Chapter – 1

Introduction
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INTRODUCTION

The present investigation deals with the “Conservation and Management of Water Resources in the Kanakapura Watershed of Ramanagara district, Karnataka, India, using Remote Sensing and GIS”.

In this chapter information is given on distribution of water in earth’s surface and Indian scenario, Hydrogeological set up of India, conservation and management of water resources, groundwater studies, concept of watershed, application of remote sensing and GIS in watershed management, Arkavathi river basin, literature review and brief introduction on study area followed with objectives adopted, data used and methodology and order of presentation.

1.1 EARTH’S WATER DISTRIBUTION

Water is widely distributed and covers about three-fourth of the earth’s surface. According to the UN estimates, the total amount of water on the earth is about 1400 million cubic kilometers which is enough to cover the earth with a layer of 3000 meters depth. However, out of the total fresh water available on the earth, about 75.2% lies frozen in Polar Regions and 22.6% is present as ground water (Srinivasa vittal 2005). The rest is available in lakes, rivers, atmosphere, moisture, soil and vegetation. This is effectively available for consumption and other uses. The crisis about water resources development and management thus arises because most of the water is not available for use and secondly it is characterized by its highly uneven spatial distribution. Accordingly, the importance of water has been recognized and greater emphasis is being laid on its economic use and better management.

No life form can be sustained without water on the planet. It is a unique natural resource among all resources available on earth. United Nations stated that water is a social and cultural good, not merely an economic commodity. Chemically water is a compound of hydrogen and oxygen with highly distinctive physical and chemical properties. Out of all the water available on the Earth, 97 % of water is saline and is in oceans, 3% of water is freshwater available in rivers, streams and glaciers. The freshwater availability on the planet is distributed unevenly. The Earth’s water distribution is presented in Table-1.1 (after Gleick 1996).
Table-1.1 : Earth’s water distribution (After Gleick 1996)

<table>
<thead>
<tr>
<th>Water Source</th>
<th>Water volume in cubic miles</th>
<th>Water volume in cubic Kilometers</th>
<th>Percentage of fresh water</th>
<th>Percentage of total water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ocean, Seas and Bays</td>
<td>321,000,00</td>
<td>1,338,000,00</td>
<td>0%</td>
<td>96.50%</td>
</tr>
<tr>
<td>Ice-caps, Glaciers and permanent Snow</td>
<td>5,773,000</td>
<td>24,064,000</td>
<td>68.70%</td>
<td>1.74%</td>
</tr>
<tr>
<td>Ground water</td>
<td>5,614,000</td>
<td>23,064,000</td>
<td>0%</td>
<td>1.70%</td>
</tr>
<tr>
<td>Fresh</td>
<td>2,526,000</td>
<td>10,530,000</td>
<td>30.10%</td>
<td>0.76%</td>
</tr>
<tr>
<td>Saline</td>
<td>3,088,000</td>
<td>12,870,000</td>
<td>0%</td>
<td>0.94%</td>
</tr>
<tr>
<td>Soil moisture</td>
<td>3,959</td>
<td>16,500</td>
<td>0.05%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Ground Ice and Permafrost</td>
<td>71,970</td>
<td>300,000</td>
<td>0.86%</td>
<td>0.02%</td>
</tr>
<tr>
<td>Lakes</td>
<td>42,320</td>
<td>176,400</td>
<td>0%</td>
<td>0.01%</td>
</tr>
<tr>
<td>Fresh</td>
<td>21,830</td>
<td>91,000</td>
<td>30.10%</td>
<td>0.01%</td>
</tr>
<tr>
<td>Saline</td>
<td>20,490</td>
<td>85,400</td>
<td>0%</td>
<td>0.01%</td>
</tr>
<tr>
<td>Atmosphere</td>
<td>3,095</td>
<td>12,900</td>
<td>0.04%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Swamp water</td>
<td>2,752</td>
<td>11,470</td>
<td>0.03%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Rivers</td>
<td>509</td>
<td>2,120</td>
<td>0.01%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Biological water</td>
<td>269</td>
<td>1,120</td>
<td>0.03%</td>
<td>0.00%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>332,500,000</strong></td>
<td><strong>1,386,000,000</strong></td>
<td><strong>100%</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

