ASSESSMENT OF GROUNDWATER RESOURCES IN UPPER KARHA RIVER BASIN, PUNE DISTRICT, MAHARASHTRA

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DECLARATION

I hereby declare that the thesis entitled ***"Assessment of Groundwater Resources in Uppe Karha River Basin, Pune District, Maharashtra"*** *completed and written by me has not previously been formed as the basis for the award of any Degree or other similar title upon me of this or any other Vidyapeeth or examining body. I understand that if my Ph.D Thesis (or part of it) is found duplicate at any point of time my research degree will be withdrawn.*

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This is to certify that thesis entitled ***"Assessment of Groundwater Resources in Uppe Karha River Basin, Pune District, Maharashtra"*** *which is being submitted herewith for the award of the Degree of Vidyavachaspati (Ph.D) in* ***Geography*** *of Tilak Maharashtra Vidyapeeth, Pune is the result of original research work completed by* ***Mr. Pravin Pannalal Gaikwad*** *under my supervision and guidance. To the best of my knowledge and belief the work incorporated in this thesis has not formed the basis for the award of any Degree or similar title of this or any other University or examining body.*

Dr. Virendra R. Nagarale
Research Guide

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CONTENTS

CHAPTER ONE
INTRODUCTION

CHAPTER TWO
REVIEW OF LITERATURE

CHAPTER THREE
RESEARCH METHODOLOGY

CHAPTER FOUR
ANALYSIS AND FINDINGS

CHAPTER FIVE
CONCLUSIONS

LIST OF FIGURES

LIST OF MAPS

CHAPTER ONE
INTRODUCTION

CHAPTER THREE
RESEARCH METHODOLOGY

CHAPTER FOUR
ANALYSIS AND FINDINGS

LIST OF TABLES

CHAPTER ONE
INTRODUCTION

CHAPTER THREE
RESEARCH METHODOLOGY

CHAPTER FOUR
ANALYSIS AND FINDINGS

LIST OF PHOTOGRAPHS

Abbreviations

BCM	Billion cubic metre
BIS	Bureau of Indian Standerds
DB	Data Base
DEM	Digital Elevation Model
E	East
ERDAS	Earth Resource Data Analysis System
ETM+	Enhanced Thematic Mapper
GIS	Geographical Information System
GSDA	Groundwater Survey and development Agency
IRS	Indian Remote Sensing
Km	Kilometer
LANDSAT	Land Remote Sensing Satellite
LISS	Linear Imaging Self Scanner
LULC	Land Use Land Cover
mgbl	Meters below ground level
MSL	Mean sea level
N	North
NRSA	National Remote Sensing Agency
S	South
SOI	Survey of India
sq.Km	Square Kilometer
SAR	Sodium Absorption ratio
TDS	Total Disolved Solid
TGA	Total Geographical Area
TH	Toatal hardness
W	West
WHO	World health organization

ASSESSMENT OF GROUNDWATER RESOURCES IN UPPER KARHA RIVER BASIN, PUNE DISTRICT, MAHARASHTRA

Abstract

Water is the important resource to keeping earth's biosphere in existence. Without this valuable resource, biotic existence is impossible on the Earth. Earth is only unique planet in the solar system having water on its surface and because of this it maintains its uniqueness in the universe. The occurrence of water beneath the crust in the form of groundwater and on the surface as surface water collectively called as hydrosphere. Water is working as external and internal medium for most of the biotic organisms and acting as a media for biochemical and chemical reactions.

The study of groundwater potential requires appropriate knowledge about occurrence and movement, which are directly or indirectly controlled by landform characteristics and other morphological parameters like as Slope, Morphometry, Soil texure, Geology etc. . There is need of study the Groundwater potentials because of its non substitutional importance. There has been increasing awareness among the geographer, geomorphologist, geologists, planners and water resources scientist, to study the potentiality, availability, development of management of groundwater resources in the last four decades. Groundwater generally escapes direct observation, except where it emerges in spring or is tapped by wells, bore wells. There is no direct method for the evaluation of groundwater. In geomorphological perspective, landforms and other morphological parameters may give indication to subsurface water conditions.

The groundwater pollution may take time depending upon the concentration of pollutants and geological structure. However, once it is polluted it shows hazardous effects and most importantly there is hardly any reversal or remedial measures. It can be quite relevant study to understand the sources of groundwater pollution and degree of intensity of pollution. It has direct bearing on sustainability of livelihood of people especially poor section of society.

The present study is an attempt to reveal such issues. For this, Upper Karha river basin , the tributary of Nira river, in Purandar Tahasil has been selected. The study has adopted weighted overlay index method approach to understand the potentiality of

the groundwater as well as the quality of the groundwater in the study region. In this sense it has academic as well as social relevance. The groundwater resource in Upper Karha basin area has been fragile because of two reasons. First, the recharging process is hindered due to rapid industrialization and urbanization. The non-percolating areas are increasing with phenomenal growth of the area. Secondly, the groundwater storage is also exposed to pollution by heavy consumption of chemical fertilizers, industrial effluents and domestic sewage. People of the area are wholly dependent on groundwater as it is the only source of drinking water for them. However, the resource is being depleted due to environmental threats like reduction in percolation, pollution and non-sustainable use. With this background, an assessment of groundwater potential and groundwater quality in Upper Karha River basin was undertaken. To find out the potentiality and the quality of groundwater in Upper Karha River basin following aims and objectives are preset:

The main objective of the present study is to assess the Groundwater Resources of the Upper Karha River Basin area and the supportive objectives are given as follows.

1. To study the Morphometric characteristics and correlate with Groundwater.
2. To assess the quality of groundwater for the domestic and agricultural utilization
3. To study the correlation between soil characteristics and Groundwater potential.
4. To quantify the ground water availability in different potential zones like Low, Moderate and High Potential zones.

Methodology is a way to systematically solve the research problem. Result and analysis of research are totally depends on methodology. To find out Groundwater potential and the quality of groundwater in the study region following methodology was adopted:

1. Library Work : Library Work was includes with intensive and extensive search of literature, references, manuals, bulletins focusing on the topic, reference books, institutes, government departments, internet etc.

2. Prefield Work Phase : This phase deals with the collection of various maps like topographical map, satellite images and piezometric water levels data from GSDA

Pune. Topographical Map (47F/15 and 47 J/3) was collected from Survey of India. Satellite Imagery – Land sat (2013) was obtained from GLCF website.

3. Field Visits : The study was supported by the primary sources of data generated through the extensive field verification survey. The primary data like Groundwater levels from open wells and soil samples were collected during field visit. The locations of sample wells are acquired from the Global positioning system instrument (GPS) from the field. The knowledge about underlying rock structure has been gathered through the open well lithology studies during the field visits. The check ground reality is also important stage in the research, so field work also helps to check ground reality of data.

4. Laboratory Work : This phase was included the digitization and preparation of various thematic layers, generation of various thematic maps using GIS techniques. i.e. Georeferencing, Digitization, Attribution, Data attachment, Final layout of different maps was analyzed. Data analysis is the integral part of laboratory work.

The Approach :

To attain actual result and conclusions, to fulfil the need of research's aim and objectives, research is ramble through various stages. The present research work is divided into five chapters. The chapter scheme and its details are as follow :

First Chapter, the major component of this chapter is devoted to the introduction of Water resources, Groundwater potential, Groundwater quality and its need. This chapter also deals with aims and objective of the present study. This chapter also explains a detailed account of location and extent of study area. Introduction of Study Area, location and Extent of the study area has been described with Physiography, Drainage, Geology and Climate. These all content provides the proper understanding about the study area. Demography and transportation are the content which explains the trace on the groundwater resources in the study area.

The Second Chapter is primarily paying attention on review of literature. To achieve aims of the study review of literature is guided; hence 'Review of Literature' is essential part of this chapter. This chapter explains a detailed review of literature to find the correct path for the present study. The extensive literature has been studied regarding groundwater in terms of Published papers in journals, published or unpublished thesis, articles in the journals books regarding Groundwater potential and quality.

The Third Chapter is straightly associated with detail methodology adopted for the present research. In this chapter the action plan for the research has been discussed. The use of weighted overlay index method is the key factor of this research and it has discussed in this chapter.

The Fourth Chapter is focused on Morphometric analysis of the study area as it is playing significant role in the potential of groundwater. The chapter also focused on the quality parameters for the drinking as well as agricultural purposes. Mainly this chapter deals with the association of landforms and other geomorphological parameters with groundwater potential and movements. In this chapter groundwater fluctuation has been discussed with reference to the water levels acquired from the field during field work.

The Fifth Chapter is the main chapter and it deal with conclusions. The detail conclusions have been discussed regarding groundwater quality and groundwater potential in this chapter. In the present chapter recommendations are suggested by the researcher.

Conclusions : To assess the quality of groundwater some parameters has take in to account like pH value of most of the samples was more than 7.0 but it is within the permissible limits given by BIS values. Further, the spatial variation in electric conductivity values shows that conductivity of the study region higher for some samples but some sample still in permissible limit. If the study area continuously does not manage their effluents it will comes in to the groundwater which peoples are using for domestic and agricultural proposes and they will expose to the illness related to contaminated groundwater. In the pre-monsoon condition the values of conductivity is higher which may be due to higher water-rock interaction and simultaneously due to higher leaching in summer season. TH and TDS values, in most of the samples exceeded the permissible limits which clearly show unsuitability of groundwater for drinking and irrigation purposes. In 50% of magnesium samples values are exceeding the permissible limit it means magnesium is in higher amount in groundwater present in the study area, while the concentration of calcium is exceeding the permissible limits in some groundwater samples. The higher concentrations values of Ca and Mg are indicator of the anthropogenic sources are present in the groundwater present in the study region. The concentration of sodium was low in majority of samples as a result of slow cation exchange process. The abnormal concentration of potassium is observed at few places in the study area it may be due to urban pollution and fertilizer leaching.

To study the groundwater potential along the Upper Karha river various aspects of the geomorphology and geology has been take in to consideration. Separate thematic raster layers of Digital elevation model, slope, soil texture, soil type, geological formation, land-use, land-cover, lineament, vegetation cover and landforms has been considered for weighted overlay index method in the Arc GIS 10.3 environment. It is reveals that the landforms and other geomorphological parameters have some control on groundwater potential and occurrence.

To conclude the research, it is clearly proven fact that landforms, land-use, land-cover, lineament, slope, soil texture, Morphometric parameter and digital elevation model are the useful parameters to decide groundwater potentiality of any geographical area. It is also proved that GIS is the tool having potential to analyze the raster thematic data and provide the solutions to the geographical problem.

CHAPTER - I

INTRODUCTION

1.1 Prologue

Water is the basic need for all forms of life, it is important resource to keeping earth's biosphere in existence. Without this valuable resource, biotic existence is impossible on the Earth. Earth is unique planet in the solar system having water on its surface and because of this it maintains its uniqueness in the universe. The occurrence of water beneath the crust in terms of groundwater and on the surface in terms of surface water collectively called as hydrosphere. The existence of water on earth is mainly in three forms namely solid in the form of ice sheets, liquid and gas in the form of water vapors. Water is working as external and internal medium for most of the biotic organisms and acting as a media for biochemical and chemical reactions. Approximately 71% area is covered by oceanic water, it is nearby two third of earth's geographical area. The oceanic water is saline in nature, only 2.6% water is present as useable freshwater in the form of groundwater and fresh water (Szewzyk et al. 2000). From available fresh water, 68.7% is in solid state as ice caps in polar region and in the form of frozen glaciers, 30.1% is beneath the surface and occurrence of it is in terms of groundwater, and only 0.3% in the form of total available surface water. It is not enough to have optimum quantity of water but the quality of water must be good for all life forms. The potential of groundwater and the quality of groundwater are the major issues related to environment or totality of human beings all over the globe. The dynamic nature of water bodies like dams, lakes, estuaries, and rivers are continuously subject to change according to geomorphological, geochemical, hydrological characteristics and geological age. About 2.6% of present total fresh water, from which 20% is constitutes as ground water. Ground water is very precious resource because occurrence of it is not clearly understood. Water is most essential parameter after oxygen for the human beings are optimizing the present available water resources for fulfilment of various needs. Therefore, peoples are formed their settlement along river banks and water bodies throughout historic period. In the ancient time peoples are curiously learnt methods of water management (Briscoe and Malik 2006). As continuous increase in population, most of the peoples are migrated to arid and semi - arid areas of the continents and because of these they are dependent on the sources of ground water for fulfilment of irrigation as well as domestic utilization purpose. In reality groundwater is playing important role and it is gaining higher importance in the contemporary civilization.

Water is one of the resources like other natural resources e.g. air in the atmosphere and various minerals present in the earth's crust sustainability of life on the planet earth. If there is disparities in such natural resources leads to adverse impact on health of flora and fauna.

In geomorphological context, a landform may give a clue to surface and subsurface water conditions. Therefore, a complete terrain classification is often required to evaluate the hydrological conditions, its availability and for this, geomorphological surveying of landforms becomes essential. Integration of hydrological, geomorphological, geological data minimizes the area for the detailed survey by sophisticated method. Landforms are the configurations of the land surface taking distinctive forms and produced by natural processes of erosion, denudation and deposition (Strahler and Strahler, 1996). The study of landforms, in a drainage basin with reference to hydrology and geomorphology context has become increasingly important for understanding the surface and subsurface water conditions. In fact geomorphology is found to have very close links with both surface and subsurface water conditions (Verstappen, 1983). Geomorphological features of a terrain, generally controls the distribution of precipitation and amount of precipitation that is contributed as runoff as well as for groundwater recharge.

With this approach, present study has been carried out to take an effort to assess groundwater potential on the basis of landform characteristics and groundwater quality for agricultural as well as domestic utilization of Upper Karha river basin of Pune district in Maharashtra. Study has been tried to focus out groundwater availability and fluctuations with respect to different seasons.

Groundwater is the fully saturated sub-surface water mainly received from atmospheric precipitation deposited in water bearing sedimentary rocks, cracks and crevices in crystalline rocks and subsequent penetration and cooling joints. When there is rain fall, after achieving critical depth of soil some of the rain water flow as overland flow, some gate evaporated due to sun light energy and the remaining amount of rain water get percolate down beneath the ground and becomes ground water. Therefore, the water infiltrated through the soil portion into the ground is the basic primary source of groundwater. Water below the ground surface occurs in four zones viz; soil moisture zone, intermediate zone, capillary zone and saturation zone. The zone in which this water is held is known as the zone of aeration or unsaturated zone, which is characterized by partially water filled and partially air-filled voids and pores. At the base of the intermediate zone, is the capillary fringe a thin layer (ranging from few cm to 3m) in which water has been drawn upward by capillary force. Vertically after the zone of aeration, zone of saturation is present in the form of water table. It is also called as phreatic zone or zone of groundwater or simply it known as water table. There is a vadose zone, lies in between the topsoil water zone and lower capillary zone, in which water percolates down to the water table.

The present study incorporates the principle source of ground water. Beside the prime sources, factors determining the occurrence of groundwater sources also discussed here. The occurrence of groundwater mainly depends upon climatic conditions, soil characteristics, vegetation cover, land use and lithology of rock in the area. Though the precipitation is prime source of groundwater recharge, out of total precipitation received, major part is lost through evapotranspiration, from soil and plants. Some part flows as runoff and only small amount of rain water infiltrates through the soil to underlying strata or aquifers (Babar 2005).

The (WHO) World Health Organization has time to time insisted that the major influencing factor which has adverse impact on general health condition and expectancy of life among the population in any developing country is absence of clean drinking water. Groundwater is important for human water supply and in Asia alone about 1 billion people are directly dependent upon this resource (Foster 1998). However, many groundwater exploitation schemes in developing countries are designed without due attention to quality issues.

In recent years, in many parts of India especially in the arid- and semi-arid regions, due to the vagaries of monsoon and scarcity of surface water, dependence on groundwater has increased tremendously. In the view of international perspective of “<1,700 m^3/person per year” as water stressed and “<1,000 m^3/person per year” as water scarce, India is water stressed today and is likely to be water scarce by the year 2050 (Sargaonkar and Deshpande 2003). It is projected that by the year 2020, the number of people living in water-scarce countries will increase from about 131 million to more than 800 million (IAH 1997).

The population of India is about 16% of the world’s population with having only 4% of the world’s fresh water resources. In present condition area under cultivation has increased from 6.5 million hectares in 1951 to 35.38 million hectares in 1993 (Singh 2006).

In general, colour and taste of the water are the two basic criteria for a consumer to decide the suitability of given water for drinking without considering other lethal chemical contaminations like arsenic, nitrate, fluoride and other heavy metal contaminations. It is therefore becomes essential to determine the present status of groundwater on the basis of its quality and thus its suitability for two major purposes viz. drinking and irrigation.

Assessment of water quality is one of the most important factors in groundwater studies. The hydro-geochemical study divulges the zones of ground water quality in terms of suitable for domestic utilization, agricultural and industrial purposes. Hence it is possible to observe and understand the change in quality of water because of interaction in between rock water or any anthropogenic influence.

1.2 Water disparities in India

The location of India is in sub-tropical region and it receives high amount of rainfall during monsoon season starting from the months of June to September. Near about 80% of rainfall receives from the southwest monsoon with 50% of the precipitation falling in 15 days only. The per year flow of estimated rainfall in the rivers of India is about 1953 km^3 and yearly assessed rechargeable ground water resources is approximately 432 km^3. Thus, India annually utilizes 690 km^3 and 396 km^3surface water resources and groundwater resources respectively (Rakesh Kumar et al. 2005). To optimum utilization or use of this valuable resource, India has making enormous investment in massive type of water infrastructure; most of it is bringing water to well known water scarcity areas. In present situation Indian dams are able to store only 30 days of rainfall thus water storage capacity to hold 200 m^3 of water per person. There is huge need of water storage to mitigate water disparities because global climate change is continuously altering the climate of Indian continent.

In India, due to physiographic structure and absence of surface water in terms of rivers, most of the population is totally dependent on groundwater resource for fulfilling their needs. The significance of water quality in health of human being has recently mesmerized a great concern of interest. In developing countries like India around 80% of all diseases are directly related to poor drinking water quality and unhygienic conditions (Pruss et al 2002).

To utilize the fresh water which is coming from precipitation on the earth as rainfall, India has to invest huge part of economy for massive water infrastructure to store maximum water in the form of dams.

In present condition due to growth of population and economic development India is experiencing serious problem of water scarcity and contamination of surface and ground water resources. In India availability of water for per person is falls under in critical lower limit according to World Research Institute guidelines. The per capita water availability of India is 497 m^3 per year. Water scarcity is becoming common issue in several parts of the country, majorly in semi-arid and arid regions of Indian continent. The over utilization and over dependence on groundwater leads to increase in basic demands of surface and ground water for domestic, agriculture, and industrial use and its results in maximum exploitation of groundwater resources in several parts of India. Some of the states like Rajasthan, Gujarat, Haryana, Punjab, Uttar Pradesh, and Tamil Nadu are facing severe water scarcity problem.

India is continuously experiencing growth in population since increasing its independence from (1947) at the time of independence the population of India was 300 million, presently as per Censes of India, 2011 it is 1.2billion and it is expected to have a rapid growth and will be 1.5 billion in 2050 AD. As per this huge population growth, approximately 85% of surface water and ground water resources are used for agriculture purpose and remaining is used for industrial as well as domestic purposes like drinking, cooking, sanitation and other purposes. As previously said that India receives a heavy rainfall from the monsoons season, because of this India is considered as water rich country. The uneven distribution of water on ground level leads to water disparities in the several states of India. Some states of Indian continent are water rich and some are struggling with critical water scarcity problems. Rapid and massive growth of population is responsible for increasing urbanization and expanding industrialization therefore it demands for more and more supply of water resources in the country. Water scarcity leads to lowering of ground water table and decline of water quality. Green Revolution Movement helps India many ways in handling the huge burden of continuous growing population but India failed to provide the safe and optimum drinking water to their countrymen. There is increase in irrigation facility and use of improved variety of seed, chemical fertilizers in agriculture sector due to green revolution and it helps to fulfilled food requirement, but same time fails to provide safe domestic water supply for population residing in rural regions of country was seriously ignored. So, most of the rural suburban and rural population of country has to rely on partially treated or totally untreated and limited in nature water resources of tube wells, dug wells, rivers and dams to fulfillment of their daily water demands. As population of country increases, water demand will also goes on increasing so conflicts related to water are becoming serious issue at all levels. At the same time water related diseases increased drastically as epidemics. In India large number of population comes across the turbulence of water future because it has a highly dynamic and changing seasonal pattern of rainfall, frequent floods, and droughts leads to epidemics in the country.

Peninsular part of India is considered as more water scarce as compared to northern India. The drought prone areas of country mostly located at western regions, because of low rainfall pattern they frequently suffered from drought. Availability of pure drinking water in drought prone areas as well as flood affected areas is very much less. On the other side India has water resource management and safeguarding of water resources on massive scale. In spite of these, water related epidemics are further increasing time to time due to poor sanitation, urbanization and water contamination. Particularly, intensive agriculture and urbanization has lead to water deterioration in terms of water quality. Hence presently available surface water cannot fulfill the demands of India’s safe drinking water requirements, near by 60% of Indian population depends on groundwater sources for their daily water uses and irrigation. Groundwater is an annually renewable resource from the annual rainfall but its distribution is uneven spatially and temporally.

1.3 Groundwater

Groundwater is the major source of water supply throughout the World and one of earth’s most important vital replenishable or renewable and commonly used unevenly distributed resources. Without this valuable and precious resource no one can imagine the existence of human life or biotic organisms (flora and fauna) on the Earth surface. Groundwater provides them water for their functioning of process of metabolism to sustain in their natural environment. Water is the most vital, important and common chemical compound of the Earth and its atmosphere. The appearance of Groundwater is dynamic in nature, it is continuously keep on changing and it is renewable natural resource. In hard rock terrain topographies the availability of Groundwater is limited because of minimum existence of joints and cracks along the massive rock masses or in simple way less availability of lineaments along the rock bodies. Groundwater occurrence in such types of rocks is highly concerned with fractured and weathered strata of particular surface. In country like India, 65 % area is covered by hard rock formation from eruption of volcanic lava flows of the total geographical area of the country.

Groundwater is the principal and major drinking water source of rural and urban population of India. When the climatic conditions are normal and rainfall is optimum, the availability of water and quality of water is acceptable for drinking purpose. During adverse climatic condition or in natural calamities like drought, floods the quality of groundwater drastically changes and groundwater resources get deteriorated.

a) Groundwater Potential

The study of groundwater potential needs to proper understanding of its occurrence origin, and underground movement, which are directly or indirectly controlled by landform characteristics. There is need of study of Groundwater potentials because of its importance. There has been increasing awareness among the geographer, geomorphologist, geologists, planners and water resources scientist, to study the potentiality, availability, development of management of groundwater resources in the last four decades. Groundwater generally escapes direct observation, except where it emerges in spring or is tapped by wells, bore wells. There is no direct method (way/approach) for the evaluation of groundwater. In terms geomorphological imprints, landforms can give basic idea about subsurface water appearance and conditions. Various landforms of structural, denudational and depositional origin play an important role in the groundwater potentials.

The storage capacity and transmissivity are the two cardinal parameters as regard groundwater bearing properties of the Deccan Traps. In Deccan Trap country, the primary porosity is due to the presence of interconnected vesicles, which is not filled with secondary minerals where the secondary porosity depends on due to weathering, and formation of joints and fractures in the rock. The groundwater potentiality depends on the extent of interconnection within the different sets of fractures, joints and weak planes and in case of vesicular basaltic unit's groundwater potentiality increases rapidly when the vesicles are interconnected.

b) Groundwater Quality

The ground water quality depends on a large number of individual physical, chemical, hydrological, and biological factors. The water which peoples are going to use for their drinking purpose must be pure and should be free from any toxic chemicals, biotic or abiotic substances and excessive presence of minerals that may be harmful to human health. The groundwater mineralization basically depends upon the parent material or lithology, present or prevailing climatic condition, daily temperature, soils, rainfall availability, geomorphology, geology, land-use and anthropogenic factors. Most of the chemical species present in immaculate groundwater is the part and parcel of mineralization of parent rock aquifer material due to various processes of weathering for example Silicate weathering, Carbonate weathering. The rainfall is another parameter responsible for mineralization in groundwater. When rainfall is heavy it increases the process of mineralization and it leads to groundwater constituent dilution. Temperature evaporation are positively correlated therefore evaporation increases as per increase in temperature, it leads to concentration of groundwater constituents. Soil is also important parameter for quality of groundwater because surface water reaches to groundwater table by passing through vadose zone or aeration zone of soil strata and fosters the mixing of ionic species into groundwater. There is contribution of geomorcephology in determining water quality, gentle slope of ground helps to increases the residence time of surface water and later on slowly it convert in to groundwater in the aquifer system, which triggers the mineralization process due to availability of good reaction time in between water and aquifer material. Land-use is the parameter which is more and more concern with groundwater quality, because when there is increase in agricultural land definitely increase the area under irrigation implies in the water logging and problem of inland salinity. The mineralization in groundwater impact the quality of groundwater in two ways, as source of nutrient in positive way and sources of deterioration substances in negative way like fluorosis and urolithiasis which have adverse effects to human life.

Thus the mineralization processes not only govern the groundwater chemistry but these mineralized products influence the human health.

A vast majority of ground water quality problems are caused by contamination, over-exploitation, or combination of the both. Most ground water quality problems are difficult to identify and complicated to resolve. The solutions are usually very costly, time taking and not always effective. The quality of groundwater is slowly but definitely declining all over the country. Deteriorated groundwater is harming the human health as well as agricultural productivity also.

c) Groundwater Contamination

The surface water and groundwater resources are the only approachable pure and fresh water resources available for use. As compare to surface water groundwater is believed to be clean and free from pollution. Groundwater can become polluted due to several types of human and by natural activities. The domestic, municipal, commercial, agricultural, and industrial activities slowly affect quality of groundwater. The human interventions like urbanization, industrialization and agriculture practices are responsible for surface water resources and groundwater resources contamination. Those areas are no longer suitable for drinking purpose. Therefore there is over burden of human in urban as well as rural ground water as a source for drinking purpose has increased, as it is considered to be less polluted comparing surface water.

The vulnerability of groundwater to contaminants generated by human activities, taking into account only the inherent hydrogeological characteristics of the area, and is independent of the nature of the contaminants. The latter is specified for a particular contaminant or group of contaminants (Alexandra et al 2006).

The human induced groundwater contamination can be sub categorize as point-source pollution of water and non point-source pollution of water. In agricultural practices excesses use of chemical fertilizers and pesticides used for crop protection or growth of crops in due course of time may reach underneath aquifers systems, especially if the aquifer is shallow and not covered or "protected" by an overlying strata having low permeability material. The water wells particularly in use for drinking-water located nearby to agriculture or cropland most of the time is contaminated by chemicals used for agriculture.

Point Sources: When the pollutants are transferred from industrial liquid waste disposal sites, municipal and household hazardous waste and refuse disposal sites in to the groundwater. The contamination or pollution from such types of sources can be measured directly or otherwise quantified and one can evaluated their impact directly. Point source pollutants are causing affect the groundwater quality directly or indirectly but impact of such pollutant are very much serious.

Non-point Sources or Diffuse Sources: when the pollutants enter in to the groundwater from over land flow, runoff, and soil erosion from agricultural lands carrying material applied during agricultural use, mainly fertilizers, herbicides and pesticides. Surface runoff from compact urban streets, commercial activities industrial sites and storage areas. There is no single outlet observes of such source but consists number of outlets in hidden form.

The non point-source substances are used over on large areas, therefore they have a larger impact on the general quality of groundwater in an aquifer than the point sources, mostly when these chemicals contaminants are used in areas that overlie aquifers that are vulnerable to pollution. If impacts from individual pollution sources such as septic drainage or tank system drain fields occur over large enough areas, they are often collectively treated as a non point source of contamination.

1.4 Impact of urbanization on groundwater quality

The rapidly growing population of urban and rural areas by natural growth or by migration in urban areas from rural areas is a main factor of environmental alteration. As further increase in population, people migrated to arid areas and semi arid areas of the world and they are mostly depends on the groundwater for domestic and irrigation purpose. Today a huge number of urban and rural peoples are depends upon groundwater for various purposes and uses. The world's rural population doubled during the twentieth century, but the urban population increased more than ten times than rural population because of migration towards urban areas from rural areas. At the tail of the twentieth century, most of the world's urban population increased in developing and undeveloped countries having low income sources or low per capita income. Due to such type of growth in population many countries has to provide fresh drinking water to their growing population and also manage the groundwater sources accordingly. Now a day there is problem in managing the groundwater resources due to burden of population on limited source of groundwater and therefore there is necessity of waste water management system dominantly for the development, protection and management of sub-surface water in urban environments.

The rapid growth in urbanization and industrialization leads to increase in contamination of groundwater quality. Urbanization impacts the quality and quantity of underground sub-surface water by drastically changing patterns and specific amount of natural groundwater recharge, it impact in terms of new abstraction regimes and adversely affecting groundwater quality.

Both the managed and planned solid municipal waste disposal in landfills and unplanned and unmanaged informal disposal in brick pits, dry river canals and active river beds, in old wells and drains, in to the street and on to disused land can contribute to the pollution load. The vulnerability of pollution is a product of the ease with which water and deteriorating substances or pollutants can encroaches to the lurking sub-surface water, the attenuation capacity of the penetrating material. The urban pollution source such as sewages and storm drainage, solid waste or waste water disposal and fuel storage tanks are unknowingly discharge below the ground surface, by passing through the protective layer provided by the surface (Foster et al. 2002). Rapid increase in concreted constructions, compact road pavement, cemented roads and other developments often reduce groundwater recharge and prevent percolation of surface water to underground aquifers. Wells and boreholes are now located near dumping grounds, cemeteries and defunct sewage due to urban sprawl or expanding urban areas. Surface runoff has increased enormously in urban areas due to increase in paved cemented areas, training of streams and construction of storm water drains. The natural recharge system is therefore continuously decreasing and it resulting in depleting groundwater reserves and aquifers beneath large cities, especially the areas those are situated on water divides of the drainage basin (Raymond et al. 2009).

The use of chemical fertilizers in urban and rural agriculture area has been increasing enormously and it is the one of main potential sources of sub-surface water pollution. The areas having heavy rainfall and natural groundwater recharge, the cascade like topography makes the study area vulnerable to contamination. By viewing the fact that water is one of the most important vital needs after air, the human beings have always exploited the water resources for satisfying their various needs. The population dependency on public general water systems that used ground water for drinking-water supplies has been increased in last 50 years, and the estimated withdrawal of groundwater increased about five-fold during that time period (Foster et al. 1998).

1.5 Geographical Information System (GIS) for Groundwater potential and Groundwater quality analysis

Geographic information system (GIS) has emerging and developing as a powerful tool or set of tool for storing, analyzing, manipulating and displaying spatial data and using these data for decision making in several areas like hydrology, engineering, environmental and earth science related fields (Burrough and McDonnell 1998).

The researchers have been using GIS as a tool or database management system in order to prepare thematic maps of groundwater potential and groundwater quality according to concentration values of different chemical constituents. In this type of studies, GIS is used to locating groundwater quality zones suitable or not suitable for different usages such as irrigation and domestic. GIS techniques facilitate integrated and conjunctive analysis of large volumes of multi-disciplinary data, both spatial and non-spatial, within the same geo-referencing system. Thus, by integrating these two spatial data management technologies, groundwater potential zone mapping and development strategies for a hard rock area can be designed. These technologies give more flexibility for updating the geographical data temporally; therefore such types of technologies are very much useful to work on hydrological data sets like groundwater potential and groundwater quality.

The use of GIS technology has greatly simplified the assessment of natural resources and environmental concerns, including groundwater. In groundwater studies, GIS is commonly used for site suitability analyses, managing site inventory data, estimation of groundwater vulnerability to contamination, groundwater flow modeling, modeling solute transport and leaching, and integrating groundwater quality assessment models with spatial data to create spatial decision support systems.

Ducci (1999) produced groundwater contamination risk and quality maps by using GIS in southern Italy. It was suggested that the use of GIS techniques is vital in testing and improving the groundwater contamination risk assessment methods. For any city, a ground water quality map is important to evaluate the water safeness for drinking and irrigation purposes and also as a precautionary indication of potential environmental health problems.

The criterion for any analysis is dependent on the objective and also the data sets. It is defined by the relative contribution of each parameter towards the desired output phenomenon and is mostly guided by human judgment. On the basis of relative importance, a set of weights is decided for different information layers and the best suitable condition is derived (Saraf and Choudhary 1998).

1.6 Groundwater quality monitoring

The pure rainwater alters its composition while passing through medium like atmosphere, streams, soil strata and weathered rocks thereby showing cumulative increase in its chemical constituents. This water flows over the surface, infiltrates through subsurface environment and acquires its quality depending upon climate, local geology (parent rock), weathering phenomenon, primary mineralization and secondary mineralization. The consumption of this water causes the impact on biotic components of that area especially if it is hard, saline, and having dominant ionic species and heavy metals. Continuous monitoring of groundwater quality is necessary because any change in availability of groundwater and any climatic stroke that induces the adverse impact of abiotic factors gets transferred to the health of the people residing in that area. These changes may be natural or anthropogenic. Natural changes include dissolution of various ions like calcium, magnesium, bicarbonates, nitrate etc. from the Earth's crust. Anthropogenic changes include addition of these ions and many other synthetic chemical compounds like pesticides and heavy metals in the water. The pre-monsoon and post-monsoon groundwater monitoring gives an idea about degree of mineralization and precipitation. The population exposed to such mineralised groundwater by way of consumption and cooking practices can be evaluated by seasonal monitoring of water quality. The problems of fluoride, arsenic and other abiotic induced epidemics can be evaluated through knowing the chemical signatures of drinking and cooking water.

The scientifically designed surveillance system of continuing measurements, observations and evaluation is necessary to study the natural groundwater related health problems (Skinner 2007). Monitoring methods may include not only sampling and analyses of groundwater quality, but also determination of groundwater level and flow directions, measurements of moistures in the unsaturated zone, geophysical surveys, evaluation of waste and other material contributing to subsurface water quality changes etc (Todd 2006). It also includes account of monitoring activities already in existence and further selection of methods, locations and frequencies for monitoring.

1.7 Major groundwater problems in Pune District

Parts of Pune district fall under rain shadow zone of Maharashtra State. It is seen from long term rainfall data that the eastern, southern, south eastern, central and north western parts around Indapur, Baramati, Purandar, Daund, Haveli, Alandi, Shirur and Bhor covering around 50% area of the district are classified as drought areas. The premo fall under rain shadow zone of Maharashtra State. It is seen from long term rainfall data that the eastern, southern, south eastern, central and north western parts around Indapur, Baramati, Jejuri, Daund, Talegaon, Dhamdhare, Alandi, Shirur and Bhor covering around 50% area of the district are classified as drought areas. The premonsoon water level trend shows fall in water level up to 20 cm/year in major parts of the district, occupying north, central, western and southern parts of the district in entire Purandhar, Bhor, Haveli, Mulshi, Maval, Ambegaon and parts of Junnar, Khed, Shirur, Daund, Baramati and Indapur talukas. Similarly as per current assessment of ground water resources it is also seen that the ground water development in Baramati, Ambegaon, Purandhar and Junnar talukas have already reached up to 100% and these talukas fall under "Semi-Critical" category. The ground water quality is mainly affected by localized nitrate contamination (Prabhat 2009).

1.8 Origin of the research Problem

The Maharashtra state enjoys a tropical monsoon climate. But being densely populated, it is facing the problems like drying up of wells, water scarcity and groundwater pollution. The over exploitation of ground water and use of untreated waste creates pollution problems, so the water demand is increases day by day. Despite the incidence of high annual rainfall and a large number of rivers, the hilly tracts and elevated areas along the western part of the state experience drought of different order, during summer. This is due to the peculiarity of the terrain characteristics, which promotes high runoff and is therefore hydro-geomorphologically unfavourable for natural groundwater recharge. The recurring incidents of drying up of streams and rivers not only result in the non-availability of water resources but also create many environmental problems such as saline water intrusion in the coastal area and general ecological degradation and regional drought.

Modern remote sensing techniques facilitate demarcation of different landforms suitable for groundwater replenishment by taking into account the diversity of factors that influences groundwater recharge. Geology, geomorphology, structure and climatic condition are the controlling factors of ground water storage, occurrence and movement in hard rock terrain. These features cannot be observed on the surface by bare eyes but can be picked up through satellite remote sensing with reasonable accuracy. Better interpretation of hydrogeological data often requires that their spatial reference be incorporated to the analysis.

