APPLICATION OF GIS BASED DRASTIC MODEL FOR GROUNDWATER VULNERABILITY ASSESSMENT IN NORTH 24 PARGANAS DISTRICT

A thesis submitted towards partial fulfilment of the requirements for the degree of Master of Engineering in Water Resources and Hydraulic Engineering

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ABSTRACT

Surface water quality is determined by hydrological responses that vary spatially. However, the sub-surface hydrologic environment has a primary influence on groundwater movement and hence pollutant migration to the subsurface water. Maps of aquifer vulnerability to pollution are becoming more in demand because, on the one hand, groundwater represents the primary source of drinking water. On the other hand, high concentrations of human/economic activities, e.g., industrial, agricultural, and household, represent actual or potential sources of groundwater contamination. There is a need to conduct studies on groundwater pollution. The main objective is to determine the vulnerable groundwater zones in North 24 Parganas district by DRASTIC Modelin a Geographical Information System (GIS), Arc GIS10.5 was used to create a map by overlaying the available hydro-geological data. This Model is based on the seven data layers that provide the input to the modelling. It corresponds to the initials of seven layers, i.e., Depth of water, Net Recharge, Aquifer media, Soil media, Topography, Impact of the vadose zone, and hydraulic Conductivity. The output map shows that the entire district has been classified into three different groundwater vulnerability zones high, moderate, and low. The more significant portion of the study area falls within the intermediate vulnerability zone, Blocks name are Amdanga, Barrackpore-II, Rajarhat, Habra-I, Gaighata, Bongaon, Bagdah, Baduria, Swarupnagar, Haroa with an index number of 97-111. Barasat-I, Barrackpore-I, Bashirhat-I, Bashirhat-II, Minakahan, Hingalganj, Sandeshkhali-I, Sandeshkhali-II blocks are in low vulnerability with an index number of 83-97, Barasat-II, Habra-II, Deganga are in high vulnerability zone of 111-125 index number. The GIS technique has proved as an efficient tool for assessing and analysing the vulnerability to groundwater pollution. The study suggests that this can be an effective tool for local authorities responsible for managing groundwater resources.

Keywords: Groundwater Pollution, ArcGIS Software, Drastic Model, Groundwater Vulnerability Zones, Raster Calculator, Weighted Sum Analysis

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CHAPTER-1: INTRODUCTION

1.1 General Background

Beyond any doubt that water is a precious and the most widely distributed resources inside the earth's crust. Total water resources of world are estimated at 1.37x10⁸ million ha-m, out of this water resources about 97.2% is salt water mainly in oceans, and about 2.8% is available as fresh water. About 2.2% is available as surface water and 0.6% as ground water of 2.8% available fresh water. Even out of this 2.2% of surface water, 2.15% is fresh water in glaciers and icecaps and only of the order of 0.1% (1.36x10⁴ M ha-m) is available in lakes and reservoirs and 0.0001% in streams. Out of 0.6% of stored ground water, only about 0.3% (41.1x10⁴ M ha-m) can be economically extracted with the present drilling technology. At present about 20% of all the water used in the world is obtained from ground water resource. As groundwater is the main source of fresh water available from the natural resources on the earth. Groundwater flow in an aquifer is governed by the aquifer's intrinsic characteristics (size, permeability, etc.) and its recharge, which – on a global level – is mainly produced by infiltration of precipitation. Most of the groundwater flow eventually ends up in springs and streams. Though a vast reserve of groundwater resources is available, every drop of groundwater needs proper management. In view of the above fact, an attempt has been made to depict the hydrogeological framework by synthesizing all the available data related to the hydrogeological condition to assess the state's ground water development prospect.

Average annual rainfall for the entire India is estimated as 1170 mm. The Himalayan region receives the maximum rainfall (about 4136mm). As of April 2015, the water resource potential or annual water availability in terms of natural runoff (flow) in rivers in India is about 1,869 Billion Cubic Meter (BCM)/year. Out of this, the usable water resources of the country have been estimated as 1,123 BCM/year. This is due to topography constraints and uneven distribution of the aid in various river basins, making it difficult to extract the entire available 1,869 BCM/year. Out of the 1,123 BCM/year, surface water and groundwater share is 690 BCM/year and 433 BCM/year, respectively. Setting aside 35 BCM for natural discharge, the net annual groundwater availability for the entire country is 398 BCM. Identifying potential groundwater zones is very important for the optimum utilization and conservation of this precious resource (Hutti & Nijagunappa, 2011). The conventional and reliable methods for determining the location of aquifers is Test drilling and stratigraphy analysis, but this method is very costly and time-consuming.

To evaluate the present area, we are using the DRASTIC model. It can be a valuable tool for identifying groundwater supplies vulnerable to contamination using basic hydro-geologic and hydro-geomorphological variables believed to influence contaminant transport from surface sources to groundwater (Rahaman 2008; Kalinski et al. 1994). The University of Kansas, where (Merchant et al. 1987 and; Merchant 1994) did the first project involving the partial automation of DRASTIC using Geographic Information System (GIS) concepts, was done by applying a commercially available Erdas Imagine software package to data compiled

for Harvey Country. Kansas (Kaplan et al. 1986) developed a GIS aimed at groundwater management for Nassau and Suffolk counties on Long Island, New York (Hendrix and Buckley 1986) used GIS technology for the study of water supply affected by naturally occurring radon contamination in dolomite aquifers with a high probability of pollution of groundwater by surface activity. DRASTIC consists of several components, the first of which is the designation of mappable hydro-geologic parameters (Aller et al., 1987). Remote sensing and geographic information system (RSGIS) technologies have emerged as an essential tool for mapping groundwater resources (Jha, Chowdhury, Chowdary, & Peiffer, 2007). Several factors, such as geology, topography, climatic conditions, soil, land use, land cover, etc., control groundwater availability in an area. Delineation of groundwater potential zones through a proper modelling approach is essential to handle the water scarcity problem of the drought-prone region.

1.1.1. Global Scenario

Groundwater renewability as part of the total water cycle is the principal difference from other mineral resources. According to calculations on a global model Water GAP-2 (Döll et al., 2003), an average perennial amount of groundwater recharge is about 14,000 km3/year for land or, in other words, about 36% of the river runoff is forming by groundwater.

1.1.2 National Scenario

In India ground water is primarily recharge by rainfall, secondarily other sources like, seepage from canals, irrigated fields, and surface water bodies. From the upper unconfined aquifers, a significant part of the groundwater withdrawal occurs, which are also the active recharge zones and hold the replenishable groundwater resource. Central Ground Water Board jointly with the concerned State Government authorities in India the replenishable groundwater resource in the active recharge zone has been assessed. As per norms recommended by the Ground Water Estimation Committee (GEC)-1997 the assessment was carried out with Block/Mandal/Taluka/Watershed as the unit. As per the latest assessment, the annual replenishable groundwater resource in this zone has been estimated as 436.15 billion cubic meters (BCM). 397.62 BCM is considered to be available for development for various uses after keeping 38.53 BCM for natural discharge during the non-monsoon period for maintaining flows in springs, rivers, and streams (Central Ground Water Board, 2020).

Table 1.1: Ground water Resources assessment 2004 to 2020

source: (Central Ground Water Board, 2020)

SI no	Ground Water Resources Assessment	2004	2009	2011	2013	2017	2020
1	Annual Ground Water Recharge	433 BCM	431 BCM	433 BCM	447 BCM	432 BCM	436 BCM
2	Annual Extractable Ground Water Resource	399 BCM	396 BCM	398 BCM	411 BCM	393 BCM	398 BCM
3	Annual Ground Water Extraction for Irrigation, Domestic & Industrial uses	231 BCM	243 BCM	245 BCM	253 BCM	249 BCM	245 BCM
4	Stage of Ground Water Extraction	58.0%	61.0%	62.0%	62.0%	63.0%	62.0%

Table 1.2: Categorization of assessment units from 2004 to 2020

source: (Central Ground Water Board, 2020)

Sl no	Categorization of Blocks/ Mandals/ Talukas	2004	2009	2011	2013	2017	2020
1	Total Assessed units	5723	5842	6607	6584	6881	6965
2	Safe	4078	4277	4503	4519	4310	4427
3	Semi-critical	550	523	697	681	972	1057
4	Critical	226	169	217	253	313	270
5	Over-Exploited	839	802	1071	1034	1186	1114
6	Saline	30	71	92	96	100	297

1.2 Groundwater Extraction and Use

In India groundwater overuse and contamination will be the main crisis for future. The situation in which, over a while, the average extraction rate from aquifers is greater than the average recharge rate is known as groundwater overuse or overexploitation. The availability of surface water is more than groundwater, in India. Though the availability of ground water in all over India is not equal but it is easily accessible and forms the largest share of India's agriculture and drinking water supply. Fig 1.1 illustrates 89% of groundwater extracted used in the irrigation sector, making it the highest category user in the country, followed by groundwater for domestic use, which is 9% of the extracted groundwater. The industrial use of groundwater is 2%,50% of urban water requirements and 85% of rural domestic water requirements are also fulfilled by groundwater. The most significant component of groundwater use is the water extracted for irrigation. The primary means of irrigation in the country are canals, tanks, and wells, including tube wells. Of all these sources, groundwater constitutes the largest share. Wells, including dug wells, shallow tube wells, and deep tube wells, provide about 61.6% of water for irrigation, followed by canals with 24.5%. Over the years, there has been a decrease in surface water use and a continuous increase in groundwater utilization for irrigation. Figure 1.2 illustrates the pattern of use of the primary sources of irrigation. As can be seen, the share of tube wells has increased exponentially, indicating the increased groundwater usage for irrigation by farmers. The dependence of irrigation on groundwater increased with the onset of the Green Revolution, which depended on the intensive use of inputs such as water and fertilizers to boost farm production. Low power tariffs have led to excessive water usage, leading to a sharp fall in water tables.

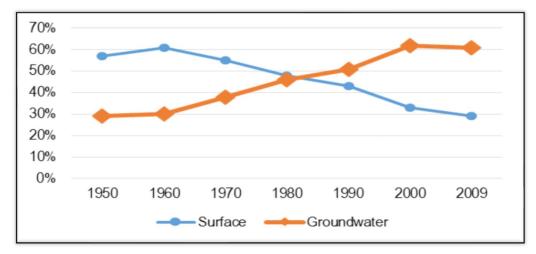


Figure 1.1: Increase in groundwater utilization for irrigation source: Agriculture Statistics at Glance 2014, Ministry of Agriculture

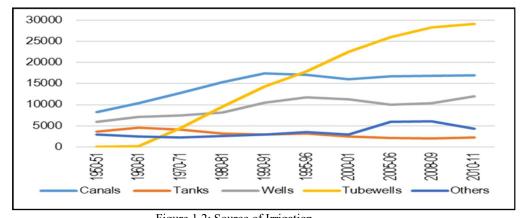


Figure 1.2: Source of Irrigation source: Agriculture Statistics at Glance 2014, Ministry of Agriculture

1.2.1 Groundwater Contamination

Groundwater contamination occurs when pollutants are released to the ground and make their way into groundwater and the presence of certain pollutants in groundwater that are more than the limits prescribed for drinking water. Arsenic, fluoride, nitrate, and iron are the commonly observed contaminants, which are known as geo-genic contaminants. Bacteria, phosphates and heavy metals are the other pollutants resulting from human activities like domestic sewage, agricultural practices, and industrial effluents. Groundwater contamination can occur from on-site sanitation system, landfill leachate, effluent from waste water treatment plants, leaking sewers, petrol filling stations, hydraulic fracturing or over application of fertilizers in agriculture. It is pointed out that nearly 60% of districts in the country have issues related to either availability

of groundwater, or quality of groundwater, or both. As per report published in central ground water board it is observed that 68 districts in 10 states are affected by high arsenic contamination in groundwater. These states are Haryana, Punjab, Uttar Pradesh, Bihar, Jharkhand, Chhattisgarh, West Bengal, Assam, Manipur, and Karnataka.

Table 1.3: Number of states and districts affected by Geogenic contaminants in India (as of July 2014)

Source: Central Ground Water Board

Geogenic Contaminants	Number of Affected States	Number of Affected Districts
Arsenic	10	68
Fluoride	20	276
Nitrate	21	387
Iron	24	297

1.2.2 Regional Scenario (West Bengal)

Annual Replenishable Groundwater Resource in 341 blocks of West Bengal is 30.36 BCM out of this net annual groundwater availability is 27.46 BCM. The annual ground water draft is 11.65 BCM so stage of Ground Water Development is 42.0%. The state can be divided into two hydrogeological unit namely fissured hard rocks & porous alluvial formations. Fissured formation includes crystalline, metasedimentary and volcanic rocks. The yield of wells tapping fractured zones varies from 10-20 m³/hr. Two third of the State is underlain by alluvial sediments mainly deposited by Ganga & Brahmaputra rivers. Based on the yield of wells tapping these alluvial sediments, aquifers of the alluvial area can be divided into three zones.

- 1. Yielding about 150m³/hr, occurs from Jalpaiguri to Cooch Bihar in north to Medinipur & 24 Parganas in South.
- 2. Yielding about 50-150 m³/hr, occurs in parts of Malda, Dinanjpur and western part of Murshidabad districts.
- 3. Yielding less than 50m³/hr, occurs as Marginal alluvial tract in parts of Birbhum, Burdawan, Bankura and Murshidabad districts.

In West Bengal groundwater contamination, presence of heavy metal and salinity is a major issue.

➤ High Arsenic (>0.05 mg/l)

In isolated patches spreading over 79 blocks in eight districts, namely, Malda, Murshidabad, Nadia, North 24 Parganas, South 24- Parganas to the east, and Haora, Hugly, and Burdwan to the west of Bhagirathi/ Hugly river, affected by arsenic contamination in groundwater. It is observed that Eastern part of the Bhagirathi/ Hugly river is much more affected than the western part. Deeper aquifers (>100 mbgl) in the same area are generally free from arsenic. Groundwater in the arsenic affected area is characterized by high iron, calcium, magnesium, bicarbonate with low chloride, sulfate, and fluoride. The maximum arsenic contamination level found in this district is 2830 µg/L in the Baduria block.

➤ High Fluoride (>1.50 mg/l)

The Task Force on Fluoride Contamination had recommended rapid assessment of fluoride concentration in groundwater in 105 blocks of 12 districts of West Bengal. After the evaluation, the final scenario regarding the high fluoride concentration in the ground water of West Bengal has been observed in 43 blocks of 7 districts, namely Bankura, Birbhum, Puruliya, Malda, Uttar Dinajpur, Dakshin Dinajpur, and South 24 Parganas. However, this problem is most serious in Bankura, Birbhum, Puruliya, and Dakshin Dinajpur districts. CGWB has found fluoride contamination above the permissible limit in Nadia and Burdwan district as well. In the state highest concentration of fluoride in groundwater has been reported from the Khyarasol block (15.9mg/lit) and Rampurhat-I block (17.9mg/lit) of Birbhum district.

- \Rightarrow High Salinity (EC > 3000 μ S/cm at 25 ° C)
 - Based on the geophysical surveys and groundwater exploration, Brackish to saline and fresh water-bearing aquifers have been deciphered in the different depth zones in the Kolkata Municipal Corporation area, South 24 Parganas parts of North 24 Parganas, Haora, and East Midnapur districts.
- ➢ High Iron (>1.00 mg/l)
 Iron content in some isolated patches of Medinipur, Haora, Hugli, and Bankura iron content is somewhat higher than 1 ppm. Sometimes, it exists more than 2 ppm in Haora and parts of the Hugli districts. Likewise, in the Himalayan foothills in the districts of Darjeeling and Jalpaiguri, groundwater in near-surface aquifers has iron as high as more than 3 ppm at places.

