow aquifers in hard rock Basaltic terrain is highly dependent on the monsoonal precipitation. However, from the hydrograph of the project area it is observed that there is an insubstantial linear rise in the water levels during high rainfall years & the groundwater level got depleted in the year 2018-19 (Fig. 6). It infers that aquifer does not get saturated fully as the rainfall is not properly harvested. In 2018-19 decrease in rainfall causes further drop of groundwater levels up to 6.86 m. An immediate impact after completion of the recharge structures is noted as rise in groundwater level in 2019-2020 by 4.08 m and mean depth to water table at 6.54 m is recorded.

While the hydrograph of mean groundwater levels of 14 villages incorporated in the project area is depicted, individual hydrographs are additionally depicted in Annexure 3 which shows the post project rise in groundwater levels due to supply side interventions.

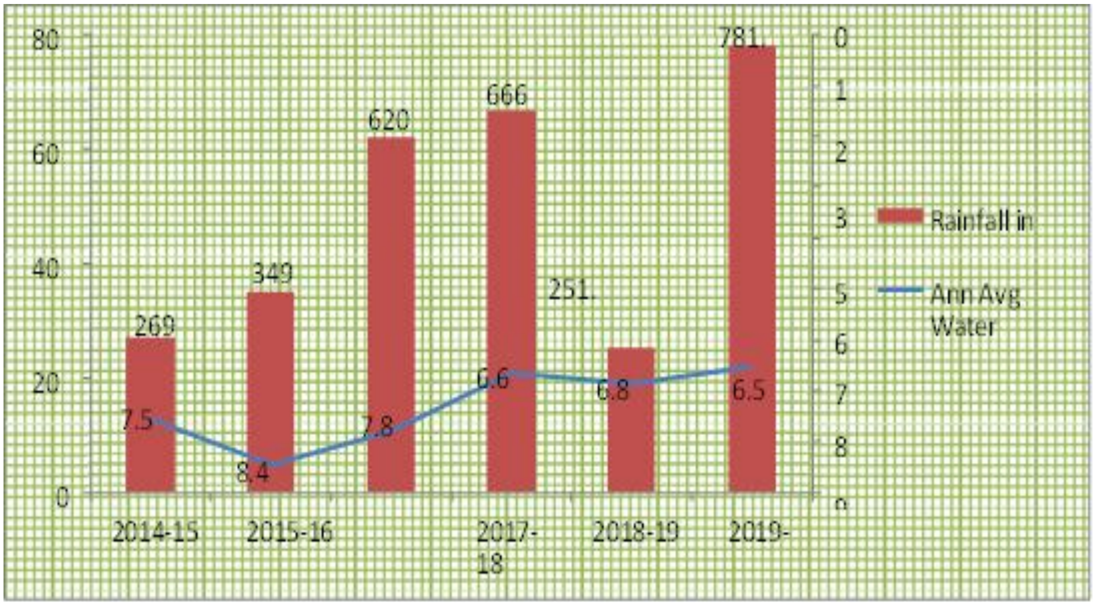


Figure 6: Hydrograph of the study area

The depth to water table of 2014 post- monsoon season are considered as base value and the rise or fall in the groundwater level of subsequent years compared to the base values are plotted. It allowed easier interpretation of the spatial distribution of the spread of rise or fall in the groundwater levels after monsoon. The rise and fall in groundwater depends on various causative factors. Therefore, it cannot be judged how the pattern of hotspot of groundwater depletion varies. However, year 2019-20 shows a much relief as the hotspot of groundwater depletion has entirely dissolved indicating good groundwater availability in the last five years span. The impact of supply side interventions in the aquifer has once again manifested its relative effect compared to the pre- project scenario.

X. GROUNDWATER DROGHT INDEX

Groundwater drought is a distinctive subset of drought resulting from the imbalanced groundwater recharge - discharge phenomenon. It may also be determined based on simple water budget model. However, since the observation wells are established in each village of the delineated aquifer and are being monitored every month through community, these continuous and spatially representative groundwater observations have been used as a framework to evaluate groundwater drought characterization. The in-situ groundwater observations collected from each village have proven beneficial in understanding the drought characteristics through each hydrological year and assessing groundwater availability for agriculture and drinking water purposes. Categorization of villages on the basis of GoI guidelines is shown in Table 5. During 2017-18, the project area shows distribution of groundwater drought index in normal to moderate categories, while the computations of 2019-2020 shows normal to mild indices (Table 5). There were only two villages in severe category during 2017-18, whereas, after the project interventions in 2019-20, all fourteen villages have been grouped under normal to mild category. It implies that the aquifer has restored groundwater recharge-discharge conditions by increase in groundwater storage and decrease in groundwater withdrawal. Computation of Groundwater Drought Index of each village is given in Annexure 4.

Sr.No	Village Name	GWDI 2017-18				GWDI 2018-19				GWDI 2019-20			
		GWDI Oct	GWDI Jan	GWDI Mar	GWDI May	GWDI Oct	GWDI Jan	GWDI Mar	GWDI May	GWDI Oct	GWDI Jan	GWDI Mar	GWDI May
1	Bodkewadi	0.21	-0.23	-0.16	0.18	0.34	0.20	-0.12	-0.42	0.27	0.11	-0.05	-0.33
2	Dalvadi	0.49	0.25	-0.30	-0.43	0.31	0.09	-0.08	-0.32	0.22	0.11	-0.07	-0.26
3	Daryachiwadi	0.45	-0.03	-0.16	-0.27	0.33	0.00	-0.07	-0.26	0.21	0.07	-0.07	-0.21
4	Jadhav Nagar	0.41	-0.25	-0.04	-0.12	0.25	0.03	-0.03	-0.25	0.31	0.06	-0.07	-0.30
5	Kurvali Kh	0.63	0.01	-0.32	-0.32	0.37	0.02	-0.11	-0.28	0.26	0.08	-0.07	-0.27
6	Mandav Khadak	0.46	-0.06	-0.15	-0.25	0.26	0.10	-0.12	-0.23	0.24	0.04	-0.05	-0.23
7	Manewadi	0.43	-0.25	0.09	-0.27	0.24	0.18	-0.05	-0.37	0.23	0.11	-0.03	-0.31
8	Miryachiwadi	0.39	0.13	-0.07	-0.45	0.34	0.07	-0.04	-0.38	0.27	0.21	-0.06	-0.42
9	Sawantwadi	0.26	0.04	0.00	-0.31	0.33	0.12	-0.06	-0.39	0.29	0.15	-0.08	-0.36
10	Tardaf	0.42	0.11	-0.06	-0.47	0.35	0.17	-0.08	-0.44	0.44	0.15	-0.21	-0.38
11	Tathawada	0.44	-0.22	0.10	-0.32	0.29	0.15	-0.08	-0.36	0.24	0.06	-0.09	-0.21
12	Upalawe	0.30	0.21	-0.05	-0.46	0.25	0.19	0.01	-0.45	0.31	0.15	-0.09	-0.37
13	Veloshi	0.40	0.04	-0.09	-0.35	0.29	0.16	0.02	-0.47	0.35	0.16	-0.11	-0.40
14	Zadakbaichiwadi	0.31	0.06	-0.04	-0.34	0.40	0.13	-0.11	-0.42	0.50	-0.03	-0.15	-0.33

Table 5: Groundwater Drought Index for 2017-18, 2018-19 and 2019-20

INCREASE IN GROUNDWATER RECHARGE

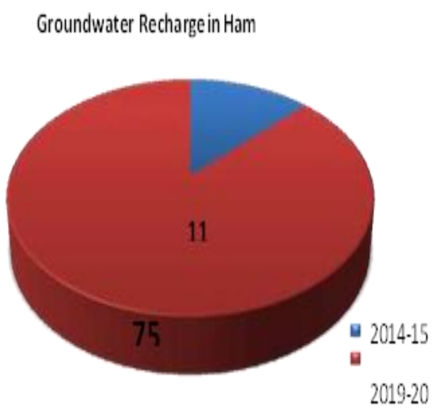


Figure 7: Groundwater recharge from supply side interventions. The percentage indicates share of recharge from supply side interventions to the gross groundwater recharge

The mapping of groundwater drought indices reveals the spatial distribution of water stressed conditions over the project area. During year 2017-18, eastern part of the project area falls in mild category (-0.16 to-0.30), while two villages from northern part of the project area are in severe (-0.46 to -0.60) category. Groundwater Drought Index for the 2019-20 shows majority of the project area in normal to mild categories. As completion of groundwater management action plan has yielded good results in 2019-20, all 14 villages have been indexed between >-0.15 to -0.30 class and categorized as normal to mild. It is apparent that rainwater harvesting structures play a major role in groundwater recharge of shallow aquifers. It facilitates augmentation and helps in retaining the water column in wells for longer period of time. The supply side interventions of the GWMAP implemented in the project area comprised of total 172 recharge structures having substantial number of direct groundwater recharge structures such as 102 recharge shafts, 66 recharge trenches with recharge shafts & 04 cement nala bandharas. In addition, total 490 structures have been converged from other schemes.The details of recharge structure implemented under Jalswarajya-II programme and other schemes are given in Annx.5. These structures varyingly get filled two times annually. Groundwater recharge of 75 Ham has been computed from these structures during 2019- 20, out of which 12 Ham recharge is contributed from Jalswarajya-II program. Thus, a significant contribution from supply side interventions of the Jalswarajya-II program is seen as compared to the groundwater recharge from water harvesting structures of 2014-15 (Fig. 7). Total rise of

64 Ham has been recorded after implementation of the project.

MANAGEMENT OF DRINKING WATER SCARCITY:

During scarcity period measures like water supply through tankers was taken up by the district authorities to mitigate shortfall of drinking water in the project area. Also, community managed the supply of drinking water from private bore wells through local bodies and regulating the water supply once in 4 days. During 2018-19, as the rainfall was low in all the villages tankers were deployed by district authorities, however, due to greater availability of groundwater, all the 14 villages have become free from drinking water scarcity in 2019-20 (Table 6). There were no tankers deployed in any of the village in the project area.