1.9 Significance of the Study

It becomes very difficult to quantify and explain the relation between geomorphic processes and hydrologic parameters of a river basin. Such kind of study of small river basin can be applicable to any other river basin having similar litho-climatic and geoenvironmental conditions for design and development of watershed. Planning and development activities in a river basin area can be efficiently formulated by following the criterions that will be evolved through this study. Such type of study has been providing a simple means to complete it with other basins to regionalize the experimental results.

1.10 Aims and objectives of the study

The present study mainly aims to determine the Groundwater potential and chemical properties of groundwater from selected area of Purandar taluka, Pune District that is Upper Karha Basin. The main focus of these investigations is therefore to highlight the level of groundwater potential and pollution in the study area. The findings are expected to be helpful in understanding the drinking water quality of the area, as well as designing the remedial measures for drinking water supply in the area. The main objectives of the study are as follows:

The main objective of the present study is to assess the Groundwater Resources of the Upper Karha River Basin area.

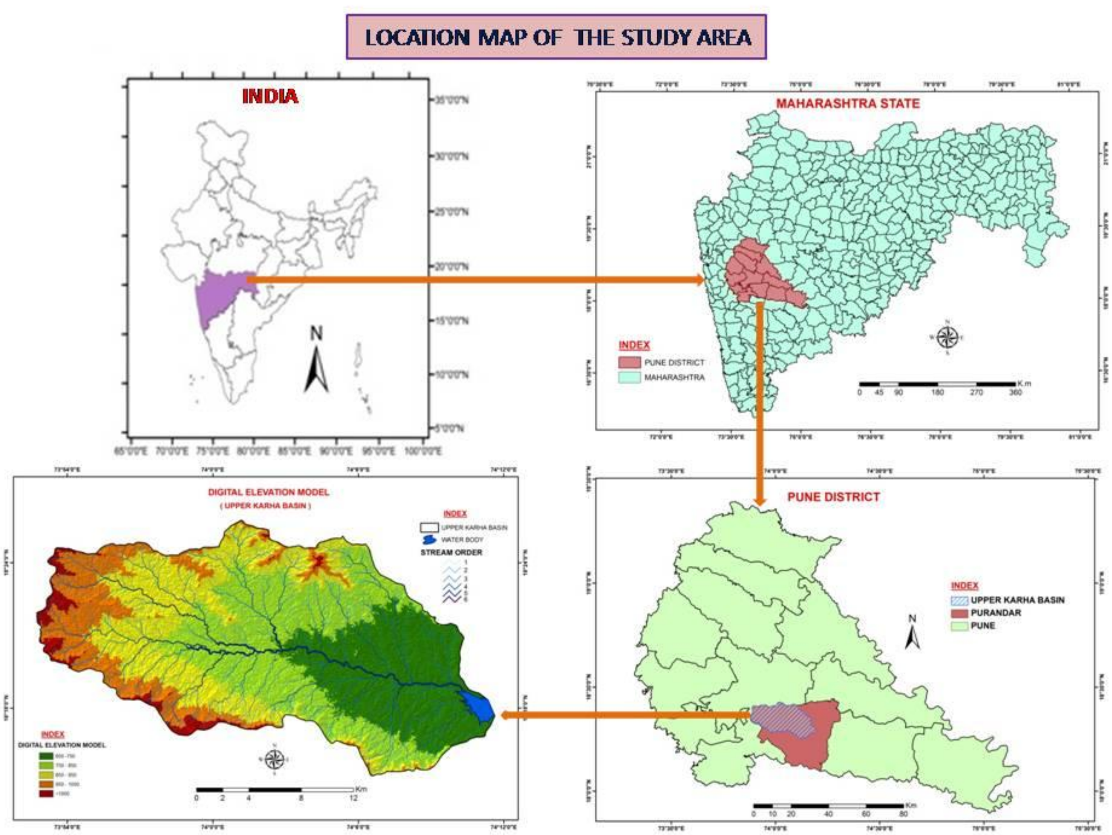
The supportive objectives are:

1. To study the Morphometric characteristics and correlate with Groundwater.
2. To assess the quality of groundwater for the domestic and agricultural utilization
3. To study the correlation between soil characteristics and Groundwater potential.
4. To quantify the ground water availability in different potential zones like Low, Moderate and High Potential zones.

1.11 Study Area

It is mandatory step in any research to study or to gather the information about the study area and to understand its physical and geo-environmental setup. To study the hydrological or Groundwater availability and potential any one need to look in to the geo-environmental condition as it has hidden influences on the groundwater availability in the study area and also health of the residing people in the study area. The environment has the great impact of physical setup of study region and it's also have impacts on the human health. In the present research geology, hydrogeology, soil, climate, and geomorphology are the parameters take in to consideration for the understanding of geo-environmental condition and physical setup of the study area.

1.11.1 Location of the Study Area

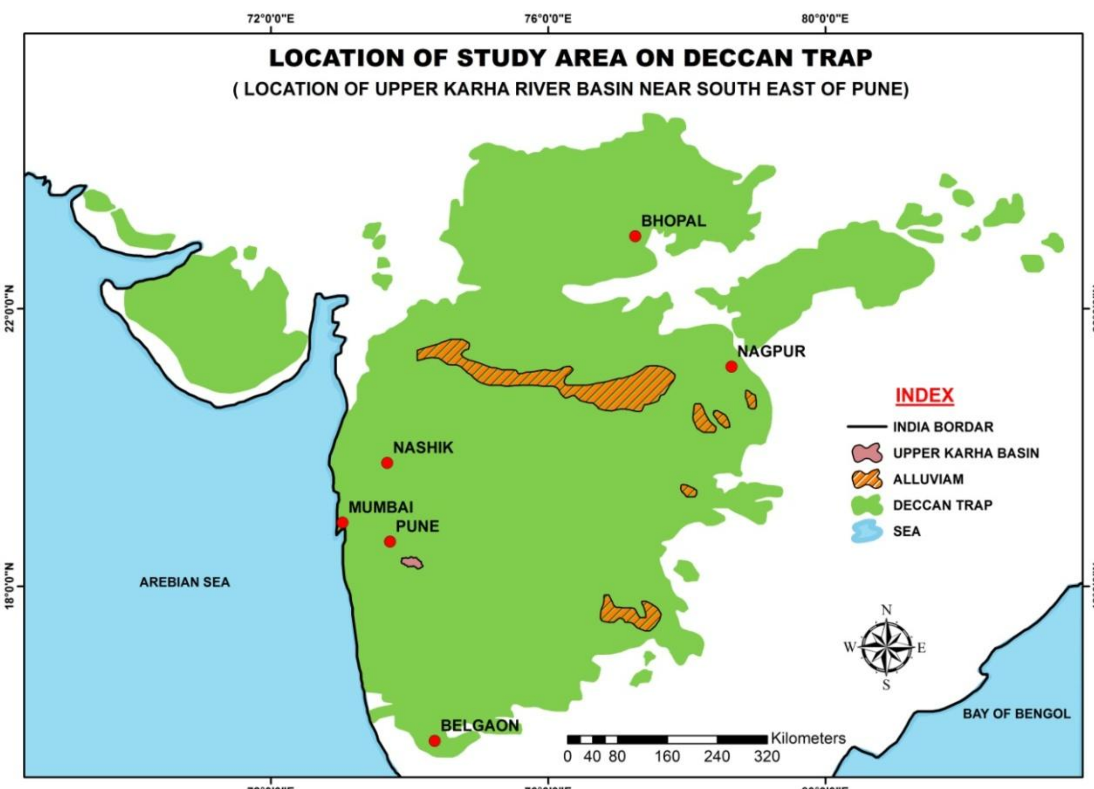


Map No. 1.1 : Location map of the study area

Upper Karha river basin is situated in the Purandar Tehasil of Pune district in Maharashtra State and is located at 18° 15’ 00’’ to 18° 25’ 00” N latitude and 73° 52’ 40” to 74° 15’ 00’’ E longitudes. It is included in toposheet no. 47F/15 and 47 J/3 of Survey of India. The total area of Upper Karha River Basin is 396.2 Sq.Km. The study area is situated in the North western part of the Purandar Tehasil and northern boundary or the part of water divider separates the study area from Pune city. The present Upper Karha basin is located in the rain fed areas of Pune district and it enjoys moderate rainfall in the period of monsoon. Saswad Jejuri and Narayanpur are the three main places in the study area and Saswad is the Tehasil place of Purandar Tehasil.

1.11.2 Geology of the Study area

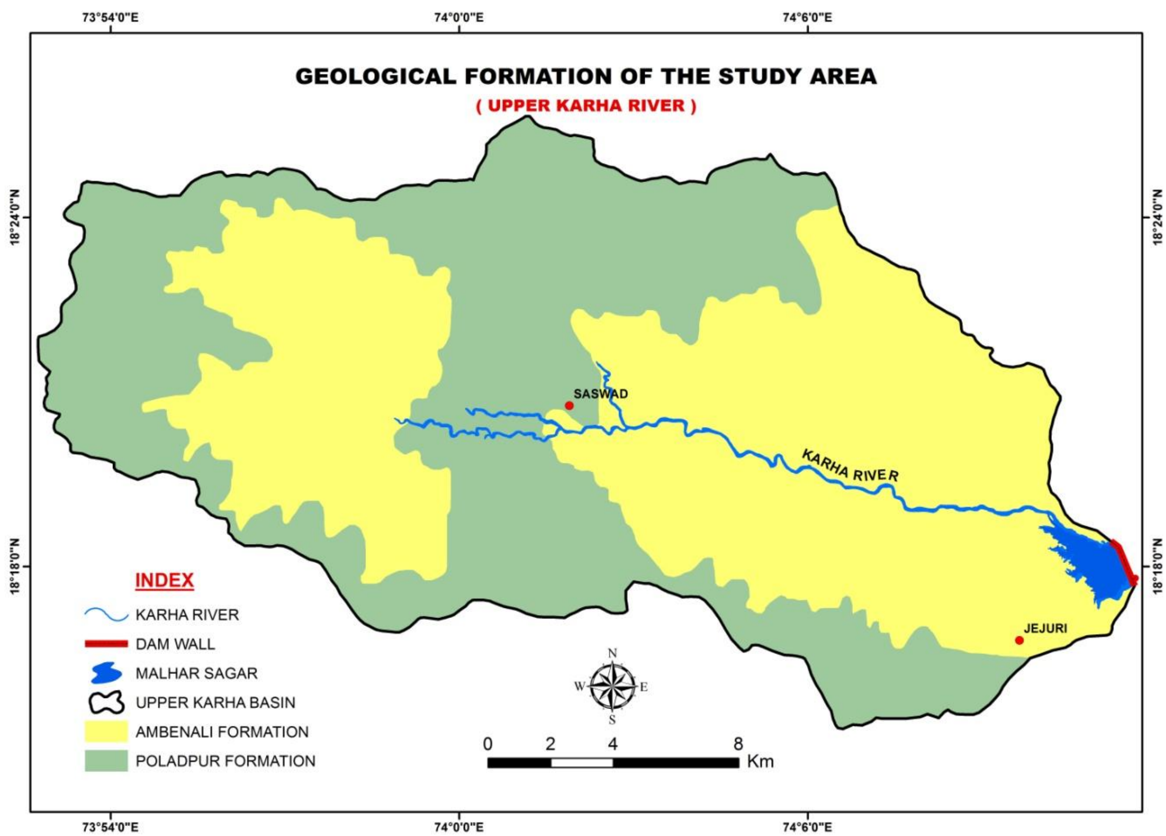
The upwelling of the strong basaltic lava flows is main reason for the formation of Deccan trap. Geologically Deccan Trap is again divided into three different sub categories. Kalasubai is the oldest formation of Deccan Trap, Lonavala and Wai are the youngest formation areas. The younger formation Wai further categorizes in Poladpur and Ambenali Formations. The rivers have their origin at in the medium rainfall zone of Western Ghats and flow in the direction of semi-arid eastward areas to fulfil the needs of water. Most of the part of Deccan Trap area is covered by rain shadow zone having semi-arid climate with scarcity of surface water resources. As a totality of this, population residing in the study area largely depends on groundwater resources as the main source of drinking, irrigating the land and for industries. The study area is characterized by partially weathered simple type basaltic flows of younger Wai formation of Deccan Trap. In the study area observed multi-aquifer system with thin strata’s of aquifer layers. The flanks of lava flows in the study region have been divided into Ambenali Formation exposed near bottom hill parts of Jejuri, eastern part of Saswad towards Malharsagar water body and nearby areas of Chambhli, Bhivri and Garade of Purandar Tehasil. The Poladpur Formation covering elevated areas near Jejuri, Askarwadi, Narayanpur and Saswad. The lava flows in the study region are comparatively low to moderately porous, fractured and jointing and have interconnectivity which helps to secondary porosity and permeability to underground groundwater reservoirs in the region. Due to further cooling process of lava flows the formation of columnar basalt takes place and it has joints and cracks allows the rain water to penetrate in side and further triggering the mechanism of weathering. It also provides the favourable hydrological condition by making the pathways in the hard basaltic terrain. The resultant porosity is mainly responsible for aquifers system present in the fracture and jointed rock systems. Basaltic flows of study area have two main categories where massive lower part is capped by vesicular upper strata. The hidden massive unit have low primary permeability or porosity and it is considered as unyielding zone because it has less amount of joints and cracks also it is hidden under cap vesicular strata, so weathering process is also less in that region. On the other side, upper vesicular strata is exposed to weathering, because of this primary porosity is high it indirectly helps in giving birth to quality aquifers. Vesicular basaltic layer is the main water-bearing horizon has great potential to hold the water in the aquifers and it found on Poladpur Formation in the study area. Underneath the fully or partially weathered rock strata, due to trickling effect in the jointing and cracks the porosity and water bearing slowly decreasing as per the depth increases and because of this reason only shallow water table aquifers systems observed in the study area.



Map No. 1.2 :Location of the study area on Deccan trap

The Upper Karha river basin is a part of Deccan Trap and it is characterized as rain scarcity zone of the Western Ghat region. In map (No-1.2) location of study area is shown and it is located on the Deccan trap. The study area is located at south east part of Pune district. The study area composed of various horizontal basaltic lava layers of varying thickness. The lava flow in the study region are varies in the thickness, starts from a 02 meters to as much as 40 meters. The strata's of Basalt in the study area is dark to grey in colour and having fine to medium grained texture. The nature of material is homogenous in appearance having partial porous spaces.

From hydrogeological point of view they are considered as hard rocks, because they have limited permeability and porosity.



Map No.1.3: Geological formation of the study area

In the map (No - 1.3) the geological formation of Upper Karha River has been shown. In present map two different geological formations are observed, one is Ambenali Formation and second is Poladpur Formation. The low laying area and the area nearby the Garade, Bivri and Chabli is composed of Ambenali formation. The area around water divider and characterized by the hilly region is composed of Poladpur formation and it includes Saswad, Narayanpur, askarwadi and Pimple village. In the Upper Karha river basin, the joints act as deposition of calcrete formations. Near Narayanpur red, clayey material known as ‘Red bole’ or the weathered layer of soil is sandwiched in between two different lava flows. Weathering, leaching and capillary action of these inter-flow horizons in the arid climate of the basin have led to deposition of calcrete in the joints and cracks of the rock structure.

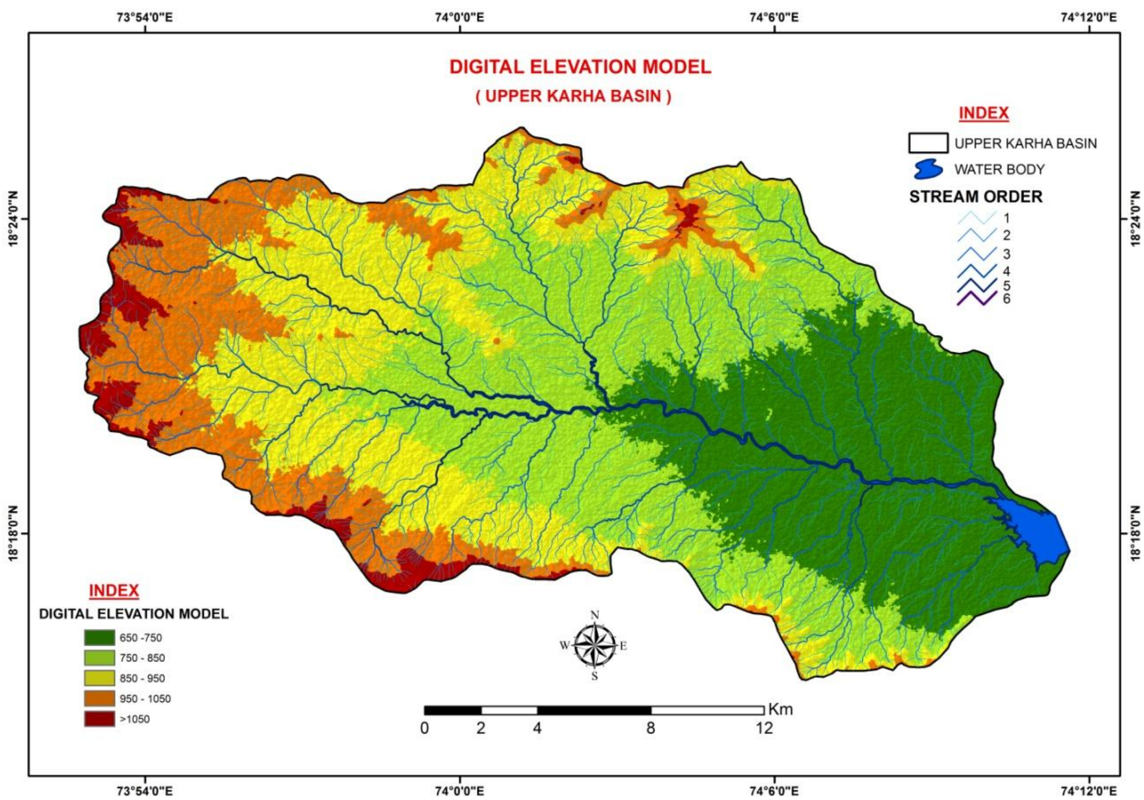
1.11.3 Geomorphology of the Study area

To study the geomorphological context about the study area gives the scenario of the landforms and the influence of landforms on the Groundwater occurrence therefore studying the physiographic features or geomorphic features becomes very important in any hydrological investigation. In the present study geomorphology is playing major role because landforms gives some clues about subsurface groundwater conditions. To understand and to quantify the subsurface groundwater occurrence and movement without understanding the surface geomorphological features is really tough task or some extent understanding the hidden groundwater resources becoming challenging task. The Upper Karha River is the part of Karha River starting at or originating at Askarwadi village up to the Malharsgar Water body. The study area is the upstream area of River Karha known as Upper Karha basin. River Karha is tributary of Nira River because Karha river tributes it’s all discharge to the Nira River at the Songaon village near Baramati.

As per the Geomorphological point of view, present study area is classified in to the two separate categories; one is hilly parts around the water divider from source area to Zendewadi at the north border and up to the Pimpale village at the south border of the study area. The second category is mostly acquired by plain region starting from Sonori village at the north border and Shivri village at the south border up to the low laying areas of Malharsgar water body at the eastern part of the study region. Mostly the hilly areas around source region are partially covered by semi deciduous and deciduous forests. The areas having gentle slope or mostly the foot hill zones of spurs are covered by grass land because of weathered and unconsolidated gentle slope areas. Valley floor are mostly having fertile black cotton soils and agricultural practices are common in this areas. During the fieldwork researcher has been observed Secondary calcretes precipitation in soil horizons exposed along the Ghat region and dug wells in the various farms. The study of geomorphic landforms helps to give an idea about Groundwater potential and its occurrence, it also helps to understand recharge and discharge zones of the particular drainage basin. In the present study geomorphology is the key aspect to study the groundwater conditions in the Upper Karha River.

a) Digital Elevation Model (DEM) of the Study area

In geographical research Digital elevation model playing important role in the modern research techniques, it gives clear cut idea about relief and geomorphology of the study area. In the present study DEM has been prepared by ASTER data having the resolution of 23.5 meters. In map (no-1.4) peak elevation observed at the Purandar fort (1170 m) near Narayanpur village and (1166 m) from MSL at Askarwadi village which is the source region of Upper Karha River.



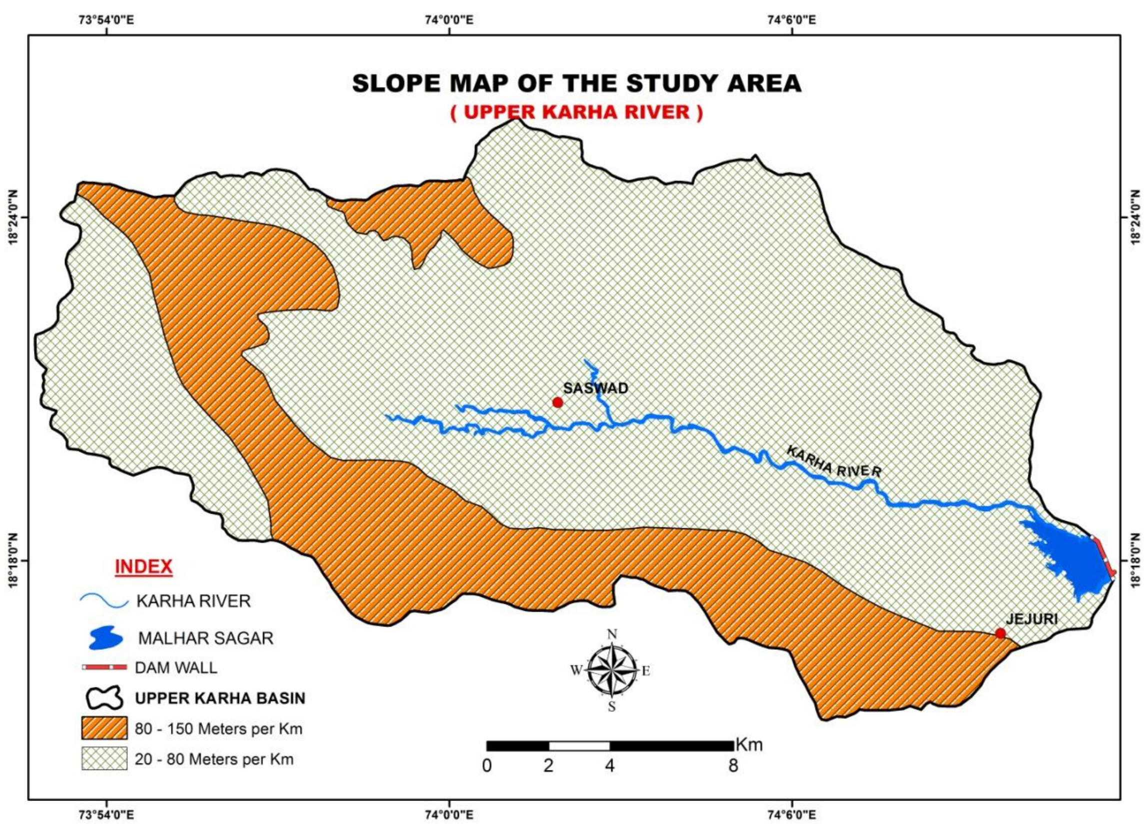
Map No.1.4: Digital elevation model of upper karha river

A digital Elevation Model is special designed type of data base which can facilitate the surface relief or topography of Geographical areas. Its help in three dimensional visualization, generalisation and view shed analysis. In the present study DEM has been prepare by using Arc GIS software version 10.3 for the purpose of elevation and relief studies and the association of those with groundwater availability.

Lowest elevation observed near Malharsagar water body south east part of the study area and it is about (648 m) from MSL. Digital elevation model helps to understand the physiographic vision or relief in terms of undulations of surfaces.

b) Slope categories in the Study area

The general idea of slopes in the groundwater studies have great importance because it is directly associated with generation of overland flow. If the slope is higher the amount of overland flow is higher and if the slope is gentle the amount of overland flow is lesser. The slope is the medium where surface water and sediments in it transferred to the low laying river channels. Transferred sediment with running surface water is itself generated by exposed rocks along the river channels and soil surfaces along tributaries in the study area.



Map No. 1.5: Slope map of the study area

In map (no-1.5) generally two types of slope has been observed, the first category having medium steepness of slope (80 to 150 meters /Km) and another category is gentle slope (20 to 80 meters/Km). These two types of slope categories put direct impact on water residence time and it indirectly impacting the percolation rate of the rain water along the study area. The areas having gentle slope is relatively good for percolation because it provides the surface for maximum residence time to the surface water but areas having steeper or medium steeper slopes are not favourable for the percolation and therefore these areas are not adding the water in to the subsurface groundwater.

1.11.4 Hydrological Characteristics

a) Surface water availability of Upper Karha Basin

Surface water availability is somewhere concerned with the surface stream network because streams allow water to drain down along the slope and percolate area along the streams, it also can be consider as the footprints of hidden appearance of subsurface water availability. In the Upper Karha River Basin mainly two types of surface water sources are observed one is in terms of seasonally running water from various streams and another is stored rain water in Dams and small water bodies along the study area. The Malharsagar water body at north east of Jejuri is major and important surface water source in the study area. It providing water supply to industries in the study area and for agriculture also. Malharsagar have the capacity of water storage about 800 million m^3 and presently the available water storage capacity is 600 million m^3. It provides irrigation facility to 350 ha. area which is nearby this water body. In the study area other small water bodies are located at Garade village (Garade Lake) and Supe Khurd (Ghorwadi Water body) situated in the source region and south part of the study area respectively.

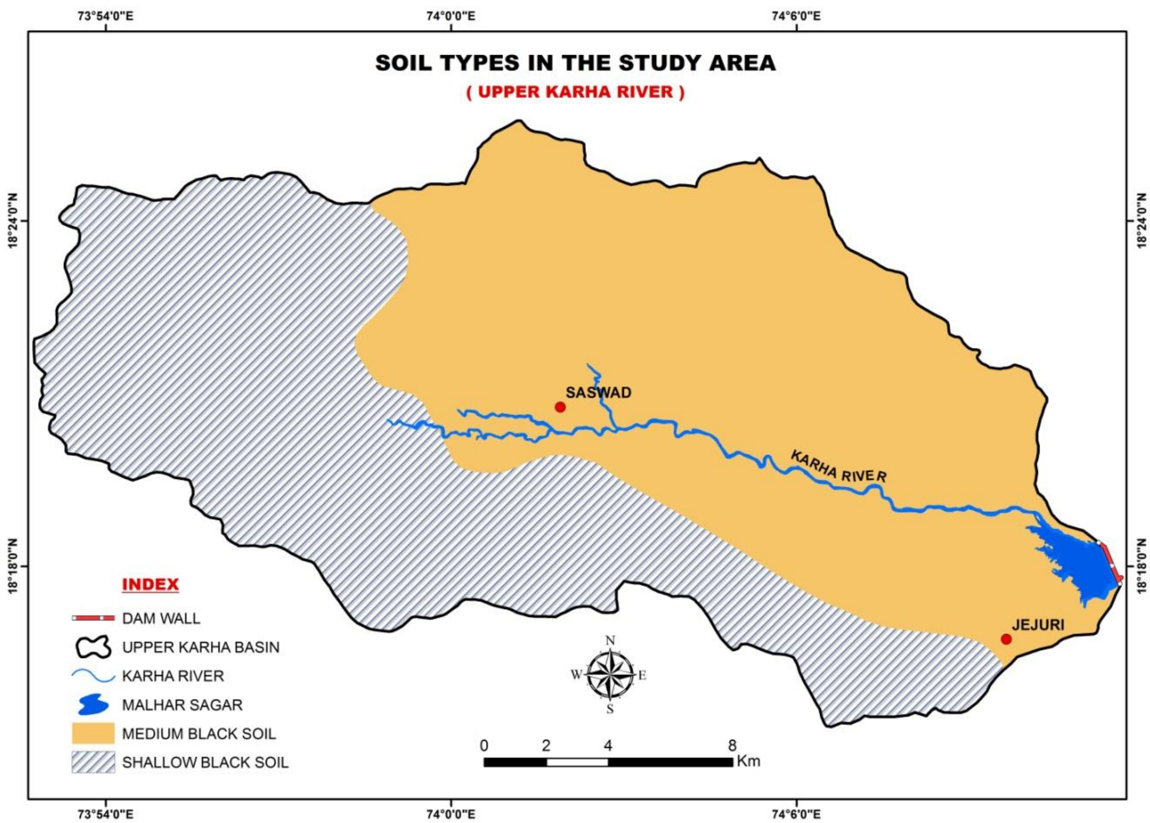
b) Groundwater availability and aquifer productivity of Upper Karha Basin

The basaltic rocks present on the Deccan trap are considered as fractured, weathered vesicular types of rock in nature. Basically it is considered as potential areas for the availability of ground water. The ground water present in shallow zones of such basalts in terms of unconfined to semi-confined aquifers. Saturated zone is about (15 to 20m) deep and depth of water table have fluctuations along weathered basaltic aquifer systems. If deeper aquifers are present beyond this limit is called as semi-confined aquifer system. The movement of groundwater in any area is always towards the low-lying areas of this region and rivers are always located on the low-lying areas. In the study area, basalt aquifers and alluvial are the important source of ground water for agriculture, industrial and domestic purpose. Utilization of groundwater for agricultural and domestic proposes is the daily and normally regular practice of the people residing in the Upper Karha river basin. In the study region Dug wells and bore wells are the principal source of acquiring ground water. The villages included in Upper Karha river basin have their own drinking water sources and peoples known these sources as community dug wells. The resident of this area uses such type of groundwater for domestic as well as agricultural practices from ancient time.

1.11.5 Types of Soil in the Study area

Soil is the parameter which firstly interacts with the rain water and it provide interface for infiltration of running water in downward direction by giving way through its pore spaces along soil horizons. Soil composition and texture indirectly affects the infiltration rate of water in terms of through flow in subsurface soil zone. The texture and composition of soil is determined by parent material or parent rock, climate of the area, and types of vegetation present in the area. The amount of precipitation, availability of moisture and temperature decides the speed and rate of physical and chemical weathering. The process of weathering is responsible for generation of soil layers by disintegrating of rock masses. In the extreme humid climate weathering process is dominant and it is the main reason for fast soil formation. The recharge of groundwater is somewhere concerned with soil properties and therefore it has great impact on the groundwater potential and occurrence in the Upper Karha river basin. The unconsolidated materials are good for infiltration of surface water but the consolidated materials are cohesive in nature and therefore they won’t allow water penetrating down to the groundwater table. In the study area salt-affected medium black soils is observed and most probably the productivity of this type of soil is decreasing day by day. Soils from Upper Karha river basin is of two types like shallow black soils covered mostly the Source region, southern and south-western parts of study area. The region around

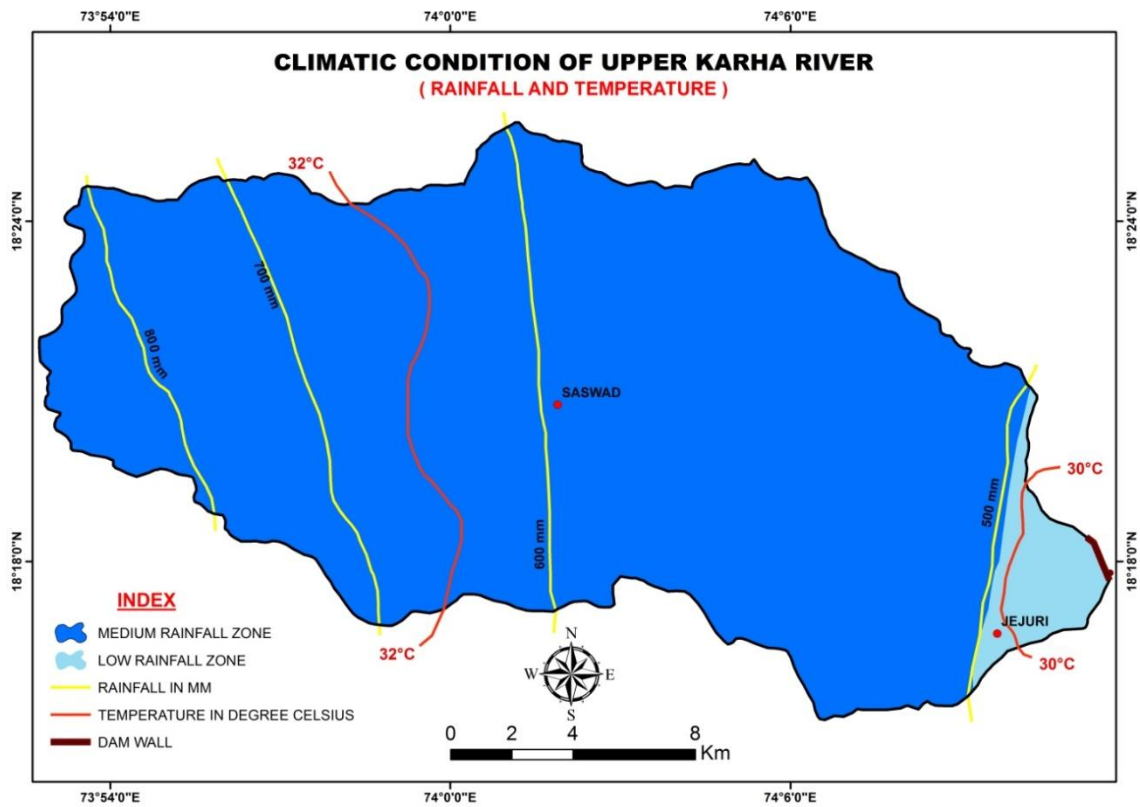
Malharsagar water body and north eastern part is covered with medium black soils. In the map (No-1.6) north eastern part is suitable for the agriculture because it is covered with medium black soil. The villages namely Zendewadi, Pawarwadi, Sonori, Vanpuri, Ambodi, Saswad, Jejuri, Khanavdi, Bhagvat vasti, Kothale, Gurhuli, Pargaon, Naralicha mala, Tathevadi and Khalad are having medium black soil. At the origin and hilly area mostly shallow black soil is observed. The villages come under this soil types are namely Askarwadi, Bhivri, Chambhli, Khoporwadi, Patharwadi, Waravdi, Thapewadi, Somardi, Garade, Kodit budruk, Narayanpur, Pimple, and Supe khurd.



Map No.1.6: Soil types in the study area

1.11.6 Climate of the Study area

As per meteorological data climate of Pune districts is divided in three seasons in one year and those are respectively summer season (March to May), monsoon season (June to October) and winter season (November to February). Basically climate of Pune district is dry in nature. The Pune district receives rainfall from southwest as and southeast monsoon. The average rainfall in Upper Karha river basin is about 760mm. The month of May is considered as hottest month in the year and December is the coldest month in the year. In the period of southeast monsoon the skies is cloudy and stronger winds are blowing, especially on the hilly areas of the Western Ghats region. The occurrence of thunderstorms is also observed in the pre-monsoon and post-monsoon periods. In this time patch Pune district experiences thunderstorms with hails. There is drop in temperature in the period of onset south west monsoon and after the monsoon withdrawal temperature is slowly rising in the month of October. The extremely high pan evaporation is observed and it is near about 172 mm. In the month of March and May the temperature condition is extremely hottest and that's why pune experiences high amount of Evaporation during this time.



Map No.1.7: Climatic condition of the study area

There is considerable fall in the average annual rainfall in last decade ad it is becoming alarming issue in terms of water availability. Map (No-1.7) shows the rain fall variation in the Upper Karha river basin. In the study region average annual rainfall ranges between 610 mm at Saswad to 478 mm at Jejuri village near Malharsagar water body. Generally the trend of rainfall is decreasing towards the Malharsagar water body (478 mm) from the source region of Askarwadi (800 mm). The pattern of annual rainfall is considered as the controlling factor of the health and socio-economic conditions of the local residents. The study area experiences severe water scarcity problem due to moderate to less rainfall and improper management water resources. The agricultural practices are totally dependent on the rainfall parameter and due to this undefined situation the agricultural area in the study region facing some problems in present situation.

