भारत सरकार
Government of India
जल शक्ति मंत्रालय,
Ministry of Jal Shakti,
जल संसाधन, नदी विकास और गंगा संरक्षण विभाग,
Department of Water Resources,
River Development and
Ganga Rejuvenation

केंद्रीय भूमि जल बोर्ड
Central Ground Water Board

NAQUIM 2.0

जल संकटग्रस्त आलोट ब्लॉक, रतलाम जिले की राष्ट्रीय जलभृत मानचित्रण एवं प्रबंधन योजना मध्य प्रदेश

NATIONAL AQUIFER MAPPING AND MANAGEMENT PLAN OF WATER STRESSED ALOT BLOCK, RATLAM DISTRICT MADHYA PRADESH

North Central Region
Bhopal 2024

भारत सरकार

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North Central Region

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डॉ. सुनील कुमार अम्बष्ट
अध्यक्ष
Dr. Sunil Kumar Ambast
Chairman

सत्यमेव जयते

भारत सरकार
जल शक्ति मंत्रालय
जल संसाधन,
नदी विकास और गंगा संरक्षण विभाग
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Government of India
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Central Ground Water Board

Message

National Aquifer Mapping and Management Programme (NAQUIM) was initiated by Central Ground Water Board (CGWB) in 2012 with the goal of mapping and managing aquifers across India to promote sustainable groundwater use. So far the entire mappable area of 25 lakh km^2 has been covered under the NAQUIM programme. While these initial efforts have been highly impactful, they faced certain limitations especially in terms of spatial resolution.

Taking it forward, CGWB has now initiated **NAQUIM 2.0,** the next phase of aquifer mapping designed to provide a deeper, more detailed understanding of India's groundwater systems. During 2023-24, CGWB had completed NAQUIM 2.0 studies in 68 study areas. The study areas were selected in consultation with the State/UT government agencies.

I am confident that this report of NAQUIM 2.0 study will serve as a critical resource for government agencies, research institutions, NGOs, and the general public. By fostering a collaborative approach to groundwater management, this report will play a key role in safeguarding and sustaining India's precious ground water resources.

(Dr. Sunil Kumar Ambast)

Chairman, CGWB

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A.K. Biswal
Regional Director

सत्यमेव जयते

भारत सरकार
जल शक्ति मंत्रालय
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Government of India
Ministry of Jal Shakti
Department of Water Resources, R D & G R
Central Ground Water Board, North Central Region, Bhopal

FOREWORD

National Project on Aquifer Mapping 2.0 (NAQUIM 2.0) aims at identification and understanding area specific groundwater related issues for recommending issue specific recommendations for better management and sustainable development of groundwater. The study involves a scientific process, where in a combination of geological, geophysical, hydrological and chemical analyses are applied to characterize the quantity, quality and sustainability of groundwater in aquifers.

Under the National Project on Aquifer Mapping 2.0 (NAQUIM 2.0), Central Ground Water Board (CGWB), North Central Region, Bhopal has taken up water stressed Alot block in Ratlam district to prepare the aquifer maps in 1:10000 scale and formulate the focused interventions for aquifer management. Water stress and ground water contamination in the Alot block stems from various reasons such as overexploitation which has led to a stage of groundwater development reaching 116% in 2009, which has further escalated to 119% by 2023, causing depletion of water levels and posing challenges for availability of drinking water, particularly during the summer months when dug wells and hand pumps are dry Consequently, residents resort to drilling exceptionally deep bore wells, reaching depths of up to 363 meters (1200 feet), to meet their water needs and contamination due to excessive use of fertilizers, irrigation through contaminated water from industrial sites. This study presents a comprehensive analysis of aquifer mapping in Alot block focusing on the delineation of aquifer boundaries, characterization of hydrogeological parameters, recharge and discharge zones and assessment of ground water quality and accodingly suitable management plan.

The study area Alot block within Ratlam district, covering an approximate area of 945 square kilometers. The area is mainly occupied by Deccan Trap Basalt followed by Vindhyan formations. It is surrounded by major and minor river courses such as Chambal, Kshipra, Maleni, and Mahi, which span from the southwestern to the north-northeastern parts of the area.

I would like to place on record, my appreciation of the efforts of Dr Rakesh Singh, Scientist D, Sh. Pradip Roy, Scientist B, Sh. Jasbanth Jani, Scientist-B, Sh. Kodali Lakshmana Pradeep, AHG, Sh. Rahul Vashist, Asst Chemist and Sh. J Sreemanarayan, STA for carrying out the study in water stressed Alot block, Ratlam district.

I sincerely hope that this report will serve as a valuable guide for sustainable development of groundwater in Alot block, Ratlam district, Madhya Pradesh.

Biswal

(Ashok Kumar Biswal)
Regional Director

Water is elixir of life

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EXECUTIVE SUMMARY

The Alot block of Ratlam district, situated in the northwestern part of Madhya Pradesh within the Chambal and Kshipra basin, is designated as a water-stressed area. This status is primarily due to the substantial reliance and excessive exploitation of groundwater for both agricultural and drinking purposes. This overexploitation has led to a stage of groundwater development reaching 116% in 2009, which has further escalated to 119% by 2023, according to the dynamic groundwater resources report of Madhya Pradesh. The region faces significant challenges in depletion of water level and availability of drinking water, particularly during the summer months when dug wells and hand pumps are dry. Consequently, residents often transport water in tanks from distant villages and resort to drilling exceptionally deep bore wells, reaching depths of up to 363 meters (1200 feet), to meet their water needs. In response to these pressing concerns, state authorities, prompted by the district collector and the Additional Chief Secretary (ACS), have initiated a request to conduct a comprehensive study of the Alot area. This study aims to explore avenues for enhancing groundwater resources and meeting the critical drinking water requirements of the region.

The predominant aquifer within the study area is mainly comprised of basalt, which presents a challenge due to its low yield characteristics across much of its depth. Deeper layers, specifically above 250 meters, primarily consist of sandstone, offering substantial yield. However, the occurrence of collapsible red bole mixed with basalt poses a significant risk of well failure. Moreover, the weathering zone in the area is characterized by notably low thickness. The primary basaltic aquifer exhibits limited potential, and the absence of proper well design exacerbates challenges associated with water management and supply to meet demand.

Central Ground Water Board, North Central Region, Bhopal taken up NAQUIM 2.0 studies in an area of 945 sq.km in Alot block, Ratlam district under AAP 2023-24. Methodologies used for the study includes direct and in-direct methods of groundwater exploration, establishment of key observation wells, periodic water level monitoring, water sample collection and analysis, presentation of data using different software etc.

This study presents a comprehensive analysis of aquifer mapping focusing on the delineation of aquifer boundaries, characterization of hydrogeological parameters, ground water level and ground water quality scenario, demarcation of safer aquifer for drinking water sustainability etc.

Possible quality management interventions in water stressed area, measures to ensure source sustainability were implemented, including the identification of probable sites for artificial recharge structures. Based on drainage distribution, soil composition, and weathering thickness derived from the VES survey and well inventory data, potential locations for additional recharge structures were determined. Moreover, areas featuring subsurface cavities or large dry fracture zones were identified for targeted recharge efforts. Recommendations for proper bore well design in locations prone to failure are discussed for sustainable groundwater management in detail in the study.

कार्यकारी सारांश

चंबल और क्षिप्रा बेसिन के भीतर मध्य प्रदेश के उत्तर-पश्चिमी भाग में स्थित रतलाम जिले का आलोट ब्लॉक जल-तनावग्रस्त क्षेत्र के रूप में नामित है। यह स्थिति मुख्य रूप से कृषि और पीने के उद्देश्यों दोनों के लिए भूजल पर पर्याप्त निर्भरता और अत्यधिक दोहन के कारण है। मध्य प्रदेश की गतिशील भूजल संसाधन रिपोर्ट के अनुसार, इस अतिदोहन के कारण भूजल विकास का एक चरण *2009* में *116%* तक पहुंच गया है, जो *2023* तक *119%* तक बढ़ गया है। इस क्षेत्र को जल स्तर में कमी और पीने के पानी की उपलब्धता में महत्वपूर्ण चुनौतियों का सामना करना पड़ता है, खासकर गर्मियों के महीनों के दौरान जब खोदे गए कुएं और हैंडपंप सूख जाते हैं। नतीजतन, निवासी अक्सर दूर के गांवों से टैंकों में पानी लाते हैं इन दबावपूर्ण चिंताओं के जवाब में, जिला कलेक्टर और अतिरिक्त मुख्य सचिव (एसीएस) द्वारा प्रेरित राज्य अधिकारियों ने आलोट क्षेत्र का व्यापक अध्ययन करने का अनुरोध शुरू किया है। इस अध्ययन का उद्देश्य भूजल संसाधनों को बढ़ाने और क्षेत्र की महत्वपूर्ण पेयजल आवश्यकताओं को पूरा करने के लिए रास्ते तलाशना है।

अध्ययन क्षेत्र के भीतर प्रमुख जलभृत मुख्य रूप से बेसाल्ट से बना है, जो अपनी गहराई में कम उपज विशेषताओं के कारण एक चुनौती पेश करता है। गहरी परतें, विशेष रूप से *250* मीटर से ऊपर, मुख्य रूप से बलुआ पत्थर से बनी हैं, जो पर्याप्त उपज प्रदान करती हैं। हालांकि, बेसाल्ट के साथ मिश्रित लाल बोले की घटना कुएं की विफलता का एक महत्वपूर्ण जोखिम पैदा करती है। इसके अलावा, क्षेत्र में अपक्षय क्षेत्र की विशेषता उल्लेखनीय रूप से कम मोटाई है। प्राथमिक बेसाल्टिक जलभृत सीमित क्षमता प्रदर्शित करता है, और उचित कुआं डिजाइन की अनुपस्थिति मांग को पूरा करने के लिए जल प्रबंधन और आपूर्ति से जुड़ी चुनौतियों को बढ़ाती है।

केंद्रीय भूजल बोर्ड, उत्तर मध्य क्षेत्र, भोपाल ने *AAP 2023-24* के अंतर्गत रतलाम जिले के आलोट ब्लॉक में *945* वर्ग किमी क्षेत्र में *NAQUIM 2.0* अध्ययन किया। अध्ययन के लिए उपयोग की गई पद्धतियों में भूजल अन्वेषण की प्रत्यक्ष और अप्रत्यक्ष विधियां, प्रमुख अवलोकन कुओं की स्थापना, आवधिक जल स्तर की निगरानी, जल नमूना संग्रह और विश्लेषण, विभिन्न सॉफ्टवेयर का उपयोग करके डेटा की प्रस्तुति आदि शामिल हैं।

यह अध्ययन जलभृत मानचित्रण का एक व्यापक विश्लेषण प्रस्तुत करता है, जिसमें जलभृत सीमाओं का चित्रण, जल विज्ञान संबंधी मापदंडों का लक्षण वर्णन, भूजल स्तर और भूजल गुणवत्ता परिदृश्य, पीने के पानी की स्थिरता के लिए सुरक्षित जलभृत का सीमांकन आदि पर ध्यान केंद्रित किया गया है।

जल तनाव वाले क्षेत्र में संभावित गुणवत्ता प्रबंधन हस्तक्षेप, स्रोत स्थिरता सुनिश्चित करने के उपायों को लागू किया गया अध्ययन में स्थायी भूजल प्रबंधन के लिए विफलता की संभावना वाले स्थानों में उचित बोरवेल डिजाइन की सिफारिशों पर विस्तार से चर्चा की गई है।

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AT A GLANCE

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3	Study Area	Alot block
4	District	Ratlam
5	Categorization as per GWRA 2023	Over-exploited
6	Principle Aquifer	Deccan Trap Basalt, Vindhyan Sandstone
7	Major Aquifer	Weathered/Vesicular/Fractured Basalt, contact zone Vindhyan Sandstone
8	Yield of Aquifer	Basalt 0.6 to 1.3 lps Vindhyan Sst: 1.5 – 17.5 lps
9	Average Water Level (mbgl)	Pre-Monsoon 4.55 to 26.2 Post monsoon 2.71 to 18.2
10	Population	111,970 (2011 Census)
11	Issues Identified	• Low ground water sustainability and deeper water levels • Improper well design • Land subsidence
12	Management strategies	• Water quality management interventions • Artificial recharge plan

CHAPTER 1

INTRODUCTION

The National Aquifer Mapping and Management programme (NAQUIM), launched by the Central Ground Water Board (CGWB) in 2012, has been pivotal in delineating and characterizing aquifers across India, including the Alot block of Ratlam district in 2018-2019. This initiative aims at developing comprehensive aquifer management plans on a 1:50,000 scale, providing critical insights for sustainable groundwater management. Despite the dissemination of NAQUIM findings to district and state administrations in Madhya Pradesh, full-scale implementation remains a challenge. A recent meeting with the Additional Chief Secretary at the Water Resources Department, Government of Madhya Pradesh in Bhopal highlighted several pertinent issues.

Therefore, the Central Ground Water Board, NCR, Bhopal, has undertaken a detailed study of the water stressed Alot block, Ratlam district under NAQUIM 2.0 study. The study area covering an approximate area of 945 square kilometers. The population within this region was recorded at approximately 111,970 according to the 2011 census. The area experiences a normal annual rainfall of about 992.85 millimeters. It is surrounded by major and minor river courses such as Chambal, Kshipra, Maleni, and Mahi, which span from the south-western to the north-northeastern parts of the area. The terrain is characterized by plains transitioning to undulating landscapes, with altitudes ranging between 434 meters and 549 meters above mean sea level There has seen substantial increase in the water abstraction structures over the years for domestic and irrigation purposes and irrigation through polluted waters which posing issues such as declining water levels, groundwater quality concerns, deeper water levels and the degradation of recharge areas. For effective monitoring of the impacts on groundwater resources and the implementation of appropriate management practices, a comprehensive understanding of the distribution and quantification of groundwater within the aquifer system is essential.

In response to this need, recognizing these limitations and anticipating future requirements, NAQUIM 2.0 has been introduced. Under NAQUIM 2.0, this study aims to conduct detailed aquifer mapping at a scale of 1:10,000. This includes the demarcation of aquifers in both horizontal and vertical extents, assessment of their suitability for drinking water supply, analysis of changes in groundwater levels over past decades, assessment of Dynamic Groundwater resources, and development of sustainable management strategies at the ground level

As per the inferences from NAQUIM-1 and GWRA 2023, the district falls in water stressed area of Madhya Pradesh which is covered by Deccan trap basalts followed by Vindhyan formations. Due to the low ground water potential and yield of shallow aquifers and the overexploitation of groundwater resources for irrigation, water scarcity has become a significant issue. Further, the developing industrial areas in Nagda a causing groundwater contamination. (Special Study in Nagda industrial area by CGWB, 2021).

1.1 OBJECTIVES OF THE STUDY

- Preparing models, cross sections etc. in large scale for deciphering aquifer disposition.
- Observation of aquifer wise groundwater levels thereby identification and delineation of recharge areas and groundwater dynamics.
- Refinement of parameters used for GWRA in study area and reassessment of groundwater resources.
- Detailed analysis of groundwater quality in the area and proposing possible remedies.
- Identification and demarcation of safer aquifers for drinking water supply, management plan for source sustainability in contaminated aquifers/vulnerable aquifers.
- Areas showing signs of subsidence. (Over exploitation/ erosion of intertrappean clays)
- The recharge from surface water bodies at suitable location can be further enhanced by constructing proper design of recharge bore wells along with them.

1.2 PRIORITY TYPE

- Alot Block of Ratlam District is taken as Water Stressed Area Category in NAQUIM 2.0 studies. A water-stressed area typically refers to a region where the demand for water exceeds the available supply or where water resources are strained due to various factors such as population growth, inefficient water management practices, Over exploitation and environmental degradation. These areas often face challenges related to water scarcity, inadequate access to clean water for drinking and sanitation, and competition for water resources among different sectors such as agriculture, industry, and households.

- Water-stressed areas can be found in various parts of the world, including arid and semi-arid regions. Efforts to address water stress typically involve implementing water conservation measures, improving water management practices, investing in infrastructure for water supply and sanitation, promoting sustainable agriculture practices, and raising awareness about the importance of water conservation among communities.

1.3 PREVIOUS STUDIES

Previous studies and reports in the area are mentioned below;

- Report on the systematic geological mapping and preliminary mineral mineral investigations in Alot tehsil and parts of Jaora tehsil in Ratlam district by GSI during the year 1969.
- District Brochure of Ratlam district has been prepared during the year of 2013.
- Report on National aquifer mapping and management of ground water resources by Mr. D. Joshi (Retd. Sc-D) during 2018 -2019.
- Special Study in Nagda industrial area by CGWB, 2021.
- Groundwater Resource Assessment of Alot block, Ratlam district using GEC-2015 methodology for the year of 2020 and 2022. The data indicates that stage of ground water extraction was 119.74% in 2020 and decreased very slightly to 119.66% by 2022. Despite this very slight decrease, the area remained under the Over exploited category for both years.

CHAPTER 2

STUDY AREA

2.1 LOCATION

The NAQUIM study area, covering approximately 945 square kilometers, is situated in the water-stressed Alot block in the western part of Madhya Pradesh. Geographically, the block lies in the northeastern part of Ratlam district, between latitudes 23°32' N to 23°50' N and longitudes 75°15' E to 75°40' E, and is represented by Survey of India Toposheet Nos. 46M/5, 46M/6, 46M/9, and 46M/10. The block is bordered by Sitamau block of Mandsaur district to the northwest, Badud block to the east, Jaora block to the south, and Rajasthan state to the north. The administrative boundaries of the study area are shown in Fig. 2.1. Alot block experiences a humid subtropical climate, marked by arid winters, hot summers, and a humid monsoon season. Summers extend from late March to mid-June, with temperatures peaking above 40°C in May. The region receives an average annual rainfall of 992.8 mm during the monsoon season from June to September (IMD).

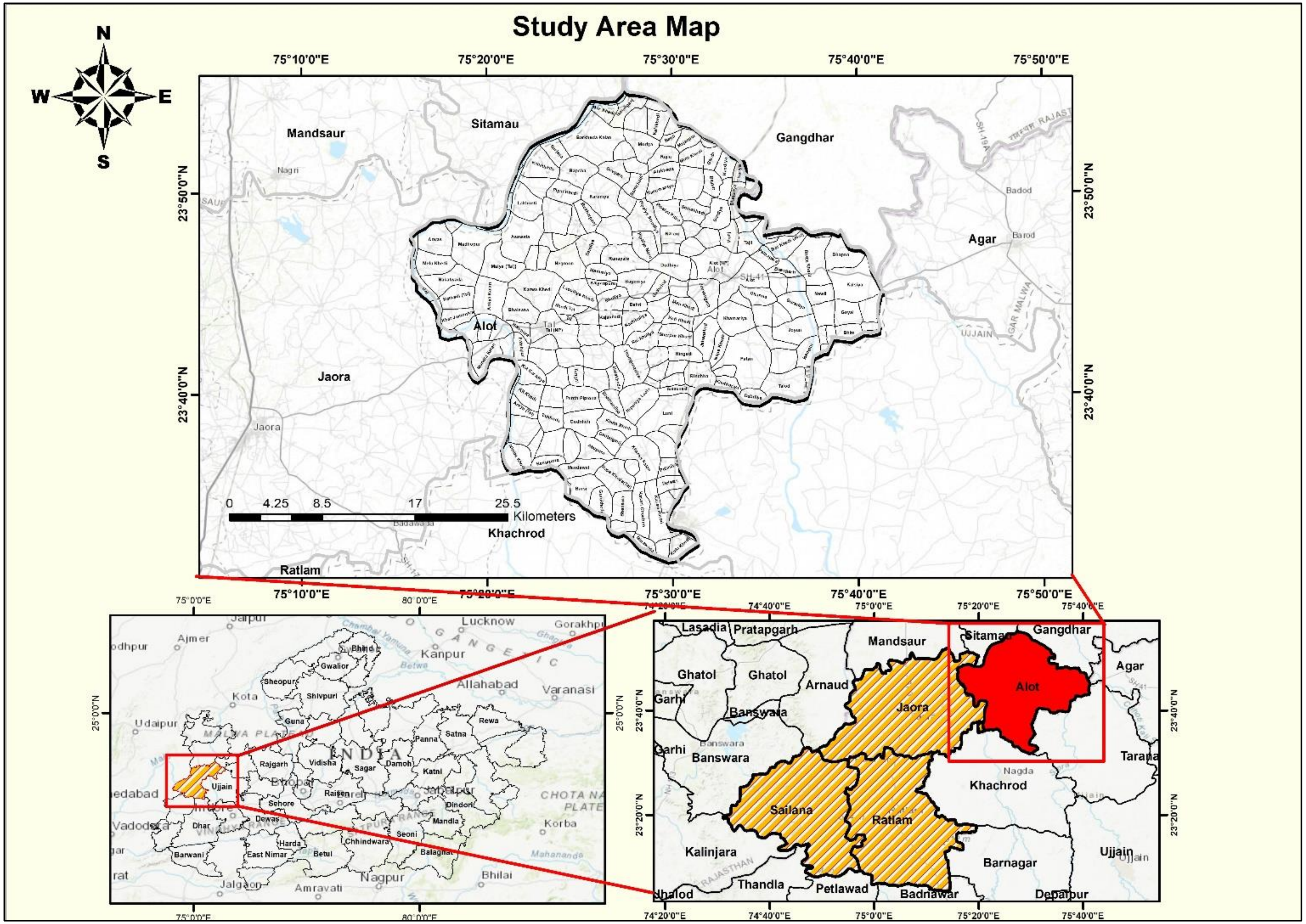


Fig. 2.1: Administrative Map of Alot block, Ratlam district.

2.2 POPULATION

According to the 2011 Census, Alot Block in Ratlam District, Madhya Pradesh, had a population of roughly 152,874. Over the years, this region has seen consistent population growth, reflecting a significant demographic shift. The growth trend in Alot Block follows a pattern similar to exponential kinetics, indicating a continuous rise in population driven by urbanization and socio-economic progress. If the growth rate continues at its historical pace, it is estimated that by 2023, the population of Alot Block could reach around 190,000. This suggests a substantial increase of approximately 24% over a 12-year span, demonstrating the region's rapid demographic expansion. Yearly population and growth data are illustrated in Fig. 2.2 and Table 2.1 below.

Table 2.1: Year wise population and annual growth

Year	Population	Annual Growth	Percentage Growth
2011	1,52,874	-	-
2012	1,56,500	3,626	2.37%
2013	1,60,200	3,700	2.36%
2014	1,63,900	3,700	2.31%
2015	1,67,700	3,800	2.32%
2016	1,71,600	3,900	2.32%
2017	1,75,600	4,000	2.33%
2018	1,79,700	4,100	2.34%
2019	1,83,900	4,200	2.34%
2020	1,88,200	4,300	2.34%
2021	1,92,600	4,400	2.34%
2022	1,97,100	4,500	2.34%
2023	2,01,700	4,600	2.33%

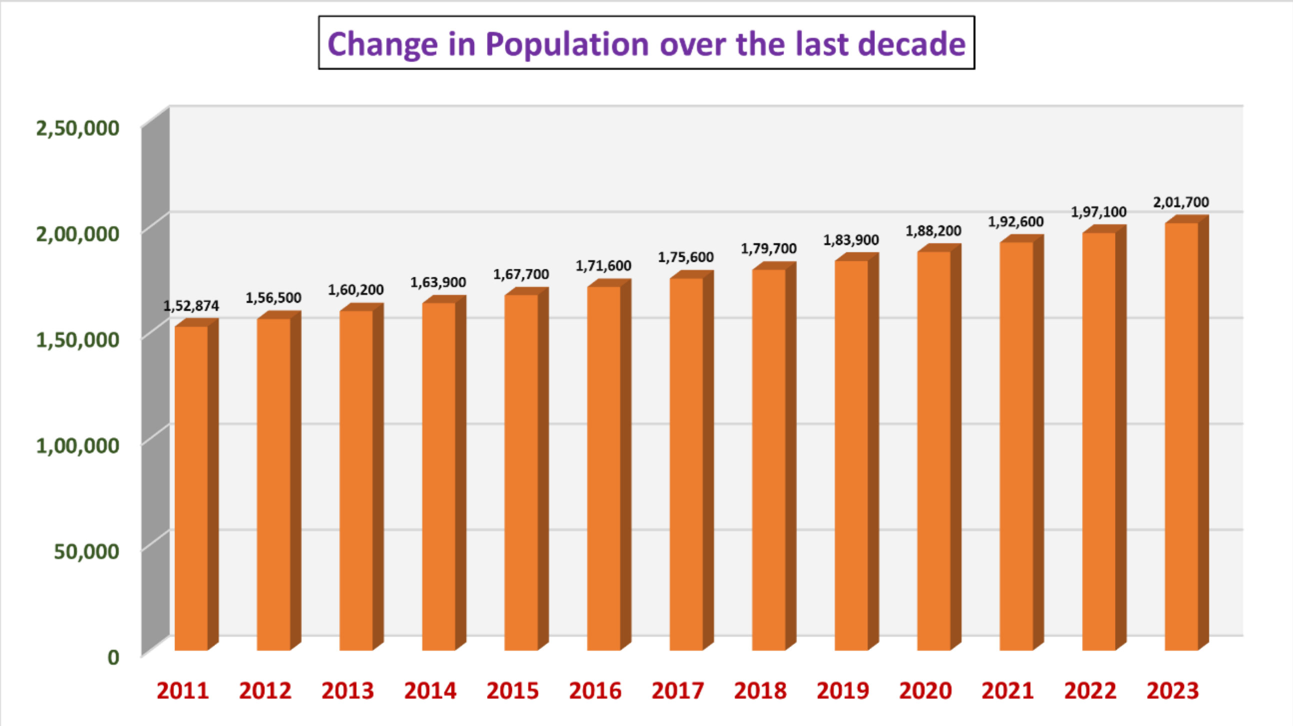


Fig. 2.2: Change in Population over the last decade. (source; Census report)

The population data from 2011 to 2023 reveals a consistent annual growth rate of approximately 2.3%, reflecting a steady increase in population over the years. This gradual population growth could lead to increased demand for water resources, affecting groundwater levels and quality. As the population expands, the stress on local aquifers and water supply systems intensifies, necessitating enhanced groundwater management strategies. The steady rise in population underscores the importance of implementing sustainable water use practices and regular monitoring of aquifer conditions to ensure that the growing needs of the population are met without depleting or degrading groundwater resources. Efficient management and conservation measures will be critical to maintaining water security in the face of ongoing demographic changes.

2.3 LAND USE AND LAND COVER PATTERN

The land use and land cover (LULC) changes in the Alot block between 2017 and 2023 suggest potential impacts on the local hydrogeological system. The decrease in bare ground from 0.04% to 0.01% indicates possible land development or vegetation growth, potentially affecting hydrogeological processes. The significant increase in built-up areas from 2.55% to 3.99% suggests urbanization or infrastructure development, altering surface runoff patterns and increasing impervious surfaces. The slight decrease in cropped areas from 94.98% to 93.33% suggests changes in agricultural practices. The slight increase in range land from 0.89% to 1.04% indicates potential changes in grazing activities, influencing infiltration rates and soil moisture dynamics. The slight increase in percentage of water bodies at 1.46% to 1.56%

can be attributed to construction of various recharge structure such as check dam, gully plug etc. Understanding these LULC changes is crucial for managing water resources and informing sustainable land and water resource management practices. Land use and land cover map and Change in land use pattern over the years etc are given in Table 2.2 and Fig. 2.3 and 2.4.

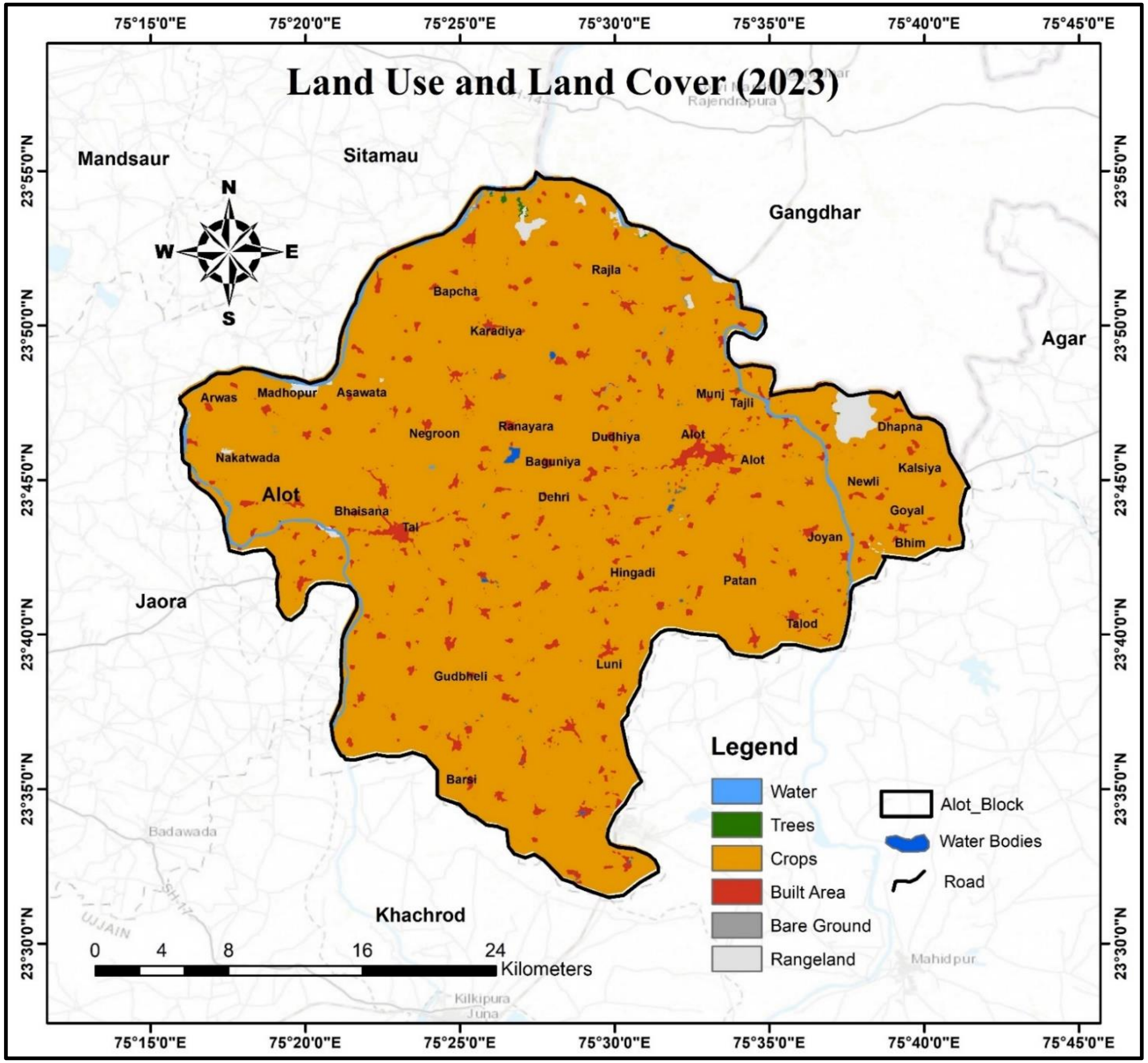


Fig. 2.3: LULC Map of Alot block, Ratlam District

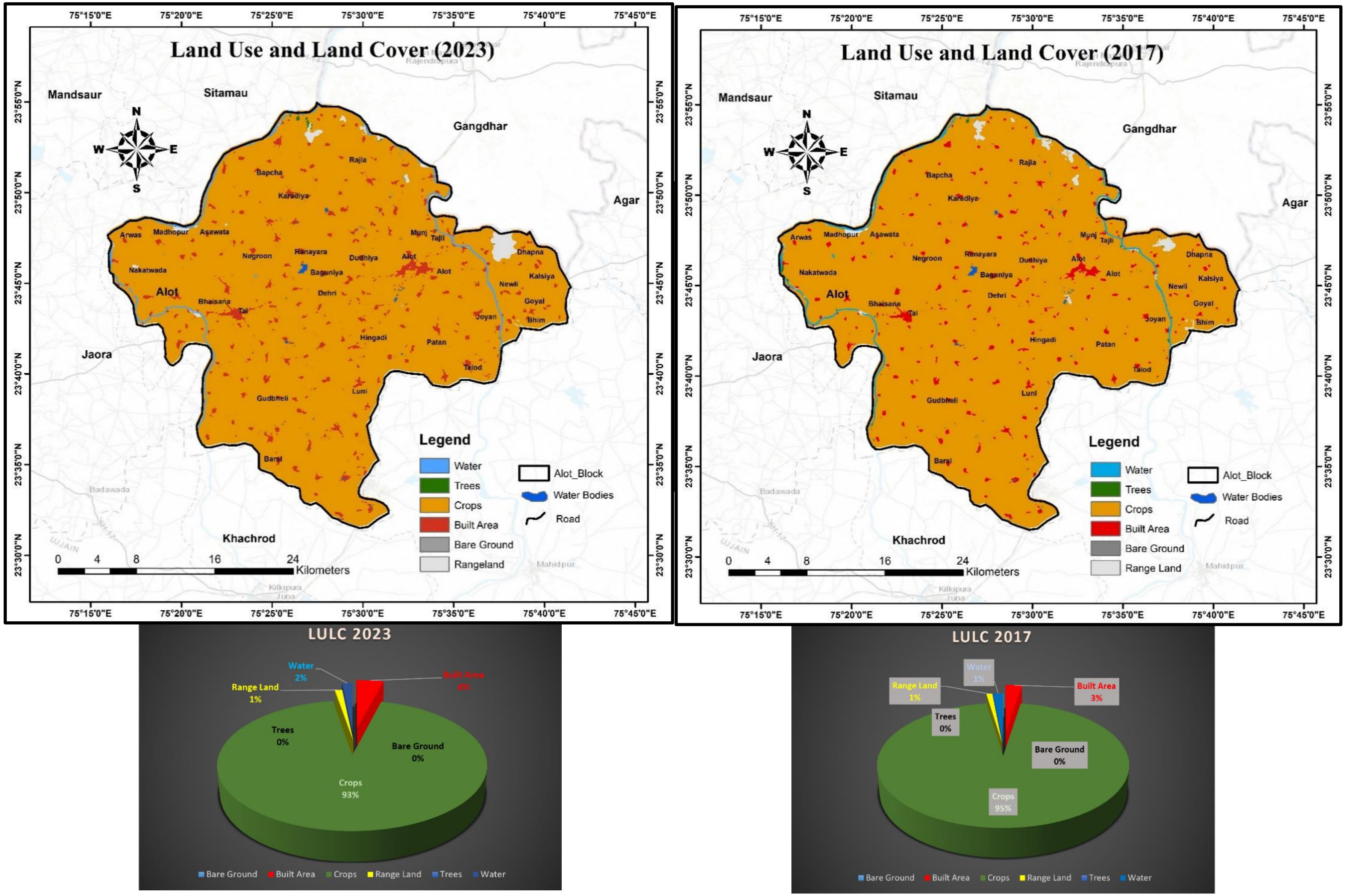


Fig. 2.4: Change in LULC of Alot block, Ratlam District.

Table 2.2: Change in Land use and cropping pattern of Alot block, Ratlam District

	2017		2023	
Type of Area	**Area (Sq. km)**	**Percentage**	**Area (Sq. km)**	**Percentage**
Bare Ground	0.35	0.04	0.084	0.01
Built Area	24.4	2.55	38.2	3.99
Crops	909.2	94.98	893.4	93.33
Range Land	8.5	0.89	9.95	1.04
Trees	0.83	0.09	0.68	0.07
Water	14	1.46	14.9	1.56

2.4 IRRIGATION & CROPPING PATTERNS

Significant portion of Alot block in Ratlam District is characterized by black cotton soil, making it a highly suitable area for agriculture. Groundwater serves as the primary source of irrigation, supporting a diverse cropping pattern in the region. During the Kharif season, the main crops cultivated include soybean, corn, and cotton, while the Rabi season focuses on wheat, gram, garlic, and other crops. Field observations revealed that surface water from rivers is also utilized for irrigation during non-monsoon periods. However, when surface water is insufficient, farmers depend on bore wells, typically operating them for 3 to 4 hours daily to meet irrigation needs.

2.5 CLIMATE AND RAINFALL

Alot Block experiences a humid subtropical climate characterized by mild, dry winters, hot summers, and a humid monsoon season. Summers begin in late April and continue until mid-June, with average temperatures around 30°C (86°F). The peak summer heat occurs in May, with temperatures frequently exceeding 40°C (104°F). The monsoon season starts in late June and lasts until late September, bringing around 1020 mm (40 inches) of rainfall, often accompanied by thunderstorms and occasional flooding. According to IMD records, the normal annual rainfall for Alot Block is 914.5 mm, with approximately 92.1% of the precipitation occurring during the southwest monsoon period from June to November. This period is critical for groundwater recharge as surplus water is available only during these months. The average temperature during this season is around 25°C (77°F), with high humidity levels. By late October, temperatures begin to rise again before transitioning into winter, which lasts from November to early March. Winters in Alot are mild, sunny, and dry, with average temperatures around 18°C (64°F) and minimal rainfall. In January, temperatures can occasionally drop close to freezing during the night. The daily mean temperature in May is 40.7°C, while the minimum temperature is 26.4°C.

