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# Use of Remote Sensing, Geophysical Data Sets and Web GIS Techniques for Development of Ground Water Information System of Udupi District

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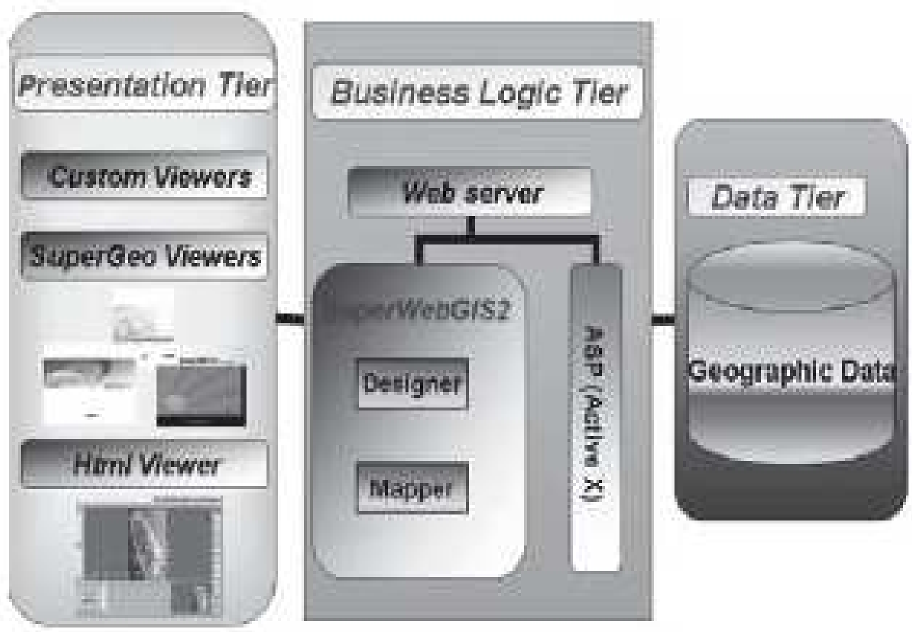
**Abstract:** Occurrence of groundwater is becoming a precious natural resource due to increasing population, agriculture, and industrial growth in the Udupi district region. For quick overview of the problem and its remedial measures, there is a need to establish ground water information system, where data from various sources can be stored and analyzed in time and space. To develop Ground Water Information System (GWIS) of river Basins of Udupi district, SuperWeb GIS has been used. It helps in analyzing various spatial and non-spatial data related to groundwater and stores data, creates hydrographs, well logs, various chemical diagrams, cross section, fence diagrams, contour maps etc. In the present paper, an approach is adopted for establishing GWIS of river Basins of Udupi has been discussed. Internet based geographical data services involve management of spatial and non-spatial (attribute) data. Geographic Information System (GIS) has come to be an indispensable tool for analyzing and managing spatial data. Data pertaining to spatial attributes can be efficiently managed using Relational Database Management System (RDBMS). The development of a Web-based system by integrating GIS and RDBMS would serve two crucial purposes. Firstly it would allow the user to operate the system without having to grapple with the underlying intricacies of GIS and RDBMS technology. Secondly, it would allow sharing of information and technical expertise among a wide range of users. The synergy of Geographical Information Systems and Web Technology allows access to dynamic geospatial information without burdening the users with complicated and expensive software. The World Wide Web provides GIS users easy access to spatial data in a distributed environment through a simple browser interface or sometimes by a lightweight client side application. The concept of Web GIS is based on how the map is produced and responds to users' interactions over the Web. The publication and distribution of spatial data are increasingly important activities enabling organizations to share domain-specific dynamic spatial information over the Web.

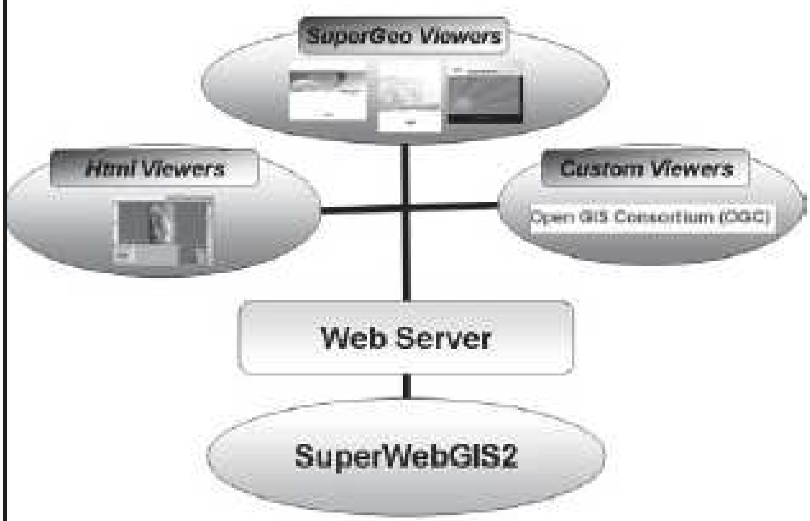
***Keywords:*** *Remote Sensing, Ground water Information system, WebGIS, SuperGIS, and SuperPad.*

## Introduction:

Planning is now a widely accepted way to handle complex problems of resource allocation and decision-making. In order to provide a more effective and meaningful direction for better planning and development, necessary support of the organization has become essential. Hence the need for a suitable information system is increasingly being felt in all planning and developmental activities, whether these are for urban or rural areas. The position with regard to information system in urban areas however is far from satisfactory. Large volume of data is gathered whenever preparation of physical plan is taken up and a good number of maps as a part of the exercise on plan formulation are also prepared. However, today no system has been built to compile this geographically referenced data on a systematic manner and store them for retrieval at a subsequent point of time. Planners and decision-makers at Micro level have to depend upon spatial and non-spatial data for optimal interpretation. Hence, the planners need to have at their disposal sophisticated data management systems to handle such spatially correlated data. The emergence of Remote Sensing and Geographic Information System as a powerful tool for spatial analysis and storage has in effect alleviated the problem by computerization of the spatial data. A flexible and user friendly soil information system and ground water information system was developed to assist planners for village level planning with reference to managing the resources of Udupi district. In the present work, an attempt has been made to develop an information system using SuperWeb GIS, which can support the planners on information retrieval by integrating the spatial and aspatial data. SuperWeb GIS offers the facility of displaying GIS data over the internet. Users from anywhere in the world can inquire, display, edit and analyze the data that have been published over the internet by means of internet browser. Using SuperWeb GIS it is very easy to design, build, manage and monitor Websites. It also enables the customization of WebPages. Super Web GIS 2 is a set of Internet Geographic Information System. Through SuperWeb GIS, the spatial map server has been built and distributes the spatial data to on-line users. More, users can use the spatial data analysis function of advanced map query. The map server built by Super Web GIS, meeting WFS and WMS specifications of OGC standards, realizes resource sharing aim. SuperWeb GIS 2 is created as a platform to distribute geospatial data and service on the web. The architecture is in a way that client sends a request then server gives a response. It is not only a solution for geospatial data sharing on internet but also a framework distributing GIS layers via internet. SuperWeb GIS 2 is of multiple Tier architecture, composed of Data Tier, Business Logic Tier and Presentation Tier as shown in Fig 1.




SuperWebGIS 2 operating architecture




SuperWebGIS 2's many browsing methods

**Study Area:**

Udupi District is in the Karnataka state of India. The three northern taluks, Udupi, Kundapur and Karkala, were separated from Dakshina Kannada District to form Udupi district. The administrative headquarters of Udupi district is Udupi. Population as per census 2001 was 2,112,243 of which 18.55% were urban. Udupi District lies between 74° 55′ E and 75° 23 ′ E longitude and 13° 05 ′ N and 13° 55′ N latitude in the coastal region of Karnataka state. The area is almost plain towards west with an undulating topography towards North–East. Rivers Sita, Swarna and Udyavara enter Udupi taluk from eastern border and these rivers originate in the western slopes of the Western Ghats. Another river Pangala, originates within the Kanara pedeplain of Udupi taluk. The mouth of Mulki river makes the southern border of the taluk. These rivers sculptured the Kanara pedeplain surfaces resulting in dendritic pattern of drainage. In addition to these major rivers, small streams like Kopla near Kaup and Perampalli near Kodi- Perampalli flow more or less parallel to the coast.

