Impact Factor (SJIF): 3.632

International Journal of Advance Research in Engineering, Science & Technology

e-ISSN: 2393-9877, p-ISSN: 2394-2444

Volume 3, Issue 5, May-2016

ASSESSMENT OF GROUND WATER VULNERABILITY TO CONTAMINATION OF BHAVNAGAR DISTRICT USING DRASTIC METHOD

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Abstract – Groundwater vulnerability is foundation stone for evaluating the risk for ground water contamination and developing management options to preserve the quality of ground water. The concept of ground water vulnerability is based on the assumption that the physical environment may provide some degree of protection for groundwater against human activities as well as natural contamination. The main objective of this study to find out the ground water vulnerable zone in Bhavnagar district using the DRASTIC model in a geographical information system environment. Determination of DRASTIC Index involves multiplying each parameter weight by its site rating and summing the total. On the basis of DRASTIC index values, a ground water vulnerability map was prepared using Arc GIS 10.2 Based on the results of the GW vulnerability assessment, the study area was divided into three zones: Low vulnerable zones ranging from 10 to 100 DRASTIC index with a geographical area of about 1% ; moderate vulnerable zones ranging from 101 to 150 with 59% geographical area and high vulnerable zones with DRASTIC index ranging from 151 to 194 with 40%.geographical area.

Key words : Groundwater vulnerability , DRASTIC parameter , GIS , Bhavnagar District, Water Quality

I. INTRODUCTION

Groundwater is one of the major sources of replenish-able Water on the earth and constitute approximately 30.1% of fresh water from the total water which only 0.86% is fresh water and total available water is 0.022%. the ground water is comparatively safe and reliable source as compared to surface water. Though not easily polluted , but once it is polluted it's expensive to treat polluted water. Due to increasing in population , changes in topography, land use cover and land use pattern and other anthropogenic activities , this resources has faced many changes that have deteriorated it and its been over exploited and stressed due to ever increasing water demand and less availability of surface water. Hence , there is a need to study this indispensible resources in detail and vulnerabilities associated with it so that preventive measures can be anticipated in advance. Several ground water methods have been developed by researchers ;but, all reports classify Groundwater vulnerability assessment methods into three categories such as overlay and index methods, methods employing process- based simulation models and statistical methods. The DRASTIC model, which belongs to the overlay and index category, is the most popular vulnerability mapping method and used as an important tool for GW planning and decision making. DRASTIC vulnerability index method is a GW quality model for evaluating the pollution potential of large areas using the seven hydrogeological factors of a region, which are a combination of geological, hydrogeological, geomorphological and meteorological characteristics of an aquifer. The DRASTIC model can be a valuable tool for identifying GW supplies that are vulnerable to contamination using basic hydrogeological variables believed to influence contaminant transport from surface sources to Ground water. The DRASTIC model evaluates the intrinsic vulnerability of GW by considering factors including depth to water table, natural recharge rates, aquifer media, soil media, topographic aspect, impact of vadose zone media and hydraulic conductivity. Usually different ratings are assigned to each factor and then summed together with respective weights to a numerical value as the vulnerability index.

II. BACKGROUND

Vulnerability is ever changing concept: it was first introduced in France in 1960s to create awareness among the people and scholars towards groundwater health. Literal definition of vulnerability assessment means that it is a system that can identify the problem , the weakness that might make the system to succumb at the time of crisis or any system which is sensitive to damage by one or the other or combination of factors. There have been many method developed for evaluation of groundwater vulnerability , which are categorized in to three main procedure viz, statistical methods, process based simulation methods and overlay index methods.

A. Overlay index method

In overlay index method, there are most used methods are : the DRASTIC method (Aller et al. 1987), the GOD system (Foster 1987), GLA (Hölting et al., 1995), KAVI (Beynen p.e. ET AL, 2012) the AVI rating system (Van Stempvoort et al. 1993), the

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SINTACS method (Civita 1994), PI (Goldscheider et al., 2000), the ISIS method (Civita and De Regibus 1995), the Irish perspective (Daly et al. 2002), RISKE (Petelet - Giraud 2000), the German method (Von Hoyer and Sofner 1998) and EPIK (Doerfliger et al. 1999).[1]