2.6 GEOLOGY

The Alot block in Ratlam District is predominantly underlain by basaltic lava flows, known as the Malwa Traps, which are associated with the middle traps of the Deccan Volcanic Province. These basaltic flows, deposited during the Late Cretaceous to Early Paleocene period, play a significant role in shaping the region's geomorphology and soil characteristics. The geological succession of the Alot block is presented in Table 2.3. According to the Geological Survey of India, seven distinct flow units have been demarcated within the study area, encompassing both the Alot and Jaora blocks, as shown in Table 2.4. The weathering of basalt begins with the formation of pale brown fragmented material mixed with brownish-yellow or pale-yellow soil. As weathering progresses, this material further disintegrates into yellowish-brown soil, eventually transforming into the region's characteristic black cotton soil, also known as regur. This type of soil, which is highly fertile, is largely derived from the weathering of vesicular basalt and "red bole" layers, which are particularly prone to degradation.

The basaltic flows in this area are occasionally interbedded with fossiliferous inter-trappean beds, indicating periods of sedimentation between volcanic events. Alluvial deposits are observed within the valleys and along the stream courses of the Kshipra and Chambal rivers, contributing to localized variations in soil composition and fertility. Laterite deposits are also found sporadically on the trap surfaces, indicating prolonged weathering processes and fluctuating climatic conditions. These geological features have significant implications for the hydrogeology and land use of the region. The geological map of the study area is depicted in Fig. 2.5, providing a visual overview of the distribution of various lithological units and their spatial relationships across the Alot block.

Table 2.3: Tentative Geological Succession in Alot block of Ratlam district

Succession	Formation	Age
Alluvium / Laterite	Clay with kankar, sand and river alluvium	Recent to Pleistocene
Deccan trap	Basaltic lava flows with red bole and inter-trappean beds	Upper cretaceous to Eocene
---Unconformity---		
Upper Vindhyan Bhander Group	Sandstone and Shale sequence with conglomerate	Upper Precambrian to Lower Proterozoic

Table 2.4: Elevation of basaltic lava Flows in Alot block, Ratlam District

Flow No.	Altitudes in meters	Thickness in meters	Lithological description and demarcating horizon
7th	584	22	Medium grained massive basalt showing spheroidal weathering at the top.
	562		
			Weathered Zone
6th	562	30	Fine to medium grained massive basalt sometimes microporphyritic - upper part is of amygdaloidal character.
	532		
			Red boles
5th	532	22	Massive basalt with amygdala character in certain parts –spheroidal weathering at the top.
	510		
			Red boles
4th	510	20	Fine grained massive basalt with spheroidal weathering.
	490		
			Red boles
3rd	490	12	Massive basalt with columnar Joints - locally vesicular character.
	478		
			Red boles
2nd	478	13	Medium grained massive basalt with spheroidal weathering - locally porphyritic nature.
	465		
1st	465		Medium grained to aphanitic massive basalt with columnar joints
	and below		
			Base not known

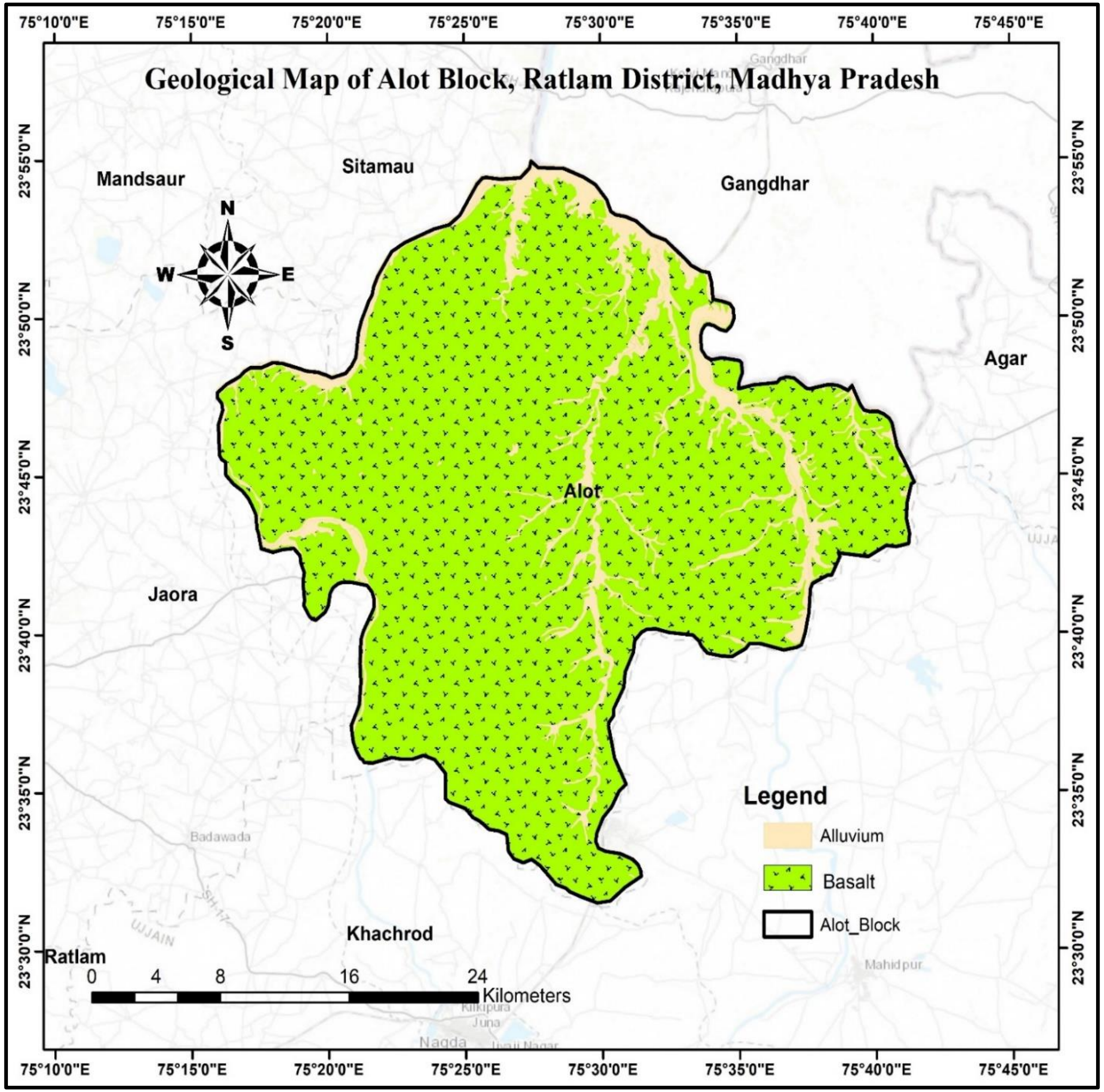


Fig. 2.5: Geological Map of Alot block, Ratlam District.

2.7 HYDROGEOLOGY

Geologically, the Alot block is predominantly occupied by Deccan Trap basalts, with narrow patches of alluvium and isolated sedimentary rocks of the Vindhyan Supergroup, forming distinct aquifer systems in the area. Groundwater occurrence and movement in the hard rock terrain are primarily governed by secondary porosity, influenced by joints, fractures, and vesicles within the basaltic lava flows. Groundwater generally exists under unconfined to semi-confined conditions.

Vindhyans:

The Vindhyan sandstone, appearing as hillocks in Alot town, is quartzitic, hard, and compact. At deeper depths, it forms a reliable aquifer with yields generally exceeding 2 liters per second (lps). The sandstone's aquifer potential increases with depth due to enhanced fracture development.

Basalts:

Basalts dominate the district, with groundwater typically occurring under phreatic conditions within shallow, weathered, jointed, and fractured horizons. However, the groundwater distribution in basalt is not uniform, varying both vertically and laterally. Key factors influencing yield include physiographic setting, weathered mantle thickness, degree of jointing and fracturing, and the characteristics of vesicular horizons. Deeper aquifers show unconfined to semi-confined conditions due to the alternating sequence of vesicular and massive basalt units. The secondary porosity of jointed and fractured massive basalt often acts as a leaky confining bed, resulting in semi-confined conditions for underlying vesicular water-bearing units. The yield in these basaltic aquifers ranges from low to moderate (1 to 3 lps).

Alluvium/Laterite:

Alluvial deposits are confined to narrow linear stretches along the river courses of Chambal and Kshipra, with thicknesses ranging from 12 to 15 meters, thinning away from the river. These deposits consist of consolidated, fine to medium-grained sand with varying yields of 1 to 5 lps.

Groundwater Occurrence:

Groundwater occurs within weathered rocks along fractures, joints, and vesicles, exhibiting considerable spatial and temporal variability due to differences in the hydrogeological environment. The study area, primarily a hard rock terrain, consists of basaltic lava flows underlain by Vindhyan sandstone and shale formations. Groundwater typically occurs in phreatic conditions up to 30 meters depth, in semi-confined conditions between 30 to 200 meters, and in confined conditions at depths between 200 to 300 meters. Three primary aquifer systems have been identified:

1. Aquifer-I: Extends up to the weathered zone (shallow aquifer).

2. Aquifer-II: Occurs within fractured/vesicular basalt between 30 to 200 meters.

3. Aquifer-III: Found at the contact between basalt and Vindhyan formations, typically at depths of 200 to 300 meters.

The distribution and depth of water-bearing fractures vary significantly across different wells, reflecting the complex hydrogeological regime of the area. The hydrogeological map of the study area is presented in Fig. 2.6.

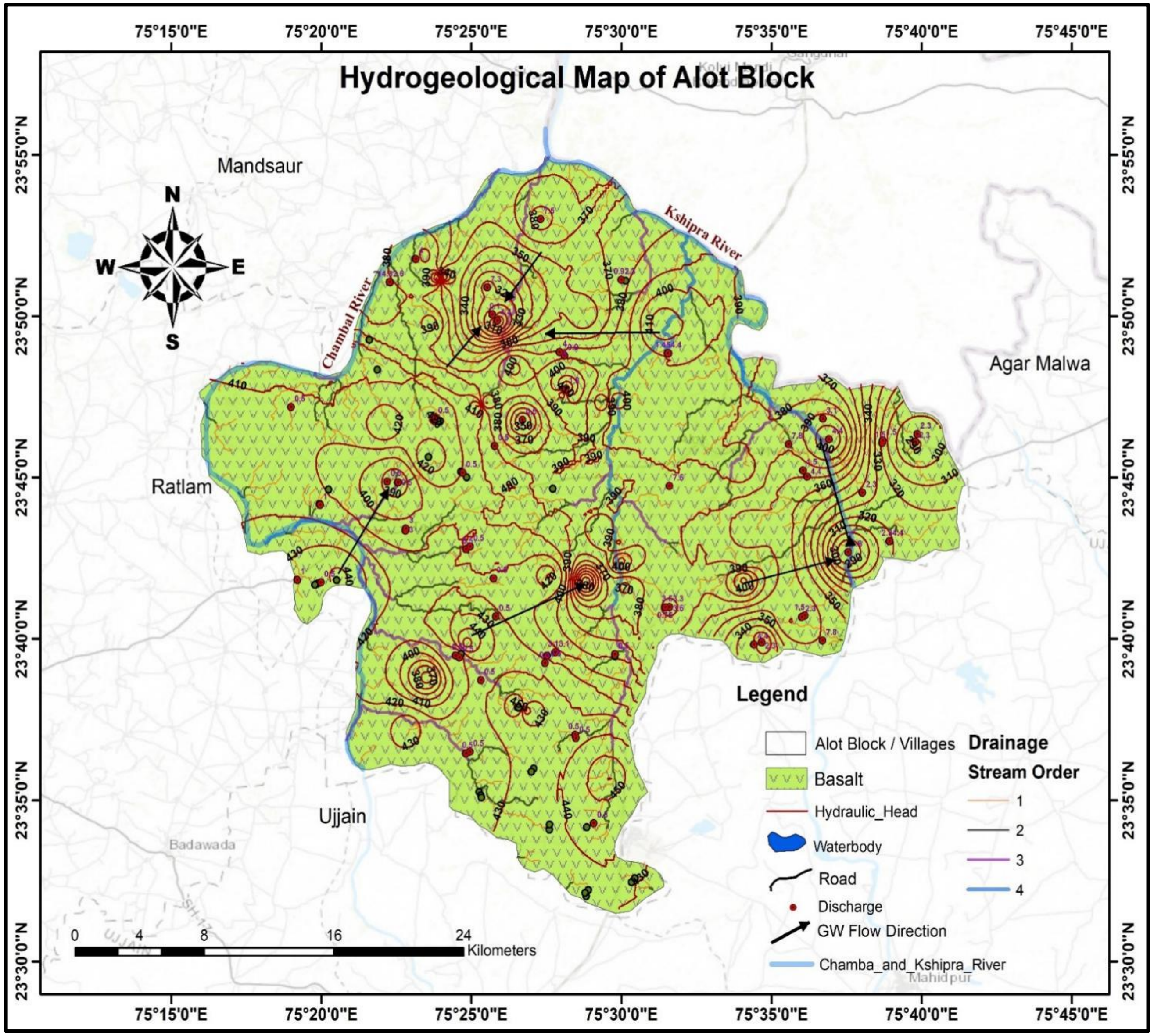


Fig. 2.6: Hydrogeological Map of Alot block, Ratlam District

2.8 GEOMORPHOLOGY AND TOPOGRAPHY (DEM)

The geomorphology of Alot Block in Ratlam District, Madhya Pradesh, is characterized by a plain terrain with moderate relief, primarily shaped by a Low Dissected Structural Lower Plateau, indicative of the Deccan Trap basalts. Pediment Pediplain Complexes along the plateau's edges reflect significant weathering and erosion, resulting in gently sloping surfaces that influence runoff and groundwater recharge.

The region's hydrological network, including rivers and streams, plays a key role in shaping the landscape through sediment transport and deposition. Younger Alluvial Plains, located in lower-lying areas, consist of recent alluvial deposits and are potential zones for groundwater recharge. Small ponds and unclassified water bodies further contribute to localized recharge opportunities.

Topographically, Alot Block exhibits varied landscapes, ranging from undulating to broken terrain, especially along the Chambal and Kshipra rivers. Elevations average around 500 meters above mean sea level (MSL), with the highest point at 507 meters MSL in the northwest and the lowest at 386 meters MSL in the central northern boundary. The flat-topped hills with gentle slopes, shaped by erosional processes on the Deccan Trap basalts, influence local drainage patterns and groundwater flow. This topographical variation directs surface runoff from higher elevations to lower areas, facilitating localized recharge in areas with conducive soil and geological conditions. Effective groundwater management and flood mitigation strategies must consider these geomorphological and topographical factors. The Digital Elevation Model (DEM) is shown in Fig. 2.7, and the geomorphological map is presented in Fig. 2.8.

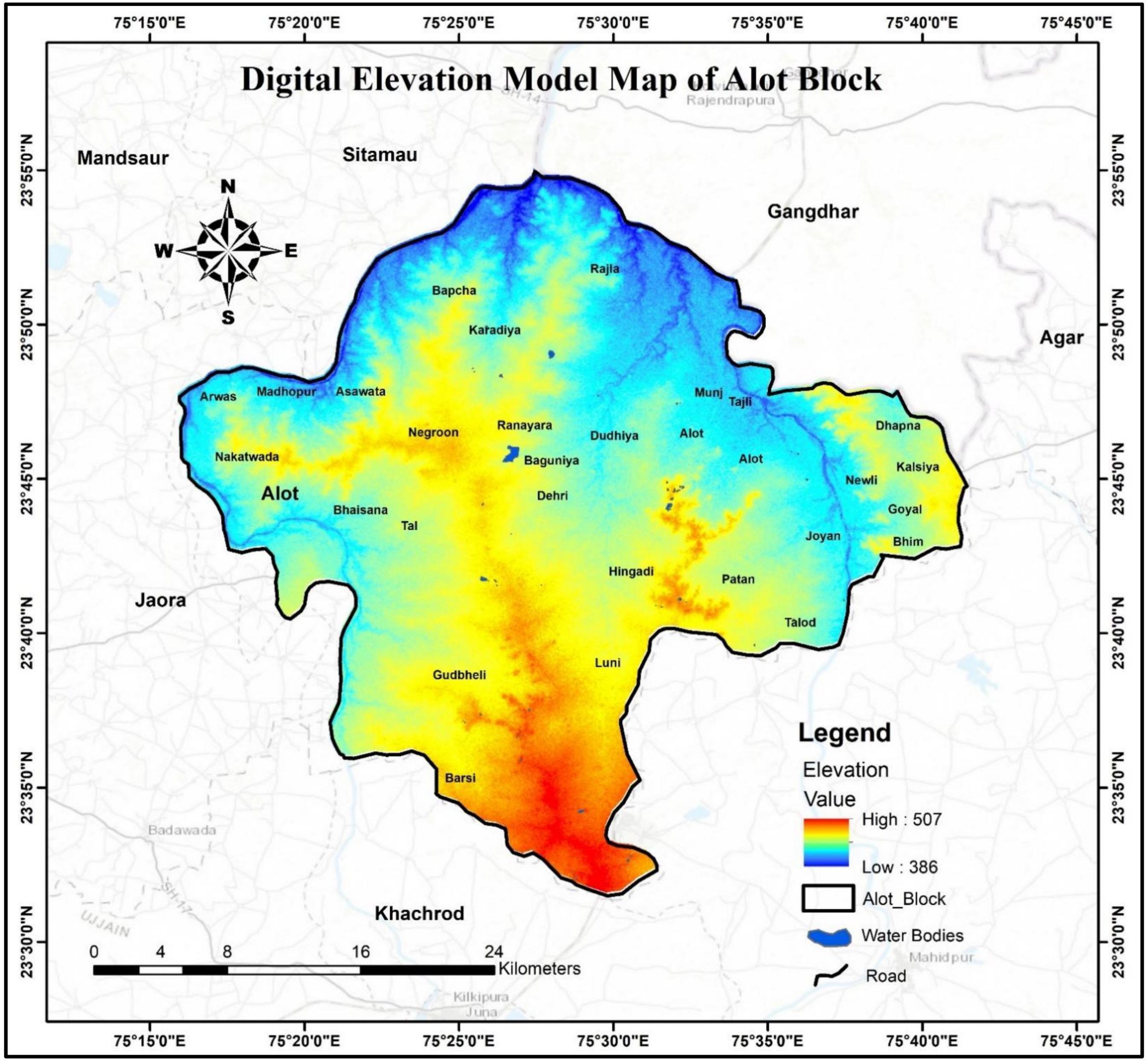


Fig. 2.7: Digital Elevation Map of Alot block, Ratlam District

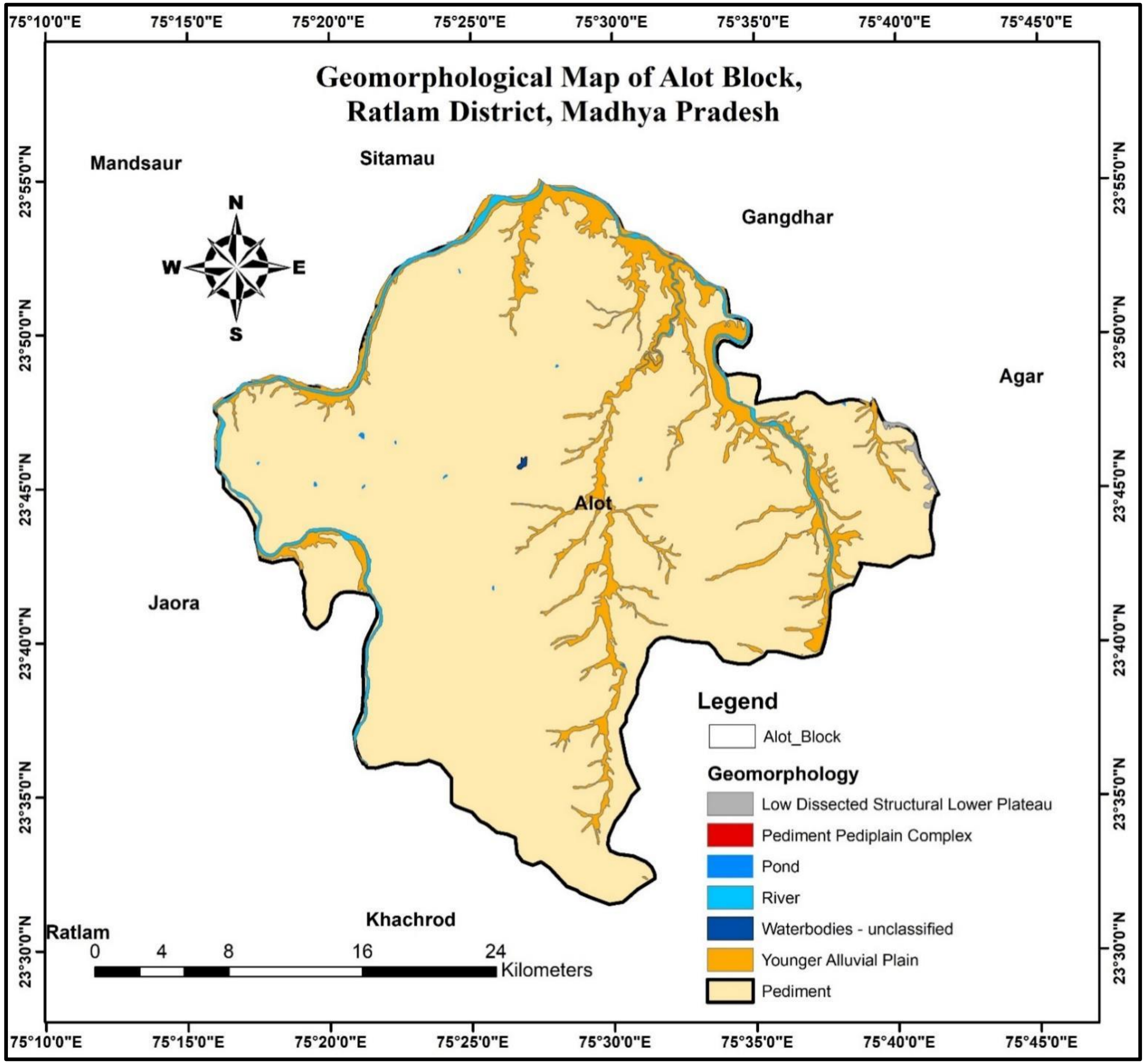


Fig. 2.8: Geomorphological map of Alot block, Ratlam District

2.9 SOIL

The soils in Alot Block, Ratlam, predominantly include black soil, lateritic soil, and silty 'Kankar' with clay admixtures, particularly along major stream banks.

- Black Soil: Characterized by high clay content, black soil exhibits excellent moisture retention capabilities, which supports groundwater recharge in regions with sufficient precipitation.
- Lateritic Soil**:** Found mainly in elevated areas, lateritic soil is highly porous, which facilitates rapid infiltration and drainage. However, its high permeability can also contribute to localized groundwater depletion.
- Silty 'Kankar' Soil: This soil, along with clay alluvium present near streams, possesses moderate permeability. It creates favourable conditions for aquifer recharge by allowing water to percolate and replenish underlying groundwater systems.

Overall, these soil types collectively influence groundwater recharge dynamics, with black soil aiding moisture retention, lateritic soil enabling rapid drainage, and silty 'Kankar' soils supporting effective water infiltration and groundwater replenishment.

2.10 DRAINAGE

The Alot Block in Ratlam District, Madhya Pradesh, is situated within the Chambal sub-basin of the Yamuna River sub-basin (part of the Ganga basin) and is influenced by the Kshipra River and its tributaries. The drainage map reveals a dendritic pattern with elevations ranging from 386 meters to 507 meters above mean sea level (MSL). The highest elevations, reaching 507 meters MSL, are found in the northwest, while the lowest point is 386 meters MSL in the central northern boundary.

This topographic variation significantly impacts surface water flow and groundwater recharge. The elevated northwest region serves as the primary catchment area, generating numerous first-order streams. These streams merge into higher-order streams as they flow south-eastward toward the lower elevations. The well-developed drainage network, including the Chambal and Kshipra rivers and their tributaries, is instrumental in channelling surface runoff, particularly during the monsoon season.

The undulating terrain and elevation gradient direct surface water flow towards the southeastern part of the block, which, due to its lower elevation, represents potential zones for groundwater recharge. The interaction between the drainage pattern and elevation profile underscores the importance of these southeastern regions in accumulating water and supporting aquifer replenishment. This understanding is vital for sustainable water resource management, emphasizing areas where surface water can be harnessed to enhance groundwater recharge. The drainage map of the study area is presented in Fig. 2.9.

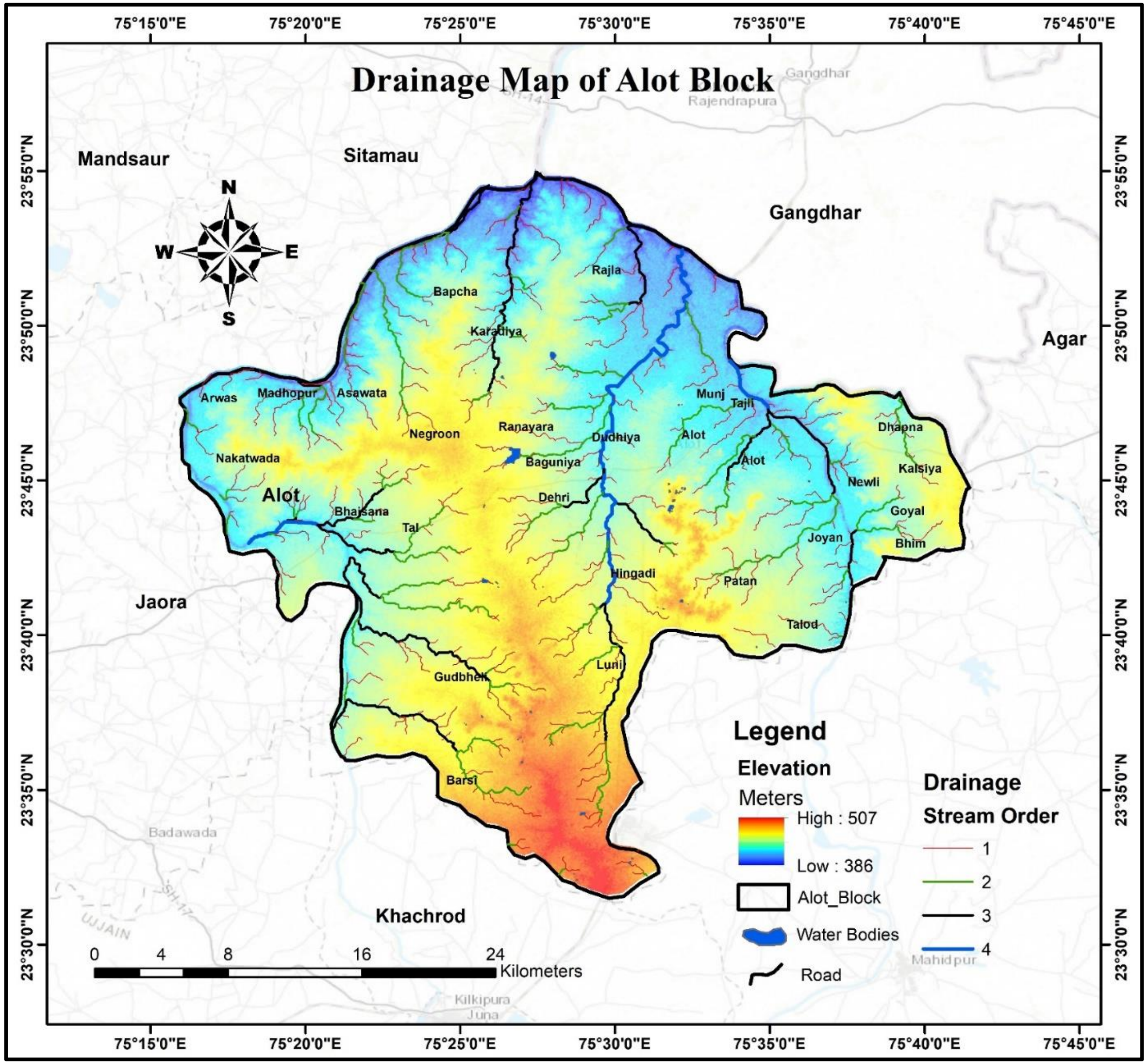


Fig. 2.9: Drainage Map of Alot block, Ratlam District

2.11 FINDINGS OF AQUIFER MAPPING AND MANAGEMENT PROGRAMME-I

As per GWRA 2022, three blocks in the district falls under semi-critical and three blocks under over- exploited category. As a part of aquifer management plan under NAQUIM, additional groundwater recharge is proposed through construction of artificial recharge structures in all blocks in the district for sustainable development of groundwater. As the area is covered with hard rocks, the thickness of the aquifers is limited. The weathered basalt generally from the shallow aquifer, which are extends up to the depth of 30 m. The fractured/jointed massive/vesicular basalt and Vindhyan sandstone form the deeper aquifer. The disposition of Aquifers and other geological units can be observed in the 2D cross section (Fig 2.10) shows that the region is dominantly occupied by basalt.

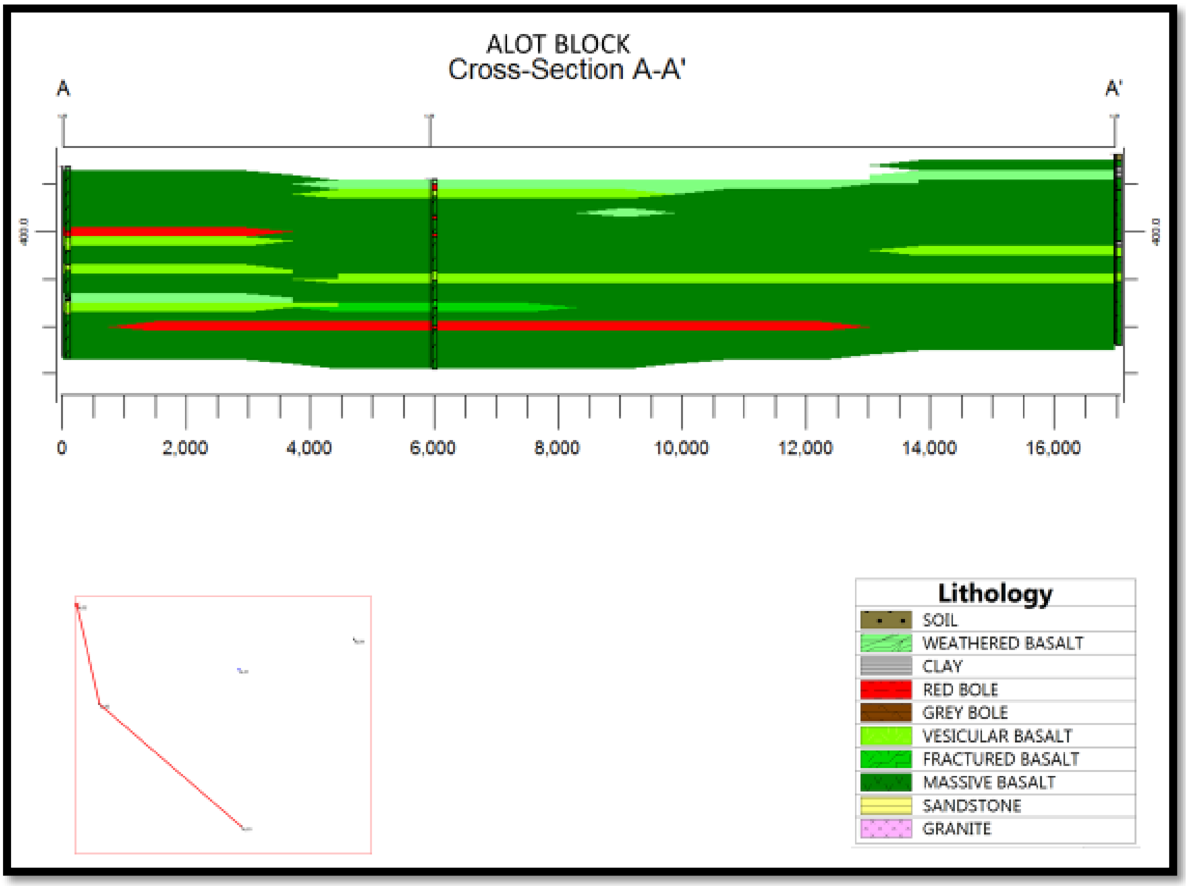


Fig. 2.10: 2D Cross Section, Alot block

CHAPTER 3

AQUIFER DISPOSITION

3.1 OBJECTIVES

The objectives of aquifer disposition are as follows:

- Delineate Aquifer Boundaries: Define the horizontal and vertical extent of aquifer boundaries.
- Demarcate Aquifers: Identify and categorize various aquifer systems within the study area.
- Determine Aquifer Characteristics: Assess and characterize the properties and behavior of each aquifer.
- Identify Recharge Zones: Pinpoint areas essential for aquifer recharge.

3.2 METHODOLOGY (Fig. 3.1)

3.2.1 Groundwater Exploration

Groundwater exploration was conducted using both direct and indirect methods, as outlined below:

1. Direct Methods

- Drilling of 6 exploratory wells, 1 observation well, and utilization of 6 existing exploration wells.
- The locations of the exploratory wells are shown in Fig. 3.2.
- Lithological profiles were obtained from drill cuttings at 3-meter intervals to assess the depth-wise occurrence and thickness of aquifers. Lithologs from wells drilled during the NAQUIM-1 studies were also incorporated.
- Using RockWorks 15 software, 2D aquifer sections and fence diagrams were created to evaluate the lateral extent and connectivity of each aquifer.
- Discharge measurements were taken from each well during drilling. Preliminary yield tests were conducted in 2 exploratory wells, and 3 slug tests were performed. Drawdown and recovery data were analyzed using Aquifer Test Pro software.

2. Indirect Methods

- Conducted 50 vertical electrical soundings (VES) in the study area using an Aquameter CRM Auto C. The maximum electrode spacing (AB/2) was 300 meters.
- Apparent resistivity values were plotted against AB/2 on a double logarithmic scale with a modulus of 62.5 mm. Data interpretation was performed using IPI2WIN software, ensuring that the final models were consistent with local hydrogeological conditions.

The results of the vertical electrical soundings, drilling, and pump yield tests are discussed in detail in this chapter.

