ISSN 0974-5904, Volume 10, No. 02

DOI:10.21276/ijee.2017.10.0217

www.cafetinnova.org

International Journal of Earth Sciences and Engineering

April 2017, P.P. 257-265

Identification of Groundwater Potential Zones Using Remote Sensing and GIS Techniques, in Muguru Addahalla Watershed, Mysore and Chamarajnagar Districts, Karnataka, India

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Abstract: *Groundwater recharge from surface water sources is an essential aspect in any watershed or a hydrological unit. For any small scale groundwater assessment, experimental approaches are usually adopted. However, recharge into aquifers depends on several hydrogeological factors on a regional scale analysis; groundwater assessment is conducted in a comprehensive approach considering all the geospatial data of different contributing factors. These factors include geomorphological, geological and structural elements like lineaments, drainage frequency, drainage density, lithology, land use and land cover. This study has been conducted with an integrated approach to identify the groundwater potential of the area, and the factors influencing groundwater recharge. The study has shown that the prevailing groundwater conditions are very good along the stream networks and the remaining zones show moderate to poor groundwater resources. It is also found that for such an integrated study, the tools and techniques of remote sensing and GIS are more useful.*

Keywords: *Groundwater assessment, Drainage, Land use. Land covers valley regions.*

1. Introduction

The pressure on both surface and groundwater resources is increasing manifold globally. In the recent years, due to several water-demanding factors like population explosion, spreading urbanization, rapid industrialization, extensive irrigation, the demand has also increased in an unexpected manner. There are incidences of human failure in managing this precious resource. The impacts of global climate change are also causing some more imbalances in replenishing the water resources. Thus, managing the available water resource for a sustainable progress is always a herculean task, and several nations are spending their annual budget for developing this sector. Such issues are much more severe in any developing country like India where the efficient management of any resource is a necessity. The population density, social and economic interfaces are adding more challenges to solve this problem. In spite of diversified advancements in technological know-how's, effective water management is still an area of great concern. Launching of satellites and probing of the earth remotely, by these satellites, is a hallmark feature of the last three decades, which has greatly enhanced our understanding of the surface dynamics and resource base. Geoexploration is the biggest beneficiary of remote sensing. It has enhanced our understanding of local and regional, lithological, structural and geomorphological features more clearly, by providing a better insight into surface and sub-surface dynamics of water resource, its utilization and management. The subject is focussed on the imbalance between recharge and withdrawal of ground water, in a typical hard rock terrain, which needs a detailed hydrological investigation. This work aims to carry out an integrated hydrogeological investigation in the hard rock aquifers of southern parts of Karnataka state, India including Remote Sensing and GIS.

2. Study Area

The Muguru Addahalla Watershed spreads over parts of two districts viz. Chamarajanagar and Mysore in the southern part of Karnataka State in India (Fig.1). The spatial extent of the watershed is 248.827 sq km. This area is covered in Survey of India toposheet numbers 57d/16, 58A/13 and 57H/4. It is bounded by latitudes 11˚ 58' 20.78'' N to 12˚ 12'33.67" N, and longitudes of, 76˚ 52' 50.34" E to 76˚ 59' 25.68" E. The geographic setting of the area is shown in Fig. 2. The satellite image of the area is shown in Fig.3. The area is well connected with all-weather motarable road (Fig.4).

3. Physiography

Physiographically, Muguru Addahalla watershed forms the 'Southerrn Maidan' region of Karnataka. It is bounded by the Doddasampige Reserve Forest area in the east and Suttur village and hamlets in the west. The River Cauvery is draining towards North, and the district headquarters Chamarajanagar is located towards the south. The Muguru Addahalla originates at Ummattur gudda in the south and it joins the Cauvery River near the village Ayyanurhundi. The

Received: December 03, 2016; Accepted: February 12, 2017; Published: April 26, 2017
International Journal of Earth Sciences and Engineering, 10(02), 257-265, 2017, DOI:10.21276/ijee.2017.10.0217

maximum elevation of the area is 900 m (AMSL) at Ummathuru gudda and the minimum elevation of 540m (AMSL) which is seent at Muguru Addahalla, where it joins the Cauvery River. The rest of the area constitutes a gently dipping plain, dissected by shallow rivulets. Much of the area is under cultivation.