**Climate and Rainfall:**

The area experiences a typical maritime climate with an average temperature of 27.5°C. Udupi district gets highest annual rainfall in Karnataka state, about 4000 mm. In this coastal district, bulk of the rainfall i.e. over 85% occurs during monsoon season. The 3575 sq km area of Udupi district has 3 rain gauge stations (1 station/1199 sq km). The temporal variation of rainfall is confined to 3 to 4 months in a year. The rainfall increases from west to east with co-efficient of variability ranging from 18.6 to 18.9%. The area receives an average Annual rainfall is 4136.3 mm.

**Geomorphology:**

The important factors governing the development of landforms are resistance to erosion, geological structures of underlying rocks, and climate of the region and vegetation cover. Studies of qualitative as well as quantitative aspects of geomorphology form the fundamentals in hydrologic research. Therefore, the geomorphic studies of Udupi taluk have been carried out and their significance in groundwater studies is discussed in this chapter. Karnataka state has spectacular landforms of diverse nature and origin. The coastal landforms on the West and the elevated interior plateaus (Karnataka plateau and Mysore plateau) in the East are the two prominent geomorphic zones in Karnataka. These two major landforms are separated by Western Ghats.

**Coastal Landform Terrain:**

Coastal landform terrain consists of coastal low land terrain and Kanara pedeplain surfaces.

**Coastal Low land Terrain:**

The coastal tract is about 320 km. long, stretching over three districts viz., South Kanara, Udupi and North Kanara, with an area of about 15,000 sq. km. The coastal low land terrain has a low relief with an elevation ranging from mean sea level to about 20 m. The NNW-SSE oriented beaches often broken by mangrove dominated estuaries, lagoons, beach ridges, back shore dunes, tidal creeks and off-shore rocky islands are common features of this terrain.

**Kanara Pedeplain:**

It is lying between coastal lowland terrain and Western flank of the Western Ghats with an average width of 50 km. It is stretching parallel to the coastal plain and Western Ghats. It extends from Goa, Maharastra in the North to Kerala in the South. Imprints of dendritic drainage pattern of West flowing rivers, occurrence of numerous lateritic mesas, gneissic inselbergs, meandering lobes and point bars are common features of Kanara Pedeplain.

**Western Ghat Scarp:**

Western Ghat scrap marks the eastern border of Kanara pedeplain. This is an undulating landscape deeply dissected into numerous ridges and scraps. It rises from 100 m to varying altitude ranging from 900 to 1900 m. Western Ghat is trending in NNW-SSE direction, almost parallel to west coast of Karnataka. The northern part of Western Ghat is made up of Deccan basalts and Southern part is mainly comprises of metasediments, granites and gneisses. Since the Deccan traps straddling the Cretaceous- Tertiary boundary are involved in the upliftment of Western Ghats, it is inferred that the uplift took place in mid to late Eocene (Radhakrishna, 1993). This terrain forms the major water divide between the East and West flowing rivers in the southern peninsular shield.

**Physiography of Udupi Taluk:**

Important physiographical features along the coast of Udupi taluk are sand dunes, beach ridges, lagoons, barrier spits, mudflats, estuaries, channel islands, tidal creeks, rocky islands, head lands of gneissic rocks etc., (Fig. 3.2). The coastline of Udupi taluk is about 50 km long. The unusual coastline is due to NNW to NW trending lineaments, which have control over the same. Coastal faulting and the uplift of Western Ghats have influenced several tectonic and geomorphological events in the West coast since late Cretaceous period (Ravindra and Krishna Rao, 1986). Lateral movements along faults explain the variations in lithology of the coast. A linear extension of sand dunes of about 2 to 3 m height is located near the beach of Kaup and near Perampalli. A long hook shaped spit of sand and/or gravel is located 4 km west of Udupi city. These sands and gravels are generally developed by the action of long shore currents. Spits and bars near Udyavara, Hoode, Kodi- Perampalli are formed by the diversion of coastal rivers along the coast-parallel longitudinal faults (Ravindra and Krishna Rao, 1986). Prominent beach ridges of consolidated sands and gravels can be seen from Kaup through Mulur to Mulky and West of Udupi city and are usually running parallel to the coast. These are paleo-beach deposits, which are formed by the continuous regression of the sea, possibly during the period of upliftment of the Western Ghats. Linear troughs of about 100-200 m widths have an elevation difference of one to two meters relative to adjacent land and are seen around Tenkanidiyur, Badaganidiyur, Perampalli and Kota. These troughs are controlled by longitudinal faults (Ravindra and Krishna Rao, 1986). Ancient streams, now filled with clay sediments, occupy these sites. Near Kapu, headlands made up of gneissic rocks of Pre- Cambrian age break the coastal line. Another unusual feature of Udupi coast is the presence of Island viz., St. Mary Island, 6 km off the coast of Udupi, near Malpe. Various landscapes developed along the Udupi coast owe their origin to fluvial and marine agencies and also formed as a result of neotectonics. The coastal low-lying terrain is bordered by pedeplain surfaces on the eastern side. These pedeplain surfaces are part of Kanara pedeplain surface. Uneven topography, with elevated portions of lateritic mesas and gneissic and granitic inselbergs of small heights are common features of Kanara pedeplain. Streams and rivulets of west flowing rivers spectacularly carve lateritic mesas of this region. The highly dissected nature of the lateritic mesas in the southern Karnataka coast is due to prevalence of upliftment activity during Holocene period (Subrahmanya, 1994). Hypsometric analysis reveals that the terrain is of monadnock phase (Sadatipour et al. 1986). It shows that eastern side of the Udupi taluk looks like a dissected area with patches of hillocks. This region mainly consists of inselbergs of gneisses and granites. In this region, groundwater is confined mainly to deep fracture zones and upper thin weathered zones of gneisses and granites. In this area the recharge to the aquifer is mainly through joints and fractures of the rocks. There are two pedeplain surfaces on the Kanara pedeplain viz., Manipal (100 – 120 m) and Brahmavara (40 – 60 m). Lateritic mesas and numerous inselbergs represent the Manipal surface with excellent mantled pediments around Manipal. Low relief lateritic plateaus and gneissic mounds represent Brahmavara surface. In this zone, groundwater occurs under unconfined condition in thick laterites and is developed mainly by open wells and small tanks. Below the laterite, deep fracture zones in gneisses and granites are also acting as potential aquifers for groundwater exploration. Coastal low land terrain is mainly covered by alluvium. Here groundwater occurs in shallow zones. Deep fracture zones within the gneisses below the alluvium are also expected to have groundwater potential. In this area exploration needs special attention, otherwise saline water may intrude into fresh water aquifers. Highly permeable nature of gravels and sands increases the absorption of water but presence of interbedded clay layers reduces the permeability.

**Drainage of Udupi Taluk:**

This coastal agro climatic west flow river basin is characterized by maritime climate. It covers parts of Mulki, Shirva, Swarna Yennehole, Madisala, Sita, Haladi, Chakra, varahi, Kollur, Baindur and Sankadagudi hole sub basins. These rivers are perennial during normal rainfall years where as tributaries and smaller streams become dry during summer. The prevailing high gradient in the hilly terrain and heavy rainfall brings great volume of water in these rivers during monsoon. These rivers join Arabian Sea and are prone to tidal effects to considerable lengths in the inland area. Drainage is shown in Fig.2. Drainage pattern provides indication of hydrogeological condition of the region. Many factors such as lithology, nature and degree of soil development, its texture and structures, moisture content, permeability, vegetation covers and degree of fracturing in rocks control the drainage pattern of the region. Rivers Sita, Swarna and Udyavara enter the Udupi taluk from eastern border. These rivers originate in the Western slopes of the Western Ghats. Another river Pangala, originates within the Kanara pedeplain terrain of Udupi taluk. The mouth of Mulky River makes the southern border of the taluk. These rivers sculptured the Kanara pedeplain surfaces resulting in dendritic pattern of drainage. In addition to these major rivers, small streams like Kopla near Kaup and Perampalli near Kodi-Perampalli flow more or less parallel to the coast. Drainage density map of the Udupi taluk has been represented in table 2. The drainage map of Udupi taluk is divided in to 2 x 2 km grid. The number of streams in each grid is counted, is plotted at the centre of each grid. The contour lines are drawn to make the areas of equal drainage density. The drainage density map of Udupi taluk shows the low drainage density on the eastern side of the taluk. This is due to the presence of highly resistant rocks like gneisses and granite and dense vegetation.