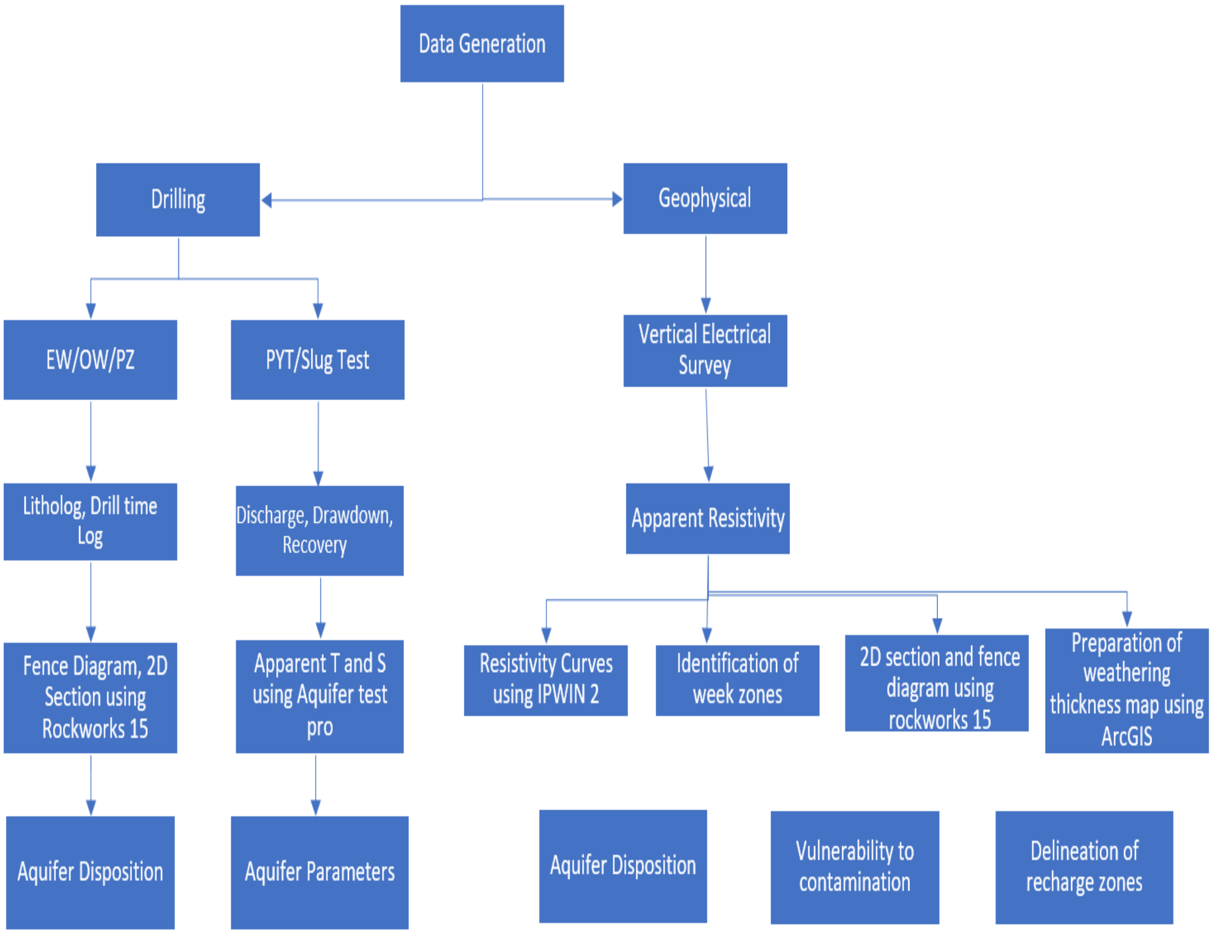


Fig. 3.1: Flow chart showing methodology used in aquifer disposition

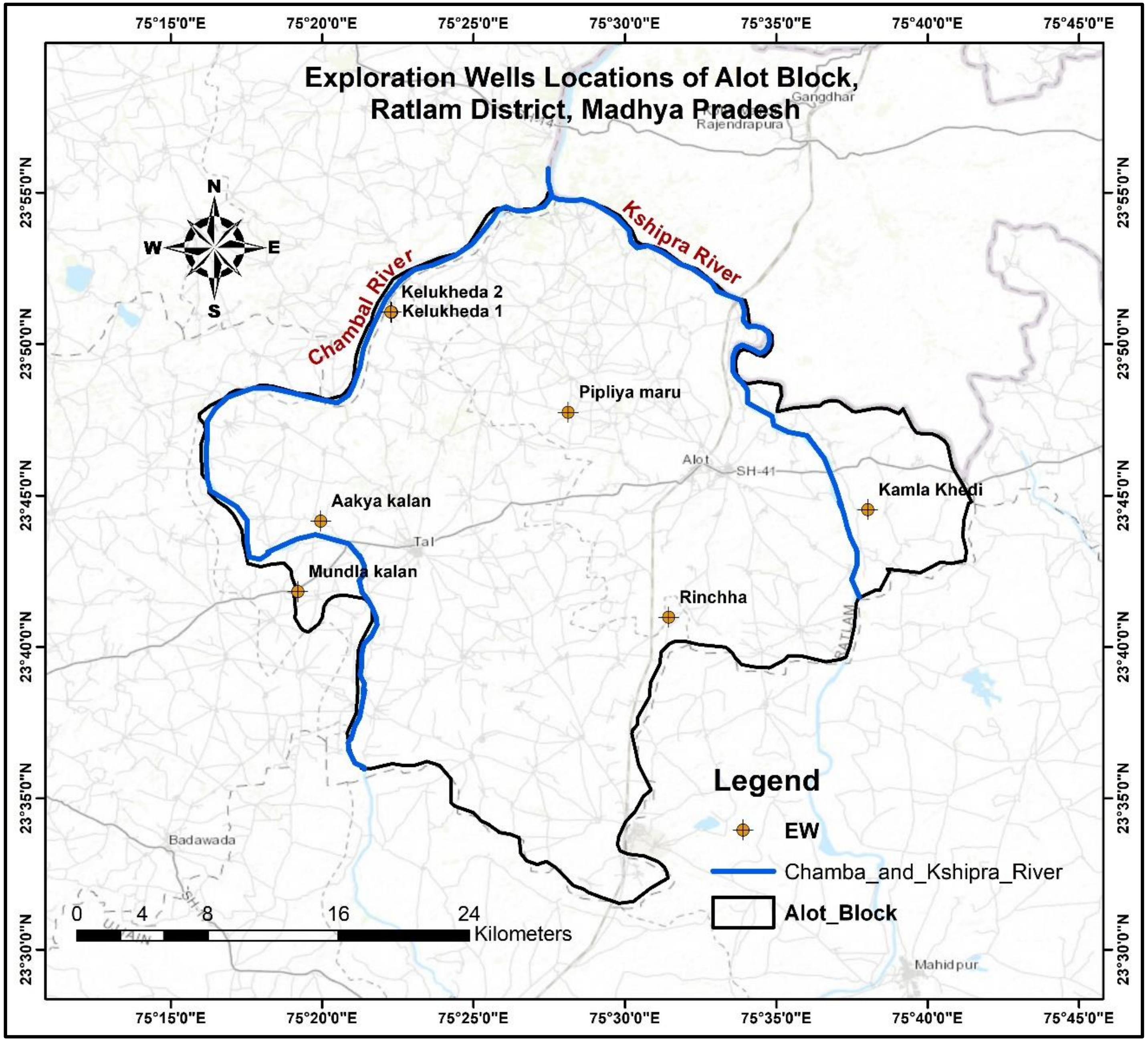


Fig. 3.2: Location Map showing locations of groundwater exploratio

3.3 RESULTS AND DISCUSSION

Two 2-dimensional aquifer sections were analyzed to determine the lateral extent and connectivity of aquifers within the study area. 2-D Cross Section A-A' (Moriya-Pipliya Maru-Kachaliya-Nipaniya Leela-Bensola) shows that the first aquifer, consisting of weathered basalt, spans elevations from 415 to 480 meters above mean sea level (amsl) with an average thickness of 10-12 meters (Fig. 3.3). This aquifer pinches out laterally at Kachaliya and extends further south toward Bensola. The second aquifer, vesicular basalt, is found at elevations of 464-428 meters amsl with an average thickness of 10 meters, predominantly along Nipaniya Leela and Kachaliya. It pinches out southwards from Kachaliya towards Bensola, with thicknesses varying between 6-8 meters from 305 to 356 meters amsl and 8-10 meters from 305 to 239 meters amsl in patches around Bensola and Pipliya Maru. The third aquifer, Vindhyan sandstone, located at the contact zone with Deccan basalt, ranges from 305 to 155 meters amsl and maintains continuity along the N-S direction. Among these, the Vindhyan sandstone represents the most significant potential aquifer. Additionally, the average thickness of massive basalt between consecutive flows is 23 meters, with three basalt flows identified up to a depth of 200 meters. Collapsible red bole formations with an average thickness of 3-6 meters are noted at elevations of 398-393 meters amsl, 296-301 meters amsl, and 197-203 meters amsl.

2-D Cross Section B-B' (Kamla Khedi-Kachaliya-Karwa Khedi-Aakya Kalan) illustrates limited lateral continuity between potential aquifers, except for Vindhyan sandstone and, to some extent, weathered basalt (Fig. 3.4). The first aquifer, weathered basalt, occurs at elevations of 418-448 meters amsl with an average thickness of 10-14 meters but pinches out laterally around Kachaliya. The second aquifer, vesicular basalt, spans elevations of 400-440 meters amsl, 386-435 meters amsl, and 379-325 meters amsl with an average thickness of 8-10 meters, predominantly along Kamla Khedi and Kachaliya, but pinches out westward towards Karwa Khedi and Aakya Kalan. The third aquifer, fractured basalt, appears in patches near Karwa Khedi and between Kachaliya and Kamla Khedi, occurring at elevations of 402-393 meters amsl and 335-342 meters amsl. The fourth aquifer, Vindhyan sandstone, shows significant potential, located at the contact zone with Deccan basalt, and extends from 379 to 235 meters amsl with consistent connectivity in the E-W direction. The average thickness of massive basalt between consecutive flows is 30 meters.

The fence diagram, created using Rockworks software (Fig. 3.5 & 3.6), highlights three consecutive basaltic flows extending up to 200 meters, with each flow averaging 60 meters in thickness. Thin red bole layers, averaging 3-6 meters in thickness, are observed at elevations of 398-393 meters amsl, 296-301 meters amsl, and 197-203 meters amsl. The weathered basalt forms a shallow, laterally extensive aquifer with good connectivity, whereas deeper aquifers, including fractured and vesicular basalt, demonstrate limited continuity. Vindhyan sandstone, however, maintains significant coverage throughout the study area. The pinching out of deeper aquifers between basalt flows increases the risk of groundwater contamination, particularly in the shallow aquifers. The fence diagram effectively represents the subsurface conditions, providing a comprehensive view based on the 3-D stratigraphic model.

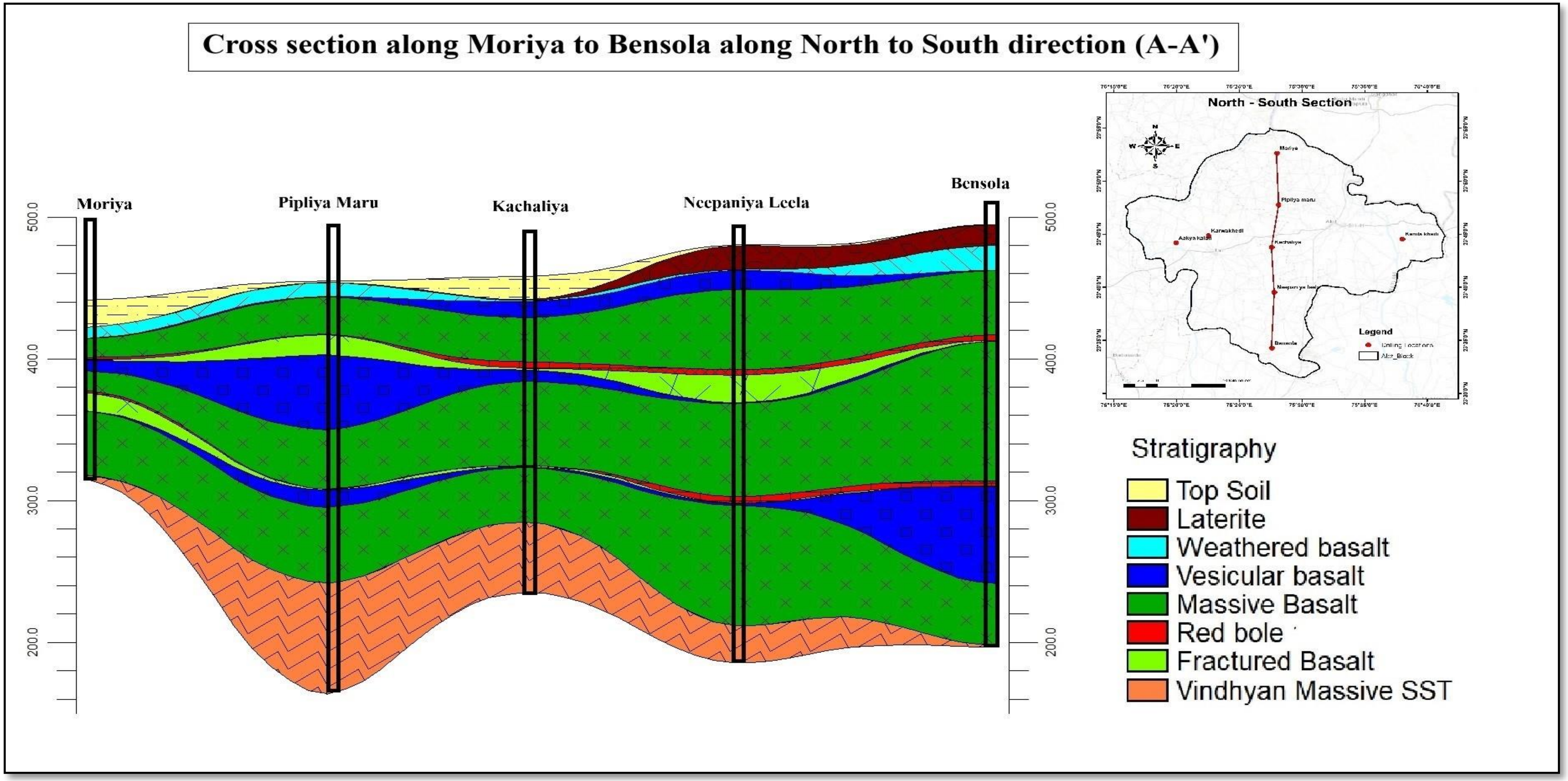


Fig. 3.3: 2-D Cross Section (A-A') from Moriya- Pipliya Maru-Kachaliya – Nipaniya Leela - Bensola (N-S)

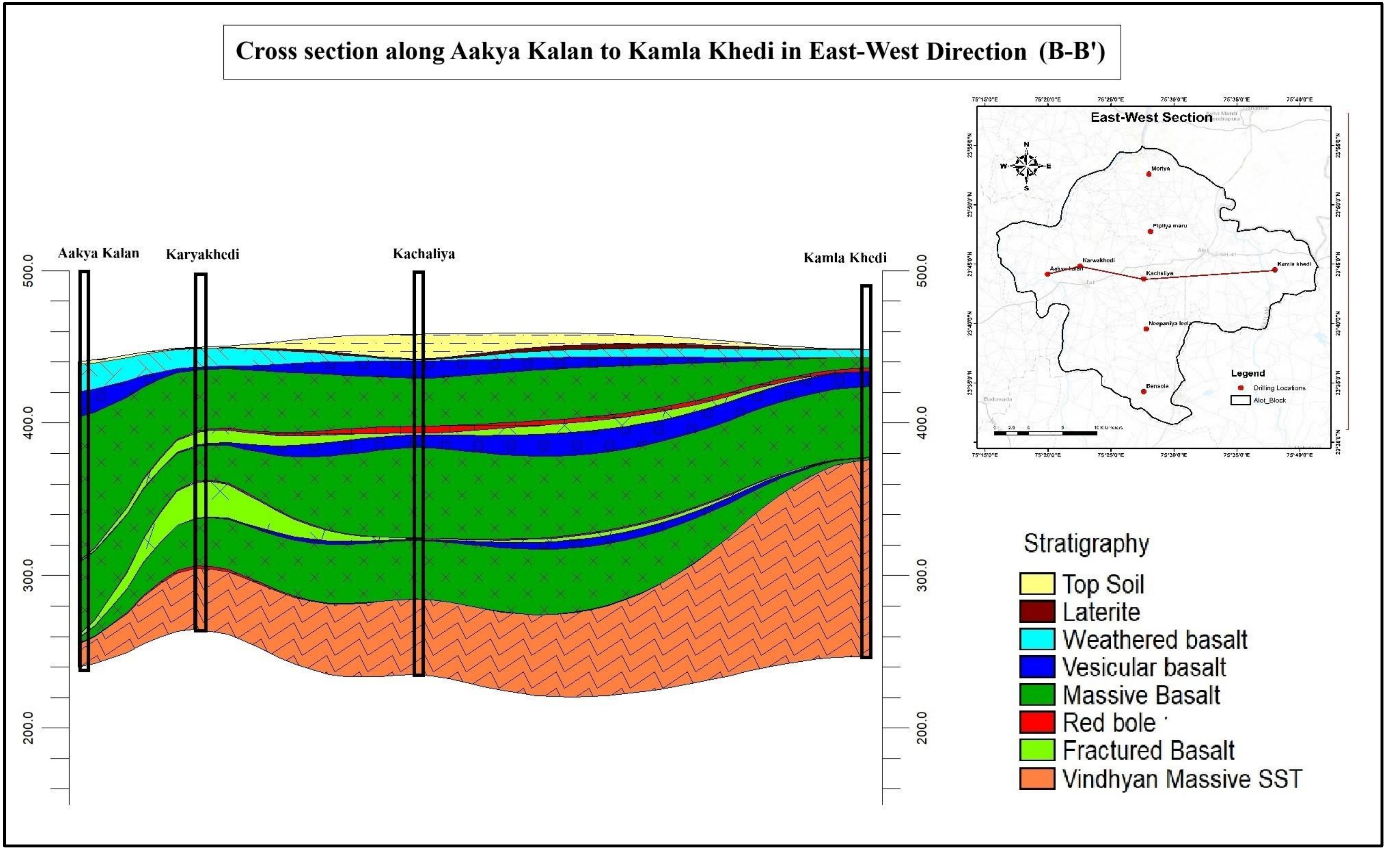


Fig. 3.4: 2-D Cross Section (B-B') from Kamla Khedi - Kachaliya – Karwa Khedi - Aakya Kalan (E-W)

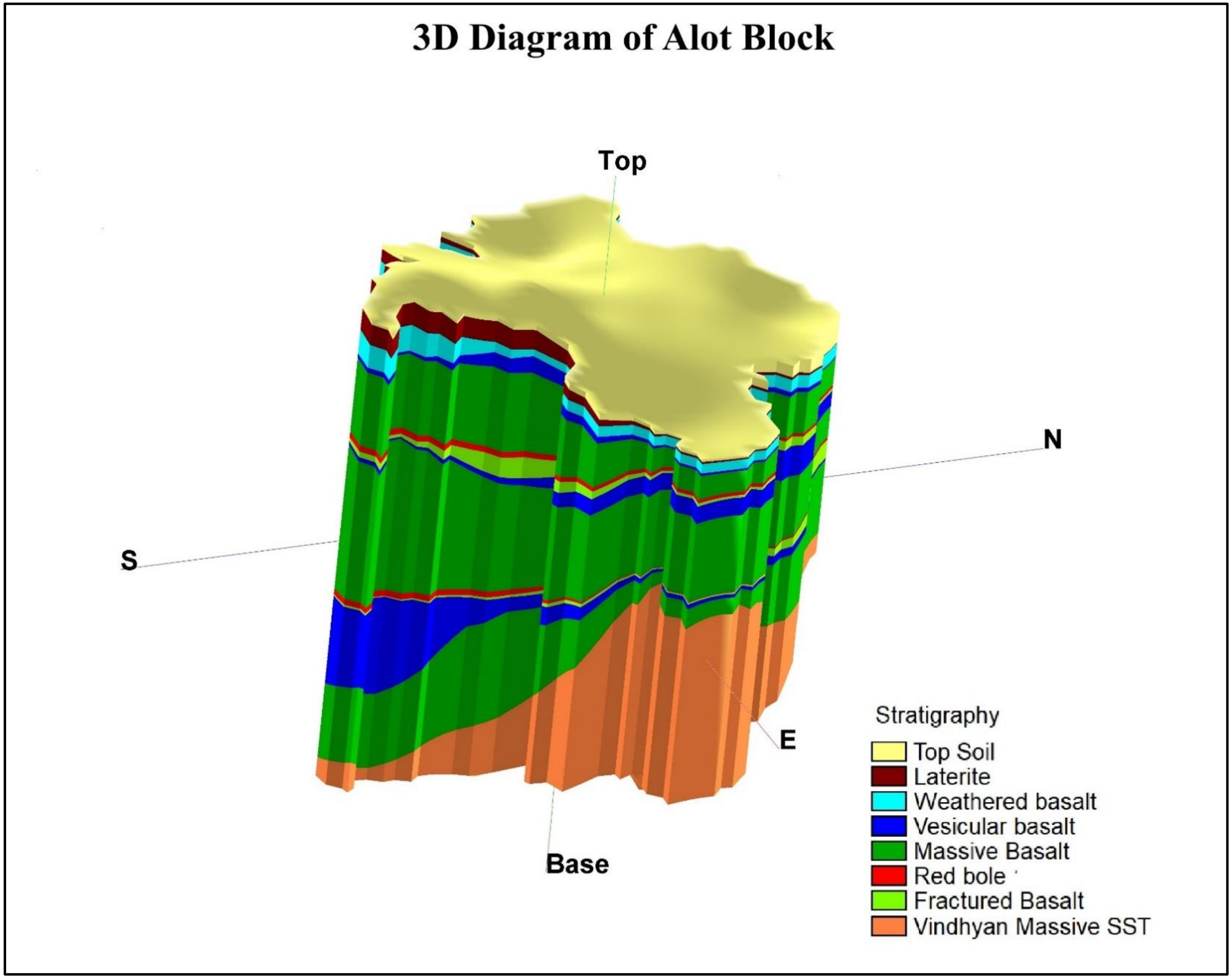


Fig. 3.5: 3-D Fence Diagram, Alot Block, Ratlam District.

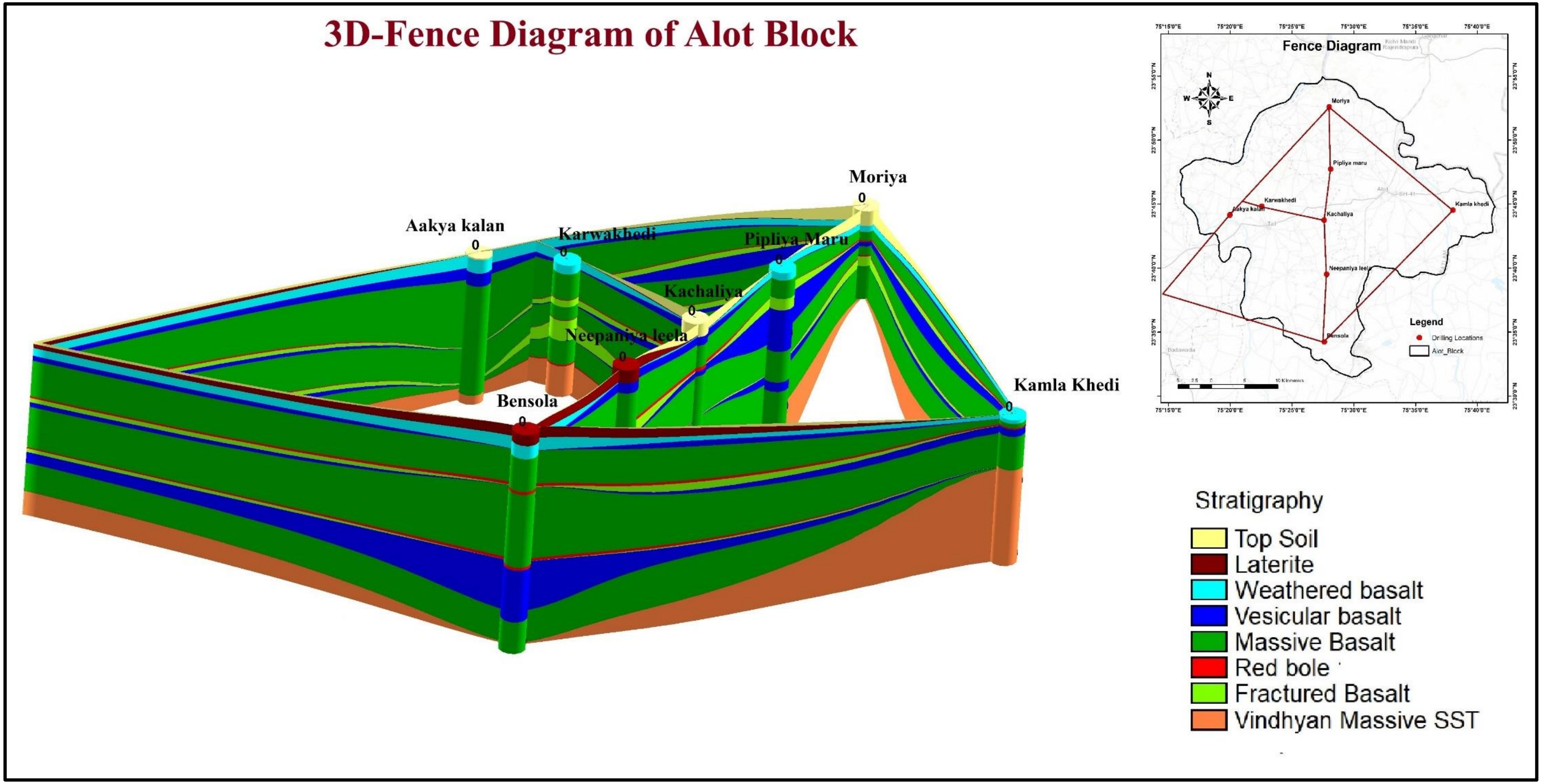
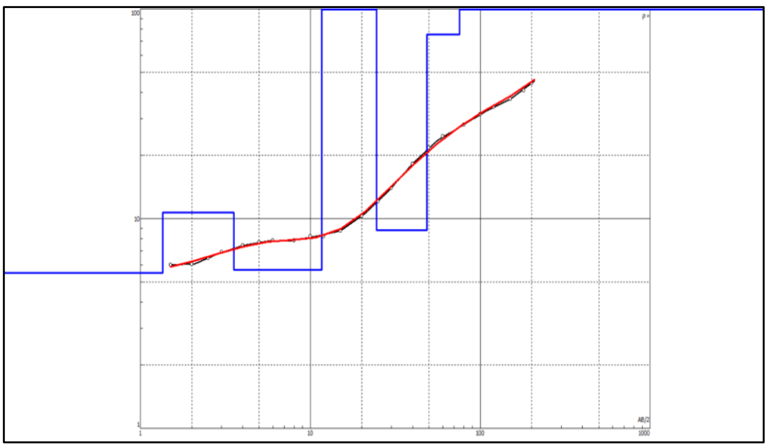


Fig. 3.6: 3-D Diagram, Alot Block, Ratlam District

3.3.1 Geophysical Studies

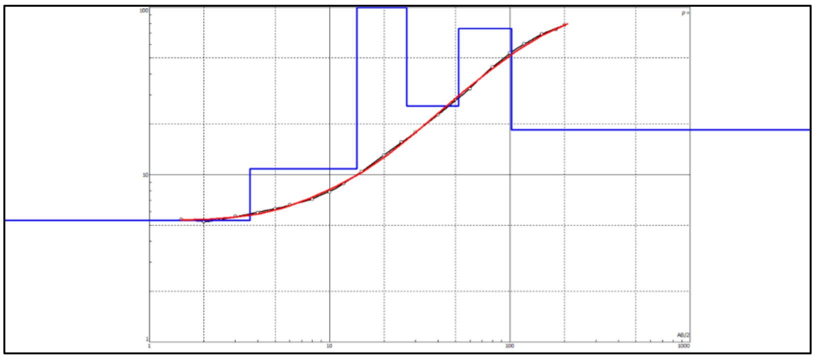
From interpreted results of 50 VES carried out in & around Water Stressed Alot Block area six to seven geo-electrical layers have been identified (Fig. 3.7 to 3.11). The geology of the study area is Deccan Trap Basalt. It comprises of several basaltic flows in geological past forming successive layers of Massive & Vesicular Basalts. The Weathered Basalt, highly Fractured Basalt, Vesicular Basalt have capabilities to form potential aquifers. From interpreted VES results the Top Soil, Weathered Zone, Fractured Zone, Massive Zone and Vesicular Zones have been identified. VES Results revel Aquifer Disposition very well. From the local geological setup >60 ohm-m resistivity is taken as Massive Formation, 10 – 30 ohm-m resistivity is taken as weathered formation, 40 – 60 ohm-m resistivity is taken as fractured formation & low resistivity in between two high resistivities of Massive Formation is taken as Vesicular Formation. From interpreted VES Results attached in **Annexure II** Weathering Thickness Map of the study area is prepared. The Map is shown below. The areas where the weathering thickness are more than 10 m form potential shallow aquifers. The area having weathering thickness more than 10 m is suitable for Artificial Recharge. The Weathering Thickness Map is prepared from interpreted VES Results. The weathering thickness of maximum area lies in 5 – 10 meters. The northern portion of the study area has weathering thickness less than 5 meters. The areas where weathering thickness is more than 5 m & Water Level is deep are suitable for artificial recharge (Fig. 3.12).

Two Cross Sections are prepared named A – A' along West – East Direction & B – B' along North – South Direction. The Cross Section A – A' is drawn in West to East Direction. Weathering Thickness is less in Eastern Part as compared to western part of the study area. The Massive Basalt is more thick in central & eastern part of the study area (Fig. 3.13). The Cross Section B – B' is drawn in North to South Direction (Fig. 3.14). In Central portion of the section weathering thickness is more as compared to Northern & Southern Portion of the Section. Massive Basalt is more thick in Northern & Southern portion of the section



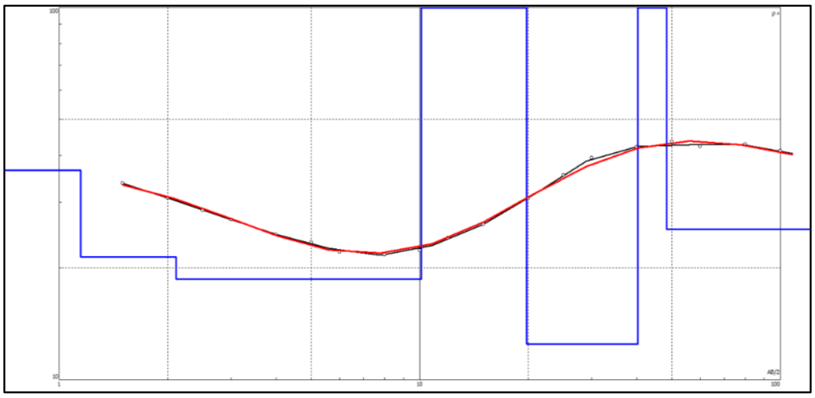
N	ρ	h	d	Alt
1	5.51	1.35	1.35	-1.353
2	10.7	2.18	3.54	-3.537
3	5.71	8.14	11.7	-11.67
4	223	12.8	24.5	-24.52
5	8.79	24.1	48.6	-48.59
6	75.3	26.8	75.4	-75.43
7	1605			

Fig. 3.7: VES Curve and interpreted layer parameters at Barkheda Kalan, Alot Block, Ratlam District



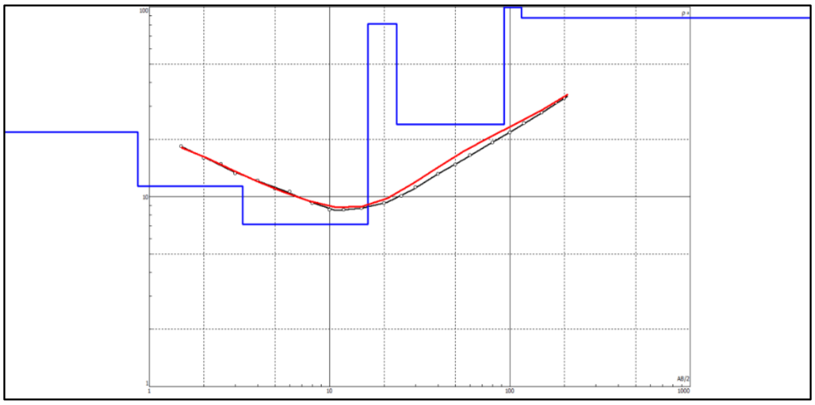
N	ρ	h	d	Alt
1	5.32	3.62	3.62	-3.623
2	10.8	10.5	14.1	-14.12
3	1975	12.6	26.7	-26.72
4	25.7	25.3	52	-52.02
5	74.3	50	102	-102
6	18.5			

Fig. 3.8: VES Curve and interpreted layer parameters at Tal, Alot Block, Ratlam District



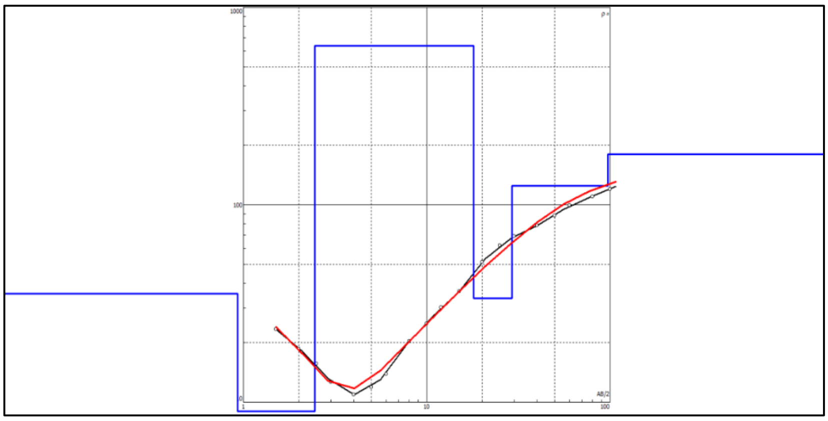
N	ρ	h	d	Alt
1	36.5	1.15	1.15	-1.148
2	21.3	0.961	2.11	-2.109
3	18.7	8	10.1	-10.1
4	167	9.71	19.8	-19.82
5	12.5	20.4	40.2	-40.18
6	307	8.21	48.4	-48.39
7	25.3			

Fig. 3.9: VES Curve and interpreted layer parameters at Melu Khedi, Alot Block, Ratlam District



N	ρ	h	d	Alt
1	21.9	0.865	0.865	-0.8655
2	11.4	2.43	3.3	-3.3
3	7.17	13	16.3	-16.31
4	81.3	7.3	23.6	-23.61
5	24	69.3	92.9	-92.91
6	303	22.7	116	-115.6
7	87.4			

Fig. 3.10: VES Curve and interpreted layer parameters at Madhabpur, Alot Block, Ratlam District



N	ρ	h	d	Alt
1	35.4	0.931	0.931	-0.9311
2	4.26	1.52	2.45	-2.45
3	638	15.6	18	-18.02
4	33.5	11.1	29.2	-29.16
5	125	68.3	97.5	-97.46
6	181			

Fig. 3.11: VES Curve and interpreted layer parameters at Nipaniya Tal, Alot Block, Ratlam District.