1.2 INDIAN SCENARIO

The water sources in India include the vast oceans surrounding the Indian peninsula – Indian Ocean, Bay of Bengal and Arabian Sea, the inland rivers - both the Himalayan Rivers and the rivers in the south, ground water and rainwater available in plenty through the abundant monsoons in India. The problem area here is the water resources management where India fails. In India, Ministry of Water Resources department is responsible for management of water resources. It looks after the water management services, the issues and problems related to the water supply, arrangement of abundant water supply facilities, methods all over formulating the water supply policies and strategies for an equated supply and division of water resources of India. Major fifteen river basins in India and average water flow and utilizable water is shown in Table-1.2 and represented in Fig.1.1.
**Surface water resources:** Water resources including rivers, lakes or fresh water wetlands are known as surface water resources. Precipitation is the natural recharging source for the surface water resources and it also maintain the hydrological cycle. Rivers are the major source of water in India. The utilizable annual surface water from rivers of the country is 690 km³. Human activities like artificial dams, reservoirs are also included in the same category and have capacity to increase utilization of the water.

<table>
<thead>
<tr>
<th>Major river basin wise average flow and utilizable water (in km³/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SL. NO</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td>1</td>
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<tr>
<td>2</td>
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<td>13</td>
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<tr>
<td>14</td>
</tr>
<tr>
<td>15</td>
</tr>
<tr>
<td><strong>Total</strong></td>
</tr>
</tbody>
</table>

**Total average annual water flow in river basins (in Km³/year):** 1953

**Total utilizable water flow in all river basins (in Km³/year):** 690
Fig. 1.1 : River basins in India (Source:www.mapofindia.com)
Groundwater resources: Water sources like subsurface water or water within aquifers are known as ground water resources. Ground water resources achieve recharging mainly through the precipitation during the monsoon season in India (http://greencleanguide.com). Canal irrigation and other form of irrigation systems also contribute to the recharging of the ground water. The annual potential of natural groundwater recharge from rainfall in India is about 342.43 km$^3$. The annual potential groundwater recharge augmentation from canal irrigation system is about 89.46 km$^3$ (Rakesh Kumar et al., 2005).

1.3 HYDROGEOLOGICAL SET UP OF INDIA

India is a vast country with a highly diversified hydrogeologic set-up. The ground water behavior in the Indian sub-continent is highly complicated due to the occurrence of diversified geological formations with considerable lithological and chronological variations, complex tectonic framework, climatological dissimilarities and various hydrochemical conditions (Jha 2009). The rock formations range in age from Archaean to Quaternary-Recent period. The Archaean rocks are present in the southern states whereas the recent sediments are confined to Indo-Gangetic alluvial plains. The major geological formations are as follows (Source: www.cgwb.gov.in):

1) Consolidated formations are represented by Igneous & Metamorphic rocks with major rock types consisting of granites, Charnockites, Quartzites & associated Phyllite, slate, basalts & associated igneous rocks.

2) The semi consolidated rock formations are represented by rocks of Mesozoic & tertiary period with major rock types represented by limestone, sandstone, pebbles & boulder conglomerates.

3) The unconsolidated formations belong to Pleistocene to recent period & represented by major rocks such as boulders, pebbles, different grade of sands, silt-clay. These rocks form the major potential aquifer zones.

The Indian subcontinent is occupied by major geological rock types such as metamorphics of Precambrian period, igneous rocks represented by basaltic rocks of Cretaceous-Eocene period, Gondwana & Vindhyan rocks which are overlain by Quaternary to Recent sedimentary deposits. The distribution of these rock types are given in geological map (Fig.1.2)
Based on the formation characteristics and hydraulic properties to store and transmit ground water hydrogeologically all the litho units can be placed under broad group of water bearing formations Viz. Porous formations which can be further classified into unconsolidated and semi consolidated formations having the primary porosity and fissured formation or consolidated formations which has the secondary or derived porosity. The Hydrogeological map showing the two groups like consolidated and unconsolidated water bearing formations along with their yield prospects are shown in Fig.1.3.

Physiographic and geomorphologic settings are among the important factors that control the occurrence and distribution of ground water (Jha 2009). Based on these factors, the country has been broadly divided into five distinct regions as below (Fig.1.3):

Northern mountainous terrain and hilly areas are highly rugged mountainous terrain in the Himalayan region in the northern part of the country extending from Kashmir to Arunachal Pradesh is characterized by steep slopes and high runoff. This region is underlain mostly by rocks such as granites, slate, sandstone and limestone ranging in age from Paleozoic to Cenozoic. The yield ranges from 1 to 40 lps. Though this area offers very little scope for groundwater storage, it acts as the major source of recharge to the vast Indo-Gangetic and Brahmaputra alluvial plains.

