STUDIES ON LAND USE/LAND COVER CHANGES AND WATER QUALITY DUE TO URBANIZATION ALONG THE COASTAL AREAS OF DAKSHINA KANNADA DISTRICT, KARNATAKA, INDIA

Thesis

Submitted in partial fulfilment of the requirements for the award of the degree of

DOCTOR OF PHILOSOPHY

by

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D E C L A R A T I O N

I hereby declare that the Thesis titled, **“STUDIES ON LAND USE/LAND COVER CHANGES AND WATER QUALITY DUE TO URBANIZATION ALONG THE COASTAL AREAS OF DAKSHINA KANNADA DISTRICT, KARNATAKA, INDIA”,** which is being submitted to the **National Institute of Technology Karnataka, Surathkal** in partial fulfillment of the requirements for the award of the Degree of **Doctor of Philosophy** in **CIVIL ENGINEERING** ***is a bonafide report of the research work carried out by me*****.** The material contained in this Research Synopsis has not been submitted to any University or Institution for the award of any degree.

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Place: NITK-Surathkal
Date: 11-05-2013.

C E R T I F I C A T E

This is to ***certify*** that the Thesis titled, **" STUDIES ON LAND USE/LAND COVER CHANGES AND WATER QUALITY DUE TO URBANIZATION ALONG THE COASTAL AREAS OF DAKSHINA KANNADA DISTRICT, KARNATAKA, INDIA ",** submitted by **B. Rajagopal** (Reg. No: **CV05F01**) as the record of the research work carried out by him, ***is accepted as the Research Thesis submission*** in partial fulfilment of the requirements for the award of the degree of **Doctor of Philosophy**.

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ABSTRACT

Increasing population and urbanization result in land use and land cover changes from local to global scales. The coastal area of Dakshina Kannada district of Karnataka, India has witnessed a phenomenal development in the last couple of decades and it is expected that this trend will continue at a much faster rate due to the setting up of Special Economic Zones (SEZs) and their expansions in Mangalore. Therefore an attempt was made in this research to study the land use/land cover changes that have taken place for 25 years from 1983-2008 and to assess the urbanization impacts on water quality. The study area lies between 12°45' N to 13°7'30" N latitude and 74°45' E to 75° E longitude having an area of about 777 square kilometres.

Six Indian Remote Sensing (IRS) satellite images were used in the study. Supervised classification with maximum likelihood algorithm was adopted in the study and the accuracy assessment was done. The results indicate that the urban/built-up area has increased by 270% and the population has increased by 215% during the study period.

A total of 1500 water samples pertaining to sea, rivers and groundwater were collected during November 2006 and October 2007 and analyzed for twenty five physical, chemical and bacteriological characteristics. The over all quality of groundwater in Mangalore city was seem to be deteriorating. The pH value showed a decreasing trend, while the concentration of Nitrates showed increasing trend, though at present it is well within the standards. The global water quality indices determined for River Nethravati varied from 'Fair' to 'Good' and the indices for River Gurpur can be categorized as 'Fair'.

Urban growth prediction helps the urban planners and policy makers in providing better infrastructure services to a huge number of new urban residents. In the study area, the urban/built-up area is predicted to increase to 381 sq. km and the population is expected to reach 2.6 millions by the year 2028. The population in the study area has already reached saturation levels; therefore any further increase in population will result in environmental degradation. This indicates that the available resources are not sustainable and the carrying capacity of the region is untenable.

Keywords: Land Use/Land Cover Change, Remote Sensing, Urbanization, Water Quality.

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NOMENCLATURE

AWQI	Acceptability Water Quality Index
CWQI	Canadian Water Quality Index
DK	Dakshina Kannada
DOC	Dissolved Organic Carbon
DWQI	Drinking Water Quality Index
EC	Electrical Conductivity
ETM +	Enhanced Thematic Mapper Plus
FCB	Fecal Coliform Bacteria
GCP	Ground Control Point
GDP	Gross Domestic Product
GEMS	Global Environment Monitoring System
GIS	Geographical Information Systems
GPS	Global Positioning System
GWQI	Global Water Quality Index
HWQI	Health Water Quality Index
IRS	Indian Remote Sensing
IGBP	International Geosphere Biosphere Programme
IHDP	International Human Dimensions Programme
LISS	Linear Imaging Self-scanning Sensor
LU/LC	Land Use/Land Cover
MSS	Multi Spectral Scanner
mg/L	Milligram per Litre
μg/L	Microgram per Litre
NRSC	National Remote Sensing Centre
RS	Remote Sensing
SEZ	Special Economic Zone
sq. km.	Square Kilometers
TDS	Total Dissolved Solids
TH	Total Hardness
TM	Thematic Mapper
TN	Total Nitrogen
TP	Total Phosphorous
TSS	Total Suspended Solids
UHI	Urban Heat Island
UNCED	United Nations Conference on Environment and Development
UNEP	United Nations Environment Programme
UNFPA	United Nations Population Fund
UTM	Universal Transverse Mercator
VOC	Volatile Organic Compound
WHO	World Health Organization

1.1 General

Increasing population and urbanization result in land use and land cover changes from local to global scales. This process, in turn, can profoundly disrupt the structure and function of ecosystems. As reported by Grimm et al. (2000), although urban areas account for only 2% of Earth's land surface, they produce 78% of greenhouse gases, thus contributing significantly to global climate changes.

Throughout history, people have settled on the coasts to take advantage of the amenities the oceans offer- a food supply, a source of transport, a defensible position and a healthy location. Half of the world's population lives within 100 kilometers of the sea and three quarters of all large cities are located on the coast. The seas and oceans are under pressure from pollution and much of this pollution comes from urban centers. One of the most damaging ways in which cities pollute coastal areas is the discharge of waste water and sewage. Many coastal cities discharge sewage, industrial effluent and other waste water directly into their surrounding seas (UN, 2005).

1.2 Urbanization trends

1.2.1 Global trends

The world is undergoing the largest wave of urban growth in history; already, over half of the world population is living in towns and cities, and by 2030 this number will swell to almost 5 billion, with urban growth concentrated in Africa and Asia (UN Habitat, 2010; UNFPA, 2007). Today, the share of urban population in the world's least developed countries is still low in comparison-30% of total population- but the rate of urban population growth is very high, at about 4% per annum. At this rate, the urban population in least developed countries will double in less than 20 years. The number of cities in the world with population greater than one million increased from 75 in 1950 to 447 in 2011 and projected to increase to 527 by 2020 (UNFPA, 2011). While the urbanization during the early 20th century was mostly confined to developed countries, more than 90% of the world urban population growth currently taking place is in developing countries. This vast urban expansion in developing countries has global implications. Cities are already the focus of nearly all major economic, social, demographic and environmental transformations. What happens in the cities of the less developed world in coming years will shape prospects for global economic growth, poverty alleviation, population stabilization and environmental sustainability (UNFPA, 2007).

1.2.2 Urbanization in India

Urbanization is taking place at a faster pace after economic liberalization in 1991 in India. India is manifesting a very rapid growth in urban population because of the opportunities presented by the information technology and allied industries. India accounts for a meager 2.4 percent of world surface area of 135.79 million square kilometers, but supports and sustains a whopping 17.5 percent of the world population. Presently about 31.2% of India's population lives in urban areas and it is projected that by the year 2050 nearly 50% of India's population will live in urban centers. The number of towns in India increased from 5,161 in 2001 to 7,935 in 2011. The number of metropolitan cities with a population of one million and above have increased from 35 in 2001 to 50 in 2011 and expected to increase to 87 in 2031 (Census of India, 2011). Urban areas generate more than two-thirds GDP and account for 90% of revenues in India. India is one of the fastest growing economies in the world today and has the potential to become the country having third largest GDP in the world in two decades (Govt. of India, 2011a). India recorded annual growth rate of 7.9 per cent per annum during the 11^{th} Five Year Plan period (2007-2012) and is targeted to grow at average annual growth rate of 8.2 percent per annum during the 12^{th} Five Year Plan period (Business Line, 2012). The investment for urban infrastructure over the period 2012- 2031 is estimated at around 720 billion USD (Government of India, 2011b). Setting up of Special Economic Zones (SEZs) in almost all major urban centers across the country creates employment opportunities and therefore large scale migration to these places further boosts the urbanization process. The phenomenon of urban development is one of the major forces driving land use change. The issue of land use/land cover change in India is of great significance because India's per-capita land resource is far below the world's average.

1.2.3 Urbanization in coastal area of Dakshina Kannada district

Dakshina Kannada (erstwhile South Kanara) is the southern coastal district of Karnataka State with an area of 4866 sq. km. The district lies between 12^0 57' and 13^0 50' North Latitude and 74^0 and 75^0 50' East Longitude. It is about 177 kms, in length and 40 kms in breadth at its narrowest and about 80 kms at its widest part. It has a population of 20,83,625 as per 2011 census. The district is surrounded by Udupi district in the North, Shimoga, Chickmagalur and Hassan districts in the East, Kasaragod district of Kerala state and Coorg district in the South and Arabian Sea in the West. The location map is shown in Fig.1.1.

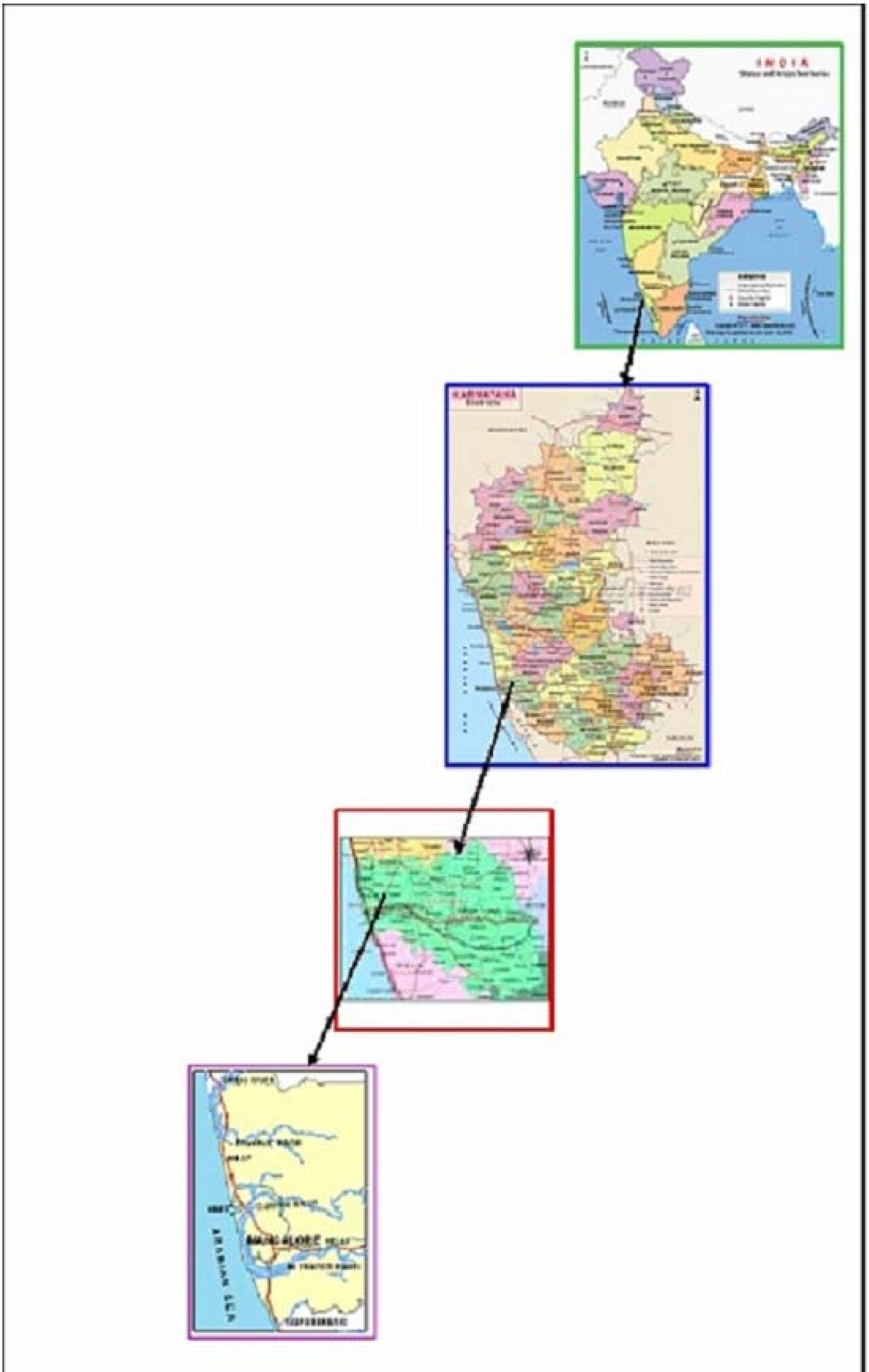


Fig.1.1 Location map

Dakshina Kannada district is having the highest literacy rate in Karnataka (88.62%) and it is well known throughout India for banking and higher and professional educational institutions. It is the second most densely populated district in Karnataka with a population density of 457 persons per sq. km.

The coastal area of Dakshina Kannada (DK) district has witnessed a phenomenal development in the last couple of decades. Increased commercial activity after the setting up of all weather, major sea port at Panambur, and industrial development in the form of petrochemicals, fertilizers, and iron ore pelletisation marked the growth of this area. Further it is expected that the trend of development will continue at a much faster rate due to the proposed setting up and expansion plans of Special Economic Zones (SEZs) in Mangalore. The number of vehicles being registered in DK district is the second highest in Karnataka state. There is an increase of more than 10% every year in the number of vehicles registered. According to Regional Transport Office, Mangalore, while the number of vehicles registered in 2010 and 2011 were around thirty thousands, in the year 2012 up to March itself, thirty five thousand vehicles were registered (The Hindu, 2012).

1.2.4 Mangalore City

Mangalore city is located on the West coast of India and it is the headquarters of DK district. It has Gurpur River on the North, Nethravati River on the South and Arabian Sea on the West. Mangalore has a modern sea port New Mangalore Port Trust (NMPT) at Panambur and an international airport at Bajpe. Mangalore has good rail connections to the rest of the country and is connected with four National Highways. NH-66 connects Mumbai to Kanyakumari through Mangalore and Madgaon (Goa). NH-75 connects Mangalore with Bangalore, NH-169 connects Mangalore with Sholapur and NH-73 connects Mangalore with Tumkur. The major industries located in Mangalore are Mangalore Refineries and Petrochemicals Limited (MRPL), Mangalore Chemicals and Fertilizers (MCF), Kudremukh Iron Ore Company Limited (KIOCL), Badisce Anilin-und Soda Fabric (BASF) India Limited and Sequent Scientific Limited. As per 2001 census, Mangalore city is spread over an area of 132.45 sq. km and has a population of 4,19,306.The decadal growth rate of population in DK district from the year 1991 to 2001 is 14.51%. At present, the domestic and industrial water requirements of the city are met largely from Thumbe vented dam on river Nethravati. This is augmented by ground water tapped from open and bore wells. Many active Non-Governmental Organizations (NGOs) are working for the welfare of the citizens in the study area.

1.3 Environmental impacts of urbanization

Rapid industrialization and urbanization result in many environmental consequences (Chen, 2002). Urbanization is an extreme case of land cover or land use change. Human activity in urban environments has impacts on local scale, including changes in atmospheric composition, impact on the water cycle, and modifying the ecosystems. The Agenda-21 (UNCED, 1992) of United Nations Conference on Environment and Development in Rio de Janeiro, Brazil recognized these roles. Therefore, the Land Use and Land Cover Change (LUCC) was treated as one core project of the International Geosphere Biosphere Programme (IGBP) and International Human Dimensions Programme on Global Environmental Change (IHDP).

Urbanization transforms natural landscape in to artificial landscape, and therefore alters radioactive, thermal, roughness and moisture properties of the surface and the atmosphere above. One of the significant environmental consequences of urbanization is the Urban Heat Island (UHI) effect. Many researchers have suggested that the UHI effect was strongly correlated with land cover conditions (Chen et al. 2006; Xian and Crane, 2006; Xu et al. 2010; Wen et al. 2011).

Urbanization impacts both water quantity and water quality. Land use changes in a watershed can impact water supply by altering hydrological processes such as infiltration, ground water recharge, base flow and runoff. For instance, covering large watershed areas with impervious surfaces frequently result in increased surface runoff and reduced local surface erosion rates. Moreover, watershed development changes land use patterns and reduces the base flow by changing ground water flow pathways to surface water bodies (Lin et al. 2007). Water quality parameters in various aquatic systems have been closely linked to the proportions or types of land uses within the watershed (Tong and Chen, 2002).

1.4 Role of remote sensing in urban growth monitoring

Accurate information on urban growth is essential for urban planning, land and water resources management, market analysis, service allocation etc., But the assessment and monitoring of urbanization and other localized land transformations is extremely difficult at regional and global scales. In many developing countries of the world, including India, there are no regionally accurate figures on land transformations. The conventional surveying and mapping techniques are time consuming and expensive for monitoring the urban growth. The remote sensing technology offers great promise for monitoring land use and land cover changes. This technology provides globally consistent, repetitive measurements of earth surface conditions relevant to climatology, hydrology, oceanography and land cover monitoring. (Masek, et al. 2000).The census data provides information on demographics and economics and the remote sensing imagery provide actual patterns of urban infrastructure. Further, the frequent revisit times of satellite sensors regularly updates the views of urban landscapes ensuring the time-series of urban growth.

1.5 Study area

The study area consists of the coastal region of the DK district in Karnataka state in India, lies between 12°45' N to 13°7'30" N latitude and 74°45' E to 75° E longitude. The location map of the study area is shown in Fig. 1.2. The study area is about 777 square kilometers along the West coast of India with Mulki and Talapadi rivers as Northern and Southern boundaries. The other two major rivers in the study area are Nethravati and Gurpur.

1.5.1 Topography and climate

The average annual rainfall in the study area is 3955 mm of which 87% is received during South-West monsoon (June to September). The climate is tropical with high humidity and the temperatures vary between 17 and 37 degrees Centigrade.The topography of the study area is undulating with dense vegetation. Lateritic soil overlies granitic gneisses and friable sandstones. Alluvial deposits occur along the river courses. The beaches are composed of sand deposits. The mean depth to water table ranges from 7 to 9 m and the mean fluctuation ranges from 6 to 7 m in the study area (Rajesh and Murthy, 1999).

1.5.2 Geology and soils

The rocks in the study area are classified as recent and sub-recent deposits and laterite formations. They include alluvial formations, clays, red and dark clay soils and laterite like or lateroid formations. Laterite like formations covers a fairly large area along the coast and little to the interiors. These rocks are of considerable thickness and they probably represent the alterations of the underlying rocks by process of laterisation and the ferruginous character at the surface is characteristic of such formations. The clays and deposits of shell lime stone are of recent origin. Along the river valleys, clays of different colours are found with alluvial material (South Kanara District Gazette, 1973). Laterite is quarried on large scale in the district and is used as building material. Tile clay of excellent quality is found in the paddy fields, beneath a covering of soil varying from 0.3 to 1.0 meter in thickness at number of places in the district. This clay is used for the manufacture of the famous “Mangalore tiles”.

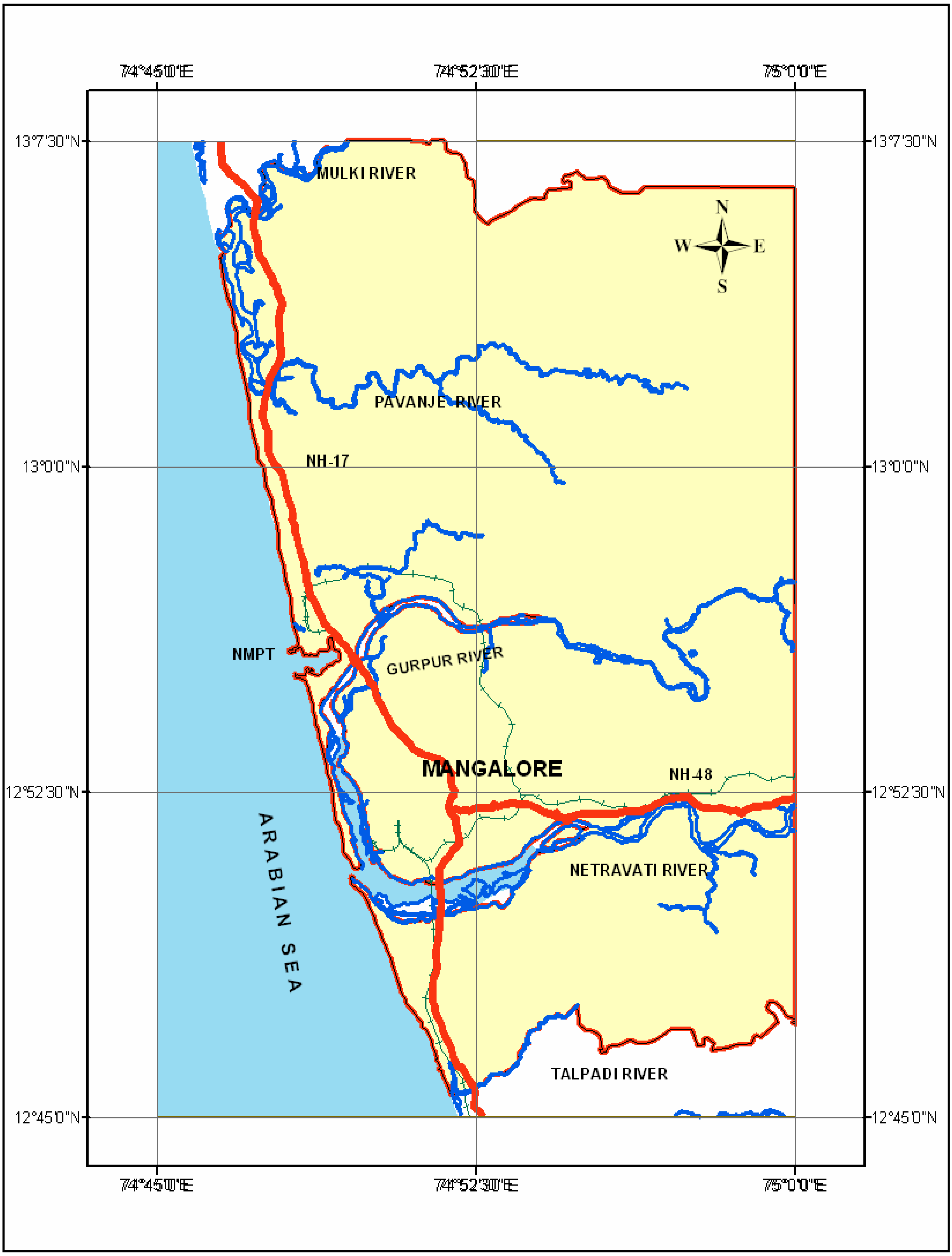


Fig.1.2 Study Area map

1.5.3 Demography

The population in Mangalore urban area has increased from 44 thousands in 1901 to 601 thousands in 2001 (Census of India, 2001). The growth of Mangalore urban population from 1901-2001 is shown in Fig.1.3.The population growth rate which was 1% per year during 1901-1911 has increased to 4% during 1991-2001.

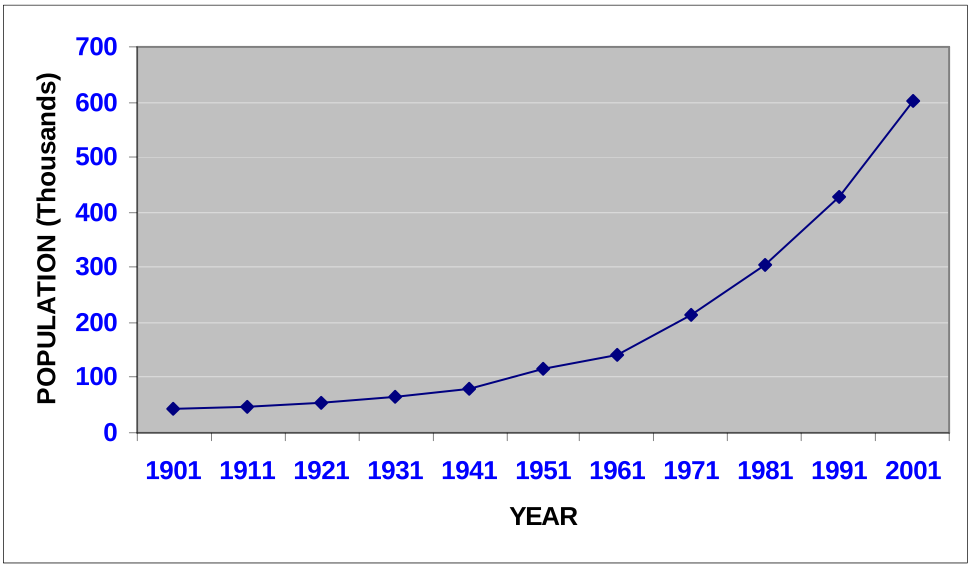


Fig.1.3 Growth of Mangalore Urban Population during 1901-2001

1.6 Research significance

The coastal area of DK district has witnessed a phenomenal development in the last couple of decades and it is expected that this trend will continue at a much faster rate due to the setting up of Special Economic Zones (SEZs) and their expansions in Mangalore. Therefore an attempt was made in this study to detect the land use/land cover changes that have taken place for 25 years from 1983-2008 and to assess the urbanization impacts on water quality.

1.7 Objectives of the study

Keeping in view the above research significance, the following specific objectives were framed for the present study.

1. To detect the Land Use/ Land Cover (LU/LC) changes in the coastal areas of Dakshina Kannada district during 1983-2008 using Remote Sensing data.
2. To study the impacts of changes in land use, urbanization and industrial activities in the coastal regions of Dakshina Kannada district.
3. To study the quality of water in the coastal areas of Dakshina Kannada district.

1.8 Organization of the thesis

The thesis is organized in five chapters and the details are as follows:

Chapter-1 **Introduction**: briefly explains the urbanization trends, describes the study area, research significance and objectives of the study.

Chapter-2 **Literature Review**: reviews the current literature pertaining to the use of remote sensing for urban land use/ land cover change studies and urbanization impacts on groundwater and surface water quality.

Chapter-3 **Materials and Methods**: describes the data used and the detailed methodology adopted for the preparation of land use/land cover maps and states the test methods used in the analysis of water samples.

Chapter-4 **Results and Discussion**: furnishes the results obtained in the study and discusses their relevance.

Chapter-5 **Conclusions**: presents brief conclusions derived from the study.

Annexure-I gives the summary statistics for open wells and **Annexure-II** gives the summary statistics of bore wells water quality monitoring.

Annexure is followed by the detailed **References**, **List of Publications** from the present study, and brief **Curriculum Vitae** of the researcher.

2.1 General

In this chapter, a brief review of the use of remote sensing technology for land use/land cover change and urbanization studies, urbanization impacts on groundwater and on surface water, status of water quality of Mangalore city and review of water quality indices is presented.

2.2 Land Use/Land Cover (LULC) change and Urbanization

During the last two decades remote sensing has been used effectively in combination with Geographical Information Systems (GIS) and Global Positioning System (GPS) for mapping urban areas, modeling urban growth, and assessing land use/land cover change. Imagery from various satellites and sensors were used in urban change analysis. Landsat and Indian Remote Sensing (IRS) were the most widely used satellites in urban change detection studies. Landsat Multi Spectral Scanner (MSS) imagery was used by Mas, 1999. Landsat Thematic Mapper (TM) imagery was used in some studies (Kwarteng and Chavez,1998; Ridd and Liu, 1998; Masak et al. 2000; Ji et al. 2001; Stefanov et al. 2001; Yeh and Li, 2001; Chen et al. 2002; Wilson et al. 2003; Yang and Lo, 2003; Dewidar,2004; Li and Yeh, 2004; Muttitanon and Thripathi, 2005; Kaya and Curran, 2006; Quan Bin et al. 2006; Wu et al. 2006; Braimoh and Onishi, 2007; Yu and Ng, 2007; Michishta et al. 2012). Landsat Enhanced Thematic Mapper plus (ETM+) sensor imagery was used in some others studies (Lu and Weng, 2006; Powell et al. 2007 and Xian, 2007). Combinations of data from different sensors of Landsat satellite have been widely used in urbanization studies like, Landsat MSS with TM data (Chen et al. 2002; Chen et al. 2005; Dietzel et al. 2005; Claudia et al. 2006), Landsat TM with ETM+ data (Davis and Schaub, 2005; Liu et al. 2005; Weng and Lu, 2008; Wilson and Lindsey, 2005; Xian and Crane, 2006; Chen et al. 2006; Xian et al. 2006; Ahanejad et al. 2009; Karolien et al. 2012), and Landsat MSS, TM and ETM+ sensors (Mundia and Ariya, 2005; Yagoub and Giridhar Reddy, 2006; Tang et al. 2007).

Indian Remote Sensing satellites IRS-1C LISS-III and Panchromatic imagery was used by Kontoes et al. (2000), IRS LISS-III imagery by Sudhira et al. (2004), IRC PAN data by Maithani, (2010) and IRS-1C LISS-III with IRS-P6 by Sinha et al. (2011), IRS-P6 LISS IV by Rajesh et al. (2012), IRS Cartosat-I by Suribabu et al. (2012) and Cartosat stereo pairs by Pandey et al. (2012). Combinations of data from Landsat and IRS satellites have been successfully utilized for urban land use/land cover studies. Landsat MSS,TM and IRS LISS-II by Pathan et al.(1993), Landsat TM,ETM+ and IRS LISS-II and LISS-III by Jat et al. (2008a), Landsat MSS,TM,ETM+ and IRS-P6 LISS-III by Joshi et al. (2008) Landsat ETM+ and IRS

LISS-III by Jain et al. (2011), Landsat MSS,TM and IRS-P6 LISS-IV by Kumar et al. (2011), and Landsat MSS, TM, ETM+, IRS-P6 LISS-III data by Punia and Singh, (2012).

The other satellite imagery used in urban growth studies were SPOT imagery (Fung and Siu, 2000; Weber and Puissant, 2003; Chou, 2005) IKONOS imagery (Ellis et al. 2006) and ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) data from Terra satellite (Rehman et al. 2012). Aerial photographs were also utilized in urban land use/land cover studies (Lopez et al. 2001; Hara et al. 2005; Pauleit et al. 2005 and Haregeweyn et al. 2012) and Compact Airborne Spectral Imager (CASI) was used in a study by Ben-dor et al. (2001).

Data obtained from more than one satellite and aerial photographs have been used in urban change analysis. Landsat and SPOT imagery was used by Quarmby and Cushnie, (1989), IKONOS imagery along with aerial photographs by Herold et al. (2003), Landsat ETM+ and IKONOS by Nichol and Wong, (2005), Landsat ETM and Radarsat-1 by Tatem et al. (2005). Landsat TM, Cartosat-1 and Radarsat-1 imagery was utilized by Kamini et al. (2006), aerial photographs, Landsat, SPOT and IKONOS imagery by Rawashdeh and Saleh, (2006), aerial photographs and Landsat MSS by Wenz et al. (2006), Landsat, SPOT, IKONOS imagery and aerial photos by Wilson and Lindsey, (2005), Landsat TM, QUICKBIRD imagery and aerial photos by Wu el al. (2006), Landsat ETM+ and NOAA aerial photographs by Martinuzzi et al. (2007). IRS and CATOSAT-1 data was used by Farooq and Ahmed, (2008), high spatial resolution colour infrared digital aerial image data and LIDAR (Light Detecting and Ranging) data by Zhou et al. (2009), Landsat MSS, TM, IRS LISS-III, PAN data of SPOT, IRS and IKONOS by Dewan et al. (2012), Landsat, IRS, QUICKBIRD imagery by Rehman et al. (2012), Landsat ETM+ and Advanced Land Observing Satellite (ALOS) Phased Array type L-band Synthetic Aperture Radar (PALSAR) data by Zhu et al. (2012).

Supervised classification with maximum likelihood algorithm has been the most widely used classification method in urban land use/land cover studies (Stefanov et al. 2001; Sudhira et al. 2004; Chou et al. 2005; Muttitanon and Thripathi, 2005; Wu et al. 2006; Yagoub and Giridhar Reddy, 2006; Tang et al. 2007; Jat et al. 2008a; Weng and Lu, 2008; Jain et al. 2011; Karolien et al. 2012; Rehman et al. 2012; Suribabu et al. 2012). In some studies, first unsupervised classification was performed to decide the clusters in the image and then supervised classification was carried out (Dewidar et al. 2004; Kaya and Curran 2006; Martinuzzi et al. 2007; Yu and Ng, 2007; Punia and Singh, 2012).

Masek et al. (2000) studied the dynamics of urban growth in the Washington DC metropolitan area during 1973-1996 and estimated that the urban/built-up area surrounding the city has expanded by 22 sq. km per year. Ji et al. (2001) estimated that the urban growth during 1989/1992 and 1996/1997 in China at 1.2 million hectares for the whole of the country and arable land lost due to urban expansion was estimated at 0.867 million hectares. Weber and Puissant (2003) studied the urbanization pressure in Tunis metropolitan area during 1986-1996 and reported an increase in urban/built-up area by 13%. The major environmental impact was the transformation of protected agricultural areas by the multiplication of informed settlements. Dewidar (2004) monitored the land use/ land cover changes for the northern part of the Nile delta, Egypt during 1984-1997 and found that the urban/built-up area has doubled and the sand dunes have decreased due to the reclamation process. Pauleit et al. (2005) investigated the changes in land use and land cover of eleven residential areas in Merseyside, UK between 1975 and 2000 and reported negative environmental impacts for all the areas. On an average, for all the sites, minimum temperatures rose by 0.3^0C and maximum temperatures by 0.9^0C, surface runoff increased by 4%, and vegetation cover lost by 51%. Wilson and Lindsey (2005) showed that the urban development in central Indiana during 1990-2000 had most significant impact on agriculture and grass land, and terrestrial vegetation cover. Wu et al. (2006) investigated the land use change during 1986-2001 in Beijing and indicated that the increase in urban/built-up land resulted in the loss of good quality agricultural land. Martinuzzi et al (2007) studied the urbanization in Puerto Rico Island and found that 11% of the island is covered by urban/built-up surfaces and 40% of the island is experiencing sprawling. Dewan and Yamaguchi (2010) have reported that during 1960-2005 in Dhaka metropolitan of Bangladesh, considerable reduction in wetlands, cultivated lands, vegetation and water bodies took place due to urban expansion. Kumar et al. (2011) analyzed the urban expansion of Ranchi urban agglomeration, India for over a period of about eight decades from 1927 to 2005. The urban/built-up growth of 474% was primarily at the expense of agricultural land and natural water bodies. Karolien et al. (2012) studied the urban growth of Kampala, Uganda and reported that the urban area has increased from 71 sq. km in 1989 to 386 sq. km in 2010 and predicted to increase to 1000 sq. km in 2030.

However, the land use and land cover changes and urbanization trends in the ecologically sensitive coastal area of DK district were not studied by the researchers so far.

2.3 Impacts of urbanization on water quality

Urbanization impacts on groundwater quality includes the increased concentration of major ions, changes in oxidation-reduction conditions, increased concentration of minor elements, increased detection frequencies of Volatile Organic Compounds (VOCs). The adverse impact of land use changes on water quality is more substantial in low urbanized sub-urban areas than those in highly urbanized central cities.

2.3.1 Urbanization impacts on groundwater

Many studies around the world have shown that land use change and urbanization impact water quality. Appleyard (1995) reported that the urban development in the coastal area near Perth, Australia has increased both the magnitude and spatial variability of ground water recharge and has caused significant changes in ground water quality. The recharge in new urban areas was estimated to be about 37% of the average annual rainfall which was greater than the recharge in undeveloped areas. The major ground water quality changes were increase in sulphate and nitrate concentrations, probably caused by the oxidation of soil held sulphides on land cleaning and fertilizer input. Barber et al. (1996) reported that the land use change from natural bush land to urban has resulted in increased nitrate concentrations and incidence of contamination by VOCs derived from urban and industrial developments. Bruce and McMahon (1996) conducted studies on shallow ground water quality beneath a major urban center Denver, Colorado, USA and reported that the sulfate (SO_4) was the predominant anion in most of the samples from the residential and commercial land use settings, where as bicarbonate (HCO_3) was the predominant anion in samples from the industrial land use settings, indicating a possible shift in rodox conditions associated with land use. Highest VOC concentrations occurred in samples from industrial settings. Grischeck et al. (1996) reported the presence of higher concentrations of nitrogen, sulphates and boron as indicators of urban impact on ground water quality. Trojan et al. (2003) showed that land use was the dominant factor affecting shallow ground water quality. Concentrations of several trace inorganic chemicals were greatest under sewered urban areas. VOC detection frequencies were 100% in commercial areas, 52% in sewered residential areas and less than 10% for other land uses. Leung et al. (2005) reported that the groundwater in highly urbanized coastal areas of Hong Kong Island exhibited a high range of Total Dissolved Solids (TDS) and were mainly dominated by Na-Cl and Na-Ca-Cl water types. Groundwater was found to be highly aggressive towards concrete. Additional Ca^{2+} was released to groundwater by corrosion of subsurface concrete materials such as building foundations and basements. In a study carried out in Seoul, Park et al. (2005) showed that the concentration of most trace metals (Fe, Mn, As, Cr, Pb, Cd) and some VOCs were significantly higher in urban areas than in other land uses. Choi et al. (2005) reported that the concentration of TDS was a useful indicator of anthropogenic contamination and it generally increases in the order of forested green zones, agricultural areas, residential areas, traffic areas, and industrial areas. The groundwater chemistry changes from Ca-HCO_3 type to a Ca-Cl (+NO_3) type, generally suggesting that the increase in Cl and NO_3 concentrations is typical of anthropogenically contaminated ground waters. The concentration of all the major ions examined increased with the degree of anthropogenic contamination. Tu et al. (2007) studied the water quality, land use and population variations for three decades in Eastern Massachusetts USA, and found high spatial correlations between water quality indicators (especially specific conductance, Ca, Mg, Na, chlorides and dissolved solids) and urban sprawl indicators. Im et al. (2008) reported an increase in total run-off of 5.5% due to land use change from forest to urban. This was due to the increase in impervious surfaces, the rates of infiltration and evapotranspiration decreased and runoff increased. Jat et al. (2008b) reported that in Jaipur city, India the groundwater level has dropped by 3-16 meters as a result of reduction in groundwater recharge due to increase in impervious surfaces. The concentration of TDS, chlorides, total hardness, nitrates and fluorides increased with urbanization. Jiang et al. (2008) concluded that in the regions where cultivated land was converted into construction land, the pH value and the concentrations of calcium, magnesium, ammonia, bicarbonates, sulphates, nitrates and chlorides increased. Fianko et al. (2009) reported high concentrations of chlorides and total dissolved solids in wells in highly populated residential areas. Johnson and Belitz (2009) correlated urban land use and VOC occurrence in California. Pandit et al. (2009) reported high nitrate concentrations in the densely populated parts of Jaipur city, India and attributed this to improper sewage disposal practices. Agetemor and Agatemor (2010) reported high concentrations of EC, TDS, lead, iron and chromium from four urban centers in Nigeria. Odukoya et al. (2010) reported that the highways constitute a major source of both metallic and nonmetallic pollution of underground water. The concentrations of lead, iron, nitrates, phosphates, sulfates and conductivity from most of the well water samples at 5-meter distance from highway were much higher than the wells which were 3-kilometers from highway. Qian et al. (2011) reported that the urban land use was the main contributing factor for increased phosphate concentrations in groundwater. Anthropogenic activities, including the use of phosphate containing products used by the urban residents, treated and untreated wastewater discharged from factories were responsible for phosphates. Atapour (2012) reported that the concentration of trace metals (Fe, P, Cu, Mo, Pb, Zn, Cr, Co, Ni, Ba, and Sr) in urban groundwater samples were higher than the natural ground water samples.

2.3.2 Urbanization impacts on surface water

Land use and land cover across 28 sub-basins within the Cosumnes watershed, California was studied by Ahearn et al. (2002) and they have concluded that population density contributed to Total Suspended Solids (TSS) loading, but did not have any impact on nitrate-N loading when the sub-watersheds with waste water treatment plants were not included in the analysis. Tong and Chen (2002) revealed a significant relationship between land use and in-stream water quality, especially for nitrogen, phosphorous and fecal coliforms. They showed that agricultural and urban lands produced much higher level of nitrogen and phosphorous than other land uses. Hatt et al. (2004) reported from a study conducted on fifteen streams in Australia that the base flow and stream event concentrations of Dissolved Organic Carbon (DOC), Total Phosphorous (TP), ammonium and Electrical Conductivity (EC) increased with the imperviousness. Schoonover and Lockaby, (2006) from a study conducted in Western Georgia, USA deduced that in watersheds having greater than 24% impervious surfaces, the nutrient and fecal coliform concentrations were higher than those in non-urban watersheds. He et al. (2008) studied the water quality in nine rivers in Xi'an, China and reported increase in organic pollution due to rapid urbanization in the region. Maillard and Santos (2008) studied the water quality parameters in the Velhas river watershed, Brazil and suggested a strong relationship between land use/land cover and turbidity, nitrogen and fecal coliforms. Bhatt and Gardner (2009) reported that higher concentrations of DOC and trace metals like barium and zinc showed strong relationship with human population density in the heavily urbanized Bhagmati river basin in Nepal. Mouri et al. (2011) studied the rural-urban catchments of Shikoku river in Japan and reported higher BOD concentrations in urban regions. The concentrations of Total Nitrogen (TN), Total Phosphorous (TP) and Suspended Solids (SS) in the river increased with the urbanization. Madrinan et al. (2012) suggested that urbanization could be associated with decreasing water turbidity. Seeboonruang (2012) demonstrated that TDS and conductivity are the two important parameters to assess the impact of land use changes on surface water quality.

2.4 Water quality of Mangalore city

The chemical quality of ground water of Mangalore city was investigated by Narayana and Suresh (1989). They concluded that the variation in the ground water chemistry may be attributed to topography with corresponding changes in the vegetative cover and the salt water intrusion. The ground water quality in Dakshina Kannada and Udupi districts was investigated by Sunil and Shrihari (2001) and they concluded that low pH, high iron content, nitrates and chlorides were some of the characteristics of ground water quality. Rajesh and Murthy (2004) have reported the enrichment of chemical constituents in ground water of Mangalore city during 1987-1998. Hegde (2007) attributed the higher values of pH in Gurpur and Nethravati rivers to the influence of fresh rocks in the catchments at higher altitudes, and high Cl^- ions to the anthropogenic sources through land discharge of sewage/effluents. Santhosh and Shrihari (2008) studied the water quality of river Nethravati at eight locations during October 2005 and February 2006 and observed that the impact of human activity was severe on most of the parameters studied. The MPN values exceeded the tolerable limits at almost all the locations. However no comprehensive studies were conducted in the coastal area of DK district covering water quality of sea, river and groundwater.