1.11.7 Natural vegetation in the Study area

Natural vegetation is determined by the topography, climate and soils. The natural vegetation is unevenly distributed in this region. The acacia type, dry deciduous type of forests is present in the study area. However thorny bushes trees are seen in the area and listed below:

a) Trees:

1) Babhul - Accacia arabica
2) Neem - Azadirachta indica
3) Ber - Zizphus jujuba
4) Jambhul - Eugenia jambolana.

b) Shrubs:

1) Ghaneri - Lantana Camara
2) Tarawad - Cassia auriculata
3) Rui - Calatrophus gigentia
4) Ghayapat - Agave species.

c) Grasses:

1) Kusali - Heteropogan contartus
2) Harali - Cynadon dactylon
3) Gajar Gavat - Parthenium histrophorus

(Source -Field survey report)

1.11.8 Demographic profile of the Purandar Tehasil

To study the demographic profile of the area is the necessary part because while studying the Groundwater quality and potential we need to understand that how many people are dependent on the present resource and how many will be impacted due to contaminated water supply. The total population of the Purandar Tehasil according to census of India 2011 is near about 2, 35,659 persons. The population residing in the rural area is much higher than the urban areas of the Purandar Tehasil. As per the data given in table (no-01) the sex ratio will be the alarming issue in the future and it is relatively same for the urban and rural areas. The schedule caste population is near about 7.20% of the total population of the Purandar Tehasil. The population of scheduled tribes is 2.60% of the total population of the Tehasil.

Table No 1.1: Demographic Profile of Purandar Tehasil

DEMOGRAPHIC INDICES	TOTAL	RURAL	URBAN
POPULATION	2,35,659	1,78,095	57,564
CHILDREN (0 - 6 YEARS)	25,037	18,761	6,276
LITERACY RATE	82.55%	80.94%	87.52%
SEX RATIO	965	965	967
SCHEDULED CASTE	7.20%	6%	11.20%
SCHEDULED TRIBES	2.60%	2.80%	2%

(Source- Census of India 2011)

1.11.9 Accessibility of the Study area

The location of the Upper Karha river basin is near to Pune city and it is the reason for the fast development of the Study area. With having the metropolitan city near the study area there is no such development in terms of road accessibility along the source region. The road connecting to the Garade, Bhivri and Naraynpur are not in that much good condition for transport. Saswad is the tahasil headquarter of Purandar tahasil. Saswad is having good connectivity with Pune by the roads. Pune to Saswad via Hadapsar (SH-64) is the best option for the access of the study area.

The medium for public transport in between Pune and Saswad by pune PMPML buses having good frequency. The state transport is another option of public transport in the study region. The route connecting to Kondhva and Saswad is relatively in good condition for transport of agricultural products to the market places in the Pune city. The study area is connected to the city by single railway line in between Pune to Kolhapur. There are two railway stations in the study area namely rajevadi and Jejuri. In terms of connectivity Saswad and Jejuri are the most populated areas are having connectivity to Pune city as well as Baramati also. Some part of the study area near basin border at the origin of the Karha river and hills side of the Jejuri and Purandar fort is little bit hard to approaches but for the local transport the unpaved roads developed by the people residing in this area for the transportation of goods and other things. As a tourist attraction place Jejuri have good connectivity with Pune by road transport.

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CHAPTER - II

REVIEW OF LITERATURE

3.1 Introduction

The literature review related to present study gives the information regarding the historical background of study, the present status of research in that field, and recent developments in the subject. It also provides a unique source of information about the groundwater contamination and its effects on human health in the rural, industrial and newly formed urban sectors, which has become path indicator for the studies and therefore forms the strong foundation of present study. In view of this, the present chapter includes the information on: The aim of literature review is to highlight what has been done so far in the field of interest and how you findings relate to earlier research. Generally, review of literature provides in-depth understanding and explanation on how your findings are similar to or novel from previous research work To considerate the research subject and for make a decision to select appropriate methodology literature review is essential, hence various reference material was reviewed like Ph.D /M.Phill dissertations, books, journals and articals. Literature which refers topics concerning to Groundwater, Watershed, Morphometry, advanced techniques likes GIS and RS was reviewed. International Level, National Level's Various Thesis, Dissertations, Many Journals interrelated to groundwater, Research Papers, Scholary Articles, Published and Unpublished Projects, Reports, Books are use to spell out concepts and update knowledge about the research problem. To considerate the research subject and for make a decision to select appropriate methodology literature review is essential.

As given in the introductory part a good quality of literature is available related to the groundwater and hydrogeomorphology. The books viz ‘Groundwater hydrology’ Todd (1980), ‘Applied Geomorphology’, H. Th. Verstappen (1983) ‘Handbook of Applied Hydrology’ Chow (1966), ‘Ground water’ P. Sankara Pitchaiah (1995) have made great work related to the groundwater, potential, and regionalization. A remarkable amount of published work, however, is available in ‘Journal of Applied Hydrology’; ‘Environmental

Geology', 'Journal of Geological Society of India, 'International Journal of Remote Sensing 'Photonirvachak i.e. Journal of the Indian Society of Remote Sensing' 'GIS Development'. Most of this work is carried out by with the help of new technique 'Geographical Information System and Remote Sensing. Krishnamurthy and Srinivas (1995) published work on 'Role of geological and geomorphological factors in groundwater exploration. All above-mentioned researchers have been made very useful work in the field of groundwater.

3.2 Review of Research Papers and Articles

Devendra Dohare, Shriram Deshpande, Atul Kotiya (2014) focused on 'Analysis of Ground Water Quality Parameters a Review'. Paper was published in Research Journal of Engineering Science. The present study was attentive the ground water quality index (WQI) for ground water of Indore City. To calculating water quality status by statistical evaluation and water quality index 27 parameters has been considered. The obtain results of the study are compared with Indian Standard Drinking Water specification IS: 10500-2012. This paper suggests that the evaluation of water quality parameters as well as water quality management practices should be carried out periodically to protect the water resources.

P.Satyanarayana, N. Appala Raju, K. Harikrishna,K. Viswanath (2013) call attention on 'Urban Groundwater Quality Assessment: A Case Study of Grater Visakhapatanam Municipal Corporation Area (Gvmc), Andhra Pradesh, India'. Paper was published in International Journal of Engineering Science Invention. This study was express that groundwater pollution is one of the environmental problems in urban areas. Visakhapatnam City of Greater Visakhapatnam Municipal Corporation's urban area was the study area. To analyzed physicochemical characteristics, 21 water samples has been collected from bore wells and the results of that analysis were compared with the water quality standards of WHO, BIS and CPHEEO. This article suggested that regular monitoring of groundwater quality is required to assess pollution activity from time to time for taking necessary measures to mitigate the intensity of pollution activity.

S. Ananthakrishnan, K. Longanathan, A. Jafar Ahamed (2012) was emphasized on 'Study on Groundwater Quality and Its Suitability for Drinking Purpose in Alathur Block :Perambalur District'. The article was published in Scholars Research Library, Archives of Applied Science Research. The study was conducted over ten villages in Perambalur district and the overall study was spread in three different seasons. i.e. pre- monsoon, monsoon and post monsoon. Ten parameters have been considered for study and the results are comparing against drinking water quality standards of Health organization and Indian Council of Medical Research. Weightage Arithmetic Method was derived for analysis related to suitability of ground water.

Eze Bassey Eze & Joel Efiong (2010) focused on the morphometric parameters of the Calabar River Basin with emphasis on its implication for hydrologic processes. According to this it was concluded that the Calabar River basin is susceptible to hydrologic processes like flooding, erosion and landslide. Calabar River Basin has 223 streams which has 516.3 km total length. The basin of Calabar River was strongly elongated, its circularity ratio was 0.34 and elongation ratio was 0.64 where the average bifurcation ratio of Calabar River Basin was 2.83. This results investigate that low values of drainage density, stream frequency and drainage intensity are imply that the surface runoff is slowly removed from basin and due to this lower part of the basin has susceptible to flooding, gully erosion and landslides. This paper also concluded that the negative activities of human are play important role on such river basin.

Yasmin B. S. & et.al (2013) accentuate on drainage pattern of the Milli watershed of Raichur. The drainage pattern of Milli watershed was dendritic. The qualitative and quantitative analysis of geomorphological parameters of Milli Watershed has been carried out using GIS. The ruggedness number of these study area was 0.07 and geometric number was 20 and according to this result it was concluded that the watershed has gentle slope.

Chakraborty S. and Paul P.K (2004) contributed on "Identification of Potential Groundwater Zones in the Baghmundi Block of Purulia District of West Bengal Using Remote Sensing and GIS" The present paper published in Journal Geological Society of

India. In present paper Morphometric and Hydrogeomorphic analysis has been done to determine the potential water- bearing zone in the study area.

Murthy K.S.R.,Amminedu E. and Rao Venkateshwara V. (2003) was scrutinizing "Integration of Thematic Maps Through GIS for Identification of Groundwater Potential Zones". This paper is published in Photonirvachak-Journal of Indian Society of Remote Sensing. The present paper focus on integrating the thematic Maps prepared from conventional and remote sensing techniques using GIS yields more and accurate results. The study also demonstrate that using remote sensing data and GIS techniques reconnaissance Mapping of Groundwater offers scope for improving the targeting of Field observations.

Krishnamurthy Jagadish and Sambaraju Kasturba(2001) was emphasized on "Project Management and Use of GIS in Danida-Assessted Rural Drinking Water Supply and Sanitation Project in Karnataka". This paper is published in Workshop on remote sensing and GIS Applications in Water Resources engineering. The present study emphasizes on Groundwater Monitoring, Water Quality studies and institutional set-up and Water supply planning and institutional set-up.

Natrajan P.M. (2001) was show up on "Application of Remote Sensing Technique to Identify the Groundwater Potential Geological and Geomorphological Settings of Tamil Nadu-India". This paper is presented and published in workshop on remote sensing and GIS Applications in Water Resources Engineering" Lucknow. In this paper an attempt is made to identify the favorable geological and Geomorphological settings of Tamil Nadu state for groundwater targeting by using the conventional and remote sensing techniques.

Kumar Ashok and Tomar Savita (1998) was documented on "Groundwater Assessment Through Hydrogeomorphological and Geophysical survey- A case study in Godavari Sub-Watershed Giridih, Bihar". Present paper published in Photonirvachak-Journal of the Indian Society of Remote Sensing. This study emphasizes on Correlation between different sub units of the same Hydrogeomorphic units and top Soil resistivity.

Saraf A.K. and Choudhury P.R. (1998) was accentuate on “Integrated remote sensing and GIS for Groundwater Exploration and Identification of Artificial Recharge Sites”, The present paper published in International Journal of Remote sensing. The present paper attempts to select suitable sites for groundwater recharge in a hard rock area through recharge basins or reservoirs, using an integrated approach of remote sensing and GIS. The integrated study helps in designing a suitable groundwater management plan for a hard rock terrain.

Sarala C, Ravi Babu P. (2012) concluded on ‘Assessment of Groundwater Quality Parameters in and Around Jawaharnagar, Hyderabad’. This paper was published in International Journal of Scientific and Research Publications. The entire study was assessed on groundwater quality parameters in the surrounding wells of Jawaharnagar, in upper Musi catchment area of Ranga Reddy district in Andhra Pradesh. The bore wells data was collected from the study area for two seasons. i.e. post monsoon and pre monsoon. The groundwater countour analysis is done by using Arc GIS. Based on the analysis, most of the area at many locations near the solid waste dumping site, hence water is unsuitable for drinking. This paper also highlight that the utilization of surface and groundwater for drinking, industrial and agricultural purpose has increased manifolds but consequently it is observed that the water is polluted and affecting the human health, soil nutrients, livestock, biomass and environment in certain area.

Neerja Kalra, Rajesh Kumar, S.S. Yadav, R.T. Singh (2012) scrutinize on ‘Physico – Chemical Analysis of Ground Water Taken from Five Blocks (Udwantnagar, Tarari, Charpokhar, Piro, Sahar) of Southern Bhojpur(Bihar)’.Paper was published in Journal of Chemical and Pharmaceutical Research. Present research paper classified water samples of five blocks which are lays in southern part of district Bhojpur, Bihar. Groundwater samples are under studied for Physico –Chemical status of ground water. In Physico – Chemical analysis various quality parameter are measured like pH, turbidity, electrical conductivity (EC), total dissolved solids (TDS),total hardness (TH), content of calcium(Ca^{2+}), magnesium (Mg^{2+}), chloride (Cl^{-}),sulphate (So_4^{2-}), Iron (Fe), DO, BOD, COD,Total alkalinity (TA), and Nitrate(No_3^{2-}) concentration present in ground water. This all paprameters were compared with ICMR standards of water quality.

Devendra Dohare, Shriram Deshpande, Atul Kotiya (2012) narrate on 'Analysis of Ground Water Quality Parameters : A Review'. Paper was published in Research Journal of Engineering Science. The present study was attentive the ground water quality index (WQI) for ground water of Indore City. To calculating water quality status by statistical evaluation and water quality index 27 parameters has been considered. The obtain results of the study are compared with Indian Standard Drinking Water specification IS: 10500-2012.This paper suggest/ recommended/imply that the evaluation of water quality parameters as well as water quality management practices should be carried out periodically to protect the water resources.

P.Satyanarayana, N. Appala Raju, K. Harikrishna,K. Viswanath (2013) was emphasized on 'Urban Groundwater Quality Assessment: A Case Study of Grater Visakhapatanam Municipal Corporation Area (Gvmc), Andhra Pradesh, India' . Paper was published in International Journal of Engineering Science Invention. This study was express that groundwater pollution is one of the environmental problems in urban areas. Visakhapatnam city of Greater Visakhapatnam Municipal Corporation's urban area was the study area. To analyzed physicochemical characteristics, 21 water samples has been collected from bore wells and the results of that analysis were compared with the water quality standards of WHO, BIS and CPHEEO. This article suggested that regular monitoring of groundwater quality is required to assess pollution activity from time to time for taking necessary measures to mitigate the intensity of pollution activity.

Patnaik et al (2002) have studied water pollution generated from major industries. Similarly, waste effluents discharged into streams may enter the aquifer body downstream, which also affects the groundwater quality.

Kamaleshwar Pratap (2000) studied groundwater assessment and concluded that the occurrence and movement of groundwater in an area is controlled by various factors. The influence of all factors need not be the same in the area. Therefore, each parameter is assigned a weightage depending on its influence on the movement and storage of groundwater. The area being underlain by hard crystalline rocks, the lithological control is less compared to the topographical control.

Salve P.R.(2008) revealed Assessment of Groundwater Quality with respect to Fluoride and concluded that though fluoride enters the body through food, water, industrial exposure, drugs, cosmetics etc drinking water is the major contributor (75 - 90 % of daily intake).

Timothy W. Collins et al (2007) focused on Charaterizing vulnerability to water scarcity. The case of a groundwater dependent, rapidly urbanizing region. A GIS approach offers technical advantages and a powerful means for visualing vulnerability issues, which strengthens the grounds for scholarly interpretation, while providing a practical basis for intervention.

Robinson and et al (2006) contributed on the spatial and the non spatial database formed is integrated for the generation of spatial distribution maps of the water quality parameters. For spatial interpolation Inverse Distance Weighted (IDW) approach in GIS has been used in the present study to delineate the locational distribution of groundwater pollutants. Groundwater mining can also threaten long term water security and has emerged as salient public policy issue (Alley et. al 1999, US Bureau of Reclamation, 2003). In the particular method the experimental variogram measures the average degree of dissimilarity between un-sampled values and a nearby data value and thus can depict autocorrelation at various distance. From analysis of the experimental variogram, a suitable model was derived by using weighted least squares and the parameters.

Singh and Lawrence (2007) was emphasized on a groundwater quality map in GIS successfully for Chennai city, Tamil Nadu, India. Preparing groundwater quality maps taking into consideration, multiple contaminants and spatial variability of these contaminants, groundwater quality assessment in Dhanbad district, Jharkhand, India was much more difficult due to the spatial variability of multiple contaminants and wide range of indicators that could be measured. Considering the above aspects of groundwater contamination and use of GIS in groundwater quallity mapping, the study was undertaken to map the groundwater quality in Gulbarga city, Karnataka, India.

Stefanoni and Hernandez (2006) studied that the co regionalization between two variables, that is the variable of interest, groundwater quality inthis case and another easily obtained and inexpensive variable, can be exploited to advantage for estimation purposes.

Burrough and McDonnell (1998) call attention on Inverse Distance Weighting (IDW). In interpolation with IDW method, a weight is attributed to the point to be measured. The amount of this weight is dependent on the distance of the point to another unknown point. These weights are controlled on the bases of power of ten. With increase of power of ten, the effects of the points that are farther diminishes. Lesser power distributes the weights more uniformly between neighboring points. In this method the distance between the points count, so the points of equal distance have equal weights.

Lin and et al (2004) was emphasized on the health problems induced by geochemical factors from China. The distribution of the endemic diseases has geographical characteristics. Among the most harmful and widely distributed of the endemic diseases are: Kaschin- Beck disease, Keshan disease, iodine deficiency, endemic fluorosis and hepatic carcinoma. The geographical environments have a close relationship to endemic diseases and are influenced by climate, geology, landform, soil, food and drinking water. Drinking water is the key issue, since polluted water or water lacking in or having an excess of certain minerals and elements, as well as water containing certain organic components, has been shown to be harmful to human health.

3.3 Review of Books

Chow Ven Te (1964) was narrate on “Hanbook of Applied Hydrology A Compendiu m of Water resource Technology”. This book is deals with information about the water quality requirements for various beneficial uses and its importance in the evaluation of a water supply source. It also focus on each major type of water supply source has certain water quality characteristics which are valuable in the preliminary and formative phases of the development of a supply, and also to determining the quality of a natural water-supply source, the procedures used in sampling the supply are very important.

Scalf Marion R., McNabb James F. And othersand (1987) was highlights the "Manual of Ground-Water Sampling Procedures”. In this book some procedures are given which are currently utilized to sample groundwater and subsurface earth materials for microbial and inorganic and organic chemical parameters.

Noor M. and Ballabh P.(2011) was description on "Exploitation of Groundwater and Their Effects”. This book focusing on Quality of groundwater, Quality of Water problem in developing Countries and Potential and constraints.

Effah Kwabena Antwi (2009) was contributed on Integrating GIS and Remote Sensing for Assessing the Impact of Disturbance on Habitat Diversity and Land Cover change in a Post mining Landscape. The entire study was assessed on Land Cover Change and tries to find some remedy to restore the damaged ecosystem. Change detection extension was used and finds the results with ‘positive change’ i.e. the area of pine, deciduous tree, lake and mixed grasslands was increased. It was also paying attention on causes of Land Cover changes in Schlabendorf, Habitat Diversity and Species Diversity in Schlabendorf.

Nagarle V.R. (2017) Purandar tahasil is a part of semi arid zone of Deccan Volcanic Province, India, facing the critical groundwater salinity problem that aggravates in drought period. In view of this the author decided to take review of inland salinity problem in the study area. The term salinity refers to the presence of excess salts/solutes in water by various geochemical and anthropogenic processes. Though the presence of high concentration of salts in irrigation water leads to the accumulation of salts in soil making it saline in nature, the problem of salinity in the area is typical of arid and semi-arid areas. The sodium plays a major role in the development of salinity in arid and semi-arid areas, as the rate of evaporation is high and precipitation is less. This leads to accumulation of sodium salts at the soil surface due to high rate of evaporation, which results in development of alkalinity in soil and enhances salinity process in ground water.

Darren et al. (2007) demonstrated that for dry land salinization to occur, it need not be necessary to have discharge zone saline in nature. Only the presence of large salt store does not necessarily lead to problems of dry land salinization if, clay-rich sediments at the site and the salt lies below the pasture root zone.

Jalali (2006) revealed that the groundwater chemistry is primarily controlled by weathering of the minerals mainly alumino-silicates. The evolution of groundwater may be controlled by more complex processes involving evaporation, precipitation and dissolution of carbonate minerals, besides cation exchange reactions between groundwater and clay minerals.

Alyamani (2000) suggested that the groundwater salinity varies and is randomly distributed. The salinity problem seems to be due to intensive evaporation that led to precipitation of evaporates (e.g. calcite, dolomite, gypsum and probably halite). The intensive irrigation activity (mineral dissolution) recharges the groundwater with a marked increase in the salinity. The local hydrogeological setting plays a strong role in determining the risk of groundwater salinity as a consequence of irrigation practice.

Subba Rao (2008) opined that various hydrogeochemical processes are involved in the development of groundwater salinity. The compositional relations and mineral saturation states indicated that the associated hydrogeochemical processes such as dissolution of oil salts, dissolution of NaCl and Ca_2SO_4, precipitation of $CaCO_3$ and ion exchange of Ca^{2+} for adsorbed Na^+ have dominant control. Evapotranspiration causes the formation of salt layers by transfer of original salts from groundwater to soil / weathered zone. Such salts are the sources of ions to reach groundwater through infiltrating recharge water. Extensive irrigation, helps in recycling of saline groundwater, irrigation-return-flow and application of agricultural fertilizers are the major human activities, which are responsible for further increasing the concentration in groundwater.

Salameh and Hammouri (2008) postulated that, the Permo-Triassic, Jurassic rocks, basaltic dykes and sills are the sources, which cause a drastic increase in the salinity of water in their study area. These rocks contain residual evaporates, contact metamorphism products, sills, dykes and secondary altered mineral assemblage of plagioclase, pyroxenes and Fe - Mn minerals also cause drastic changes in ionic ratios, saturation indices and groundwater changes in ionic ratios.

Rajmohan and Elango (2004) concluded that the composition of groundwater depends on the recharge from lakes and rivers. In addition, control of silicate mineral weathering on the concentration of major ions in the groundwater aided by rock-water interaction, dissolution and deposition of carbonate and silicate minerals, ion exchange was brought out.

Janardhana Raju (2007) pinpointed that, the seasonal variation in groundwater quality due to agricultural and domestic activities through infiltration and percolation during monsoon. Thus, the overall quality of groundwater of an area is controlled by lithology apart from other local environmental conditions.

Trabelsi (2007) related the origin of salinity to the existence of various salinisation processes such as: dissolution of gypsum and calcite dispersed through reservoir rock, ion exchange, intensive agricultural practices and sea water intrusion, enhanced by excessive withdrawal of groundwater.

Manish Kumar et al. (2006) gave detailed account of the hydrochemical processes responsible for the quality of groundwater which included simple dissolution, mixing, evaporation and weathering of carbonate / silicate minerals and surface water interaction besides reverse ion exchange. Highly saline and brackish groundwater is associated with long history of evaporation and oxidation of sulphur gases in low-lying areas.

Koc (2008) opined that poor planning of irrigation water led to heavy salt loads adversely affecting the environment in the Great Menderes River Basin. Duraiswami et al. (2009) studied the salinity model for the Karha river basin by remote sensing and GIS techniques.

Piper (1944) discovered a diagram named after him as piper diagram. Piper diagrams are a type of trilinear diagram broadly used in hydrogeology as they illustrate the hydrochemical characteristics of groundwater by representing the concentration of anions and cations in separate triangular diagrams. Geochemically similar waters are clustered in clearly defined areas, indicating water-mixture phenomena, precipitation, dissolution, etc.

Richards (1954) has given a formula called Sodium adsorption ratio (SAR). Sodium is a unique cation because of its effect on soil (when present in exchangeable form) as it causes adverse physico-chemical changes in the soil, particularly to the soil structure. A high salt concentration in the water leads to the formation of saline soil and the higher concentration of sodium leads to development of alkali soil. Usually SAR less than 3.0 will not be a threat to vegetation while SAR greater than 12.0 is considered sodic and threatens the survival of vegetation by increasing soil swelling (dispersion) and reducing soil permeability

Kuipers et al, (2004). The compounding effects of discharging water with high SAR is that it produces soils that are unsuitable for agriculture, grazing and it creates hazards such as fugitive dust from wind and increased sediment loading of local streams and rivers from surface runoff and damages the stream channel integrity

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CHAPTER - III

RESEARCH METHODOLOGY

3.1 Introduction

The main aim of the present research work is to assess Groundwater Potential and Groundwater quality of Upper Karha river basin. In present stage the study area is passes through different developing conditions and due to the proximity to Pune city urbanization slowly penetrating in the study region. This fast changing scenario is making so many changes in the water demand of the study area but when we look at the availability and the quality of groundwater to mitigate the need of present changing population it is becoming a big issue in terms of planning and managing the resources of the particular place. The industries in the study area are growing rapidly due to the road connectivity and nearness of Pune metropolitan region and it had adverse impact on groundwater quality itself. The farmers residing in the study are uses the chemical fertilizers in huge amount to increase the crop production but on the other hand he is adding the contaminant to the groundwater. The soil quality is also deteriorating in the study area. In the present chapter detail methodology adopted for the understanding each and every issue related to groundwater potential and quality assessment has been discussed. GIS mapping tools and techniques were used for making the various maps to understanding the spatial variations of the geographic parameters related to groundwater. The detail plan of study is given bellow as follows

3.2 Detailed plan of methodology

Geographic personality of an area is the result of the total effect of a particular combination of natural factors and human interventions. Man is continuously altering his surrounding by using the knowledge gain and such activities may leads to some geographical issues. A broad procedure will involve the following steps and systematically represented as follows.

<u>Preparatory Phase</u>

- Base map preparation (on the basis of SOI toposheets and cadastral maps)
- Acquisition of satellite data
- Acquisition of secondary data

<u>Analytical Phase</u>

Cartographic analysis

- Analysis of basin morphometry
- Classification of landforms on the basis of their origin (Denudational, structural and depositional)

Field analysis

- Field surveys for verification (ground truthing) of morphometric characteristics
- Field visits for collection of water samples

Laboratory analysis

- Analysis of groundwater samples in different seasons.
- Verification / comparison with satellite data
- Generation of map layers
- Preparation of database in such a way that a groundwater zones will be displayed in basin map.

3.3 Database

a) Primary Data

Data pertaining to Groundwater for various properties detection have collected directly by performing groundwater surveys in the field, which really helped in the understanding the quality of groundwater and severity of the groundwater scarcity and contamination. Representative samples from various villages under consideration have collected and analysed in the laboratory. The representative groundwater samples have been collected by random sampling method and sample is evenly distributed along the study area. In order to undertake the present study a detail plan of fieldwork has been prepared, which involves the GPS survey of sampling wells.

b) Secondary data

In order to analyse the problem the data have been collected from variety of sources. Secondary data have been collected from various institutes with fieldwork. Base map have been prepared from S.O.I toposheet at 1: 50,000 scale. Various thematic maps have been prepared to indicate the groundwater potential and quality of groundwater variation. Remote sensing with G.I.S application has performed to delineate, and map the groundwater potential and quality respectively. Preparation of the maps has been done by using G.I.S. software namely Global Mapper, Surfer (Demo Version), Arc GIS 10.3 etc.

c) Fieldwork components

In order to undertake the present study a detail plan of fieldwork has been prepared, which involves the groundwater sample and well survey at reconnaissance level. A pilot survey has been carried out in the month of November 2013. The second fieldworks has been arranged in the month of February 1013 and completed accordingly. As most of the research is mainly depend on primary data collection, various field surveys has been carried out by the researcher during the study period for collecting groundwater samples and related information from the field. During the field work sample well locations has been selected randomly on the both banks of the river Karha and for the remaining area also. Researcher has taken care of sample collection methods and standard procedure has been followed during research period.

Fieldwork components are summarized as follows –

1. Collection of evenly distributed and representative groundwater samples from various dug wells according to variation in water quality using l litter sampling bottle in the field.
2. Field measurement of, Well depth, & diameter of the well and information about physical appearance of groundwater.
3. Locating benchmark & spot height with the help of SOI Toposheet for the identification of self location on map.
4. Soil sample has been collected to understand the texture of soil in the study area.
5. GPS (Global Positioning System) survey has been carried out to measure location reference in terms of latitude and longitude for the sample sites in the field.

d) Laboratory components: -

Laboratory components consist of determination of physical, chemical properties of Groundwater samples and soil samples collected from the field, computation of various formulae; the groundwater samples collected in the field are subsequently processed into the laboratory. For the determination of groundwater quality and its suitability for agricultural, industrial and domestic proposes various method has been followed in the laboratory. To understand the soil texture of the soil in the study area, samples are processed in the laboratory by using weighing machine for the weight of the soil and sieves are use to understand the texture of soil. Some of the physical parameters of the groundwater like Bulk colour, appearance, and physical contaminants, etc. have been determined by field observations. The chemical properties of groundwater sample related to groundwater pH, groundwater conductance, amount of total dissolved solid present in the groundwater, amount of total Nitrogen, Phosphorus, Potassium, etc have been determined with the help of various methods.

The laboratory component also consists of mapping of different chemical parameters of the groundwater samples. Different thematic maps have thus been prepared considering the base map. Along with these maps different maps of the area related to the overall physiography of the region has been prepared. These include DEM map, % Slope map, & Drainage map etc.

3.4 Base map preparation

The base map has been prepared form S.O.I. sheet No. 47F/15 and 47 J/3 at 1:50,000 scales surveyed in 1974-75. As well as used tahsil map from census book for the purpose of cropping clear basin boundary. All these maps have prepared using some software namely Global Mapper 11.0, Arc GIS 10.3 package and the steps followed are given below;

1. SOI topomap have been digitised (basin Boundary) for the preparation basin map
2. DEM is used for preparation of the relief analysis like slope and elevation and it also helps to demarcation of streams.
3. Processing in Arc GIS and Global mapper Version 10.3 and 11.0 respectively really helped lot in preparing of Digital elevation model.
4. For the generation of DEM Aster data has been used and the resolution of ASTER data is 23.5 meters.

The use of software no doubt is very much helpful in the understanding of the relief from the map. 3D generation of orthographic and perspective views is performed using DEM. The digital elevation model facilitates us 3D vision of the study area.

3.5 Hydro-chemical data collection

The last five year data of groundwater quality of some GSDA wells from study area was collected from Groundwater Survey and Development Agency (G. S. D. A.), Pune office to understand the variation in the physico-chemical properties of groundwater of the study area but sample wells of GSDA are falls outside of the area and only few wells nearby the study area has been monitored by the GSDA pune, so it is not benefited in the research at any point of time in the research. This is the reason why research is fully dependent on primary data collected from the field.

3.6 Groundwater sampling and analyses

The quality of data obtained on studies pertaining to chemistry of waters depends on the type of investigations, purpose of the study, sampling techniques and analytical methods used. In view of this, certain steps were taken to fulfill the objectives of present study as well as to collect reliable data on physico-chemical properties of groundwater. These are as follows:

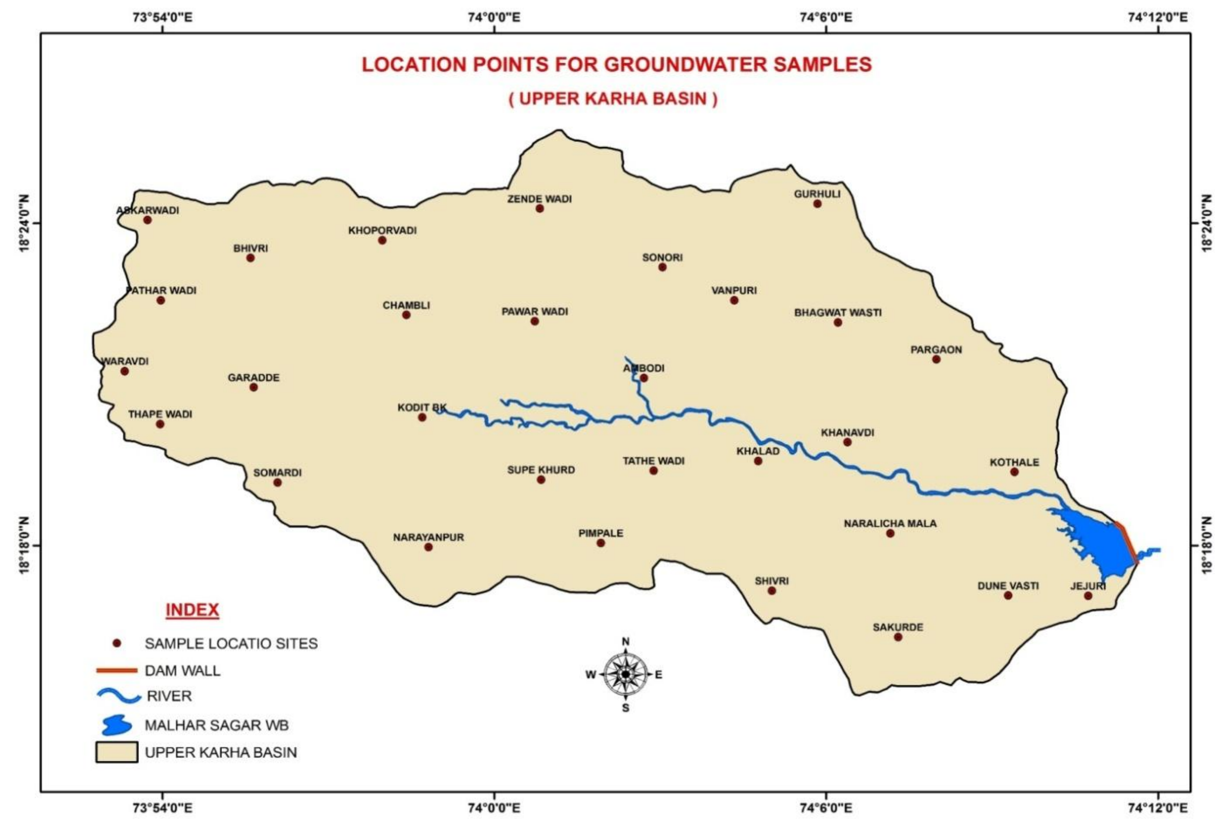
1) Selection of suitable groundwater sampling stations.
2) Periodic and seasonal collection of groundwater samples at fixed stations.
3) Analyses of groundwater samples by suitable and standard methods.
4) Evaluation of groundwater chemistry data.
5) Generation of Various thematic maps is comes under analysis work.
6) Generation of Groundwater Quality and potential maps of the study area.

Each step is significant and has to be undertaken with utmost care. The rationale for selecting sample sites, procedures for collection of samples and details of analytical methods employed are given in the following paragraphs.

3.7 Selection of groundwater sampling stations

Sampling for groundwater is an important aspect in hydrochemical investigations. The first juncture of planning of the sampling program is the selection of suitable sites. The study area is known for its pristine geochemistry and meager anthropogenic interventions of contaminants from domestic sewage and industrial effluents. Since the purpose of this study was to generate a data base on the potential of groundwater and quality of groundwater of Upper Karha basin, it was essential to have sampling sites chosen from the areas which were not covered by GSDA, Pune for groundwater quality assessment. The sampling program was designed accordingly. Random sampling technique was adopted for the selection of water sampling wells and due consideration was given to represent each selected area as industrial, urban and rural sector. Random sampling method was employed so as to represent complete area under investigation. Water samples were collected at various stations from dug wells. A total of 30 groundwater samples were collected for water quality during field work along the GPS location. These water samples were investigated for characterizing the contamination of the groundwater and to decide the quality of that sample in the study area. To understand the physico-chemical processes controlling the mineralization of groundwater.

The water samples were collected in one liter capacity pre-washed poly-ethylene containers. To analyze those groundwater samples there need to be well established and equipped lab. The groundwater sample needs to be handle carefully and take care of the tightness of sample container otherwise same contaminants enter in the container during travel time to the laboratory. For trace element analyses, water samples were collected in containers and acidified with 2 ml conc. HNO_3. Prior to collecting water samples, the containers were rinsed with water for 2 to 3 times and dried in sun light for one day.



