SUSTAINABLE ASPECTS OF RURAL WATER SUPPLY, QUALITY AND SANITATION SOURCE USING RS & GIS: A CASE STUDY

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ABSTRACT

Access to safe drinking water remains an urgent necessity in the world as it is directly related to health. Groundwater accounts for more than 80 per cent of the rural domestic water supply in India (World Bank 2010). The main aim and objective of present research study is on applicability of satellite remote sensing techniques for sustainability of rural water supply sources of Medchal mandal in Ranga Reddy district. The integrated groundwater prospects maps are prepared by using different thematic layers like Geology, Geomorphology, Structures (Lineaments), Hydrology, etc. Drinking water quality data of rural water supply sources situated in Medchal mandal are studied for the parameters like Fluoride, Total Dissolved Solids, Total Hardness, Alkalinity, pH & Chloride to assess the spatial distribution of groundwater quality in terms of potable or non-potable. Satellite Remote Sensing and GIS studies are employed by making use of other collateral data, Well Inventory data and Rural Water Supply data are incorporated. Groundwater quality data acquired are spatially interpolated using Inverse Distance Weightage (IDW) method to demarcate the spatial (locational) variations. Water demand is calculated for present (2012) and designed period of 20 years (2032). After detailed well inventory combined with integrated groundwater prospects and quality studies, the problematic habitations are found out and plan of action and remedial measures have been proposed. The plan includes proposing water harvesting structures to either dilute the areas where the water quality problem is there or to increase the groundwater reserves through artificial recharge in areas where there is sustainability problem.

Keywords: Groundwater, Prospects, Quality, Sustainability, Remote Sensing, GIS.

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Introduction

Due to various natural and anthropogenic activities, the ground and surface water resources substantially stand prone for pollution. Medium resolution satellite images are increasingly used in groundwater exploration because of their utility in identifying various ground features, which may serve as direct indicators of presence of groundwater (Ramamoorthy P, 2011). The groundwater is the only source available for the study area. For the study area, the water demand for 20 years of each habitation is calculated and compared with the existing water demand. If the existing demand is not sufficient to meet the requirement, additional sources and its suitable locations are proposed along with rainwater harvesting structures for the sustainability of the sources using Remote Sensing and GIS techniques. The spatial distribution of groundwater quality has been generated by using different parameters of a source. Element-wise groundwater quality maps are generated by using the interpolation technique namely Inverse Distance Weightage (IDW) method. The six elements considered for the mapping are pH, Total Alkalinity (TA), Total Hardness (TH), Total Dissolved Solids (TDS), Chloride (Cl) and Fluoride (F).

Location

The project area falls in parts of Survey of India Toposheets 56 K/06 & K/10. It lies in between 17º 33' – 17º 42' North Latitudes and 78º 24' – 78º 36' Eastern Longitudes. Location map is as shown in Figure 1. The area covered is 18,311 hectares.
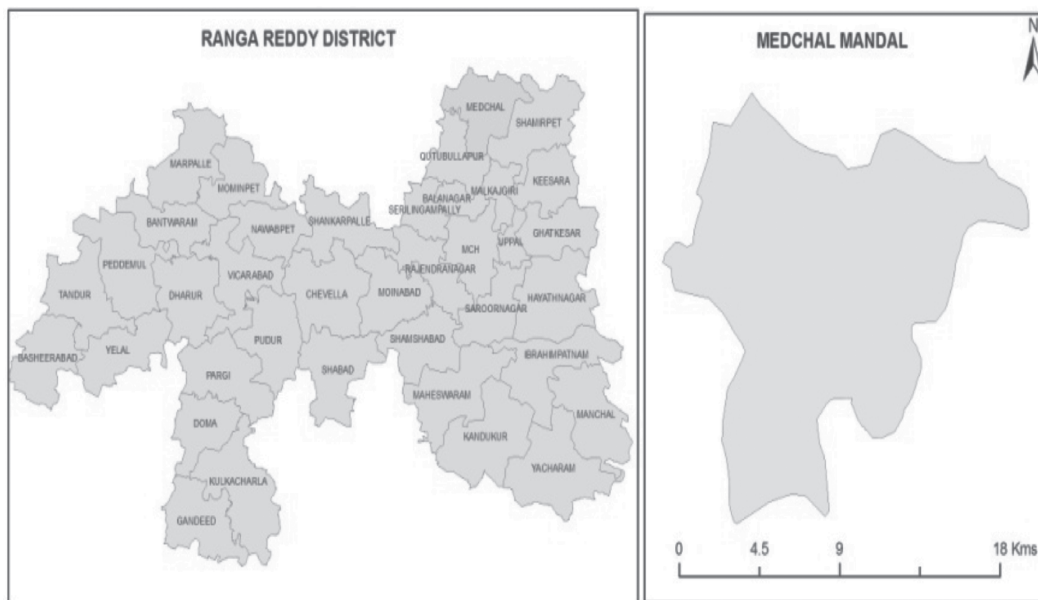