2.5 Water quality indices

The Water Quality Index is a single numeric score that describes the water quality condition at a particular time and location. Most water quality indices rely on normalizing, or standardizing data parameter by parameter according to expected concentrations and some interpretation of ‘good’ versus ‘bad’ concentrations. Although many water quality indices were developed since 1970s (Ott, 1978; Bhargava, 1983; Cude, 2001; Sargaonkar and Deshpande 2003; Liou et al. 2004; Lumb et al. 2006; Santhosh and Shrihari 2008 etc.) a single globally acceptable water quality index is not available. The United Nations Environment Programme (UNEP) under the Global Environment Monitoring System (GEMS) / Water programme had selected the Canadian Water Quality Index (CWQI) as the model for the development of the global water quality indices. The Canadian model was preferred as it requires the use of a benchmark or guideline which allowed the comparison of values with the World Health Organization’s Drinking Water Quality Guidelines (WHO, 2004). Following the WHO guidelines, the following three global water quality indices were developed.

1. Drinking Water Quality Index (DWQI), which includes all parameters from the WHO guideline including microbes; and

2. Health Water Quality Index (HWQI), in which only health and microbial measurements are included to assess human health issues; and

3. Acceptability Water Quality Index (AWQI), which only includes acceptability criteria.

From a purely human health perspective, the HWQI will provide a more relevant assessment of water quality as it includes only parameters that have the potential to result in adverse health effects in humans. The AWQI will provide assessment of the public's perception of the quality of water, rather than specific health issues, as it assesses parameters that may cause unacceptable taste or odour. These parameters do not necessarily have any detrimental health effects. The DWQI is composed of both the HWQI and AWQI and, as such, will give an overall picture of the quality of water (UNEP GEMS / Water programme).

3.1 General

In this chapter, the methodology for preparation of land use/land cover maps, the details of water quality sampling locations and test methods adopted in the water quality analysis, and the methodology for the determination of global water quality indices are presented.

3.2 Land Use/Land Cover change

3.2.1 Data Used

Conventional data and six Indian Remote Sensing (IRS) cloud free and post-monsoon satellite images were used in this study. The details of conventional data and remote sensing data used in the present study are shown in Table 3.1(a) and Table 3.1(b) respectively.

3.2.2 Methodology

The flow chart for the preparation of Land Use/Land Cover maps is shown in Fig.3.1. Standard image processing techniques in the digital image processing software ERDAS IMAGINE 9.0 ® such as image extraction, rectification, restoration and classification were used in the analysis. Trimble GPS was used for obtaining exact Latitude and Longitude information of Ground Control Points (GCPs). The areas belonging to different classes for the year 1983 were calculated by tracing the toposheets and using electronic planimeter Ushikata® X-PLAN 360d.The population in the study area for the years 1983, 1989, 1997, 2000, 2003, 2006 and 2008 were calculated using Census records of 1981, 1991 and 2001 using the increase in growth per year in that particular decade.

3.2.2.1 Remote sensing data acquisition

For land use/land cover change and urban studies, obtaining images of a near anniversary data is important. The time at which the images were acquired was also considered important since the proceeding status of the newly grown urban areas were to be determined. Keeping these points in view, the screening and selection of images was carried out at National Remote Sensing Centre (NRSC), Hyderabad, India. As very few good cloud free images were available for the coastal areas of DK district, getting exact anniversary date data was not possible. Therefore, the available best cloud free data to the nearest possible anniversary date were selected and purchased from NRSC.

Table 3.1.Details of data used

(a) Conventional data

Description of the data	Source
Toposheet Nos. 48K/16/SE, 48K/16/SW, 48L/13/NE, 48L/13/NW, 48L/13/SE and 48L/13/SW Scale- 1:25,000 Year: 1982-83	Survey of India Government of India, New Delhi
District Census Handbooks Dakshina Kannada district 1981, 1991 and 2001	Directorate of Census Operations, Government of Karnataka, Bangalore

(b) Remote Sensing data

Satellite & Sensor	Date of Pass	Path & Row	Spectral Bands (nm)	Spatial Resolution (m)
IRS 1A LISS- II	21.11.1989	028,058	B:450-520 G:520-590 R:620-680 N:770-860	36
IRS 1C LISS-III	23.01.1997	097,064	G:520-590 R:620-680 N:770-860 S:1550-1700	23.5(G,R,N) 70.5(S)
IRS 1C LISS-III	08.01.2000	097,064	G:520-590 R:620-680 N:770-860 S:1550-1700	23.5(G,R,N) 70.5(S)
IRS 1C LISS-III	19.03.2003	097,064	G:520-590 R:620-680 N:770-860 S:1550-1700	23.5(G,R,N) 70.5(S)
IRS 1C LISS-III	24.01.2006	097,064	G:520-590 R:620-680 N:770-860 S:1550-1700	23.5(G,R,N) 70.5(S)
IRS 1C LISS-III	14.01.2008	097,064	G:520-590 R:620-680 N:770-860 S:1550-1700	23.5(G,R,N) 70.5(S)

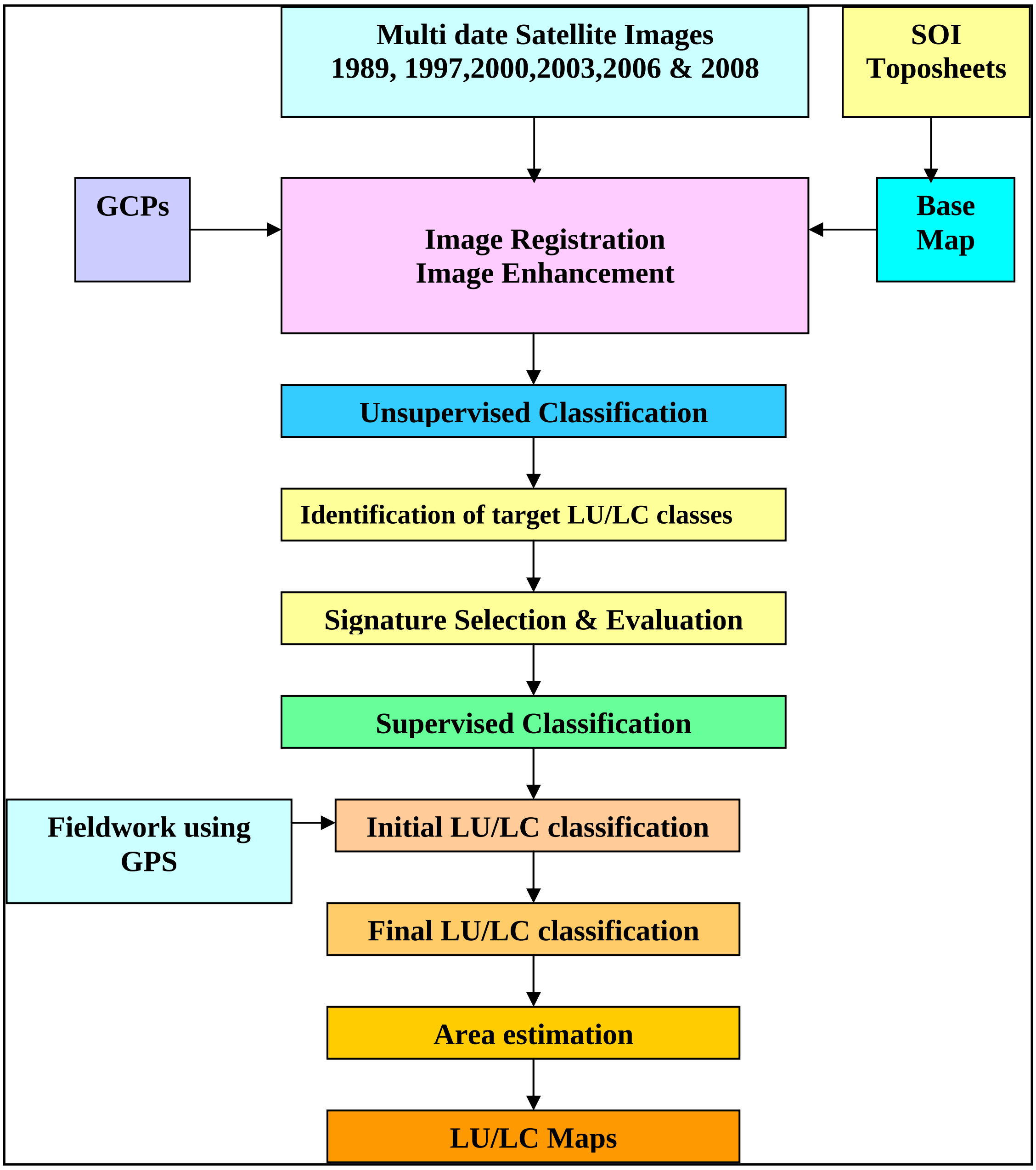


Fig.3.1 Flow diagram showing the methodology for preparation of LU/LC maps

3.2.2.2 Preparation of base map

Six Survey of India toposheets having a scale of 1:25,000 were traced, scanned and then imported in to the ERDAS Imagine environment. Then they were geo-referenced using Geometric projection and Lat/Long spheroid. The base map was prepared from the toposheets by sub-setting and mosaicing.

3.2.2.3 Pre-processing of satellite imagery

Image to map registration was carried out using base map. Then the images were made in to sub-sets of required size and shape as that of the study area. These images were reprojected using Universal Transverse Mercator (UTM) projection in zone 43(72^0 E to 75^0 E) as study area lies in this region. Spatial enhancement was carried out by edge enhancement technique and radiometric enhancement was done by histogram stretch method.

3.2.2.4 Image classification

3.2.2.4.1 Unsupervised classification

A 14-class classification system was followed as suggested in the National Remote Sensing Agency (NRSA) manual with suitable modifications to account for the topography of the study area. First unsupervised classification was done to understand the spectral variations using ISODATA (Iterative Self-Organizing DATa Analysis) algorithms in the image processing software. ISODATA method uses a minimum spectral distance to assign a pixel to a cluster. The resulting clusters were assigned to one of the fourteen classes with the help of the ground truth information.

3.2.2.4.2 Supervised classification

Extensive field work was carried out to gain the knowledge about the study area. The personal experience and long acquaintance of the study area by the research supervisors was an added advantage. Ground truth information was obtained pertaining to all land cover classes using GPS instrument. Signature files for different classes were first created and then evaluated for spectral separability using signature editor, and after much iteration the desired signature files were finalised for use in supervised classification. Then supervised classification was carried out by using three algorithms, namely, Maximum Likelihood, Minimum distance to mean and Mahalanobis distance algorithm.

3.2.2.5 Classification accuracy Assessment

One of the most common means of expressing classification accuracy is the preparation of a classification *error matrix* (*confusion matrix* or a *contingency table*) (Lillesand et al. 2004). The error matrix for each classification was prepared by considering 500 randomly chosen reference points. The producer's accuracies and user's accuracies for different classes were calculated. The *kappa* (KHAT) *statistic* is a measure of the difference between the actual agreement between reference data and automated classifier and the chance agreement between the reference data and random classifier and is an indicator of the extent to which the percentage correct values of an error matrix are due to "true" agreement versus "chance" agreement (Lillesand et al. 2004). The kappa statistic for all the methods of classifications was calculated.

3.3 Water Quality Monitoring

3.3.1 Sample collection

Water samples were collected every month from November 2006 to October 2007 from 125 randomly selected locations in the study area (open well water samples-75, bore well samples-19, surface water samples-19 and sea water samples-12). Sea water samples were collected from a distance of about 100 meters from the high tide line. Many wells in public places and religious places were selected. Surface water samples include samples from all the rivers and ponds in the study area. Nethravati river water was collected from three sampling locations and Gurpur river water from four sampling locations. The latitude and longitude of the sampling locations have been noted using Trimble GPS instrument. The sampling locations of open wells, bore wells, surface water and sea water are shown in Fig. 3.2 to 3.5. The details of sampling locations, like sample ID, latitude and longitude information for open wells, bore wells, surface water and sea water are shown in Tables 3.2 to 3.5 respectively.

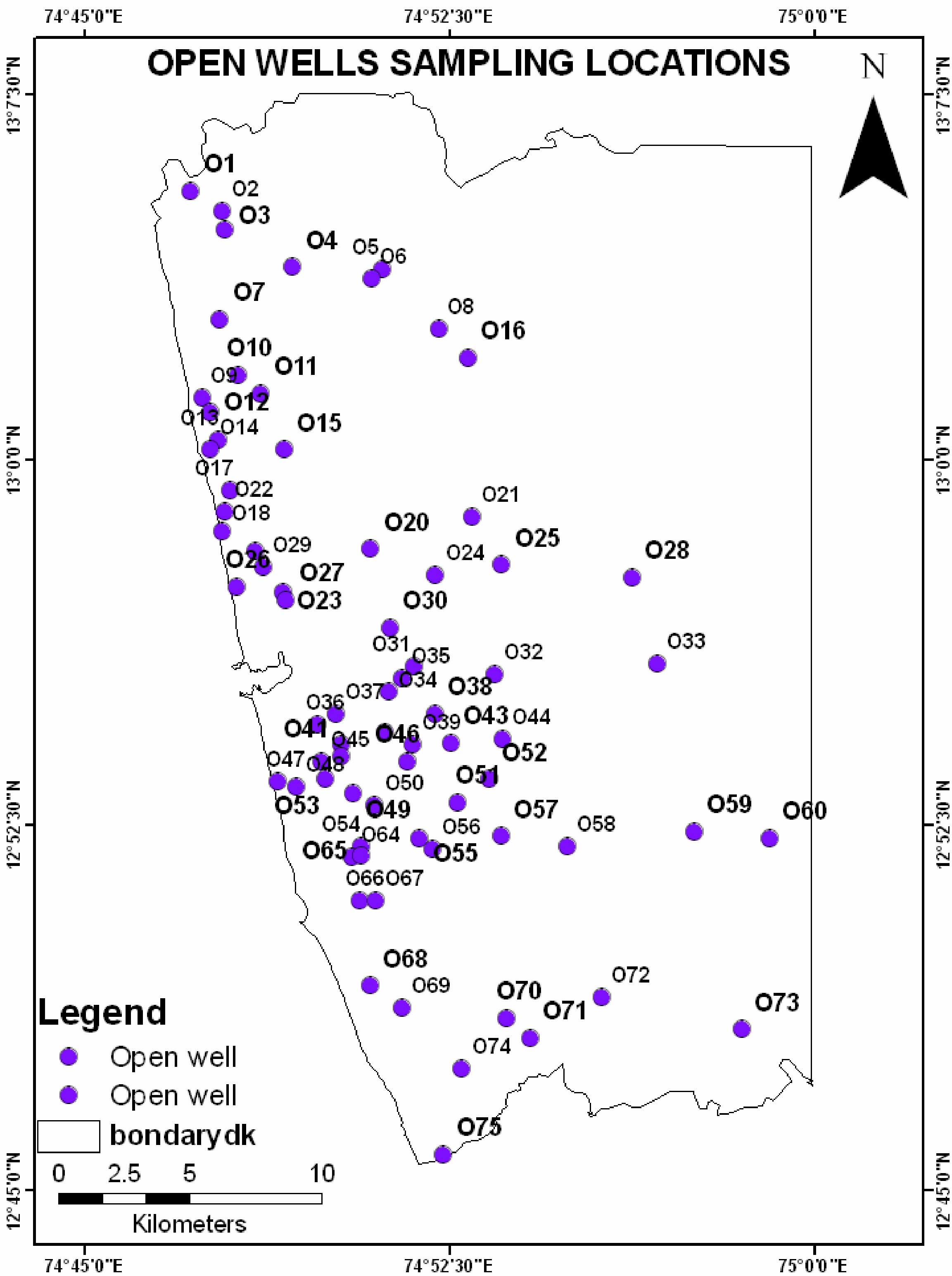


Fig. 3.2 Open wells sampling locations

Table 3.2 List of Open wells sampling locations

Sl.No.	Sample ID	Location	Latitude	Longitude
1	O-01	Mulki	13^0 05' 32.363"	74^0 47' 11.200"
2	O-02	Mulki-Karnad Road	13^0 05' 06.504"	$74^0$47' 49.863"
3	O-03	Kolnad Industrial Area	13^0 04' 11.456"	74^0 47' 53.923"
4	O-04	Punaroor	13^0 03' 56.494"	74^0 49' 14.202"
5	O-05	Kinnigoli-1 (St. Mary Prim. School)	13^0 03' 52.561"	74^0 51' 07.547"
6	O-06	Kinnigoli-2(Sriram Mandir)	13^0 03' 44.402"	74^0 50' 53.821"
7	O-07	Haliyangadi	13^0 02' 54.321"	74^0 47' 46.323"
8	O-08	Kateel	13^0 02' 42.720"	74^0 52' 16.373"
9	O-09	Mukka	13^0 01' 16.145"	74^0 47' 24.536"
10	O-10	Chelar MRPL Colony	13^0 01' 44.455"	74^0 48' 08.754"
11	O-11	Chelaru	13^0 01' 21.133"	74^0 48' 36.159"
12	O-12	NITK-1 Professors Quarters	13^0 00' 57.963"	74^0 47' 34.779"
13	O-13	NITK-2 IV Block Hostel	13^0 00' 24.227"	74^0 47' 44.582"
14	O-14	Thadambail	13^0 00' 12.617"	74^0 47' 34.612"
15	O-15	Katipalla	13^0 00' 01.729"	74^0 49' 25.050"
16	O-16	Permude	13^0 00' 12.786"	74^0 52' 52.210"
17	O-17	Surathkal	12^0 59' 21.990"	74^0 47' 59.281"
18	O-18	Hosabettu	12^0 58' 32.032"	74^0 47' 49.093"
19	O-19	Kulai Primary School	12^0 58' 08.062"	74^0 48' 29.024"
20	O-20	Jokatte	12^0 58' 10.343"	74^0 50' 52.331"
21	O-21	Bajpe	12^0 58' 49.351"	74^0 52' 57.305"
22	O-22	Idya	12^0 58' 56.124"	74^0 47' 52.915"
23	O-23	Baikampady-1	12^0 57' 16.160"	74^0 49' 04.279"
24	O-24	Karambar	12^0 57' 38.047"	74^0 52' 14.727"
25	O-25	Bajpe Airport	12^0 57' 50.526"	74^0 53' 33.591"
26	O-26	Chitrapur	12^0 57' 23.416"	74^0 48' 07.302"
27	O-27	Baikampady-2	12^0 57' 06.880"	74^0 49' 08.075"
28	O-28	Kaikamba	12^0 57' 35.000"	74^0 56' 15.000"
29	O-29	Panambur	12^0 56' 48.052"	74^0 48' 38.915"
30	O-30	Kunjathbail	12^0 56' 32.999"	74^0 51' 16.211"
31	O-31	Jyothinagar-Markada	12^0 55' 45.000"	74^0 51' 45.000"
32	O-32	Mudushedde	12^0 55' 35.373"	74^0 53' 24.634"
33	O-33	Kanjilkudil	12^0 55' 49.342"	74^0 56' 46.082"
34	O-34	Shanthinagara	12^0 55' 15.000"	74^0 51' 15.000"
35	O-35	Kavoor	12^0 55' 30.000"	74^0 51' 30.000"
36	O-36	Kodical	12^0 54' 34.261"	74^0 49' 47.361"
37	O-37	Kottara Chowk	12^0 54' 47.270"	74^0 50' 09.367"
38	O-38	Padavinangadi	12^0 54' 46.763"	74^0 52' 11.162"
39	O-39	Patchanadi	12^0 54' 47.148"	74^0 53' 23.113"
40	O-40	Ashoknagar-Kodical Road	12^0 54' 08.594"	74^0 49' 55.894"

Sl.No.	Sample ID	Location	Latitude	Longitude
41	O-41	Urva Stores	12^0 53' 55.007"	74^0 50' 15.317"
42	O-42	Landlinks	12^0 54' 23.884"	74^0 51' 09.652"
43	O-43	Shakthinagar	12^0 54' 11.415"	74^0 52' 31.502"
44	O-44	Kudupu	12^0 54' 15.087"	74^0 53' 34.442"
45	O-45	Ashoknagar-Kodical Road	12^0 53' 48.550"	74^0 49' 51.237"
46	O-46	Yeyyadi Industrial Area	12^0 53' 48.213"	74^0 51' 37.298"
47	O-47	Thannirbavi	12^0 53' 23.922"	74^0 48' 56.716"
48	O-48	Sulthan Battery	12^0 53' 17.390"	74^0 49' 20.894"
49	O-49	KSRTC Bus Stand	12^0 53' 08.512"	74^0 50' 30.816"
50	O-50	Kadiri	12^0 52' 53.512"	74^0 50' 57.421"
51	O-51	Maroli	12^0 52' 57.754"	74^0 52' 39.833"
52	O-52	Kulashekhara	12^0 53' 26.094"	74^0 53' 18.304"
53	O-53	Kudroli	12^0 52' 33.814"	74^0 49' 55.781"
54	O-54	Milagre's Church	12^0 52' 02.942"	74^0 50' 40.608"
55	O-55	Pumpwell Circle	12^0 52' 12.860"	74^0 51' 52.555"
56	O-56	Kankanady R.S.	12^0 52' 00.212"	74^0 52' 52.508"
57	O-57	Padil	12^0 52' 15.996"	74^0 53' 32.865"
58	O-58	Adyar	12^0 52' 04.065"	74^0 54' 55.197"
59	O-59	Farangipet	12^0 52' 21.971"	74^0 57' 31.091"
60	O-60	Thumbe	12^0 52' 14.395"	74^0 59' 04.420"
61	O-61	Madankapu	12^0 53' 09.957"	75^0 01' 06.829"
62	O-62	B.C. Road	12^0 52' 50.771"	75^0 01' 21.175"
63	O-63	Bantwal	12^0 53' 46.631"	75^0 02' 29.397"
64	O-64	Railway Colony	12^0 51' 49.873"	74^0 50' 29.543"
65	O-65	Mangalore R.S.	12^0 51' 51.854"	74^0 50' 40.138"
66	O-66	Mangaladevi	12^0 50' 57.328"	74^0 50' 39.138"
67	O-67	Jappinamogaru	12^0 51' 00.021"	74^0 51' 57.732"
68	O-68	Ullal Dargah	12^0 49' 11.775"	74^0 50' 52.227"
69	O-69	Thokkottu-Kapikad	12^0 48' 44.218"	74^0 51' 31.007"
70	O-70	Derlakatte	12^0 48' 31.916"	74^0 53' 40.031"
71	O-71	Natekal	12^0 48' 07.494"	74^0 54' 08.832"
72	O-72	Mangalore University	12^0 48' 58.599"	74^0 55' 36.687"
73	O-73	Mudupu-Mulur	12^0 48 '18"	74^0 58' 30"
74	O-74	Someshwar	12^0 47' 30.093"	74^0 52' 45.148"
75	O-75	Talapadi	12^0 45' 43.709"	74^0 52' 22.148"

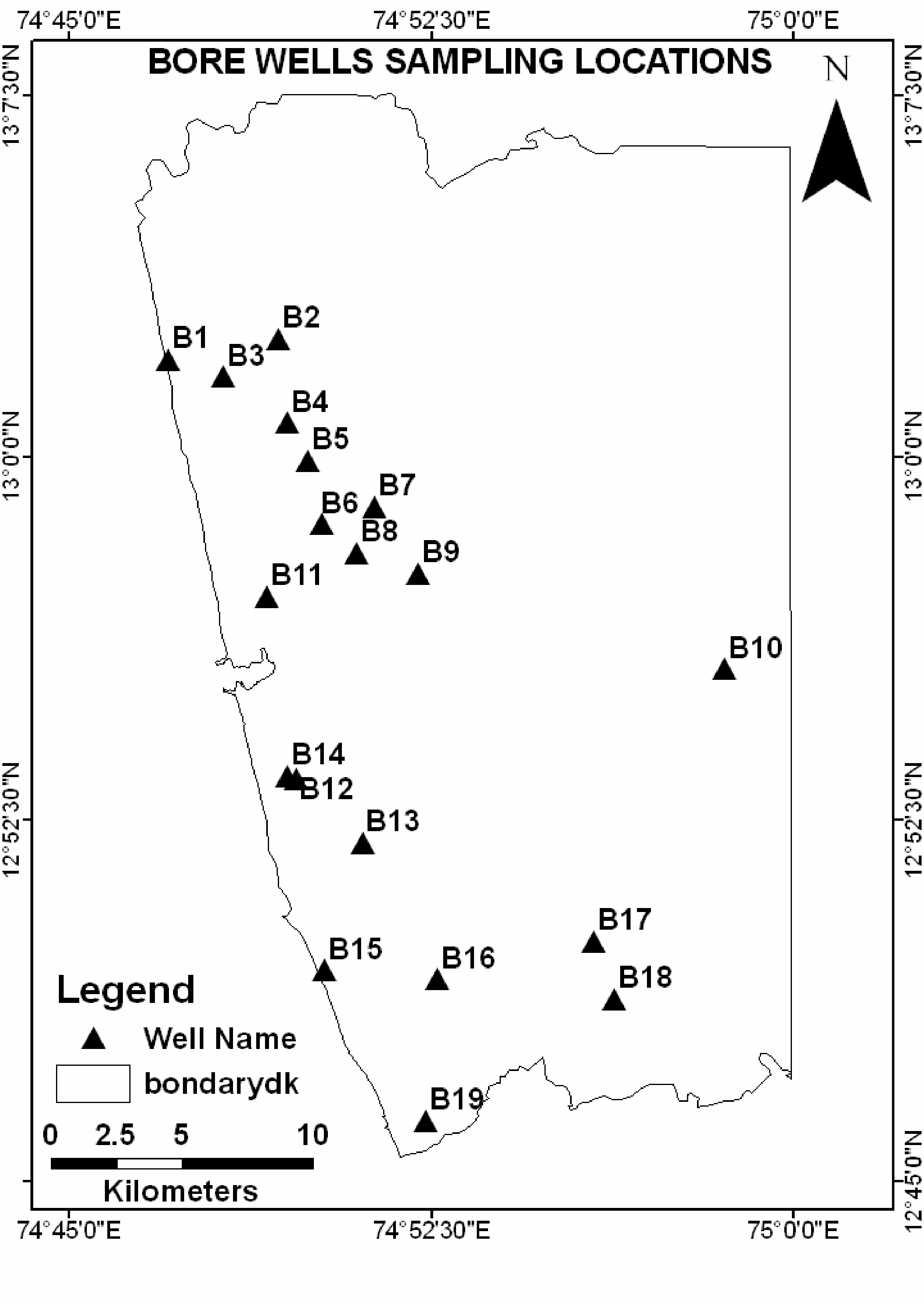


Fig. 3.3 Bore wells sampling locations

Table 3.3 List of Bore wells sampling locations

Sl.No.	Sample ID	Location	Latitude	Longitude
1	B-01	Shasihitulu	13^0 02' 01.427"	74^0 47' 04.023"
2	B-02	Pakshikere	13^0 02' 29.149"	74^0 49' 20.421"
3	B-03	Chelaru	13^0 01' 42.402"	74^0 48' 11.084"
4	B-04	Surinje	13^0 00' 43.775"	74^0 49' 28.833"
5	B-05	Katipalla-Kaikamba Road	12^0 59' 59.818"	74^0 49' 56.942"
6	B-06	Mangalpet	12^0 59' 37.811"	74^0 50' 12.593"
7	B-07	Kalavar	12^0 58' 57.015"	74^0 51' 19.841"
8	B-08	Jokatte	12^0 58' 10.585"	74^0 50' 56.438"
9	B-09	Karambar	12^0 57' 35.902"	74^0 52' 12.904"
10	B-10	Badakabail	12^0 55' 37.734"	74^0 58' 33.840"
11	B-11	Kodical Katte	12^0 54' 25.953"	74^0 49' 04.081"
12	B-12	ISKCON	12^0 53' 21.976"	74^0 49' 41.231"
13	B-13	Galaxy Apartments	12^0 52' 00"	74^0 51' 05"
14	B-14	Bengre	12^0 53' 23.922"	74^0 49' 30.135"
15	B-15	Ullal – Kotepura Road	12^0 49' 23.954"	74^0 50' 15.239"
16	B-16	Kuttara	12^0 49' 10.347"	74^0 52' 38.808"
17	B-17	Gramachavadi	12^0 49' 58"	74^0 55' 52"
18	B-18	Pajira	12^0 48' 45"	74^0 56' 15"
19	B-19	K C Nagara	12^0 46' 16.273"	74^0 52' 21.855"

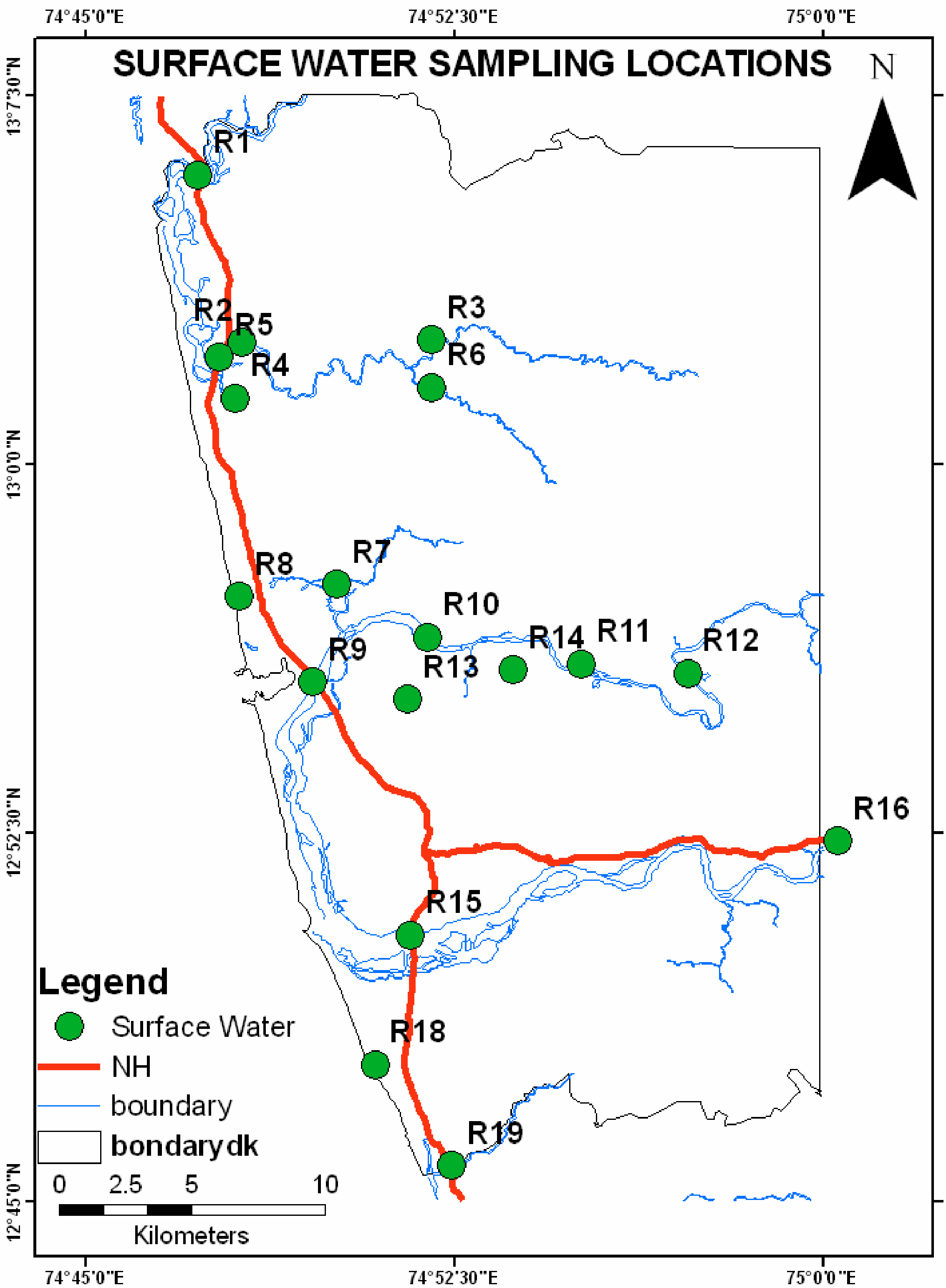


Fig. 3.4 Surface water sampling locations

Table 3.4 List of Surface water sampling locations

Sl.No.	Sample ID	Location	Latitude	Longitude
1	R-01	Shambhavi River (Mulki Bridge on NH-66)	13^0 05' 52.620"	74^0 47' 16.444"
2	R-02	Pavanje Vented Dam	13^0 02' 29.149"	74^0 48' 11.365"
3	R-03	Nandini River	13^0 02' 33.103"	74^0 52' 02.677"
4	R-04	Mahalingeshwara Tank	13^0 02' 11.635"	74^0 47' 40.354"
5	R-05	Pavanji River (Bridge on NH-66)	13^0 01' 56.464"	74^0 47' 34.667"
6	R-06	Yekkar River	13^0 01' 33.522"	74^0 52' 01.405"
7	R-07	Thokkur Stream	12^0 57' 32.437"	74^0 50' 06.613
8	R-08	Chitrapur Nala	12^0 57' 18.169"	74^0 48' 07.717"
9	R-09	Gurpur River (Kulur Bridge on NH-66)	12^0 55' 35.093"	74^0 49' 37.122"
10	R-10	Gurpur River (Maravoor Bridge)	12^0 56' 27.157"	74^0 51' 57.710"
11	R-11	Gurpur River (Gurpura Bridge on NH- 169)	12^0 55' 56.427"	74^0 55' 06.076"
12	R-12	Gurpur River (Addur Bridge)	12^0 55' 44.205"	74^0 57' 13.958"
13	R-13	Kavoor Kere	12^0 55' 10.293"	74^0 51' 33.484"
14	R-14	Pilikula Lake	12^0 55' 48.359"	74^0 53' 42.580"
15	R-15	Nethravati River (Bridge on NH-66)	12^0 50' 25.328"	74^0 51' 35.756"
16	R-16	Nethravati River (Thumbe Vented Dam)	12^0 52' 20.341"	75^0 00' 17.912"
17	R-17	Nethravati River (Pane Mangalore Bridge on NH-75)	12^0 52' 48.487"	75^0 02' 22.316"
18	R-18	Someshwara Temple Tank	12^0 47' 45.093"	74^0 50' 53.395"
19	R-19	Talapadi River (Bridge on NH-66)	12^0 45' 42.899	74^0 52. 24.626

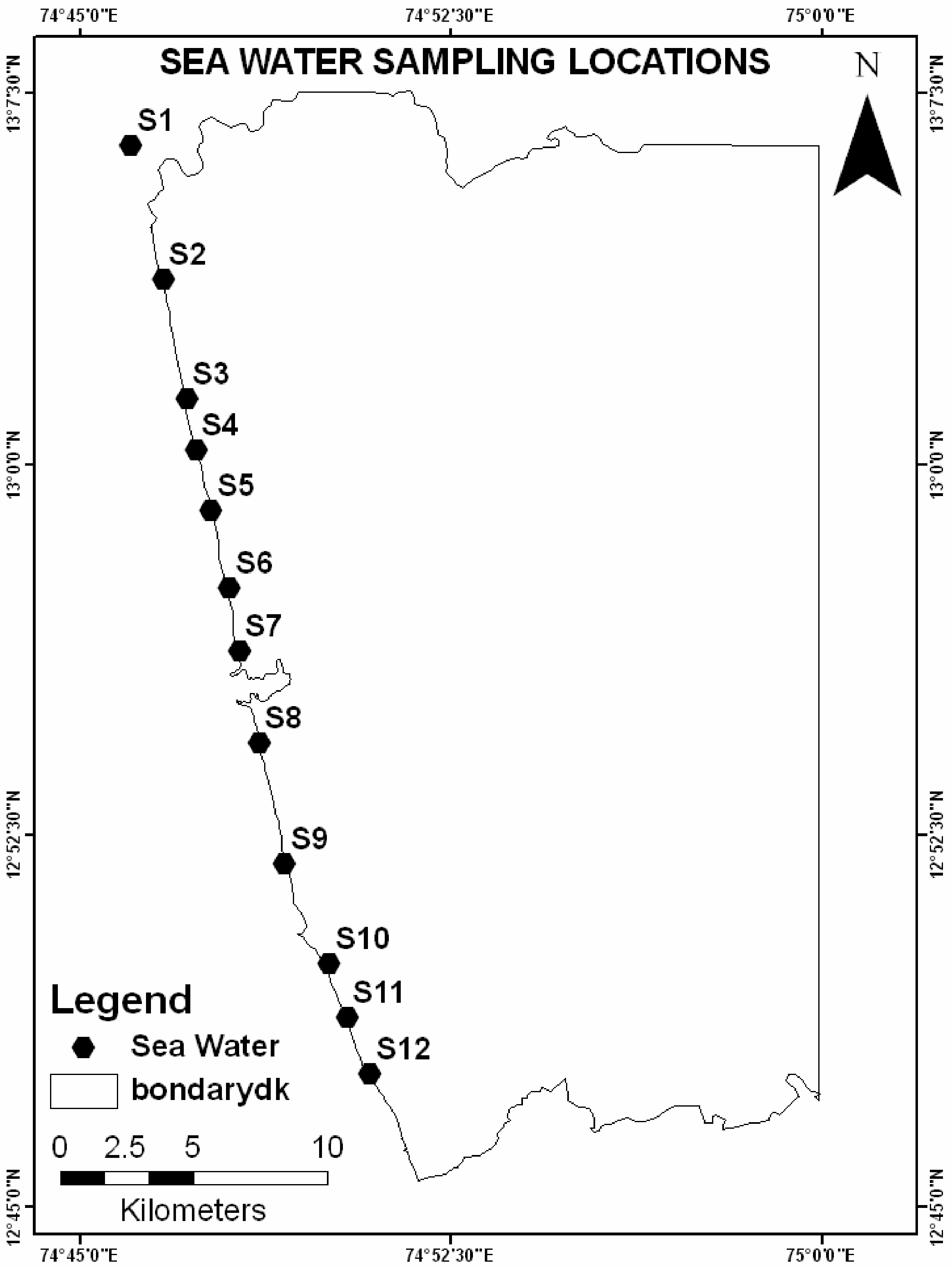


Fig. 3.5 Sea water sampling locations

Table 3.5 List of Sea water sampling locations

Sl.No.	Sample ID	Location	Latitude	Longitude
1	S-01	Hejamadi	13^0 06' 26.261"	$74^0$46' 02.882"
2	S-02	Shasihitulu	13^0 03' 43.872"	74^0 46' 41.365"
3	S-03	Mukka	13^0 01' 17.970"	740 47' 10.211"
4	S-04	Surathkal	13^0 00' 16.454"	74^0 47' 21.216"
5	S-05	Idya	12^0 59' 03.987"	74^0 47' 40.165"
6	S-06	Chitrapur	12^0 57' 29.043"	74^0 48' 02.653"
7	S-07	Panambur	12^0 56' 12.568"	74^0 48' 14.216"
8	S-08	Thannirbavi	12^0 54' 21.115"	74^0 48' 37.895"
9	S-09	Bengre	12^0 51' 55.540"	74^0 49' 09.053"
10	S-10	Kotepura	12^0 49' 53.737"	74^0 50' 02.261"
11	S-11	Ullal	12^0 48' 48.133"	74^0 50' 24.381"
12	S-12	Someshwara	12^0 47' 40.443"	74^0 50' 52.353"

The details of total number of samples collected and analyzed are shown in Table.3.6. The sample collection, preservation and analysis were carried out as per the methods prescribed in the *Standard Methods* (APHA, 1998).

Table 3.6 Details of number of samples analyzed

Type of sample	No. of samples analyzed
Open well samples	900
Bore well samples	228
Surface water samples	228
Sea water samples	144
Total number of samples	1500

3.3.2 Water quality analysis

The water samples were analyzed for twenty five physico-chemical and bacteriological characteristics as per the procedures given in *Standard Methods* (APHA, 1998). The list of the tests performed, the methods and instruments used are shown in Table 3.7.

Table 3.7 Test Methods Used in the Analysis of Water Samples

Sl. No.	Parameter	Method used	Instruments Used	Reference to *Standard Methods*(APHA,1998)
1.	pH	In situ measurement	Hanna Combo PH & EC	Sec.4500 B; 4-87
2.	Temperature	In situ measurement	Hanna Combo PH & EC	Sec.2550 B; 2-61
3.	Conductivity	In situ measurement	Hanna Combo PH & EC and Elico Water Quality Analyser PE 136	Sec.2510 B; 2-46
4.	TDS	In situ measurement	Hanna Combo PH & EC and Elico Water Quality Analyzer PE 136	Sec.2540 C; 2-56
5.	DO	Membrane Electrode Method	Lovibond Senso Direct Oxi 200	Sec.4500-O G(4-134)
6.	Turbidity	Nepholometric method	Systronics Digital Nephelo-Turbidity Meter 132	Sec.2130 B(2-9)
7.	Total Alkalinity	Titration method		Sec.2320 (2-27)
8.	Chlorides	Argentometric method		Sec.4500Cl – B(4-67)
9.	Total Hardness	EDTA Titrimetric method		Sec.2340 C(2-37)
10.	Sulfates	Turbidimetric method	Systronics Spectrophotometer 169	Sec.4500 E(4- 178)
11.	Nitrates	Brucine method	Lovibond Spectrophotometer PC Spectro	Sec.4500 (4-114)
12.	Fluorides	Ion-selective Electrode method	Orion Expandable Ion Analyzer EA-940	Sec.4500 F- C(4-81)
13.	Iron	Phenanthroline method	Lovibond Spectrophotometer PC Spectro	Sec.3500-Fe (3-75)
14.	Manganese	Persulfate method	Lovibond Spectrophotometer PC Spectro	Sec.3500-Mn (3-83)
15.	Sodium	Flame Photometric method	Systronics Flame Photometer 128	Sec.3500-Na B(3-98)
16.	Potassium	Flame Photometric method	Systronics Flame Photometer 128	Sec.3500-K B(3-87)
17.	Calcium	Flame Photometric method	Systronics Flame Photometer 128	Sec.3500-Ca A(3-63)
18.	Magnesium	Calculation method		Sec.3500-Mg (3-82)
19.	Cadmium	Anodic Stripping Voltammetry (ASV)	Metrohm 797 VA Computrace	Sec.3130 (3-52)

20.	Copper	Anodic Stripping Voltammetry (ASV)	Metrohm 797 VA Computrace	Sec.3130 (3-52)
21.	Lead	Anodic Stripping Voltammetry (ASV)	Metrohm 797 VA Computrace	Sec.3130 (3-52)
22.	Zinc	Anodic Stripping Voltammetry (ASV)	Metrohm 797 VA Computrace	Sec.3130 (3-52)
23.	Salinity	Calculation method		Sec.2340 C (2-37)
24.	Total Coliforms	Multiple Tube Fermentation Technique		Sec.9221 (9-47)
25.	Fecal Coliforms	Multiple Tube Fermentation Technique		Sec.9221 (9-47)

3.4 Determination of Global Water Quality Indices

The global water quality indices are based on the water quality index (WQI) endorsed by the Canadian Council of Ministers of the Environment (CCME, 2001). The indices allow measurements of the frequency and extent to which parameters exceed their respective guidelines at each monitoring station. Therefore, the index reflects the quality of water for both health and acceptability, as set by the World Health Organization. The Canadian Water Quality Index is calculated using three factors: scope (F1) the percentage of parameters that exceed the guideline, frequency (F2) the percentage of individual tests within each parameter that exceeded the guideline and amplitude (F3) the extent (excursion) to which the failed test exceeds the guideline.

