Summary and Conclusion

Water is very important for sustenance of life. Water not only sustains life, but also determines the quality of life. Assessing water quality is just as important as quantity in water resources planning and management. However, as consequences of diversified human activities in the recent times, a serious problem of deterioration in water quantity and quality has been observed. There are several reasons for paucity of water and most important among them is increasing population. Increasing population and changing environment in the present sophisticated world demand increased needs of consumptive and non-consumptive water. Thus, it is true that fresh water is indispensable for human survival and is an essential requirement for sustainable development.

In many parts of India, water is already being transferred out of irrigation and it is being put into urban-industrial uses, putting additional stress on the performance of the irrigation sector. Like in other parts of India, in Hunsur also, agricultural, domestic and industrial sectors are competing more and more for a limited supply of water. Greater access and an improvement in socio-economic situation in Hunsur have resulted in high demand for water from domestic sector in coming years.

Keeping in mind the paucity of water resources to cater to the multi various needs of the growing population of Hunsur taluk, coupled with the vagaries of monsoon precipitation and dearth for quality of water, the candidate has selected the problem entitled” Environmental Management of Water Resources for Sustainable Development in Western Part of Hunsur, Karnataka, India Using Remote Sensing and GIS “for better sustainable utilization of water resources.

In the present work, different approaches have been adopted to assess and manage the changing pattern of water quantity and quality of water resources of the study area. For this purpose detailed analysis of geology, meteorology, geomorphology particularly the morphometric analysis of Lakshmantirtha river basin, groundwater prospecting, Environmental Impact Assessment with special reference to water quality has been attempted and water conservational measures for the area have been suggested. Based on the integrated investigations, results and discussions, the candidate has drawn conclusions as follows:
The study area, western part of Hunsur Taluk, is located 30-35 Km in the north western part of Mysore city. The study area covers an area of 633.77 sq.km.

The study area lies over the hard rock terrain of peninsular gneiss which runs from N-S, E-W direction more or less with gently undulating plains with high grounds seldom give rise to small hillocks and mounds. The area is also represented by ultramafic dykes trending from N-S and NW-SE directions. These dykes appear in field as boulders strewn ridges running for considerable distances. Younger pegmatite veins also are seen occurring as small bands within peninsular gneiss complex trending towards NW-SE and S-W.

Mapping and classifications of soils have been carried out using LISS III plus PAN merged imageries. Seven sub-groups namely Kandic Paleustalfs, Rhodic Paleustalfs, Kanhalpic Haplustalfs, Lithic Ustorthents, Typic Ustrovepts, Ustic Haplohumults, and Ustic Paleuhumults have been identified. These soils are considered to be residual concentrations derived by the weathering of parent rocks represented by gneisses of the basement complex. These soils are highly porous and having high degree of infiltration and water holding capacity. Among the 7 soil subgroups, Typic Ustrovepts and Rhodic Paleustalfs are having relatively higher Available Water Capacity (AWC) compare to the others and are well drained which show good groundwater prospects.

Hydrometeorological parameters like temperature, relative humidity, wind speed, rainfall and its distribution have been analyzed. The study indicates that the average of maximum temperature of 33.84°C is recorded in the month of April and the average of minimum temperature of 13.95°C is recorded in the month of January. The Relative Humidity (RH) for a normal year in the study area increases from April and reaches maximum in August and gradually decreases and reaches minimum in the month of March. The mean % of RH varies from 39-85%. The average rainfall of the study area for the period 1985-2005 is 930 mm. Annual rainfall in the study area during 2002 was very low and fell under severe drought condition. South-West monsoon and North-East monsoon, contribute 90% of the annual rainfall. By using Inverse Distance Weighted (IDW) method, spatial distribution of rainfall for 5 rainfall gauge stations was carried out. The results indicated that south-western part of the study area receives higher precipitation compare to the north-eastern part which is mainly due to its hilly and forest area.

For determination of the effect of climatic change on rainfall distribution and its trend, Mann-Kendal and seasonal Kendal test is performed and the results revealed no significance trend.
By using smoothing technique, the scatter plot (mean precipitation of 3 seasons) revealed temporary upward and downward trend of rainfall (1985-2005). It is noticed that there is slight decrease in the amount of precipitation during the 21 years.

- Morphometric analysis of the Lakshmamitirtha sub-basin and its watersheds has been carried out taking the hydrological boundary into consideration. Laskmantirtha river is found to be of 6th order.
- The stream length ratio of the sub-basin and its watersheds are changing haphazardly which is attributed due to differences in slope and topographic conditions of the study area.
- The bifurcation ratio varies from one order to its next order. These irregularities are dependent upon the geological and lithological conditions of the drainage basin. The lower values are characteristics of the watersheds, which have suffered less structural disturbances, and the higher values indicate strong structural control on the drainage pattern.
- Drainage density values of the sub-basin and the watersheds are all indicative of very coarse to coarse drainage texture which is having highly permeable subsoil, dense vegetative cover and low relief.
- All the three shape parameters viz., elongation ration, circularity ratio and form factor are suggestive of an elongated shape for the basin in turn has an effect on the discharge characteristic of the basin.
- The higher values of relief ratio and relative relief values are indicative of watersheds located in the south-western part of the sub-basin having steeper slope and high relief compare the remaining watersheds having lower to gentle slope values.
- The hypsometric analysis reveals the monadnock stage of the sub-basin. Few watersheds located at south-western and western part of the sub-basin are also at the monadnock stage. The remaining water sheds are the mature stage. The water sheds of monadnock stage and the mature ones approaching monadnock stage need minimum mechanical and vegetative measures to arrest sediment loss but may require more water harvesting type structures to conserve water at appropriate locations in the watershed for conjunctive water use.
- Factor analysis is carried out to determine the interrelationship between the different morphometric units and categorized them into 5 factors.
• By using the capabilities of remote sensing and GIS techniques different thematic layers like hydrogeomorphological, lithology, soil, slope, drainage density, lineament map, lineament density, DEM and land use/land cover have been prepared.