Beyond any drought that water is the most significant resources for the development of all kinds. Now a days, factors like limited water reservoirs, water supply, global water demand, regional disparities, groundwater contamination and climate change make water resource management a significant challenge. District North 24 Parganas is the second densest populated district in India, where ground water contamination and the salinity is the major issue even after 75 years of independence, presence of arsenic in drinking water and increase salinity area in groundwater is the main threat for the inhabitants of this region. Thus management of water resources in North 24 Parganas requires proper planning and participation of everyone to conserve this asset. Groundwater is utilized in North 24 Parganas for drinking and agricultural purposes with increasing demand. A modelling approach using ArcGIS software has been used to evaluate the groundwater vulnerability by integrating the Environmental Protection Agency (EPA) of the United States has developed a DRASTIC method to classify the pollution potential of aquifers (Aller et al. 1987) into Arc GIS 10.5 software. In this current research study, an attempt has been made to map the groundwater vulnerability zones in the study area by Raster Analysis and Weighed Sum Analysis.

1.3 Description of Study Area

North 24 Parganas is a district in southern West Bengal, of eastern India. North 24 Parganas extends in the tropical zone from latitude 22° 11′ 06″ north to 23° 15′ 02″ north and from longitude 88°20′ east to 89°05′ east. It is bordered to Nadia by north, to Bangladesh (Khulna Division) by north and east, to South 24 Parganas and Kolkata by south and to Kolkata, Howrah and Hoogly by west. Barasat is the district headquarters of North 24 Parganas. North 24 Parganas is West Bengal's most populous district. It is the tenth-largest district in the State by area. The district lies within the Ganga–Brahmaputra delta. The major distributary of river Ganga that is river Hooghly flows along the western border of the district. There are many other distributary branches, sub-branches of Ganga river and other local rivers, which include the Ichhamati, Jamuna, and Bidyadhari. It comprises 22 community development blocks administrative units with a total area of 4094 km².

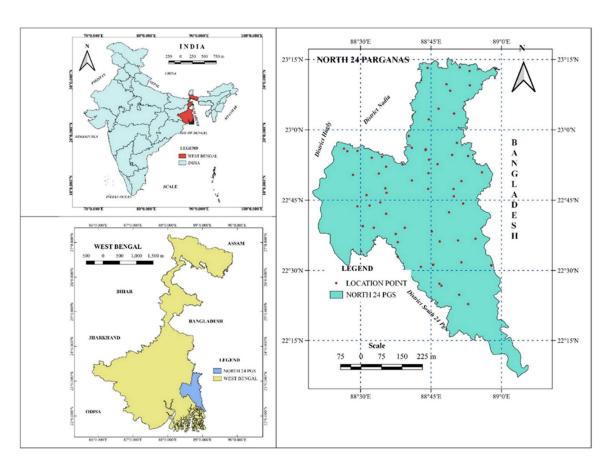


Figure 1.3: Location map of study area

1.3.1 Scope of the Study

Despite threats from polluting activities, groundwater is often surprisingly resilient, and water quality over large areas of the world generally remains good. In part, this is because many aquifer systems possess a natural capacity to attenuate and thereby mitigate the pollution. Though groundwater is not easily contaminated yet once this occurs, it is difficult to remediate. The replacement cost of a failing local aquifer

is generally high, and its loss may stress other water resources looked to as substitutes. Thus it is essential to identify which aquifer systems and settings are most vulnerable to degradation. The vulnerability studies enable the assessment of how severe the likely consequences of pollutant loading may be. Timely evaluation of groundwater resources vulnerability prevents their qualitative alteration, deterioration, or pollution. Groundwater vulnerability assessment must be interrelated with and integrated into master plans to support the planning, policy, and strategy of groundwater resources protection and quality conservation.

1.3.2 Research Objectives

To evaluate the groundwater vulnerability by integrating the DRASTIC Model into Arc GIS 10.5 software in the study area is the main objective of the present research work. To apply the DRASTIC Model seven parameters are needed, such as Depth of water, Net Recharge, Aquifer media, Soil media, Topography, Impact of the vadose zone, and Hydraulic Conductivity. By Raster Analysis and Weighed Sum Analysis, Mapping of the potential groundwater vulnerability zones in the study area is done.

1.3.3 The Methodology Adopted for the Research

The overall research methodology is mainly divided into five components

- Literature Review for Identification of goal and objective
- Collection of the information of the present situation by primary surveyand secondary survey
- Data Presentation and Organisation of data analysis
- Development of a method to assess the groundwater vulnerability Zones in the study area
- Output and result in analysis for Identifying strategies for scientific and sustainable management of groundwater resource.

Hydro geological parameters were considered for mapping the vulnerability of the area. Arc-GIS software was used for mapping Soil media, Aquifer media, topography, recharge, Vadose zone, ground water depth, and Hydraulic conductivity to identify the potential pollution zones of my study area. SCS runoff method was used for calculating runoff to determine the net recharge of the study area.

1.3.4 The Proposed Outcome of the Research Study

The following outcome would possibly have emerged through this research study:

- 1. A map showing groundwater potential pollution zones in the study area., which is categorized into three different groundwater potential zones: high, moderate, and low.
- 2. It is possible to identify areas that are more likely to be susceptible to groundwater contamination relative to one another
- 3. An idea about the condition of groundwater resource which is helpful for the planning of future artificial recharge projects in the study area to ensure sustainable groundwater utilization.

1.3.5 Outline of the Thesis

The thesis consists of six chapters.

- Chapter 2 contains a literature review.
- Chapter 3 describes the study area and its characteristics.
- Chapter 4 conceptualization of ground water vulnerability
- Chapter 5 illustrates the research methodology and concept behind the study.
- Chapter 6 describes the results and discussions.
- Chapter 7 the conclusion has been given.
- References are given at the end of the dissertation.

CHAPTER-2: LITERATURE REVIEW

There are various studies have been made to analyse aquifer vulnerability assessment using DRASTIC with high-resolution data for sustainable groundwater management. It helps in identifying relative groundwater pollution vulnerability by assigning ratings and relative weights of each hydro-geologic parameter. These methods have been developed to evaluate groundwater vulnerability are overlay and index methods (Gogu and Dassargues, 2000), process-based simulation model, and statistical-based data processing (McLay, C. D. A., et al. 2001). The overlay and index methods are widely used due to the accessibility of spatial data, the flexibility of incorporating other factors, and the simplicity of calculation. One of the overlay and index models is "DRASTIC" (Aller, 1987), which has been frequently used in groundwater vulnerability studies.

2.1 Research Review of International and National scale on Groundwater Vulnerability Assessment

- ➤ Aller, L., et al. (1987) created the DRASTIC Model by exploring the physical characteristics inherent in each hydro geologic setting that affect the groundwater pollution potential. These factors have been arranged to form the acronym, DRASTIC, for ease of reference. A numerical ranking system to assess groundwater pollution potential in hydro geologic settings has been devised using the DRASTIC factors. The system contains three significant parts: weights, ranges, and ratings. Each range for each DRASTIC factor has been evaluated for the others to determine the relative significance of each range to pollution potential. Based on the graphs, the range for each DRASTIC factor has been assigned a rating that varies between 1 and 10. The factors of 'D', 'R', 'S', 'T', and 'C' have been assigned one value per range. 'A' and I have been assigned a "typical" rating and a variable rating. The variable rating allows the user to choose either a typical value or to adjust the value based on more specific knowledge. This system allows the user to determine a numerical value for any hydro-geologic setting by using an additive model. Once a DRASTIC Index has been computed, it is possible to identify areas that are more likely to be susceptible to groundwater contamination relative to one another. The higher the DRASTIC Index, the greater the groundwater pollution potential.
- ➤ Civita, et al. (1994) developed SINTACS Model. The SINTACS model depends mainly on both aquifer characteristics and the hydro-geological environment. The acronyms SINTACS stands for the seven parameters are (i) Water table depth (S), (ii) Effective infiltration (I), (iii) Unsaturated zone (N), (iv) Soil media (T), (v) Aquifer media (A), (vi) Hydraulic conductivity (C) and (vii) Topographic slope (S). Various hydro-geological settings are represented by seven parameters which are further sub- divided into ranges or zones. The various approaches developed for evaluating aquifer vulnerability include process-based, statistical, overlay and index methods. This Model is much suitable for regional-scale assessment. The inputs for the SINTACS model are acquired from remote sensing and geographic information system (GIS) techniques. The SINTACS model is a

development of the United States DRASTIC model adapted to Mediterranean conditions. The SINTACS model is preferred for different considerations which include its low cost, depending on available data sets, and relative, dimensionless and non-measurable properties that depend on aquifer characteristics. SINTACS model is a point count system model group with all factors that have not only its score but also an additional weight is set to increase or decrease its importance during the analysis.

- ➤ Ribeiro et al. (2000) introduced the SI method for the estimation of the groundwater vulnerability to pollutants generated in areas at medium and large in Portugal. SI is obtained by removing S, I, and C from DRASTIC and including the land use parameter (LU) that incorporates the agricultural activities' impact (especially nitrates) on the water quality. Therefore, this method assesses the specific vulnerability of groundwater. The essential land-use activities classes and the corresponding rating values (displayed inside the brackets) vary between 0 (for semi-natural zones and forest) and 100 (for mines, landfill, and industrial discharge).
- ➤ Civita, et al.(2004) evaluated relative groundwater pollution vulnerability by assigning ratings and relative weights of each hydro-geologic parameter. The seven parameters are used to define the hydrogeological setting on any area and they are further subdivided into ranges (or) zones. Each zonehas been assigned different ratings on a scale of 1 in 10 based on the rating chart. The relative importance within each parameter to determine aquifer vulnerability is indicated by ranges or zones. The weights on the scale of 1 to 5 are assigned to each of seven parameters
- Mendoza, J.A., et al. (2006) introduced the Modified DRASTIC (DRASTICM) Model afterscientific studies pointed out that geologic structures have a significant impact on highly fractured environments' vulnerability. Therefore, in a study performed for a region from Nicaragua, Mendoza, and Barmen (2006) modified the DRASTIC index by including the influence of the length, connectivity, and lineament density. They introduced the lineament influence, denoted by 'M', in the new Model, called Modified DRASTIC. Where 'R' is the rating; 'M' is the lineament factor. A rate between 0 and 3 was assigned to the influence of the lineament. Mendoza and Barmen also proposed the classification of groundwater vulnerability degree as very high (MDI > 199), high (MDI between 160 and 199), moderate (MDI in the range 120–159), low (MDI between 80 and 119), and very low (MDI < 79). The results show that D and T are the factors with a significant influence on vulnerability prediction. Compared to DRASTIC, the modified DRASTIC gives a better estimation of the contamination risk in zones with high fractured structures.
- ➤ Qinghai et al. (2007) initiate the use of DRASIC-LU as a version of DRASTIC for assessing the groundwater pollution risk in some sub-regions of India (Ganga Plain). Due to the topographic small variation, the parameter 'T' was removed from the DRASTIC index and was replaced by the

- parameter 'L' (land use), which reflects the land use impact on the water quality. Qinghai et al. (2007) introduced the hydraulic conductivity values in concordance with the experimental data
- Wang, Y., et al (2007) emphasized the limitations of DRASTIC's application for urban areas as the terrain where the cities are situated is mostly flat, so the T factor in the DRASTIC Model is not relevant. The values of the soil media can be hardly obtained because the ground surface is mostly covered by concrete. The hydraulic conductivity is not relevant. Therefore, they built the DRAMIC index, by replacing in DRASTIC the 'S' factor by the thickness of the aquifer 'M', and the 'C' factor by the contaminant impact (denoted by C as well). It must be noticed that DRAMIC does not consider the pollutants' properties, but their stability and infiltration capacity into the aquifer. where R is the rating. The main factors considered in DRAMIC are the stability of the pollutant and the easiness of the pollutant infiltration.
- ➤ Qinghai, G. et al. (2007) introduced DRARCH model for studying the water vulnerability at arsenic in the Taiyuan basin and is based on simulation of the solute transport. Building a series of contaminant transport models employing Hydrus1D and use each model index in the simulations of the contaminant transport, the author increased the accepted index value and computed the associated migration distance of the contaminant. Analysing the relationship between the index values and the pollutant's simulated migration distances, the indexes' ratings were determined. Using the factorial analysis, the weighting of each index was finalized. The vulnerability spatial variation over the basin was estimated by applying the ordinary kriging. The 'D' and 'R' indices from DRASTIC are kept in the DRARCH model, while the other indices were replaced by Aquifer thickness (A); The ratio of the clay layers' thickness to the vadose zone thickness (R), introduced for emphasizing that the clay has a specific surface area and an adsorption capacity greater than other sediments; The coefficient of pollutant's adsorption by the sediment in the vadose zone (C); Aquifer hydraulic conductivity (H). The indices weights are 2, 1, 7, 9, 7, and 5, respectively. Where 'V' is the DRARCH score, 'R' is the rating value, 'w' is the parameter weight.
- Rahman, A. et al. (2008) finds out the groundwater vulnerable zones in shallow aquifers in Aligarh and its surrounding areas, which is one of the fastest-growing big cities of north India, using the DRASTIC Model in a Geographical Information System (GIS) environment. This Model is based on the seven data layers that provide the input to the modelling. ILWIS 3.0 (Integrated Land and Water InformationSystem) and ArcView 3.2a GIS software were used to find out the water vulnerable zones in shallowaquifers. The study shows that more than 80% of the city's groundwater is under medium to high vulnerability to water pollution which is the main cause of concern for nearly 0.8 million people livingin Aligarh.

- Chitsazan, M., et al. (2009) uses a GIS-based DRASTIC model for assessing aquifer vulnerability in Kherran Plain. The state of groundwater pollution is a critical issue with increasing population and agricultural development in Iran. Seven major hydro-geological factors (Depth to water table, net Recharge, Aquifer media, Soil media, Topography, Impact of vadose zone, and hydraulic Conductivity) were incorporated into the DRASTIC Model and geographical information system (GIS) was used to create a groundwater vulnerability map by overlaying the available hydrogeological data. The output map shows that the west and southwest of the aquifer are under medium vulnerability while small areas on the northwest and east of the study area have no risk of pollution. Other parts of the aquifer have low vulnerability. For testing of the vulnerability assessment, 27 groundwater samples were collected from the different vulnerability zones of the study area. The chemical analysis results show that the southwest and west parts of the aquifer (moderate vulnerability zones) have higher nitrate concentrations relative to the rest of the aquifer, which is located in a low vulnerability zone.
- ➤ Zhou, J. et al. (2010) put forward the DRAV Model which is a model designed by modifying DRASTIC for taking into account the groundwater characteristics from the arid zones. Generally, in arid areas, there is no horizontal runoff, the DRASTIC 'T' term was removed, and 'S' was replaced by 'V' (vadose zone's lithology). The factors D, R, and A were kept in the new Model. The DRAV index is a linear combination of the factors D, R, A, and V with the normalized weights 0.20, 0.15, 0.31, and 0.34, respectively.
- Alam et al. (2012) indicated that industrial and sewage pollution, pesticides, and fertilizers alter groundwater quality. Studies concerning groundwater vulnerability showed an increasing impact of land use on water contamination. They proposed a new index, DRASTIC-LU, adding "the land use pattern" (LU) parameter. Where the land use rating and weight are L_R and Lw, respectively. Since this approach considers many layers of the vadose zone, it is expected to provide more accurate results.
- Lurong, Y., et al. (2013) maps groundwater vulnerability for 21 major aquifers in Oklahoma using the DRASTIC Model and the Pesticide DRASTIC model. Comparing the vulnerability maps generated by DRASTIC and Pesticide DRASTIC models, and incorporating pollutant loading information into the DRASTIC map and the Pesticide DRASTIC map to gain a comprehensive view of contamination risk for hydro geologic basins in Oklahoma, vulnerability is defined as the sensitivity of groundwater quality to a contaminant load on the land surface, which is determined by the intrinsic characteristics of the aquifer. A variety of methods have been developed to evaluate groundwater vulnerability: overlay and index methods (Gogu and Dassargues, 2000), process-based simulation model, and statistical-based data processing (McLay, C. D. A., et al. 2001) The overlay and index methods are