B. Process Based Simulation Methods.

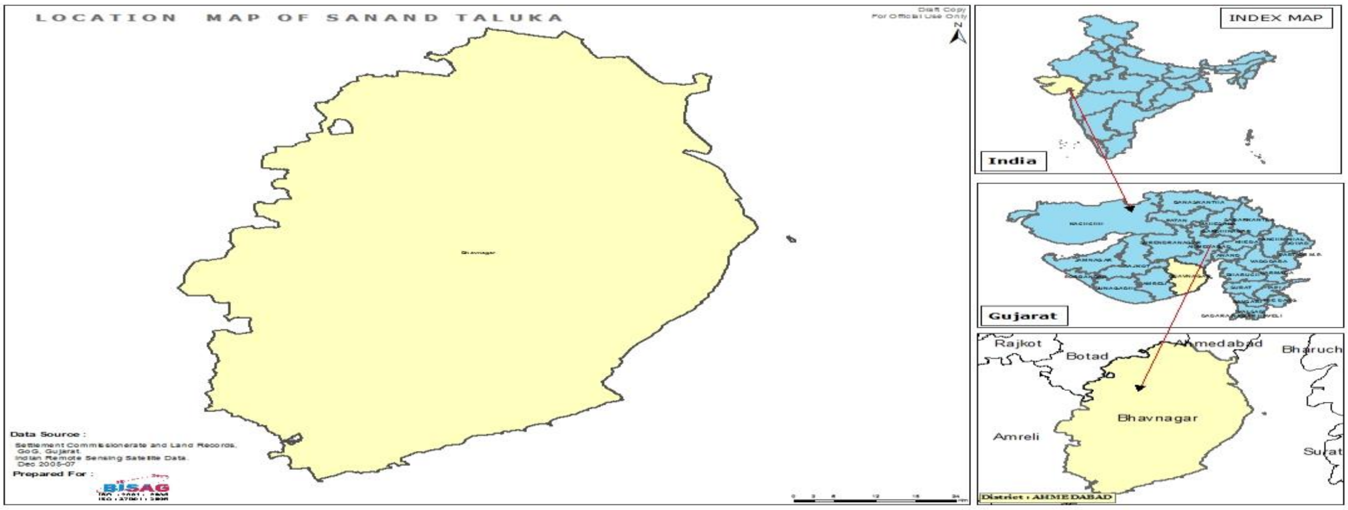
These methods are more complex and constitute and explicit and require large data. These are complex models and it varies from simple to complex 3-D simulation models. Behaviour Assessment Model (Jury and Ghodrati, 1989), and Attenuation Factor (Rao et. al. 1985) is analytical solution of advection dispersion equation are used to measure groundwater vulnerability. Neukam C. and Azzam R. (2009) used numerical simulation model of water flow and solute transport with transient boundary and links them to unsaturated strata and hydrologic & hydrogeologic characteristic and uses transit time t50. Meta models has also been used for vulnerability assessment of the aquifer. Meta Model is the “model of a model” based on multiple regression analysis, Kriging, Artificial Neural Network (ANN) etc. Complex simulation models had been approximated using a statistically significant function (Wu and Babcock, 1999; Pineros Garcet et al., 2006). [1]

C. Statistical Method

These methods are generally based on probability theory and require extensive field data, thence, derive the response variables such as contaminant probability occurrence and concentration. Using this method one can predict the occurrence or non-occurrence of a contaminant (specific vulnerability) in the area of interest..

III.STUDY AREA

Bhavnagar district is situated in south east corner on Saurashtra peninsula of Gujarat between 21.18^{0} North Latitude and 71.03^{o} to 72.09^{o} east longitude. It is surrounded by Surendranagar and Ahmedabad district on North , Rajkot and Amreli district on the west , Arabian sea on south and gulf of cambay on East. It has a cost line of about 152 kms .it has a geographical area of 9971 sq. kms. The average rainfall of the district is 732 mms .



(Source: Bhaskaracharya Institute for space Application and Geo -informatics)
Fig. 1: Location Map of Study area

A. Topography

The slope of the study area is 0-1% . The gradient of slope is towards the North- East cost at the apex of Gulf of Khambhat. The extensive hilly region along the cost between Gogha to Chhaya villages. The hill ranges fall in the inland portionaway from the coast. The maximum elevation of 300.61 m is at Trambak hill And 203.7 m at Tansa hill.