Map No 3.1: Map showing sampling stations in the study area

Table 3.1: Location of groundwater samples from study area using GPS

Locational information			
Sr .no	**Village name**	**Longitude**	**Latitude**
1	ZENDE WADI	74.0137068	18.40450953
2	TATHE WADI	74.04803088	18.32317297
3	KHALAD	74.07953199	18.32615054
4	KHANAVDI	74.10640778	18.33196631
5	PARGAON	74.1331972	18.35768432
6	GURHULI	74.09743443	18.40599469
7	VANPURI	74.07235664	18.37605059
8	SAKURDE	74.12171115	18.27149604
9	PIMPLE	74.03212722	18.30069578
10	NARAYANPUR	73.98021405	18.29942791
11	KODIT.BK	73.97830885	18.33970518
12	GARADE	73.92752778	18.34902778
13	BHIVRI	73.92656723	18.38919511
14	CHAMBHLI	73.97348972	18.37148213
15	THAPE WADI	73.89935415	18.33759969
16	PATHAR WASTI	73.89953056	18.3760451
17	VARAVADI	73.88862114	18.35403024
18	SOMARDI	73.93472999	18.31946515
19	ASKARWADI	73.89551467	18.40094276
20	KHOPOR WADI	73.96627888	18.39466859
21	SUPE.KH	74.01414453	18.32036192
22	SONORI	74.05069021	18.38632481
23	AMBODI	74.04512007	18.35192715
24	PAWAR WADI	74.01220233	18.36951584
25	SHIVRI	74.08365859	18.2858804
26	DUNE WASTI	74.15484288	18.28438904
27	KOTHALE	74.15678998	18.32276258
28	NARALICHA MALA	74.11936304	18.30370731
29	BHAGWAT WASTI	74.10354939	18.36918179
30	JEJURI	74.17897989	18.28427388

(Source – Field Survey by author)

3.8 Physico-chemical analyses of groundwater samples

After sampling, samples were immediately brought to analytical laboratory and stored at 4^0C. Various physico-chemical parameters analyzed include pH (Digital pH meter DPH504), Electrical conductivity (Digital EC meter DEM900). Total Alkalinity (TA) as HCO_3^-, Calcium (Ca^{2+}), Magnesium (Mg^{2+}) Total Hardness (TH), Chloride (standard titrimetry method), Sulphate (Turbidometry method) phosphate (Stannous chloride method), Nitrate (Brucine sulphate method), Sodium (Na^+) and potassium (K^+) were determined by flame photometric method using Systronic instrument.

3.9 Data processing tools and techniques

GIS is tool for collecting, storing, retrieving, transforming and displaying spatial data for a particular set of purposes. GIS is effective means for the spatial analyses and integration to produce the desirable output and has been used by scientists of various disciplines for spatial queries, analysis and integration for the last three decades (Burrough and Mc Donnell 1998). The variation in the seasonal behavior of heavy metals is largely controlled by the geoenvironmental backgrounds of the area (Pawar et al. 1999). Therefore, in the present work, spatial variation in groundwater quality behavior of aquifer system in pre monsoon and post monsoon condition has been analyzed by using GIS based various thematic maps and analyses techniqes. GIS technique is the modern technique which facilitates weighted index method to generation of various maps required for study.

3.10 Raster Maps, Images and data

Topographic maps (toposheets 47J47F/15 and 47 J/3 on 1:50000 scales) prepared by Survey of India were used to generate drainage map, sample location maps. Geological map of Pune district prepared by Geological Survey of India (2001) was digitized. Basin boundary map of Upper Karha river basin was also prepared. Various GIS tools and techniques were used to prepare various thematic maps in successive chapters to fulfillments of the objectives decided in the previous chapter by the researcher. The present research is totally GIS base work which shows the capabilities of the techniques to solve the geographical issue related to any geographical area.

3.11 Various tools used for data conversion into vector form

Toposheets were attached with masking and mosaic method of GIS tools to prepare single image for Study area. The prepared mosaic was geo-referenced using GIS tools. This image was used as a raster for preparation of various layers related to study. The thematic layers of groundwater chemistry were prepared in Arc-GIS 10.3 software. The various maps related to Purandar taluka were prepared using various tools in Arc-GIS 10.3 software like location of study area, Geological map of study area. These thematic maps were used for various interpretation and correlation with geochemical data. Data analysis was performed to identify and locate the areas of highly contaminated zones as well as levels of contamination of the same.

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CHAPTER - IV

ANALYSIS AND FINDINGS

4.1 Introduction

Water is the main source for all forms of life and keeping the biosphere in a sustainable form. Evaluation and development is not possible on this planet earth without water. Presence of water makes the earth a unique planet in the universe as its surface is covered abundantly by water, besides its occurrence within the crust and the atmosphere. Groundwater is a natural resource, fundamental to life, livelihood, food security and sustainable development. It is also a scarce resource. In Indian context country has more than 17 % of the world's population, but has only percent of world's renewable water resources with 2.6 percent of world's land area. There are other controls on utilizable quantities of water owing to uneven distribution over space and time. In addition, there are iniquitous distribution and lack of a unified perspective in planning, management and use of water resources (National Water Policy, 2012).

In geomorphological context, a landform may give a clue to surface and subsurface water conditions. Therefore, a complete terrain classification is often required to evaluate the hydrological conditions, its availability and for this, geomorphological surveying of landforms becomes essential. Integration of hydrological, geomorphological, geological data minimizes the area for the detailed survey by sophisticated method. Landforms are the configurations of the land surface taking distinctive forms and produced by natural processes of erosion, denudation and deposition (Strahler and Strahler, 1996). The study of landforms, in a drainage basin with reference to hydrology and geomorphology context has become increasingly important for understanding the surface and subsurface water conditions. In fact geomorphology is found to have very close links with both surface and subsurface water conditions (Verstappen, 1983). Geomorphological features of a terrain, generally controls the distribution of precipitation and amount of precipitation that is contributed as runoff as well as for groundwater recharge.

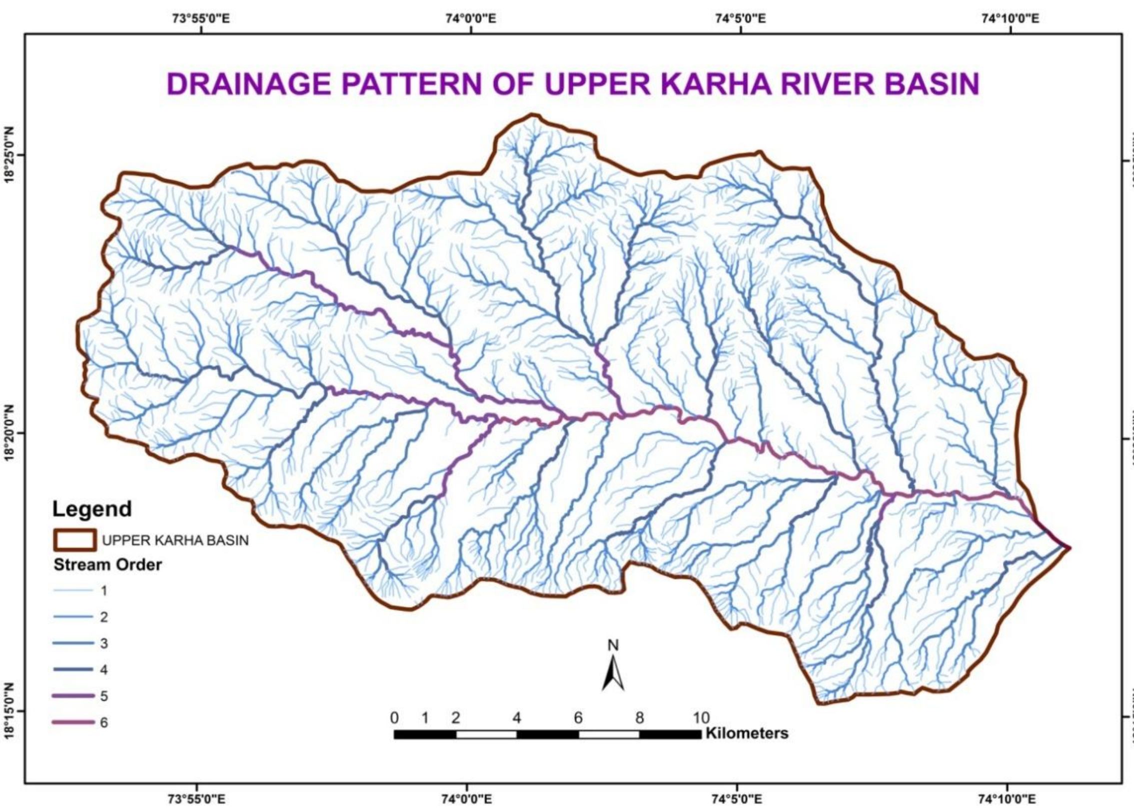
With this approach, the study has been carried out to take an effort to prepare a groundwater potential zone map on the basis of landform characteristics of Upper Karha river basin of Pune district in Maharashtra. Study has been tried to focus out groundwater availability and fluctuations with respect to different seasons. It also focuses on groundwater quality for the domestic as well as agricultural purpose.

4.2 Morphometric analysis of Upper Karha Basin

Morphometric analysis refers as the determinable evaluation of form characteristics of the surface of the earth and any landform unit. This is the common technique in basin analysis, as morphometry form an ideal areal unit for interpretation and analysis of fluvially originated landforms where they demonstrations and example of open systems of operation. The arrangement of the drainage basin stream system is expressed quantitatively with stream order, drainage density, bifurcation ration and stream length ratio (Horton, 1945). It incorporates determinable and countable study of the various parameters such as stream segments, basin length, basin perimeters, basin area, altitude of specific point, slope of the area, volume, profiles of the land portion which shows the nature of development of the basin. It is a common belief among hydro geologists that the surface drainage characteristics of a region determine the sub-surface groundwater status like depth of water table in that region to a significant extent.

Geographical Information system (GIS) and Remote sensing operations using satellite images are used as a potential and powerful tool for analyzing morphometry of any drainage basin. Many researchers have carried out morphometric analysis using these new techniques. Digital Elevation Model (DEM) and Shuttle Radar Topography Mission (SRTM) are widely used in drainage basin analysis.

Landforms are basically defined as the ‘the function of the interaction between forces applied and the materials responding to these forces’. The variations in the intensity, magnitude and frequency of forces and levels of response of the material give to different landforms. The study of landforms not only includes their morphometric characteristics and evolution but also refers to their accumulation and interrelationship as well as the individual landform spread over a given landscape. Various properties of landforms are result of a variety of geomorphic processes and hence, the evolution of landscape needs to take into account all the quantifiable dimensions of the landforms. This becomes essential because the processes are too slow to observe in their entirety. Hence, the information about the processes as well as their role in shaping the landscape needs to be inferred through terrain analysis.



Map No 4.1: Drainage network map of Upper Karha River Basin

4.2.1 Morphometric analysis and GIS

Morphometric analysis is referred as the quantitative evaluation of form characteristics of the earth surface and any landform unit. Geographical information system is the sutable and easy to use technique in drainage basin analysis, as morphometry creat an ideal areal unit for interpretation and analysis of fluvially shaped landforms where they are good example of open systems of operation. Geographical information system is modified modern tool to analyze spatial and non-spatial data sets on drainage, geology, and landforms parameters to understand their interrelationship. All basic information indicated that remote sensing and geographical information system (GIS) as powerful set of tools for assessing drainage basin morphometry and continuous monitoring of drainage basin. The use of (GIS) technique in drainage basin analysis has becoming as a powerful set of tool in recent years particularly for remote areas with limited access.

4.2.2 Linear aspects

The streams present in drainage network transport water and sediments of the basin to single outlet, which is known as the higher order of the drainage basin and that highest order conveniently, take in to consideration for naming that basin. As the size of rivers basins and size river varies greatly as per the order of the basin. To assign stream ordering is the primary stage of basin morphometry. Linear Aspects of Morphometric analysis is includes the Stream Order, Stream length, Stream number, Bifurcation Ratio. Linear aspects are helpful for investigation of the earth surface. Drainage network is most important drainage basin parameter which is vulnerable to change in geomorphic or morphometric environment of any drainage basin. The geological structure and lithology of the area influence the settings of the drainage network or drainage pattern. If the rocks are resistance to the erosion and weathering process that rock definitely differs with the rock type and creates various drainage patterns depending upon hardness of that rock. When surface is essentially flat and rock is homogeneous in nature without any structural or directional control pattern develops along the basin is dendriatic.

Linear morphometric relationships describe streams' hierarchical location in the drainage network, stream number and lengths of segments, and offer a measure of the basin's geometric homogeneity. Stream ordering schemes were first proposed by Horton (1945) then revised by Strahler (1952, 1957) and Shreve (1967). Lineaments are the most prominent features in the rock structure which tells about presence of groundwater.

a) Stream order (U)

To assign stream order is the basic stage in morphometric analysis of a any drainage basin, it based on the hierarchic making of streams proposed by Strahler (1964). It is defined as a measure of the position of a stream in the hierarchical relationship between stream segments their connectivity and the discharge affecting from contribution affecting from contribution catchments. The Strahler's method has been followed in this study; according to his definition the smallest head water tributaries are called first order steams.

Table No.4.1: Stream Order of Upper Karha River Basin

Sr. No	Stream Order	Streams Number	Sr. No	Stream Order	Streams Number
1	1st	1330	4	4th	24
2	2nd	336	5	5th	7
3	3rd	89	6	6th	1

(Source – complied by Researcher)

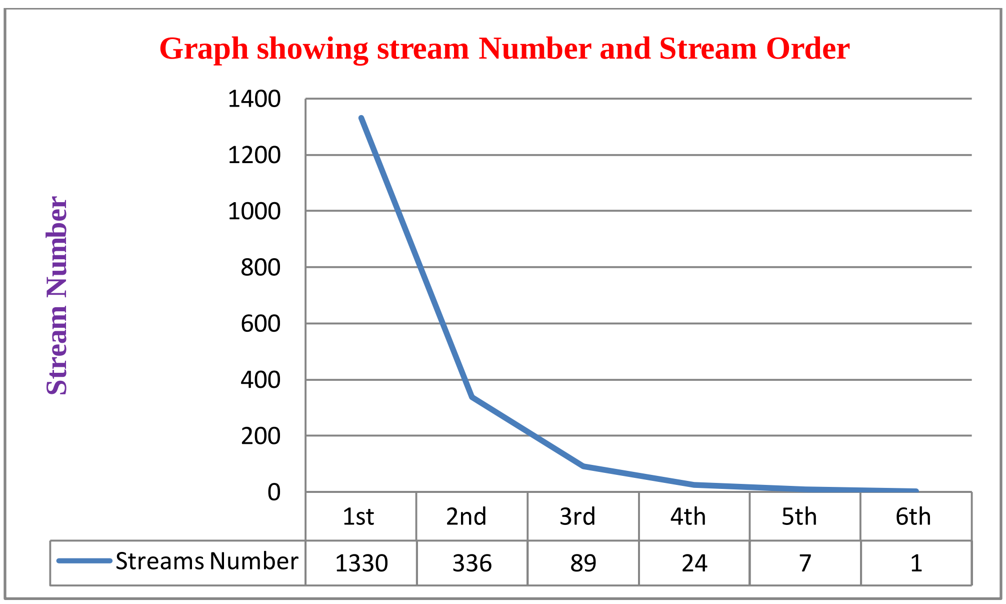


Fig. No:4.1 Stream Order of Upper Karha River Basin

Where two first order streams meet, a second order streams is created. Where two second order streams meet, third order stream is created and so on. It has been retrieved that the highest order in study area. Horton (1945) laws of stream numbers states that the number of streams segments of each order forms an inverse geometric Sequence against plotted order. Most of the time drainage networks of drainage basin show a liner relationship with minute deviation as compare to straight line. Plotting the logarithm of number of streams against stream's order shows a straight line which states the number of streams usually decreases as the stream order increase.

The total numbers of streams are 1787out of which 1330 are of first order 336 are second orders, 89 third orders 24 fourth order, 7 fifth order and 1 sixth order stream observed in the study region from the DEM map extracted in the software. As per law of stream number the number of streams decreases as the stream order increases. The streams have been formed in dendritic drainage pattern. The calculation number of streams in number of orders retrieved that number of stream segments are decrease as the stream order is increase.

b) Stream number

After assigning stream orders, the segments of each order are counted to get the number of segments of the given order. By counting each stream in the drainage basin gives the total number of the streams. It is obvious that the total number of streams gradually decreases as the stream order increases. With the application of GIS, total number of streams of each order present in study area and the total streams were also computed. The total number of stream segments present in each order is the stream number. 'Nu' is number of streams of order 'u'. The total number of stream segments is found to decrease as the stream order increases in the basins.

c) Stream lengths (LU)

The steam length is calculated on the basis of the law proposed by Horton (1945). The stream length of all given orders in drainage basin has been calculated using Arc GIS 10.3 software. The stream length has an significant and confined relationship with the surface flow discharge or simply called overland flow. Longer the length of stream slower the appearance of flood and smaller the length higher the chances of floods in the drainage basin. Stream length has been calculated by using digitization method in Arc GIS software.

Table No 4.2: Morphometry (Linear Aspects) of Upper Karha River Basin

Sr.No.	Stream Order 'u'	Stream Number 'Nu'	Bifurcation Ratio 'Rb'	Mean Length of segment 'Lu' in km	Length Ratio 'RL'
1	1	1330	3.96	0.56	1.34
2	2	336	3.78	0.75	2.40
3	3	89	3.71	1.80	2.06
4	4	24	3.43	3.70	1.76
5	5	7	7.0	6.51	5.59
6	6	1	--	36.38	--
Total or Average		1787	4.38	--	2.63

(Source – Field Investigation)

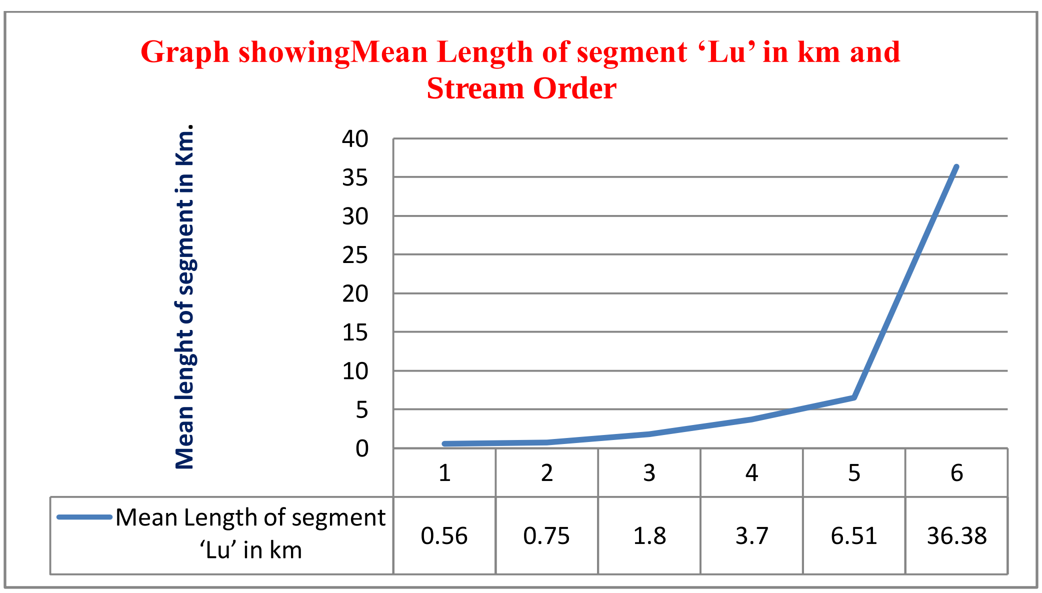


Fig. No. : 4.2 Mean Stream Length

Horton stated that the mean length of stream segments of a given order is smaller than that of higher order and it is in particular ratio called "length ratio". The length ratio is defined as the ratio of mean channel length of an order to that of lower order (Lu+1). Mathematically the length ratio (RL) is given by the formula:**(**RL = Lu / Lu + 1). The length ratio of the Karha basin is 2.63 and the values are presented in table 4.2

d) Mean stream length

The mean stream length is a dimensionless property, characterizing the size aspects of drainage network and its linked surface. It is obtained by dividing the total length of stream order by total number of segments in the order (Table 4.2). The present area mean stream length varies from 0.56 and 36.38. Mean stream length of any given order is greater than that of the lower order and less than of its next higher order, but present study 6th order stream having the highest mean stream length and it is about 36.38 Km.

e) Stream length ratio

It is the ratio between mean lengths of streams of any two successive orders. Horton's law of stream length states that mean length of stream segments of each of the successive stream orders present in given basin tends to more or less a direct geometric sequence, with lengths of the stream increasing towards higher order of the stream. Upper Karha river basin shows discrepancy in stream length ratio in between streams of different order present in particular basin. Change of stream length ratio from one order to another order indicates their late youth stage of geomorphic development

The counts of stream channel in its order are known as stream number. The number of the stream segments decreases as the order increases, the higher amount streams order indicates lesser permeability and infiltration. The number of streams had high influence, on slope character of that region. The total numbers of streams are 1787 and on the basis of all stream order and stream length the graph has been prepared. The average stream length ratio of the Upper Karha river basin is 2.63 and its speaks about drainage conditions of the basin.

f) Bifurcation ratio (RB)

Bifurcation ratio related to the branching pattern of the drainage network is defined as a ratio of the number of streams of a given order to the number of streams of the next higher order. Bifurcation ratio in drainage basin analysis supposed to be controlled by drainage density, entrance angles of streams, lithological distinctiveness, basin shape, basin area etc. (Singh 1998) Bifurcation values are ranging from 3.96 to 7. The higher values of 1^{st}, 2^{nd}, $3^{rd,}$ 4^{th} and 5^{th} order streams indicate well developed stream network. The bifurcation value for 5^{th} order stream is very high as compared to the overall bifurcation ratio of the basin. Bifurcation values ranging from 3 to 7 suggest that it is a natural river system where homogeny is seen with respect to climate prevailing in the area, rock type and stage of development of the drainage basin. The purpose of stream ordering is not only to index size and scale but also to afford an approximate index of the amount of stream flow which can be produced by particular network. It is the ratio of number of streams of any given order to the number of streams in the next lower order (Horton, 1945). In the Upper Karha river basin bifurcation ratio ranges from3.96.to 7.00. The mean bifurcation ratio for upper Karha river basin is 4.38. This means that on an average, there are 4.38 times as many channel segments to any given order as of the next higher order. The average bifurcation ratio of the basin reveals that there appears to be strong geological control in the development of the drainage.

$Rb = N\mu / N\mu + 1$

Where,

Rb=Bifurcation Ratio

$N\mu$ = number of segments of a given order

$N\mu +1$= number of segments of the next higher order

The bifurcation ratio is mainly speaks about the Geological and structural control on the study area, so it is use full parameter to understand Groundwater conditions of any drainage basin.

Table No-4.3: Bifurcation Ratio Analysis of Upper Karha River Basin

Sr. No	Stream Order	Total Stream Length (km)	Total Streams	Ratio
1	1st	745.64	1330	3.96
2	2nd	251.84	336	3.78
3	3rd	160.63	89	3.71
4	4th	88.87	24	3.43
5	5th	45.56	7	7.0
6	6th	36.38	1	--
TOTAL		**1328.92**	**1787**	**21.88**
Mean Bifurcation Ratio				**4.38**

(Source – Field Investigation)

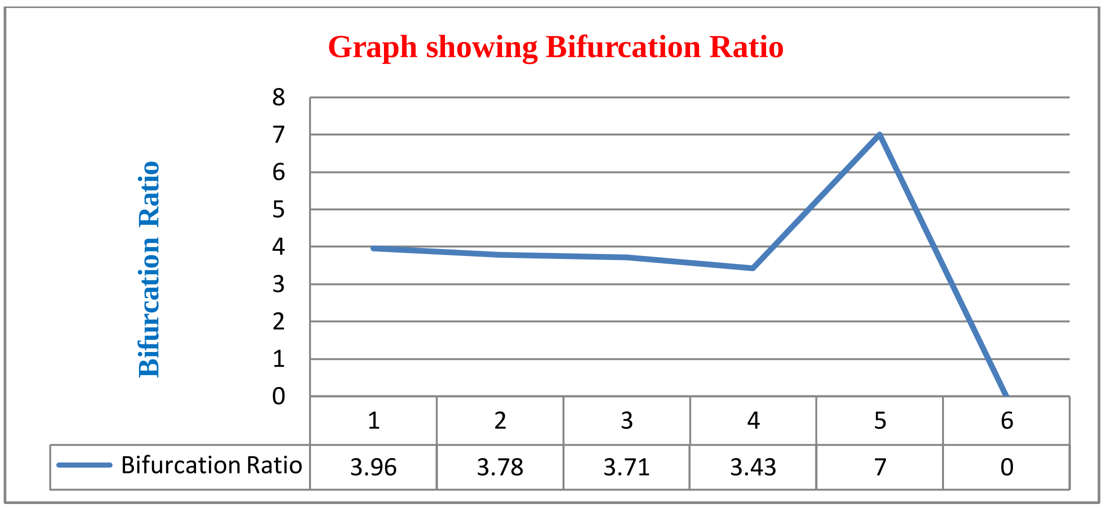


Fig. No. 4.3 Bifurcation Ratio Analysis

4.3 Areal aspects

The areal aspect is the two dimensional properties of a basin. It is feasible to demarcate and delineate the area of the drainage basin which tribute water to each stream segment in the basin area. The drainage basin can be traced or can be identified from where the stream has its confluence point with the stream of higher order along hill tops to pass upslope of the source and return to the point of junction or confluence with higher order stream. This line separates slopes which feed water towards the streams from those which drain in to other streams. The knowledge of hydrologic significance on fluvial Morphometry is obtained by the relationship of stream discharge to the area of drainage basin. The plan metric parameters directly affect the size of the storm hydrograph and magnitudes of peck and mean runoff in the basin area. Area of a basin (A) and perimeter (P) are important parameters in quantitative geomorphology. The area of the drainage basin is defined as the total area expected upon a horizontal plane. The perimeter is the total length of the basin boundary of that particular drainage basin. It is measured along the divide between watersheds and may be used as an indicator of watershed size and shape. The study of aerial aspects include different morphometric parameters, like drainage density, texture of drainage, drainage ratio, form factor, circulatory ratio, length of the overland flow and elongation ratio. Basin area is a very important factor in the study of Morphometry and it is related to various factors such as drainage density, stream frequency, drainage texture, and slope. As the first order stream starts to flow in its own way it takes its source from head ward erosion. It increases the stream length and basin area. Where the area is homogeneous this law works but varies if relief characteristics limit the functioning of basin development. (Singh et al. 1982)

a) Drainage area (A)

Drainage area is most important basin parameter, it is mainly responsible to change in geomorphic environment. The drainage pattern of an area refers the design of the stream courses and their tributaries. It is influenced by the slope of the land lithology and structure. The distribution and attitude of the rock systems and their arrangement also control the drainage pattern. A study of drainage pattern and drainage texture is helpful in the interpretation of geomorphic features and understanding land form evolution. Geological structure and lithology influence the arrangement of the drainage line or network pattern. Resistance to the erosion of the rock differs with the type of the rock and forms various drainage patterns. When rock is homogeneous and surface is basically flat without any directional control dendriatic pattern developed. The drainage network development in the Upper Karha river basin is very typical which is seen everywhere in the hilly basaltic area. The network development in Karha River is mainly controlled by structure. The area of Upper Karha river basin is about 396.2 sq. km. The drainage area (A) is possibly the single most important watershed characteristic for hydrologic design. It reflects the volume of water that can be generated from rainfall. The basin area of Upper Karha river is homogeneous in respect of lithology, geological structure, climate and vegetation cover.

b) Drainage texture (RT)

Drainage texture is the product of drainage density and drainage frequency Horton (1945) defined drainage texture on the basis of frequency of the streams, whereas number of stream per unit area is nothing but the stream frequency. It is related to the degree of looseness of drainage. An essential geomorphic concept is drainage texture by which we means the relative spacing of drainage lines Horton (1945) has pointed out that what we usually refer to as drainage texture assuredly includes both drainage density and stream frequency The texture of drainage is depends upon a various natural factors like climate, rainfall, vegetation, rock and soil type, infiltration capacity, relief and development stages in the drainage area or watershed present in the area (Smith, 1950). The vegetation is helps to produce a fine texture, whereas resistant and massive rocks cause coarse texture of drainage basin. Meager vegetation of parched climate causes finer drainage textures than the drainage texture developed on same rock types in a humid climatic condition. Fine drainage texture of dendritic pattern indicated that the rock formations are impervious and the permeability is low. Soils formed in such area are deep, heavy and slowly permeable. The texture of drainage is defined as the number of total streams segments of total orders per perimeter of the area (Horton). Smith (1950) classified drainage texture into five categories i.e., very coarse (<2), coarse (2-4), moderate (4-6), fine (6-8) and very fine (>8). Horton (1945) acknowledged infiltration capability as the single significant factor which have impact on drainage texture and considered drainage texture which includes frequency of the streams and drainage density. In the case of upper Karha river basin drainage texture is very fine because the value is about 15.10 so the permeability of study region is very less.

c) Drainage density (D)

Drainage density is a significant factor affecting the flow, infiltration capacity etc. It is defined as the ratio of the total length of channels of all orders in a basin to the area of the basin. It has been observed that low drainage density leads to coarse drainage texture while high drainage density decides fine drainage texture properties. It is an average length of channel per unit area of the drainage basin. According to Horton, drainage density is the length of streams per unit of the drainage area.

$$D = \sum Lu / Au$$

Where,

$\sum Lu$ = total length cumulated for each stream order within a given basin area Au.

$$D = 1328.92 / 396.2 = 3.35 \text{ km /sq.Km}$$

The drainage density of Upper Karha river basin is 3.35. The density is high due to the regions of weak or impermeable surface materials and sparse vegetation.

Table No-4.4: Morphometry of Upper Karha River Basin

Upper Karha Basin	Frequency	Circularity Ratio	Form Factor	Elongation Ratio	Relief Ratio
	4.51	0.53	0.34	0.37	13.16

(Source – Field Investigation)

d) Stream frequency (FS)

The term stream frequency is defined as the number of total stream segment present in drainage basin of all order per unit area. As per the size a large size basin may be full of as many sufficient sub tributaries or tributaries per unit of area as a small basin, and in addition to that, it generally contains a larger stream or streams (Horton 1945). It means stream frequency is nothing but total number of streams segment present in any described drainage area or watershed. The stream frequency is computed by the formula i.e.

$F = \sum Nu / Au$

The stream frequency of upper Karha river basin is 4.51, so the texture of the drainage network is of good quality.

e) Circularity ratio (RC)

Circularity ratio is the ratio of the area of the basin to the area of a circle having the same circumference as the perimeter of the basin (Miller, 1953). It is influenced by the length and frequency of streams, geological structures, land – use, land cover, prevailing climatic conditions, relief of the basin and slope of the watershed. The form factor and circularity ratio are the dimensions to analyze the delineate or demarcate outline form of the basin. The circularity ratio of any given basin is the ratio of the area of basin as a circle having the same perimeter as the basin. The value of these ratio approaches to 1 as the shape of the basin approaches a circle. If the values are approaches to '0' it means basin is not circular in shape .It can be calculated as using following formula.

$RC = \text{Area of basin} / \text{Area of Circle} = 4\pi A / P^2$

The circularity ratio of Karha basin is 0.53. Therefore it is semi circular shaped basin because value is approaching towards 1 but not perfectly.

f) Form factor (RF)

Form factor is the numerical index (Horton, 1932) normally used to represent different basin shapes. If the value of form factor is smaller, the basin is more elongated. The basins with having high form factors have high peak surface water flows of shorter duration of time, whereas, the drainage basin has elongated shape with low form factors have lower peak flow of longer time duration. If the basin is elongated in shape it will give maximum time for water percolation. The form factor is defined as the ratio of area of drainage basin to the square of that particular basin length. Horton (1932) suggested the 'form factor' which can be expressed as:

$$F = A / L^2$$

If the 'F' value is higher, then the basin shape is more circular. The 'F' value of Upper Karha river basin is 0.34, Which is medium so it is semi circular shaped basin.

g) Elongation ratio (RE)

Elongation ratio can be defined as the ratio in between diameter of a circle with having same area as that of the drainage basin and the maximum length of the drainage basin. The information about shape of any basin is confirmed by an elongation ratio (Re), simply it is the ratio between the diameter of the circle having same area as the drainage basin. A circular shaped basin is more proficient for discharge or run-off than an elongated shape drainage basin. These values can be grouped into 4 categories namely a circle > 0.9, b Oval 0.9 to 0.8, c Less elongated <0.7, the elongation ratio of Upper Karha river basin 0.37 It is very significant index in the analysis of basin shape to give an idea about the hydrological character of the drainage basin. Values of elongation ratio normally vary from 0.6 to 1.0 with a wide variety of climatic conditions and geological types. Re values close to in the range 0.6 to 0.8 are usually associated with high relief and steep ground slope (Strahler, 1964). These values can be grouped in to three categories namely; Circular, Oval and Elongated. Elongation ration is another parameter introduced to analyze the basin shape. This is defined as the ratio of diameter of circle having area equal to the basin area to the basin length. The elongation ratio of the study area is 0.37 it indicates the Upper Karha River basin is less elongated in shape.

4.4 Relief aspects

The relief aspects of any drainage basin tells about three dimensional features of the drainage basin, it involving area, volume and altitude as vertical dimension of landforms features wherein diverse morphometric methods are used to investigate terrain characteristics. Relief is the difference in elevation of two points, like the heights point on the water divide and lowest point on the valley floor of the region. The relief related measurements like relief ratio, basin length and total relief have been carried out. The various parameters related to the relief aspects of basin and channel network are given bellow

a) Basin relief (H)

Relief of a basin is the maximum vertical distance from the stream mouth (h) to the highest point on the divide (H). The total relief (H) of Upper Karha river basin is 450 meter.

Basin Relief = (H-h) = (1050-650) = 450 meter.

b) Relief ratio (RH)

The relief ratio is the ratio of maximum relief to horizontal distance along the longest dimension of the basin parallel to the principal drainage line is termed as relief ratio (Schumm, 1956). The Relief ratio basically decreases with the increase in area and size of sub-basin of a given drainage basin. The relief ratio is the ratio between total basin relief that is difference in between highest point and the lowest point present in that basin (i.e., difference in elevation of basin mouth and summit) with basin length. It is calculated by using formula as : Rh = H/ Lb.

The relief ratio of Upper Karha river basin is 13.16. It clearly indicates that the relief of the Upper Karha river basin does not have very undulations. The slope angles are also gentle in nature.

c) Basin shape

The shape of the drainage basin generally governs the amount at which the rain water is transported to the main channel having higher order. Basin shape is the main indicator which is used to analyze basin characteristics and relief related information in the studies of morphometry. The elongation ratio of drainage basin is calculated by dividing the diameter of a circle having same area as the drainage basin by the maximum length of the drainage basin, measured from its outlet to its boundary or origin of the river. Three parameters viz. Circulatory Ratio (Rc), Elongation Ratio (Re) and form factor (Rf) can be used for characterizing drainage basin shape, which is an important parameter from hydrological point of view. The shape of the basin on the basis of the above parameters is semi circular in nature.

4.5 Groundwater quality assessment

The source of water supply to the area is through bore wells and dug wells. Irrigated agriculture is depending on adequate water supply of suitable quality. Water quality concern has been plentiful and readily available. For irrigation, the quality of water determines if optimum returns of from the soil can be obtained as the quality affects the soil, crop and water management. Nearly all water contains dissolve salts and trace elements, many of which results from the natural weathering of the earth’s surface (Sultana Nahid and et.al 2009). In most of the irrigation conditions, the principal water quality concern is levels of salinity in the water, since salts content in the irrigation water can affect both the soil structure and yields of crop. The elaboration and implementation of sustainable water use strategies based on the detailed data on the seasonal variation of the water quality that is strongly related to dilution processes taking place during high flow periods especially in post-monsoon seasons, and to the loads of soluble compounds carried by the return waters utilized for drinking and irrigation (Crosa, et al., 2006). The results reveal that except some of the sample’s parameters like, EC, TDS. All other quality parameters are safe for irrigation and drinking purpose. Groundwater in study area is utilized for both agricultural and drinking purposes hence the hydrochemistry is discussed to understand water rock interaction process and to investigate the concentration of the total dissolved constituent present in groundwater with respect to the standards of safe potable water. In the modern world human health is main concern and groundwater indirectly has association with human health, so studying groundwater quality becomes important issue in recent trained. In this topic groundwater quality is the one of the parameter take in to consideration for the assessment.

4.5.1 Role of Geology in Groundwater quality

Geologists use a wide variety of methods to understand the Groundwater potentiality and occurrence of groundwater underneath the rock structure like as field work, rock description, geophysical techniques, chemical analysis, numerical modeling and physical experiments. In practical terms, geology is important for mineral and exploitation, evaluating water resources, perceptive of natural hazards, the environmental problems remediation and providing insights into past change in climate. Geology, a major academic discipline, also plays a role in Groundwater studies. The area consists of Deccan Trap encompassing different types of basaltic flows, separated by red bole. The basaltic lava flows belonging to Deccan volcanic province that flooded during upper Cretaceous to Eocene age.

Table No.4.5 The Stratigraphic sequence and lithology

Formation	Age	Lithology
Deccan Trap	Upper Cretaceous to Eocene	Vesicular and Amygdaloidal Zeolitic Basalt inter bedded with red bole.

