Groundwater Quality Scenario in Karnataka State

- An Overview

1. Introduction

Water, the most abundant material on the earth, is vital for life. While all the water available on the earth is not suitable for consumption, its quality takes the first attribute for making it consumable. Water being a chemical substance has its own characteristics that define its quality. The term "quality" when applied to water generally encompasses physical, chemical and biological characters attributed in the combined form. Generally, water seldom occurs in its purest form. The rainwater, which is supposed to be pure, normally gets admixed with oxygen, carbon-di-oxide, dust and suspended materials from the atmosphere and becomes impure. Rainwater, while percolating through soils and rocks, dissolves some more constituents (mineral and salts) and forms groundwater. Groundwater also keeps moving in the subsurface either through fractures or pores in the rocks and during its travel modifies its composition. Groundwater in general is better for consumption compared to the surface water, as it is free from bacteria. However, human activities on the surface such as unhygienic sanitation, improper disposal of wastes (both solid and liquid) leads to bacterial contamination of the groundwater. It is a common experience that quality of water varies from one well to the other owing to the continuous movement of groundwater. Information on the quality of groundwater in terms of the extent of the chemical constituents and its biological purity at any place and the variation of the same across the region provides better insight not only in to the problems with regard to drinking water but also about its suitability for agriculture. Information on the status of water quality and its variation in Karnataka is provided in this report along with few related data.

Water quality monitoring has become an integral part of the water supply system since the launch of National Drinking Water Mission and provision of safe drinking water to communities has been one of the action agenda of the Government of Karnataka. Water quality analysis is the prerequisite for identification of problematic sources that provides insight to not only for selection of locations but also for proper development of safe source of water supply. The Rural Development and Engineering Department (RDED) has been analyzing the quality of any newly developed groundwater / surface water source in the state. If the quality parameters are within the prescribed permissible limits, the source is used for the supply of drinking water and if the quality parameters do not conform to the standards, the source is abandoned. In areas where there are no sources of good quality water, people are allowed to use the developed source only with a caution to adopt methods of treatment. During the year 2000-01, a programme of testing water quality for organised water supply scheme analysing 14 parameters has been carried out.

For this purpose, Karnataka Rural Water Supply & Sanitation Agency (KRWSSA) - the agency set up by Government of Karnataka, has embarked upon ***Jal-Nirmal Yojana,*** a project aimed at supply of safe drinking water to the rural communities. Under this programme, a comprehensive study of the quality of groundwater being supplied in rural areas has been taken up and water quality mapping, building of GIS database and taluk and district profiles have been generated.

2. Demography

As per the 1991 census, Karnataka State had a population of 449,77,200. Of this, rural population was 310,69,412 and the urban population was 139,07,788. The total number of villages / habitations in Karnataka State are 56,682 (Table: 1). Karnataka State has 27 Districts, namely, Bagalkot, Bangalore (Rural), Bangalore (Urban), Belgaum, Bellary, Bidar, Bijapur, Chamarajanagara, Chikmagalur, Chitradurga, Dakshina Kannada, Davanagere, Dharwad, Gadag, Gulbarga, Hassan, Haveri, Kodagu, Kolar, Koppal, Mandya, Mysore, Raichur, Shimoga, Tumkur, Udupi and Uttara Kannada.

3. Physical profile of Karnataka

Karnataka State is located in the southwestern part of India (Fig.1) covering an area of 1,91,789 sq. km. It is bounded by Andhra Pradesh State on the northeastern and eastern portions, Tamil Nadu State on the southeastern portion, Kerala State on the southwestern portion, Maharashtra and Goa States on the northwestern portion and western portion of the State is bounded by Arabian Sea. The State lies between 11° 35' - 18° 29' N Latitude and 74° 05' - 78° 34' E Longitude.

3.1 Physiography

The physiographically Karnataka State can be divided into two major classes, namely, coastal region, which is sub-divided into the Coastal Plains and the Western Ghats, and the Karnataka Plateau, which is sub-divided into Malnad and Maidan. The Maidan is further sub-divided into Northern and Southern Maidan, the latter being at much higher general elevation than the former. Besides a narrow belt between the Maidan and the Malnad is often referred to as Semi-Malnad.

Coastal Region

The coastal line has a length of about 400 km. and there is a gradual transition between the Konkan coast in the north and the Kerala coast in the south. The coastal region is further divided into two parts, the plains and the Western Ghats, the former being a narrow stretch rarely exceeding 30 km. in width and at places, the crests of the adjoining Western Ghats reaching the sea as close as 13 km. The differential erosion, river piracy and faulting on a variety of lithological formations combine to dissect the plains to a large extent.

Table 1: Demographic details of Karnataka (as per 1991 census)

Sl. No.	District	Geographical Area (sq.kms)	Number of Villages	Number of Hamlets	Total Number of Habitations	Rural Population	Urban Population	Total Population
1	**Bagalkot**	6,592	608	26	634	1,005,229	389,313	1,394,542
2	**Bangalore Rural**	5,815	1,713	1,681	3,394	1,369,908	303,286	1,673,194
3	**Bangalore Urban**	2,190	681	604	1,285	669,909	4,169,253	4,839,162
4	**Belgaum**	13,415	1,138	368	1,506	2,741,820	841,786	3,583,606
5	**Bellary**	8,419	517	651	1,168	1,125,746	530,254	1,656,000
6	**Bidar**	5,448	587	225	812	1,010,095	245,703	1,255,798
7	**Bijapur**	10,475	639	289	928	1,234,015	299,433	1,533,448
8	**Chamarajanagar**	5,685	446	384	830	759,690	123,675	883,365
9	**Chikkamagalur**	7,201	1,021	2,345	3,366	845,422	171,861	1,017,283
10	**Chitradurga**	8,388	932	437	1,369	1,095,247	217,470	1,312,717
11	**Dakshina Kannada**	4,843	371	2,766	3,137	1,115,818	517,574	1,633,392
12	**Davanagere**	6,018	786	298	1,084	1,118,714	440,508	1,559,222
13	**Dharwad**	4,230	455	39	494	652,726	722,169	1,374,895
14	**Gadag**	4,657	307	43	350	561,085	297,957	859,042
15	**Gulbarga**	16,224	1,295	1,001	2,296	1,972,366	609,803	2,582,169
16	**Hassan**	6,814	2,369	1,531	3,900	1,296,962	272,722	1,569,684
17	**Haveri**	4,851	582	48	630	1,065,448	203,765	1,269,213
18	**Kodagu**	4,102	291	282	573	410,514	77,941	488,455
19	**Kolar**	8,223	2,889	853	3,742	1,699,906	516,983	2,216,889
20	**Koppal**	8,458	588	121	709	810,007	148,071	958,078
21	**Mandya**	4,961	1,365	508	1,873	1,377,570	266,804	1,644,374
22	**Mysore**	6,269	1,203	731	1,934	1,465,034	816,619	2,281,653
23	**Raichur**	5,559	808	411	1,219	1,019,758	332,051	1,351,809
24	**Shimoga**	8,465	1,440	2,984	4,424	981,171	471,088	1,452,259
25	**Tumkur**	10,598	2,537	2,947	5,484	1,923,656	382,163	2,305,819
26	**Udupi**	3,598	244	3,657	3,901	815,852	245,020	1,060,872
27	**Uttara Kannada**	10,291	1,264	4,376	5,640	925,744	294,516	1,220,260
	Total	**191,789**	**27,076**	**29,606**	**56,682**	**31,069,412**	**13,907,788**	**44,977,200**

Coastal Plains: The plains are partly formed by marine denudation, but the level character of the land is severely restricted directly by the Western Ghats and transverse intrusion. Estuarine plains of the Kali, the Tadri, the Gangavali and the Sharavati rivers, separated by two east-west Sahyadri offshoots, border the coastline. Since the valley flanks are faulted, the coastal low lands find an extension along the major river valleys.

Western Ghats: To the east of the coastal plains, the general elevation is higher and increase in height occurs abruptly resulting in Western Ghats sections. The Western Ghats rise in a series of terraces, but the general elevation is lower as compared to the stretch in the north (Maharashtra) or in the south (Kerala). The Western Ghats run NNW to SSE for about 320 km. The eastern slope is comparatively gentler. From this main range are the offshoots that run both eastward into the Malnad and westward into the coastal plains.

Karnataka Plateau

The Karnataka Plateau has two natural sub-divisions, the Malnad and the Maidan, which include the Northern upland or the Deccan trap and the Southern upland. In a variety of attributes of physical as well as cultural landscapes, the distinction between the Malnad and Maidan is sharp.

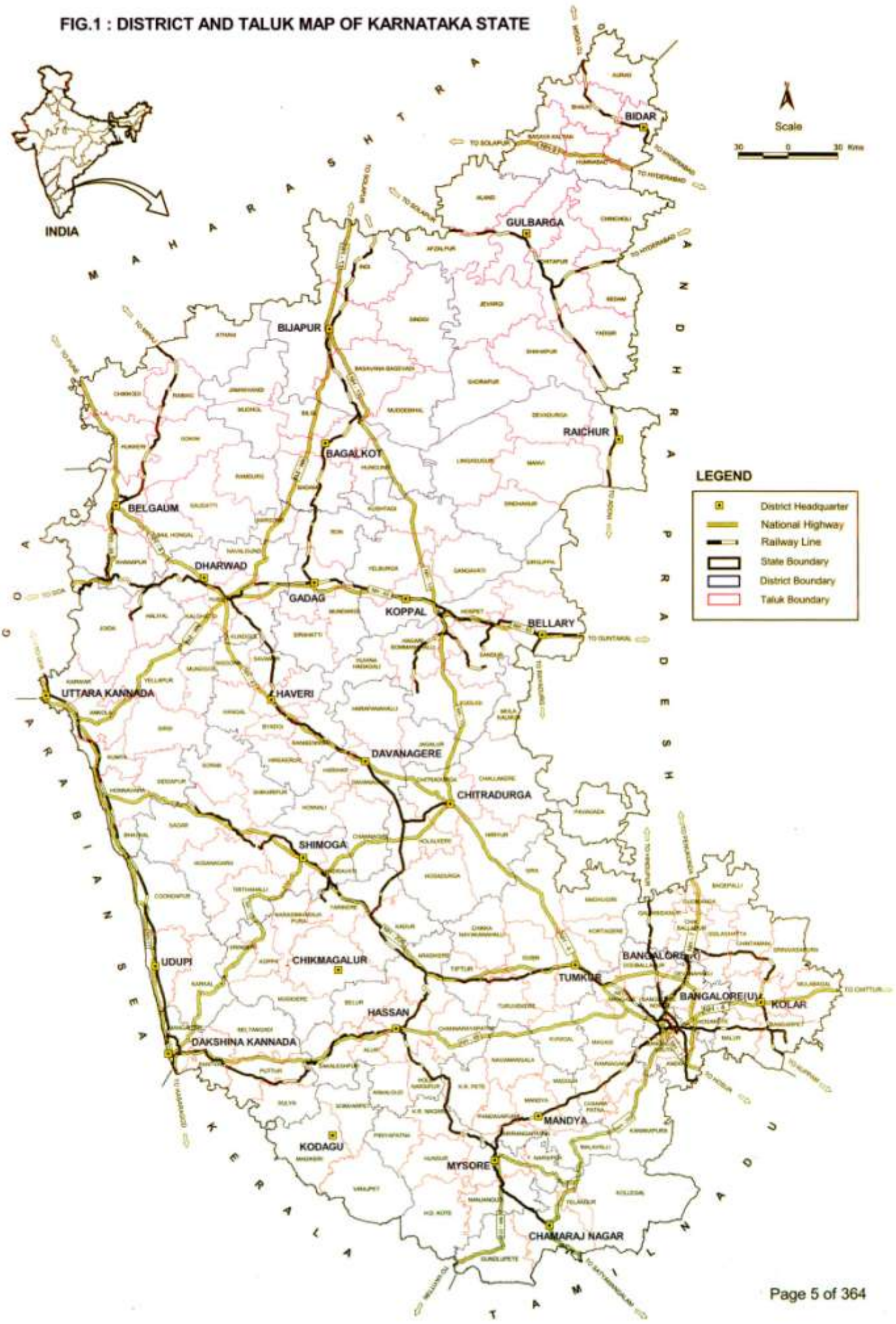
The Malnad: The general elevation of the Malnad is slightly greater than that of plateau, but the country is rugged with a number of hills that receive larger amount of rainfall and are forested and support one of the largest plantation economies in the country. The valleys in this tract are often 30 to 40 km. wide. The deeply dissected ghat edges with deep gorges, waterfalls, river captures and the watersheds interlacing with denser Evergreen and Semi-Evergreen forests constitute the core of the Malnad.

The Maidan: The region is characterised by undulating landscape with rather broad-based valleys. The Maidan is relatively flat surface, a plateau rising between 450 to 700 m in the northern part of the State and between 900 to 1200 m in the south.

Southern Maidan: The Southern Maidan is bounded by 650 m contour and is characterised by a higher degree of slope. The southern upland consists of a series of rolling granitic hills between Tumkur and Kolar districts.

Northern Maidan: The Northern Maidan provides a mountainous treeless expansive plateau landscape. The river plains of the Krishna, the Bhima and the Tungabhadra with the intervening watersheds, the step like landscapes, laterite escarpments, hills and ridges break the monotony of the Northern Maidan.

FIG.1 : DISTRICT AND TALUK MAP OF KARNATAKA STATE



3.2 Drainage

There are seven river basins, which drain the State (Fig.2 ; Table 1.2).

Table 1.2 River basins of Karnataka

Sl. No.	Name of the basin	Catchment area (sq.kms)	% of total area of the State
1	Krishna basin	1,13,271	59.10
2	Godavari basin	4,405	2.30
3	Cauvery basin	34,273	17.80
4	West flowing rivers	26,214	13.70
5	North Pennar	13,610	7.10
6	South Pennar		
7	Palar		

Krishna Basin: The Krishna basin extending over 2,59,000 sq.kms. is spread over three States, viz., Maharashtra, Karnataka and Andhra Pradesh States covering 27%, 44% and 29% respectively of the total area. The Krishna rises in the Western Ghats just north of Mahabaleshwar in Maharashtra State. The river Krishna's course for 483 kms. lies in the Karnataka State. Its major tributaries in Karnataka State are - Bhima, Dudhganga, Tungabhadra, Hiranyakeshi, Ghataprabha and Malaprabha. Nearly 60% of the State's area lies in the Krishna basin and covers 13 districts, five of which lie wholly in the basin (Bellary, Bijapur, Chitradurga, Gulbarga and Raichur districts) and eight partially (Belgaum, Dharwad, Chikmagalur, Shimoga, Tumkur, Hassan, Bidar and Uttara Kannada). Considering the utilisability of water resources both for consumptive (chiefly irrigation) and non-consumptive (chiefly hydro-power generation) the river flows that can be put to use on a dependable basis in this basin is estimated to be 26,800 MCM.

Cauvery Basin: The Cauvery Basin, extending over 81,155 sq.kms. is spread over three States viz., Karnataka, Kerala and Tamil Nadu. A basin area of 42% lies in Karnataka, 4% in Kerala and 54% in the Tamil Nadu States. River Cauvery has its origin in the Western Ghats in Kodagu district and first 320 km of its course lies in Karnataka State. The Cauvery basin covers 18% of the State area comprising of seven districts, viz., Mysore and Mandya districts (wholly) and Kodagu, Chikmagalur, Hassan, Tumkur and Bangalore districts (partially). Its major tributaries in Karnataka are Hemavathi, Kabini, Arkavathi and Shimsha.

Godavari Basin: The catchment area of the Godavari basin in Karnataka State is 4405 sq.kms. A small part of the Godavari basin lies in Bidar district of Karnataka and Manjra and Karanja Rivers are its major tributaries. Considering the utilisability of water resources both for consumptive (chiefly irrigation) and non-consumptive (chiefly hydro-power development) the river flows that can be put to use on a dependable basis in this basin is estimated to 560 MCM.