Figure 1: Location Map of the Study Area

Climate and Rainfall

The climate of the area is classified as "Tropical Rainy", the minimum daily temperature is 16° C and maximum is 43° C. The normal annual rainfall for the mandal is 820 mm.

Data Used

The following of data are used in the study area:

- Topographical map of Survey of India (SoI) on 1:50,000 scale.

- Satellite Data (IRS) viz. IRS-P6 LISS III geo-coded on 1:50,000 scale.

- The geographic coordinates of all the water supply sources and overhead / ground level reservoirs, etc., are collected during well inventory.

Methodology

The following is the brief methodology adopted in the study area:

1. The present population is projected up to 20 years to calculate the water demand and plan of action for future.

2. Different thematic layers like Settlement, roads, drainage, lithology, geomorphology, structural layers, etc., are prepared by using integrated Remote Sensing and GIS techniques. The doubtful locations are noted down for well inventory and field visit.

3. Reconnaissance and well inventory data are collected in support of classification of hydro-geomorphological units and additionally the geographic coordinates of all the drinking water sources like MPWS / PWS / Direct Pumping wells; Habitation / Village Centres like Anganwadi / School / Racha Banda; Storage Reservoirs (OHT / GLSR) are collected. Pre-field doubtful locations are clarified in the field.

4. Post-field interpretation is carried out by incorporating the well inventory data and final thematic layers are prepared using Remote Sensing and GIS techniques.

5. Element-wise (pH, TDS, TH, TA, F & No3) and Integrated groundwater quality layers are prepared for pre and post-monsoon season by using the true geographical coordinates collected during well inventory data.

6. Integrated RS & GIS based study is taken for decision making and proposed sustainability structures and remedial measures as required.
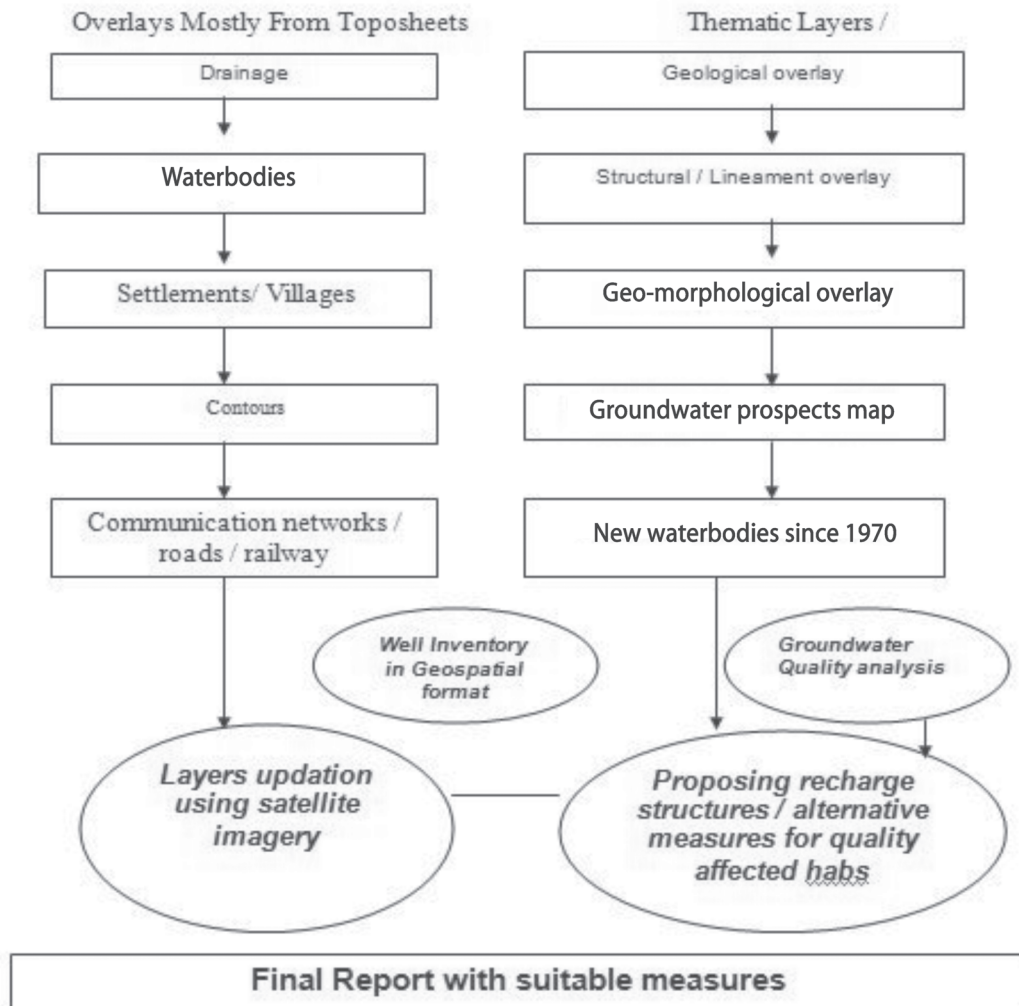
Figure 2: Methodology Flow Chart