Presence of porous laterite, sparse vegetation and high relief due to lateritic mesas favours the high drainage density in the central portion of the taluk.

**1. Morphometric Analysis of Drainage Basins:**

Morphometric analysis of the drainage basin is of great importance in understanding their hydrological behavior. It is a systematic analysis of the geometry of a drainage basin and its stream channel system. It requires measurement of linear aspects of drainage network (stream order, stream number, bifurcation ratio, stream length, length ratio etc.), areal aspects of the drainage basin (basin area, basin shape, drainage texture etc.) and relief aspects of channel network and contributing ground slope (hypsometric analysis). Some of these parameters are useful in understanding the groundwater situations of the region. Correlation can be established between various geomorphic characteristics of the basin with its precipitation and run-off, climate, vegetative cover, lithology and soils.

**Linear Aspects of the Drainage Basins:**

The linear aspects of a basin include the stream order U, stream number N, bifurcation ratio R, stream length L, length ratio R and length of overland flow L.

**Stream Orders (U):**

The stream orders for Sita, Swarna, Udyavara and Pangala rivers have been carried out as designated by Strahler (1952). Rivers Sita, Swarna and Udyavara are sixth order basin while Pangala river is a fourth order basin. In a river basin, the number of segments of any given order is less than the previous lower order, but more than the next higher order. This observation leads to the bifurcation ratio R, which is the ratio of number of segments of a given order N to the number of segments to the next higher order N .The bifurcation ratio will not be precisely the same from one order to the next, because of chance variation in the watershed geometry, but it will tend to be constant throughout the series. This observation formed the basis of Horton's law of stream number, which states that the numbers of stream segments of each order form an inverse geometric sequence with order number. k is the trunk order. It is observed that this law is applicable to all the four river basins of the study area viz., Sita, Swarna, Udyavara and Pangala and the geomopholical map of udupi district derived as shown in fig.6. Bifurcation ratio shows a small range of variation from region to region, except where powerful geological controls dominate (Strahler, 1956). Bifurcation ratio is an index of relief and dissection (Horton, 1945). Bifurcation ratio ranges between 3 and 5 for river basins in which the geological structured have not distorted the drainage pattern and the basins have reached mature stage of river development (Shreeve, 1965; Ongley, 1964). Bifurcation ratios of Sita, Swarna and Pangala rivers range from 3 to 5 indicating that the geological structures have not distorted the drainage pattern. But the bifurcation ratio of Udyavara river is not within the above range revealing that the drainage network is controlled by geological structure like lineaments.

**Stream Lengths:**

From the drainage map, it is apparent that the first order segments have on an average the shortest length and the segments become longer as the stream order increases. The mean stream length increases as the stream order increases and as such mean stream length of any given order is greater than that of the lower order and has less than that of the next higher order. This proportion of length increase is known as the length ratio R, and tends to be constant for a given drainage basin. The length ratio R is the ratio of mean length of segments of order u to mean length of segments of the next lower order. This leads to the law of stream lengths (Horton, 1946), which states that the mean length of stream segment of each of the successive orders of a basin tend to approximate a direct geometric sequence in which the first term is the average length of the first order segment as shown in table 2.

***Table 1:*** *Measures of Intensity of Dissection of Sita, Swarna, Udiyavar, Pangala River Basin*

| Sl. NO | Parameters | Sita | Swarna | Udyavara | Pangala |
|---|---|---|---|---|---|
| 1 | Total Stream Length KM (Lu) | 1156.5 | 1429.95 | 439.5 | 69.5 |
| 2 | Total Number Of Streams (Nu) | 1621 | 1568 | 538 | 66 |
| 3 | Length Of The Basin KM (Lb) | 49.5 | 55 | 31.3 | 15.6 |
| 4 | Width Of The Basin KM (Bb) | 18.5 | 24 | 14.3 | 6.9 |
| 5 | Drainage Density KM (D) Km/Km$^2$ | 1.69 | 1.63 | 1.4 | 1.04 |
| 6 | Constant of Channel Maintenance ( C) Km$^2$/Km | 0.559 | 0.556 | 0.616 | 0.96 |
| 7 | Stream Frequency (F) L/Km | 2.5 | 1.9 | 1.61 | 1.134 |

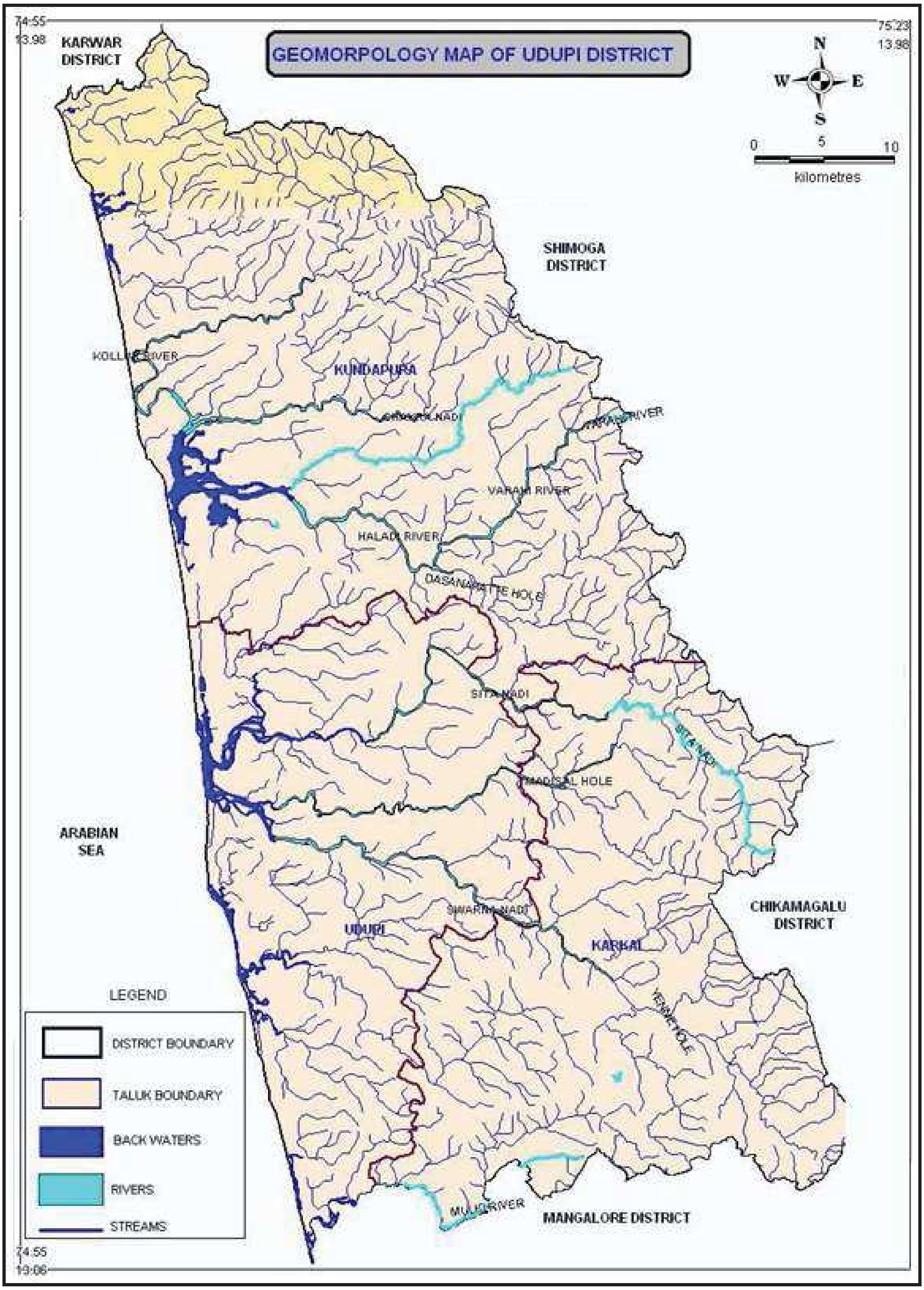



*Figure 3:* *Geomorphological Map of Udupi District*

The district comprises of three distinct physiographic units viz., (i) Narrow stretch of coastal tract (ii) Up land area (iii) The hilly terrain. The coastal areas exhibit coastal beach, spits and creeks and backwater swamps with the surface features of sandy strips and linear troughs. The coastal parallel troughs are seen around Parampalli, Kota and Manur. The area adjoining the coastal stretch exhibits forested high hilly topography with deep valleys. Most part of the district is rugged terrain and demarcates areas with slopes of less than 2%, 2 to 5% and more than 5%. About 50.68% of the district falls under 2 to 5% slope and remaining fall under more than 5% slope. The slope map generated as shown in Figure.4. Most part of Lateritic capped pediplains have an elevation ranging from 40 to 60 m msl which is an important physiographic feature. Upland pediplain area intercepted with low hills between Western Ghats and the coast, which is moderately cultivated. Western ghats and forested area located on the eastern part of the district.