The index equation generates a number between 1 and 100, with 1 being the poorest and 100 indicating the best water quality. Within this range, designations have been set by CCME (2005) to classify water quality as poor, marginal, fair, good or excellent. These same designations were adopted for the indices determined here. The designations are presented in Table 3.8.

Table 3.8 WQI Designations (CCME, 2005)

Designation	Index Value	Description
Excellent	95-100	All measurements are within objectives virtually all the time
Good	80-94	Conditions rarely depart from natural or desirable levels
Fair	65-79	Conditions sometimes depart from natural or desirable levels
Marginal	45-64	Conditions often depart from natural or desirable levels
Poor	0-44	Conditions usually depart from natural or desirable levels

The WHO guidelines divide water quality parameters into two categories:

i. Health guidelines, which take into account chemical and radiological constituents that have the potential to directly adversely affect human health; and

ii. Acceptability guidelines, which include parameters that may not have any direct health effects but result in objectionable taste or odour in the water (WHO, 2004). The World Health Organization (WHO) guidelines for water quality are presented in Table3.9.

Canadian Council of Ministers for the Environment (CCME, 2001) recommended that a water quality index should be calculated for a station only when a minimum of four parameters were analyzed and four sampling visits per year were conducted. In the present study seven parameters (Cadmium, Copper, Fecal Coliform Bacteria (FCB), Fluorides, Lead, Manganese and Nitrates were considered for determination of Health Water Quality Index (HWQI), nine parameters (Chlorides, Hardness, Iron, pH, Sodium, Sulfates, TDS, Turbidity and Zinc) were considered for determination of Acceptability Water Quality Index (AWQI) and all the above sixteen parameters were considered for calculation of Drinking Water Quality Index (DWQI). All the parameters were measured twelve times in one year.

Table 3.9 World Health Organization Drinking Water guidelines (WHO, 2004)

Parameter	Unit	Guideline	Guideline Type
Cadmium	μg/L	3	Health
Chlorides	mg/L	250	Acceptability
Copper	μg/L	2000	Health
FCB	per 100 ml	0	Health
Fluorides	mg/L	1.5	Health
Hardness	mg/L	200	Acceptability
Iron	mg/L	0.3	Acceptability
Lead	μg/L	10	Health
Manganese	μg/L	400	Health
Nitrates	mg/L	50	Health
pH		6.5-8.0	Acceptability
Sodium	mg/L	200	Acceptability
Sulfates	mg/L	250	Acceptability
TDS	mg/L	600	Acceptability
Turbidity	NTU	5	Acceptability
Zinc	mg/L	3	Acceptability

4.1 General

In this chapter, the land use/land cover changes in the study area during the years 1983-2008, urbanization and its driving forces, urban growth predictions, water quality changes in the region and the determination of global water quality indices and their significance are presented.

4.2 Land Use/Land Cover (LU/LC) change

The areas belonging to different classes for the year 1983 were calculated by tracing the toposheets and using electronic planimeter Ushikata® X-PLAN 360d. The areas under different classes in the years 1983, 1989, 1997, 2000, 2003, 2006 and 2008 are furnished in Table 4.1. The problem of class separability / intermixing was faced with regard to urban versus sand and wetlands versus mangroves and this has been resolved by incorporating the ground truth information from several field visits. The Land use/Land Cover maps of coastal area of DK district for the years 1989, 1997, 2000, 2003, 2006 and 2008 are shown in Figures 4.1 to 4.6.

Table 4.1 LU/LC change in the coastal area of DK district during 1983-2008

Class	Area in sq. km in each class in Year						
	1983	1989	1997	2000	2003	2006	2008
Urban/Built-up land	36.09	40.36	56.43	73.18	90.35	110.41	133.68
Crop Land	85.26	83.76	69.99	48.66	45.83	39.04	34.95
Agricultural Plantation	34.05	46.83	68.90	74.14	75.83	79.15	82.81
Evergreen/Semi-evergreen forest	66.61	63.14	61.03	59.48	58.45	56.28	54.51
Deciduous forest	112.15	105.79	99.64	97.76	93.56	88.24	86.11
Degraded or scrub land	71.92	72.90	82.11	71.00	77.01	83.57	75.66
Forest plantation	5.05	15.66	24.30	33.62	44.55	48.65	53.93
Mangrove	71.46	68.85	45.45	42.20	40.37	37.22	35.15
Marshy/Swampy land	43.10	35.48	22.08	67.77	43.38	31.80	21.08
Land with or without scrub	98.45	92.62	85.39	37.84	43.16	51.77	47.85
Sandy area	9.30	11.59	11.03	10.23	15.60	8.43	7.39
Barren rocky/Sheet rock	113.29	105.62	100.06	85.82	72.69	57.77	39.12
River/Tank	20.93	23.21	20.46	22.56	18.44	22.57	23.22
Open Quarry	9.42	11.24	30.19	52.78	57.83	62.16	81.60
Total (in sq. km)	**777.06**	**777.06**	**777.06**	**777.06**	**777.06**	**777.06**	**777.06**

4.2.1 Land use / Land Cover change during 1983-1989

During this period the urban/built-up area has been increased by 12%, agricultural plantations have increased by 38%, forest plantations have doubled and open quarries have increased by 19%. Marshy lands have reduced by 11% and land with or without scrub have reduced by 9%. The major driving forces for this period were the increased commercial activity due to the expansion of all weather sea port, New Mangalore Port Trust (NMPT) at Panambur, starting of major industries like Mangalore Chemicals and fertilizers (MCF) and Kudremukh Iron Ore Company Limited (KIOCL), beginning of new railway line connecting Mangalore and Hassan, up gradation of Mangalore municipality to Mangalore City Corporation, establishment of Mangalore University at Mangalagangotri and the industrial estate at Baikampady. The land use/land cover map for the year1989 is shown in Fig.4.1.

4.2.2 Land use / Land Cover change during 1989-1997

The major industries like Mangalore Refineries and Petrochemicals Limited (MRPL) and Badische Anilin- und Soda-Fabrik (BASF) India Limited have been started in the study area during this period. This has boosted the growth of places like Surathkal in the study area. The population of Surathkal town in the study has shown decennial increase of over 115% during the years 1981-1991. Infosys has started its Mangalore office at Kottara in the year 1995. There is a sharp increase of 40% in urban area during this eight years period. The area under agricultural crop land has reduced by 16% but the area under agricultural plantations has been increased by 47%. Forest plantations have increased by 55%. Area under mangroves has reduced by 33% and the area under barren rock / sheet rock has reduced by 19%. The area of open quarries has increased by 1.7 times. The industrialization has been the main driving force for the development during this period. The land use/land cover maps for the years 1989 and 1997 are shown in Fig.4.1. and 4.2. respectively.

4.2.3 Land use / Land Cover change during 1997-2000

The urban/built-up area has increased by 30%, forest plantations have increased by 38% and open quarries have increased by 75% during 1997-2000. Commissioning of Konkan Railway connecting Mangalore directly to Mumbai through Goa in the year 1998 has boosted the development during this period. The area under agricultural crop land has come down by 30%, the degraded or scrub land by 14% and land with or without scrub by 17%. The land use/land cover maps for the years 1997 and 2000 are shown in Fig.4.2 and 4.3. respectively.

4.2.4 Land use / Land Cover change during 2000-2003

During this period, the built up area has been increased by 23%, forest plantations by 32% and open quarries by 10%. Sandy area has increased by 52% and area under water has decreased by 18%. The year 2002 recorded the lowest rainfall of 3069 mm. As per the records of the Nethravati river gauging station at Bantwal there was no water flow in river in the year during from January to June 2003. The land use/land cover maps for the years 2000 and 2003 are shown in Fig.4.3. and 4.4. respectively.

4.2.5 Land use / Land Cover change during 2003-2006

The urban/built-up area has been increased by 22%, forest plantations by 9% and open quarries by 7%. The area under barren rock/ sheet rock has reduced by 20% and area under crop land by 15%. The land use/land cover maps for the years 2003 and 2006 are shown in Fig.4.4 and 4.5. respectively.

4.2.6 Land use / Land Cover change during 2006-2008

Setting up of Mangalore Special Economic Zone (MSEZ) for petrochemicals and SEZ for Information Technology (IT) and IT enables services (ITES) at Mudipu near Mangalore University has boosted the growth of this region. During these two years only the urban area has increased by 21%. Four laning of National Highway-66 from National Institute of Technology Karnataka Surathkal to BC Road on NH-75 and road widening works taken up in Mangalore city have contributed to the increase in urban/built-up area. Mangalore is emerging as alternate destination to Bangalore for IT and ITES services. The traffic has increased so much that it necessitated construction of seven fly-overs in the study area. The area under agriculture has come down by 10%, land with or without scrub has decreased by 8% and barren rocky areas have reduced by 32%. The land use/land cover maps for the years 2006 and 2008 are shown in Fig.4.5. and 4.6. respectively.

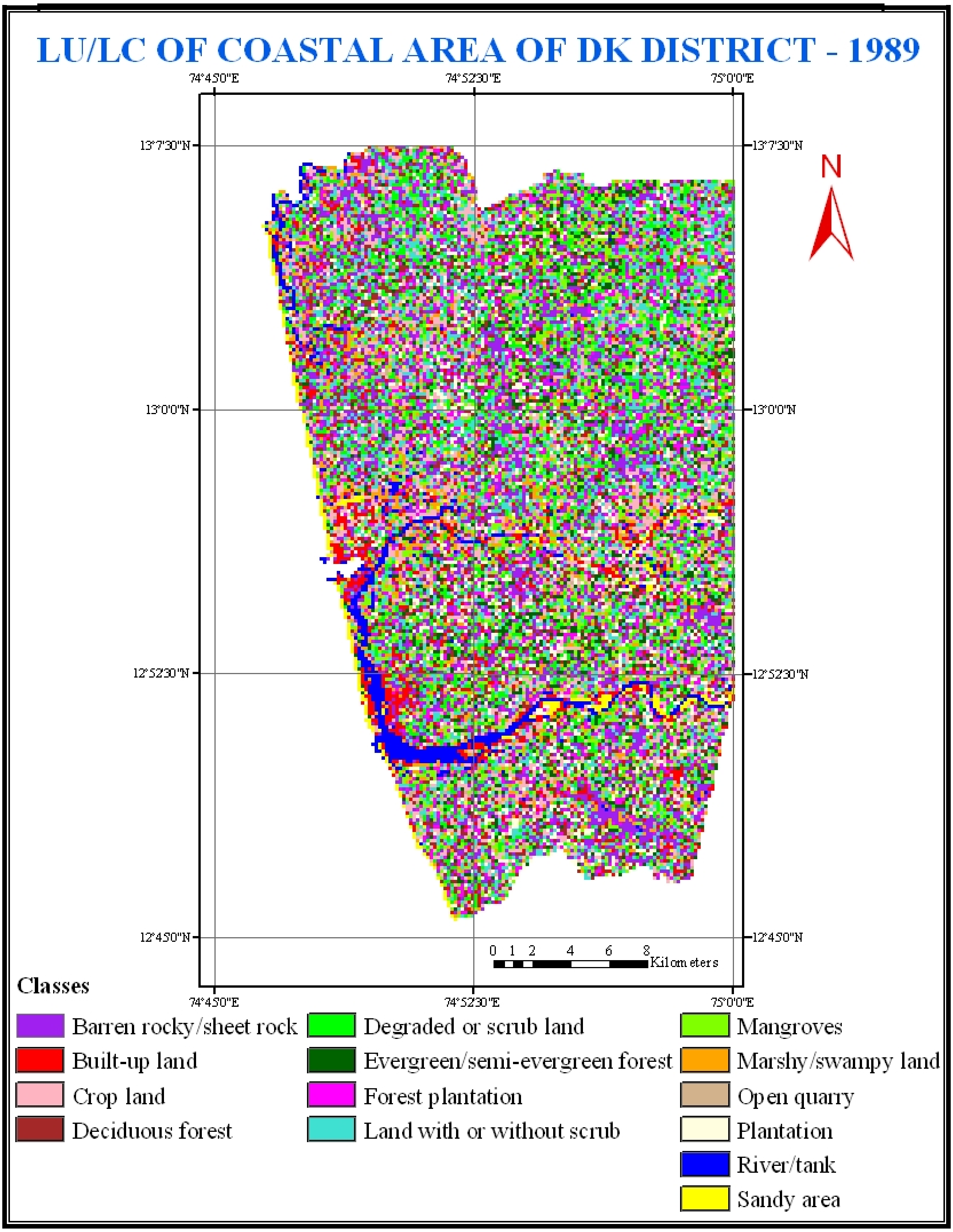


Fig.4.1. LU/LC map of the coastal area of DK district for the year 1989

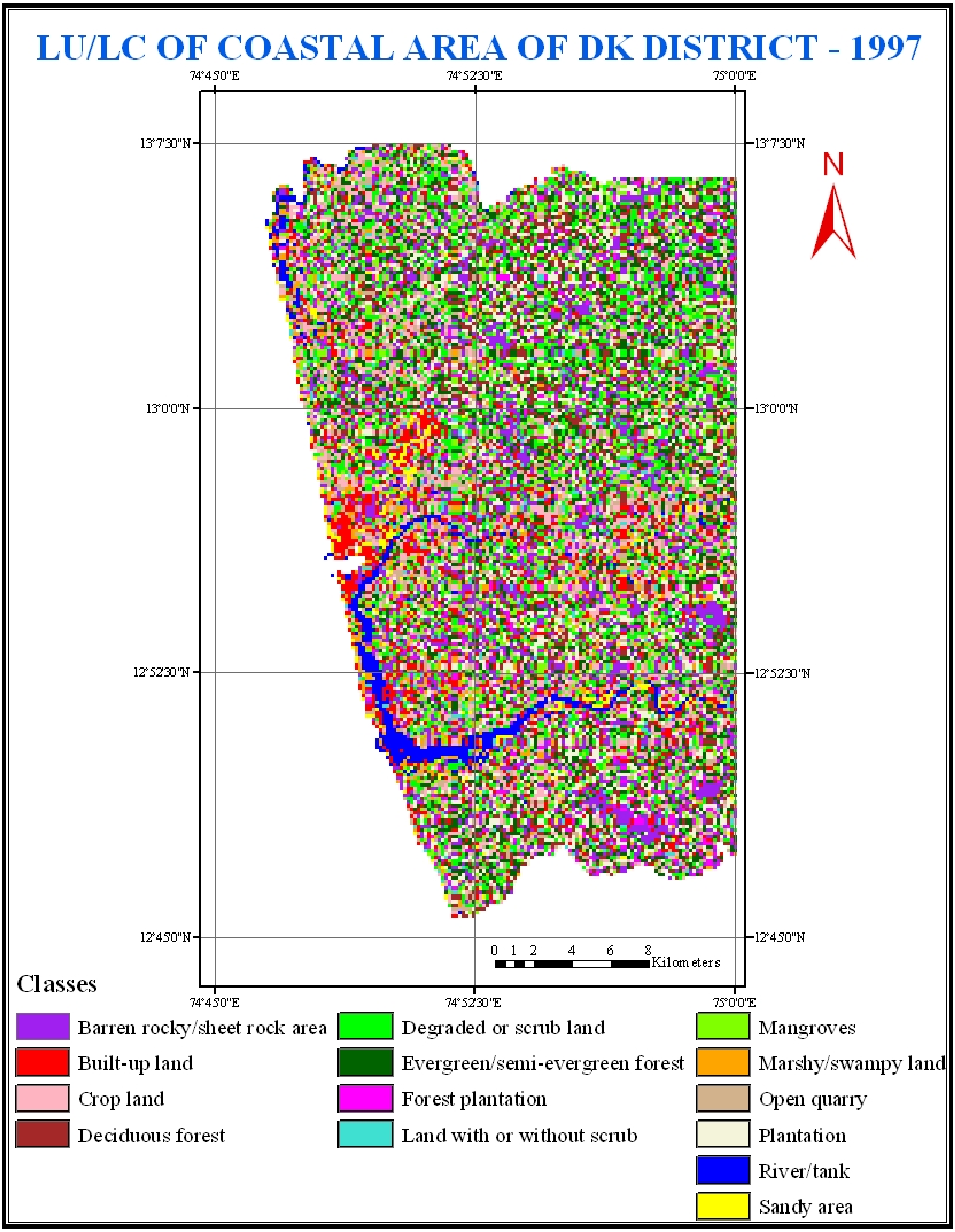


Fig.4.2. LU/LC map of the coastal area of DK district for the year 1997

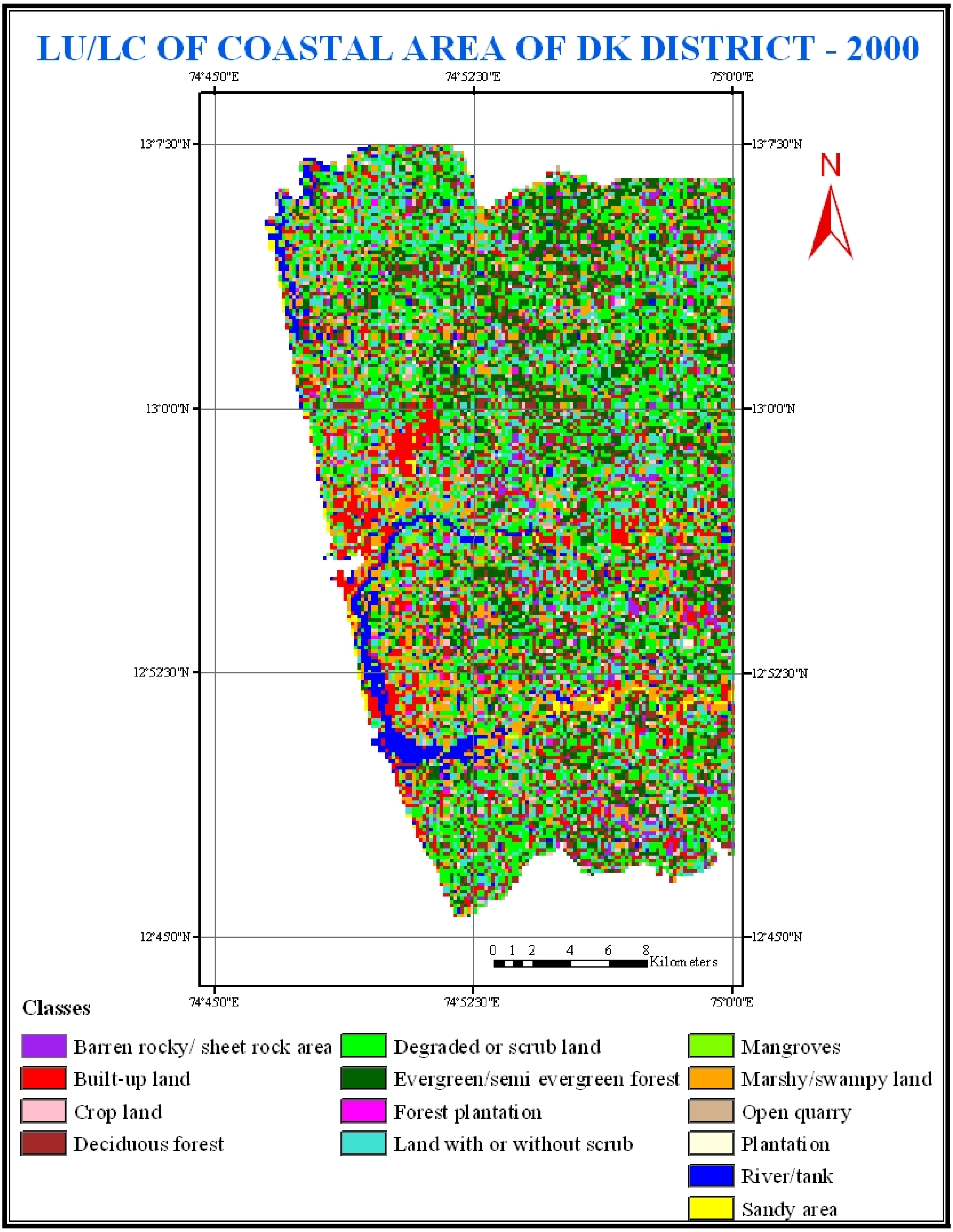


Fig.4.3. LU/LC map of the coastal area of DK district for the year 2000

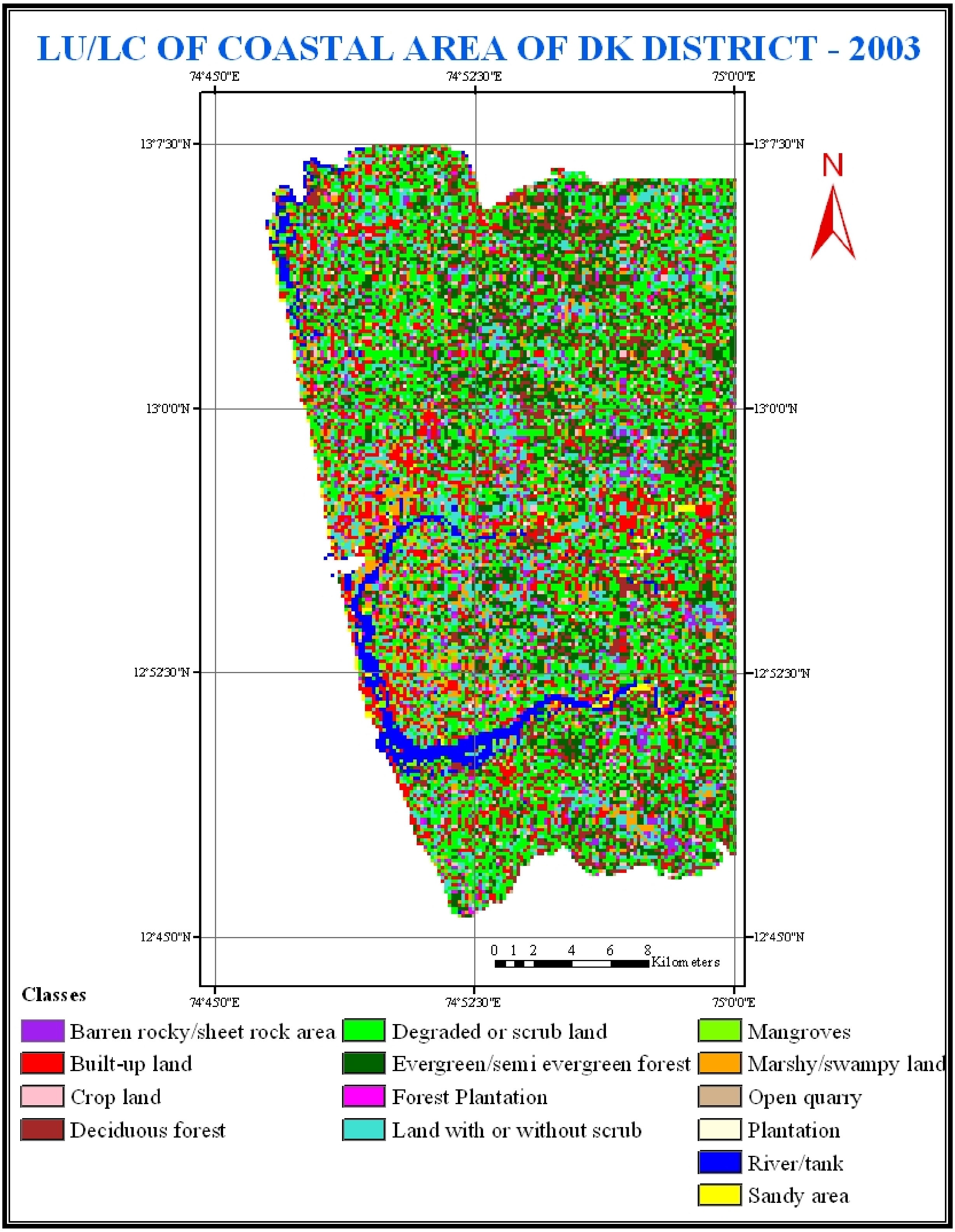


Fig.4.4. LU/LC map of the coastal area of DK district for the year 2003

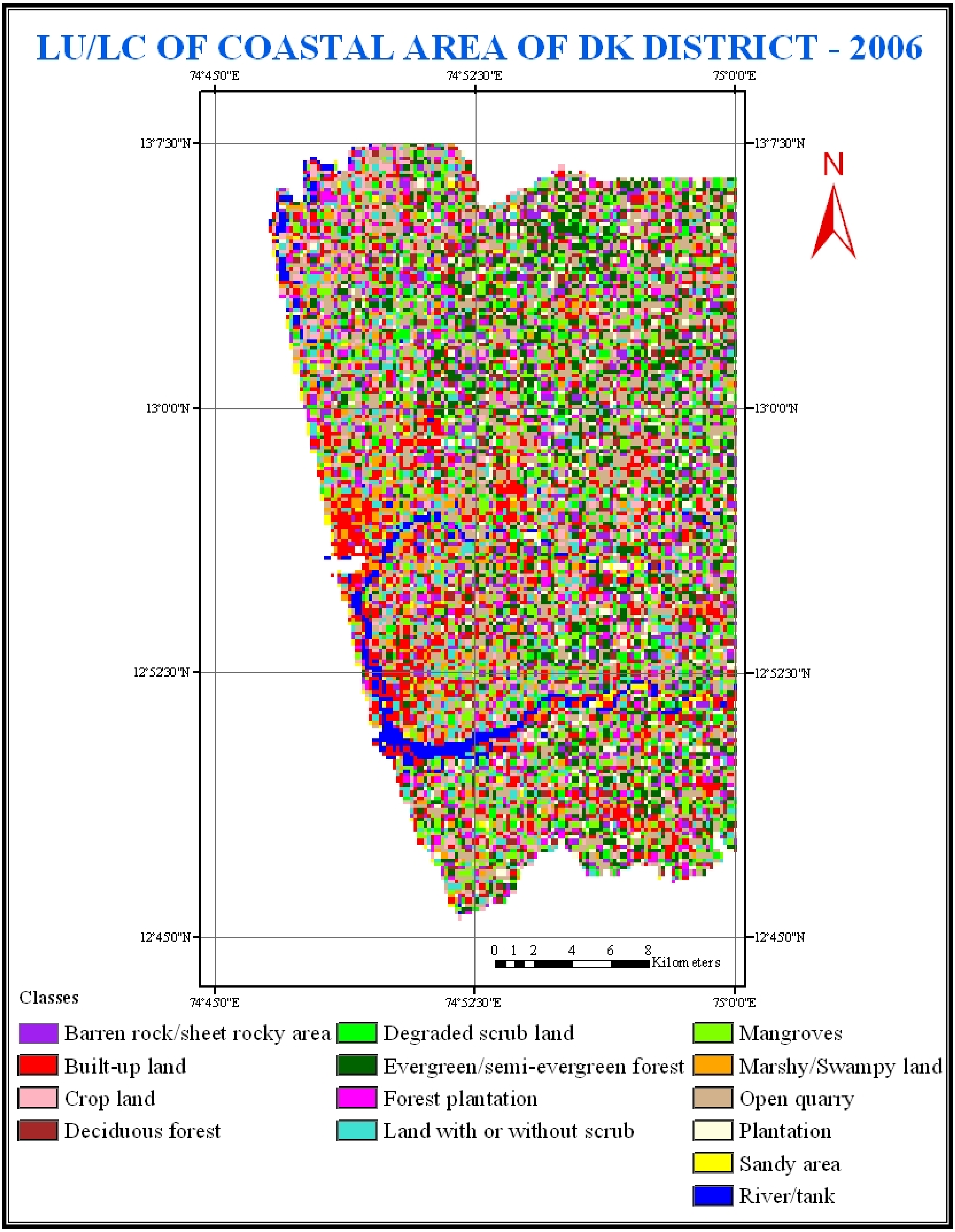


Fig.4.5.LU/LC map of the coastal area of DK district for the year 2006

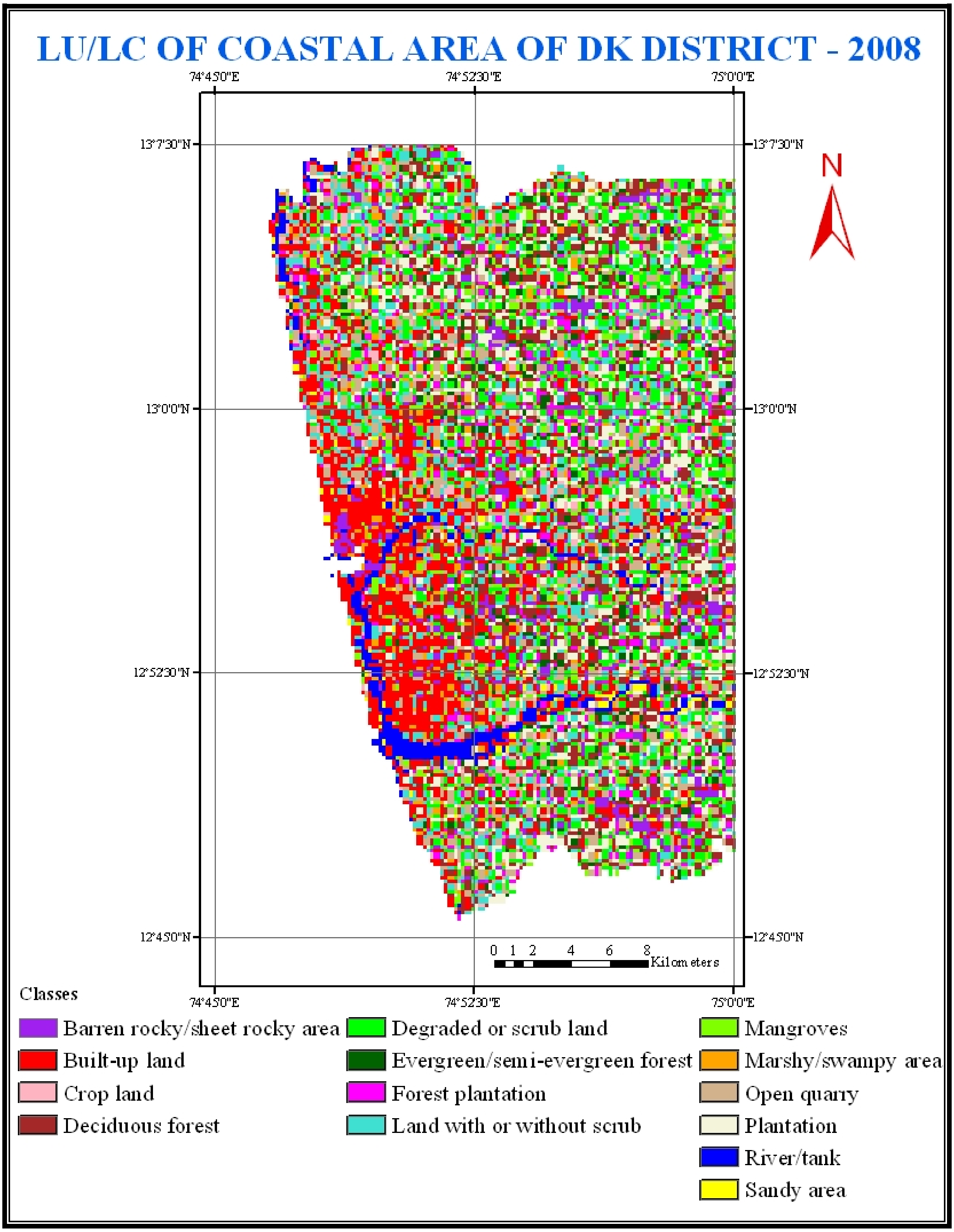


Fig.4.6.LU/LC map of the coastal area of DK district for the year 2008

4.3. Land use / Land Cover change during 1983-2008

Time series plots showing change in area under different classes during 1983-2008 are shown in Fig.4.7 to 4.10. The urban/built-up area in coastal region of DK district has increased from 36 sq. km in 1983 to 134 sq. km in 2008 showing a sharp growth of 270% during the study period. The area under conventional cultivation like paddy has reduced by 59% but the area under agricultural plantations like cashew nut, coconut, areca nut, banana and rubber have increased by 143% and therefore the total area under agriculture has remained almost the same. The area of evergreen/semi-evergreen forest, deciduous forest and mangroves have decreased by 18% , 23% and 50% respectively where as there is a ten fold increase in the area under forest plantations. This is due to social forestry and forest plantation activities taken up by State forest department. The marshy/swampy area has decreased by 51%. This is due to the large scale filling up of low lying marshy lands in places like Adyar, Baikampady Kottara, Kulur, Kulai and expansion of urban/built-up areas. Conversion of agricultural land to commercial use all along the major highways has increased the built up area. The land with or without scrub and barren lands have been reduced by 51% and 65% respectively. There is eight fold increase in the area covered by quarries. It is estimated that the clay to the tune of 3.2 million tons and laterite and hard rocks to the tune of 2.4 million tons is quarried every year (Shrihari, 2010). The area covered by water has almost remained constant at about 22 sq. km through out the study period except in the year 2003 where it is reduced to 15 sq. km. As per the records of Central Water Commission the flow in the river Nethravati is the least in that year. Accordingly the area covered by sand is maximum of 18 sq. km in the in the year 2003 where as in other years it is around 10 sq. km. The change in area of each class from 1983 to 2008 is shown in Fig.4.11.

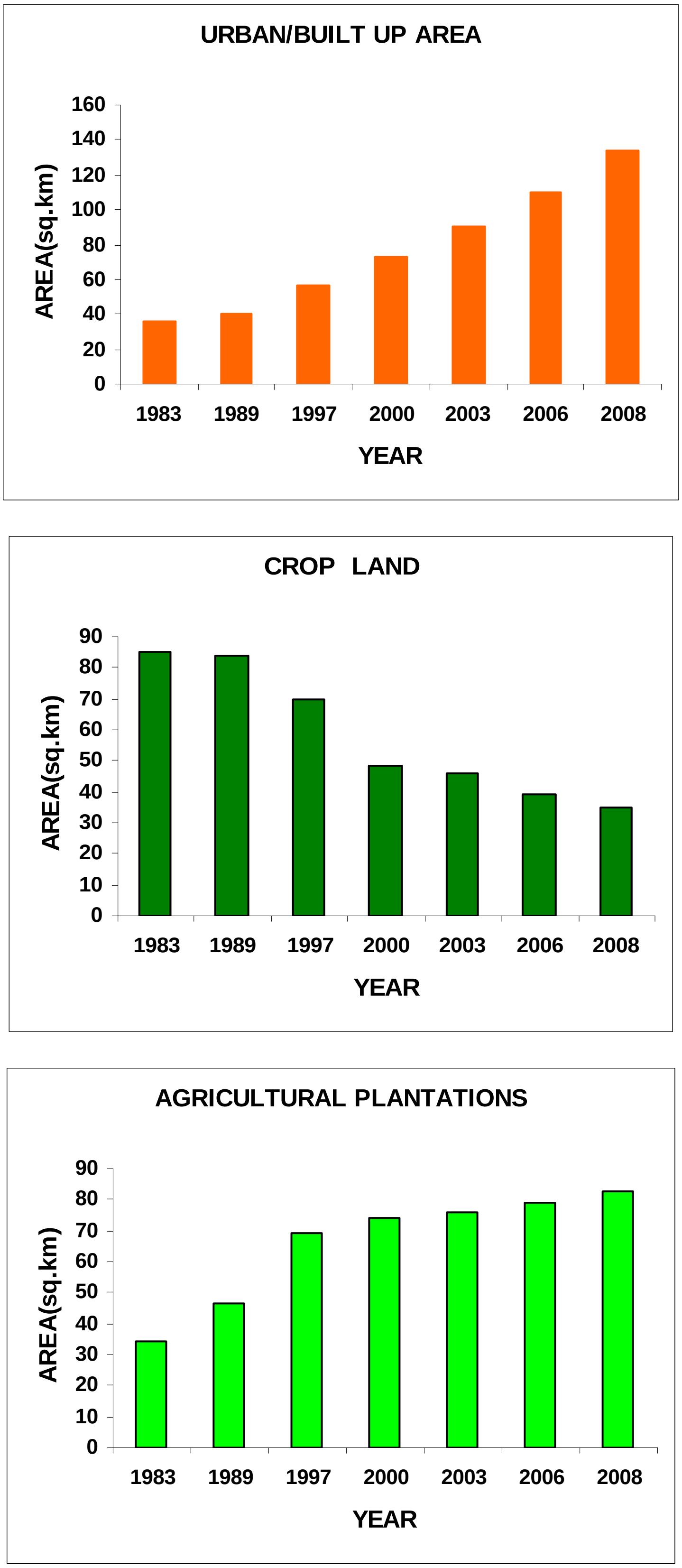


Fig.4.7.Time-Series Plot showing the changes in urban/built-up area, crop land and agricultural plantations in the study area during 1983-2008

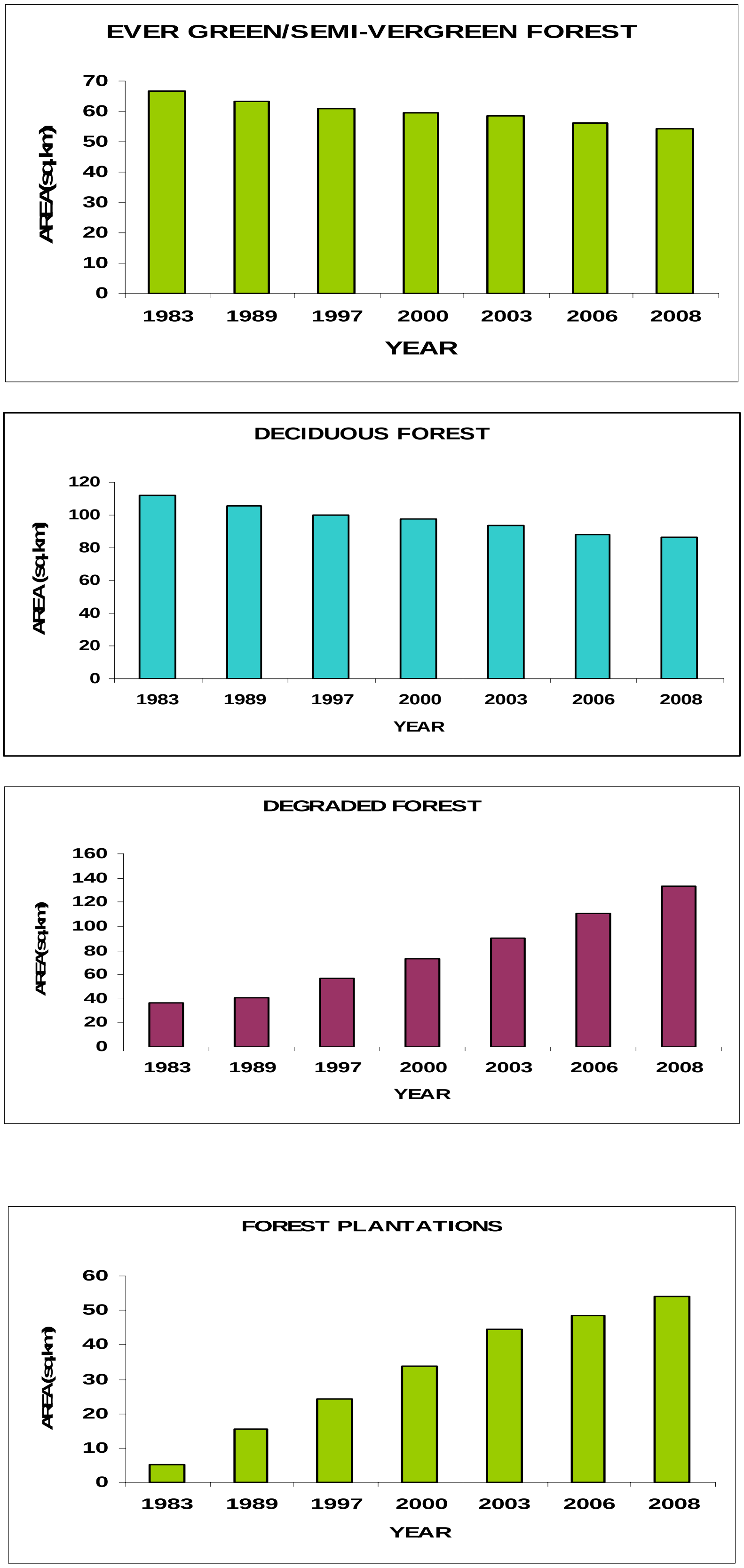


Fig.4.8.Time-Series Plot showing the changes in evergreen/semi-evergreen forest, deciduous forest, degraded forest and forest plantations in the study area during 1983-2008

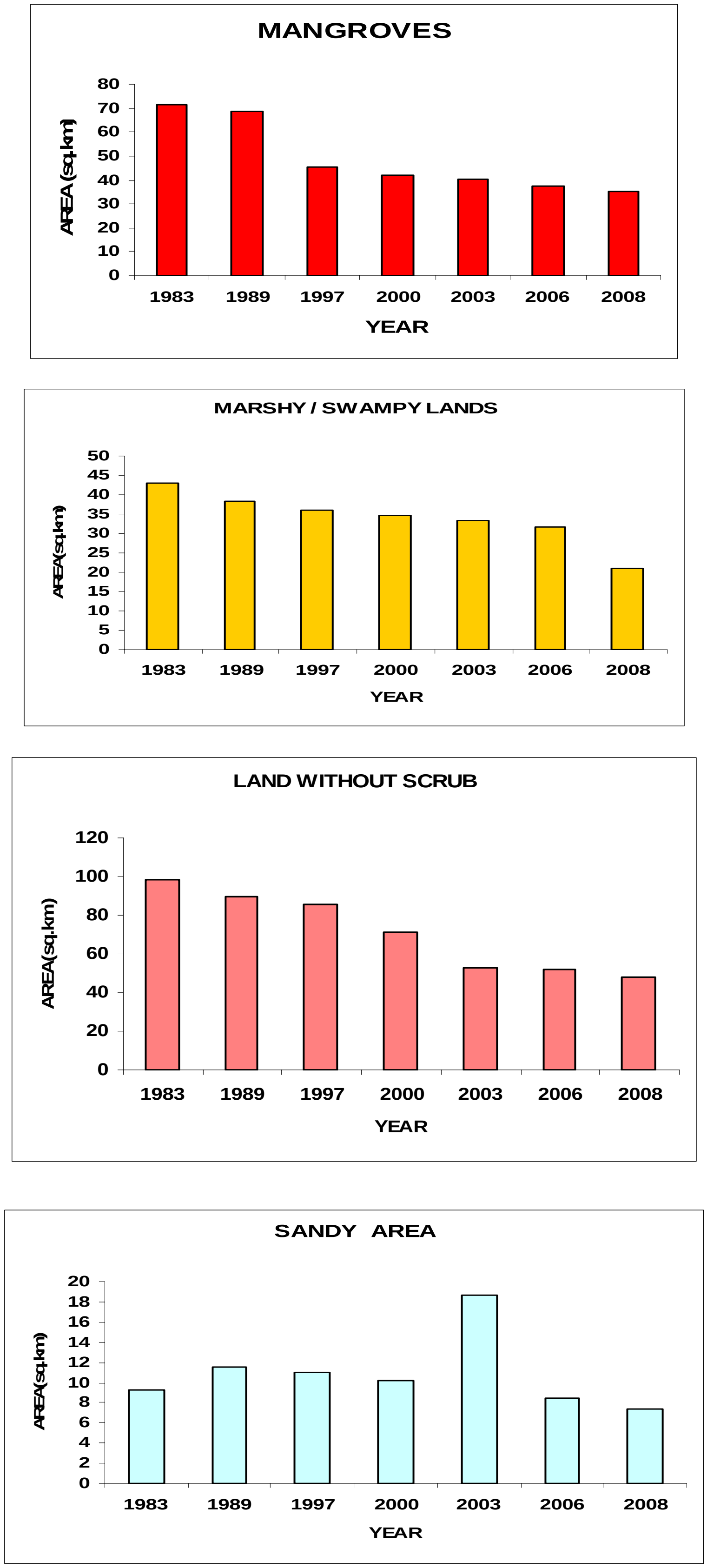


Fig.4.9.Time-Series Plot showing the changes in mangroves, marshy/swampy lands, land without scrub and sandy area in the study area during 1983-2008.