Indo-Gangetic-Brahmaputra Alluvial Plains regions encompasses an area of about 850,000 sq.km covering states of Punjab, Haryana, Uttar Pradesh, Bihar, Assam and West Bengal accounting for more than one fourth of country’s land area, comprises the vast plains of Ganges and Brahmaputra rivers and are underlain by thick piles of sediments of Tertiary and Quaternary age. This vast and thick alluvial fill, exceeding 1000 m at places, constitute the most potential and productive ground water reservoir in the country. These are characterized by regionally extensive and highly productive multi-aquifer systems. The ground water development in this region is still sub-optimal, except in the states of Haryana and Punjab. The deeper aquifers available in these areas offer good scope for further exploitation of ground water with suitable measures. In Indo-Gangetic- Brahmaputra plain, the deeper wells have yield ranging from 25-50 lps (Source: www.cgwb.gov.in ).
Fig.1.2: Geological map (Source: CGWB)
Fig.1.3: Hydrogeological map of India (Source: CGWB)
Peninsular shield area are located south of Indo-Gangetic-Brahmaputra plains and consist mostly of consolidated sedimentary rocks, deccan trap basalts and crystalline rocks in the states of Karnataka, Maharashtra, Tamil Nadu, Andhra Pradesh, Orissa and Kerala. Occurrence and movement of ground water in these formations are restricted to weathered residues and interconnected fractures at deeper levels and they have limited ground water potential. The rocks are commonly weathered to a depth of 30 m under the tropical conditions in central and southern part of the peninsular region. Ground water occurs mainly in the weathered and fractured zones of rocks, within depth of less than 50 m, occasionally down to 100 m, and rarely below this depth. Locally deep circulation of ground water is indicated, as instanced by striking solution cavities or deeper water bearing fractures. Ground water development is largely through dug wells. The valley fills in this region are often dependable sources of water supply. The yield of wells tapping deeper fractured zones in hard rocks varies from 2-10 lps.

Coastal areas have a thick cover of alluvial deposits of Pleistocene to Recent age and form potential multi-aquifer systems in the states of Gujarat, Kerala, Tamil Nadu, Andhra Pradesh and Orissa. However, inherent quality problems and the risk of seawater ingress impose severe constrains in the development of these aquifers. In addition, the ground water over-development in these areas entails the risk of saline water ingress. Ground water prospects in these aquifers vary widely depending on the local conditions and may range from 5-25 lps.

Cenozoic Fault basin and low rainfall areas has been grouped separately owing to its peculiarity in terms of presence of three discrete fault basins, the Narmada, the Purna and Tapti valleys, all of which contain extensive valley fill deposits. The fill ranges in thickness from about 50 to 150 m. The aquifer systems in arid and semi-arid tracts of this region in parts of Rajasthan and Gujarat receive negligible recharge from the scanty rains and the ground water occurrence in these areas is restricted to deep aquifer systems tapping fossil water. In parts of Purna valley the ground water is extensively saline and unfit for many purposes. The yield potential of the wells varies from 1-10 lps.
1.4 CONSERVATION AND MANAGEMENT OF WATER RESOURCE

A river basin is a hydrological unit from where any rainwater falling emerges from single point. Many rivers which are now running dry or carrying loads of sewage are now being sought to be revived. A river basin approach is thought as a best way to proceed ahead to restore the ecological system of our rivers. Major river basins of Karnataka are represented in Fig.1.4.

The uneven distribution of rainfall has often threatened human welfare, livelihood and economic development. The growing scarcity of water is due to the rapid growth of population, rising demand for food and cash crops, increasing urbanisation and rising standard of living. All these have increased the acuteness of the problem of water scarcity in present and future.

Water management is the control and movement of water resources to minimize damage to life and property and to maximize efficient beneficial use. Good water management of dams and levees reduces the risk of harm due to flooding. Irrigation water management systems make the most efficient use of limited water supplies for agriculture. Drainage management involves water budgeting and analysis of sub-surface drainage systems. Sometimes water management involves changing practices, such as groundwater withdrawal rates, or allocation of water to different purposes. The management of water resources has changed drastically over the past 20 years. Previous management models failed to respond to the combined pressure of an accelerated and increasing demand as well as a constant degradation of the water quality sources for supply systems. In effect, many of the worst cases of environmental degradation can be explained by human mismanagement rather than environmental and natural phenomenon (Yapo Alle-Ando, 2005).