- widely used due to the accessibility of spatial data, the flexibility of incorporating other factors, and the simplicity of calculation. One of the overlay and index models is "DRASTIC" (Aller, 1987), which has been frequently used in groundwater vulnerability studies.
- Gupta N et al. (2014) In this study, the researcher prepare a groundwater vulnerability map of Jabalpur district, Madhya Pradesh using GIS and application of DRASTIC model. Seven hydrological parameters like depth to water, net recharge, aquifer media, soil media, impact of Vadose zone and hydraulic conductivity are considered. The weights assigned to each of the parameter on the scale of 1 to 10 and 1 to 5 respectively and the DRASTIC Vulnerability index (DVI) is calculated as the sum of product of ratings. The result from DRASTIC model 3 vulnerability zone is classified (vulnerability index ranges from 47-209), low vulnerable zone (about 5.0% area), medium vulnerable zone (about 76.0% area), high vulnerable zone (about 9.0% area). The study also gives an idea about increasing of groundwater demand for population growth, industrial demand and agricultural sector for this reason soon the district will fall into exploited zone. For the management decision for sustainable use of the aquifer the map formed can be used.
- Saha D, et al. (2014) in this study, the main aim of research is to estimate groundwater vulnerability of by application of DRASTIC model and Pesticide DRASTIC models in the southern part of the Gangetic plains in the state of Bihar. For the DRASTIC and Pesticide DRASTIC models seven hydrogeological parameters are considered, the parameters are depth to water level, net recharge, aquifer material, soil material, topography, impact of vadose zone and hydraulic conductivity. By adding land use (LU) as an additional parameter, a third model, Pesticide DRASTIC LU has been adopted, to assess its impact on vulnerability zonation. The DRASTIC model identify two vulnerable categories, moderate and high, while moderate, high and very high vulnerable categories revealed by the Pesticide DRASTIC model. The vulnerability mostly affected by depth of the water table. A linear regression between groundwater NO₃ concentrations and the vulnerability zonation revealed better correlation for Pesticide DRASTIC model, emphasising the effectiveness of the model in assessing groundwater vulnerability in the study region. Considering all three models, the most vulnerable areas were found to be concentrated mainly in two zones, (i) in the south-western part along Ekangarsarai-Islampur patch and (ii) around Biharsharif-Nagarnausa area in the central part. Both zones were characterised by intensive vegetable cultivation with urban areas in between.
- ➤ Lathamani R., et al. (2015) evaluate Aquifer Vulnerability in Mysore city, Karnataka, India using Drastic Model and GIS. The DRASTIC Model was adapted in the present study to investigate the vulnerability of groundwater. The data collected were converted into digital format to insert into the Geographical Information System (GIS) environment. The ArcGIS 9.1 was used to manipulate the data and the weightage of each parameter was assigned as per Aller et al. (1987). The technique of

"inverse distance weighted" (IDW) interpolation in GIS was used to prepare the data for the entire city using sample points of net recharge and depth to water levels. Once the spatial vulnerability of groundwater was detected using Arc GIS, the primary sample, water quality data retrieved from 53 samples of groundwater were used to assess. the accuracy of DRASTIC Model. In the study area, DRASTIC index value was recorded < 70 to more than 100. The main reason for very high vulnerability in October is the high net recharge (10+ mm) and 60 % of the area has 0 - 2% slope ranges, which allowed the water to percolate more easily into the soil. High net recharge correlated well with the slope of the region. Very high nitrate concentration in the post-monsoon season (October) gives more credence to the vulnerability model.

- ➤ Singh A. et al (2015) established DRASTICA Model as a modified DRASTIC model which includes the anthropogenic influence in urbanized environments. A new factor (A anthropic factor) was introduced, with the weight equal to 5. The index is computed as in DRASTIC, adding the new term, 'AR' and 'Aw, where 'AR' is the rating and 'Aw' the weight. The rating and weighing of the other parameters were kept as in DRASTIC. Four vulnerability categories were built (low, moderate, high, and very high), corresponding to values of vulnerability indexes. In a study of the water pollution impact in Lucknow, India, DRASTICA better performs by comparison to DRASTIC, when the models were validated using field data.
- Ahirwar S, et al. (2017) In the study, to find out groundwater contamination potentiality of upper Betwa watershed DRASTIC model is used considering seven hydrogeological parameters viz: depth of water, net-recharge, aquifer media, soil media, topography, impact of vadose zone and hydraulic conductivity. Using the ArcGIS software, the ground water vulnerability map has been done by overlaying the seven layers. Based on groundwater vulnerability map, the watershed has been divided in 3 vulnerable zones, low vulnerability zone (42.83 sq km), moderate with (369.21 sq km) and high having (270.96 sq km). Also Nitrate concentration over the area has been validated by DRASTIC model, and found 3 vulnerable zone as per nitrate contamination, zero nitrate contamination area known as low vulnerable zone. While range 1.6-10 ppm nitrate concentration in the moderate zone. However, ranges 11-40 ppm in of nitrate concentration in groundwater is in high vulnerable zone. So, for the prediction of groundwater vulnerability in the watershed and in similar areas DRASTIC model is applicable.
- Thapa, R., et al. (2018) analyze the sensitivity and map the groundwater vulnerability zones through a comparative approach of different vulnerability models in Birbhum district, West Bengal, India. The assessment of groundwater vulnerability is essential especially in developing areas, where agriculture is the main source of the population. In the present study, four different overlays and indexmethods, namely, DRASTIC, modified DRASTIC, pesticide DRASTIC, and modified pesticide DRASTIC are implemented to identify the most appropriate method that predicts the vulnerable zoneto groundwater pollution. Sensitivity analysis reveals that net recharge is the most influential parameter of the

vulnerability index. Reported nitrate concentrations in groundwater are considered for validation of the model-generated final output map.

- ★ Kumar A, et al. (2018) In this study, with conventional DRASTIC parameters a significant parameter added, which is land use (LU) and the modified model termed as DRASTICLU. Geographic information system (GIS) use to make and integrate different parameter maps led to locate the risk zones in a catchment of Damodar River, Jharkhand, India. Finally considering groundwater contamination DRASTIC-LU 4 vulnerability zone is classified as, low risk (19.50%), moderate risk (34.02%), high risk (29.90%) and very high risk (16.58%) zones. Spearman's rank correlation coefficient (q) is use for Validation of models and for nitrate concentration in groundwater receiver operating characteristic curve is used, which indicated DRASTIC-LU (ρ=0.893; AUC =71.65%) had a better agreement than DRASTIC model (ρ =0.7818; AUC= 67.36%). Thus, such modification in DRASTIC improves the performance of the model.
- Mondal I., et al. (2019) use a GIS-based DRASTIC model for assessing groundwater vulnerability in the Jangalmahal area, West Bengal, India. Groundwater vulnerability assessment to delineate areas that are more susceptible to contamination from anthropogenic sources has become an important element for sensible natural resource management and land use and land cover planning of the Jangalmahal area. The study area reveals that about 43.5% of the watershed area is exposed to high-risk, 11.6% exposed to medium-risk, and 45.26% exposed to the watershed are dominated by high vulnerability classes while the north-western and middle portions are characterized by moderate vulnerability classes. The elevated northern and lower part of the study area shows the low aquifer vulnerability zone. The estimated DRASTIC index gives an indicator of the prevailing vulnerability in this Jangalmahal area.
- Maqsoom, A., et al. (2020) assessed groundwater susceptibility in regions where land-use types and anthropogenic activities represent considerable threats to groundwater pollution Considering the importance of anthropogenic activities, this research primarily utilizes an adjusted DRASTIC model called DRASTICA, which incorporates anthropogenic impact as a parameter in the Model. The resulting map, which depicts vulnerability to groundwater contamination, reveals that 19% of the study area is classed as having a high vulnerability, 42% has a moderate vulnerability, 37% has a low vulnerability, and 2% has a very low vulnerability to groundwater contamination. They used the nitrate concentration in groundwater to verify the formulated results, and the single parameter sensitivity analysis and map removal sensitivity analysis to analyze the model sensitivity. The groundwater zones exposed to anthropogenic pollution can be better classified with the help of the proposed DRASTICA model, particularly in and around built-up environments. The responsible authorities can use this groundwater contamination data as an early warning sign, so they can take practical actions to avoid extra pressure on this vital resource.

- Paul S, et al. (2021) in this study, by using DRASTIC and certain improved version of DRASTIC techniques, aiming to find the major susceptible zones of aquifer contamination in various locations of North 24 Parganas district. For this technique eight hydro-geological parameters are considered. To find the most sensitive parameter for ground water vulnerability a sensitivity analysis was also done. From the various part of the district total 64 numbers groundwater samples were collected and to determine their accuracy the water quality was compared to DRASTIC result. The result from DRASTIC model 4 vulnerability zone is classified, low vulnerable zone (about 14.20%), moderately high vulnerable zone (about 24.28%), high vulnerable zone (about 37.67), and very highly vulnerable zone (about 20.45%). After comparison of the four models we observed that the modified DRASTIC AHP is reliable and the most suited for evaluating groundwater susceptibility. The accuracy level of 87.50 percent. The observation from this vulnerability zone maps gives an idea which might be used in future for management and long-term planning about groundwater conservation in the North 24 Parganas and peripheral zones.
- ➤ Bera A, et al. (2021) in this study by using DRASTIC index vulnerability mapping of semi- arid watershed of Nangasai basin has been done where agriculture is the main source of economy. Like any other place of our country to increase food productivity farmers are use more and more fertilizer and pesticides in agriculture day by day which mixed up with ground water and contaminated the same, it affects human health badly. The final vulnerability map has been done by overlay weighted method with help of DRASTIC index after considering total 7 hydrological parameters. Total 5 vulnerable classes (very high, high, moderate, low, and very low) are classified. High ground water contamination has been observed in the south and south-eastern regions of the basin namely Deghi, Bankada, Baram, Macha, Katin, Tilabani. The water quality parameters like nitrate and TDS with accuracy of 89% and 86% respectively have been used for validating the model. This method is scientifically approved for controlled and managed lower risk contamination in anthropogenic and agricultural contamination. For groundwater pollution and its planning, this map can be use as base map.

CHAPTER-3: DESCRIPTION OF THE STUDY AREA

3.1 Location of study area

North 24 Parganas is a district located in south eastern part of West Bengal, extends in the tropical zone from latitude 22°11′ 06″ north to 23°15′02″ north and from longitude 88°20′ east to 89°05′ east, has a 230 km international border with Bangladesh. Soil characteristic of this district is mainly alluvial silt and clay, the district situated in the mature portion of Ganga-Brahmaputra delta. World's largest single patch mangrove forest Sundarbans extension is present in the southern part of this district. The annual rain fall of this district ranges about 1500 mm, received rainfall amount is lot which keeps the ground water alive. Hugli and Ichhamati are the two main river which flow through the western to eastern end of this district. A number of tidal rivers such as Kalindi, Raimangal, Dansa, Beneti, Haribhanga, Bidyadhari and others enriched the southern part of this district. It comprises 22 community development blocks and administrative units with a total area of 4094 sq km out of this area 625.78 sq km is urban and 3468.22 sq km is rural, population of 10,009,781 (2011).

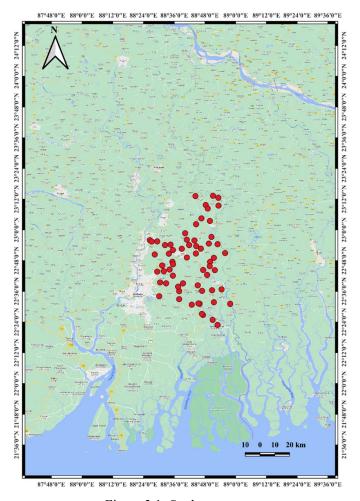


Figure 3.1: Study area map

3.1.1 Population of Rural and Urban

The district has a total area of 4094 sq km, 625.78 sq km is urban, and 3468.22 sq km is rural. Out of a total population of 10,009,781 in the district 5,732,162 (57.27%) are in urban area and 4,277,619 are in rural area. 1,355,449 households are in urban, 993,234 are in rural area. 4,679,327 literate people are in urban, 2,929,366 are in rural area.

Table 3.1: Population Census Data

Source: https://www.census2011.co.in

Blocks	Population 2011
Barasat-I	294628
Barasat-II	200918
Barrackpore -I	194333
Barrackpore -II	217171
Rajarhat	189893
Amdanga	191673
Habra-I	225200
Habra-II	176490
Gaighata	330287
Bongaon	380903
Bagdah	242974
Swarupnagar	256075
Baduria	285319
Deganga	319213
Basirhat-I	171613
Basirhat-II	226130
Hingalganj	174545
Haroa	214401
Hasnabad	203262
Minakhan	199084
Sandeshkhali-I	164465
Sandeshkhali-II	160976

3.1.2 Climate and Temperature

The climate is tropical, like the rest of the Gangetic West Bengal. It is also characterised by the Monsoon, which lasts from early June to mid September. The weather remains dry during the winter (mid November to mid February) and humid during summer. [Temperature ranges from 41 °C in May and 10 °C in January while relative humidity ranges between 50% in March & 90% in July. The average annual rainfall is 1,579mm. Hot humid summer, a characteristic of the tropical climatic region, prevails all over the district. The monsoon mainly occurs during the months of July, August and September. During this period almost two-third of the normal annual rainfall occurs which leads to sultry weather, flood and water logging in low areas.

3.1.3 Rainfall

The Indian Meteorological Department, Nagpur, vide letter No. NAGPUR RMC/CS-312, dated 18th January, 2016 has provided the period of Rainy Season viz. Normal dates of Onset and Withdrawal of South West Monsoon over India as state-wise. The duration for the period is 10th June to 15th October. Generally, 85 percent of the rainfall is received during the monsoon period. The annual precipitation of the district is around 1661.1 mm (ranges between 1500-1800 mm), while the temperate varies throughout the year is 33.2° C to 19° C with relative annual humidity of 72% to 83%.

3.1.4 Slope and Physiography

The general slope of the district is from west to east direction. Major part of the study area is gentle slope (1-2 degrees). Low or gentle slope is favorable for groundwater recharge zone.

North 24 Parganas is a deltaic district of West Bengal. It embraces the moribund delta in the north, matured delta in the middle, and active delta in the south and a depressed zone of brackish marshes between the active and the mature delta. Most of the soils derived from alluvial deposits are azonal with little or no profile development. Clay loam is the predominating type. Clays with or without muck soils occur in swamps and alluvial lakes. These soils have been formed from deposits brought by tidal currents. The active delta still growing southwards is a system of innumerable tidal rivers, canals and creeks, saline soils, swamps and marshes. A part of this active delta contains forests. Known as Sunderbans, this part of the active delta region is under reserve forests. Quite a large part of Sunderbans has been brought under cultivation. Even then the area of Sunderbans spread over 24 Parganas (north and south) is 1629 sq. km. Sunderbans is a mangrove forest. All the mangroves protect the shore from erosion and aid in accumulation of deposit mud. Snails, crabs and other marine species usually populate heavily beneath mangroves. of peat and

The district falls under the lower Gangetic deltaic plain land. There is no hill in the district. Broadly the district may be divided into three physiographic zones.

- loam to recent alluvium. It occupies the northern and eastern parts having a local slope towards south and drained by these two rivers.
- > North Bidyadhari Plain: North Bidyadhari Plain is full of sewerages and marshes with salt water lake region.
- > North Hugli Flat: North Hugli Flat is a raised alluvium strip along the Hugli river lying on the Western part of the district. In fact this zone is formed by silts of Hugli river.

3.1.5 Forest Cover

The district has no forest area as such except the Sunderbans Reserve Forests. The total area under reserve forest is 91.98 hectares covering 1.05% of the total geographical area of the district. Out of these 91.98 hectares, 63.00 hectares have been earmarked as Bhibhuti Bhushan Wildlife Sanctuary. However, these forests being positioned in the largest delta of the world, has a major role to play in maintaining the ecological balance of southern part of the State.

The forests of Sundarban can be classified in to following categories:

- (i) Mangrove Scrub: The Mangrove Scrub is formed along the edge of tidal water ways and sheltered muddy coast. The forest is usually dense with average height 3-6 m. The plant species are evergreen type with leathery leaves.
- (ii) Mangrove Forest: Mangrove Forest is also evergreen but of moderate height. It is usually found in the Tidal mud flats on the bank of deltaic streams which are permanently wet with salt water and are reached by the tidal forces.
- (iii) Salt Water Mixed Forest: This type of forests is spread over the mouths of larger river streams. The Ground is susceptible to the tidal waves but the volume of silt deposition is lesser than that of the fresh water region. The soil is comparatively stiffer with lesser presence of humus. The trees are not very large.
- (iv) Brackish Water Mixed Forest: The trees are usually very tall with pneumatophores and rare presence of stilt roots. The soil is usually not very salty, especially during the Monsoons.
- (v) Palm Swamp Type Forest: This type of forests usually exists in the dryinner land. Tidal salt water sometimes reaches this part.