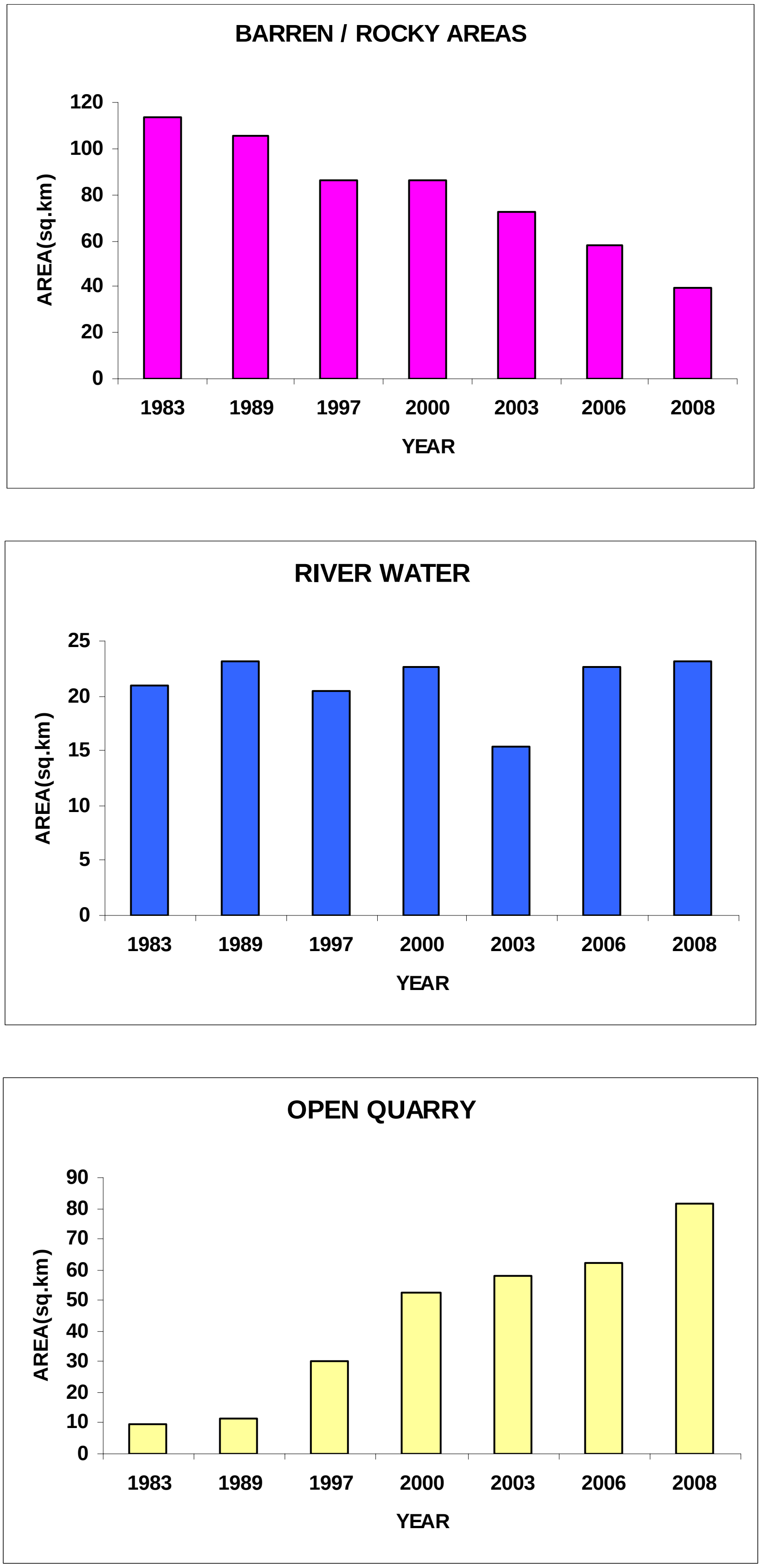


Fig.4.10.Time-Series Plot showing the changes in bareren/rocky area, river/tank, and open quarry in the study area during 1983-2008

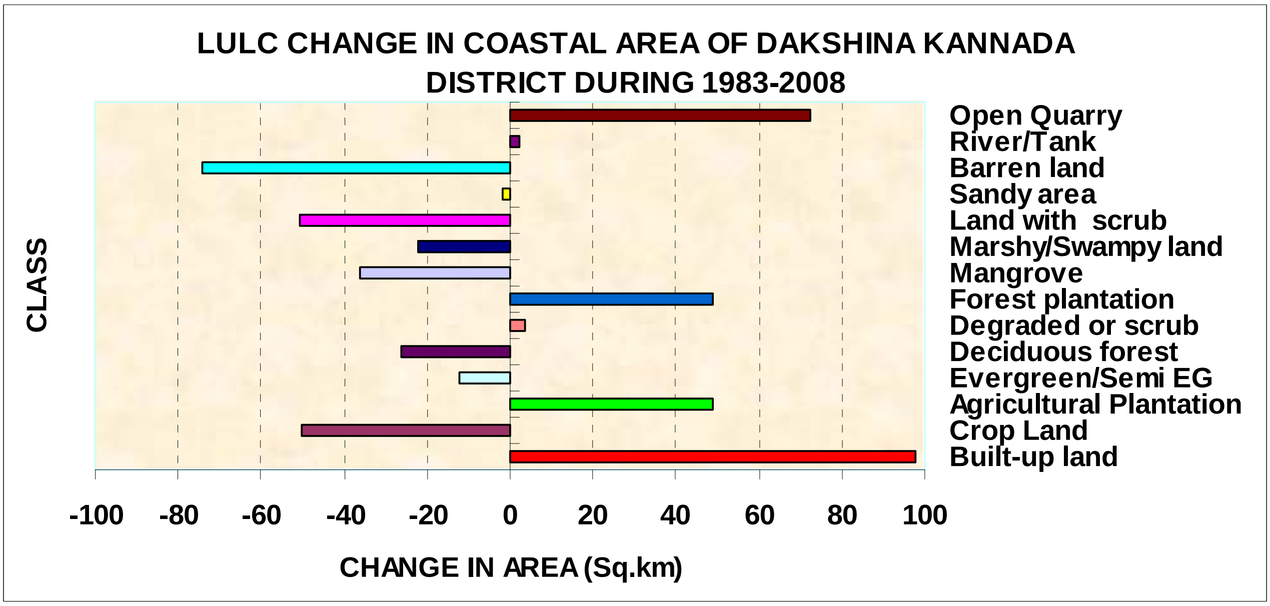


Fig.4.11. LULC change in coastal area of DK district during 1983-2008

4.4 Classification Accuracy Assessment

The error matrix prepared for land use/land cover classification for the years 1989 and 2008 are shown in Tables 4.2 and 4.3. respectively. The producer's accuracies and user's accuracies for different classes for the years 1989, 1997 and 2000 are shown in Table 4.4 and for the years 2003, 2006 and 2008 are shown in Table.4.5. The kappa statistic for all the methods of classifications is calculated and found that the maximum likelihood algorithm has given high kappa statistics. The overall accuracy of classifications varied from 79% to 86.6% and Kappa statistic varied from 0.761 to 0.850.The overall accuracies and Kappa statistics obtained for all the land use/land cover classifications for different years are shown in Fig.4.12.

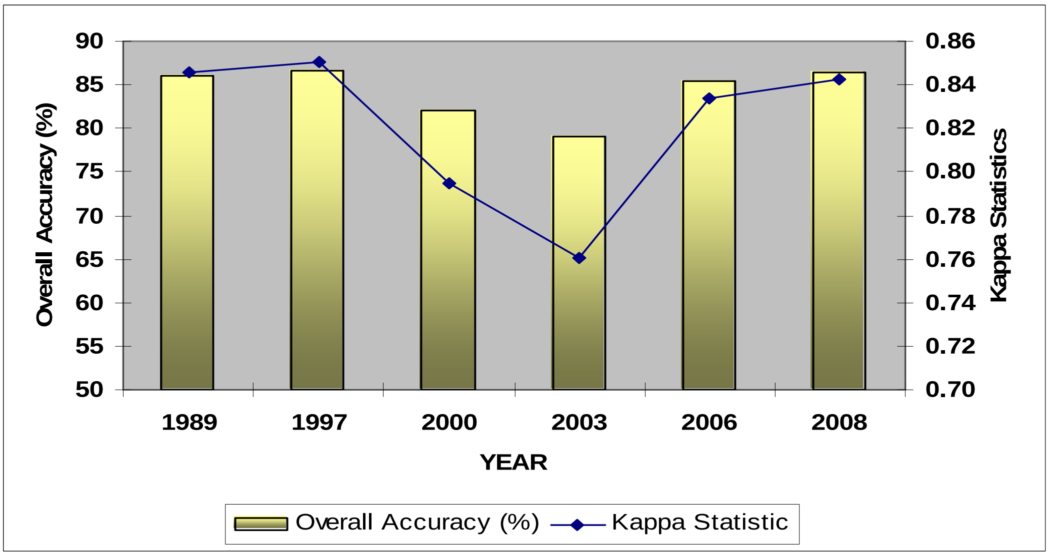


Fig.4.12.Overall Accuracy and Kappa Statistics of the Classifications

Table 4.2 Error Matrix for the Year 1989

	Reference data														
Classified Data	Urban/Built-up land	Crop land	Plantation	Evergreen/semi-evergreen forest	Deciduous forest	Degraded or scrub land	Forest plantation	Mangroves	Marshy/swampy land	Land with or without scrub	Sandy area	Barren rocky/sheet rock	River / Tank	Open Quarry	**Row Total**
Urban/Built-up land	**28**	0	0	0	0	0	0	0	0	0	1	0	1	0	**30**
Crop land	0	**73**	5	0	0	0	0	0	1	0	0	0	0	0	**79**
Plantation	0	2	**32**	0	2	2	0	0	1	0	0	0	0	0	**39**
Evergreen/semi-evergreen forest	0	0	0	**31**	6	1	0	0	0	1	0	0	0	0	**39**
Deciduous forest	0	0	3	1	**28**	1	0	0	0	1	0	0	0	0	**34**
Degraded or scrub land	0	0	3	3	1	**62**	0	0	0	2	0	0	0	0	**71**
Forest plantation	0	0	1	0	0	0	**21**	0	0	0	0	0	0	0	**22**
Mangroves	0	0	1	0	0	0	1	**28**	7	0	0	0	0	0	**37**
Marshy/swampy land	0	0	0	0	0	0	0	6	**10**	0	0	0	0	0	**16**
Land with or without scrub	0	0	0	0	0	0	0	0	1	**47**	2	2	0	0	**52**
Sandy area	2	0	0	0	0	0	0	0	0	0	**3**	0	0	0	**5**
Barren rocky/sheet rock	0	0	0	0	0	0	0	0	0	0	0	**48**	1	4	**53**
River/tank	0	0	0	0	0	0	0	0	1	0	0	0	**14**	0	**15**
Open quarry	0	0	0	0	0	0	0	0	0	0	0	3	0	**5**	**8**
Column Total	**30**	**75**	**45**	**35**	**37**	**66**	**22**	**34**	**21**	**51**	**6**	**53**	**16**	**9**	**500**

Table 4.3 Error Matrix for the Year 2008

Reference data															
Classified Data	Urban/Built-up land	Crop land	Plantation	Evergreen/semi-evergreen forest	Deciduous forest	Degraded or scrub land	Forest plantation	Mangroves	Marshy/ swampy land	Land with or without scrub	Sandy area	Barren rocky/ sheet rock	River / Tank	Open Quarry	**Row Total**
Urban/Built-up land	**113**	1	0	0	0	0	0	0	2	0	2	1	2	0	**121**
Crop land	1	**7**	0	0	0	0	0	0	0	0	0	0	0	0	**8**
Plantation	0	2	**67**	4	2	0	1	0	0	0	0	0	0	0	**76**
Evergreen/semi-evergreen forest	0	0	0	**11**	0	0	0	0	0	0	0	0	0	0	**11**
Deciduous forest	0	1	9	5	**56**	1	0	0	0	0	0	0	0	0	**72**
Degraded or scrub land	6	2	1	2	1	**69**	0	0	1	0	0	3	1	0	**86**
Forest plantation	0	0	2	0	0	0	**13**	0	0	0	0	0	0	0	**15**
Mangroves	0	0	0	0	0	0	0	**5**	2	0	0	0	0	0	**7**
Marshy/swampy land	0	0	0	0	0	0	0	0	**2**	0	0	0	0	0	**2**
Land with or without scrub	3	0	0	1	0	0	0	0	1	**27**	1	0	0	0	**33**
Sandy area	0	0	0	0	0	0	0	0	0	0	**0**	0	0	0	**0**
Barren rocky/sheet rock	0	0	0	0	0	0	0	0	0	0	0	**20**	0	1	**21**
River/tank	0	0	0	0	0	0	0	0	1	0	0	0	**13**	0	**14**
Open quarry	0	0	0	0	0	0	0	0	0	0	0	4	0	**29**	**33**
Column Total	**123**	**14**	**79**	**23**	**59**	**70**	**14**	**5**	**9**	**27**	**3**	**28**	**16**	**30**	**500**

Table 4.4 Overall Accuracy Assessment of the Classification for the Years 1989, 1997 and 2000

Class	Year 1989			Year 1997			Year 2000		
	Classification Accuracy (%)		Kappa Statistics	Classification Accuracy (%)		Kappa Statistics	Classification Accuracy (%)		Kappa Statistics
	Producers Accuracy	Users Accuracy		Producers Accuracy	Users Accuracy		Producers Accuracy	Users Accuracy	
Urban/Built-up land	93.33	93.33	0.9291	97.37	90.24	0.8944	90.00	90.00	0.889
Crop Land	97.33	92.41	0.9106	100.00	90.41	0.8895	50.00	100.00	1.000
Plantation	71.11	82.05	0.8028	92.31	88.24	0.8648	100.00	71.43	0.699
Evergreen/Semi-evergreen forest	88.57	79.49	0.7794	85.94	93.22	0.9223	25.00	100.00	1.000
Deciduous forest	75.68	82.35	0.8094	89.29	89.29	0.8793	100.00	62.50	0.583
Degraded or scrub land	93.94	87.32	0.854	89.23	86.57	0.8456	14.29	100.00	1.000
Forest plantation	95.45	95.45	0.9525	44.44	50.00	0.4908	100.00	75.00	0.742
Mangrove	82.35	75.68	0.7390	90.91	76.92	0.7640	100.00	100.00	1.000
Marshy/Swampy land	47.62	62.50	0.6086	46.67	77.78	0.7709	75.00	75.00	0.728
Land with or without scrub	92.16	90.38	0.8929	20.00	33.33	0.3266	20.00	100.00	1.000
Sandy area	50.00	60.00	0.5951	16.67	50.00	0.4877	0.00	0.00	0.000
Barren rocky/Sheet rock	90.57	90.57	0.8945	90.91	86.21	0.8450	100.00	75.00	0.734
River/Tank	87.50	93.33	0.9311	83.33	83.33	0.8271	66.67	100.00	1.000
Open Quarry	55.56	62.50	0.6181	85.71	78.26	0.7731	100.00	81.82	0.800
Overall Classification Accuracy	**86.00 %**		**0.8453**	**86.60 %**		**0.8501**	**82.00%**		**0.7949**

Table 4.5 Overall Accuracy Assessment of the Classification for the Years 2003, 2006 and 2008

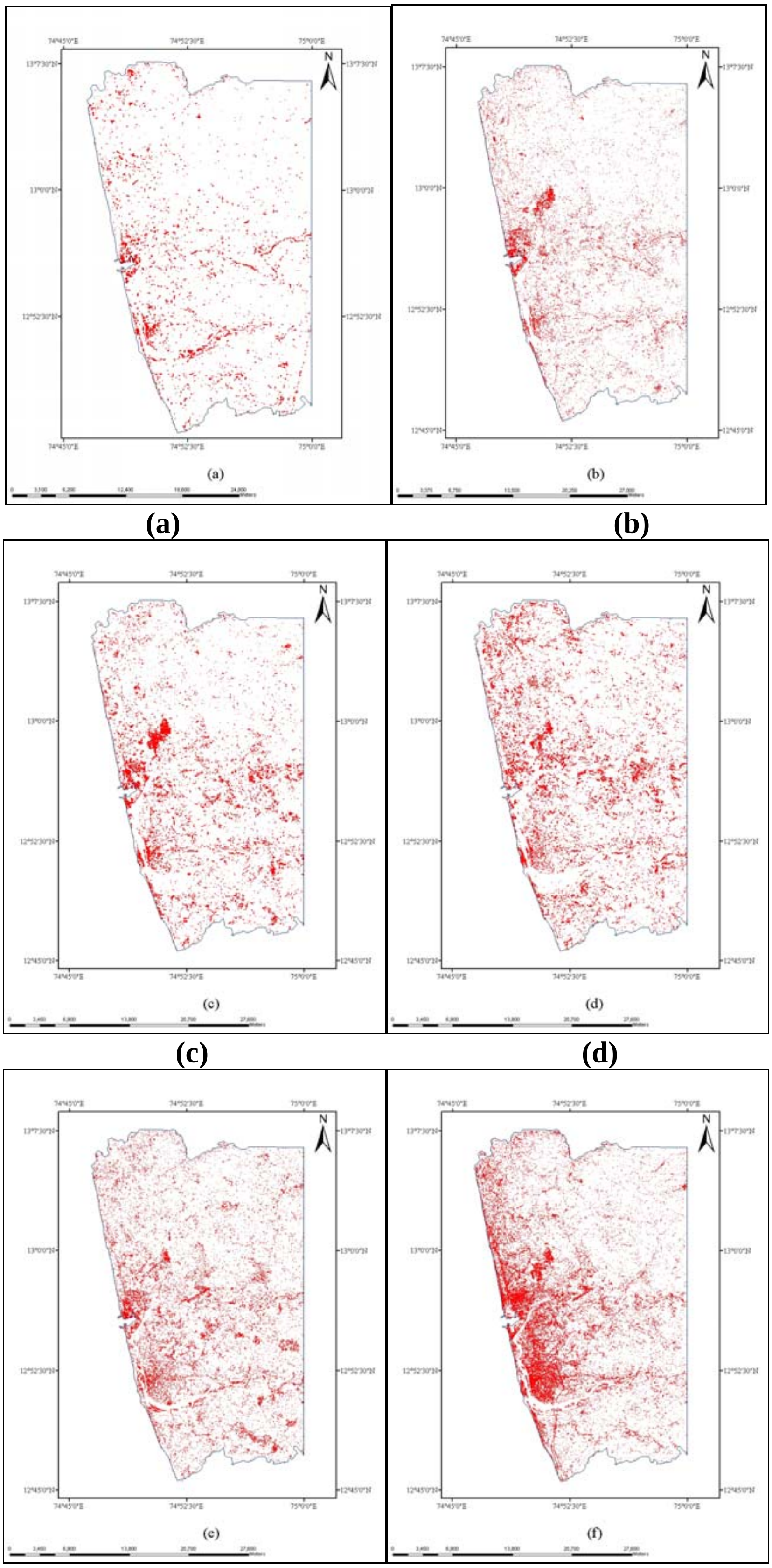
Class	Year 2003			Year 2006			Year 2008		
	Classification Accuracy (%)		Kappa Statistics	Classification Accuracy (%)		Kappa Statistics	Classification Accuracy (%)		Kappa Statistics
	Producers Accuracy	Users Accuracy		Producers Accuracy	Users Accuracy		Producers Accuracy	Users Accuracy	
Urban/Built-up land	63.64	77.78	0.750	96.15	93.75	0.9258	91.87	93.39	0.9123
Crop Land	0.00	0.00	0.000	85.29	90.63	0.8994	50.00	87.50	0.8714
Plantation	100.00	77.78	0.761	72.73	91.43	0.906	84.81	88.16	0.8594
Evergreen/Semi-evergreen forest	71.43	83.33	0.821	94.37	83.75	0.8106	47.83	100.00	1.0000
Deciduous forest	81.82	75.00	0.719	64.29	69.23	0.6834	94.92	77.78	0.7480
Degraded or scrub land	33.33	100.00	1.000	84.00	95.45	0.9522	98.57	80.23	0.7701
Forest plantation	80.00	57.14	0.549	82.61	76.00	0.7484	92.86	86.67	0.8628
Mangrove	100.00	100.00	1.000	81.82	64.29	0.6264	100.00	71.43	0.7114
Marshy/Swampy land	45.45	83.33	0.813	46.67	87.50	0.871	22.22	100.00	1.000
Land with or without scrub	50.00	100.00	1.000	93.33	73.68	0.7287	100.00	81.82	0.8078
Sandy area	100.00	100.00	1.000	40.00	100.00	1.0000	---	---	0.0000
Barren rocky/Sheet rock	80.00	44.44	0.415	59.46	95.65	0.9530	71.43	95.24	0.9496
River/Tank	33.33	100.00	1.000	75.00	75.00	0.7439	81.25	92.86	0.9262
Open Quarry	100.00	55.56	0.532	98.10	85.83	0.8207	96.67	87.88	0.8711
Overall Classification Accuracy	**79.00%**		**0.7608**	**85.40 %**		**0.8337**	**86.40 %**		**0.8422**

4.5 Urbanization and the driving forces

The major driving forces for the fast urbanization during the study period 1983-2008 were the enhanced economic activity due to continuous expansion of the all weather sea port NMPT, setting up of major industries like MRPL, MCF, BASF India Limited, KIOCL and industrial estate at Baikampady with about 1500 units. Improved transportation facilities due to four laning of Highways, Mangalore-Bangalore broad gauge line, starting of Konkan railway, expansion of Mangalore airport also contributed to urbanization process. Due to the availability of quality higher educational institutions and setting up of SEZs for petrochemicals and information technology fields the urbanization is expected to continue further in the study area. The rate of increase in built up area per year which was 0.71 sq. km in 1983 has risen to11.64 sq. km in 2008. The progression of urban/built-up area from 1989 to 2008 is shown in Fig. 4.13(a) to 4.13(f). The land use consumption has increased from 109 sq. m per person in 1983 to 128 sq. km per person in 2008 showing the signs of sprawling in the study area.

4.6 Population growth trends in the study area

Census is conducted every 10 years in India. The population in Mangalore urban area has increased from 44 thousands in 1901 to 601 thousands in 2001.The population growth rate which was 1% per year during 1901-1911 has increased to 4% during 1991-2001.The population in the study area for the years 1983, 1989, 1997, 2000, 2003, 2006 and 2008 were calculated using Census records of 1981, 1991 and 2001 using the increase in growth per year in that particular decade. The population has increased from 332 thousands in 1983 to over one million in 2008.The population in the study area has increased by 215% during 1983-2008. The growth of population during 1983-2008 is shown in Fig.4.14.



(a) (b)

(c) (d)

(e) (f)

Fig. 4.13.Map showing the urban /built-up area in the year (a) 1989 (b) 1997 (c) 2000 (d) 2003 (e) 2006 and (f) 2008

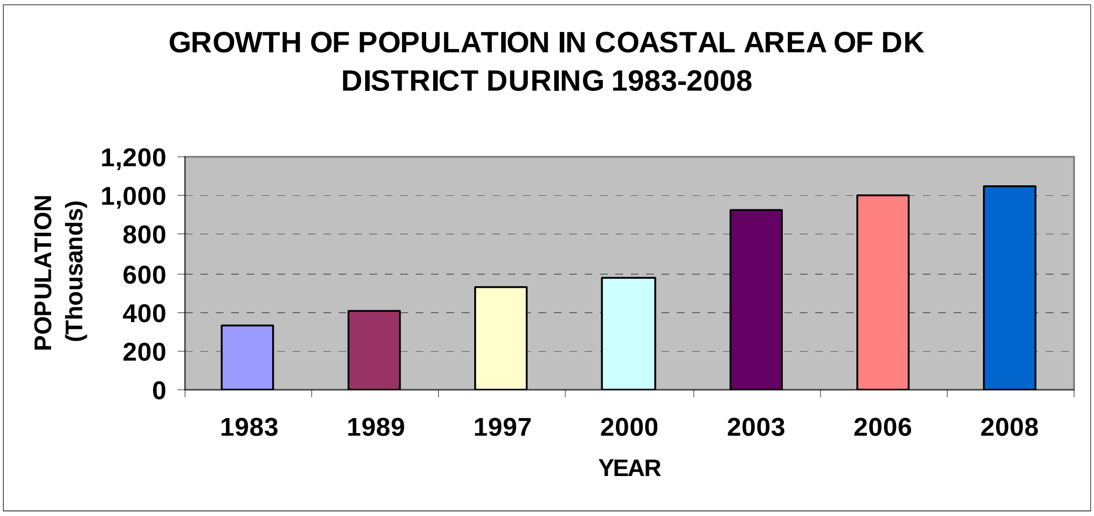


Fig.4.14. Population Growth in the coastal area of DK district during 1983-2008

4.7 Population growth and environmental concerns

In 2011 the world population surpassed the seven billion mark and, according to United Nations projections the world population will grow to over nine billion by 2050. The rapid growth of the world population is a recent phenomenon. About 2000 years ago, the population of the world was about 300 millions. It took more than 1600 years to the world population to double to 600 million. The rapid growth of the population started in the year 1950. World population reached one billion for the first time in 1804. Due to the high growth rate, it is taking less time to add an additional billion population. It took 123 years to reach two billion in 1927, 32 years to reach three billion in 1959, 15 years to reach four billion in 1974, 13 years to reach five million in 1987, only 12 years to reach six billion in 1999 and another 12 years only to reach seven billion in 2011 (UNFPA, 2011). According to UN projections, in the year 2025, India with 1.46 billion populations will overtake China with 1.39 billion populations as the world's most populous nation. The increase in human population is an environmental concern for several reasons like more usage of natural resources, increased land development for both agriculture and habitation, more energy demand, greater pressure on wildlife and marine life and generation of more wastes.

4.8 Population pressure in the study area

The population in the region is expected to increase further due to industrialization, availability of quality higher educational facilities and flourishing construction industry. The saturation population calculated using the logistic curve method is 1.07 million. The population in the study area has already reached saturation levels; therefore any further increase in population will result in environmental degradation. This indicates that the available resources are not sustainable and the carrying capacity of the region is unsustainable.

4.9 Urban growth prediction

Urban growth prediction helps the urban planners and policy makers in providing better infrastructure services to a huge number of new urban residents.

4.9.1Urban/Built-up area prediction

MINITAB statistical software was used for prediction of urban/built-up areas and population in future. The trend analysis plot for urban/built-up area is shown in Fig.4.15. Quadratic distribution was found to be best fitted for the urban growth of the study area as compared to linear, exponential, logarithmic and power distribution. The following quadratic relationship of urban growth was adopted for future projections of urban/built-up areas.

$$A = 4.86089X^2 - 15.3860X + 48.699$$

where X = number of years from 1983

Using the above relation, the urban/built- up areas for the future years were predicted and are shown in Table 4.6.

Table 4.6 Urban growth projections for the coastal area of DK district

Year	Urban/built-up area in sq. km	Population in millions
2013	179.181	1.401
2018	236.708	1.772
2023	303.958	2.198
2028	380.929	2.679

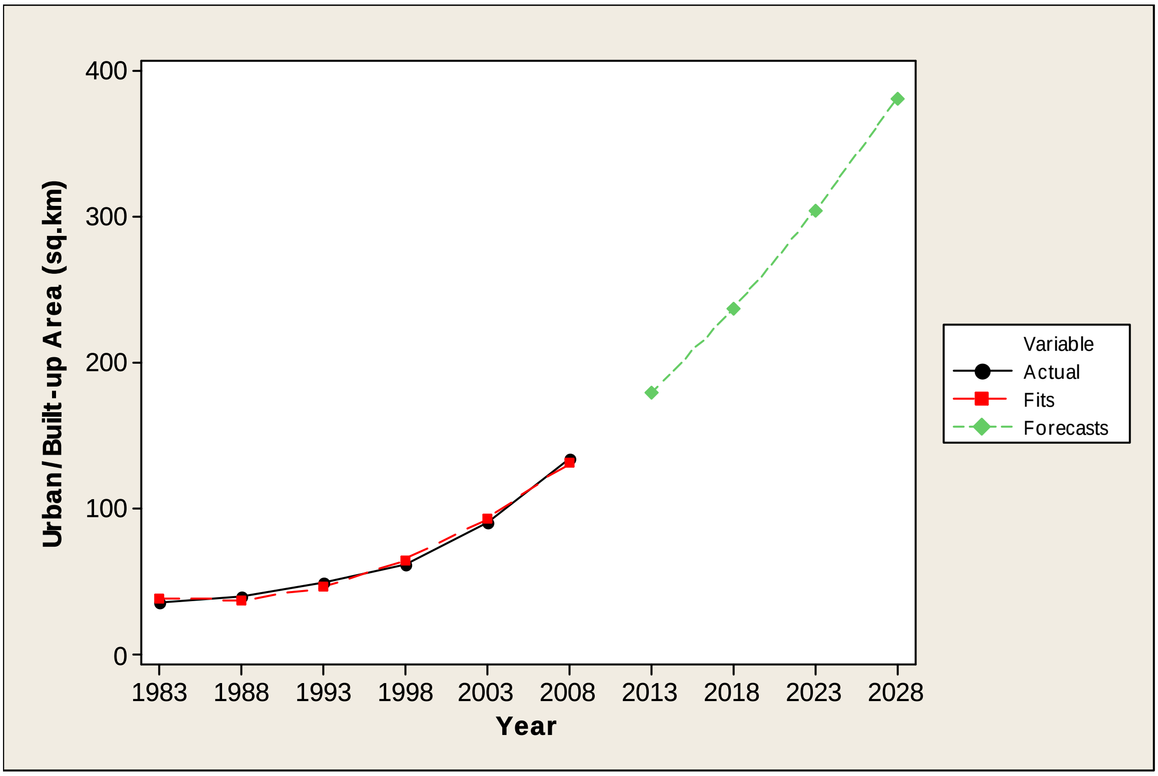


Fig.4.15. Urban/built-up area trend analysis for the coastal area of DK district

4.9.2 Population growth prediction

Similarly trend analysis plot for urban population growth is shown in Fig.4.16. In this case also, the quadratic distribution was found to be best fitted for the urban growth of the study area as compared to linear, exponential, logarithmic and power distribution. The following quadratic relationship of urban growth was adopted for future projections of population growth.

$$P = 27628.3X^2 - 43426.5X + 350765$$

where X = number of years from 1983

Using the above relation, the populations for the future years were predicted and are shown in Table 4.6.

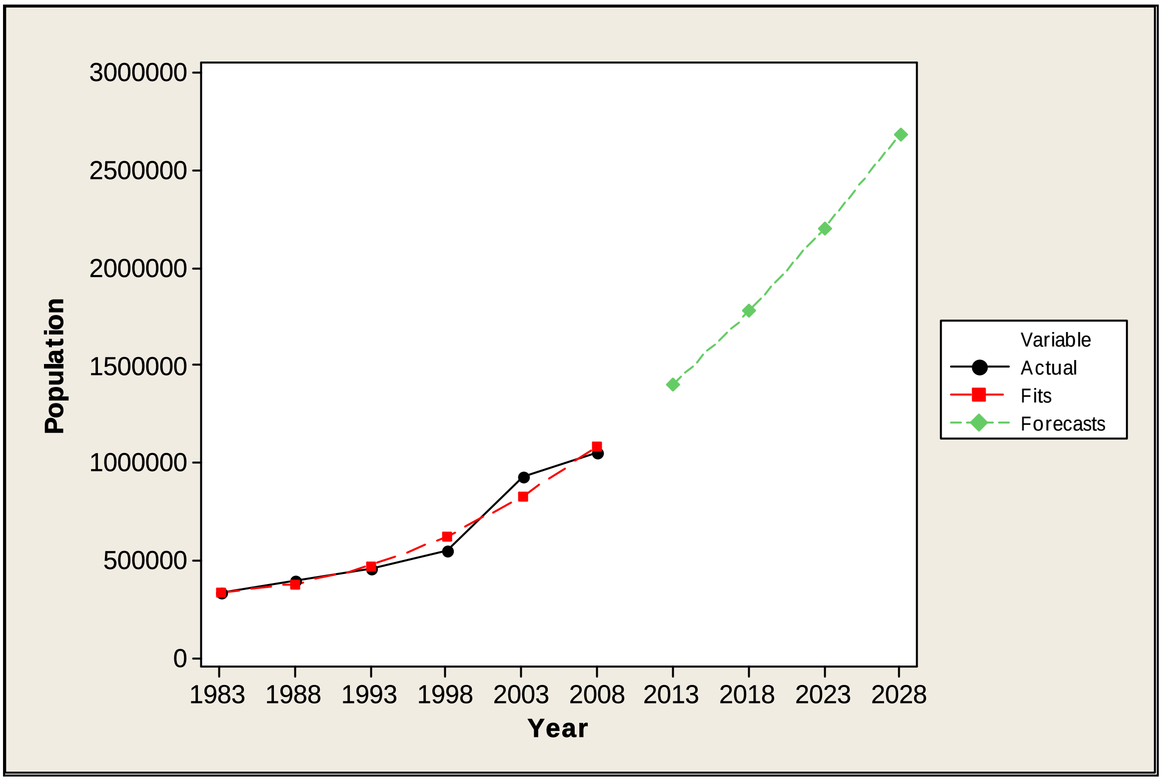


Fig.4.16. Population trend analysis for the coastal area of DK district

4.10 Water Quality changes in the region

4.10.1 Open wells

The pH value of 545 samples (61% of open well samples) was less than 6.50. The Total Dissolved Solids were in excess at four sampling locations, O-22, O-26, O-68 and O-75 (Idya, Chitrapura, Ullal Dargah and Talapadi) while chlorides were in excess at one location, O-75 (Talapadi). Salt water intrusion may be the cause for this as the three of the four sampling locations, O-22, O-26 and O-75 (Idya, Chitrapura and Talapadi) are with in 300 meters from the coast Nitrates were in excess at seven locations, O-22, O-36, O-47, O-54, O-62, O-68, and O-69 (Idya, Kodical, Thannirbavi, Milagre's Church, B.C. Road, Ullal Dargah and Thokkottu-Kapikad). Iron content was in excess at four sampling locations, O-17, O-22, O-72 and O-74 (Surathkal, Idya, Derlakatte and Someshwara). Turbidity was more at one sampling location, O-17 (Surathkal) and Manganese was more at one location, O-12, (NITK Professor's Quarters). All the open well samples from the study area contained coliform organisms. The ratio of Total Coliforms to Fecal Coliforms varied from 0.79 to 3.20.

4.10.2 Bore wells

The pH value in 44 samples (19% of bore well samples) was less than 6.50. Iron was in excess in 189 samples (83% of samples) and turbidity was in excess in 175 samples (77% of samples). The Total Dissolved Solids and chlorides were in excess at two sampling locations, B1 and B15 (Shasihitulu and Ullal-Kotepura Road). Salt water intrusion may be the reason for this as these sampling locations are within 100 metres from the coast. Magnesium content was in excess at three locations, B12, B14 and B15 (ISKCON, Bengre and Ullal- Kotepura Road). All the bore well samples from the study area contained coliform organisms. The ratio of Total Coliforms to Fecal Coliforms varied from 1.00 to 1.80.

There is no difference in trends of water quality indices in open well samples and bore well samples. The global water quality indices varied from ‘Fair’ to ‘Good’.

4.10.3 Surface water

The quality of water in Nethravati river at sampling location R-15 (Nethravati bridge) is affected by tidal waves where as the quality at location R-16 (Thumbe vented dam) meets the desirable limits. The quality of water in Gurpur river at sampling locations R-9 and R-10 (Kulur bridge and Maravoor bridge) are affected by tidal fluctuations in the Arabian Sea where as the quality at locations R11 and R-12 (Gurpura and Addur bridge) meet the desirable limits. The quality of water in Shambhavi river at location R-1 (Mulki bridge) and in Pavanje river at R-5 (Pavange bridge) is affected by tidal waves. All the surface water samples from the study area contain coliform organisms.

4.10.3.1 Nethravati River water quality

The results of the physico-chemical and bacteriological analysis of water samples are presented in Table 4.7. Out of the sixteen parameters analyzed three parameters viz. Fecal Coliform Bacteria (FCB), Iron and Turbidity exceeded the WHO guideline values during the study period of one year.

The presence of FCB in all the river water samples can be attributed to the anthropogenic impacts. In the pilgrimage centers located on the upstream section of the river, the pilgrims use river water for bathing and washing cloths. Uncontrolled non-point discharge of sanitary wastes in to the river without treatment is also a contributing factor. As the Thumbe vented dam is being used as source for drinking water needs of Mangalore city, any laxity in treatment will endanger the health of the city population.

The average iron concentration in streams is about 0.7 mg/L and the WHO guideline is 0.3 mg/L. Increased iron levels in water can cause stains in plumbing, laundry and cooking utensils, and can impart objectionable tastes and colors to foods. Iron was present in excess during the monsoon months of June and July. Presence of Iron in excess quantities in 83% bore well samples, and occurrence of Iron and turbidity in excess quantities in River water samples during monsoon months can be attributed to the mineral composition of the aquifer. This could be due to the runoff and siltation from areas where the soil has soluble Iron. Laterite, which is abundant in the region and is quarried as a building material has large concentration of soluble Iron.

Turbidity in water is caused by suspended and colloidal matter such as clay, silt, and finely divided organic and inorganic matter, plankton and other microscopic organisms. The WHO guideline for turbidity is 5 NTU (nephelometric turbidity units). The study area receives very heavy rainfall during monsoon months from June to September and the River Nethravati is in spate and carries large quantities of silt and clay in to the sea. Therefore the turbidity was in excess quantities during the months of June, July and August. The sedimentation and filtration units of the treatment plant should be monitored carefully during monsoon months to clarify the water to potable limits.

The descriptive statistics (mean, median, standard deviation, minimum and maximum) of the water quality parameters are shown in Table 4.8.

4.10.3.2 Gurpur River water quality

The results of the physico-chemical and bacteriological analysis of water samples are presented in Table 4.9. Out of the sixteen parameters analyzed only four parameters viz. pH, FCB, Iron and Turbidity exceeded the WHO guideline values during the study period of one year. The presence of FCB in all the river water samples can be attributed to the anthropogenic impacts. Iron was present in excess during the monsoon months of June to August. This can be attributed to runoff and siltation from areas where the soil has soluble Iron. The turbidity was in excess quantities during the months of June to September. The descriptive statistics (mean, median, standard deviation, minimum and maximum) of the water quality parameters are shown in Table 4.10.

