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Use of GIS and Electrical Resistivity Survey to Assess the Rainwater Harvesting Potential Carried in the Wadala Village Region of North Solapur Taluka, Solapur District for Watershed Management of the Region

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Abstract

In watershed management, rainwater is the only source which needs to be conserved and collected from the open sources. The other way of collection is in the form of groundwater i.e. Aquifer. Solapur district receives average rainfall and the present selected study area receives poor rainfall, i.e., 534 mm. This village forms the major developed region in North Solapur, but due to high irrigation in the region over-exploitation has taken place which has depleted the groundwater of the region. Population of the Wadala is 5000, whereas house holdings are 1000. To improve the economic status of the region, the people's participation has created a miraculous change in the region by help of Pani Foundation and Jalyukt Shivar Program. To assess the area's water potential growth, the studies were carried and it has given a wide justice to state that the work done in the region is appropriate. For assessment of the water potential after the programs, use of GIS and geophysical studies has been carried out in the region to map the surface water regions as well as groundwater level. The area possesses percolation tanks, continuous contour trench (CCT), farm ponds and Nala deepening activities. The thematic maps have helped to understand the harvesting structures, and that has helped to conserve the surface water into sub-surface water bodies in the water depleted region.

Keywords: Rain water harvesting, groundwater, RS and GIS, Solapur

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INTRODUCTION

Water is considered as the most essential necessity for the living organisms in our society [1]. So, considering the present scenario of over-exploitation, this water needs to be conserved for future generation, which in turn will help in food, environmental conservation and sustainable development of the future generations too. A watershed is described as a geo-hydrological unit that has a network of drains that reach a common location [2–4]. Every land area on Earth is a portion of a watershed. The Wadala village watershed from North Solapur Tehsil of Solapur District was one of the first to be designated as a watershed for the village development. The Wadala watershed's implementation by the Grampanchayat and the involvement of the public, in the 2019, Pani Foundation and Jalyukt Shivar Program are two other significant factors that were taken into consideration

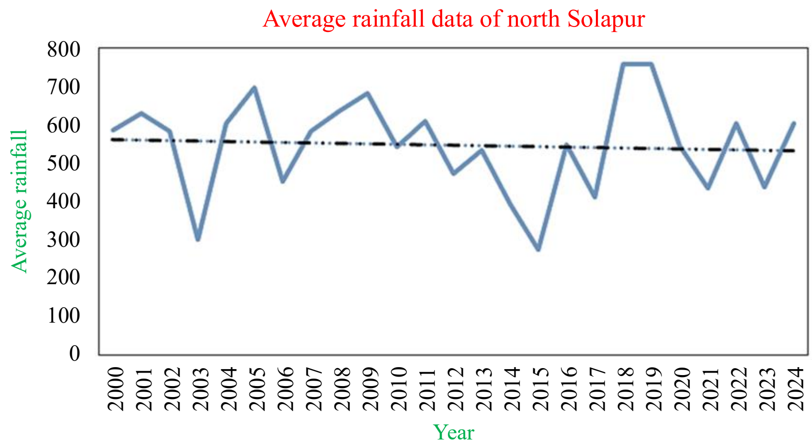

Figure 1. Average annual rainfall of Wadala region (2000–2024).

while choosing it for the research. In addition to the Grampanchayat office's records and reports, the village committee's records provided the project specifics. Interviews were used to gather information from the recipients, plan the program, and determine the resulting benefits in order to gauge the program's effect on the community and its stakeholders. Geophysical and RS-GIS research have also been used as the foundation for scientific evaluation [5–7].

The problem statement raised due to Wadala region being a drought area and water availability in this area is less. The region receives varying rainfall data, i.e., in 2015 273 mm and in 2014 602 mm. Overall the 24 years rainfall data has been analyzed for the present study area which shows a falling trend (Figure 1).

OBJECTIVES

The objectives of the present project are:

1. To locate the water conservation structures,
2. To determine the overall and particular watershed structure's capacity to store water, and
3. To plan and calculate the structure of the watershed [1, 2, 5–7].

STUDY AREA

Wadala village in North Solapur tehsil, Maharashtra, India, is the study area. It includes the nearby villages of Gawadi Darphal, Ranmasle, Nannaj, and Vangi, as well as the odhas of Telelavan, Lendi, and Asar. It is 25 km away from the city of Solapur. On the 1:50000 scale, it is situated between North latitudes 17052′00″ and 17054′00″ and East longitudes 75049′00″ and 75051′00″. Its area is 16.5 km^2 and is shown on the Toposheet No. 47O/13 or Open Series Map No. E43P13 survey of India. There is an average rainfall of 538 mm (Figure 2). The salient features of the Wadala village are tabulated in Table 1.

MATERIALS AND METHODS

The research region is located in Toposheet No. 47 O/13 of the Geological Survey of India (GSI) and Open Series Map No. E43P13 or Toposheet No. 47O/13. The toposheets have a contour spacing of 20 m and a scale of 1:50000. Images have been classified using Erdas Imagine (2011) [3, 8, 9]. Raster and vector-based analyses, including Map Overlay, Proximity Analysis, Local and Zonal Function, and the creation of Raster Stream Network and Stream Order maps, are possible with ArcGIS Desktop 10.0. Sentinel images (January 2024) with a resolution of 10 m, carto-DEM (resolution 30 m), geological maps, contour maps, rainfall data, etc. are among the datasets employed in the current study. For the watershed's accountability, the measurements pertaining to the CCT, percolation tanks, gabions, and nala deepening are used to determine the rainfall and collected volume (Figure 3) [10]. The actual water quantity will be determined in relation to the precipitation during the winter and summer seasons using geophysical data, and the ground water recharge will be presented using GIS (Figure 4).

