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Appraisal of Water Resources Development Action Plan for Groundwater Recharge in Raghunathapalli Watershed Jangaon District Telangana State India

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Abstract
Water is elixir of life which needs regular assessment for maintaining ecological balance. Micro watershed wise (a few thousand hectares of extent) water resource action plan is need of the hour especially for a hard rock terrain like Raghunathapalli watershed of Jangaon District. Geologically, the area is underlain by Quartzite and Pelitic Schist of Older Metamorphics and Leuco Granite / Grey Alkali FelpsarGranite Terrain (Peninsular Gneissic Complex) belonging to Archeans. The Archeans are intruded at several places by several Pegmatite Veins and Basic Dolerite Dykes. The average annual rainfall of the study area for the past 19 years is 946 mm and that of monsoonal rainfall is 746 mm. In order to do artificial ground water recharge, the study and analysis of parameters that control the ground water recharge is very important for effective ground water recharge. The spatio-temporal variations in rainfall, regional/local distribution in geological formations and geomorphic composition of various units have led to uneven occurrence and distribution of water resources. Different thematic layers like Geology, Geomorphology, Stream Network, Micro Watersheds, Digital Elevation Model, Contours (2m), Base Layers, Soil and Ground Water Potential maps are prepared using Geospatial technologies like Remote Sensing & GIS. Existing Recharge Structures are marked using 1:25,000 scale Survey of India Toposheets and new locations are updated with high resolution satellite imagery. Micro watershed wise Water Balance studies are carried out and Water Resources Development Action Plan is prepared using Ridge to Valley concept with new artificial recharge structures like Check Dams (22), Percolation Tanks (10), Contour Trenches (68Kms), Subsurface Dyke (2), Farm Pond (268), Recharge Pit (179), Recharge Shaft (16), Desilting Tank (24 nos) etc at suitable terrain conditions. Newly proposed locations for constructions of Rainwater harvesting structures in the gap areas will improve the ground water regime and improves the sustainability of wells for agriculture in the drought prone area of Raghunathapalli watershed. Thus Geospatial technologies are cost effective tools for management and conservation of water resources.

Keywords: Remote Sensing, Groundwater, GIS, Geospatial, Watershed, Recharge, Action Plan, Conservation

1. LOCATION

The study area (Raghunathapalle watershed) falls between the geographic co-ordinates of Longitudes (Cartesian X) 79°7'12''E -79°16'58''E; and Latitudes of 17°43'20''N - 17°52'22''N (Cartesian Y). The location map is shown in Fig. 1. It is falling in upstream network of part of Aaleru Vagu (Musi Sub Basin, Krishna Basin) and at the Drainage divide areas of Godavari and Krishna Basins. The hydrological location map of the basin is shown in Fig. 2. The Raghunathapalle watershed falls in Jangaon District of Telangana state. The total area of the basin is 126 Sq. Kms. The project area covers part of Survey of India (SoI) Toposheet nos. on 1:25,000 scale - 56O1/SE, 56O1/SW, 56O/2NE, 56O/5SW, 56O/6NW. The tributaries are ephemeral in nature and flows in Monsoon season only. Hence effective management of water resources is needed for management and sustainability of water resources.