The lack of proper supplies of water lies at the root of many of the difficulties experienced by developing countries. Besides fulfilling basic life requirements, water availability is a cornerstone of satisfactory sanitation, public health, agricultural production, industry, recreation, environmental maintenance, and urban development. Unfortunately, the development of major water works is beyond the capability of single individuals, so here more than ever there has to be an integrated effort between user communities, the scientists and engineers that design and construct the water works, and the public agencies that help fund and manage such works.
Fig. 1.4: River basins of Karnataka

Study area
Ground water and surface water are interconnected and interdependent in almost all ecosystems. Ground water plays significant roles in sustaining the flow, chemistry, and temperature of streams, lakes, springs, wetlands, and cave systems in many settings, while surface waters provides recharge to ground water in other settings. Ground water has a major influence on rock weathering, stream bank erosion, and the headward progression of stream channels. In steep terrain, it governs slope stability and in flat terrain, it limits soil compaction and land subsidence. Pumping of ground water can reduce river flows, lower lake levels, and reduce or eliminate discharges to wetlands and springs. It also can influence the sustainability of drinking water supplies and maintenance of critical ground water dependent habitats. Increasingly, attention is being placed on how to manage ground water and surface water resources on public lands in a sustainable manner. The potential for ground water resources to become contaminated from anthropogenic as well as natural sources is being scientifically assessed. Each ground water system and development situation is unique and requires a specific analysis to draw appropriate conclusions.

Ground water is a valuable commodity and its use is growing nationwide. Careful inventory of the quantity and quality of ground water is needed to provide sufficient information to appraise the value and provide appropriate information ground water resources. The following are the objectives of ground water inventory and monitoring (USDA, 2007):

- To ensure timely availability of hydro geological resource information needed for the periodic assessment land resource management planning.
- To provide Subwatershed wise status and to enhance the potential by integrating combining data sets.
- To classify ground water potential zones and to establish baseline ground water quality.
- Identify the needs and opportunities for improving watersheds and improving ground water quality and quantity.
- Take appropriate steps to address the needs and take advantage of the opportunities. In areas where ground water that has become contaminated from human sources, evaluate the risks of exacerbating the problem, and other relevant factors before making a decision to try to clean up the ground water.
- Ground water regions are geographic areas where the composition, arrangement, and structure of rock units that affect the occurrence and availability of ground water are similar.
1.5 CONCEPT OF WATERSHED

The concept of watershed as a planning unit for development of water and land recourses has gained importance since 1974 when the ministry of agriculture, government of India initiated various development programmes Drought Prone Area Programme (DPAP), Desert Development Programme (DDP), Hill Area Development Programme (HADP) etc. Therefore it is necessary to delineate watershed boundaries at various levels of hierarchy to identify development activities under various schemes in each watershed. Drainage network helps in delineation of watershed and for suggesting various water harvesting structures and soil conservation measures.

Watersheds are natural hydrologic entities that cover a specific areal extent of land from which rainwater flows to defined gully, stream or river at any particular point. The size of the watershed is dependent on the size of the stream or river, the point of interception of the stream or river and the drainage density and its distribution (Srinivasa vittala, 2005).

The All India Soil and Survey (AIS & LUS, 1990) ministry of agriculture have developed a hierarchical system of watershed delineation like water resource region, basin, catchment, sub-catchment, and watershed. However, for IMSD study of the following six levels of watershed delineation have been decided. These are as follows:

1. Catchment
2. Sub catchment
3. Watershed (± 500 sq.km).
4. Sub-watershed (± 30-50 sq.km)
5. Mini watershed (± 10-30 sq.km)
6. Micro watershed (± 5-10 sq.km)

Watershed is a physiographic unit that can be used conveniently for integrated development or small natural unit areas. It is the basin of a tributary. It is developed taking into consideration the land capability and the local needs of the people.

Entire water and land development management activities are being perceived in an integrated manner. Implementation of rural development schemes, watersheds will be the unit of management. Most of the developmental activities are highly interlinked. Successful and effective implementation of one activity is highly dependent on successful implementation of others. Hence activities are mutually dependent. This concept is new to the line departments at the district level which have
been hitherto functioning in an isolated manner. Therefore the district officials are being given orientation training for realizing the importance of such integrated approach of watershed management by national institute of agricultural extension management, Hyderabad at the apex level and similar institutions at the state level at instance of the ministry of rural areas and employment, government of India.