Table 4.7 Results of water quality analysis for River Nethravati

Parameter	Unit	Nov-06	Dec	Jan-07	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct-07
Cadmium	µg/L	2.39	2.28	2.23	2.97	2.89	2.51	2.67	2.29	1.29	1.38	2.59	2.23
Chlorides	mg/L	10	9	10	9	10	9	12	10	8	9	16	10
Copper	µg/L	5.69	7.43	6.59	4.52	6.97	8.82	4.57	3.61	2.89	3.17	4.58	5.21
FCB	Per 100 ml	**9**	**9**	**2**	**9**	**4**	**9**	**2**	**4**	**9**	**17**	**9**	**4**
Fluorides	mg/L	0.08	0.04	0.05	0.09	0.02	0.03	0.01	0.00	0.08	0.05	0.09	0.07
Hardness	mg/L	23	21	25	24	24	25	23	10	12	12	14	15
Iron	mg/L	0.14	0.16	0.08	0.11	0.09	0.12	0.15	**1.43**	**2.75**	0.21	0.25	0.21
Lead	µg/L	5.63	4.19	6.38	3.67	7.50	8.56	6.34	5.21	4.59	3.67	4.29	4.69
Manganese	µg/L	0.06	ND	1.12	ND	2.23	ND	2.37	1.08	ND[a]	0.05	3.39	4.03
Nitrates	mg/L	1.39	2.16	1.75	2.17	1.09	2.11	0.05	1.17	2.13	3.46	3.42	5.09
pH		7.85	7.93	7.89	8.00	7.85	7.82	7.83	7.81	7.14	7.09	7.36	6.82
Sodium	mg/L	5.6	6.2	4.9	4.5	5.3	5.1	4.9	3.4	4.1	5.2	5.7	8.2
Sulfates	mg/L	2.08	2.59	2.23	1.87	1.51	1.22	4.65	1.24	14.81	2.39	2.47	0.14
TDS	mg/L	21	25	28	30	31	36	27	11	12	18	35	12
Turbidity	NTU	1.6	1.1	1.3	2.5	1.8	3.1	2.9	**15.9**	**35.7**	**18.9**	4.2	12.0
Zinc	µg/L	8.56	11.25	13.64	15.28	14.39	6.26	7.86	16.97	21.67	9.65	18.94	12.34

Table 4.8 Descriptive statistics of water quality parameters for River Nethravati

Parameter	Unit	Mean	Median	Standard Deviation	Minimum	Maximum
Cadmium	µg /L	2.31	2.34	0.52	1.29	2.97
Chlorides	mg/L	10.17	10	2.08	8	16
Copper	µg /L	5.34	4.90	1.82	2.89	8.82
FCB	Per 100 ml	7.25	9	4.27	2	17
Fluorides	mg/L	0.05	0.05	0.03	ND	0.09
Hardness	mg/L	19.00	22	5.86	10	25
Iron	mg/L	0.48	0.16	0.81	0.08	2.75
Lead	µg /L	5.39	4.95	1.54	3.67	8.56
Manganese	µg /L	1.19	0.57	1.47	ND	4.03
Nitrates	mg/L	2.17	2.12	1.32	0.05	5.09
pH		7.62	7.83	0.40	6.82	8
Sodium	mg/L	5.26	5.15	1.19	3.4	8.2
Sulfates	mg/L	3.10	2.16	3.84	0.14	14.81
TDS	mg/L	23.80	26	8.94	10.8	36
Turbidity	NTU	8.42	3	10.57	1.1	35.7
Zinc	µg /L	13.07	12.99	4.67	6.26	21.67

Table 4.9 Results of Water Quality Analysis for River Gurpur

Parameter	Unit	Nov-06	Dec	Jan-07	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct-07
Cadmium	µg/L	0.01	0.02	0	0.12	1.23	1.87	2.11	1.27	0.13	0.43	0.64	0.42
Chlorides	mg/L	17	21	23	25	187	202	187	18	8	12	10	13
Copper	µg/L	4.56	6.12	3.24	1.27	3.48	4.43	2.34	1.89	1.27	2.32	1.75	1.28
FCB	per 100 ml	9	9	4	9	9	9	4	4	9	17	9	9
Fluorides	mg/L	0.07	0.12	0.16	0.02	0.63	0.09	0.17	0.05	0.08	0.05	0.09	0.07
Hardness	mg/L	20	23	25	25	56	76	46	12	12	8	10	12
Iron	mg/L	0.14	0.11	0.08	0.01	0.05	0.08	0.12	0.87	1.41	1.23	0.24	0.21
Lead	µg/L	1.23	1.92	2.34	1.67	2.01	1.65	1.29	1.98	2.82	1.98	2.19	2.05
Manganese	mg/L	0.02	0.01	1.02	0.05	1.28	0.07	1.38	0.23	0.02	0.08	2.21	1.95
Nitrates	mg/L	3.75	3.16	2.87	1.72	3.16	3.78	0.04	1.23	1.28	1.98	2.19	2.26
pH		7.55	7.62	7.38	6.81	6.89	6.96	6.85	6.63	6.36	6.54	6.41	6.36
Sodium	mg/L	5.4	6.3	7.1	14.4	45.9	113	42.1	10.2	5.5	6.1	5.4	8.4
Sulfates	mg/L	6.76	5.1	4.74	3.88	7.58	9.85	6.42	2.65	5.39	3.47	2.15	0.07
TDS	mg/L	40	47	60	65	277	778	256	34	18	17	14	12
Turbidity	NTU	4.7	2.8	3.7	2.1	2.8	3.6	3.2	25.9	29.1	17.8	7.9	4.9
Zinc	µg/L	4.23	3.41	6.96	5.41	6.09	2.82	3.56	6.21	7.63	4.02	5.67	6.54

Table 4.10 Descriptive Statistics of Water Quality Parameters for River Gurpur

Parameter	Unit	Mean	Median	Standard Deviation	Minimum	Maximum
Cadmium	µg/L	0.69	0.43	0.75	0	2.11
Chlorides	mg/L	60.25	19.5	79.7	8	202
Copper	µg/L	2.83	2.33	1.56	1.27	6.12
FCB	per 100 ml	8.42	9	3.5	4	17
Fluorides	mg/L	0.13	0.09	0.16	0.02	0.63
Hardness	mg/L	27.08	21.5	21.32	8	76
Iron	mg/L	0.38	0.13	0.5	0.01	1.41
Lead	µg/L	1.93	1.98	0.44	1.23	2.82
Manganese	µg/L	0.69	0.16	0.83	0.01	2.21
Nitrates	mg/L	2.29	2.23	1.12	0.04	3.78
pH		6.86	6.83	0.45	6.36	7.62
Sodium	mg/L	22.48	7.75	31.88	5.4	113
Sulfates	mg/L	4.84	4.92	2.64	0.07	9.85
TDS	mg/L	134.78	43.5	222.19	12	778
Turbidity	NTU	9.04	4.2	9.62	2.1	29.1
Zinc	µg/L	5.21	5.54	1.56	2.82	7.63

4.10.3.3 Determination of Global Water Quality Indices

The global water quality indices for the two major rivers in the study area, river Nethravati and river Gurpur were determined.

Drinking Water Quality Index(DWQI): For Nethravati river, out of the sixteen parameters considered for the determination of DWQI, the three failed parameters were Fecal Coliform Bacteria (FCB), Iron and Turbidity and the numbers of failed tests were 17 out of total of 192.The DWQI calculated was 80.09 and therefore it can be designated as ‘Good’. The detailed calculation of the global water quality indices for river Nethravati is shown in Table.4.11. In an earlier work using Bhargava method Santhosh and Shrihari (2008) reported the water quality index for Nethravati river to vary from ‘Excellent’ to ‘Fair’. For Gurpur river, out of the sixteen parameters considered for the determination of DWQI, the four failed parameters were pH, FCB, Iron and Turbidity and the number of failed tests were 22 out of total of 192.The DWQI calculated was 73.56 and therefore it can be designated as ‘Fair’. The detailed calculation of the global water quality indices for river Gurpur is shown in Table.4.12.

Health Water Quality Index(HWQI):For Nethravati river, out of the seven parameters considered for the determination of HWQI only one parameter, FCB had failed and the number of failed tests were 12 out of total of 84.The HWQI calculated for River Nethravati was 75.50 and therefore it can be designated as ‘Fair’. For Gurpur river, out of the seven parameters considered for the determination of HWQI only one parameter, FCB had failed and the number of failed tests were 12 out of total of 84.The HWQI calculated for River Gurpur was 68.09 and therefore it can be designated as ‘Fair’.

Acceptability Water Quality Index (AWQI): For Nethravati river, out of the nine parameters considered for the determination of AWQI, only two parameters, Iron and Turbidity failed and the numbers of failed tests were 5 out of total of 108.The AWQI calculated 83.42 and therefore it can be designated as ‘Good’. For Gurpur river, out of the nine parameters considered for the determination of AWQI, only three parameters, pH, Iron and Turbidity failed and the number of failed tests were 10 out of total of 108. The AWQI calculated was 77.78 and therefore it can be designated as ‘Fair’.

Table 4.11 Determination of Global Water Quality Indices for River Nethravati

Index	Scope	Frequency	Amplitude	Total Excursion	Normalized Sum of Excursions (nse)	WQI	WQI Designation
	F1	F2	F3				
DWQI	18.75	8.85	73.03	0.38	27.56	80.09	Good
HWQI	14.29	14.29	50.00	0.60	37.31	75.50	Fair
AWQI	22.22	4.63	23.03	0.21	17.58	83.42	Good

Table 4.12 Determination of Global Water Quality Indices for River Gurpur

Index	Scope	Frequency	Amplitude	Total Excursion	Normalized Sum of Excursions (nse)	WQI	WQI Designation
	F1	F2	F3				
DWQI	25	11.46	110.9	0.58	36.61	73.6	Fair
HWQI	14.29	14.29	89	1.06	51.45	68.1	Fair
AWQI	33.33	9.26	21.9	0.2	16.86	77.8	Fair

4.10.3.4 Parameters contributing to the Indices

To understand which parameters were contributing the most to the water quality indices, the parameters that exceeded the guideline within each index were plotted as percentage of total exceedances for river Nethravati and river Gurpur and are shown in Fig.4.15 and Fig.4.16 respectively. For Nethravati river, in case of DWQI, FCB accounted for 69% of the exceedances, Iron accounted for 16% and Turbidity 15%.In case of HWQI, the sole contributor to the index was FCB and in case of AWQI, Iron contributed 52% and Turbidity contributed 48%.For Gurpur river, in case of DWQI, FCB accounted for 80% of the exceedances, Turbidity accounted for 11%, Iron accounted for 8% and pH for 1%.In case of HWQI, the sole contributor to the index was FCB and in case of AWQI, Turbidity contributed 55%, Iron contributed 40% and pH contributed 5%.

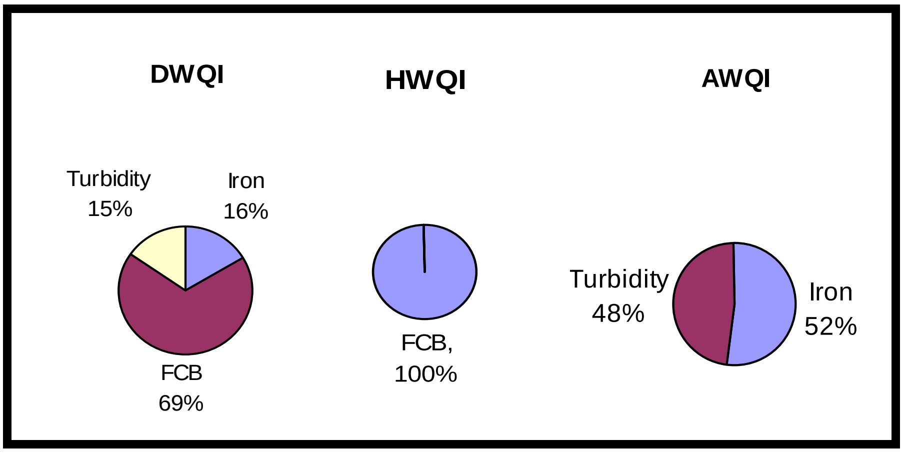


Fig.4.17.Parameters that exceeded the guideline (percentage of total exceedance for DWQI, HWQI and AWQI for Nethravati river

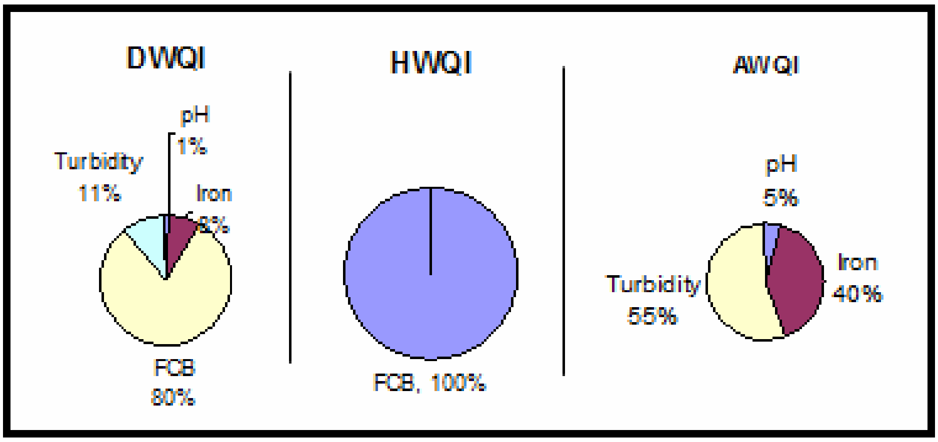


Fig.4.18. Parameters that exceeded the guideline (percentage of total exceedance for DWQI, HWQI and AWQI for Gurpur river

4.10.3.5 Significance of global water quality indices

The global water quality indices developed help in assessment of changes in water quality over time and space. They can also be used to evaluate the successes and shortcomings of domestic policy and international treaties designed to protect the aquatic resources. Thus the global water quality indices will act as key indicators towards the environmental performance of the region.

4.10.4 Sea Water

The pH of the sea water samples ranged from 8.03 to 8.71, temperature varied from 28.3 to 32.7^{0}C, salinity varied from 25.3 to 44.1‰, conductivity from 45.45 to 48.49mS/m, Total Dissolved Solids from 24,610 to 25,890 mg/L, Dissolved Oxygen from 5.38 to 7.70 mg/L, turbidity from 2.1 to 23.4 NTU, alkalinity from 104 to 158 mg/L, hardness from 6,000 to 7,720 mg/L. The major constituents of sea water, chlorides varied from 17,800 to 24,400 mg/L, sodium from 9,300 to 12,020 mg/L, magnesium from 1,200 to 1,320 mg/L, sulfates from 2,470 to 3,010 mg/L, calcium from 390 mg/L to 430 mg/L, and potassium from 340 to 430 mg/L. The concentration of nitrates ranged from 0.21 to 10.86 mg/L, iron from 8.8 to 12.1 µg/L, manganese from 17.5 to 29.5 µg/L, cadmium from 0.12 to 0.15 µg/L, copper from 0.23 to 0.28 µg/L, lead from 1.65 to 1.91 µg/L, zinc from 0.78 to 0.95 µg/L. The BOD varied from 1.2 to 3.5 mg/L and COD varied from 100 to 140 mg/L. The Total Coliforms ranged between 13 to 900 MPN per 100 ml sample and the Fecal Coliforms ranged from 13 to 500 MPN per 100 ml sample.

4.11 Changes in groundwater quality in Mangalore city during 1987-2007

The chemical properties Calcium(Ca^+), Magnesium(Mg^+),Sodium(Na^+),Potassium (K^+), Bicarbonates (HCO_3^-), Total Hardness (TH) as $CaCO_3$, Chlorides (Cl^-), Nitrates (NO_3^-), Sulfates (SO_4^-), Total Dissolved Solids (TDS), Electrical Conductivity (EC) and pH of the samples tested are shown in Table 4.13.

Table 4.13 Chemical characteristics of ground water of Mangalore city

Sl. No.	Sampling Location	Ca^+	Mg^+	Na^+	K^+	HCO_3^-	TH	Cl^-	NO_3^-	SO_4^-	TDS	EC	pH
1	O-20	8.56	20.31	32.1	1.9	69	105	51	19.67	30.14	235	379	6.57
2	O-21	6.16	3.06	5.6	2.1	20	28	18	5.68	1.59	53	85	5.96
3	O-23	6.6	1.09	21.5	2.6	17	21	32	10.26	9.82	88	142	5.18
4	O-24	5.12	7.10	15.2	1.2	35	42	29	12.56	8.43	136	219	6.87
5	O-25	3.4	0.12	2.5	1.5	10	9	12	2.13	1.43	7	12	5.46
6	O-27	7.56	15.82	23.6	6.9	66	84	46	10.28	16.49	137	221	6.28
7	O-28	6.32	5.39	2.5	1.2	28	38	14	2.64	0.49	33	54	6.18
8	O-29	10.24	9.33	21.3	6.5	21	64	39	20.46	10.28	153	246	6.15
9	O-30	6.76	41.33	7.9	0.9	158	187	48	25.69	10.47	262	423	6.59
10	O-31	4.96	1.60	9.8	1.5	14	19	18	18.79	1.75	63	102	5.85
11	O-32	4.2	6.93	12.6	1.1	48	39	19	19.83	2.15	89	143	6.19
12	O-34	10.16	16.91	22.3	2.9	95	95	42	4.53	5.68	208	336	6.87
13	O-35	5.16	23.11	12.3	2.7	89	108	58	25.49	9.64	176	284	7.09
14	O-36	7.92	2.72	29.8	2.9	12	31	54	31.49	3.21	159	257	5.15
15	O-37	16.84	22.82	56.4	6.9	146	136	68	4.26	17.62	280	452	6.82
16	O-38	5	5.71	9.8	1.5	28	36	21	15.67	8.64	85	137	6.25
17	O-39	10.24	2.28	18.9	4.3	28	35	19	13.49	22.15	95	153	6.21
18	O-40	6.16	1.85	15.4	2.6	12	23	31	3.59	8.75	84	136	5.28
19	O-41	6.16	6.22	15.6	4.5	32	41	29	23.47	13.87	125	201	5.67
20	O-42	4.6	1.58	10.9	2.2	15	18	18	4.52	3.35	43	69	5.21
21	O-43	2.76	1.24	4.8	0.9	11	12	10	3.35	2.57	26	42	5.09
22	O-44	3.36	0.87	5.6	2.1	11	12	10	3.52	2.25	20	32	5.21
23	O-45	8.12	6.49	14.2	3.1	25	47	28	32.59	25.67	127	205	5.67
24	O-46	6.72	5.39	11.9	1.2	24	39	24	7.83	9.63	101	163	5.69
25	O-47	22.72	52.29	87.4	21.0	170	272	56	123.67	36.85	624	1006	8.16
26	O-48	10.56	18.61	19.8	9.3	107	103	39	18.76	18.63	234	378	6.96
27	O-49	4.2	4.50	15.3	2.6	18	29	39	5.49	15.43	102	164	5.42
28	O-50	5.04	14.43	7.9	2.9	59	72	18	1.87	8.61	115	185	6.15
29	O-51	4.24	0.34	8.7	2.6	11	12	22	12.36	1.87	40	65	5.21
30	O-52	9.84	3.26	21.3	6.9	11	38	31	31.48	14.27	153	246	5.26
31	O-53	21.04	31.93	45.3	10.2	254	184	78	3.64	33.15	456	735	7.45
32	O-54	8.64	13.22	16.4	4.9	45	76	30	31.48	29.61	177	285	6.23
33	O-55	4.24	6.42	28.7	4.5	19	37	38	18.97	8.63	150	242	6.89
34	O-55	8.6	0.36	10.8	1.3	23	23	23	15.46	5.13	78	125	5.64
35	O-56	3.86	30.46	15.6	6.8	109	135	23	31.49	6.47	195	314	6.47

Sl. No.	Sampling Location	Ca^+	Mg^+	Na^+	K^+	HCO_3^-	TH	Cl^-	NO_3^-	SO_4^-	TDS	EC	pH
36	O-57	14.68	9.31	36.7	3.6	63	75	48	3.47	23.16	228	368	6.87
37	O-59	10.68	14.17	28.6	6.5	64	85	48	25.61	21.09	218	352	6.95
38	O-60	5.04	1.31	6.5	1.2	19	18	14	2.16	4.53	48	78	5.87
39	O-64	6.36	19.22	12.3	2.5	65	95	25	9.67	2.56	177	285	6.23
40	O-65	9.52	20.70	18.7	3.1	97	109	36	6.98	23.54	215	346	6.69
41	O-66	4.96	5.49	10.4	2.2	45	35	12	2.31	1.58	56	90	6.77
42	O-67	8.76	34.77	32.5	2.9	187	165	46	16.54	30.18	283	457	7.19
	Average this study	7.76	11.67	19.18	3.81	56.40	67.43	32.48	16.27	12.18	150.78	243.19	6.19
	Rajesh & Murthy	35.00	9.03	32.63	11.23	170.00	-	48.02	3.45	13.02	244.00	487.00	6.56
	Narayana & Suresh	23	5.00	21.0	9.0	57		47	-	27	-	388	6.41

The summary statistics mean, median, standard deviation, sample variance, minimum and maximum of the chemical parameters are shown in Table 4.14.

Table 4.14 Summary statistics of chemical quality of Mangalore City

Parameter	Mean	Median	Standard Deviation	Sample Variance	Minimum	Maximum
Ca^+	7.76	6.48	4.37	19.06	2.76	22.72
Mg^+	11.67	6.45	12.29	151.09	0.12	52.29
Na^+	19.18	15.35	15.66	245.19	2.50	87.40
K^+	3.81	2.65	3.57	12.75	0.90	21.00
HCO_3^-	56.67	30.00	56.42	3183.54	10.00	254.00
TH	67.43	40.00	57.66	3324.25	9.00	272.00
Cl^-	32.48	29.50	16.40	269.08	10.00	78.00
NO_3^-	16.27	12.46	19.67	386.87	1.87	123.67
SO_4^-	12.18	9.19	10.15	103.00	0.49	36.85
TDS	150.78	131.44	116.86	13657.31	7.44	623.72
EC	243.19	212.00	188.49	35528.89	12.00	1006.00
pH	6.19	6.20	0.73	0.54	5.09	8.16

4.11.1 Chemical quality of groundwater in Mangalore city

The correlation coefficients for the chemical parameters are shown in Table 4.15. Concentration of Calcium as Ca varied from 2.76 to 22.72 mg/L and showed good correlation with Na, TDS, EC, K, SO_4, Cl^- and TH. Magnesium as Mg varied from 0.12 to 52.29 mg/L and correlated well with TH, HCO_3, TDS, EC and pH. Five sampling locations, O-30, O-47, O-50, O-57 and O-67 (Kunjathbail, Thannirbavi, Kudroli, Padil, and Jappinamogaru) have recorded higher concentrations more than the standard of 30mg/L. The maximum value of 52.29 mg/L was recorded at open well O-47 (Thannirbavi) which is located at 100 m from the Arabian Sea.

Table 4.15 Correlation coefficients of chemical parameters of Mangalore City

	Ca^+	Mg^+	Na^+	K^+	HCO_3^-	TH	Cl^-	NO_3^-	SO_4^-	TDS	EC	pH
Ca^+	1.00											
Mg^+	0.59	1.00										
Na^+	0.86	0.63	1.00									
K^+	0.77	0.61	0.82	1.00								
HCO_3^-	0.68	0.90	0.61	0.54	1.00							
TH	0.70	0.99	0.71	0.68	0.92	1.00						
Cl^-	0.72	0.64	0.75	0.52	0.71	0.70	1.00					
NO_3^-	0.47	0.55	0.63	0.74	0.28	0.57	0.31	1.00				
SO_4^-	0.73	0.59	0.70	0.61	0.60	0.66	0.64	0.45	1.00			
TDS	0.85	0.88	0.87	0.80	0.84	0.93	0.79	0.65	0.76	1.00		
EC	0.85	0.88	0.87	0.80	0.84	0.93	0.79	0.65	0.76	1.00	1.00	
pH	0.61	0.78	0.62	0.55	0.77	0.80	0.58	0.39	0.56	0.77	0.77	1.00

Sodium concentration varied from 2.5 to 87.4 mg/L and showed good correlation with TDS, EC, K, Cl. TH, and SO_4. Potassium varied from 0.9 to 21 mg/L and correlated well with TDS, EC, K and NO_3. Bicarbonates ranged from 10 to 254 mg/L and had good correlation with TH, Mg, TDS, EC, pH and Chlorides. Total Hardness varied from 9 to 272 mg/L and had correlated well with TDS, EC, Mg, Na, Cl and pH. Chlorides concentration ranged from 10 to 78 mg/L and had good correlation with TDS, EC, Na, Ca and HCO_3.

Nitrates (NO_3) concentration varied from 1.87 to 123.67 mg/L and had good correlation with K, TDS, EC and Na. At open well, O-47 (Thannirbavi) the nitrates concentration recorded was 123.67 mg/L which is much higher than the acceptable higher limit of 45 mg/L. The contamination of ground water due to the near by septic tank may be the reason for this high value. The sulfates concentration varied from 0.49 to 36.85 mg/L and had correlated well with TDS, EC, Ca, Na and Chlorides.

The Total Dissolved Solids have ranged from 7.44 to 623.7 mg/L and the Electrical Conductance has varied from 12 to 1006 mho/cm. The open well, O-47 has recorded the highest TDS of 623.7 mg/L which is more than desirable limit of 500 mg/L. As this well is in close proximity to the sea, salt water intrusion may be the reason for this high value.

The pH of open well water samples from the study area varied from 5.09 to 8.16.The highest value is observed at O-47. 27 of 42 water samples (64%) have pH value less than 6.50 which is the desirable minimum value as per standards. This phenomenon of low pH is conformity with the earlier study conducted by Sunil and Shrihari (2002).

4.11.2 Changes in groundwater quality in Mangalore city

The water quality results obtained from the present study were compared with two earlier investigations reported for the study area to understand the changes in ground water quality in Mangalore city. The first study considered for comparison was by Narayana and Suresh in which fifty six groundwater samples were analyzed during the pre-monsoon period in March 1987 (Narayana and Suresh, 1989). The second study considered was by Rajesh and Murthy in which fifteen open well samples were collected during the pre-monsoon period of May 1998 (Rajesh and Murthy, 2004). The present sample locations are not the same as those in the earlier studies. Therefore, the mean values of the concentration of different parameters of the present study were compared with the mean values of the earlier studies. There was marked difference in the concentrations of nitrates and pH.

The mean concentration of nitrates has increased from 3.45 mg/L in 1998 to 16.27 mg/L in 2007 there by recording almost five fold increase. This may be due to the fast urbanization that has taken place in the study area. The concentration of chlorides and sulphates and bacterial contaminations were more in coastal urban areas than in the other land uses (Shrihari, 2010). The mean value of pH has decreased from 6.41 in the year 1987 to 6.19 in 2007 showing the acidic nature of water in Mangalore city. The percentage of samples whose pH was less than 6.50 had increased from 50% in 1987 to 53% in 1998 to 64% in this study. The low pH can be attributed to the recharge of shallow ground water aquifers through sanitary effluents, septic tanks, and municipal drainage.

The average concentration of FCB in core urban and industrial areas was 176 MPN per 100 ml. where as in non-urban areas it was only 52. This demonstrates that the land use/land cover changes due to urbanization enhanced the presence of FCB. The enhancement or otherwise of the trace metals due to urbanization in the study area can not be established as there are no reported literatures available. However, the concentrations of trace metals were with in the permissible limits.

The trend of groundwater quality deterioration is continuing in the coastal Karnataka region. In a study carried out by Shrihari (2010) based on the water samples analyzed during 2008-2010, the concentrations of TDS, chlorides, sulfates and MPN values were much higher in industrial and urban areas as compared hinterland.

5.1 Conclusions

1. Satellite remote sensing has been effectively used to study the land use/land cover changes that took place in fast urbanizing coastal area of Dakshina Kannada district, Karnataka, India during the years 1983 to 2008. The results indicate that the urban/built-up area has increased by 270% during the study period. The population has increased by 215% during the same period.

2. The global water quality indices for the two major rivers in the study area were computed. The global water quality indices for River Nethravati varied from ‘Good’ to ‘Fair’ and the indices for River Gurpur can be categorized as ‘Fair’. The determination of global water quality indices will help in assessment of changes in water quality over time and space and will act as key indicators towards the environmental performance of the region. Fecal Coliform Bacteria (FCB) was the most important parameter contributing to the water quality indices.

3. The over all quality of groundwater in Mangalore city is deteriorating. In 61% of the open well samples and 19% of the bore well samples pH is less than 6.50. The concentration of Nitrates is showing an increasing trend, though at present it is well within the standards.

4. Urban growth prediction helps the urban planners and policy makers in providing better infrastructure services to a huge number of new urban residents. In the study area, the urban/built-up area is projected to increase to 381 sq. km and the population is expected to reach 2.68 millions by the year 2028.

5. The population in the study area has already reached saturation levels; therefore any further increase in population will result in environmental degradation. This indicates that the available resources are not sustainable and the carrying capacity of the region is unsustainable.

APPENDIX -I

WATER QUALITY MONITORING:OPEN WELLS SUMMARY STATISTICS

SUMMARY STATISTICS FOR **PH**

Parameter/Sampling Location	O-1	O-2	O-3	O-4	O-5	O-6	O-7	O-8	O-9	O-10	O-11	O-12	O-13	O-14	O-15
Mean	6.51	6.50	6.63	5.75	5.29	5.26	6.64	5.99	6.71	6.68	5.98	6.66	5.60	6.38	6.20
Median	6.47	6.805	6.575	6	5.46	5.37	6.76	6.035	6.69	6.83	6.24	6.525	5.555	6.375	6.375
Standard Deviation	0.198	0.553	0.233	0.560	0.437	0.526	0.501	0.420	0.350	0.834	0.734	0.390	0.308	0.213	0.646
Minimum	6.22	5.51	6.31	4.34	4.26	4.02	5.45	5.19	6.27	5.12	5.08	6.21	5	6.08	5.14
Maximum	6.95	7.07	7.04	6.16	5.68	5.86	7.24	6.57	7.62	7.66	6.89	7.61	6.12	6.77	7.13

Parameter/Sampling Location	O-16	O-17	O-18	O-19	O-20	O-21	O-22	O-23	O-24	O-25	O-26	O-27	O-28	O-29	O-30
Mean	5.25	6.638	8.1658	5.8067	6.32	5.5325	7.21	5.634	6.2525	5.2242	7.983	6.228	5.8167	6.0933	6.74583
Median	5.15	6.695	8.22	5.94	6.345	5.925	7.22	5.395	6.385	5.345	7.875	6.285	6.18	6.11	6.88
Standard Deviation	1.0114	0.529	0.1523	0.6148	0.3127	0.7445	0.3948	0.65	0.6154	0.3481	0.323	0.301	0.6836	0.0967	0.56281
Minimum	3.86	5.9	7.88	4.29	5.67	3.98	6.58	4.82	4.76	4.27	7.57	5.36	4.68	5.9	5.86
Maximum	6.65	7.55	8.35	6.4	6.75	6.14	8.14	6.63	6.87	5.56	8.55	6.58	6.48	6.25	7.43

Parameter/Sampling Location	O-31	O-32	O-33	O-34	O-35	O-36	O-37	O-38	O-39	O-40	O-41	O-42	O-43	O-44	O-45
Mean	5.57	6.36	6.53	6.70	6.66	5.06	6.95	5.98	5.98	5.02	5.80	5.34	5.12	4.91	5.96
Median	5.795	6.495	6.65	6.945	6.925	5.155	6.86	6.335	6.18	5.12	5.835	5.345	5.13	4.975	5.9
Standard Deviation	0.58	0.56	0.49	0.48	0.60	0.27	0.20	0.74	0.44	0.30	0.48	0.27	0.24	0.51	0.29
Minimum	4.34	5.49	5.85	5.7	5.46	4.48	6.72	4.94	5.25	4.23	5.04	4.79	4.68	4.28	5.58
Maximum	6.19	6.98	7.13	7.08	7.17	5.33	7.31	6.74	6.45	5.28	6.42	5.78	5.45	5.48	6.37

Parameter/Sampling Location	O-46	O-47	O-48	O-49	O-50	O-51	O-52	O-53	O-54	O-55	O-56	O-57	O-58	O-59	O-60
Mean	5.53	8.19	7.06	5.43	6.27	5.21	5.27	7.46	6.36	6.56	5.61	6.59	6.94	6.31	5.81
Median	5.59	8.21	7.095	5.43	6.17	5.235	5.265	7.485	6.275	6.45	5.62	6.615	7.01	6.335	5.78
Standard Deviation	0.31	0.16	0.16	0.10	0.27	0.28	0.11	0.17	0.25	0.60	0.22	0.24	0.22	0.36	0.44
Minimum	4.94	7.83	6.71	5.25	5.91	4.71	5	7.19	6.13	5.49	5.11	6.17	6.53	5.73	5.16
Maximum	5.95	8.42	7.25	5.57	6.82	5.71	5.4	7.69	6.83	7.4	5.97	6.96	7.16	6.95	6.38

Parameter/Sampling Location	O-61	O-62	O-63	O-64	O-65	O-66	O-67	O-68	O-69	O-70	O-71	O-72	O-73	O-74	O-75
Mean	6.01	6.18	6.78	6.38	6.98	6.19	7.18	6.91	5.24	6.13	6.90	6.96	6.23	7.12	7.46
Median	6.16	6.155	6.665	6.375	6.785	6.185	7.165	6.865	5.37	6.225	6.96	6.9	6.465	7.105	7.49
Standard Deviation	0.44	0.32	0.28	0.20	0.40	0.38	0.30	0.20	0.36	0.52	0.69	0.18	0.41	0.15	0.22
Minimum	4.89	5.62	6.4	6.1	6.51	5.64	6.67	6.69	4.23	5.19	5.42	6.71	5.47	6.93	6.92
Maximum	6.39	6.62	7.25	6.75	7.54	6.77	7.89	7.34	5.56	6.77	7.64	7.21	6.56	7.43	7.79

SUMMARY STATISTICS FOR **TEMPERATURE(IN 0^0C)**

Parameter/Sampling Location	O-1	O-2	O-3	O-4	O-5	O-6	O-7	O-8	O-9	O-10	O-11	O-12	O-13	O-14	O-15
Mean	28.1	28.6	28.7	29.5	28.9	28.6	28.1	28.9	28.2	29.3	28.2	28.9	29.3	28.8	29.1
Median	28.1	28.6	28.3	29.4	28.75	28.6	28.15	28.9	28.1	29.2	28.2	28.85	29.3	29.05	29.15
Standard Deviation	0.683	0.669	1.010	0.992	1.410	0.768	0.578	1.019	0.468	0.730	0.408	0.642	0.726	0.764	0.729
Minimum	27.1	27.5	27.4	28.1	27.1	27.2	27.1	27.6	27.5	28.5	27.4	28.1	28.1	27.4	27.7
Maximum	29.1	29.7	30.3	31.2	31.4	29.9	28.9	30.5	28.9	30.9	28.7	30.1	30.2	29.8	30.3

Parameter/Sampling Location	O-16	O-17	O-18	O-19	O-20	O-21	O-22	O-23	O-24	O-25	O-26	O-27	O-28	O-29	O-30
Mean	28.0	27.8	28.6	28.3	28.3	28.3	28.7	29.0	28.3	28.1	29.0	28.3	28.5	29.5	28.3
Median	28.1	28.2	28.55	28.35	28.4	28.3	28.5	29.1	28.45	28.2	29	28.45	28.55	29.5	28.3
Standard Deviation	0.620	1.105	0.499	0.924	0.355	0.584	0.650	0.429	0.558	0.479	0.698	0.878	0.507	0.839	0.614
Minimum	26.8	25.2	27.6	26.7	27.7	27.1	27.9	28.4	27.4	27.1	27.9	25.8	27.2	28.3	27.4
Maximum	28.7	29.2	29.3	30.1	28.8	29.3	29.9	29.7	29	28.8	30.5	29.3	29	31.1	29.1

Parameter/Sampling Location	O-31	O-32	O-33	O-34	O-35	O-36	O-37	O-38	O-39	O-40	O-41	O-42	O-43	O-44	O-45
Mean	28.7	28.9	28.5	29.1	28.8	28.5	28.8	28.9	28.8	28.4	28.7	29.2	29.5	28.2	28.7
Median	28.55	28.8	28.45	29.1	28.7	28.35	28.5	28.85	28.8	28.4	28.5	29	29.35	28.25	28.55
Standard Deviation	0.537	0.624	0.463	1.084	0.949	0.852	0.947	0.507	0.533	0.820	0.892	0.852	0.817	0.276	0.918
Minimum	28.1	27.8	27.8	26.8	27.6	27.2	27.8	28.2	27.8	26.8	27.6	28.4	28.5	27.8	27.4
Maximum	29.7	29.8	29.1	31	30.8	30.2	31	29.8	29.6	29.9	30.5	31.3	31.5	28.7	30.8

Parameter/Sampling Location	O-46	O-47	O-48	O-49	O-50	O-51	O-52	O-53	O-54	O-55	O-56	O-57	O-58	O-59	O-60
Mean	29.1	29.9	28.7	29.4	29.6	28.9	27.9	29.5	29.9	28.8	29.2	29.6	28.8	29.3	28.8
Median	28.9	29.9	28.55	28.95	29.1	28.9	27.9	29.15	30.3	28.7	29	29.3	28.65	29.25	28.65
Standard Deviation	0.709	0.947	0.978	0.835	1.416	0.500	1.024	1.301	1.537	1.062	0.919	0.955	0.531	0.599	0.578
Minimum	28.2	28.5	27.4	28.5	28.2	28.1	25.2	27.3	26.4	26.9	28.1	28.6	28.1	28.3	28
Maximum	30.8	31.8	30.5	31.1	33.2	29.8	29.1	32.4	32.1	31.1	31.1	32	29.7	30.6	30

Parameter/Sampling Location	O-61	O-62	O-63	O-64	O-65	O-66	O-67	O-68	O-69	O-70	O-71	O-72	O-73	O-74	O-75
Mean	28.8	28.6	28.8	29.0	29.5	29.3	29.5	31.7	28.5	29.0	28.5	29.9	29.0	29.4	28.9
Median	28.55	28.45	28.85	28.75	29.6	29.25	29.5	31.15	28.25	29.15	28.55	29.8	28.95	29.05	28.7
Standard Deviation	0.807	0.838	0.780	0.719	1.158	0.964	1.000	1.273	0.792	0.649	0.535	1.124	0.471	1.097	0.665
Minimum	27.8	27.5	27.6	27.8	27.4	28.2	28.2	30.5	27.5	27.6	27.7	28.1	28.2	28.1	28.1
Maximum	30.1	30.1	30.3	30.2	31.3	31	31.5	34.3	30	29.8	29.1	32.2	30	32	30.2

SUMMARY STATISTICS FOR **CONDUCTIVITY**

Parameter/Sampling Location	O-1	O-2	O-3	O-4	O-5	O-6	O-7	O-8	O-9	O-10	O-11	O-12	O-13	O-14	O-15
Mean	489.50	281.92	150.67	51.92	97.58	66.08	233.58	99.83	246.25	221.58	81.33	125.92	56.25	175.33	72.00
Median	475.5	223.5	141.5	52	87.5	66.5	243	101.5	244	238.5	76	124.5	57	171	68
Standard Deviation	45.19	181.87	25.17	20.39	33.04	13.03	103.76	11.22	22.56	58.78	14.77	14.52	15.90	69.43	16.31
Minimum	430	90	125	20	62	44	90	80	208	110	63	103	30	68	50
Maximum	569	605	203	85	164	90	387	118	281	312	110	150	78	314	105

Parameter/Sampling Location	O-16	O-17	O-18	O-19	O-20	O-21	O-22	O-23	O-24	O-25	O-26	O-27	O-28	O-29	O-30
Mean	73.30	435.17	559.17	116.42	308.08	74.50	471.92	215.42	183.67	16.08	520.67	168.67	36.83	221.50	396.00
Median	79.5	383	569	107	316	74.5	389.5	182	219	12	469.5	164.5	33.5	222	395.5
Standard Deviation	34.10	172.06	100.69	25.95	101.78	17.89	310.32	76.43	75.02	6.82	340.49	51.84	27.86	47.68	129.17
Minimum	6	241	340	85	120	40	70	135	80	10	140	100	10	167	210
Maximum	139	836	730	170	460	110	1109	342	290	28	1160	264	92	298	592

Parameter/Sampling Location	O-31	O-32	O-33	O-34	O-35	O-36	O-37	O-38	O-39	O-40	O-41	O-42	O-43	O-44	O-45
Mean	75.67	163.83	106.08	310.25	231.25	280.83	463.25	127.75	206.08	139.50	193.75	54.25	33.25	24.36	244.00
Median	85	160.5	108.5	305.5	230	253	428	125.5	205	139	192	50.5	36.5	25	248.5
Standard Deviation	27.54	20.89	13.21	29.62	58.22	59.69	93.45	11.49	38.53	17.80	23.68	17.60	8.39	7.39	31.82
Minimum	28	131	83	270	168	235	370	110	145	109	158	26	20	10	187
Maximum	105	215	124	367	331	421	661	145	267	170	230	85	43	32	290

Parameter/Sampling Location	O-46	O-47	O-48	O-49	O-50	O-51	O-52	O-53	O-54	O-55	O-56	O-57	O-58	O-59	O-60
Mean	144.17	731.50	399.75	203.92	201.58	67.00	244.17	629.50	270.83	198.83	109.25	351.00	352.42	354.33	79.33
Median	138	709.5	398.5	199.5	191.5	70.5	246.5	705.5	269	187.5	109.5	327	360	355.5	77
Standard Deviation	17.98	119.89	23.28	35.33	48.42	10.67	10.77	234.64	32.59	43.78	11.87	53.35	24.98	25.45	16.52
Minimum	121	567	361	152	132	40	229	305	220	141	90	286	300	309	53
Maximum	171	1006	450	270	310	79	265	971	329	298	132	474	386	400	120

Parameter/Sampling Location	O-61	O-62	O-63	O-64	O-65	O-66	O-67	O-68	O-69	O-70	O-71	O-72	O-73	O-74	O-75
Mean	88.08	309.17	385.08	304.00	335.42	145.92	459.00	738.92	190.25	137.92	167.75	227.25	77.17	342.25	1004.42
Median	91.5	299.5	374.5	306	337.5	150.5	438.5	660.5	186	131	165.5	231	75.5	348.5	894.5
Standard Deviation	8.18	36.48	29.44	26.18	30.86	35.00	102.54	314.93	21.31	43.65	30.88	16.89	11.31	146.74	517.39
Minimum	73	263	352	264	268	88	326	511	163	82	124	185	60	131	410
Maximum	97	400	460	349	375	220	640	1647	230	210	222	248	94	670	1831