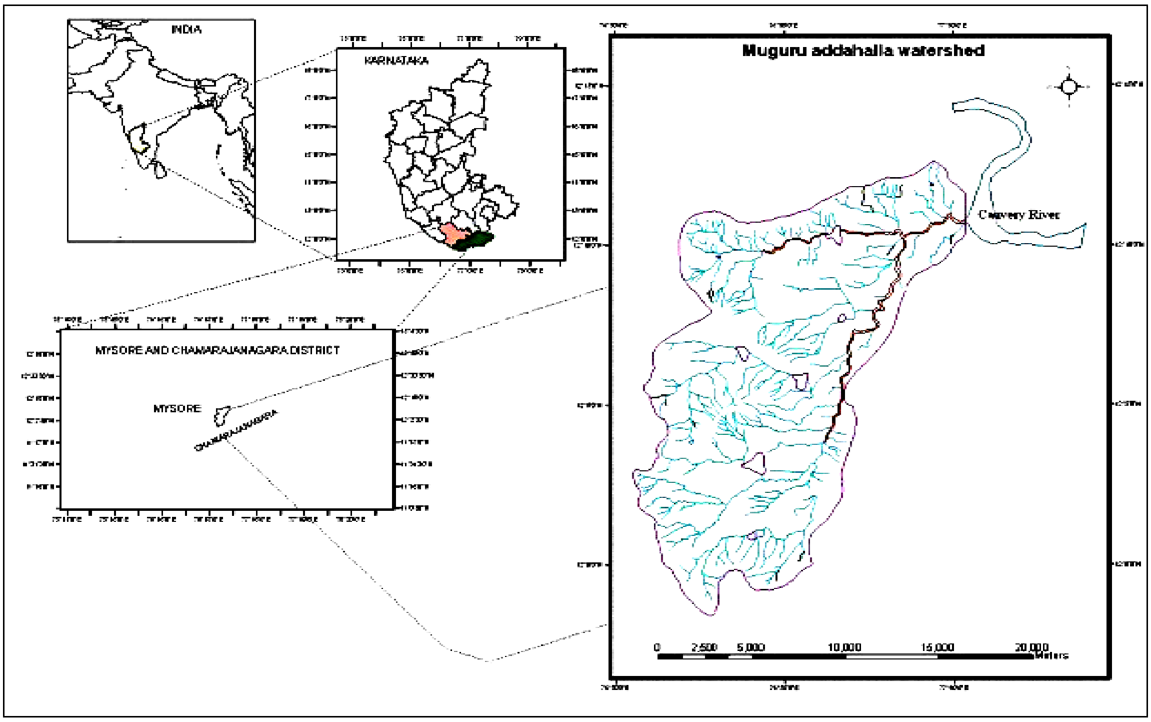

Figure.1 *Location Map of the Muguru Addahalla Watershed*

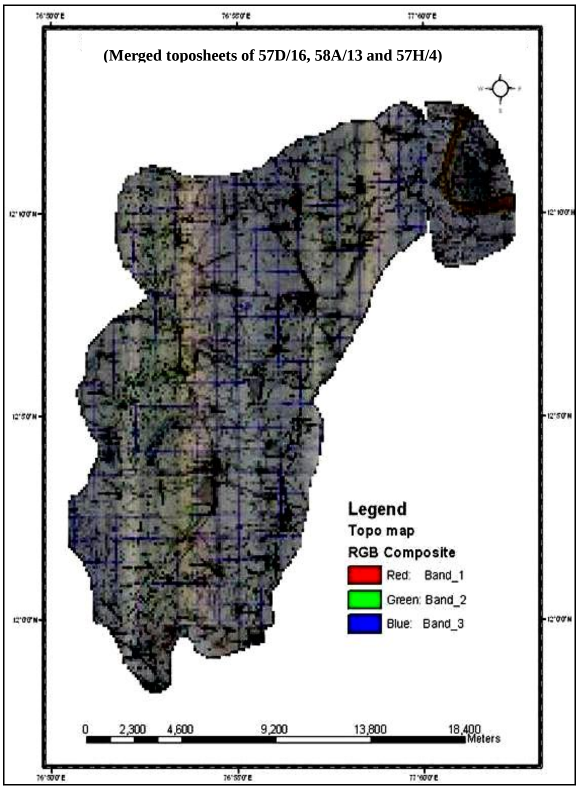

Figure.2 *Topo Map of the Muguru Addahalla Watershed*

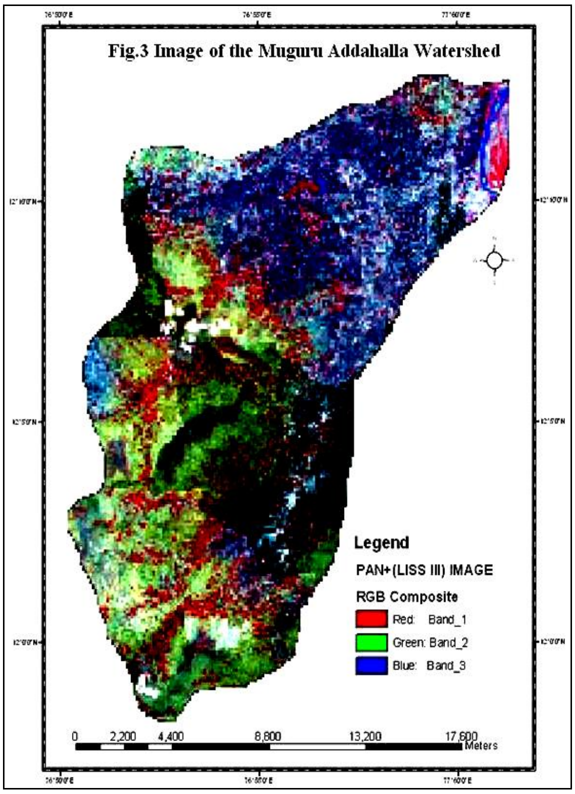

Figure.3 *Image of the Muguru Addahalla Watershed*

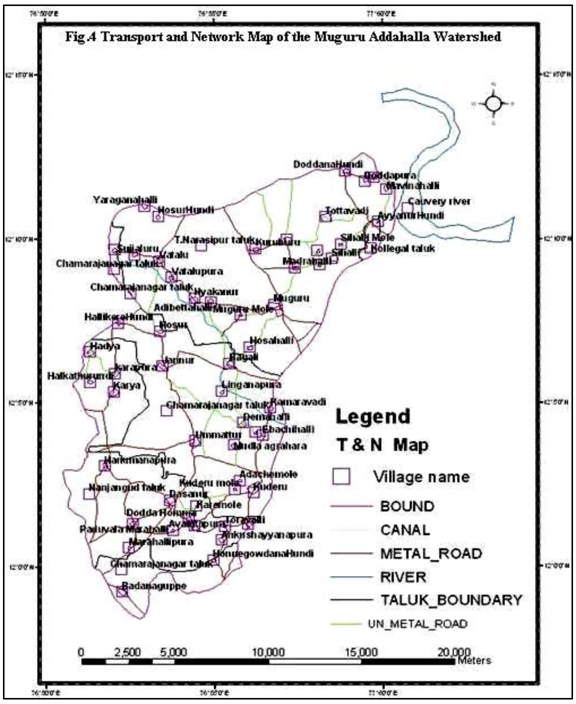

__Figure.4__ Transport and Network Map of the Muguru Addahalla Watershed

4. Materials and Methods

In the recent decades, extensive studies have been made for ground water exploration in hard rock terrains using remote sensing and GIS techniques (Venkatachalam et al., 1991[23] Haridass et al., 1994[8]; Chi and Lee, 1994[5]; Krishnamurthy et al.,[12]; Pal et al., 1997) [16]. The present methodology includes generation of thematic maps such as lithology, landforms, structures, land use/land cover, soil slope maps on 1:50,000 scale using IRS 1D (PAN+LISS III) merged satellite data and other collateral information. Lithological Map was updated from the published geological data on 1:2,50,000 scale and by using satellite data. Geomorphology (Landforms), land use/land cover and lineament maps were interpreted from satellite imagery. Slope map was prepared from SOI India topographical sheets on 1:50,000 scale. Soil map of the study area was digitized from 1:2,50,000 scale soil map of Karnataka prepared by NBSS & LUP. All thematic maps were converted into the vector format by digitization. Depending upon the perceived importance of their role in occurrence and movement of ground water, appropriate weightages have been assigned for individual themes. All the maps were integrated by overlay techniques using GIS to delineate the ground water potential zones.

5. Results and Discussion

5.1. Geology of the area