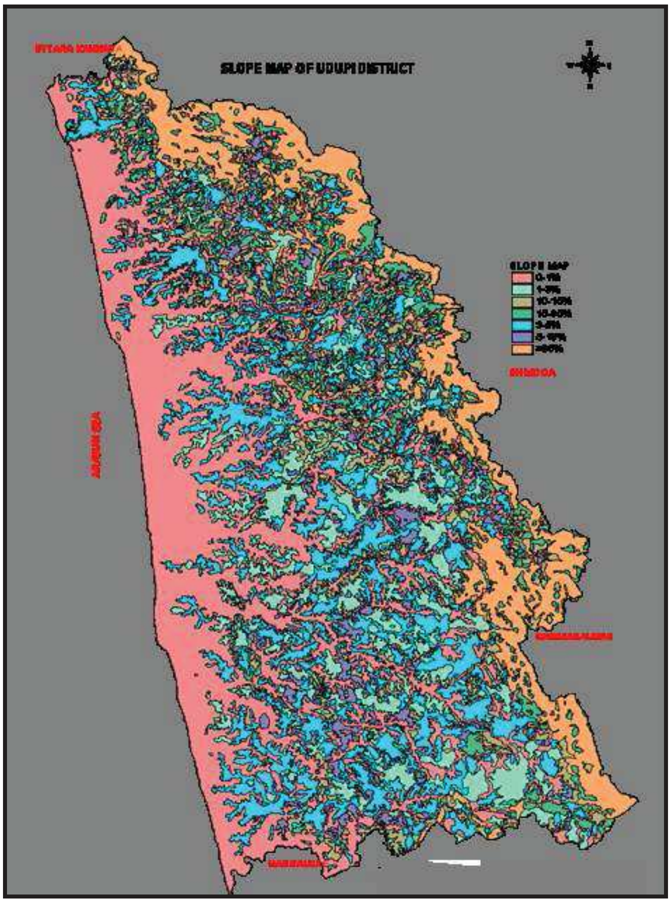



***Figure 4:*** *Slope Map of Udupi District*

**Soil Type:**

The district is covered with three types of soils i) sandy soil covering the beaches and the adjoining stretches ii) yellow loamy soil and iii) red lateritic soil as shown in Figure 5. The sandy soils are confined to a narrow strip of the coast having width ranging from less than 100 m to as much as a kilometer. These fine to medium textured sands are characterized by their extremely high rate of infiltration and act as a good recharge media for ground water. Yellow loamy soils are transported from origin and are found mostly along river banks and lower reaches of valleys. They are mostly used for tile industries. This soil type is very well suited for irrigation and shows good response to irrigation practices. Red lateritic soil is the most dominant soil type in the area. The texture of these soils varies from fine to coarse. The soil in the valleys and immediate slopes are rich in loam where as in upper slopes and pediplains are much coarser in nature. The degree of leaching undergone by this soil type is also variable.

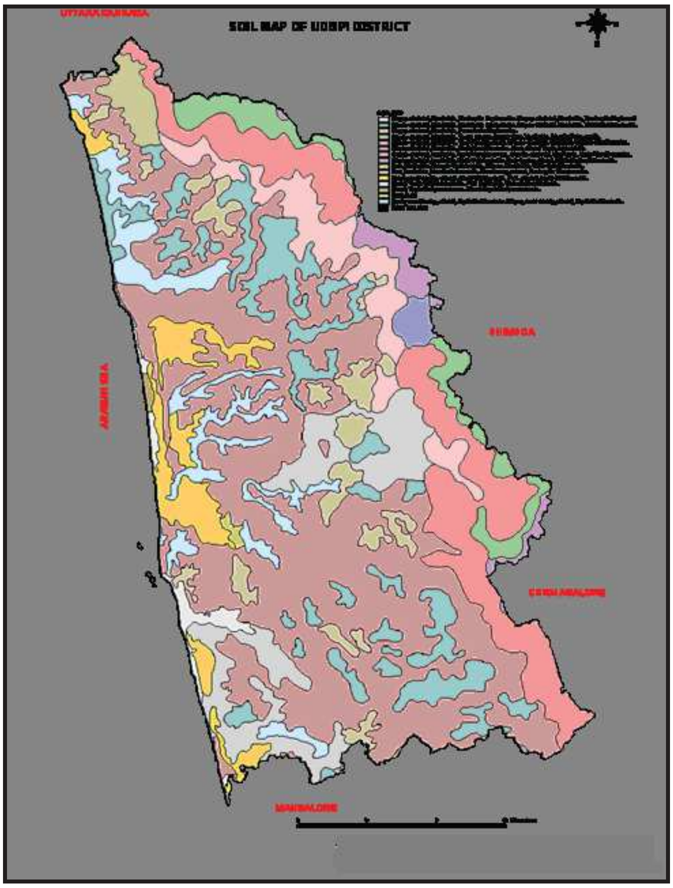



***Figure 5:*** *Soil Map of Udupi District*

**Geology:**

Geologically the rocks like Granitic gneisses with occasional laterite capping and unconsolidated river and marine sediments, occupy the area. The gneiss, which is wide spread in the distinct outcrops at varying magnitude especially along river courses. Basic intrusives like dolerites and gabbros and acidic intrusives like pegmatite and quartz veins and pink porphyritic granites are found all over the district. The recent alluvium and colluvial deposits occur along the river banks and sea coast. The exposures of crystalline rocks found as isolated hills along the shore and off shore. The black clayey marine sediments with a thickness of 0.30m to >1.00m occur as lenses along the coast and in the deltaic islands. Its occurrence is marked at a depth range of 5.00 to 6.00 mbgl.

**Hydrogeology:**

Ground water in the region mainly occur in various geologic formations like beach alluvium, coastal sediments, laterites and in weathered and fractured granitic gneisses under phreatic and semi-confined to confined conditions, but mainly under water table conditions. Coastal alluvium along with the laterites, which underlie them, occurs as an aquifer of phreatic nature. Ground water occurs in weathered mantle and fractured crystalline formations under semi confined to confined conditions. The ground water in and below the black clayey horizons of coastal sediments found with high salinity, which marks the index bed for saline water and fresh water interface. Dug wells are the most common groundwater abstraction structures encountered in lateritic terrain. Hydrogeology of the district is represented in Fig.3 Based on the morphogenetic and geological diversities and aquifer characteristics; Udupi district can be subdivided in to two broad hydrogeological units

a) Hard and fissured formations in the pediplain

b) Porous unconsolidated formations in the coast.

**Occurrence of Ground Water:**

As per the occurrence and behavior of ground water, ground water system of the district is described under four zones in general.

**a). Shallow Zones Up to 25m:**

It generally comprises of weathered and fractured granites and gneisses. Ground water occurs in the pore spaces of weathered and fractured formation under phreatic condition. The granitic gneisses are traversed by intrusives of younger granites, pegmatities and quartz veins. In weathered granite and gneissic formations the specific capacity values ranges from 6 to 215 lpm/m and unit area specific capacity ranges from 0.2 to 19.5 lpm/m/$m^2$. Transmissivity of granite gneiss in dug well section ranges from 5 to 141 $m^2$/day. Permeability ranges from 1.8 to 86 $m^2$/d. Specific capacity for laterite ranges from 6 to 1624 lpm/m and permeability range from 5 to 354 $m^2$/day. Yield of dug wells ranges from 18 to 296 $m^3$/d for sand and 18 to 36 $m^3$/d for clay.

**b). Moderately Deep zone (25-60 m):**

The aquifers in the depth range of 25 to 60m are grouped as moderately deep zone category. The aquifers of this category consist of weathered and fractured granitic gneisses. Ground water occurs in the pore spaces under semi-confined conditions. T value ranges from 3 to 62 $m^2$/day. In general, the yield in the area is $<$2lps.