B. Drainage

In general flow of streams is towards gulf of Khambhat. The direction of the streams in each talukas are not same.

C. Soil

Soil texture attributes based on the dominate soil type having variation of texture. The infiltration rate of the soil depends on the soil texture of the area. Soil texture depends on the relative proportion of sand , silt and clay. In Bhavnagar area predominant soil group is of sine sand soil. 80% of the area is covered by the fine sand soil. Other area is covered by loamy , clayey , fine loamy and clayey skeletal.

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D . Geology

Bhavnagar district has basalt rock in Talaja , palitana , mahuva , Gadhada , Sihor , Botad etc. and other taluka has alluvial rock type.

IV. Material & Methodology

The main data used was groundwater exploration data, CGWB report ,population data, hydro-meterological data, Aster DEM, with resolution 30 m. The method used to assess the groundwater vulnerability is DRASTIC method which is proposed by Aller et al (1987) can be applied on the regional scale and intrinsic vulnerability of the aquifer under study can easily be obtained. This is one of the most widely used method among the many available owing to the fact that it is very easy to apply in the data insufficient area, where monitoring has been scarce, and also allows systematic evaluation of the parameters under study. This type vulnerability assessment gives fair preliminary results for identifying vulnerable area and later on focus on management plans, policy planning and decision making. The seven parameters that are taken in to consideration under this are, depth to water table, net recharge, aquifer media, soil media, topography, impact of Vadose zone and hydraulic conductivity. For overlay analysis the weights and ratings are given to each of the seven parameters, each is classified in to classes on the scale of 1-10, in which 1 denotes least vulnerable while 10 is for the most vulnerable areas. This rating is further scaled into weights based on the importance of the parameter in determining aquifer characteristics, these scaled on 1-5 where, 1 is least significant and 5 is most significant. The calculated DVI is classified in to further classes. it shows the susceptible area of groundwater contamination relatives to other.

The DRASTIC vulnerability index (DVI) is calculated by linear addition of the weights and rating, the formula is given below:

DVI = DrDw+RrRw+ArAw+SrSw+TrTw+IrIw+CrCw

Where, D,R,A,S,T,I,C = depth of water table , net recharge, aquifer media , soil media , topography , impact of vadose zone , hydraulic conductivity

r = ratings of parameters.

w = weight of parameters

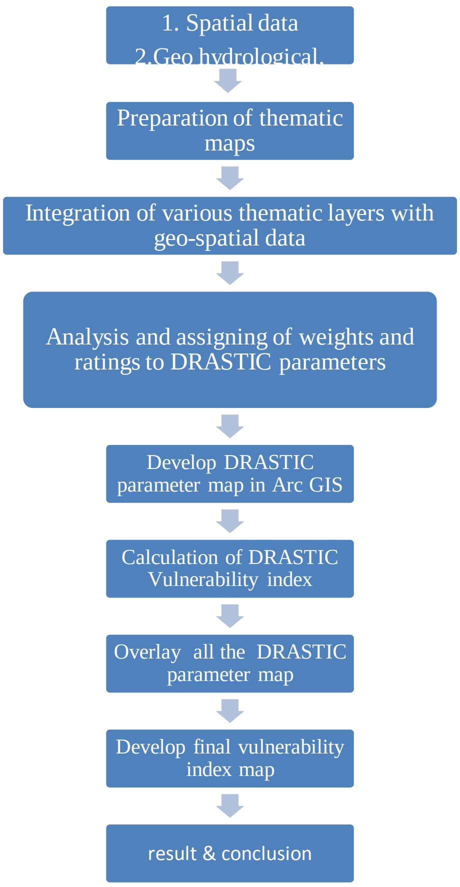

Fig. 2 Methodology Flow Chart

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Table 1 DRASTIC Rating and Weight values for the various hydrological parameter

Drastic Parameter	Range	Rating	Weight
Depth To Water Table (M)	0-5	10	
	5-30	9	
	30-45	7	5
	45-60	5	
	60-80	3	
	80-100	2	
	100-150	1	
Net Recharge (MCM/YEAR)	40-60	1	
	60-80	3	
	80-100	5	4
	100-120	7	
	120-140	10	
Aquifer Media	Alluvium	10	3
	Jointed Basalt	9	
Soil Media	Clayey	1	2
	Fine loamy	3	
	Clayey skeletal	4	
	Loamy	5	
	Fine sand	9	
Topography (%)	0-1	10	
	1-3	9	
	3-5	7	
	5-10	5	1
	10-15	3	
	15-35	1	
Impact Of Vadose Zone	Weathered Basalt	9	5
Hydraulic Conductivity (M/Day)	0.01 – 1.5	3	3