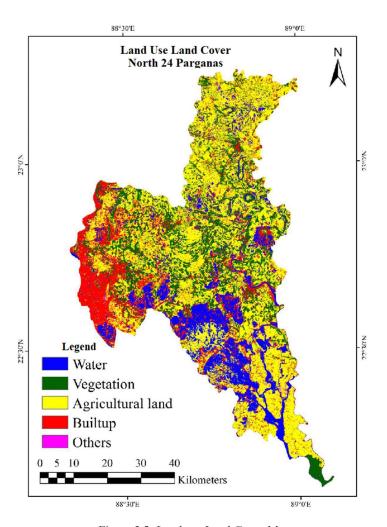


Figure 3.2: Land use Land Cover Map Source: DSR report North 24 Parganas

3.1.6 Geology & Minerals

The district of North 24 Parganas of West Bengal occurs in the southern part of the Bengal basin. The basin is actually a peri-cratonic basin and comprises of Ganga-Brahmaputra delta. It had broken from the Gondowanaland along the margin of the Indian plate and then moved towards north in the early Cretaceous (125Myr ago) period. The collision of the Indian and Euratia plates began in the early Eocene (40-41 Myr ago) period and resulted in the Himalayas and subsequently Himalayan Rivers like Ganga and Brahmaputra. Due to this the two groups of sediments from Ganga and Brahmaputra sediments got subsequently merged. There is a thickening of the Ganga-Brahmaputra delta towards the south. This occurs by the deposition of sediments not only of Ganga but also of the rivers Mayurakhi, Ajoy, Damodar etc. originating from the Chotanagpur uplands lying in the west in a word, geologically it is composed of alluvium of almost identical nature. The district falls under the lower Gangetic deltaic plain land. There is no hill in the district. Broadly the district may be divided into three physiographic zones.

➤ Ichhamati-Raimangal Plain: Ichhamati-Raimangal Plain contains soil of mature black or brownish loam to recent alluvium. It occupies the northern and eastern parts having a local slope towards south

and drained by these two rivers.

- North Bidyadhari Plain: North Bidyadhari Plain is full of sewerages and marshes with salt water lake region.
- > North Hugli Flat: North Hugli Flat is a raised alluvium strip along the Hugli River lying on the Western part of the district. In fact this zone is formed by silts of Hugli River.

3.1.7 Soil Type:

The district of North 24 Parganas falls within the new alluvium sub-region of the lower Gangetic Plain (Zone-Ill) and considered being most fertile for crop production. The soil type varies from sandy to clay sandy loam being the predominant ratio of high: medium: low land is 17:33:39. The soil of northern part of district is sandy, in the central middle part it is sandy with clay loam and in southern side it is clay loam. The physiographic structure of the district is mostly plain. As the district falls within the Gangetic delta, the soil of the district is very favorable for cultivation. Shallow black and brown soils are also found. Soil of different wetland areas is usually grey to greyish black in colour, silty clay to silty clay loam in texture having high water retentive capacity. In marshy areas silt and clay predominate over sand. In brackishwater (Brackish water is water that is saltier than fresh water, but not as salty as seawater) bheries the pH of the surface soil is almost neutral varying between 6.5 and 7.5, while the subsoil is acidic. In general bheri soils are poor in nitrogen (14.0-17.8 mg N/10O g) but medium in organic carbon content (0.53-0.69% C) and rich in phosphorus (8.1-12.4 mg P₂O₅/100 g), while both organic carbon (0.89%) and available nitrogen (19.0 mg N/10O g) were higher in sewage polluted saline bheries because of higher organic loads.

Depending upon the soil types the district is divided in two separated zones:-

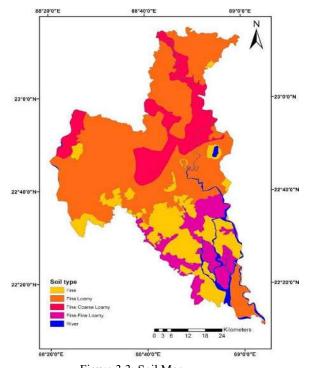


Figure 3.3: Soil Map Source: West Bengal Mineral Development And Trading Corporation Limited

3.1.8 Geomorphology and Hydrogeology

North 24 parganas district is characterized by a part of alluvial tract of Lower Ganga Basin, which shows gentle southerly slope with some local elevations and depressions. This flat alluvial plain is dissected by numerous meandering rivers and streams, viz. Hugli, Bidyadhari, Raimangala, etc. with dendritic drainage pattern. A small portion is flood plain near adjoining parts of banks of major river. Within flat topography, vast fields are often found submerged. In the south in N 24 parganas, there are some marshy lands which are mostly converted into paddy fields and also residential localities, eg. Salt Lake City and New Town Complex. The elevation varies from 15m in the north west (BarrackporeII Block) to (-) 0.01 m towards southeast (Hingalganj block); the average slope of the area is 0.065 m /Km.

Groundwater occurs in a thick zone of saturation in the alluvium deposited by the river system. The sand and gravel horizons of different textures constitute main aquifers. Groundwater in the northern and central part of the district occur under water table conditions. However, in isolated patches in Barrackpore, Amdanga, Hadra- II and Rajarhat blocks, the top clay and sandy clay locally thick (20- 30 metre) imparting semi-confined nature to the ground water body. In the southern and south eastern part of the district, comprising Hasanbad, Hindalganj, Sandeshkhali and Minakhan blocks, ground water occurs under confined condition. Depth to water level in unconfined aquifer during pre-monsoon period (2006) varies from 2.00 to 13.60 mbgl whereas that to post monsoon it is from 1.64 to 10.66 mbgl. Piezometric head in confined aquifer during pre-monsoon period (2006) varies from 3.47 mbgl to 6.25 mbgl whereas that to post monsoon period (2006) varies from 1.91 mbglto 5.89 mbgl.

3.1.9 Water Quality Scenario of Study Area

Water quality is poorly understood due to the variety in the interactions between water and soluble minerals, sparingly soluble minerals, and salts, both natural and anthropogenic. Despite the complex hydro and biogeochemical factors, the number of dissolved constituents in groundwater is limited. In addition to the trace constituents in water, the significant components are Na⁺, Ca²⁺, Mg²⁺, SO₄²⁻ (as acid and salts), Cl⁻, HCO₃⁻, etc., and the secondary constituents are Fe²⁺, Sr²⁺, K⁺, CO₃²⁻, NO₃⁻, and F⁻ (fluoride).

The water mainly neutral to mildly alkaline in nature and pH value ranges between 7.5 and 8.2. Total hardness as CaCO₃ ranges from 140-670 mg/l. Generally iron content is above permissible limit in all the blocks ranges from 1.23-18.10 mg/l. but in few places, it is found even of the order of 0.09-0.56 mg/l. Shallow aquifers within the depth of 100 mbgl show Arsenic concentration > 0.05 mg/l occurring in 253 mouzas in 17 blocks of the district. Deeper aquifers down to the depth of 350 mbgl are arsenic free.

3.1.10 Groundwater fluctuation of the study area

Groundwater level of pre-monsoon and post-monsoon reflects the actual groundwater condition of the area. Groundwater level data of different (64 nos) observatory wells for the period of 2017-18 to 2021–22 has been collected from the State Water Investigation Directorate (SWID), Government of West Bengal. Locations of School of Water Resources Engineering

groundwater observatory wells. The mean pre- monsoon groundwater level varies from 1.10 m to 14.5 m below ground, with a majority of the area having a mean pre-monsoon groundwater depth of 5 to 8 m. On the other hand, the mean post-monsoon groundwater level varies from 0.5 m to 12.55 m. Groundwater level for the pre-monsoon is very low in Amdanga, Barasat-I, Habra-I, Habra-II, Rajarhat, Barrackpore-I and Sandeshkhali-I blocks. It increases in the post-monsoon season. Higher groundwater fluctuation indicates excellent recharge capacity, and in turn, it reflects the excellent potentiality zones of groundwater. The fluctuation rate is high in Amdanga, Barasat-I, Habra-I, Habra-II and Rajarhat blocks, whereas the rate is low in parts of Barrackpore-I, Baduria, Minakhan, Hasnabad blocks. Due to COVID 19 pandemic 2020-21 Pre monsoon and Post monsoon data has not been collected by the directorate.

Table 3.2: Yearly Ground Water trends for North 24 Parganas from 2017-18 to 2021-22 Source: State Water Investigation Directorate (SWID), Government of West Bengal and Central Ground Water Board, Government of India.

Financial Year	Yearly Rainfall (mm)	Pre monsoon ground water level (GWL) (m bgl)		Post monsoon ground water level (GWL) (m bgl)		
		Minimum Maximum		Minimum	Maximum	
2017-18	1523	1.10	13.20	0.50	10.3	
2018-19	1523	1.78	13.10	1.53	12.22	
2019-20	1523	1.56	13.67	1.90	12.55	
2020-21	1934	-	-	-	-	
2021-22	1525	1.73	14.50	0.61	10.86	

3.1.11 Water Resources Problem of the Study Area

In North 24 Parganas availability of groundwater is good but on the other side is ground water commination is the major issue of this district, is a worst arsenic affected district in West Bengal state; 21 of 22 blocks of the district are identified as arsenic affected. The maximum arsenic contamination level found in this district is 2.830 mg/L in the Baduria block. Higher Iron concentration is another problem of this district, all blocks in district is contaminated by Iron. However, salinity problems in south eastern part (Barasat–II, Hasnabad, Hingalganj, Minakhan, Sandeshkhali I & II) of the district does exist, where fresh water aquifers underlies saline aquifer. From the long term monitoring of water level, declining trend (38 cm/year pre-monsoon time) has been observed in some parts of district specially in Amdanga block. Because of the known health and economic impacts associated with groundwater contamination, steps to assess the vulnerability of groundwater must be taken for sustainable groundwater protection and management planning. Vulnerability of groundwater refers to the intrinsic characteristics that determine the sensitivity of the water to being

adversely affected by an imposed contaminant load. The DRASTIC method (Aller et al., 1987), developed by the U.S. Environmental Protection Agency, is the most widely used method for identifying the areas where groundwater supplies are most susceptible to contamination. It is a relatively quick and simple to use process for assessing susceptibility to a large extent. Vulnerability to contamination is a dimensionless index function of hydrogeological factors, anthropogenic influences, and sources of contamination in any given area (Plymale and Angle 2002). The index consists of seven parameters with different weighting factors. The DRASTIC parameters are weighted from one to five according to their relative importance in contributing to the contamination potential (Aller et al., 1987). The resulting index is a comparable measure of vulnerability to contamination; higher index values are more vulnerable than those with a lower index.

CHAPTER-4: CONCEPTUALISATION OF GROUNDWATER VULNERABILITY

The concept of groundwater vulnerability is based on the assumption that from natural and human impacts the physical environment may provide some degree of protection to groundwater. Vulnerability due to external effects is not uniform for all type of aquifer. Groundwater vulnerability is a non-directly measurable property and is based on assessing several parameters that vary over regions as a function of the physical environment. The principal vulnerability parameters are connected with the hydrogeological and geological settings like hydraulic properties of the groundwater system, climate, and topography. However, the selection and valuation of parameters vary according to the goals and scope of a vulnerability assessment. The type of an aquifer and its position in the geological environment (whether shallow or deep, unconfined or confined) have a crucial influence on groundwater vulnerability.

A vulnerability map is based on the assessment and display of several parameters, which vary over regions as a function of the physical environment. The principal attributes used in groundwater vulnerability assessment (intrinsic and specific) are recharge, soil, properties, and the unsaturated and saturated zone characteristics. (Richts & Vrba, 2016).

4.1 Intrinsic Parameters of Groundwater Vulnerability

The aquifer's nature and geometry, porosity, hydraulic conductivity, transmissivity, storage properties, and groundwater flow direction are the main parameters for aquifer vulnerability assessment. Hydraulic conductivity is the primary importance. The attributes of secondary importance, topography, groundwater/surface water relation, and the nature of the aquifer's underlying unity are usually included in vulnerability assessment. Their range for vulnerability assessment varies with the area. Depending on the natural conditions, the importance may be greater in flat recharge areas, in the sector of surface stream bank infiltration into a shallow aquifer, and in the aquifer where groundwater has contact with the underlying strata. An important attribute is a topography, which influences recharge, soil development, and groundwater flow direction and velocity.

➤ Depth to Water (D)

The gap between the water table and the land surface is the depth to the groundwater table, which plays an active role in evaluating a certain area's susceptibility to pollution. The depth to water is primary importance because of the distance (the stretch of the material that a pollutant must cover before reaching the aquifer) and the sum of time (duration throughout which the contact of the pollutant with the immediate media (aquifer or soil) is sustained can be determined.

➤ Net Recharge (R)

Water from precipitation and various other artificial source seep into the soil and reach down to the ground water table. This amount of water percolating per unit area of soil is referred as net recharge.

High recharge indicates higher vulnerability to contamination and vice-versa (Bera et al., 2021) Millimeter per year unit is used to define net recharge. This study's net recharge criterionis the sum of precipitation without considering surface runoff and evapotranspiration. The source of recharge is the annual rainfall data taken from a local climatology station for a 10-year period.

➤ Aquifer Media (A)

An aquifer is a body of rock and/or sediment that holds groundwater. Groundwater is the word used to describe precipitation that has infiltrated the soil beyond the surface and collected in empty spaces underground. The underlaying rock structure highly affected the rate of permeability and dissolution of the contaminants into the groundwater thereafter. For the assessing the ground water quality the aquifer media hance is an important tool. Lower permeability and greater thickness of the aquifer is categorized as lower risk.

➤ Soil Media (S)

The uppermost part of vadose zone with active biological activities is the soil media. The soil media actively operates in the permeation of contaminants through the formations and controls the recharge of the area. Soil media plays a crucial role in removal of the pollutants by effective adsorption, and attenuation. Being chemically active and rich in organic matter the soil media helps in greater cationic exchange and removal of heavy metals. The soil highly affects the presence of contaminants and in their passage vertically into the vadose zone (Aller et al., 1987). There is generally a variation in the thickness as we move in depth Soil properties affect groundwater pollution potential as they control the movement of air and contaminant.

Topography (T)

The slope of an area simply implies by topography. This factor highly influences the velocity of surface runoff, thereafter influencing the rate of infiltration. Topography gives a clear view of where the pollutants tend to concentrate, infiltrate and contaminate the subsurface water. Higher the slope of an area, lower is the rate of infiltration and lesser are the chances of contaminants to seep downwards.

> Impact of the Vadose Zone (I)

There is an unsaturated region known as the vadose zone between the ground surface and the water level. The presence of this zone greatly influences the percolating water. The impact of the vadose zone on potential groundwater contamination is in principle identical to that of characteristic soil cover. The effect of vadose zone is a problematic phenomenon, depending on aquifer layers and topographic characteristics. A higher impact of the vadose zone if it is composed of porous soils.

➤ Hydraulic Conductivity (C)

This final component of the DRASTIC model can be described in terms of aquifer material and its ability to transmit water for a given hydraulic gradient. Hydraulic conductivity of an aquifer is the ability of the aquifer to spread water depends on its permeability and the amount of saturated zone.

with high conductivity is vulnerable to considerable contamination of groundwater. However, the impurity can immigrate immediately through the aquifer. This phenomenon is distinct from an aquifer with impermeable media, and it still has water content in the presence of fractures.

4.1.1 Methods and Techniques of Groundwater Vulnerability Assessment

Depending upon the physiography of the study area, the purpose of the study, quantity, and quality of data, several methods and techniques available for the assessment of groundwater vulnerability. Civita (1994) grouped the available methods into three basic categories:

- i. Hydrogeological complex and setting methods
- ii. Parametric system methods, and
- iii. Analogical relation and numerical model methods.