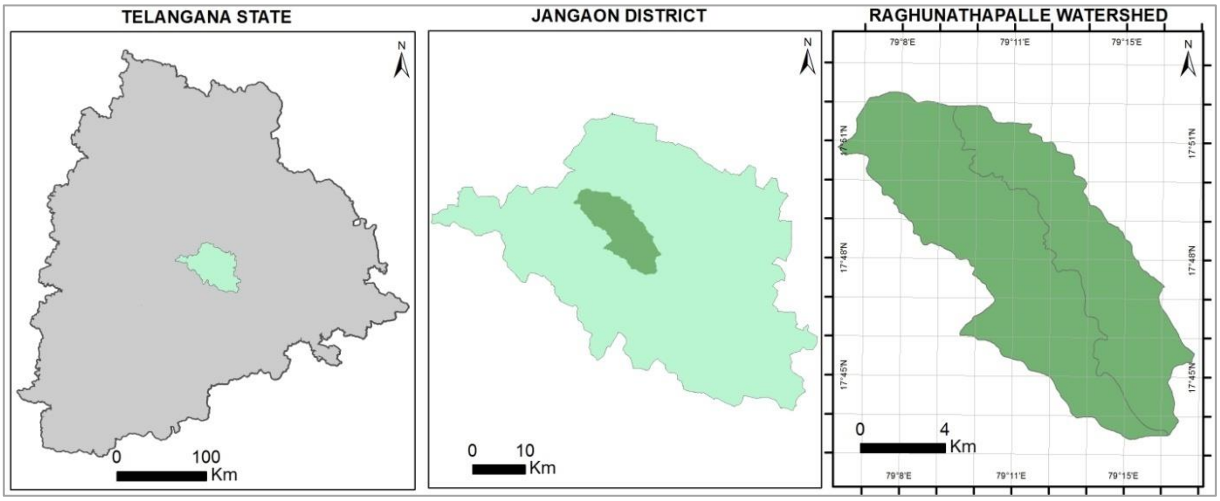

Fig. 1 - Location Map of the study area

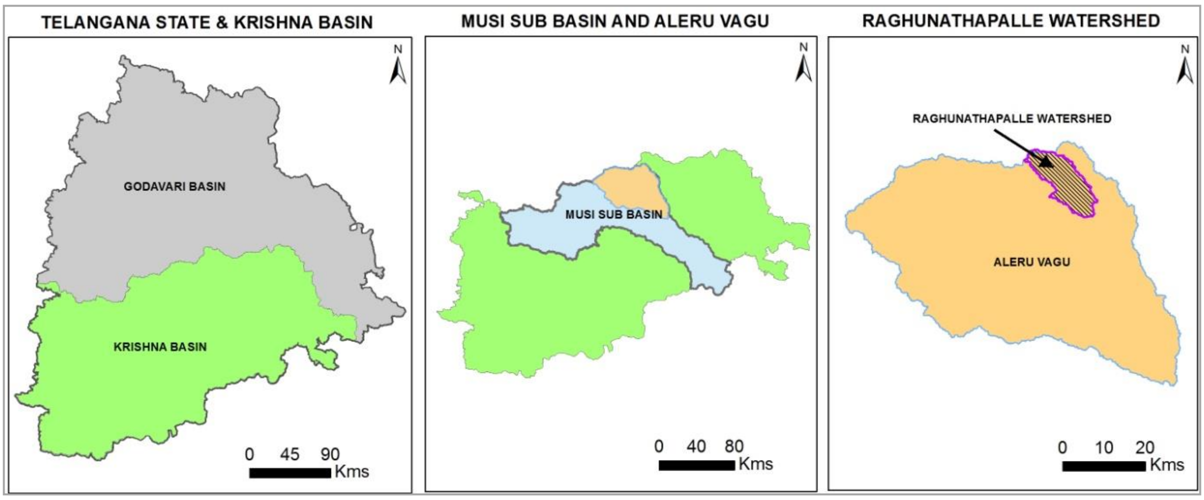

Fig. 2 - Hydrological Location Map of the study area

2. RAINFALL

The rainfall data of the study area from 2004-05 to 2022-23 years is collected from Telangana State Development Planning Society (TSDPS), Planning Department, Govt. of Telangana state. The study area is covered with 3 Raingauge stations as interpreted from Theissein Polygons and shown in Fig 3. The statistics of monsoonal rainfall (June, July, August and September months) is shown in Table 1

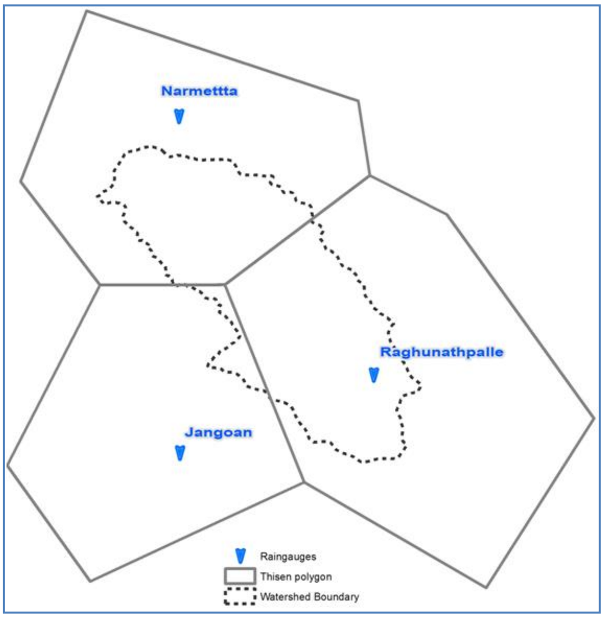

Fig. 3 - Theissen Polygon and Raingauge stations in the study area

Table 1 - Monsoon Rainfall of study area rain gauges (in mm)

Year	Jangaon	Narmetta	Raghunathpalle
2004-05	661.3	456.4	376
2005-06	969.8	921	1134
2006-07	751.4	614.7	500.2
2007-08	879.2	1037.7	729.9
2008-09	949.1	751.8	939.3
2009-10	570.9	389.8	570.4
2010-11	694.1	755.4	818.2
2011-12	581.7	711.4	492.6
2012-13	425	615.4	629.9
2013-14	542.8	705.9	740.6
2014-15	330	450.4	529.4
2015-16	669.4	508.2	661.8
2016-17	732.6	919.8	1150.2
2017-18	546.13	538.55	475.55
2018-19	494.2	571.3	844.5
2019-20	731	806.8	1007.9
2020-21	1087.4	1313.2	1375.8
2021-22	789.1	1131.3	870.2
2022-23	839.1	1091.3	1140.2

Average	**697.06**	**752.12**	**788.77**

3. THEMATIC LAYERS

3.1 Geology

The study area is underlain by rock formations belonging to Peninsular Gneissic Complex (PGC) groups of rocks like Grey Alkali Feldspar Granite, Leuco Granite which are intruded by Pegmatite Veins and Dolerite dykes at several places. The primary porosity is limited to overlying weathered/semi weathered horizons only. However the secondary porosity like fractures, faults, shear zones developed during prolonged geological times provide the promising ground water potential. The Geological map is shown in Fig. 4.