• Different hydrogeomorphic units viz., residual hills, Linear ridges, pediment inselberg complex, pediments, shallow weathered pediplains, moderately weathered pediplains and valley fills have been delineated.

• Seven slope categories have been categorised for the present work based on AIS and LUS. According to slope analysis most of the area falls under the first and second category, nearly level and very gentle sloping area, which are important from the groundwater prospecting point of view.

• Drainage density map of the study area is prepared. The higher values indicate lower-infiltration rate compare to the lower-density areas which are favourable for high infiltration rate.

• Lineament analysis reveals that three main lineament trends exists all over the study area i.e., NE–SW, NW–SE and latitudinal. Using rose diagram for analysis of the lineaments, it is found that the majority of the lineaments are in the NW-SE directions which are parallel to the faulting of west cost of India indicating these lineaments are syngenetic and sympathetic tectonic event. Lineament density map indicated the variations in the potential of groundwater in the study area.

• The DEM provides a detailed topographic picture of the area. The topography is undulating and plain in the central, eastern and north-eastern parts shows minimum relief.

• The landuse/landcover revealed different classes like settlement, agricultural land, scrub forest, dense mixed jungle, forest plantation, waste land, tank and streams. The water bodies and the agricultural lands have higher potential of groundwater.

• Groundwater prospect zone is prepared by using Arc GIS (v.9.1). The groundwater prospect map has been categorized into five zones, from groundwater potential point of view; Excellent, Good, Good-Moderate, Poor and Poor-Nil (Run-off zone).

• Spatial distribution of water level maps for 11 observation wells revealed that during post-monsoon recharge of the groundwater takes place and the water level during this season increases significantly compares to pre-monsoon season.
• Areas of recharge and discharge have been delineated with grid deviation water table map. The positive zones, mainly the western part, are recharge zones and negative zones, north-eastern and eastern parts, are discharge zones. The wide spacing of contours and the disposition in discharge is suggestive of flat to gentle hydraulic gradient of water table.

• Non-parametric Regional Kendall for trend detection of water level revealed a decline of water level for the majority of the monitoring station. The decline of water level in most of the monitoring stations is attributed to the variation in the amount of rainfall through the years and increase in anthropogenic activities and demand.

• Electrical conductivity (EC) analysis revealed almost 75% of the groundwater samples are categorized under ‘permissible’ class and 75% of the surface water samples are categorized under ‘good’ class and the remaining were categorized under ‘excellent’ class.

• The spatial distribution maps of the groundwater samples revealed that the north-eastern part of the study area are having higher concentration of TDS and EC compare to the south-western part. The spatial distribution maps of the surface water samples reveal that western part of the study area are having higher concentration of TDS and EC compare to the eastern part.

• The high concentration of NO₃ in some of the groundwater samples were attributed mainly due to the excess use of fertilizers for agricultural activities.

• Based on Hill Piper’s diagram, the alkaline earths (Ca and Mg) and weak acids (CO₃ + HCO₃) mainly dominate the chemical character of the surface and groundwater samples of the study area.

• Gibb’s diagram indicates that all the groundwater samples of pre-monsoon and post-monsoon season’s fall in the rock dominance and evaporation crystallization dominance area.

• Some locations of Lakshmantirtha River stretch exhibits low level of DO and higher levels of BOD and COD compared to other areas which is mainly attributed to sewage and organic pollution.

• According to USSL classification, 6% and 11% of the groundwater samples during pre-monsoon and post-monsoon fall under ‘saline’ water type which are not suitable for potable and irrigation usage.
By applying Independent student t-test in SPSS software, it is found that there is a significant difference of means of the chemical constituents between pre-monsoon and post-monsoon seasons in the surface and groundwater water samples at 5 % level. This is mainly due to monsoon precipitation and recharge of groundwater which in turn increases the concentration of the chemical constituents in the water samples.

Principal Component Analysis (PCA) for surface and groundwater samples during pre-monsoon and post-monsoon seasons has been carried out. By using this technique the important hydrochemical variables have been categorized into components/factors which may be interpreted as having vital importance to the water quality status of the surface and groundwater resources.

Environmental Impact Assessment (EIA) of the study area has been carried out following ‘Battelle Environmental Evaluation System’, where the impacts are assessed under 4 broad categories viz., Ecology, Physical-chemical, Aesthetics and Social. Out of the total assigned 231, 171 points could be awarded to the study area. This means that, the environmental conditions in the study area is in “Good condition” and corresponds to class II.

**Suggestions:** Based on the assessment, results and analysis the following suggestions are made for better water resources management.

- automation of canal system of the study area
- Conjugative use of water resources
- command area development
- Rainwater harvesting
- Proper matching between cropping pattern and water availability
- Environmental education to the farmers
- Use of organic manure by the farmers is encouraged rather than usage of chemical fertilizers which increases the NO₃ concentration in groundwater resources.
- Since concentration of TDS and hardness currently exceed safe limits for drinking waters in some of the groundwater samples, softening techniques like lime soda and ion-exchange process are suggested.