The methodology followed is shown below in the form of a flow chart (Figure 2):

Thematic Maps

The following are the different thematic maps prepared as part of project:

Villages, Population and Drinking Water Demand: The total number of Gram Panchayats in the mandal are 18; villages are 26; and habitations & tandas are 45. The locations of Gram Panchayats/villages/habitations/tandas are given in Figure3 as a point layer. Habitation-wise present and project population is calculated. As per Government of India norms, drinking water is provided at the rate of 40 litres per capita daily (LPCD) (Ministry of Drinking Water & Sanitation (MDWS), GoI.).
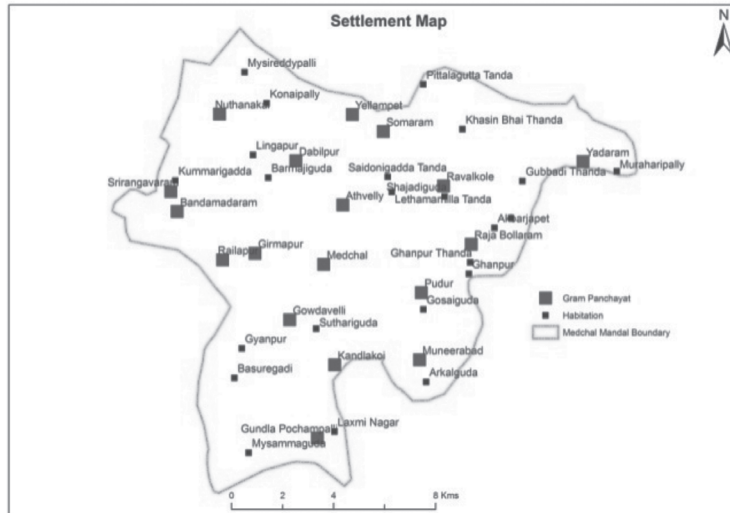
Figure 3: Locations of Settlements