The point countsystem models also called the parametric weighting and rating methods, differ from the rating systems. In addition to rating multiplier (importance weight), each parameter is assigned to reflect the relationships among the parameters and their importance for vulnerability assessment. The point-count methods DRASTIC(Aller et al., 1987) and SINTACS (Civita et al., 1991) are the well-known one's technique has provided an efficient tool for assessing and analyzing the vulnerability to groundwater pollution.

4.2 Groundwater Recharge Estimation

To ensure sustainable groundwater supplies to satisfy the needs of a growing population, increase of groundwater recharge has become necessary. The amount of water passing through the unsaturated zone into an aquifer during a specified period is known as recharge, usually expressed as annual net recharge. The importance of recharge varies with the change of climatic conditions. The availability of water for groundwater recharge from all these sources may vary considerably from place to place. For a realistic assessment of the source water available for recharge in any given situation the following information may be required

- i. The quantum of non-committed water available for recharge
- ii. Time for which the source waterwill be available.
- iii. Quality of source water and the pre-treatment required.
- iv. Conveyance system required to bring the water to the proposed recharge site.

Rainfall and runoff available constitute the major sources ofwater for groundwater recharge and also is the primary source of recharge into the groundwater reservoir. Seepage from tanks, canals, and streams and the return flow from applied irrigation are the some other significant recharge sources. For proper evaluation of source water availability, a thorough understanding of rainfall and runoff is essential. Collection and analysis of hydro-meteorological and hydrological data have a vital role for assessing source water availability for planning and design of groundwater recharge schemes.

4.2.1 Estimation of Direct Runoff from Rainfall

In this method of runoff estimation, the effects of the surface conditions of a watershed area are evaluated using land use and treatment classes. Land use is the watershed cover. It includes every kind of vegetation, litter, and mulch, and fallow and non- agricultural uses such as water surfaces (lakes, swamps, etc) and impervious surfaces (roads, roofs, roofs, etc.). Land treatment applies mainly to agricultural land uses and includes mechanical practices such as contouring or terracing and management practices such as grazing control or rotation of crops. The classes consist of use and treatment combinations actually to be found on watersheds. Land use and treatment classes are readily obtained either by observation or by measuring plant and litter density and extent on sample areas.

4.2.2 Hydrological Soil Groups:

There are four soil groups used in determining the hydrological soil cover complexes, which are used to estimate the runoff from rainfall. A generalized soil map of India, giving the broad classification of all the significant soils in India, is shown in Figure 4.1. Major characteristics of these groups are described in Table. The variety is vast, but the groups can be divided into sub-groups whenever such

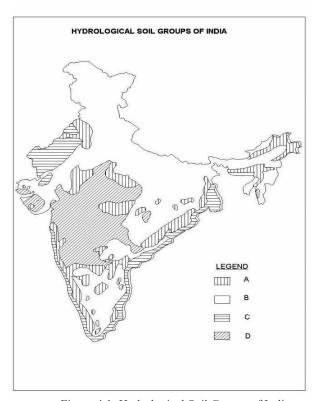


Figure 4.1: Hydrological Soil Groups of India

a refinement is justified. The infiltration rates and permeability of soils in different groups are shown in Table 4.1 respectively. In these tables, the infiltration rate is when water enters the soil at the surface and is controlled by surface conditions. Permeability rate is the rate at which water moves in the soil, influenced by the nature and characteristics of soil horizons.

Table 4.1: Hydrological Soil Groups

Hydrological Soil	Type of soil	Runoff potential	Final Infiltration Rate (mm/hr)	Remarks
A	Deep, well-drained sands and gravels	Low	>7.5	High rate of water transmission
В	Moderately deep, well-drained with moderately fine to coarse textures	Moderate	3.8-7.5	Moderate rate of water transmission
С	Clay loams, shallow sandy loam, soils with moderately fine to fine textures	Moderately high	1.3-3.8	Moderate rate of water transmission
D	Clay soils that swell significantly when wet, heavy plastic and soils with a permanent high water table	High	<1.3	Low rate of water transmission

4.2.3 Land Use and Treatment Classes:

The commonly used land use and treatment classes are briefly described below. These classes are used in determining hydrologic soil-cover complexes, which are used in one of the methods for estimating runoff from rainfall.

- > Cultivated lands: These include all field crops such as maize, sugarcane, paddy, and wheat.
- Fallow lands: These are lands taken up for cultivation but are temporarily out of cultivation for not less than one year and not more than five years. Current fallow lands are cropped areas kept fallow during the current year.
- > Uncultivated lands include:
 - Permanent pastures and other grazing lands.
 - Cultivable waste, which islands are available for cultivation, is taken up for cultivation or abandoned after a few years for one reason or another. Land once cultivated but uncultivated for 5 years in succession shall also be included in this category.
- Forest area includes all lands classed as forest under any legal enactment dealing with forest or administered as forest, whether State-owned or private and whether wooded or maintained as potential forest land.
- > Tree crops include woody perennial plants that reach a mature height of at least 8 feetand have well-defined stems and a definite crown shape.
- Lands put to non-agricultural uses are areas occupied by buildings, roads, railroads etc.
- ➤ Barren and uncultivable lands include areas covered by mountains, deserts etc.

4.2.4 Rainfall – Runoff Equations:

The data generally available in India comprise rainfall measured by non-recording rain gauge stations. Rainfall-runoff relation developed for such data is given below

$$Q = \frac{(P - I_a)^2}{(P - Ia + S)}$$
 (Eq.1)

Where

Q = Actual runoff in mm,

S = Potential maximum retention in mm

Ia=Initial abstraction during the period between the beginning of rainfall and runoff in equivalent depth over the catchment in mm.

In areas covered by black soils having Antecedent Moisture Conditions (AMC) II and III, Ia in the equation is equal to 0.1S, whereas in all other regions, including those with black soils of AMC I, Ia is equal to 0.3S. To show this relationship graphically, 'S' values are transformed into 'Curve

Numbers (CN)' using the following equation

$$CN = \frac{25400}{254 + S}$$

Using the above equation, the following equations have been developed:

$$Q = \frac{(P-0.3S)^2}{(P+0.7S)}$$
....(Eq.2)

$$Q = \frac{(P-0.1S)^2}{(P+0.9S)}....(Eq.3)$$

Equation 2 applies to all soil regions of India except black soil areas referred to in the section on 'Hydrological Soil Groups'. Equation 3 applies to black soil regions. This equation should be used with the assumption that cracks, which are typical of these soils when dry, have been filled. The runoff curve numbers (AMC II) for hydrologic soil cover complexes and curve number adjustments for AMCs (AMC I and AMC II) for Indian conditions presented in the Table 4.2. Values of CN for different soils are given in Table 4.3.

Table 4.2: Rainfall Limits for Antecedent Moisture Condition

AMC	Soil characteristics	Total 5 day Antecedent Rainfall (mm)	
Group		Dormant Season	Growing Season
I	Soils are dry but not to wilting point; satisfactory cultivation has taken place	Less than 13	Less than 36
II	Average condition	13 - 28	36 - 53
III	Heavy rainfall or light rainfall and low temperatures have occurred within the last 5 days saturated soil	Over 28	Over 53

Table 4.3: Runoff Curve Numbers for Hydrologic Soil Cover for agricultural lands $Complexes \ (For \ watershed \ Condition \ II \ and \ Ia = 0.25)$

Land Use/ Cover	Treatment/ Practice	Hydrologic Condition	Curve	Curve Number for HydrologicSoil Group		
			A	В	C	D
Fallow	Straight Row	-	77	86	91	94
Row Crops	Straight Row	Poor	72	81	88	91
	Straight Row	Good	67	78	85	89
	Contoured	Poor	70	79	84	88
	Contoured	Good	65	75	82	86
	Contoured Terraced	Poor	66	74	80	82
	Contoured Terraced	Good	62	71	78	81
Small Grain	Straight Row	Poor	65	76	84	88
	Straight Row	Good	63	75	83	87
	Contoured	Poor	63	74	82	85
	Contoured	Good	61	73	81	84
	Contoured Terraced	Poor	61	72	79	82
	Contoured Terraced	Good	59	70	78	81
Close seeded legumesor rotation meadow	Straight Row	Poor	66	77	85	89
	Straight Row	Good	58	72	81	85
	Contoured	Poor	64	75	83	85
	Contoured	Good	55	69	78	83
	Contoured Terraced	Poor	63	73	80	83
	Contoured Terraced	Good	51	67	76	80
Pasture or Range		Poor	68	79	86	89
		Fair	49	69	79	84
	Contoured	Good	39	69	79	84
	Contoured	Poor	47	67	81	88
	Contoured	Fair	25	59	75	83
		Good	6	35	70	79
Meadow (Permanent)		Good	30	58	71	78
Woodlands(FarmWoodlots)		Poor	45	66	77	83
		Fair	36	60	73	79
		Good	25	55	70	77
Farmsteads			59	74	82	86
Roads (Dirt)			72	82	87	89
Roads (Hard Surface)			77	84	90	92

4.3 Models to Assess Groundwater Vulnerability

➤ Ribeiro (2000) introduced the SI method for the estimation of the groundwater vulnerability to pollutants generated in areas at medium and large in Portugal. SI is obtained by removing S, I, and C from DRASTIC and including the land use parameter (LU) that incorporates the agricultural activities' impact (especially nitrates) on the water quality. Therefore, this method assesses the specific vulnerability of groundwater.

The SI index is computed by:

$$SI = D_R D_w + R_R R_w + A_R A_w + T_R T_w + L_{UR} L_{Uw}$$
, ----- (Eq 4.1)

The essential land-use activities classes and the corresponding rating values (displayed inside the brackets) varies between 0 (for semi-natural zones and forest) and 100 (for mines, landfill, and industrial discharge), with intermediate values as follows:

- < 90—Paddy fields, Irrigated perimeters irrigated,
- < 80—Shipyard and quarry,
- < 75—Green and continuous urban zones and artificially covered zones
- < 70—Discontinuous urban zones and Permanent cultures
- < 50—Aquatic media, agro-forest zones, pastures.
- ➤ Civita & DeMaio (2004) evaluated relative groundwater pollution vulnerability by assigning ratings and relative weights of each hydro-geologic parameter. The seven parameters are used to define the hydro-geological setting on any area, and they are further subdivided into ranges (or) zones. Each zone has been assigned different ratings on a scale of 1 in 10 based on the rating chart. The relative importance within each parameter to determine aquifer vulnerability is indicated by ranges or zones. The weights on the scale of 1 to 5 are assigned to each of seven parameters. Then computation of SINTACS Intrinsic Vulnerability Index (SIVI) is done using the following equation.

$$SIVI = \sum_{i=1}^{T} P_i x W_i$$
 (Eq 4.2)

Where, 'Pi' = ratings for seven parameters; Wi = relative weight for each parameter.

Mendoza, J.A. & Barmen, G. (2006) introduced Modified DRASTIC (DRASTICM) Model after scientific studies pointed out that geologic structures have a significant impact on highly fractured environments' vulnerability. Therefore, in a study performed for a region from Nicaragua, Mendoza, and Barmen (2006) modified the DRASTIC index by including the influence of the length, connectivity, and lineament density. They introduced the lineament influence, denoted by 'M', in the new model, called Modified DRASTIC, whose index, MDI, is defined by

$$MDI = DRASTIC \text{ index} + 5MR, ----- (Eq 4.3)$$

Where 'R' is the rating; 'M' is the lineament factor. A rate between 0 and 3 was assigned to the influence of the lineament. Mendoza and Barmen also proposed the classification of groundwater vulnerability degree as very high (MDI > 199), high (MDI between 160 and 199), moderate (MDI in the range 120–159), low (MDI between 80 and 119), and very low (MDI < 79). The results show that D and T are the factors with a significant influence on vulnerability prediction. Compared to DRASTIC, the modified DRASTIC gives a better estimation of the contamination risk in zones with high fractured structures.

➤ Qinghai et al. (2007) initiate the use of DRASIC-LU as a version of DRASTIC for assessing the groundwater pollution risk in some sub-regions of India (Ganga Plain). Due to the topographic small variation, the parameter 'T' was removed from the DRASTIC index and was replaced by the parameter 'L' (land use), which reflects the land use impact on the water quality. Qinghai et al. (2007) introduced the hydraulic conductivity values in concordance with the experimental data. The new index is defined by:

The terms have the same significance as in Equations 4.4. The index varies in the interval [140, 180], which is divided in four sub-intervals: [140, 150] - for low vulnerability zones, [150,160] - for moderate vulnerability zones, [160, 170] - for high vulnerability zones and [170, 180] - for very high, respectively.

Wang, Y., et al (2007) emphasized the limitations of DRASTIC's application for urban areas as the terrain where the cities are situated is mostly flat, so the T factor in the DRASTIC model is not relevant. The values of the soil media can be hardly obtained because the ground surface is mostly covered by concrete. The hydraulic conductivity is not relevant. Therefore, they built the DRAMIC index, by replacing in DRASTIC the 'S' factor by the thickness of the aquifer 'M', and the 'C' factor by the contaminant impact (denoted by C as well). It must be noticed that DRAMIC does not consider the pollutants' properties, but their stability and infiltration capacity into the aquifer.

The DRAMIC Index is computed by the relation

DRAMIC index =
$$2D_R + 3R_R + 4A_R + 2M_R + 5I_R + 1C_R$$
....(Eq 4.5)

where R is the rating. The main factors considered in DRAMIC are the stability of the pollutant and the easiness of the pollutant infiltration.

> Zhou, J. et al. (2010) put forward the DRAV Model which is a model designed by modifying DRASTIC for taking into account the groundwater characteristics from the arid zones. Generally, in

arid areas, there is no horizontal runoff, the DRASTIC 'T' term was removed, and 'S' was replaced by 'V' (vadose zone's lithology). The factors D, R, and A were kept in the new model. The DRAV index is a linear combination of the factors D, R, A, and V with the normalized weights 0.20, 0.15, 0.31, and 0.34, respectively.

Alam et al. (2012) indicated that industrial and sewage pollution, pesticides, and fertilizers alter groundwater quality. Studies concerning groundwater vulnerability showed an increasing impact of land use on water contamination. They proposed a new index, DRASTIC-LU, adding "the land use pattern" (LU) parameter. The DRASTIC-LU index is computed by:

$$DRASTIC-LU = D_RD_w + R_RR_w + A_RA_w + S_RS_w + T_RT_w + I_RI_w + C_RC_w + L_RL_w, \dots (Eq 4.6)$$

Where the land use rating and weight are L_R and L_W , respectively. The other acronyms have the same significance as in the DRASTIC index. The parameter of the vadose zone impact (IR) is computed by

$$I_{R} = T/\sum_{i=1}^{n} \frac{T_{i}}{I_{r_{i}}}$$
 (Eq 4.7)

where 'T' is the vadose zone total thickness, 'Ti' is the ith layer thickness and 'Iri' is the ith layer rating. Since this approach considers many layers of the vadose zone, it is expected to provide more accurate results.

➤ Chenini et al. (2015) proposed DRIST model considering only parameters related to the unsaturated aquifer zone, while DRASTIC works with the aquifer saturated zone characteristics. The calculation of the DRIST vulnerability index is similar to that for DRASTIC (but ignoring A and C parameters). Chenini et al. (2015) proposed a Modified DRASTIC method. The difference between these approaches resides in the estimation of factors A and I. In the new one, the lithology is substituted by permeability. The permeability map of the vertical vadose zone is realized based on the vertical permeability formula:

$$K_1 = H/\sum_{i=1}^{p} (h_i/k_i)$$
 -----(Eq 4.8)

Where, ' K_1 ' is the vertical average permeability (m/s); 'H' is the unsaturated zone total thickness (m); ' h_i ' is the thickness of the i^{th} layer (m), ' k_i ' is the permeability of the i^{th} layer (m/s), and 'p' is the number of layers.

The saturated zone's permeability map is determined using the formula of horizontal permeability.

$$K = (\sum_{i=1}^{p} (h k))/(\sum_{i=1}^{p} h)$$
 (Eq 4.9)

Where 'K₂' is the average horizontal permeability (m/s), 'h_i', 'k_i' and 'p' have the same significance as in formula while $\sum_{i=1}^{p} h_i$ at the denominator of the formula is the saturated zone total thickness (m).