4.5.2 Role of Hydrogeology in Groundwater Quality

The area consists of Deccan Trap, encompassing different types of basaltic flows, separated by red bole. The occurrence of groundwater is found in shallow and deep aquifers. The Deccan Trap consists of four types of rocks like compact, amygdaloidal, vesicular, and tachylitic basalt. The groundwater is found in compact basalt due to the presence of secondary porosity, i.e. Fracture and joints in the rocks. Depth of the dug wells are varies as per the rock hardness. The chemical composition of groundwater of the study area is shown in table no.4.5. The chemical composition of the groundwater is totally controlled by nature of geochemical reaction and processes, velocity and volume of groundwater flow, lithology, precipitation and role of anthropogenic activity (Matthes and Harvey,1982; Subba Rao and Reddy 1991, Bhatt and Sakalani, 1996.).

4.5.3 Role of Hydrochemistry in Groundwater Quality

The chemical constituents of groundwater are result of geochemical processes occurring due to the reaction of water and geologic materials (Appelo et al. 1996). The hydrochemistry of the groundwater assesses based on EC, TDS, Ca, Mg, TH, Na, K, NO_3, SO4 etc. (Table no - 4.6.). In post-monsoon period (October 2014) it is observed that the average concentration of EC, TDS, Cl, Ca, Mg, TH, TA, are within the permissible limit. The pre-monsoon seasons the concentration of these elements increases, in post-monsoon seasons may be due to the effects of leaching during rainy season (K. Srinivasamurthy, et. al 2009). The concentration of sodium (Na) was more in pre-monsoon and potassium (K) has remained constant values in both the seasons, it is indicating that lower geochemical mobility. Nitrate (NO3) and sulphate (SO4) shows more concentration indicate infiltration of surface water into groundwater during rainy season. Nitrogen in groundwater is mainly derived from fertilizer or nitrogen fixing bacteria leaching of animal's dung in agriculture field, sewage and septic tank from city area or industrial influent.

4.6 Assessment of Groundwater quality in the Study area

The groundwater quality standards for drinking water have been mentioned by the World Health Organization (WHO) in 2004.The behavior of major ions (Ca, Mg, Na, K, HCO3, SO4, Cl) and important physico-chemical parameters such as pH, electrical conductivity of groundwater (EC), total dissolved solids in groundwater (TDS), and total hardness of groundwater (TH) and the suitability of groundwater in the study area are discussed below. The values of groundwater samples are compared with BIS and WHO standards for the quality assessment of groundwater for domestic as well as agricultural practices. The data has been analyzed and represents in terms various thematic maps and finally by using weighted overlay index method the areas of ground water suitability and non suitability has been find out with the help of raster analysis techniques.

Table No.4.6 Physico-chemical parameters and it's comparison with standards

Parameters	WHO (2004)	Highest Desirable Limit	ISI (1995)	Post-monsoon 2016/2017		
	MPL		MPL	Min.	Max.	Ave.
pH	8.5	6.5-8.5	6.5-9.2	8.00	9.1	8.52
EC	1400	....	....	516.00	2930	1123
TDS	1500	500	1500	336.00	1885	719.60
Cl	1000	250	1000	28.00	568.00	179.66
Ca	500	75	200	14.00	192.00	62.92
Mg	100	50	100	5.00	48.00	24.00
CO_3	……	300	600	Nil	90.00	30.00
HCO_3	……	…….	…….	214.00	732.00	446.60
Na	22.00	…..	……..	14.00	40.30	22.44
K	…..	…….	…….	0.40	3.20	1.46
SO4	400	200	400	24.00	68.00	42.40
NO_3	45.00	…….	45.00	35.20	44.50	40.53
TA	…	300	600	214.00	792.00	465.10
TH	…….	…….	…..	82.00	600	298.40

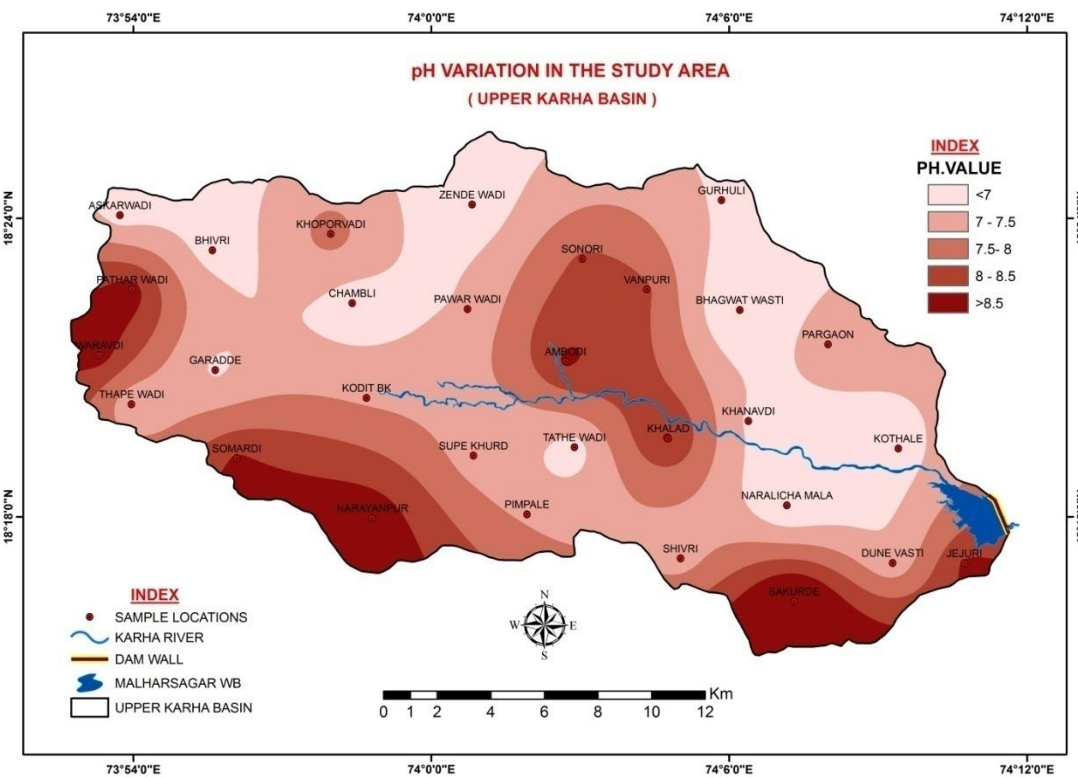
(Source – WHO, ISI and Field work)

4.7 Groundwater suitability for drinking in Upper Karha River Basin

The exploratory results have been evaluated to determine the appropriateness of groundwater in the study region for drinking and agricultural purposes. The analytical outcome in terms of results for all the parameters of the groundwater samples in the study area from post monsoon are presented in the (Appendix – I)

a) pH

Power of hydrogen (pH) is a measure of the balance in between the concentration of hydrogen ions and hydroxyl ions in water. The (pH) of water gives very important information in many types of geochemical equilibrium or solubility calculations (Hem1985). The limit of (pH) value for drinking water is specified as 6.5–8.5 (WHO2004, 1996; ISI1993, 1995).



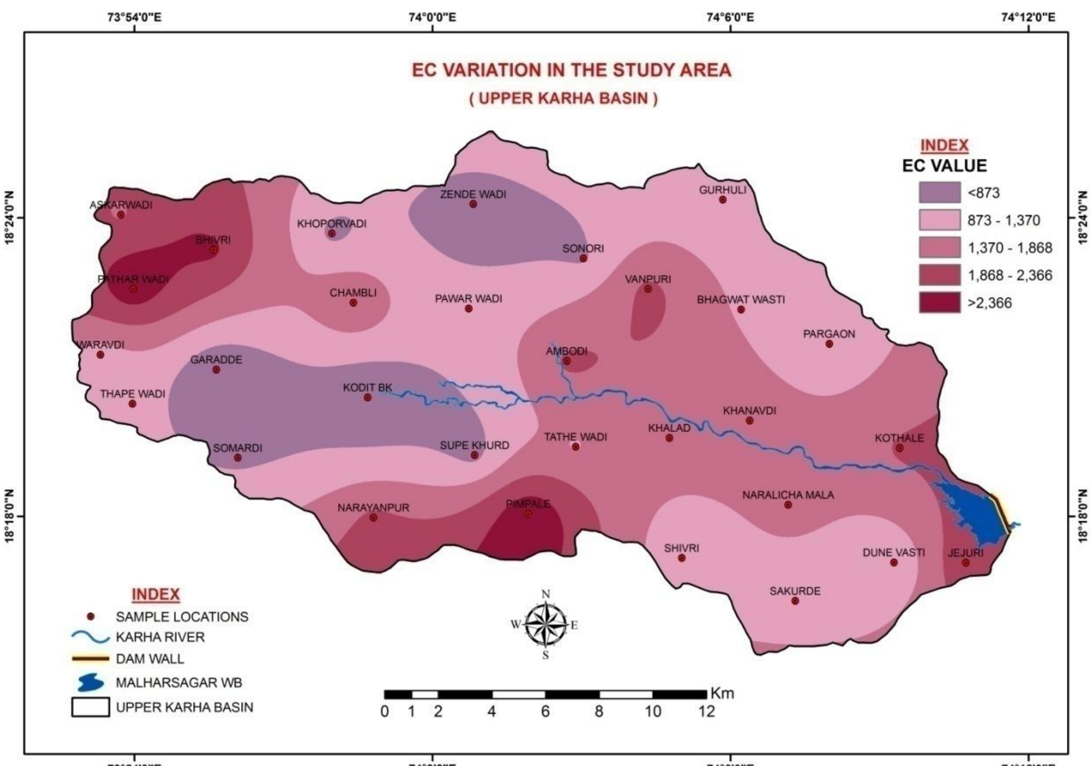
Map No 4.2: pH variation in Upper Karha River Basin

The (pH) value variation in most of the groundwater samples in the study area varies from 6.5-9.00 and average is 8.52. In map (no 4.2) (pH) variation of study area is displayed and it clearly mentioning that the villages namely Pathar Wadi, Waravdi, Narayanpur, Ambodi, Sakurdi and Jejuri showing high Ph value it indicates that the

Groundwater present in this area is not suitable for drinking as per values are concern. All remaining villages in the study area are comes under permissible limit category but with this improper management of west water the will become contaminated in the future.

b) Electrical Conductivity (EC)

Electrical conductivity is a measure of water capacity to convey electric current (Sarath Prasanth.et.al. 2012.). It is used to calculate approximately the amount of dissolved solids present in the water. It definitely increases as the quantity of dissolved mineral (ions) increases. In the study area, the value of conductivity ranged between 816.00 and 2930 and average is 1123 S/Cm.

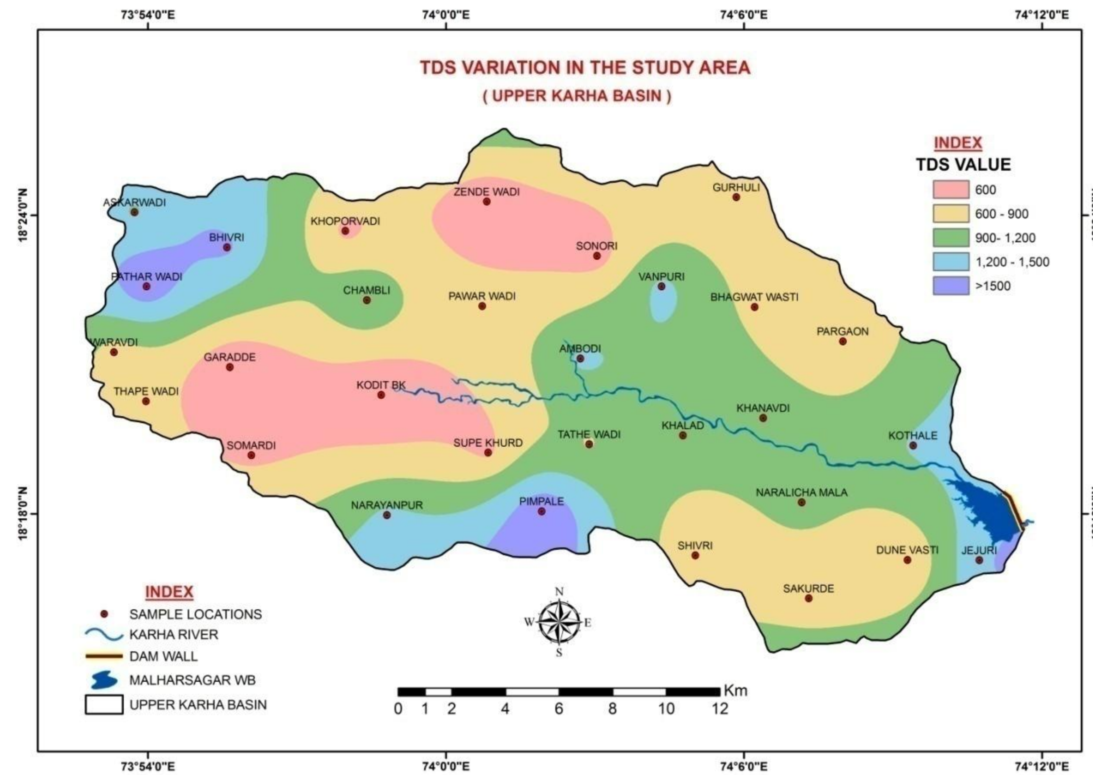


Map No 4.3: Distribution of EC

The maximum concentration of electrical conductivity (EC) in the study is 2930 S/Cm (0.25 ds/m) which is above WHO (1996) permissible limit. This could be related total slightly acidic condition (Obiefuna and Sheriff - 2011). In map (no-4.3) the villages namely Bivri, Patharwadi and Pimple showing higher concentration of EC which leads to higher conductance of water in terms of minerals.

c) Total dissolved solid (TDS)

Total Dissolved Solid (TDS) generally reflects the amount of minerals content that dissolved in the water, and this controls its suitability for use. High concentration of total dissolved solid may cause adverse taste effects. Highly mineralized water may also deteriorate domestic plumbing and appliances (Obiefuna and Sheriff, 2011).

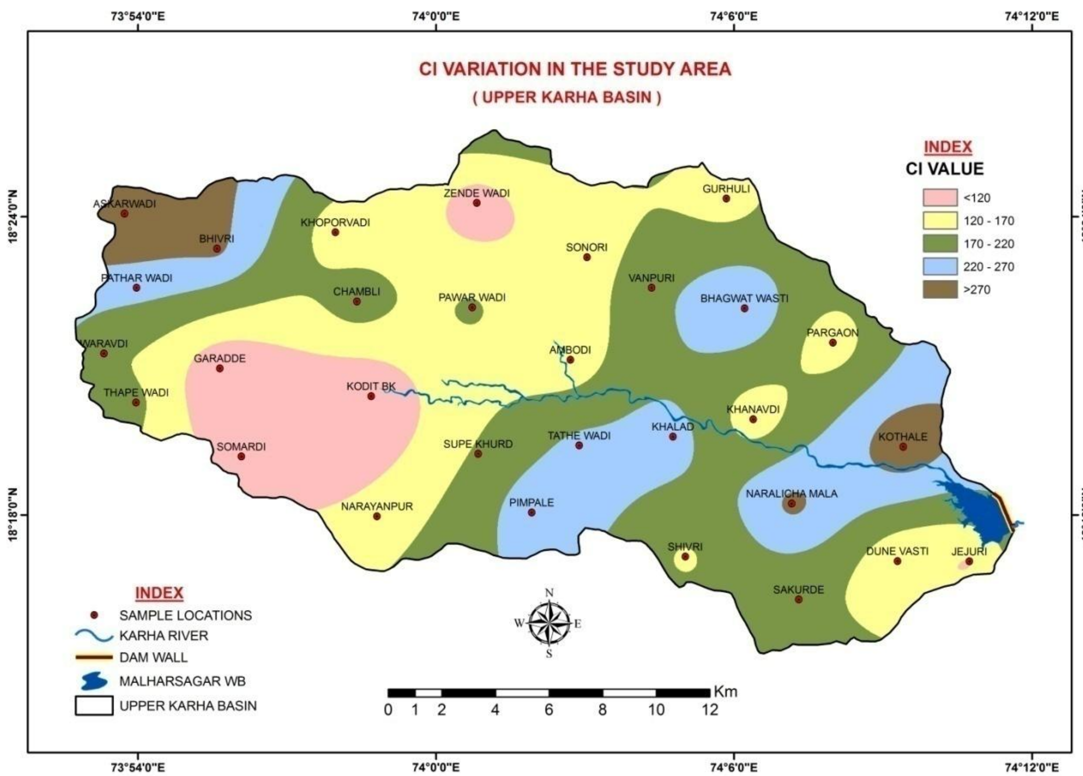


Map No 4.4: Distribution of TDS

In the study area, the concentration value of TD ranged between 336.00 to 1885 mg/L with the average value is 719.60 in post-monsoon season and the average concentration of TDS is within the permissible limit. It must be said that the water is thus good for human consumption (domestic) and agricultural purposes. The higher concentration of TDS is observed at bhivri, Patharwadi and Pimple villages.

d) Chloride (CL^-)

A major ion that may be associated with Individual Septic Disposal System (ISDSS) is chloride (Canter and Knox, 1985). Chloride is there in all-natural waters, typically in relatively small amounts; however, chloride also can be derived from human sources. Chloride is not effectively removed by the septic systems and therefore, remains in their effluent high concentration of chloride in water is known to cause no health hazard, hence, its readily available in almost all potable water.

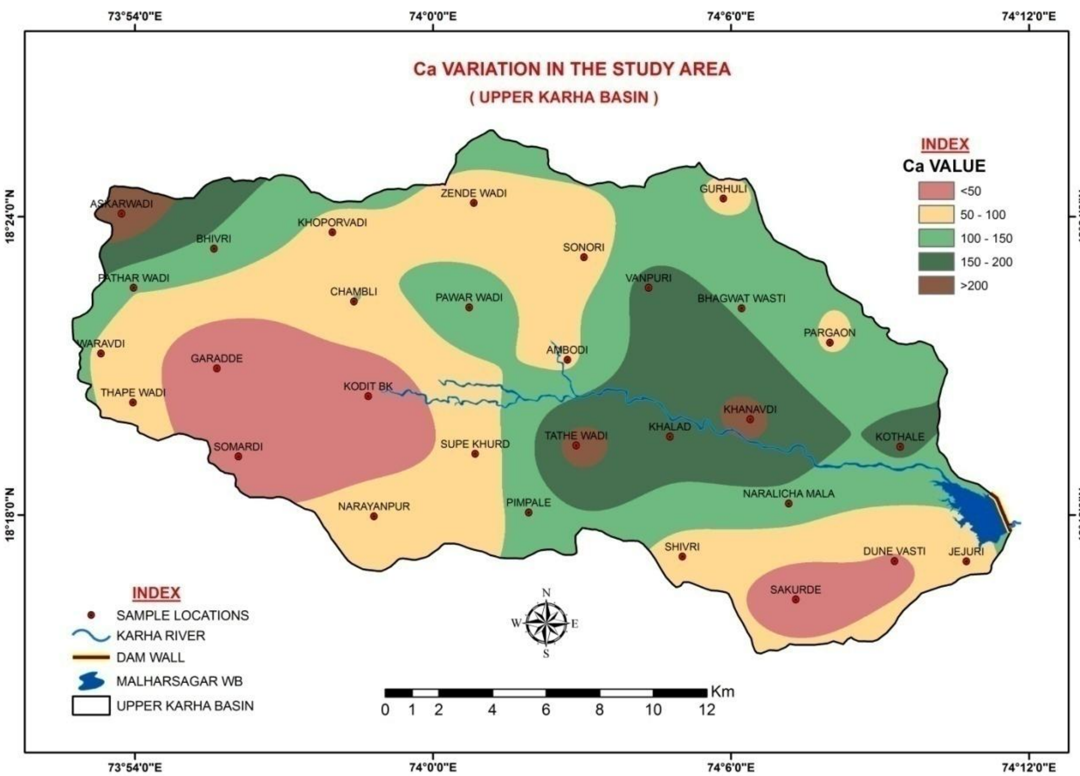


Map No 4.5: Distribution of Cl

In the study area, the concentration of chloride is range between 28.00 to 568 mg/L, and average is 179.66 in post- monsoon season. The average value of the Chloride is within the permissible limit. In map (no-4.5) Bhivri, Askarvadi Naralicha Mala and Kothale village showing the higher concentration of Cl. The villages namely Garade, Zendevadi, Somardi and Kodit budruk showing the lowest concentration of Cl in the study area.

e) Calcium (Ca^{2+}mg/L)

Calcium present in water contributes to the hardness of water resource and it is the fifth and most common element found in the majority of natural waters. The sources of calcium matter in ground water especially in sedimentary rocks types are calcite, aragonite, gypsum and anhydride (Obiefuna and Sheriff, 2011).

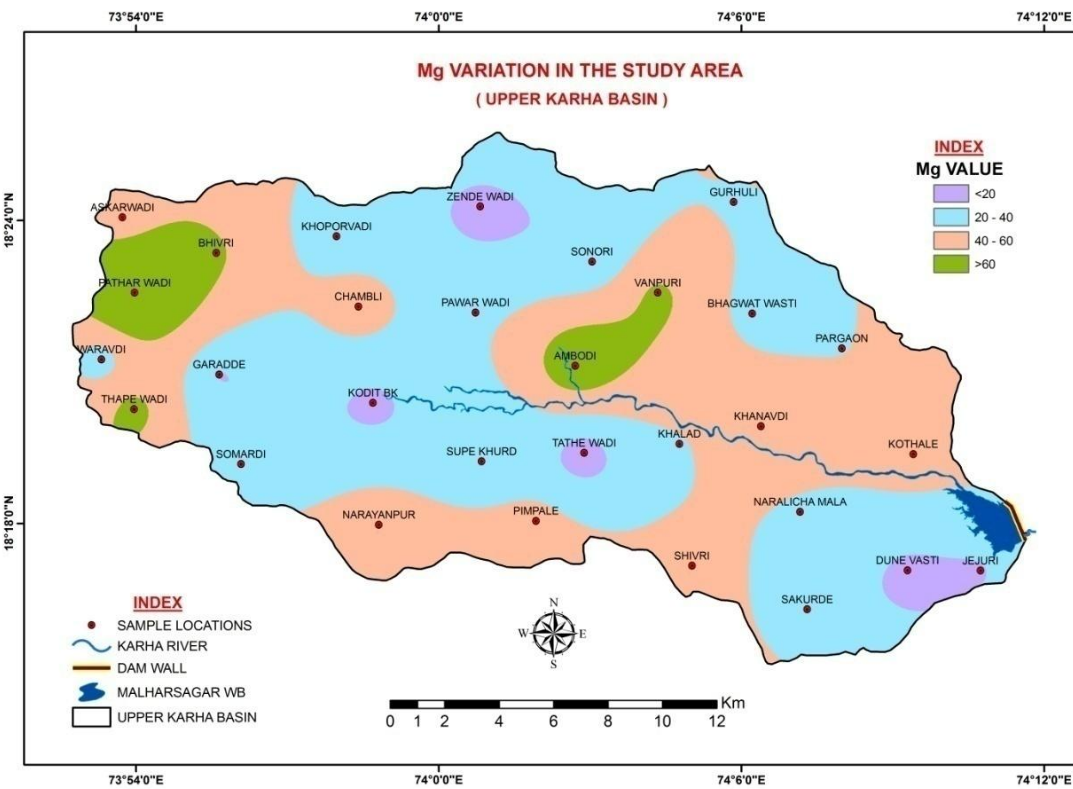


Map No4.6: Distribution of Ca

The calcium concentration in the sampled well in the study area is 14.00 to 192.00 and average is 62.92 in post monsoon season. All the values of Ca are within the permissible limit of (WHO1996). The possible source of this calcium is limestone or gypsum. The calcium concentration is very much high at the villages askarwadi, tathewadi, Khanavdi, vanpuri, Khalad, Kothale, Patharwadi and Bhivri. The lowest concentration of Calcium is observed at the villages Garade, Kodit Budruk, Somardi, Sakurde, Chambhli, Sonor, Zendewadi, Narayanpur, Supe khurd, Shivri, Dune wasti, and Pargaonin the study area.

f) Magnesium (Mg^{2+})

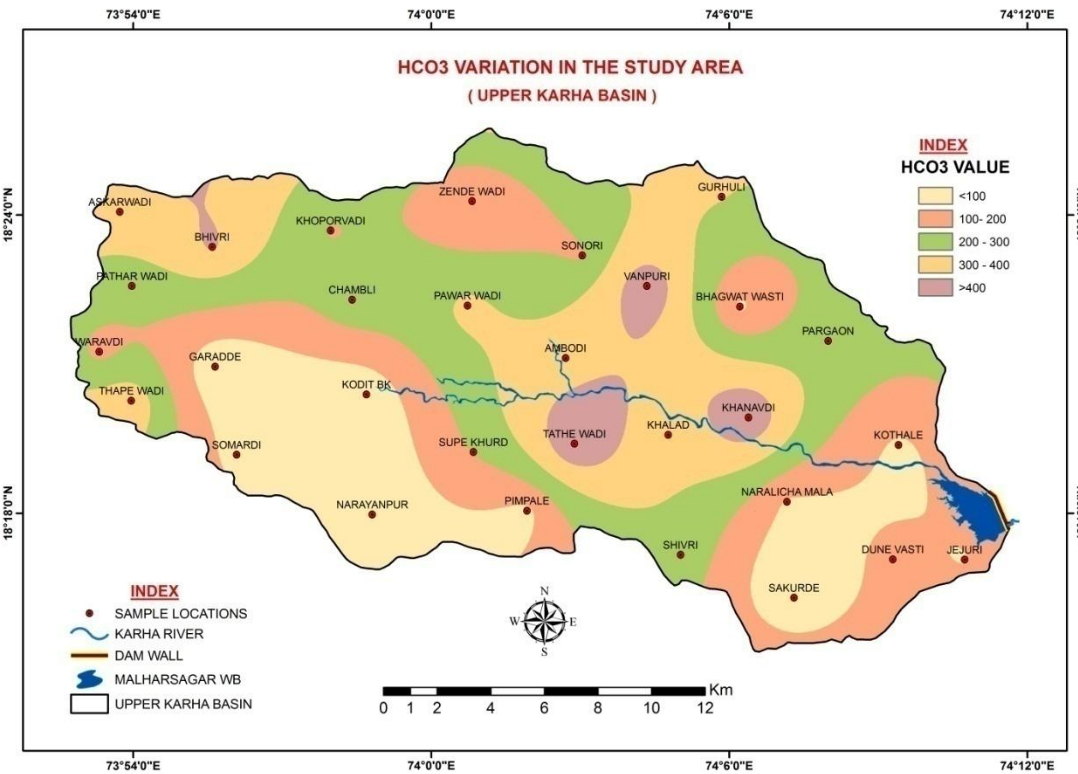
Magnesium is one of the most common elements in the earth's crust. It is present in all-natural waters. It is an important contributor to water hardness. The sources of magnesium in natural ground water are mafic minerals and dolomites (amphibole) in rocks. The solubility of dolomite in water depends on the composition. The concentration of (Mg) in study area is ranges from 5.00 to 48.00 and average is 24.75. All the values of Mg in study area are within the permissible limit and the water quality is good for the health.



Map No 4.7: Distribution of Mg

g) Total alkalinity

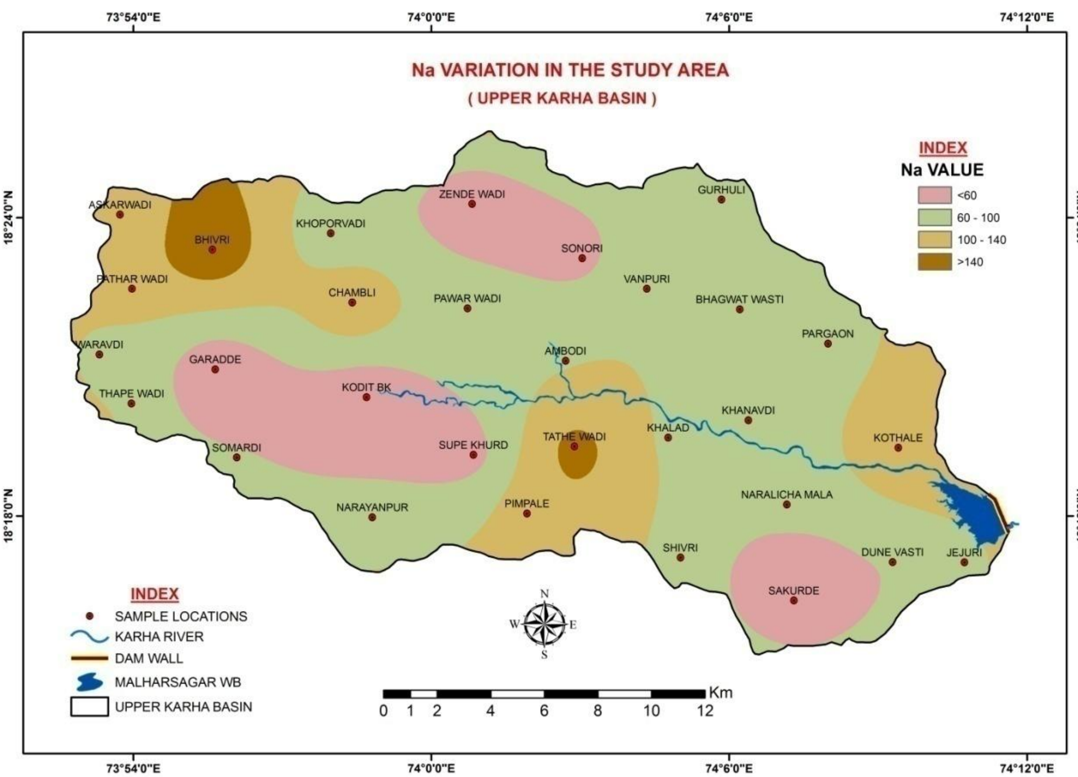
Total alkalinity is a measure of the capacity of water or any solution to neutralize or "buffer" acids. This quantification of acid-neutralizing capacity is significant in figuring out how "buffered" the water is against abrupt changes in pH. The alkalinity supposed to not be confused with pH values. The pH is a quantification of the hydrogen ion (H^+) concentration, and the pH scale shows the concentration of the acidic or basic character of a solution at a given temperature. The reason alkalinity is sometime mystified with pH is for the reason that the term alkaline is used to explain pH conditions greater than 7 (basic). The mainly important compounds in water that decide alkalinity include the carbonate (CO_3^{2-}) as well as bicarbonate (HCO^{3-}) ions. Carbonate ions can react with and neutralize 2 hydrogen ions (H^+) and the bicarbonate ions are capable to neutralize H^+ or hydroxide ions (OH^-) present in particular water.



Map No 4.8: Distribution of HCO^3

h) Sodium (Na)

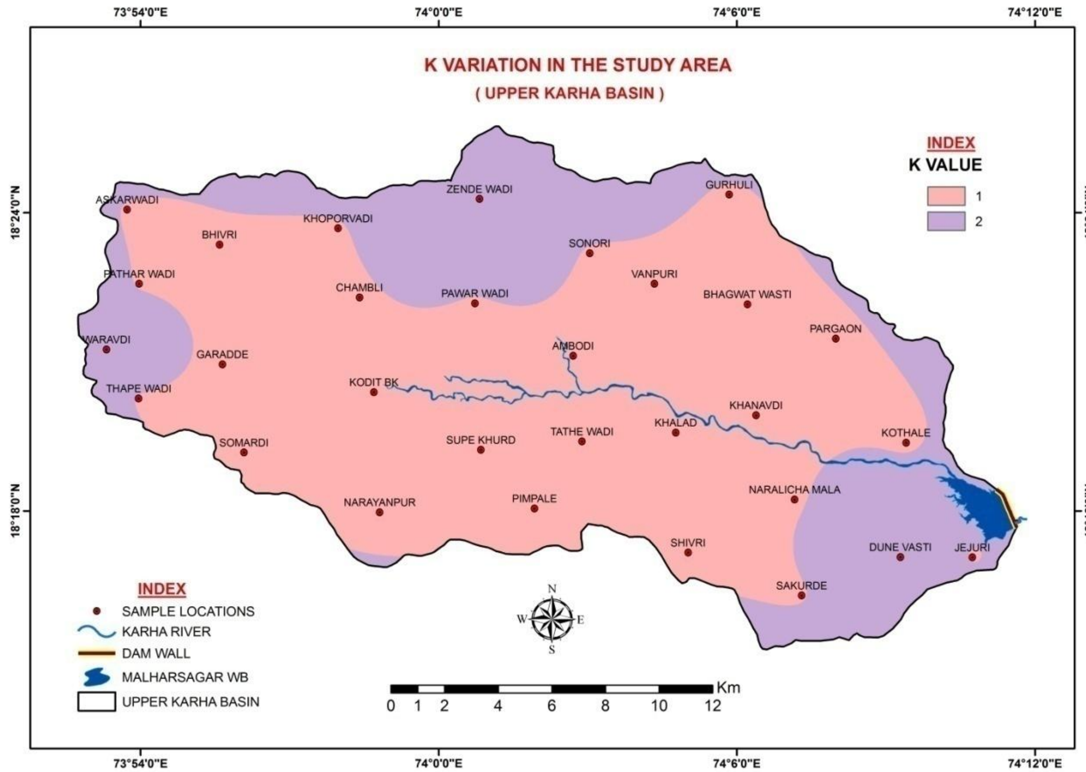
Sodium is an important constituent for determining the quality of irrigation water. Sodium bearing minerals elements akin to albite and other members of plagioclase feldspars, nepheline and sodalite weather to release the primary soluble sodium products (Pradhan Biswajeet, et. al.2011). Most sodium salts are readily soluble in water, but take no active part in chemical reactions. Sodium has extensive variations in its concentration in ground water. The sodium content of the samples was determined by a flame photometer. Sodium content in the water samples varies between 14.00 and 40.30 and average is 23.44 in post monsoon season. In map (no-4.9) the villages namely Tathewadi and Bhivri are showing the higher concentration of Na in groundwater samples of that area. The study of distribution of Sodium is the important parameter to study in the assessment of groundwater quality.



Map No 4.9: Distribution of Na

i) Potassium

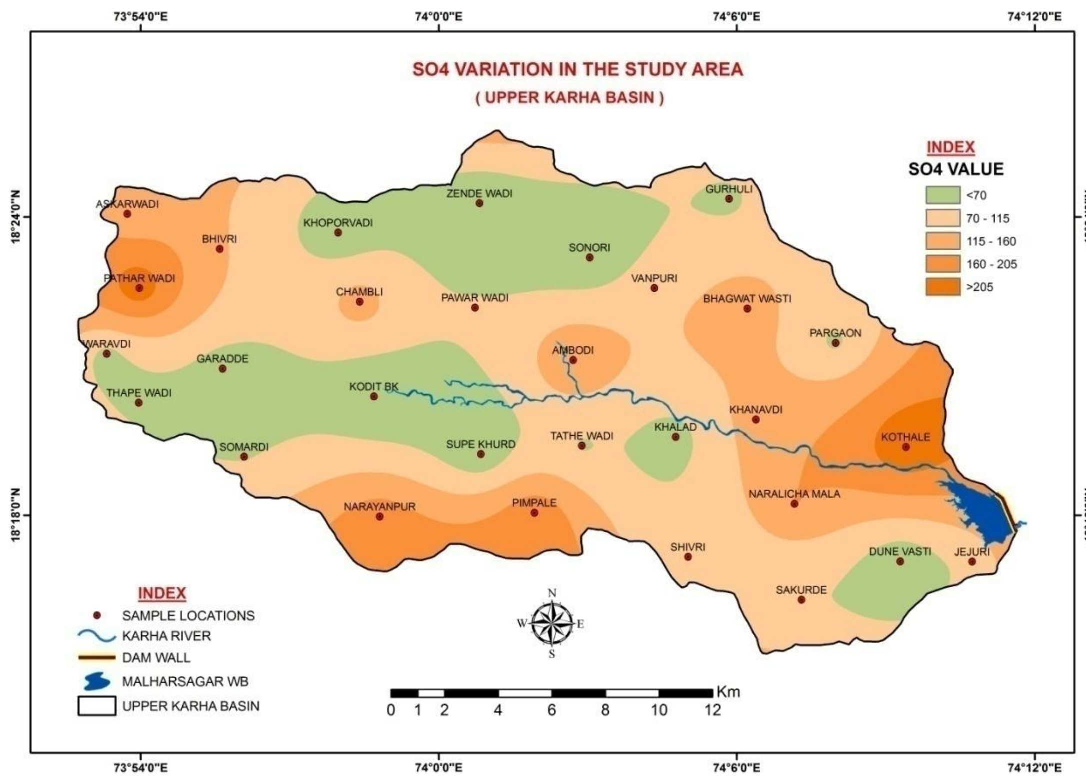
The potassium is almost as plentiful as sodium in igneous rocks, its concentration in ground water is relatively very less as compared to sodium nearly one-tenth or one-hundred that of sodium (Pradhan Biswajit and et, al.2011). This is due to the fact that the potassium minerals are resistant to decomposition by weathering. The potassium concentration in the water was deter-mined with the help of Flame photometer. The concentration of Potassium in study area in post monsoon varies from 0.40 to 3.20 and average is 1.46.