A. Depth to Water Table

The depth to water is important, primarily because, it determines the depth of material through which a contaminant must travel before reaching the aquifer, and it may help to determine the amount of time during which contact with the surrounding media is maintained. The depth to water table (DTWT) was measured from tube wells. In the study area ground water table increase than past years. The rating and weight are as indicated in table.

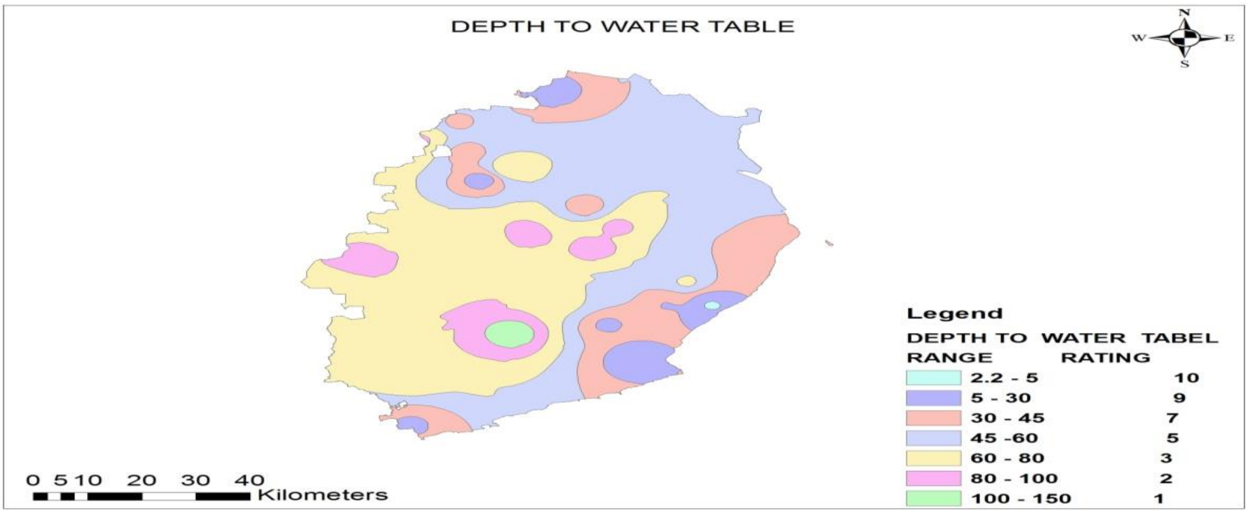

Fig. 2 Depth of Water Table map of Bhavnagar district

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B.Net Recharge

The primary source of GW is precipitation, which infiltrates through the ground and reaches the water table. Net recharge indicates the amount of water per unit area of land, which penetrates the ground surface and reaches the water table. This recharge water is thus available to transport a contaminant vertically to the water table and horizontally within the aquifer. More the water that leaks through, the greater the potential for the recharge to carry pollutants into the aquifer. Recharge is enhanced by practices such as irrigation or artificial recharge. In the study area net recharge is between 40 – 180 MCM/year.