Lithologically, this study area is made up of gneisses, amphibolites, ultramafics and younger dykes. Among them, gneisses are the predominant litho units. They are part of the Peninsular Gneisses, which are predominant in the southern parts of Karnataka. Amphibolites and ultramafics are noticed as enclaves within the gneissic rocks. Dykes represent the youngest episodes of igneous activities. Besides the different rock types, drainage pattern, distribution of joints, fissures, fractures and different lithological units have been studied. From the hydrogeological perspective, the rock types of this watershed are generally poor for groundwater infiltration, owing to their low and inherent porosity and permeability. However, weathering has produced vast structures of soil cover, which are, to a greater extent, facilitates sub-surface percolation and infiltration. Also, the contact zones between different lithounits (though found to be less) could augment sub-surface movement. However, dykes have also a significant role to play, by serving as barriers and could store copious ground water. The textures and structures of the rocks also influence weathering besides playing vital role in the ground water accumulation, movement and acquiring chemical characteristics. Large scale structures like faults, shear zones and other week planes affect greatly the ground water accumulation and surface run-off. The groundwater levels of this region have already gone beyond the depth of 200m below ground level. The porosity and permeability factors in rocks are also important characteristics to evaluate transmissivity, specific retention and specific yield. These properties vary from place to place and thus studying their hydrogeological conditions is necessary for quantifying them. Demarcation of lineament in different areas and their relation to rock types and lithologic contacts has also been studied. Similarly different litho boundaries have also been recognized as shown in Table 1.