Map No 4.10: Distribution of Potassium in the study area

j) Sulphate (SO_4^{2-}) mg/L

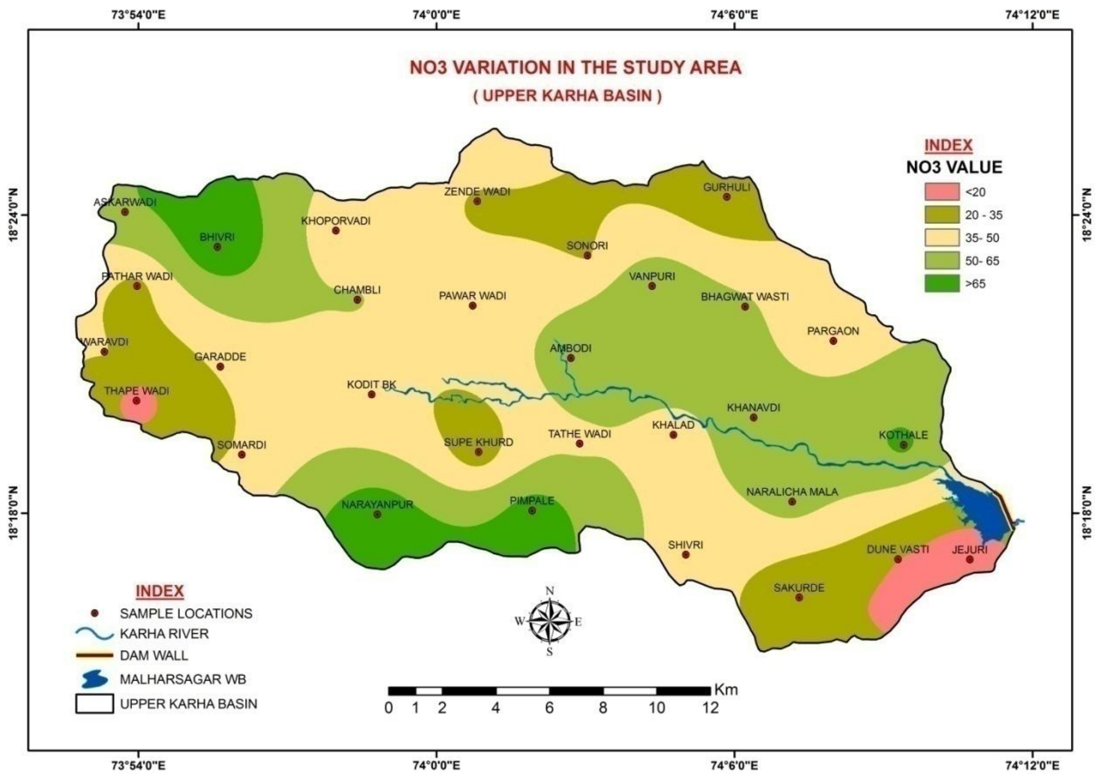
Sulphate occurs in water as the inorganic sulphate salts as well as dissolved gas (H_2S). Sulphate is not a harmful substance although high amount of sulphate in water may have a laxative effect. The concentration of sulphate (SO_4^{2-}) in study area is in between 24.00 to 68.00 with the average value of 42.40011mg/L in post-monsoon season. The highest permissible limit of SO_4 is 300 all the values are below this limit. The high concentration of sulphate in the other settlements is likely due to the dissolution of gypsum. The distribution of sulphate along the study area is shown in (map no 4.11) and it clearly indicates that the concentration of sulphate is as compare higher at the Narayanpur, Pimple, Pathar wadi, Chambhli, Bhivri, Askarwadi, kothale, Ambodi, Bhagwat wasti and khanavdi. All these values are below the permissible limit but at some locations the concentrations is little bit high as compare to other sample locations of the study area. Even though the sulphate is not harmful but keeping its concentration in control is the need of the hour.



Map No 4.11: Distribution of Sulphates

k) Nitrate (NO3):

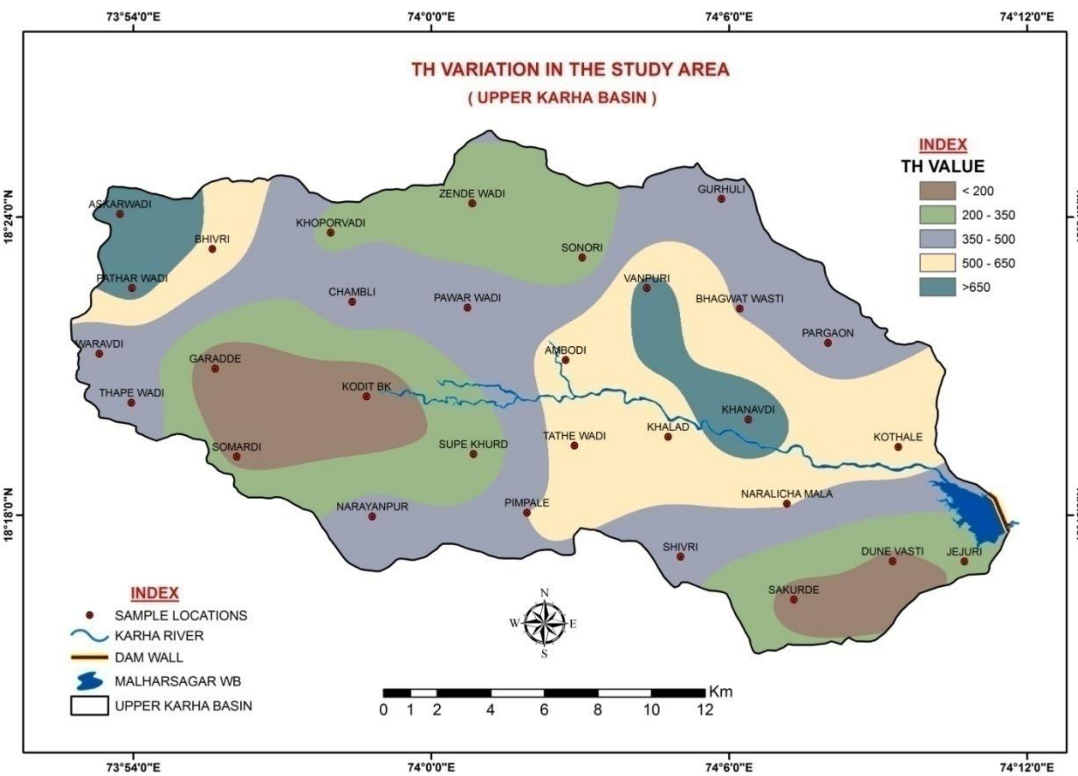
Sources of nitrate in water include human activity such as appliance of fertilizer in farming related practices, human and animal waste which somewhere related to population. The concentration of NO_3 is ranges from 35.20 to 44.50 and average is 40.53 in post-monsoon season. The possible cause may be the highly populated and the human waste management system is poor (shallow pit toilets and open defecation in the bushes) and the use of nitrogenous manures and animal dung in farming is a likely source of input into the ground water of this chemical (Obiefuna and Sheriff, 2011). In the present map (no 4.12) the distribution of Nitrate has been shown and it is indicating that the concentration of nitrate is much higher at Bivri, Narayanpur and Pimple villages respectively and the moderately high concentration is observed at the Kothale, Khanavdi, Ambodi, Naralichamala, vanpuri and Bhagvat vasti villages. All other villages are having comparatively medium concentration amount of nitrates along the study area and it may causes the health related issues for the residents of the study area.



Map No 4.12: Distribution of NO3

l) Total hardness (TH)

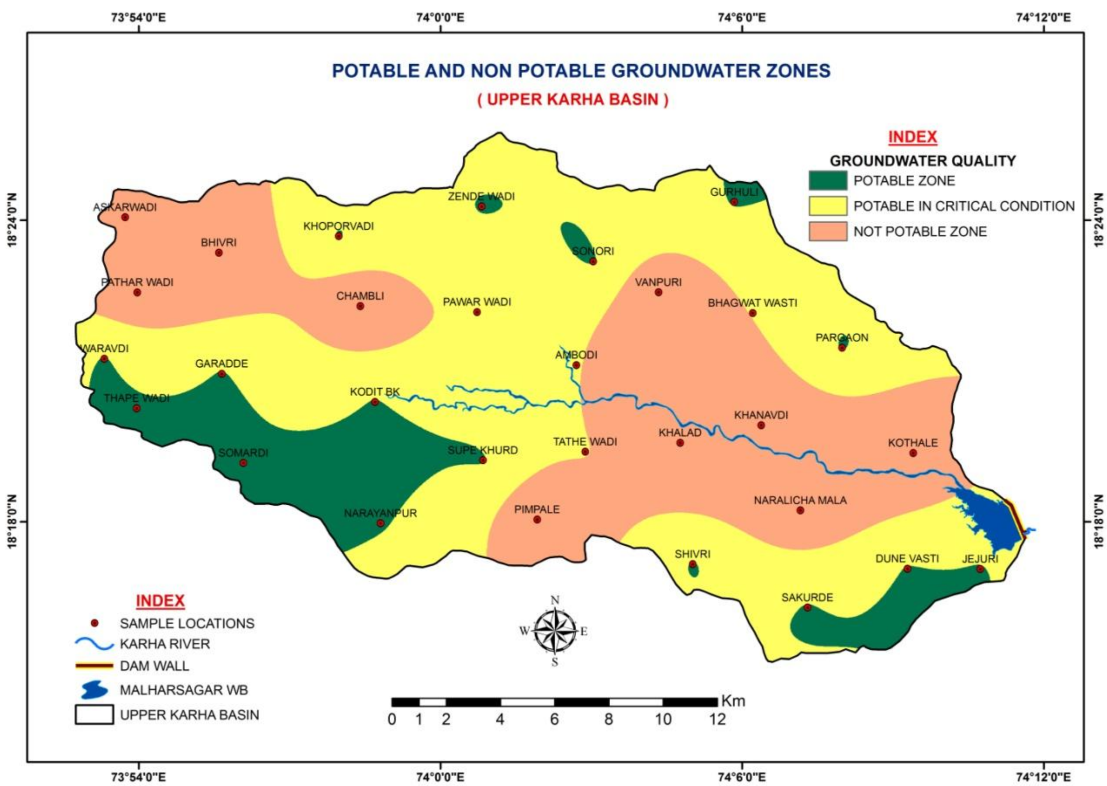
The total hardness is varying from 82.00 to 600.00 and average is 298.40 in post-monsoon season. Groundwater of the total study area lies within the maximum acceptable limit prescribed by ISI. Sawyer and Mc Carty (1967) classified groundwater, based on TH, as ground water with total hardness of 75, 75–150, 150–300 and 300 mg/l, designated as soft, moderately hard, hard and very hard, respectively. Very few samples in the study area are falling under the category of very hard type of groundwater and it is not at all suitable for drinking purposes. The hardness is increases due to presence of metallic minute particles in dissolved forms in the water. In the map (no-4.13) the distribution of total hardness is displayed in five different categories and as per the distribution the higher total hardness is found along Askar wadi,Pathar wadi,Bhivri, Khanavdi and vanpuri. The lowest concentration is observed at Kodit budruk, Garade, Somardi, Sakurde and Dune vasti. All remaining area is falls under moderately hard groundwater areas and such type of water is not good for the health of people.



Map No 4.13: Distribution of TH

4.8 Potable and non potable ground water Zones in the Study area

Assessment of such issues is really having great concern with people residing in the study area. It will give clue to managing the resources or use of resources through proper methods and it will make them think about the sustainability of the resource in terms of water quality. In the present research to understand the groundwater suitability for the drinking purpose Weighted overlay index method has been potentially used in the Arc GIS environment. This tool facilitates all those raster operations of the thematic layers prepared for each parameter and displayed it in such way that software can easily perform the raster operations on it. Finali the out put map is generated wich ables to disply the potable and non potable zones of the Groundwater in the study area. The map of groundwater potable and non potable zones clearly give us the idea about the areas of sutaible groundwater for drinking and non sutable areas for drinking along the Upper Karha river basin and from which people can understand the areas of contaminated water. Some areas are falls under potable in critical condition it means that it is on the edge of contamination and in futre the sample sites may have contaminated water in this areas.



Map No- 4.14 : Potable and non potable groundwater zones along the study area

In above map (no- 4.14) three groups of groundwater are displayed and those are Potable, non potable and potable in critical condition. The potable zone is observed along the villages namely Sakurde, Dune vasti,Thape Wadi, Somardi, some part of Zendewadi, sivri, Narayanpur,Jejuri, Sonori and Pargaon. The groundwater quality of these areas is in good condition. Most of the villages are falls under non potable groundwater zones namely Pimple, Naralicha Mala, Kothale, Khalad, Khanavdi, Patharwadi, Askarwadi, Bhivri and Chambhli. The remaining villages from these two categories are comes under potable in critical condition because the groundwater present in this area is on the margins of contamination levels or permissible limits mentioned by BIS and WHO Standards. These areas can be utilizes by applying some primary water purification processes and can be make suitable for drinking in the critical conditions.

4.9 Assessment of Ground water quality for Irrigation purposes

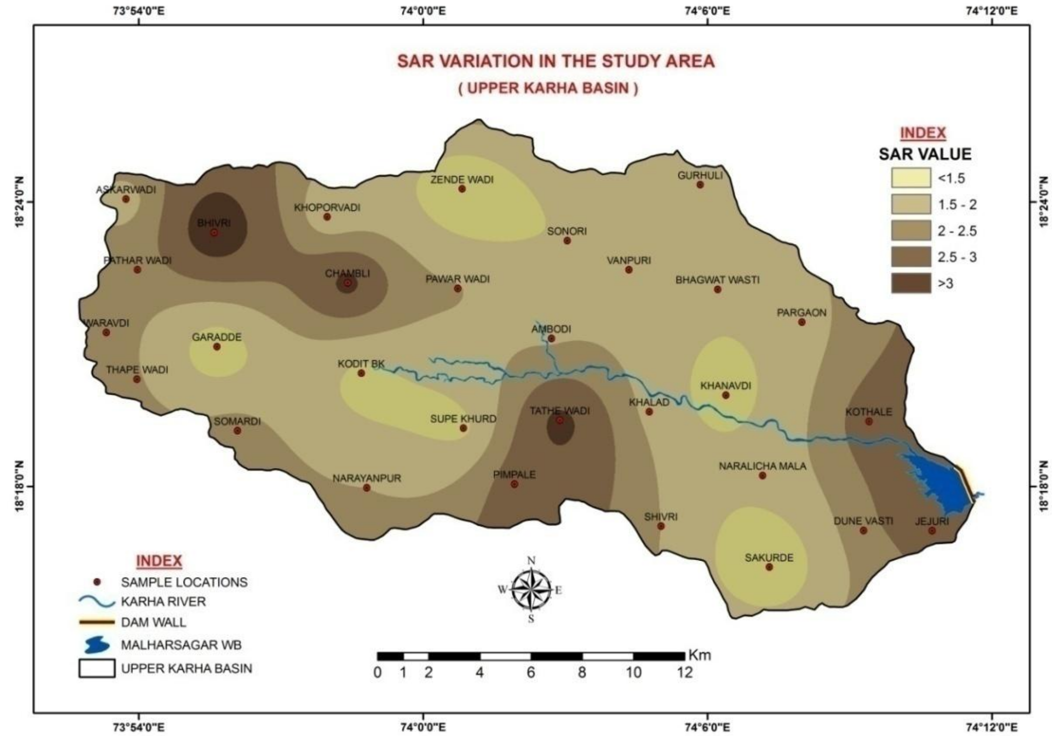
The assessment of the groundwater quality of the present study area was carried out to decide its suitability for domestic and agricultural purposes. The water for each of these purposes is requiring some desired safety standard that has been set by either World Health Organization or agencies (Obiefuna and Sheriff, 2011).Most of the population in the study area is depending upon agricultural earnings and hence it is becoming a mandatory task to assess the quality of groundwater for the agricultural uses. The SAR and RSC are the parameter which conceders very much important to assess the quality of groundwater for its suitability of agricultural uses.

a) Sodium adsorption ratio (SAR)

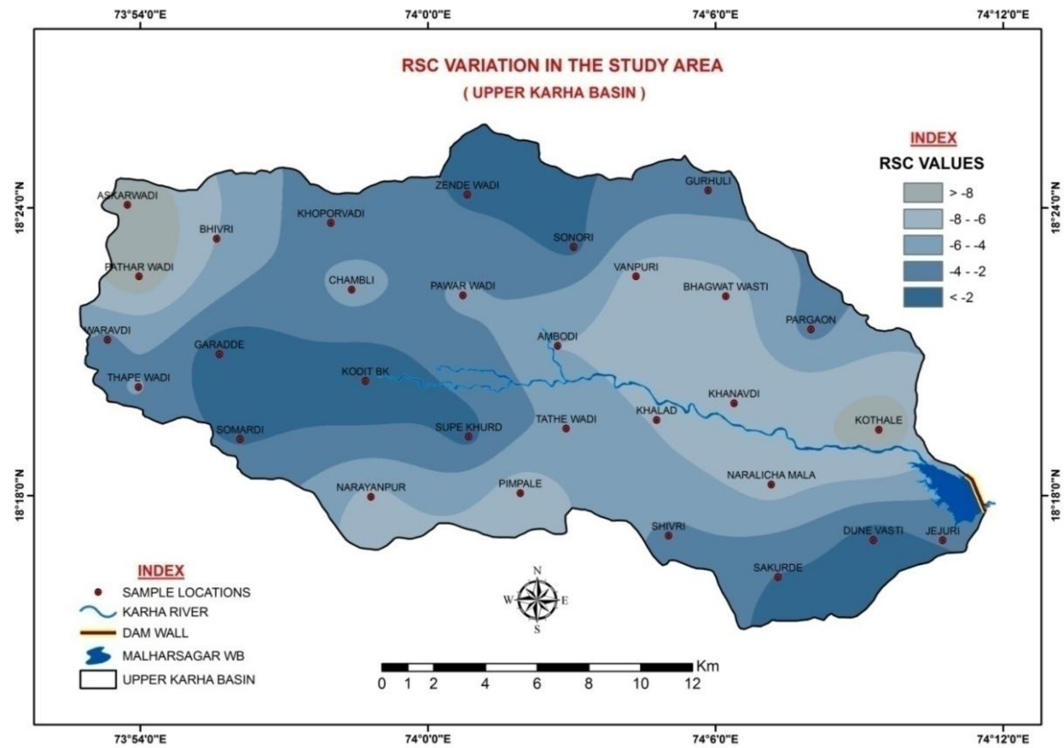
The sodium adsorption ratio is the basic parameter used for understanding the suitability of ground water quality for agricultural purposes. It also used in management and understanding about sodium affected soil areas in the region. It is working as indicator for irrigation suitability. Irrigation is the important factor for the agriculture sector in the study area, so studying its suitability have great concern here. Sodium adsorption ratio is calculated by using following formula and sodium adsorption ratio is calculated for all the samples collected from the field.

$$\text{S.A.R.} = \frac{Na^{+}}{\sqrt{\frac{1}{2}(Ca^{2+} + Mg^{2+})}}$$

As per the classification of SAR ratio suggested by Raghunath (1987) if ratio less than 10 it is very good quality for irrigation purposes. On the basis of SAR values all water samples from the study area belongs to very good quality.



Map No 4.15: Distribution of Sodium adsorption ratio



Map No 4.16 : Distribution of Residual sodium carbonate

b) Residual Sodium Carbonate (RSC)

The values for RSC is calculated as per Eaton, (1950) RSC= (CO3 + HCO3) - (Ca+ Mg) All values expressed in meq/L. Accordingly Lloyd and Heathcote (1985) have classified irrigation water based on RSC as Suitable (< 1.25), marginal (1.25 to 2.5) and not suitable (> 2.5).

According to RSC values of water samples from study area range from -10.2 to -1.2 suggesting that the all of the samples suitable to irrigation.

c) Piper diagram

The Piper- tri-linear diagram (1953) is used to infer hydro-geochemical facies. These plots include two triangles, one for plotting cations and the other for plotting anions (figure 4.6). The anions and cation fields are collective to show a single point in a diamond-shaped field, from which inference is drawn based on hydro-geochemical facies concept. These types of tri-linear diagrams are very useful in bringing out chemical relationships within groundwater samples in more unambiguous terms rather than with other possible plotting methods. The analyzed chemical data of representative water samples from the study area is obtainable by plotting them on a Piper-tri-linear diagram for post-monsoon season. These diagrams explain the analogies, non similarities and different types of ground waters in the study area. The concept of hydro-chemical facies was developed to understand and identify the water composition in different classes. Facies are recognizable parts of different characters belonging to any genetically related system.

Hadrochemical facies are distinct zones that possess action and anion concentration categories. To define composition class, Back and co-workers (1965) suggested subdivisions of the tri-linear diagram (figure 4.4). Piper diagrams are an good example of water quality diagrams which are almost certainly the most regularly used in today's practices. The subdivisions of the trilinear or piper diagram depict that Na-Ca-HCO3, NaCa HCO3, Mg-HCO3, and HCO3 type of water was dominated during post-monsoon in study area (Fig.4.4). The considerable change in the hydro-chemical facies was noticed during the study period (post-monsoon), which was might be due to the leaching of alkali salts through precipitation (TomarVikas et.al 2012). Hydro chemical evaluation of groundwater indicates that Na-Ca-HCO3 type water dominates during pre-monsoon and Mg-HCO3 during post monsoon seasons of the year and $NaHCO_3$ waters shows high sodacity with high soluble sodium percentage and residual sodium carbonate.

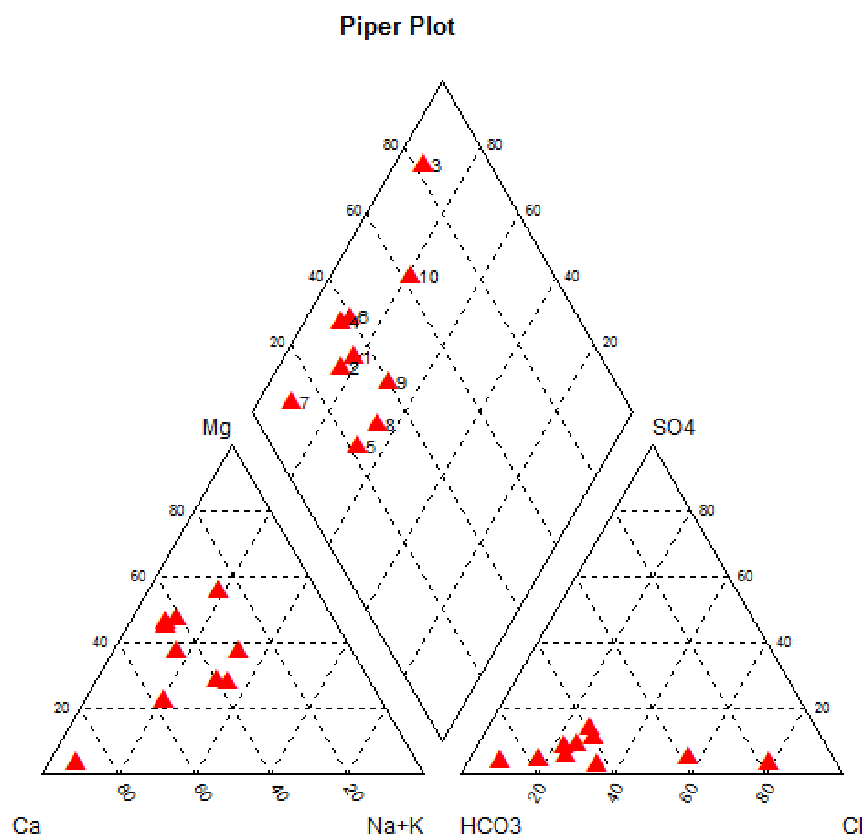


Figure 4.4: Classification diagram for anion and cation facies in the form of major-ion percentages (Piper, 1953; Back and Hanshaw, 1965; Sadashivaiah et al., 2008).

d) Salinity hazard and alkali hazard

Based on EC values, Richards classified total concentration of soluble salts in irrigation water into four groups. High-salinity problems are encountered where irrigation activity is in poor drainage agricultural soils and where water logging allows the water table to rise close to the root zone of plants, causing accumulation of sodium salts in the soil solution through capillary rise following surface evaporation. The sodium or alkali hazard in the use of water for irrigation is determined by the absolute and relative concentration of cations. The relative activity of sodium ion in the exchange reaction with soil is expressed in terms of SAR. If high sodium content and low calcium content is present in waters used for irrigation purpose, the base-exchange complex may become saturated with sodium. This can destroy the soil structure due to the de-flocculation (dispersion of clay particles) process. The U.S. salinity Laboratory's Diagram uses electrical conductivity, and SAR classifies groundwater. The groundwater quality of study area according to U.S. Salinity Diagram is classified into four classes (Table 4.7). This classification is mainly based on the concentration electrical conductance ranging from excellent to unsuitable. Only 10% of the groundwater samples are falling in unsuitable field.

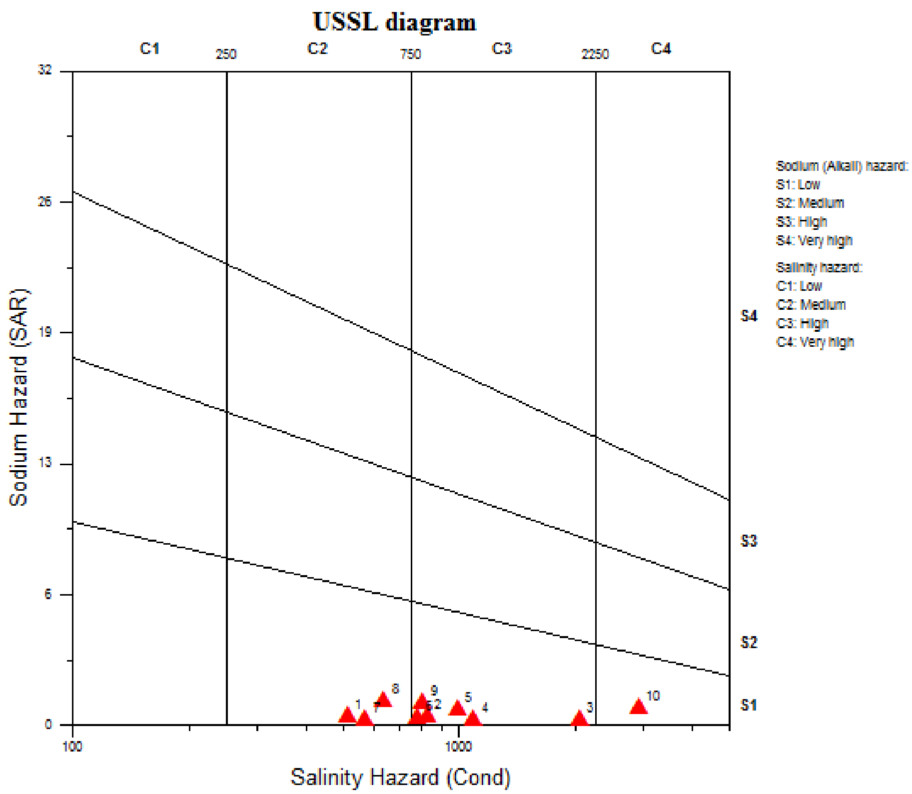


Figure 4.5 U.S. Salinity Diagram

As per the salinity hazard diagram most of the samples are falls under C2 and C3 quadrants it means some samples are good in quality for agriculture and some of them are on the marginal line. Few samples are falls under C4 quadrant which shows unsuitable nature for the agricultural practices and may be samples present in C3 quadrant will contaminate in future.

Table. 4.7 Classification of Groundwater on U.S. Salinity

Salinity hazard class	EC in (Micromohs /cm)	Remark on quality	Percentage of Samples
C_1	100-250	Excellent	Nil
C_2	250-750	Good	30%
C_3	750-2,250	Doubtful	60%
C4	>2,250	Unsuitable	10%

(Source - U.S. salinity Laboratory)

4.10 Groundwater potential

Groundwater is the fully saturated sub-surface water mainly received from atmospheric precipitation deposited in water bearing sedimentary rocks, cracks and crevices in crystalline rocks and subsequent penetration and cooling joints. When rain falls is appears, some of the rain water converted in to run-off, some get evaporates and the remained soaks into the ground. Therefore, the water soaks into the ground or infiltrated water is the primary source of groundwater. Water below the ground surface occurs in four zones viz; soil moisture zone, intermediate zone, capillary zone and saturation zone. The zone in which this water is held is known as the zone of aeration or unsaturated zone, which is characterized by partially water filled and partially air-filled voids and pores. At the base of the intermediate zone, is the capillary fringe a thin layer (ranging from few cm to 3m) in which water has been drawn upward by capillary force. Underneath the zone of aeration, lies the zone of saturation. This is also known as phreatic zone or groundwater zone or water table. There is a vadose zone, lies in between the topsoil water zone and lower capillary zone, in which water percolates down to the water table. The present chapter incorporates the principle source of ground water. Beside the prime sources, factors determining the occurrence of groundwater sources also discussed here. The occurrence of groundwater mainly depends upon climatic conditions, soil characteristics, vegetation cover, land use and lithology of rock in the area. Though the precipitation is prime source of groundwater recharge, out of total precipitation received, major part is lost through evapotranspiration, from soil and plants. Some part flows as runoff and only small amount of rainwater infiltrates through the soil to underlying strata or aquifers (Babar 2005).

4.10.1 Sources of groundwater

Groundwater includes all sub-surface water in a solid liquid or gaseous state other than that which is chemically combined with any mineral present (Siddharth K, 2000).

There are four sources a ground water.

I. Connate water
II. Juvenile water
III. Meteoric water
IV. Condensational water

(I) Connate water: Connate water is the water trapped in the interstices of sedimentary rocks at the time of their depositions. It is usually highly mineralized and is not involved in active groundwater circulation, although connate waters may be expelled from their original location by compaction pressure and migrate, accumulating in more permeable formations.

(II) Juvenile water: The water that originates from the interior of the earth from condensation of steam of uncertain origin and has not previously existed as water in any state. Juvenile water is that water which is considered to have been generated in the interior of the earth and have reached the upper level of the earth surface for the first time. It is furthermore called as magmatic water. The term was coined by Meinzer (1923) who contrasted juvenile with meteoric water.

(III) Meteoric water: Meteoric water is derived by precipitation in any form from the atmosphere. It falls as precipitation and became groundwater by infiltration. Meteoric water constitutes the bulk of groundwater and this is evident in the fluctuation of water level in winter and summer seasons. The term originally defined by (Meinzer 1923 and K.Siddhartha 2000) in contrast to Juvenile water.

(IV) Condensational water : In the deserts of arid or semi arid regions, particularly in summer the land is always warmer than air in the soil. In such situation, the water is the results in a difference of pressure between the water vapor in the atmosphere and the water vapor in the soil. The water vapor from the atmosphere penetrates into the rocks and is converted into water as the temperature of the water vapor drops below. This water is the basic source of replenishment in arid and semi-arid areas.

4.10.2 Factors determining the occurrence of groundwater sources

The occurrence of ground water sources in any region are not evenly distributed but controlled or determined by various factors. Its occurrence is determined by climate (occurs at greater depths in deserts and shallow depths in humid regions) and topography (higher at high altitude and lower near the valley flats/ water sources). The materials types i.e. underground rock structures determining porosity and permeability that plays important role in water infiltrations.

a) Topography : The upper Karha river basin is confined by high hill ranges comprising of Deccan Trap Basaltic lava flows. The height of the all hill ranges varies from 1000 to 1250 m comprising 12% of the basin area. The piedmont topography of the study area having average height of 700 to 1000 m and its comprising 27% of the basin area. The Valley plains below 700 m comprises 61% basin area. These three zones categorized namely. Runoff zone, recharge zone and storage zone are the topographic expressions.

b) Type of material / Underground rock structure : Upper Karha river basins covers hard and massive basalt. Laterite is developed as capping on basaltic flow and occurs at various altitudes, mainly it founds near Narayanpur and Garade. Average depth of sammital sediment/kaolinitic clay deposits varies between 2 to 5 m. Porosity (texture) and permeability are two most important properties, which determines the storage and movement of groundwater. Porosity (Texture) and permeability of the soils in the Karha Basin are comparatively permeable however water-holding capacity is medium. Still it bears aquiclude properties. Weathered basaltic terrain bears water, which is percolated through the faults joints and weaker zones and carried by same type of zones. Water percolated and seeped through these faults and weaker zones. Veins like calcite and other vesicles have good storage capacity.

4.10.3 Prime groundwater sources in the basin

Groundwater refers to water in a zone of Saturation consists of geologic stratum usually referred as aquifer. Aquifer is a self-defining term as it split into aqua + fer, where aqua means water and fer refers to bearing. Groundwater hydrology is defined as the science of the occurrence, distribution and movement of water underneath the surface of the earth. Geohydrology has an identical connotation, and hydrogeology plays an important role in determining the water bearing, storing and transmitting capacity of rocks. Three major geological features - (a) lithology (b) geomorphology and (c) structure, controls the flow and occurrence of the groundwater in nature. Rainfall is a prime source to recharge to the groundwater. Rainfall and aquifer characteristics with infiltration capacity of the Upper Karha river Basin have been discussed below, which contributes as a main source of groundwater.

a) Infiltration: - Infiltration is the vertical movement of water through the soil surface into the soil. Under specified conditions, the actual rate at which the water is absorbed by soil is known as infiltration rate and the maximum rate at which the water can penetrate the soil under a given set of conditions is defined as the infiltration capacity (Horton, 1932). The rate of infiltration is determined by the soils initial moisture content, surface permeability, physical and chemical characteristics, temperature, duration and intensity of rainfall. Infiltration occurs mainly by diffusion, suction and gravitation. Rainwater infiltrates into land surface both vertically as well as horizontally. The horizontal movement is due to transmission of moisture by soil matrix. A portion of the infiltrated rainwater finally reaches the groundwater storage or aquifer which develops the quantity and quality of groundwater. In Upper Karha River Basin hilly area i.e. moderate to steep slope (upto 30^0) are characterized by coarser soil texture. Hence in the hilly region, with medium vegetation cover and medium rainfall (800 mm) zone of the Upper Karha River Basin shows medium rate of infiltration capacity. Soil profile on the gentle slope (0^0 to 2^0) topography shows soil with loamy texture indicates low infiltration capacity. In the Upper Karha River Basin silt and clay content of the soil increases with decreasing gradient of the surface.

b) Other Sources: - Surface water is a common term usually describing any water body of running or standing on the surface in the form of streams, rivers, lakes, ponds and reservoirs. Surplus precipitation that escapes evapo-transpiration or infiltration, become surface runoff and directly contributes to the streamflow. The rainwater may either in the form of overland and seep from the soil may reach the river as subsurface flow or known as throughflow.

c) Open well lithologs: - The details of the well lithologs for 30 wells in the Upper Karha River Basin have been accurately observed. These observed (field survey) litholog units were also compared with the litholog constructed by GSDA, Pune. The variation in the thickness of the lithological units with their material composition was also considered during the well inventory. From this data detail open well lithologs of 30 wells were prepared.

Depending upon the well location, two or more lithological units recorded to get further information. Wells situated in or along the channel or foothill zones shows alluvium, colluvium, gravel and sand, jointed basalt with massive basalt at the base. Study of lithologs indicates that some of the sections can independently act as an aquifer for that well. The open wells are helpful to understand underground lithological structure in the geomorphological and hydrological studies.