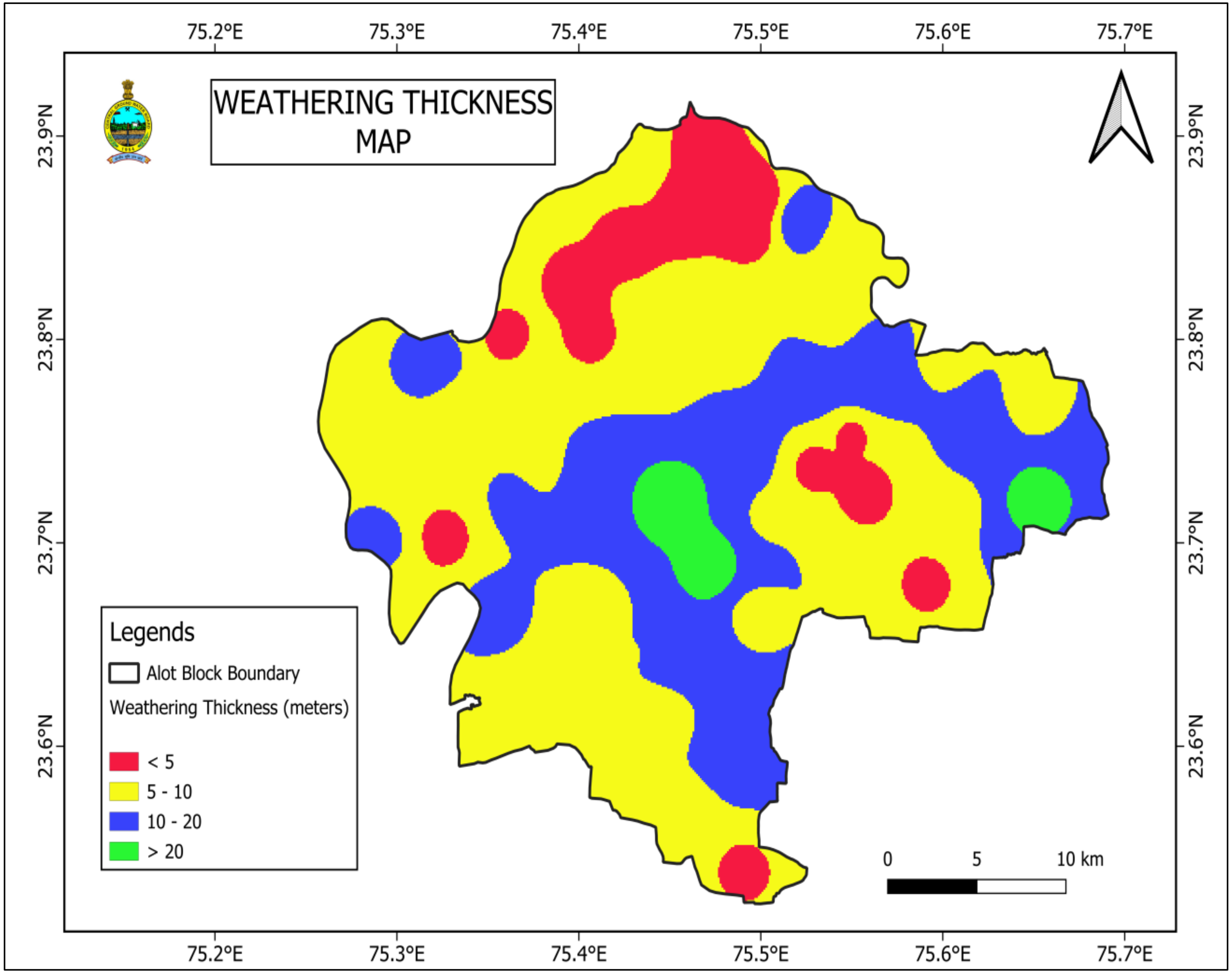
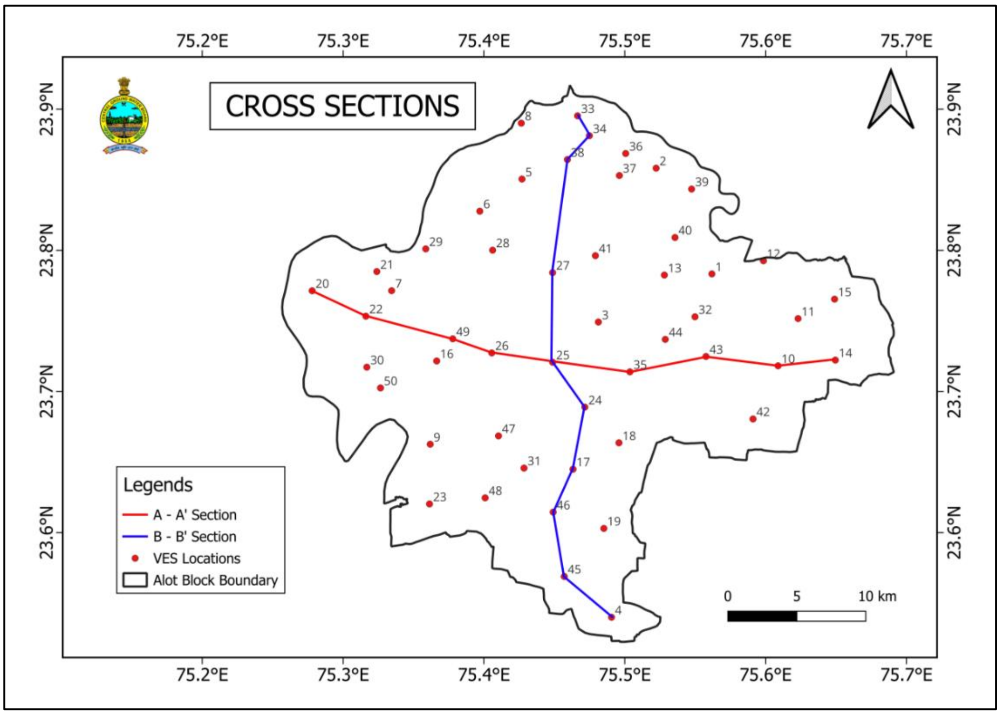


Fig. 3.12: Weathering Thickness Map of the study area



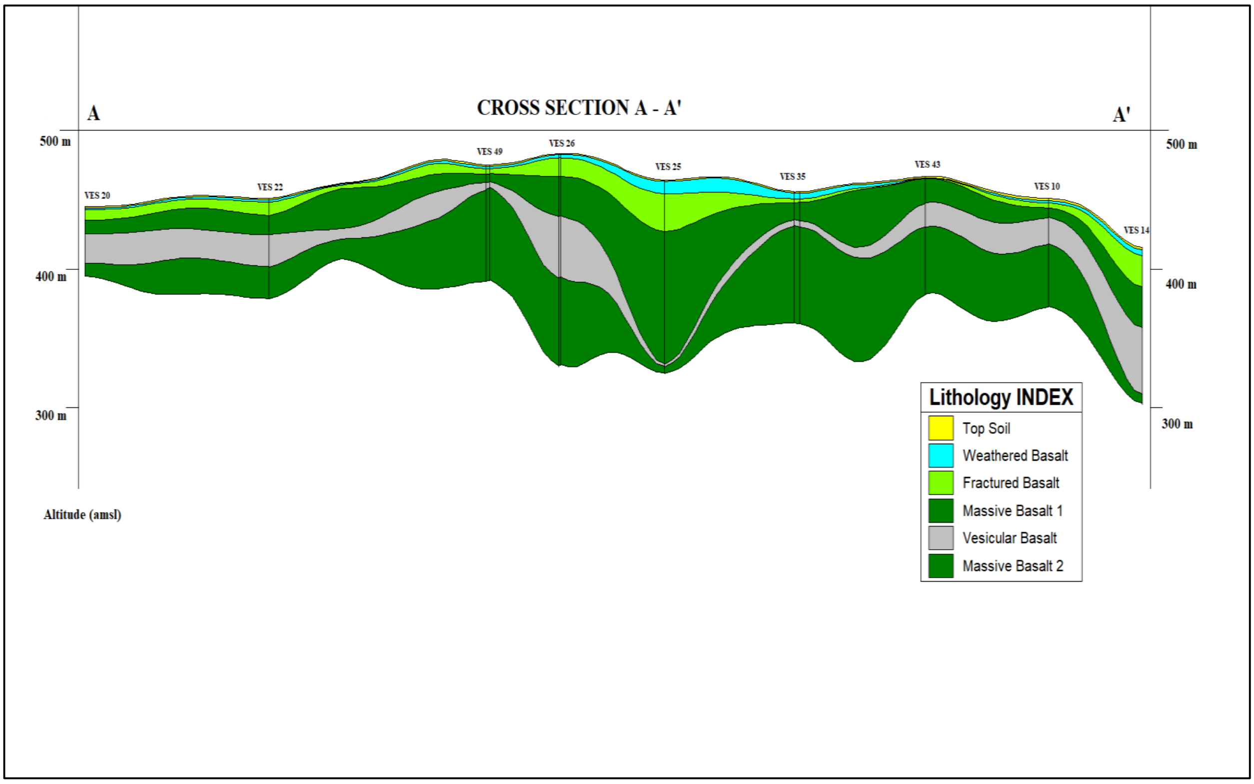
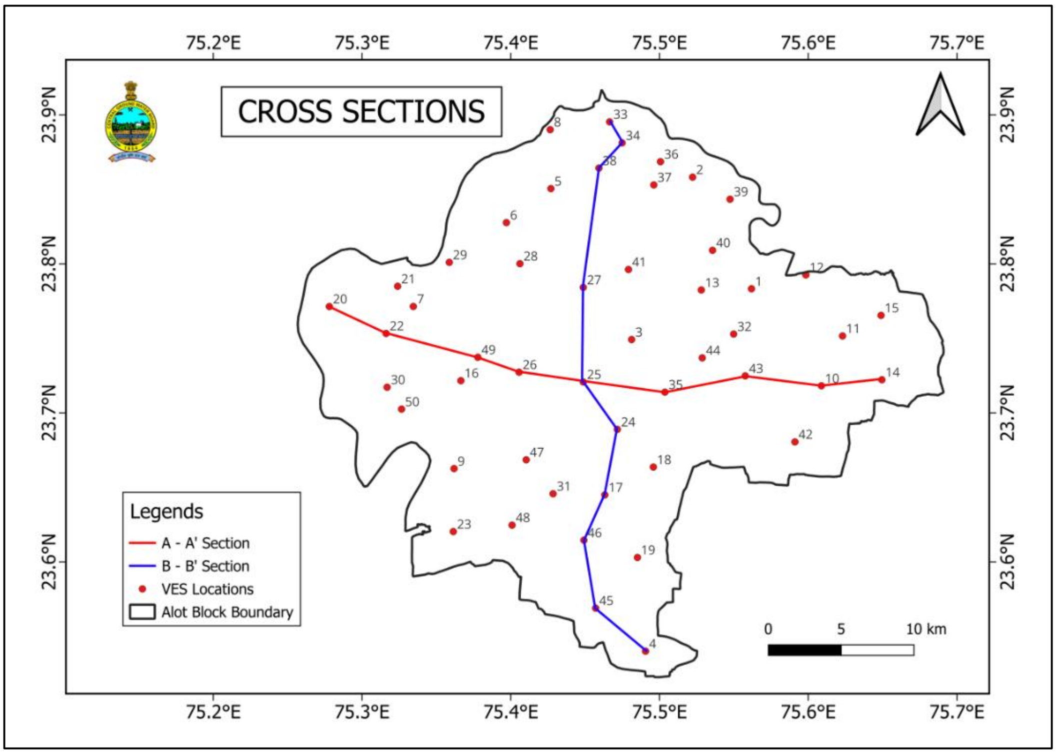


Fig. 3.13: Cross Section Along A-A'



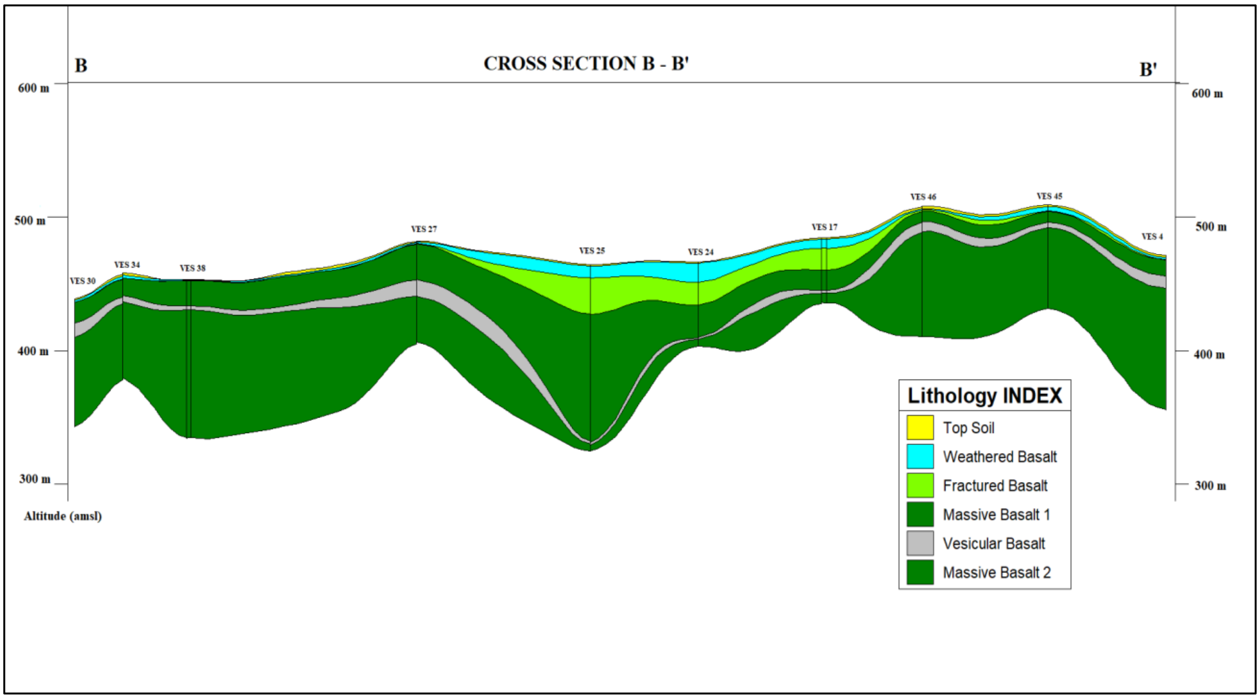


Fig. 3.14: Cross Section Along B-B'

Fence Diagram are prepared based on interpreted VES Results. The Fence Diagram are shown below (Fig. 3.15)

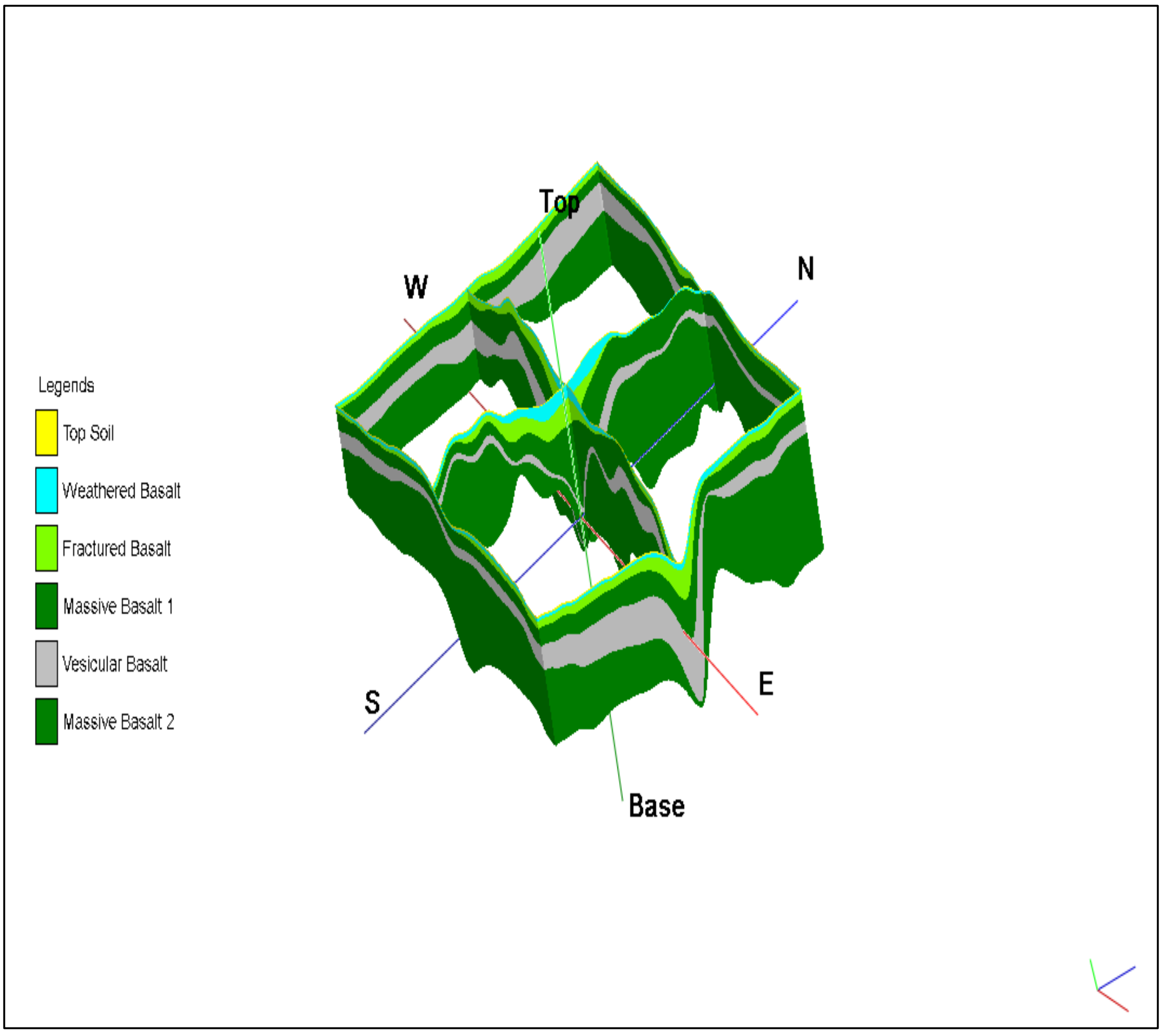


Fig. 3.15: Fence Diagram

An attempt was made to correlate the VES result with existing litho section in the study area. An Exploratory well was drilled in Pipaliya Maru Village of Alot Block. In that village one VES was also carried out. The interpreted VES result has been correlated with litholog and it was correlated with each other shown in Fig 3.16 and Table 3.1

Table 3.1: The correlation between VES and Exploratory data is shown below

From VES Data			From Exploration Data	
Resistivity (Ohm-m)	**Depth (mbgl)**	**Inferred Lithology**	**Depth (mbgl)**	**Lithology**
198	0.75	Top Soil		
49.6	12.4	Weathered Basalt		
60.2	9.04	Weathered Basalt	11.1	Weathered Basalt
328	38.6	Massive Basalt	35.5	Massive Basalt
54.3	47.8	Vesicular Basalt	50.8	Vesicular Basalt
656	88.4	Massive Basalt	81.3	Massive Basalt
22.9	114	Vesicular Basalt	117.9	Vesicular Basalt
401				

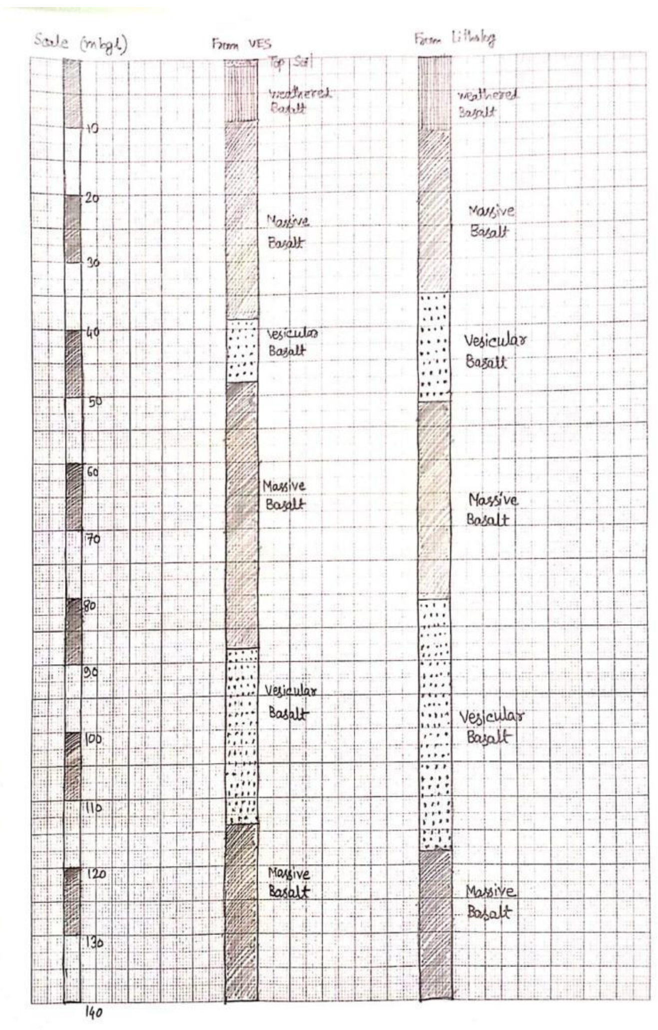


Fig. 3.16: Correlation between Exploratory well and VES data

CHAPTER 4

GROUND WATER REGIME

4.1 OBJECTIVES

The study aims to achieve the following objectives: determine water levels across various aquifers, including both shallow and deeper formations; evaluate seasonal fluctuations in groundwater levels; and analyse these variations to guide sustainable resource management. Through systematic monitoring and analysis, the study seeks to enhance understanding of recharge patterns, ensure effective utilization of water resources, and support the preservation and renewal of aquifers.

4.2 METHODOLOGY

To evaluate the depth to the water table in both shallow and deeper aquifers, data were systematically collected from 94 monitoring stations, which included predominantly dug wells and 71 bore wells. These wells were strategically positioned across the study area to ensure comprehensive representation of the principal aquifers (Fig 4.1). Measurements of groundwater levels were taken using a sounder during the pre-monsoon period in June and the post-monsoon periods in November and January of 2023. Concurrently, essential geographical information, such as latitude, longitude, and elevation, was recorded during field visits.

Data were organized in MS Excel, and ArcGIS 10.3.1 was utilized for processing and map creation. Inverse Distance Weighting (IDW) interpolation was applied to estimate groundwater levels at locations between monitoring points based on existing data. To assess seasonal variations in groundwater levels for 2023, changes between pre-monsoon and post-monsoon periods were calculated. The fluctuation data were analyzed and processed in MS Excel to evaluate groundwater level trends and variability.

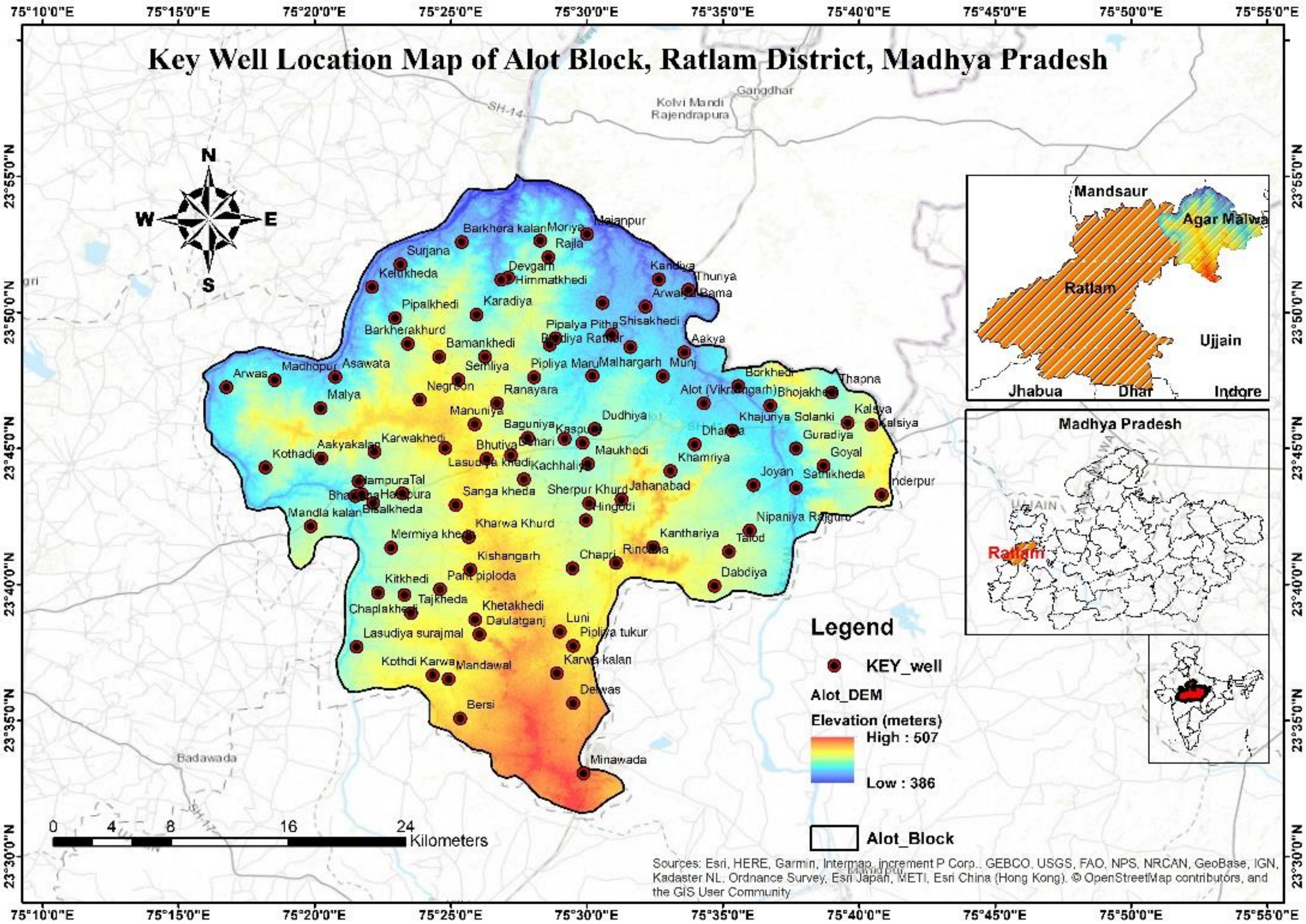


Fig. 4.1: Key well location map of Alot block, Ratlam district, Madhya Pradesh

4.3 RESULT AND DISCUSSION

Analysis based on data from seven recent exploration wells, six previously drilled wells, and a pre-monsoon inventory of 224 wells reveals two major aquifers providing significant water yields. The water levels within these aquifers have been categorized into three distinct zones:

- **Aquifer I:** Dug well zone, up to 30 meters below ground level (mbgl)
- **Aquifer II:** Main aquifer comprising Basalt
- **Aquifer III:** Main aquifer at the contact zone between Basalt and Vindhyan Sandstone

4.3.1 Pre-monsoon Depth to Water Level in Shallow Aquifers

During the pre-monsoon period, the depth to the water level in Aquifer I ranges from 4.55 mbgl at Kharwa Khurd to 26.2 mbgl at Kharwa Kalan. Most wells in the study area have water levels between 10 and 15 mbgl. The second most common depth range is 15 to 20 mbgl, with a few localized areas exhibiting water levels between 0 and 5 mbgl (Fig. 4.2 and Table 4.1).

4.3.2 Post-monsoon Depth to Water Level in Shallow Aquifers

Post-monsoon data indicates that the depth to the water level varies from 2.71 mbgl at Alot-Vikramgarh to 18.22 mbgl at Luni. The predominant water levels observed are between 5 and 10 mbgl. Other significant ranges include 0 to 5 mbgl and 10 to 15 mbgl, which are evenly distributed across the study area. Pockets with water levels greater than 15 mbgl are primarily found in the southeastern part of the region (Fig. 4.3 and Table 4.1).

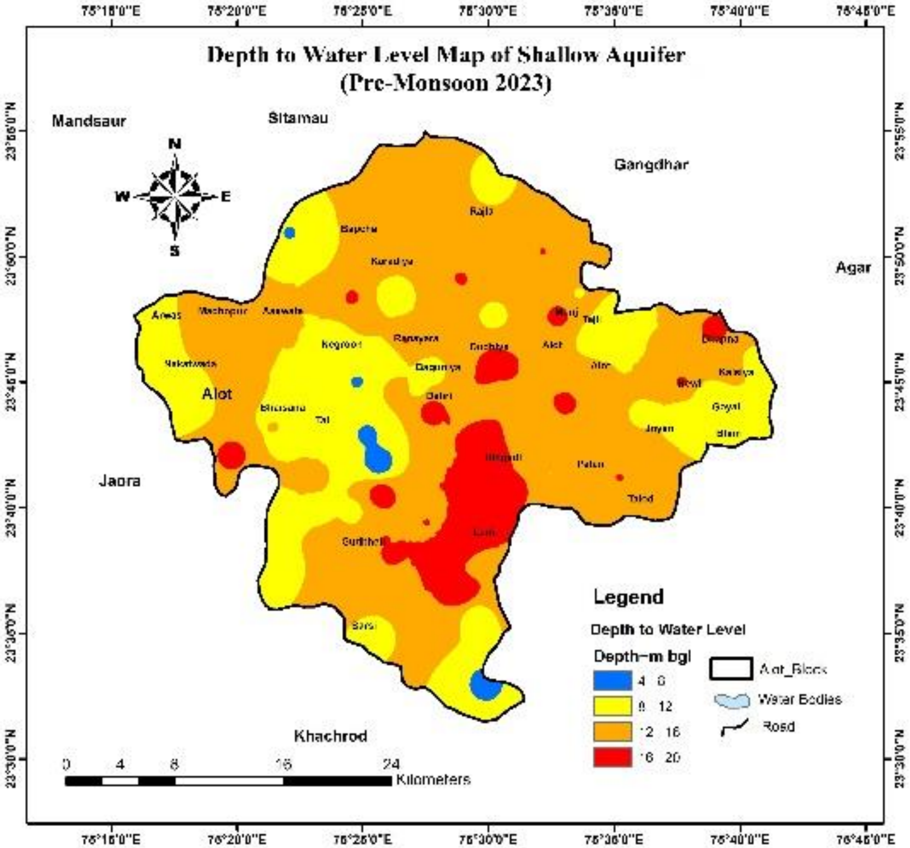


Fig. 4.2: Pre-monsoon Depth to water level

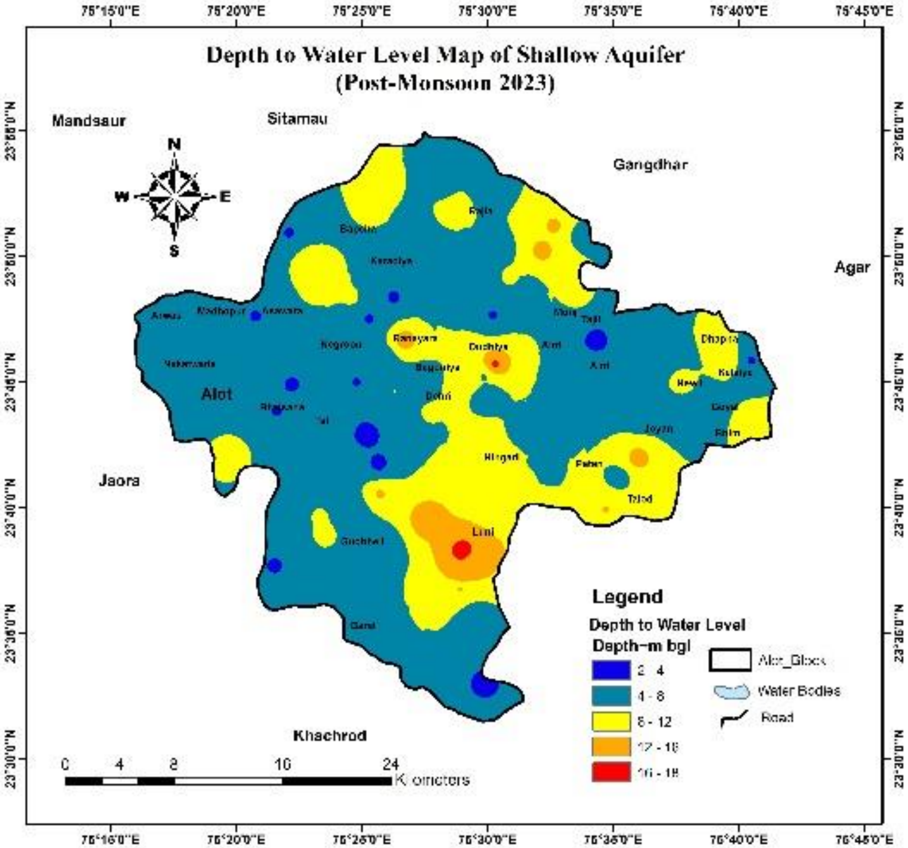


Fig.4.3: Post-monsoon Depth to water level

Table 4.1: Pre and Post monsoon Depth to water level

Pre-Monsoon WL (mbgl)	Percentage
0 - 5	1
5 - 10	23
10 - 15	43
15 - 20	32
>20	1

Post-Monsoon WL (mbgl)	Percentage
0 - 5	25
5 - 10	56
10 - 15	17
15 - 20	2

4.3.3 Post-monsoon depth to water level of deeper aquifer

Post-monsoon measurements for the deeper aquifer reveal a depth to water level ranging from 7.1 mbgl at Mundla Kalan to 167.25 mbgl at Karadiya. Predominantly, water levels are observed between 30 and 90 mbgl. In addition, levels between 90 and 300 mbgl are noted in subsequent areas, while the remaining regions show depths ranging from 0 to 30 mbgl (Fig.4.4, 4.5 and Table 4.2).

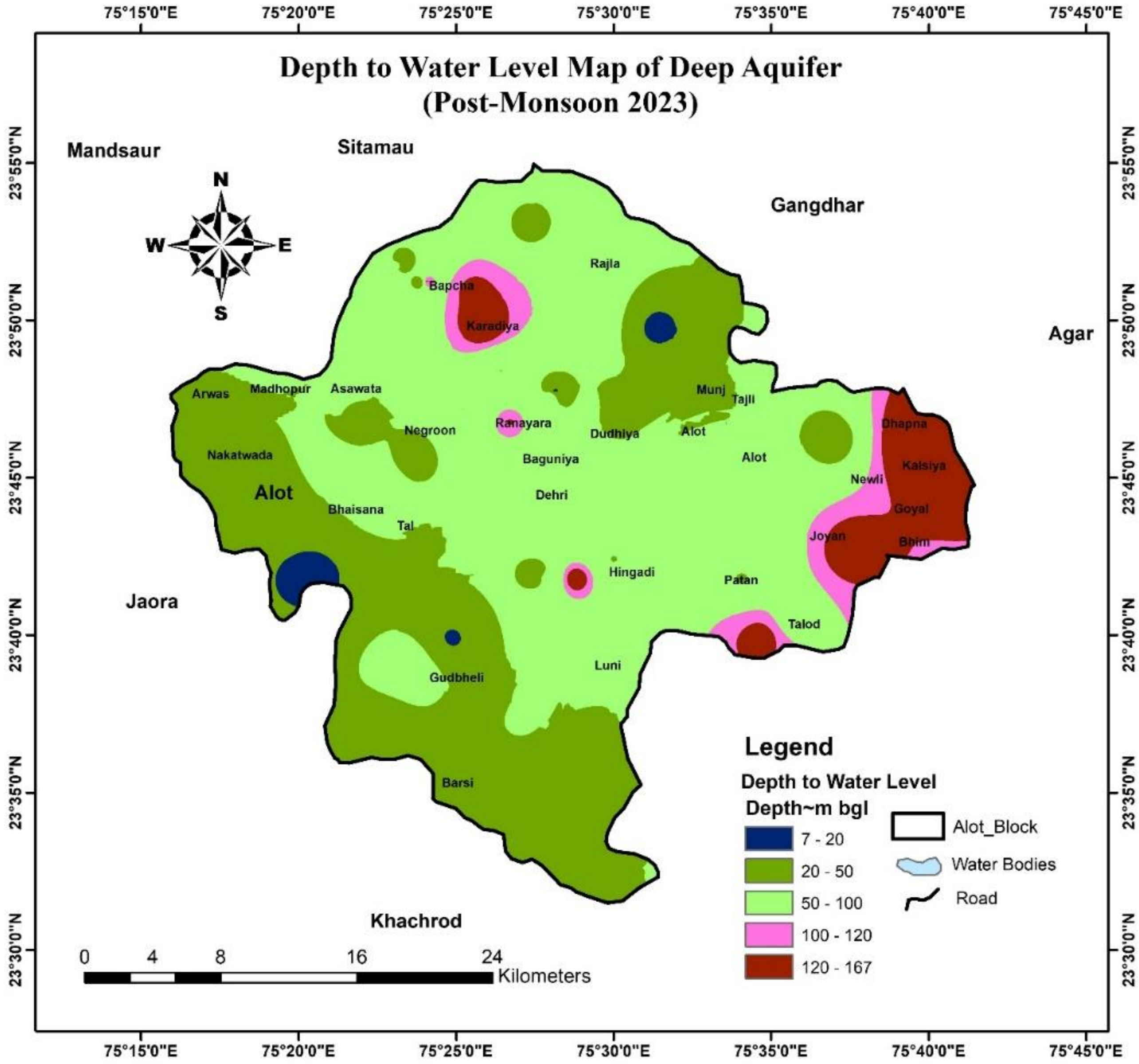
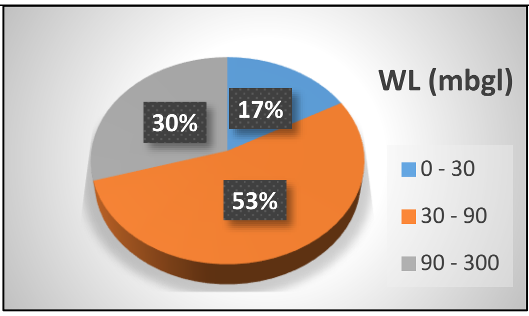


Fig. 4.4: Post-monsoon Depth to water level



Post Monsoon WL (mgbl)	Percentage
0-30	17
30-90	53
90-300	30

Fig. 4.5: Groundwater levels observed during monitoring of Key observation wells

Table 4.2: WL distribution in water stressed Alot block, Ratlam district

S NO.	MONTH	WL DISTRIBUTION (mbgl)			
		Shallow		Deep	
		MIN.	MAX.	MIN.	MAX.
1	MAY (PRE-MONSOON)	4.55	26.2	-	-
3	NOVEMBER (POST-MONSOON)	2.71	18.22	7.1	167.25

4.3.4 Seasonal Water Level Fluctuations in Shallow Aquifers

The assessment of seasonal water level fluctuations reveals notable variability across the study area. The most substantial fluctuation, measuring 11.48 meters, is recorded at Daulatganj, while the smallest fluctuation, at 0.27 meters, is observed at Inderpur. These fluctuations are classified into four categories: low, moderate, high, and very high. The analysis indicates that approximately 54% of the wells are situated in the high fluctuation zone, reflecting poor aquifer storage capacity. Conversely, 43% of the wells are in the low to moderate fluctuation zones, suggesting favourable aquifer storage conditions. Only 3% of the wells fall into the very high fluctuation zone, which signifies inadequate aquifer storage capacity. Water level fluctuation map of shallow aquifer was shown below in Fig. 4.6, 4.7 and Table 4.3 details has been attached in **Annexure IV.**

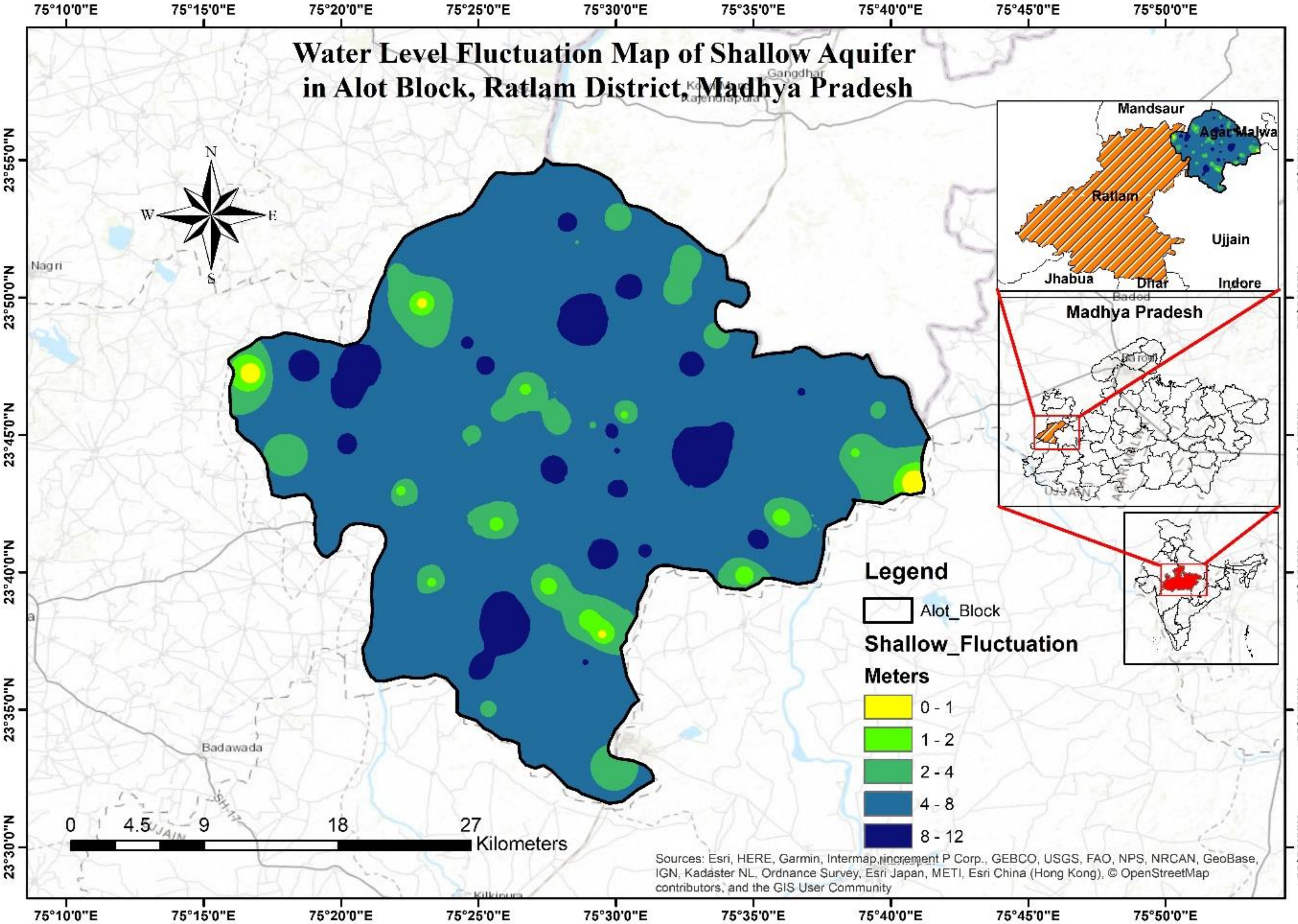


Fig. 4.6: Fluctuation map of shallow aquifer

Table 4.3: WL distribution in water stressed Alot block, Ratlam district

Category	Fluctuation	No of wells	Percentage of wells
Less water level fluctuation	0 - 2	13	14
Moderate water level fluctuation	2 - 5	27	29
High water level fluctuation	5 - 10	50	54
Very high water level fluctuation	>10	3	3

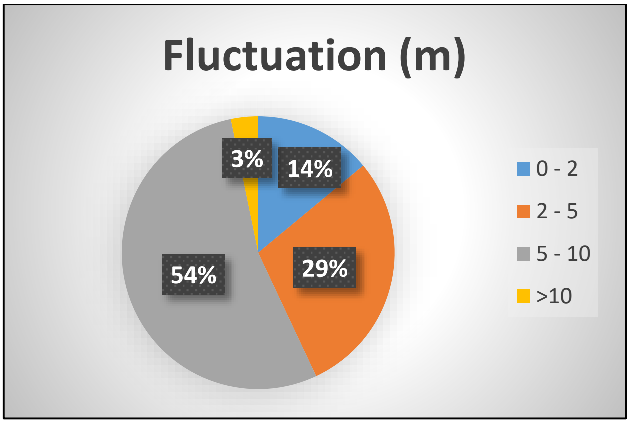


Fig. 4.7: Diagram showing Fluctuation (m) in shallow aquifer

4.3.5 Groundwater Flow Direction

A groundwater flow direction map was generated for the post-monsoon period shown in Fig.4.8 Throughout both the pre-monsoon and post-monsoon periods, groundwater flow is directed towards the Chambal and Kshipra Rivers, indicating that these rivers are receiving groundwater, or are in an effluent condition. In the study area groundwater movement is predominantly influenced by topography, which provides a detailed hydrogeological analysis of subsurface flow patterns. The hydraulic head, ranging from 277 to 460 meters above mean sea level, defines the hydraulic gradient that directs groundwater flow.