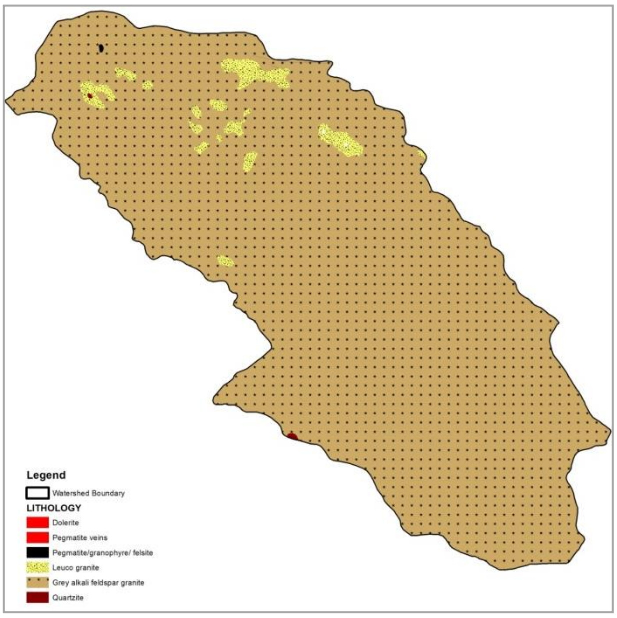

Fig. 4 - Geology Map of the study area

Granitic terrain is composed of igneous rocks formed by the cooling and solidification of magma. One of the most distinctive features of granitic terrain is its rugged and mountainous topography. This is due to the fact that granite is a relatively hard and resistant rock that is resistant to weathering and erosion. Over time, the uplift and erosion of granitic terrain result in development of a variety of landforms.

3.2 Geomorphology

Granite is a type of igneous rock that is characterized by its coarse-grained texture and high silica content. It is a common rock type that is found in many parts of the world, and it is known for its durability and resistance to erosion. The development of landforms in granite terrain is influenced by a variety of factors, including the structure and texture of the rock, the climate, and the erosional processes that operate on the rock.

Here are some common granite landforms:

1. Granite domes: In areas where the granitic rock is exposed at the surface, the rock may weather and erode in a way that creates rounded, dome-shaped landforms. These granite domes can be quite large and are often popular hiking and climbing destinations.

2. Tors: A tor is a large, exposed granite rock that is often found on a hilltop or ridge. Tors are created by the weathering and erosion of the surrounding rock, leaving the more resistant granite standing as a prominent feature.
3. Rock outcroppings: The exposure of granitic rock at the surface can result in the formation of rocky outcroppings and cliffs. These features can be quite dramatic and are often popular with rock climbers.
4. Boulders: Granite boulders can be found scattered throughout granite terrain, often left behind by the erosion and weathering of the surrounding rock.
5. Inselbergs: An inselberg is a large, isolated rock hill or mountain that rises abruptly from a flat or gently sloping terrain.

The mapping of landforms is carried out using remote sensing techniques with deductive approach using additional data like survey of India toposheets, limited field checks etc. The Geomorphology/Landforms map is shown in Fig. 5

In the study area the following landforms are observed:

Flood Plain Shallow (FPS) - Flood Plains receive good amount of recharge from the alluvium which is deposited during repeated flood. The thickness of Alluvium and weathered material is in the range of <10 m

Pediplain Moderate (PPM) - Pediplain Moderately weathered land form is formed due to coalescence of several pediments which forms good recharge zone due to thick weathering (10-20 m)

Pediplain Shallow (PPS) - Shallow weathered pediplain is formed where the thickness of weathering material is below 10m. Lineament zones like Faults / fracture zones in PPS unit act as conduits for movement and occurrence of ground water with enhanced storability of aquifer.

Buried Pediplain Shallow (BPS)- Shallow weathered buried pediplains are same as PPS where the combined thickness of transported material and depth of weathering is below 10m.

Pediment Inselberg Complex (PIC) - Gently undulating plain dotted with rock outcrops with or without thin veneer of soil cover. Pediments show limited to moderate recharge whereas Inselbergs are run-off zones.

Structural Hill (SH) - Structure Hills (SH) show Linear to arcuate trend which depicts definite structural control and acts as run-off zone except valleys portions.

Dyke Ridge (DR) - A narrow linear / curvilinear resistant ridge formed by dolerite dyke which blocks the movement of water at on surface or underground unless cut by fractures.

Inselberg (I) - A massive isolated hill rising abruptly from the ground which forms essentially run-off zone.

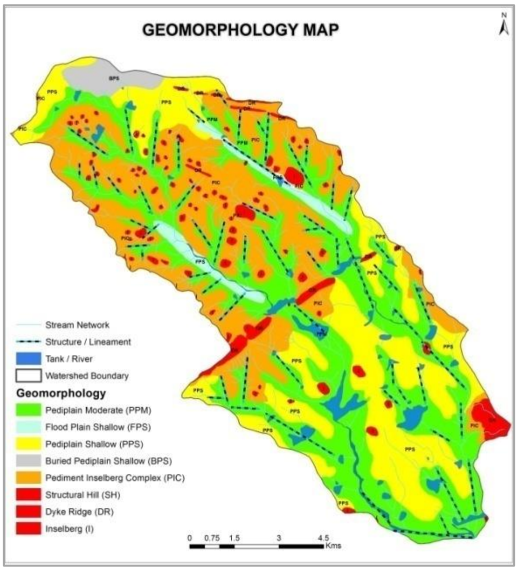

Fig. 5 - Geomorphology / Lineament Map of the study area

3.3 Structure Map

Different types of discontinuities like fractures, joints, faults, and fissures etc which influence the availability of ground water are mapped using the satellite remote sensing techniques. The fractures, faults or shear zones are promising zones for availability of good amount of aquifer in the country rocks. The lineaments which may represent fractures or fissures are interpreted from satellite data and represented with land forms in Fig. 5.