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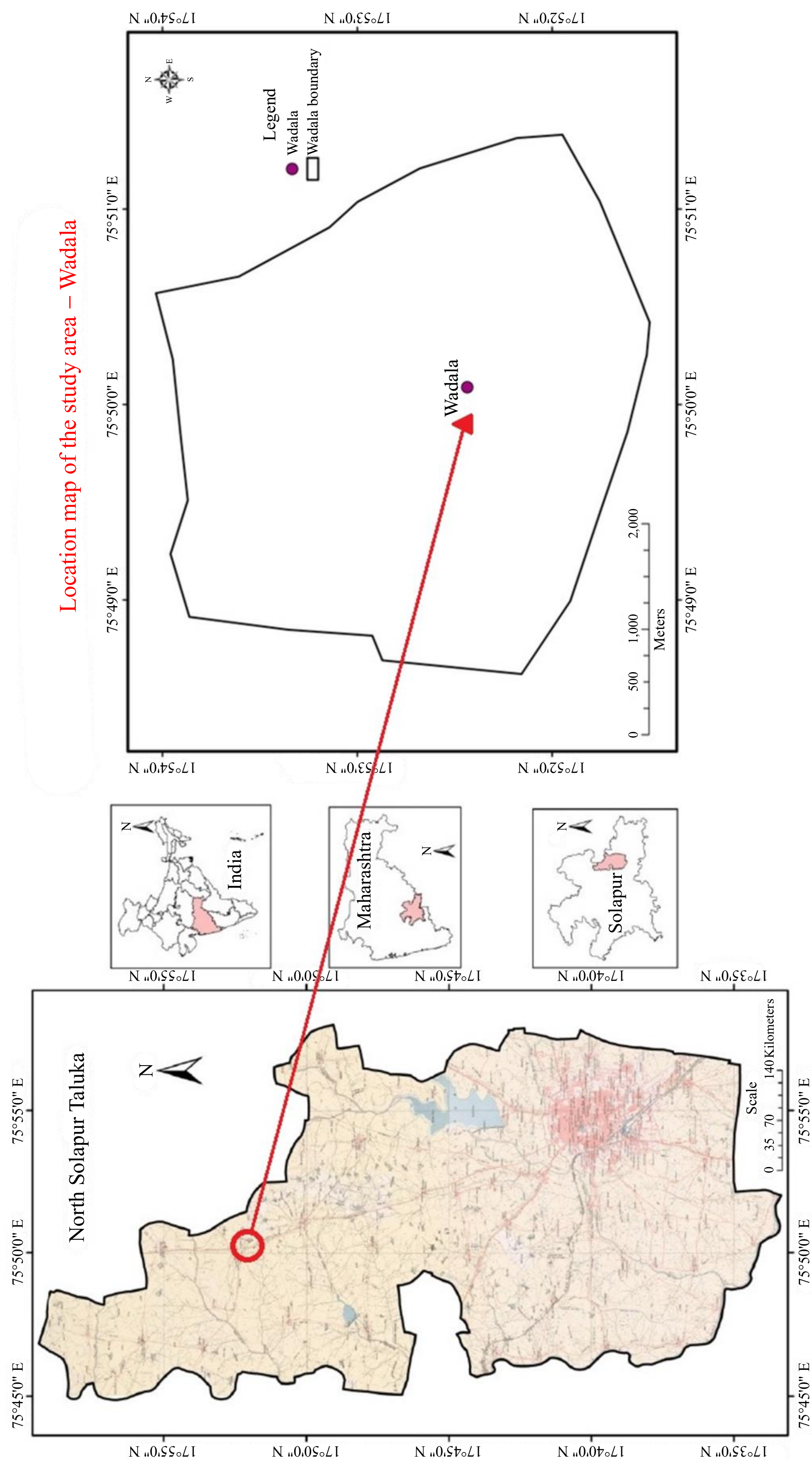


Figure 2. Location map of the study region.

Table 1. General information of wadala village.

S.N.	Description	Area
1	Village topographic area	1653.81 ha
2	Area under flow	1165 ha
3	Horticulture area	75 ha
4	Cultivated area	1090 ha
5	Fallow area	232.13 ha
6	Population	5144
7	Average rainfall	538 mm
8	Number of wells	201
9	No. of drilling wells	47
10	Runoff from rain	8897.5 TCM
11	Water requirement for village	7488.88 TCM
12	Water interruption due to previous and new proposed work	870.55 TCM
13	Total area under crop cultivation	1512.10 ha
14	Average area under kharif season crop	451 ha
15	Average area under rabi season crop	999.5 ha
16	Crop area under drip irrigation	87 ha
17	Sugarcane crop area under drip irrigation	18 ha
18	Area below orchard	40.40 ha
19	Farm ponds under national orchar scheme	1

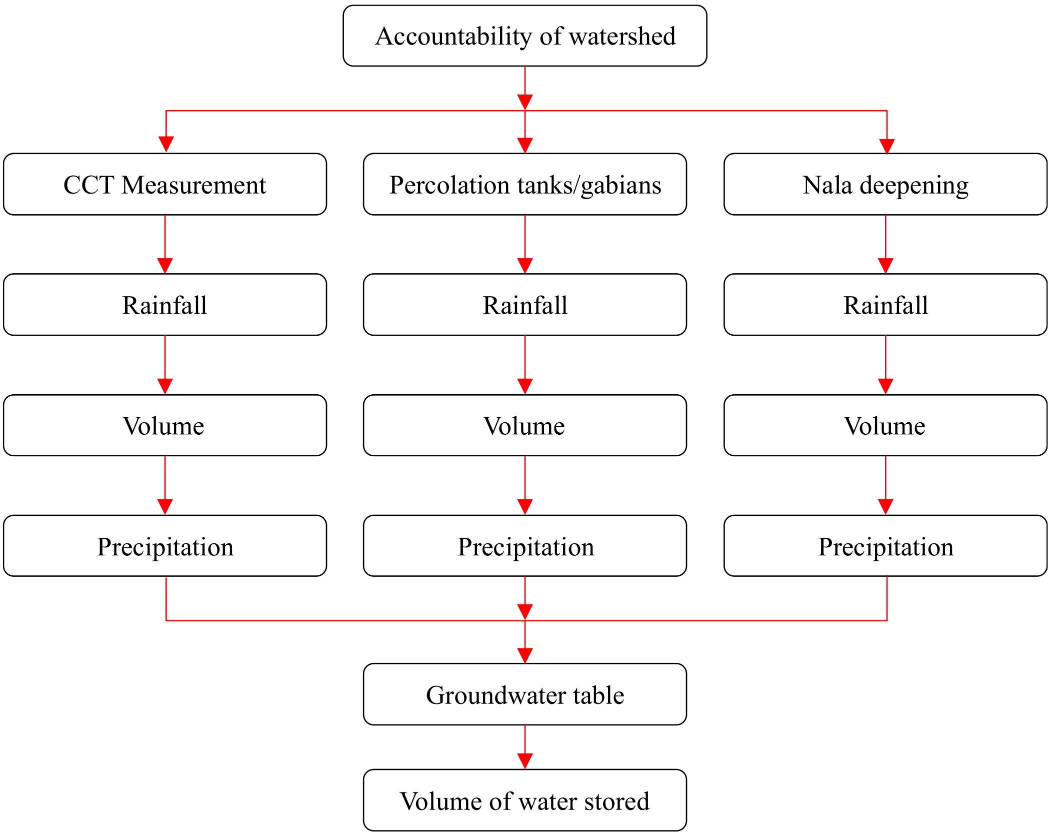


Figure 3. Methodological Steps for calculating the volume of water to be stored in the irrigated structures of Wadala Village.