Drainage Layer: Drainage in the study area is drained maximum by 5th order stream network. By making use of ArcGIS, a drainage layer is prepared. Density is medium to fine. It is medium in pegmatites and in highly permeable soils (sandy soils) covered over weathered pediment and pediplain zones of granites. It is fine in the granitic pediment inselberg complex and pediment units. Drainage pattern is mostly sub dendritic. It is depicted in Figure 4.
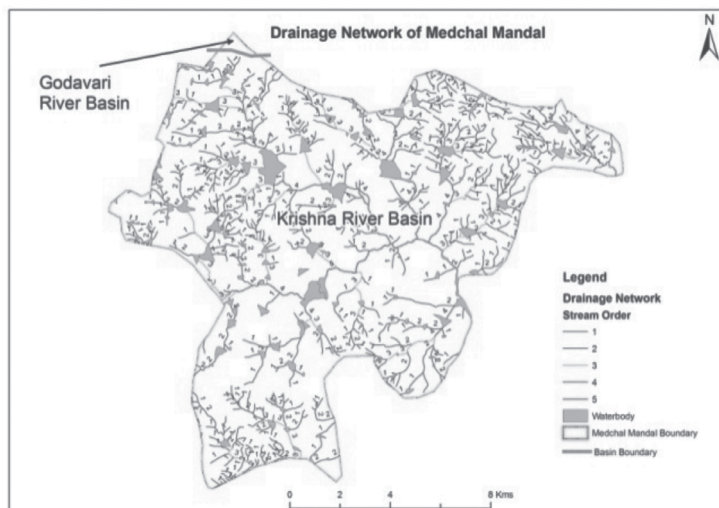

Figure 4: Map Depicting Drainage Network

Groundwater Status of Habitations/Villages:
A settlement layer (Figure 5) was generated with help of the toposheets and then, new settlements were added to the layer by interpreting their locations from the imagery and by collecting of geographic coordinates of settlements like the Gram Panchayat office building in case of a Gram Panchayat and school/anganwadi centre in case of village/habitation. Overall there are 18 Gram Panchayats, 26 villages and 45 habitations.
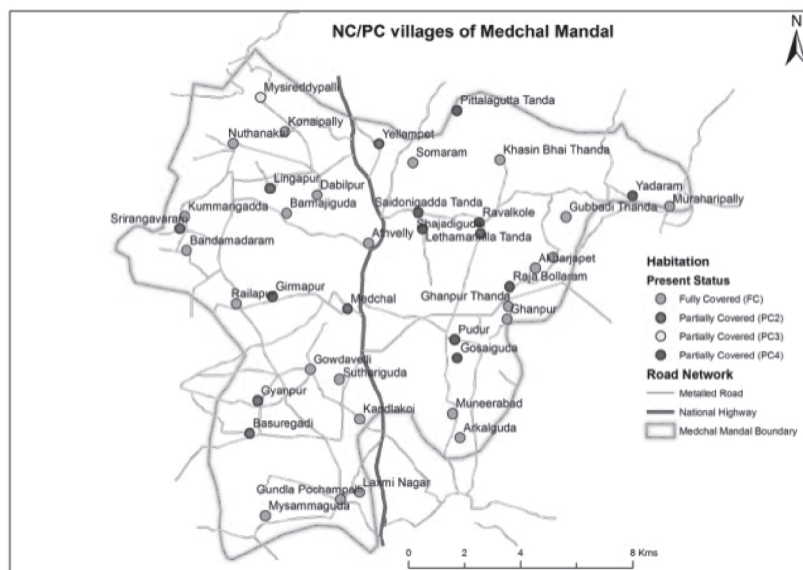

Figure 5: Map Showing Status of Present Habitations in Terms of LPCD

Waterbody Layer: Waterbody layer was generated with help of the toposheets (56 K/6 & K/10 surveyed during 1971-73). And then newly implemented waterbodies were interpreted from the imagery. Figure 6 indicates both new and old waterbodies. 137 waterbodies were demarcated from the toposheet and two new waterbodies were interpreted from imagery.
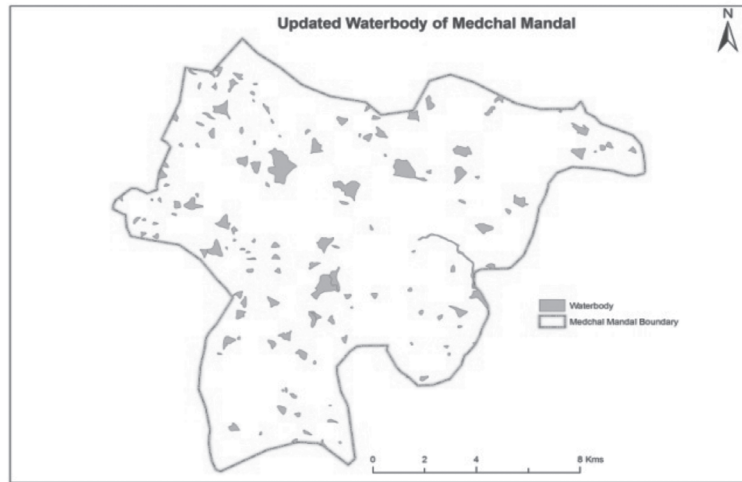
Figure 6: Map Showing Updated Waterbody Using Satellite Imagery