FIG.2 : DRAINAGE MAP OF KARNATAKA STATE

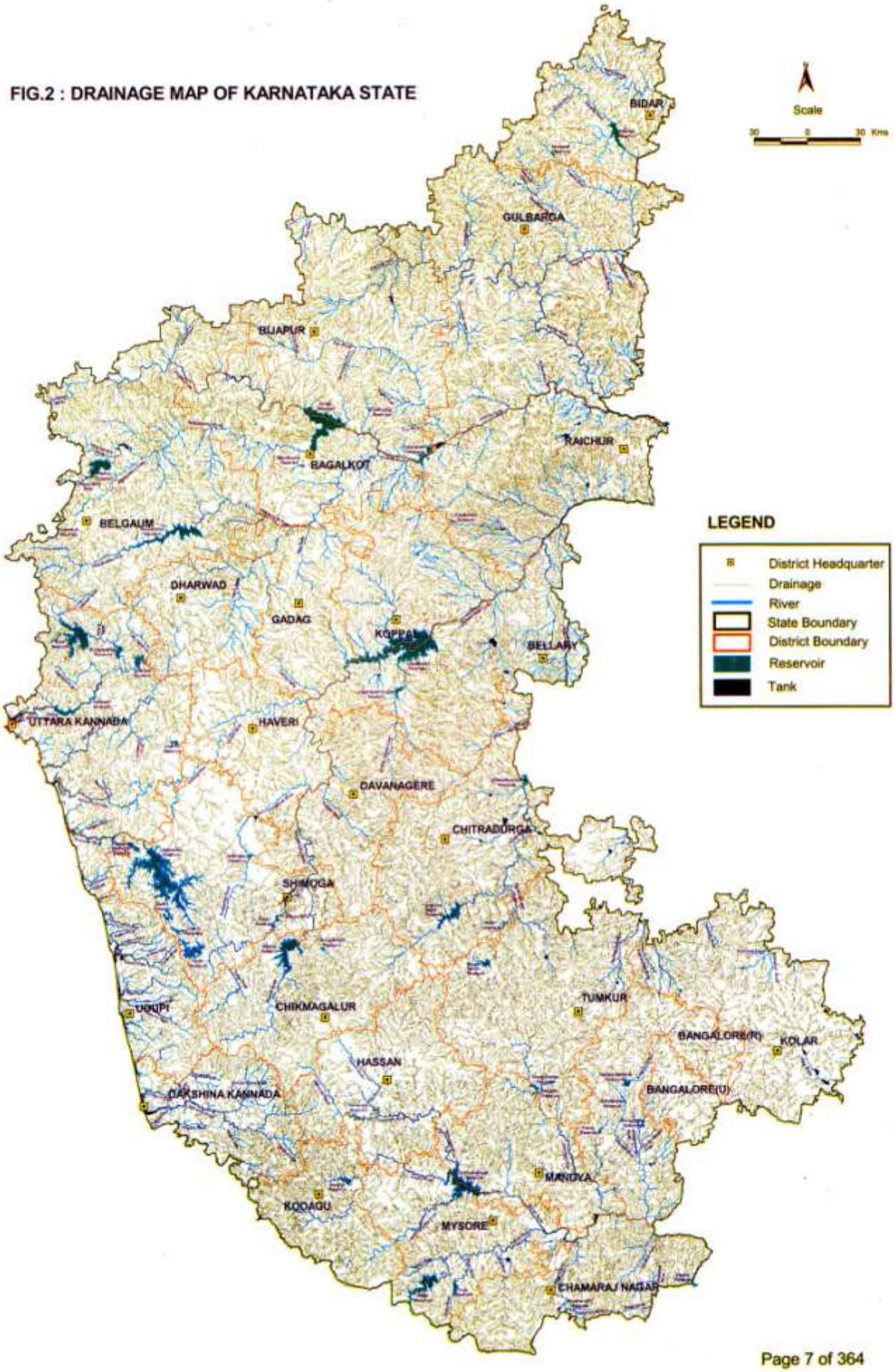
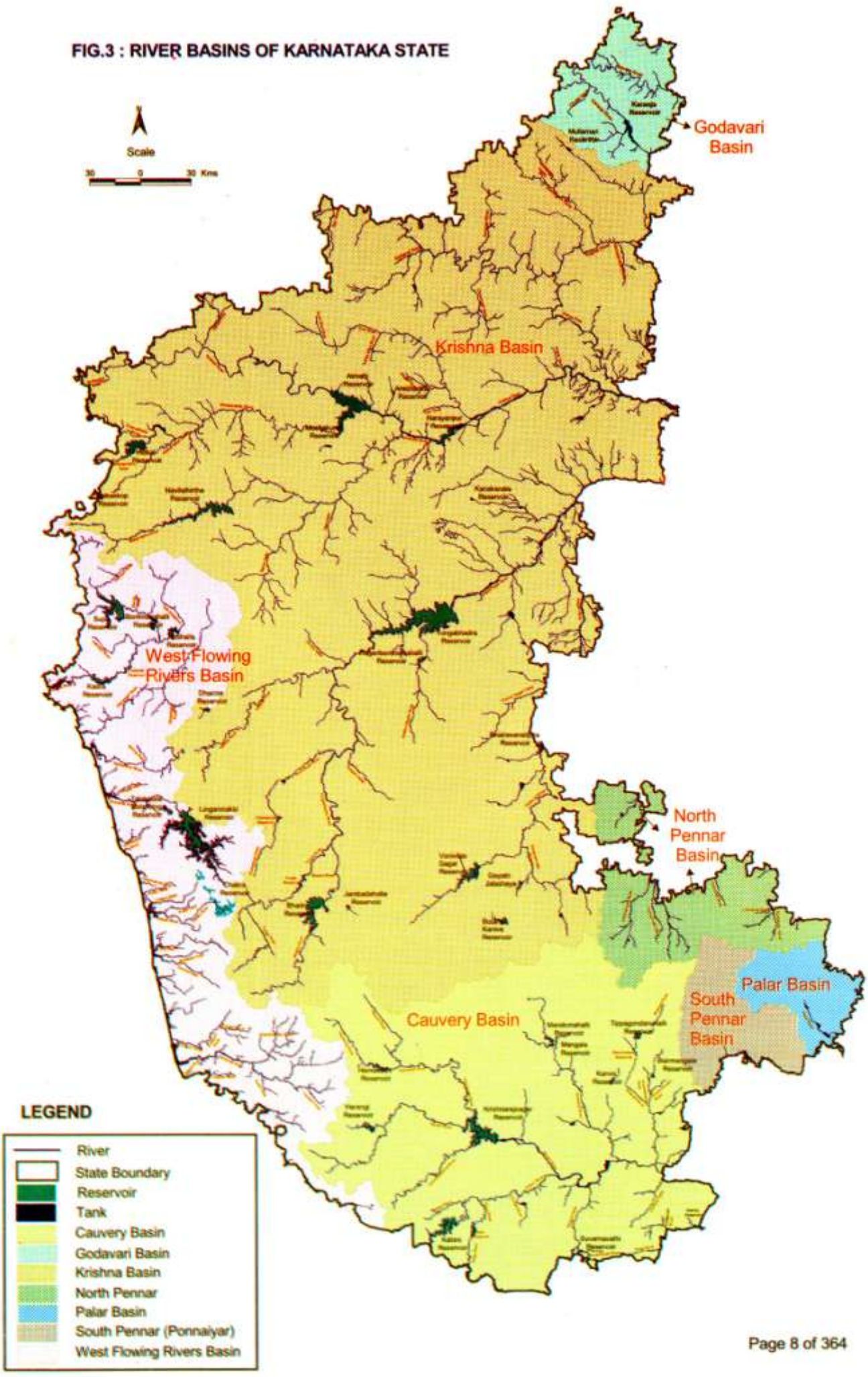


FIG.3 : RIVER BASINS OF KARNATAKA STATE



Pennar and Palar Basin: The North Pennar, the South Pennar and the Palar rivers drain about one fifth of Tumkur district, one third of Bangalore district and the whole of Kolar district. The aggregate basin area of all these rivers in the state is 13,160 sq.kms. The Uttara Pinakini (Pennar), the Dakshina Pinakini and the Palar rivers are the three major rivers draining in this catchment. Considering the utilisability of water resources both for consumptive (chiefly irrigation) and non-consumptive (chiefly hydro-power development) the river flows that can be put to use on a dependable basis in this basin is estimated to 990 MCM.

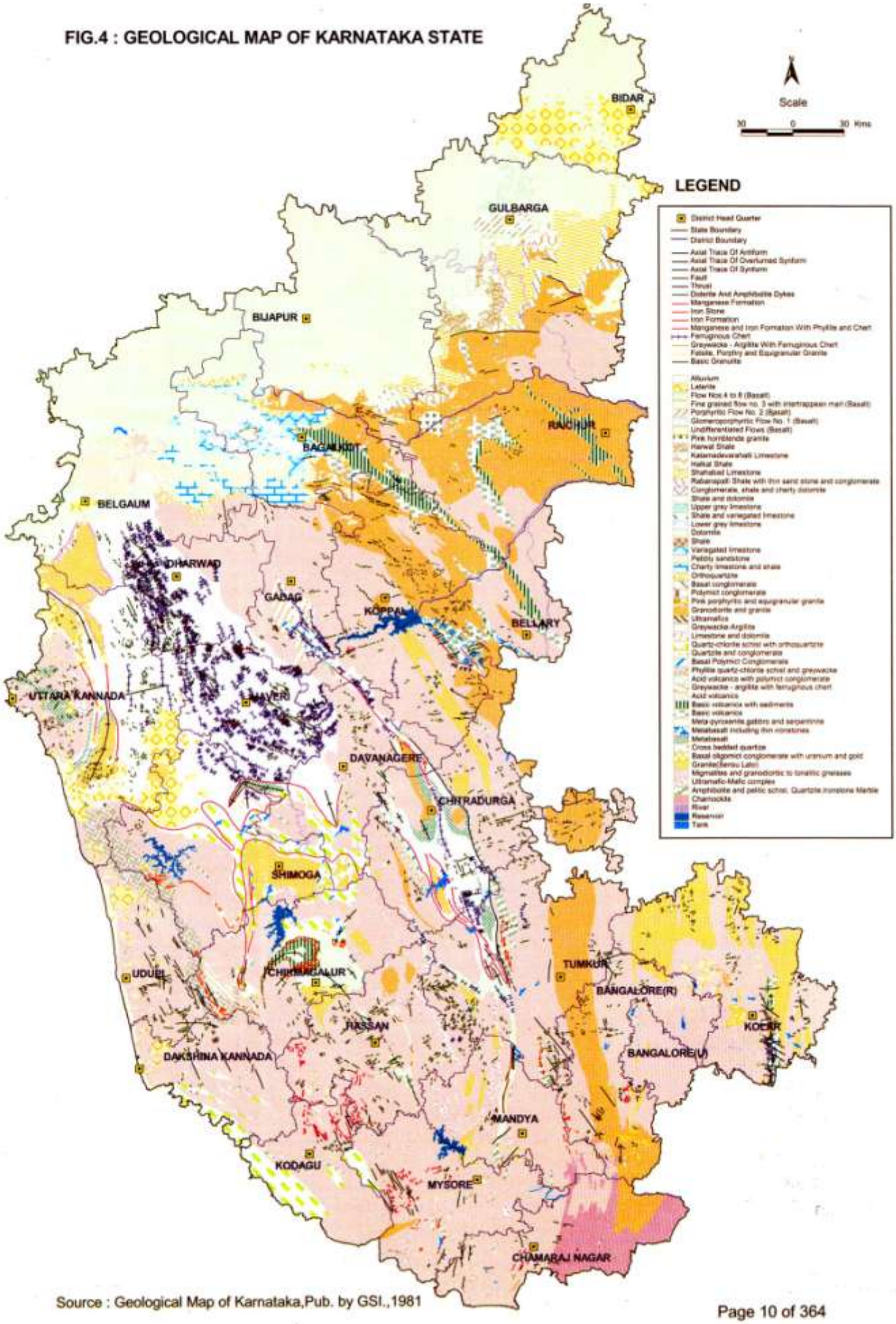
West flowing rivers: The total catchment area of all west flowing rivers is 26,214 sq.kms. comprising of major rivers like Sharavathi, Netravathi, the Kali, the Gangavali (Bedti) and Aghanashini which rise on the western side of the ghats and drain into the Arabian Sea through the districts of Uttara Kannada and Dakshina Kannada. A small part of the catchment area of these rivers however lies in the Dharwad, Shimoga, Chikmagalur, Hassan, Belgaum and Kodagu districts. Mahadayi, Varahi, Barapole and Chakra are the other small rivers, which are west flowing. Considering the utilisability of water resources both for consumptive (chiefly irrigation) and non-consumptive (chiefly hydro-power development) purposes, the river flows that can be put to use on a dependable basis in this basin is estimated to 22,000 MCM (Fig. 3)

4. Geology

Karnataka forms one of the oldest terrains in the world comprising of oldest rocks. From the geological point of view, these rocks have been classified as hard/crystalline rocks i.e., the rocks that are hard and lack primary porosity. As majority of these rocks lack primary porosity, the depth of weathering and the fractures resulted due later geological phenomena facilitate accumulation of groundwater and the host of minerals in these rocks along with the influence of the climate control the quality of the groundwater. The crystalline terrain of Karnataka consists of rocks that range in age from Archaean to Proterozoic sedimentary rocks, followed by basaltic flows of Upper Creataceous forming plateau, the laterites of tertiary capping the older rocks and the recent beach sediments.

The oldest rocks belonging to the Archaean age called the Sargurs are exposed in Kolar, Bangalore (Rural), Mysore and Chamarajanagar districts in the southern part of the State. The gray gneisses called the "Peninsular Gneisses cover major part of the state excepting the northwestern region. Overlying the gneisses are the various schist belts consisting of a variety of meta-sediments and volcanic rocks. These rocks, generally trending in NNW-SSE direction are exposed in the central part of the State covering Hassan, Tumkur, Chitradurga, Shimoga, Haveri, Dharwad and Gadag districts and are commonly called as "green stone belts". The pink to gray coloured coarse grained rocks called 'Closepet Granite' occur almost parallel to the schistose rocks and in the northern part of the State spread over vast areas and also occur as isolated patches. These granites extend from south of Kabbal to north of Bellary and are predominantly exposed in Bangalore (Rural), Tumkur, Chitradurga, Koppal, Bellary and Raichur districts. The Proterozoic sedimentary rocks called "Kaladgi and Bhima" groups covering the northern districts

FIG.4 : GEOLOGICAL MAP OF KARNATAKA STATE



Source : Geological Map of Karnataka,Pub. by GSI.,1981

of Belgaum, Bijapur, Dharwad and Gulbarga succeed the Closepet granite. The horizontal flows of basalts forming the tabletop landscape cover major part of northern Karnataka. The laterites of Tertiary age are seen forming a thick crust in the costal part of Karnataka and part of Bidar and Belgaum districts. The coastline deposits seen all along the west coast of Karnataka essentially consisting of beach sands represent the Tertiary to Recent deposits in the State. The Geological map of Karnataka (Fig.4) shows the disposition of various rock types.

5. Climate

The entire coastal belt of the Karnataka State is covered by Tropical monsoon climate, the southern half experiences the seasonally dry tropical savanna climate and the northern half experiences the hot, semi-arid, tropical steppe type of climate. The climate of the State varies with the season. The winter season from January to February is followed by the summer season from March to May. The period from June to September constitutes the southwest monsoon season and the period from October to December forms the post monsoon season. The period from October to March covering the post-monsoon and winter seasons is generally pleasant over the entire State except during a few spells of rain associated with northeast monsoon which affect the southeastern parts of the State during the October to December. The months of April and May are hot, very dry and generally uncomfortable. Weather tends to be oppressive during June due to high humidity and temperature. In comparison, the next three months (July, August and September) are somewhat comfortable due to reduced day temperature although the humidity continues to be very high.

Both the day and night temperature is more or less uniform over the State, except at the coastal region and high elevated plateau. The temperature generally, decreases towards southwestwards over the State due to higher elevation and attains lower values at high-level stations. The April and May are the hottest months throughout the State. In May, the mean maximum temperature shoots up to 40°C over the northeastern corner of the State, decreasing southwestwards towards the Western Ghats region and the coastal belt. Over the coastal region the temperature is of the order of 32°C. Over Madikeri, a hill station, the mean maximum temperature varies from 26°C to 29°C in the summer months (March & May). The highest temperature recorded at an individual station is 45.6°C. The December and January are the coldest months when the minimum temperature for the State as a whole is 17.5°C, varying from 21°C in the coastal region to 16°C in the interior. The lowest temperature recorded at an individual station is 2.8°C. Both the maximum and the minimum temperature rise rapidly from January onwards till May. The increase in maximum temperature in the period of January to May ranges from 5°C to 10°C in the interior Karnataka to the north and south, whereas, over the coastal area the increase is even less than 1°C. From June onwards both the maximum and minimum temperature start falling, the former very rapidly while the latter very slowly. From the beginning of June to end of July the maximum temperature falls by about 5°C to 10°C in the interior Karnataka while the fall is about 4°C over the coastal area. The fall in the minimum temperature during the

period June to September is 1°C to 2°C over the state except over the coastal area where it is less than 1°C. From August onwards the maximum temperature starts rising and a secondary maximum is reached during October in interior Karnataka. The night temperature starts falling rapidly after November while the day temperature follows this trend after October and both attain the lowest values by December/January.

The relative humidity is generally high during the period May to October. During May, the relative humidity over north interior Karnataka is 50%, increasing to above 60% in south interior Karnataka and to 75% over coastal Karnataka. The humidity increases as the southwest monsoon advances into the State and reaches the highest value during July. During this month the humidity is around 75% in interior Karnataka and 90% and over in coastal Karnataka.

6. Agro-climatic Zones

Based on the climate, rainfall, topography, soil, availability of water, cropping pattern and other agro-meteorological characteristics the country has been divided in to 15 agro-climatic zones and Karnataka State comes under the zones IX, X and XII, i.e., the Western Plateau & Hill Region (IX), the Southern Plateau & Hill Region (IX) and the West Coast Plain & Ghat Region.