__Table.1__ Categorization of lithology based on Quadrangle map of GSI, using remote sensing and GIS

Sl. No	Lithology code	Area/sq km	Percentage of the area cover
1	GTGN	247.0975	99.28
2	DYKE	0.9647	0.39
3	UM	0.2144	0.09
4	AMP	0.6084	0.24

GTGN:Gneisses Granodiorite, Tonalite and Migmatite gneiss.
AMP: Amphibolite and Hornblende schist.
UM : Metaultramafics, Metapyroxenite, Serpentinised dunite and Peridotite.
Dyke : Dolerite\Gabbro dyke.
GSI : Geological Survey of India.
GIS : Geographical Information System.

Among the different lithologies, granitoids cover the largest area of 99.28% followed by dykes (0.39%) and amphibolites (0.24%). The ultramafics occupy the least area (0.09 %.).

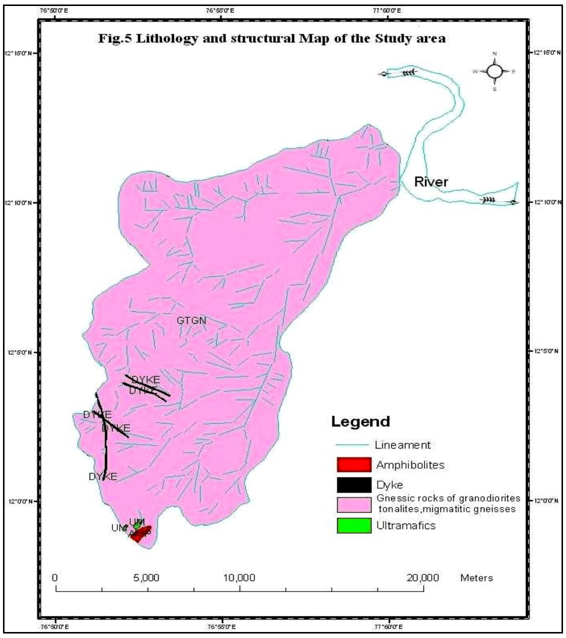

Figure.5 *Lithology and Structural Map of the study area*

Table.2 *Lineament Classification (Based on Kowalik and Gold 1976)*

Sl. No.	Lineament Class	Length(km)
1	Short /Minor	1.6 to 10
2	Intermediate	10 to 100
3	Long / major	100 to 500
4	Mega	>500

5.2. Lineaments

The rock types of the study area display shears, joints, faults and lineaments which appear to be moderate in the intensity of developing groundwater poetntial zones. As joints, fractures, and shears are smaller and localized, they could not be quantified through Remote sensing data. However, linear features like lineaments have been quantified. The term lineament was originally used by Hobbs (1904) [9] to describe linear features that are "significant lines of land scape" although linear features had been discussed since 1800's (Hodgson, 1974). Lineaments are both local and regional features. Bhave et al, (1989) opined that the term lineament is preferentially used to define the unidirectional earth features of larger magnitude. The other synonyms related to lineaments are linear, lineation, geofracture, suture, mega fracture and shear. Several tectonic process and related parameters are involved in the formation of lineaments (Rakshit an Prabhakara Rao, 1989) and they act as neotectonic windows (Ramaswamy, 1997). Lineaments have major tectonic, magmatic and neotectonic significance, and their role in surface and sub surface hydrology is assuming more and more importance. Lineaments of the study are investigated and interpreted in the background of their regional studies carried by early workers. Kowalik and Gold (1976) suggested a classification of lineaments based on their lengths as shown in (Table.2). Most of the drainage network in the study area is controlled by these lineaments (Figure.5). Many structural features like fold axis, faults and shears, besides dyke bodies normally appear on remote sensing data products, as lineaments. Often the lineaments develop in a systematic way and hence a methodical statistical analysis of lineament pattern provides information regarding their tectonogenesis and relevance to ground water movement.

Table.3 *Distribution of Lineaments in the study area*

Lineament range in km	Total length of lineamentin each class(km)	Total no of lineaments
Less than 1Km	113.80	188
1 to 2km	67.43	51
2 to3 km	137.47	12

The lineaments are aligned along N-S, E-W, NW-SE, NE-SW, NNE-SSW, NNW-SSE directions (Figure.2). It can be seen that 2 to 3 km long lineaments are aligned along the stream courses, shears and less frequently along the contacts of different litho units. One to two km and less than 1 km long lineaments are found along the sides of the drainage segments. Joints, fracture and fissure zones and contact zones of litho boundary. All these characteristics are identified on the satellite imageries, based on parameters like colour, tone, texture, pattern and association. Lineaments, especially tectnogenic ones are known to be excellent sites for groundwater movement and storage. The ground water potential of the study area has been appraised from this angle, because of the presence of a good network of lineaments, which contribute significantly for ground water potential. As such, the bedrocks of the study area are not so favorable for ground water movement, due to their inherent properties, but are rendered considerably favorable due to the existence of lineaments (Table.3).