Table 6: Drinking water scarcity measures

Sr.No.	ame of the Village	Tanker Status Whether Tanker Deployed (Yes / No) If Yes, Period								
		2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23
1	Bodakewadi	No	No	No	No	No	No	No	No	No
2	Dalvadi	No	No	No	No	No	No	No	No	No
3	Daryachiwadi	No	Yes/ 90 Days	Yes/ 90 Days	No	Yes/ 90 Days	No	No	No	No
4	Jadhavnagar	No	No	No	No	No	No	No	No	No
5	KuravliKhurd	Yes/90 Days	No	Yes/ 90 Days	No	Yes/ 90 Days	No	No	No	No
6	Mandavkhadak	No	No	No	No	Yes/ 90 Days	No	No	No	No
7	Manewadi	No	No	No	No	Yes/ 90 Days	No	No	No	No
8	Miryachiwadi	No	No	No	No	No	No	No	No	No
9	Sawantwadi	Yes/ 90 Days	No	No	No	Yes/ 90 Days	No	No	No	No
10	Tardaf	No	No	No	No	No	No	No	No	No
11	Tathavada	Yes/ 90 Days	Yes/ 90 Days	Yes/ 90 Days	Yes/ 90 Days	Yes/ 90 Days	No	No	No	No
12	Upalave	Yes/ 90 Days	No	No	No	Yes/ 90 Days	No	No	No	No
13	Veloshi	Yes/ 90 Days	No	No	No	Yes/ 90 Days	No	No	No	No
14	Zadakbaichiwadi	No	No	No	No	Yes/ 45 Days	No	No	No	No

XI. COMMUNITY AWARENESS AND GROUNDWATER MANAGEMENT

The community participation in the entire groundwater management process has been to the core of all activities. The project was successful to complete 80% of stipulated activities. Formulation of Grampanchayat Level Committees (GPLC) and Groundwater Management Association (GWMA) have been completed successfully. Periodic meetings of these committees were organized at village level. Various training programs for water budgeting and management and regulation were held at village level. IEC activities have been organized at village level through corner meetings and SHG meetings with the help of support organization.

Also, various IEC activities were organized at schools. Village community was provided training on monitoring and recording of groundwater level and rainfall of their village. The village community actively provided baseline data while field surveying which was used for project planning. “Banganga Bhujal Vyavsthapan Sanstha” (the GWMA) formed in the project has been very active and involved in community decision making and managing resources. Various community engagement and participatory activities are enumerated in the detail project Report. The economic indicator showing number of people benefiting and the level of income increased could not be assessed due to paucity of timeframe and required budgetary component. However, this impact indicator of community awareness considered number of meetings conducted, number of awareness programs, participatory activities and trainings held that lead to improved groundwater management actions.

Changes In Microirigation Practices

The total area under cultivation is 3350 ha. In year 2013-14, the area covered under drip micro-irrigation was 50.38 ha, whereas, after community awareness activity, there has been substantial increase in the usage of drip micro-irrigation. It is reported that 71.04 ha area has been brought under drip micro-irrigation in 2019-20. That means micro-irrigation practice has increased by 20.66 ha (Table 9). It is notable that the area under micro-irrigation has been increased successively as compared to project initiation stage in 2013-14 as a result of demand side efforts taken by all the stakeholders and has created a positive impact due to Jalswarajya - II program interventions. It reflects that community has become quite aware about judicious utilization of groundwater resource for agriculture and domestic purposes.

Table 7: Progressive increase in area covered under drip micro-irrigation

Sr. No	Criteria	2014-2015 (in field)	2018-2019 (in field)
1	Name of crops	Pomegranate, Sugarcane, Banana, Tomato, Chilli, Onion, Vegetables	Pomegranate, Sugarcane, , Tomato, Chilli, Onion, Vegetables
2	Total area under cultivation in Ha	3350	3776.5
3	Area covered under Drip and Sprinkler micro irrigation in Ha	50.38	71.04

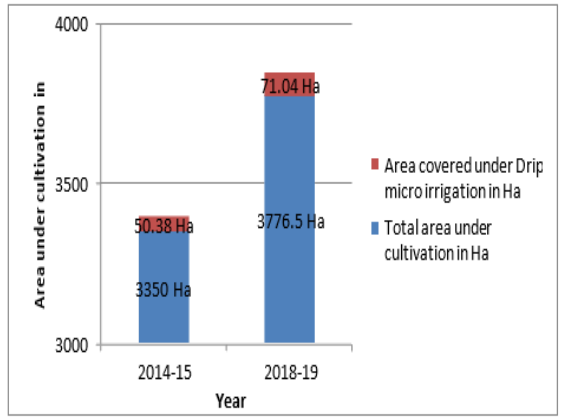


Figure 8: Growing micro-irrigation practices in the study area

Further impact of increase in micro-irrigation has reflected in reduction of gross groundwater draft so that the groundwater recharge-discharge conditions get more balanced. There lies a vast scope for adaptation of micro-irrigation practices as most of the area under cultivation is yet to be covered (Fig. 8). There are wide range of factors that hinder and constrain practicing micro-irrigation techniques. The spectrum of obstacles is spread from economic constraints to lack of knowledge and tendency to cultivate high water requiring crops that inhibit water saving techniques to take place. However, the change in the drip irrigation practices over last four years is suggestive of essential shift in participatory resource management process. It is observed that number of farmers adopting water saving techniques for irrigation purposes have increased considerably.

XII. IMPACT OF GROUNDWATER MANAGEMENT ACTION PLAN (GWMAP)

The post implementation scenario of GWMAP, encompassing supply and demand side interventions, has enabled change detection in the hydrogeological parameters such as groundwater storage, groundwater draft, stage of development etc. The comparison between these parameters for hydrological year 2014-15 and year 2019 -2020 is given in Table 8. A distinct change in the groundwater recharge an draft is noted (Fig. 9). A significant positive impact in gross groundwater recharge is seen as it has been increased from 475 Ham in 2014-15 to 637 Ham during 2019-20. An increased net groundwater availability by 154 Ham is found to be beneficial in restoring recharge-discharge balance. During year 2014-15, the gross groundwater recharge was 475 Ham and gross Groundwater draft computed was 637 Ham.

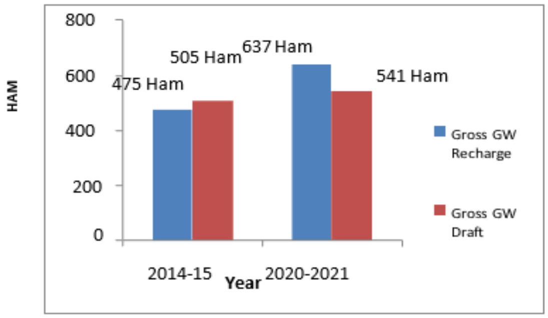


Figure 9: Comparison of groundwater recharge and draft of 2014-15 and 2019-20

The stage of groundwater development which had gone high upto 112% before the project initiation has now been reduced to 89 % transforming the aquifer from over-exploited state to semi-critical zone. The aquifer which was groundwater deficient has now retained groundwater balance of 64 Ham ascribed to successful implementation of the GWMAP.It is evident that the supply side interventions have elevated groundwater recharge and the demand side interventions with the help of community participation like adoption of micro- irrigation practices have gradually decreased groundwater withdrawal.