**c). Deep zone (60-100m):**

The aquifer occurring between the depths of 60 to100 mbgl are grouped as deep zone category. Aquifers of this category also consist of semi-weathered and fractured granite and gneisses. The presence of productive fractures also seen in this zone. Ground water occurs in fractured and jointed formations under semi confined/confined conditions. In these aquifers transmissivity is in the range of 68 to 228 $m^2$/d. In general the yield distribution is in the range of 2 to 4 lps. The Resistivity ranges of major litho-units which influences the ground water are as shown in Table 2.

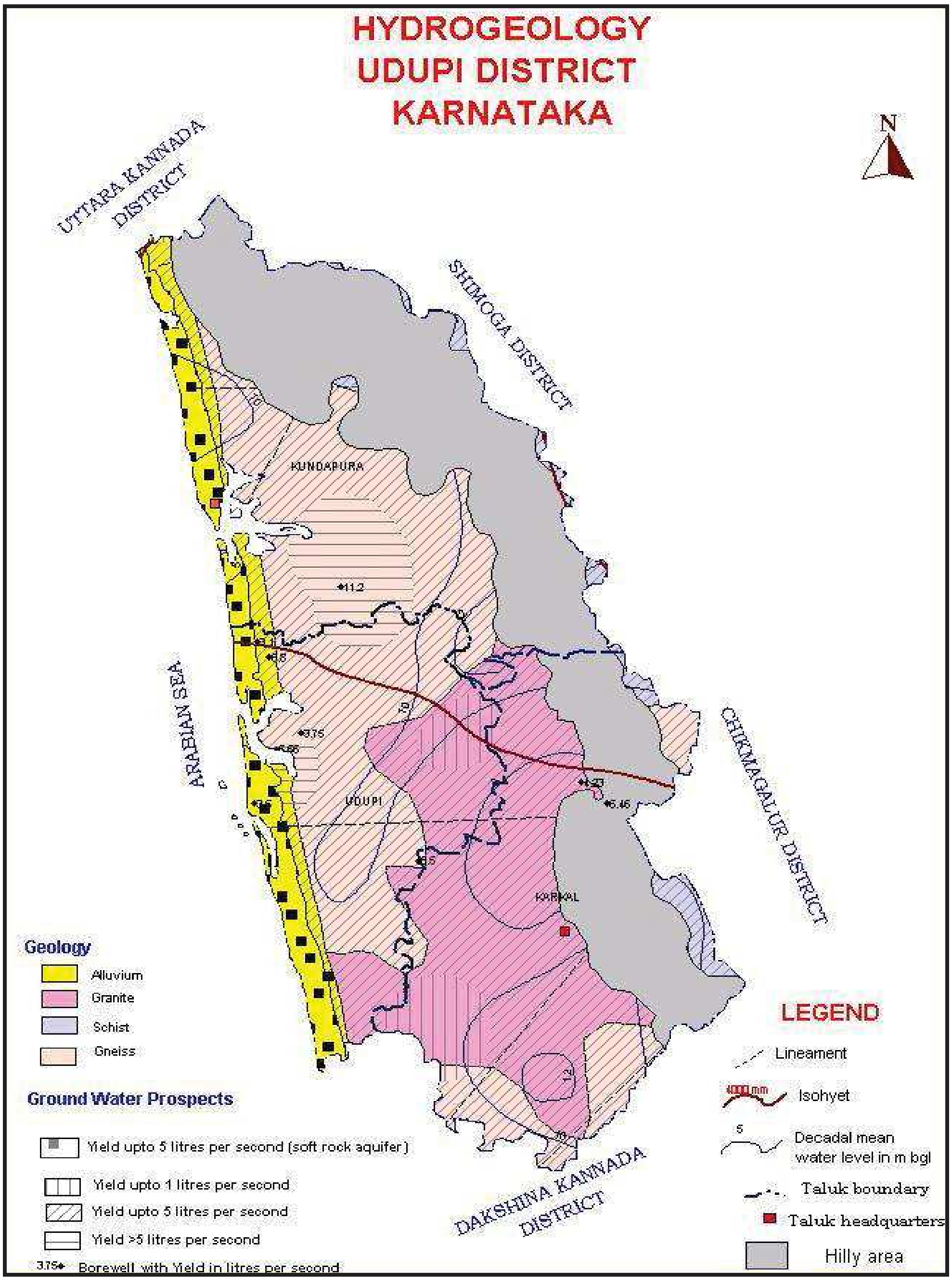



***Figure 6:*** *Hydrogeology map of Udupi District (Source: CGWB, Bangalore)*

***Table 2:*** *Resistivity Ranges of Major Litho-Units of Udupi Taluk*

| Litho-units | Resistivity ranges in Ohm-m | | | Remarks |
|---|---|---|---|---|
| | Maximum obtained | Minimum obtained | Normal range | |
| Soil | 8000 | 14 | "--" | A wide range of resistivity is due to change in composition, moisture content, and salinity. |
| Laterite | 6600 | 120 | 650 - 1500 | Variation in thickness, composition and texture. |
| Litho-margic clay | 410 | 4 | 25 - 100 | Shallow aquifer |
| Semi-weathered gneiss | 4800 | 400 | "--" | Not favourable for groundwater accumulation. |
| Semifractured gneiss | 600 | 450 | "--" | Not favourable for groundwater accumulation. |
| Fractured gneiss | 300 | 40 | 40 - 300 | Groundwater potential |
| Alluvium (Salinity zone) | 9.5 | 3 | "--" | Low resistivity is due to high salinity |
| Saturated sand | 160 | 160 | "--" | Groundwater potential |
| Gneiss | ☐ | 300 | "--" | Bed rock |

**d) Very Deep Zone (Beyond 100m):**

Aquifers of this category exist in semi-weathered and fractured granites and gneisses and ground water occurs under semi confined/ confined conditions in fractures and joints. In these aquifers transmissivity is in the order of 2 to 124 $m^2$/day and yield is in the range of 2 to 4 lps.

**Depth to Water level:**

CGWB has set up 24 NHS stations all over the district and is monitoring them four times a year. Other than this, DMG, Government of Karnataka, has also set up monitoring stations along all streches of the district as depicted in Figure 7. Among the CGWB NHS stations, 4 are in alluvium formations, 6 are in granitic gneisses, 2 are in granites, and 11 are in laterites. Ground water levels are essentially controlled by lithology, physiographic features, and rainfall distribution in space and time. Hence in pediplain areas, depth to water level is highly variable. The water level in general shows recession from November to May**.** The depth to water level for premonsoon and post monsoon for the year 2006 (Based on NHS data) is shown in Fig. 8 and 9 respectively. Behavior of ground water table during pre and post monsoon- 2006 and Long-term water level trend in the last decade (1996-2006) is discussed below. During Premonsoon, May 2006, the depth to water level varies between 1.55 to 12.33 mbgl in the district. Premonsoon water level is in the range of 5 to 10 mbgl mostly found in lateritic terrain. Depth to water level is more than 10 mbgl occurs mainly in gneissic terrain as isolated patches. Water level less than 5 mgl occurs along the coastal belt. Post monsoon water level for November 2006 varies between 1.36 to 10.33 mbgl in the district.