1.6 REMOTE SENSING AND GEOGRAPHICAL INFORMATION SYSTEM (GIS) TECHNOLOGY PERSPECTIVE FOR CONSERVATION AND MANAGEMENT OF WATER RESOURCE

Remote sensing is a technology with its advantages of spatial, spectral and temporal availability of data covering large and inaccessible areas within short time has become a very handy to evaluating, and managing vital groundwater resources (Chowdhury et al., 2003). The hydrogeologic interpretation of satellite data have been proved to be a valuable survey tool in areas of the world where little geologic and cartographic information exists or is not accurate. Satellite data provides quick and useful baseline information about the factors controlling the occurrence and movement of groundwater like lithology, geology, soils, geomorphology, drainage patterns, lineaments, land use/cover etc. All the controlling factors have rarely been studied together because of the non-availability of data, integrating tools and modeling techniques. Structural features such as faults, fracture traces and other such linear or curvilinear features can indicate the possible presence of groundwater. Similarly other features like sedimentary strata (alluvial deposits and glacial moraines) or certain rock out crops may indicate potential aquifers. Shallow groundwater could also be inferred by soil moisture measurements and by changes in vegetation types and pattern. In arid regions, vegetation characteristics may indicate groundwater depth and quality. Groundwater recharges and discharge areas in drainage basins can be detected from soils, vegetation and shallow/perched groundwater (Madan et al., 2006). Furthermore differences in surface temperature resulting from near-surface groundwater measured by remote sensing have also been used to identify alluvial deposits, shallow groundwater, and springs or seep (Myers and Moore, 1972). According to Van de Griend et al., (1985) suggests that if surface temperature measurements were made using thermal infrared sensors after a long period without rain, it should be possible to map the regions of shallow water table and infer ground water recharge and discharge. The important physical features of the landscape which can be derived from satellite imagery or aerial photographs and used for assessing groundwater conditions i.e., occurrence, depth, flow patterns, quantity, or quality under a variety of hydrogeologic settings can be interpreted.
GIS is used as an efficient tool for organizing, storing, analyzing, displaying and reporting the spatial information. GIS allowed the creation and modification of the analysis that makes the best use of available data. GIS also supported methods to apply guidelines and criteria set by local and India’s national management regulations (Dhanapal 2012). Few major steps of GIS spatial analysis for conservation and management include:

1. Defining criteria for the analysis
2. Defining data needs and base map
3. Acquisition and preparation of the data as thematic maps
4. Creating GIS model/overlays
5. Integration of thematic layers
6. Integration of spatial and non-spatial data
7. Evaluating results and refinement of the model

For any development project, the protection of water resources is extremely important. Construction over the drainage path or watershed can affect the water resources of the region. The establishment and maintenance of buffer zones along shorelines or streams is a common management practice used in ecological planning. The buffer analysis tool in GIS helps in setting buffer zones for the water bodies.

The modest beginning of surface water inventory the remote sensing application scenario has witnessed a phase transition from resource mapping to decision-making. A number of case studies on command area development, groundwater inventory, canal alignment, irrigation performance evaluation, flood mapping, drought assessment etc., have proved beyond doubt that integration of remote sensing and conventional approach significantly decrease the cost and time involved as well as improve the steadfastness. Satellite remote sensing along with appropriate collateral data enable the inventory of quantity, quality as well as the values of the resources. The repetitive nature of space-based earth observation provides the unique opportunity to do the accounting on a periodic basis. Remote Sensing and GIS have thus become important tools for evaluation of the physical attributes of water and land resources in the country and provides a unique opportunity towards comprehensive monitoring of water resources dynamics in the country.
Managing water resources is a major challenge for the country. Water resources development calls for addressing the key issues of storage, conversation and subsequently utilization (Roy et al., 2007). Towards evolving comprehensive management plan in suitable conservation and utilization of water resources space technology plays a crucial role in managing country’s available water resources. Systematic approaches involving judicious combination of conventional ground measurements and remote sensing techniques pave way for achieving optimum planning and operational of water resources projects. The synoptic and repetitive coverage provided by the satellites can effectively complement the conventional data to monitor the progress and impact of the above projects. Thus, remote sensing imagery from the polar orbiting satellites is a potential tool for mapping and monitoring of many water resources management projects. Remote sensing in combination with the geographical Information System (GIS) produces the terrain maps in locating accuracy and containing detailed information of the variables under study. In India, satellite remote sensing technology is being used effectively in the areas of irrigation performance evaluation, snowmelt-runoff forecasts, reservoir sedimentation, watershed treatment, drought monitoring, flood mapping and management etc.