The general flow trends from regions of higher hydraulic head in the central and southern parts of the block towards lower elevations in the north and northeastern directions. This pattern demonstrates that the Kshipra and Chambal Rivers serve as primary regional discharge zones, capturing groundwater as it moves downgradient. Observed contour bends and localized high-head areas suggest potential structural controls or variations in subsurface permeability that may impact recharge and discharge dynamics. The interpretation of groundwater flow direction highlights the crucial role of these rivers in the regional groundwater system and identifies key areas for targeted groundwater management and recharge enhancement.

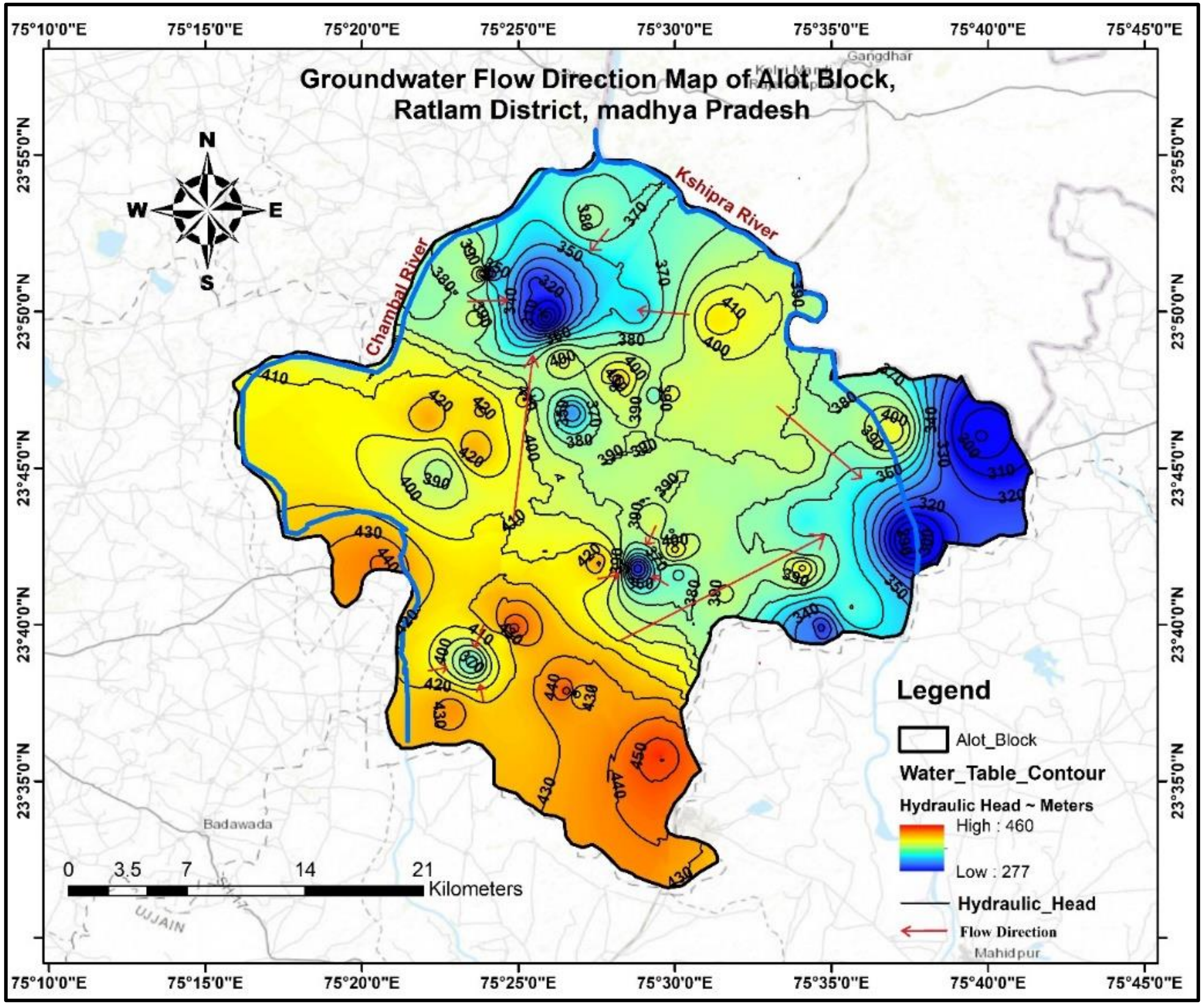


Fig. 4.8: Groundwater contour map of Phreatic Aquifer with flow direction of groundwater

CHAPTER 5

ASSESSMENT OF GROUNDWATER RESOURCES

5.1 OBJECTIVE

Estimating groundwater resources involves quantifying the availability, quality, and sustainability of aquifers, ensuring water security in regions dependent on groundwater for drinking and irrigation. Effective management of these resources mitigates risks of over-extraction and contamination, thereby supporting long-term environmental integrity and socio-economic stability.

5.2 METHODOLOGY

Ground water resource as in 2023 have been estimated following the guidelines mentioned in the GEC 2015 methodology using appropriate assumptions depending on data availability. The methodology recommends aquifer wise ground water resource assessment of both the Groundwater resources components, i.e., Replenishable ground water resources or Dynamic Ground Water Resources and In-storage Resources or Static Resources (Fig. 5.1). INDIA - GROUNDWATER RESOURCE ESTIMATION SYSTEM (IN-GRES) is a Software/Web-based Application developed by CGWB in collaboration with IIT-Hyderabad.

It will provide common and standardized platform for Ground Water Resource Estimation for the entire country and its pan- India operationalization (Central and State Governments). The system will take 'Data Input' through Excel as well as Forms, compute various ground water components (recharge, extraction etc.) and classify assessment units into appropriate categories (safe, semi-critical, critical and over-exploited). The Software uses GEC 2015 Methodology for estimation and calculation of Groundwater resources. It allows for unique and homogeneous representation of groundwater fluxes as well as categories for all the assessment units (AU) of the country. In this chapter we try to modify the variables by which we can assess the dynamic ground water resources based on data collected during field study, Exploration drilling, district authorities. (Source: Collected during NAQUIM 2.0 field study and data collected from Patwari and Sarpanch through SDM, Collectorate, District authorities)

URL of IN-GRES http://ingres.iith.ac.in

Ground Water Assessment has been done for Unconfined Aquifer

The stage of ground water extraction is defined by.

$$\text{Stage of GW Extraction} = \frac{\text{Existing Gross GW Extraction for all Uses}}{\text{Annual Extractable GW Resources}} * 100$$

The existing gross ground water extraction for all uses refers to the total of existing gross ground water extraction for irrigation, drinking/domestic, industrial and all other purposes.

5.3 CATEGORIZATION OF ASSESSMENT UNIT

The categorization based on status of ground water quantity is defined by Stage of Ground Water Extraction as given below (Table 5.1 to 5.7):

Table 5.1: Categorization of Assessment Unit

S. NO.	STAGE OF GROUND WATER EXTRACTION	CATEGORY
1.	≤ 70%	Safe
2.	> 70% and ≤90%	Semi-critical
3.	> 90% and ≤100%	Critical
4.	> 100%	Over Exploited

Normal Annual Rainfall of A lot block: 886.8 mm (Monsoon), 66.7 mm (Non-monsoon)

Table 5.2: Area Details of Alot block, Ratlam district (GWRE 2023)

Total Geographical Area (ha)				
Recharge Worthy Area (ha)			Hilly Area(ha)	Total
Command Area	Non Command Area	Total		
0	94500	94500	0	94500

Table 5.3: Ground Water Recharge Scenario of Alot block, Ratlam district

Recharge from Rainfall – Monsoon Season (Ham)	12135.84
Recharge from Other Sources – Monsoon Season (Ham)	1064.33
Recharge from Rainfall-Non Monsoon Season (Ham)	0
Recharge from Other Sources- Non Monsoon Season (Ham)	3684.08
Total Annual Ground Water Recharge (Ham)	16884.25
Total Natural Discharges (Ham)	1688.43
Annual Extractable Ground Water Resource (Ham)	15195.82

Table 5.4: Recharge from Other Sources in Alot block, Ratlam district

Recharge from Canals (in Ham)	0
Recharge from Surface Water Irrigation (in Ham)	0
Recharge from Ground Water Irrigation (in Ham)	4361.21
Recharge due to Tanks and Ponds (in Ham)	41.06
Recharge due to Water Conservation Structures (in Ham)	346.12
Recharge due to Pipelines (in Ham)	0
Total Recharge from Other Sources (in Ham)	4748.40

Table 5.5: Normal Annual Rainfall (mm) Alot block, Ratlam district

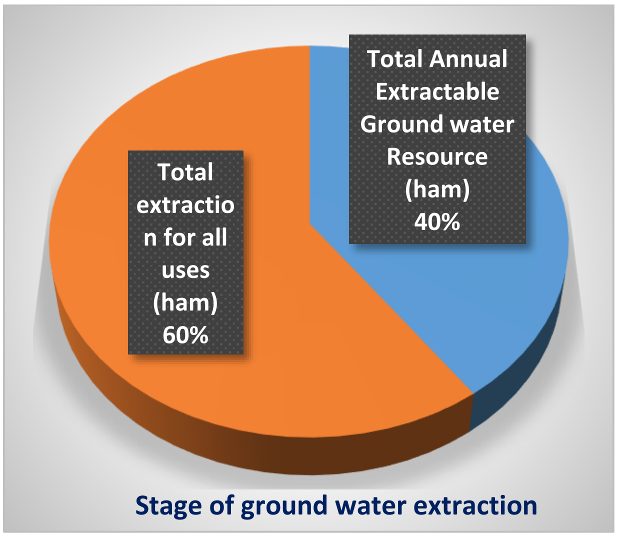
Normal Annual Rainfall (mm)	**886.8 mm (Monsoon), 66.7 mm (Non-monsoon)**
Average Pre-monsoon Water level (mbgl) Range	4.55 – 20.2
Average Post-monsoon Water Level (mbgl) Range	2.71 – 18.2
Average Fluctuation (m) Range	0.27 – 11.48
Number for Irrigation structure	
DW with electric /diesel pump	15500
Bore well	17800

Table 5.6: Ground Water Extraction Scenario Alot block, Ratlam district

Ground Water Extraction for Irrigation Use (Ham)	17432.72
Ground Water Extraction for Industrial Use (Ham)	2.59
Ground Water Extraction for Domestic Use (Ham)	591.58
Total Extraction (Ham)	18699.48
Total Annual Extractable Ground water Resource (ham)	12031.20
Stage of Ground Water Extraction (%)	155.42
Categorization	Over exploited

Table 5.7: Change in Dynamic Groundwater Resources in Year 2020, 2022 and 2023

Year	Annual Extractable Ground-water Resources (mcm)	Total Extraction (Ham)	Stage of Groundwater Extraction (%)
2020	151.09	180.91	7119.74 %
2022	151.46	181.24	119.66 %
2023	120.31	181.42	155.42 %



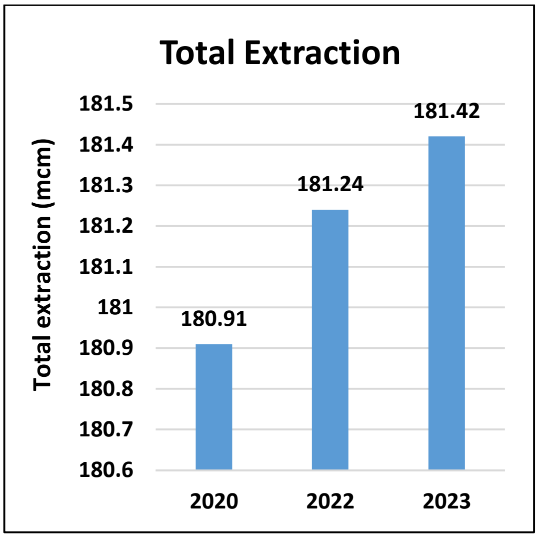


Fig. 5.1: Change in Dynamic Groundwater Resources 2023 and Extraction in Year 2020, 2022 and 2023

5.4 RESULTS AND DISCUSSION

The Study area of Alot Block is underlain by Deccan Trap Basalt. Dynamic ground water resources of the block have been estimated on basis of block wise. Out of 945 sq. km of geographical area, 945 sq. km (100%) is ground water recharge worthy area. The entire block falls under non-command area. The block is categorized as Over-exploited. The highest stage of ground water development is computed as 155.42 %. Total Annual Extractable Ground water Resource (ham) in the study area is 12031.20 Ham and Total extraction for all uses is 18699.48 Ham, making Stage of Ground Water Extraction to 155.42 % as a whole for study area.

CHAPTER 6

WATER QUALITY OF ALOT BLOCK

6.1 OBJECTIVE

The primary objectives of this chapter are to assess the quality of groundwater in both shallow and deep aquifers within the study area. The goals are to gain a comprehensive understanding of the groundwater quality and to identify potential contamination sources, including geogenic, anthropogenic and industrial activities.

6.2 METHODOLOGY

Water samples were systematically collected as per 1:10,000 scale from various sources within the study area. A total of 355 water samples were collected from dug wells, hand pumps, bore wells, rivers, tube wells tapping different depths and covering different parts of the Alot block during both pre-monsoon (226Nos.) and post-monsoon (129 Nos.) seasons representing mainly shallow and deeper aquifer. 7 locations from exploratory wells/boreholes representing the deep aquifer and 2 from surface water sources during pre and post monsoon. Information regarding exploratory wells and key wells established can be found in **Annexure I and Annexure III** and the spatial distribution is illustrated in **Fig. 6.1**. Samples were collected using clean double stopper polyethylene bottles. The samples were then analysed for a comprehensive range of water quality parameters, including temperature, pH, electrical conductivity (EC), total hardness, major ions (calcium, magnesium, sodium, potassium), alkalinity (carbonate, bicarbonate), and various contaminants such as chloride, fluoride, nitrate, sulfate, phosphate, silica, as well as trace/heavy metals (copper, iron, zinc, arsenic, chromium, manganese, lead, uranium). Additionally, Detailed analytical results for these parameters of pre monsoon are provided in **Annexure V and Annexure XV**

The analysis of the water samples was conducted using various standard methods as outlined in the 23rd edition of the American Public Health Association (APHA) manual. Specifically, measurements were performed using a microprocessor-based pH meter, electrical conductivity meter, UV-VIS spectrophotometer (Shimadzu, UV-1201), and flame photometer (Systronics 128). Analytical grade (AR) reagents were utilized for these analyses. Additionally, the heavy/trace elements were analysed using a Thermo iCAP RQ 01459 inductively coupled plasma mass spectrometer (ICP-MS), which was calibrated to the trace elements standard of Certified Reference Material (CRM) in the Regional Chemical Laboratory of Central Groundwater Board, Northern Region, Lucknow.

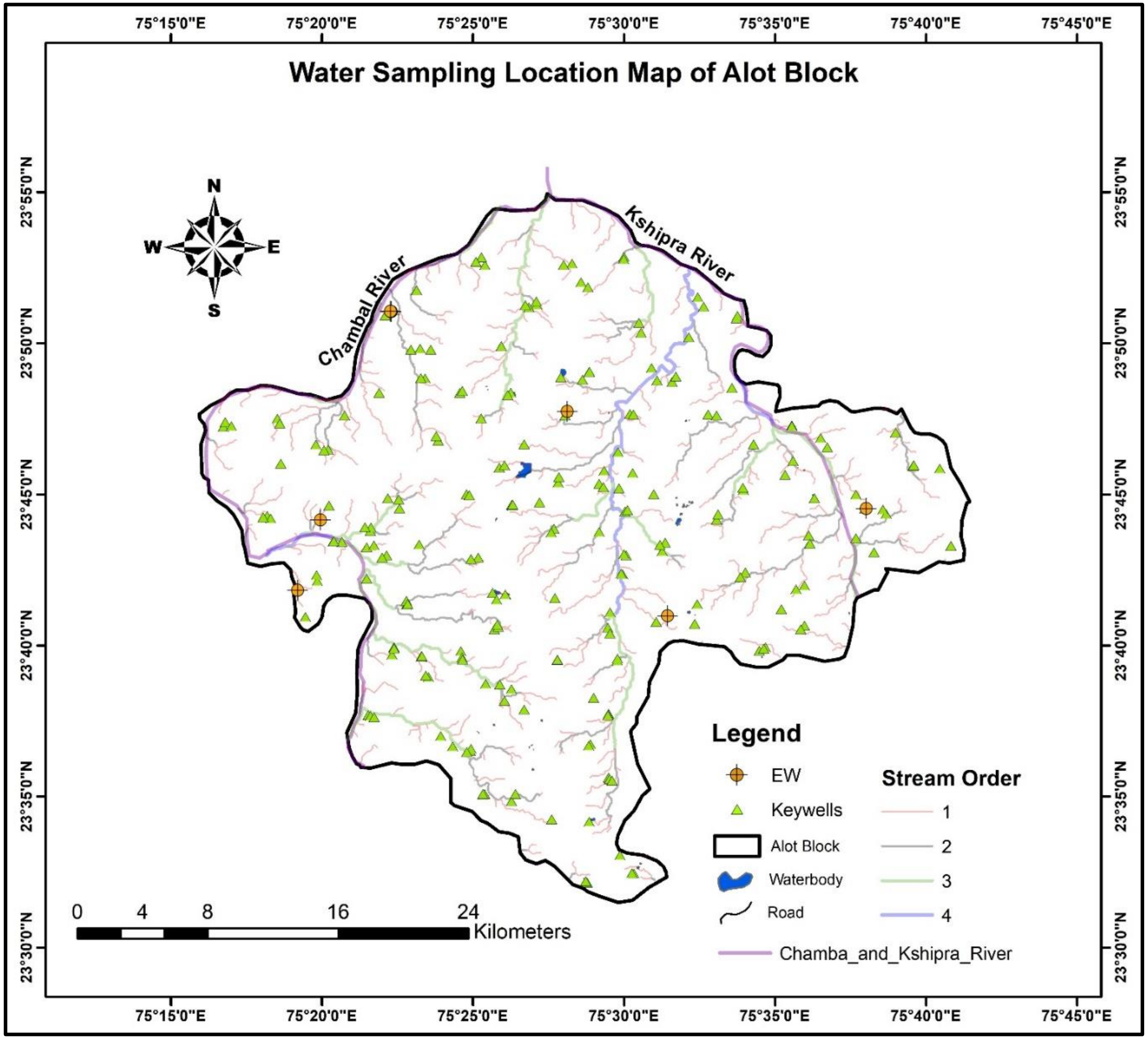


Fig. 6.1: Water Sampling Location Map

6.3 RESULT AND DISCUSSION

6.3.1 Groundwater Quality

6.3.1.1 Temperature

Cool water is generally more palatable than warm water. High water temperature enhances the growth of microorganisms and may increase taste, odour, colour and corrosion problems. In the study area, the water temperature carried out during the sampling and observed in between 24.4 to 32.2°C & 24.7 to 38.4°C in pre-monsoon while in post-monsoon 22.5 to 27.9°C & 22.5 to 28.2°C in Shallow and deeper aquifer respectively. The maximum temperature observed at dug well Asawata (32.2°C) & bore well Karwakhedi (38.4°C) in pre-monsoon and in post-monsoon at dug well and hand pump of Kachaliya (28.4°C) & bore well Bisal Kheda (28.2°C) in shallow and deeper aquifer.

6.3.1.2 Hydrogen Ion Concentration (pH)

The pH is a measure of the intensity of acidity or alkalinity and measures the concentration of hydrogen ions in water. Pure water is neutral, but when minerals/chemicals are mixed with water, the mixture can become either acidic or basic. The High pH value may cause a bitter taste for human consumption and it may lead to encrustation to water pipes and water-using appliance. It is observed that the pre monsoon pH value of all samples ranged between 6.74 to 8.10 with an average of 7.24 and 7.14 to 7.99 with an average of 7.54 in shallow aquifer& Deeper aquifer; whereas for post monsoon season it was ranged in between 6.80 to 8.24 with an average of 7.38 and 6.91 to 8.10 with an average of 7.51 in shallow aquifer & Deeper aquifer. It is significant to mentioned that none location showed delineation of the maximum permissible limit for pH) 8.5 (described BIS (IS 10500:2012) recommendation). The ground water of the study area can be assessed as slightly acidic and neutral to slightly alkaline.

6.3.1.3 Electrical Conductivity (EC)

The estimates the amount of total dissolved salts (TDS) or determines the levels of ions (salinity) in water; but not specifically what the ions are. Salt content is an important factor in water use. The high salinity in groundwater imparts bad taste for drinking purpose as well as increases the cost of water treatment.

The temporal distributions in Pre-Monsoon (PRM) and Post-Monsoon (POM) samples are presented in Table 6.1. it was observed that the during pre-monsoon, EC ranged from 595 to 5025 (Avg 1730) μS/cm/cm at 25°C and 647 to 4311 (Avg 1746) μS/cm at 25°C whereas from

550 to 7391 (Avg 1940) µS/cm at 25°C and 540 to 3862 (Avg 2052) µS/cm at 25°C during post-monsoon in shallow & deeper aquifer respectively.

In general, the ground water quality in pre-monsoon & post-monsoon season in shallow and deeper aquifer of the Alot block is fresh in about 6.0% & 3.4% and 3.5% & 4.4% of the ground water monitoring wells as indicated by the EC value less than 750 µs/cm at 25°C. In about 74.4 % and 78.8% of samples of shallow aquifer and 72.7% and 64.4% samples of deeper aquifer in pre-monsoon and post-monsoon season, the EC varies between 751 -2250 µs/cm at 25°C and 13.5% & 15.3% and 14.8% & 24.4% of samples of shallow and deeper aquifer during pre-post monsoon season are between 2251-3000 µs/cm at 25oC indicating that the ground water is slightly mineralized and about 8.3% & 5.9% and 12.5% & 13.3% of ground water samples in monitoring wells the EC is more than 3000 µs/cm at 25oC respectively in shallow and deeper aquifer during both season indicating that the ground water is highly mineralized. The highest value observed in the dug well Hampura (4843 µS/cm at 25°C) & hand pump Madhopur (5025 µS/cm at 25°C) in shallow aquifer during pre-monsoon and highest value observed in dug well Hampura (4311 µS/cm at 25°C) in shallow aquifer during post-monsoon season . The highest value observed in the deeper aquifer at bore wells Surjana (7391 µS/cm at 25°C) and Bisal Kheda (3862 µS/cm at 25°C) during pre & post-monsoon season respectively. Electrical conductivity shows that the ground water of water stress Alot block is moderately to high saline in nature in dug well zone. The spatial distribution of electrical conductivity of shallow aquifer during pre and post monsoon 2023 is shown in **Fig.6.2 and Fig.6.3** respectively. and the frequency distribution is given in **Table 6.1**.

Table 6.1: Frequency distribution of Shallow and Deeper aquifer

EC	Shallow Aquifer		Deeper Aquifer	
	Pre Monsoon	Post Monsoon	Pre Monsoon	Post Monsoon
No. of Samples	133	85	88	42
Min.	595	647	550	540
Max.	5025	4311	7391	3862
Mean	1746	1763	1985	2058
< 750	6.0	3.5	3.4	4.4
750- 2250	74.4	78.8	72.7	64.4
2250-3000	13.5	15.3	14.8	24.4
> 3000	8.3	5.9	12.5	13.3

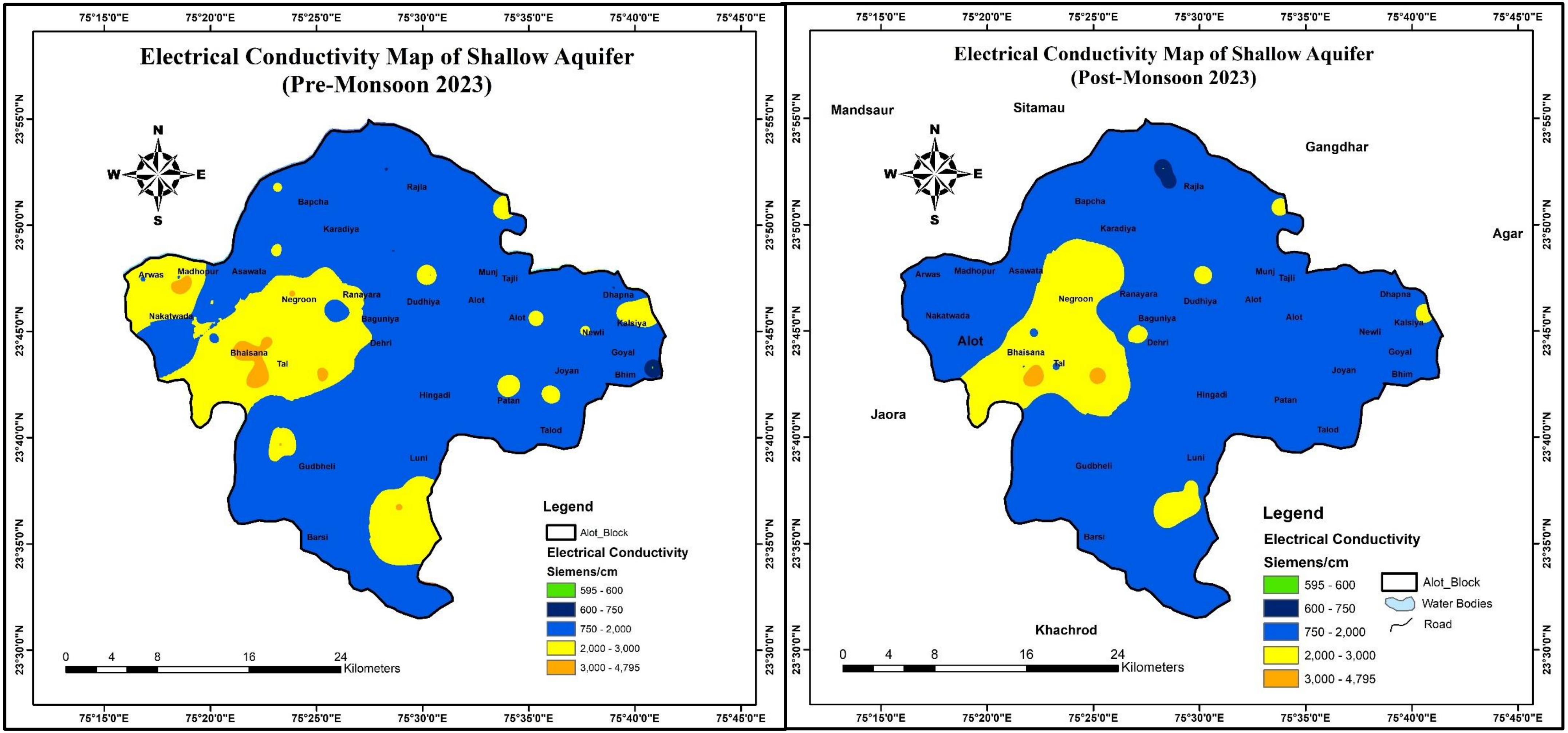


Fig. 6.2: Spatial distribution of electrical conductivity of shallow aquifer (Pre and Post-Monsoon, 2023)

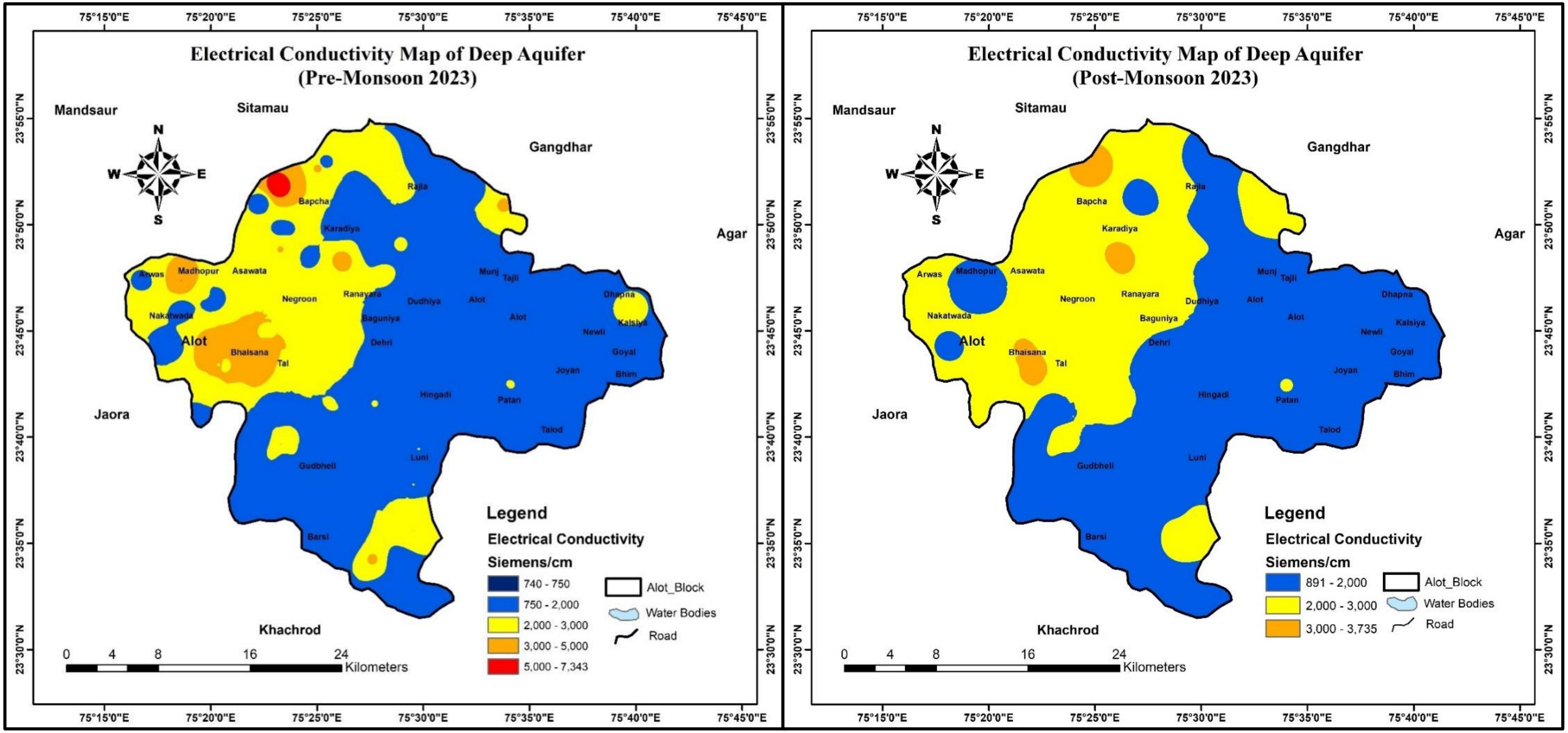


Fig. 6.3: Spatial distribution of electrical conductivity of deep aquifer (Pre and Post-Monsoon, 2023)

6.3.1.4 Chloride

Chloride is present in all-natural waters, mostly at low concentrations. It is highly soluble in water and moves freely with water through soil and rock. In ground water the chloride content is mostly below 250 mg/l except in cases where inland salinity is prevalent and in coastal areas. The main source of chloride is sedimentary rock. The excess concentration of chloride is corrosive to metals. The appreciable increase of chloride concentration in groundwater is the result of lateral movement, maybe away from the source-point.

The temporal distributions in Pre-Monsoon (PRM) and Post-Monsoon (POM) samples are presented in Table 6.2. It was observed that during pre-monsoon, Chloride ranged from 32 to 1395 (Avg 255) mg/l & 37 to 2187 (Avg 347) mg/l whereas from 62 to 960 (Avg 276) mg/l & 57 to 887 (Avg 349) mg/l during post-monsoon for shallow and deeper aquifer respectively. The Pre-monsoon and Post-monsoon distribution of chloride concentrations in the examined groundwater samples and the results suggested that the shallow aquifer of the study area is pointy affected by chloride pollution since 89 out of 133 examined point (69.9%) & 46 out of 85 examined point (54.1%) had chloride less than BIS desirable limit (250 mg/l) and for deeper aquifer. Pre and Post monsoon data shows 43 out of 88 examined point (48.9%) & 17 out of 45 examined point (37.8%) had chloride less than BIS desirable limit (250 mg/l) but in shallow aquifer 44 out of 133 examined point (30.8%) and 39 out of 85 examined point (45.9%) and for deeper aquifer 45 out of 88 examined point (47.7%) and 28 out of 45 examined point (62.2%) less than BIS permissible limit (1000 mg/l) in both seasons. The highest value observed in the hand pump Madhopur (1395mg/l) & bore well Surjana (2187mg/l) in pre-monsoon respectively for shallow and deeper aquifer. On the other hand locations reported lessened chloride concentrations in groundwater due to the dilution process during the post-monsoon season. The frequency distribution is given in Table 6.2.

Table 6.2: Frequency distribution (in %) of chloride concentration (mg/l)

Chloride	Shallow Aquifer		Deeper Aquifer	
	Pre Monsoon	Post Monsoon	Pre Monsoon	Post Monsoon
No. of Samples	133	85	88	45
Min.	32	62	37	57
Max.	1395	960	2187	887
Mean	255	276	347	349
<250	66.9	54.1	48.9	37.8
250-1000	30.8	45.9	47.7	62.2
>1000	2.3	0.0	3.4	0.0

6.3.1.5 Fluoride

The fluoride content in groundwater has been reported in many places in different states in India. Fluorine is a fairly common element but it does not occur in the elemental state in nature because of its high reactivity. Fluorine is the most electronegative and reactive of all elements that occur naturally within many types of rock. It exists in the form of fluorides in a number of minerals of which fluorspar, cryolite, fluorite and fluorapatite are the most common. Fluorite (CaF_2) is a common fluoride mineral.

Most of the fluoride found in groundwater is naturally occurring from the breakdown of rocks and soils or weathering and deposition of atmospheric particles. Most of the fluorides are sparingly soluble and are present in ground water in small amounts Fluoride is best known for its use in small quantities to help reduce dental caries (cavity) frequency in teeth. The excessive intake of fluorine compounds over an extended period may cause yellowing of teeth, hypothyroidism, or brattling of bones and teeth (Fluorosis). BIS has recommended an upper desirable limit of 1.0 mg/l of F^- as desirable concentration of fluoride in drinking water, which can be extended to 1.5 mg/l of F in case no alternative source of water is available. Water having fluoride concentration of more than 1.5 mg/l are not suitable for drinking purposes.

Pre and post-monsoon data of fluoride concentration in ground water reveals that in shallow aquifer fluoride ranges between 0.09 to 1.49 mg/l & 0.13 to 1.25 mg/l and for deeper aquifer it is found between 0.11 to 1.60 mg/l and 0.21 to 1.39 mg/l during both season.

The fluoride content in groundwater of shallow and deeper aquifer in major part of the Alot block is found to be less than 1.0 mg/l during both seasons. The data pertained to deeper aquifer in pre-monsoon' F-concentration revealed that 4 (4.5%) locations had the fluoride concentration beyond BIS permissible limit (1.5 mg/l).The differentiated distribution of fluoride in the study area could be plausible due to the control of typical hydrogeological conditions of the study area and water-rock interaction span (i.e., residence time) The differentiated distribution of fluoride in the study area could be plausible due to the control of typical hydrogeological conditions of the study area and water-rock interaction span (i.e., residence time).