5.3. Soil cover

Soil serves as a natural medium for the growth of the plants. Next to water and air, soil is the most essential medium for the existence of all life on earth. Soils are the basis of support for most life and a source of nutrients for all kinds of life in one way or the other. It is well-known that soil is produced by the weathering process. It gets mixed with decayed vegetation and other organic matter and forms humus rich top soil over the parent rock or at some distance which forms 'A' horizon. Below this would be 'B' horizon and followed by 'C' horizon. Soils play an important role in the accumulation of ground water. Soil structure and texture which are controlled by the percentage of sand, silt and clay, play a dominant role in the ground water infiltration. The sand (0.06mm to 2mm in diameter) helps in high infiltration, whereas the silt (0.002mm to 0.06mm diameter) is having medium infiltration and the clay (below 0.02mm diameter) is found to show very low rate of infiltration. The soil map of the study area is shown in (Figure. 6). Based on the physical property and broad chemical composition of the soil cover, soil map of the study area has been prepared (Figure. 7). This map is useful for delineating the run-off potential zones.

5.4. Natural vegetation as Landuse/Land cover pattern

Vegetation also plays an important role in the run-off process. Different types of natural pattern like forest and plantation are part of land use/land cover map which are also important for proper groundwater management. Waste lands have also been considered in the land use/land cover map for proper groundwater management. For this, the infrared and visible regions of the electromagnetic spectrum are found to be more useful. Different shades of cropping pattern can be easily identified by the red band of false colour composites (FCC). The higher water concentration in any region can be inferred from the thickness of the vegetation which is represented in dark red colour on the imagery. The land cover encompasses natural cover of the land like hills, rivers and related geomorphological features. Whereas, the land use signifies the natural cover of the land by human activity. For example, all buildings, cities, and agricultural grazing lands etc belong to landuse categories. The proper land use pattern improves agricultural production like food and fodder and contributes for the ecological balance of any area. Thus, the land cover and land use development are based on the integrated management of soil, water and other resources (Figure. 9).

5.5. Geomorphology

Geomorphology is the science of landforms. Their systematic study is important in order to interpret them as signatures of the past and ongoing geological processes. These geomorphic features have a great bearing on the water resources of any area. Geological agents like rivers, glaciers, winds, etc relentlessly operate on the earth crust to bring about the changes of degradation and aggradation and these features are important from the point of understanding surface and subsurface water movement (Figure.8).

5.6. Residual Hills

These are formed due to differential weathering and erosion on a more resistant formation (controlled by rock type). The structures which controll their formation are joints and fractures. The lithology in residual hill area is dominant with granodiorite, tonalite and migmatitic gneiss. They are the prominent and elevated features in the study area. Such hills are noticed in north-west and adjacent areas of Hanumanapura. They are also noticed around Karya and also west and north west of Ummatturu village. Residual hills cover an area of 3.0958 sq km (1.24% of the watershed).

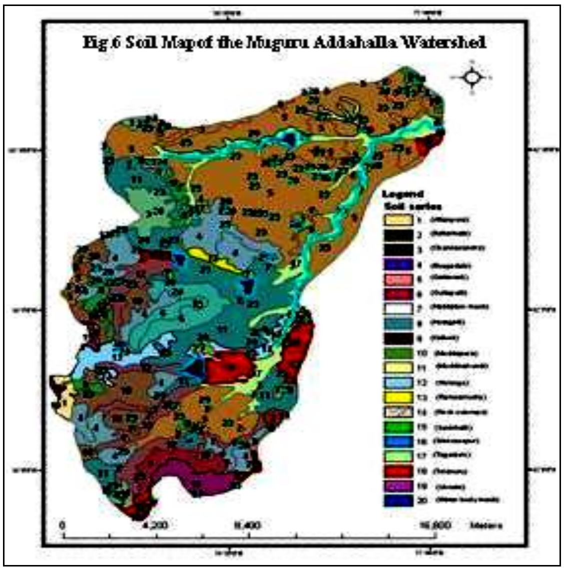

Figure.6 *Soil Map of the Muguru Addahalla Watershed*

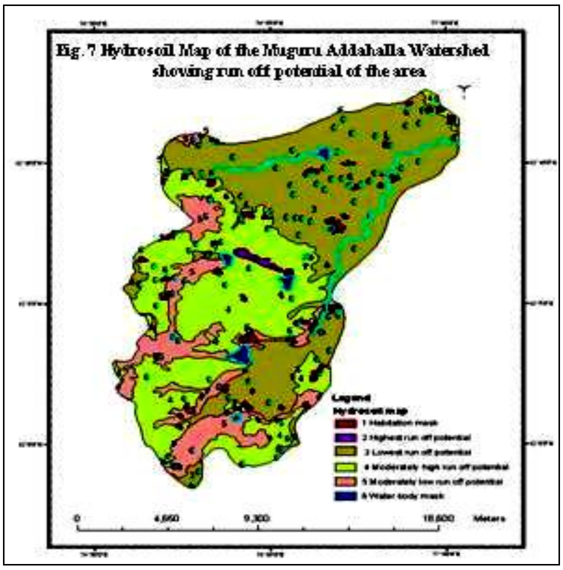

Figure.7 *Hydrosoil Map of the Muguru Addahalla Watershed showing runoff potential of the area*

The tributary Muguru Addahalla originates at Ummattur gudda at an altitude of 900 ft from MSL as a first order stream.