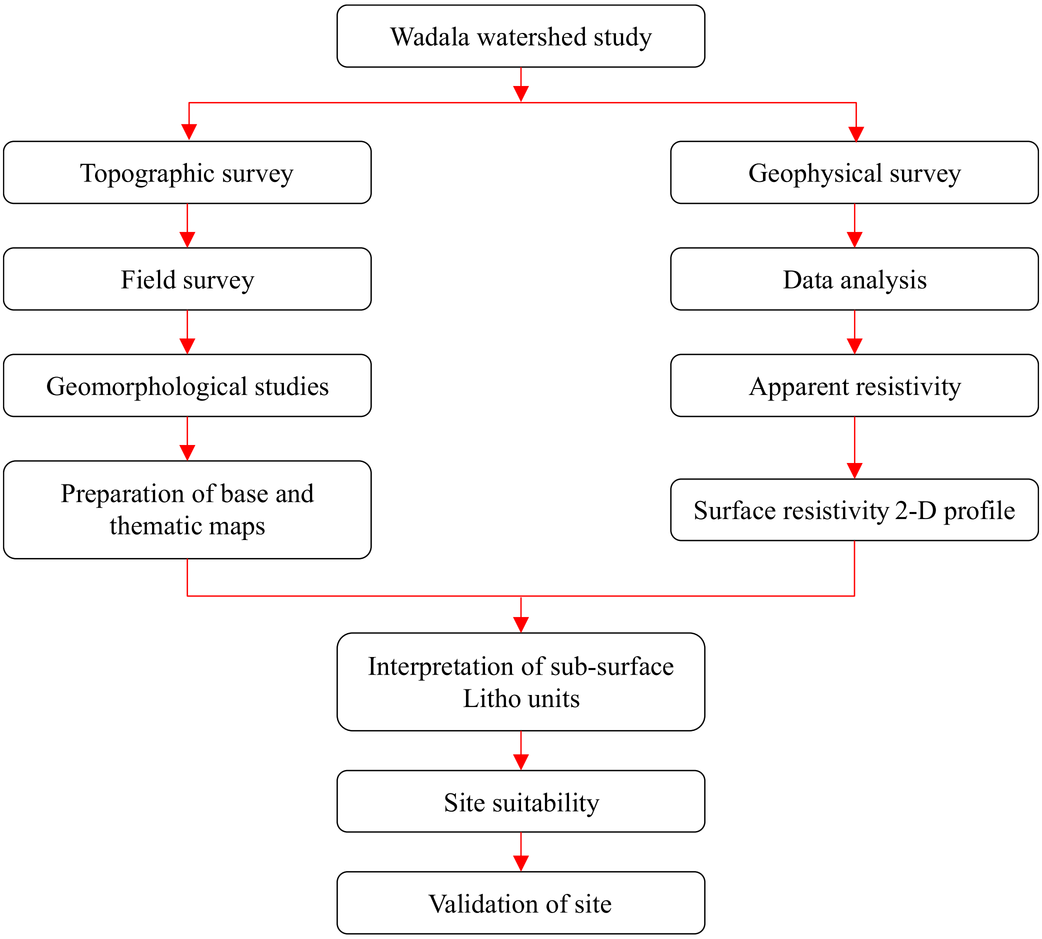


Figure 4. Methodology for Preparation of GIS Maps and Geophysical Survey for deciding the validated site for Watershed Management.

RESULTS AND DISCUSSION

During the studies the Rabbi Water Usage Index was calculated with the help of different crop patterns adopted by the farmers of the study area i.e. Sorghum, Wheat, Gram etc. and vegetables i.e. Onion. The summer crop pattern also are considered [11, 12]. The ratio of water requirement of rabbi and summer season crop adoption and the remaining water for Rabbi and summer crop season gave the Rabbi Water Usage Index i.e. 1.14, which is more than 1 hence this watershed is under unsafe condition.

In 2019, the Grampanchayat of Wadala region and the citizens of Wadala had a common campaign of Jalyukt Shivar program and Pani Foundation which created a miracle in the region. The Wadala village has three distinctive streams i.e. Telelavan, Lendi and Asar which majorly flow in the rainy season and halfly in the winter season. During summer season, due to present treatments of KT weirs and nalla deepening, these streams were found to be filled with water. To understand its topography, the GIS maps have been generated (Figure 5).

Through this Jalyukt Shivar Program and Pani Foundation, the following conservation work in the study area was carried out by people's participation, and few government organizations and some NGOs' involvement (Table 2).

Recharge Due to Existing and Extended Soil and Water Conservation Works

The ratio of water requirement of rabbi and summer season crop adoption and the remaining water for Rabbi and summer crop season after adopting the above structures gave the Rabbi Water Usage Index i.e. 0.89, which is less than 1 hence this watershed is now under safe condition.

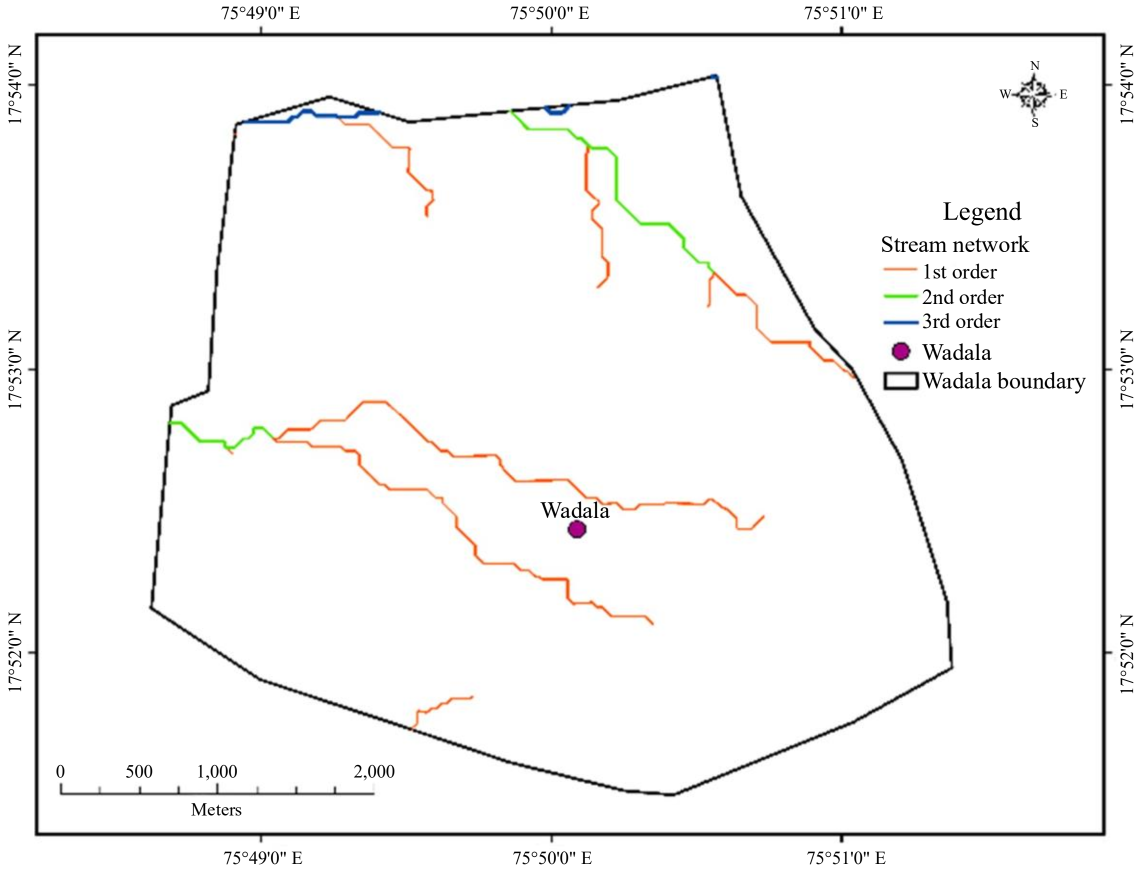


Figure 5. Drainage Map of Wadala Village.