The maximum of fluoride concentration has been observed in the deeper aquifer at Baguniya (1.60 mg/l) in pre-monsoon and all the samples collected from shallow and deeper aquifer during pre and post-monsoon season found within the permissible limit of 1.5 mg/l as per BIS (IS 10500:2012). The frequency distribution is given in Table 6.3**.**

Table 6.3: Frequency distribution (in %) of fluoride concentration (mg/l)

Fluoride	Shallow Aquifer		Deeper Aquifer	
	Pre Monsoon	Post Monsoon	Pre Monsoon	Post Monsoon
No. of Samples	133	85	88	45
Min.	0.09	0.13	0.11	0.21
Max.	1.49	1.25	1.6	1.39
Mean	0.54	0.51	0.75	0.61
<1.0	87.2	96.5	69.3	91.1
1-1.5	12.8	3.5	26.1	8.9
>1.5	0.0	0.0	4.5	0.0

6.3.1.6 Nitrate

Nitrate is one of the major indicators of anthropogenic sources of pollution. The negative charge and high mobility favours its persistence in nature and transport along the ground water flow path. There are three major sources of Nitrate (NO_3^-) in groundwater -biological fixation, precipitation, dry deposition, and the application of fertilizers (Bermer & Bermer, 1987). Nitrate salts are highly soluble in groundwater whose presence is tied to nature's nitrogen cycle. The primary sources of nitrate introduction in groundwater come from the decomposition of animal and plant waste, septic systems, or agricultural field run-off from fields fertilized with ammonia. The BIS has set a desirable recommended limit of nitrate as 45 mg/l with no additional relaxation.

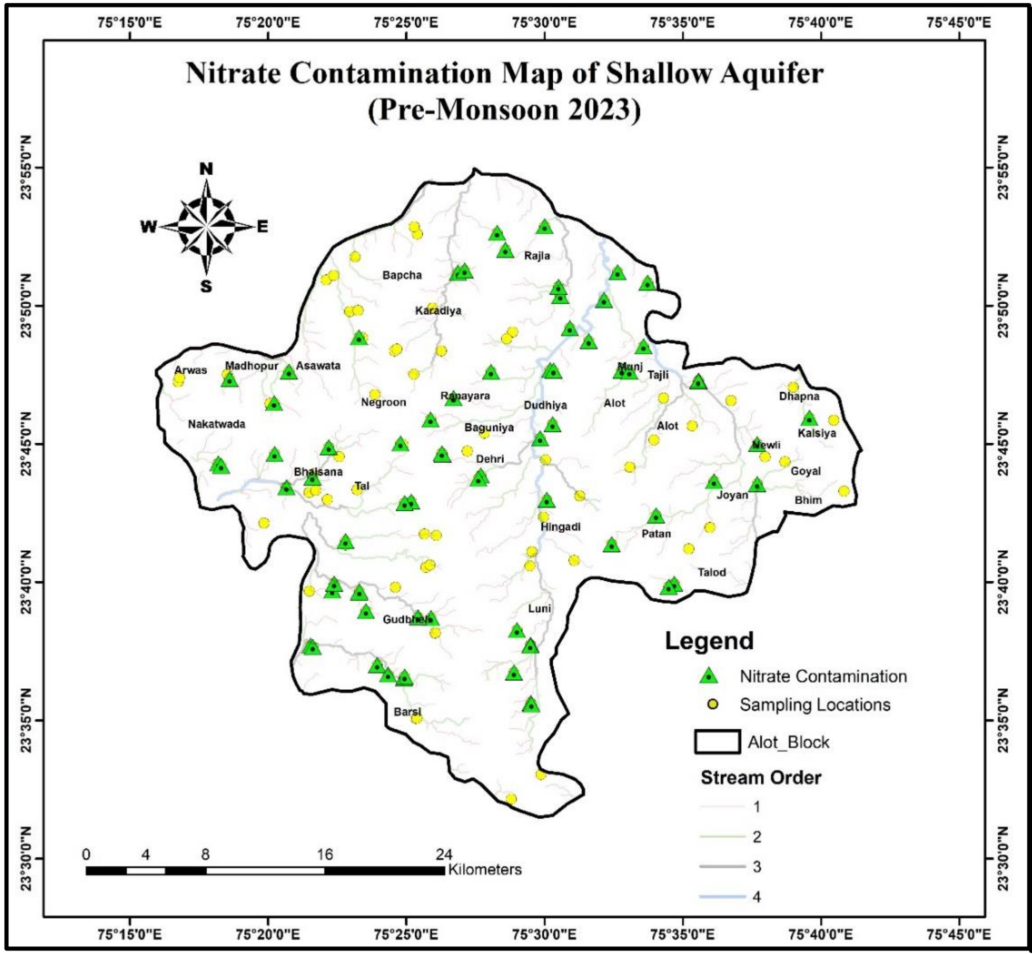
It was observed that in shallow aquifer of the study area during pre-monsoon, Nitrate ranged from 5 to 201 (Avg 51) mg/l whereas from 25 to 155 (Avg 68) mg/l during post-monsoon and for deeper aquifer Nitrate ranged from 3 to 117 (Avg 36) mg/l whereas from 8 to 92 (Avg 41) in both seasons. Out of 133 locations, 63 (47%) & out of 85 locations, 14 (16.4%) for Shallow aquifer and out of 88 locations, 66 (75%) and out of 45 locations, 29 (64%) locations of deeper aquifer had nitrate level within the BIS allowable limit (45 mg/l) respectively in pre and post-monsoon seasons. On the contrary, 70 (53%) & 22 (25%) and 71 (84%) & 16 (36.0%) locations in shallow and deeper aquifer respectively in both seasons exhibited an exceeded NO3- concentrations over BIS limit.

Highest concentration of nitrate is reported in the water sample collected from shallow aquifer of hand pump Patan village (201 mg/l) monsoon & (155 mg/l) in pre and post monsoon and for deeper aquifer at bore well Thuriya village (117 mg/l) & (92 mg/l) in pre and post-monsoon.

Further, Human anthropogenic activities are the main causative agents in the increase of nutrients like nitrate, phosphates, chlorides, and calcium and ultimately lead to eutrophication (Shekhar et al., 2008). The point value maps of nitrate contamination for pre and post monsoon-2023 of shallow and deep aquifer are given in Fig. 6.4, and Fig. 6.5**,** Nitrate concentration of shallow and deep aquifer of pre monsoon is tabulated in Table 6.4 & **Annexure V**

Table 6.4: Frequency distribution (in %) of Nitrate concentration (mg/l)

Nitrate	**Shallow Aquifer**		**Deeper Aquifer**	
	Pre Monsoon	**Post Monsoon**	**Pre Monsoon**	**Post Monsoon**
No. of Samples	133	85	88	45
Min.	5	25	3	8
Max.	201	155	117	92
Mean	51	68	36	41
<45	47	16	75	64
>45	53	84	25	36



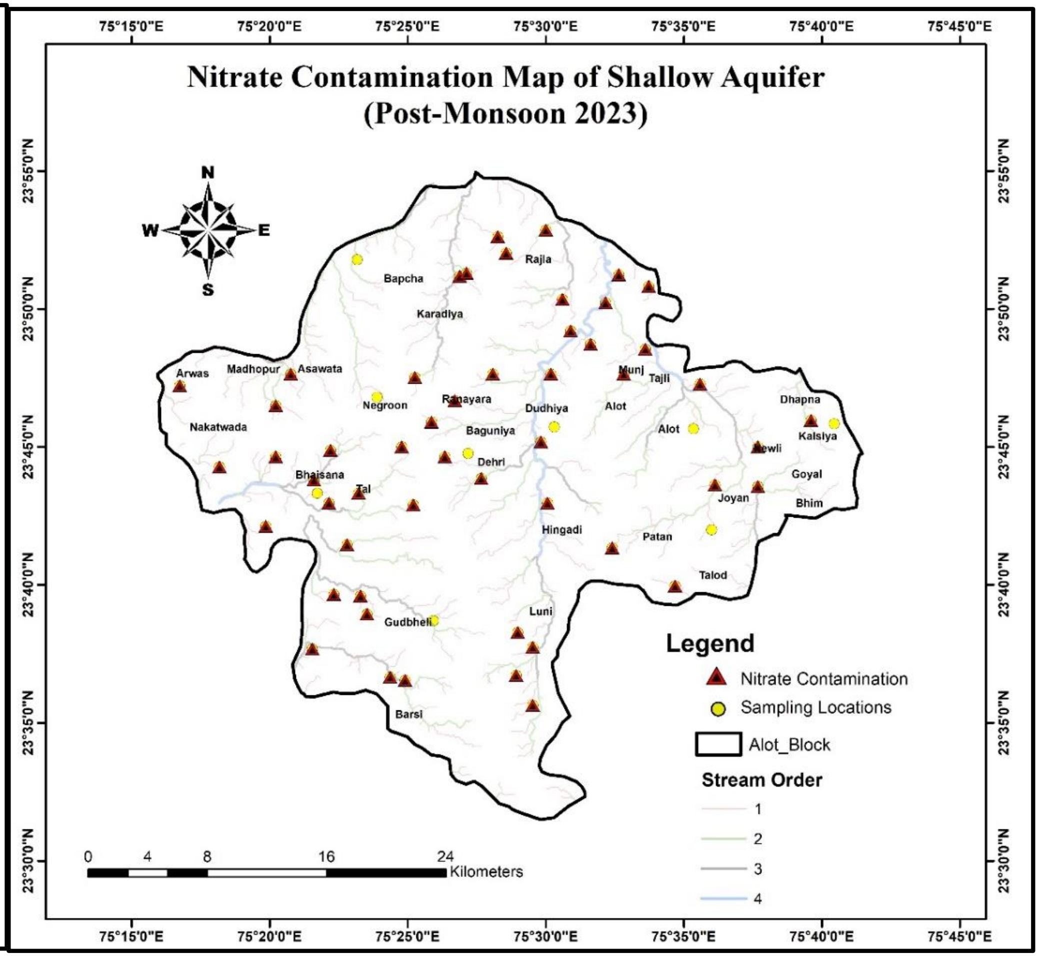


Fig. 6.4: Nitrate Contamination map of shallow aquifer (Pre and Post-Monsoon, 2023)

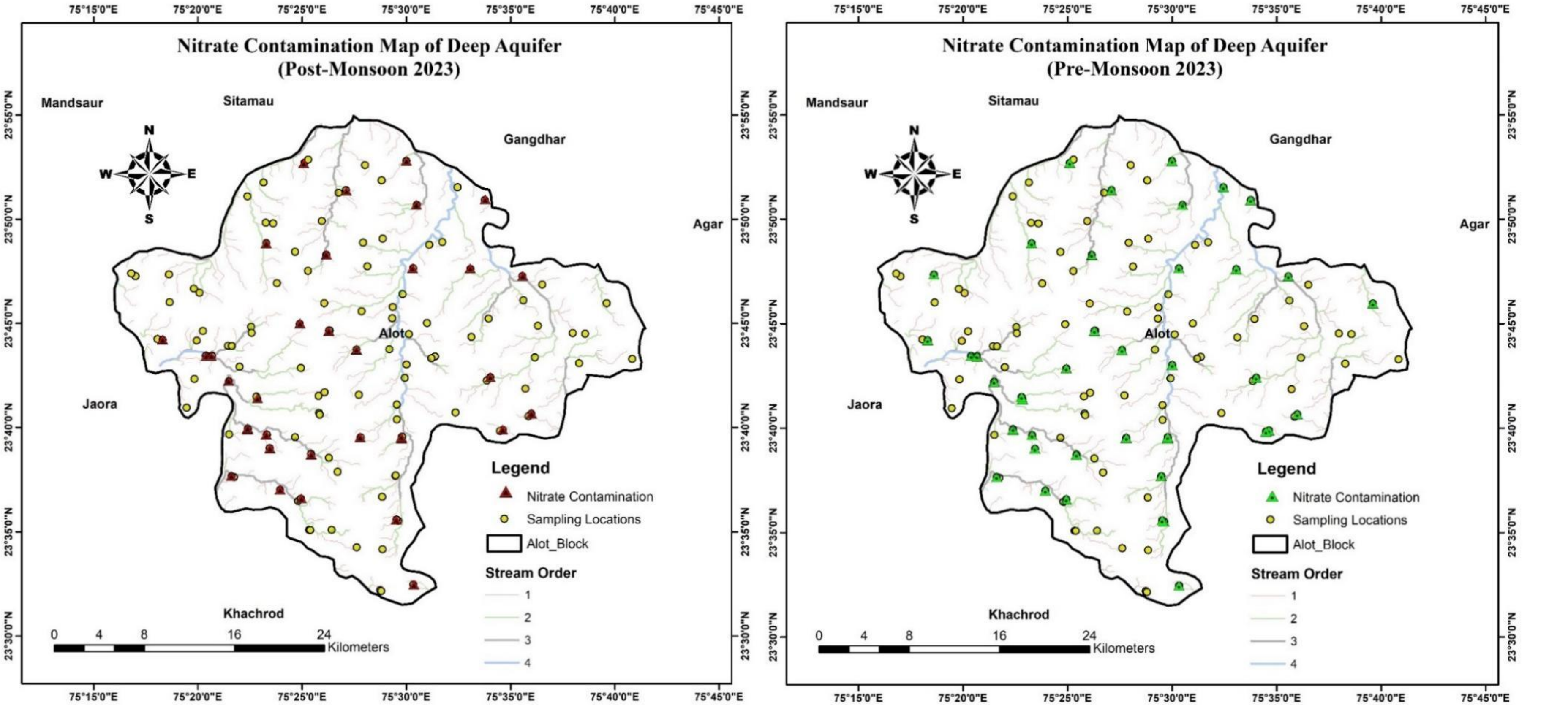


Fig. 6.5: Nitrate Contamination map of deep aquifer (Pre and Post-Monsoon, 2023)

6.3.1.7 Total Hardness

Determination of hardness is a useful test that provides an assessment of the quality of water for households and industrial uses. Water hardness is measured by adding up the concentrations of calcium and magnesium and converting this value to an equivalent concentration of calcium carbonate ($CaCO_3$). Based on the total hardness, the water samples of both seasons are classified applying the method proposed by Sawyer & McCarty (1967) as follows for household use (See Table 6.5):

Table 6.5: Classification of Ground waters Based on Total Hardness (Sawyer & McCarty, 1967).

Total Hardness ($CaCO_3$) mg/l	Water Type	% Of Samples in Shallow Aquifer		% Of Samples in Deeper Aquifer	
		Pre-monsoon	post-monsoon	Pre-monsoon	post-monsoon
<75	Soft	0.00	0.0	0.0	0.0
75-150	Moderately High	1.50	1.2	4.5	2.2
150-300	Hard	18.80	11.8	27.3	22.2
>300	Very Hard	79.70	87.1	68.2	75.6

It is apparent form the table that majority of water samples of shallow and deeper aquifer in both seasons fall either in hard or very hard classes for household use. Ca and Mg based minerals of alluvial/sandstone/lime stone/ granitic aquifers' material might be responsible for higher TH in groundwater. When hard water is heated, $CaCO_3$ precipitates which clogs pipes and industrial boilers. As per Bureau of Indian Standard (BIS): 10500-2012 (Drinking Water), the acceptable limit for total hardness is 200 mg/l and permissible limit is 600 mg/l in absence of alternate sources.

Around 80% ground water samples collected from shallow and deeper aquifer of study area during pre-monsoon and post-monsoon have total hardness value within permissible limit i.e. 200-600 mg/L as CaCO3 On an average less than 10% samples from both the aquifers falls within acceptable limit and 10 -13 % samples have the total hardness value more than permissible limit. The Percent Distribution and Basic Statistics of Total Hardness is given below (Table 6.6).

Table 6.6: Frequency distribution (in %) of total hardness (mg/l)

TH	Shallow Aquifer		Deeper Aquifer	
	Pre Monsoon	Post Monsoon	Pre Monsoon	Post Monsoon
No.of Samples	133	85	91	42
Min.	104	130	119	110
Max.	1025	795	1748	910
Mean	444	430	413	419
<200	4.5	2.4	11	7.1
200-600	82.0	84.7	76	81.0
>600	13.5	12.9	13	11.9

The maximum total hardness observed in the shallow aquifer at hand pump Chapla khedi village (1025 mg/l) & (795 mg/l) in both season and for deeper aquifer at bore well Aakya Kalan village (1748 mg/l) & Bisal Khedi Village (910 mg/l) in pre and post monsoon.

6.3.1.8 Chemistry of Heavy Metals

There are 35 metals that concern us because of occupational or residential exposure; 23 of these are the heavy elements or heavy metals/ metalloid viz. antimony, arsenic, bismuth, cadmium, cerium, chromium, cobalt, copper, gallium, gold, iron, lead, manganese, mercury, nickel, platinum, silver, tellurium, thallium, tin, uranium, vanadium, and zinc. Heavy metals are chemical elements with a specific gravity is at least 5 times more than specific gravity of water. The specific gravity of water is 1 at 4°C (39°F). Some well-known toxic metallic elements with a specific gravity that is 5 or more times that of water are arsenic, 5.7; cadmium, 8.65; iron, 7.9; lead, 11.34; and mercury, 13.546. Heavy metals/ metalloid are common applications in industries such as pesticides, batteries, alloys, electroplating, textile dyes, steel, and so forth manufacturers.

In small quantities of certain elements are nutritionally essential for healthy life. Some of these are referred as trace elements (e.g. iron, copper, manganese, and zinc). These elements or some form of them are commonly found naturally in foodstuffs, fruits and vegetables and also commercially available as multi-vitamin products, but large amount of any may cause acute or chronic toxicity (poisoning). In the Earth's crust, chromium is in ultramafic rocks and serpentinites of ophiolite. The chromium compounds are widely used in various industrial processes e.g. textile dying, tanneries, metallurgy, metal electroplating and photography. Arsenic (As) is a naturally occurring trace element found in rocks, soils and the water in contact with them. Arsenic has been recognized as a toxic element and is considered a human health hazard. Uranium occurs naturally in ground water and surface water. Uranium has both natural and anthropogenic source that could lead to the aquifer. Uranium is a radioactive element, high uranium concentration can cause impact on water, soil and health. These sources include leaching from natural deposits, release in mill tailings, and emissions from the nuclear industry, combustion of coal and other fuels and also use of phosphate fertilizers that contains uranium and contribute to ground water pollution.

Heavy metal toxicity can result in damage or reduce to mental and central nervous function, lower energy levels, blood composition, lungs, kidneys, liver, and other vital organs. Long-term exposure may result slowly in physical, muscular, and neurological degenerative processes that mimic Alzheimer's disease, Parkinson's disease, muscular dystrophy, and multiple sclerosis.

In study area, all the ground water samples collected from shallow and deeper aquifer has the iron concentration within acceptable limit during pre and post monsoon sample analysis. For shallow aquifer iron concentration found between BDL to 2.38 and for deeper aquifer, it has been found between BDL to 0.47. Maximum iron concentrations 1.48 & 2.37 mg/l has been found in hand pump at Gudbeli village and dugwell at Borekhedi village during pre-monsoon in shallow aquifer. In deeper aquifer maximum iron concentration 0.47 mg/l has been found in bore well (Bisal Kheda) during post-monsoon. The Percent Distribution and Basic Statistics of Iron is given below. Frequency distribution of iron concentration is tabulated in Table 6.7**.**

Table 6.7: Frequency distribution of Iron concentration

Iron	**Shallow Aquifer**		**Deeper Aquifer**	
	Pre Monsoon	**Post Monsoon**	**Pre Monsoon**	**Post Monsoon**
No. of Samples	133.00	85.00	88.00	45.00
Min.	0.00	0.00	0.00	0.00
Max.	2.38	1.25	0.47	0.27
Mean	0.13	0.11	0.05	0.03
<1.0	98.50	97.65	100.00	100.00
>1.0	1.50	2.35	0.00	0.00

Manganese (Mn) is an essential trace element for human health. The BIS has set health-based desirable and permissible guideline values for manganese in drinking water as 0.1 mg/l and 0.3 mg/l respectively to ensure protection against manganese toxicity. BIS has recommended acceptable limit of manganese concentration in drinking water is 0.10 mg/l and 0.30 mg/l as permissible limit in absence of alternate source. In study area, around 97% the ground water samples collected from shallow and deeper aquifer has the Mn concentration within desirable limit during pre and post monsoon sample analysis. Highest concentration of Mn is found in water sample collected from shallow aquifer of dug wells at Pipliyatukur village (2.79 mg/l), Pant Piploda village (0.53 mg/l) and in dug well Kothdi Karwa village (1.24 mg/l) during pre and post-Monsoon, and in deeper aquifer of bore well at Aakya Kalan village (0.52 mg/l) in pre-Monsoon. More than 97% samples have manganese concentration within acceptable limit. Frequency distribution of Manganese concentration is given in Table 6.8**.**

Table 6.8: Frequency distribution of Manganese concentration

Manganese	**Shallow Aquifer**		**Deeper Aquifer**	
	Pre Monsoon	**Post Monsoon**	**Pre Monsoon**	**Post Monsoon**
No. of Samples	133	85	88	45
Min.	0.000	0.000	0.000	0.00
Max.	2.796	1.248	0.528	0.047
Mean	0.033	0.017	0.014	0.002
<0.1	95.5	98.8	96.6	100.0
0.1-0.3	3.0	0.0	1.1	0.0
>0.3	1.5	1.2	2.3	0.0

6.3.2 Mechanisms of Controlling Groundwater Chemistry

6.3.2.1 Water Type and Relationships (Hydro-chemical Diagrams)

The concept of hydro-chemical facies has been used (Seaber, 1962; Morgan &Winner, 1962; Back, 1960) to denote the diagnostic chemical character of water solutions in hydrological systems. Hydro-chemical facies depict the overall scenario of the interaction of groundwater solutions within a lithological structure. They are quite beneficial in interpreting the groundwater transition and pattern of its flow (Jain et al, 2018). Statistically distribution diagrams such as Piper trilinear, Chadha, Durab etc. are widely used to gain better insight into hydro chemical processes operating in the groundwater system. Among the options listed, we have chosen the Piper-trilinear model, which is the most widely adopted worldwide, for our convenience. In piper diagram (1944), the water samples are plotted on trilinear diagram to know the hydro -chemical regime of the study area. These plots include two triangles, one for plotting cations and the other for anions. The cations and anions fields are combined single point in a diamond - shaped field, from which inference is drawn based on the hydro -geochemical facies concept.

The Piper trilinear diagram has been widely used to graphically representation of dissolved constituents in natural water from different sources. As per Piper-trilinear diagram (Fig. 6.6, 6.7 and **Annexure V)**, The Piper diagram analysis showed that during the pre and post-monsoon seasons in the study area, roughly 40.6% & 26.1% and 16.5% & 26.7% of groundwater respectively had Calcium Bi-carbonate type i.e. temporary hardness, characterized by higher levels of calcium and magnesium ions compared to sodium and potassium ions, as well as elevated concentrations of CO_3^{2-} and HCO_3^- anions relative to SO_4^{2-} and Cl^- anions. The study clearly indicates that Na-Cl type (saline type of water) of water predominated during pre & post-monsoon season (27.1%) & (43.2%) and (25.9%) & (57.8%) in shallow and deeper aquifer. This variation in chemical facies can be attributed to dissolution of salts deposited by evapotranspiration of irrigation water and subsequent mixing with groundwater (Table 6.9).

Table 6.9: Chemical Quality from Piper Diagram of Shallow and Deeper aquifer

Type of Water	**Shallow Aquifer**		**Deeper Aquifer**	
	% of Samples pre-monsoon	**% of Samples post-monsoon**	**% of Samples pre-monsoon**	**% of Samples post-monsoon**
Ca-Cl Type	NIL	NIL	NIL	NIL
Ca-Mg-Cl Mixed Type	23.3	40.0	13.6	2.2
Ca-Na-HCO_3 Mixed Type	9.0	17.6	17.0	13.3
$CaHCO_3$ Type	40.6	16.5	26.1	26.7
Na-Cl Type	27.1	25.9	43.2	57.8
$NaHCO_3$ Type	NIL	NIL	NIL	NIL

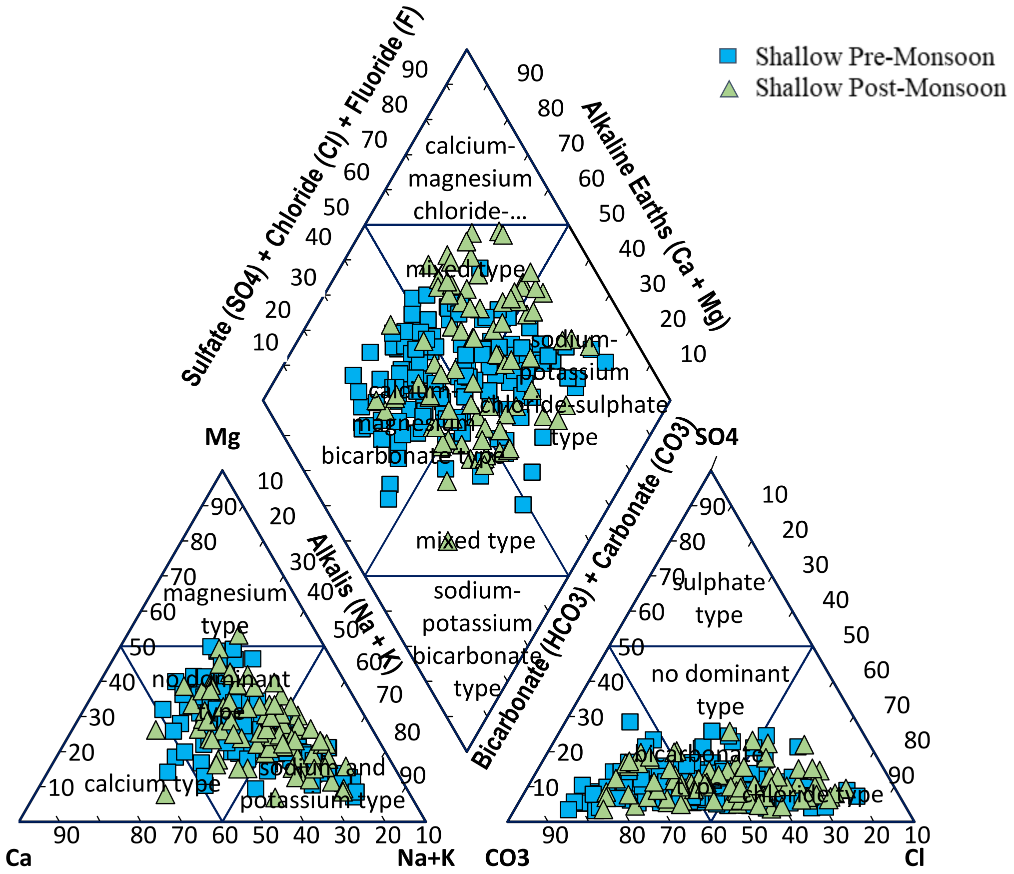


Fig. 6.6: Piper linear diagram for shallow aquifer

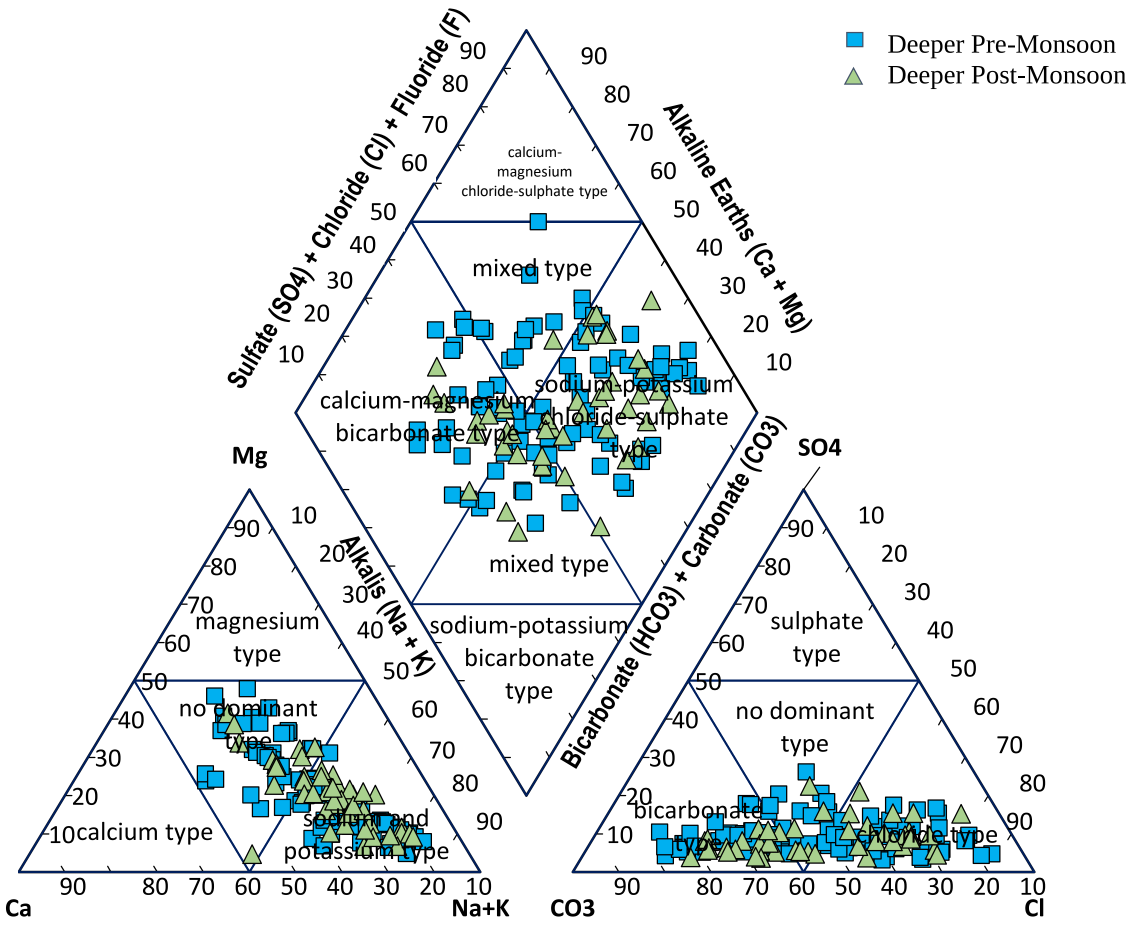


Fig.6.7: Piper linear diagram for deeper aquifer

6.3.3 Assessment of Water Quality for Irrigation Purposes

The US Salinity Diagram classify the water for irrigation purpose. It is assumed that the water will be used for irrigation purpose based upon its soil texture, infiltration rate, drainage and climate. The chemical data of all the water samples from Alot block is plotted on U.S. Salinity Laboratory diagram. The US Salinity Diagram shows that the ground 5.7 % samples are C2-S1 Class (Medium Salinity & Low Sodium), 58.94 %of samples are C3-S1 Class (High Salinity & Low Sodium), 14.73 % of samples are C3-S2 Class (High Salinity & Medium Sodium), 3.15 % of samples are C4-S1 Class (Very High Salinity & Low Sodium), 12.63 % of samples are C4-S2 Class (Very High Salinity & Medium Sodium), 3.15 % of samples are C4-S3 Class (Very High Salinity & High Sodium) and 1.05 % of samples are C4-S4 Class (Very High Salinity & Very High Sodium) of water. In those area, C2-S1 and C3-S1 Classes of water may be used for irrigation purpose for most of the crops and C3-S2, C4-S1, C4-S2, C4-S3 C4-S1

Classes of water may be used for irrigation, considering the salinity content of the ground water.

6.3.4 Gibbs Diagram and Water–Rock Interaction

Mechanisms controlling groundwater chemistry Gibbs diagram and water–rock interaction. The groundwater chemistry is a major aspect of deter-mining its use for domestic and irrigation purposes. Chemistry of groundwater is greatly controlled by the interaction of groundwater with aquifer minerals. The contributions of rock/soil–water interaction and anthropogenic influences on groundwater can be studied by various hydrogeochemical processes (Singh et al. 2011). To obtain an insight into hydrogeochemical processes, Gibbs (1970) has proposed scatter diagram method illustrating three important natural mechanisms controlling the major ion chemistry of the groundwater including water–rock interaction, evaporation and atmospheric precipitation. The TDS concentrations were plotted against the ratios of Na /(Na + Ca) for cations and Cl/(Cl + HCO_3) for anions.

It was found that majority of the samples collected from Shallow and deep aquifers falls in rock dominance during both the seasons. The data points on the Gibbs diagram suggests groundwater chemistry of Shallow and deep aquifers of Alot block is controlled principally by rock weathering and to some extent evaporation-crystallization is the dominant factor leading to in-creased salinity and therefore poor quality of groundwater (Subba Rao 2002; Srinivasa moorthy et al. 2008). This reflected the significance of water–rock interactions as the major source of dissolved ions controlling the chemical composition of these waters (Li et al. 2015; Raju et al. 2015).

Next to rock dominance, a few groundwater samples of Shallow and deeper aquifer fell into evaporation dominant area, signifying the role of evaporation on shallow groundwater chemistry evaporation greatly increases the concentrations of ions formed by chemical weathering of the rock, leading to higher salinity. The TDS concentrations were plotted against the ratios of Na/ (Na + Ca) for cations and Cl/ (Cl + HCO_3) for anions (Fig. 6.8 and 6.9).

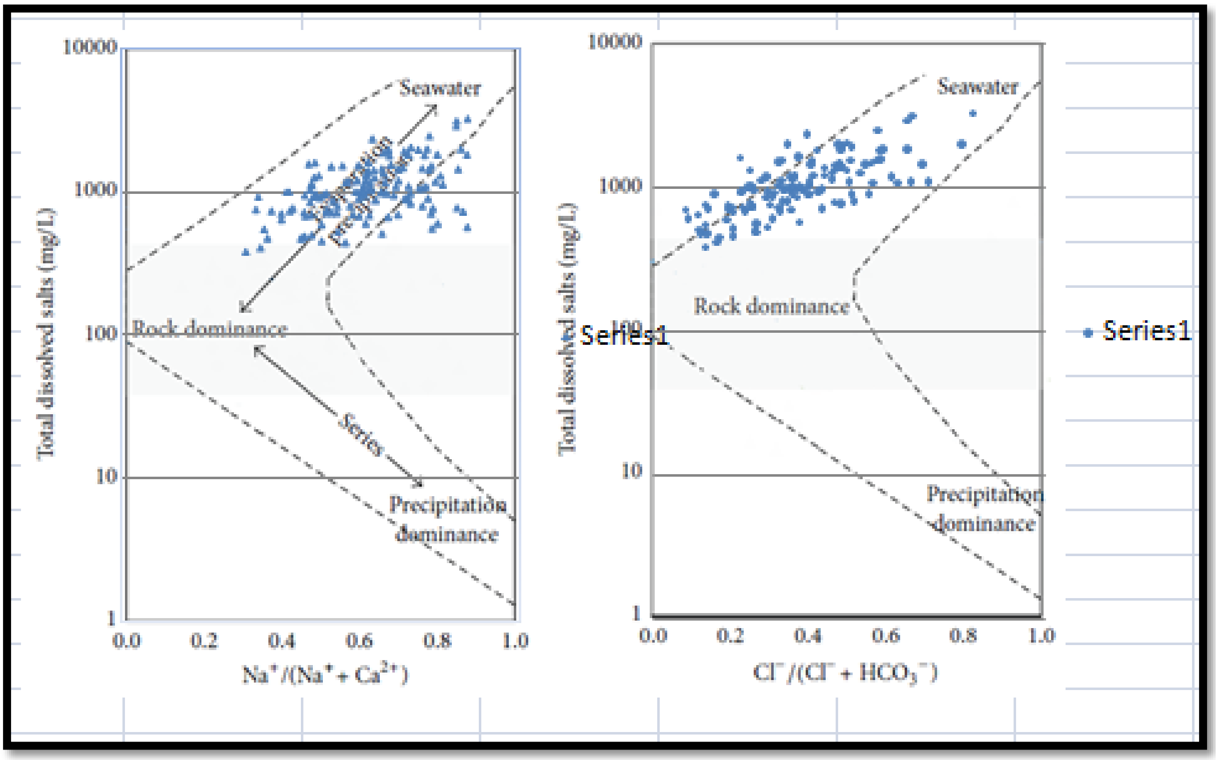


Fig. 6.8: Gibb's Diagram for shallow Aquifer

6.3.4 Effect of Monsoon on Groundwater Quality of the study area

To examine the effect of monsoon on ground water quality a paired t-test employed on 85 number of samples in shallow aquifer and 45 nos. in deeper aquifer. These collected from the same sample source during pre- and post-monsoon. Results of paired t-test is being given below. A t-test is a statistical hypothesis test that is used to determine whether there is a significant difference between the means of two groups. It helps you assess whether any observed differences between the groups are likely to have occurred by chance or if they are statistically significant.

At 95 % confidence level and with a degree of freedom 50, outcome of t-test reveals that, mean value of parameter such as temperature, pH, electrical conductivity, bio-carbonate, sulphate, nitrate, total hardness, calcium, magnesium, sodium, potassium, arsenic and lead has been changed significantly. While parameter like chloride, fluoride, iron, manganese, copper, zinc, chromium and uranium remained unchanged after monsoon in shallow aquifer.