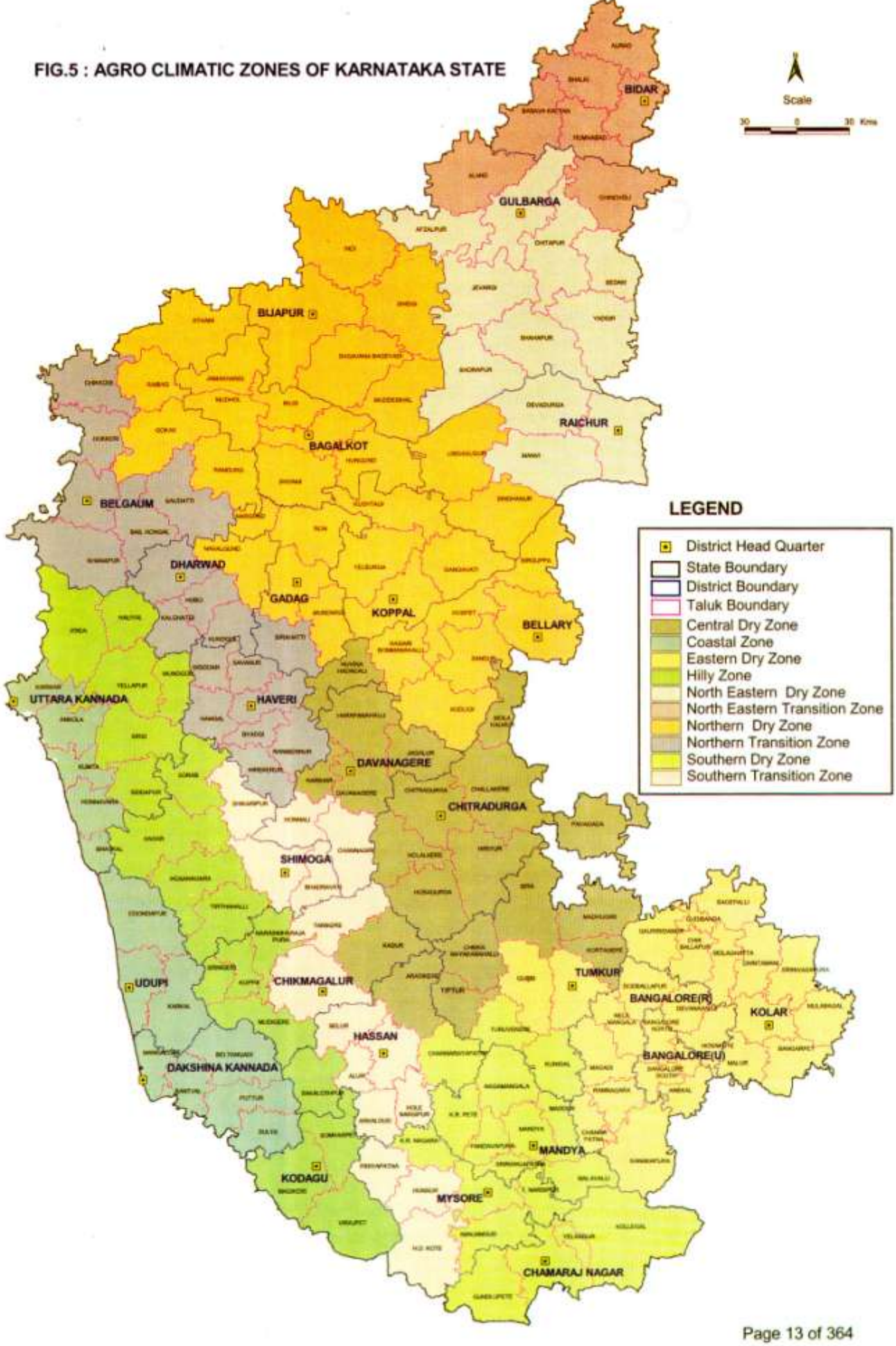
The Karnataka State has further been divided into ten different Agro-climatic zones based on the climate. They are, (i) Northeastern Transition zone, (ii) Northeastern Dry zone, (iii) Northern Transition zone, (iv) Central Dry zone, (v) Eastern Dry zone, (vi) Southern Dry zone, (vii) Southern Transition zone, (viii) Northern Transition zone, (ix) Hilly zone and (x) Coastal zone (Fig.5).

Northeastern Transition zone: This zone covers the Bidar district, Aland and Chincholi taluks of Gulbarga district. In the zone average annual rainfall varies from 850 to 950 mm and the annual average minimum and maximum temperatures range from 20 - 22°C and 31 - 32°C respectively. The minimum and maximum Potential Evapo-Transpiration (PET) for this zone are 109 mm and 217 mm.

Northeastern Dry zone: This zone covers the Gulbarga, Afzalpur, Chitapur, Sedam, Jevargi, Shahpur, Shorapur and Yadgir taluks of Gulbarga district and Raichur, Manvi and Deodurg taluks of Raichur district. This zone receives average annual precipitation of the range of 600 to 700 mm with average annual minimum and maximum temperatures of 21 - 23°C and 32 – 34°C respectively. The minimum and maximum Potential Evapo-Transpiration (PET) for this zone are 117 mm and 235 mm.

Northern Dry zone: This zone consists of Indi, Sindagi, Bijapur, Basavana Bagewadi, Muddebihal taluks of Bijapur district; Jamkhandi, Mudhol, Bilgi, Bagalkot, Badami, Hungund taluks of Bagalkot district; Lingsugur and Sindhanur taluks of Raichur district; Bellary, Sirguppa, Hospet, Sandur, Hagari Bommanahalli taluks of

FIG.5 : AGRO CLIMATIC ZONES OF KARNATAKA STATE



Bellary district; Koppal, Yelburga, Kustagi, Gangavati taluks of Koppal district; Gadag, Mundargi, Ron, Naragund taluks of Gadag district; Ramdurg, Raibag, Gokak, Athani taluks of Belgaum district and Navalgund taluk of Dharwad district. This zone experiences an annual average rainfall of 800 to 1000 mm and annual average minimum and maximum temperatures of 18 - 20°C and 31 - 33°C. The minimum and maximum Potential Evapo-Transpiration (PET) for this zone are 104 mm and 224 mm.

Central Dry zone: The Central Dry zone comprises of Kudligi, Huvinahadagali taluks of Bellary district, Davanagere, Harihara, Jagalur, Harapanahalli taluks of Davanagere district, Challekere, Chitradurga, Molkalmur, Holalkere, Hosadurga, Hiriyur taluks of Chitradurga district, Sira, Chikkanayakanahalli, Pavagada, Madhugiri, Tiptur, Koratagere taluks of Tumkur district, Arasikere taluk of Hassan district and Kadur taluk of Chikmagalur district. This zone receives an average annual rainfall in the range of 600 to 800 mm and the minimum and maximum average annual temperatures are of the range 18 - 20°C and 29 - 31°C respectively. The minimum and maximum Potential Evapo-Transpiration (PET) for this zone are 104 mm and 195 mm.

Eastern Dry zone: This zone covers the Gauribidnur, Gudibanda, Bagepalli, Chikballapur, Sidlaghatta, Kolar, Chintamani, Srinivaspura, Mulbagal, Malur and Bangarpet taluks of Kolar district and Bangalore North, Bangalore South & Anekal taluks of Bangalore Urban district and Gubbi & Tumkur taluks of Tumkur district and Hosakote, Devanahalli, Doddaballapur, Nelamangala, Magadi, Ramanagara, Channapatna and Kanakapura taluks of Bangalore district. In the zone average annual rainfall varies from 670 to 890 mm and the annual average minimum and maximum temperatures range from 17°C to 20°C and 32°C to 34°C respectively. The minimum and maximum Potential Evapo-Transpiration (PET) for this zone are 98 mm and 166 mm.

Southern Dry zone: This zone covers Turuvekere and Kunigal taluks of Tumkur district, Channarayapatna taluk of Hassan district, Nagamangala, Maddur, Mandya, K.R.Pet, Srirangapatna, Pandavapura, Malavalli taluks of Mandya district, Mysore, K.R.Nagar, Nanjanagud, T.Narasipura taluks of Mysore district and entire Chamarajanagar district. The Southern dry zone receives the annual average rainfall of the range of 650 to 850 mm and annual average minimum and maximum temperatures are of the range 18 - 20°C and 29 - 31°C respectively. The minimum and maximum Potential Evapo-Transpiration (PET) for this zone are 106 mm and 166 mm.

Southern Transition zone: This zone consists of H.D.Kote, Hunsur, Piriyapatna taluks of Mysore district, Belur, Alur, Hassan, Arkalgud, Holenarsipur taluks of Hassan district, Tarikere and Chikmagalur taluks of Chikmagalur district, Bhadravathi, Shimoga, Shikaripura taluks of Shimoga district, Channagiri and Honnali taluks of Davanagere district. The Southern Transition zone experiences an average annual rainfall of 800 to 1000 mm and average annual minimum and maximum temperatures of the range 18 - 19°C and 29 - 32°C respectively. The

minimum and maximum Potential Evapo-Transpiration (PET) for this zone are 95 mm and 157 mm.

Northern Transition zone: This zone covers the Shirahatti taluk of Gadag district, Savanur, Shiggaon, Hanagal, Haveri, Byadgi, Hirekerur, Ranebennur taluks of Haveri district, Hubli, Dharwad, Kundgol, Kalaghatgi taluks of Dharwad district and Bailhongal, Belgaum, Sauvadatti, Khanapur, Chikkodi, Hukkeri taluks of Belgaum district. This zone receives an annual average rainfall of 900 to 1200 mm and average annual minimum and maximum temperatures of 18 – 20°C and 30 - 32°C respectively. The minimum and maximum Potential Evapo-Transpiration (PET) for this zone are 90 mm and 165 mm.

Hilly zone: The Hilly zone comprises of Supa, Haliyal, Mundgod, Yellapur, Sirsi, Sidddapur taluks of Uttara Kannada district, Sagar, Soraba, Hosanagara, Thirthahalli taluks of Shimoga district, Koppa, Narasimharajapura, Sringeri, Mudigere taluks of Chikmagalur district, Sakaleshpur taluk of Hassan district and entire Kodagu district. This zone receives an average annual rainfall of 3000 to 3200 mm. This area experiences average annual minimum and maximum temperatures of the range 16 - 18°C and 26 - 28°C respectively. The minimum and maximum Potential Evapo-Transpiration (PET) for this zone are 80 mm and 140 mm.

Coastal zone: The Coastal zone consists of Ankola, Karwar, Kumata, Honnavar, Bhatkal taluks of Uttara Kannada district, Coondapur, Udupi, Karkala taluks of Udupi district and Mangalore, Bantwal, Belthangadi, Puttur, Sulya taluks of Dakshina Kannada district. This area receives an average rainfall of the range 3100 to 3400 mm annually and experiences average annual minimum and maximum temperatures of 22 - 24°C and 30 - 32°C respectively. The minimum and maximum Potential Evapo-Transpiration (PET) for this zone are 90 mm and 140 mm.

7. Soil

Karnataka State forms a part of Deccan Plateau. The soils are mainly derived from granites, gneisses and basalts. Besides these, some part is having lateritic and alluvial soils. The major soils found are black cotton soils, black soils, red soils, reddish brown soils, lateritic soils and coastal alluvial soils. The black cotton soils seem to be transported soils found in part of Belgaum, Dharwad, Gadag, Haveri, Bijapur, Bagalkot, Gulbarga, Bellary and Raichur districts. The black soils derived from the Deccan traps/basalts are found in parts of Belgaum, Bijapur, Gulbarga and Bidar districts. The red and reddish brown soils derived from granites and gneisses are spread over Chitradurga, Haveri, Tumkur, Shimoga, Chikmagalur, Bangalore Urban and Rural, Kolar, Mandya, Mysore, Hassan and Chamarajanagar districts. The lateritic soils are found in hilly zones and coastal zones of the Agro-climatic zones. They are also found in patches in Bidar, Bangalore and Kolar districts. The coastal alluvial soils are found in coastal belt of Uttara Kannada, Udupi and Dakshina Kannada districts.

8. Groundwater Occurrence

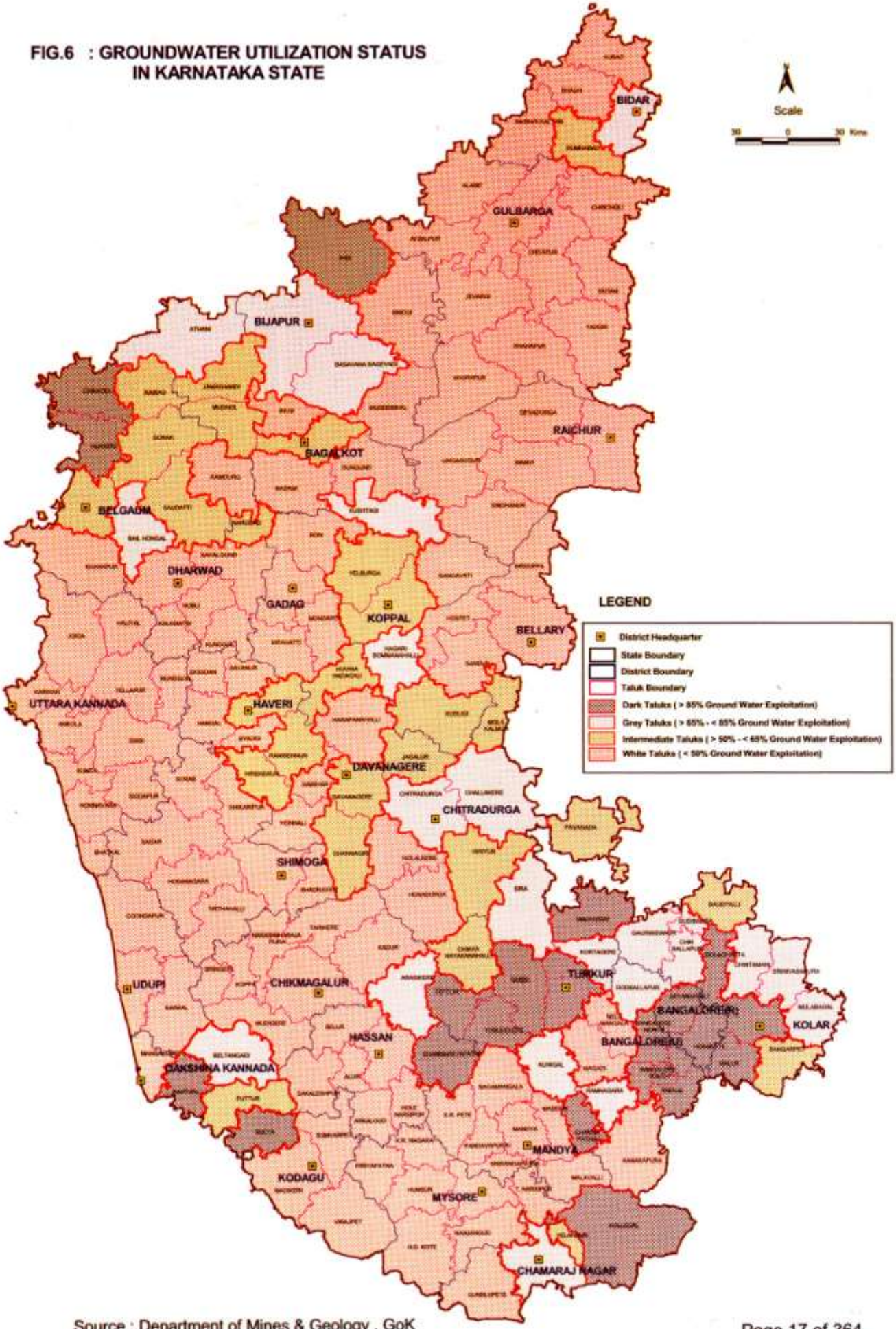
The water occurring below the saturated zone in the subsurface (beneath the ground) is generally defined as groundwater. Groundwater occurs in permeable geologic formations known as 'Aquifers', i.e., formations having open spaces either cracks, fractures or inter-granular spaces, which permit appreciable amount of water to move through them under ordinary field conditions.

The Karnataka State forms a part of the Deccan Plateau at an average elevation of 700 m above MSL and is almost wholly composed of hard, compact, crystalline rocks. The terrain conditions along with the climate which cover a greater part of the State is Semi-arid with an average rainfall of 600 mm only, sets a limit to the occurrence and circulation of groundwater. The hard rocks of Karnataka not possessing the primary porosity allow accumulation and circulation of groundwater only in the shallow weathered zones and the fractured horizons in the deeper portions. In northern district of the State covered by basalt flows, groundwater occurs in the weathered mantle and in the permeable zones occurring in-between flows. Groundwater gets annually replenished mainly as a result of infiltration of rainwater and to a little extent through seepage from streams, tanks, reservoirs and water applied for irrigation. The fluctuation in water table between dry and wet season indicates that the weathered mantle and jointed bedrock have good recharge potential. A preliminary assessment however, puts the annual recharge of groundwater at 12,000 MCM.

Groundwater development status is normally determined by the extent of Dynamic Resources. Dynamic Resource is a variable and replenishable part of groundwater resource added yearly to groundwater system, which can be obtained without disturbing the sub surface storage of groundwater. It is the upper limit of safe yield / exploitation. Groundwater exploitation in excess to dynamic resource will induce irreversible damages to groundwater system unless attempts are made to augment recharge / replenishment to compensate the excess draft. The dynamic resource is estimated taking in to consideration of – (i) Recharge through rainfall, (ii) Leakage / seepage through surface water bodies and (iii) Percolation of the irrigation water.

The Department of Mines & Geology, Government of Karnataka has classified the state into **white, intermediate, gray and dark** blocks (Fig.6) based on the groundwater resource and its status of development (normal annual recharge and the withdrawal for irrigation). Fig.6 indicates that considerable portion of the state has already crossed the safe limit of groundwater exploitation.

FIG.6 : GROUNDWATER UTILIZATION STATUS IN KARNATAKA STATE



Source : Department of Mines & Geology , GoK

9. Water Quality Standards and Significance

The quality of drinking water affects health of the consumers because not only certain diseases and toxic chemical compounds may be transmitted by water, but also the very inherent constituents of groundwater may not be suitable for consumption. Experience has shown that community health and water quality are directly related to each other and that an improvement of water quality of the drinking water supply ensures improvement in the community's health. Therefore a good water supply system is one that provides adequate water of acceptable quality. A Water Supply Engineer is expected to know the details of waterborne diseases, different chemicals, biological parameters that make the water unsuitable for consumption and also the means of these getting in to the water supply system.

9.1. Attributes of Drinking Water

Following are the attributes that make water suitable for community's consumption:

- Free from pathogens
- Colourless and clear
- Palatable, free from odours and preferably cool
- Reasonably soft (not hard)
- Neither forming scales nor corrosive
- Free from objectionable substances such as hydrogen sulfide, iron, and manganese;
- Unpolluted by substances in quantities that are toxic or have adverse physiological effects and available in adequate quantities

Standards of water quality are presented in page 19.