3.4 Hydrogeomorphology

Geology and geomorphology are two related but distinct branches of earth science that are concerned with the study of the Earth's surface and subsurface

Geology is the study of the Earth's physical structure, composition, and history, including its rocks, minerals, and fossils. Geologists study the formation, structure, and composition of the Earth's crust, as well as the processes that have shaped the Earth's surface over time, including tectonic activity, volcanic eruptions, and erosion

Geomorphology, on the other hand, is the study of the Earth's surface landforms, including their origin, development, and change over time. Geomorphologists study the processes that shape the Earth's surface, such as weathering, erosion, and deposition, as well as the factors that influence these processes, such as climate, topography, and geology.

Granitic terrain can have complex hydrogeology due to the nature of the rock, which is typically hard and impermeable. However, fractures and joints in the rock can create pathways for water to flow through, making granitic terrain an important groundwater resource in some areas. Here are some key aspects of the hydrogeology of granitic terrain:

- Porosity and permeability: The porosity of granite is generally low, meaning that there are relatively few spaces between the mineral grains that can hold water. However, fractures and joints in the rock can increase the permeability of the rock, allowing water to flow through more easily.
- Fractures and joints: Fractures and joints in granite can create conduits for groundwater flow. These features can be natural, or they may be the result of human activities such as quarrying or drilling
- Aquifers: In some areas, the fractures and joints in granite can form significant groundwater reservoirs, known as aquifers. These aquifers can be an important source of water for drinking, irrigation, and other uses
- Springs: Springs can occur in granitic terrain where groundwater is forced to the surface due to changes in the elevation or pressure gradient. Springs can be an important source of freshwater for plants and animals, as well as for human communities.

Hydrogeomorphology is a subfield of geomorphology that focuses on the interactions between water and landforms. It is the study of how water shapes the land and how landforms influence the movement and behavior of water.

In the study area the hydrogeology of different land forms is as mentioned below:

Flood Plain Shallow (FPS) - Very Good
Pediplain Moderate (PPM) - Good
Pediplain Shallow (PPS) - Moderate
Buried Pediplain Shallow (BPS) - Moderate
Pediment Inselberg Complex (PIC) - Low
Structural Hill (SH) - Limited to valleys portions only
Dyke Ridge (DR) - Mainly run-off zone
Inselberg (I) - Mainly run-off zone.

3.5 Digital Elevation Model:

The Digital Elevation Model (DEM) is used for depicting the elevation zones and Slope maps. The DEM is prepared using 5M contour data from Survey of India Topo sheets on 1:25,000 scale. The topo sheets are rectified on to high resolution satellite data. From this the spatial database of contour map is prepared using ESRI Arc GIS 10.3 software. The Traingular Irregular Netwrork (TIN) is processed from this elevation data. The TIN is converted to raster form for further processing and the Digital Elevation Model is prepared after removing the sinks in the raster dataset using spatial analysis tools available in Arc GIS software. Later from the DEM closely spaced contours (2m interval) and slope maps are prepared which are useful in preparation of water resources development action plan. The DEM map is shown in Fig. 6

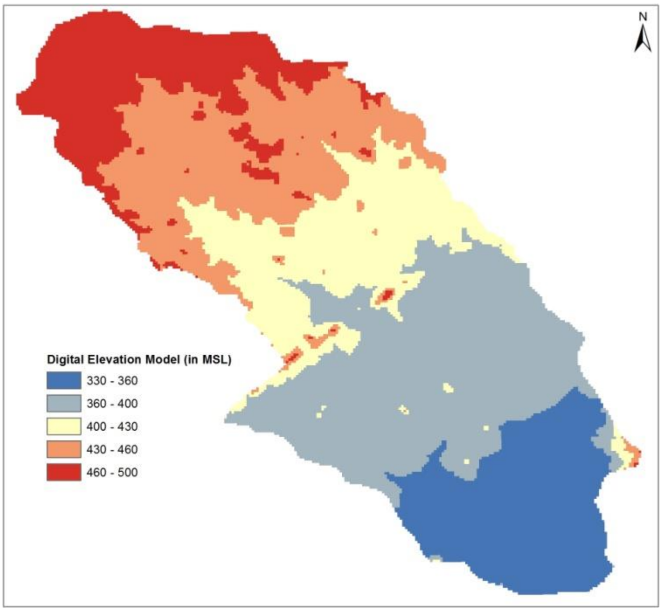

Fig. 6. Digital Elevation Model (DEM) of the study area

3.6 Cadastral Data:

Cadastral Maps, also referred to as Bhu Naksha, are register of property titles in digital form of land records that show all the boundaries of different parts of land parcels based on their length, area, and direction. The cadastral parcel data is being used in identifying a place of interest in study area by its survey number, Longitude, Latitude etc. The cadastral map is shown in Fig. 7

Fig. 7. Cadastral Map of the study area

3.7 Soil Map:

The soil map of the study area is prepared using Remote Sensing and GIS techniques. The principal soil types are Chalka soils (Red sandy loam soils) developed in Granitic terrain. The salt affected soils are observed in the low lying / valley portions where intense agriculture activity is there. Dubba soils (Red loamy sands soil) are seen over Dolerite dykes. The soil map is as shown in Fig. 8.