5.7. Pediments

Gently sloping smooth surfaces of eroded bedrocks between hills and plains with veneer of detritus lithologies like granodiorite, tonalites and migmatitic gneisses constitute pediments. Fractures play an important role in their formation. These pediments are situated west and north-west of Ummatturu village, west of Paduvalamarahalli, south-west of Hanumanapura, and west and north-west of Bagali village. The total area covered by pediments is 5.715 sq km (2.3% of the watershed).

5.8. Pediment -Inselbergs

Isolated low relief hills surrounded by gently sloping, smooth, erosional bed rocks constitute the pediment inselbergs. Bedrocks like granodiorites and migmatitic gneisses are the mail lithology controlling the pediment inselbergs. Again, here also, the joints fracture, and lineaments have controlled their formation. Prominent pediment inselbergs are situated in north east of Hallikerehundi. The area occupied by them is 0.1461 sqkm (0.06% of the total area).

Table.4 *Soil series of the study area (In sq kms)*

Sl. No	Soil Series	Area in Sq Km	Percentage
1	Allianpura	1.8346	0.74
2	Ballaryhatti	0.784	0.31
3	Channasandra	6.231	2.5
4	Enugadale	23.7054	9.52
5	Gattavadi	81.5316	32.75
6	Guttapalli	9.2768	3.73
7	Habitation Mask	6.7249	2.7
8	Hutagalli	5.5013	2.21
9	Kalkeri	3.9779	1.6
10	Muddapura	14.5425	5.84
11	Muddinahundi	32.2275	12.95
12	Nelsoge	14.5872	5.86
13	Ram Samudra	7.1248	2.86
14	Rock Outcrops	1.1177	0.45
15	Sankihalli	0.083	0.033
16	Srinivasapur	0.1689	0.07
17	Tagaduru	19.0016	7.63
18	Telanuru	10.5272	4.23
19	Unnala	5.2207	2.1
20	Water Body Mask	4.7472	1.91

5.9. Pediment -Inslberg Complex

They are isolated low relief hills surrounded by gently sloping smooth bed rocks (Fig.4.10). As the dominant lithology in the area is granitoids, these pediment inselberg complexes are also encompassed by granodiorite, tonalitic and migmatitic gneisses. These are controlled by structure like joints, fracture and lineaments. The only difference between the pediment inselberg complex and pediment inselberg is that in case of pediment inselberg, it is a single isolated low relief hill but in the case of pediment inselberg complex it is more than one isolated low relief hill but occurring closely. These land forms are observed in north east of Badanaguppe village. The area covered by them is 1.607 sq km (0.65% of the total area).

5.10. Pediplain -shallow

These are formed by coalescence of buried pediments, where a thick overburden of weathered materials accumulates. The intensely weathered areas of granitoids constitute these landforms. Varying thickness of shallow overburden is observed in such areas. Weathering of the bedrocks has been initiated by fractures, joints and minor lineaments. The area covered by such land forms is huge in the study area and account for 107.81 sq km (43.31%of the total area). These land forms are spread over Hosahalli, Badanaguppe, Hanumanapura, Honnegowdanahundi, Karya, Kuderu, Demahalli, Hallikerehundi, Dasanuru, Ummatturu, Jennuru, Jennuru Hosuru and Bagali, Hosuru Hundi village areas.

5.11. Pediplain -moderate

Flat and smooth buried pediplain and pediment with moderately thick overburden are called pediplain moderate. Thickness of weathered material is high when compared to pediplain shallow. The weathered materials are chiefly constituted by gneisses and migmatites. They are extended towards south-west of Demahalli upto Dasanur, Ankushayyanahalli, Badanaguppe, Karya and Hanumanapura villages covering a total area of 34.1008 sq km (13.7%of the total area).

5.12. Pediplain shallow command area

They are the shallow land forms, occurring in the command area. Like in other areas, they are formed by **c**oalescence of buried pediments where a thick overburden of weathered materials occurs to form the pediplain at shallow depth. The overburden is a weathered material of granodiorite, tonalitic and migmatitic gneisses with varying thickness. The weathering is controlled by fracture, faults and lineaments. It is extended towards north, north-east and north-west of Bagali, Hyakanur and Vatalu villages and the areal extent is 66.0929 sq km (26.56% of the total area).