CHAPTER-5: METHODOLOGY

In this chapter, methodologies to achieve various activities of the study objectives are discussed. The various activities carried out in the study is shown through the flow chart in (Figure 5.1)

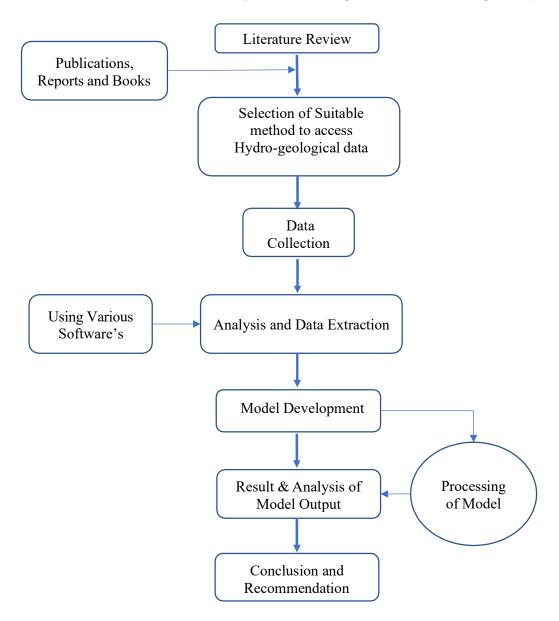


Figure 5.1: Flowchart of methodology

Though in North 24 Pargaganas district the groundwater is easily available but ground water contamination is the serious issue. The major part of this district, fine loam soil zone with a flat slope and with average altitude less than 10.0 m. Thus, the average recharge of this portion of is quite high due to high monsoon rainfall and capillary permeability of Gangetic alluvial soil (Paul S et al., 2021). But due to high growth of population along with agricultural needs suction of groundwater is increasing day by day, Arsenic contamination is serious issue, increasing salinity

zone in southern part along with presence of Iron in groundwater all over the district is the present scenario. Majority part of people depend on groundwater for domestic, irrigation, and other various purposes all over the year, but excessive use of groundwater has worse need the situation. Therefore, proper evaluation, planning, and management of groundwaterare essential for this region.

5.1 Literature Review

A literature review was carried out to select the method for mapping groundwater vulnerability. Based on the literature review, scientific and secondary data were collected for better knowledge of the survey field. Many of the reviewed studies were organized worldwide. These reviewed studies have helped to estimate groundwater pollution potential zones of the aquifer in different zones of the world. These studies were helpful by providing a general outline of how to map different groundwater zones and widen the disciplines of the research and analysis.

5.2 Data Collection

The data relating to the depth of water were collected from the State Water Investigation Directorate (SWID), Government of West Bengal (2017-18), Total 64 nos. point location data were collected and considering average value of this data, due to nonvalidity of other parameters data and rainfall data were collected from Agriculture Department, Government of West Bengal, from which net recharge is calculated by The Soil Conservation Service Curve Number (SCS-CN) method. The map relating to aquifer media and soil media has been collected from the Geological Survey of India, Kolkata, and NationalBureau of Soil Survey and Land Use Planning, 2010. Hydraulic conductivity data were collected from the Central Ground Water Board, Government of India (Report on aquifer planning and management plan, parts of North 24 Parganas, South 24 Parganas and Howrah Districts) The topography of the study area was prepared based on processing both SRTM 90 DEM and ASTER DEM data. The impact of the vadose zone was prepared based on the map collected from the Geological Survey of India, Kolkata. Satellite Image (Landsat-8 OLI) download from USGS website. Toposheet of this district, scale 1:50000 collected from Survey of India (SOI). Soil map of North 24 parganas district collected from (NBSS).

5.3 Data Analysis

The data collected were converted into digital format to insert into the Geographical Information System (GIS) environment. The ArcGIS 10.5 was used to manipulate the data, and the weightage of each parameter was assigned as per Aller et al. (1987). The technique of "inverse distance weighted" (IDW) interpolation in GIS was used to prepare. The DRASTIC formula was used in

the ArcGIS raster calculator to find out the vulnerability of groundwater. The 100 meters' spatial pixel resolution (raster Grid) raster layer was used for all raster manipulations.

5.3.1 Brief Description of ArcGIS Software:

ArcGIS is a geographic information system (GIS) for working with maps and geographic information maintained by the Environmental Systems Research Institute (ESRI). It is used for creating and using maps, compiling geographic data, analyzing mapped information, sharing and discovering geographic information, using maps and geographic information in a range of applications, and managing geographic information in a database. The system provides an infrastructure for making maps and geographic information available throughout an organization, community, and openly on the Web. In the study, ArcMap, ArcCatalog, and Arc Toolbox applications of ArcGIS 10.5 have been used. ArcMap is the application used to view, edit and query geospatial data, and create maps. The ArcMap interface has two main sections, including a table of contents on the left and the data frames which display the map. Items in the table of contents correspond with layers on the map. ArcCatalog is a data management application used to browse datasets and files on one's computer, database, or other sources. In addition to showing what data is available, ArcCatalog also allows users to preview the data on a map. ArcCatalog also provides the ability to view and manage metadata for spatial datasets. Arc Toolbox contains geoprocessing, data conversion, and analysis tools, along with much of the functionality in Arc Info.

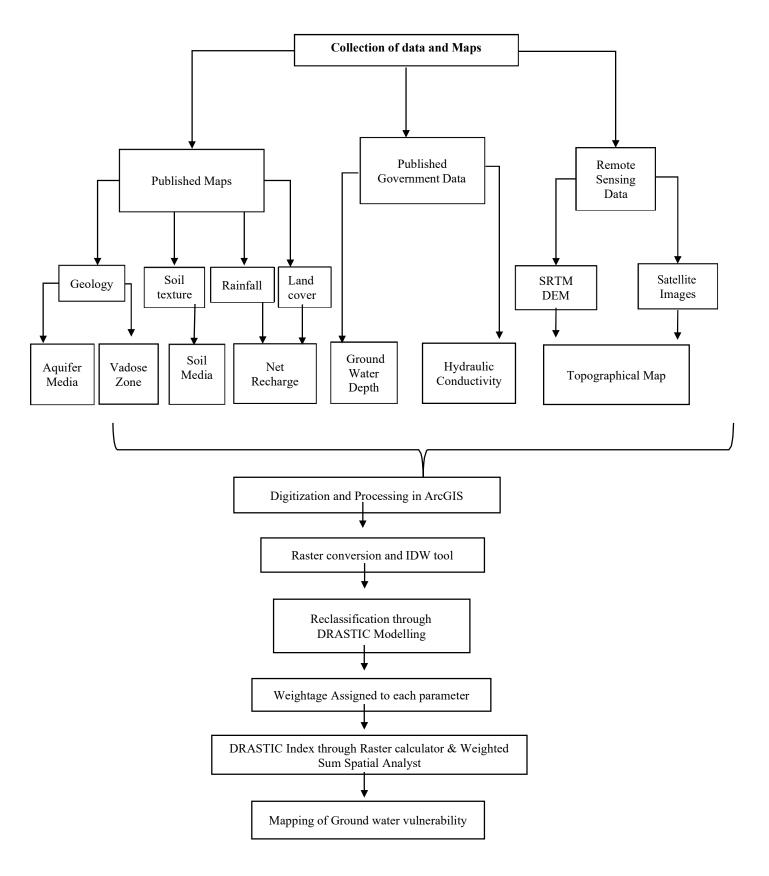


Figure 5.2: Flow diagram of Research Methodology

5.4 DRASTIC Model for Mapping Vulnerability

The DRASTIC method has been most commonly used for mapping vulnerability in porous aquifers (Aller et al.,1987). The objective of this study was to determine the aquifer vulnerability by integrating the DRASTIC Model into ArcGIS. The purpose of this project is to create a methodology that will permit the groundwater pollution potential of any hydrogeologic setting to be systematically evaluated with existing information.

The most critical capable factors that control the groundwater pollution potential were determined to be:

- D Depth of water
- R Net Recharge
- A Aquifer media
- S Soil Media
- T Topography (Slope)
- I Impact of Vadose zone
- C Hydraulic Conductivity of the Aquifer

A numerical ranking system to assess groundwater pollution potential in hydrogeologic settings has been devised using the DRASTIC factors. The system contains three significant parts: weights, ranges, and ratings.

- (1) Weights–Each DRASTIC factor has been assigned a relative weight ranging from 1 to 5. The most significant factors have weights of 5; the least significant, a weight of 1.
- (2) Ranges—Each DRASTIC factor has been divided into either ranges or significant media types which have an impact on pollution potential.
- (3) Ratings—Each range for each DRASTIC factor has been evaluated with respect to the others to determine the relative significance of each range with respect to pollution potential. Based on the graphs, the range for each DRASTIC factor has been assigned a rating that varies between 1 and 10. The factors of D, R, S, T, and C have been assigned one value per range. "A" and "I" have been assigned a "typical" rating and a variable rating. The variable rating allows the user to choose either a typical value or to adjust the value based on more specific knowledge

The equation for determining the DRASTIC Index is:

D = Depth to water, R = Net recharge, A = Aquifer media, S = Soil media, T = Topography (Slope), I = Impact of the vadose zone, C = hydraulic Conductivity, r = rating, w = weighting.

Once a DRASTIC Index has been computed, it is possible to identify areas that are more likely to be susceptible to groundwater contamination relative to one another. The higher the DRASTIC Index, the greater the groundwater pollution potential.

5.4.1 Assigned Weights Ranges and Ratings for DRASTIC Feature

Table 5.1: Weights for Drastic Features (Aller et al.,1987).

Sl.no	Feature	Weights
1	Depth of water (Dw)	5
2	Net Recharge (Rw)	4
3	Aquifer Media (Aw)	3
4	Soil Media (Sw)	2
5	Topography (Tw)	1
6	Impact of Vadose Zone (Iw)	5
7	Hydraulic Conductivity (Cw)	3

Table 5.2: Depth of Water in meter (Dr)

Ranges	Ratings
0 to 1.5	10
1.5 to 3.0	9
3.0 to 5.0	7
5.0 to 9.0	5
9.0 to 12.0	3

Table 5.3: Net Recharge (Rr)

Range (mm/year)	Ratings
0 - 50.0	1
50 -100	2

Table 5.5: Aquifer Media (Ar)

Range	Rating
Fine Sand	5
Fine to medium	6
Medium Sand	7

Table 5.6: Soil Media (Sr)

Range	Rating
Fine Soil	3
Fine Loamy	4

Table 5.4: Topography (Tr)

Range (percent)	Ratings
0-2	10
2-6	9
6-12	5
12-18	3

Table 5.7: Impact of the Vadose Zone (Ir)

Range	Rating
Silt and Clay	3
Medium Sand	6

Table 5.8: Hydraulic Conductivity (Cr)

Range (m/day)	Rating
0 - 10.0	1
10.0 - 20.0	2
20.0- 30.0	3
30.0 - 50.0	4

5.5 Overlay/Index Analysis by Arc GIS Software:

Overlay/Index analysis is a multi-criteria analysis wherein analysis can be carried out with complex things to find out specific themes with the help of the assignment of rank to the individual class of feature and then assign weightage to the particular feature considering its influence over theme. All the thematic maps were converted into raster format and superimposed by the weighted method, which consists of rank and weightage wise thematic maps and integration of them through GIS. Integration of thematic maps for carrying out multi-criteria or overlay analysis in a GIS environment was done using ArcGIS software.

5.5.1 Inverse distance weighted (IDW) (Spatial Analyst)

Interpolates a raster surface from points using an inverse distance weighted (IDW) technique. It determines cell values using a linearly weighted combination of a set of sample points. The weight is a function of inverse distance. The surface being interpolated should be that of a locational dependent variable. This method assumes that the variable being mapped decreases in influence with space from its sampled location. For example, when interpolating a surface of consumer purchasing power for retail site analysis, the purchasing power of a more distant place will have less influence because people are more likely to shop closer to home.

How (IDW) (Spatial Analyst) works:

- The input point features containing the z-values to be interpolated into a surface raster
- The field holds a height or magnitude value for each point.
- > This can be a numeric field or the Shape field if the input point features contain z-values
- ➤ The output interpolated surface raster. It is always a floating-point raster.
- The cell size at which the output raster can be created.

5.5.2 Reclassify (Spatial Analyst)

The reclassification tools reclassify or change cell values to alternative values using a variety of methods. You can reclass one weight at a time or groups of values at once using alternative fields; based on a criterion, such as specified intervals (for example, group the values into 10 intervals); or by area (for example, group the values into 10 groups containing the same number of cells). The tools are designed to allow you to easily change many values on an input raster to desired, specified, or alternative values. All reclassification methods are applied to each cell within a zone. That is, when using an alternative value to a current value, all the reclassification methods apply the alternative value to each cell of the original zone. No reclassification method applies alternative values to only a portion of an input zone.

How to Reclassify (Spatial Analyst) works:

- ➤ Input datasets. Decide which datasets you need as inputs.
- ➤ Derive datasets. When applicable, create the datasets that you can derive from your base input datasets— for example, slope and aspect can be derived from the elevation raster. Create data from existing data to gain new information.
- ➤ Reclassify or rescale datasets. Reclassify each dataset to a common scale (for example, 1 to 10), giving higher values to more suitable attributes.
- ➤ Weight and combine datasets. Weight datasets that should have more influence in the suitability model if necessary, then combine them to find suitable locations.

5.5.3 Weighted Sum Spatial Analyst (WSSA)

Weighted Sum Spatial analyst (WSSA) is a simple and straightforward method for a combined analysis of multiclass maps. Weight represents the relative importance of a parameter and the objective. Overlays several rasters', multiplying each by their given weight and summing them together.

How Weighted Sum works

The Weighted Sum tool provides the ability to weigh and combine multiple inputs to create an integrated analysis. It is similar to the Weighted Overlay tool in that multiple raster inputs, representing various factors, can be easily combined, incorporating weights or relative importance.

By not rescaling the reclassified values back to the evaluation scale, the analysis maintains its

resolution. For example, in a suitability model, if there are ten input criteria that were reclassified to a 1 to 10 scale (10 being the most favourable) and no weights were assigned, the values on the output from Weighted Sum could range from 10 to 100. For the same input, Weighted Overlay would normalize the 10 to 100 reclassified analysis range to the evaluation scale, for example, back to the 1 to 10 scale. Maintaining the model resolution in Weighted Sum can be helpful when you want to identify only a few top favourable locations or a specified number of sites.

The Weighted Sum tool is useful when you want to maintain the model resolution or when floating-point output or decimal weights are required. Weighted Sum works by multiplying the designated field values for each input raster by the specified consequence. It then sums (adds) all input raster's together to create an output raster.

The steps for analyzing Weighted Sum Spatial analyst (WSSA):

- Add rasters. Click the Input raster's arrow and click an input raster, or browse to an input raster and click Add. The raster is added to the Weighted Sum table. Repeat to enter the next raster, and so on.
- > Select the field. For each input raster, click the field column to specify the area to be used in the overlay analysis. A drop-down list -appears, displaying all valid fields for the input. The field must be a numeric field.
- Assign weights for input rasters. Each input raster can be weighted, or assigned a percentage influence, based on its importance. For each input raster, click on the weight column to specify a value. The weights can be any floating-point value (negatives included).
- > Run the tool. The cell values of each input raster are multiplied by the raster's weight.

 The resulting cell values are added to produce the final output raster.

5.5.4 Raster Calculator

Builds and executes a single Map Algebra expression using Python syntax in a calculator-like interface. The Raster Calculator tool allows you to create and manage a Map Algebra expression

> Calculator and operator buttons:

The calculator buttons allow you to enter numeric values into the expression. The operator buttons will enable you to enter mathematically (addition, division, and so on) and logical (more significant than, equal to, and so forth) operators into the expression. By clicking any of these buttons, that number or operator will be entered into the terminal where the

pointer is currently positioned.

➤ Tools:

The tool list is a convenient selection of tools that can be used in the Map Algebra expression. By clicking a tool in the list, the tool name and open and close parentheses [()] will be placed in the expression where the pointer is currently positioned. The remaining input required by the tool must then be entered.