Table 2. Jalyukt Shivar Program and Pani Foundation.

S.N.	Name of Work	Number /ha	Evaporation (%)	Remaining available water (%)	Total storage capacity (TCM)	Total No. of fills during monsoon	Total available water (TCM)
(a)	*(b)*	*(c)*	*(d)*	*(e)=100–(d)*	*(f)*	*(g)*	*(h)={(e)×(f)} /{100×(g)}*
1	CCT repair	1/26.11	50	50	2.35	2	4.70
2	Deepening CCT	1/0.75	50	50	0.1	2	0.20
3	Water absorbent paddy	1/4.36	50	50	0.525	2	1.05
4	Loose boulder	47	0	0	0	0	0
5	Gabion structure	1	0	0	0	0	0
6	Compartment bunding	1039.78	50	50	337.93	2	675.87
7	Farm ponds (without lining)	78	50	50	34.165	2	68.33
8	Soil drain structure	5	30	70	14	2	28.00
9	Cement drain structure	3	30	70	18.2	1	18.20
10	Sinab shelling	1	30	70	3.5	1	3.50
11	Deepening of drain	6.5 km	0	0	0	0	0
12	Village pond repair	0	50	50	0	0	0
13	Percolation tank	2	50	50	28	1	28.00
14	Percolation tank repair	2	50	50	10.5	1	10.50
15	KT weir	2	30	70	21	1	21.00
16	KT weir repair	2	30	70	11.2	1	11.20

S.N.	Name of Work	Number /ha	Evaporation (%)	Remaining available water (%)	Total storage capacity (TCM)	Total No. of fills during monsoon	Total available water (TCM)
(a)	*(b)*	*(c)*	*(d)*	*(e)=100–(d)*	*(f)*	*(g)*	*(h)={(e)×(f)} /{100×(g)}*
17	Forestry dams	23	0	0	0	23	0
18	Well refilling	98	0	0	0	98	0
						Total =	*870.55*
Percolation Tank, KT Weir, Storage Tank, Irrigation Ponds etc.		In all these storage schemes, the water storage and irrigation potential are drawn and the project report is approved, as per the guidelines in the Minor Irrigation Code (M. I. Manual), as drawn and measured under existing conditions, or any updated method may be used.					

Geophysical Studies

Geophysical surveys, i.e., electrical soundings are carried out in the 16.5 km^2 area of Wadala Village which is based on the stream order, slope gradient of the area, contours in the region, availability of spread area etc. Use of GIS for preparation of thematic maps of the study region have helped in deciding the sites of water conservation. The contour map helps to understand the topography of the Wadala village (Figure 6).

Beyond all this, the drainage map of the village is prepared by using the GIS tool. The area has three orders of streams (Figure 7), i.e., Telelavan, Lendi and Asar odhas which flow majorly during the rainy season and half of winter season.

The Aspect Map derived for the Wadala Village premises states the slope topography of the area (Figure 8), while the Slope Map of Wadala village was derived to understand the actual sloping direction in the region as well as the topographical changes in the region (Figure 9 and Table 3).

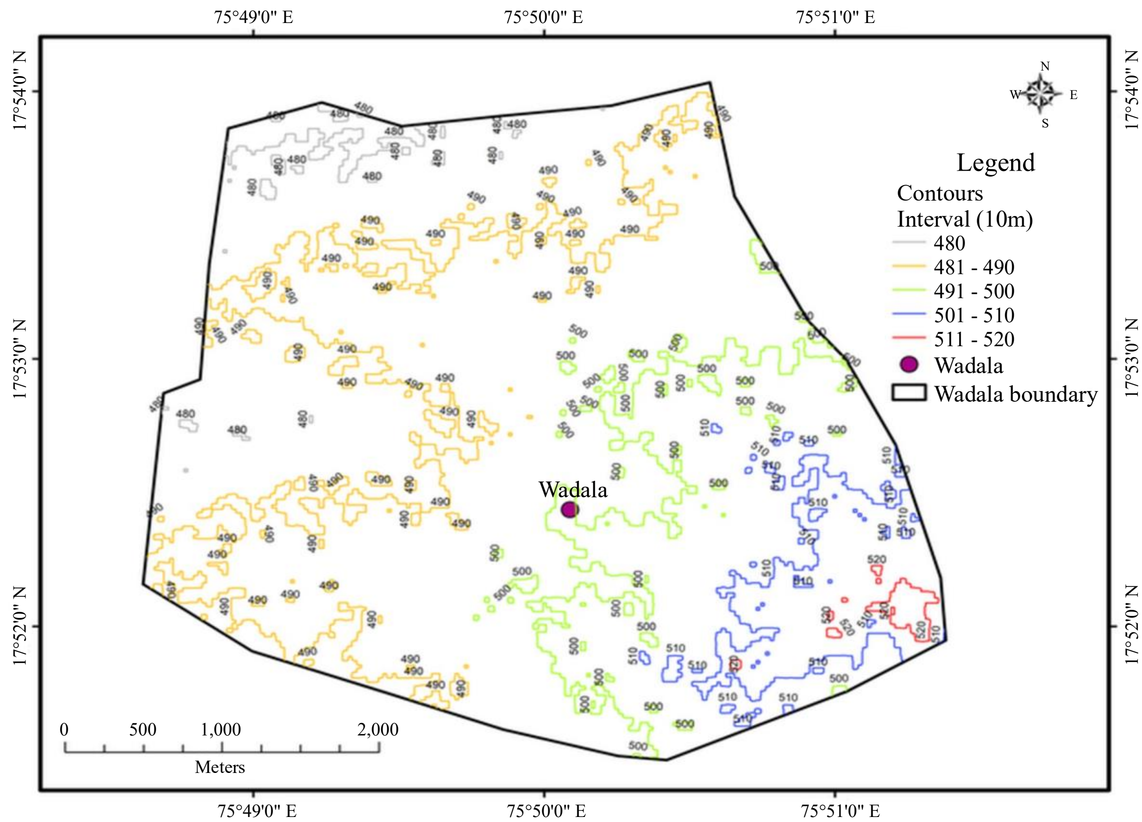


Figure 6. Contour Map of Wadala Region.