At 95 % confidence level and with a degree of freedom 50, outcome of t-test reveals that, mean value of parameter such as temperature, pH, electrical conductivity, chloride, sulphate, nitrate, total hardness, calcium, potassium, lead and uranium has been changed significantly. While parameter like bio-carbonate, fluoride, magnesium, sodium, iron, manganese, copper, zinc, arsenic and chromium remained unchanged after monsoon in deeper aquifer.

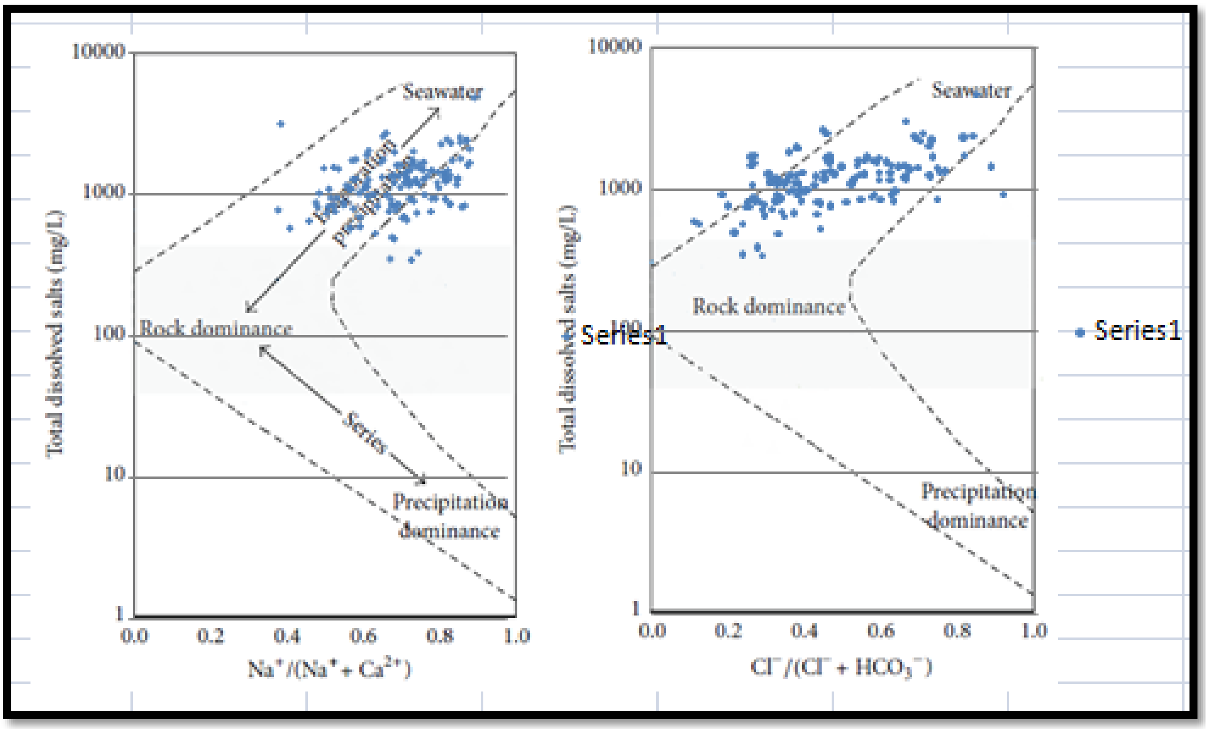


Fig. 6.9: Gibb's Diagram for deeper Aquifer (Pre & Post-Monsoon)

6.3.5 Groundwater Quality for Irrigation:

6.3.5.1 Residual Sodium Carbonate (RSC)

The water having high concentration of bicarbonates show the tendency of calcium and magnesium precipitated as carbonates. Quantity of this effect, an experimental parameter termed as residual sodium carbonate was coined by Eaton, 1950. The residual sodium carbonate (RSC) can be calculated by the given equation as follows:

$RSC = (CO_3^{2-} + HCO_3^{-}) – (Ca^{2+} + Mg^{2+})$

Where, the concentration of CO_3^{2-}, HCO_3^{-}, Ca^{2+} and Mg^{2+} ions expressed in mEq/L

The RSC is classified into three types (Alaya et al. 2014). They are suitable (< 1.25 meq/l), marginally suitable (1.25–2.50 meq/l), and unsuitable (> 2.50 meq/l) types for irrigation purposes. The RSC varied from -9.58 to 3.09 & -8.7 to 7.79 meq/l, and – 24.35 to 4.74 & -6.4 to 6.79 meq/l in shallow and deeper aquifer during both period. According to the classification, 92.5% & 80.7% and 88.2% & 84.4% of the groundwater samples of shallow and deeper aquifer belong to good categories in both the periods; 5.3 % & 10.2% and 5.9 % & 6.7 % of the groundwater samples of shallow and deeper aquifer fall under doubtful class and whereas 2.3 % & 9.1% and 5.9 % & 8.9 % of the groundwater samples of shallow and deeper aquifer for both the seasons under in the unsuitable class for irrigation purposes. The frequency distribution of RSC is given in Table 6.10.

Table 6.10: Frequency distribution of RSC Values

RSC	Shallow Aquifer		Deeper Aquifer	
	Pre Monsoon	Post Monsoon	Pre Monsoon	Post Monsoon
No. of Samples	133	85	88	45
<1.25	92.5	88.2	80.7	84.4
1.25 - 2.50	5.3	5.9	10.2	6.7
>2.50	2.3	5.9	9.1	8.9

6.3.5.2 Suitability for irrigation use

The suitability of groundwater for irrigation is contingent on the effects of the mineral constituents in the water on both the plants and soil. The important hydro-chemical parameters of groundwater used to determine its suitability for irrigation are electrical conductivity (EC), sodium percent (Na%), sodium adsorption ratio (SAR), and residual sodium carbonate (RSC). EC is a good measure of salinity hazard as it reflects the total dissolved solids (TDS) in groundwater.

Electrical conductivity and sodium concentration are very important in classifying irrigation water. The high salts in the water, besides affecting the growth of the plants directly, also affect the soil structure, permeability and aeration, which indirectly affect the plant growth. The U. S. Salinity Laboratory (1954) proposed a diagram for studying the suitability of groundwater for irrigation purposes based electrical conductivity and sodium adsorption ratio. In this diagram, irrigation water are classified as low (EC = 250 µS cm-1), medium (EC = 750-2250 µS cm-1) and very high (EC = 2250-5000 µS cm-1), salinity classes (USSL 1954). High salt concentration in water leads to formation of saline soil, while a high sodium concentration leads to development of an alkaline soil. The sodium or alkali hazard expressed in terms of SAR and estimated by the formula:

$$SAR = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}}$$

Concentrations are in mEq/L

On the basis of SAR value, water are classified into low (SAR<10), medium (SAR 10-18), high (SAR 18-26) and very high (SAR>26) alkali waters. There is a significant relationship between SAR values of irrigation water and the extent to which sodium is absorbed by the soils. If water used for irrigation is high in sodium and low in calcium, the cation exchange complex may become saturated with sodium. This can destroy the soil structure owing to dispersion of the clay particles. The calculated value of SAR in the groundwater of shallow and deeper aquifer of Alot block ranges from. 0.73 to 16.9 (avg. 3.84) & 0.98 to 12.2 (avg. 4.09) and 1.38 to 24.9 (avg. 5.5) & 1.47 to 14.9 (avg. 6.1) during pre and post-monsoon period. According to SAR values of Shallow and deeper aquifer are fall in Excellent to Good Class during both seasons. Highest SAR (18-26 Doubtful) value 24.94 is found in deeper aquifer bore well at Surjana. The frequency distribution of RSC is given in Table 6.11.

Table 6.11: Frequency distribution of SAR Values

SAR	Shallow Aquifer		Deeper Aquifer	
	Pre Monsoon	**Post Monsoon**	**Pre Monsoon**	**Post Monsoon**
No.of Samples	133	85	88	45
Min.	0.73	0.98	1.38	1.47
Max.	16.91	12.14	24.94	14.97
Mean	3.84	4.09	5.59	6.11
<10 Excellent	96.2	96.5	87.5	86.7
10 to 18 Good	3.8	3.5	11.4	13.3
18 to 26 Doubtful	0.0	0.0	1.1	0.0
>26 Unsuitable	0.0	0.0	0.0	0.0

The US Salinity Diagram shows that the ground water of shallow and deeper aquifer about 5.3 % & 2.3% and 2.4% & 2.2% samples are falls in C2-S1 Class (Medium Salinity & Low Sodium) and majority of samples 67.6% & 55.7% and 72.9 % & 40.0% of shallow and deeper aquifer falls in the categories C3S1 during pre and post-monsoon period, indicating high salinity and low alkali water. High salinity water (C3) cannot be used on soils with restricted and requires special management of salinity control. Such water can be used to irrigate salt-tolerant and semi tolerant crop under favourable drainage conditions.

About 13.5% & 12.9% of shallow and 11.4% & 17.8% deeper aquifer samples falls in C4-S2 Class (Very High Salinity & Medium Sodium) during both season, 3% & 5.9% of Shallow and 5.7% & 11.1 % deeper aquifer samples falls in C4-S3 (Very high salinity high-sodium water) and 0.8 % & 0.0 % and 4.5 % & 2.2% of samples are C4-S4 Class (Very High Salinity & Very High Sodium), C2-S1and C3-S1Classes of water may be used for irrigation purpose for most of the crops and C3-S2, C4-S1, C4-S2, C4-S3 and C4-S1 Classes of water may be used for irrigation, considering the salinity content of the ground water. During post-monsoon, dugwell at Dehari, bore wells at Jamuniya Shankar, Bensola & Surjana in shallow aquifer and bore well at Jamuniya Shankar village of deeper aquifer in post-monsoon season falls in C4-S4 Class (Very High Salinity & Very High Sodium) is generally not suitable for irrigation purpose.

The results of electrical conductivity and SAR of Alot block area plotted on U.S. Salinity Laboratory diagram (Fig. 6.10 & Fig. 6.11).

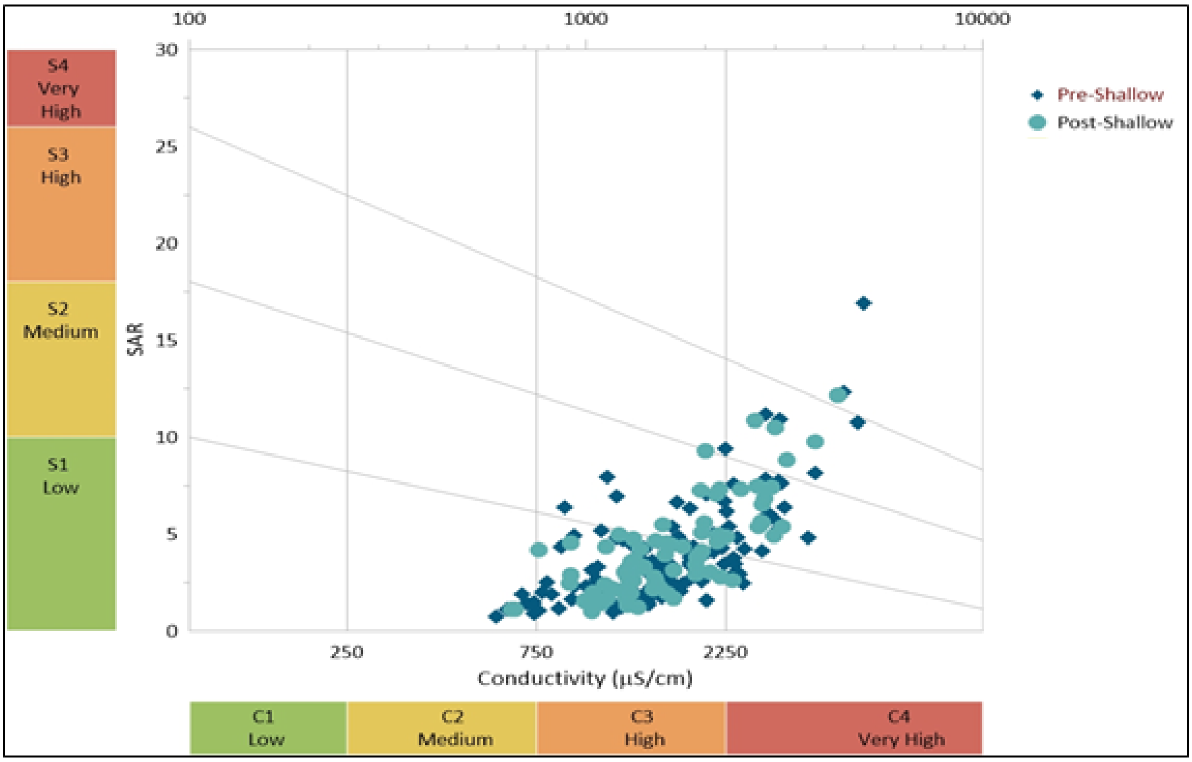


Fig. 6.10: USSL Classification for Shallow aquifer

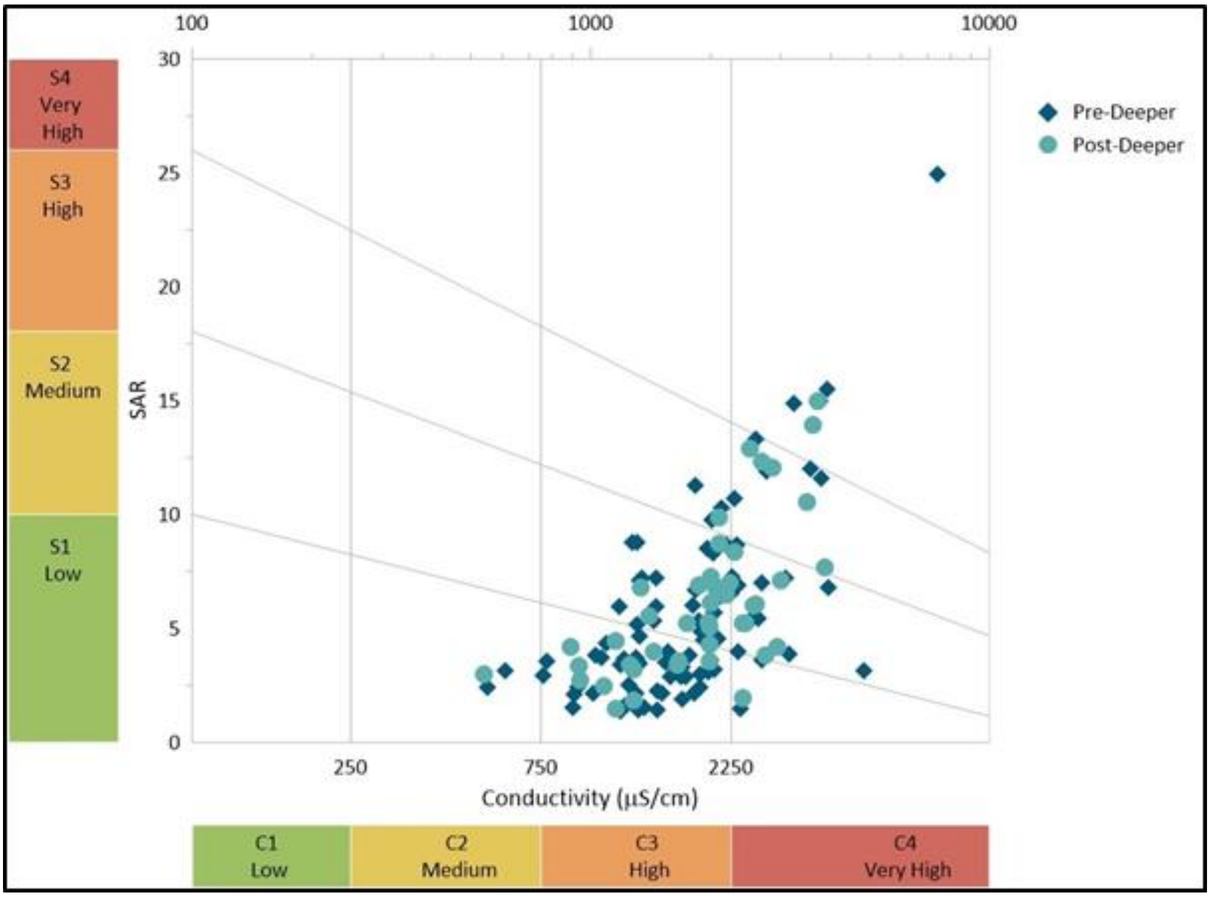


Fig. 6.11: USSL Classification for Deeper aquifer

6.4 SURFACE WATER QUALITY

The surface water samples collected from Chambal and Kshipra rivers flowing from Alot block during pre and post-monsoon season have varied range of pH from 7.60 to 7.90 and 7.80 to 7.61 for Chambal and Kshipra respectively for both periods. As per BIS (IS 10500:2012) recommendation, all the water samples have pH recorded within the permissible limits of 6.5 to 8.5, the maximum pH recorded in the water sample of Chambal River (7.90). The surface water of the study area can be assessed as slightly alkaline. The electrical conductivity of surface water samples in varies from 1962 to 1373 µS/cm at 25°C for Chambal river and 1540 to 1164 µS/cm at 25°C for Kshipra river pre & post-monsoon respectively. The electrical conductivity of all the surface water of Alot block as less than 2000 µS/cm at 25°C. The maximum electrical conductivity has been observed at Chambal river i.e. 1962 µS/cm at 25°C. So, electrical conductivity of surface water is good.

All the surface water are having fluoride concentration is within the permissible limit of 1.5 mg/l as per BIS (IS 10500:2012). The maximum of fluoride concentration has been observed at Kshipra river during post-monsoon i.e. 0.55 mg/l The nitrate concentration is within the acceptable limit of 45 mg/l during both seasons. The highest concentration of nitrate is reported in the surface water sample Chambal river during pre-monsoon (11 mg/l).

The range of Total Hardness (as $CaCO_3$) in surface water samples of study area is 406 to 475 mg/l during pre monsoon and 270 to 420 mg/l post monsoon period for both rivers water. The total hardness in the surface water samples of both seasons is within the permissible limit is 600 mg/l in absence of alternate sources. Maximum total hardness observed at Chamble river during pre-monsoon at 475 mg/l.

The Piper diagram shows that the surface water samples of A lot Block are Calcium Bi-carbonate type (temporary hardness) of water. The US Salinity Diagram shows that the ground water samples of both river samples fall in C3-S1 Class (Medium Salinity & Low Sodium) Class of water may be used for irrigation purpose for most of the crops.

CHAPTER 7

SOURCE SUSTAINABILITY STUDY

7.1 OBJECTIVE

This chapter aims to categorize the gram panchayats or villages as per risk assessment carried out within the study area in order to prioritize the ground water sustainability measures.

7.2 METHODOLOGY

The present study utilizes the data collected from the field combined with data from various state departments such as rainfall data collected from IMD etc. As per the SOP on sustainability of ground water resources there are 8 steps to follow which was shown in the Fig. 7.1.

Step 1: Collection of basic information.

Step 2: Assessment of Demand and Supply.

Step 3: Assessment of Monsoon Run off.

Step 4: Risk assessment of villages.

Step 5: Drinking water source sustainability measures.

Step 6: Source protection.

Step 7: Ground water monitoring.

Step 8: Financial and technical support.

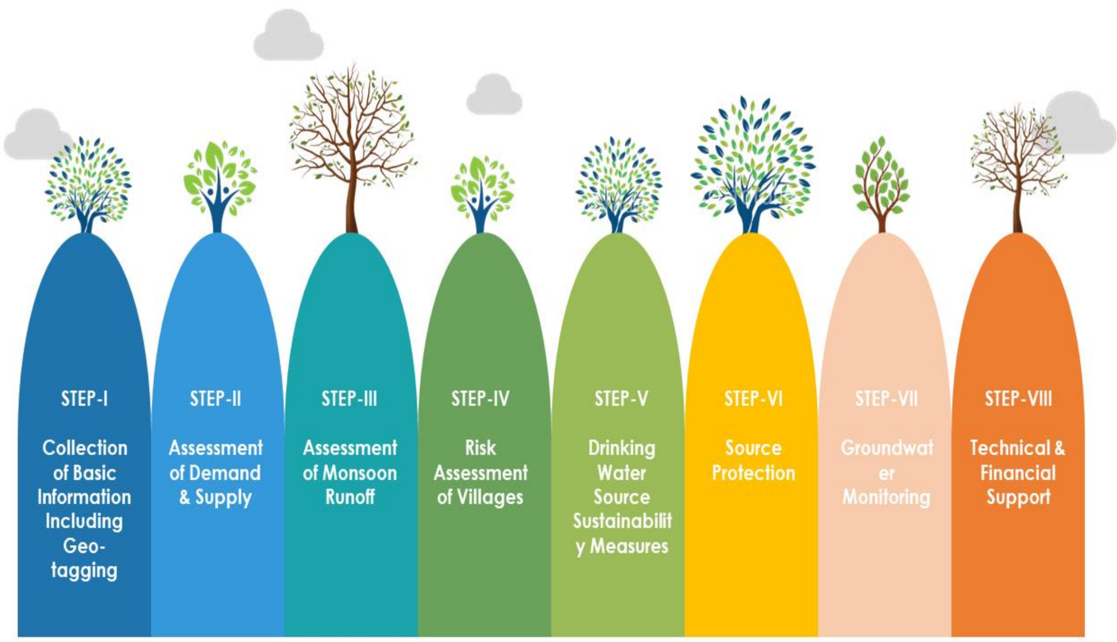


Fig. 7.1: Steps for risk assessment of villages

The factors which is used to for risk assessment include rainfall, terrain slope, aquifer potential, sustainability, depth to water level and water quality risk assessment of villages can be done and can be categorized as Safe, At risk and High Risk which was shown in Table 7.1 and the risk assessment of villages for three different rainfall zones have shown in the Fig.7.2 and Fig.7.3 mainly shows the risk assessment of villages in the study area as the rainfall is mainly greater than 750 mm

Safe villages are those which do not require any intervention and can support existing ground water based schemes in long term. At Risk villages are those where gap between demand and supply is positive. These villages can only be sustained by undertaking recharge/conservation interventions. High Risk villages are those where sources cannot be sustained even if various interventions are taken up.

Table 7.1: Risk assessment of villages for different rainfall zones

Parameter	Safe	AtRisk	High Risk
Normal Annual Rainfall (mm)	75(	<750but >500	<500
Tube well/ Bore well Discharge (lp	> 3		< 1
Whether Discharge is available throughout the year	Yes	No	No
Terrain	in/Valleys Pla	Pla in/Valley	Hills/ High Slopes
Depth to Water Level (m bgl)	<10	10- 20	>
Quality			
Iron (ppm)		> 1	
Fluoride(ppm)	< 1.5	1.5	> 1.5
Arsenic (ppb)	10	> 10	10
Salinity (TDS)	< 500	500-2000	>2000

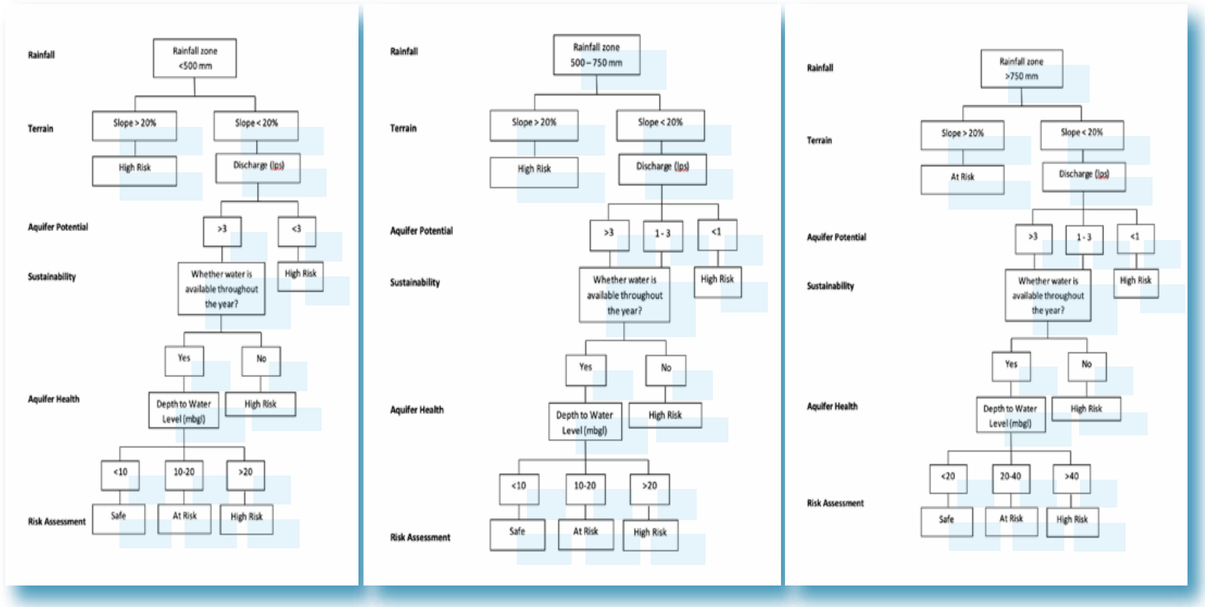


Fig. 7.2: Risk assessment of villages based on 3 different rainfall zone

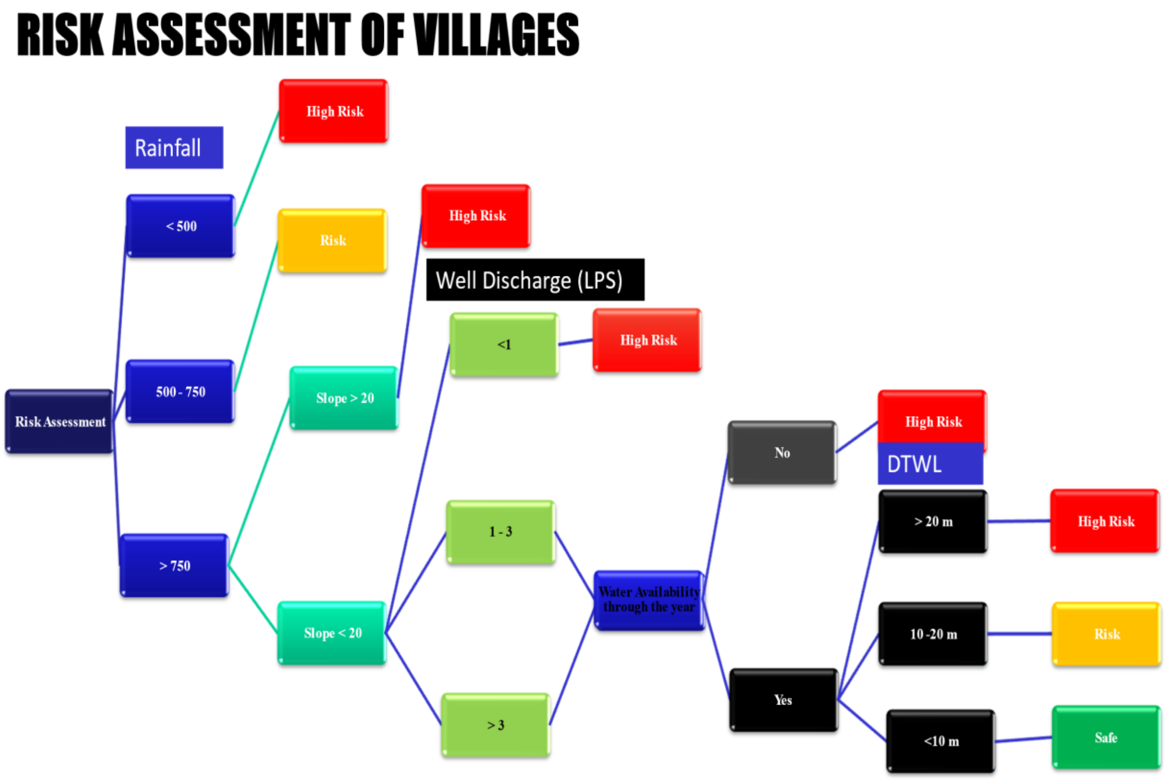


Fig. 7.3: Risk assessment of villages in Alot block

7.3 RESULTS AND DISCUSSION

Based on above methodology, villages have been categorized into Safe, At risk and High risk villages. As per the previous and recent rainfall data we have taken the normal annual rainfall of 992.85 mm has been considered for all over the study area. Slope has been taken from Arc GIS software for the assessment villages and from the field carried out in the assessment villages and well inventory data, farmer feedback form and depth to water level data from bore wells and dug wells in the post monsoon has been utilized to categorize the villages. For example categorization of one village Bensola has been demonstrated below with the data collected from the field as well from district authorities and data tabulated in the Table 7.2:

As above demonstrate village it comes under the rainfall zone of greater than 750 mm so for the next step the slope is < 20 degree so it is not categorized as high risk so followed to next step discharge which is 1-3 lps so it is not categorized as high risk and water available throughout the year so we proceeded to next step i.e., depth to water level value 55 mbgl which is greater than 40 mbgl so it comes under High risk category. So village has been categorized under High Risk category.

In similar way we categorized 55 villages which is covering 40 gram panchayats out of 91 gram panchayats in the study area as per risk assessment. Out of these 55 villages the Safe villages are 9, At Risk villages are 8 and High risk villages are 38 (Table 7.3). The number of categorized villages as per risk assessment are shown in the Table 7.4 and the villages with locations are attached in table.

Table 7.2: Sailent details of village Bensola

S No	Village/GP	Bensola
1	**Rainfall:**	992.85 mm
2	**Slope**	< 20
3	**Discharge**	1-3 lps
4	**Water available throughout the year:**	Yes
5	**Depth to water level:**	> 55 mbgl
6	**Category:**	High risk

Table 7.3: No. of categorised villages as per risk assessment

Category	No of villages
Safe	9
At Risk	8
High Risk	38

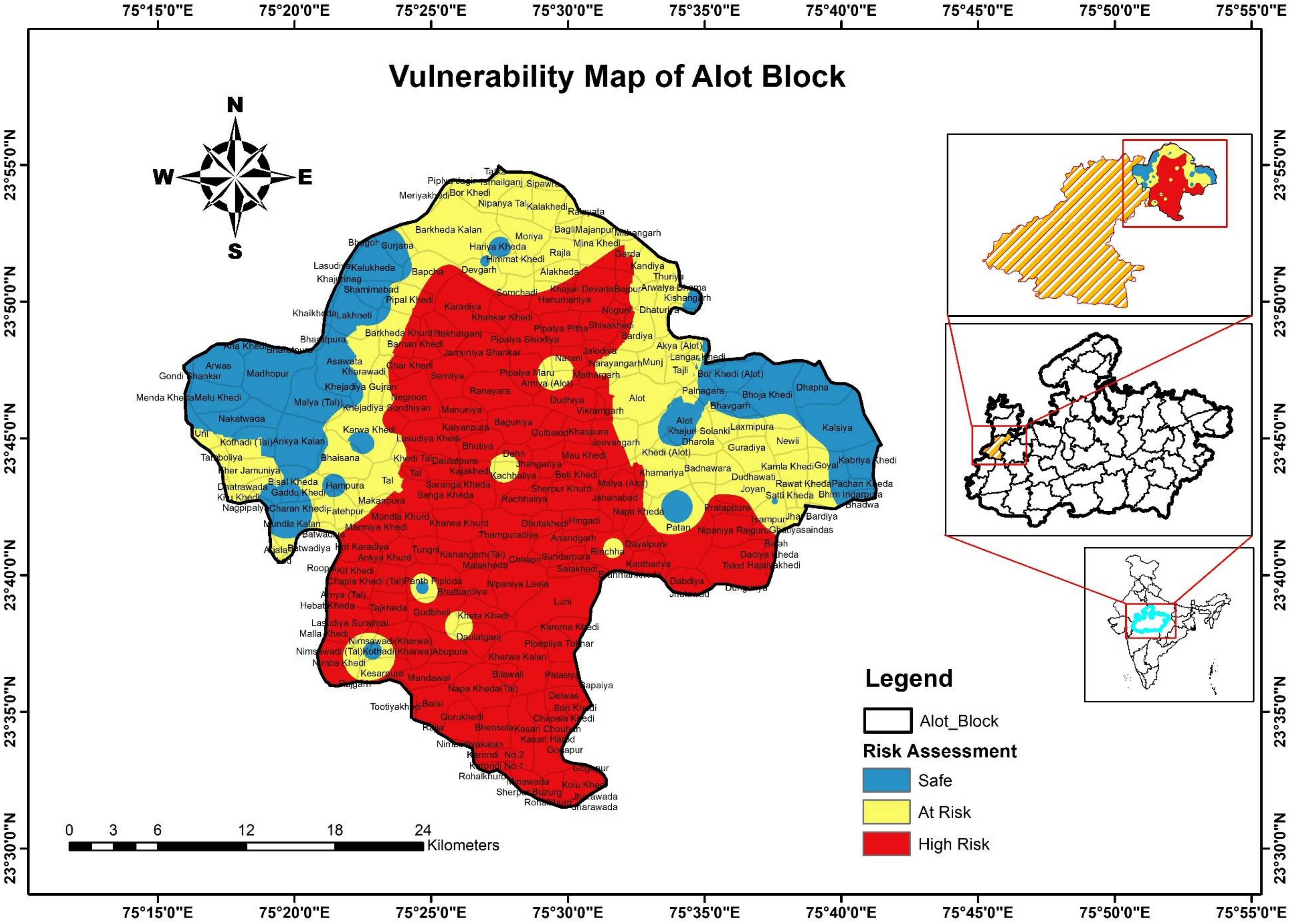


Fig. 7.4: Vulnerability map of Alot block

Table 7.4: Categorization of villages as per risk assessment.

S.No	Village Panchayat	Village	Rainfall (mm)	Slope (degree)	Discharge (lps)	Whether water is Available through out the year	DT WL (mbgl)	Category
1	Aakyakalan	Aakyakalan	992.85	<20	1 to 3	Yes	16	Safe
2	Arwaliya Solanki	Arwaliya Solanki	992.85	<20	1 to 3	Yes	46.45	High risk
3	Asawata	Asawata	992.85	<20	<1	No		High risk
4	Bhensola	Bhensola	992.85	<20	1 to 3	Yes	122	High risk
5	Bhensola	Karondi 1	992.85	<20	1 to 3	Yes	56	High risk
6	Bhensola	Karondi 2	992.85	<20	1 to 3	Yes	59.85	High risk
7	Bhim	Bhim	992.85	<20	1 to 3	Yes	88	High risk
8	Bhojakhedi	Bhojakhedi	992.85	<20	>3	Yes	19.15	Safe
9	Bisalkheda	Bisalkheda	992.85	<20	1 to 3	Yes	20.1	Safe
10	Dabdiya	Dabdiya	992.85	<20	1 to 3	Yes	121.9	High Risk
11	Daulatganj	Daulatganj	992.85	>20	1 to 3	No	28.13	High Risk
12	Delwas	Chapalakhedi	992.85	<20	1 to 3	Yes	125	High Risk
13	Dharola	Badnawara	992.85	<20	1 to 3	Yes	51.8	High Risk
14	Himmakhedi	Himmatkhedi	992.85	<20	1 to 3	Yes	17.96	Safe
15	Himmakhedi	Hariyakheda	992.85	<20	1 to 3	Yes	26.72	At risk
16	Himmakhedi	Ismailganj	992.85	<20	1 to 3	Yes	14.55	Safe
17	Hingadi	Hingadi	992.85	<20	1 to 3	Yes	47.72	High Risk
18	Hingadi	Dhutakhedi	992.85	<20	1 to 3	No	96	High Risk
19	Hingadi	Anandgarh	992.85	<20	1 to 3	No	88.76	High Risk
20	Jamuniyashankar	Jamuniyashankar	992.85	<20	1 to 3	Yes	55.44	High Risk
21	Joyan	Joyan	992.85	<20	1 to 3	Yes	33.46	At risk
22	Joyan	Isampur	992.85	< 20	1 to 3	Yes	19.55	Safe
23	Kachhalia	Kachhalia	992.85	<20	1 to 3	Yes	29.36	At risk
24	Kalsya	Kalsya	992.85	<20	1 to 3	Yes	75.7	High risk
25	Kalsya	Dhapna	992.85	<20	1 to 3	Yes	66.4	High risk
26	Karadiya	Karadiya	992.85	<20	<1	No	131	High Risk

S.No	Village Panchayat	Village	Rainfall (mm)	Slope (degree)	Discharge (lps)	Whether water is Available through out the year	DT WL (mbgl)	Category
27	Karwa Khedi	Karwa Khedi	992.85	<20	1 to 3	Yes	65.9	High Risk
28	Karwa Khedi	Khejadiya Sondhiyan	992.85	<20	<1	Yes	41.85	High Risk
29	Kasari Chouhan	Kasari Chouhan	992.85	<20	1 to 3	Yes	102	High Risk
30	Kelukheda	Kelukheda	992.85	<20	> 3	Yes	25.38	At risk
31	Kelukheda	Shaminabad	992.85	<20	1 to 3	Yes	29.56	At risk
32	Kishangarh	Kishangarh	992.85	<20	1 to 3	No	91	High risk
33	Kishangarh	Malakheda	992.85	<20	1 to 3	No	75.2	High risk
34	Kolukhedi	Kolukhedi	992.85	<20	1 to 3	Yes	75.6	High risk
35	Mandawal	Mandawal	992.85	<20	1 to 3	Yes	45.22	High Risk
36	Mundala kala	Mundala kala	992.85	<20	1 to 3	Yes	12.39	Safe
37	Negroon	Negroon	992.85	<20	1 to 3	No	44.4	High Risk
38	Nipaniya Leela	Nipaniya Leela	992.85	<20	1 to 3	Yes	79	High Risk
39	Nipaniya Rajguru	Nipaniya Rajguru	992.85	<20	< 1	Yes	60.6	High Risk
40	Panth Pipoloda	Panth Piploda	992.85	<20	>3	Yes	11.04	Safe
41	Patan	Patan	992.85	<20	1 to 3	Yes	44.82	High Risk
42	Pipal Khedi	Pipal Khedi	992.85	<20	1 to 3	Yes	64.24	High Risk
43	Pipal Khedi	Lakhneti	992.85	<20	>3	Yes	18	Safe
44	Pipliya Maru	Pipliya Maru	992.85	<20	1 to 3	No	42.56	High risk
45	Pipliya Maru	Narani	992.85	<20	1 to 3	Yes	32.71	At Risk
46	Ranayara	Ranayara	992.85	<20	<1	No	122	High Risk
47	Rinchha	Rinchha	992.85	<20	1 to 3	Yes	34.8	At Risk
48	Semliya	Semliya	992.85	<20	1 to 3	Yes	73.88	High Risk
49	Sherpurkhurd	Sherpurkhurd	992.85	<20	1 to 3	Yes	64.13	High Risk
50	Surjana	Surjana	992.85	<20	1 to 3	No	44.3	High Risk
51	Surjana	Bapcha	992.85	<20	1 to 3	No	73.43	High Risk

S.No	Village Panchayat	Village	Rainfall (mm)	Slope (degree)	Discharge (lps)	Whether water is Available through out the year	DT WL (mbgl)	Category
52	Tajkheda	Tajkheda	992.85	<20	1 to 3	No	97.24	High Risk
53	Tajkheda	Nimsawadi Kharwa	992.85	<20	1 to 3	Yes	24.96	At Risk
54	Talod	Talod	992.85	<20	1 to 3	Yes	76.2	High Risk
55	Thamguradiya	Thamguradiya	992.85	<20	1 to 3	No	44.07	High Risk

CHAPTER 8

GROUNDWATER RELATED ISSUES

8.0 INTRODUCTION

The studies under NAQIUM 2.0 are proposed based on issues specific and will be undertaken in prioritized focus area. The study area has been identified based on Ground Water related issues. Understanding the issues is essential before recommending management interventions. Therefore, field work was conducted throughout the study area. The methodology involved detailed mapping of aquifers, identifying and mapping sources of contamination, collecting and analysing groundwater, surface water and rainwater samples for quality monitoring, conducting well inventories, and monitoring water levels. Additionally, feedback from farmers was collected to provide valuable insights into local groundwater conditions and challenges.