There are four main areas in the tool dialog box that are used to create a Map Algebra expression:

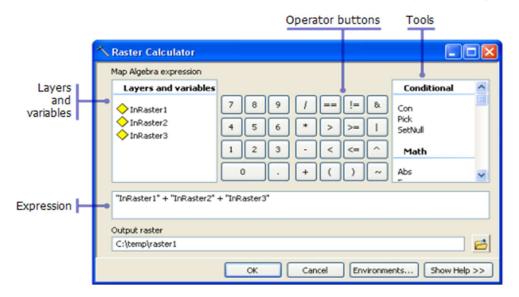


Figure 5.3: Raster calculator toolbox

Source: ArcGIS software 10.5 Manual

Layers and variables

The input Layers and variables list identifies the input that can be used in the Map Algebra expression. When the tool is used in Model Builder, the list will contain the layers in the table of contents, outputs created in the Model, and other model variables.

> Expression

The expression is the Map Algebra expression to be executed. The expression must be entered with valid syntax.

5.6 Steps for Mapping Vulnerability Maps in Arc GIS 10.5 Software:

- ➤ Open Arc GIS 10.5.and add data x y coordinates to the data point exported from the excel file.
- > Open the attribute table by right-clicking on the layer file in the table of content.

- > Select joint and relate tool by right-clicking in layer file to export the data in the attribute table
- > Open tool arc box and select IDW analysis tool to interpolate the point data by selecting the table of content file and layer file

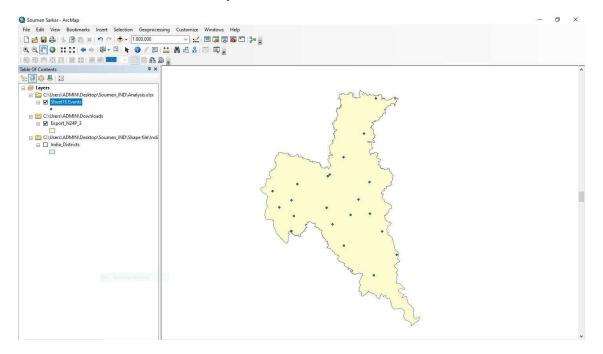


Figure 5.4: IDW Analysis

- Classifying the label of the IDW map by left-clicking on properties
- ➤ Classify the data by Reclassify analysis tool in tool arc box according to the rating given in the Drastic table.
- > Open the raster calculator analysis to add weight rating from the drastic table and generate the index.
- > Select the weighted sum spatial analysis tool from the tool arc box and generate the vulnerability map.

CHAPTER-6: RESULTS AND DISCUSSIONS

The present study helped determine groundwater's vulnerability to contamination in the North 24 Parganas district by employing the DRASTIC Model in the GIS platform. Vulnerability of groundwater refers to the intrinsic characteristics that determine the sensitivity of the water to being adversely affected by an imposed contaminant load. It is a relatively quick and simple to use method for assessing the susceptibility of a large area.

6.1 Generation of Topographical Map

It refers to the slope of an area. It allows a more significant infiltration of recharge water and a greater possibility for contaminant migration. It will be related to higher groundwater contamination. The topography map and contour were prepared in the ArcGIS software using the SRTM DEM and divided into one.

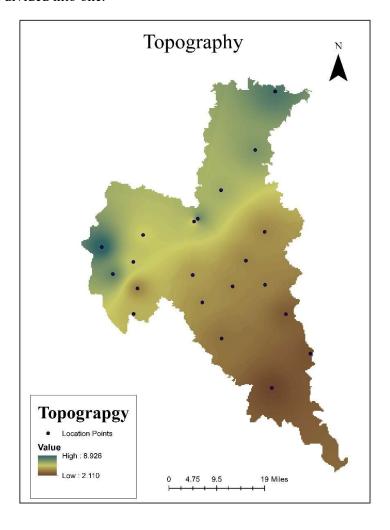


Figure 6.1 : Topographical map of the study area

The general elevation ranges between 1.92 m and 9.419 m. Slope ranges between 2 and 6 percent majority portion of the district.

6.2 Delineation of the spatial distribution of water depth

Depth to water level, which defines the uppermost surface of the zone, Depth to the water level is inverse relation with groundwater pollution. Depth to the water level is one of the most critical factors because it determines the thickness of material through infiltrating water. Must travelbefore reaching the aquifer-saturated zone (Aller et al., 1987). The deeper the water level, the greater is the chances of loss of the pollutants of the water. A low depth to water parameter will lead to a higher vulnerability rating. In general, the aquifer potential protection increases withdepth to water. The maximum and minimum water depths are 1.545 and 10.017 m bgl. The average water level is 4.545 m bgl from the data given in table 6.1. These data are divided into five categories. After that, it was converted into a grid to make it raster data from GIS operations by IDW (Spatial Analyst) and reclassified with DRASTIC rating by Reclassify (Spatial Analyst). The depth to water table interval range, rating, weight, and resulting index are portrayed in . Areas with high water levels are vulnerable because pollutants have a short distance to travel before contacting the Groundwater. Therefore, the deeperthe groundwater level is low weak and smaller the rating value. The areas having low water tabledepth are highly vulnerable to contamination.

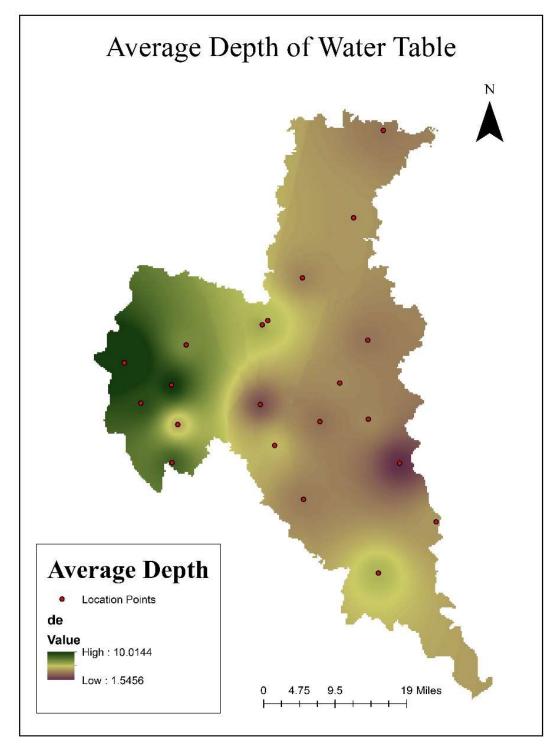


Figure 6.2: Depth of water map of the study area

Table 6.1: Average depth of water for 2017-18

Source: State Water Investigation Directorate (SWID),

Government of West Bengal, 2017-18

Block	Longitude	latitude	Avg depth (m)
Amdanga	88.5070	22.8021	5.81
Barasat-I	88.4789	22.7248	7.872
Barasat-II	88.4908	22.6487	4.088
Barrackpore-I	88.3883	22.7674	10.017
Barrackpore-II	88.42	22.69	7.304
Rajarhat	88.4798	22.5754	6.788
Habra_I	88.6535	22.8408	5.316
Habra-II	88.6639	22.8488	4.836
Gaighata	88.7308	22.9309	3.411
Bongaon	88.8291	23.0467	3.722
Bagdah	88.8863	23.2147	3.156
Baduria	88.8023	22.7286	3.508
Swarupnagar	88.8564	22.8112	3.108
Haroa	88.6772	22.6085	4.342
Deganga	88.6495	22.6872	2.350
Bashirhat-I	88.8572	22.6591	3.458
Bashirhat-II	88.7641	22.6544	3.063
Minakhan	88.7326	22.5047	3.214
Hasnabad	88.9174	22.5745	1.545
Hingalganj	88.9877	22.4613	3.775
Sandeshkhali-I	88.8767	22.3627	5.063
Sandeshkhali-II	88.8767	22.3627	4.247

6.3 Estimation of the Net Recharge of the study Area:

Net recharge plays a crucial role in the migration of pollutants, as it reflects the quantity of water that reaches the groundwater table after penetration through the ground surface. Precipitation is the primary source of recharge. More recharge leads to a greater probability for the contaminants to reach the water table. Millimetre per year unit is used to define net recharge. Land uses/land covers (LULCs) and soils are sensitive parameters in calculating the recharge amount. Consider regional LULC and soil characteristics, the Soil Conservation Service (SCS) runoff curve number (CN) method was used to estimate potential recharge with precipitation, soils, and LULCs. Potential recharge was computed as precipitation minus surface runoff which is determined by the SCS-CN method. Precipitation data is collected from Department of Agriculture, Government of West Bengal. LULC data from United States Geological Survey and soil data Bhuvan-NRSC were used to produce a potential recharge map using the SCS-CN method. The Curve Number is a dimensionless parameter indicating the runoff response characteristic of a drainage basin. In the Curve Number Method, this parameter is related to land use, land treatment, hydrological

condition, hydrological soil group, and antecedent soil moisture condition in thedrainage basin

Table 6.2: Net Recharge Calculation,

Source: Department of Agriculture, Government of West Bengal

Block	Rainfall (mm)	P (inch)	S (inch)	Ia (inch)	(p-Ia)	(p-Ia)^2	q (inch)	Net recharge (inch)	Net Recharge (mm/year)
Amdanga	1134	44.646	1.765	0.353	44.293	1961.87	42.596	2.05	52.070
Barasat-I	1133.7	44.634	1.765	0.353	44.281	1960.807	42.584	2.05	52.070
Barasat-II	1240	48.819	1.765	0.353	48.466	2348.953	46.763	2.056	52.222
Barrackpore-I	1133.7	44.634	1.765	0.353	44.281	1960.807	42.584	2.05	52.070
Barrackpore-II	1133.7	44.634	1.765	0.353	44.281	1960.807	42.584	2.05	52.070
Rajarhat	1255	49.409	1.765	0.353	49.056	2406.491	47.352	2.057	52.248
Habra_I	1373.2	54.063	1.765	0.353	53.71	2884.764	52.001	2.062	52.375
Habra-II	1252	49.291	1.765	0.353	48.938	2394.928	47.234	2.057	52.248
Gaighata	1280	50.394	1.765	0.353	50.041	2504.102	48.336	2.058	52.273
Bongaon	1285.7	50.618	1.765	0.353	50.265	2526.57	48.56	2.058	52.273
Bagdah	1290	50.787	1.765	0.353	50.434	2543.588	48.729	2.058	52.273
Baduria	1410	55.512	1.765	0.353	55.159	3042.515	53.449	2.063	52.400
Swarupnagar	1410	55.512	1.765	0.353	55.159	3042.515	53.449	2.063	52.400
Haroa	1404	55.276	1.765	0.353	54.923	3016.536	53.213	2.063	52.400
Deganga	1404	55.276	1.765	0.353	54.923	3016.536	53.213	2.063	52.400
Bashirhat-I	1340	52.756	1.765	0.353	52.403	2746.074	50.696	2.06	52.324
Bashirhat-II	1430	56.299	1.765	0.353	55.946	3129.955	54.235	2.064	52.426
Minakhan	1407	55.394	1.765	0.353	55.041	3029.512	53.331	2.063	52.400
Hasnabad	1232	48.504	1.765	0.353	48.151	2318.519	46.448	2.056	52.222
Hingalganj	1230.8	48.457	1.765	0.353	48.104	2313.995	46.401	2.056	52.222
Sandeshkhali-I	1340.2	52.764	1.765	0.353	52.411	2746.913	50.704	2.06	52.324
Sandeshkhali-II	1340.2	52.764	1.765	0.353	52.411	2746.913	50.704	2.06	52.324

Initial abstraction Ia has been assumed as a function of the Maximum Potential Retention, S. The Relationship between Ia and S was expressed as

$$Ia = 0.2S$$
 -----(Eq 6.1)

Maximum potential retention, S, has been obtained using the Weighted Curve Number value.

The potential maximum retention is obtained by the following equation.

$$S = \frac{25400}{CN} - 254...$$
 (Eq. 6.2)

Here in our study area, we have considered Land Use or Cover as Fallow is agricultural land with maximum potential for runoff because the land is kept bare. Hydrological Soil Group is Group C for Soils having moderate infiltration rates when thoroughly wetted and an average rate of water transmission. The Curve Number is a dimensionless parameter indicating the runoff response characteristic of a drainage basin. In the Curve Number Method, this parameter is related to land use, land treatment, hydrological condition, hydrological soil group, and antecedent soil moisture School of Water Resources Engineering

conditionin the drainage basin.

The relationship of rainfall-runoff is expressed by the following equation,

$$Q = \frac{(P-I_a)^2}{(P-Ia+)}$$
.....(Eq 6.3)

[Where, Q= Actual Runoff, in inches; (P-Ia) = Amount of Rainfall available for Runoff, in inches.

S= Potential maximum retention after runoff begins, inches;]

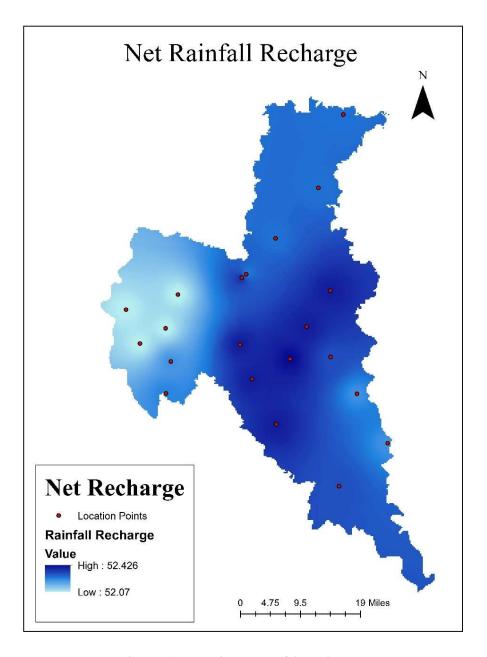


Figure 6.3: Net Recharge Map of the study area

Examples are moderately deep to deep, moderately well to well-drained soils with moderately fine to moderately coarse textures. Soils having low infiltration Antecedent Moisture Condition is AMC 11 in Average condition. Table 8 of Curve Numbers for Hydrological Soil-Cover Complexes for Antecedent Moisture Condition Class 11 and I; = 0.2 S, (after Soil Conservation Service 1972) CN number is 85.Net recharge was computed precipitation minus actual runoff, which is determined by the SCS-CN method. Net recharge estimated in this study may not reflect the exact amount of recharge but rather indicates the net recharge rate. Estimation of potential recharge (potential infiltration rate) ignored evapotranspiration (ET) because ET occurs after infiltration. Based on the study area, the average annual recharge value was 52.27 mm, corresponding to the DRASTIC rating of 1 shown in (Table 6.6) More recharge leads to a greater chance for the contaminants to reach the water table.

6.4 Generation of Aquifer Media Map

The aquifer media of the study area shows almost homogeneous characteristics through out the district. Due to small change in aquifer media, however there is some variation. The northern part of the district consists fine to medium sand cover an area about 66.0% while the fine sand covering the remaining southern area of 34.0%.

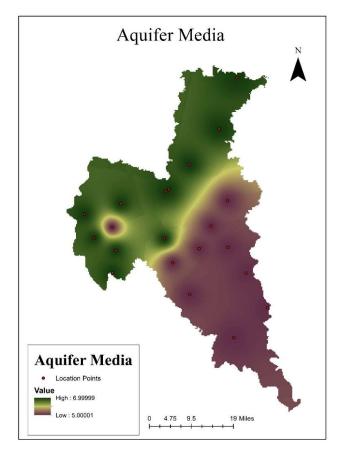


Figure 6.4: Aquifer Media Map of the study area

An aquifer media map was prepared from the Geological Survey of India, Kolkata, and lithology data from India Water Resources Information System India. In general, with an increment in the grain size and the number of fractures or openings within the aquifers, the permeability increases, and the attenuation capacity becomes lower, resulting in higher pollution potential. So coarser (saturated or unsaturated) media is assigned a higher rating value as compared to finer media. After that, by raster conversion in Arc GIS software and IDW tool prepared the aquifer map and reclassified it four types of media with Drastic rating is given in (Figure 6.4). In general, the larger the grain size and the more fractures or openings within the aquifer, the higher the permeability, the lower the attenuation capacity, and consequently, the greater the pollution potential. The material of the aquifer determines the mobility of the contaminant through it.