Table 8: Comparative hydrogeological parameters of 2014-15 and 2019 -2020

Sr.No.	Monsoon Recharge	2014-2015	2019-2020
1	Rainfall recharge during monsoon (by WTF) in Ham =(area x wtf x sy)	315	369
2	Recharge from WCS during monsoon in Ham (25% of total storage)	11	75
3	Recharge from groundwater irrigation during monsoon in Ham (10 % of water applied) as per GEC norms	11	8
4	Groundwater Draft during monsoon in Ham	113	78
5	Total groundwater recharge during monsoon in Ham =(1+2+(4-3)	428	515
	Non-Monsoon Recharge		
6	Recharge from WCS during non-monsoon in Ham(25 % of total storage)	11	75
7	Recharge from canal in Ham	0	0
8	Recharge from Surface water irrigation during non- monsoon in Ham	0	0
9	Recharge from Groundwater irrigation during non- monsoon in Ham (10% of water applied) as per GEC norms	36	46
10	Recharge from Tanks and ponds in Ham (as per GEC norms)	0	0
11	Total groundwater recharge during non-monsoon in Ham	47	122
12	Gross groundwater recharge (5+11) in Ham	475	637
13	Net groundwater availability in Ham (12-(5% of 12)by deducting base flow	451	605
14	Gross groundwater draft for all uses (from earlier computations) in Ham	505	541
15	Stage of groundwater extraction (14/13) x100 in %	112	89
16	Groundwater surplus (+)/deficit(-) = 13-14 in Ham	-54	64

Groundwater quality index:

The Groundwater Quality Index (GWQI) for 42 samples before and after GWMAP implementation has been computed from different locations of fourteen villages to depict the overall water quality status and for easier interpretation of the groundwater quality monitoring data. There is a temporal change observed in the GWQI, as overall percentage of samples in each category before and after implementation of the GWMAP is shows variation (Table 9). It indicates the progress of groundwater quality scenario after the implementation of supply and demand side interventions. However, small variation in the range of individual parameter has been observed (Table 10). The computed GWQI values ranges from 41.6 to 182.1 before implementation and from 40.70 to 241.23 after implementation of supply side interventions. Almost 16.66% of the samples show GWQI value below 50 i.e. excellent groundwater quality for drinking. About 71.42% of water samples are in good groundwater quality, & 9.52% of water samples are of poor quality, especially the villages Jadhavnagar, Kuravli Khurd, Mandavkhadak. Post- project GWQI of each village is depicted in Fig. 10. High value of GWQI (>100) at these sources have been detected mainly due to the higher concentration of Iron, Nitrate, TDS, Hardness, Fluorides, Bicarbonate and Chloride in the groundwater. The analysis reveals that these villages need some degree of treatment before consumption. The "Water Quality Monitoring and Surveillance Program" of the state government conducts regular monitoring of groundwater quality from the drinking water sources. The concerned Grampanchayat are made aware of the poor quality sources and kind of precautions to be taken before consumption.

Table 9: GWQI before and after implementation of supply side interventions

GWQI value	Groundwater quality		Percentage of groundwater samples	
			Before project implementation	After project implementation
<50	Excellent		11.90	16.66
50-100	good water		76.19	71.42
100-200	poor water		11.90	9.52
200-300	very poor water		Nil	2.38
>300	Water unsuitable	for	Nil	Nil
	drinking			
	Total Samples		42	42

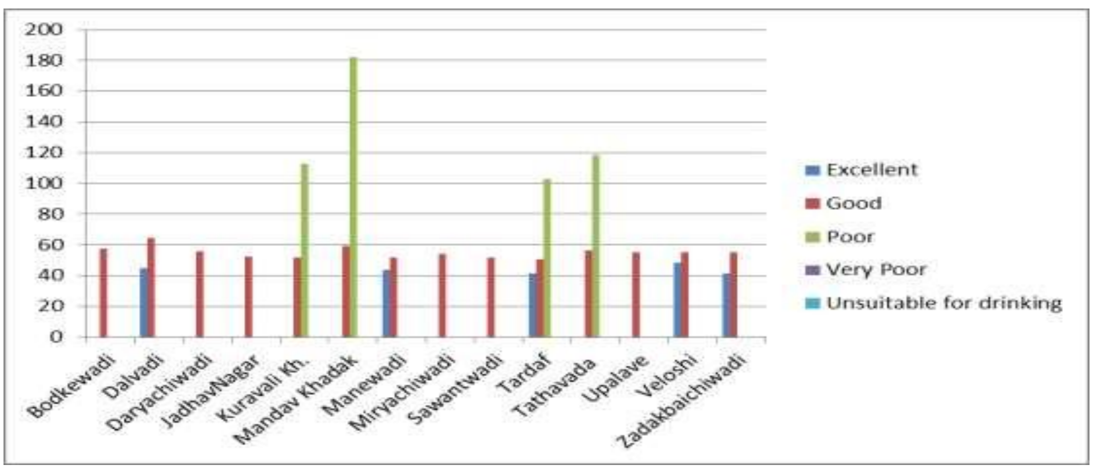


Figure 10a: Pre-project GWQI of villages in the study area

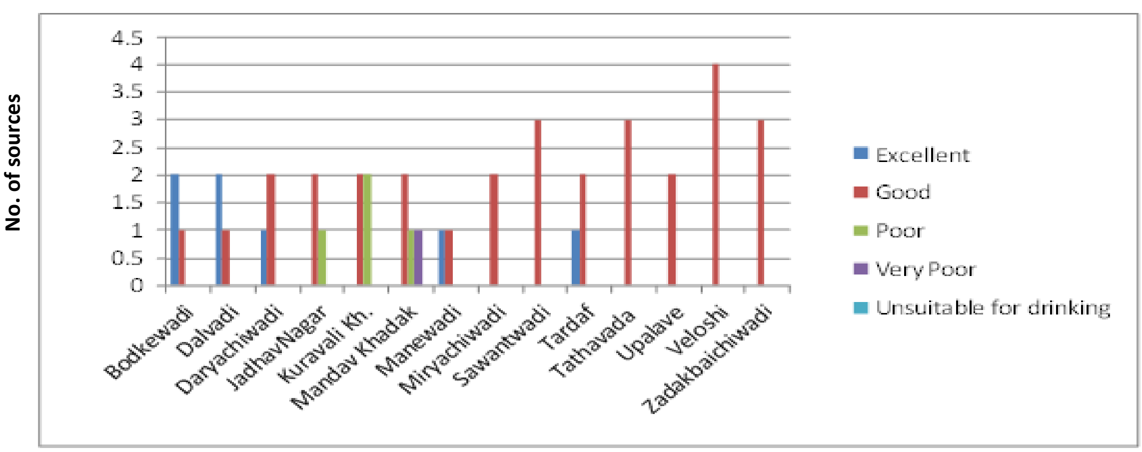
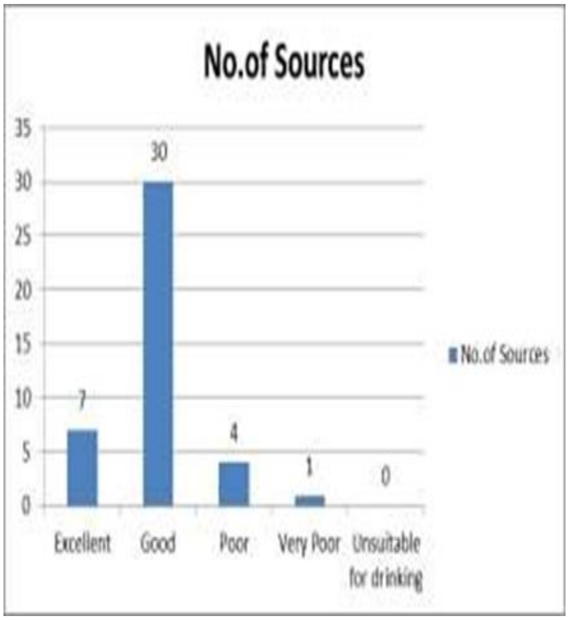


Figure 10b : Post-project GWQI of villages in the study area



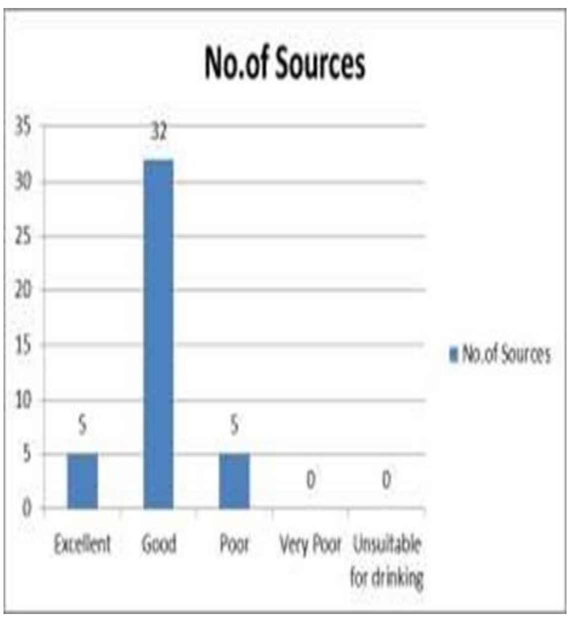


Figure 10c : GWQI of sources during Pre and Post-project period

While there is a marginal variation in the analyses pH and Fluoride, a considerable variation is noticed in the concentration of Nitrate, Iron, and Total Dissolved Solids. It is indicative of increased agricultural activity in the area. A word of caution is needed to protect the groundwater quality from the threat of land use activities. Subsequently, the awareness programs among the communities, through GWMA, is recommended for the proper remedial measures and opting organic fertilizers while farming.