9.2. Environmental significance of water quality

Water that is clear and colourless gives an impression that it is safe for human consumption. This may not be always true as many of the bacteria and objectionable matter may be present in invisible form. These may be added to water either naturally or due to certain activities and therefore it is important to understand their environmental significance. Water quality attributes are classified as physical, chemical and biological nature and significance of some of the parameters are mentioned as follows:

Table: 1a Drinking water Standard Specification (IS 10,500 - 1991)
(Physical, Chemical and Bacteriological parameters)

Sl. No.	Parameter	Unit	Permitted limit	Remarks
1	Colour	Hazen Unit (HU)	25	Consumer acceptance decreases.
2	Appearance	-	Clear	Consumer acceptance decreases.
3	Turbidity	NTU	10	Consumer acceptance decreases.
4	Conductivity	mmhos/cm	-	Indicates the concentration of the free ions present.
5	pH	-	6.5 - 8.6	It affects the mucous membrane in humans and water supply hardware system.
6	Total Dissolved Solids (TDS)	mg/l	2000	Potability decreases. May cause gastrointestinal irritation.
7	Total Hardness (TH)	mg/l	600	Encrustation in water supply structure and adverse effects on domestic use.
8	Calcium Hardness (Cal H)	mg/l	200	Encrustation in water supply structure and adverse effects on domestic use.
9	Chlorides (Cl)	mg/l	1000	Taste, corrosion and palatability are affected.
10	Sulphates (SO_4)	mg/l	400	Causes gastrointestinal irritation.
11	Fluoride (F)	mg/l	1.5	Causes fluorosis, mottling of teeth and affects bone development.
12	Alkalinity (Alk)	mg/l	600	Causes unpleasant taste.
13	Iron (Fe)	mg/l	1	Taste and appearance are affected. Has adverse effect on domestic uses and the structure. Promotes iron bacteria.
14	Arsenic (As)	mg/l	0.05	Beyond this, the water becomes toxic
15	Nitrate (NO_3)	mg/l	45	May cause methaemoglobinemia / blue baby syndrome.
16	Bacteria (E.Coli.)	MPN/100 ml	0	Causes diarrhea, typhoid and other pathogenic diseases.

9.2.1. Physical

Turbidity: Any turbidity in water is associated with pollution and associated health hazards arising out of it. Increased turbidity makes treatment difficult and costly due to increase in chemical coagulation costs and increased cleaning of filters. In turbid waters the pathogenic organisms may be trapped in the turbid particles and hence protected from the disinfectant.

Colour: Natural colour may be acquired by water from decay in swamps and forests but the colour may not be harmful. The fact is that, though water may be potable, its having colour is aesthetically not acceptable and the consumers tend to seek water from other sources, which may not be safe.

Taste and odour both should not be noticeable to consumers. Taste is not measurable but should not be objectionable. For odour, thresh hold odour numbers (TON) are given to indicate the dilutions required for the odour to disappear. It should be preferably one or less than 3.

9.2.2. Chemical

pH of water: It is a factor to be considered for chemical coagulation, disinfection, water softening and corrosion control.

Alkalinity: is a measure of the content of bicarbonates, carbonates and causticity of waters. Waters that contain alkalinity are unpalatable. Chemically treated water sometimes may have high alkalinity. Alkalinity is important in coagulation and corrosion control.

Hardness: Calcium and Magnesium compounds cause hardness- soap consuming property. Hardness is derived by water largely from contact with soil and rock formations. In general, hard waters originate in areas where topsoil is thick and limestone formations are present. Soft waters originate where topsoil is thin and limestone formations are absent.

Total dissolved Salts (TDS): Water with TDS of less than 2000mg/l are suitable for domestic use. Waters with higher TDS have a laxative effect upon people who are not adjusted to it. Conventional treatment methods don't address the removal of TDS.

Chlorides: The presence of chlorides cause salty taste if present beyond 1000 mg/l. Abnormal presence of Chlorides in water indicates contamination of ground water with waste water.

Nitrogen salts: They may be reported in the form of free ammonia and Nitrates-nitrates in terms of Nitrogen. When present beyond trace amounts, they indicate pollution by human wastes. Water containing ammonical nitrogen indicate recent pollution; water-containing nitrogen in the form of nitrates indicate pollution a long

time back. The amount of ammonical nitrogen determines the efficacy of chlorination.

Fluorides: Minimum of 1 mg/l may be required to prevent dental cavities; but beyond 1.5 mg /l may cause staining of teeth and also skeletal fluorosis.

Iron: Iron may be present in water as a dissolved impurity from the earth's crust or enter the water supplies from corroded pumps and pipes. Excess iron may cause staining of clothes during washing and stains on plumping fixtures.

10. Groundwater Quality Mapping – GIS approach

Groundwater has always been considered to be of high quality and a readily available natural resource. Water, either surface water or groundwater in natural environment contains some amount of chemical substances and impurities. Since environment is a dynamic system and community is also a part of the system, quality of water is always a function of natural and anthropogenic activities and interactions both in space and time. Determining the quality of groundwater is as important as detection of its contamination and it's being underground poses many constraints. Since groundwater has a geographical context, study of its quality, quantity and variation of both over large region is very important, particularly in the context of rural water supply programs.

Any natural resource possessing multidimensional aspects is well understood if represented in spatial format. The natural resources particularly, the water - surface water and groundwater and the related landscape elements that control the distribution of particular resource, if represented in the form of proper maps; are amenable for better insight so that actions to be taken for development and management could be derived. Since the groundwater is available in landscape and the community uses it for their sustenance, each habitation has particular history related to the quality attached with. The conventional method of preparation of maps, keeping the records of chemical analysis and trying to relate to the analytical procedures like multi-layer integration, tabular/attribute data linkage needed for planning becomes laborious and time consuming and if the information has to be retrieved, it results in repetition of the whole activity. At the same time, the multitudinal dimensions of information if linked properly and provided with a synoptic view, creates a knowledge base that is essential for development oriented planning. In this regard, the KRWSSA decided to adopt a Geographic Information System (GIS) approach to develop a Spatial Information and Knowledge base on the groundwater quality of Karnataka to establish its relationship with the influencing factors like geology, drainage, soil and the habitations. Based on the exercise carried out groundwater quality variation in Karnataka has been established.

GIS is a tool to analyse the spatial data and to establish a link between spatial and attribute databases, with the advantage of the whole system being put on a retrievable mode, while giving the user the options of value addition, updation and

analysis through the various interfaces. Advantages of GIS are flexibility in data handling, speed, accuracy, cost effectiveness, handles huge volume of data and consistency in performance

In the present study, the tabulated water quality analyses provided by RDED were sorted for the standard fourteen parameters and the data was normalised. The village wise database has been generated and the analytical data has been grouped into two classes viz., permissible limit and above permissible limit categories. The highest number of samples falling in any one category have been considered for average calculations and tabulated in XLS format. For generating the Iso-concentration (water quality contour maps) maps Surfer, Arc/Info and Arc/View soft wares were used.

11. Groundwater quality variation in Karnataka

With a view to understand the broader quality criteria affecting the groundwater source in Karnataka, Rural Development Engineering Department, RD & PR, Govt. of Karnataka, has collected 1,54,491 water samples, covering 33,667 villages / habitations and analysed the water samples for 14 major parameters during the summer of year 2000. A large quantum of data has thus been accumulated. Compilation, assimilation, analysis and standardization of the secondary data has resulted in the preparation of 175 taluk and 27 district profiles and the spatial variation maps were prepared on GIS platform by IN-RIMT, Bangalore. The quality concerns become very important as the groundwater depletion is worsening rapidly. The water quality data in entire Karnataka State has reflected the contamination of groundwater with bacteria and presence of excess Fluoride (F), Total dissolved salts (TDS), Total Hardness (TH), Iron (Fe) and Nitrate (NO_3) (beyond permissible limits).

11.1 Turbidity

Turbidity, in groundwater mainly depends on the amount of suspended particles, which imparts cloudy appearance or muddy colour to the water.

In the State, about 26% of the villages/habitations have shown higher turbidity (permissible limit is 10 JTU). Higher turbidity is recorded from the districts of Chikmagalur, Bangalore (Urban), Chitradurga, Mysore, Belgaum, Bagalkot, Koppal, Chamarajanagar, Shimoga etc. (Table: 2). In general, the excess turbidity ranges between 10.1 and 550 JTU and the highest turbidity of 7050 JTU is recorded in a groundwater sample collected from Chokkahalli in Kolar district.

Table: 2 Turbidity levels in Groundwater

Sl. No.	Districts	Min-Max	Number of samples affected	Percentage of villages affected
1	Bagalkot	10.5-568	382	42.28
2	Bangalore (R)	10.1-536	561	10.85
3	Bangalore (U)	11-349	1066	65.61
4	Belgaum	10.5-224	1020	42.69
5	Bellary	11-2290	471	33.94
6	Bidar	11-33	27	3.36
7	Bijapur	10.5-245	120	12
8	Chamarajanagara	10.1-285	551	41.34
9	Chikmagalur	10.1-954	2974	68.54
10	Chitradurga	10.1-559	1012	39.29
11	Dakshina Kannada	10.4-198	700	42.8
12	Davanagere	10.6-81.6	28	2.69
13	Dharwad	11-35	8	2.24
14	Gadag	10.05-25	70	13.09
15	Gulbarga	11-150	196	16.94
16	Hassan	12-90	101	3.39
17	Haveri	10.1-120	502	27.06
18	Kodagu	10.1-687	412	37.2
19	Kolar	10.1-7050	167	4.01
20	Koppal	11-540	624	45.05
21	Mandya	10.3-50	24	1.33
22	Mysore	10.1-814	2019	56.77
23	Raichur	11-36	381	25.82
24	Shimoga	10.2-357	1405	44.04
25	Tumkur	10.2-305	1136	22.9
26	Udupi	10.1-194	984	39.55
27	Uttara Kannada	10.2-550	1214	36.23

11.2 Colour

The presence of organic matter and iron may impart colour to groundwater (permissible limit 25 HU). The water gets colouration due to the presence of suspended or coagulated matter and higher the intensity more will be the Turbidity. Densely coloured water is unfit for human consumption. The higher colour intensity in the State is observed in the districts of Chamarajanagar, Chikmagalur, Koppal, Mandya, Mysore, Shimoga, Tumkur etc. Generally, the higher colour intensity recorded in the State ranges from 26 to 500 HU. A groundwater sample from Arakere village in Mysore district has shown abnormal colour intensity of 1250 HU (Table: 3).

Table: 3 District wise Colour intensity in groundwater

Sl.No	Districts	Min-Max	Number of samples affected	Percentage of villages affected
1	Bagalkot	-	-	-
2	Bangalore (R)	-	-	-
3	Bangalore (U)	-	-	-
4	Belgaum	27-1080	104	6.51
5	Bellary	25-241	111	11
6	Bidar	28-90	10	1.32
7	Bijapur	-	-	-
8	Chamarajanagara	26-812	2582	92.98
9	Chikmagalur	26-1032	1172	27.05
10	Chitradurga	30-320	279	14.44
11	Dakshina Kannada	-	-	-
12	Davanagere	-	-	-
13	Dharwad	-	-	-
14	Gadag	-	-	-
15	Gulbarga	27-200	42	3.54
16	Hassan	26-90	18	0.64
17	Haveri	-	-	-
18	Kodagu	-	-	-
19	Kolar	45-85	56	1.24
20	Koppal	26-333	179	17.19
21	Mandya	30-301	356	15.66

Sl.No	Districts	Min-Max	Number of samples affected	Percentage of villages affected
22	Mysore	26-1250	640	26.50
23	Raichur	30-100	35	0.79
24	Shimoga	26-175	824	37.33
25	Tumkur	25-520	403	9.31
26	Udupi	-	-	-
27	Uttara Kannada	-	-	-

11.3 Chemical Characters

11.3.1 Total Dissolved Salts (TDS)

The Total Dissolved Salts (TDS), is represented by the Total amount of salts dissolved in water. In natural water, the dissolved salts mainly consist of inorganic salts like carbonates, bicarbonates, chlorides and sulphates together with a small amount of organic matter and dissolved gases. Determination of TDS alone does not give a clear picture of the type of contamination. However, many dissolved substances are undesirable in water and impart unpleasant colour, taste and odour.

Nearly 4% of the samples analysed in the State (5842 samples) covering 3067 villages / habitations (nearly 9% of the sampled villages), have higher TDS content (permissible limit of TDS is 2000 ppm). Extreme average concentration of TDS in the range greater than 4000 ppm and ranging between 2000-4000 ppm are seen as isolated patches predominantly in the districts of Bagalkot, Bijapur, Raichur, Dharwad, Koppal, Bellary, Chitradurga, Gadag, Davanagere, Mandya, Mysore, Bangalore Urban and Belgaum etc (Figs.7, 7A and Table: 4).

Table: 4 District wise concentration of Total Dissolved Salts (TDS) in groundwater

Sl. No.	Districts	Min-Max	Number of samples affected	Percentage of villages affected
1	Bagalkot	2001-8870	257	22.14
2	Bangalore (R)	2010-5220	42	1.01
3	Bangalore (U)	2007-15120	154	15.95
4	Belgaum	2004-10008	281	11.35
5	Bellary	2004-10300	440	26.47

Sl. No.	Districts	Min-Max	Number of samples affected	Percentage of villages affected
6	Bidar	2020-3180	20	2.34
7	Bijapur	2002-12810	565	31.07
8	Chamarajanagara	-	-	-
9	Chikmagalur	2100-3780	12	0.46
10	Chitradurga	2000.32-10800	680	26.52
11	Dakshina Kannada	2023-2039	2	0.16
12	Davanagere	2002-7467	268	17.86
13	Dharwad	2001-8020	40	8.01
14	Gadag	2010-8494	161	24.7
15	Gulbarga	2008-8667	50	5.42
16	Hassan	2001-15950	88	2.41
17	Haveri	2017-5430	58	5.63
18	Kodagu	-	-	-
19	Kolar	2001-8622	175	4.578
20	Koppal	2002-8400	438	23.28
21	Mandya	2001-12425	466	14.26
22	Mysore	2004-6278	325	11.99
23	Raichur	2010-26660	400	22.43
24	Shimoga	2010-3110	51	3.26
25	Tumkur	2003-8090	623	9.92
26	Udupi	2398-4659	3	0.44
27	Uttara Kannada	2050-8900	38	1.79

FIG.7 : VARIATION OF TOTAL DISSOLVED SALTS (TDS) IN KARNATAKA STATE (2000-2001)