6.5 Generation of Soil Media map:

Soil media affects the transport of the contaminant and water from the soil surface to the aquifer. It goes down from the top surface to about 6ft below. The soil characteristics determine the infiltration rate. The permeability depends on the texture of soil. Soil acts as a passage for the downward vertical movement of the contaminated materials to reach groundwater and affects the Vulnerability. There is generally a variation in the thickness as we move in depth. Soil properties affect groundwater pollution potential as they control the movement of air and contaminant. The soil of study area is classified into three two of soil as fine soil and fine loamy soil with a corresponding rating of 3 and 4. The parameter was assigned a weight of "2" in the Model. Infiltration capacity heavily depends on the soil texture. The infiltration capacity of the fine-grained soil is low compared to coarse-grained soil because of porosity and permeability. In general, soil pollution potential is primarily affected by the type and amount of clay present, the shrink/ swell potential (controlling the development of macro-pores and other secondary permeability features), and the soil grain size.

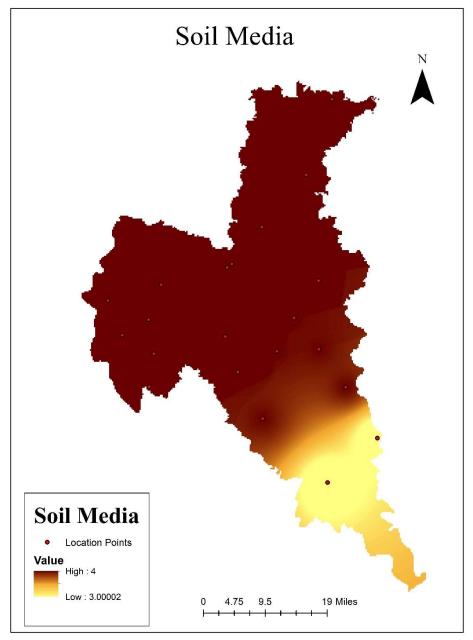


Figure 6.5: Soil Media Map Of The Study Area

6.6 Evaluation of Impact of the Vadose Zone in the Study Area

There is an unsaturated region known as the vadose zone between the ground surface and the water level. The percolating water is greatly influenced by the presence of this zone Movement of water within the vadose zone is studied in hydro-geology and is of importance to contaminant transport. Based on the geological description of the study area, the vadose zone has been classified into two categories as silt and clay, medium sand. The rating of the impact of the Vadose zone ranges as 3 and 6 as shown in (Table 6.6). The impact of the vadose zone is a complex phenomenon, combining aquifer media and topographic characteristics. If the vadose zone is highly absorbent, then this will lead to a high vulnerability rating. The weightage of this

parameter is maximum as this hasa vital effect on groundwater vulnerability assessment.

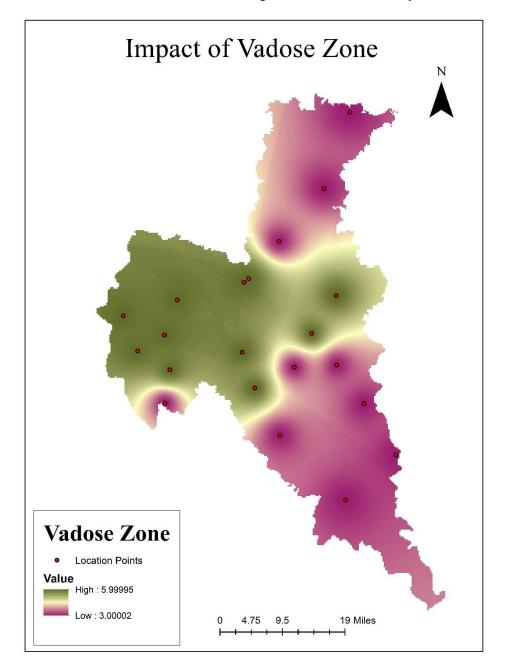


Figure 6.6: Vadose zone map of the study area

6.8 Determination of Spatial Distribution of Hydraulic Conductivity in the study area:

This final component of the DRASTIC model can be described in terms of aquifer material and its ability to transmit water for a given hydraulic gradient. Hydraulic conductivity of an aquifer is the ability of the aquifer to spread water depends on its permeability and the amount of saturated zone. As the conductivity increase, the dispersion of contaminants in the aquifer also increases. An areawith high conductivity is vulnerable to considerable contamination of groundwater. Hydraulic conductivity values were calculated after calculating transmissibility data. The value of transmissivity data are taken from Aquifer mapping and management of ground water resources in parts of North 24 Parganas, South 24 Parganas and Howrah Districts West Bengal, Central Ground Water Board, 2021 given in table 6.3 and have been mapped as shown in (Figure. 6.7).

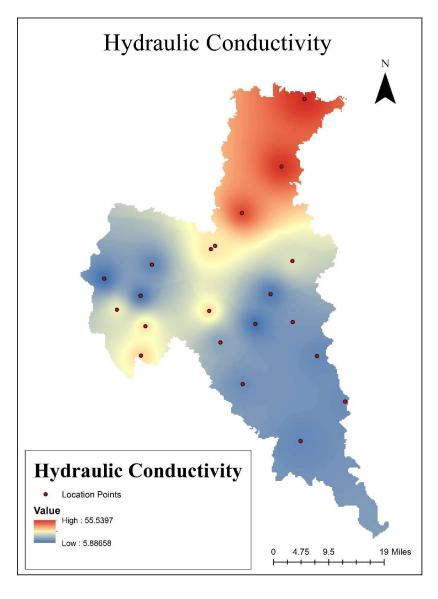


Figure 6.7: Hydraulic conductivity of the study area

The ranges provided in the DRASTIC method and validated using values in 22 blocks range from 5.8 to 55.6 m/day.

On this basis, Hydraulic Conductivity (k) was estimated by

Hydraulic conductivity (m/day) = Transmissivity (m2/day)/Thickness of aquifer (m)-- (Eq 6.1)

Table 6.3: Hydraulic conductivity of Aquifer media of North 24 Parganas Source: Central Ground Water Board, Government of India

Sl. no	Block	longitude	latitude	Transmissivity (T)(sqm/Day)	Transmissivity (T)(sqm/s)	Saturated Aquifer thickness (H)(m)	Hydraulic conductivity (K) (m/s)	Hydraulic conductivity (K)(m/Day)
1	Amdanga	88.507	22.8021	1473.67	0.01706	150.00	0.000114	9.8496
2	Barasat-I	88.4789	22.7248	645.28	0.00747	93.00	0.00008	6.9120
3	Barasat-II	88.4908	22.6487	2021.00	0.02339	60.00	0.00039	33.6960
4	Barrackpore-I	88.3883	22.7674	530.00	0.00613	90.00	0.000068	5.8752
5	Barrackpore-II	88.42	22.69	1628.60	0.01885	57.00	0.000331	28.5984
6	Rajarhat	88.4798	22.5754	2003.00	0.02318	57.00	0.000407	35.1648
7	Habra-I	88.6535	22.8408	5076.80	0.05876	152.00	0.000387	33.4000
8	Habra-II	88.6639	22.8488	2273.34	0.02631	68.00	0.000387	33.4300
9	Gaighata	88.7308	22.9309	7035.50	0.08143	135.00	0.000603	52.0992
10	Bongaon	88.8291	23.0467	7359.28	0.08518	134.00	0.000636	54.9504
11	Bagdah	88.8863	23.2147	7331.28	0.08485	132.00	0.000643	55.5552
12	Baduria	88.8023	22.7286	729.14	0.00844	95.00	0.000089	7.6896
13	Swarupnagar	88.8564	22.8112	2921.92	0.03382	113.00	0.000299	25.8336
14	Haroa	88.6772	22.6085	822.42	0.00952	54.00	0.000176	15.2064
15	Deganga	88.6495	22.6872	2921.92	0.03382	85.00	0.000398	34.3872
16	Bashirhat-I	88.8572	22.6591	449.40	0.0052	35.00	0.000149	12.8736
17	Bashirhat-II	88.7641	22.6544	449.40	0.0052	69.00	0.000075	6.4800
18	Minakhan	88.7326	22.5047	822.42	0.00952	73.00	0.00013	11.2320
19	Hasnabad	88.9174	22.5745	822.42	0.00952	81.00	0.000118	10.1952
20	Hingalganj	88.9877	22.4613	822.42	0.00952	75.00	0.000127	10.9728
21	Sandeshkhali-I	88.8767	22.3627	822.42	0.00952	83.00	0.000115	9.9360
22	Sandeshkhali-II	88.8767	22.3627	822.42	0.00952	94.00	0.000101	8.7264

Table 6.4: Ranking and weightage assigned to various parameters of the study area shown below

Features	Weightage	Ranges	Ratings	
Depth of Water (m)		0.0 -1.5	10	
		1.5-3.0	9	
		3.00 - 5.00	8	
	5	5.0 -7.0	7	
		7.0 - 9.0	6	
		9.0 - 12	5	
Net Recharge (mm/Year)		0 - 50.0	1	
(min rear)	4	50 -100	2	
Aquifer media		Fine Sand	5	
	3	Fine to medium	6	
		Medium Sand	7	
Soil media		Fine Soil	3	
	2	Fine Loamy	4	
Topography(percent)		0 - 2.0	10	
		2.0- 6.0	9	
	1	6.0- 12.0	5	
		12.0- 18.0	3	
Vadose Zone	5	Silt and Clay	3	
	<i>3</i>	Medium Sand	6	
Hydraulic Conductivity (m/day)		0 - 10.0	1	
	2	10.0 - 20.0	2	
	3	20.0- 30.0	3	
		30.0 - 60.0	4	

6.9 Assessment of Groundwater Vulnerability:

The groundwater vulnerability of the study area presents in (Figure. 6.20 and Figure. 6.21) based on Weighed Sum Analysis overlay map of the DRASTIC index. The estimated DRASTIC index gives an indicator of the prevailing vulnerability in the district. The DRASTIC scores obtained from the Model vary from 88 to 125.

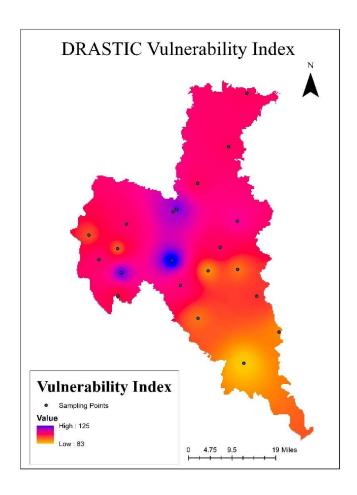


Figure 6.8: Drastic Index Map Of The Study Area

Since the minimum possible DRASTIC index for using these parameters is 23 and the maximum is 230, this range is divided into three classes (Aller et al., 1987). Three classes have categorized the vulnerability index: high vulnerability (111-125), medium vulnerability (97-111), lowvulnerability (83-97), Blocks of Barasat-I, Barrackpore-I, Bashirhat-I, Bashirhat-II, Minkahan, Hingalganj, Sandeshkhali-I and Sandeshkhali-II are in low vulnerability. Whereas Barasat-II, Habra-II and Deganga are in high vulnerability zone and rest in medium vulnerability, each of these parameters impacts pollution potential with its subjective rating. The weight multipliers are then used for each factor to balanceand enhance its importance. Raster layers of the

concentration of each parameter were provided using interpolation tools in ArcGIS10.5. Additionally, in this study, Reclassified analysis toolwas used for rating analysis. After that IDW interpolation method was used to prepare the rating map for each of the seven layers. In ArcGIS10.5, the Map Algebra expression of Raster Calculatorwas used to aggregate several input raster layers and create a raster output. The final DRASTIC vulnerability index map can be computed by the weighted sum analysis of the seven layers using the equation below (Aller et al., 1987).

Drastic Index =
$$DwDr + RwRr + AwAr + SwSr + TwTr + IwIr + CwCr - (Eq 6.5)$$

After putting the drastic Weight according to the study area, the equation becomes,

Drastic Index =
$$5Dr + 4Rr + 3Ar + 2Sr + 1Tr + 5Ir + 3Cr - (Eq 6.6)$$

The rates and weights of the study area of each parameter of the DRASTIC Model are given in (Table 6.6). The parameters vary from 1 to 10, with the higher values describing higher pollution potential. The groundwater vulnerability map was mapped and analyzed that the North 24 Parganas districtfalls under the medium vulnerability zone with contamination from natural and anthropogenic activities. This analysis suggests that this can be used for the prioritization of vulnerable areas inorder to prevent further pollution to already more polluted areas. There should be detailed and frequent monitoring in high and very high vulnerable zones to monitor the changing level of pollutants.

CHAPTER 7: CONCLUSION

It is very crucial and essential to investigate the vulnerability of groundwater aquifer systems in the study area in the North 24 Parganas district; West Bengal is under constant threats from potential pollution sources, both natural and anthropogenic. Despite threats, the quality of groundwater in the study area is generally reasonable. Contamination of aquifer systems does not occur very quickly, but once the groundwater is already contaminated, it becomes challenging to combat or remediate aquifer contamination. Analysis shows that water depth is the most influential parameter for groundwater vulnerability, followed by aquifer media and vadose zone. The presentstudy reveals that the vulnerability zones were classified three-zone, namely low, moderate and high vulnerable zones. These results were included as raster or vector layers in the database together with generated thematic maps. GIS spatial analysis functions have permitted to development of a groundwater prospective zone map by means of overlaying thematic maps. GIS technology and remote sensing are beneficial for demarcating the critical zones on a scientific basis where further remedies should be taken. The output map is obtained to determine the vulnerability of groundwater in the areas underlain by hard rocky terrain plateau aquifers and to identify the vulnerable groundwater zones.

The DRASTIC model, which is used for preparing the pollution potential map, can be used as a screening tool to assess the degree of groundwater vulnerability to pollution of a particular area. The study suggests that this can be used for the prioritization of the vulnerable regions in order to prevent further decay to already more polluted areas. There should be detailed and frequent monitoring in high and very high vulnerable zones in order to monitor the changing level of pollutants.

7.1 Limitations of the Study

Despite its popularity, the DRASTIC method does have some disadvantages, which have been concluded.

- > The influences of regional characteristics are not accounted for in the technique, and so the same weights and rating values are used everywhere.
- ➤ Due to nonvalidity of point wise details of the study area the average was taken in block wise, which may vary the result but it gives an idea of water scenario of this district.
- In addition, there is no standard algorithm to test and validate the method for an aquifer.
- > Recently, some researchers have tried to correlate the vulnerability index with chemical or contaminant parameters. Others have attempted to associate land use with vulnerability but have not used it to correct the rates or weights of the DRASTIC model.

- In our study we don't look on other parameter of ground water contamination, like Arsenic, Iron etc.
- ➤ Inadequate knowledge of the soil-rock-groundwater system;

7.2 Future Scope of the Study:

It has been noted that a clearer understanding of the state of aquifers in India will help in their management and governance at the local level. Mapping aquifers effectively for a complete assessment of groundwater resources. The CGWB in 2012 started the National Project on Aquifer Management (NAQUIM) to identify and map aquifers and quantify the available groundwater potential. This project highlighted the need for a shift in the groundwater sector from development to management. It aims to increase groundwater resource management by (i) identifying and mapping aquifers, (ii) quantifying the available groundwater potential, and (iii) proposing plans appropriate to the scale of demand, aquifer characteristics, and the institutional arrangements for management. (iv)Contamination of groundwater by industries. Ministry of Water Resources, in coordination with the Central Pollution Control Board, should devise an effective mechanism to identify critically polluted areas located in dark blocks. Steps to minimize and control the dumping of industrial waste into surface water and underground aquifers should also be taken. A study to assess land use and the proportion of agricultural land falling under dark blocks (overexploited assessment units) should be initiated. This will help determine suitable cropping patterns in areas that are water-stressed. Additionally, an impact study to determine losses caused to agriculture, economy, health, and environment due to dark blocks should be carried out.

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