Table 10: Concentration of major parameters analyzed for GWQI Parameter

	Concentration (mg/L)	
	Before project implementation	After project implementation
pH	7.2 to 7.9	6.9 to 8.4
TDS	298 to 1472	317 to 2022
Nitrate	8.24 to 91.61	0.00 to 220
Fluoride	0.01 to 1.24	0.00 to 1.07
Sulphate	0.05 to 16.23	1.00 to 18.00
Iron	0.01 to 1.2	0.00 to 0.71

Land use pattern:

The analysis of satellite imageries of pre-project and post-project scenario has been carried out to detect change in LULC pattern in the project area. The seven spectral classes assessed to examine the influence of project interventions on the compositional make-up of landscape pattern gives the understanding of the impacts (Table 11).

Table 11: Comparison of LULC dynamics of the study area

Sr. No.	Land use pattern	2014-15 (% area)	2019-20 (% area)	Difference %
1	Agriculture land (Irrigated crop land)	63.0	69.0	9.5
2	Agriculture land (Fallow Land)	0.0	0.0	0.0
3	Reserved Forest / Vegetation	4.8	4.1	-14.6
4	Built-Up Land	0.5	1.8	260.0
5	Water Bodies	3.8	4.3	13.2
6	Waste land (Land with scrub)	27.9	20.8	-25.4
7	Waste land (Land without scrub)	0.0	0.0	0.0
8	Total	100.0	100.0	

Figure 11: Land use & Land cover pattern in the project area

Community approach in the implementation of the project has its own fruitful significance. The IEC activities & strengthening of the villages through various capacity building activities are showing better results after the completion of physical project works. It can be deciphered that there has been a positive change and rise in the agriculture land area post year 2014-15 by 9.5 %. Also there has been rise in water bodies by 13.2 % in the project area. As the comparison of pre and post-project scene is of late rabi season, i.e. just before harvesting, a considerable change in the LULC pattern is noticed. Agricultural land, one of the major land cover classes of the area, shows a significant increase from 63% to 69%.Similar observation was recorded for water bodies which have increased from 3.8% to 4.3%. The waste land has decreased from 4.8% to 4.1%. Profound increase in the agricultural activity indicates a dependent relationship of socio-economic growth with greater availability of groundwater storage.The hike in the agriculture has been complemented with increase in adoption of micro- irrigation techniques. Such changes in LULC pattern are significant for the interpretation of project interventions and evaluating growth patterns.

XIII. IMPACT ASSESSMENT OF THE PROJECT

The implementation of Groundwater Management Action Plan (GWMAP) has shown several benefits. The study has made greater availability of groundwater storage; solved the drinking water scarcity and ultimately resulted in social welfare. Table 12 summarizes the significance of each impact with respect to various indicators. The study as a whole has a positive environmental and socio-economic impact and renders the participatory groundwater management experience as pilot for implementing such plans in other areas. Moreover, the this study activities have ensured sustainability of groundwater resource and facilitated self- sustenance of the villages.

Table 12: Summary of impacts

Impact	Cause	Significance
Positive		
	Groundwater recharge increased by 162 Ham. The supply	
	side interventions of the study contributed 12 Ham	

Increase in groundwater availability	Additional groundwater recharge. Annual groundwater recharge from water harvesting structures increased from 11 Ham to 75 Ham. The net groundwater availability increased	Environmental
	by 154 Ham. The increase in groundwater storage facilitated in restoring recharge-discharge balance.	
Change stage in of groundwater development	The stage of groundwater development decreased from 112% to 89% after the project implementation. It has helped in bringing the area from over-exploited to semi- critical zone and release the restrictions imposed on groundwater development to a certain extent in the area.	Economic
Significant saturation of the aquifer	Pre and post-monsoon groundwater levels are raised by 8.5 m and 4.42 m respectively. The saturation has helped in sustaining the groundwater availability round the year.	Socio- economic
Normalized groundwater drought index	In year 2019-2020, all fourteen villages shows normalized Groundwater Drought Index. After completion of supply and demand side interventions, no drinking water scarcity was reported in year 2019-2020.	Environmental
Micro-irrigation practices	A positive attitude of farmers developed regarding conservation of groundwater resources for agriculture	Economic
increased	purpose. Micro-irrigated (drip) area increased by 20.66 ha.	
	Village community is aware and involved in optimized use	
Groundwater awareness in the community	of groundwater resources. Farmers adopting water saving techniques for irrigation purposes have increased. The cumulative effect of demand management and raised awareness resulted in reduced groundwater draft.	Socio- economic
Groundwater Quality Index	About 16.66% samples show excellent GWQI and 71.42% samples show good GWQI. Villages with high TDS are tackled by installing RO system to provide safe drinking	Socio- environmental
	water.	

XIV. CONCLUSIONS AND RECOMMENDATION

The Aquifer Delineation and Community based Groundwater Management project implemented in BAS-1/BAM 85 over-exploited mini-watershed of Satara district has showcased a good example of participatory groundwater management endeavor. The comprehensive GWMAP prepared with the help of community has proved beneficial in providing sustainable groundwater resource. Though the impact such as reversing the decline of water, changing the over exploited status to safe and elevating the socio-economic status require substantial time span to produce desired results, positive changes noticed in some of the key indicators shows required drift in the participatory groundwater management process. The project activities have been profound enough to make an impact based on technical indicators which satisfy the above criteria. Thus, the main objective of this impact assessment study is to evaluate the Aquifer Level Groundwater Management Initiatives based on tangible and intangible benefits of various components implemented in line with the above mentioned objectives of the project. The supply side interventions helped in increasing the groundwater storage by 12 Ham. Moreover, the pre and post-monsoon groundwater levels are significantly raised by 0.76 m and 0.38 m respectively. Community awareness on judicious use of groundwater resource has resulted into adoption of micro-irrigation practices on total 71.04 ha agricultural land. The over-exploited state (112%) of the area has now approached semi-critical stage (89%). The villages show normalized groundwater drought index and no drinking water scarcity reported in year 2019-20. Conclusively, the project is a good success as its appraisal through Impact Evaluation Index has attained the score 30 and renders it in “Very Good” performance category. The project has also shown moderate impact on groundwater quality as about 71.42% samples have shown good groundwater quality index, yet, parameters like Nitrogen, Chlorine, and Total Dissolved Solids show slight increased concentration. However, these impacts can be minimized and even eliminated if proper remedial measures are adopted through community awareness programs. There are few recommendations proposed to keep the aquifer in safe zone and in sustained state. Firstly, the operation and maintenance (O&M) of recharge structures must be done by GWMA and village community, preferably through beneficiary groups. It will help in contributing towards greater groundwater storage. The GWMA needs to make an annual action plan of O&M of all recharge structures. Furthermore, community has to diligently continue monitoring of groundwater levels and rainfall as per the prescribed schedule. Subsequently, GWMA should carry on planning of water resources through "Annual Water Budgeting" every year with necessary technical support from the Groundwater and Agriculture Departments.

The key to sustenance is strengthening the awareness and knowledge of groundwater resource. Therefore, water accounting activity shall empower them to enhance the decision making ability and foresightedness. Accordingly, community awareness programs at periodic intervals are recommended to motivate and adopt best practices. This scientific project blended with participatory approach has paved the way for future practices with recommended strategies in other regions to efficiently manage groundwater resources.

ACKNOWELDEMENT

The author is thankful to anonymous reviewers for their constructive feedback on an earlier draft. We acknowledge the Groundwater Surveys and Development Agency, department for granting access facilities and archives.

REFERENCES

[1] APHA (American Public Health Association) Standard method for examination of water and wastewater, NW, DC 20036, 1994.

[2] BISIS 15792 (2008) Artificial recharge to groundwater: guidelines. Bureau of Indian Standards, New Delhi.

[3] BIS (Bureau of Indian Standard) (2012) 10500, Indian standard drinking water specification, Second revision.

[4] Bhusari, V., Katpatal, Y.B. & Kundal, P. An innovative artificial recharge system to enhance groundwater storage in basaltic terrain: example from Maharashtra, India. Hydrogeol J 24, 1273–1286 (2016). https://doi.org/10.1007/s10040-016-1387-x.

[5] Bhusari, V., Katpatal, Y.B. & Kundal, P. Performance evaluation of a reverse-gradient artificial recharge system in basalt aquifers of Maharashtra, India. Hydrogeol J 25, 689–706 (2017). https://doi.org/10.1007/s10040-016-1499-3.