4.10.4 Potential

The study of groundwater potential requires appropriate knowledge of its or source, occurrence and movement, which are directly or indirectly controlled by landform characteristics. There is need of study of Groundwater potentials because of its importance. There has been increasing awareness among the geographer, geomorphologist, geologists, planners and water resources scientist, to study the potentiality, availability, development of management of groundwater resources in the last four decades. Groundwater generally escapes direct observation, except where it emerges in spring or is tapped by wells, bore wells. There is no direct method for the evaluation of groundwater. In geomorphological perspective, landforms may give indication to subsurface water conditions. Various landforms of having structural, denudational and depositional origin play an significant role in the understanding of groundwater potentials. On the basis of landforms and their characteristics identified in the upper Karha River Basin, the groundwater potential zones can be classified as Good, Moderate, Low zone, Very low zone and no groundwater zone. In the present chapter occurrence of groundwater and relationship between landforms and groundwater potentials have been discusse. As the main aim of the present investigation is Assessment of groundwater potentials, landforms present in the upper Karha River Basin and their groundwater potentiality has been described in detail in this chapter. The last section attempts different maps showing various groundwater potential zones, on the basis of landform and other important parameters like landuse and landcover , DEM, Slope, Drainage density, lineaments presents in the study area and soil texture etc.

4.10.5 Groundwater occurrence

The Upper Karha River Basin is underlained by basaltic rock. The storage capacity and transmissivity are the two cardinal parameters as regard groundwater bearing properties of the Deccan Traps. In Deccan Trap country, the primary porosity is due to the presence of interconnected vesicles, which is not filled with secondary minerals where the secondary porosity depends on due to weathering, and formation of joints and fractures in the rock. The groundwater potentiality depends on the extent of interconnection within the different sets of fractures, joints and weak planes and in case of vesicular basaltic unit's groundwater potentiality increases rapidly when the vesicles are interconnected.

The occurrence of groundwater aquifer zones (within 15.5 m BGL) have been studied in detail by inventorying a total of 30 open wells along the study area. The total depth of open wells ranges from 3.3m to 15.1m BGL with an average of 8.01m BGL. The well diameter ranges from 2.3m to 12.2m with an average of 7.27m. Water table fluctuation ranges from 3.3m to 15.1m BGL in post monsoon.

4.10.6 Geomorphology and groundwater

Geomorphologists found to have very close links with both surface and subsurface water conditions. Geomorphological features of a terrain control the distribution of precipitation and amount of precipitation that contributes to the runoff and groundwater recharge. A specific asset of geomorphology is that it aids to describe and evaluate the environment in which the water circulates, thus providing hydrologists working in areas where essential data are lacking with information enabling him to understand the situation and to make the proper decisions.

Schumm (1964) emphasized this role of geomorphology and mentioned that a general relationship exists between hydrological and geomorphological variables. Infiltration, moisture content of soil, angle of slope and relief are the important geomorphological factors determine the groundwater (subsurface water) flow. For the infiltration, fracture and permeability of rock, soil cover, steepness of the slope and vegetative cover effectively works together. Thus infiltration estimation or measurements plays an important role in the study of groundwater condition. Soil characteristics its structure, organic matter, moisture content, $_{p}H$ are important. Infiltration in dry soil is maximum and in moist soil it is minimum. The degree to slope also plays an important role in the infiltration. Slopes with convex elements in plan tend to spread the overland flow and thus favour infiltration, whereas concave slopes in plan promote concentration of flow and linear runoff. The geomorphological situation can also give clue to the hydro-geomorphologists in the other environment e.g. springs may occur in the areas where a capping of resistant and pervious rocks (such as limestone beds and ferricretes). Comparatively shallow groundwater may occur where alluvial and/or colluvial deposits cover the bedrock. Generally speaking, one can justify that geomorphology contributes to the location of recharge or intake areas of groundwater and the prediction of recharge of various groundwater zones (Knisel, 1972, cf. Verstappen, 1983).

On the basis of geomorphological study the features such as dykes and faults observed in the particular region become barrier for the horizontal movement of groundwater. Drainage density also has a bearing on the permeability of the rocks, the amount of geological control on the drainage pattern and the integration and homogeneity of the patterns (Schumm, 1964). The assessment of the groundwater recharge potential is facilitated by a study of the texture and permeability of the superficial materials and deposits in the riverbed.

4.10.7 Landforms and groundwater potential

Considering the role of geomorphology in groundwater potentials discussed earlier, study of groundwater potential requires appropriate and in depth understanding of its origin, occurrence and movement, which are directly or indirectly influenced by the landform characteristics. Various landforms specially structural, denudational and depositional landforms play vital role in the groundwater potentials. Some of the important fluvial landforms, their characteristics and groundwater potential in the Upper Karha River Basin are discussed below.

4.10.8 Structural landforms

The landforms which owes its existence to a resistant rock layer. Many features are formed due to the tectonic readjustments that take place within the crust of the earth (Nath et al., 2000). The tectonic readjustment plays an important role in the formation and evolution of landscape and landforms. The most important features of this category found in the study area are structural hills and lineaments.

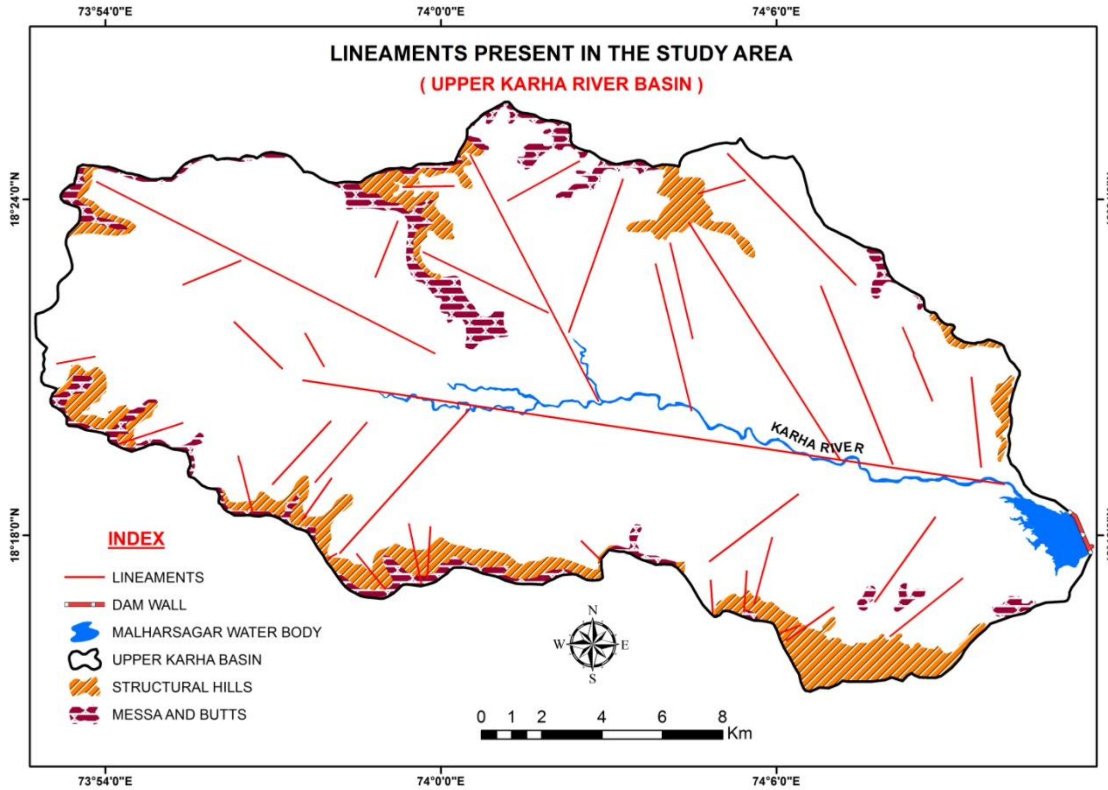
a) Structural Hills (SHL)

Structural hills are massive linear or arcuate hills exhibiting definite trend lines dominated by hard unweathered basalt rock (Vittala, et al., 2005). These hills are structurally controlled with complex folding faulting criss-crossed by number of joints and fractures, which facilitates infiltration and acts as runoff zone. In the Upper Karha River Basin, structural hills are observed prominently in the peripheral area (divide) of basin. Structural hills found in the Upper Karha River Basin are devoid of water bearing aquifers however gloomy aquifer available due to highly jointed and fractured basalt with thin soil cover at the hill top and on the slopes. Generally, the groundwater potential is very poor in structural hills owing to their poor permeability where surface runoff is greater.

b) Lineaments (LNMT)

A lineament is defined as a large-scale linear fracture, which express itself in terms of topography, which in itself, an expression of the underlying structural features. In simple words lineaments are linear fractures commonly associated with dislocation and deformation. Lineaments are important in the rocks where secondary permeability and porosity dominate and inter-granular characteristics combine in secondary openings influencing weathering, soil water and groundwater movements.

Lineaments provide the pathways for groundwater movement and are hydro-geologically very important (Sankar et.al 1996). The lineament intersection areas are considered as groundwater potential zones. Lineaments joints, fractures etc. developing generally due to tectonic stress and tension, provide important clue on surface features and are responsible for infiltration surface runoff into subsurface and also for development and storage of groundwater (Subba Rao et. al 2001). Lineaments (LNMT) have been observed in the Upper Karha River Basin, at the south, southeastern and northern part. Most prominent lineaments having NE-SW trend are running between the village saswad, and Jejuri. These lineaments are running almost parallel to main stream of Karha River. These lineaments had given an advantage of groundwater convergence from western and eastern part of the basin.



MAP No- 4.17 : Lineaments in the study area

The lineament observed as the manifestation of straight stream course near Jejuri region. Along this lineament, high moisture zone and dense vegetation is noted during field check. Along the northern part of the river Karha more lineaments are observed as compare to southern bank of the river. Some areas having small length of lineaments but the density of lineament in such areas are high. Lineaments are basically weaker zones along the rocks which allows penetration of water in to the rock masses and enrich the groundwater table in the study area.

c) Dyke (DYK)

A sheet like intrusion of igneous rock usually oriented vertically which cut across the structural planes. The wall or trough formed by differential weathering of such an intrusion when exposed as the land surface. Dykes have moderate to good groundwater potentials. During field work set of two small dykes approximately trend in NE-SW, discontinuously observed from Saswad to Karkhel but not in major size and also not continuous.

d) Messa/Butt (MSBT)s

These are the erosional features, which are structurally controlled made up essentially of horizontally layered rocks, having a cap of hard and resistant rock that has escaped erosion. These features with steep sided slope at the top has poor groundwater potential The forts presents in and along the south western water divide of basin Upper Karha river i.e. Purandar represented by Messa and Butts. Another Mesa has been observed near the village Khoporvadi, Chambhli, Zendewadi, Sonori, askarwadi and Thapewadi. The messa and butts are considered as non productive areas for the groundwater availiability.

e) Denudational Hills (DNHL)

These hills are marked by sharp to blunt crestline's with rugged tops indicating that the surface runoff at the upper reaches of the hill has caused rill erosion. Groundwater potential is moderate to poor in this region. These hills are observed near, Garade, Somardi and Jejuri region of Upper Karha River Basin.

4.10.9 Denudational Landforms

The surface of the earth is constantly being acted upon by different kinds of exogenetic forces like wind, water and ice. These forces tend to bring physical and chemical weathering of bed rock and also transport and deposit the weathered debris in certain locations on the earth (Nath et al., 2000). This complete phenomenon is referred to as a denudational process and this gives rise to many denudational landforms such as pediment, pedeplain, insulbergs, tors etc. among these, pediment and pedeplain observed in the study area are discussed with reference to their groundwater potentiality. Surface geometry, the chemical constituents of rocks, tectonic setting and climate are the main factors determine the denudational processes.

a) Pediment (PDMT)

Pediment is a gently sloping landform with erosional bedrock situated between hills and plains consisting of veneer of detritus and undulating rock floor (Gopinath and Seralathan, 2004). The groundwater condition in pediment zone is expected to vary depending upon the type of underlying folds, fractures and the degree of weathering. Generally pediments do not favor much infiltration and therefore, these areas are not favorable for groundwater explorations.

In the present research Upper Karha River Basin, Pediment is observed along the down slopes of structural hills and foothill zones. The foothill zone found all along the periphery of the Upper Karha river and its tributaries and sub tributaries. From the groundwater point of view this unit falls in poor to moderate groundwater potential zone. In this zone most of irrigation depends on dug wells. In the pediment areas the groundwater availability is depends on the rock lithology.

b) Pedeplain(PDPL)

This geomorphic unit is developed as a result of continuous process of pediplaination. Pedeplain are found to be good for groundwater potentiality. Groundwater exploration can be done mainly through dug wells. Pedeplain is the gently sloping undulating plain of large areal extent. These are formed as a result of continuous process of pedimentation with intensive weathering under semiarid climatic conditions (Spark, 1960). Pedeplain, are located between pediment and alluvial plains in the Upper Karha River Basin. Pedeplain have fairly weathered thick mantle underlain by weathered and fractured basalt locally known as murum, indicates high porosity and permeability. In the Upper Karha Basin pedeplain unit has an average elevation of 550 to 750m ASL. Pedeplain have moderate to good groundwater potential.

4.10.10 Depositional Landforms (Fluvial)

These types of landforms occur in old stage of river, where the lack of erosion and transportation work. Fragments of soil, regolilth, and bed rock that are removed from the parent rock mass transported by fluvial agent and deposited elsewhere to make an entirely diverse bunch of surface features–the depositional landforms. Alluvial plain, valley fills are two hydrogeomorphic units that have come in to existence due to fluvial depositional processes in the Karha Basin. These features occupy the valley part and are composed of loose deposits of permeable material like sand, silt, clay. Near about approximately 30% of the basin occupied by these landforms.

a) Alluvial Plain (APLN)

Alluvial plains are level to gently sloping plains with undulating topography composed of unconsolidated sediments or partly consolidated sediments such as sand, slit and clay (Nagarale et al., 2007). These fluvial depositional plains are developed on either sides of the river and their tributaries. From the river banks it extends from few hundred meters to 1-2 km laterally. It is highly permeable zone helping in partial bank recharge and subsurface flow. Groundwater in alluvial plain occurs under semi confined to perched water table conditions with shallow water levels. Groundwater prospects in alluvial plain is invariably found to be good and it is a promising zone for the same through which groundwater has been tapped by digging numerous wells and tube wells, giving high yield of water.

b) Valley Fills(VF)

The unconsolidated materials partly filling the river valley are termed valley fills, which are formed by depositional processes at the youthful stage of river. Valley fills consisting of loose sediment deposits of boulders, cobbles, pebbles, gravel, sand and silt brought in by the stream. They show a high range of grain size and less compaction, which gives high permeability resulting high infiltration. They are confined to narrow linear depressions. Lithologically valley fills comprises weathered and erosional products of surrounding rock consists of cobbles, pebbles, sand, silt, clay and gravels (Magar et al., 2007). Valley fills are observed near Malharsagar water body but very small area is occupied by valley fills, characterized by high porosity and high permeability resulting in high infiltration rate. Groundwater potential in this zone is fairly good. In the Upper Karha River Basin valley fills zone is mostly occupied by cultivation. Owing to large amount of recharge from both valley side slopes, they are most favorable groundwater zones.

Valley fills are basically considered as potential zones for the groundwater availability and movement. As in this research only upstream area is considered for the research and this is why the area under valley fill is very much less in the study region. The valley fill mostly observed near Mallhar Sagar water body, so even though the area having good potentiality of groundwater it does not uses ground water resource and total need of water is fulfilled by the surface water by malhar Sagar water body.

At the eastern side of Malhar Sagar water body, big dam wall restrict the flow of river and water gets stored in the Malhar sagar Lake and this is the reason for high water table in this area. Jejuri is the place having nearness of water body but even though it falls under low groundwater potential zone. It may be because of the lithology, slope of the area and closeness of water divider of Jejuri Gad and Kade Pathar.

The opposite side having gentle slope than the Jejuri area and that’s why the area showing high groundwater table at this particular location. Hence it is the fact that landforms are playing significant role in understanding of Groundwater potential zones of any Geographical region. Land forms are the feature on the surface which speaks about ground water availability. Landforms also give some clues in terms of morphological signs which predicts the movement and appearance of Groundwater.

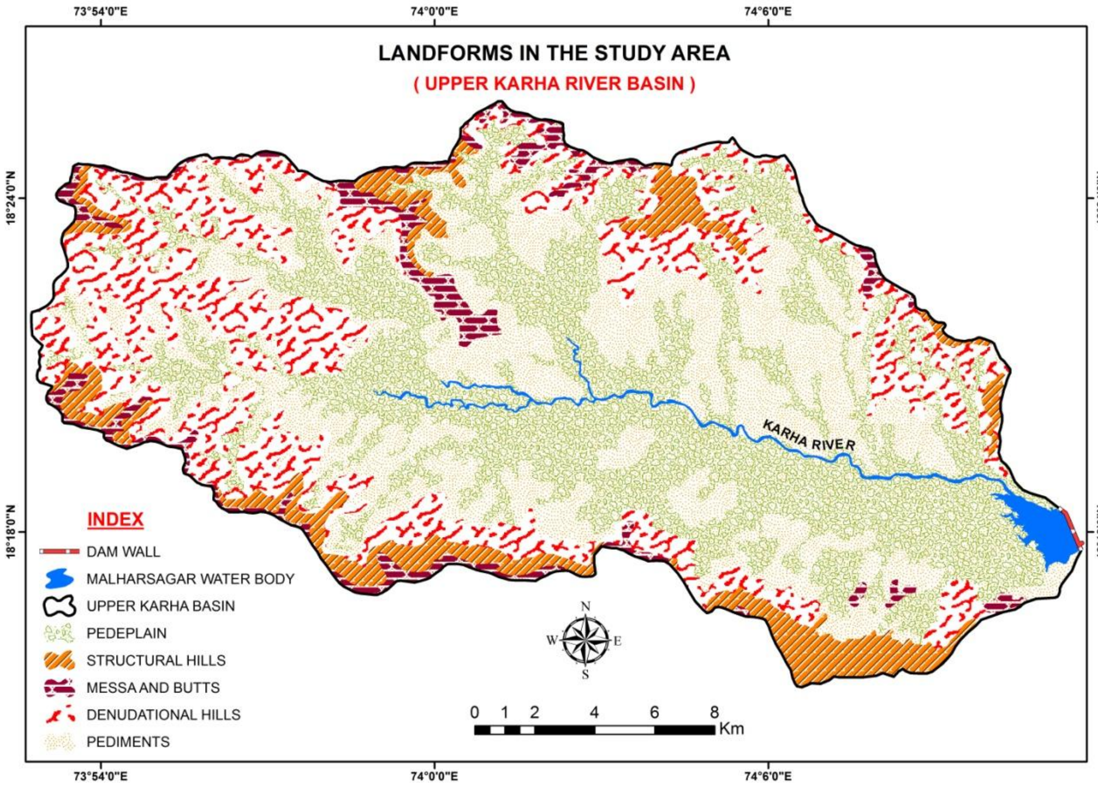
In Map (no-4.18) landforms classification of Upper Karha river basin has been shown and it indicates the Geomorphological landforms having structural, denudational and depositional characteristics. The landforms of the study area is playing major role in the groundwater potential and its availability, because landforms and there process of evolution have direct influence on groundwater occurrence.

As per the landforms is concern low laying areas present in the study region shows the optimum occurrence of groundwater. In the following table configuration has been given about landforms and their association with surface material. The following table also tells about structural, denudational and depositional landforms and lithology of the surface present in the study area of Upper Karha River Basin. The map shown bellow is really important geomorphological parameter to investigating groundwater sources and movement of groundwater along the study area.

Table 4.8: Landform Units in the Upper Karha River Basin

Landforms	Geomorphic Unit for Groundwater Prospect	Surface Material, Lithology
Structural Landforms	Structural Hills (SHL)	Thin soil, bare rock surface, sparse grass cover
	Lineaments (LNMT)	Expressed in terms of topography
	Dykes (DYK)	Expressed in terms of topography
	Messa Buttes (MSBT)	Flat gentle slope surface with bare rock, thin soil layer
Denudational Landforms	Denudational Hills (DNHL)	These are marked by rugged tops with sparse grass cover
	Pediment (PDMT)	Medium soil thickness, Veneer of detritus, sparse shrubs & Grass cover
	Pedeplain (PDPL)	Thick soil, fractured and weathered basalt, thick vegetation
Depositional Landforms (Fluvial)	Alluvial Plain (ALPN)	Alluvial soil, Agri. Crops
	Valley Fills (VF)	Alluvial & colluvial deposits, Crop plantation

(Source - Field Investigations and SOI Toposheets)



Map No 4.18: Landforms along Upper Karha River Basin

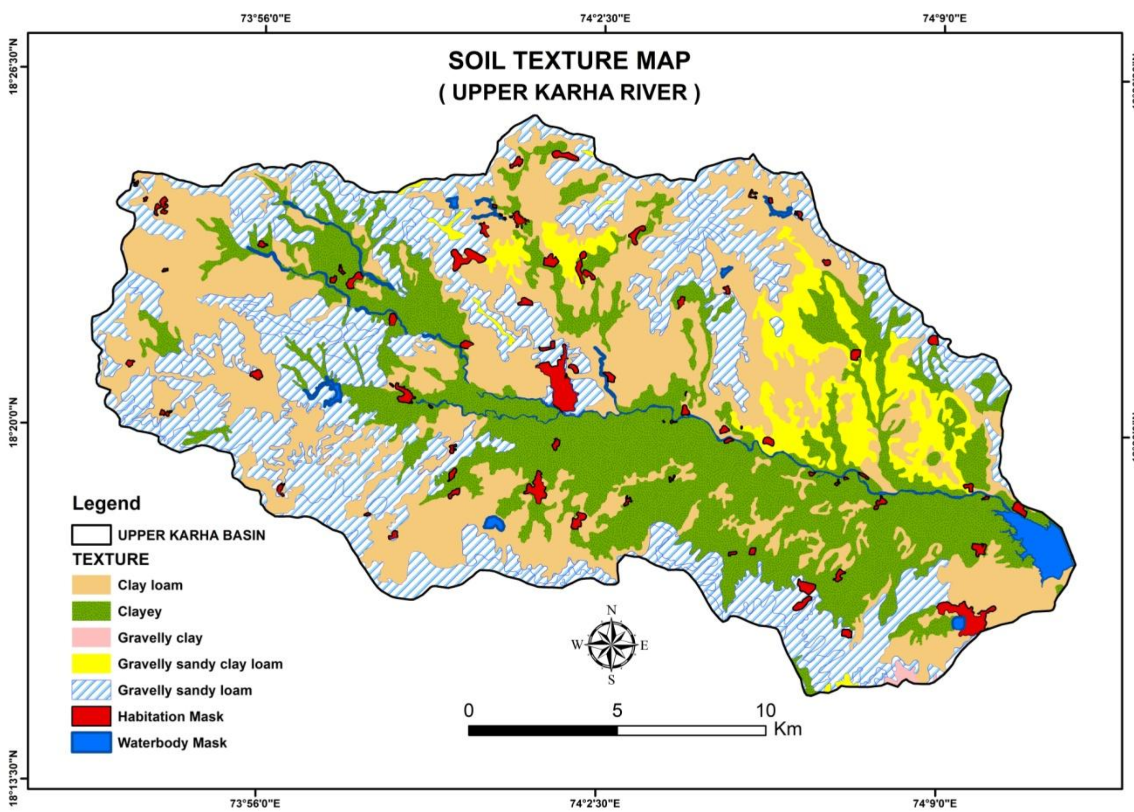
The landforms of Upper Karha river basin are playing significant role in the appearance of groundwater of the study area. All peripheral area of the drainage basin is associated with structural landforms and those landforms are showing very different properties for the groundwater occurrence. Most of the area is covered with structural hills and mesa and butts near the periphery of the drainage basin of Upper Karha river basin which considered as bad areas for the groundwater occurrence and in such areas the potential of groundwater is very low. In other words these areas are considered as no groundwater areas.

In the weighted index method the raster layer of landforms are playing very important role and final output of groundwater potential is product of such various raster thematic layers considered for the study. The present method is inbuilt programme in Arc GIS 10.3 software tool kit and it is easy to use because of its user friendly interface for the GIS learners. By using such techniques geographer can do quality research in the field of geography, Hydrology, Geology etc.

4.11 Soil texture

Texture relates to the amount of sand, silt, and clay in the soil and structure relates to the arrangement of the sand, silt, and clay into peds. Texture and structure greatly affect groundwater recharge by influencing water and overlying material relationships. Soils that expand and shrink with wetting and drying affect the stability of building foundation is important soil characteristic because it helps to determine water intake rates, amount of aeration and important factor which affect on water percolation. The texture of soil is refers to the comparative amounts of differently sized particles of soil. Soil texture is totally depends upon the comparative amounts of sand, silt, and clay presents in soil.

Texture defines the ability of soil for enriching the groundwater and increasing in water table, which is one of the main factors for groundwater potential.



Map 4.19. :Texture Distribution of Soil in Upper Karha River Basin

Map No. 4.19 indicates texture distribution of Upper Karha River Basin. Middle part of Karha basin shows concentration of clay soil and it also observed near confluence point of streams with Malharsagar water body. Source region of basin show the high percentage sandy clay and it also appears in the North, North west and East side of Upper Karha river basin. In Upper Karha river basin 34.21% area is under the clay texture of soil, Clay loam covers 37.52% and Gravelly sandy loam soil covers 10.61% area. While, Gravelly sandy clay loam soil cover 13.77% area, Gravelly sandy clay soil cover 3.66 % area. Remaining area represents the water bodies present in the study area.

4.12 Land use classification

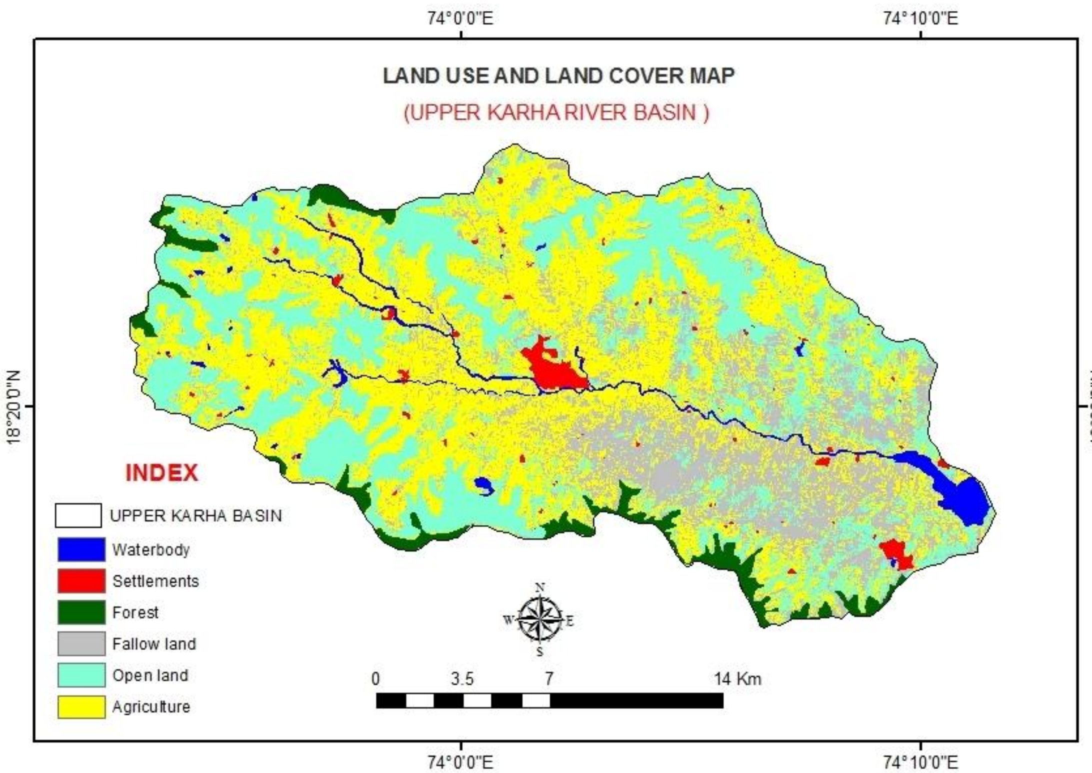
Knowledge of land use is important for planning and management activities regarding water use in the region. The physical, cultural, social, and economical factors have combined influence on the land use pattern of study area. The land use pattern of study area is divided into five categories. Following table shows land resource categories and the area occupied by them respectively.

Table No. 4.9: Distribution of land use in Upper Karha River basin

Sr. No.	Land Use	Area (sq.km)	Percentage to the total Geographical area
1	Agricultural	117.93	29.78
2	Fallow land	84.03	21.22
3	Open land	113.11	28.56
4	Settlements	29.3	7.40
5	Water body	33.7	8.51
6	Forest	17.95	4.53

(Source – complied by Research)

Urbanization has progressed at an extraordinary rate in recent decades and this growth is projected to continue throughout the century. Urban areas are the hubs of social processes, driving many changes through material demands that affect land use and cover, biodiversity and water resources, locally to globally. Forests play a crucial role in terrestrial ecosystems and provide a multitude of services such as shelter, habitats, fuel, food, fodder, fibre, timber, medicines, security and employment; regulating freshwater supplies; storing carbon and cycling nutrients; and helping to stabilize the global climate.



Map No. 4.20: land use classification in Upper Karha River Basin

Historically, forests have been under pressure due to increasing demands for shelter, agricultural land, and fuel and timber extraction, but in recent decades this pressure has increased due to competing demands for agricultural expansion and biofuel production, rapid urbanization and infrastructure development, and increased global demand for forest products. The forest covers near about 17.95 sq.km., it is 4.53 percent of the total area. The area covered by water is about 33.7 sq.km. 8.51 % out of the total basin area. The area under agriculture is 117.93 sq.km, 29.78 % of the total study area. Normally it is recognized that higher is covered under agricultural land in upper karha river basin. Fallow land covers 84.03 sq.k.m 21.22% and area under open land is 113.11 sq.km 28.56 % of the total geographical area.

4.13 Vegetation cover

The type and quality of vegetative cover on watershed lands influence runoff, infiltration rates erosion and sediment production and the rate of evapotranspiration. Dense cover of vegetation is a most powerful weapon for reducing erosion. The area under study experience semiarid climate hence the vegetation cover in the study area show variation from tropical ever green to tropical deciduous forest. The study area is partly covered by the Western Ghats thus a large variety of the vegetative cover in this area. Forest land of the study area is divided into three categories i.e. Deciduous, evergreen and mixed. All these types are found in study area. The southern and southeastern part of study area is occupied by the tropical evergreen type of dense vegetation. This vegetation is found on the hill tops and on moderate to gentle slopes. Vegetation consist of trees like Mango, Jambhul , Bamboo, Jackfruit, Herbs, Shrubs, weeds and grasses are mostly observed along the valley flats, gently sloping ground and on the flat ridges. As compare with the southern part the northern and western part of the study area is occupied by the sparse vegetation comprising of Xerophytes and deciduous types of vegetation.

4.14 Groundwater fluctuation studies

Groundwater fluctuation studies are very much important to understand Potential and availability of the groundwater, sub surface groundwater movement, generally characteristics of rocks having high water holding capacity known as aquifer. Water bearing sub surface rock responds to hydraulic stresses due to change in levels of groundwater with reference to seasonal variation. Recharge and discharge are two important parameters responsible for Hydraulic stresses. When groundwater discharge is less than groundwater recharge the water bearing rock maintained the gap in storage and therefore there is rise in water table. But when the discharge is more than recharge the situation get reversed and because of this there is fall in groundwater level. To maintain the equilibrium for long time there should be balance in between recharge and discharge. It doesn't mean that the water holding rock is always in equilibrium. Equilibrium is basically depends on some factors namely type of aquifer and pattern of rainfall during that time span. In the season of monsoon basically storage of groundwater is takes place because recharge is higher than discharge and the reason for that, is continuous rainfall in the season of monsoon. Storage is increasing slowly and due to this there is rise in water levels. In non-monsoon seasons the rate of discharge is more than the recharge. So to respond this situation the groundwater levels goes down slowly. If the yearly recharge is approximately equal to yearly discharge then there is no notable change observed in the storage of ground water and hence no big difference observed in water levels. However there is no rain fall then the annual discharge always exceed the annual recharge it results in lowering the groundwater table.

Upper Karha river basin enjoys wet season during whole monsoon and then monsoon season is followed by long dry season, so there is more discharge than that of recharge and it results in over exploitation of groundwater resources along the study area. In study area groundwater is used through bore wells and dug wells for domestic as well as agricultural and industrial purpose. To analyze the groundwater potential through groundwater fluctuation or groundwater level researcher has to be fix the location of observations wells. Total 30 observation wells have been selected to monitor and analyse underneath groundwater potential. All sample observations wells are randomly selected from the field. While making observations Pre-Monsoon, Post-Monsoon and one odd season Groundwater levels from the desire wells have been take in to consideration. Depth to the groundwater from surface is measured in meters along the all observation wells as observed Groundwater level. Total depth and diameter of the well also measured during field work by the researcher.

During field work sample wells are monitored for the study of groundwater fluctuations in the Upper karha river basin and for thie locational information twelve channel garmin GPS has been used. The instrument namely Global positioning system helps to identify and demarcation of sample location wells during field work. Locating same well in different season is really hard task because of changing land use of the study area but hand held GPS is really helps during study period. In the following table groundwater levels observations has been given and all depth measurements are in meters. The name of the villages and the locational information of samples is also given.

Table 4.10 – Information related to ground water levels (values in Meter)

Location Information			Jan-14		May-14		Oct-14	
Village Name	**Longitude**	**Latitude**	**Measure**	**Observe**	**Measure**	**Observe**	**Measure**	**Observe**
ZENDE WADI	74.0137068	18.4045095	2.5	10.7	5.6	7.6	3.5	9.7
TATHE WADI	74.04803088	18.323173	11.9	9.9	14.2	7.6	12.2	9.6
KHALAD	74.07953199	18.3261505	13.25	2.9	14.85	1.3	12.75	3.4
KHANAVDI	74.10640778	18.3319663	13.25	2.9	14.75	1.4	7.9	8.25
PARGAON	74.1331972	18.3576843	8.3	1.9	9.9	0.3	2.7	7.5
GURHULI	74.09743443	18.4059947	4.5	5.3	6.2	3.6	4.5	5.3
VANPURI	74.07235664	18.3760506	8	1.4	9.1	0.3	8.1	1.3
SAKURDE	74.12171115	18.271496	10.25	4.55	6.1	8.7	5.9	8.9
PIMPLE	74.03212722	18.3006958	6.2	2.2	6.9	1.5	6.4	2
NARAYANPUR	73.98021405	18.2994279	4.55	8.85	6.45	6.95	4.2	9.2
KODIT.BK	73.97830885	18.3397052	9.1	1.3	9.3	1.1	2.8	7.6
GARADE	73.92752778	18.3490278	6.6	1.05	7	0.65	3.5	4.15
BHIVRI	73.92656723	18.3891951	3.5	1.4	4	0.9	2.9	2
CHAMBHLI	73.97348972	18.3714821	6.3	6.9	8.5	4.7	1.8	11.4
THAPE WADI	73.89935415	18.3375997	2.27	4.12	3.8	2.59	1.1	5.29
PATHAR WASTI	73.89953056	18.3760451	13.7	2.25	15.1	0.85	8.2	7.75
VARAVADI	73.88862114	18.3540302	3.5	2.3	4.7	1.1	3.7	2.1
SOMARDI	73.93472999	18.3194651	10.45	0.95	7.2	4.2	2.4	9
ASKARWADI	73.89551467	18.4009428	10.1	1.9	8.1	3.9	3.7	8.3
KHOPOR WADI	73.96627888	18.3946686	4.9	5.4	8.25	2.05	3.1	7.2
SUPE.KH	74.01414453	18.3203619	11.8	3.2	13.28	1.72	4.8	10.2
SONORI	74.05069021	18.3863248	5	4.4	8	1.4	0.9	8.5
AMBODI	74.04512007	18.3519271	10.9	6.5	14.35	3.05	10.6	6.8
PAWAR WADI	74.01220233	18.3695158	9.3	2.1	9.7	1.7	8.4	3
SHIVRI	74.08365859	18.2858804	2.27	4.12	3.14	3.25	1.1	5.29
DUNE WASTI	74.15484288	18.284389	9.2	1.2	7.3	3.1	5.2	5.2
KOTHALE	74.15678998	18.3227626	6.1	2.2	6.3	2	4.4	3.9
NARALICHA MALA	74.11936304	18.3037073	7.2	1.4	8	0.6	5.1	3.5
BHAGWAT WASTI	74.10354939	18.3691818	5.3	2.1	6.3	1.1	4.7	2.7
JEJURI	74.17897989	18.2842739	1.7	0.8	2.1	0.4	1.3	1.2

All depth values are in meters

(Source – Field work survey)

a) Pre-monsoon

In the pre monsoon season ground water levels have been measured in the month of May, 2014. For carrying out present study 30 wells has been demarcated as observation wells. Out of 30 wells 6 wells have less than 5 m gbl (Meters below ground level), 10 wells have below than 10 m gbl and remaining wells ware have greater than 10 m gbl ground water level. The average groundwater level during pre-monsoon season in the study area is about 8.013 m gbl. The runoff area has the highest depth of groundwater level and it is about 14.75. The lowest depth is observed in the zone of saturation and it is about 3.3 m gbl.

b) Post-monsoon

In the post monsoon season ground water levels have been measured in the month of October, 2014. Out of 30 wells 15 wells have less than 5 m gbl (Meters below ground level), 7 wells have below than 10 m gbl and remaining 3 wells ware have greater than 10 m gbl ground water level. The average groundwater level during post monsoon season in the study area is about 5.115 m gbl. It means there is increase in water table during session of monsoon and thats why such huge fluctuation is observed in groundwater levels along the study region. Therefore groundwater fluctuation studies are important to understand Groundwater occurrence below the surface and its potential also

c) Odd season observations of groundwater levels

Instead of taking only two readings in terms of pre monsoon and post monsoon season researcher had took odd season observation during pilot field work in the month of January 2014. The odd season ground water levels have been measured in the month of January, 2014. Out of 30 wells 7 wells have less than 5 m gbl (Meters below ground level), 7 wells have below than 10 m gbl and remaining 11 wells ware have greater than 10 m gbl ground water level. The average groundwater level during odd season in the study area is about 6.7 m gbl. Odd seasons observations helps to understand the conditions before monsoon and after the monsoon.