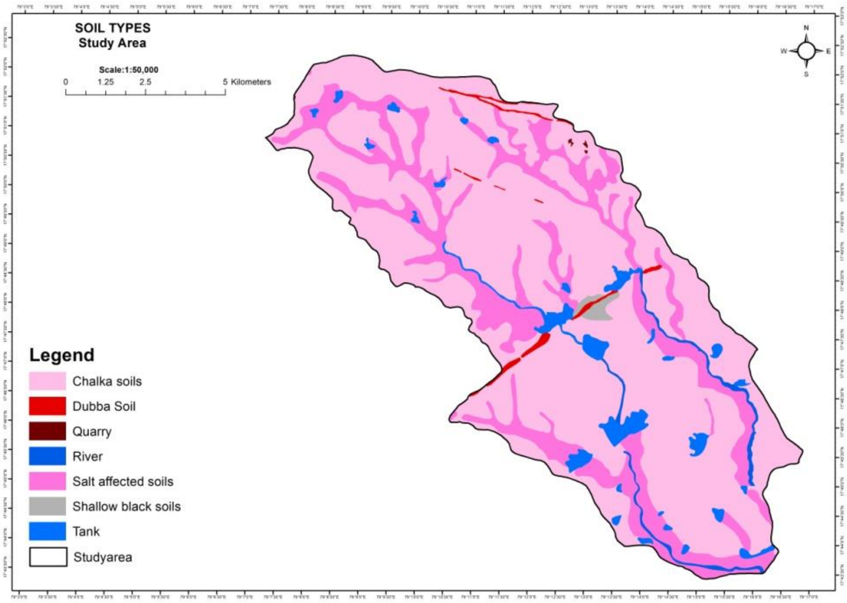

Fig. 8. Soil map of the study area

3.8 Micro Watersheds Map:

The Micro watersheds of a few thousand hectares of the study area is prepared using Survey of India Toposheet and Stream Network, Waterbodies and Contours data. There are about 20 nos of Micro watersheds in the area and are shown in Fig. 9

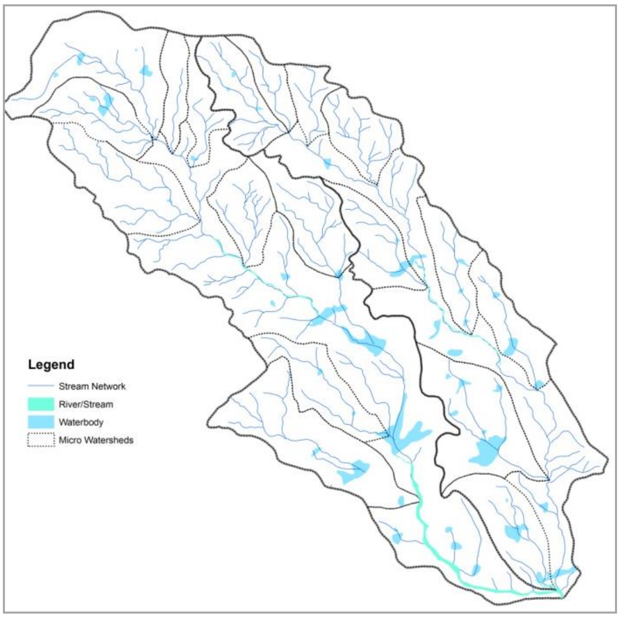

Fig. 9. Micro watersheds in the study area

3.9 Slope Map

The slope is the average drop in elevation per unit distance. It is expressed in Percentages. There are 6 categories of slope classes identified in the study area from Class I to VI. The slope map is depicted in Fig. 10. The upside of the catchment area is showing high slope as compared to downstream areas.

Majority area of Dykes and Hills forms in high slope areas; whereas Plain areas at low slope areas. Comparatively Pediment Core Stone complexes in between are showing with medium sloping areas.

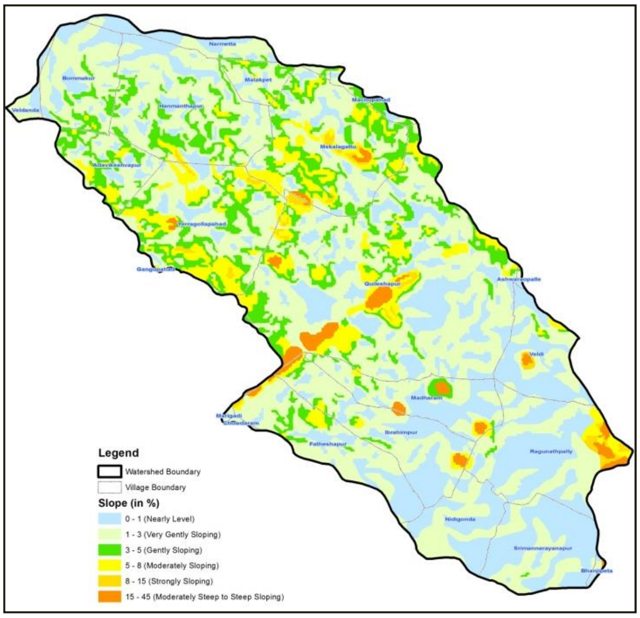

Fig. 10. Slope Map of the study area

4. MATERIALS AND METHODOLOGY

Primarily, input data / thematic layers of the project area are prepared. The process flow chart is shown in Figure. 11. The base layers like transport, locations of habitations, cadastral layers are prepared using RS&GIS techniques. The hydrology layer consisting of Stream Network, Waterbodies, Rivers etc are prepared after updating with temporal satellite data. The volume/capacities of existing water bodies (in Cum) are prepared using the empirical formulae =
(1/2) **(x)** Area of water body (Sq. m) **(x)** Average Height of the structure or bund (m)

Assessment of micro-watershed wise surface-runoff is carried out using monsoonal average rainfall data for 19 years (2004 to 2023).