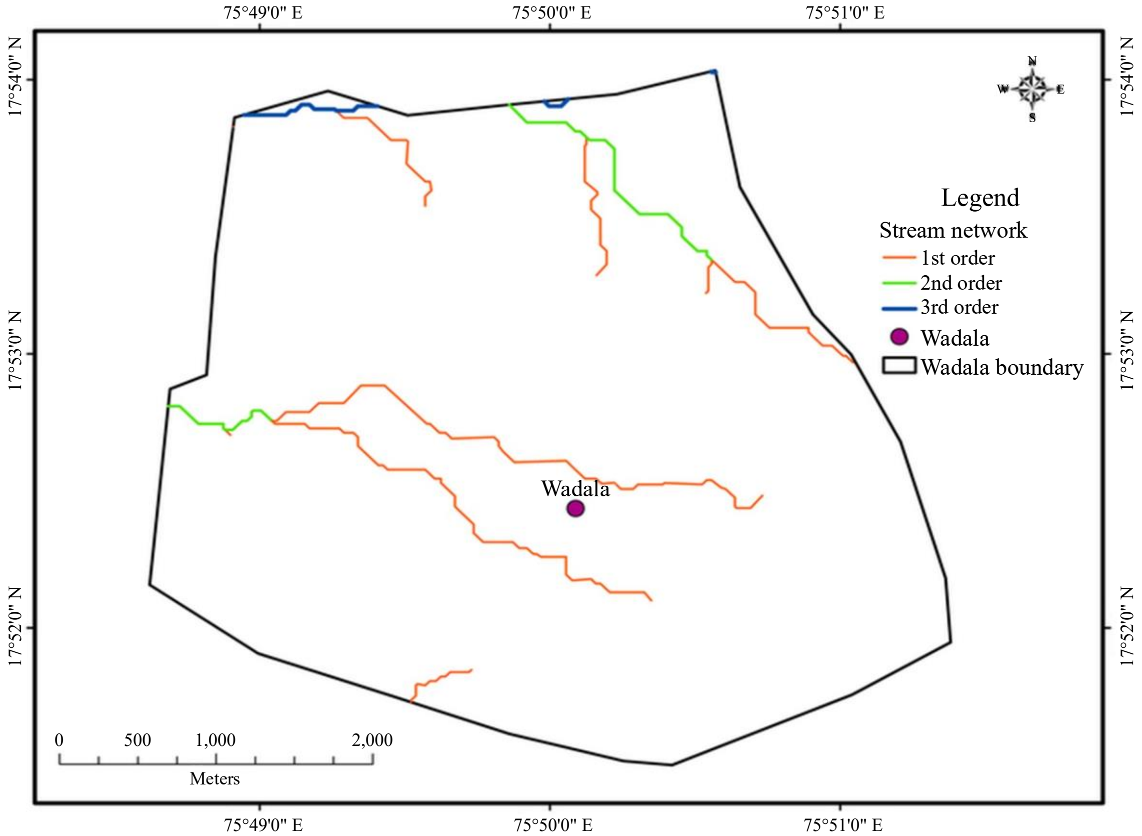


Figure 7. Drainage Map of Wadala Region.

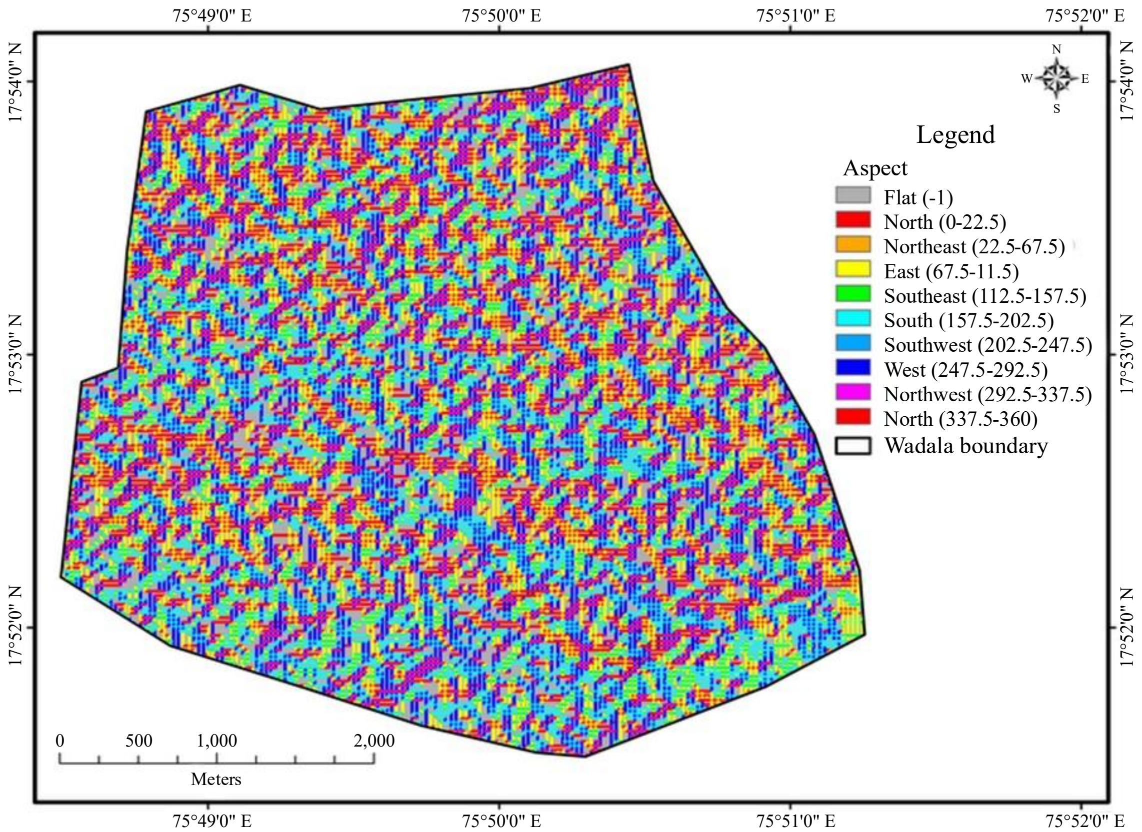


Figure 8. Aspect Map of Wadala Region.