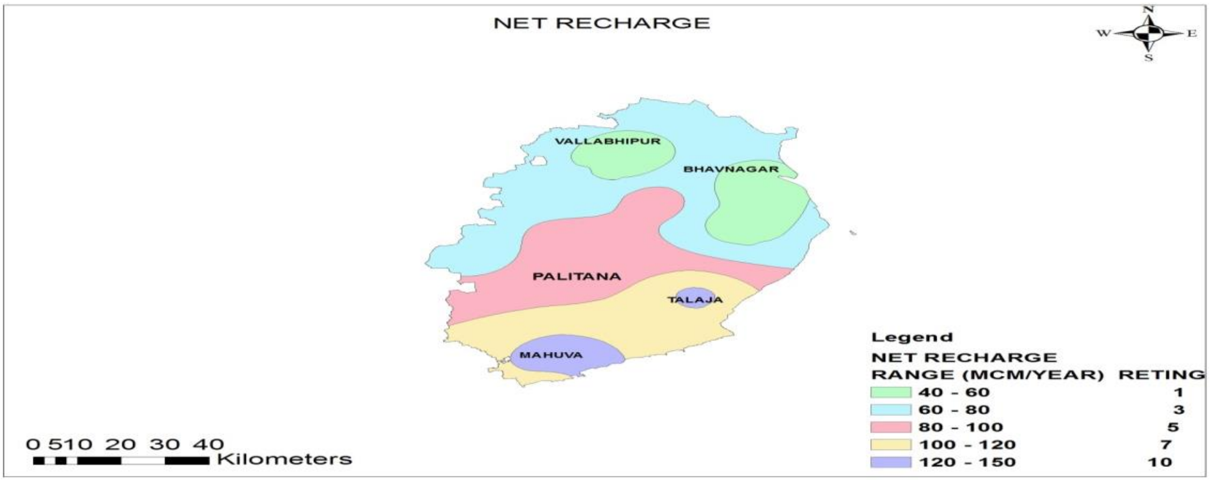

Fig .3 Net Recharge Map of Bhavnagar District

C. Aquifer Media

Aquifer media refers to the consolidated or unconsolidated medium which serves as aquifer. The aquifer media is defined by geology. In Bhavnagar district 80 % aquifer media is Jointed Basalt and 20% aquifer media is Alluvium. The rating is applied to each aquifer media based on their permeability. The alluvium aquifers are the most vulnerable to contamination and hence it was assigned the rating of 10 due to its high permeability. The Jointed Basalt is less permeable than the alluvium hence the rating is 9 for Jointed Basalt.

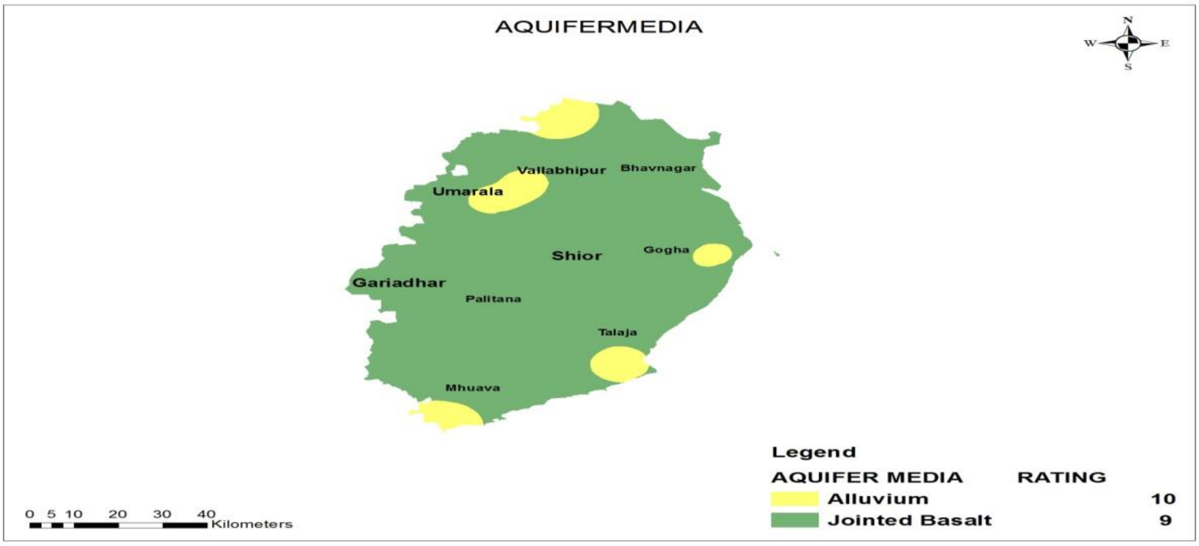

Fig .4 Aquifer Media Map of Bhavnagar District

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D. Soil Media

Soil media refers to that uppermost portion of the vadose zone characterized by significant biological activity. Soil is commonly considered as the upper weathered zone of the earth which average 1.5m or less in area. Soil has an significant impact on the amount of recharge which can infiltrate the ground hence the ability of a contaminant to move vertically in to the vadose zone. Agriculture activity on the earth by using pesticide , which is a contaminant source for ground water. In Bhavnagar district , there is a soil like clayey , loamy , clayey loam fine sand and clayey skeletal.