SUMMARY STATISTICS FOR **TDS (mg/L)**

Parameter/Sampling Location	O-1	O-2	O-3	O-4	O-5	O-6	O-7	O-8	O-9	O-10	O-11	O-12	O-13	O-14	O-15
Mean	297.3	155.5	92.6	31.7	59.0	38.3	133.7	60.2	146.7	133.1	47.2	72.6	36.1	104.4	43.8
Median	294.7	123.3	86.8	31.7	51.7	40.2	119.5	62.0	149.4	145.5	45.5	73.0	36.0	105.2	41.8
Standard Deviation	36.22	104.95	16.03	12.48	20.30	9.68	61.50	8.25	19.31	37.39	10.63	12.32	8.88	34.62	10.76
Minimum	213.9	55	77.5	12.4	38	24.8	55.8	44.64	102.92	68.2	27.9	43.4	22.32	40	27.28
Maximum	345	347	126	51	101	55	236	72	174	192	68.2	93	48	158.72	65

Parameter/Sampling Location	O-16	O-17	O-18	O-19	O-20	O-21	O-22	O-23	O-24	O-25	O-26	O-27	O-28	O-29	O-30
Mean	42.8	268.7	346.4	70.6	192.7	44.3	303.6	134.9	104.8	10.8	334.7	101.9	23.1	136.6	240.8
Median	46.2	235.4	349.6	65.5	194.4	44.2	239.5	123.7	130.5	11.3	336.4	91.5	20.5	131.8	240.6
Standard Deviation	21.23	107.16	57.26	17.54	58.63	11.36	176.28	42.02	41.30	4.02	177.69	32.47	16.82	32.05	80.51
Minimum	3	142	233.12	47.74	104.16	24.8	78.12	88.04	49.6	6.2	101.7	67	6.2	103.54	130.2
Maximum	85	517	452.6	105.4	285.2	67	677	209	146	17	603	163	57	182	364

Parameter/Sampling Location	O-31	O-32	O-33	O-34	O-35	O-36	O-37	O-38	O-39	O-40	O-41	O-42	O-43	O-44	O-45
Mean	42.8	99.5	63.4	186.8	139.6	168.4	276.4	77.5	126.3	84.4	117.1	32.5	19.5	13.9	149.8
Median	50.8	99.1	67.0	183.5	122.1	155.0	259.3	80.0	127.0	85.7	117.0	31.3	22.5	14.9	152.5
Standard Deviation	19.34	13.62	10.57	23.62	39.09	40.31	66.90	10.54	23.80	14.96	20.09	11.69	6.03	4.93	20.27
Minimum	11.78	81	42.16	138.88	104	104.16	161.2	52.08	89	48.36	68.82	13.64	8.68	6.2	110.98
Maximum	63.24	131	75	224	204	256	408	89	165	105.4	142.6	51	26.04	20	179

Parameter/Sampling Location	O-46	O-47	O-48	O-49	O-50	O-51	O-52	O-53	O-54	O-55	O-56	O-57	O-58	O-59	O-60
Mean	86.7	434.5	239.3	124.7	119.4	41.7	146.4	386.5	160.9	117.2	64.6	215.9	211.5	211.3	48.4
Median	85.2	426.5	241.6	124.0	118.0	40.2	152.8	434.0	160.2	115.4	66.0	202.7	219.5	218.6	46.5
Standard Deviation	14.84	79.97	29.59	24.48	40.63	10.53	16.88	144.10	28.22	31.19	10.34	30.84	25.90	32.11	10.99
Minimum	51.46	322.4	155	78.12	23	24.8	95.48	189.1	96.72	56.42	40.92	177.9	144.46	124	29.14
Maximum	105	623.7	279	167.4	192.2	67	158	602	203	172	81	287	239	248	74.4

Parameter/Sampling Location	O-61	O-62	O-63	O-64	O-65	O-66	O-67	O-68	O-69	O-70	O-71	O-72	O-73	O-74	O-75
Mean	52.4	187.0	231.6	184.8	200.8	92.4	284.3	434.5	113.5	85.0	103.5	138.0	45.7	198.4	617.3
Median	56.5	183.0	231.0	188.0	207.3	92.5	271.9	379.1	112.3	80.0	101.6	141.0	45.5	192.5	554.2
Standard Deviation	6.84	30.34	31.32	22.87	28.57	21.57	60.10	176.39	18.27	27.37	18.89	15.79	7.87	99.98	311.01
Minimum	35.96	118.4	150.04	127.1	130.2	55.8	217	254.8	72.54	50.84	76.88	91.76	32.24	67.58	254.2
Maximum	58	248	285.2	213	232	136.4	401	916	142	130.2	138	153.8	58.28	415.4	1123

SUMMARY STATISTICS FOR **DO(mg/L)**

Parameter/Sampling Location	O-1	O-2	O-3	O-4	O-5	O-6	O-7	O-8	O-9	O-10	O-11	O-12	O-13	O-14	O-15
Mean	6.0	6.2	6.5	6.7	6.4	6.4	6.9	7.0	6.4	6.2	6.4	6.4	5.9	6.5	6.9
Median	5.93	6.14	6.42	6.635	6.185	6.46	6.735	6.95	6.82	6.035	6.425	6.44	5.5	6.4	6.96
Standard Deviation	0.84	0.71	0.59	0.66	0.62	0.67	0.65	0.81	0.98	0.62	0.42	0.43	0.91	0.37	0.31
Minimum	4.21	5.08	5.89	5.62	5.32	5.16	5.34	5.08	4.43	5.58	5.38	5.36	4.23	5.74	6.36
Maximum	7.37	7.39	7.45	7.69	7.6	7.57	7.65	7.88	7.38	7.42	6.93	6.98	7.61	7.16	7.41

Parameter/Sampling Location	O-16	O-17	O-18	O-19	O-20	O-21	O-22	O-23	O-24	O-25	O-26	O-27	O-28	O-29	O-30
Mean	6.6	6.1	6.0	6.6	6.7	6.5	4.1	6.0	6.0	6.3	5.9	6.6	6.3	7.0	7.0
Median	6.59	6.01	6.03	6.335	6.625	6.585	4.04	5.995	5.82	6.42	6.01	6.55	6.18	7.03	6.985
Standard Deviation	0.42	0.64	1.10	0.50	0.30	0.70	1.92	0.82	0.61	0.49	1.09	0.28	0.53	0.54	0.46
Minimum	5.65	5.31	4.4	6.11	6.21	5.22	1.43	4.37	5.23	5.15	3.01	6.23	5.42	5.93	6.13
Maximum	7.16	7.24	7.72	7.45	7.12	7.36	6.75	7.2	7.15	6.86	7.12	7.09	7.44	7.65	7.68

Parameter/Sampling Location	O-31	O-32	O-33	O-34	O-35	O-36	O-37	O-38	O-39	O-40	O-41	O-42	O-43	O-44	O-45
Mean	6.9	6.2	6.8	6.6	6.9	6.0	6.2	6.0	6.6	6.1	6.3	6.2	6.7	6.0	6.4
Median	7	6.285	6.66	6.52	6.85	6.245	6.63	6.605	6.705	6	6.18	6.63	6.805	5.745	6.42
Standard Deviation	0.49	0.47	0.39	0.52	0.38	0.91	0.79	1.34	0.22	0.76	0.53	1.01	0.39	0.57	0.82
Minimum	6.05	5.61	6.38	5.62	6.32	4.51	4.74	3.72	6.19	5.21	5.79	4.51	5.78	5.37	5.32
Maximum	7.42	6.97	7.59	7.58	7.56	7.29	6.85	7.39	6.93	7.43	7.23	7.36	7.19	6.96	7.79

Parameter/Sampling Location	O-46	O-47	O-48	O-49	O-50	O-51	O-52	O-53	O-54	O-55	O-56	O-57	O-58	O-59	O-60
Mean	6.8	6.5	6.2	6.2	6.5	6.4	5.9	5.9	7.2	5.9	5.7	6.3	5.4	5.7	5.4
Median	6.79	6.435	5.865	6.715	6.515	6.285	5.96	6.23	7.21	6.195	5.52	6.18	5.385	5.765	5.03
Standard Deviation	0.38	0.77	0.76	1.16	0.43	0.48	0.71	1.15	0.31	0.68	1.12	0.44	0.66	1.08	0.87
Minimum	6.22	4.93	5.41	3.88	5.77	5.72	4.82	3.06	6.78	4.53	4.11	5.81	4.04	3.97	4.42
Maximum	7.62	7.51	7.81	7.14	7.09	7.41	7.25	7.31	7.85	6.41	7.41	7.44	6.3	7.42	7.01

Parameter/Sampling Location	O-61	O-62	O-63	O-64	O-65	O-66	O-67	O-68	O-69	O-70	O-71	O-72	O-73	O-74	O-75
Mean	6.0	6.0	6.4	6.9	7.4	6.6	6.1	6.0	6.0	6.7	6.2	7.2	7.0	6.4	6.3
Median	5.745	5.59	6.27	7.12	7.31	6.83	6.5	5.805	5.745	6.745	6.595	7.1	6.98	6.34	6.615
Standard Deviation	0.72	0.79	0.66	0.62	0.29	0.80	1.07	0.57	0.49	0.54	1.06	0.45	0.22	0.54	0.95
Minimum	5.08	5.11	5.56	5.7	7.06	4.74	4.13	5.37	5.52	5.85	4.01	6.42	6.72	5.31	4.82
Maximum	7.46	7.56	7.69	7.8	7.96	7.29	7.13	7.08	7.19	7.74	7.34	8.08	7.44	7.35	7.76

SUMMARY STATISTICS FOR **TURBIDITY IN NTU**

Parameter/Sampling Location	O-1	O-2	O-3	O-4	O-5	O-6	O-7	O-8	O-9	O-10	O-11	O-12	O-13	O-14	O-15
Mean	0.6	1.7	1.6	0.9	0.5	0.4	2.8	2.0	1.3	0.7	1.6	1.5	1.2	1.1	1.9
Median	0.4	1.7	1.05	0.7	0.5	0.4	2.7	0.75	1.5	0.75	1.55	0.8	1.2	0.65	1.1
Standard Deviation	0.54	1.08	1.38	0.59	0.12	0.20	0.67	2.78	0.61	0.29	0.74	1.44	0.90	0.69	2.01
Minimum	0.1	0.2	0.2	0.3	0.3	0.1	1.9	0.4	0.4	0.2	0.4	0.3	0.1	0.5	0.5
Maximum	1.7	3.5	4.7	2.1	0.7	0.8	4.2	9.7	1.9	1.1	2.7	4.3	2.6	2.4	7.5

Parameter/Sampling Location	O-16	O-17	O-18	O-19	O-20	O-21	O-22	O-23	O-24	O-25	O-26	O-27	O-28	O-29	O-30
Mean	1.8	7.0	0.6	0.6	3.2	1.4	2.0	1.4	1.4	1.3	1.0	0.8	0.9	0.9	0.9
Median	1.1	1.9	0.55	0.65	3	1.15	1.75	1.4	1.4	1.25	0.9	0.85	0.8	0.9	0.75
Standard Deviation	1.71	13.14	0.19	0.23	1.75	0.87	1.78	0.61	0.71	0.38	0.36	0.21	0.44	0.19	0.79
Minimum	0.3	0.3	0.3	0.1	0.9	0.4	0.4	0.5	0.3	0.8	0.6	0.5	0.5	0.5	0.2
Maximum	5.9	46.1	0.9	1	6.6	3.3	7.2	2.5	2.5	1.9	1.7	1.2	1.9	1.2	2.9

Parameter/Sampling Location	O-31	O-32	O-33	O-34	O-35	O-36	O-37	O-38	O-39	O-40	O-41	O-42	O-43	O-44	O-45
Mean	0.8	1.0	1.1	1.4	0.5	0.8	2.0	0.7	1.9	1.0	0.9	0.5	1.0	0.7	1.7
Median	0.8	0.9	1.1	1.45	0.55	0.7	1.8	0.6	1.2	0.85	0.8	0.5	0.9	0.8	1.5
Standard Deviation	0.21	0.53	0.27	0.28	0.25	0.45	0.82	0.25	1.75	0.56	0.30	0.15	0.36	0.39	1.49
Minimum	0.3	0.3	0.7	0.9	0.1	0.2	1.4	0.3	0.5	0.5	0.4	0.3	0.4	0	0.3
Maximum	1	1.9	1.5	1.8	0.9	1.5	4.5	1.1	6.3	2.5	1.6	0.8	1.8	1.6	5.8

Parameter/Sampling Location	O-46	O-47	O-48	O-49	O-50	O-51	O-52	O-53	O-54	O-55	O-56	O-57	O-58	O-59	O-60
Mean	0.5	1.4	0.8	1.6	2.0	1.4	1.1	1.0	0.5	0.8	1.4	2.2	3.7	0.9	0.8
Median	0.5	0.6	0.85	1.25	1.85	1.2	1.05	0.95	0.35	0.8	1.15	0.95	3.15	0.9	0.8
Standard Deviation	0.21	2.48	0.25	1.74	0.63	0.57	0.53	0.14	0.60	0.42	0.61	2.99	2.02	0.31	0.41
Minimum	0.2	0.4	0.3	0.3	1.1	0.6	0.4	0.8	0.1	0.2	0.8	0.1	1.6	0.5	0.2
Maximum	0.9	9.2	1.2	6.8	3.5	2.2	2	1.3	2.3	1.7	2.5	9	8.7	1.5	1.6

Parameter/Sampling Location	O-61	O-62	O-63	O-64	O-65	O-66	O-67	O-68	O-69	O-70	O-71	O-72	O-73	O-74	O-75
Mean	1.7	1.5	1.0	1.2	1.9	4.0	0.7	1.0	2.3	1.7	1.5	1.0	0.7	2.1	1.6
Median	1.45	1.3	0.95	0.9	1.15	3.9	0.65	0.85	2.4	1.55	1.4	0.8	0.7	1.8	1.5
Standard Deviation	1.19	0.65	0.45	0.79	2.08	3.23	0.23	0.67	1.51	0.89	1.23	0.91	0.28	1.13	0.63
Minimum	0.6	0.8	0.4	0.1	0.4	0.4	0.3	0.2	0.3	0.4	0.1	0.3	0.2	0.8	0.7
Maximum	4.7	2.8	1.9	3.1	7.7	10.5	1.1	2.7	5.75	3.2	4.3	3.7	1.1	4.7	2.5

SUMMARY STATISTICS FOR **ALKALINITY (mg/L)**

Parameter/Sampling Location	O-1	O-2	O-3	O-4	O-5	O-6	O-7	O-8	O-9	O-10	O-11	O-12	O-13	O-14	O-15
Mean	58.3	38.3	41.6	15.8	11.9	13.0	51.6	32.0	77.3	57.7	19.5	37.4	16.8	13.4	20.9
Median	58	42	45	16.5	12	13	48	32.5	78	63	19.5	39	13	13	19.5
Standard Deviation	4.07	16.46	8.78	4.15	1.51	2.86	11.49	2.66	5.28	32.95	6.13	10.23	8.45	2.43	6.50
Minimum	52	19	28	10	10	10	39	28	66	17	12	12	7	10	13
Maximum	65	66	52	22	14	18	77	35	87	111	29	50	30	18	34

Parameter/Sampling Location	O-16	O-17	O-18	O-19	O-20	O-21	O-22	O-23	O-24	O-25	O-26	O-27	O-28	O-29	O-30
Mean	21.5	84.1	170.0	18.6	60.3	16.9	165.5	31.8	30.9	9.5	153.6	46.3	20.6	15.2	138.8
Median	13.5	73	175.5	19.5	59	18	144.5	18	31	10	158	59.5	19	13	155
Standard Deviation	15.59	47.61	42.76	6.80	14.35	4.91	78.95	20.93	6.64	0.90	45.90	20.97	10.46	5.62	47.41
Minimum	8	25	45	7	37	10	98	14	20	8	96	15	10	11	67
Maximum	51	190	210	28	84	23	364	76	47	11	235	66	46	31	201

Parameter/Sampling Location	O-31	O-32	O-33	O-34	O-35	O-36	O-37	O-38	O-39	O-40	O-41	O-42	O-43	O-44	O-45
Mean	13.8	40.2	44.8	88.3	70.2	12.0	125.8	22.2	32.2	11.2	26.6	12.2	9.6	10.7	33.0
Median	13.5	41.5	45	88	64.5	11.5	139	23	32.5	11.5	25.5	12	10	10.5	33.5
Standard Deviation	2.34	9.07	4.25	13.84	16.96	1.91	46.73	5.41	3.88	1.47	5.40	1.53	1.68	1.42	7.24
Minimum	10	26	38	68	51	10	13	14	25	8	19	10	7	9	23
Maximum	18	52	51	117	114	16	177	30	38	13	38	15	13	13	45

Parameter/Sampling Location	O-46	O-47	O-48	O-49	O-50	O-51	O-52	O-53	O-54	O-55	O-56	O-57	O-58	O-59	O-60
Mean	18.9	199.0	112.2	19.1	69.4	9.6	12.7	215.1	43.4	24.3	19.3	114.3	70.3	62.7	24.3
Median	19.5	192.5	110.5	18.5	61.5	10	12	261.5	43.5	22	18.5	114.5	70	63.5	25
Standard Deviation	5.04	32.75	12.66	4.46	21.00	1.08	3.77	95.52	3.70	6.68	4.81	6.20	6.91	11.01	3.52
Minimum	11	156	93	12	52	8	8	58	37	16	13	105	59	43	18
Maximum	27	256	135	28	130	11	20	314	49	37	28	126	83	77	29

Parameter/Sampling Location	O-61	O-62	O-63	O-64	O-65	O-66	O-67	O-68	O-69	O-70	O-71	O-72	O-73	O-74	O-75
Mean	25.6	37.8	55.2	79.0	91.3	43.0	132.8	74.4	10.9	22.5	51.3	106.8	20.7	54.2	104.5
Median	25.5	37.5	59	78.5	90	44	134.5	73.5	11	24.5	56	107.5	21.5	51	109
Standard Deviation	7.46	4.24	11.16	11.70	6.18	6.81	51.75	10.16	1.68	8.07	13.27	6.30	2.81	22.40	25.94
Minimum	16	31	34	61	83	32	42	61	7	12	17	97	16	25	65
Maximum	38	45	69	98	102	52	223	90	13	35	63	115	25	100	138

SUMMARY STATISTICS FOR **CHLORIDES (mg/L)**

Parameter/Sampling Location	O-1	O-2	O-3	O-4	O-5	O-6	O-7	O-8	O-9	O-10	O-11	O-12	O-13	O-14	O-15
Mean	87.63	63.63	37.08	15.92	21.25	18.25	36.79	22.75	40.50	40.17	21.42	19.17	20.92	31.00	22.08
Median	87.25	40.5	33.5	16	21	17.5	28.5	18.5	33.5	28.5	21	18	21	31	18.5
Standard Deviation	5.419	51.995	15.565	1.929	3.079	3.441	18.392	8.843	16.412	22.413	4.337	4.152	4.870	8.367	10.492
Minimum	79	20	19	13	17	14	15	15	26	24	15	14	14	19	11
Maximum	99	183	70	19	28	24	64	40	80	96	30	28	32	50	44

Parameter/Sampling Location	O-16	O-17	O-18	O-19	O-20	O-21	O-22	O-23	O-24	O-25	O-26	O-27	O-28	O-29	O-30
Mean	24.20	73.17	75.83	23.50	59.42	18.42	50.58	36.92	24.08	12.33	43.92	37.00	12.92	36.33	38.25
Median	20	72.5	72.5	21	57.5	16.5	59.5	36	26.5	12	45	34.5	12.5	36.5	37.5
Standard Deviation	8.626	12.209	11.248	8.318	26.949	5.915	23.020	5.915	6.842	1.497	20.839	13.922	1.379	10.714	10.855
Minimum	15	53	60	14	20	11	20	28	12	10	16	21	11	17	22
Maximum	40	101	98	40	108	30	82	47	32	15	75	73	16	55	56

Parameter/Sampling Location	O-31	O-32	O-33	O-34	O-35	O-36	O-37	O-38	O-39	O-40	O-41	O-42	O-43	O-44	O-45
Mean	18.08	19.50	14.00	39.83	50.00	51.83	53.67	18.92	22.58	31.33	29.38	17.17	9.75	8.90	31.33
Median	18	19.5	14	41	37.5	53	51	18.5	23.5	32	29	18	9.5	9	31
Standard Deviation	1.782	2.067	1.477	6.658	33.144	8.066	24.377	1.975	4.274	2.535	4.478	3.099	1.603	0.876	4.579
Minimum	15	16	12	28	11	32	25	16	15	26	22	12	8	8	24
Maximum	22	24	16	49	117	63	99	22	29	34	37	21	13	10	40

Parameter/Sampling Location	O-46	O-47	O-48	O-49	O-50	O-51	O-52	O-53	O-54	O-55	O-56	O-57	O-58	O-59	O-60
Mean	23.50	55.58	42.17	48.75	20.33	20.58	35.42	55.67	31.25	34.33	20.08	25.67	49.92	47.83	13.75
Median	23.5	55.5	42	47.5	20	19	35.5	53.5	31	32.5	20.5	25.5	48.5	48	14
Standard Deviation	1.977	14.482	5.357	13.778	2.902	5.885	4.719	29.849	6.412	9.566	3.397	4.030	10.570	8.222	2.301
Minimum	20	34	32	31	16	14	28	21	22	23	14	19	35	27	10
Maximum	27	87	53	80	26	34	44	108	40	54	26	33	69	62	18

Parameter/Sampling Location	O-61	O-62	O-63	O-64	O-65	O-66	O-67	O-68	O-69	O-70	O-71	O-72	O-73	O-74	O-75
Mean	15.92	58.67	47.08	24.50	28.58	25.92	42.92	56.17	38.42	22.25	20.58	12.92	31.42	48.42	201.58
Median	15.5	58.5	48	25.5	28	26	40	55	38.5	19.5	20	13.5	33	45.5	215
Standard Deviation	2.968	8.711	8.522	4.908	8.929	11.851	11.277	5.271	5.107	11.234	4.358	1.311	10.783	20.147	125.414
Minimum	12	46	27	16	18	10	28	48	31	10	14	10	15	20	61
Maximum	21	78	61	31	49	55	66	67	46	44	27	14	50	92	456

SUMMARY STATISTICS FOR **HARDNESS (mg/L)**

Parameter/Sampling Location	O-1	O-2	O-3	O-4	O-5	O-6	O-7	O-8	O-9	O-10	O-11	O-12	O-13	O-14	O-15
Mean	125.5	55.2	46.7	16.4	20.5	17.2	59.5	28.7	89.7	77.3	21.8	35.6	14.0	17.3	35.8
Median	126	48.5	48	16	20.5	17.5	55.5	28.5	91	76.5	22	29	13.5	16.5	33.5
Standard Deviation	3.75	32.71	13.10	3.73	4.30	4.90	17.43	6.95	6.49	32.33	5.46	14.98	4.49	5.41	11.26
Minimum	119	20	28	10	14	10	38	18	78	25	14	20	10	10	22
Maximum	133	113	68	24	28	24	93	40	100	130	35	65	27	27	65

Parameter/Sampling Location	O-16	O-17	O-18	O-19	O-20	O-21	O-22	O-23	O-24	O-25	O-26	O-27	O-28	O-29	O-30
Mean	27.2	125.2	221.0	22.2	76.8	23.8	163.7	20.0	34.0	9.3	169.8	75.0	25.0	59.5	191.7
Median	24.5	108	221	21.5	82	23	161.5	18	35	9	185.5	81	20.5	56.5	206
Standard Deviation	10.53	62.24	33.46	4.17	34.33	6.62	57.45	6.97	10.25	1.54	65.49	15.27	10.29	10.79	76.41
Minimum	14	51	176	16	25	14	89	14	18	7	86	46	15	46	81
Maximum	45	232	284	30	120	33	268	40	50	12	258	96	42	82	282

Parameter/Sampling Location	O-31	O-32	O-33	O-34	O-35	O-36	O-37	O-38	O-39	O-40	O-41	O-42	O-43	O-44	O-45
Mean	20.8	40.3	44.0	96.0	89.0	32.9	134.3	35.3	52.2	30.8	53.4	19.0	14.7	13.4	62.2
Median	21	40	43.5	98	80	32.5	150	36	51.5	31	43	17.5	12.5	13	66.5
Standard Deviation	2.89	5.47	3.54	15.00	24.71	8.14	42.66	4.83	13.82	10.75	30.95	6.28	5.57	3.27	15.21
Minimum	16	32	38	70	62	20	58	26	32	16	30	14	10	8	34
Maximum	26	48	51	115	130	46	186	42	75	57	143	38	29	20	80

Parameter/Sampling Location	O-46	O-47	O-48	O-49	O-50	O-51	O-52	O-53	O-54	O-55	O-56	O-57	O-58	O-59	O-60
Mean	36.3	246.0	130.7	44.2	71.8	14.4	46.3	197.3	73.8	37.3	24.6	132.9	87.4	86.6	26.6
Median	36.5	259	128	47.5	72	14.5	47	207	78.5	38	25.5	145.5	89	85	27.5
Standard Deviation	4.20	40.66	21.05	11.76	8.16	2.97	6.41	82.33	18.41	4.29	3.53	36.99	10.44	8.11	6.53
Minimum	30	152	94	25	58	10	34	96	40	28	19	78	68	76	16
Maximum	45	292	163	64	88	19	58	312	95	43	30	174	102	106	39

Parameter/Sampling Location	O-61	O-62	O-63	O-64	O-65	O-66	O-67	O-68	O-69	O-70	O-71	O-72	O-73	O-74	O-75
Mean	33.8	66.2	90.3	107.5	112.5	62.8	196.4	132.2	30.3	29.9	52.8	108.3	20.0	65.6	176.1
Median	32	67	91	106	117	52	200.5	134.5	31	30	56.5	108.5	19.5	64.5	174
Standard Deviation	10.29	5.52	5.63	13.92	11.57	31.82	56.89	12.78	5.16	5.28	20.85	13.99	2.73	23.52	66.01
Minimum	21	54	76	84	88	32	120	102	20	20	20	82	16	30	90
Maximum	63	76	98	129	125	143	269	150	37	38	77	129	25	118	302

SUMMARY STATISTICS FOR **SULFATES (mg/L)**

Parameter/Sampling Location	O-1	O-2	O-3	O-4	O-5	O-6	O-7	O-8	O-9	O-10	O-11	O-12	O-13	O-14	O-15
Mean	24.38	3.64	6.69	2.24	3.13	2.42	10.45	4.84	11.34	2.75	3.20	2.33	2.10	5.32	3.02
Median	23.88	3.265	5.31	2.185	2.625	2.23	10.28	4.155	10.34	2.48	3.36	2.04	2.385	5.325	2.775
Standard Deviation	1.619	1.953	3.737	0.804	1.612	1.255	3.607	1.957	7.106	1.847	1.278	1.980	1.000	1.276	1.972
Minimum	22.46	0.14	1.78	0.14	0.256	0.5	4.53	2.73	1.28	0.14	1.58	0.29	0.43	3.88	0.58
Maximum	27.67	6.61	12.87	3.31	5.67	4.52	16.96	8.69	27.98	7.26	5.82	7.62	3.16	7.83	6.04

Parameter/Sampling Location	O-16	O-17	O-18	O-19	O-20	O-21	O-22	O-23	O-24	O-25	O-26	O-27	O-28	O-29	O-30
Mean	2.79	24.37	15.29	1.04	26.13	1.48	26.75	6.37	7.08	1.92	16.43	14.83	1.27	9.64	8.61
Median	2.495	21.89	17.475	0.93	25.91	1.765	26.62	5.065	6.495	1.36	18.62	14.11	0.79	7.87	9.09
Standard Deviation	2.246	20.211	8.382	0.506	2.515	0.705	3.243	4.477	1.659	1.165	7.203	2.456	1.432	6.128	2.428
Minimum	0.07	4.46	1.08	0.36	22.92	0.14	21.13	2.14	5.46	0.79	3.38	12.65	0.07	2.73	4.46
Maximum	5.67	71.15	25.73	2.08	30.14	2.23	31.41	18.98	10.93	3.88	26.52	21.49	5.25	20.27	13.23

Parameter/Sampling Location	O-31	O-32	O-33	O-34	O-35	O-36	O-37	O-38	O-39	O-40	O-41	O-42	O-43	O-44	O-45
Mean	1.18	4.12	2.79	5.09	9.91	3.25	16.75	9.27	25.88	8.03	12.16	2.28	3.17	1.41	23.08
Median	1.185	3.77	2.54	4.6	11.29	3.185	15.56	9.74	25.66	8.515	12.05	2.115	3.415	1.33	23.295
Standard Deviation	0.465	2.555	1.528	2.673	7.586	1.579	2.920	1.531	4.709	2.305	1.040	1.212	0.943	0.709	1.583
Minimum	0.14	0.51	0.51	2.37	0.14	0.79	13.58	6.76	17.97	4.16	10.45	0.79	1.15	0.14	20.57
Maximum	1.79	8.05	5.25	10.98	19.77	5.32	22.35	11.06	32.7	12.43	13.87	4.89	4.24	2.73	25.67

Parameter/Sampling Location	O-46	O-47	O-48	O-49	O-50	O-51	O-52	O-53	O-54	O-55	O-56	O-57	O-58	O-59	O-60
Mean	8.60	18.67	18.63	14.54	11.69	2.05	12.52	23.65	25.54	10.14	3.19	7.94	22.54	17.94	3.52
Median	7.87	16.55	17.76	14.615	10.925	2.37	12.225	23.82	25.495	7.37	3.02	4.42	22.42	18.67	2.835
Standard Deviation	3.084	6.485	2.279	3.222	3.991	0.819	2.269	6.711	2.006	5.392	1.333	7.331	1.636	2.616	2.047
Minimum	5.17	13.15	16.32	10.85	4.24	0.14	10.06	12.15	22.93	4.03	0.14	1.58	20.27	13.73	0.65
Maximum	13.37	36.85	23.43	21.06	20.41	2.8	16.89	33.15	29.61	19.41	5.13	21.74	26.24	21.09	8.62

Parameter/Sampling Location	O-61	O-62	O-63	O-64	O-65	O-66	O-67	O-68	O-69	O-70	O-71	O-72	O-73	O-74	O-75
Mean	2.70	5.36	31.84	18.89	23.29	5.57	28.39	33.20	5.24	5.52	4.70	6.20	2.21	21.01	77.11
Median	2.605	4.705	31.225	23.14	23.03	5.36	28.715	32.72	5.52	5.605	5.18	5.26	1.945	25.735	85.965
Standard Deviation	1.154	4.404	2.483	10.995	2.448	2.413	4.333	2.760	2.059	1.595	1.166	2.977	1.387	9.167	31.209
Minimum	0.58	0.79	28.68	0.29	19.91	1.58	21.35	29.68	1.37	2.59	2.54	3.45	0.14	5.89	35.22
Maximum	4.89	14.09	36.94	32.77	27.85	10.85	36.3	38.88	8.41	8.2	6.08	13.15	4.74	30.23	120.03

SUMMARY STATISTICS FOR **FLUORIDES (mg/L)**

Parameter/Sampling Location	O-1	O-2	O-3	O-4	O-5	O-6	O-7	O-8	O-9	O-10	O-11	O-12	O-13	O-14	O-15
Mean	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.3	0.2	0.2	0.2	0.2	0.1
Median	0.09	0.085	0.125	0.1	0.06	0.065	0.055	0.04	0.03	0.275	0.225	0.12	0.135	0.18	0.075
Standard Deviation	0.04	0.05	0.06	0.04	0.03	0.02	0.02	0.02	0.02	0.21	0.13	0.18	0.16	0.13	0.03
Minimum	0.05	0.04	0.05	0.04	0.03	0.03	0.02	0	0.01	0.09	0.09	0.05	0.06	0.08	0.01
Maximum	0.18	0.21	0.25	0.17	0.12	0.11	0.09	0.08	0.05	0.83	0.56	0.71	0.6	0.51	0.12

Parameter/Sampling Location	O-16	O-17	O-18	O-19	O-20	O-21	O-22	O-23	O-24	O-25	O-26	O-27	O-28	O-29	O-30
Mean	0.1	0.1	0.3	0.1	0.1	0.1	0.4	0.1	0.1	0.1	0.2	0.1	0.1	0.0	0.1
Median	0.06	0.1	0.3	0.05	0.06	0.05	0.29	0.08	0.09	0.05	0.15	0.1	0.065	0.05	0.06
Standard Deviation	0.05	0.05	0.15	0.02	0.02	0.02	0.18	0.03	0.03	0.02	0.06	0.06	0.03	0.02	0.03
Minimum	0.01	0.05	0.17	0.01	0.04	0.01	0.16	0.02	0.06	0.02	0.08	0.06	0.01	0.01	0.01
Maximum	0.15	0.21	0.7	0.09	0.09	0.09	0.75	0.13	0.15	0.09	0.28	0.23	0.1	0.09	0.09

Parameter/Sampling Location	O-31	O-32	O-33	O-34	O-35	O-36	O-37	O-38	O-39	O-40	O-41	O-42	O-43	O-44	O-45
Mean	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.1	0.2	0.1	0.1	0.1	0.3	0.1	0.1
Median	0.125	0.145	0.125	0.05	0.075	0.155	0.165	0.15	0.21	0.06	0.065	0.135	0.285	0.075	0.12
Standard Deviation	0.05	0.04	0.04	0.03	0.03	0.07	0.06	0.04	0.06	0.03	0.04	0.06	0.12	0.05	0.04
Minimum	0.08	0.06	0.07	0.01	0.04	0.07	0.07	0.09	0.08	0.02	0.01	0.07	0.12	0.04	0.05
Maximum	0.23	0.18	0.19	0.11	0.12	0.29	0.28	0.23	0.31	0.12	0.15	0.28	0.59	0.19	0.19

Parameter/Sampling Location	O-46	O-47	O-48	O-49	O-50	O-51	O-52	O-53	O-54	O-55	O-56	O-57	O-58	O-59	O-60
Mean	0.2	0.4	0.0	0.1	0.2	0.1	0.3	0.2	0.1	0.2	0.1	0.3	0.2	0.1	0.1
Median	0.185	0.345	0.04	0.14	0.16	0.125	0.3	0.18	0.09	0.22	0.125	0.24	0.14	0.115	0.055
Standard Deviation	0.09	0.20	0.02	0.09	0.09	0.06	0.17	0.14	0.04	0.09	0.07	0.13	0.06	0.04	0.02
Minimum	0.07	0.19	0.01	0.02	0.07	0.05	0.06	0.07	0.02	0.14	0.05	0.08	0.08	0.06	0.02
Maximum	0.36	0.88	0.07	0.36	0.38	0.25	0.7	0.56	0.17	0.47	0.27	0.57	0.26	0.17	0.09

Parameter/Sampling Location	O-61	O-62	O-63	O-64	O-65	O-66	O-67	O-68	O-69	O-70	O-71	O-72	O-73	O-74	O-75
Mean	0.1	0.1	0.1	0.0	0.1	0.0	0.3	0.0	0.1	0.2	0.1	0.2	0.1	0.1	0.1
Median	0.12	0.135	0.14	0.025	0.135	0.04	0.27	0.03	0.06	0.19	0.145	0.16	0.06	0.07	0.1
Standard Deviation	0.04	0.04	0.05	0.02	0.10	0.02	0.13	0.02	0.02	0.07	0.05	0.10	0.04	0.03	0.04
Minimum	0.05	0.07	0.06	0.01	0.01	0.01	0.16	0.01	0.03	0.11	0.05	0.08	0.02	0.02	0.05
Maximum	0.17	0.19	0.21	0.06	0.34	0.06	0.62	0.07	0.08	0.33	0.22	0.42	0.13	0.11	0.19

SUMMARY STATISTICS FOR **NITRATES (mg/L)**

Parameter/Sampling Location	O-1	O-2	O-3	O-4	O-5	O-6	O-7	O-8	O-9	O-10	O-11	O-12	O-13	O-14	O-15
Mean	31.2	25.0	3.3	6.2	13.2	8.7	5.4	3.2	6.3	3.1	3.4	6.4	5.6	6.5	9.2
Median	29.8	27.0	1.8	6.2	13.9	8.1	5.5	3.0	6.0	2.6	2.6	5.3	4.8	5.0	7.2
Standard Deviation	5.58	11.47	4.18	1.52	3.02	2.39	2.03	1.95	2.70	1.41	2.00	4.02	3.68	4.26	5.06
Minimum	23.65	7.67	0.86	3.64	8.87	5.43	1.52	1.08	2.53	1.51	1.64	2.35	1.86	2.53	4.37
Maximum	45.4	37.89	15.79	8.43	17.45	13.68	9.72	7.31	11.61	5.98	7.48	14.77	12.4	16.79	19.66

Parameter/Sampling Location	O-16	O-17	O-18	O-19	O-20	O-21	O-22	O-23	O-24	O-25	O-26	O-27	O-28	O-29	O-30
Mean	9.4	31.0	22.6	9.3	26.8	7.8	78.5	13.7	15.1	3.4	17.8	11.1	3.7	29.1	36.9
Median	8.6	31.1	20.2	8.5	24.1	6.8	58.8	13.1	15.8	3.3	10.1	11.5	3.8	29.7	31.5
Standard Deviation	3.87	11.24	6.67	4.06	8.60	3.61	49.71	3.17	7.52	0.93	14.32	3.18	0.74	7.09	17.31
Minimum	4.26	15.23	15.48	4.23	18.43	4.13	36.46	9.64	5.67	1.84	6.82	6.47	2.31	18.76	18.74
Maximum	16.98	53.38	38.41	15.29	49.96	17.86	185.9	20.24	29.54	4.79	55.8	15.23	4.85	41.52	60.6

Parameter/Sampling Location	O-31	O-32	O-33	O-34	O-35	O-36	O-37	O-38	O-39	O-40	O-41	O-42	O-43	O-44	O-45
Mean	20.2	25.3	4.4	7.8	31.4	40.9	5.0	18.0	16.5	8.6	28.7	7.2	5.6	3.9	44.6
Median	20.0	25.0	3.6	6.1	30.2	36.7	5.5	18.0	16.8	4.9	28.3	7.7	5.4	3.9	39.3
Standard Deviation	4.03	5.07	2.13	4.38	10.15	12.66	1.79	2.47	2.24	7.79	9.47	1.95	1.75	0.58	21.90
Minimum	14.58	17.41	2.32	3.67	18.73	28.45	1.13	13.24	12.48	2.21	15.41	3.64	3.19	2.84	15.46
Maximum	25.92	35.36	9.32	17.61	57.82	68.55	7.38	21.69	19.7	22.25	42.25	9.67	9.11	4.74	75.9

Parameter/Sampling Location	O-46	O-47	O-48	O-49	O-50	O-51	O-52	O-53	O-54	O-55	O-56	O-57	O-58	O-59	O-60
Mean	10.0	88.0	23.2	13.5	3.7	15.0	36.8	4.2	40.3	24.0	12.8	26.2	4.9	30.7	2.5
Median	9.8	89.8	23.2	9.7	2.6	14.9	36.9	3.5	39.5	24.0	13.4	26.6	4.0	27.6	2.5
Standard Deviation	2.14	50.66	6.64	12.12	3.34	5.91	7.61	2.95	16.95	4.09	3.40	5.34	2.54	9.56	0.54
Minimum	6.49	21.2	15.43	5.13	1.09	7.82	25.16	1.16	20.26	17.85	7.43	17.53	2.17	20.14	1.82
Maximum	14.08	184.3	40.82	48.46	13.27	22.39	50.34	12.85	70.14	33.21	19.32	34.68	11.06	46.68	3.61

Parameter/Sampling Location	O-61	O-62	O-63	O-64	O-65	O-66	O-67	O-68	O-69	O-70	O-71	O-72	O-73	O-74	O-75
Mean	4.6	50.9	20.5	13.7	9.6	4.4	21.0	62.8	37.9	25.5	17.7	2.3	5.3	2.9	11.2
Median	4.6	48.1	20.3	14.3	8.7	4.5	21.4	56.0	33.9	25.3	17.7	2.4	2.4	2.9	10.9
Standard Deviation	1.12	12.72	5.09	4.90	4.16	1.67	3.33	21.86	13.81	6.62	2.87	0.93	4.75	1.40	4.73
Minimum	2.84	35.48	13.61	7.42	5.45	1.78	15.22	38.47	20.17	16.72	12.3	0.61	1.12	1.19	3.95
Maximum	6.89	78.5	31.89	23.42	21.37	6.83	25.26	99.05	60.55	41.08	21.95	3.67	15.3	6.37	20.47

SUMMARY STATISTICS FOR **SODIUM (mg/L)**

Parameter/Sampling Location	O-1	O-2	O-3	O-4	O-5	O-6	O-7	O-8	O-9	O-10	O-11	O-12	O-13	O-14	O-15
Mean	46.52	47.18	13.13	10.17	14.41	9.35	17.01	10.84	19.11	11.78	10.59	12.63	10.11	18.11	11.53
Median	44.55	34.25	11.85	10.55	13.7	9.1	14.3	10.15	16.55	11.7	11.55	10.6	9.05	18.8	8.55
Standard Deviation	11.97	35.34	4.31	2.99	4.36	3.29	9.92	2.91	6.82	6.34	4.57	5.43	4.92	7.69	9.52
Minimum	33.9	11.2	8.1	3	7.8	4.9	7.9	7.7	13.6	4.6	4.3	6.4	4.5	6.2	7.4
Maximum	79	118.3	23.3	13.6	21.8	14.4	39.5	18.5	37.4	25.2	17.1	21.8	20.1	35.1	41.3

Parameter/Sampling Location	O-16	O-17	O-18	O-19	O-20	O-21	O-22	O-23	O-24	O-25	O-26	O-27	O-28	O-29	O-30
Mean	8.29	42.48	50.45	13.08	32.42	7.65	42.26	20.98	14.56	2.99	27.98	21.02	4.14	16.78	10.92
Median	8.65	35.65	48.3	10.75	32.3	8.25	40.05	19.3	15.15	2.65	21.75	20.2	4.1	17.5	9.9
Standard Deviation	3.15	16.68	9.85	5.88	2.82	2.43	22.35	9.66	3.19	1.75	13.74	4.53	1.44	5.92	3.39
Minimum	3.3	25.9	38.5	7.5	28.3	4.2	13.1	11.5	9.9	0.9	13.3	16.3	1.9	7.1	6.8
Maximum	13.9	80	77.2	27.5	38.4	12.5	100.3	43.4	18.6	7.6	47.7	32.2	7.5	29.2	19.8