1.7 KANAKAPURA WATERSHED (STUDY AREA)

The Kanakapura watershed forms a part of Arkavathi river basin which is one of the principal tributaries of the river Cauvery in Karnataka. Its catchment area is about 4351sq.km. Its origin is generally traced to the southern part of Nandi hills 3000 m above sea level (location: 13° 23’ N, 77° 41’ E). From the origin its total length is about 161 km. It flows through Doddaballapur, Bangalore North, Nelamangala, Magadi, Ramanagaram and Kanakapura taluks. It has tributaries coming from Bangalore city and Anekal taluks also.

Ground water in the basin is mostly in the fractured aquifer as the weathered aquifer has been exploited over the years. Hydrology of the basin is changing fast due to urban agglomeration. This has also affected the quality of ground water in the basin. Therefore there is need to protect the precious groundwater through proper land use practices, preventing pollution of ground water by point sources, proper waste disposal and large scale rain water harvesting.
Arkavathi River is being polluted by accumulated waste water discharges from Bangalore thus rendering the river waste unfit for use even during monsoon. All water bodies connected to the river are also polluter resulting in contamination of ground water in all aquifers. Since major portion of surface water and entire ground water regime is polluted the demand for clean and safe water variety of needs is not being met. To protect this precious resource one needs a stringent enforcement system meant for its conservation, sanitation and supply. Groundwater is the source of drinking water especially in rural areas.

Land use in geographic areas that replenish groundwater and surface water resources is increasingly recognized as an important factor affecting drinking water quality. Industrial and agricultural activities often impose significant pressures to the groundwater quality and consequently degrade wet land ecosystem that depend mostly on subsurface water flow. Efforts to understands the implications for health particularly outcomes with long latency or critical exposure windows, have been hampered by lack of historical exposure data for unregulated pollutants. The present study has been conducted around Kanakapura taluk, Karnataka.

1.7.1 Locality and objectives of the present investigation: Kanakapura watershed covers an area of 815.5 km² and it is located between 12°016’N- 12°35’ N and 77°015’E -77°38’ E falls in Survey of India (SOI) toposheet numbers bearing - 57H/6, 57H/7, 57H/10 and 57 H/11 on 1:50000 scale . Location map of the study area is shown in Fig.1.5. According to IMSD Technical Guidelines (NRSA, 1995), the Kanakapura watershed has been divided into nine sub-watersheds namely Bannimukudlu, Bennagodu, Dodda Alahalli, Gadasahalli, Horalagallu, Kodihalli, Madarahalli, Maralebbekupe, and Mudagod which range in area from 30 to 251 km². These sub-watersheds have been named based on the villages at the outlet and map shown along with the road layer of the study area Fig.1.6. The river Arkavathi is a tributary of the Cauvery River. It flows from North to South and confluences near Kanakapura. Fig.1.7 representing the sangam region of Arkavathi and Cauvery rivers.

Kanakapura is a town and the headquarters of Kanakapura taluk in the Ramanagara district in the state of Karnataka, India. Kanakapura is located at 12°33’N 77°25’ E 12.55°N 77.42°E. It has an average elevation of 638 metres (2093
feet). Kanakapura is situated about 55 km south to Bangalore on National Highway NH-209, on the banks of the river Arkavathi. The taluk has geographical area of 1,59,426 hectares consisting of 6 hobli’s such as 1) Kasaba 2) Harohalli 3) Maralawadi 4) Kodihalli 5) Sathanur 6) Uyyamballi. There are 43 Grama Panchayaths in the taluk and located about 27 km from Ramanagara. As of 2001 India census Kanakapura had a population of 47,047. Males constitute 52% of the population and females 48% of the population. Kanakapura has an average literacy rate of 66%, higher than the national average of 59.5%; male literacy is 72%, and female literacy is 59%. In Kanakapura, 11% of the population is under 6 years of age.