5.13. Pediplain -moderate command area

Flat and smooth buried pediplain and pediment with moderate thickness of overburden occurring in command area are termed as pediplain moderate command area. The lithology here is granodiorite, tonalitic and migmatitic gneisses. They are controlled by fracture and lineaments. Thickness of the weathered material is high compared to pediplain shallow command area**.** It is extended towards west and south-west of Ayyanurhundi, and extends up to Hanumanapura. They are also observed close to Marahallipura, Badanaguppe, karapura and Ankushayyanapura.Dasanuru, Ummatturu and Kuderu. The areial extention of the land form is 25.553 sq km (10.28% of the total area). Besides mapping and delineating the above land forms, the water bodies have also been delineated using toposheets updated with imageries. These surface water bodies influence the surrounding bore wells and ground water recharge conditions. Out of the total surface water bodies the stream occupies 2.23 sq km (0.9% of the total area) and by lakes (tanks) 2.51 sq.km (1.01% of the total area).

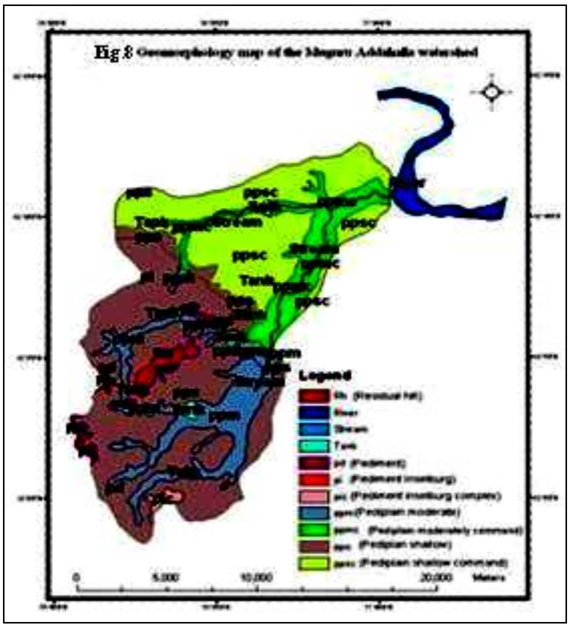

Figure.8 *Geomorphology Map of the Muguru Addahalla Watershed*

5.14. Rainfall pattern in the study area

To assess the climatic condition and rainfall pattern, the 20 years annual average rainfall data has been taken from T.Narasipura, Nanjangud and Chamarajnagar taluks (which fall within the studied watershed) to evaluate the precipitation potential and hydrological conditions. Other meteorological data of Mysore and Chamarajanagar districts have also been collected for assessing hydrogeomorphological conditions. In the study area, the premonsoon starts from January and ends at May and southwest monsoon starts from June and ends at September. Northeast monsoon starts from October and stretched up to December. The annual rainfall data accounting is from January to December. The rainfall data .collected was from 1987 to 2006 and is presented in Table 5. The Annual average rainfall for 20 years of T.Narasipur taluk is found to be 759.18 mm, the Nanjangud taluk is 775.075 mm and the Chamarajanagar taluk 806.833 mm. The annual average rainfall of 20 years rainfall data of the above three locations i.e is for the study area is 780.325 mm. From the climatic data, it has also been inferred that the annual maximum temp is 36.2˚C and average annual extreme temp is 39.4˚C. The average rainfall of the study area is 780.325 mm. These factors are critical for agriculture productivity in the study area.

Table.5 *Average annual rainfall of Nanjangud, T.Narasipur & Ch.Nagar taluks*

Nanjangud			T. Narasipura	Ch.Nagar		Study area average
Sl.No	Year	Annual	Annual	Year	Annual	Average
1	1987	631.7	617.1	1981	947.7	732.1
2	1988	765.9	661.3	1982	546.9	658.0
3	1989	647.8	567.6	1983	513.8	576.4
4	1990	384.1	400.3	1984	715.3	499.9
5	1991	830.0	1012.2	1985	544.3	795.5
6	1992	845.4	682.8	1986	751.5	759.9
7	1993	714.7	1227.8	1987	903.0	948.5
8	1994	1348.3	882.0	1988	1115.0	1115.1
9	1995	683.2	647.0	1989	1058.4	796.2
10	1996	692.5	840.2	1990	340.3	624.3
11	1997	735.2	643.0	1991	804.8	727.6
12	1998	543.0	717.8	1992	813.5	691.4
13	1999	707.5	1242.2	1993	602.0	850.5
14	2000	947.1	977.1	1994	846.1	923.4
15	2001	970.7	593.2	1995	645.4	736.4
16	2002	541.4	456.0	1996	981.2	659.5
17	2003	579.0	563.1	1997	748.6	630.2
18	2004	856.7	807.0	1998	985.2	882.9
19	2005	1118.4	1084.2	1999	1055.0	1085.8
20	2006	958.9	561.7	2000	1218.7	913.1