Geology of the Area:: The area comprises Peninsular Gneissic Complex of Archaean age and pegmatites. Peninsular Gneissic Complex are intruded by pegmatites, quartz reefs and dolerite dykes. Pegmatites are mostly seen on elevated areas, on the west borders of the study area. Interpretation is carried out using Geological Survey of India (GSI) Geology map with Remote Sensing & GIS techniques and a layer of geology is generated by using ArcGIS software. Here the importance of one layer overlaying over another with background as image is very useful in interpretation. On the image layer, drainage, water-body and height layers are superimposed and the interpretation is made.

Structure of the Area:: With the superposition of geology, drainage and height layer over the image, it is possible to demarcate structural features in the area. Demarcated features are lineaments. They are weak planes like joints, faults and fracture zones and act as conduits for movement of groundwater. As such, lineaments are most potential zones for groundwater. They are identified with any linearly aligned features such as vegetation, waterbodies or narrow linearly arranged vegetation and shown in Figure 7. In the study area, NW-SE and NNE-SSW oriented lineaments are most potential than those oriented in other directions.
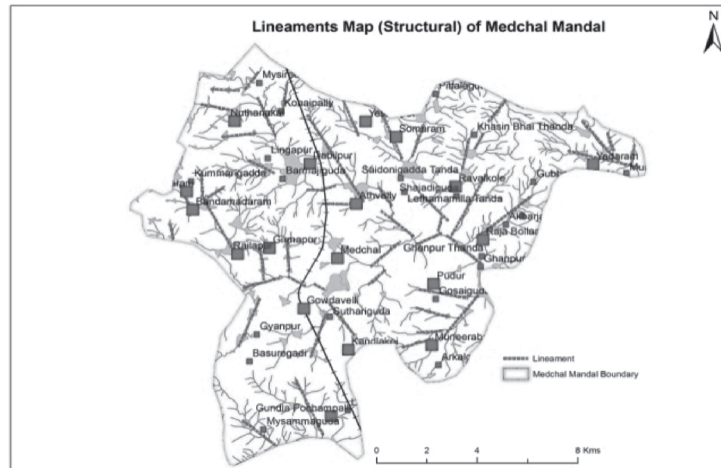
Figure 7: Map Showing Structures (Lineaments) of the Study Area

Geomorphology of the Area: By incorporating the Remote Sensing and GIS, onscreen digitisation is carried out by interpretation and a layer of geomorphology is generated using ArcGIS (Figure 8). Here the importance of superimposition of layers is made use of. Geomorphology layer presents information on landforms. Landforms depend primarily on the rock type, exogenic and endogenetic processes.
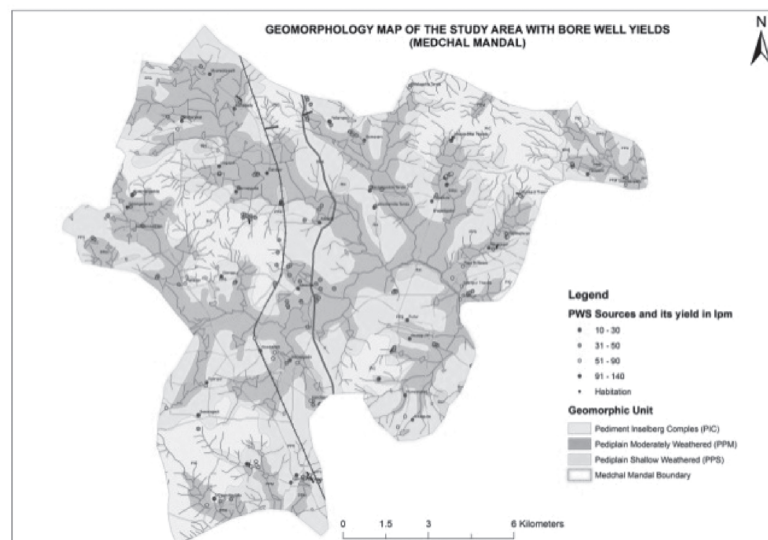