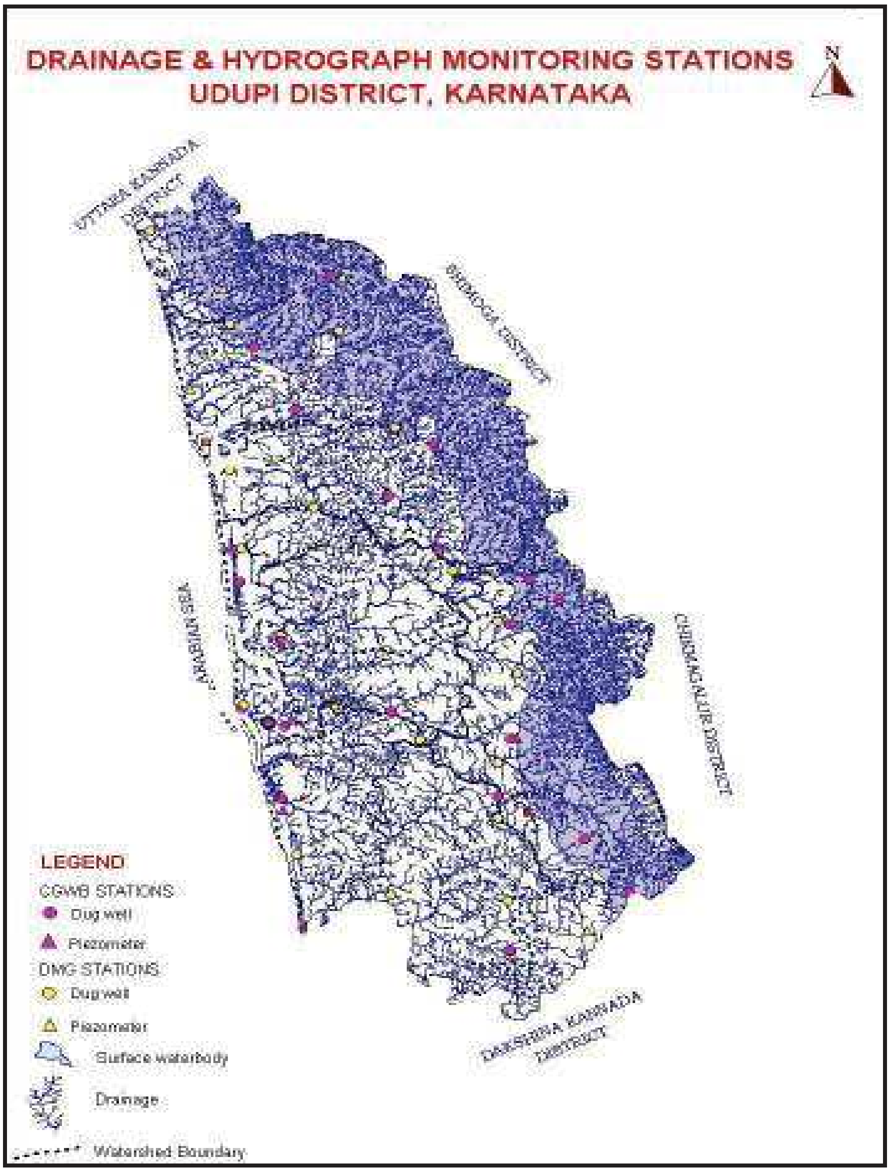



***Figure 7:*** *DHM Station Map of Udupi District (Source: CGWB, Bangalore)*

**Seasonal Fluctuation:**

Ground water level fluctuates from season to season due to the seasonal variations of rainfall. The water levels are deepest before commencement of southwest monsoon i.e., in May and shallowest during November. Rise after rains indicate the built up of ground water storage. which gets depleted by evaporation and exploitation during non-monsoon period. In general Udupi district shows water level fluctuation between 2 and 4m. Fluctuation of more than 4 m occurs in eastern and southern part of the district.

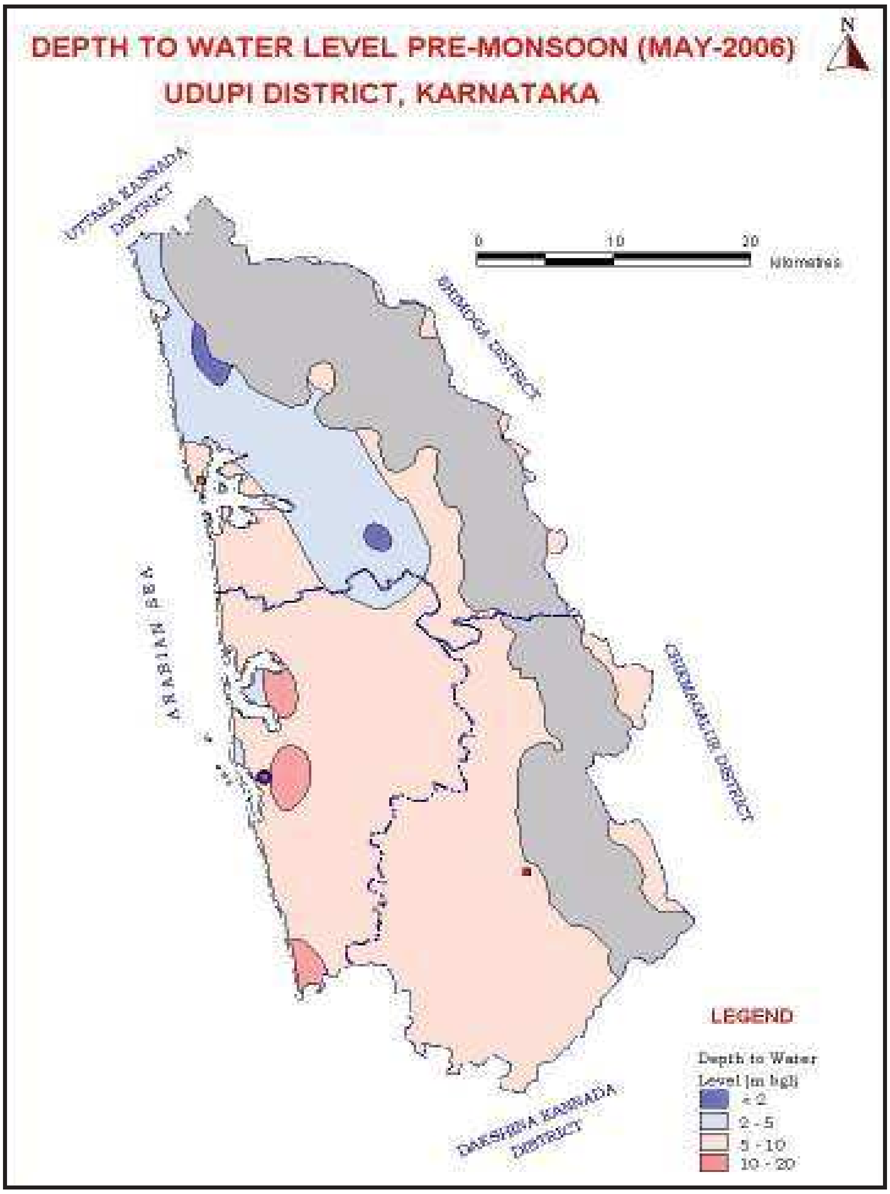



***Figure 8:*** *Depth to Water Level map of Udupi District (Pre-Monsoon)*

**Long-Term Water Level Trend:**

The comparative study of hydrographic network stations of CGWB in the district of Udupi during last decade (1996-2006) show fall in water level by 0.130 to 0.386 m/year and rise in water level by 0.066 to 0.542 m/year during Premonsoon season (May 1996 - May 2006). Long term Water level trend during post monsoon (November 1996- November 2006) show fall in water level by 0.014 to 0.348m/year and rise in water level by 0.014 to 0.254 m/year. Decadal mean water level of May 1996-2006 varies from 2.01 to 13.26 mbgl, and that of November 1996-2006 varies from 1.29 to 9.59 mgbl.