The rainfall data of the study area is analysed micro-watershed-wise for identifying the amount of total monsoonal (June-September) rainfall followed by estimation of the run-off yield in the micro-watershed. The runoff in the catchments is assessed normally using Soil Conservation Service (SCS) curve number method. The Curve Number method is a versatile and widely used procedure for runoff estimation. However, for the present purpose of estimation of yield on operational basis, the following empirical formula is used.

Run-off Yield of micro-watershed **(Cu. m)** =
(1/2) **(x)**Average (for 19 years) monsoonal rainfall, in mtrs **(x)** Area of the micro-watershed (in Sq. mtrs) **(-)** Interception loss of **10%(-)** Evaporation loss of **10%**

Finally the balance yield available for further conservation is arrived at based on the existing storage capacities of Waterbodies.

Normally, 20% of the balance yield is considered for harvesting leaving 80% for downstream requirements towards riparian rights and environmental flow. However, as this 20% of the balance yield is not sufficient to augment the severely depleted ground water resource in the Over Exploited & Critical GEC Basin, it is proposed to consider 40% of the Balance yield for the proposed conservation under this programme leaving 60% flow towards environmental flows. In this connection, it is to be noted that this 40% of the Balance yield also which will be in the form of conserved ground water will become part of the hydrological cycle downstream in the form of discharge.

The hydrogeological parameters which control the ground water recharge in the village is derived based on the interpretation of high resolution satellite images in conjunction with limited ground truth data. This data is analyzed / processed in GIS environment for identifying site-specific recharge structures and finally a rain water harvesting plan for water recharge is prepared.

For the hydrological data analysis, the basin at macro-level is taken for Raghunathapalli watershed which is sub-watershed of AleruVagu / Musi-sub basin / Krishna basin as per hydrological hierarchy, whereas the micro-watersheds delineated within the macro watershed is considered as a unit area for estimation of balance yield and subsequent identification of site-specific recharge structures.

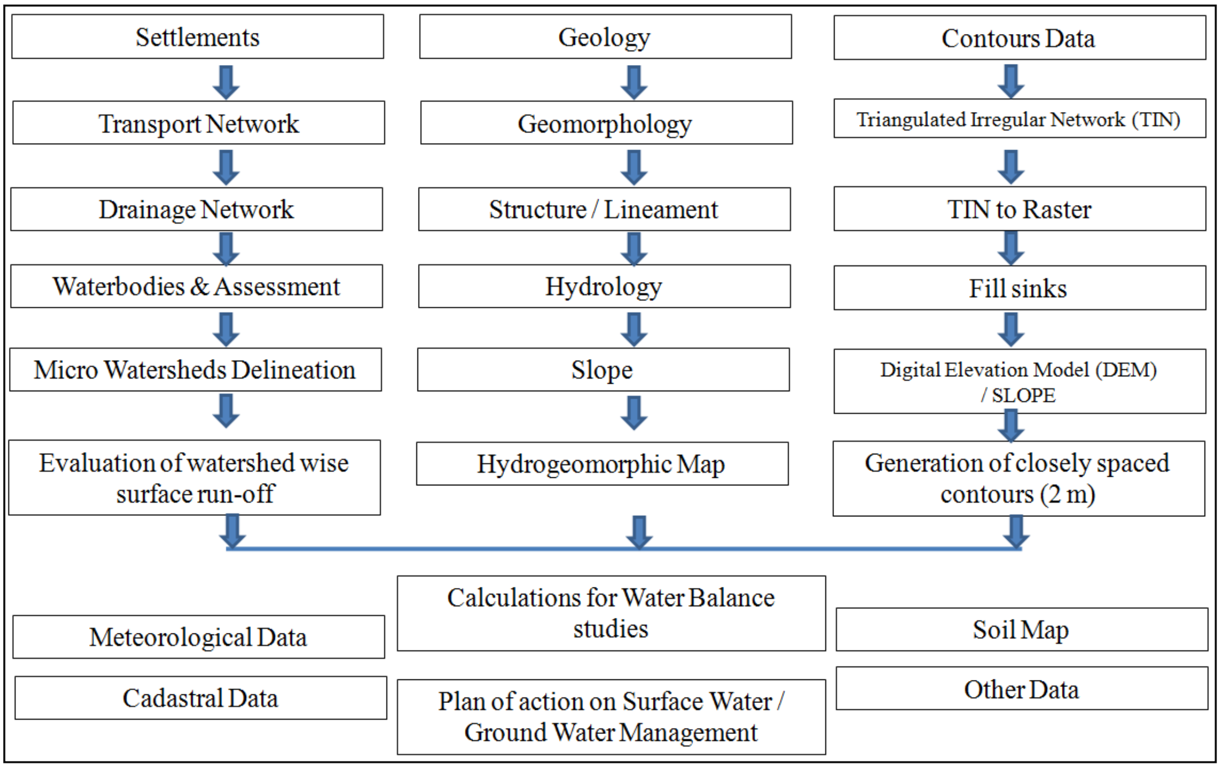

Fig. 11 - Methodology adopted for the project

The entire process of preparation of micro watershed wise rain water harvesting plan and the methodology adopted for carrying out the process are explained below:

- The existing water bodies are identified with the help of Survey of India Toposheets, and other collateral high resolution satellite data.