Figure 8: Map Showing Geomorphology with Respect to Borewell Yields of the Study Area

Natural processes on existing terrain lead to various landforms; it is a continuous process in geological time scale. As such, a particular type of terrain will exhibit only a specific type of land forms. In the granitic terrain - hills, piedmont, pediplain and valley sequence is common. Over image, geology, drainage, waterbody and height layers are superposed. In the study area, land forms such as residual hill, inselberg, pediment-inselberg complex, pediment, intrusive pediments, weathered pediment features and pediplains are demarcated.

Groundwater Prospects Map: Groundwater Prospects Map is generated by integrating the layers of Geology, Structure and Geomorpholgy with satellite interpretation. Groundwater prospect zones are demarcated in the map (Figuew 9). In this area, Moderately Weathered Pediment (PPM) has maximum groundwater prospects followed by Shallow Weathered Pediment (PPS). Inselbergs (I), Residual Hills (RH) and Pediment Inselberg Complexes (PIC) have poor groundwater prospects. Lineaments are more promising zones in all these units. In PPM, the discharges expected can be in the range from 100 to 150 lpm. In the PPS, the range can be from 50 to 100 lpm and in PIC the range of discharges can be from 30 to 50 lpm. In these areas and in the remaining areas lineaments are most promising zones.
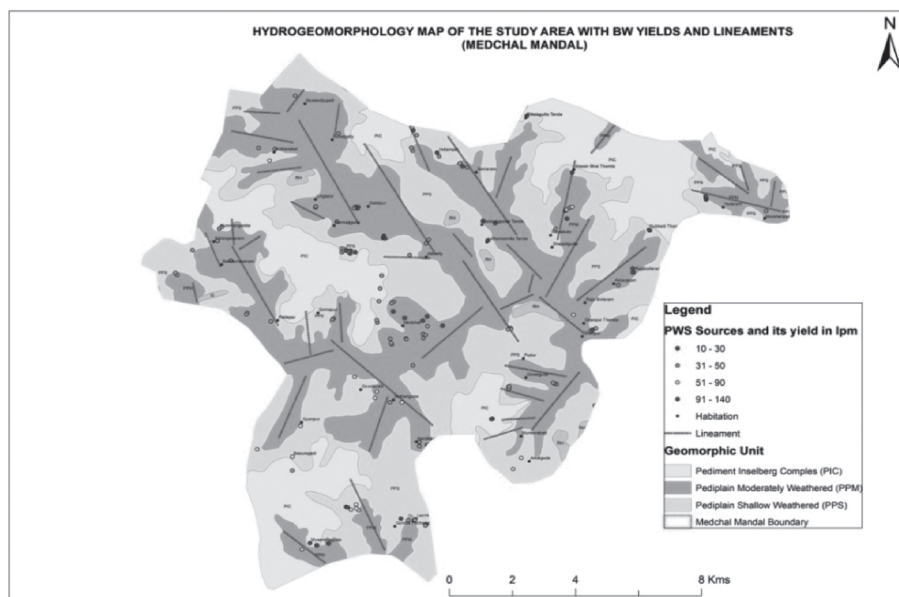

Figure 9: Map Showing Hydro-geomorphology with Respect to Borewell Yields of the Study Area

Environmental Aspects (Groundwater Quality)