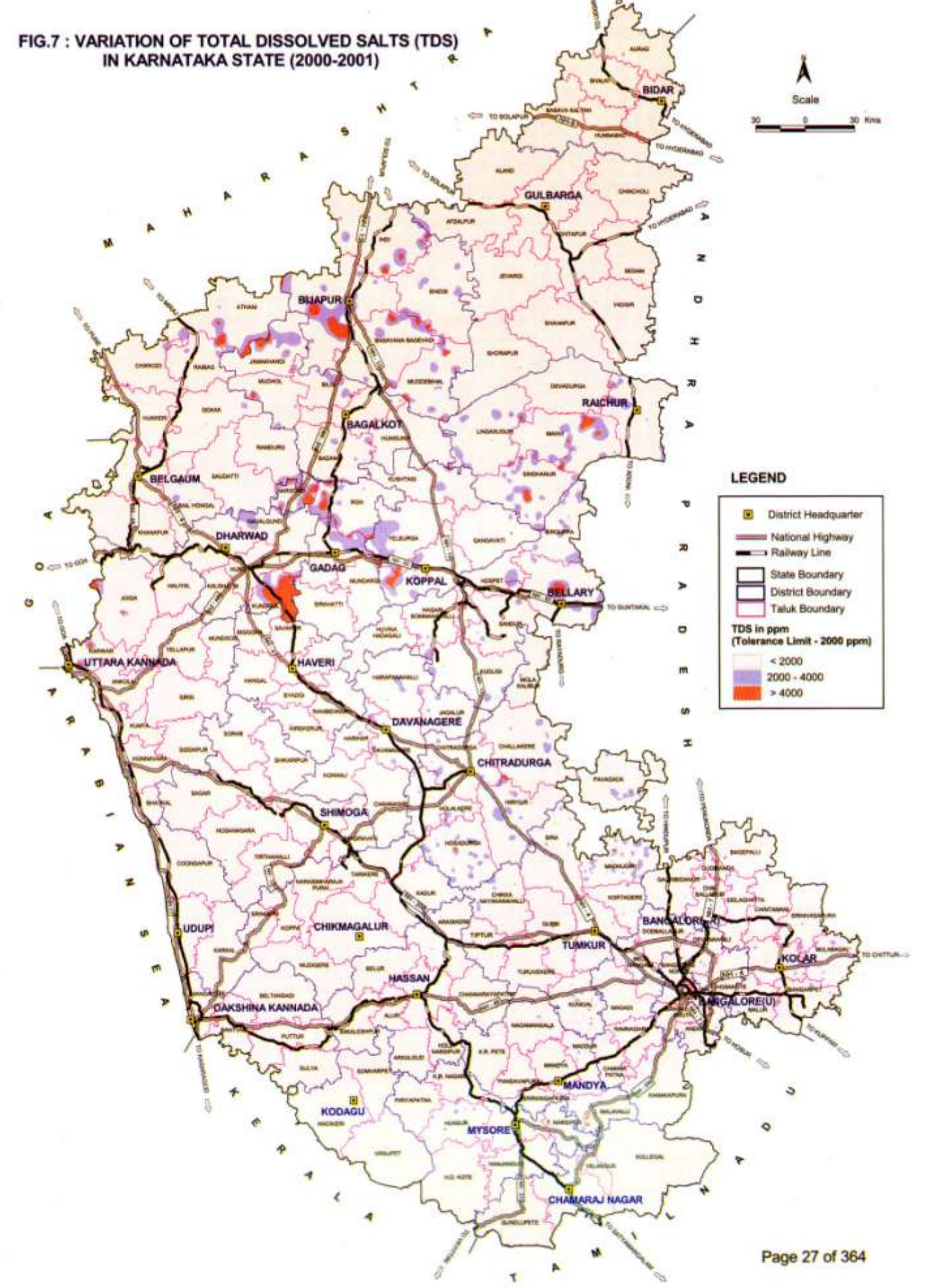
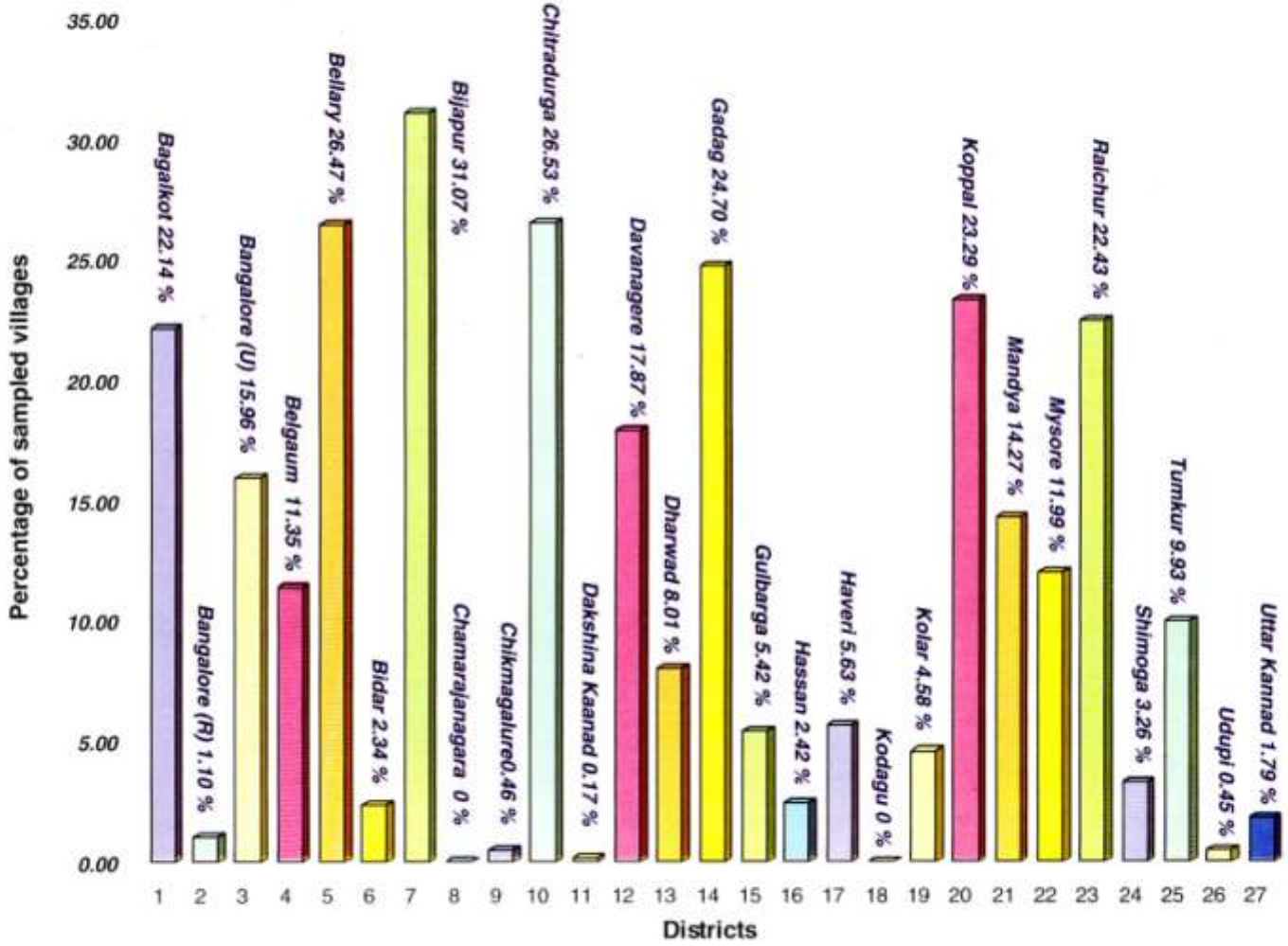


Fig. 7A : Percentage of villages having higher TDS content in Karnataka



11.3.2 Total Hardness (TH)

The Total Hardness is the sum of concentration of carbonate and non-carbonate hardness.

Water hardness is said to be Carbonate hardness, if the water contains calcium and magnesium bicarbonate and such a hardness is known as temporary hardness. Water is said to be having non-carbonate hardness, if the water contains chlorides and sulphides of calcium and magnesium. Such hardness is known as permanent hardness.

In the entire State, about 25% of the sampled villages/habitations have recorded higher TH content (permissible limit 600 ppm). In Karnataka, higher average concentration of TH is seen as isolated patches in portions of Bijapur, Bagalkot, Belgaum, Chitradurga, Gulbarga, Dharwad, Gadag, Koppal, Bellary, Haveri and Davanagere districts in the north and central part and Mysore, Mandya, Tumkur, Chitradurga, Bangalore (R), Bangalore (U) and Kolar etc. in the southern portion. The maximum TH content of 8600 ppm is reported from Garakahalli village, Srirangapatna taluk, Mandya District. The western portion of the State covering Uttara Kannada, Udupi, Shimoga and Dakshina Kannada districts have not reported any above permissible level concentration of TH (Figs. 8, 8A and Table:5).

Table: 5 District wise concentration of Total Hardness (TH) in groundwater

Sl. No.	Districts	Min-Max	Number of samples affected	Percentage of villages affected
1	Bagalkot	602-9720	783	48.32
2	Bangalore (R)	601-2920	434	9.63
3	Bangalore (U)	604-4600	95	7.52
4	Belgaum	601-5050	1639	45.49
5	Bellary	602-5200	700	38.53
6	Bidar	660-2400	4	0.43
7	Bijapur	604-6000	1115	53.81
8	Chamarajanagara	-	-	-
9	Chikmagalur	602-3142	295	6.64
10	Chitradurga	600.2-4861	1817	56.42
11	Dakshina Kannada	692-1708	8	0.84
12	Davanagere	604-4812	1654	63.93
13	Dharwad	602-4212	247	33.01
14	Gadag	600.1-5395	293	41.36
15	Gulbarga	602-2990	1194	62.26

Sl. No.	Districts	Min-Max	Number of samples affected	Percentage of villages affected
16	Hassan	601-3000	773	17.22
17	Haveri	604-4320	661	36.4
18	Kodagu	684-1068	23	6.97
19	Kolar	604-2032	497	12.02
20	Koppal	601-4193	905	41.85
21	Mandya	604-8600	2508	55.01
22	Mysore	601-3178	1387	37.88
23	Raichur	610-4970	228	15.35
24	Shimoga	610-1050	43	3.16
25	Tumkur	602-4462	1983	30.55
26	Udupi	728-1476	4	0.67
27	Uttara Kannada	620-960	15	0.76

11.3.3 Chloride (Cl)

Chlorides are generally present in water in the form of Sodium chloride. The concentrational variation of chloride imparts salty taste to the water. Chloride salts are highly soluble and generally do not react and hence remains stable once they enter the solution. Abnormal chloride contents in groundwater may be due to either pollution or leaching of saline residues in the soil.

About 2% of the sampled villages (1134 samples covering 742 villages) in the State have analysed higher Chloride content (beyond the permissible limit of 1000 ppm). Slightly higher chloride content is noticed mainly in Bijapur, Bellary, Koppal, Bagalkot, Gadag, and Davanagere districts in the northern part of the State. The highest Chloride content (28500 ppm) is reported from Madagiri camp in Manvi taluk of Raichur district (Table: 6).

FIG.8 : VARIATION OF TOTAL HARDNESS (TH) IN KARNATAKA STATE (2000-2001)

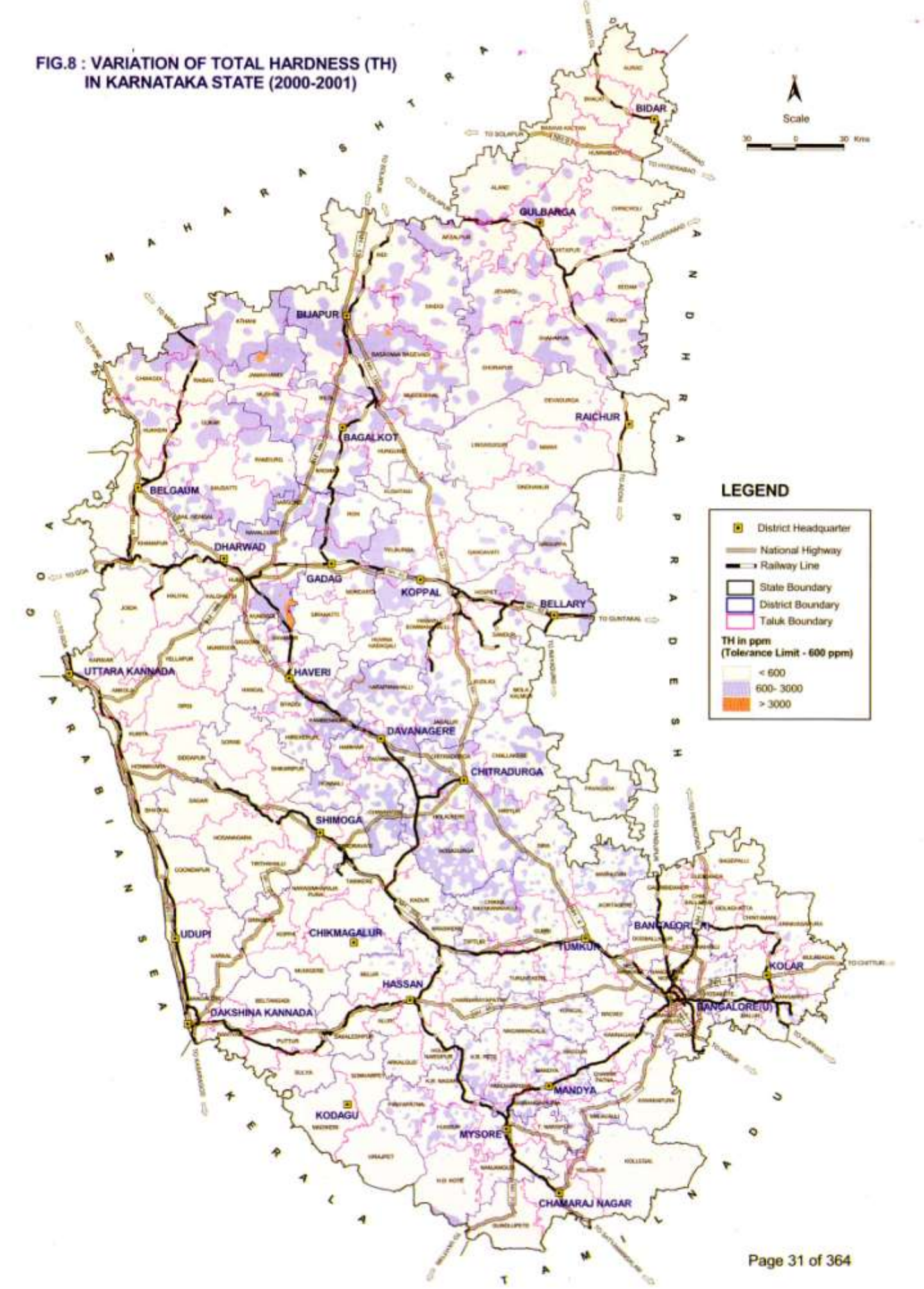


Fig. 8A : Percentage of villages having higher TH content in Karnataka

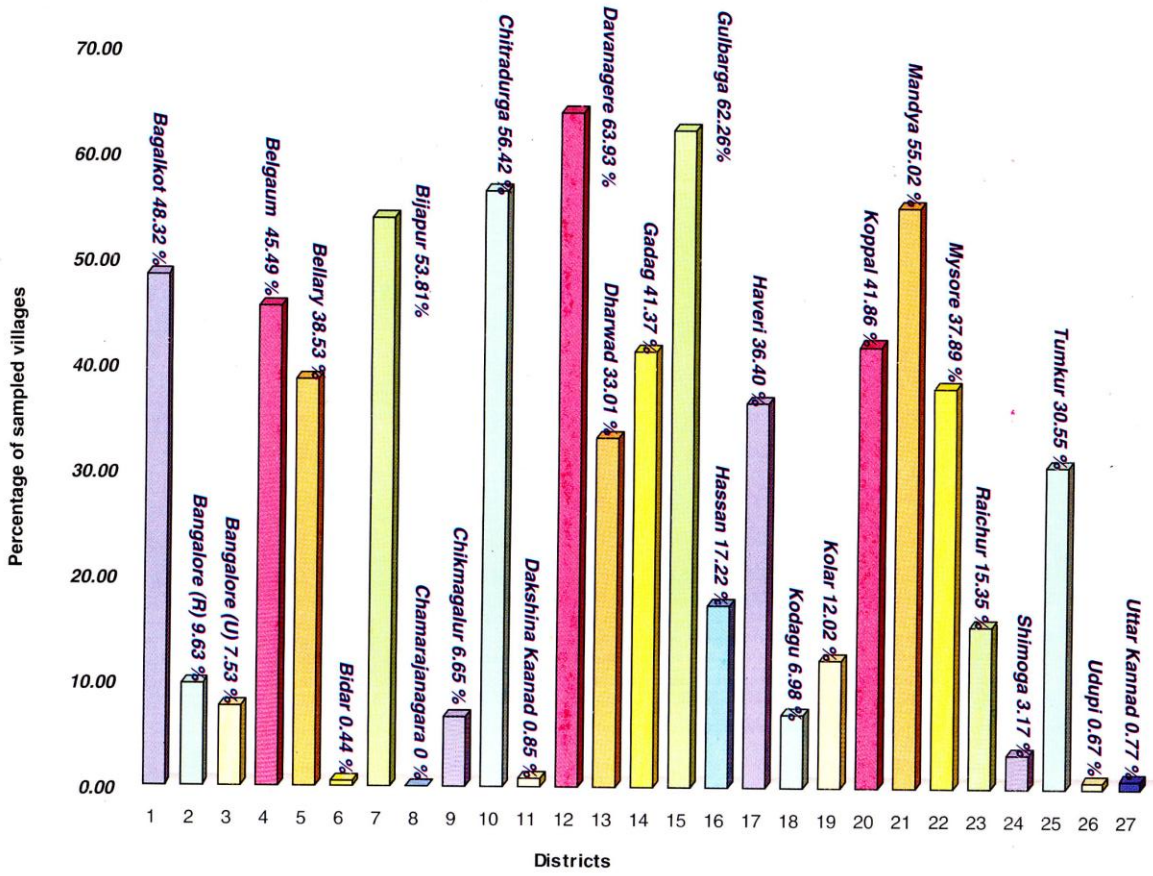


Table: 6 District wise concentration of Chloride (Cl) in groundwater

Sl. No.	Districts	Min-Max	Number of samples affected	Percentage of villages affected
1	Bagalkot	1010-4113	67	8.22
2	Bangalore (R)	1008-2220	15	0.52
3	Bangalore (U)	1009-5918	20	1.91
4	Belgaum	1005-7171	42	2.60
5	Bellary	1004-2900	85	6.29
6	Bidar	2600	1	0.14
7	Bijapur	1010-38107	122	10.03
8	Chamarajanagara	-	-	-
9	Chikmagalur	1010-1800	22	0.87
10	Chitradurga	1004-3325	89	4.05
11	Dakshina Kannada	1140-1420	3	0.33
12	Davanagere	1002-2922	153	11.23
13	Dharwad	1013-2099.2	21	3.84
14	Gadag	1006-4107	82	14.28
15	Gulbarga	1037-1540	10	0.79
16	Hassan	1055-6360	8	0.26
17	Haveri	1008-3750	28	3.43
18	Kodagu	-	-	-
19	Kolar	1020-2788	42	1.18
20	Koppal	1002-2464	100	5.93
21	Mandya	1005-1899	45	1.95
22	Mysore	1001-1290	20	0.90
23	Raichur	1010-28500	78	4.89
24	Shimoga	1100-1910	5	0.38
25	Tumkur	1001-9643	72	1.56
26	Udupi	1146-3506	4	0.67
27	Uttara Kannada	-	-	-

11.3.4 Sulphate (SO_4)

The sulphate content varies widely in groundwater and is mainly due to the traverse of water through the rocks containing sulphide minerals or gypsum. The sulphate ion is stable in most environments and forms sulphate of common cations in groundwater. The reduction of sulphate by bacteria and precipitation by gypsum are the means of removal of sulphate from groundwater.

In Karnataka State, approximately 3% of the villages have reported higher Sulphate concentration in the range of 401 - 9902 ppm (permissible limit is 400 ppm) and are mostly from Bijapur, Gadag, Gulbarga, Koppal, Bellary, Bagalkot and Belgaum districts located in the northern part (Table: 7).