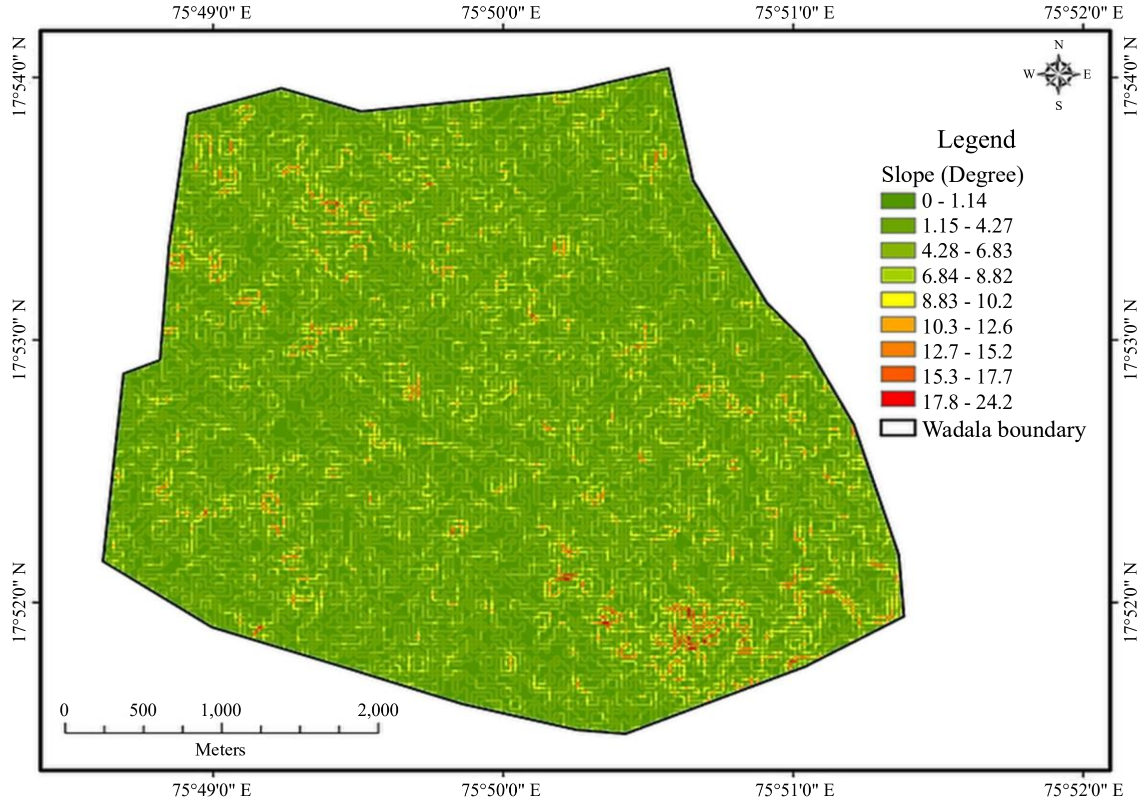


Figure 9. Slope Map of Wadala Region.

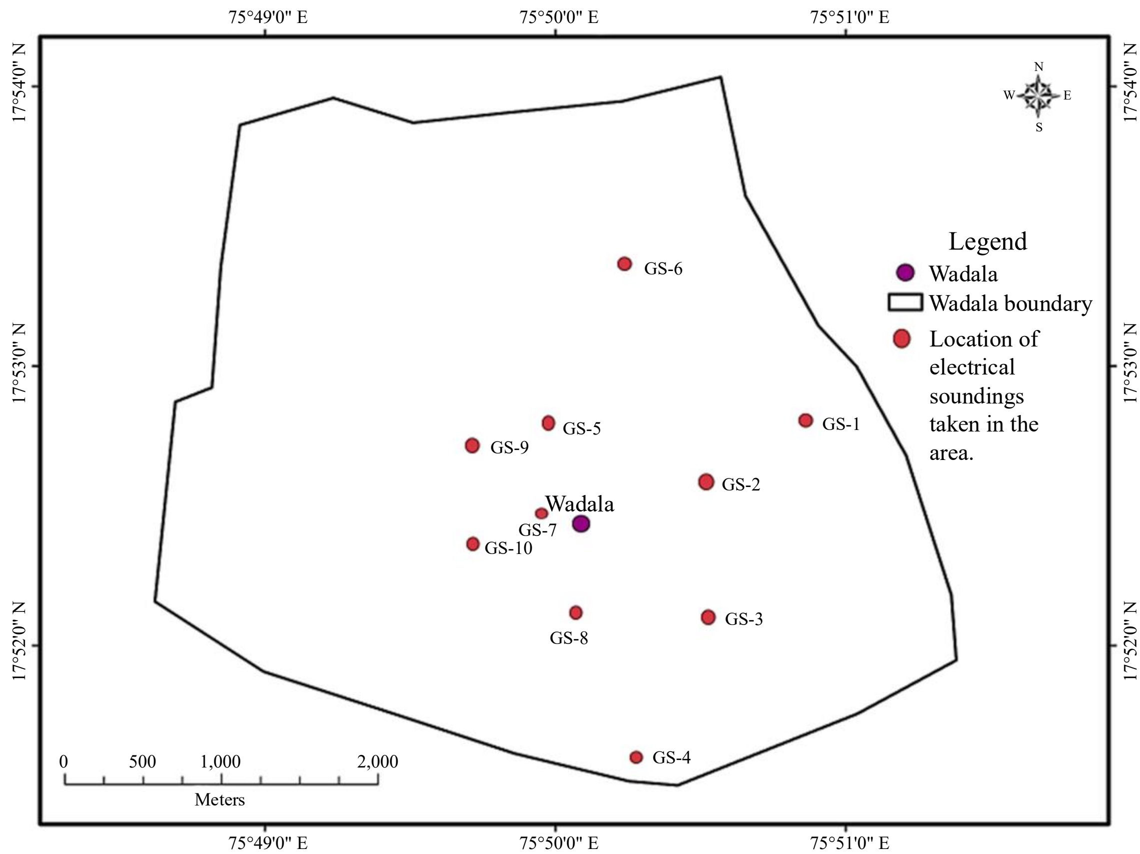
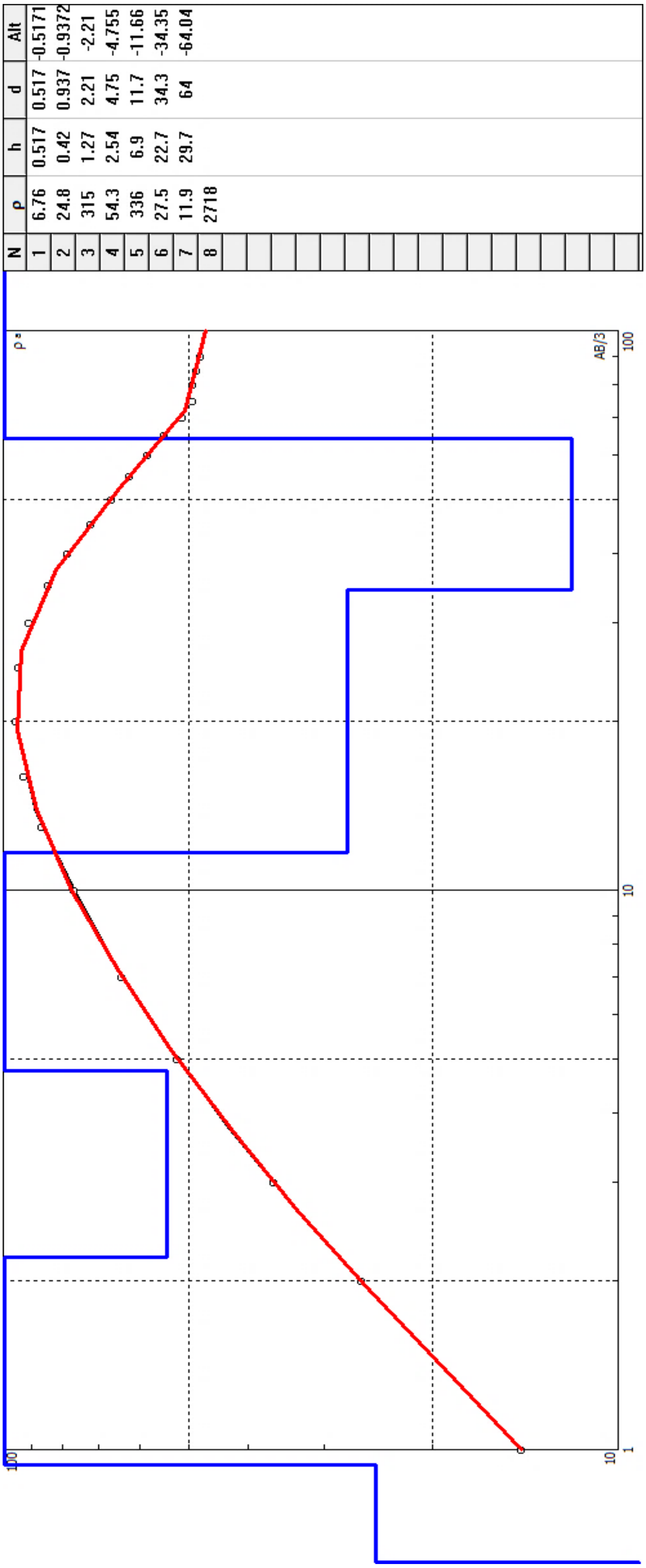


Figure 10. Location Map of the Electrical Soundings taken in the study area.