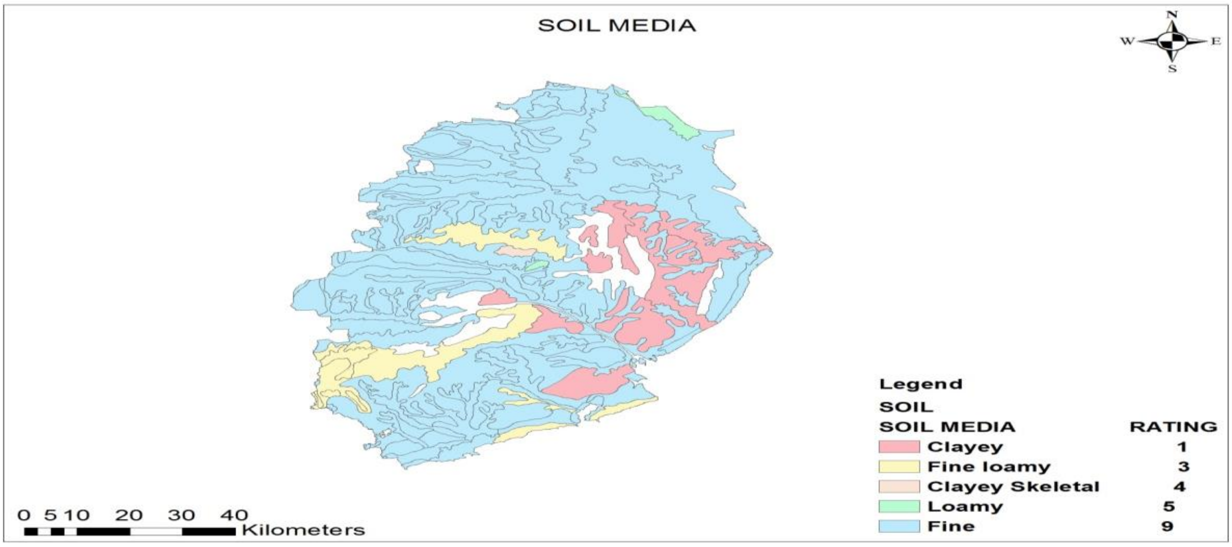

Fig .5 Soil Media Map of Bhavnagar District

E. Topography

Topography is refers to the slope and slope variability of the land surface. Topography controls the likelihood of a pollutant disposed as a runoff or retaining it in the area remains long enough to infiltrate .If the topography is flat , there is more chances of ground water contamination due to less surface runoff. If the topography is steep , due to more surface runoff there is a less chances of ground water contamination. In Bhavnagar district , there is 90 % area have a flat slope. The slope of the study area were derived from DEM image classified according to criteria. The resulting slope map was converted into a grid coverage considering that pixel values in this grid coverage are based on the slope ratings.