5.15. Assignments of weightages

The different thematic maps of the study area were prepared by making use of a base map. This base map was prepared using Survey of India toposheets bearing nos. 57D/16, 58A/13, 57H/4 in 1:50,000 Scale. PAN+LISS merged data was used for preparing various thematic maps. Visual interpretation and validation with field checks were carried out. In all these interpretations software's like Autocad 2000, Erdas imagine 8.7, Arcview 3.2 and Arc GIS 9.0 to be used. For image and topomap mosaicking and subsetting of different scenes, Atuocad-2000, ARC view-3.2, ERDAS IMAGINE 8.7 and Arc GIS 9.0 were used.

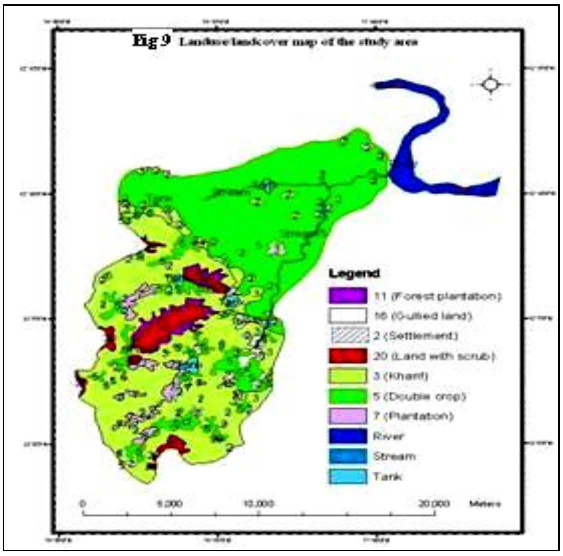

Figure.9 *Landuse/Landcover map of the study area*

5.16. Land use/ land cover of the study area

Using remote sensing and GIS techniques, the study area is classified into different categories from the point of utility and natural cover, as double crop, kharif, plantations, land with scrub, settlement, stream, tank gullied land and forest plantations.

5.17. Hydrologic significance in soil and land use/land cover

Soils play an important role in a) encouraging or discouraging the recharge of groundwater and b) determining the quality parameters of groundwater. The Soil texture is an important parameter which determines the water retention and infiltration capacity. Coarse textured soils may be permeable and will encourage the recharge of groundwater and poor in the case of fine textured soils. Where the clay content is more, the porosity and permeability will be comparatively less and may support surface water bodies. The infiltration capacity of the ground water is depending on the ratio of percentage of sand, silt and clay and composition of the soil .If the runoff potential of the hydrosoil is more, the infiltration capacity of the water towards the ground is more and vice- versa. Forest land and plantation lands also play vital role in balancing the ecosystem and biodiversity. Trees and plantation are useful to prevent soil erosion and increase the ground water resource through the water infiltration.

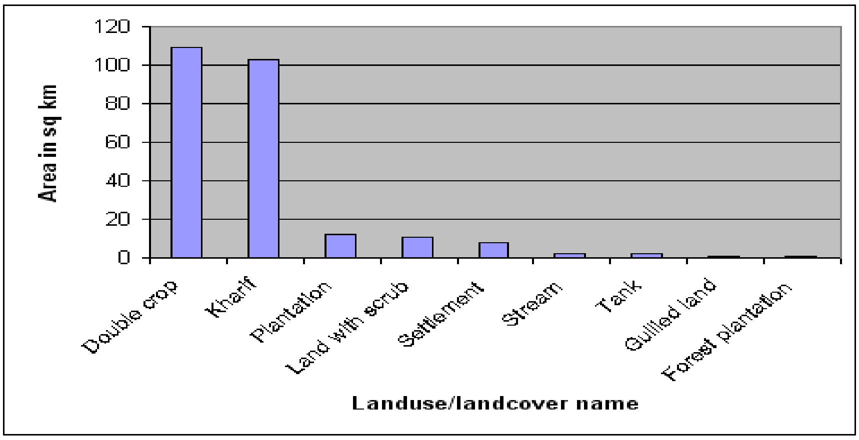

Figure.10. *Graphical representation of landuse/landcover*

6. Conclusions

Integration of various thematic maps prepared from remote sensing and collateral data using GIS yields more accurate results. Excellent groundwater potential zones are found on both side of lineament and the major river courses. Major portion of southeastern part are occupied by poor to moderate potential zone due to its topography and forest cover. Good prospect zones are seen in nearly level to very gentle slope with agriculture land. Out of 2522 Sq.km, 50.51, 87.21, 123.14, 5.30 sq.km. The area falls under excellent, good, moderate and poor ground water prospect zones respectively.

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