[6] Bouwer H, Rice RC (1976) A slug test method for determining hydraulic conductivity of unconfined aquifers with completely or partially penetrating wells. Water Resource Research, Vol. 12, No. 3, 423-428.

[7] Groundwater Estimation Committee (GEC), 2015. Detailed guidelines for implementing the groundwater methodology. Central Ground Water Board. Ministry of Water Resources. Government of India.

[8] CGWB (2000) Master plan for artificial recharge to groundwater in Maharashtra. CGWB, Ministry of Water Resources, GoI, New Delhi.

[9] CGWB (1982) Manual of evaluation of aquifer parameters. CGWB, Ministry of Irrigation, GoI, New Delhi.

[10] CGWB (1986) Manual on analysis of pumping test data of large diameter wells. Technical Series M, CGWB, Ministry of Water Resources, GoI, New Delhi.

[11] David Keith Todd and Larry W. Mays Groundwater Hydrology, 3rd Edition, Wiley.

[12] G.G. Deshpande, June 1998, Geology of Maharashtra, 1st Edition, Geological Society of India.

[13] Department of Agriculture, Cooperation & Farmers Welfare Ministry of Agriculture & Farmers Welfare, Government of India, New Delhi, December 2016, Manual for Drought Management.

[14] Gao, B.C. 1996. NDWI: A normalized difference water index for remote sensing of

vegetation liquid water from space. Remote Sensing of Environment 58: 257-266.

[15] GSDA and CGWB (2012) Report on dynamic groundwater resources of Maharashtra as on March 2008. Groundwater Survey and Development Agency, Nagpur, India and CGWB, New Dehli.

[16] GSDA and CGWB (2016) Report on dynamic groundwater resources of Maharashtra as on March 2008. Groundwater Survey and Development Agency, Nagpur, India and CGWB, New Dehli.

[17] Groundwater Survey and Development Agency , Water Supply and Sanitation Department, Government of Maharashtra, Reference Book; https://gsda.maharashtra.gov.in

[18] Maharashtra Groundwater (Regulation of Drinking Water Purpose) Act, 1993 (II.4). No. XXVIII of 1993.

[19] Megha Shinde (Daga), Detail Hydrogeological Survey of Watershed MR-36A, Taluka-Umarga, District- Osmanabad, Maharashtra, India", International Journal of Science & Engineering Development Research (www.ijrti.org), ISSN: 2455-2631, Vol.8, Issue 5, page no.2102 - 2112, May 2023

[20] Megha Shinde (Daga), S.B. Gaikwad, Vijay Gendle, Quality Manual of District Water Testing Laboratory (DWTL) Osmanabad, Maharashtra, India Published in Volume 8 Issue 5, May-2023, IJNRD

[21] Megha Shinde (Daga), Chandrakant Bhoyar,Ramesh Gudepu, Brief Hydrogeological Studies of Watersehd MR03, (3/7), in Context of Groundwater Estimation, Washi, Osmanabad, Maharashtra, India, Int. Jour. of Inn. Sci. and Res. Tech., Vol8, Issue 1, Jan2023.

[22] Megha S Shinde, Prakash Bedse : A Paradigm of Water Conservation Excellence Kirkasal, Man, Satara, Maharashtra, India May 2025, International Journal of Science and Research (IJSR) 14(5):846-852

[23] Megha S. Shinde, Neilarmstrong M. Sayyed , Priyanka Thorat, November 2025 Comprehensive hydrogeological study of Katarkhatav Village of Satara Maharashtra, India, 2025 IJRTI | Volume 10, Issue 11

[24] Government of Maharashtra, July 2018, Maharashtra Groundwater (Development and Management) Act, 2009.

[25] Project Management Unit, Water Supply and Sanitation Department, Government of Maharashtra, October 2014, Jalswarajya - II Program Manual.

[26] Project Management Unit, Water Supply and Sanitation Department, Government of Maharashtra, October 2014, Environment Management Manual.

[27] Project Management Unit, Water Supply and Sanitation Department, Government of Maharashtra, October 2014, Community Operation Manual.

[28] Ramakrishnaiah, C. R., AU - Sadashivaiah, C.Ranganna, G.2009,1900/01/01, Assessment of Water Quality Index for the Groundwater in Tumkur Taluk, Karnataka State, India, E-Journal of Chemistry, 10.1155/2009/757424, https://doi.org/10.1155/2009/757424.

[29] Ramesh Gudepu, Megha Shinde (Daga) Udayalaxmi G Comprehensive hydrogeological Survey of Upper Sina River of (SA-2) in the in Ahmednagar District, Maharashtra, India, (IJERT), Vol. 12 Issue 04, April-2023

[30] Ramesh Gudepu, G. Udayalaxmi, Megha Shinde (Daga), Jan 2023, Spatial Subsurface apparent resistivity distribution using different current electrode (AB/2) configuration (VES) and GIS in the miniwatershed. Ahmednagar, Maharashtra, India, JETIR Vol-10, Iss-1 20.

[31] Rouse, J.W., Jr., R.H. Haas, J.A. Schell, and D.W. Deering. 1973. Monitoring the vernal advancement and retrogradation (green wave effect) of natural vegetation. Prog. Rep. RSC 1978-1, Remote Sensing Center, Texas A&M Univ., College Station, 93p. (NTIS No. E73-106393).

[32] Rouse, J. W., R. H. Haas, J. A. Schell, and D. W. Deering (1973) 'Monitoring vegetation systems in the Great Plains with ERTS', Third ERTS Symposium, NASA SP-351 I, 309- 317.

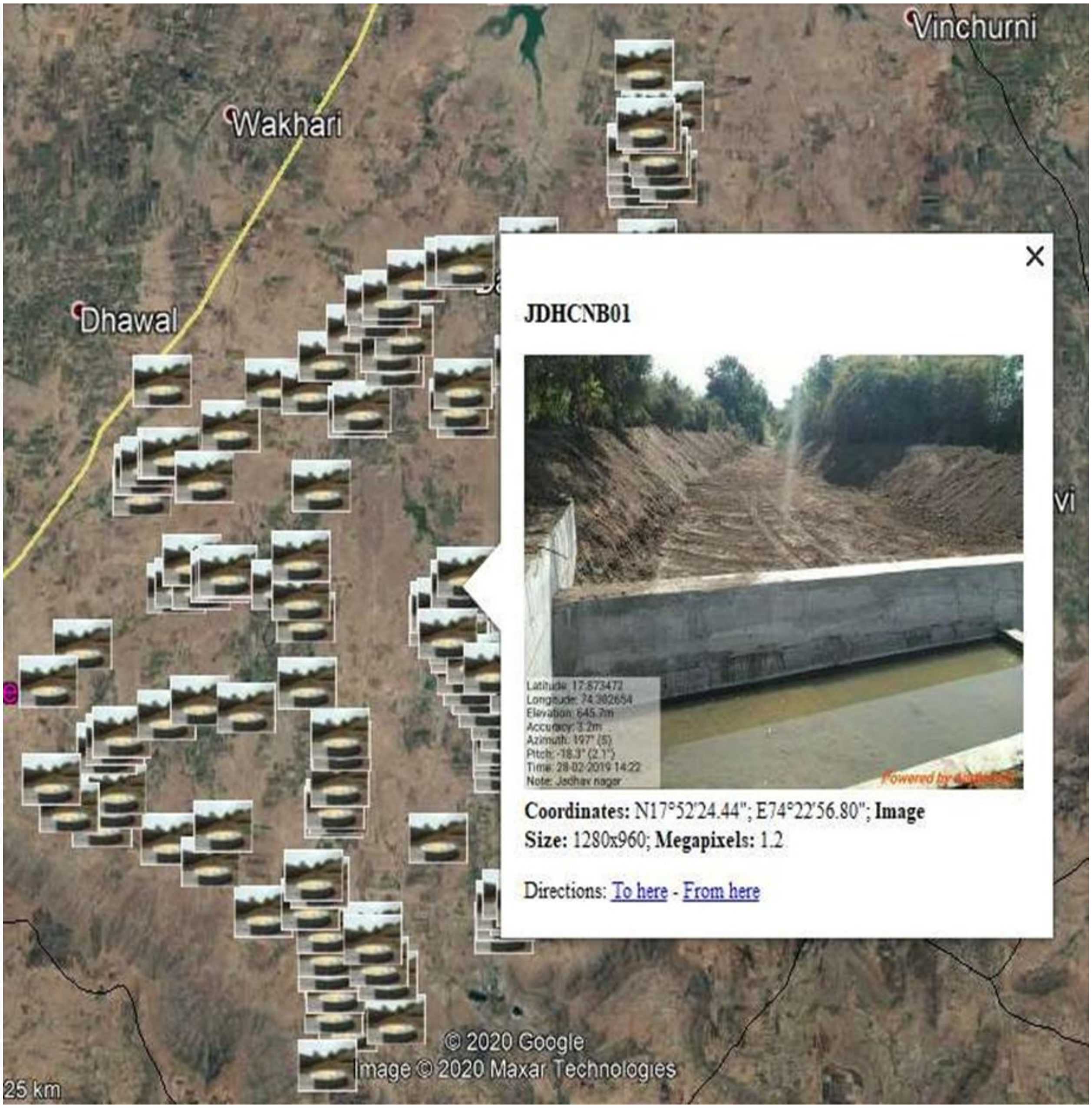
[33] WHO (World Health Organization) Guidelines for drinking water quality, 2nd Ed., 1993, Vol 1.