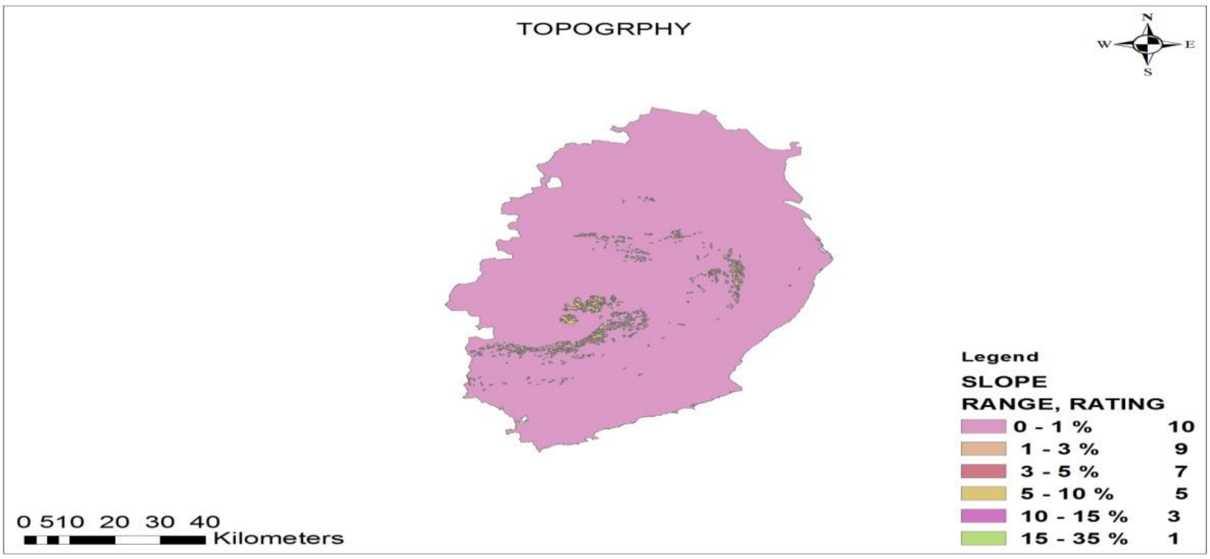

Fig .6 Map of Topography

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F. Impact of Vadosezone

Vadose zone is define as area which is lies above the water table and this zone is unsaturated. It is made from saturated and unsaturated zone and vary from depth to depth. Vadose zone plays important role same like soil in percolation of the recharge water to the aquifer media and for transportation of contamination so the weight of this parameter is "5" due to more significant of vulnerability. Vadose zone in Bhavnagar district is weathered basalt. The rating of this parameter is "9" due to high permeability.

Fig 7 Map of Vadose Zone

G. Hydraulic Conductivity

Hydraulic conductivity is an important parameter of aquifer which is characteristic of the geological properties. It governs the rate at which the water flows in the aquifer's saturated zone Hence, contaminant transportation is checked by hydraulic conductivity of the aquifer system. Hydraulic conductivity has weight of "3" which indicate that relative significance in this method. Hydraulic conductivity is obtained by the pumping test. The hydraulic conductivity of weathered basalt aquifer system vary from 0.0 to 15 m/ day .

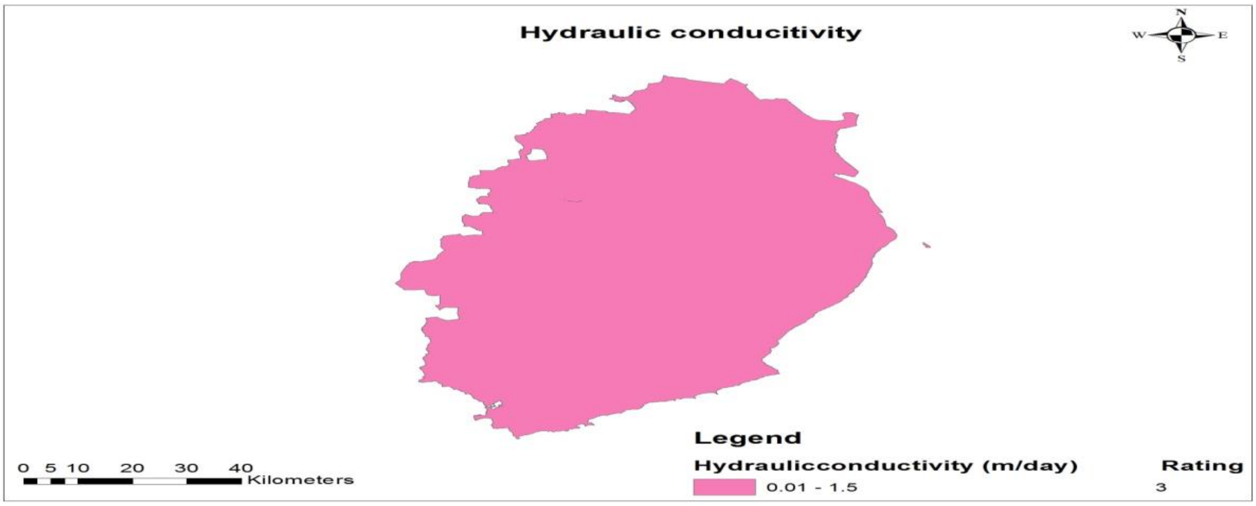

Fig . 8 Map of Hydraulic Conductivity

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V. Result & Discussion

The DRASTIC Method used produced the map to show the area of low, medium and high vulnerability. The district 's geological and hydro-geological set up determines the aquifer characteristics and in the present study area the groundwater resources are well protected by the soil, aquifer media, vadose zone, and topography. Around 1% area shows low ground water vulnerability, and around 59 % area shows medium ground water vulnerability . while 40% area shows high ground water vulnerability.