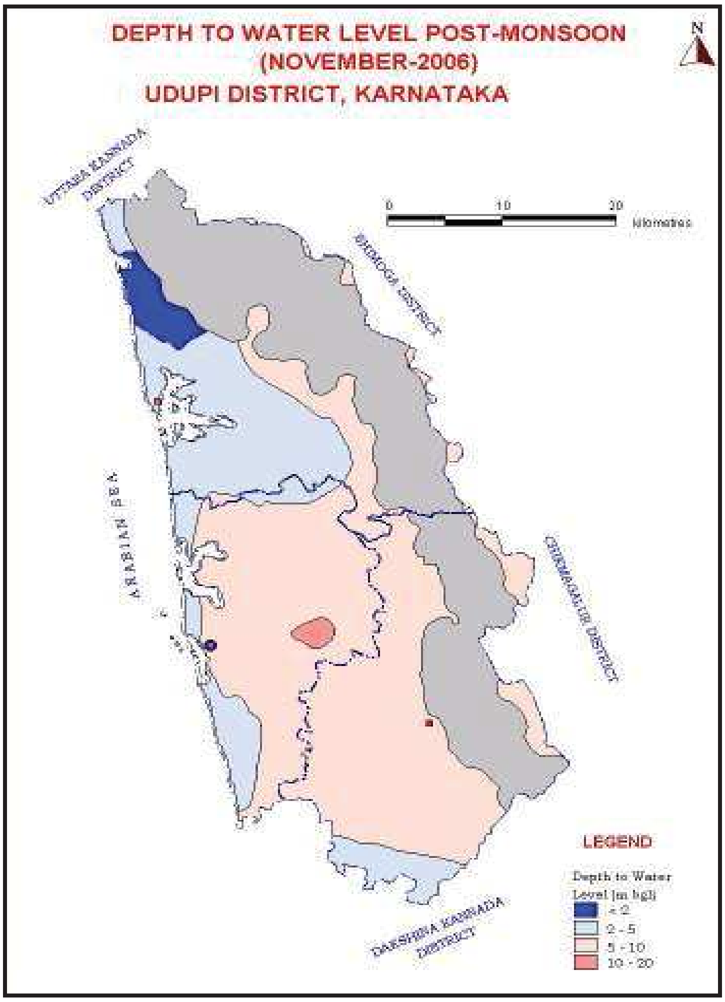



***Figure 9:*** *Depth to Water Level map (Post-Monsoon) (Source: CGWB, Bangalore)*

**Ground Water Quality:**

In general, the quality of ground water at certain depths in the sandy aquifer are found good and portable and in the adjoining areas covered by lateritic/weathered gneissic rocks, it is fresh to alkaline. The dug wells in the alluvial area generally yield saline water during summer months and get fresh water during monsoon periods. The water samples collected from the dug wells /shallower zones during May-2006 indicate the EC value as 500 to 10430µ/cm at 25 µc in the higher order and 200 to 500 µ/cm in the lower order. The EC in some of the deeper bore well located at places recorded as high as 18830 µ/cm at 25 µc are saline. Some parts of Udupi and Kundapura taluks have chloride concentration up to 4000 mg/l. Ground water quality of Udupi district is given in Fig. 10. Some groundwater in the area is contaminated from the salinity of tidal recharge. This contamination is more pronounced in wells along the stream courses up to the distance where tidal effect extends. Further, Ground water in proximity to stream course is contaminated with seepage of domestic waste. As a general rule, pumpage must be distributed in time and space and there should not be any concentration of wells to avoid saline water ingress.

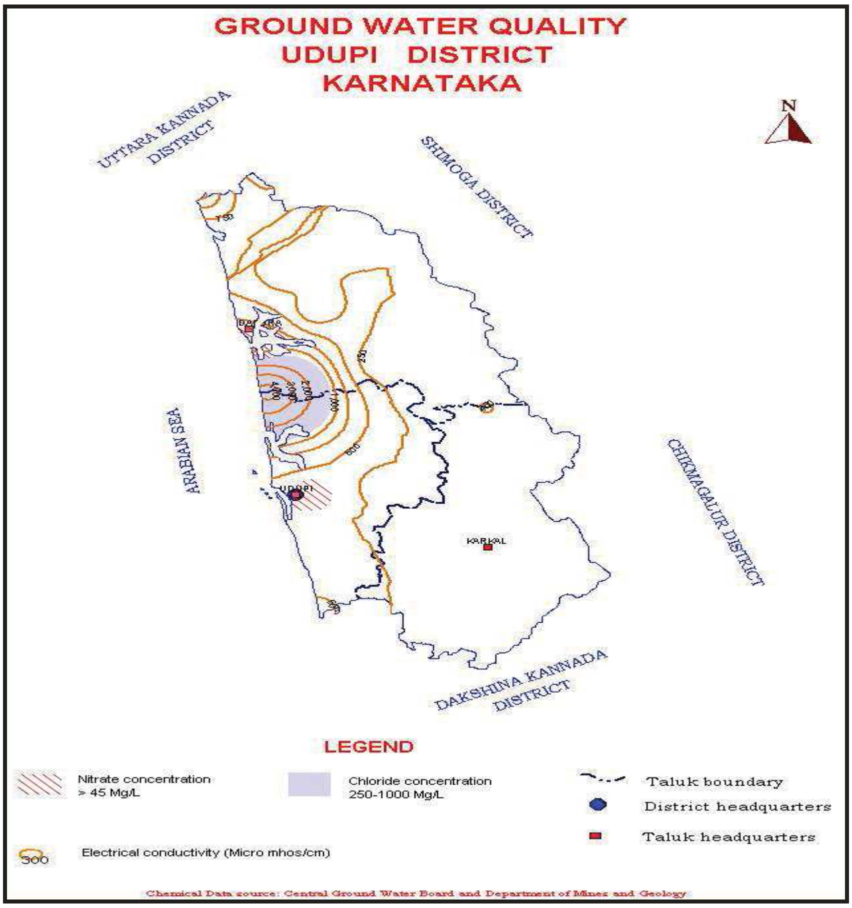



***Figure 10:*** *Ground Water Quality Map of Udupi District (Source: CGWB, Bangalore)*

Ground water development is low to moderate in Udupi district as indicated by the latest ground water resource assessment. As per the latest ground water based on GEC 96 methodology, the entire district falls in safe category from ground water utilisation point of view. The Geographic Information System (GIS) and Ground Water for Window (GWW) has helped in creating interactive ground water information system (Fig. 11, 12 & 13). The scattered non-standard data on different parameters available with different user's agencies have been well arranged in retrievable format in GWW. Now the GWIS of Udupi basin is providing well arranged and structured database. The created information system in GIS and GWW may be used to the standard ground water modeling package. However due to lack of interface between GIS package and GWW, the data related to other natural resources can not be actively linked together. There is further scope for development of interface between GIS software. At present there is no common platform for creation of GWIS in the country. The approach adopted in the creation of GWIS for Udupi river Basin of Karnataka state may be used in the other parts of Country. GWIS of these areas has provided opportunity to understand the different themes of ground water in integrated manner. Information on topography, villages, communication network, drainage, surface water, geomorphology, aquifer geometry, aquifer hydro geophysical properties, and groundwater development feasibility, geohydrology, and land use, demographic themes have been created, analyzed and prepared in SuperWeb GIS environment. Besides this the available database contains information about water table data of more than 200 sites, vertical electrical sounding response of 200 sites, 10 years meteorological data, data of hydrographs stations mentioned by Central Ground Water Board and State Ground Water Board. A location detail of these data has been incorporated in the thematic maps. But the huge data on single theme "groundwater" was not integrated. The groundwater data collected and generated has been rearranged in the GWW format. The data import to GWW is simple and it imports data in ASCII format. In the study area authentic bore litholog data is not available where as interactive display of well log, cross-section and fence diagram is one of important facilities available in GWW. The Geographic Information System (GIS) and Ground Water for Window (GWW) has helped in creating interactive ground water information system. The scattered non-standard data on different parameters available with different user's agencies have been well arranged in retrievable format in GWW. The GWIS of Udupi basin is providing well arranged and structured database. The created information system in GIS and GWW may be used to the standard ground water modeling package. However due to lack of interface between GIS package and GWW, the data related to other natural resources can not be actively linked together. There is further scope for development of interface between GIS software. At present there is no common platform for creation of GWIS in the country. The approach adopted in the Udupi, Karnataka of GWIS for river Basins of Karnataka state may be used in the other parts of Country. GWIS of these areas has provided opportunity to understand the different themes of ground water in integrated manner.