[34] World Meteorological Organization (WMO) and Global Water Partnership (GWP), 2016: Handbook of Drought Indicators and Indices

(M. Svoboda and B.A. Fuchs). Integrated Drought Management Programme (IDMP), Integrated Drought Management Tools and Guidelines Series 2. Geneva.

[35] Aquifer Maps and Groundwater Management Plan of Satara District, Maharashtra AAP 2019-20

Annexure 1: Geo tagged Map of Groundwater Recharge Structures



Annexure 2: Impact Evaluation Ranking Framework

Indicator	Categories	Value	Rank
(1) Change in groundwater level (m) (observed from average ground water level trend of October 2014 and 2019)	>3	High rise	5
	2-3	Moderate rise	4
	1- 2	Low to moderate rise	3
	Up to 1	Merge rise	2

	<0	No rise/depletion continued	1
(2) Groundwater Drought Index	>-0.15	Normal /No drought	5
	-0.16to-0.30	Mild drought	4
	-0.31to-0.45	Moderate drought	3
	-0.46to-0.60	Severe drought	2
	<-0.60	Extreme drought	1
(3) Decrease in groundwater draft (%) (observed from groundwater level trend from Oct to May 2014 and 2019)	80-100	Very high	5
	60-80	High	4
	40-60	Moderate	3
	20-40	Low	2
	0-20	Meagre	1
(4) Reduction in water supply by Tankers (%)	80-100	No Tanker	5
	60-80	High	4
	40-60	Moderate	3
	20-40	Low	2
	0-20	Meagre	1
(5) Community awareness on	Very good	All activities implemented	5
groundwater management	Good	Up to 80% activities	4
(based on number of stipulated	moderate	Up to 60% activities	3
demand side activities	Low	Up to 40% activities	2
implemented)	Very low	Up to20% activities	1
(6) Changes in micro irrigation (%)	>40	Very high	5
	30-40	High	4
	20-30	Moderate	3
	10-20	Low	2
	0-10	Marginal	1
(7) Stage of groundwater development %	<70	Safe	5
	70-90	Semi critical	4
	90-100	Critical	3
	100-110	Over exploited	2
	>110	Over exploited	1
(8) Overall Water Quality Index of the aquifer	<50	Excellent	5
	50-100	Good water	4
	100-200	Poor water	3
	200-300	Very poor water	2
	>300	Water unsuitable for drinking	1

Note: The highlighted values are of present study impact assessment.

Annexure 3: Groundwater Level Monitoring Records

Assessment Indicator 1: Change in groundwater level	
2014 - 15	
Definition:	
Annual change in groundwater table (m) =	[[Mean* annual ground water table depth during the current year (in m)] - [Mean* annual ground water table depth during the previous year (in m)]
Name of Aquifer:	BAS/BM-85/01
Name of GSDA Office submitting the data:	Office of Senior Geologist, GSDA, Satara
Record of Water Table Depth: Mean monthly values of water table, in meters, are calculated for each piezometer/observation well, from daily or less frequently collected values. Water table depth should be recorded in relation to an established datum, such as m below msl. Use the extra sheets for additional data.	

Observation well		Monsoon					Post-monsoon					Pre-monsoon					Avg. Depth
No.	Location	Jun	Jul	Aug	Sept	Avg. June to Sept	Oct	No v	Dec	J an	Avg. June to Sept	Feb	Mar	Apr	May	Avg. June to Sept	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Observation Well Records (Dug Wells / Open Wells)																	
1	Bodakewadi OBW-01	10.60	9.80	7.60	5.30	8.33	4.00	4.30	4.80	7.20	5.08	7.40	8.20	8.80	11.30	8.93	7.44
2	Bodakewadi OBW-02	9.50	8.70	6.70	4.70	7.40	3.80	4.10	5.20	7.60	5.18	8.60	8.80	9.30	9.80	9.13	7.23
3	Dalvadi OBW-01	10.00	9.10	7.10	5.00	7.80	3.00	3.20	4.30	5.60	4.03	6.60	8.20	10.00	10.30	8.78	6.87
4	Dalvadi OBW-02	11.00	10.00	7.80	5.50	8.58	4.10	4.30	5.20	7.10	5.18	8.20	10.20	11.80	12.60	10.70	8.15
5	Daryachiwadi OBW -01	13.80	12.60	9.80	6.80	10.75	4.60	3.50	4.80	7.00	4.98	8.60	10.20	11.60	13.80	11.05	8.93
6	Daryachiwadi OBW-02	13.90	13.00	10.00	7.00	10.98	4.00	4.20	6.30	8.20	5.68	10.20	10.80	12.40	14.00	11.85	9.50
7	Jadhav Nagar OBW -01	12.20	11.80	10.10	7.10	10.30	4.30	4.50	4.90	7.40	5.28	8.20	10.80	11.40	12.60	10.75	8.78
8	Jadhav Nagar OBW-02	8.80	8.20	7.40	5.20	7.40	4.10	4.30	4.40	4.60	4.35	6.50	8.00	8.30	8.80	7.90	6.55
9	Kurvali Kh OBW-01	12.20	11.30	8.80	6.20	9.63	5.10	5.40	5.90	7.50	5.98	8.20	8.80	10.20	12.40	9.90	8.50
10	Kurvali Kh OBW-02	11.50	10.10	8.30	5.60	8.88	4.30	4.10	4.70	5.60	4.68	7.50	6.20	8.30	11.40	8.35	7.30
11	Mandav Khadak OBW-01	8.60	7.20	6.40	5.20	6.85	1.40	2.50	3.70	6.80	3.60	6.60	7.20	7.80	8.80	7.60	6.02
12	Mandav Khadak OBW-02	10.60	7.80	6.00	4.20	7.15	4.00	4.40	4.80	5.80	4.75	7.50	8.60	9.40	10.80	9.08	6.99
13	Manewadi OBW-01	17.00	15.80	12.30	8.60	13.43	6.20	6.40	8.40	9.60	7.65	10.80	12.30	14.90	17.30	13.83	11.63
14	Manewadi OBW-02	10.90	10.10	7.90	5.50	8.60	3.50	3.70	4.30	6.10	4.40	7.60	8.60	9.10	11.10	9.10	7.37
15	Miryachiwadi OBW-01	8.00	7.20	6.70	4.70	6.65	3.10	3.20	4.20	4.70	3.80	6.00	7.40	7.60	8.00	7.25	5.90
16	Miryachiwadi OBW-02	9.20	8.20	6.40	4.50	7.08	4.10	3.90	4.60	5.20	4.45	7.20	7.60	7.90	9.00	7.93	6.48
17	Sawantwadi OBW-01	11.80	10.10	8.50	6.00	9.10	4.60	4.40	4.80	5.50	4.83	7.70	8.40	10.40	12.00	9.63	7.85
18	Sawantwadi OBW-02	12.70	11.80	9.10	6.40	10.00	5.10	5.40	6.30	7.10	5.98	8.40	10.80	11.60	12.90	10.93	8.97
19	Tardaf OBW -01	10.40	9.70	7.50	5.30	8.23	4.20	4.00	4.60	6.10	4.73	7.60	8.80	9.20	10.60	9.05	7.33
20	Tardaf OBW -02	8.30	7.80	6.00	4.20	6.58	3.80	3.90	4.30	5.70	4.43	7.10	7.60	8.00	8.30	7.75	6.25
21	Tathawada OBW-01	10.30	9.20	8.00	5.60	8.28	3.20	3.40	5.20	6.20	4.50	8.20	8.60	9.60	10.50	9.23	7.33