Table 2 Classification of DRASTIC vulnerability index

Class	index
Low	0-100
Medium	101-150
High	150-194

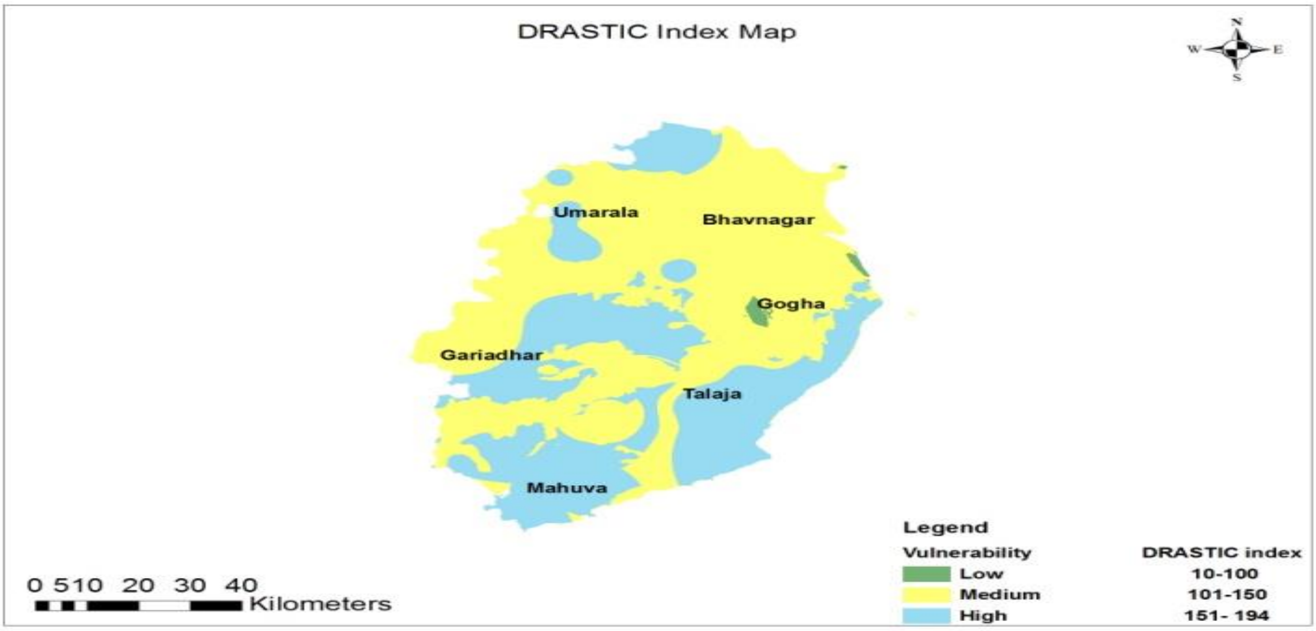

Fig 8 Vulnerability Map of Bhavnagar District

VI . CONCLUSION

Ground water contamination in the study area are related with natural causes and anthropogenic activities. Major part of the area is highly vulnerable (>150 vulnerability index) to pollution from the sea side as well as from inland industries and agriculture activity. The present study of ground water hazard vulnerability assessment and mapping will help in proper ground water management.

Validation of DRASTIC Model

For validation of the vulnerability assessment, Ground water samples were collected from different vulnerability zones of the study area for estimation of concentration of fluoride , chloride , Sodium ,Total Hardness , Electric Conductivity, TDS.. It has been observed that chloride, TDS, Total Hardness and fluoride are in desirable limit. Sodium is in permissible limit in some part of district and other part has above permissible limit.

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ACKNOWLEDGEMENTS

The authors are thankful to the Director, Bhaskaracharya Institute for Space Applications and Geo-Informatics (BISAG), Gandhinagar and his technical staff for their support during this study. The authors are thankful to the staff of civil department of L.D. College of Engineering, Ahmedabad for their support during this study. The authors are also thankful to the Central Ground water Board, Ahmedabad and State Ground Water Board, Gandhinagar for sharing data.

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