Parameter/Sampling Location	O-31	O-32	O-33	O-34	O-35	O-36	O-37	O-38	O-39	O-40	O-41	O-42	O-43	O-44	O-45
Mean	12.13	12.03	8.50	23.45	11.36	39.85	43.38	12.04	15.76	19.73	19.03	12.00	5.63	6.36	19.89
Median	10.5	10.9	7.65	22.6	11.3	37.05	43.65	10.85	13.6	18	18.2	11.95	5.4	6.55	19.45
Standard Deviation	3.77	7.65	2.57	5.89	2.50	11.29	14.48	3.03	4.83	6.18	5.85	2.18	1.65	1.85	5.49
Minimum	8.7	1.9	5.2	15.8	5.3	26.5	18.2	7.6	11.7	13.2	12.3	7.8	3.5	3.6	13.5
Maximum	21.4	32.6	13	39.8	14.3	65.1	61.6	18.5	25.5	35.5	33.1	14.8	8.3	8.9	33.7

Parameter/Sampling Location	O-46	O-47	O-48	O-49	O-50	O-51	O-52	O-53	O-54	O-55	O-56	O-57	O-58	O-59	O-60
Mean	13.25	35.83	26.89	22.47	12.80	9.35	27.03	43.64	19.70	24.97	13.35	18.89	37.77	34.35	10.29
Median	11.9	32.8	23.5	18.65	10.2	9.35	26.15	44.25	19.7	26.05	12.05	17.75	37.5	31.1	9.7
Standard Deviation	4.32	18.01	11.36	10.17	6.91	1.18	6.04	18.81	3.42	8.45	3.44	4.63	9.27	9.61	3.63
Minimum	9.3	17.4	16.7	14.1	7.1	7.5	20.4	14.2	13.9	14.6	9.6	13.5	23.5	27.4	5.9
Maximum	24	87.4	58.5	50.4	30.6	11.6	43.7	69.3	25.5	40.8	20.7	31.7	60.5	61.9	18.1

Parameter/Sampling Location	O-61	O-62	O-63	O-64	O-65	O-66	O-67	O-68	O-69	O-70	O-71	O-72	O-73	O-74	O-75
Mean	10.78	40.73	26.08	15.79	19.83	15.31	34.71	41.52	25.43	16.97	14.86	6.03	22.13	34.39	511.00
Median	9.3	37.8	25.2	15.35	19.9	13	34.5	41.25	25.55	15.95	14.35	5.75	22.05	31.8	325.5
Standard Deviation	3.53	7.96	7.19	3.20	2.66	6.94	6.45	4.96	5.11	10.50	5.99	2.85	5.77	16.25	498.61
Minimum	6.8	31.8	17.5	11.2	15.4	9.8	23.6	35.4	19.7	5.3	7.5	2.1	13.1	13.3	53.5
Maximum	19.2	57.2	44.8	22.9	24.9	33.6	42.8	48.6	39.7	44.2	29.1	10.8	31.4	69.4	1485

SUMMARY STATISTICS FOR **POTASSIUM (mg/L)**

Parameter/Sampling Location	O-1	O-2	O-3	O-4	O-5	O-6	O-7	O-8	O-9	O-10	O-11	O-12	O-13	O-14	O-15
Mean	11.68	4.58	5.55	2.64	4.93	2.18	5.38	1.93	3.78	1.68	1.72	3.07	1.70	2.18	1.72
Median	10.8	4.5	5.3	2.95	5.55	1.4	5.45	1.55	4.15	1.4	1.3	1.55	0.8	1.05	1.75
Standard Deviation	2.41	1.59	1.24	0.81	1.31	1.56	2.42	1.34	1.33	0.97	1.11	2.48	1.40	1.78	1.02
Minimum	9.1	1.4	3.7	0.7	2.3	0.7	0.8	0.3	1.3	0.5	0.2	0.1	0.4	0.5	0.3
Maximum	17.5	6.9	7.8	3.3	6.3	4.5	8.4	4.1	5.6	3.1	3.4	6.7	3.9	4.6	3.2

Parameter/Sampling Location	O-16	O-17	O-18	O-19	O-20	O-21	O-22	O-23	O-24	O-25	O-26	O-27	O-28	O-29	O-30
Mean	3.56	16.78	6.48	1.73	3.49	2.91	12.22	3.97	1.63	1.42	6.04	13.31	1.83	5.60	1.82
Median	2.4	15.35	5.85	1.05	3.7	2.2	10.75	3.4	1.05	1.2	5.75	9.1	1.85	5.55	1.4
Standard Deviation	2.12	8.59	1.86	1.71	1.45	1.57	5.08	2.25	1.50	1.04	1.29	15.96	0.99	1.47	1.26
Minimum	1.5	6.9	4.9	0.1	0.5	0.7	6.9	1.2	0.1	0.4	4.9	3.6	0.5	3.5	0.3
Maximum	7.6	35.1	11.8	5.1	5.5	5.7	22.9	8	4.4	3.7	9.8	63.2	3.8	8.2	4.2

Parameter/Sampling Location	O-31	O-32	O-33	O-34	O-35	O-36	O-37	O-38	O-39	O-40	O-41	O-42	O-43	O-44	O-45
Mean	2.34	4.43	2.01	3.10	2.53	5.07	8.61	3.37	9.11	3.05	6.44	2.18	1.83	2.35	5.36
Median	2.25	3.75	1.85	2.65	2.2	4.8	8.6	3	9.2	2.55	5.45	2	1.25	2.2	4.4
Standard Deviation	1.58	3.45	1.24	1.81	1.39	1.61	1.92	1.76	3.97	2.13	3.03	1.13	1.15	0.96	2.75
Minimum	0.1	0.4	0.4	0.5	0.8	2.9	5.3	0.9	3.9	0.9	3.4	0.8	0.7	0.9	2.9
Maximum	4.9	11.2	4.1	6.7	4.9	8.7	11.5	6.5	18.3	8.2	13.8	4.3	3.8	3.8	12.5

Parameter/Sampling Location	O-46	O-47	O-48	O-49	O-50	O-51	O-52	O-53	O-54	O-55	O-56	O-57	O-58	O-59	O-60
Mean	1.82	8.61	13.45	4.32	5.38	2.76	8.43	11.49	7.77	5.48	2.41	8.02	4.79	10.26	2.28
Median	0.85	7.4	12.45	3.7	3.65	2.85	7.75	10.95	7.65	4.7	2	7.55	4.2	9.45	1.9
Standard Deviation	1.92	4.19	3.87	2.56	4.90	1.88	2.86	2.42	2.50	2.72	1.36	3.18	2.24	3.47	1.42
Minimum	0.1	5.4	8.2	1.1	1.7	0.2	4.3	8.5	4.2	3.1	0.4	4.5	2.4	5.8	0.5
Maximum	4.9	21	20.5	10.7	18.7	5.7	14.1	15.4	13.8	12.8	4.5	15.4	10.5	19.3	4.6

Parameter/Sampling Location	O-61	O-62	O-63	O-64	O-65	O-66	O-67	O-68	O-69	O-70	O-71	O-72	O-73	O-74	O-75
Mean	2.36	2.59	25.61	4.20	5.25	3.97	4.15	15.29	2.63	3.08	2.18	1.94	1.27	5.73	44.67
Median	2.1	2.4	25.4	3.7	4.35	3.55	3.2	15.2	1.75	1.95	2.1	1.45	0.9	5.05	39.05
Standard Deviation	1.47	1.76	4.03	1.95	2.32	2.30	1.87	1.68	2.26	2.62	1.23	1.62	1.02	3.94	32.97
Minimum	0.1	0.1	19.5	1.2	2.9	1.4	1.8	12.9	0.2	0.6	0.4	0.2	0.2	0.4	0.1
Maximum	4.8	5.6	32.6	8.6	11.3	9	7.6	18.8	7.6	9	4.4	4.9	3.3	11.2	94

SUMMARY STATISTICS FOR **CALCIUM (mg/L)**

Parameter/Sampling Location	O-1	O-2	O-3	O-4	O-5	O-6	O-7	O-8	O-9	O-10	O-11	O-12	O-13	O-14	O-15
Mean	14.37	8.72	8.18	5.49	7.07	3.50	9.03	5.14	11.38	5.90	5.69	7.26	3.66	3.54	4.85
Median	15.24	8.26	8.5	5.42	7.3	3.78	8.54	5.36	10.82	6.38	5.72	6.5	3.64	2.44	5.36
Standard Deviation	6.46	4.80	1.67	1.93	2.42	1.49	2.61	2.47	1.70	1.86	1.56	2.26	1.31	2.93	2.02
Minimum	2.04	0.08	5.04	1.52	1.04	0.6	5.68	0.76	9.12	3.28	3.56	4.08	0.2	0.28	0.12
Maximum	23.56	19.04	10.36	9.08	10.4	5.56	15.28	8.2	14.52	8	7.92	10.76	5.04	9.16	7.28

Parameter/Sampling Location	O-16	O-17	O-18	O-19	O-20	O-21	O-22	O-23	O-24	O-25	O-26	O-27	O-28	O-29	O-30
Mean	5.45	17.36	20.83	6.58	8.75	5.60	21.25	5.90	6.30	2.68	18.10	8.47	4.89	11.16	8.74
Median	5.96	16.94	22.28	6.2	8.7	5.96	22.86	6.06	6.2	2.6	17.6	8.56	4.62	11.16	9.08
Standard Deviation	2.08	5.83	3.21	1.37	1.99	1.92	5.41	0.93	1.62	0.72	4.95	1.21	1.24	4.07	2.06
Minimum	1.12	7.88	14.68	5.04	4.52	0.48	12.92	4.2	3.12	1.12	10.36	6.52	2.6	2.16	4.8
Maximum	8.44	28	23.84	9.2	11.68	7.64	29.64	7.16	8.6	3.92	27.16	10.68	6.36	16.64	11.68

Parameter/Sampling Location	O-31	O-32	O-33	O-34	O-35	O-36	O-37	O-38	O-39	O-40	O-41	O-42	O-43	O-44	O-45
Mean	5.85	7.08	4.56	11.06	6.05	9.23	18.46	7.48	9.73	8.20	7.59	5.07	3.84	3.42	9.11
Median	6	6.84	4.26	11.4	5.62	8.28	17.8	7.66	9.6	7.08	8.02	5.18	3.1	2.98	10.34
Standard Deviation	1.18	1.74	1.62	2.16	1.57	3.03	2.45	2.11	1.29	3.30	1.64	2.20	1.95	1.27	3.19
Minimum	3.44	4.2	2.6	6.52	3.16	5.24	14.68	3.44	7.84	2.72	3.88	0.28	2.08	2.12	0.96
Maximum	8.2	9.72	8.48	14.24	9	14.92	22.32	10.76	12.2	12.84	9.52	8.56	8.44	6.56	12.28

Parameter/Sampling Location	O-46	O-47	O-48	O-49	O-50	O-51	O-52	O-53	O-54	O-55	O-56	O-57	O-58	O-59	O-60
Mean	8.26	16.36	13.96	9.74	7.47	4.80	12.54	21.49	11.49	6.52	6.68	9.38	16.38	15.02	5.48
Median	8.36	18.16	13.7	9.72	7.06	4.98	12.4	20.98	11.82	6.08	6.52	9.64	16.4	15.02	5.1
Standard Deviation	1.46	5.58	3.05	3.66	2.44	0.97	1.81	6.14	1.91	2.16	1.11	3.98	2.83	2.34	2.24
Minimum	5.12	6.24	10.12	2.96	3.72	2.72	9.84	12.96	7.92	3.76	4.92	1.56	10.76	10.68	2.36
Maximum	10.24	22.72	18.36	14.24	11.12	6.24	15.52	31.44	14.72	10.6	8.6	14.8	21.56	18.24	9.36

Parameter/Sampling Location	O-61	O-62	O-63	O-64	O-65	O-66	O-67	O-68	O-69	O-70	O-71	O-72	O-73	O-74	O-75
Mean	5.60	8.52	13.65	11.23	11.63	7.29	14.05	17.71	4.90	5.89	5.94	4.55	5.47	12.25	54.32
Median	5.18	9.02	14.5	10.28	11.72	7.12	13.62	18.08	4.46	6.32	5.76	3.8	6.08	12.44	53.7
Standard Deviation	1.36	1.79	4.62	3.49	3.85	1.54	3.78	3.80	2.30	2.62	1.77	1.84	1.24	3.85	33.76
Minimum	3.44	4.92	6.16	6.36	6	4.96	8.76	11.48	2.32	1.28	3.64	2.48	3.4	4.6	3.04
Maximum	8.64	10.76	19.28	17.68	17.16	10.16	20.16	26.36	9.24	10.32	9.72	8.24	7	18.04	102

SUMMARY STATISTICS FOR **IRON (mg/L)**

Parameter/Sampling Location	O-1	O-2	O-3	O-4	O-5	O-6	O-7	O-8	O-9	O-10	O-11	O-12	O-13	O-14	O-15
Mean	0.02	0.08	0.14	0.01	0.08	0.02	0.04	0.06	0.08	0.05	0.06	0.05	0.03	0.03	0.09
Median	0.02	0.08	0.11	0.01	0.06	0.01	0.01	0.02	0.03	0.02	0.02	0.03	0.01	0.01	0.04
Standard Deviation	0.01	0.07	0.09	0.00	0.07	0.01	0.05	0.07	0.08	0.07	0.08	0.06	0.04	0.03	0.13
Minimum	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Maximum	0.03	0.26	0.29	0.02	0.23	0.05	0.16	0.24	0.26	0.22	0.25	0.19	0.12	0.1	0.43

Parameter/Sampling Location	O-16	O-17	O-18	O-19	O-20	O-21	O-22	O-23	O-24	O-25	O-26	O-27	O-28	O-29	O-30
Mean	0.04	0.85	0.07	0.01	0.04	0.04	0.21	0.02	0.02	0.03	0.06	0.08	0.02	0.04	0.05
Median	0.03	0.09	0.06	0.01	0.03	0.03	0.04	0.02	0.02	0.02	0.04	0.04	0.02	0.02	0.03
Standard Deviation	0.03	2.47	0.08	0.00	0.03	0.03	0.47	0.01	0.01	0.02	0.07	0.12	0.01	0.05	0.05
Minimum	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Maximum	0.08	8.67	0.24	0.02	0.11	0.09	1.64	0.06	0.03	0.07	0.27	0.43	0.02	0.19	0.14

Parameter/Sampling Location	O-31	O-32	O-33	O-34	O-35	O-36	O-37	O-38	O-39	O-40	O-41	O-42	O-43	O-44	O-45
Mean	0.02	0.02	0.02	0.16	0.09	0.06	0.15	0.04	0.04	0.04	0.07	0.15	0.02	0.01	0.07
Median	0.02	0.01	0.02	0.12	0.02	0.03	0.19	0.03	0.05	0.04	0.03	0.17	0.01	0.01	0.05
Standard Deviation	0.02	0.01	0.01	0.20	0.13	0.07	0.12	0.03	0.03	0.03	0.07	0.10	0.01	0.00	0.06
Minimum	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Maximum	0.06	0.03	0.03	0.7	0.45	0.21	0.34	0.12	0.09	0.1	0.23	0.3	0.03	0.02	0.2

Parameter/Sampling Location	O-46	O-47	O-48	O-49	O-50	O-51	O-52	O-53	O-54	O-55	O-56	O-57	O-58	O-59	O-60
Mean	0.03	0.11	0.04	0.05	0.16	0.01	0.02	0.09	0.02	0.06	0.07	0.12	0.03	0.01	0.02
Median	0.02	0.02	0.03	0.03	0.17	0.01	0.01	0.11	0.01	0.05	0.07	0.05	0.02	0.01	0.02
Standard Deviation	0.02	0.28	0.03	0.06	0.12	0.01	0.01	0.07	0.02	0.05	0.06	0.26	0.02	0.01	0.01
Minimum	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Maximum	0.08	1	0.09	0.23	0.36	0.03	0.04	0.19	0.08	0.15	0.24	0.93	0.07	0.03	0.04

Parameter/Sampling Location	O-61	O-62	O-63	O-64	O-65	O-66	O-67	O-68	O-69	O-70	O-71	O-72	O-73	O-74	O-75
Mean	0.02	0.11	0.02	0.02	0.08	0.11	0.05	0.02	0.08	0.16	0.05	0.07	0.03	0.71	0.04
Median	0.02	0.10	0.01	0.02	0.06	0.04	0.03	0.01	0.06	0.07	0.05	0.05	0.03	0.70	0.01
Standard Deviation	0.02	0.10	0.01	0.02	0.06	0.17	0.05	0.01	0.09	0.27	0.04	0.09	0.03	0.70	0.04
Minimum	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Maximum	0.06	0.3	0.05	0.06	0.21	0.62	0.15	0.05	0.3	0.98	0.12	0.33	0.08	1.81	0.1

SUMMARY STATISTICS FOR **MANGANESE (ug/L)**

Parameter/Sampling Location	O-1	O-2	O-3	O-4	O-5	O-6	O-7	O-8	O-9	O-10	O-11	O-12	O-13	O-14	O-15
Mean	9.083	9.833	13.167	10.917	6.917	13.667	8.167	7.000	6.167	11.667	10.167	106.00	9.833	13.750	12.833
Median	5.000	5.500	6.500	7.500	6.000	9.000	6.000	6.500	5.500	9.000	8.500	92.500	7.000	8.500	10.500
Standard Deviation	10.264	12.677	17.188	11.548	5.869	13.117	7.861	6.267	6.900	8.732	9.456	35.517	10.197	15.627	12.869
Minimum	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	64.000	0.000	0.000	0.000
Maximum	30.000	40.000	50.000	34.000	19.000	41.000	24.000	21.000	20.000	26.000	31.000	170.00	32.000	45.000	36.000

Parameter/Sampling Location	O-16	O-17	O-18	O-19	O-20	O-21	O-22	O-23	O-24	O-25	O-26	O-27	O-28	O-29	O-30
Mean	12.500	13.750	13.917	2.917	13.500	10.333	10.750	7.417	8.750	8.583	20.417	7.667	7.250	21.250	10.500
Median	7.500	8.500	9.500	0.000	9.000	8.500	9.500	8.500	6.500	7.500	20.000	7.500	7.000	20.500	9.500
Standard Deviation	14.706	15.650	13.794	3.895	11.989	9.547	8.465	6.557	8.192	8.959	12.817	8.435	7.665	13.095	9.160
Minimum	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Maximum	48.000	46.000	41.000	10.000	38.000	28.000	28.000	19.000	26.000	29.000	48.000	30.000	20.000	45.000	30.000

Parameter/Sampling Location	O-31	O-32	O-33	O-34	O-35	O-36	O-37	O-38	O-39	O-40	O-41	O-42	O-43	O-44	O-45
Mean	6.750	10.583	10.500	13.917	17.500	10.583	20.083	13.667	21.333	6.583	12.833	21.250	14.333	5.300	8.583
Median	7.500	9.000	8.000	13.500	13.500	7.500	19.000	13.000	19.500	6.000	9.000	19.500	12.000	3.500	8.500
Standard Deviation	6.196	9.120	9.995	10.950	14.132	13.097	12.760	10.748	13.733	7.379	12.576	15.345	11.081	6.634	7.681
Minimum	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Maximum	20.000	28.000	30.000	36.000	46.000	47.000	49.000	30.000	49.000	20.000	40.000	47.000	40.000	20.000	20.000

Parameter/Sampling Location	O-46	O-47	O-48	O-49	O-50	O-51	O-52	O-53	O-54	O-55	O-56	O-57	O-58	O-59	O-60
Mean	11.583	17.750	20.250	21.417	12.667	10.583	26.083	10.667	5.167	21.000	21.417	9.750	19.917	11.583	5.417
Median	10.000	13.500	17.000	20.500	13.000	11.000	26.000	11.500	3.000	19.000	19.500	9.500	20.500	11.000	3.000
Standard Deviation	10.621	13.632	14.104	13.420	9.792	9.681	13.215	7.536	6.337	14.161	13.899	7.325	13.352	9.327	6.557
Minimum	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Maximum	30.000	43.000	46.000	50.000	30.000	30.000	48.000	20.000	20.000	42.000	41.000	20.000	42.000	30.000	20.000

Parameter/Sampling Location	O-61	O-62	O-63	O-64	O-65	O-66	O-67	O-68	O-69	O-70	O-71	O-72	O-73	O-74	O-75
Mean	11.000	17.000	7.000	12.083	12.000	5.333	20.083	6.667	9.167	10.667	13.500	8.083	12.833	11.833	14.833
Median	8.500	12.000	7.500	12.000	14.000	5.500	17.500	7.000	9.500	11.500	11.000	9.000	13.000	8.500	13.000
Standard Deviation	10.540	15.285	7.122	9.385	10.296	6.035	13.608	6.827	7.017	7.572	7.622	6.973	7.685	12.408	11.661
Minimum	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Maximum	30.000	49.000	20.000	30.000	30.000	20.000	42.000	20.000	20.000	20.000	30.000	20.000	25.000	40.000	40.000

SUMMARY STATISTICS FOR **MAGNESIUM (mg/L)**

Parameter/Sampling Location	O-1	O-2	O-3	O-4	O-5	O-6	O-7	O-8	O-9	O-10	O-11	O-12	O-13	O-14	O-15
Mean	21.76	8.11	6.37	0.65	0.69	2.05	8.97	3.84	14.88	15.21	1.85	4.24	1.18	2.04	5.76
Median	20.73	9.84	6.83	0.38	0.50	2.26	7.84	4.68	15.35	15.08	1.23	2.82	0.80	1.99	5.19
Standard Deviation	4.37	6.59	3.37	0.65	0.73	1.58	3.46	2.80	1.83	7.70	1.65	3.34	1.05	1.19	2.77
Minimum	16.06	0.53	1.97	0.05	0.00	0.22	5.39	0.36	11.30	1.56	0.39	0.34	0.10	0.34	3.69
Maximum	31.08	15.89	11.91	2.24	2.77	4.98	15.77	7.19	17.64	29.60	6.34	12.83	3.84	3.99	13.90

Parameter/Sampling Location	O-16	O-17	O-18	O-19	O-20	O-21	O-22	O-23	O-24	O-25	O-26	O-27	O-28	O-29	O-30
Mean	3.30	19.87	41.05	1.39	13.33	2.37	26.86	1.28	4.44	0.62	30.28	13.08	3.11	7.68	41.27
Median	3.04	15.25	40.10	1.43	15.36	2.86	26.17	0.83	5.21	0.40	32.93	14.73	2.54	7.39	45.71
Standard Deviation	2.11	12.29	6.89	0.46	8.01	1.36	12.26	1.73	2.88	0.57	13.94	4.29	2.71	2.40	19.14
Minimum	0.87	6.49	33.85	0.61	0.63	0.27	11.28	0.02	0.27	0.12	12.98	4.69	0.10	4.23	12.59
Maximum	7.17	39.37	55.11	2.04	23.38	4.57	50.28	6.20	8.43	2.24	51.15	19.37	7.41	11.69	65.61

Parameter/Sampling Location	O-31	O-32	O-33	O-34	O-35	O-36	O-37	O-38	O-39	O-40	O-41	O-42	O-43	O-44	O-45
Mean	1.51	5.50	7.92	16.61	17.95	2.39	21.43	4.04	6.77	2.49	8.37	1.53	1.23	1.18	9.57
Median	1.62	6.45	7.81	17.01	16.46	2.52	26.27	4.65	6.09	1.82	5.70	1.19	1.28	1.34	9.51
Standard Deviation	0.98	2.11	1.26	3.85	6.24	1.26	9.81	2.25	3.61	2.87	7.18	1.20	0.54	0.66	3.68
Minimum	0.12	2.55	5.54	10.81	10.57	0.61	2.21	0.34	2.21	0.02	3.18	0.32	0.10	0.05	4.20
Maximum	3.01	8.09	10.33	22.04	28.36	4.35	32.54	7.63	13.46	10.67	29.23	4.03	1.92	1.97	15.94

Parameter/Sampling Location	O-46	O-47	O-48	O-49	O-50	O-51	O-52	O-53	O-54	O-55	O-56	O-57	O-58	O-59	O-60
Mean	3.79	49.84	23.27	4.81	12.90	0.59	3.62	34.88	10.96	5.11	1.91	26.60	11.29	11.91	3.13
Median	3.78	53.29	22.61	5.39	13.34	0.47	3.06	34.46	12.44	5.42	2.20	31.43	11.36	11.38	3.18
Standard Deviation	1.74	9.72	5.23	2.25	2.03	0.35	1.82	19.35	3.91	1.19	1.27	10.17	2.14	1.98	1.92
Minimum	1.56	24.08	14.19	0.58	10.04	0.10	0.27	12.73	4.91	2.79	0.29	10.69	6.20	9.77	0.36
Maximum	7.82	59.97	30.79	6.90	15.21	1.31	6.63	65.05	16.69	6.68	3.50	38.90	14.12	15.09	6.34

Parameter/Sampling Location	O-61	O-62	O-63	O-64	O-65	O-66	O-67	O-68	O-69	O-70	O-71	O-72	O-73	O-74	O-75
Mean	4.82	10.90	13.66	19.30	20.27	10.82	39.19	21.36	4.39	3.69	9.23	23.54	1.53	8.49	9.79
Median	4.97	10.96	13.40	19.22	20.70	8.04	41.87	21.55	5.15	3.92	9.67	23.33	1.37	6.28	6.00
Standard Deviation	2.05	0.99	2.21	4.21	4.57	7.80	13.40	2.05	1.93	1.37	5.31	4.07	1.18	5.06	11.62
Minimum	1.90	8.87	10.38	13.15	12.71	3.69	23.38	16.86	1.58	0.53	1.07	15.82	0.07	3.77	0.15
Maximum	10.06	12.30	18.52	24.91	26.07	30.98	54.31	25.30	7.05	5.54	15.16	29.72	3.77	19.97	37.52

SUMMARY STATISTICS FOR **CADMIUM (ug/L)**

Parameter/Sampling Location	O-1	O-2	O-3	O-4	O-5	O-6	O-7	O-8	O-9	O-10	O-11	O-12	O-13	O-14	O-15
Mean	2.294	3.445	5.008	2.998	2.276	4.338	3.113	6.185	1.399	3.333	4.928	1.097	1.201	3.106	5.454
Median	2.535	3.820	5.080	3.010	2.820	4.355	2.865	6.810	1.615	3.130	4.505	1.350	1.375	3.580	4.880
Standard Deviation	1.353	1.238	1.767	1.426	1.612	1.667	1.250	2.555	1.177	1.132	1.563	0.885	1.012	1.292	2.054
Minimum	0.000	1.270	1.580	0.000	0.000	1.270	1.430	2.150	0.000	1.640	2.880	0.000	0.000	0.000	2.870
Maximum	4.110	5.560	8.510	5.380	4.260	6.970	5.640	9.750	3.450	5.640	7.850	2.460	2.870	4.580	9.520

Parameter/Sampling Location	O-16	O-17	O-18	O-19	O-20	O-21	O-22	O-23	O-24	O-25	O-26	O-27	O-28	O-29	O-30
Mean	2.426	1.662	6.129	1.318	2.347	1.538	5.134	5.553	1.839	1.337	5.775	5.534	5.403	4.703	6.078
Median	2.385	1.720	6.065	1.600	1.990	1.450	5.345	5.555	1.800	1.215	5.680	5.490	5.460	4.885	6.170
Standard Deviation	1.653	1.163	2.135	0.874	1.839	1.172	1.974	2.306	1.501	1.103	1.793	1.818	1.726	1.933	1.500
Minimum	0.000	0.000	2.590	0.000	0.000	0.000	2.470	2.170	0.000	0.000	2.890	2.840	2.970	1.290	3.690
Maximum	4.560	3.460	9.310	2.460	5.360	3.670	8.540	8.970	4.560	3.560	8.540	8.970	8.790	7.320	8.360

Parameter/Sampling Location	O-31	O-32	O-33	O-34	O-35	O-36	O-37	O-38	O-39	O-40	O-41	O-42	O-43	O-44	O-45
Mean	1.537	3.656	2.594	2.180	1.113	4.749	7.198	5.280	4.393	7.252	1.093	6.324	3.835	2.085	1.780
Median	1.625	3.700	2.685	2.205	1.240	4.695	7.100	5.300	4.350	6.985	1.160	6.345	4.045	2.555	1.615
Standard Deviation	1.070	1.236	1.604	1.055	0.733	1.171	2.026	1.932	1.819	1.690	0.761	1.367	1.314	1.799	1.267
Minimum	0.000	1.590	0.000	0.000	0.000	2.580	3.950	1.280	1.390	4.210	0.000	4.190	1.580	0.000	0.000
Maximum	3.180	5.640	5.310	3.770	2.150	6.470	9.650	8.520	6.970	9.450	2.360	8.670	5.670	5.540	3.640

Parameter/Sampling Location	O-46	O-47	O-48	O-49	O-50	O-51	O-52	O-53	O-54	O-55	O-56	O-57	O-58	O-59	O-60
Mean	6.350	3.911	1.588	4.906	6.838	2.357	3.417	5.053	5.557	5.319	6.452	3.577	1.514	4.319	1.409
Median	6.425	3.740	1.745	4.725	6.605	2.500	3.230	4.340	5.575	5.130	6.310	3.440	1.340	4.180	1.570
Standard Deviation	1.906	1.488	1.028	1.283	2.074	1.271	1.392	2.272	1.345	1.780	1.739	0.795	1.177	1.092	0.785
Minimum	3.780	1.870	0.000	2.870	3.950	0.000	1.460	1.850	3.670	2.470	3.670	2.580	0.000	2.190	0.000
Maximum	8.960	6.970	3.540	7.420	9.680	4.670	5.860	8.640	7.650	7.850	9.850	5.270	3.540	6.380	2.480

Parameter/Sampling Location	O-61	O-62	O-63	O-64	O-65	O-66	O-67	O-68	O-69	O-70	O-71	O-72	O-73	O-74	O-75
Mean	2.867	1.215	3.269	1.525	6.492	2.369	2.555	2.728	1.216	5.985	6.547	2.916	3.907	1.206	6.784
Median	2.655	1.455	2.980	1.210	6.360	2.030	2.275	2.515	1.375	5.830	6.385	2.870	3.935	1.285	6.405
Standard Deviation	1.435	0.814	1.087	1.336	2.180	1.246	2.043	0.997	0.815	1.406	1.861	0.887	1.522	0.852	1.945
Minimum	0.000	0.000	1.850	0.000	3.470	1.020	0.000	1.250	0.000	4.150	3.670	1.290	1.560	0.000	3.870
Maximum	5.460	2.360	5.360	4.210	9.670	4.580	6.980	4.520	2.310	8.540	9.640	4.250	6.390	2.640	9.760

SUMMARY STATISTICS FOR **COPPER (ug/L)**

Parameter/Sampling Location	O-1	O-2	O-3	O-4	O-5	O-6	O-7	O-8	O-9	O-10	O-11	O-12	O-13	O-14	O-15
Mean	6.211	6.323	15.920	6.777	9.256	6.824	6.772	27.453	4.461	12.876	13.144	4.252	19.808	41.447	12.113
Median	6.380	6.225	15.560	6.775	8.865	6.970	7.055	27.485	4.575	12.410	13.575	4.230	19.845	40.785	12.290
Standard Deviation	1.769	1.795	3.480	1.716	3.133	1.503	1.724	9.506	0.993	2.689	2.107	1.483	3.451	2.937	2.218
Minimum	3.670	3.670	10.290	4.190	5.280	4.270	4.250	15.270	2.580	8.370	9.680	1.390	14.870	36.540	7.530
Maximum	8.970	9.850	21.360	9.630	14.700	9.640	9.310	40.010	6.340	16.470	16.350	6.970	25.670	46.970	15.480

Parameter/Sampling Location	O-16	O-17	O-18	O-19	O-20	O-21	O-22	O-23	O-24	O-25	O-26	O-27	O-28	O-29	O-30
Mean	8.003	2.133	2.239	2.651	3.461	5.905	8.881	3.933	39.690	6.474	34.593	3.171	9.144	14.948	31.469
Median	8.175	2.140	2.525	3.105	3.405	5.675	8.545	4.290	39.870	6.315	35.095	3.650	9.285	14.570	32.400
Standard Deviation	1.797	1.587	1.746	1.923	2.536	1.919	4.453	2.401	2.876	1.645	6.213	1.504	2.430	2.716	8.193
Minimum	4.290	0.000	0.000	0.000	0.000	3.670	2.670	0.000	35.470	4.290	23.140	0.000	5.610	10.250	18.600
Maximum	10.260	4.590	5.270	5.370	7.850	9.640	16.980	7.820	45.410	9.640	46.670	5.280	13.680	19.010	43.510

Parameter/Sampling Location	O-31	O-32	O-33	O-34	O-35	O-36	O-37	O-38	O-39	O-40	O-41	O-42	O-43	O-44	O-45
Mean	3.343	11.512	12.169	3.939	8.214	13.197	16.924	12.716	11.332	15.551	3.447	2.767	3.806	14.960	27.616
Median	3.900	10.820	12.340	4.215	7.850	13.440	16.495	12.810	11.775	14.105	3.655	3.055	3.925	15.100	27.540
Standard Deviation	1.874	3.061	2.493	2.356	1.701	2.279	4.843	3.916	3.708	3.733	1.651	1.678	2.301	2.121	7.798
Minimum	0.000	6.340	8.760	0.000	5.620	9.300	10.270	6.340	6.340	11.240	0.000	0.000	0.000	11.360	15.260
Maximum	5.680	16.350	16.980	8.670	11.260	17.560	26.500	18.790	16.390	23.680	5.640	5.230	7.850	18.790	42.510

Parameter/Sampling Location	O-46	O-47	O-48	O-49	O-50	O-51	O-52	O-53	O-54	O-55	O-56	O-57	O-58	O-59	O-60
Mean	6.222	2.758	4.530	30.828	15.587	7.513	5.783	3.444	3.157	4.900	8.049	4.283	6.917	6.332	8.371
Median	6.115	2.380	4.570	31.575	15.910	7.200	5.365	3.945	3.570	5.425	8.255	4.410	6.395	6.585	8.530
Standard Deviation	1.848	1.967	1.961	8.394	3.951	1.787	1.845	2.068	2.065	1.922	2.766	2.531	1.530	1.615	1.523
Minimum	3.670	0.000	0.000	18.700	9.870	4.590	3.640	0.000	0.000	0.000	3.670	0.000	4.290	3.660	5.950
Maximum	9.680	5.670	7.520	41.260	22.310	10.270	9.410	6.380	6.390	6.870	12.340	8.670	9.850	8.570	10.360

Parameter/Sampling Location	O-61	O-62	O-63	O-64	O-65	O-66	O-67	O-68	O-69	O-70	O-71	O-72	O-73	O-74	O-75
Mean	6.475	2.924	11.534	35.464	13.863	4.908	11.904	6.593	3.455	4.958	4.408	14.004	11.418	12.353	39.200
Median	6.380	2.980	11.515	35.865	14.110	4.985	11.905	6.270	3.395	4.940	4.255	13.660	11.265	12.770	41.820
Standard Deviation	1.911	1.691	3.136	4.978	2.291	1.377	1.977	2.106	2.308	2.418	2.020	2.425	2.095	2.380	8.781
Minimum	3.690	0.000	6.390	26.740	9.330	2.390	8.640	3.680	0.000	0.000	0.000	10.390	8.360	8.530	25.840
Maximum	8.970	5.210	16.980	41.260	16.540	6.980	15.490	9.840	7.560	8.750	7.410	17.850	14.780	15.460	49.600

SUMMARY STATISTICS FOR **LEAD (ug/L)**

Parameter/Sampling Location	O-1	O-2	O-3	O-4	O-5	O-6	O-7	O-8	O-9	O-10	O-11	O-12	O-13	O-14	O-15
Mean	10.909	5.798	4.954	4.658	6.844	6.952	5.683	5.449	5.288	13.565	16.642	6.183	5.923	12.667	6.516
Median	10.275	5.475	4.750	4.285	7.150	6.745	5.025	5.705	5.590	12.385	15.895	5.975	5.835	12.355	6.340
Standard Deviation	3.491	1.754	1.505	1.098	1.597	1.337	2.087	1.631	1.527	3.891	4.127	1.654	1.493	2.274	1.666
Minimum	6.310	3.470	2.900	2.390	4.090	5.260	3.210	3.220	2.540	8.620	10.290	4.250	3.340	9.870	3.640
Maximum	17.550	9.670	7.850	6.340	8.950	8.940	9.180	8.970	7.150	21.360	25.670	8.950	8.970	16.970	8.970

Parameter/Sampling Location	O-16	O-17	O-18	O-19	O-20	O-21	O-22	O-23	O-24	O-25	O-26	O-27	O-28	O-29	O-30
Mean	13.073	28.808	4.642	10.407	23.838	6.772	6.262	7.469	28.494	7.866	4.603	5.132	7.374	15.144	7.588
Median	13.655	31.025	5.335	10.335	25.010	6.510	6.050	7.460	28.175	7.845	4.250	5.385	7.840	14.940	7.725
Standard Deviation	2.350	13.842	2.431	3.612	7.099	1.534	1.847	1.922	10.585	1.810	1.508	2.051	1.697	3.397	1.441
Minimum	10.250	8.760	0.000	5.260	12.480	4.260	3.610	4.090	12.340	4.370	1.860	0.000	4.160	9.850	5.630
Maximum	16.470	49.780	7.490	16.540	36.970	8.950	9.210	10.250	42.360	10.230	7.860	8.510	9.850	21.340	10.290

Parameter/Sampling Location	O-31	O-32	O-33	O-34	O-35	O-36	O-37	O-38	O-39	O-40	O-41	O-42	O-43	O-44	O-45
Mean	5.853	7.118	8.879	18.037	15.019	6.662	12.355	6.222	7.412	5.990	4.308	20.194	18.265	5.200	13.520
Median	6.095	7.130	9.215	17.715	14.975	6.340	11.320	6.305	7.540	5.375	4.400	20.125	17.240	4.895	13.680
Standard Deviation	1.948	1.887	2.664	4.651	3.518	1.602	3.231	1.414	1.522	2.080	1.636	4.355	5.035	1.310	2.281
Minimum	1.810	4.280	5.310	10.290	8.610	4.230	7.850	4.260	4.650	3.540	0.000	12.380	10.290	3.670	9.870
Maximum	8.910	10.370	13.670	25.970	20.130	8.940	18.940	8.610	9.640	10.280	6.380	26.580	26.980	7.630	16.580

Parameter/Sampling Location	O-46	O-47	O-48	O-49	O-50	O-51	O-52	O-53	O-54	O-55	O-56	O-57	O-58	O-59	O-60
Mean	9.069	5.157	13.056	9.248	6.931	6.223	10.834	4.958	5.558	6.198	7.029	13.099	5.691	5.343	6.473
Median	8.945	5.550	13.570	9.070	6.940	6.325	10.815	5.060	5.860	6.360	6.980	13.030	5.575	5.470	6.020
Standard Deviation	2.739	2.091	2.086	2.320	1.381	1.596	3.641	2.680	1.758	2.485	1.547	2.547	1.981	1.020	1.974
Minimum	5.240	0.000	10.280	5.320	4.780	3.460	4.380	0.000	2.870	0.000	4.280	8.970	2.340	3.680	3.560
Maximum	15.640	7.630	16.980	13.680	9.140	9.610	15.870	8.670	8.970	9.680	10.270	16.970	8.640	6.970	9.640

Parameter/Sampling Location	O-61	O-62	O-63	O-64	O-65	O-66	O-67	O-68	O-69	O-70	O-71	O-72	O-73	O-74	O-75
Mean	7.153	18.070	8.554	4.952	7.448	5.717	25.863	7.452	5.220	12.802	4.366	5.709	6.520	6.628	5.431
Median	7.495	17.705	8.395	4.545	8.085	5.105	25.660	6.975	4.940	12.910	4.410	5.990	6.520	6.650	6.030
Standard Deviation	1.596	6.462	1.434	1.928	2.097	2.034	3.640	1.974	2.287	2.543	2.446	1.519	1.620	1.696	2.609
Minimum	4.630	10.250	6.310	0.990	4.220	3.540	20.480	4.850	0.000	8.540	0.000	3.160	4.650	3.670	0.000
Maximum	9.680	28.970	10.490	8.750	10.590	9.540	32.690	11.190	8.550	16.340	7.850	7.890	9.670	9.640	8.640

SUMMARY STATISTICS FOR **ZINC (ug/L)**

Parameter/Sampling Location	O-1	O-2	O-3	O-4	O-5	O-6	O-7	O-8	O-9	O-10	O-11	O-12	O-13	O-14	O-15
Mean	4.364	3.930	3.185	5.560	4.037	4.970	4.268	6.058	3.492	8.779	11.553	3.695	2.616	22.505	4.492
Median	3.965	3.405	3.135	5.180	3.820	4.675	4.555	6.105	3.305	7.690	10.250	3.705	2.695	20.595	4.300
Standard Deviation	2.077	1.635	1.169	2.208	1.359	1.361	1.214	2.127	1.373	3.437	3.351	1.131	0.767	10.583	1.592
Minimum	1.290	1.870	1.430	2.570	2.270	3.340	2.140	2.730	1.670	3.630	7.650	2.190	1.130	10.870	2.150
Maximum	7.190	6.830	5.510	9.740	6.750	7.930	6.750	9.290	5.920	13.760	16.800	5.890	3.930	45.320	7.190

Parameter/Sampling Location	O-16	O-17	O-18	O-19	O-20	O-21	O-22	O-23	O-24	O-25	O-26	O-27	O-28	O-29	O-30
Mean	4.388	24.785	30.803	7.859	50.268	6.594	14.104	9.090	3.581	5.977	32.872	8.643	6.616	13.352	11.519
Median	4.005	16.455	22.185	6.625	43.230	6.300	10.735	8.135	3.770	5.795	31.985	7.940	6.710	12.145	10.790
Standard Deviation	2.746	18.191	18.919	3.019	18.149	2.180	8.363	4.262	2.091	1.955	16.059	3.943	3.108	4.874	4.296
Minimum	0.000	8.830	12.530	3.850	31.650	3.520	6.590	3.970	0.000	2.190	12.650	3.850	0.000	6.610	5.720
Maximum	8.720	65.910	75.310	13.150	87.640	10.530	35.620	17.740	6.720	8.820	67.840	19.270	11.730	21.690	20.380