- Study and analysis of topography and hydrogeomorphology of terrain is prepared by making use of high resolution satellite data as briefed below:
  The basic Hydrogeomorphic units are delineated by considering the lithological, structural, geomorphological and hydrological aspects of the area. Most of the geological linear features are assumed to be the zone of fractured bed rocks with considerable porosity and permeability where enhanced well yields can be expected. The Rain water harvesting structures (RWHS) are proposed on GIS platform by using Remote Sensing & GIS techniques by considering the drainage nodes on 1st, 2nd and 3rd order streams, intersection of drainage nodes, slope categories (0-5% slopes), Geomorphology (shallow and moderately weathered pediplain zones), Land use / Land cover (by eliminating the command areas, double crop areas, barren rocky / stony waste, built up, and mining areas), and soil (red soil are considered and leaving the black soil areas). Delineation of pertinent area (such as open deep-seated fractures, weathered residuum, old channel courses etc.) in the composite map for groundwater development, for construction of artificial recharge structure and for surface water storage augmentation by water impounding structure.

5. RESULTS & DISCUSSION

The locations of some of the proposed structures are verified during the ground truth for its suitability and one of the locations and its ground photograph is depicted in Fig. 12

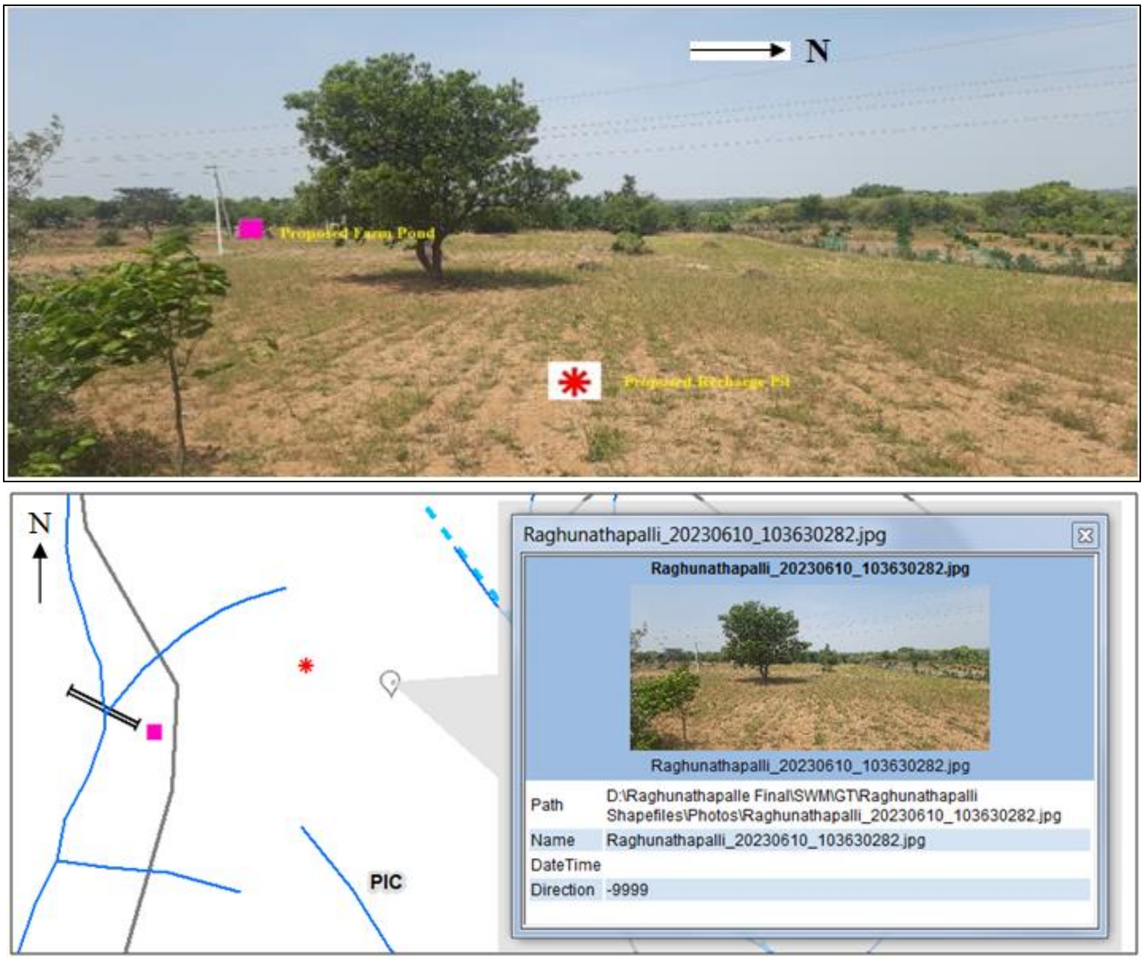

Fig. 12. Proposed recharge measures verification at study area and Geo-tagged photo

It is revealed that the utility of Remote sensing and GIS technique helps in delineating groundwater prospects zones represented with various hydro-geomorphic units. The various hydro-geomorphic units are classified as high, medium low and poor zones of groundwater.

Water Resources Development action plan is prepared in suitable locations at Micro-watershed level in gap areas where surplus run-off water is available and by considering the terrain conditions like Rock type, Landforms, Weathering profile, Slope, Lineaments, Recharge conditions, Soil etc. The final action plan is as shown in Fig. 13.