There are 60 nos of drinking water quality tested sources (PWS/MPWS) in Medchal mandal for which the geographic coordinates are collected during well inventory. The locations of groundwater samples are given in Figure 10.
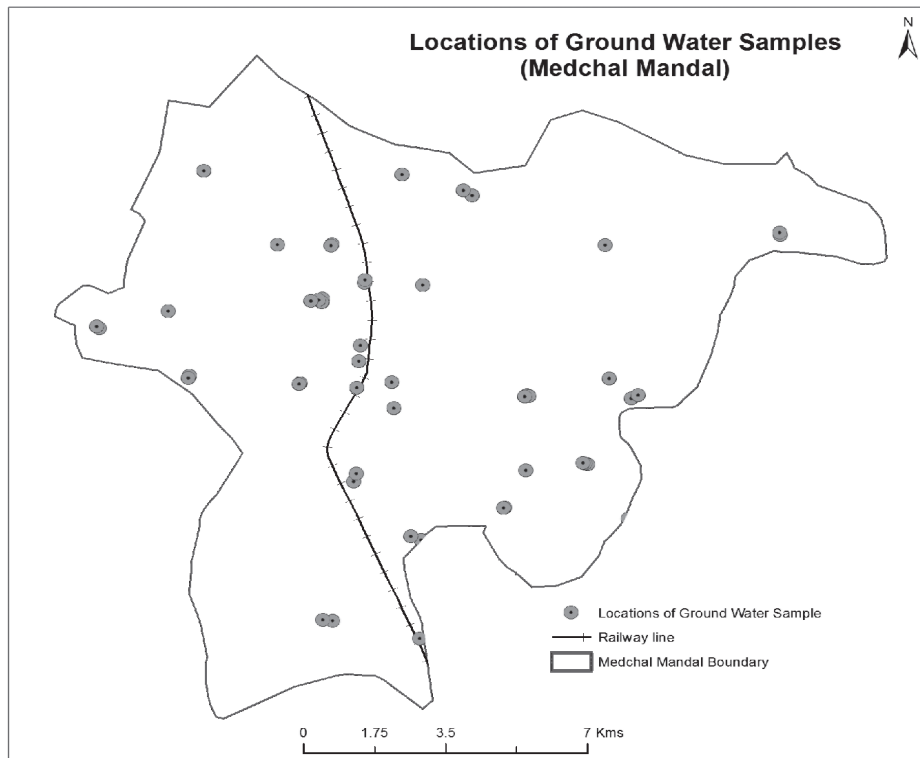

Figure10: Locations of Quality Tested Groundwater Samples

The spatial distribution of different chemical elements in the study area is carried out by making use of Inverse Distance Weightage (IDW) interpolation technique. It is observed that the quality is within the permissible limits for Total Dissolved Solids, Total Hardness, Chloride, pH and Alkalinity. But the fluoride is marginally affected.

Fluoride: The distribution of fluoride map is given in Figure 11. It is observed that the southern area of the study area is fluoride affected marginally. A small area to the north and central areas is also showing more than permissible limits in fluoride.
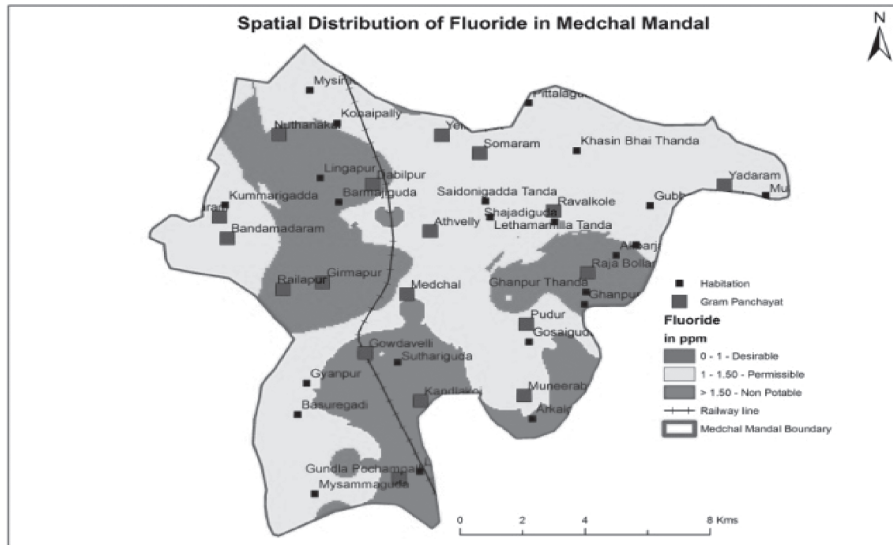
Figure11: Spatial Distribution of Fluoride in the Study Area