Parameter/Sampling Location	O-31	O-32	O-33	O-34	O-35	O-36	O-37	O-38	O-39	O-40	O-41	O-42	O-43	O-44	O-45
Mean	15.248	4.989	5.848	6.687	15.050	15.404	7.593	15.303	14.254	21.738	9.464	69.957	17.706	6.651	28.467
Median	14.670	4.795	5.795	6.815	14.265	15.070	7.560	14.580	14.550	20.250	9.340	71.890	17.795	6.855	30.195
Standard Deviation	4.637	1.951	2.029	1.489	3.411	5.309	2.373	4.233	3.590	8.067	1.844	20.508	4.797	3.940	8.862
Minimum	8.740	2.710	2.260	3.210	10.680	6.430	4.310	9.670	8.610	10.670	6.340	36.970	10.290	0.000	12.390
Maximum	23.740	8.930	9.040	8.610	21.640	23.690	10.790	23.140	20.190	38.730	12.360	98.630	25.610	12.340	42.310

Parameter/Sampling Location	O-46	O-47	O-48	O-49	O-50	O-51	O-52	O-53	O-54	O-55	O-56	O-57	O-58	O-59	O-60
Mean	15.523	3.788	6.725	23.858	15.278	11.187	6.889	12.422	8.568	4.935	14.783	7.459	5.000	6.620	6.130
Median	15.450	4.120	6.740	21.480	14.725	10.770	6.885	12.710	8.140	5.510	14.840	7.415	4.995	6.360	6.170
Standard Deviation	3.962	2.236	1.910	7.127	3.875	2.978	1.720	2.614	2.637	2.662	3.499	1.900	1.029	2.035	1.695
Minimum	10.240	0.000	3.450	14.250	9.640	6.370	3.580	8.670	4.320	0.000	9.870	4.250	3.250	4.280	3.780
Maximum	25.400	6.970	10.240	38.940	21.370	15.470	9.310	17.960	13.670	8.100	20.370	10.580	6.780	10.870	8.640

Parameter/Sampling Location	O-61	O-62	O-63	O-64	O-65	O-66	O-67	O-68	O-69	O-70	O-71	O-72	O-73	O-74	O-75
Mean	9.552	14.866	8.588	18.343	4.577	6.266	13.729	14.943	5.121	14.538	5.283	5.943	9.193	13.076	13.843
Median	9.830	14.545	8.730	18.670	4.965	6.100	13.960	14.160	5.430	13.670	5.250	6.365	9.250	13.000	13.565
Standard Deviation	3.054	4.882	2.343	4.654	2.417	1.808	4.161	2.729	2.206	3.922	1.903	1.512	3.269	2.535	5.724
Minimum	4.290	7.350	5.280	10.250	0.000	3.670	6.850	10.250	0.000	9.850	1.550	3.120	4.250	9.870	6.340
Maximum	14.570	23.360	13.450	25.670	8.310	9.670	21.670	19.510	7.910	23.470	8.550	7.940	14.570	17.840	25.680

SUMMARY STATISTICS FOR **TOTAL COLIFORMS AS MPN per 100 ml**

Parameter/Sampling Location	O-1	O-2	O-3	O-4	O-5	O-6	O-7	O-8	O-9	O-10	O-11	O-12	O-13	O-14	O-15
Mean	27	27	86	29	19	117	26	24	29	87	73	56	39	426	208
Median	28	27	75	26	19	100	23	22	27	90	70	45	40	350	220
Standard Deviation	6.18	6.15	38.25	9.61	6.26	73.65	12.18	8.51	9.61	29.95	23.93	36.30	13.46	175.37	97.87
Minimum	14	17	40	17	9	33	11	11	17	40	34	17	23	280	80
Maximum	34	34	170	50	30	300	50	40	50	130	110	140	70	900	350

Parameter/Sampling Location	O-16	O-17	O-18	O-19	O-20	O-21	O-22	O-23	O-24	O-25	O-26	O-27	O-28	O-29	O-30
Mean	395	173	577	81	118	46	738	177	141	147	692	768	133	217	92
Median	350	170	500	60	130	45	500	155	135	130	500	500	120	170	85
Standard Deviation	202.99	66.92	388.81	72.70	39.96	16.99	574.49	91.59	48.14	76.50	469.45	547.50	68.40	118.04	37.04
Minimum	220	70	220	33	50	17	80	70	60	33	300	170	50	90	34
Maximum	900	280	1600	300	170	70	1600	350	220	300	1600	1600	280	500	140

Parameter/Sampling Location	O-31	O-32	O-33	O-34	O-35	O-36	O-37	O-38	O-39	O-40	O-41	O-42	O-43	O-44	O-45
Mean	73	48	299	113	107	98	91	54	74	76	94	122	69	78	48
Median	70	37	195	110	100	90	85	50	55	57	90	110	60	70	50
Standard Deviation	17.75	26.71	254.18	36.46	39.16	33.61	35.19	22.41	49.04	69.53	28.43	42.18	35.72	38.86	17.51
Minimum	50	26	50	60	50	50	34	26	23	17	50	70	27	34	23
Maximum	110	110	900	170	170	170	140	90	170	240	140	220	140	170	80

Parameter/Sampling Location	O-46	O-47	O-48	O-49	O-50	O-51	O-52	O-53	O-54	O-55	O-56	O-57	O-58	O-59	O-60
Mean	61	133	179	59	138	87	282	92	108	114	382	549	546	549	149
Median	32	130	155	60	130	80	255	85	65	110	350	425	350	425	120
Standard Deviation	63.84	75.38	75.97	25.45	62.25	42.75	124.08	39.41	129.30	34.23	203.69	406.01	402.16	406.01	91.70
Minimum	17	26	90	26	60	26	130	34	27	70	140	170	220	170	50
Maximum	240	280	350	110	280	170	500	170	500	170	900	1600	1600	1600	350

Parameter/Sampling Location	O-61	O-62	O-63	O-64	O-65	O-66	O-67	O-68	O-69	O-70	O-71	O-72	O-73	O-74	O-75
Mean	426	703	166	105	98	86	612	34	118	78	98	96	386	84	172
Median	350	500	170	95	100	70	500	31	100	75	90	50	300	80	155
Standard Deviation	253.03	491.16	82.51	56.34	32.43	57.63	403.41	12.38	51.90	35.16	35.12	133.72	284.30	29.68	91.04
Minimum	140	170	50	34	50	33	170	22	60	26	50	4	50	50	50
Maximum	900	1600	350	220	140	240	1600	60	230	140	170	500	900	140	350

SUMMARY STATISTICS FOR **FECAL COLIFORMS IN MPN per 100 ml**

Parameter/Sampling Location	O-1	O-2	O-3	O-4	O-5	O-6	O-7	O-8	O-9	O-10	O-11	O-12	O-13	O-14	O-15
Mean	21	20	69	23	14	80	19	18	17	60	53	37	24	282	168
Median	22	21.5	60	22.5	13.5	70	19	14	17	60	50	28.5	24.5	290	155
Standard Deviation	6.53	5.85	33.43	7.43	5.40	51.88	7.25	7.27	7.10	22.33	22.37	25.82	7.90	84.08	90.16
Minimum	9	11	30	12	6	21	9	9	7	26	21	11	11	170	50
Maximum	30	27	140	40	23	190	33	30	33	90	90	90	40	500	300

Parameter/Sampling Location	O-16	O-17	O-18	O-19	O-20	O-21	O-22	O-23	O-24	O-25	O-26	O-27	O-28	O-29	O-30
Mean	273	146	373	48	88	34	608	151	115	122	540	525	91	177	71
Median	280	140	325	36.5	90	31.5	350	135	110	110	350	325	90	140	70
Standard Deviation	97.76	65.85	192.46	40.43	38.81	13.24	529.63	79.02	35.29	72.48	401.04	416.60	36.05	80.72	25.97
Minimum	140	40	170	21	40	14	60	70	60	26	280	170	40	90	33
Maximum	500	220	900	170	140	60	1600	300	170	280	1600	1600	170	350	110

Parameter/Sampling Location	O-31	O-32	O-33	O-34	O-35	O-36	O-37	O-38	O-39	O-40	O-41	O-42	O-43	O-44	O-45
Mean	63	39	237	93	78	48	72	54	39	59	68	94	57	62	36
Median	60	33	225	90	75	45	65	50	30	45	60	90	45	55	40
Standard Deviation	14.85	19.98	157.61	33.12	32.98	19.24	33.39	22.41	26.08	50.55	22.61	32.88	34.41	32.28	12.69
Minimum	40	21	50	40	30	23	21	26	14	14	40	50	23	33	17
Maximum	90	90	500	140	140	90	130	90	90	170	110	170	130	140	60

Parameter/Sampling Location	O-46	O-47	O-48	O-49	O-50	O-51	O-52	O-53	O-54	O-55	O-56	O-57	O-58	O-59	O-60
Mean	45	95	146	46	100	73	202	72	82	96	333	439	351	418	111
Median	23	90	135	40	90	70	170	65	45	90	300	350	325	350	100
Standard Deviation	45.63	48.20	63.17	20.97	46.71	37.37	77.56	34.46	90.02	29.99	205.35	240.51	97.28	249.14	64.87
Minimum	11	21	80	21	40	21	110	23	23	60	130	170	220	140	40
Maximum	170	170	300	90	220	140	350	140	350	140	900	900	500	900	280

Parameter/Sampling Location	O-61	O-62	O-63	O-64	O-65	O-66	O-67	O-68	O-69	O-70	O-71	O-72	O-73	O-74	O-75
Mean	337	533	149	104	93	67	424	28	86	61	76	58	255	66	143
Median	325	350	155	95	95	55	350	24.5	75	55	70	31.5	260	60	130
Standard Deviation	207.16	414.97	71.66	57.76	34.20	41.89	246.41	10.12	33.43	26.83	28.11	80.52	153.43	29.68	70.11
Minimum	130	140	50	34	40	21	140	17	50	23	40	4	33	40	50
Maximum	900	1600	280	220	140	170	900	50	140	110	140	300	500	130	300

SUMMARY STATISTITICS FOR **SALINITY**

Parameter/Sampling Location	O-1	O-2	O-3	O-4	O-5	O-6	O-7	O-8	O-9	O-10	O-11	O-12	O-13	O-14	O-15
Mean	0.188	0.145	0.097	0.059	0.068	0.063	0.096	0.071	0.103	0.103	0.069	0.065	0.068	0.086	0.070
Median	0.188	0.103	0.091	0.059	0.068	0.062	0.081	0.063	0.091	0.081	0.068	0.063	0.068	0.086	0.063
Standard Deviation	0.010	0.094	0.028	0.003	0.006	0.006	0.033	0.016	0.030	0.040	0.008	0.007	0.009	0.015	0.019
Minimum	0.173	0.066	0.064	0.053	0.061	0.055	0.057	0.057	0.077	0.073	0.057	0.055	0.055	0.064	0.050
Maximum	0.209	0.360	0.156	0.064	0.081	0.073	0.146	0.102	0.174	0.203	0.084	0.081	0.088	0.120	0.109

Parameter/Sampling Location	O-16	O-17	O-18	O-19	O-20	O-21	O-22	O-23	O-24	O-25	O-26	O-27	O-28	O-29	O-30
Mean	0.074	0.162	0.167	0.072	0.137	0.063	0.121	0.097	0.073	0.052	0.109	0.097	0.053	0.096	0.099
Median	0.066	0.161	0.161	0.068	0.134	0.060	0.137	0.095	0.078	0.052	0.111	0.092	0.053	0.096	0.098
Standard Deviation	0.016	0.022	0.020	0.015	0.049	0.011	0.042	0.011	0.012	0.003	0.038	0.025	0.002	0.019	0.020
Minimum	0.057	0.126	0.138	0.055	0.066	0.050	0.066	0.081	0.052	0.048	0.059	0.068	0.050	0.061	0.070
Maximum	0.102	0.212	0.207	0.102	0.225	0.084	0.178	0.115	0.088	0.057	0.165	0.162	0.059	0.129	0.131

Parameter/Sampling Location	O-31	O-32	O-33	O-34	O-35	O-36	O-37	O-38	O-39	O-40	O-41	O-42	O-43	O-44	O-45
Mean	0.063	0.065	0.055	0.102	0.120	0.124	0.127	0.064	0.071	0.087	0.083	0.061	0.048	0.046	0.087
Median	0.063	0.065	0.055	0.104	0.098	0.126	0.122	0.063	0.072	0.088	0.082	0.063	0.047	0.046	0.086
Standard Deviation	0.003	0.004	0.003	0.012	0.060	0.015	0.044	0.004	0.008	0.005	0.008	0.006	0.003	0.002	0.008
Minimum	0.057	0.059	0.052	0.081	0.050	0.088	0.075	0.059	0.057	0.077	0.070	0.052	0.044	0.044	0.073
Maximum	0.070	0.073	0.059	0.118	0.241	0.144	0.209	0.070	0.082	0.091	0.097	0.068	0.053	0.048	0.102

Parameter/Sampling Location	O-46	O-47	O-48	O-49	O-50	O-51	O-52	O-53	O-54	O-55	O-56	O-57	O-58	O-59	O-60
Mean	0.072	0.130	0.106	0.118	0.067	0.067	0.094	0.131	0.086	0.092	0.066	0.076	0.120	0.116	0.055
Median	0.072	0.130	0.106	0.116	0.066	0.064	0.094	0.127	0.086	0.089	0.067	0.076	0.118	0.117	0.055
Standard Deviation	0.004	0.026	0.010	0.025	0.005	0.011	0.009	0.054	0.012	0.017	0.006	0.007	0.019	0.015	0.004
Minimum	0.066	0.091	0.088	0.086	0.059	0.055	0.081	0.068	0.070	0.072	0.055	0.064	0.093	0.079	0.048
Maximum	0.079	0.187	0.126	0.174	0.077	0.091	0.109	0.225	0.102	0.128	0.077	0.090	0.155	0.142	0.063

Parameter/Sampling Location	O-61	O-62	O-63	O-64	O-65	O-66	O-67	O-68	O-69	O-70	O-71	O-72	O-73	O-74	O-75
Mean	0.059	0.136	0.115	0.074	0.082	0.077	0.108	0.131	0.099	0.070	0.067	0.053	0.087	0.117	0.394
Median	0.058	0.136	0.117	0.076	0.081	0.077	0.102	0.129	0.100	0.065	0.066	0.054	0.090	0.112	0.418
Standard Deviation	0.005	0.016	0.015	0.009	0.016	0.021	0.020	0.010	0.009	0.020	0.008	0.002	0.019	0.036	0.226
Minimum	0.052	0.113	0.079	0.059	0.063	0.048	0.081	0.117	0.086	0.048	0.055	0.048	0.057	0.066	0.140
Maximum	0.068	0.171	0.140	0.086	0.118	0.129	0.149	0.151	0.113	0.109	0.079	0.055	0.120	0.196	0.854

APPENDIX-II

WATER QUALITY MONITORING: BORE WELLS SUMMARY STATISTICS

SUMMARY STATISTICS FOR **pH**

Parameter	B-1	B-2	B-3	B-4	B-5	B-6	B-7	B-8	B-9	B-10	B-11	B-12	B-13	B-14	B-15	B-16	B-17	B-18	B-19
Mean	7.56	6.72	6.54	6.28	7.12	6.90	5.96	6.98	6.69	6.98	6.94	6.54	6.54	8.29	6.83	6.58	6.74	6.77	7.29
Median	7.61	6.74	6.54	6.31	7.32	6.89	6.51	6.99	6.86	7.02	6.98	6.50	6.54	8.28	6.78	6.67	6.76	6.77	7.29
Stand Dvn.	0.27	0.12	0.19	0.28	0.96	0.20	1.89	0.27	0.52	0.46	0.27	0.20	0.16	0.14	0.24	0.43	0.17	0.15	0.05
Minimum	6.97	6.43	6.25	5.51	4.43	6.64	0.00	6.67	5.66	6.11	6.56	6.27	6.29	8.09	6.52	5.72	6.50	6.54	7.21
Maximum	7.89	6.89	6.82	6.61	8.11	7.34	6.89	7.34	7.31	7.61	7.28	7.00	6.83	8.61	7.19	7.11	7.12	7.01	7.36

SUMMARY STATISTICS FOR **TEMPERATURE IN ^{0} C**

Parameter	B-1	B-2	B-3	B-4	B-5	B-6	B-7	B-8	B-9	B-10	B-11	B-12	B-13	B-14	B-15	B-16	B-17	B-18	B-19
Mean	28.92	29.43	28.68	29.13	28.38	28.95	26.64	28.61	29.41	29.72	29.13	30.17	28.97	29.37	30.36	30.02	28.83	28.77	29.72
Median	28.90	29.15	28.60	29.10	28.25	28.80	28.60	28.60	29.30	29.45	28.75	30.10	28.90	29.10	29.95	30.05	28.65	28.65	29.65
Stand Dvn.	1.05	1.77	0.99	0.75	0.87	0.59	8.44	0.58	1.12	1.31	1.31	1.36	0.73	1.10	1.30	1.24	0.86	0.86	0.71
Minimum	27.50	27.20	27.50	27.90	27.30	28.10	0.00	27.80	27.90	28.10	27.40	28.30	27.60	28.00	28.90	27.60	27.50	27.00	28.70
Maximum	31.30	33.00	30.50	30.40	30.60	30.10	30.70	29.90	31.20	32.10	31.40	32.50	29.90	31.90	33.50	32.00	30.40	30.10	31.00

SUMMARY STATISTICS FOR **CONDUCTIVITY**

Parameter	B-1	B-2	B-3	B-4	B-5	B-6	B-7	B-8	B-9	B-10	B-11	B-12	B-13	B-14	B-15	B-16	B-17	B-18	B-19
Mean	1454	248	233	77	448	150	173	178	278	323	441	765	215	654	1000	174	192	173	241
Median	1352	252	229	75	411.5	144.5	146.5	207.5	287.5	331.5	438.5	748.5	222.5	670.5	1061	185.5	221.5	190.5	238.5
Stand Dvn.	641.32	46.19	35.07	12.51	67.70	18.53	91.09	56.71	84.05	35.72	22.88	136.85	29.41	72.00	467.04	29.95	56.25	43.43	27.74
Minimum	820	160	180	63	387	128	0	75	180	239	409	558	160	530	360	130	100	98	177
Maximum	3276	323	305	110	600	180	278	232	372	362	487	1020	245	756	1647	212	245	227	288

SUMMARY STATISTICS FOR **TOTAL DISSOLVED SOLIDS (mg/L)**

Parameter	B-1	B-2	B-3	B-4	B-5	B-6	B-7	B-8	B-9	B-10	B-11	B-12	B-13	B-14	B-15	B-16	B-17	B-18	B-19
Mean	899	149	138	46	264	88	108	110	172	187	264	451	129	392	623	111	117	107	145
Median	825	155	139	45	251	85	99	125	177	196	269	440	136	410	647	114	133	116	147
Stand Dvn.	395.8	32.1	27.4	9.7	55.1	16.0	55.5	32.5	48.5	32.1	34.2	93.3	21.2	56.9	261.5	22.1	32.4	24.1	21.7
Minimum	500	96	88	26	154	51	0	47	110	135	164	319	84	275	220	79	61	74	102
Maximum	2031	198	189	68	372	112	171	142	229	224	302	622	148	456	948	159	152	141	176

SUMMARY STATISTICS FOR **DO (mg/L)**

Parameter	B-1	B-2	B-3	B-4	B-5	B-6	B-7	B-8	B-9	B-10	B-11	B-12	B-13	B-14	B-15	B-16	B-17	B-18	B-19
Mean	6.16	5.50	6.59	5.85	6.34	6.27	5.81	5.90	5.86	5.80	5.99	5.93	6.99	5.95	5.65	5.32	6.48	6.76	6.41
Median	5.84	5.10	6.53	5.81	6.50	6.40	6.45	5.76	5.63	5.72	6.25	5.50	7.00	5.89	5.60	5.59	6.39	6.75	6.78
Stand Dvn.	1.02	1.01	0.16	0.55	0.76	0.49	1.96	0.62	0.59	0.77	0.80	1.11	0.38	1.07	0.73	0.87	0.39	0.41	0.77
Minimum	5.11	4.01	6.32	5.23	5.15	5.46	0	5.23	5.27	4.6	4.22	4.81	6.43	4.81	4.81	3.4	5.98	6.16	4.8
Maximum	7.64	6.89	6.84	6.59	7.34	6.9	7.36	7.11	6.98	6.88	6.91	7.39	7.8	7.63	6.93	6.15	7.37	7.28	7.15

SUMMARY STATISTICS FOR **TURBIDITY IN NTU**

Parameter	B-1	B-2	B-3	B-4	B-5	B-6	B-7	B-8	B-9	B-10	B-11	B-12	B-13	B-14	B-15	B-16	B-17	B-18	B-19
Mean	0.95	114.98	41.38	18.59	6.61	9.20	26.18	37.77	60.78	40.48	58.29	38.14	0.94	0.93	8.09	116.69	62.38	36.62	21.82
Median	0.65	116.00	39.80	16.10	4.10	4.30	26.30	33.95	53.10	38.75	62.35	27.50	0.60	0.80	8.00	127.00	63.45	38.45	19.90
Stand Dvn.	0.56	14.76	19.61	8.59	5.96	7.34	15.17	14.20	31.96	21.10	26.21	25.81	0.58	0.39	3.40	30.01	21.09	17.38	7.33
Minimum	0.5	87.5	12.3	9.3	2.5	3.2	0	16.9	24.1	13.5	7	13.5	0.3	0.5	2.3	33.6	25.6	10.5	12.3
Maximum	2.1	136.7	70.5	41.2	23.6	24.3	54.2	55.4	125.7	79.4	95.5	98.7	1.8	1.8	13.5	139.3	88.9	62.3	36.4

SUMMARY STATISTICS FOR **ALKALINITY (mg/L)**

Parameter	B-1	B-2	B-3	B-4	B-5	B-6	B-7	B-8	B-9	B-10	B-11	B-12	B-13	B-14	B-15	B-16	B-17	B-18	B-19
Mean	243	57	97	29	185	57	64	102	118	170	180	77	71	140	89	64	61	54	73
Median	237	59	98.5	25.5	188	57	71	101.5	133	171.5	180	74.5	70.5	139.5	89	64	60.5	52	75
Stand Dvn.	24.76	10.26	7.91	5.05	14.32	4.12	20.49	3.99	28.08	11.88	7.86	8.82	5.16	8.63	6.67	7.21	3.95	6.60	6.52
Minimum	212	40	85	23	154	51	0	95	72	140	165	65	63	125	81	52	56	45	61
Maximum	292	73	109	36	200	65	75	109	145	183	197	96	80	152	100	79	69	67	82

SUMMARY STATISTICS FOR **CHLORIDES (mg/L)**

Parameter	B-1	B-2	B-3	B-4	B-5	B-6	B-7	B-8	B-9	B-10	B-11	B-12	B-13	B-14	B-15	B-16	B-17	B-18	B-19
Mean	287.3	25.75	13.67	17.75	18.17	14.92	28.67	13	19.33	13.42	29.83	199.4	13.58	75.25	166.8	12.38	12.58	11.83	33.38
Median	298.5	24.5	12.5	17.5	18	12.5	31.5	12.5	20.5	13.5	30	197	13	78.5	204	12	12	12	34
Stand Dvn.	185.70	5.40	4.01	5.55	2.55	5.04	9.33	1.48	3.94	2.11	2.12	28.31	2.47	21.58	84.82	1.69	2.39	0.94	6.12
Minimum	92	20	10	10	14	10	0	11	12	10	26	156	10	49	42	10	10	10	24
Maximum	790	38	24	27	24	26	34	16	24	17	33	258	18	131	265	15.5	19	13	43

SUMMARY STATISTICS FOR **HARDNESS (mg/L)**

Parameter	B-1	B-2	B-3	B-4	B-5	B-6	B-7	B-8	B-9	B-10	B-11	B-12	B-13	B-14	B-15	B-16	B-17	B-18	B-19
Mean	324.58	60.42	81.08	23.92	64.08	47.08	70.92	80.75	88.42	151.25	150.75	258.08	80.67	199.17	209.08	51.92	44.92	36.17	86.17
Median	263	64.5	82	23.5	60.5	46.5	76.5	80.5	99.5	158.5	151	260	75	197	230.5	54.5	48.5	37.5	86.5
Stand Dvn.	164.61	25.25	10.26	5.65	8.82	5.11	28.47	9.65	31.54	24.17	8.42	28.32	25.95	11.54	56.75	11.97	11.54	5.92	6.94
Minimum	185	25	65	15	54	39	0	65	42	108	135	214	54	184	120	27	17	23	74
Maximum	712	102	99	34	82	56	112	98	124	184	162	310	154	224	274	65	58	46	95

SUMMARY STATISTICS FOR **SULFATES (mg/L)**

Parameter	B-1	B-2	B-3	B-4	B-5	B-6	B-7	B-8	B-9	B-10	B-11	B-12	B-13	B-14	B-15	B-16	B-17	B-18	B-19
Mean	27.06	19.33	14.37	1.64	4.86	8.29	2.90	14.58	6.73	5.07	15.43	17.38	13.39	20.69	30.02	8.04	3.18	11.11	10.67
Median	25.78	20.84	13.48	1.44	4.77	7.05	2.88	13.91	6.94	4.16	14.31	17.66	14.66	18.94	29.58	7.39	2.30	11.07	10.40
Stand Dvn.	7.30	7.67	3.29	1.28	1.33	2.72	1.50	2.41	2.53	3.46	4.43	3.02	9.14	4.85	11.80	4.90	2.54	2.38	3.34
Minimum	16.74	7.47	10.99	0.07	2.80	5.53	0.00	11.21	1.37	1.15	7.40	12.36	1.29	14.29	13.23	0.29	1.37	7.43	5.68
Maximum	39.17	30.04	21.35	3.38	7.55	13.08	5.25	19.32	10.09	15.02	23.68	22.57	29.11	29.67	55.63	16.65	10.44	15.27	16.48

SUMMARY STATISTICS FOR **NITRATES (mg/L)**

Parameter	B-1	B-2	B-3	B-4	B-5	B-6	B-7	B-8	B-9	B-10	B-11	B-12	B-13	B-14	B-15	B-16	B-17	B-18	B-19
Mean	14.61	6.12	14.01	5.52	4.57	3.99	24.63	13.48	13.28	4.83	6.56	12.59	2.76	74.33	55.70	4.02	2.27	2.62	7.64
Median	13.69	5.88	13.91	5.54	4.24	3.64	24.56	14.74	13.03	4.34	6.62	13.07	1.99	71.46	51.29	4.33	1.97	2.23	7.18
Stand Dvn.	6.15	1.52	4.54	1.35	1.12	1.26	11.27	5.59	3.83	1.70	1.73	6.26	2.55	26.10	19.59	1.46	1.33	1.89	2.37
Minimum	7.42	3.96	7.53	3.52	3.05	2.06	0.00	4.86	8.31	2.78	4.21	1.65	0.21	38.74	30.19	1.19	0.64	0.39	4.23
Maximum	26.22	9.37	21.52	8.94	6.59	6.14	48.79	21.43	20.57	8.13	10.26	20.82	8.53	134.35	92.34	6.22	4.69	5.68	11.58

SUMMARY STATISTICS FOR **FLUORIDES (mg/L)**

Parameter	B-1	B-2	B-3	B-4	B-5	B-6	B-7	B-8	B-9	B-10	B-11	B-12	B-13	B-14	B-15	B-16	B-17	B-18	B-19
Mean	0.06	0.05	0.05	0.22	0.10	0.06	0.12	0.14	0.10	0.12	0.10	0.41	0.05	0.07	0.32	0.10	0.20	0.21	0.11
Median	0.07	0.05	0.04	0.23	0.09	0.05	0.12	0.14	0.09	0.13	0.08	0.38	0.05	0.08	0.30	0.08	0.19	0.22	0.10
Stand Dvn.	0.02	0.02	0.02	0.12	0.03	0.03	0.05	0.05	0.04	0.04	0.05	0.16	0.03	0.02	0.09	0.06	0.05	0.05	0.05
Minimum	0.03	0.01	0.02	0.08	0.06	0.02	0.06	0.05	0.05	0.05	0.04	0.21	0.00	0.02	0.16	0.04	0.14	0.09	0.05
Maximum	0.09	0.08	0.08	0.46	0.15	0.12	0.21	0.23	0.19	0.21	0.17	0.80	0.09	0.10	0.52	0.23	0.29	0.29	0.19

SUMMARY STATISTICS FOR **SODIUM (mg/L)**

Parameter	B-1	B-2	B-3	B-4	B-5	B-6	B-7	B-8	B-9	B-10	B-11	B-12	B-13	B-14	B-15	B-16	B-17	B-18	B-19
Mean	249.37	28.70	14.35	18.81	74.94	11.45	23.73	11.84	22.70	16.15	36.55	64.35	13.08	53.06	212.05	7.72	9.03	9.88	16.03
Median	160.15	23.02	10.95	16.20	72.95	10.40	22.30	10.35	22.25	15.45	33.65	54.55	12.95	54.50	251.05	6.90	9.15	9.85	15.80
Stand Dvn.	271.01	23.21	8.13	8.81	12.74	3.97	10.96	4.51	4.50	3.72	11.48	22.19	2.08	15.62	129.80	3.35	1.41	1.57	4.10
Minimum	47.1	0.6	7.6	7.1	54.7	6.8	0	6.5	15.8	11.5	24.6	32.4	9	23.1	21.8	3.1	6.6	7.5	8.1
Maximum	1020	63.8	34.7	34.7	96.8	19.8	47	19.7	31.5	22.9	66.6	102.1	16.1	86.2	363	14.2	11.1	12.7	23.4

SUMMARY STATISTICS FOR **POTASSIUM (mg/L)**

Parameter	B-1	B-2	B-3	B-4	B-5	B-6	B-7	B-8	B-9	B-10	B-11	B-12	B-13	B-14	B-15	B-16	B-17	B-18	B-19
Mean	23.00	2.21	3.47	2.43	5.13	3.17	2.57	3.19	3.13	4.53	4.70	9.53	1.95	9.40	17.88	3.17	2.06	1.53	6.69
Median	15.75	2.05	2.4	2.4	5.15	3.6	2.55	2.3	2.65	4.4	4.05	8	1.55	8.95	16.75	2.85	1.15	1	6.35
Stand Dvn.	23.11	1.62	3.36	1.11	2.23	2.07	1.59	2.77	1.10	2.23	1.87	5.25	1.28	4.63	5.09	1.84	1.44	1.25	2.54
Minimum	5.2	0.1	0.2	0.6	1.2	0.5	0	0.4	1.8	1.4	2.6	3.5	0.9	4.6	10.3	0.2	0.7	0.1	1.2
Maximum	90	5.3	10.5	4	8.2	7.2	6.1	9.2	5.2	9.1	9.1	20.2	5.2	18.9	28.5	6.8	4.5	3.7	11.9

SUMMARY STATISTICS FOR **CALCIUM (mg/L)**

Parameter	B-1	B-2	B-3	B-4	B-5	B-6	B-7	B-8	B-9	B-10	B-11	B-12	B-13	B-14	B-15	B-16	B-17	B-18	B-19
Mean	26.25	3.12	3.73	3.79	6.19	3.57	4.15	3.35	4.59	4.41	4.88	6.67	2.18	19.98	19.26	1.92	2.33	2.21	3.99
Median	18.92	2.4	2.658	3.12	4.86	2.46	3.02	2.4	3.68	3.76	4.384	4.12	1.7	11.38	16.96	1.62	1.88	1.62	2.762
Stand Dvn.	17.31	1.94	3.85	2.12	4.41	3.34	4.13	3.56	2.66	2.26	1.89	5.39	1.14	20.07	9.53	1.20	1.20	1.36	3.98
Minimum	12.2	1.4	1.72	1.96	3.32	1.84	0	1.72	2.16	2.76	2.6	2.32	1.248	5	11.44	0.88	1.12	1.04	0.96
Maximum	72.4	8.52	15.72	9.52	19.68	13.96	16.6	14.6	10.72	11.2	9.84	17.8	4.92	63.24	47.88	5.32	5.36	5.88	14.92

SUMMARY STATISTICS FOR **MAGNISIUM (mg/L)**

Parameter	B-1	B-2	B-3	B-4	B-5	B-6	B-7	B-8	B-9	B-10	B-11	B-12	B-13	B-14	B-15	B-16	B-17	B-18	B-19
Mean	62.93	12.79	17.44	3.51	11.81	9.27	14.71	17.59	18.70	34.08	33.67	58.66	18.28	36.26	39.11	11.45	9.50	7.44	18.52
Median	44.55	14.20	18.30	3.71	11.94	9.66	16.32	17.81	20.98	35.81	33.41	58.09	17.33	39.73	46.55	12.24	10.49	8.09	18.78
Stand Dvn.	37.13	6.93	2.52	1.28	2.29	2.46	7.06	2.17	8.83	6.11	1.67	6.13	5.92	10.65	16.08	3.16	2.87	1.56	3.18
Minimum	37.03	0.90	13.78	0.29	6.03	2.70	0.00	14.22	3.69	23.43	30.74	47.12	11.45	13.10	6.15	5.01	2.48	3.94	10.86
Maximum	165.60	23.11	21.97	5.13	15.60	11.52	24.79	21.89	28.34	42.55	36.04	69.91	34.43	45.73	56.01	15.22	12.26	9.09	22.10

SUMMARY STATISTICS FOR **IRON (mg/L)**

Parameter	B-1	B-2	B-3	B-4	B-5	B-6	B-7	B-8	B-9	B-10	B-11	B-12	B-13	B-14	B-15	B-16	B-17	B-18	B-19
Mean	0.07	3.27	1.84	1.51	0.90	1.21	3.34	2.13	4.19	4.57	5.75	3.15	0.09	0.06	1.24	6.74	3.33	3.21	2.38
Median	0.08	2.91	1.50	1.30	0.65	0.92	3.00	2.00	3.92	3.68	5.55	3.58	0.08	0.05	1.27	7.23	2.50	3.26	2.33
Stand Dvn.	0.04	1.49	1.16	0.87	0.69	0.69	1.69	0.87	2.33	3.07	2.18	1.09	0.04	0.05	0.59	2.98	2.84	1.28	1.14
Minimum	0.01	1.26	0.69	0.69	0.11	0.58	0.00	0.74	1.39	1.23	2.12	1.46	0.03	0.01	0.13	2.59	1.19	1.11	0.34
Maximum	0.12	5.93	4.69	3.98	2.33	2.82	5.79	3.82	9.44	10.93	10.16	5.00	0.19	0.18	2.05	11.34	11.58	5.12	4.36

SUMMARY STATISTICS FOR **MANGANESE (ug/L)**

Parameter	B-1	B-2	B-3	B-4	B-5	B-6	B-7	B-8	B-9	B-10	B-11	B-12	B-13	B-14	B-15	B-16	B-17	B-18	B-19
Mean	8.83	4.08	2.67	2.50	3.00	3.33	3.33	3.17	4.00	2.50	3.25	4.08	1.50	3.17	3.33	2.92	8.17	8.50	4.33
Median	9	4	2.5	2.5	3	2.5	4	3	4.5	2.5	3	3.5	1	3	3	2.5	7	7.5	4
Stand Dvn.	8.12	3.23	2.46	2.20	1.91	3.20	1.97	2.37	2.34	2.20	1.96	2.97	1.78	1.95	2.74	2.71	8.13	8.28	3.08
Minimum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Maximum	25	9	7	6	6	8	6	7	7	6	6	9	5	6	8	8	21	24	9

SUMMARY STATISTICS FOR **CADMIUM (ug/L)**

Parameter	B-1	B-2	B-3	B-4	B-5	B-6	B-7	B-8	B-9	B-10	B-11	B-12	B-13	B-14	B-15	B-16	B-17	B-18	B-19
Mean	1.084	2.223	3.569	6.646	0.788	1.858	0.838	1.685	0.659	2.878	5.136	0.439	0.714	1.998	1.832	0.393	3.224	2.547	8.007
Median	1.105	2.160	3.450	6.585	0.955	1.770	1.135	1.315	0.655	2.680	4.805	0.365	0.770	1.630	1.815	0.330	3.350	2.515	8.185
Stand Dvn.	0.755	0.539	1.236	1.960	0.481	0.640	0.712	0.620	0.623	1.233	1.718	0.417	0.476	0.959	0.554	0.430	0.787	0.936	1.243
Minimum	0.000	1.560	1.540	3.670	0.000	1.020	0.000	1.070	0.000	1.230	2.690	0.000	0.000	0.890	0.980	0.000	1.870	1.230	5.960
Maximum	2.360	3.450	5.620	9.870	1.280	2.870	1.870	2.690	1.450	5.230	8.020	1.030	1.250	3.640	2.960	1.230	4.260	4.260	9.810

SUMMARY STATISTICS FOR **COPPER (ug/L)**

Parameter	B-1	B-2	B-3	B-4	B-5	B-6	B-7	B-8	B-9	B-10	B-11	B-12	B-13	B-14	B-15	B-16	B-17	B-18	B-19
Mean	1.21	2.08	1.51	1.07	2.01	1.25	1.14	2.96	42.23	3.08	6.40	1.09	1.38	2.47	3.02	1.16	4.55	3.62	14.56
Median	1.2	2.085	1.55	1.075	1.87	1.1	1.24	3.105	43.79	3.14	6.385	1.175	1.325	2.585	3.04	1.26	4.255	3.655	13.68
Stand Dvn.	0.84	0.50	1.02	0.65	0.47	0.76	0.79	1.04	10.96	0.85	1.41	0.76	1.09	1.10	0.95	0.85	1.57	0.60	4.06
Minimum	0	1.23	0	0	1.21	0	0	1.25	25.63	1.85	4.23	0	0	1.26	1.64	0	2.51	2.61	9.83
Maximum	2.35	2.89	3.67	2.15	2.87	2.75	2.34	4.29	56.98	4.25	8.63	2.36	3.67	4.25	4.26	2.36	7.85	4.52	23.56

SUMMARY STATISTICS FOR **LEAD (ug/L)**

Parameter	B-1	B-2	B-3	B-4	B-5	B-6	B-7	B-8	B-9	B-10	B-11	B-12	B-13	B-14	B-15	B-16	B-17	B-18	B-19
Mean	8.145	11.407	14.563	16.669	10.540	9.968	34.943	4.527	36.389	24.453	11.700	35.584	52.038	8.134	9.391	24.668	12.043	6.833	16.358
Median	7.650	10.860	14.215	16.295	10.830	9.750	35.535	4.245	36.220	24.135	12.050	37.210	49.090	8.320	9.560	25.235	12.150	6.680	16.740
Stand Dvn.	2.317	3.222	2.668	2.608	2.534	2.566	5.425	1.875	4.967	3.607	2.018	4.488	11.185	1.322	2.350	3.145	2.144	2.122	3.069
Minimum	5.190	5.340	10.210	12.480	5.210	6.390	25.430	0.000	28.760	19.830	7.630	26.340	39.540	5.460	5.470	18.750	8.520	3.640	10.250
Maximum	12.360	16.970	18.630	21.760	13.670	14.520	45.090	6.970	45.920	32.160	14.580	40.920	71.850	10.250	13.470	29.540	15.680	11.270	20.880

SUMMARY STATISTICS FOR **ZINC (ug/L)**

Parameter	B-1	B-2	B-3	B-4	B-5	B-6	B-7	B-8	B-9	B-10	B-11	B-12	B-13	B-14	B-15	B-16	B-17	B-18	B-19
Mean	41.83	44.53	120.84	130.86	42.44	61.76	42.79	84.25	62.15	66.24	44.59	120.25	77.60	34.21	29.80	57.87	60.52	57.18	210.86
Median	42.36	44.48	124.67	131.36	40.56	61.54	40.27	79.31	61.91	65.29	48.06	121.98	77.42	33.48	30.56	55.31	59.19	57.66	208.96
Stand Dvn.	9.42	10.98	21.95	17.84	13.19	14.14	15.51	29.91	10.32	16.76	13.22	20.01	12.66	10.99	5.69	16.24	20.78	10.77	40.63
Minimum	23.46	29.63	87.63	96.31	21.34	38.41	24.67	41.69	42.69	38.74	26.54	87.63	56.38	19.87	20.17	36.74	36.74	39.65	146.23
Maximum	54.69	69.38	152.97	158.31	63.97	85.64	75.31	136.97	76.34	94.25	67.85	154.89	96.38	52.34	37.85	98.64	97.41	75.61	297.51

SUMMARY STATISTICS FOR **TOTAL COLIFORMS IN MPN per 100 ml**

Parameter	B-1	B-2	B-3	B-4	B-5	B-6	B-7	B-8	B-9	B-10	B-11	B-12	B-13	B-14	B-15	B-16	B-17	B-18	B-19
Mean	98	12	84	80	32	44	45	47	90	96	25	96	14	95	94	76	69	85	301
Median	85	10.5	75	65	30	40	40	45	85	80	24.5	100	10.5	90	75	70	60	75	205
Stand Dvn.	69.26	7.36	43.40	40.26	7.87	18.06	13.57	15.31	62.33	67.61	7.84	59.18	13.13	61.45	64.58	58.45	39.99	46.61	322.15
Minimum	40	2	26	26	22	23	26	26	17	22	12	23	4	26	22	12	23	40	23
Maximum	300	26	170	140	50	80	70	70	220	220	40	230	50	220	220	170	140	220	900

SUMMARY STATISTICS FOR **FECAL COLIFORMS IN MPN per 100 ml**

Parameter	B-1	B-2	B-3	B-4	B-5	B-6	B-7	B-8	B-9	B-10	B-11	B-12	B-13	B-14	B-15	B-16	B-17	B-18	B-19
Mean	75	10	69	68	29	39	39	42	79	87	23	82	11	83	84	66	62	73	215
Median	65	9	65	60	28	37	40	40	80	80	22.5	85	9	90	75	60	55	70	195
Stand Dvn.	52.31	6.44	34.63	27.63	6.33	13.40	10.24	11.57	47.05	56.22	7.30	43.28	8.03	47.96	50.59	49.35	35.11	35.13	185.83
Minimum	30	2	26	26	21	21	23	26	17	21	9	23	4	26	22	12	21	33	23
Maximum	220	23	140	110	40	60	60	60	170	170	33	170	30	170	170	140	130	170	500

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PUBLICATIONS FROM PRESENT RESEARCH WORK

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