N	ρ	h	d	Alt
1	6.76	0.517	0.517	-0.5171
2	24.8	0.42	0.937	-0.9372
3	315	1.27	2.21	-2.21
4	54.3	2.54	4.75	-4.755
5	336	6.9	11.7	-11.66
6	27.5	22.7	34.3	-34.35
7	11.9	29.7	64	-64.04
8	2718			

Figure 11. Graphical representation of curve matching of VES near Gawalewadi.

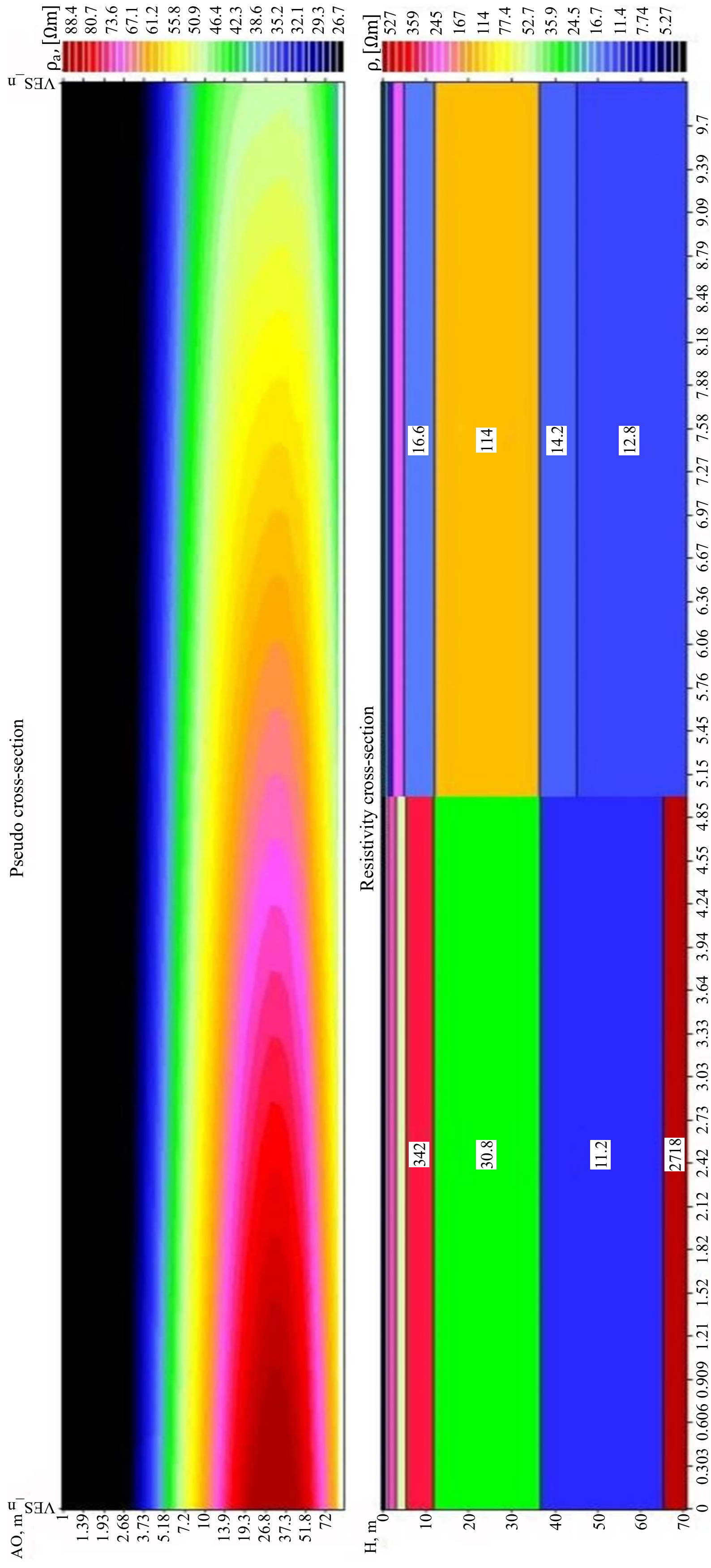


Figure 12. 2 D section of Near Gawalewadi area and Wadala Pattern nala deepening.

Table 3. Lithological details of 2D section of Near Gawalewadi and Wadala Pattern nala deepening.

Lithology	Thickness (m)
Soil and weathered basalt	0–5
Compact basalt (with fractures)	5–9
Vesicular amygdaloidal basalt	9–14
Compact basalt (with connecting joints)	14–19
Jointed vesicular amygdaloidal basalt	19–25
Compact basalt	25–42
Vesicular amygdaloidal basalt	42–51
Compact basalt	51–72

Figure 13. Section showing compact massive basalt at Gawalewadi.

Figure 14. Section showing compact massive basalt at Wadala Pattern Nala.

So, considering the above all data, the locations for the electrical resistivity sounding survey are decided and they were found to be the more appropriate for getting the exact data and that has been interpreted with graphical representation and photographic interpretation (Figure 10).

The electrical resistivity survey (VES) carried at Gawalewadi region has been represented with the graph in Figure 11 while the 2D section of the alternative survey regions have been represented in Figure 12 which shows both the Gawalewadi and near Wadala pattern nala section, which shows more or less similar lithological section (Table 3).

The lithological variations give an idea about the elevation difference with reference to rock types exposed in the Gawalewadi village region (Figure 13) and Wadala pattern Nala Deepening (Figure 14). Varying lithological sequence gives an idea about the difference in the elevation as well as the rock types exposed in the near Gawalewadi region (Figure 13) and Wadala Pattern Nala deepening (Figure 14).

On similar grounds the other eight locations have been identified based on the sloping ground, drainage pattern nearby and available space for survey. On the basis of the same, the following interpretation has been done:

- The electrical resistivity soundings of GS-1 and GS-2 states that the region has about 12 ft weathered basalt for which the open dug well at Gawalewadi is covered by stone pitching (Figure 15). 5–10 m of below formation is compact basalt having fractures within it. The evidences are noted at Wadala pattern nala open dug well. The CCT constructed in the upward region of the Shaikh Farid Baba Darga region helps in recharging the groundwater of these areas. Beyond all, the Nala deepening 1 which starts from the Wadala pattern, Nala towards the Solapur Barshi road also helps in conserving the surface run off water during rainy season.