22	Tathawada OBW-02	9.80	8.70	6.70	4.70	7.48	3.70	3.60	4.30	4.90	4.13	6.10	7.40	8.20	9.50	7.80	6.47
23	Upalawe OBW-01	11.40	10.60	8.20	5.80	9.00	3.90	4.10	5.20	6.30	4.88	8.40	9.20	10.10	11.60	9.83	7.90
24	Upalawe OBW-02	9.70	9.00	7.00	4.90	7.65	4.10	4.00	4.90	5.40	4.60	6.00	11.30	12.30	9.90	9.88	7.38
25	Veloshi OBW-01	9.40	8.80	6.80	4.80	7.45	3.20	3.10	3.70	4.80	3.70	5.40	6.20	7.40	9.60	7.15	6.10
26	Veloshi OBW-02	11.70	10.90	8.40	5.90	9.23	4.70	4.70	5.40	6.60	5.35	7.60	7.30	8.80	11.90	8.90	7.83
27	Zadakbaichiwadi OBW-01	11.20	9.60	7.40	5.20	8.35	3.70	3.60	4.30	4.90	4.13	5.60	7.20	8.70	10.50	8.00	6.83
28	Zadakbaichiwadi OBW -02	10.60	11.80	9.90	6.90	9.80	3.20	3.60	4.30	5.80	4.23	7.20	8.60	9.80	10.80	9.10	7.71
Average Depth (m)		10.90	9.96	7.96	5.60	8.60	3.96	4.06	4.92	6.26	4.80	7.54	8.69	9.75	11.08	9.26	7.56

Change in Groundwater Table	Pre-monsoon	Post-monsoon
Mean* annual ground water table depth during the current year (in m) (A)	9.26	4.80
Mean* annual ground water table depth during the previous year (in m) (B)	NA	NA
Annual Change in Groundwater Table in (m) = (A) – (B)	NA	NA

Assessment Indicator 1: Change in groundwater level

2019 - 20

Definition:

Annual change in groundwater table (m) =	[[Mean* annual ground water table depth during the current year (in m)] - [Mean* annual ground water table depth during the previous year (in m)]
Name of Aquifer:	BAS/BM-85/01
Name of GSDA Office submitting the data:	Office of Senior Geologist, GSDA, Satara

Record of Water Table Depth: Mean monthly values of water table, in meters, are calculated for each piezometer/observation well, from daily or less frequently collected values. Water table depth should be recorded in relation to an established datum, such as m below msl.

Use the extra sheets for additional data.

Observation well		Monsoon					Post-monsoon					Pre-monsoon					Avg. Depth
No.	Location	Jun	Jul	Aug	Sept	Avg. June to Sept	Oct	No v	Dec	J an	Avg. June to Sept	Feb	Mar	Apr	May	Avg. June to Sept	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Observation Well Records (Dug Wells / Open Wells)																	
1	Bodakewadi OBW-01	9.10	7.40	6.10	2.90	6.38	1.20	3.50	3.70	4.10	3.13	4.40	5.30	6.30	7.50	5.88	5.13
2	Bodakewadi OBW-02	8.80	6.40	5.60	5.50	6.58	2.20	3.40	6.70	6.90	4.80	7.50	8.10	9.60	9.90	8.78	6.72
3	Dalvadi OBW-01	10.10	8.20	7.10	4.70	7.53	1.50	3.50	5.30	5.70	4.00	6.10	7.40	8.10	9.50	7.78	6.43
4	Dalvadi OBW-02	11.20	7.30	6.20	3.30	7.00	1.30	3.60	5.50	5.70	4.03	8.20	10.20	12.40	12.60	10.85	7.29
5	Daryachiwadi OBW -01	13.50	9.30	7.40	5.80	9.00	1.70	4.50	6.90	7.30	5.10	8.10	8.80	9.20	10.20	9.08	7.73
6	Daryachiwadi OBW-02	10.70	8.10	7.70	6.90	8.35	3.40	5.20	8.50	8.70	6.45	8.80	8.70	9.60	10.60	9.43	8.08

7	Jadhav Nagar OBW - 01	11.20	7.10	6.40	4.20	7.23	1.20	4.30	6.20	6.90	4.65	7.40	8.40	9.80	10.80	9.10	6.99
8	Jadhav Nagar OBW-02	8.20	6.30	5.50	3.20	5.80	1.10	3.50	4.50	4.70	3.45	5.10	8.30	7.10	8.50	7.25	5.50
9	Kurvali Kh OBW-01	12.40	10.00	6.70	5.70	8.70	3.80	5.00	7.70	7.90	6.10	8.30	9.80	11.20	12.20	10.38	8.39
10	Kurvali Kh OBW-02	9.80	6.10	5.40	4.80	6.53	1.30	3.60	6.00	6.40	4.33	7.30	8.30	9.10	10.80	8.88	6.58
11	Mandav Khadak OBW-01	10.00	6.20	5.80	5.50	6.88	2.00	4.50	6.40	7.60	5.13	8.00	8.60	9.40	10.40	9.10	7.03
12	Mandav Khadak OBW-02	9.70	7.30	6.10	4.90	7.00	1.30	5.50	6.60	6.80	5.05	7.40	9.40	9.50	10.50	9.20	7.08
13	Manewadi OBW-01	17.40	9.50	7.60	6.60	10.28	3.00	7.20	7.60	8.30	6.53	9.20	10.30	13.20	14.20	11.73	9.51
14	Manewadi OBW-02	9.80	6.20	5.20	3.60	6.20	1.60	4.10	4.30	4.60	3.65	5.10	7.40	8.10	9.10	7.43	5.76
15	Miryachiwadi OBW-01	6.40	4.80	3.70	2.10	4.25	1.50	2.40	2.60	2.80	2.33	3.60	4.80	6.50	7.50	5.60	4.06
16	Miryachiwadi OBW-02	9.20	6.70	4.30	3.00	5.80	1.30	4.30	6.40	7.10	4.78	8.10	9.40	10.30	10.50	9.58	6.72
17	Sawantwadi OBW-01	10.70	8.30	6.10	3.50	7.15	1.50	4.60	4.90	5.10	4.03	6.80	7.40	8.30	10.30	8.20	6.46
18	Sawantwadi OBW-02	10.40	5.00	3.90	2.30	5.40	1.60	4.20	4.60	4.80	3.80	6.10	6.50	8.20	9.50	7.58	5.59
19	Tardaf OBW -01	9.00	6.70	5.10	2.10	5.73	2.10	3.40	4.10	5.40	3.75	7.60	9.40	10.30	11.30	9.65	6.38
20	Tardaf OBW -02	8.30	5.00	3.20	2.30	4.70	2.20	4.60	5.00	5.20	4.25	6.00	7.10	7.60	8.50	7.30	5.42
21	Tathawada OBW-01	9.40	6.40	5.20	4.70	6.43	1.80	4.50	5.90	6.30	4.63	6.90	7.60	8.40	8.60	7.88	6.31
22	Tathawada OBW-02	10.80	5.60	4.60	3.90	6.23	2.40	5.20	5.90	6.80	5.08	7.10	8.40	10.50	10.60	9.15	6.82
23	Upalawe OBW-01	12.40	7.60	5.40	2.10	6.88	1.30	2.60	2.90	3.40	2.55	4.70	5.10	6.10	7.10	5.75	5.06
24	Upalawe OBW-02	11.60	8.10	6.00	2.30	7.00	1.20	3.90	7.50	7.70	5.08	10.30	10.80	11.40	11.50	11.00	7.69
25	Veloshi OBW-01	8.70	7.10	2.10	1.70	4.90	1.20	3.00	3.30	3.40	2.73	4.30	5.50	6.80	8.00	6.15	4.59
26	Veloshi OBW-02	13.00	8.20	7.20	5.40	8.45	3.20	5.50	6.40	7.00	5.53	7.60	8.10	8.90	9.90	8.63	7.53
27	Zadakbaichiwadi OBW-01	13.10	7.00	4.10	1.50	6.43	1.20	4.80	7.00	7.20	5.05	7.50	8.40	9.30	10.30	8.88	6.78
28	Zadakbaichiwadi OBW -02	9.60	5.00	4.20	2.70	5.38	1.20	4.30	4.60	4.80	3.73	6.30	6.80	8.60	9.60	7.83	5.64
Average Depth (m)		10.52	7.03	5.50	3.83	6.72	1.80	4.24	5.61	6.02	4.42	6.92	8.01	9.06	10.00	8.50	6.54
Change in Groundwater Table													Pre-monsoon			Post-monsoon	
Mean* annual ground water table depth during the current year (in m) (A)													8.50			4.42	
Mean* annual ground water table depth during the previous year (in m) (B)													8.91			4.90	
Annual Change in Groundwater Table in (m) = (A) – (B)													-0.407142857			-0.488392857	

Annexure 4: Computation of GWDI

The formula used for computing GWDI:
The rate of depletion of groundwater table is useful for making an assessment of groundwater availability for agriculture and drinking water supply purposes. The monthly groundwater (GW) table records are required for a minimum period of 10 years for computation of mean value of monthly ground water depletion rate. When rate of depletion of groundwater table in a given month/period is more than the corresponding mean value then it is an indication of water deficit. The computation procedure for Ground Water.
Drought Index (GWDI) is as follows:
GWDIij= (MGWD j - GWD ij)/ (GWD imax)
Where,
GWDIij = Groundwater Drought Index for ith month and jth year. MGWDj = Mean depth to groundwater table below surface (in meter) GWDij = Depth to groundwater table in ith month and jth year (in meter). GWDimax = Max depth to groundwater table in ith month in available data set for n number years (in m).
i = 1, 2, 3, 4,... , 12.
j = 1, 2, 3,.., n.
n = total numbers of years for which monthly groundwater records are used.