Table: 7 District wise concentration of Sulphate (SO_4) in groundwater

Sl. No.	Districts	Min-Max	Number of samples affected	Percentage of villages affected
1	Bagalkot	402-3200	221	17.28
2	Bangalore (R)	402-710	15	0.45
3	Bangalore (U)	447-1678	14	0.9
4	Belgaum	408-4580	273	11.44
5	Bellary	401-6100	203	11.92
6	Bidar	-	-	-
7	Bijapur	402-2440	727	36.86
8	Chamarajanagara	-	-	-
9	Chikmagalur	441-721	3	0.15
10	Chitradurga	401-4300	120	5.42
11	Dakshina Kannada	-	-	-
12	Davanagere	448-758.14	8	0.56
13	Dharwad	420-1222	18	4.48
14	Gadag	402-2890	193	27.08
15	Gulbarga	402-2118	131	10.4
16	Hassan	417-2700	25	0.86

Sl. No.	Districts	Min-Max	Number of samples affected	Percentage of villages affected
17	Haveri	462-596	9	1.23
18	Kodagu	-	-	-
19	Kolar	410-1000	51	1.33
20	Koppal	401-1820	181	11.71
21	Mandya	444-889	4	0.22
22	Mysore	401-899	21	0.95
23	Raichur	409.6-9902	10	0.9
24	Shimoga	420-1143	5	0.47
25	Tumkur	415-4200	28	0.71
26	Udupi	-	-	-
27	Uttara Kannada	420-800	3	0.15

11.3.5 Fluoride (F)

Higher concentration of fluoride is harmful and causes mottling of Teeth (tooth decay) due to formation of excessive cavities in the teeth of young children during calcinations of their permanent teeth. Higher fluoride concentration greater than permissible limit (greater than 1.5 ppm) may be harmful causing spotting and discolouration of teeth. Prolonged consumption of fluoride rich water also results in physical disability (rheumatic arthritis etc.) and malformation of bones.

In the State, the excess Fluoride content in drinking water has affected nearly 17% of the sampled villages (Fig. 9, 9A and Table: 8). Higher average concentration of Fluoride ranging between 1.5-4.5 ppm is seen in the central, northern and eastern Karnataka covering mainly the districts of Koppal, Bellary, Gulbarga, Davanagere, Bagalkot, Dharwad, Gadag, Chitradurga, Tumkur, Bijapur, Bangalore Urban etc. Isolated patches with concentration of greater than 4.5 ppm are seen in Gulbarga, Bellary, Koppal and parts of Bijapur districts.

Table: 8 District wise concentration of Fluoride (F) in groundwater

Sl. No.	Districts	Min-Max	Number of samples affected	Percentage of villages affected
1	Bagalkot	1.6-11.1	275	22.48
2	Bangalore (R)	1.51-10.05	660	13.99
3	Bangalore (U)	1.51-7.2	485	28.2
4	Belgaum	1.51-115	289	12.28
5	Bellary	1.51-37.2	1412	60.28
6	Bidar	1.6-9	56	5.41
7	Bijapur	1.57-31.14	528	27.26
8	Chamarajanagara	1.55-1.8	16	2.38
9	Chikmagalur	1.51-6.9	60	2.76
10	Chitradurga	1.504-5.2	1097	39.06
11	Dakshina Kannada	1.78	3	0.5
12	Davanagere	1.51-7.04	1045	40.78
13	Dharwad	1.51-21.3	128	22.75
14	Gadag	1.55-4.2	276	38.69
15	Gulbarga	1.6-16.3	1929	50.85
16	Hassan	1.51-8.7	309	6.08
17	Haveri	1.52-10.8	145	10.57
18	Kodagu	-	-	-
19	Kolar	1.51-10.3	828	15.72
20	Koppal	1.51-16.6	1778	72.6
21	Mandya	1.51-21.93	326	9.47
22	Mysore	1.51-4.52	177	6.29
23	Raichur	1.6-8.9	575	29.71
24	Shimoga	1.6-9.3	138	8.73
25	Tumkur	1.51-33.2	1564	16.75
26	Udupi	1.6-7	16	3.14
27	Uttara Kannada	1.52-4	27	1.48

FIG.9 : VARIATION OF FLOURIDE (F) IN KARNATAKA STATE (2000-2001)

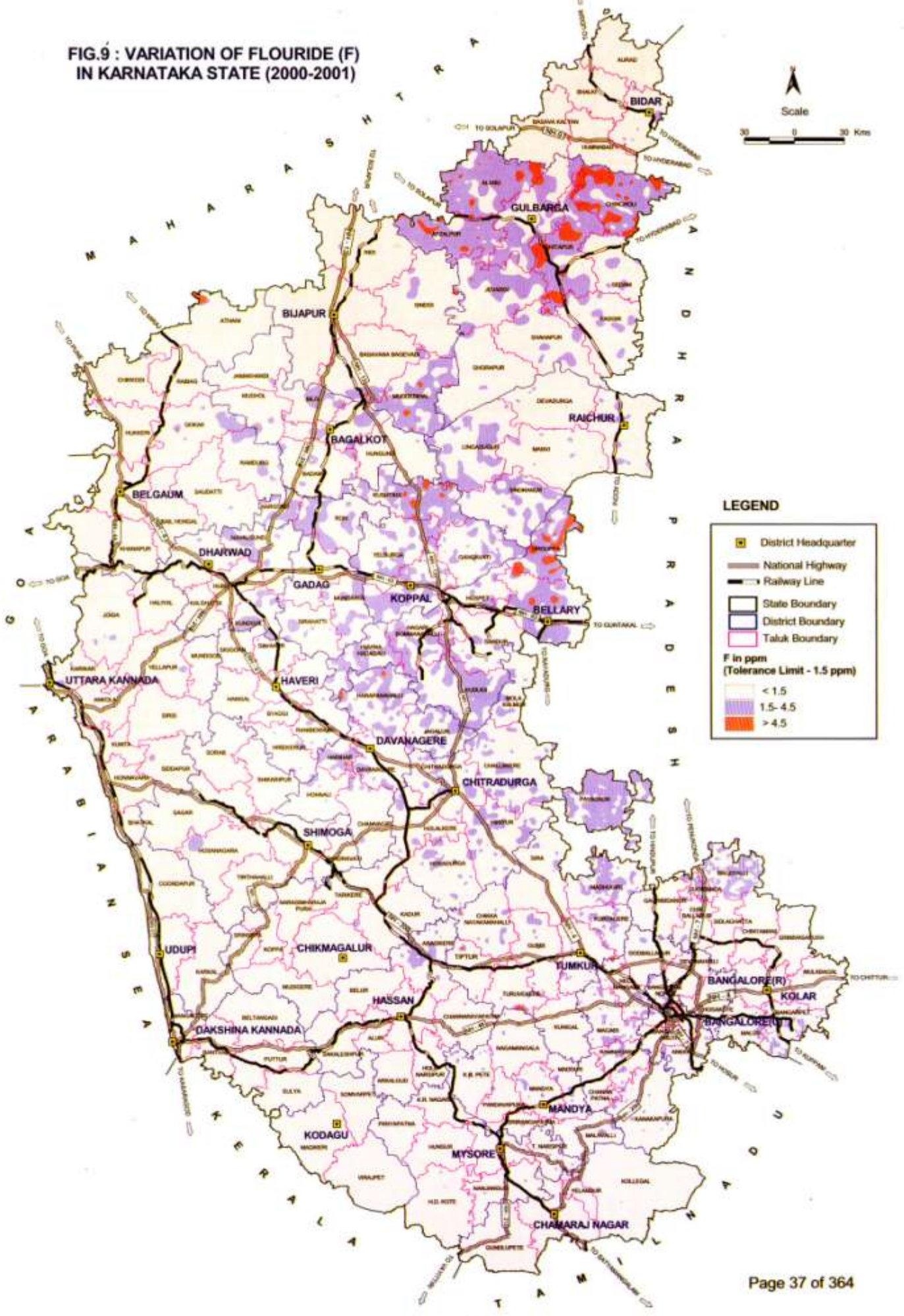
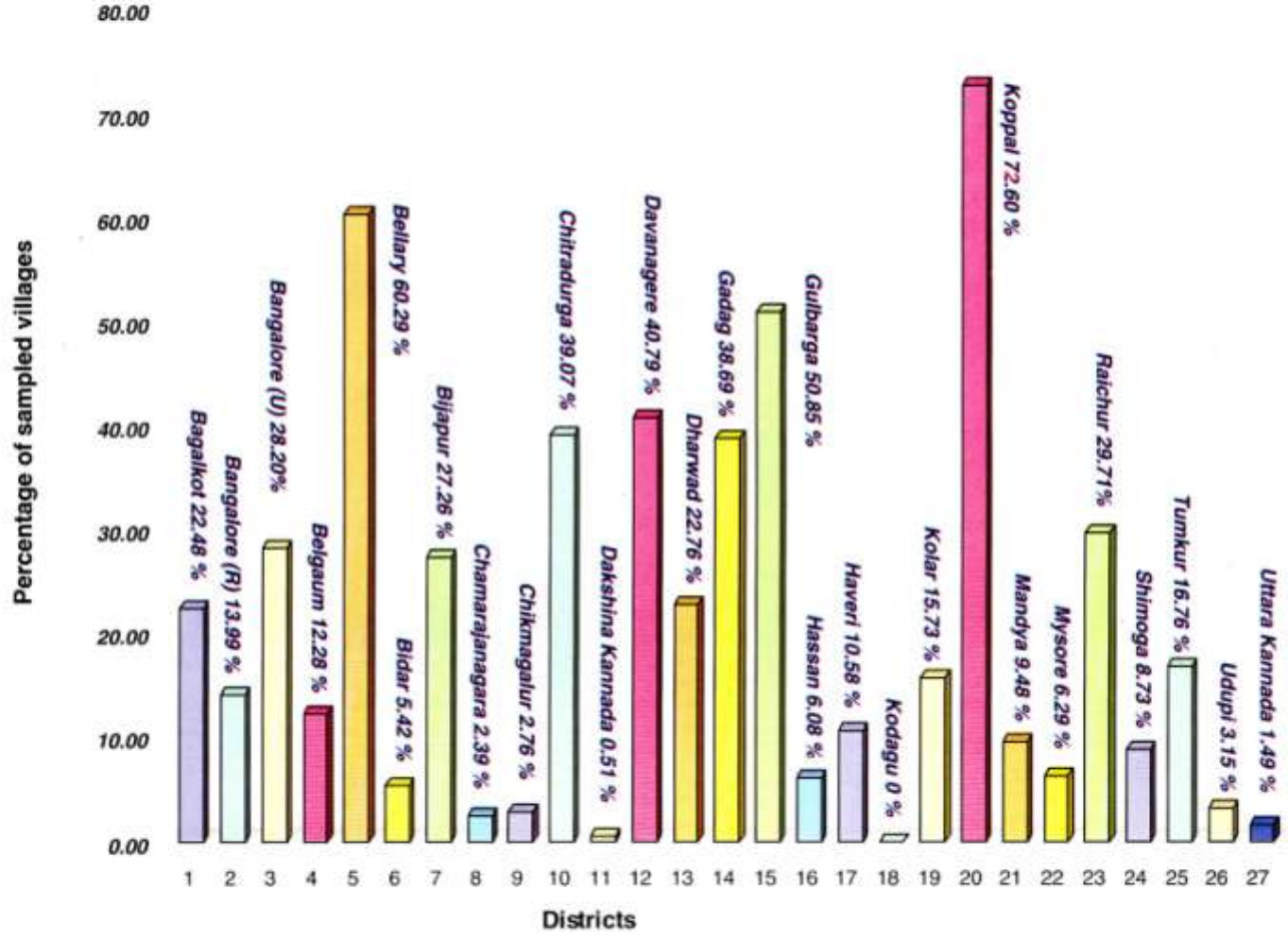


Fig. 9A : Percentage of villages having higher Fluoride concentration in Karnataka



11.3.6 Nitrate (NO_3)

Most of the rocks contain very small amount of nitrate and nitrate reported in natural water is essentially from organic sources or industrial / agricultural chemicals. The presence of Nitrate in water indicates the presence of fully oxidized organic matter and such water may not be harmful. However, the presence of higher concentration of Nitrate in water may adversely affect the health of infants, causing a disease known as "Blue Baby Syndrome" (Mathemoglobinemmia). Higher concentration of Nitrate constituent in the analysed drinking water samples probably indicates that, the accumulation of Nitrate is due to intense irrigational activity and may be because of excessive application of chemical fertilizers for achieving higher agricultural produce.

In Karnataka, about 10% of the villages have analysed NO_3 content beyond the permissible limit (100 ppm) (Table: 9). Higher nitrate concentrations in the range of 101 - 1000 ppm are recorded mainly in Davanagere, Bellary, Bagalkot and Chitradurga districts in the central part and Chamarajanagara, Kolar, Tumkur and Mysore districts in the southern part of the State. The maximum content of 6064 ppm has been recorded in the groundwater sample collected from Jalageri village in Bijapur district.

Table: 9 District wise concentration of Nitrate (NO_3) in groundwater

Sl. No.	Districts	Min-Max	Number of samples affected	Percentage of villages affected
1	Bagalkot	104-1056	84	9.40
2	Bangalore (R)	103-222	144	2.86
3	Bangalore (U)	-	-	-
4	Belgaum	177-806	11	0.74
5	Bellary	101-1275	503	27.13
6	Bidar	101-420	80	8.35
7	Bijapur	102-6064	81	6.50
8	Chamarajanagara	101-180	183	14.03
9	Chikmagalur	128-160	2	0.10
10	Chitradurga	101-270	334	14.91
11	Dakshina Kannada	-	-	-
12	Davanagere	100.5-2490	635	14.94
13	Dharwad	128.9-1306.8	22	4.49
14	Gadag	517	1	0.30

Sl. No.	Districts	Min-Max	Number of samples affected	Percentage of villages affected
15	Gulbarga	261-520	4	0.46
16	Hassan	105-1740	24	0.45
17	Haveri	100.65-2104	36	1.79
18	Kodagu	-	-	-
19	Kolar	101-1942	975	20.93
20	Koppal	-	-	-
21	Mandya	101-987	153	4.96
22	Mysore	100.76-650	890	20.02
23	Raichur	101-370	137	9.87
24	Shimoga	-	-	-
25	Tumkur	101-866	2577	34.70
26	Udupi	-	-	-
27	Uttara Kannada	110-251	5	0.80

11.3.7 Iron (Fe)

In water samples, iron may occur in true solutions in colloidal state that may be peptized by organic matter, inorganic or organic iron complexes or relatively coarse suspended particles. Iron in water causes staining of the clothes and porcelain. Bitter taste is detectable at levels above the permissible limit (1 ppm) of iron.

In Karnataka, nearly 28% of the villages / habitations have higher Iron content. The samples collected from Mandya and Tumkur districts in the southern part of the State have recorded extreme iron concentration, much higher than the permissible limit. Dakshina Kannada, Chikamagalur, Haveri, Dharwad, Belgaum, Udupi, Kodagu, Mysore, Shimoga, Gulbarga, Chitradurga, Bijapur, Bellary, Bangalore Urban, Bagalkot etc. are the other districts where higher iron content is generally varying between 1.1 - 15 ppm. The highest iron concentration of 1221.6 ppm is recorded from the groundwater sample collected from Hosakoppal village, Maddur taluk in Mandya district (Fig. 10, 10a and Table: 10).

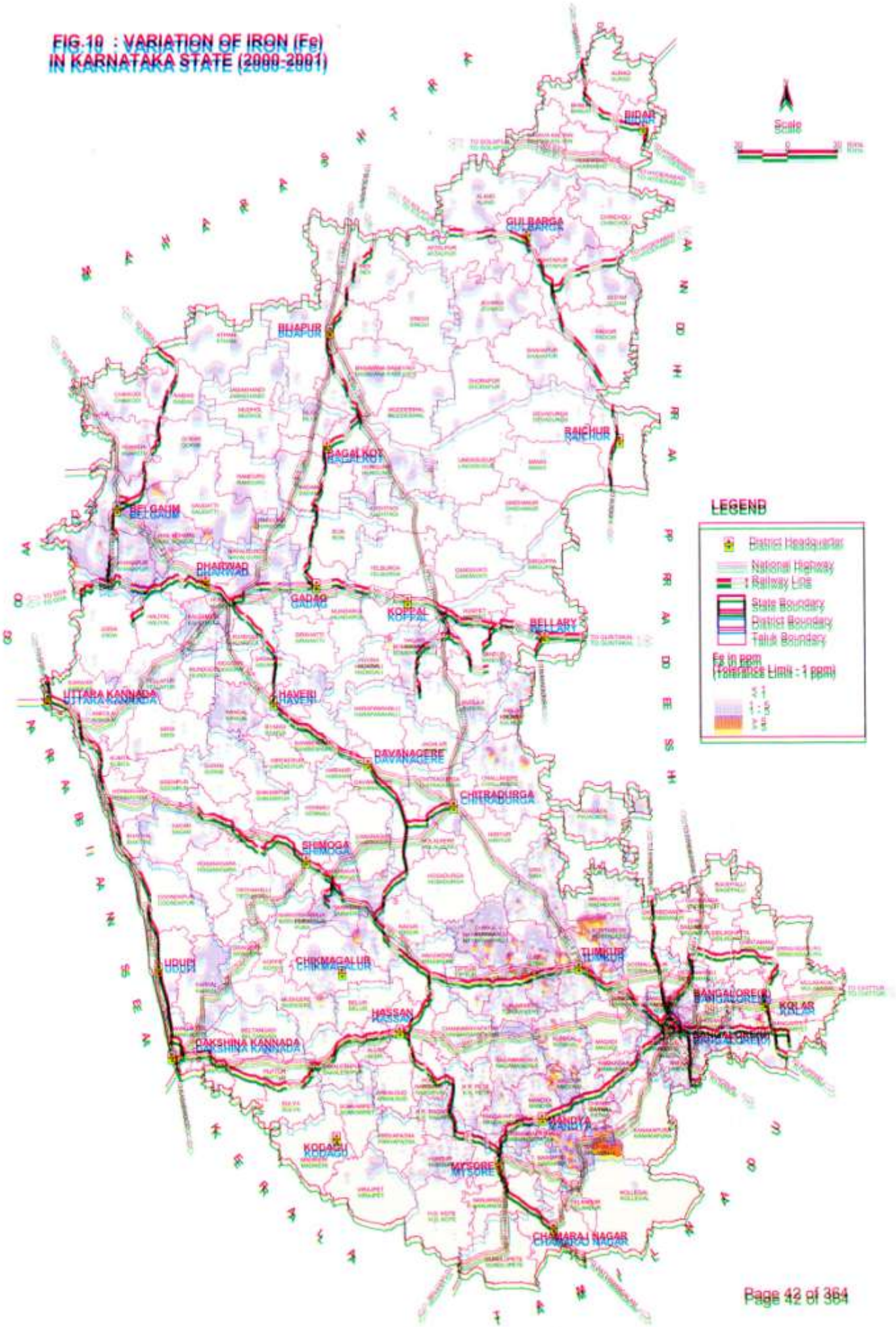
The possible reasons for the unusually high concentration of iron in the above samples may be due to:

- Rusting of the iron piping due to improper maintenance.
- Leaching of iron due to weathering and chemical disintegration.