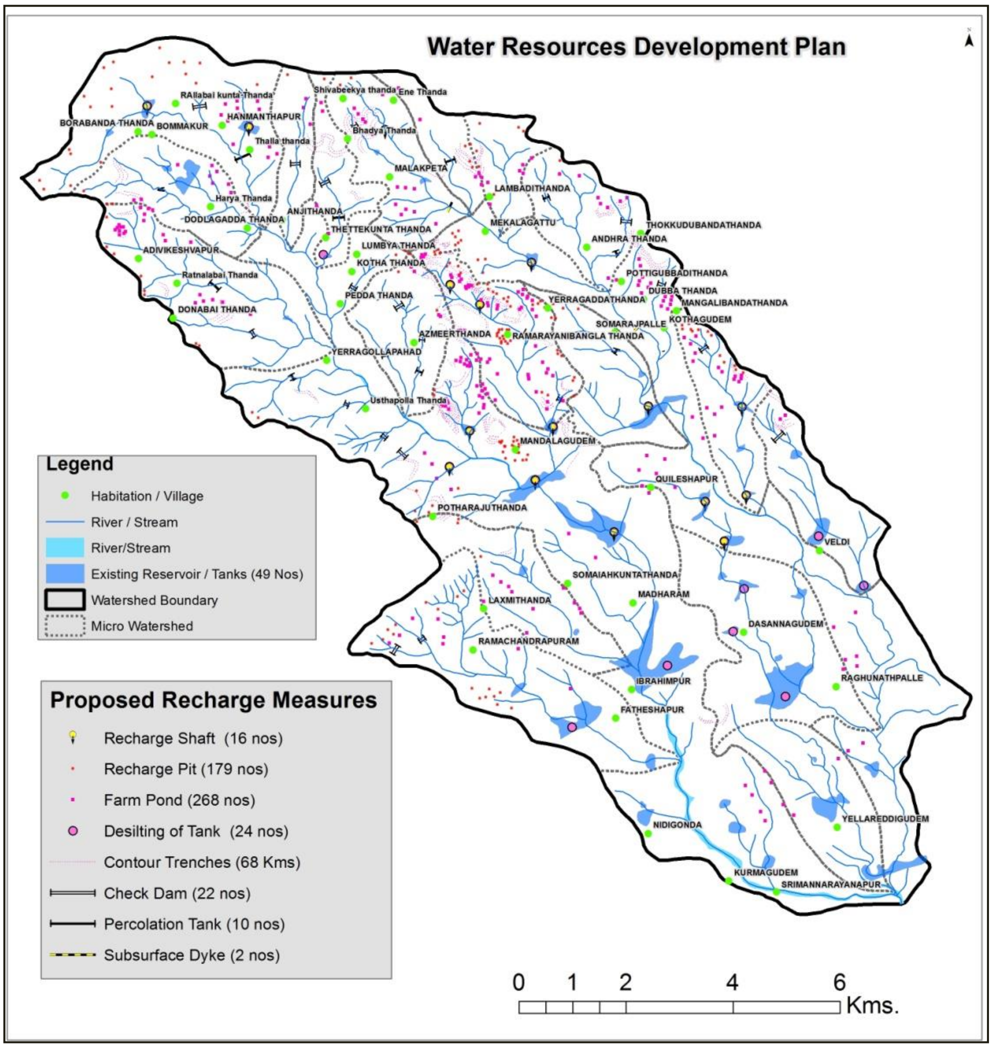

Fig. 13. Water Resources Development Action Plan of the study area

6. CONCLUSIONS

The following different suitable harvesting structure locations are identified in the study area scientifically based on the terrain conditions, micro watershed wise availability of water and its utility:

- Check Dams (22 nos) - Check Dams which are built across channels or gullies helps to reduce the velocity of intensive flow which results in augmentation of Ground water recharge, increase vegetation, reduce flood peak discharge etc.

- Percolation Tanks (10 nos) - Percolation tanks are small ponds proposed in low lying and highly permeable land, where the surface runoff is made to percolate and recharges the ground water storage several times.
- Sub-surface Dyke (2 nos) -It is an underground dam built with the intention of obstructing base flow and stores water, thereby increasing the amount of water stored in the upstream area aquifer.
- Contour Trenches (68 Kms) - Contour furrows are trapezoidal / V-shape trenches dug all along the contours to arrest the erosion. This measure is effective in reducing surface run-off to increase infiltration particularly at high sloping areas which improve soil moisture as well as ground water recharge. Fertile soil particles are not lost by water and wind erosion.
- Recharge Shaft (16 nos) - Recharge shaft wells with filter media are proposed in existing tanks where the rain water will be recharged speedily in to the aquifers.
- Recharge Pit (179 nos) - A percolation pit, is a simple hole dug into the ground. It facilitates groundwater recharge through infiltration of surface runoff into the soil or rock at drainage divide areas and increases soil moisture.
- Farm Pond (268 nos) - Farm ponds have a significant role in rainfed farming system where it helps in mitigating the ill effect of rainfall variability as it stores water from rainfall excess and provides for utilization during prolonged dry spells by means of supplemental/protective irrigation, providing drinking water for cattle, saves from top soil erosion.
- De-silting Tank (24 nos) - Desilting is a process where accumulated silt is removed from tank. The desilting activity enhances water holding capacity and accumulated silt can be used in the agricultural fields, owing to the rich minerals present in it.

7. ACKNOWLEDGMENTS

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