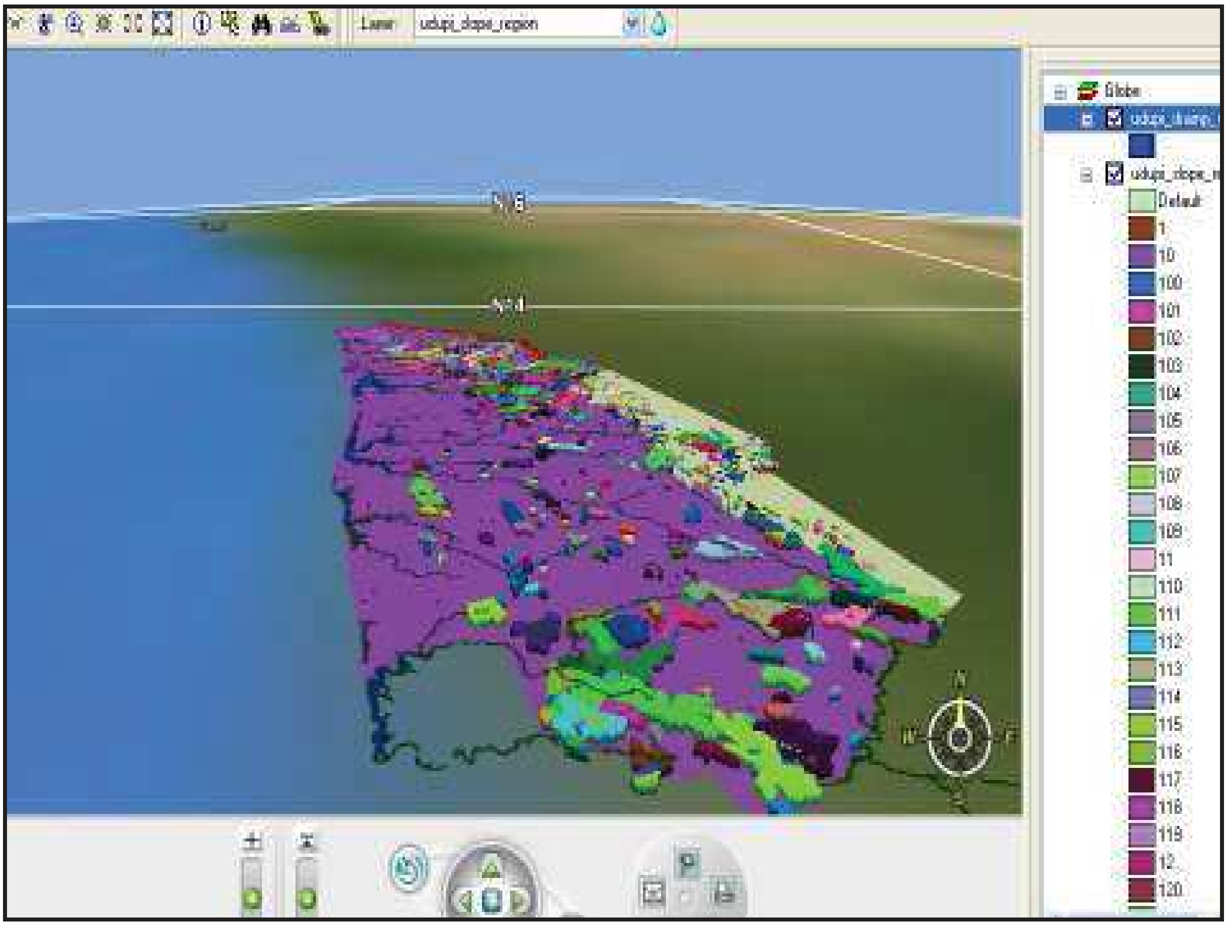



***Figure 11:*** *Overlaid Image of Drainage with Slope of Udupi District*

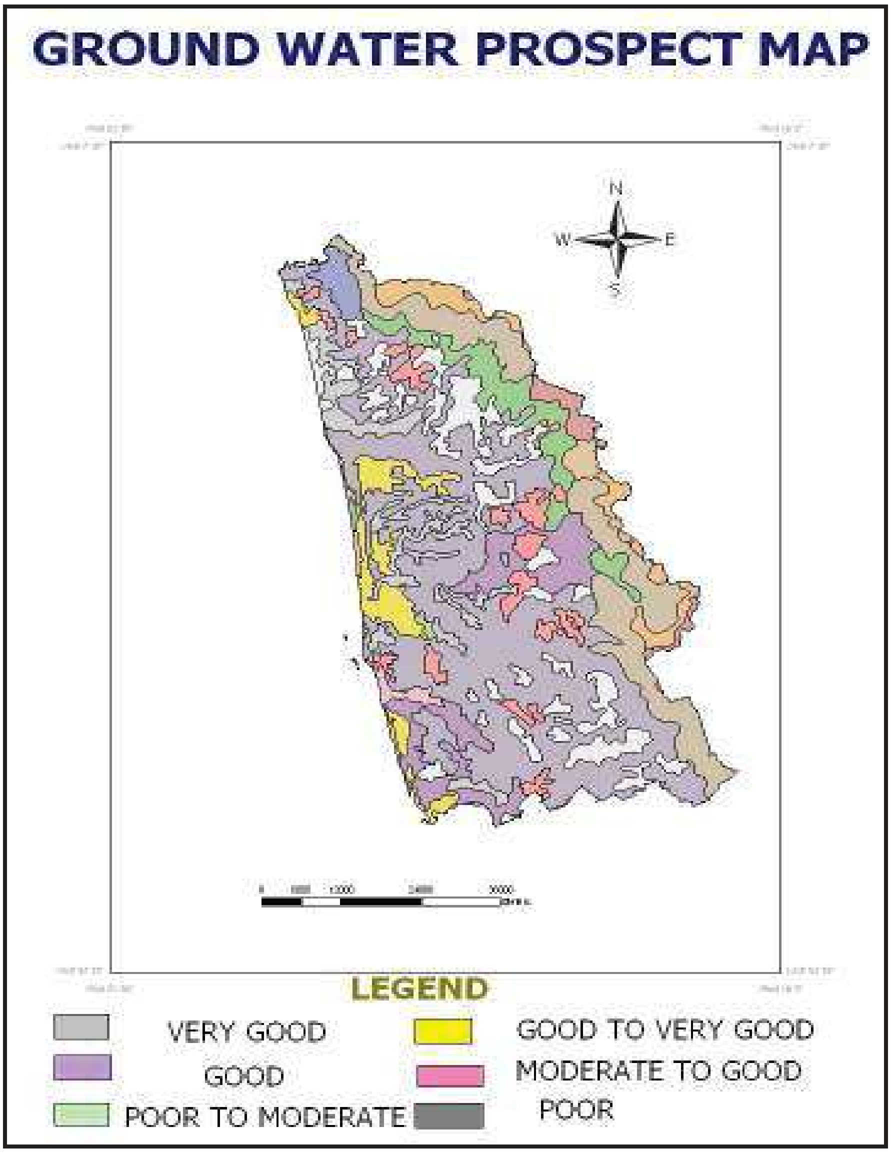



***Figure 12:*** *Ground Water Prospect Map of Udupi District*

***Table 3:*** *Ground Water Prospect and Soil Distribution Area Wise*

| Soil Order Type | Area in Sq.Km | GW Prospect | Area in Sq.Km |
|---|---|---|---|
| Ultisols | 1182.5 | VERY GOOD | 512.1 |
| Alfisols | 1624.9 | GOOD | 1654.3 |
| Entisols | 719.4 | GOOD TO MODERATE | 452.7 |
| Inceptisol | 42.8 | POOR TO MODERATE | 537.7 |
| Rocky land | 5.2 | POOR | 418 |
| Total | 3574.8 | Total | 3574.8 |

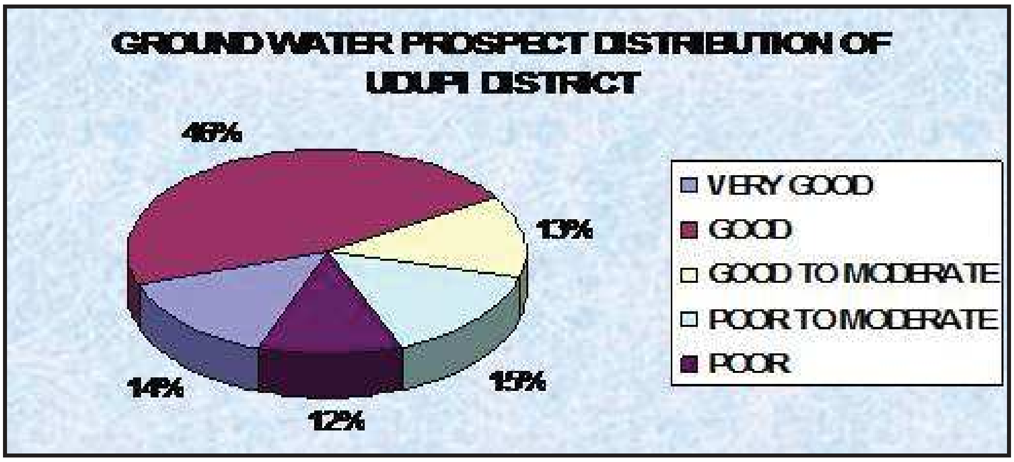



***Figure 13:*** *Ground Water Prospect Distribution Chart of Udupi District*

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