9.1 Discussions

The total study area comprises of 3883 km². The Remote Sensing data has been used to prepare the drainage map which helped in the delineation of the watershed boundaries along with toposheets. The drainage network in the sub-basins belongs to dendritic, sub-dendritic to sub-parallel type. This indicates that the rocks in the study area have uniform resistance and the drainage is structurally controlled at places.

The study area comprises parts of Arkavathy, North Pennar, South Pennar and Palar basins. The study area is Gneissic and Granitic Terrain. The study area majorly consists of three types of soil viz., clayey soil, gravelly clayey soil and laterite. The thickness of soil layer varies from less than a meter to a few meters towards the river valley. The study area experiences semi-arid climatic condition with an annual rainfall of 805 mm. Due to high intensity and scanty rainfall, vegetation growth is moderate. The land forms are undulating with gently sloping topography with sporadic small hillocks. The minimum elevation is 850 m and highest elevation is 1150 m in south-western part.

Integration of different data layers in a GIS environment followed by spatial and statistical analysis of the data has been used to understand the correlation between different themes and nature of groundwater of the study area.

There are four types of lineaments. They trend almost NW-SE, NNW-SSE, NNE-SSW and E-W. The areas where either the fault or lineaments control the drainage they are the areas having good infiltration of groundwater.

The classification of a landscape into geomorphological units is commonly performed through Landsat ETM+ remote sensing data interpreting and the
Discussions and Conclusion

The same technique has been used to study landforms. The study area comprises of landforms such as pediplain, denudational hills, inselbergs, pediments, and the valley fills. Majority of the study area comprises of pediplains, which are flat to gently sloping topographic features. Valley fills are observed near banks of streams and rivers. The groundwater prospects are good along the valley fills and moderate to good in pediments areas, especially along fractures and lineaments intersections.

These digitized drainages have been used for the morphometric analysis. 60 Fourth order sub-basins have been selected for morphometric analysis. The variation in stream length ratio might be due to change in slope and topography. The bifurcation ratio in 45 sub-basins indicates structure doesn’t exercise a dominant influence and produces sharp peak and 15 sub-basins indicates some sort of geological control, these basins yields low, but extended peak flow and the presence of low drainage density in 41 sub-basins suggesting that it has highly permeable sub-soil and coarse drainage texture.

High circularity ratio is observed in 45 FOSBs indicate that they are more or less circular in shape and are characterized by high to moderate relief and drainage system is not structurally controlled and the remaining 15 sub basins indicating that they are elongated in shape. Texture ratio indicates 21 sub basins having very coarse and 39 numbers of FOSBs having related to coarse drainage texture ratio. The values of form factor suggest that all the FOSBs are sub-circular and elongated. Elongation ratio indicates that the 54 sub-basins are region of very low relief whereas other sub-basins are associated with moderate to high relief and steep ground slopes. Length of overland flow indicates that 28 numbers of FOSBs influence of high structural disturbance, low permeability, steep to very steep slopes and high surface runoff and the remaining 32 sub basins having very less structural disturbance, less runoff conditions and having higher overland flow. Constant of Channel Maintenance indicates that 19 sub basins are required more than 0.6 Km$^2$ area to maintain one kilometre length stream channel, which in turn indicates that these sub basins are comparatively permeable than remaining sub basins.
Discussions and Conclusion

The morphometric analysis is carried for Kumudvathi sub-watershed using Toposheets, CartoDEM and Aster GDEM by Remote Sensing and GIS tools. It has been found that the study area is a 5th order drainage basin in all three sources. Dendritic drainage pattern is seen in the hilly and plateau parts of the drainage basin indicating the homogeneity in texture and lack of structural control. The basic and derived parameters from High resolution CartoDEM are matching with toposheets, whereas in the low resolution Aster GDEM not matching with toposheets.

Rainfall being the only source of water in the region, sustenance of the forest depends on amount of rainfall, water availability in the year. From the graphical method specifies the increasing trend of rainfall for Pre-monsoon, South-West Monsoon, North-East monsoon and annual. The study reveals that the periodicity varies from 3 and 14 years by moving average and autocorrelation study; 3 to 49 years by Fourier analysis and 2 to 50 years by smoothing fourier analysis. Rainfall in the study area is influencing in South-Western part for Pre-monsoon, South-West Monsoon, North-East monsoon and annually. The southwest and southeast parts of the study area experience the more rainfall whereas the less rainfall areas are the northern parts of the study area.