4.15 Groundwater fluctuations in the study area

To study the fluctuation of groundwater in the study region researcher has split study area in three parts like as run off zone recharge zone and saturation zone. It is observed that there is quick storage in the recharge zone during monsoon period. In the Saturation zone the rate of enrichment of groundwater is high and in the run-off zone there is no big change observed, it may be because of this is the origin of the river and the topography is undulating. From the above study we comes to know that in the run-off zone there is scarcity of ground water for non-monsoonal period and depth to the groundwater during monsoon season is near by 10 m gbl, so the groundwater table is very low in this area. During field work in the non-monsoonal season some wells are found totally dry, so it gives idea of groundwater scarcity problem in the study region. Well Depth in Meters on Y axis and Name of villages on X axis.

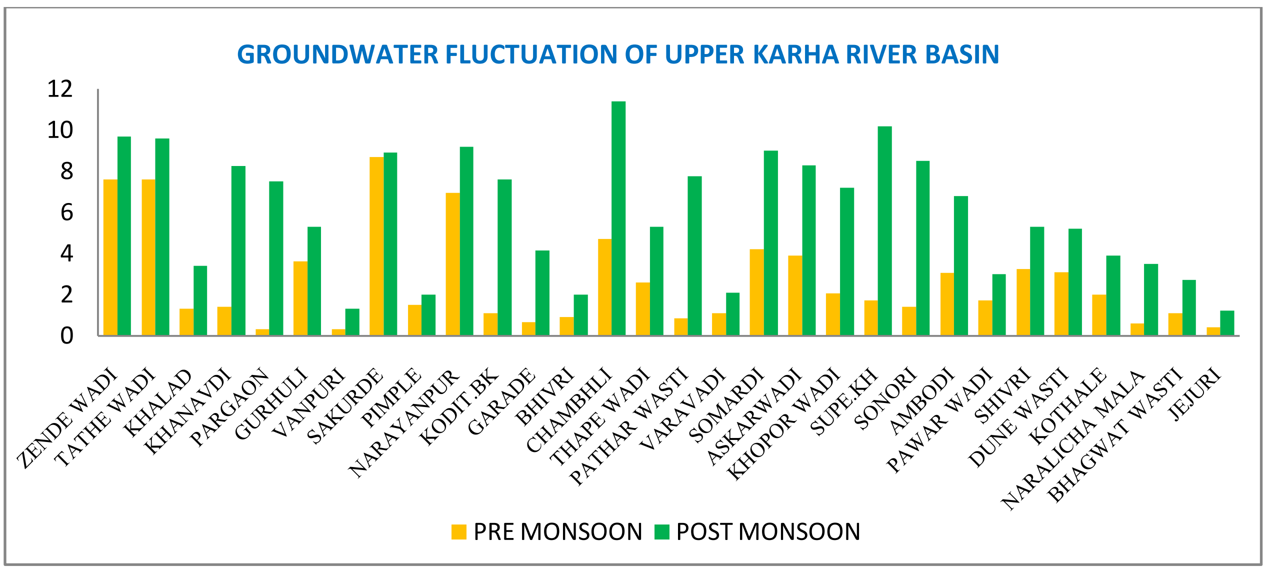
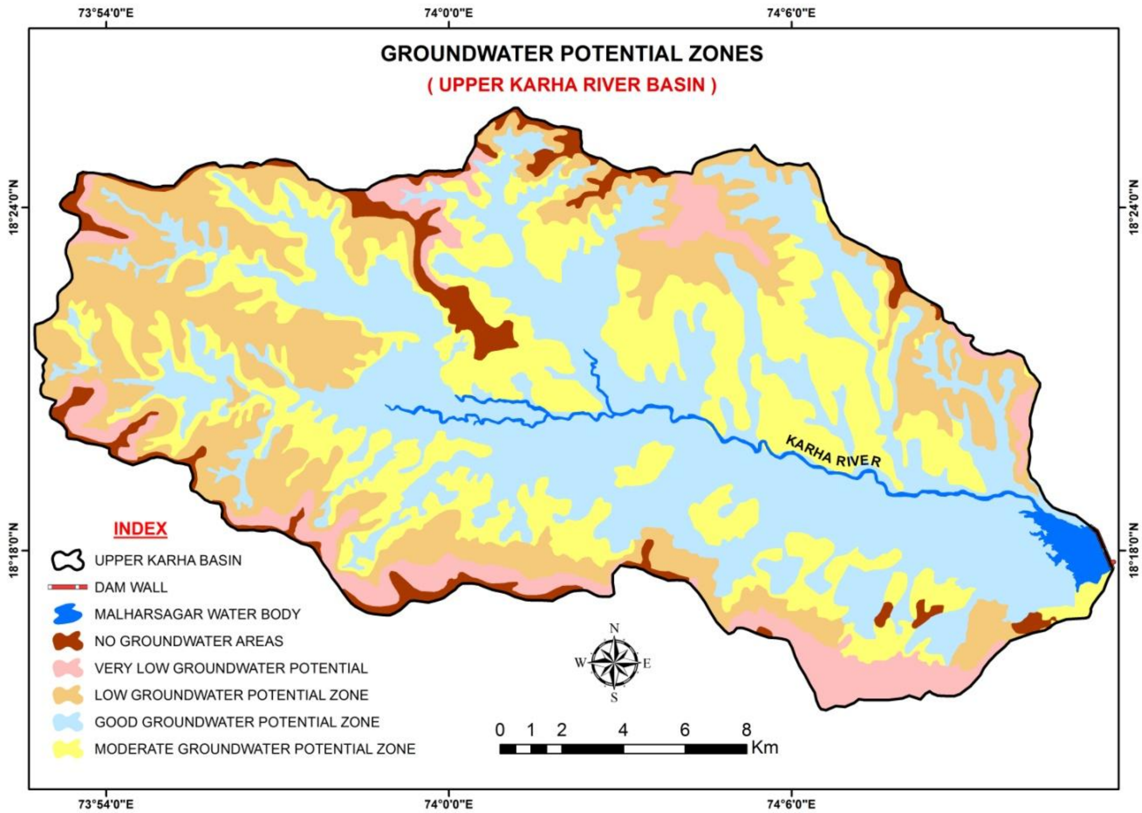


Fig 4.6 – Groundwater fluctuation of Upper Karha River Basin

From the above graph it indicates the fluctuation of groundwater during pre-monsoon post monsoon and odd season. It helps to understand groundwater potential, groundwater movement and availability of groundwater in the Upper Karha river basin. In the study area some locations are having very less amount natural recharge and it may be because of the lithology of the study area.

4.16 Groundwater potential zones of Upper Karha river basin

The assessment of groundwater potential in the Upper Karha river basin is the prime objective of this research and for the fulfillment of this objective weighted overlay index method has been use with the help of Arc GIS 10.3 version.



MAP No. 4.21 : Groundwater Potential Zones of Upper Karha River Basin

In weighted overlay index method various thematic raster layers has been incorporated like Land-use, Slope, Soil texture, Lineament, Drainage density, Soil type, DEM map and Landforms of Upper Karha river basin. Study area has been categorized in five different groundwater potential zones. The area along both of the banks of river Karha has good potential of groundwater but occurrence of groundwater continuously decreases towards the water divides of the study region. At the origin of Karha river basin groundwater sources are very much limited and the villages namely Askarwadi, Jejuri, Pawarwadi, Khoporvadi, Pargaon and some areas of Zendewadi also having the no groundwater recources. The villages namely Narayanpur, Sakurde, Thape wadi, Waravdi, Gurhuli and Kothale have low and very low groundwater potential. The villages having good and moderate groundwater potentials are namely Supe khurd, tathewadi, Khalad, chambhli, Kodit budruk, Ambodi, Kothale and Naralicha mala. The zones are delineated by using GIS techniques and it is usefulto carried out such studies potentially.

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CHAPTER -V

CONCLUSIONS

5.1 Introduction

The impact of industrialization and growing population, which consequently result in the urbanization, increased pressure on the natural resources like groundwater. As an environmental issue the demand for ample amount and safe supply of water is continuously increasing as activates associated with industries with continuous increase in the irrigated area of agriculture. In the rural area groundwater pumping rate is as high as replenishment of groundwater. Such type of groundwater withdrawal results in the critical water shortages and it further leads to groundwater scarcity. In the present times in many parts of the India, water is becoming scarce item especially because of its uncontrolled use and excess pollution due to many types of anthropogenic activities. In the areas which newly come in to existence as urban areas, dumping of waste and its unplanned and unhygienic disposal practice had indirect adverse impact on water, air and degradation of land and therefore in the nearby areas of cities of the India there is lack of enough and safe drinking water.

An idea about water disparities for Indian context with importance of the good quality drinking water in relation with human health and need it is becoming necessity to understand the potential of present research work. The findings of the present research are expected to be very helpful in understanding the potential and quality of groundwater in the newly rural, urban and industrial areas. As a part of this research the management strategies for Groundwater potential and drinking water supply becomes easy for the planners. Such types of research will definitely helps to manage the resources of urban as well as rural areas potentially and give the permanent solutions for the groundwater scarcity and groundwater contamination in present context. The present work also revels the water suitability of groundwater for agricultural as well as domestic purposes.

The Purandar taluka comprises of 108 villages and 3 towns having only two urban centre i.e. Saswad and jejuri. The population of the Purandar taluka according to the census, 20011 is 2, 35,659 with 51,259 households. Total 220 industries are in existence in the study area having industrial water demand near about 0.00440 BCM. The industries are mainly chemical, electrical, automobile, electronics in nature and this is the reason for groundwater contamination in the study area. Agriculture is the main sector in the region having 9176 hectors of net irrigated area and 2748 hectors of partially irrigated area of the total geographical area of Purandar taluka. The remaining area is totally depending upon rainfall for their agricultural activities and the average rainfall is further increases the stress on the available groundwater and surface water resources in the study region.

5.2 Conclusions

As per the climatic characteristics of the study area are concerned the area lies in the river basin of Karha or it is the part of river Karha starting from Askarwadi up to the Malharsagar water body having unique climatic characteristics. The Upper Karha river basin receives an average rainfall of 650 mm which is considered as below average rainfall. The temperature ranges from 30°C to 32°C, the temperature at the peak in summer it may reach up to 40°C and some time above. The relative humidity of total Pune district is low throughout the year. So, generally the climate of the study area is moderately dry and hot. The below average rainfall is the climatic reason for the water disparities in the study region but planning fully management of surface and groundwater resource will be the desire solution for the water scarcity and contaminated groundwater problem in the study area. For the management geology, geomorphology, slope, soil type, soil texture etc. parameter has been taken in to consideration.

All these geographical, Geological, geo- hydrological and morphological themes have great concern with groundwater occurrence and underground movement of groundwater. Landforms provide valuable information about groundwater availability, while other parameters are also having great concern with groundwater appearance.

In present aspect total study area is investigated for its geomorphologic, geographical, hydrological and geological characteristics. Geologically, Purandar taluka is located in the Pune district of Maharashtra state comprising a part of semiarid region of the Deccan trap having harder basaltic rock topography. Lithologically the Upper Karha river basin is divided into two types as per their geological formation process, first one is Ambenali formation and second one is Poladpur formation. For the evaluation of quantitative Morphometric and geomorphic characteristics of Purandar taluka drainage map was prepared in vector form with the help of (Arc GIS 10.3) software. This software facilitates many more tools to work on geomorphological phenomenon and make the complex problem very easy by providing vector and raster analysis techniques. Preparation of drainage map has been done by using Survey of India (S.O.I) Toposheets as a raster layer in the GIS environment. The Upper Karha river basin is falls under dendritic type of river pattern having geological and structural control on some parts of the drainage basin. The dendritic pattern is mostly observed drainage pattern in the lower order streams along all over the study region but occurrence of dendritic drainage pattern is non uniform in nature due to the variation in lithology of the Upper Karha river basin. Mostly strong and significant structural control over the drainage development is observed in the middle part of the study region in the form of drainage divider which distributes in to two flows near Saswad. Morphometric investigation provides the knowledge about the basin shape its texture, drainage density which having direct impact on groundwater availability. The Upper karha river basin is semi circular in shape as per the elongation and circularity ratios are concerned that's why overland flow generated after rainfall quickly drain down the water through its stream network to the Malharsagar water body and hence the residence time of water over land patch is minimizes which has adverse impact on infiltration or percolation capacity of study region. Morphometric parameters also reviles that the relief of the study region is undulating in nature and terrain is rugged. The drainage texture is course and it definitely have relation with groundwater occurrence. Soils from study are of two types like shallow black soils (inseptisoles), medium black soils (vertisoles). The area having imprints of diverse agriculture and the type of soil in the study region doesn't affect that much the cropping pattern of upper karha river basin but irrigation facility is the most important controlling factor for the agricultural sector. The irrigation facility is directly dependent upon rainfall occurs in the study region because ground water and surface water are the major sources which provide irrigation facility to the study area.

Slope of the study area also have great concern with the generation of overland flow or runoff, if the slope is higher the runoff is higher. In the Upper Karha river basin the slope is little bit high around the water divider region and this is why the rain water quickly drains down to the main flows of the higher order streams present in the low laying areas of the study region. Most of the area is relatively flat because the slope angle is gentle and it is good condition for the natural groundwater recharge but unfortunately only few hectors of the study region is able to naturally recharge its groundwater from rainfall. It may be possible that slope is gentle in most the region but other factors should be in favor with along the slope then it will be benefited to the aquifer system in terms of natural aquifer recharge by rain water or surface water.

To study the groundwater potential researcher needs to study vegetation cover of the study region because vegetation cover is somewhere responsible for the rainfall and the groundwater potential. Plants increases residence time of rain water on the land by obstructing the overland flow, plants reduces the runoff and facilitate the percolation. Plants provide moisture to the atmosphere through evapotranspiration and indirectly it helps to rainfall. In the Upper Karha river basin vegetation cover is very less and it is about 17.95 sq.km, (4.53%) of total study area.

The vegetation cover is present near peripheral area of drainage basin and remaining area has very scanty vegetation cover it leads to generation of high overland flow. Less vegetative covers is responsible many ways for the high runoff and less percolation, further more it is responsible for low groundwater potential. To protect any geographical land and keep in sustenance the vegetation cover must be 33% but in present condition the situation is becoming critical. The vegetation cover is continuously shrinking due to unplanned urbanization and industrialization in the study area. In present days agricultural area is also converge in to the built-up area and this is one of the reasons for low infiltration capacity.

a) Drinking Groundwater quality

To complete the present research work, a well plan fully designed methodology was adopted to assess groundwater potential and quality. Total 30 water samples were collected from pre decided locations for assessment of groundwater quality of Upper Karha river basin. The 16 parameters (pH, EC, TDS, Ca, Mg, Na, K, HCO_3, Cl, SO_4, PO_4, NO_3, TH, SAR, Fe, Cu) were selected for physico-chemical analyses by using standard methods given by APHA (2005). In addition to that for the interpretation of spatial distribution, data is incorporated and treated with the help of GIS thematic layer techniques.

The groundwater quality data procured from Groundwater Surveys and Development Agency (GSDA, Pune) and was not enough for the present study region because the sample locations of the sample wells are very less and they are located outside of the study area. Therefore present study is totally based on data collected from the field during fieldwork. Same data has been used for present study in order to prepare a database on groundwater and finally prepare a groundwater quality map for whole Upper Karha river basin.

To assess the quality of groundwater some parameters has take in to account like pH value of most of the samples was more than 7.0 but it is within the permissible limits given by BIS values. Further, the spatial variation in electric conductivity values shows that conductivity of the study region higher for some samples but some sample still in permissible limit. If the study area continuously does not manage their effluents it will comes in to the groundwater which peoples are using for domestic and agricultural proposes and they will expose to the illness related to contaminated groundwater. In the pre-monsoon condition the values of conductivity is higher which may be due to higher water-rock interaction and simultaneously due to higher leaching in summer season. TH and TDS values, in most of the samples exceeded the permissible limits which clearly show unsuitability of groundwater for drinking and irrigation purposes. In 50% of magnesium samples values are exceeding the permissible limit it means magnesium is in higher amount in groundwater present in the study area, while the concentration of calcium is exceeding the permissible limits in some groundwater samples. The higher concentrations values of Ca and Mg are indicator of the anthropogenic sources are present in the groundwater present in the study region. The concentration of sodium was low in majority of samples as a result of slow cation exchange process. The abnormal concentration of potassium is observed at few places in the study area it may be due to urban pollution and fertilizer leaching.

Finally by using all these thematic raster layers map of groundwater suitability for drinking purposes is generated with the help of Arc GIS 10.3 software by using weighted overlay index method. In this map three zones have been displayed the different categories of groundwater suitability, three zones are namely potable, non potable and potable in critical condition. Most of the villages come under the potable in critical condition category and the villages are namely Koparwadi, Pawarwadi, Tathewadi, Ambodi, Pargaon, Zendewadi and Sakurde. These villages are on the border of permissible limit, if the concentration of the groundwater element is slightly increases they will become non potable for the people in the study area. Secondly non potable zone is taking attention towards the severity of the contamination. The groundwater presents in the villages namely Askarwadi, Patharwadi, Bhivri, Chambhli, Pimple, Vanpuri, Khalad, Naralicha mala and Khalad are non potable.

The people residing in this area are really in critical condition because they are consuming contaminated groundwater continuously. Remaining few area is showing the good properties for drinking as it falls under potable zone of the groundwater in the present map and the villages are thapewadi, Somardi, Narayanpur, Supe khurd and some parts of Jejuri, Sonori and Gurhuli. The study confirming that the GIS tool which used for this study is self justifying the use of technology to understanding the problem in any geographical region. In the modern world such types of tools will really helpful to the geographers as well as planners to solve any geographical, hydrological, or environmental related issue and suggest the desire solutions base model with minimum cost and keeping environment sustainability as priority for the development and all the practices associated with residents.

b) Agricultural suitability of Groundwater

The data regarding ionic exchange was plotted on piper Trilinear Diagram which shows that hydrochemical facies occurring in the study area are scattered in the Ca+Mg–HCO_3+CO_3 dominant groundwater water type it indicates dissolution of primary types of silicates due to process of chemical weathering. While Ca+Mg–HCO_3+CO_3 and Na+K–HCO_3+CO_3 major water facies get created during pre-monsoon seasons.

The groundwater suitability for irrigation purposes was measured by calculating Sodium absorption ratio (SAR). In the Upper Karha river basin all the groundwater samples have shown SAR values less than 10 it means groundwater from study area can thus be graded as good for irrigation use.

By graphically representations of the chemical data for irrigation suitability diagram shows that major high salinity–low sodium and high salinity-medium sodium waters are present in the study area which should be drain down to solve the salinity problem. If the residents of the study region continuously use such types of groundwater it will definitely increases the salt affected areas in the future. To overcome on this problem special management for salinity control is needed and farmers should plant the crops with having good salt tolerance. It will help to maintain soil health as well as it also controls contamination of groundwater in the study region.

The concluding part of study regarding water quality highlights that Purandar taluka has been experiencing fast industrial development and modification with increasing urbanization which is leading to unpredictable changes in the land-use land –cover patterns. These types of situation impose adverse impact on groundwater quality because of an improper and unplanned disposal of waste on land surface and discharging running water, which penetrate downward to the aquifers and leads to deteriorating the quality of groundwater in the study region. The severity and area covered of groundwater pollution in the different sampling sites. All the present results confirm that the quality of ground water is not upto the mark in Upper Karha river basin and is continuously degrading. At present time groundwater is not very bad but if the same practices continue in future, the ground water resource will be completely contaminated and becomes unsuitable for drinking and other uses. It is correct time to preserve and protect this valuable ground source and do something for its sustenance.

c) Groundwater potential

To study the groundwater potential along the Upper Karha river various aspects of the geomorphology and geology has been take in to consideration. Separate thematic raster layers of Digital elevation model, slope, soil texture, soil type, geological formation, land-use, land-cover, lineament, vegetation cover and landforms has been considered for weighted overlay index method in the Arc GIS 10.3 environment. It is reveals that the landforms have some control on groundwater occurrence. In the areas of structural hills near the water divider very low groundwater potentiality is observed but at the low laying areas near Malharsagar water body shows good potentiality of groundwater. Mesa and butts represent no groundwater is available in nearby areas of Koparwadi, Chambhli, Askarwadi, jejuri and Narayanpur. Whereas the area closes to right bank of river karha which is coverd with pedeplain showing the good potentiality of the groundwater. The villages located on pedeplain are namely Naralicha mala, kothale, Khalad, Ambodi, Gurhuli, Sonori and Kodit budruk showing god groundwater potential. The remaining area is having low to moderate groundwater potential as per the landform classification of the study area. For the purpose of interpretation map showing potentiality have been categories in five different zones namely no groundwater zone, very low groundwater zone, low groundwater zone, moderate groundwater zone and good groundwater zone.

Land use patterns also played significant role in the identification of groundwater potential zones along study area. The areas covered with grass and vegetations are hold the soil and increase the resistance to the surface water flow hence it helps to increases percolation in the soil horizon. In the upper karha river basin area under vegetation is less so it has the adverse impact on groundwater potentiality while the open land is also majorly observed along the study region it increases overland flow quickly. Agricultural fields also dominant land use observed in the study area it shows there is burden of irrigation on groundwater resources because of low rainfall occurs in the study area.

Lineaments are the prominent feature of geology as well as geomorphology because these are the weaker zones along the rock strata which allow rain water percolate down to the groundwater table present in hidden aquifer. In Upper karha river basin some major and minor lineaments are observed during field work. One major lineament is observed in between Saswad and Jejuri and remaining area all the minor lineaments. The areas with lineaments are considered as good for the groundwater potential.

Soil texture, soil types, slope of the ground drainage density etc. are the parameters which helps many ways to understand the groundwater potentiality of the study area. These morphological parameters have control on geographical phenomenon and keeping in this mind all these aspects take in to consideration for good results.

To conclude the research it is clearly proven fact that landforms, land-use, land-cover, lineament, slope, soil texture, Morphometric parameter and digital elevation model are the useful parameters to decide groundwater potentiality of any geographical area. It is also proved that GIS is the tool having potential to analyze the raster thematic data and provide the solutions to the geographical problem.

5.3 Recommendations

Finally, here attempt has been made to give trustworthy remedial measures to fight with further groundwater contamination in the Upper Karha River Basin. The recommendations are given bellow separately for groundwater potential as well as groundwater quality of study region

a) Groundwater potential

- To construct the Continuous contour trench (CCT) along the areas having high slopes nearby basin border to increases percolation of water.

- To construct water absorption deep trenches (WADT) in the areas where barren and hill slopes are present, it helps to increases the water storage capacity and leads to enrich the groundwater table.
- Farm ponds can also be the helpful to store the rain water and prevent the water miss use. These methods will support the agricultural production by providing water in the season's rain fall unavailability.
- The Contour Bunding is one of the best options to increase the groundwater potential in the study area. The contour bunds should be created perpendicular to the slope along the spurs of the hills.
- Gabion structure can be constructed along the relatively flat areas to increase the groundwater table.
- Farmers should plow or plough their farm perpendicular to the slope, so that there is restriction in the water flow and it increases resident time of water in the farm.
- Trees should be planted on open land and along the slopes, it can hold the soil as well as helps to increases groundwater table.
- People residing in the study area should manage each drop of water plan fully to mitigate the water scarcity.
- Use rainwater harvesting techniques where such techniques can be installed and work for the groundwater enrichment.
- Soak pits also can be a good option to increases percolation of waste water in to the soil.

b) Groundwater quality

- Correct methods of treatment and disposal of the industrial and municipal waste.
- Design the proper drainage for the domestic and agricultural wastes.
- Farmers should reduce usage of chemical and hazardous fertilizers in their farms.
- Promote farmers for switch to organic farming by using domestic waste
- Maintain hygienic conditions in the study area.
- All inhabitants should be aware of the situation and should be given proper knowledge to improve their own hygienic habits.

- The public should train to protect potable water from further contamination.
- Micro level research should be carried out for a detailed study on groundwater quality and to find out some additional efficient remedial measures to conquer the groundwater contamination problem in the Upper Karha River Basin

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APPENDIX – I

GROUNDWATER QUALITY DATA OF SAMPLES COLLECTED FROM THE FIELD

LOCATIONAL INFORMATION			PH	EC	TDS	TH	Ca	Mg	Na	K	HCO_3	Cl	SO_4	NO_3	SAR	RSC	Na %
ZENDE WADI	74.0137068038	18.4045095335	7	499.8	324.9	203.8	59.6	13.3	30.5	2	117.6	88.2	18.6	36.6	0.94	-2.75	32.92
TATHE WADI	74.0480308753	18.3231729675	7.1	1332.8	866.3	513.5	191.3	8.6	156.8	1	478.2	237.2	63.2	52.4	3.04	-4.92	67.31
KHALAD	74.0795319904	18.3261505368	8.2	1607.2	1044.7	517.4	144.3	38.1	94.1	1	317.5	245	48.4	49	1.81	-6.78	40.02
KHANAVDI	74.1064077834	18.3319663060	7.2	1705.2	1108.4	678.2	183.5	53.3	72.5	1	482.2	135.2	141.1	62	1.22	-8.16	23.54
PARGAON	74.1331971964	18.3576843167	7.5	911.4	592.4	360.6	80	39.1	74.5	1	270.5	139.2	57.8	44	1.72	-4.19	45.42
GURHULI	74.0974344262	18.4059946888	7.2	921.2	598.8	364.6	81.5	39.1	78.4	1	301.8	145	58.8	22.4	1.8	-3.92	47.3
VANPURI	74.0723566437	18.3760505912	7.9	1999.2	1299.5	639	149	64.8	102.9	1	462.6	207.8	99	69.8	1.78	-7.6	35.43
SAKURDE	74.1217111546	18.2714960432	8.8	1156.4	751.7	160.7	18.8	27.6	25.6	1	23.5	184.2	68.2	22.5	0.88	-2.94	34.98
PIMPLE	74.0321272170	18.3006957794	7.5	2871.4	1866.4	458.6	98.8	51.4	129.4	1	94.1	248.9	213.6	82.8	2.65	-8.07	62.03
NARAYANPUR	73.9802140490	18.2994279050	8.4	1999.2	1299.5	411.6	72.1	56.2	90.2	1	74.5	141.1	203.8	86.8	1.95	-7.36	48.15
KODIT.BK	73.9783088498	18.3397051794	7.5	372.4	242.1	86.2	9.4	15.2	27	1	43.1	66.6	19.6	40.2	1.27	-1.24	68.75
GARADE	73.9275277778	18.3490277778	7.2	372.4	242.1	105.8	11	19.1	24.5	1	43.1	72.5	43.1	40.3	1.04	-1.63	50.83
BHIVRI	73.9265672320	18.3891951103	7.1	2459.8	1598.9	552.7	116	63.8	181.3	1	399.8	286.2	124.5	88.8	3.38	-6.58	72.13
CHAMBHLI	73.9734897171	18.3714821298	7.1	1881.6	1223	439	89.4	52.4	147	1	274.4	201.9	146	56.8	3.07	-5.7	73.62
THAPE WADI	73.8993541480	18.3375996860	7.3	1146.6	745.3	458.6	72.1	67.6	98	1	372.4	184.2	59.2	15.6	2	-5.02	46.95
PATHAR WASTI	73.8995305631	18.3760450978	8.3	2763.6	1796.3	642.9	92.5	100	126.4	1	247	243	254.8	32.8	2.18	-10.06	43.2
VARAVADI	73.8886211439	18.3540302427	8.3	1127	732.6	321.4	80	29.5	90.2	2	180.3	172.5	51	39	2.2	-4.4	61.72
SOMARDI	73.9347299926	18.3194651450	8.2	784	509.6	192.1	32.9	26.7	69.6	1	82.3	94.1	64.8	40.5	2.2	-2.91	79.62
ASKARWADI	73.8955146706	18.4009427600	7.1	1813	1178.5	705.6	207	45.7	103.9	1	348.9	323.4	127.4	69.4	1.71	-10.16	32.42
KHOPOR WADI	73.9662788830	18.3946685916	7.7	754.6	490.5	297.9	75.3	26.7	61.7	1	199.9	139.2	29.1	42.6	1.57	-3.72	45.6
SUPE.KH	74.0141445316	18.3203619215	7.4	714	502	218	59.8	22.7	46.5	1	212.8	177.4	22.1	26.9	1.31	-2.48	42.14
SONORI	74.0506902148	18.3863248134	7.9	812	414	226	62.4	19.8	52	1	198.6	144.9	23.8	36.8	1.48	-2.53	48.17
AMBODI	74.0451200731	18.3519271467	8.2	1960	1274	525.3	76.8	81	99	1	341	133.3	170.5	68.2	1.89	-6.69	41.4
PAWAR WADI	74.0122023326	18.3695158355	7.3	1127	732.6	439	117.6	35.2	95.1	1	321.4	178.4	74.2	44	1.99	-5.18	47.66
SHIVRI	74.0836585929	18.2858804032	7.4	921.2	598.8	368.5	65.9	49.5	85.3	1	266.6	160.7	68.9	45.9	1.95	-4.39	50.86
DUNE WASTI	74.1548428800	18.2843890427	7.3	872.2	566.9	176.4	43.9	16.2	68.2	2	152.9	121.5	26.1	21.4	2.25	-1.82	85.07
KOTHALE	74.1567899794	18.3227625818	7.1	1930.6	1254.9	560.6	136.4	53.3	142.1	1	101.9	317.5	265.6	75.6	2.63	-10.01	55.77
NARALICHA MALA	74.1193630377	18.3037073068	6.9	1639	1039	468	114.8	36.8	78.8	1	104.7	289.6	167.8	62.4	1.65	-7.55	39.55
BHAGWAT WASTI	74.1035493892	18.3691817903	6.8	1296	789	444	122.7	32.4	74.2	1	98.6	276.7	149.5	58.1	1.55	-7.65	37.12
JEJURI	74.1789798884	18.2842738829	8.2	2303	1497	223.4	59.6	18.1	85.3	1	109.8	115.6	83.3	4.2	2.5	-3.23	83.98
		Maximum	8.8	2871.4	1866.4	705.6	207	100	181.3	2	482.2	323.4	265.6	88.8	3.4	-1.2	85.1
		minimum	6.8	372.4	242.1	86.2	9.4	8.6	24.5	1	23.5	66.6	18.6	4.2	0.9	-10.2	23.5
		Average	7.6	1401.8	906	392	90.8	40.1	87	1.1	224.1	182.4	98.1	47.9	1.9	-5.3	51.5
		Standard deviation	0.5	686.6	449	174.4	50.2	21.6	38.9	0.3	137	71.7	71.1	21.4	0.6	2.6	16.2
		BIS Standards	6.5-8.5	1400	500	300	75	30	250	10	-	250	250	45	-	-	-

APPENDIX – II

Groundwater types

Village Name	Longitude	Latitude	Groundwater Type
ZENDE WADI	74.0137068	18.40450953	Ca-Na-Mg-Cl-HCO3
TATHE WADI	74.04803088	18.32317297	Ca-Na-HCO3-Cl
KHALAD	74.07953199	18.32615054	Ca-Na-Mg-Cl-HCO3
KHANAVDI	74.10640778	18.33196631	Ca-Mg-HCO3-Cl
PARGAON	74.1331972	18.35768432	Ca-Na-Mg-HCO3-Cl
GURHULI	74.09743443	18.40599469	Ca-Mg-Na-HCO3-Cl
VANPURI	74.07235664	18.37605059	Na-Mg-Cl
SAKURDE	74.12171115	18.27149604	Na-Ca-Mg-Cl-SO4
PIMPLE	74.03212722	18.30069578	Mg-Na-Ca-SO4-Cl
NARAYANPUR	73.98021405	18.29942791	Na-Mg-Cl
KODIT.BK	73.97830885	18.33970518	Na-Mg-Cl-SO4
GARADE	73.92752778	18.34902778	Na-Ca-Mg-Cl-HCO3
BHIVRI	73.92656723	18.38919511	Na-Ca-Mg-Cl-HCO3-SO4
CHAMBHLI	73.97348972	18.37148213	Mg-Na-Ca-Cl-SO4-HCO3
THAPE WADI	73.89935415	18.33759969	Ca-Na-Mg-Cl-HCO3
PATHAR WASTI	73.89953056	18.3760451	Na-Mg-Ca-Cl-HCO3-SO4
VARAVADI	73.88862114	18.35403024	Ca-Na-Mg-Cl-HCO3
SOMARDI	73.93472999	18.31946515	Ca-Na-Mg-Cl-HCO3
ASKARWADI	73.89551467	18.40094276	Na-Mg-Ca-Cl-HCO3
KHOPOR WADI	73.96627888	18.39466859	Na-Mg-Ca-Cl-HCO3
SUPE.KH	74.01414453	18.32036192	Na-Mg-Ca-Cl-HCO3
SONORI	74.05069021	18.38632481	Na-Mg-Ca-Cl-HCO3
AMBODI	74.04512007	18.35192715	Mg-Na-Ca-Cl-HCO3
PAWAR WADI	74.01220233	18.36951584	Na-Ca-Cl-HCO3
SHIVRI	74.08365859	18.2858804	Ca-Na-Mg-Cl-SO4
DUNE WASTI	74.15484288	18.28438904	Ca-Na-HCO3-Cl-SO4
KOTHALE	74.15678998	18.32276258	Ca-Mg-Na-Cl-HCO3-SO4
NARALICHA MALA	74.11936304	18.30370731	Ca-Mg-Na-Cl-HCO3-SO4
BHAGWAT WASTI	74.10354939	18.36918179	Ca-Mg-Na-Cl-HCO3-SO4
JEJURI	74.17897989	18.28427388	Ca-Na-HCO3-Cl

1. ORIGIN OF THE KARHA RIVER

2. CCT AT GARADE VILLAGE

3. RED BOLE WELL AT NARAYANPUR

4. HIGH GROUNDWATER TABLE AT PIMPLE

5. RED BOLE WELL AT TATHEWADI

6. WELL HAVING CONTAMINATED WATER AT KODIT BUDRUK

7. VERY HIGH GROUNDWATER TABLE AT ASKARWADI

8. VERY LOW GROUNDWATER TABLE AT KHANAVDI

9. APPROXIMATLY DRY WELL AT KHALAD

10. APPROXIMATLY DRY WELL AT JEJURI

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