Results and Discussion

By taking into consideration geology, geomorphology, groundwater quality, structural aspects and well Inventory data, the final action plan for Sustainability of Rural Water Supply schemes is prepared and shown in Figure12.
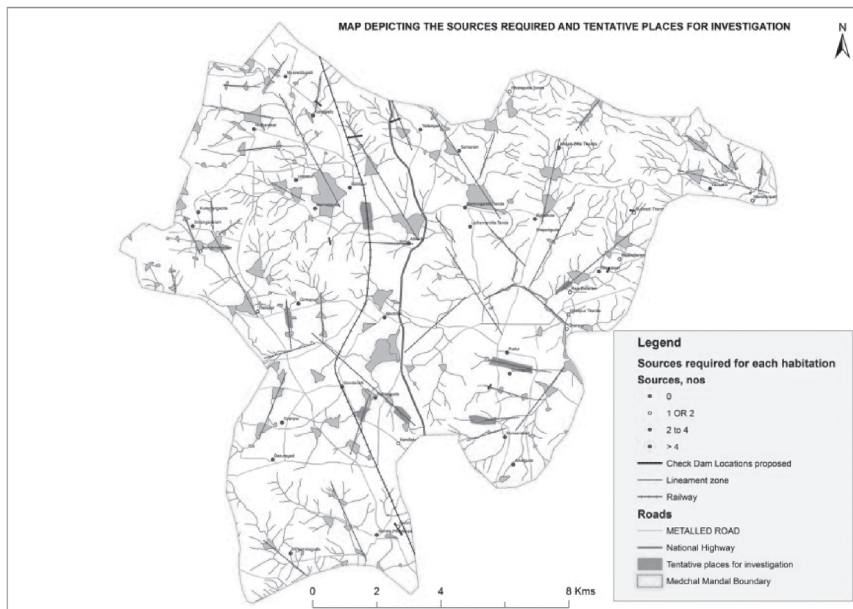

Figure12: Final Action Plan Map of the Study Area

In the final map the following aspects are shown:

1. Number of sources required for each habitation/village – After considering the existing borewell yields, the balance yield up to year 2032 is calculated and shown with different point symbols.

2. The tentative location areas for future geophysical investigations that can be taken near to a particular habitation / village are shown with a green band.

3. The locations of sustainability structures like check dams / percolation tanks, etc., are shown in the map with a line symbol.

Rural people are largely dependent on public water supply schemes for drinking purposes which are developed by the Rural Water Supply & Sanitation Department. The consumption of drinking water is directly related to health and other related issues. Water needs to be supplied in sufficient quantity to meet the basic needs of drinking, bathing, cleaning utensils etc. When the quantity is insufficient, people have to travel long distances to fetch water and a lot of time is wasted. On most occasions, women bear the burden. When the quality is not up to the standard, people fall prey to different diseases. For this, the rural water supply sources develop sustainability in terms of quality as well as quantity, with scientific mapping of resources so that the required goal is fulfilled.

Conclusion

By assessing the overexploitation, drinking water demand versus supply and quality problem and to plan suitably, the following remedial measures are proposed long-term and short-term to maintain the sustainability of drinking water sources:

Short-term Remedial Measures

●   The fluoride distribution reveals that the southern area of the study area around Athvelly village and in Yellampet villages is affected with fluoride marginally which is out of range. This concentration may cause affects of dental carries. This could be eliminated by dilution with good quality water or by increasing groundwater by constructing check doms, percolation tanks, etc.

●   As the area is under speedy development, rooftop rain water harvesting can be taken up in addition to recharge measures mentioned above.

●   The required quantity is developed only when it is used judiciously. Different types of recharge measures can be taken up and as the area is overexploited, stringent law can be imposed on groundwater extraction, especially for industrial and agriculture purpose. The domestic water will be given top priority wherever other uses dominate.

●   To minimise the fluoride concentration and by using the Remote Sensing and GIS technology and as a precautionary measure check dams are proposed in the study area to overcome the problem of drinking water.

Long-term Remedial Measures

As there is tremendous demand of groundwater for agriculture / industrial purposes, for which the area is falling in overexploited zone and lots of money is spent every year on drilling of new borewells, especially in Medchal village, it is recommended to adopt surface-based water supply – as distance source (River-based) scheme. Thus, Remote Sensing & GIS are effective tools in preparation of a plan of action on improving sustainability of RWS sources for providing safe drinking water.

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