Table: 10 District wise concentration of Iron (Fe) in groundwater

Sl. No.	Districts	Min-Max	Number of samples affected	Percentage of villages affected
1	Bagalkot	1.1-12	304	33.22
2	Bangalore (R)	1.01-32	464	9.31
3	Bangalore (U)	1.01-14.82	1490	73.14
4	Belgaum	1.2-17.1	1689	59.16
5	Bellary	1.01-18	335	24.24
6	Bidar	1.3	1	0.14
7	Bijapur	1.01-4.4	389	32.34
8	Chamarajanagara	1.2-5	200	25.52
9	Chikmagalur	1.01-22.64	1136	29.36
10	Chitradurga	1.01-55.8	597	21.63
11	Dakshina Kannada	1.01-9.46	786	46.86
12	Davanagere	1.1-43	6	0.56
13	Dharwad	1.02-16	430	45.51
14	Gadag	-	-	-
15	Gulbarga	1.2-20.2	872	46.21
16	Hassan	1.01-8.24	457	13.33
17	Haveri	1.2-5	478	27.19
18	Kodagu	1.2-5	126	29.3
19	Kolar	1.02-30	211	4.54
20	Koppal	1.1-4.6	13	1.98
21	Mandya	1.004-1221.6	3530	65.55
22	Mysore	1.0038-7.4	875	29.55
23	Raichur	1.1-17	171	14.56
24	Shimoga	1.1-6.5	1158	42.41
25	Tumkur	1.01-101	3690	53.34
26	Udupi	1.01-8	857	50.78
27	Uttara Kannada	1.1-17	191	7.89

FIG.10 : VARIATION OF IRON (Fe)
IN KARNATAKA STATE (2000-2001)



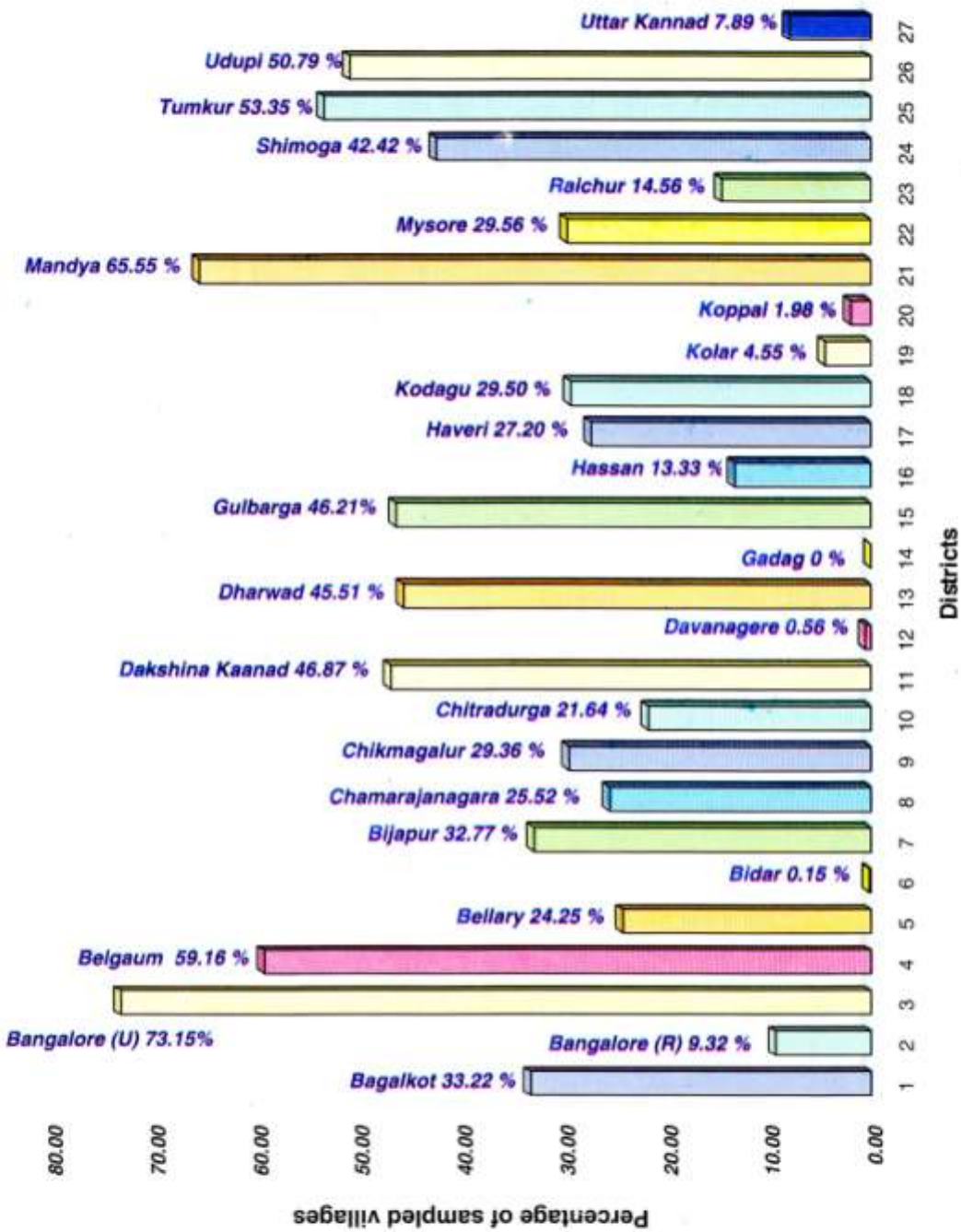


Fig. 10A : Percentage of villages having higher Iron content in Karnataka

11.3.8 Bacteria (*E.coli*)

Presence of Bacteria is most dangerous and these pathogens can harm on consumption. As per the drinking water specifications, the water should not contain any Bacteria. In the State, about 23% of the analysed samples covering 48% of sampled villages have reported the presence of Bacteria indicating non-hygienic and improper sanitation conditions prevalent in the rural sector. Bacterial incidence in the drinking water is commonly seen in almost all the districts with the percentage of affected villages ranging between minimum 15.96 in Davanagere and maximum 89.58 in Mandya district. Raichur, Koppal, Shimoga, Uttara Kannada, Kodagu, Gulbarga, Chikmagalur, Bidar, Belgaum and Bangalore Urban districts have more than 50% villages from where the groundwater samples affected by bacterial incidence in the drinking water source have been collected (Fig. 11 and Table: 11).

Table: 11 District wise Bacterial incidence in groundwater

Sl. No.	Districts	Min-Max	Number of samples affected	Percentage of villages affected
1	Bagalkot	1-17	256	29.03
2	Bangalore (R)	1-10444	2357	39.78
3	Bangalore (U)	1-900	1199	70.79
4	Belgaum	1-20	1368	53.39
5	Bellary	1-300	1034	48.75
6	Bidar	1-18	892	81.99
7	Bijapur	Present	461	33.62
8	Chamarajanagara	Present	612	49.40
9	Chikmagalur	Present	1685	50.54
10	Chitradurga	2-321	904	43.04
11	Dakshina Kannada	1-6	248	33.84
12	Davanagere	1-5	152	15.96
13	Dharwad	Present	101	28.85

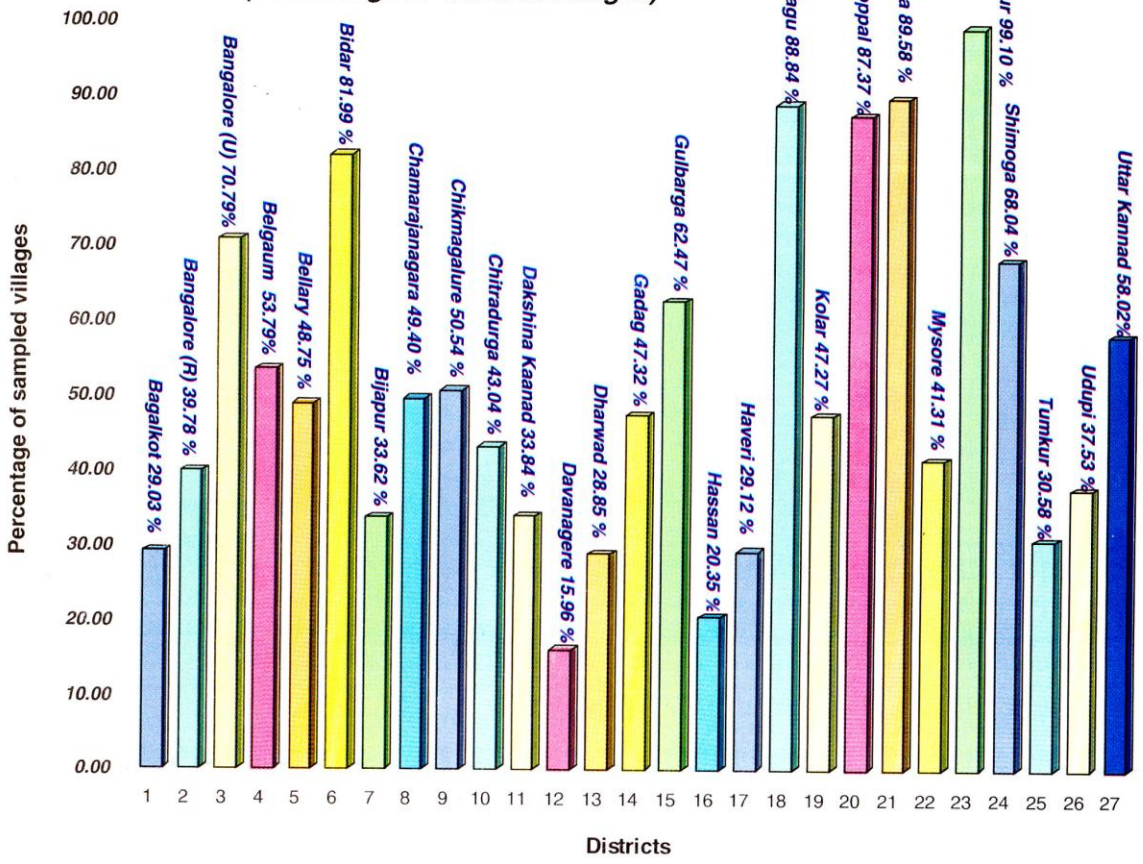
Sl. No.	Districts	Min-Max	Number of samples affected	Percentage of villages affected
14	Gadag	4-140	291	47.32
15	Gulbarga	1-52	1919	62.47
16	Hassan	2-12	577	20.35
17	Haveri	Present	339	29.12
18	Kodagu	Present	622	88.84
19	Kolar	1-965	1789	47.27
20	Koppal	1-26	1749	87.37
21	Mandya	1-624	5249	89.58
22	Mysore	1-400	895	41.31
23	Raichur	1-82	3372	99.10
24	Shimoga	1-10	1786	68.04
25	Tumkur	1-300	1976	30.58
26	Udupi	1-9	468	37.53
27	Uttara Kannada	1-46	2561	58.02

11.3.9 Arsenic (As)

Arsenic even in minor concentration is dangerous to human health and can prove fatal (permissible limit is 0.05 ppm).

In the entire Karnataka State, 70 samples covering 51 villages have indicated the presence of Arsenic content in the analysed samples. The samples are from the districts of Bagalkot: 5-20 ppm (30 samples), Bijapur: 5-10 ppm (12 samples), Haveri: 3 ppm (26 samples) and Kolar 3 ppm (2 samples).

Fig. 11: Bacterial incidence in Karnakata (Percentage of affected villages)



12. Suggestive methods for quality enhancement

The surface / groundwater as it is, is unsuitable and must be treated and purified prior to its supply to the public for domestic or any other use. The required quantum of treatment to be given for particular water essentially depends upon the quality and the chemical characteristics of water. Based on the quality needed for particular use, the supply systems are designed – in the present case, drinking water supply. The water must, therefore, be made safe, clean and suitable for human taste. For different parameters, different corrective procedures are being adopted.

In the present study encompassing Karnataka State, the 1,54,491 samples analysed show contamination mainly with Bacteria, higher turbidity and higher concentrations of TDS, TH, Fluoride, Nitrate and Iron.

Few of the general procedures mentioned here can be adopted for enhancing the water quality.

- **Turbidity**

Turbidity and Colour beyond limit are not harmful constituents. They are mainly due to suspended or colloidal matter and sometimes may lead to unpleasant odour. Simple filtration or application of sand layer can reduce turbidity to a great extent and in-turn reduces the colour intensity as well making the water safe for consumption.

- **Hardness**

Removal of hardness from water is called water softening. The advantage of softening helps mainly in reduction of soap consumption, reduction in the cost of maintenance of plumbing and better taste. In general, two types of hardness are identified.

1) Temporary or carbonate hardness caused by carbonates and bi-carbonates of calcium and magnesium, which can be easily removed by boiling of water or by adding lime.

2) Permanent or non-carbonate hardness is caused by sulphates, chlorides and nitrates of calcium and magnesium and their removal need adoption of special methods such as (i) Lime-Soda process, (ii) Base-exchange or Zeolite process and (iii) Demineralisation process.

PRIORITY LEVELS OF TECHNICAL OPTIONS FOR WATER QUALITY

Sl. No.	Parameter	Available options	Accepted / Recommended options in order of priority
1	Fluoride	a) Alternate local /distant ground water source (with appropriate ground water recharge arrangements) b) Local / distant surface source c) Blending with non – fluoride water wherever feasible d) Dual supply with different service level (drinking, cooking and other purposes) e) Household defluoridation units f) Nalagonda Technique (using Alum), Ion exchange process (using activated Alumina)	a. Where isolated small number of habitations are affected b. Where large number of contiguous villages are affected c. Where fluoride concentration is marginally higher (1.5-2 mg/l) and fluoride free water is available d. Where community is aware able to distinguish the difference (on pilot basis) e. Can be tried on an experimental basis f. Can be tried on an experimental basis
2	Nitrate	a. In areas affected with Nitrate, open well sources shall be avoided b. Alternatively, bore well with at least 10 meters casing is recommended. Flushing is to be done first, before commissioning the supply	a. In areas affected with Nitrate, open well sources shall be avoided b. Alternatively, bore well with at least 10 meters casing is recommended. Flushing is to be done first
3	TDS	a) Alternate distant source / ground water b) Alternate local / distant surface source c) Blending, if possible	a. Alternate distant source / ground water b. Alternate local / distant surface source c. Blending, if possible
4	Iron	a) Treatment for iron removal b) Regular use of bore wells to avoid accumulation of corrosion products from iron pipes	a. Creating awareness to avoid long idling of bore wells b. Store water longer and strain through cloth c. Change the GI pipe to PVC casing d. Use PVC pipe for new bore wells e. Install iron removal plant
5	Bacteria (Coliforms)	a) Disinfections	a. Continuous chlorination of water supply to maintain a minimum residual concentration of 0.02 mg / lit

13. Conclusion

Water is an elixir for the mankind and its quality determines health of communities. As all the water that is available on the earth is not suitable for consumption, understanding its quality becomes the prime concern of any water supply program. As groundwater is found to be most appropriate source and at the same time has a geographical context, study of its quality, quantity and variation of both over large region is very important, particularly in the context of rural water supply programs. Conventional method of keeping records of chemical analysis and trying to relate the influencing factors like geology, drainage, soil and the habitations needed for planning becomes laborious and time consuming and if the information has to be retrieved, it results in repetition of the whole activity. At the same time, the multitude information if linked properly and provided with a synoptic view creates a knowledge base that is essential for development oriented planning. In this regard, the initiatives taken by the KRWSSA to adopt a Geographic Information System (GIS) approach to develop Spatial Information and Knowledge based on the groundwater quality of Karnataka has been found to be very useful.

As per the available data, 69 taluks spread over 18 districts are affected by chemical contamination of the drinking water sources. In general, the problems are due to Fluoride, Total dissolved salts, Iron and nitrate.

Thorough study of analytical data and the analysis of spatial variation of quality across the state have provided a clear picture of groundwater quality in Karnataka as follows:

- *Turbidity*: In the State, confined mainly to the southern and the western parts, higher turbidity and colour intensity have been recorded mostly in Chikmagalur, Bangalore (Urban), Chitradurga, Mysore, Belgaum, Bagalkot, Koppal, Chamarajanagar, Shimoga districts.