Land use and land cover change studies' showing agricultural land is declining from 52 percentages in 1973 to 31 percentage in 2014. The remaining types of land use and land cover are indicating increasing in order. Wasteland and Built-up Land, Water bodies, Forest/Grassland and Others are increased from 423 to 830 km², 153 to 215 km², 450 to 762 km², and 805 to 871 km² respectively.

The resistivity survey indicates that the first layer is top soil having resistivity range of 16 Ω m at Hesarghatta and 722 Ω m at Devanahalli extends in the depth range of 0.4m and 5.5 m below ground level. This is underlain by the second layer which is having resistivity range of 9.71 Ω m at Karahalli and 1135 Ω m at Karahalli and depth range of 1.31m and 67m. Third layer, with resistivity range of 13.9 Ω m at Karahalli and 1660 Ω m at STS BSF, Yelahanka extends in
Discussions and Conclusion

the depth range of 2.72m and 204m. This is correlated to semi weathered and fractured formations. Fourth layer is massive with resistivity value of 69.2 Ω m at IAF HQTC, Hebbal and 1239 Ω m at Karahalli. The hard rock formation is 9.34m and 22.5m.

Long-term and short-term water table fluctuation has been prepared. The comparative hydrographic study of observation bore wells falling within the study area shows a gradual declining trend due to less recharge from rainfall as well as over exploitation. Depth to water level for pre monsoon 2011, august 2011 and post monsoon 2011 and pre monsoon 2012, august 2012 and post monsoon 2012 indicating central and eastern part of the study area having deeper water levels at 30 to 55 m bgl and the remaining part the area highlighting 5 to 30 m bgl.

Annual fluctuation study reveals for pre monsoon 2010 to pre monsoon 2011 and august 2010 to august 2011 rise in water levels in northern part and fall in south and eastern part, whereas fall in water table levels presenting for post monsoon 2010 to post monsoon 2011. Annual fluctuation of pre monsoon 2011 to pre monsoon 2012 and post monsoon 2011 to post monsoon 2012 indicates rise in 0 to 4 m bgl in south and western part and fall in rest of the area, while august 2011 to august 2012 showing rise for 0 to 4 m bgl in northern part and fall in rest of the area. Seasonal fluctuation study reveals for pre monsoon 2011 to august 2011 and pre monsoon 2012 to august 2012 indicating rise of 0 to 2 m bgl in entire study area, except fall of water levels in eastern part. In pre monsoon 2011 to post monsoon 2011 and pre monsoon 2012 to post monsoon 2012 rise of 0 to 4 m bgl, except fall in eastern part.

Decadal fluctuation for pre monsoon 2012 with respect to 2002 -2011 indicating rise in water level of 0 to 2 m bgl in south-western part and fall of 5 to 50 m bgl in rest of the area. In august 2012 and post monsoon 2012 with respect to 2002 -2011 illustrating fall of water levels from 5 to 50 m bgl. The comprehensive study of ground water specifies eastern part of the study area having more vulnerable compared to the rest of the area.
Flow pattern analysis is carried out to know the groundwater flow direction using spatial distribution of hydraulic head. The fluctuation of head with time can be interpreted with the understanding of boundary conditions. The water level contour and groundwater flow direction maps are prepared using water level data. The possible flow directions are indicated by the arrows in 2D maps. The equipotential lines are widely spaced in most of the study area.

Groundwater potential zones are delineated by weightage and ranking method for different layers. The study area has been classified into five categories from very poor at urbanized areas and excellent in the parts of pediplain agricultural. Excellent potential zone is surrounds an area of 1107 km\(^2\), Good potential zone holds for an area of 2253 km\(^2\), Moderate potential zone of 78 km\(^2\), Poor potential zone of 215 km\(^2\) at villages and Very poor potential zone of 230 km\(^2\) at urbanized areas. The study area holds majorly of Good potential zone and helps to increase the groundwater levels by artificial structures. From the field observations has been carried out to verify the behaviour of potential zones.