Examining the available literature pertaining to the study area, it is known that the earlier workers (GSI & ISRO, 1994; Gupta and Ganesh Raj, 1992; Gupta et al. 1990; CGWB, 1994) were carried out hydrogeological investigations on 1:50000 scale using satellite imageries for the Kanakapura watershed in Kanakapura taluk, Ramanagara district. The data on watershed and sub-watershed level pertaining to morphometry, geology, soil, hydrogeomorphology and lineament studies including, evaluation of ground water prospective zones and hydrogeochemistry including proposing methods of conservation and management of water resources is lacking. Hence, the study area was chosen and investigation carried out with following objectives.

1. To understand the geological setting including intensity of weathering and structures those are favorable for the movement and storage of groundwater.
2. To evaluate the groundwater prospect zones based on morphometric parameters, average depth of rainfall, hydrogeomorphic units and lineament analysis including the available bore-well data.
3. To find the suitability of groundwater both for irrigation and drinking purposes based on hydrogeochemical parameters/ions.
4. To prioritize the sub watersheds for conservation and management of water resources based on the integrated approach by using geological factors, morphometric parameters, hydrogeomorphic units, land use and land cover mapping by weightage factor analysis.
Fig.1.5: Location map of Kanakapura watershed

Fig.1.6: Road map of the Kanakapura watershed
1.8 DATA USED AND METHODOLOGY

The digital satellite data of IRS LISS III (23.5m spatial resolution, 2003) and PAN (5.8 m resolution, 2003) merged satellite data of Geocoded FCC of bands - 2 3 4 , (Fig.1.8) on 1:50,000 scale data were used for preparation of thematic maps. Landsat TM 2009-01-12 2009 path 144 and row 51 data is used for the digital supervised and unsupervised classification respectively (Data Source NRSC, Hyderabad, KSRSAC Mysore and USGS, NASA website).

The various base maps like settlement, transport network, village boundary and contours and thematic maps like drainage, geology, soil, slope, hydrogeomophology, lineaments, bore well details, land use / land cover maps are scanned and converted into vectorised drawings using GIS Software’s. The various GIS software’s such as ESRI – ArcGIS (Arc Map- Arc Info, Arc View & Arc Scene), Rockworks, Q-GIS and surfer are used for analysis of various themes and generation of outputs (Data Source NRSC, Bhuvan, Hyderabad, KSRSAC Mysore and USGS , Department of Mines and Geology).

Climatic records such as temperature, wind speed, vapour pressure and relative humidity data were collected from Indian Meteorological Department (IMD), Government of India, Bangalore and interpreted. Rainfall data of different rain gauge stations of the study area has been collected from statistical department, Government of Karnataka, Ramanagara and Bangalore and various maps have been prepared using this data.

Various type of litho units, hydrogeomorphic units, soils and land use / land cover in the study area were observed during the field check has been carried out in two sessions in the month of April and November 2012. Geological mapping of the study area has been carried out using toposheets, Geological Society of India (GSI) map, other collateral data and soil map is also prepared for each sub-watershed using merged satellite data and other collateral data collected from soil department of Karnataka.

Morphometric analysis has been carried out for the entire Kanakapura watershed and also for nine sub-watersheds. The drainages are initially derived from SOI toposheets bearing number 57H/6, 57H/7, 57H/10 and 57 H/11 and later new drainages and tanks were updated by using IRS LISS III + PAN merged satellite image. Stream orders were derived and numbered with the help of ArcGIS software.
The contour was derived from Cartosat-1 Digital Elevation Model (DEM) for the entire Kanakapura watershed and ArcGIS - Arc Info & Arc Scene software is used to generate various hydrological thematic maps. Slope map was produced for each sub-watershed using contour data based on the guidelines of All India Soil and Land Use Survey (AIS&LUS 1990) to obtain different slope categories in each sub-watershed.

The basic visual interpretation key elements such as tone, texture, size, shape and association were considered while interpreting various hydrogeomorphic units and mapped from merged satellite data is Geocoded, FCC bands 2 3 4 and topographic maps were used as reference. Ground truth checks have been made with reference to all the hydrogeomorphic units during field visits. Lineament map have been prepared using the same merged satellite data and rose diagrams have been prepared for each sub-watershed to delineate the direction of lineament. Lineament density map has been prepared for the entire Kanakapura watershed. The existing borewell data were collected from Department of Mines and Geology, Ramanagarm District and plotted on the lineament map.

Groundwater prospect maps have been prepared for each sub-watershed by integrating various thematic maps viz., DEM, slope, geological, hydrogeomorphological, lineament, soil, land use / land cover and bore well data maps.