Groundwater Drought Index (GWDI) Groundwater deficit class

Sr. No.	Class	Categories
1	> -0.15	Normal
2	-0.16 to -0.30	Mild
3	-0.31 to -0.45	Moderate
4	-0.46 to -0.60	Severe
5	< -0.60	Extreme

Assessment Indicator-2: Groundwater Drought Index (GWDI) - 2014-15

Name of Aquifer - BAS/BM-85/01

Taluka - Phaltan,

District - Satara

	2014-15					
Village Name	October water level	January water level	March water level	May water level	Mean	Maximum
Bodkewadi	4.00	7.20	8.20	11.30	7.68	11.30
Dalvadi	3.00	5.60	8.20	10.30	6.78	10.30
Daryachiwadi	4.60	7.00	10.20	13.80	8.90	13.80
Jadhav Nagar	4.30	7.40	10.80	12.60	8.78	12.60
Kurvali Kh	5.10	7.50	8.80	12.40	8.45	12.40
Mandav Khadak	1.40	6.80	7.20	8.80	6.05	8.80
Manewadi	6.20	9.60	12.30	17.30	11.35	17.30
Miryachiwadi	3.10	4.70	7.40	8.00	5.80	8.00
Sawantwadi	4.60	5.50	8.40	12.00	7.63	12.00
Tardaf	4.20	6.10	8.80	10.60	7.43	10.60
Tathawada	3.20	6.20	8.60	10.50	7.13	10.50
Upalawe	4.10	5.40	11.30	9.90	7.68	11.30
Veloshi	3.20	4.80	6.20	9.60	5.95	9.60
Zadakbaichiwadi	3.70	4.90	7.20	10.50	6.58	10.50

Village Name	GWDI 2014-15			
	GWDI Oct	GWDI Jan	GWDI Mar	GWDI May
Bodkewadi	0.33	0.04	-0.05	-0.32
Dalvadi	0.37	0.11	-0.14	-0.34
Daryachiwadi	0.31	0.14	-0.09	-0.36
Jadhav Nagar	0.36	0.11	-0.16	-0.30
Kurvali Kh	0.27	0.08	-0.03	-0.32

Mandav Khadak	0.53	-0.09	-0.13	-0.31
Manewadi	0.30	0.10	-0.05	-0.34
Miryachiwadi	0.34	0.14	-0.20	-0.28
Sawantwadi	0.25	0.18	-0.06	-0.36
Tardaf	0.30	0.13	-0.13	-0.30
Tathawada	0.37	0.09	-0.14	-0.32
Upalawe	0.32	0.20	-0.32	-0.20
Veloshi	0.29	0.12	-0.03	-0.38
Zadakbaichiwadi	0.27	0.16	-0.06	-0.37

Assessment Indicator-2: Groundwater Drought Index (GWDI) 2019-20

Name of Aquifer - BAS/BM-85/01 Taluka - Phaltan, District - Satara

	2019-20					
Village Name	October water level	January water level	March water level	May water level	Mean	Maximum
Bodkewadi	2.90	4.10	5.30	7.30	4.90	7.30
Dalvadi	4.70	5.70	7.40	9.10	6.73	9.10
Daryachiwadi	5.90	7.30	8.80	10.20	8.05	10.20
Jadhav Nagar	4.30	6.90	8.40	10.80	7.60	10.80
Kurvali Kh	5.80	7.90	9.80	12.20	8.93	12.20
Mandav Khadak	5.60	7.60	8.60	10.40	8.05	10.40
Manewadi	6.60	8.30	10.30	14.20	9.85	14.20
Miryachiwadi	2.30	2.80	4.80	7.50	4.35	7.50
Sawantwadi	3.60	5.10	7.40	10.30	6.60	10.30
Tardaf	2.10	5.40	9.40	11.30	7.05	11.30
Tathawada	4.80	6.30	7.60	8.60	6.83	8.60
Upalawe	2.30	3.40	5.10	7.10	4.48	7.10
Veloshi	1.90	3.40	5.50	7.80	4.65	7.80
Zadakbaichiwadi	1.70	7.20	8.40	10.30	6.90	10.30

Village Name	GWDI 2019-20			
	GWDI Oct	GWDI Jan	GWDI Mar	GWDI May
Bodkewadi	0.27	0.11	-0.05	-0.33
Dalvadi	0.22	0.11	-0.07	-0.26
Daryachiwadi	0.21	0.07	-0.07	-0.21
Jadhav Nagar	0.31	0.06	-0.07	-0.30
Kurvali Kh	0.26	0.08	-0.07	-0.27
Mandav Khadak	0.24	0.04	-0.05	-0.23
Manewadi	0.23	0.11	-0.03	-0.31
Miryachiwadi	0.27	0.21	-0.06	-0.42
Sawantwadi	0.29	0.15	-0.08	-0.36
Tardaf	0.44	0.15	-0.21	-0.38
Tathawada	0.24	0.06	-0.09	-0.21
Upalawe	0.31	0.15	-0.09	-0.37
Veloshi	0.35	0.16	-0.11	-0.40
Zadakbaichiwadi	0.50	-0.03	-0.15	-0.33

Annexure 5: Groundwater Recharge Structures in the Study Area

Assessment Indicator 3: Increase in total recharge capacity					
	Aquifer No: BAS/BM-85/01		Block: Phaltan	District: Satara	
A: Details of recharge structures implemented under Jalswarajya-II Program					
Sr. no.	Type of Structure	Total No.	Total Capacity in Ham	Total storage Capacity in Ham	Total Estimated Groundwater
1	Recharge Trench with shafts	66	0.02	1.32	1.98
2	Recharge Shafts	102	0.01	1.02	2.04
3	Recharge Trenches	0	0	0	0
4	Gabion Bandhara	0	0	0	0
5	Cement Nala weirs	4	2	8	8
6	Under Ground Bandhara	0	0	0	0
7	Water Absorption trenches	0	0	0	0
8	Well Flooding	0	0	0	0
	Total	172	2.03	10.34	12.02
B: Details of recharge structures implemented under Other Schemes					
Sr. no.	Type of Structure	Total No.	Total Capacity in Ham	Total storage Capacity in Ham	Total Estimated Groundwater Recharge in Ham (Gross Storage x No. of fillings x Recharge factor)
1	Recharge Trench with shafts	0	0	0	0
2	Recharge Shafts	33	0.01	0.33	0.66
3	Recharge Trenches	0	0	0	0
4	Gabion Bandhara	0	0	0	0
5	Cement Nala weirs	118	2	236	236
6	Under Ground Bandhara	0	0	0	0
7	Water Absorption trenches	0	0	0	0
8	Farm Pond	70	0.05	3.5	0.875
9	Percolation Tank	40	0.6	24	28.8
10	Earthern Nalla Band	229	0.1	22.9	22.9
11	Well Flooding	0	0	0	0
	Total	490	2.76	286.73	289.2
C: Total recharge structures in the Aquifer Area					
Sr. no.	Type of Structure	Total No.		Total Capacity in Ham	Total Estimated Groundwater Recharge in Ham
A	Total structures under JS-II	172		10.34	12.0
B	Total structures by other schemes	490		286.73	289.2

C	Area (A+B)	662		297.07	301.3
D	Total	662		297.07	301

ACRONYMS AND ABBREVIATIONS

DTC	: District Technical Committee
FCC	: False Color Composite
Fig.	: Figure
GSDA	: Groundwater Surveys and Development Agency
GPLC	: Gram Panchayat Level Committee
GWMA	: Groundwater Management Association
GWMAP	: Groundwater Management Action Plan
GWDI	: Groundwater Drought Index
GWQI	: Groundwater Quality Index
ha	: Hectare
Ham	: Hectare Meter
IEC	: Information, Education and Communication
lpm	: liters per minute
LULC	: Land Use Land Cover
m bgl	: Meter below Ground Level
Mg/L	: Milligrams per Litter
NDVI	: Normalised Difference Vegetation Index
NDWI	: Normalised Difference Water Index
NRSC	: National Remote Sensing Centre
O & M	: Operation and Maintenance
RO	: Reverse Osmosis
SHG	: Self-help Group
SO	: Support Organization
TSG	: Technical Support Group
VWSC	: Village Water and Sanitation Committee
WCS	: Water Conservation Structure
WTF	: Water Table Fluctuation

PLATE 1: FIELD PHOTOGRAPHS OF THE SUPPLY SIDE INTEREVENTION STUDY

PLATE 2: FIELD PHOTOGRAPHS OF THE IEC PROGRAMME IN VILLAGE COMMUNITY