The water samples were analyzed for pH, EC, TDS, soluble cations and anions following the standard procedures. The water quality parameters were compared with the standard desirable limits prescribed by World Health Organization (WHO) and Indian Standard (ISI) for using the groundwater. The spatial distribution pattern of hydrochemistry in the study area indicates that the constituents exceed permissible limits in parts of the study area. Groundwater pH is more than 8.5 near the lowlands and quarry regions, while the highlands regions are generally good for drinking purposes. Potassium concentrations in two samples are exceeding permissible limits in urbanised area. Fluoride concentrations in the groundwater ranges from 0.5 to 4.1 and continuing consumption of higher concentrations can cause dental fluorosis and in extreme cases even skeletal fluorosis. In north-western and south-western parts of the study area exceeds the permissible limits.
Discussions and Conclusion

The order of abundance of major cations in groundwater is Ca>Na>Mg>K and anion is HCO₃>Cl>SO₄. The predominant major cations trends in both the groundwater and rock samples of the study area are found similar in the order of Ca>Na>Mg>K. Therefore, from the results obtained it is possible that the high concentration of dissolved solids in the groundwater samples derived from the soluble rock units and hence the chemistry of the groundwater is controlled by the composition of the rocks.

Analyses based on USSL and Wilcox classification it is found that most of the groundwater in the study area is suitable for irrigation. The groundwater has mostly low salinity and low sodium which range from good to permissible quality with respect to irrigational use.

9.2 Findings

The morphometric study for fourth order sub basins and Kumudvathi sub-watershed reveals that the Cauvery, north pennar and south pennar basins are falls in mature stage of erosion. Two new major water bodies in the study area recognized from lulcc studies in Arkavathy River namely, Manchanabele dam in 1982 with an area of 1.97 km² and Yettinamane Guruganji (Y G) Gudda Reservoir an area of 1.48 km² at Magadi Taluk. 522 Small water bodies are decreased in 2014 as compared to 1972 water bodies and also the new water bodies have been added in abandoned quarry regions and also by check dams to increase the overall water bodies’ area from 1973 to 2014. These water bodies’ are acting as recharge barriers to the groundwater. The rainfall directly proves the Köppen Classification system of Climatic zones for the study area. The rainfall study reveals that number of rainy days is declining with increasing rainfall and pointing towards high intensity rainfall in the study area. The high intensity rainfall infers more runoff and the more runoff directly indicates less infiltration of water to the groundwater. Geophysical studies reveal the different subsurface layers and its thickness. The resistivity in the area varies from 16 Ω m at Hesaraghatta and 722 Ω m at Devanahalli.
9.3 Conclusions

The satellite imagery helped in delineation of basin boundaries, lithological units, structural, geomorphic units, drainage pattern, land use etc., and GIS databases are useful in evaluation and preparation of thematic maps.

The study comprises of granitic gneissic, closepet granite with small patches of laterites. Lineament analysis showed that in the areas studied the direction NW-SE, NNW-SSE, NNE-SSW and E-W dominate.

The flow direction analysis has been carried out to delineate streams using CartoDEM and Aster GDEM. The derived CartoDEM and Aster GDEM drainages have been compared with toposheets indicate that the high resolution CartoDEM yields very good results.

The rainfall study indicates increasing trend with number of rainy days decreasing over the five decades. This indicates the high intensity rainfall. There exists both short and larger interval periodicity.

Groundwater Potential zone map derived from Geographic Information System technique has been validated by superimposing the yield of water in bore wells data. Ground water potential zone are matching of about 42 Percent and nearly matching of 45 percent in the stretch. A marginal error of not matching indicates the developed GIS model is useful.

The study of groundwater levels highlights the decreasing trend throughout the study area. Majority of declination is observed at northern and south-eastern part. Flow net analysis indicates movement of groundwater is towards western, southern and south-eastern direction. Recharge and Discharge areas have been delineated. This may be used effectively to construct artificial recharge structures. Storage structures like form ponds, gokatte, kalyani may be constructed in the discharge areas. Check dams, gulli plugs and point recharge structures may be constructed in the recharge areas.

Interpretation of hydrochemical analysis reveals that the groundwater in study area is hard, fresh to brackish and alkaline in nature. The chemical
characteristic of the groundwater shows cationic chemistry is dominated by alkaline-earth metal Ca and Mg while anionic chemistry is primarily dominated by HCO3. Groundwater samples fall under the calcium-magnesium-bicarbonate category.

Intensive agriculture and use of fertilizers have significantly contributed to potassium, fluorides, sulphate and nitrate in the groundwater. The high content of sodium, nitrates and incidence of fluorides makes groundwater quality moderate.

Most of the samples in the study area fall in the suitable range for irrigation purpose.