According to the guidelines of NRIS Node Design and Standards land use / land cover maps were prepared. Visual interpretation method was adopted for IRS LISS III FCC of band 2, 3, 4, 1:50,000 scale and unsupervised digital classification method has been carried out using Landsat TM 2009 data acquired on 01-12 2009 path 144 and row 51 data for the delineation of various land use/land cover classes. (Fig.1.10) During the interpretation, wherever doubtful units were encountered, ground truth survey was undertaken to verify the same.

The various hydrogeochemical parameters like electrical conductivity, pH, TH and TDS have been determined along with major ions like Ca, Mg, Na, K, Fe, HCO₃, Cl, F, NO₃ and SO₄. The spatial distribution of water samples for evaluation of quality was carried out using Arc GIS software. The hydrogeochemical classification of groundwater determined using Wilcox, USSL, Gibb’s and Hill Piper diagrams to find the suitability of groundwater for both irrigation and drinking purposes. The groundwater chemistry data were collected from Mines and Geology department, Ramanagara District and used for interpretation.
Fig.1.7: The Sangam (region of Arkavathi river joins Cauvery river)

Fig.1.8: Overlay of sub-watersheds on the satellite image of the study area IRS (LISS III + PAN merged – Geocoded FCC of bands 2 3 4)
Fig. 1.9: Cartosat1 DEM 2011 map of the study area

Fig. 1.10: LANDSAT TM 2009 image of Kanakapura watershed overlaid with the nine subwatershed boundary
Topologically cleaned and built for all the themes using ArcInfo software before creating spatial database. Spatial distribution analysis has been carried out using ArcGIS - ArcInfo and ArcScene software. Arc Info is used to create DEM using interpolation technique and Arc Scene is used to create DEMs in various angles. Once the analysis of all themes is completed, ArcMap is used to create various layouts to generate outputs. Digital Image Processing software ERDAS is used to geo-reference merge the digital satellite image of LISS III and PAN data and digital classification.

1.9 ORDER OF PRESENTATION

The thesis has been subdivided into 9 chapters. The data obtained and its interpretation carried out and presented in each chapter are as follows;

Chapter-2 concerns with hydrometeorology. The various hydrometeorological parameters like temperature, relative humidity, vapour pressure, wind speed and rainfall were presented. The Thiessen polygon, Iso-hyetal methods to analyze the spatial distribution of the seasonal and annual distribution of rainfall maps have been prepared using ArcGIS software and analyzed.

Chapter-3 embodies data on morphometric analysis and its interpretation. The various aspects such as linear, relief and aerial aspects are interpreted. The different linear aspects such as stream order and its number, stream length, mean stream length, stream length ratio and bifurcation ratio and relief aspects such as relief ratio, total relief and aerial aspect like basin area, basin perimeter, drainage density, stream frequency, length of overland flow, texture ratio, form factor, circularity ratio and elongation ratio have been described, interpreted and calculated. Using remote sensing satellite imageries and GIS newly updated drainages and tanks have been identified and also included for morphometric analysis.

Chapter-4 describes general geology of South India in general. In particularly the geology and soil of the study area and understanding the relationship between soils and parent material is essential to formulate any land based production system. In all sub-watersheds soils have been classified up to sub-group level and interpreted.
Chapter-5 deals with the identification of prospect zones of ground water. The aspects of DEM, slope analysis, geology, hydro geomorphic units, lineament analysis along with bore well locations are vital inputs for identifying the ground water prospect zones. The area statistics for each category of ground water prospect and geomorphic units were computed and incorporated in enriching the conservation and management of the watershed.

Chapter-6 describes the information on existing land use/land cover and pattern of their spatial distribution forms the basis for any development planning. The current land use/land cover classification done based on the NRSC, 1989, digital classification employed and maps, charts, statistics were generated and presented.

Chapter-7 concerns with the ground water quality assessment, based on the hydrogeochemistry. The usability of available ground water is determined by its chemical parameters such as Na, K, Fe, HCO₃, Cl, & F etc,. Groundwater samples representing 32 borewells were collected for both pre and post-monsoon seasons was presented, plotted on various geochemical diagrams and interpreted to evaluate the quality of groundwater according to WHO and ISI standards for both pre and post-monsoon seasons.

Chapter-8 is about with the integrated approach to prioritize the sub watersheds for conservation and management of water resources based on the data on geology, rainfall, morphometric parameters, hydrogeomorphic units, land use and land cover mapping by weighted factor analysis.

Chapter-9 Provides summary and conclusions.