- *Total Dissolved Salts (TDS)*: Higher TDS content has been recorded mainly in the districts of Bagalkot, Bijapur, Raichur, Dharwad, Koppal, Bellary, Chitradurga, Gadag, Davanagere, Belgaum etc in the northern part and Mandya, Mysore and Bangalore Urban in the southern part of the State.

- *Total Hardness*: Stretching in a NNW-SSE trending belt, higher concentration of Total Hardness is recorded in the districts of Bijapur, Bagalkot, Belgaum, Chitradurga, Gulbarga, Dharwad, Gadag, Koppal, Bellary, Haveri and Davanagere in the north and central part and Mysore, Mandya, Tumkur, Chitradurga, Bangalore (R), Bangalore (U) and Kolar in the southern part of the State.

- *Chloride:* Generally excess chloride is recorded mainly in Bijapur, Bellary, Koppal, Bagalkot, Gadag, and Davanagere districts in the northern part of the State.

- *Sulphate*: The higher sulphate content in drinking water is recorded mostly in Bijapur, Gadag, Gulbarga, Koppal, Bellary, Bagalkot and Belgaum districts located in the northern part of the State.

- *Fluoride*: Higher concentration of fluoride has been recorded in the villages located mainly in Koppal, Bellary, Gulbarga, Davanagere, Bagalkot, Dharwad, Gadag, Chitradurga, Tumkur, Bijapur and Bangalore Urban districts. Isolated patches with concentration of Fluoride greater than 4.5 ppm are seen in Gulbarga, Bellary, Koppal and parts of Bijapur districts. It is commonly reported in groundwater samples almost throughout the State.

- *Nitrate*: Higher nitrate concentration has been recorded from mainly Davanagere, Bellary, Bagalkot and Chitradurga districts in the central part and Chamarajanagara, Kolar, Tumkur and Mysore districts in the southern part of the State.

- *Iron*: In the State, sampled villages located mostly in the districts of Mandya, Tumkur, Dakshina Kannada, Chikamagalur, Haveri, Dharwad, Belgaum, Udupi, Kodagu, Mysore, Shimoga, Gulbarga, Chitradurga, Bijapur, Bellary, Bangalore Urban, Bagalkot etc. have recorded higher iron content.

- *Bacteria*: In Karnataka State, sampled villages located mostly in the districts of Davanagere, Mandya, Koppal, Shimoga, Uttara Kannada, Kodagu, Gulbarga, Chikmagalur, Bidar, Belgaum and Bangalore Urban etc. have recorded the incidence of bacteria in the drinking water sources.

Turbidity and Colour beyond limit are not harmful constituents and are due to suspended or colloidal matter. Simple filtration or application of sand layer can reduce turbidity to a great extent and inturn reduce the colour intensity as well and hence make the water safe for consumption. Total dissolved Salts even though not harmful, increase the salinity of water and simple precipitation and filtration can reduce its intensity to a large extent. Water softening ie., removal of hardness is done by boiling, adding lime, demineralization and base exchange processes. Iron concentration in water can be brought down by careful development of the bore well, usage of PVC pipes and precipitation by iron bacteria. Fluoride content, the most hazardous constituent can be reduced by defluoridation by either activated alumina, bonechar or Nalagonda technique and Bacterial incidence in groundwater, indicator of poor sanitary conditions around the source in the rural areas, can be controlled by boiling, chlorination or treatment with lime, Ozone, Iodine and Bromine, Ultraviolet rays, Potassium permanganate and Electra Katadyn process in addition to imparting proper hygienic and sanitation knowledge to the rural populace.

Keeping in tune with the initiatives at the national level, the action agenda of Karnataka State is being accomplished with the commitment to provide rural community with safe drinking water. The GIS database of the entire state, created for the first time in the country would go a long way in Water quality monitoring also.

The outputs of water quality mapping exercise provide a synoptic view of the taluk/district/state and would form a powerful tool for monitoring of water quality across the State. The GIS database also helps in decision-making process by identifying the most sensitive zones that need immediate attention. The planning process can also foresee the quality fluctuations and decide upon the priority, schedule, corrective measures and protection aspects with finer details.

Table: 12 Comprehensive analysis of water quality data of Karnataka State

Sl. No.	Name of the Districts	Number of villages/ habitations	Number of sampled villages	Number of samples analysed	Water quality scenario	Bact (c/100 ml) -0	Tur (10) JTU	Color (25) HU	Cond - mmhos/ cm	pH (6.5-8.5)	TDS (2000) ppm	TH (600) ppm	CalH (200) ppm	Cl (1000) ppm	SO_4 (400) ppm	F (1.5) ppm	NO_3 (100) ppm	Alk (600) ppm	Fe (1) ppm	As (0.05) ppm
1	Bagalkot	705	596	2979	No. of samples beyond permissible limit	256	382	-	-	36	257	789	625	67	221	275	84	358	304	30
					No. of villages affected	173	252			20	132	288	209	49	103	134	56	122	198	26
					Range	1-17	10.5-568	-	100-19300	5.56-9.2	2001-8870	602-9720	201-2032	1010-4113	402-3200	1.6-11.1	104-1056	608-2000	1.1-12	5-20
2	Bangalore (R)	3067	2866	9528	No. of samples beyond permissible limit	2357	561	-	-	283	42	434	2206	15	15	660	144	151	464	-
					No. of villages affected	1140	311	-	-	287	29	276	1016	15	13	401	82	107	257	-
					Range	1-10444	10.1-536	-	6-15000	1.2-9.85	2010-5220	601-2920	201-1452	1008-2220	402-710	1.51-10.05	103-222	607-2622	1.01-32	-
3	Bangalore(U)	1308	890	3904	No. of samples beyond permissible limit	1199	1066	-	-	256	154	95	632	20	14	489		51	1490	-
					No. of villages affected	630	584	-	-	137	142	67	325	17	8	251		42	651	-
					Range	1-900	11-349	-	187-30844	5.18-9.93	2007-15120	604-4600	201-3400	1009-5918	447-1679	1.51-7.2		610-830	1.01-14.82	-
4	Belgaum	1473	1075	6909	No. of samples beyond permissible limit	1368	1020	104	-	424	281	1639	1100	42	273	280	11	12	1689	-
					No. of villages affected	574	459	70	-	205	122	489	387	28	123	132	8	12	636	-
					Range	1-20	10.5-224	27-1080	10-8600	0.5-9.62	2004-10008	601-5050	201-1740	1005-7171	450-4582	1.51-115	177-806	608-2014	1.2-17.1	-
5	Bellary	1026	763	3756	No. of samples beyond permissible limit	1034	471	111	-	245	440	700	367	80	203	1412	503	193	335	-
					No. of villages affected	372	259	84		100	202	294	167	48	91	460	207	96	185	
					Range	1-300	11-2290	25-241	129-10120	8.51-9.8	2004-10300	602-5200	200.4-988	1004-2400	401-6100	1.51-37.2	101-1275	604-4720	1.01-15	
6	Bidar	779	683	2653	No. of samples beyond permissible limit	892	27	10	-	42	20	4	116	1	-	56	80	10	1	-
					No. of villages affected	560	23	9	-	39	16	3	80	1	-	37	57	10	1	
					Range	1-18	11-33	28-90	1-5700	6-9.2	2020-3180	600-2400	210-909	2900		1.6-9	101-420	610-2250	1.3	
7	Bijapur	774	708	4545	No. of samples beyond permissible limit	461	120	-	-	154	565	1115	382	122	727	528	81	22	389	12
					No. of villages affected	231	85	-	-	107	220	381	183	71	261	193	46	18	229	12
					Range	Present	10.5-245	-	81-18610	6.16-10.35	2002-12810	604-6000	201-1603	1010-38107	402-2440	1.57-31.14	102-6014	604-992	1.01-4.4	5-10
8	Chamarajanagara	882	670	5083	No. of samples beyond permissible limit	612	551	2582	-	269			1912	-	-	16	183	2977	299	-
					No. of villages affected	331	277	673	-	174			577	-	-	16	94	613	171	-
					Range	Present	10.1-285	26-812	10-3680	5.7-9.2			200.1-464	-	-	1.55-1.8	101-180	610-2000	1.2-5	
9	Chikmagalur	2495	1955	7685	No. of samples beyond permissible limit	1685	2974	1172	-	796	12	236	1431	22	3	60	2	1289	1136	
					No. of villages affected	988	1340	529	-	336	9	130	399	19	3	54	2	405	574	
					Range	Present	10.1-954	26-1032	8-270000	5.1-9.45	2100-3780	602-3142	201.1-1458	1010-1800	441-721	1.51-6.9	128-160	610-7800	1.01-22.64	
10	Chitradurga	1597	1308	6340	No. of samples beyond permissible limit	904	1012	279	-	323	680	1817	4136	89	120	1097	334	788	597	
					No. of villages affected	563	514	189	-	178	347	738	1124	53	71	511	195	420	283	
					Range	2-321	10.1-559	30-320	92-11080	6-9.5	2000.32-10800	600.2-4861	201-3002	1004-3325	401-4300	1.504-5.2	101-270	600.1-2981	1.01-55.8	-
11	Dakshina Kannada	1695	591	6647	No. of samples beyond permissible limit	248	700	-	-	165	2	8	4	3	-	3	-		786	
					No. of villages affected	200	253	-	-	98	1	5	2	2	-	3	-		277	-
					Range	1-6	10.4-198	-	0.36-3820	5-9.8	2023.2035	602-1708	201.6-332	1140-1420		1.78			1.01-9.46	
12	Davanagere	1220	890	5148	No. of samples beyond permissible limit	152	28	-	-	513	268	1654	1157	153	8	1045	0.35	296	6	
					No. of villages affected	142	24	-	-	264	109	569	405	100	5	363	133	162	5	-
					Range	1-5	10.6-81.6	-	0.36-98200	0.4-9.9	2002.7467	604.4812	201.6-9260	1002.2942	446.758.14	1.51-7.04	120-5.2400	604.4584	1.1-43	-
13	Dharwad	441	312	1874	No. of samples beyond permissible limit	101	8	-	-	503	40	247	104	21	18	128	22	1	430	
					No. of villages affected	90	7	-	-	156	25	103	51	12	14	71	14	1	142	
					Range	Present	11-35	-	10-31242	1.18-10.32	2001.802C	602.4212	200.3-1592.2	1013.2096.2	420.1222	1.51-21.3	128.9-1306.8	735	1.02-16	
14	Gadag	367	336	1461	No. of samples beyond permissible limit	291	70			210	161	293	293	82	103	270	1	77		
					No. of villages affected	159	44			116	83	139	136	48	51	130	1	42		
					Range	4-140	10.05-25	-	130-23340	5.22-9.98	2010-8494	600.1-5395	202.7720	1004-4107	402-2800	1.55-4.2	517	601-5404		
15	Gulbarga	1562	885	5709	No. of samples beyond permissible limit	1919	196	42		81	50	1194	772	10	131	1920	4	88	872	
					No. of villages affected	564	150	35		53	48	551	370	7	12	450	4	52	404	
					Range	1-52	11-150	27-200	100-23000	5.98-9.53	2008-8667	602-2999	201-1530	1.037-1540	402-2116	1.6-16.3	261-520	610-1244	1.2-20.2	

Comprehensive analysis of water quality data of Karnataka State (continued)

Sl. No.	Name of the Districts	Number of villages/ habitations	Number of sampled villages	Number of samples analysed	Water quality scenario	Bact (c/100 ml) -0	Tur (10) JTU	Color (25) HU	Cond - mmhos/ cm	pH (6.5-8.5)	TDS (2000) ppm	TH (600) ppm	CalH (200) ppm	Cl (1000) ppm	SO_4 (400) ppm	F (1.5) ppm	NO_3 (100) ppm	Alk (600) ppm	Fe (1) ppm	As (0.05) ppm
16	Hassan	3458	2648	10804	No. of samples beyond permissible limit	577	101	18	-	6	88	773	705	8	25	309	24	315	457	-
					No. of villages affected	539	90	17	-	6	64	456	340	7	23	161	12	204	353	-
					Range	2-12	12-90	26-90	27-8341	6.11-8.8	2001-15950	601-3000	201-960	1055-6360	417-2700	1.51-8.7	105-1740	602-2700	1.01-8.24	-
17	Haveri	771	728	3519	No. of samples beyond permissible limit	339	502	-	-	122	58	661	354	28	9	145	36	14	478	26
					No. of villages affected	212	197	-	-	65	41	265	169	25	9	77	13	11	198	11
					Range	Present	10.1-120	-	8-14230	8.51-9.13	2017-5430	604-4320	201-1424	1008-3750	462-596	1.52-10.8	100.65-2104	604-11025	1.2-5	Dirty
18	Kodagu	852	215	1185	No. of samples beyond permissible limit	622	412	-	-	213	-	23	82	-	-	-	-	34	126	-
					No. of villages affected	191	80	-	-	53	-	15	64	-	-	-	-	29	63	-
					Range	Present	10.1-687	-	10-2500	5.1-9.1	-	684-1068	201.2-890	-	-	-	-	610-820	1.2-5	-
19	Kolar	4161	3211	7510	No. of samples beyond permissible limit	1789	167	56	-	236	175	497	250	42	51	828	975	100	211	2
					No. of villages affected	1518	129	40	-	181	147	386	180	38	43	505	672	86	146	2
					Range	1-965	10.1-7050	45-85	0.75-18000	0.8-9.2	2001-8622	604-2032	201-664	1020-2788	410-1000	1.51-10.3	101-1942	604-1020	1.02-30	3
20	Koppal	675	657	4509	No. of samples beyond permissible limit	1749	624	179	-	480	438	905	494	100	181	1778	-	381	13	-
					No. of villages affected	574	296	113	-	203	153	275	172	39	77	477	-	133	13	-
					Range	1-26	11-540	26-333	100-18360	0.25-9.36	2002-8400	601-4193	201-2024	1002-2464	401-1820	1.51-16.6	-	602-4645	1.1-4.6	-
21	Mandya	2048	1794	8467	No. of samples beyond permissible limit	5249	24	356	-	207	466	2508	1975	45	4	326	153	353	3530	-
					No. of villages affected	1607	24	281	-	161	256	987	832	35	4	170	89	200	1176	-
					Range	1-624	10.3-50	30-301	5-9650	0.29-11.42	2001-12425	604-8600	201-3800	1005-1899	444-889	1.51-21.93	101-987	604-6000	1.004-1221.6	-
22	Mysore	2028	1668	8069	No. of samples beyond permissible limit	895	2019	640	-	37	325	1387	1699	20	21	177	890	714	875	-
					No. of villages affected	689	947	442	-	30	200	632	603	15	16	105	334	371	493	-
					Range	1-400	10.1-814	26-1250	30-9170	4.2-9.8	2004-6278	601-3178	200.08-1280	1001-1290	401-899	1.51-4.52	100.76-650	601-2251	1.0038-7.4	-
23	Raichur	955	1003	3666	No. of samples beyond permissible limit	3372	381	35	-	213	400	228	1008	78	10	575	137	24	171	-
					No. of villages affected	994	259	29	-	155	225	154	516	49	9	298	99	23	146	-
					Range	1-82	11-36	30-100	100-28020	1.37-9.5	2010-26660	610-4970	210-3200	1010-26500	409.6-9902	1.6-8.9	101-370	610-1470	1.1-17	-
24	Shimoga	3545	1042	10010	No. of samples beyond permissible limit	1786	1405	824	-	240	51	43	13	5	5	138	-	28	1158	-
					No. of villages affected	709	459	389	-	141	34	33	12	4	5	91	-	17	442	-
					Range	1-10	10.2-357	26-175	10-31000	4.6-9.1	2010-3110	610-1050	201-425	1100-1910	420-1143	1.6-9.3	-	607-800	1.1-6.5	-
25	Tumkur	4063	3777	11752	No. of samples beyond permissible limit	1976	1136	403	-	183	623	1983	3072	72	28	1564	2577	430	3690	-
					No. of villages affected	1155	865	352	-	143	375	1154	1328	59	27	633	1312	317	2015	-
					Range	1-300	10.2-305	25-520	0.13-10230	1.9-9.4	2003-8090	602-4462	201-1735	1001-9643	415-4200	1.51-33.2	101-866	602-12065	1.01-101	-
26	Udupi	1489	445	4913	No. of samples beyond permissible limit	468	984	-	-	184	3	4	16	4	-	16	-	3	857	-
					No. of villages affected	167	176	-	-	89	2	3	8	3	-	14	-	3	226	-
					Range	1-9	10.1-194	-	2.47-25000	1.8-9.3	2398-4659	728-1476	202-257	1146-3506	-	1.6-7	-	640-2160	1.01-8	-
27	Uttara Kannada	3872	1951	5866	No. of samples beyond permissible limit	2561	1214	-	-	695	38	15	-	-	3	27	5	7	191	-
					No. of villages affected	1132	707	-	-	432	35	15	-	-	3	25	4	6	151	-
					Range	1-46	10.2-550	-	5-9920	0.30-11.1	2050-8900	620-960	-	-	420-800	1.52-4	110-251	610-950	1.1-17	-
Total		**47309**	**33667**	**154491**	No. of samples beyond permissible limit	**34862**	**18155**	**6811**	**-**	**7120**	**5637**	**19305**	**25081**	**1136**	**2263**	**14142**	**6881**	**8716**	**20456**	**70**
					No. of villages affected	**16204**	**8811**	**3202**	**-**	**3933**	**3067**	**8408**	**9661**	**744**	**1091**	**5762**	**3434**	**3501**	**9450**	**51**
					Range	**1-10444**	**10.1-7050**	**26-1250**	**0.13-623000**	**0.25-11.42**	**2001-26660**	**601-8600**	**201-9260**	**1001-28500**	**401-9902**	**1.51-37.2**	**101-6064**	**601-12065**	**1.0038-1221.6**	**3-10**