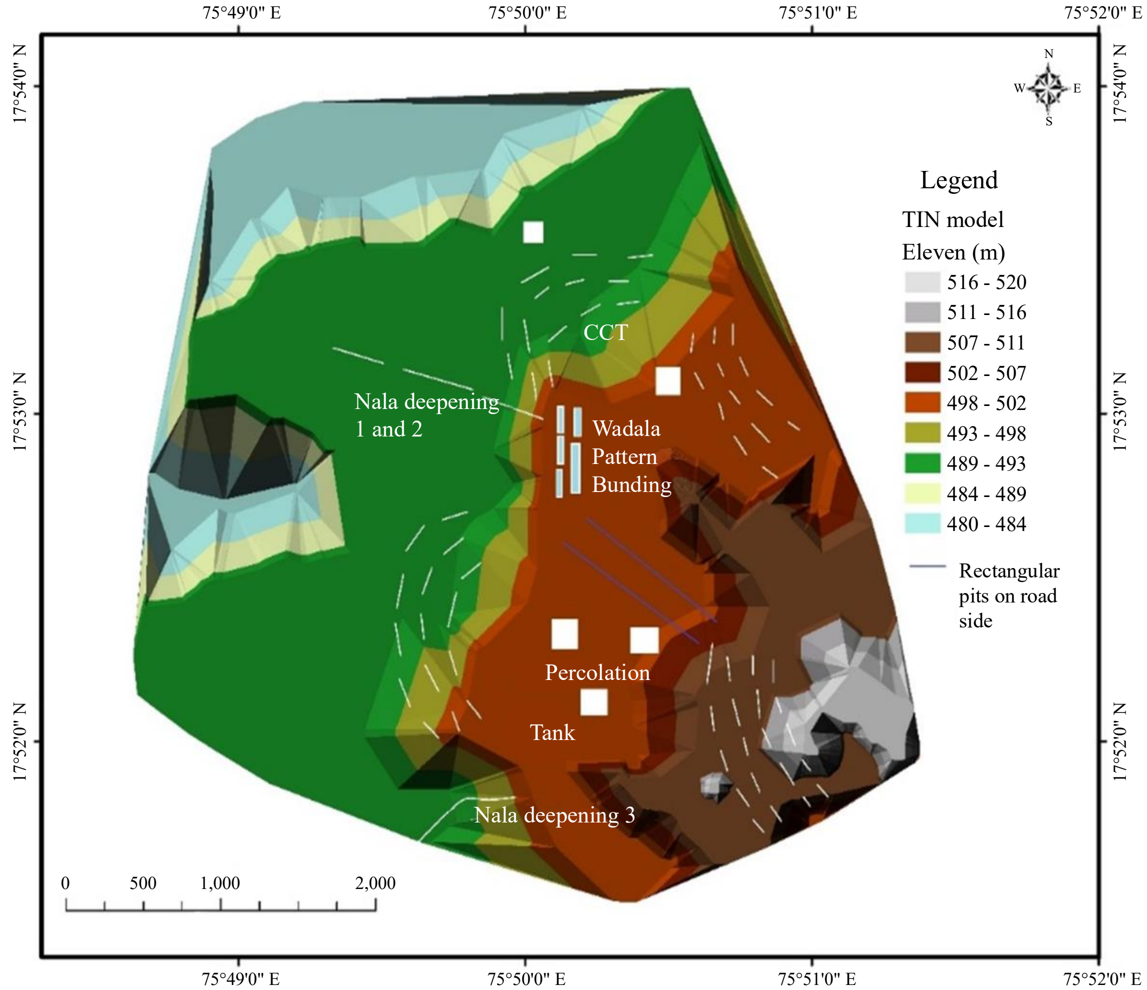


Figure 15. DEM Model of the Wadala Village Region.

- The electrical resistivity soundings of GS-3 and GS-4 state that the region has about 10 ft soil or weathered basalt for which the open dug well near Lokmangal Institute is covered by stone pitching for 8 ft (Figure 11). 4–17 m of below formation is compact basalt having fractures within it. The evidences are noted in the Figure 15 opposite of at Lokmangal Bus Stop open dug well. The CCT and three Percolation tanks constructed in the upward region of these both locations and below the Shaikh Farid Baba Darga region help in recharging the groundwater of these areas. Beyond all, the Nala deepening 3 which starts from the Solapur Barshi road also helps in conserving the surface run off water during rainy season.
- The electrical resistivity soundings of GS-5 and GS-6 state that the region has about 6 ft soil or weathered basalt for which the open dug well near Barshi Road shows the said evidences (Figure 14). 2–17 m of below formation is compact basalt which is highly jointed. The evidences are noted in the Figure 15 near the Asar Odha open dug well. The CCT and nala deepening of 1 helps in recharging the groundwater of these areas. Beyond all, the Nala deepening 2 which starts from the Solapur Barshi road also helps in conserving the surface run off water during rainy season.
- The electrical resistivity soundings of GS-7 and GS-8 state that the region has about 15 ft soil or weathered basalt for which there is the open dug well occurring behind the Bharat Petroleum Unit. About 18 m of below formation is compact basalt. The evidences are noted in the dug wells near the Manasvi Academy. The CCT and nala deepening of 1 helps in recharging the groundwater of these areas. Beyond all, the CCT constructed in the farms near Solapur Barshi road also helps in conserving the surface run off water during rainy season.

- The electrical resistivity soundings of GS-9 and GS-10 state that the region has about 7 ft soil or weathered basalt for which there is the open dug well occurring near the Nala Deepening 2 (North Western side of Wadala Village). About 8 ft below formation is compact basalt having joints. The evidences are noted in the dug wells near the Nala Deepening 2 (North Western side of Wadala Village). The nala deepening of 2 helps in recharging the groundwater of these areas. Beyond all, the Canal constructed in the South side of Wadala Village area also helps in conserving the water.

Based on all, the above experimental data and physical verification of the sites in the study region, a DEM model is prepared for the further use of the decision makers what has been done till date and what has to be done in future too (Figure 15).

The DEM model states that the various works done during the Jalyukt Shivar and Pani Foundation program are valid and now these need to be reworked for further growth and implementation of water conservation. The work carried during these programs are three nala deepenings, various percolation tanks, and CCTs at different locations covering nearly 600 ha area of the study region and also rectangular pits on the road side of the Shaikh Farid Baba Darga. The Wadala pattern Nala banding is unique in its own which covers major filtration part of surface water.

CONCLUSION

Digital Elevated Model (DEM) is prepared by overlaying the weighted operation, throughout the study area (Figure 15). Every single drop of rain is collected in the form of sub-surface water by means of Close Contour Trenches (CCT), Percolation tanks and by Nala Deepening.

Declaration of Interest

Wadala region has seen several draughts and this manuscript will help the decision makers in identifying the suitable sites for rainwater harvesting and this will definitely increase the groundwater potential of the area. Increase in groundwater will help the citizens of Wadala region in improving the economy by adopting cash crop pattern and will increase the employment in agriculture field.

Acknowledgement

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