8.1 FARMERS FEEDBACK

During the field study, interactions were conducted with farmers, and 7 feedback responses were collected (Farmers feedback proforma and photographs are given in **Annexure-XIV**. These interactions provided valuable insights into the challenges and concerns faced by the farmers, encompassing aspects such as agricultural practices, resource utilization, and working conditions. Summary of the feedback collected from the farmers is given below;

- Farmers, in regions where agricultural lands are distant from surface water bodies, farmers often resort to constructing deep bore wells to access groundwater. These wells typically reach depths of 800 to 1000 feet, tapping into the contact zones between sandstone and basalt formations. The discharge rates of these wells can vary significantly, generally ranging from 3 to 10 liters per second (lps), with some even exceeding 10 lps. This high yield is crucial for sustaining intensive agricultural practices in areas lacking surface water resources. On the other hand, smaller-scale farmers, constrained by financial resources, can usually only afford to drill bore wells to depths of 400 to 600 feet. The discharge rates of these shallower wells are markedly lower, typically between 0.5 to 1.5 lps.
- Additionally, farmers located near the Chambal and Kshipra rivers often opt for more direct irrigation methods by installing pumps directly into the rivers, leveraging the abundant surface water for their agricultural needs. This variability in water access and

discharge rates reflects the diverse strategies employed by farmers based on their proximity to water sources and financial capacities.

- In the central part and southern part of the study area observed that farmers are using compressor pumps in the deep bore wells and store the water in cement tanks or dug wells for irrigation and drinking. Most of the dug wells observed in these areas having deep water level maximum upto 26 mbgl and become dry if irrigation has done for 2 hours continuously.
- In both the eastern and western regions, particularly along the Chambal and Kshipra rivers, groundwater levels are relatively shallow. Bore wells tend to have reduced depths, and dug wells remain functional throughout the year. However, water quality presents a significant concern, especially in the Chambal river belt, where issues related to contamination or salinity may be prevalent.
- The predominant crops cultivated during the Kharif season include soybean, urad and moong. These crops are typically sown with the onset of the monsoon and harvested before the winter season. During the Rabi season, the main crops grown are gram, wheat, peas and garlic. These crops are sown after the monsoon ends and are harvested in the spring.

8.2 GROUNDWATER RELATED ISSUE

Groundwater issues can be quite complex, as groundwater is a crucial resource for drinking water, agriculture, and industry. Here are some problems related to groundwater

8.2.1 Deeper water level

During the field work deeper water levels has been observed in both dug wells and bore wells. Areas showing deeper water levels i.e., more than 10 mbgl has observed in the dug wells and more than 50 mbgl has observed in the bore wells which was shown in **Fig 8.1** The maximum water level observed in dug wells ranging upto 18.22 mbgl and bore wells upto 167.65 mbgl. In summer months bore wells are the major source of water and tapping it from 900 ft depth bore well.

8.2.2 Nitrate Contamination in Shallow Aquifer and Deep Aquifer

During the extensive field work ,224 samples are collected during Pre-monsoon study for ground water quality study in water stressed Alot block, it is observed that nitrate levels exceeding the BIS permissible limit (>45 mg/l) in 50 key wells representing the shallow aquifer and 48 key wells representing the deeper aquifer. After the Post monsoon analysis it is observed that almost all wells showing the nitrate contamination in shallow aquifer i.e., nearly 46 wells and 29 wells showing the contamination in deeper aquifer shown in **(Fig. 8.1)**.

8.2.3 High Value of EC observed in Shallow Aquifer and Deep Aquifer

The samples collected all over the study area for groundwater quality revealed the high values of EC observed in shallow and mainly in deep aquifer. It is observed that values more than 2000 µs/cm is observed in 26 key wells of shallow aquifer and 45 key wells in deeper aquifer. After Post monsoon analysis values more than 2000 µs/cm is observed in 15 key wells of shallow aquifer and 13 key wells in deeper aquifer and point locations are shown in **Fig. 8.1.**

8.2.4 Improper Well Design

Alot study area is majorly occupied with Deccan traps in which basalt hard rock has multiple collapsible formations such as intervening clays such as red boles so well construction was a primary issue combined with deeper water levels, leading to the short-term functionality of wells. Most of the handpumps and bore wells are abandoned during the field study. Area having collapsible formations are shown in **Fig 7.1.**

8.2.5 Limited Phreatic Aquifer thickness

As the study area majorly occupied with hard rock except along the Chambal, Luni and Kshipra in which marginal alluvium is present most of the area facing a major issue with the limited phreatic aquifer thickness **(Fig. 8.1)**, resulting in low yield and sustainability challenges.

8.2.6 Land subsidence

Land subsidence in basaltic terrain can occur due to the flushing of intertrappean red bole beds, which are clay-rich layers interspersed between basaltic lava flows. These red bole beds act as impermeable barriers, controlling groundwater flow within the basaltic sequence. However, excessive groundwater extraction or heavy rainfall can cause the red bole beds to erode and flush out, reducing their ability to retain water. This leads to destabilization of the overlying basalt layers. The loss of these beds diminishes soil cohesion and can trigger subsidence, where the ground surface gradually sinks. This subsidence can damage infrastructure, alter drainage patterns, and reduce agricultural productivity, highlighting the need for sustainable water management in basaltic regions. Area having land subsidence are shown in **Fig 8.1.**

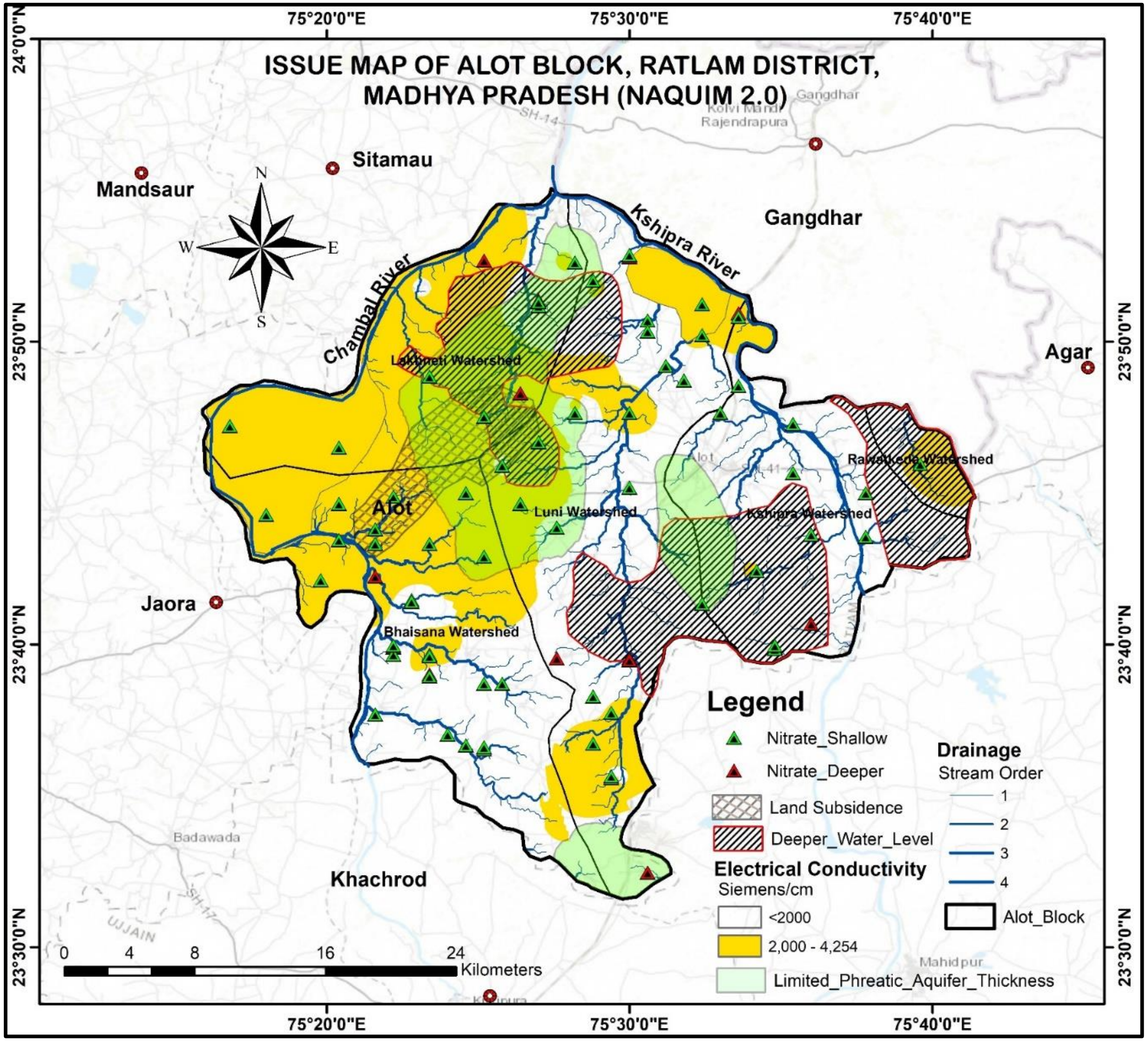


Fig. 8.1: Showing map of groundwater related issues within the study area

CHAPTER 9

GROUNDWATER MANAGEMENT PLAN

9.1 DELINEATION OF RECHARGE WORTHY AREA AND PROPOSED ARTIFICIAL RECHARGE PLAN

9.1.1 Objective

The primary goal of this chapter is to delineate recharge-prone zones within the study area and develop an Artificial Recharge Plan aimed at addressing the deeper groundwater levels in both shallow and deeper aquifers.

9.1.2 Methodology

9.1.2.1 Delineation of Recharge worthy zone in the study area

As the study area is predominantly composed of hard rock formations, including Vindhyan Sandstone and Deccan Trap basalt, recharge zones have been identified specifically for the unconfined or shallow aquifers. This is due to the limited recharge potential of the semi-confined and deeper aquifers in such hard rock terrain. To identify these recharge-worthy zones, five watersheds — Luni, Rawatkheda, Kshipra, Bhaisana, and Lakhneti — have been delineated within the study area. The following factors were considered in the demarcation process: land use/land cover, decadal post-monsoon water table depth, weathering thickness, rainfall, slope, presence of water bodies and drainage.

9.1.2.1.1 Drainage

The drainage network significantly influences groundwater recharge by directing surface water into permeable zones, where it infiltrates and replenishes aquifers. In areas with well-developed drainage, gentle slopes, and permeable soils, recharge is more effective, making the drainage system a vital component in sustaining groundwater levels, especially in hard rock terrains. Drainage Map was prepared using Digital elevation data.

9.1.2.1.2 Land use/Land cover

Land use and land cover (LULC) significantly impact groundwater recharge. Natural vegetation and permeable surfaces promote infiltration, enhancing recharge, while urbanization, deforestation, and impermeable surfaces reduce it by increasing runoff. Managing LULC is crucial for maintaining groundwater levels, particularly in areas with limited natural recharge potential. LULC 2022 map was prepared using USGS sentinel data on 10 m resolution and it is estimated that about 93 % study area is covered with cropped area.

9.1.2.1.3 Post-Monsoon Depth to Water Level

Post-monsoon water level depths are crucial in groundwater recharge assessment. Shallow depths indicate effective recharge from monsoon rains, enhancing aquifer replenishment. However, deeper levels suggest limited recharge, potentially due to over-extraction or poor infiltration. Monitoring these levels helps in sustainable groundwater management and planning recharge interventions.

9.1.2.1.4 Weathering Thickness

Weathering thickness plays a vital role in groundwater recharge by influencing the permeability and porosity of the subsurface. A thicker weathered zone allows greater infiltration of rainwater, enhancing recharge. Conversely, a thinner or less weathered layer may limit water movement, reducing the recharge potential and affecting groundwater availability. Weathering thickness map was prepared using key wells data of shallow aquifer falls within the study area.

9.1.2.1.5 Rainfall

Rainfall is the primary source of groundwater recharge, replenishing aquifers through infiltration. The amount, intensity, and duration of rainfall determine how effectively water penetrates the soil and reaches the water table. Consistent rainfall supports sustainable recharge, while irregular or intense rainfall may lead to runoff, reducing recharge efficiency. The study area receives average 992.8 mm of rainfall from South-west monsoon during June to September. Theissen polygon method was used to calculate monsoonal rainfall for each watershed.

9.1.2.1.6 Slope

Slope significantly influences groundwater recharge by affecting the movement of surface water. Gentle slopes promote infiltration, allowing rainwater to percolate into the ground, enhancing recharge. Steeper slopes, however, cause rapid runoff, reducing the time for water to infiltrate, thus limiting recharge potential and contributing to surface erosion. For this study, area having slope greater than 20% is not considered for artificial recharge. Slope map was prepared using Digital elevation data of SRTM on 30 m resolution. Data has been obtained from USGS Earth explorer.

All the layers were prepared in ArcGIS 10.8 and integrated to delineate the artificial recharge zone. The layers of drainage, Land use/land cover, post monsoon depth to water level, weathering thickness and slope are shown in **Fig. 9.1.**

9.1.2.1.7 For preparation of Artificial Recharge Plan

Artificial Recharge plan was prepared for the areas suitable for recharge. All the five watersheds were taken to propose artificial recharge structures. Two crucial aspects for devising an artificial recharge plan include determining recharge-efficient water and assessing available space. The calculation process for both is outlined below:

➢ **For computing Recharge efficient water:**

- Determine the watershed area and deduct the extent of non-rechargeable zones, if present within the watershed, to compute the effective rechargeable area in Ha.
- Compute the monsoonal rainfall (mm) for the particular watershed using Theissen polygon method. Rainfall should be converted into inches.
- For the computed rainfall, determine the surface runoff coefficient **(Annexure VI)**
- Calculate the surface runoff using the following formula;

9.1.2.1.8 Surface runoff- Area (Ha)* Runoff coefficient* Rainfall (m)

- Calculate the baseflow which is considered as 25% of surface runoff.
- Compute surplus runoff by deducting baseflow from surface runoff.
- Determine the committed runoff, accounting for 70% of surplus runoff, allocated for non-rechargeable purposes.
- Calculate non-committed runoff, representing 30% of surplus runoff, which is designated for recharge purposes.
- Calculate evaporation losses, equivalent to 25% of non-committed runoff, representing the amount of water lost through evaporation from surface water bodies or soil.
- Recharge-efficient water is determined by subtracting evaporation losses from non-committed runoff, representing the portion of water available for groundwater recharge.

➢ **For assessing available storage for artificial recharge:**

- Determine the specific yield based on the lithology of the watershed according to established standard norms. **(Annexure-VII)**
- Compute the unsaturated thickness by analysing historical depth to post-monsoon water level for each watershed.
- Calculate the available volume for storage using following formula;

Available storage- Area (Ha)* specific yield* Unsaturated thickness (m).

- The water resource needed to fill the available space is determined by adding 133% to the available space, accounting for losses.

9.1.3 Result and Discussion:

The recharge-worthy zone map was created by integrating all the aforementioned layers with particular emphasis placed on slope and post-monsoon depth to water level layer, assigning them greater weightage in the integration process. The map is displayed in **Fig. 9.1.**

In the delineated five watersheds, some portion of area not suitable for artificial recharge in 4 watersheds except Rawat kheda watershed. In that areas water conservation structures are proposed as alternate source for drinking and irrigation. Area suitable for recharge proposed with conservation with recharge like check dam with recharge shafts are to be proposed. A village has been selected as a case study to serve as a model for other villages within the study area. During the field study, specific locations for recharge structures were ground-truthed with the assistance of MGNREGA and the watershed department. These verified locations have been documented and are included in **Annexure XIII** of this report consequently, rooftop rainwater harvesting with recharge wells or abandoned wells is proposed for all Watersheds where govt buildings are available. The calculation procedure details are outlined as follows:

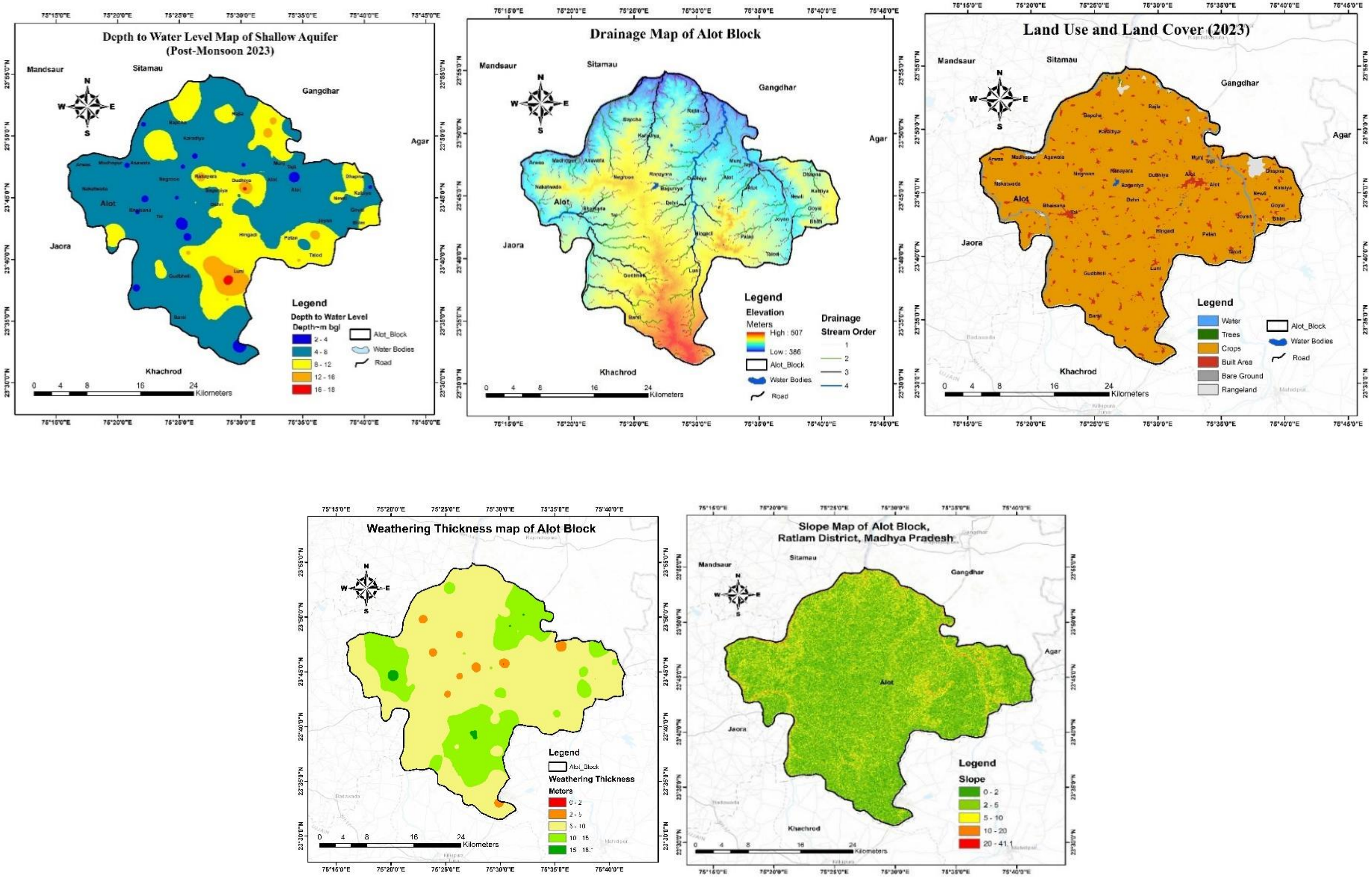


Fig .9.1: Different Layers used to demarcate the recharge worthy zone in and around the study area

9.1.3.1 Rawat Kheda Watershed

Recharge efficient water;

- Total Area of watershed= 2212.17 Ha
- Recharge worthy area= 2212.17 Ha
- Monsoonal Rainfall= 992.8 mm= 0.9928 m
- Surface runoff coefficient= 27.4%, 0.274 (From strange table)
- Surface runoff = A*RC*RF (m)

  =2212.17*0.274*0.9928

  = 601.77 Ha-m
- Baseflow (25% of surface runoff) = 150.44 Ham
- Surplus runoff (surface runoff-baseflow) = 451.328 Ham
- Non-committed runoff (30% of surplus runoff) =135.39 Ham
- Evaporation losses (25% of non-committed) = 33.85 Ham
- Recharge efficient water = (Non-committed runoff- Evaporation losses); 135.39-33.85= **101.548 Ham**

Available storage:

Deccan Trap basalt covers all Watershed, with a specific yield of 3% for both formations according to standard norms. Therefore, a specific yield of 3% is taken for this watershed.

- Specific Yield- 3%- 0.03

Based on the post-monsoon depth to water level data spanning from field key wells

- Unsaturated thickness for AR= (7.535-3) =4.535 mbgl
- Available storage volume- A*Sy*Unsaturated Thickness= 2212.12*0.03*4.535= 300.96 Ham
- WR Required to fill the available storage volume= 300.96* 1.33= **400.284 Ham**

Since the recharge-efficient water quantity is less than the available storage volume, the proposed total recharge from rooftop rainwater harvesting will be based on the quantity of recharge-efficient water.

The number of proposed artificial recharge structures are designed in accordance with field conditions not on the quantity available for recharge. **Table: 9.1** shows the proposed artificial recharge structures.

Table 9.1: Proposed Artificial Recharge Structures within Rawat Kheda Watershed

Type	Water intake capacity	Nos.	Unit Cost (in lakhs)	Total Cost (in lakhs)	Total Recharge
Check dam with recharge shaft (size-15 m (L)* 300m (water spread area)* 1.5 m (H)	0.7 ham (3 times filling) Total- 2.1 Ham	11	10	110	23.1 Ham
Gully plug (mainly for conservation of soil moisture, infiltration, to stop soil erosion)	0.001 Ham (3 times filling) Total- 0.003 Ham	13	0.5	6.5	0.039 Ham
Percolation tank	2 (including 3 times filling)	2	20	40	40 Ham
Recharge shaft					
				Total- 156.5	Total Recharge from all Structures= 63.1 Ham

Total 63.1 Ham recharge is possible through construction of aforementioned structures.

The location of each structure is given in **Annexure-VIII** and illustrated on **Fig.9.4.**

9.1.3.2 Kshipra Watershed

Recharge efficient water:

- Total Area of watershed= 16410 Ha
- Rainfall = 992.8.3 mm = 0.9928m
- Surface runoff coefficient= 27.4%, 0.274 (from strange table)
- Surface runoff = A *RC*RF

  = 16410*0.274*0.9928

  = 4463.96 Ham
- Baseflow (25% of surface runoff) = 1115.99 Ham
- Surplus runoff (surface runoff-baseflow) = 3347.974 Ham
- Non-committed runoff (30% SR) = 1004.39 Ham
- Evaporation losses (25% of non-committed) = 251.09 Ham
- Recharge efficient water= 1004.39 – 251.098 = **753.294 Ham**

Available storage:

Watershed is entirely covered by Deccan trap basalt, Hence

- Specific Yield- 3%- 0.03

Based on the post-monsoon depth to water level data from field key wells;

- Unsaturated thickness for AR= (7.402-3) = 4.402 mbgl
- Available storage volume- A*Sy*Unsaturated Thickness =16410*0.03*4.402 = 2167.104 Ham
- Water Resource required to fill the available storage volume= 2167.1* 1.33

  = **2882.249 Ham**

Since the recharge-efficient water quantity is less than the available storage volume, the proposed total recharge from artificial recharge structures will be based on the quantity of recharge efficient water.

The number of proposed artificial recharge structures are designed in accordance with field conditions not on the quantity available for recharge. **Table: 9.2** shows the proposed artificial recharge structures.

Table: 9.2 Proposed Artificial Recharge Structures within Kshipra Watershed

Type	Water intake capacity	Nos.	Unit Cost (in lakhs)	Total Cost (in lakhs)	Total Recharge
Check dam with recharge shaft (size-15 m (L)* 300m (water spread area)* 1.5 m (H)	0.7 ham (3 times filling) Total- 2.1 Ham	33	10	330	69.3 Ham
Gully plug/ Nala bunds (mainly for conservation of soil moisture, infiltration, to stop soil erosion)	0.001 Ham (3 times filling) Total- 0.003 Ham	79	0.5	39.5	0.237 Ham
Percolation tank	20 (including 3 times filling)	4	20	80	80 Ham
Conservation Ponds		3	20	60	
				Total- 509.5	Total Recharge from all Structures = 149.53 Ham

Total 745 Ham recharge is possible through construction of aforementioned structures

The location of each structure is given in **Annexure-IX** and illustrated on **Fig.9.4.**

9.1.3.3 Luni Watershed

Recharge efficient water:

- Total Area of watershed = 23700 Ha
- Rainfall = 992.8 mm = 0.9928 m
- Surface runoff coefficient- 27.4%, 0.274 (Using strange table)
- Surface runoff = A*RC*RF (m)

  = 23700*0.274*0.9928

  = 6647 Ham
- Baseflow (25% of surface runoff) = 1611.76 Ham
- Surplus runoff (surface runoff-baseflow) = 4835.28 Ham

- Non-committed runoff (30% of surplus runoff) = 1450.58 Ham
- Evaporation losses (25% of non-committed) = 362.64 Ham
- Recharge efficient water= 1450.58 – 362.64 = **1088 Ham**

Available storage:

Deccan trap basalt cover whole area of Luni watershed, Hence specific yield is taken as 3%.

- Specific Yield - 3%- 0.03 (based on lithology)

Based on the post-monsoon depth to water level data from field key wells;

- Unsaturated thickness for AR= (8.22-3) = 5.22 mbgl
- Available storage volume- A*Sy*Unsaturated Thickness=23700*0.03*5.22

  = 3711.42 Ham

- Water resource required to fill the available storage volume= 3711.42* 1.33

  = 4936.18 Ham

Since the recharge-efficient water quantity is less than the available storage volume, the proposed total recharge from artificial recharge structures will be based on the quantity of recharge efficient water and numbers are suggested based on field condition. Proposed artificial recharge structures are tabulated in **Table: 9.3.**

Table: 9.3 Proposed Artificial Recharge Structures within Luni Watershed

Type	Water intake capacity	Nos.	Unit Cost (in Lakhs)	Total Cost (in Lakhs)	Total Recharge
Check dam with Recharge shaft (size-15 m (L)* 300m (water spread area)*1.5 m (H)	0.7 ham (3 times filling) Total- 2.1 Ham	61	10	610	128.1 Ham
Gully plug (mainly for conservation of soil moisture, infiltration, to stop soil erosion)	0.001 Ham (3 times filling) Total- 0.003 Ham	98	0.5	49	0.294 Ham
Percolation tank	20 (including 3 times filling)	13	20	260	260 Ham
Conservation ponds		7	20	140	
				Total-1059	Total Recharge- 388.39 Ham

Total 388.39 Ham recharge is possible through construction of aforementioned structures.

The location of each structure is given in **Annexure-X** and illustrated in **Fig.9.4.**

9.1.3.4 Lakhneti Watershed

Recharge efficient water:

- Total Area of watershed= 11180 Ha
- Rainfall= 992.8.3 mm= 0.9928m
- Surface runoff coefficient= 27.4%, 0.274 (from strange table)
- Surface runoff = A *RC*RF

  = 11180*0.274*0.9928

  = 3041.26 Ham
- Baseflow (25% of surface runoff) = 760.3 Ham
- Surplus runoff (surface runoff-baseflow) = 2280.94 Ham
- Non-committed runoff (30% SR) = 684.28 Ham
- Evaporation losses (25% of non-committed) = 171.07 Ham
- Recharge efficient water = 684.28 – 171.07 = **513.21 Ham**

Available storage:

Watershed is entirely covered by Deccan trap basalt, Hence

- Specific Yield- 3%- 0.03

Based on the post-monsoon depth to water level data from field key wells;

- Unsaturated thickness for AR= (9.11-3) = 6.11 mbgl
- Available storage volume- A*Sy*Unsaturated Thickness =11180*0.03*6.11 = 2049.2 Ham
- Water Resource required to fill the available storage volume= 2049.29* 1.33

  = **2725.56 Ham**

Since the recharge-efficient water quantity is less than the available storage volume, the proposed total recharge from artificial recharge structures will be based on the quantity of recharge efficient water.

The number of proposed artificial recharge structures are designed in accordance with field conditions not on the quantity available for recharge. **Table: 9.4** shows the proposed artificial recharge structures.

Table: 9.4 Proposed Artificial Recharge Structures within Lakhneti Watershed

Type	Water intake capacity	Nos.	Unit Cost (in lakhs)	Total Cost (in lakhs)	Total Recharge
Check dam with Recharge shaft (size-15 m (L) * 300m (water spread area) * 1.5 m (H)	0.7 ham (3 times filling) Total- 2.1 Ham	63	10	630	132.3 Ham
Gully plug/Nala bund (mainly for conservation of soil moisture, infiltration, to stop soil erosion)	0.001 Ham (3 times filling) Total- 0.003 Ham	70	0.5	35	0.21 Ham
Percolation tank	20 (including 3 times filling)	11	20	220	220 Ham
				Total-885	Total Recharge from all Structures= 352.5 Ham

Total **352.5** Ham recharge is possible through construction of aforementioned structures.

The location of each structure is given in **Annexure-X**I and illustrated in **Fig.9.4.**

9.1.3.5 Bhaisana Watershed

Recharge efficient water:

- Total Area of watershed= 21740 Ha
- Rainfall= 992.8.3 mm= 0.9928m
- Surface runoff coefficient= 27.4%, 0.274 (from strange table)
- Surface runoff = A *RC*RF

  = 21740*0.274*0.9928

  = 5913.87 Ham
- Baseflow (25% of surface runoff) = 1478.46 Ham
- Surplus runoff (surface runoff-baseflow) = 4435.4 Ham
- Non-committed runoff (30% SR) = 1330.62 Ham

- Evaporation losses (25% of non-committed) = 332.65 Ham
- Recharge efficient water= 1330.62 – 332.65 = **997.965 Ham**

Available storage:

Watershed is entirely covered by Deccan trap basalt, Hence

- Specific Yield- 3%- 0.03

Based on the post-monsoon depth to water level data from field key wells;

- Unsaturated thickness for AR= (5.08-3) = 2.08 mbgl
- Available storage volume- A*Sy*Unsaturated Thickness =21740*0.03*2.08 = 1359.57 Ham
- Water Resource required to fill the available storage volume= 1359.57* 1.33

= **1804.24 Ham**

Since the recharge-efficient water quantity is less than the available storage volume, the proposed total recharge from artificial recharge structures will be based on the quantity of recharge efficient water.

The number of proposed artificial recharge structures are designed in accordance with field conditions not on the quantity available for recharge. **Table: 9.5** shows the proposed artificial recharge structures.

Table: 9.5 Proposed Artificial Recharge Structures within Bhaisana Watershed

Type	**Water intake capacity**	**Nos.**	**Unit Cost (in lakhs)**	**Total Cost (in lakhs)**	**Total Recharge**
Check dam/ Stop dam with Recharge shaft (size-15 m (L)* 300m (water spread area)* 1.5 m (H)	0.7 ham (3 times filling) Total- 2.1 Ham	59	10	590	123.9 Ham
Gully plug (mainly for conservation of soil moisture, infiltration, to stop soil erosion)	0.001 Ham (3 times filling) Total- 0.003 Ham	95	0.5	47.5	0.285 Ham
Percolation tank	20 (including 3 times filling)	14	20	280	280 Ham

Type	Water intake capacity	Nos.	Unit Cost (in lakhs)	Total Cost (in lakhs)	Total Recharge
Renovation of stop dam	0.7 ham (3 times filling) Total- 2.1 Ham	01	2.5	2.5	2.1 Ham
Renovation of pond	20 (including 3 times filling)	01	5	5	20 Ham
				Total- 925	Total Recharge from all Structures = 426.2 Ham

Total 426.2 Ham recharge is possible through construction of aforementioned structures.

The location of each structure is given in **Annexure-X**II and illustrated in **Fig.9.4.**

Roof top rainwater harvesting should be implemented in every govt building in every urban region (Tal and Alot) and every panchayat buildings i.e., school, panchayat bhawans, community health centers etc.

As per Model building bye laws, roof top area of 100 Sq-m or more is suitable for Roof top rainwater harvesting.

Consider,

- Area of Roof top=100 Sq-m

  = 0.01 Ha

- Rainfall= 75 mm, as per norm (maximum amount of daily Rainfall in 2 spells)

  =0.075 m

- Run-off coefficient= 0.85 (CGWA portal)
- Quantum of run-off available= 100* 0.075* 0.85 m3/hr

  = 6.375 m3/hr

  = 0.0006375 Ham/hr

- Average recharge capacity of unconfined aquifer within watershed= 0.85 lps

  =3.06 m3/hr.

- Water available from 1 rooftop- 6.375 m3/hr
- No. of Borewells= 6.375/3.06 = 2.08 (**2 Borewells**)

Proposed depth- (Depth approx. 10 mbgl or as per field condition)

- Minimum size of Filtration tank required,

(Depth-2.5 m, length and width 1.6 m)

- If the total recharge efficient water- 100 Ham
- No. of house hold required- 1000000/6.375

- 156,862 (approx.)

To recharge 100 Ham, a total of **1,56,862** households with an average area of 100 sq-m each are needed. Additionally, 1 filtration tanks, with two number of borewells (BW), having a depth of 10 mbgl, are required for this purpose. Schematics of filtration tank and roof top rain water harvesting with recharge well are shown in **Fig.9.2 and 9.3**.

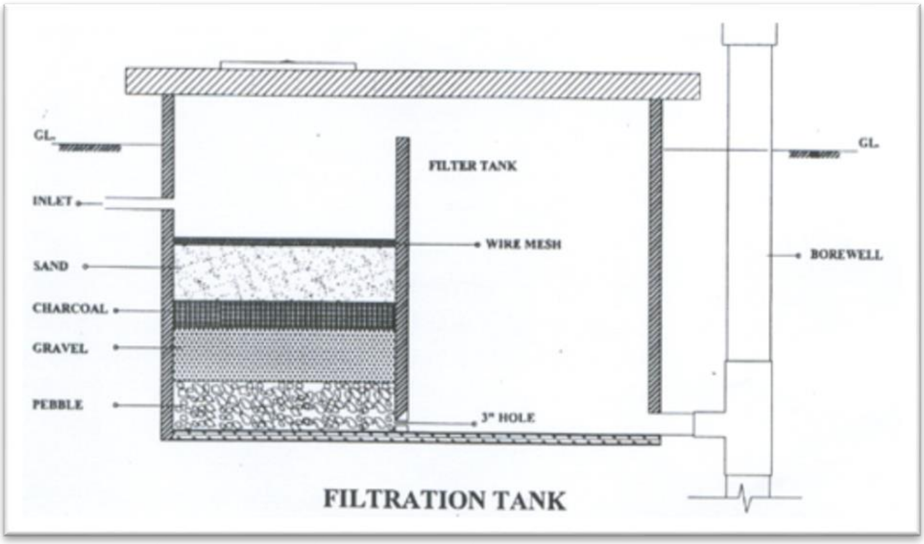


Fig. 9.2 Schematics of Filtration Tank (Source: MPPCB)

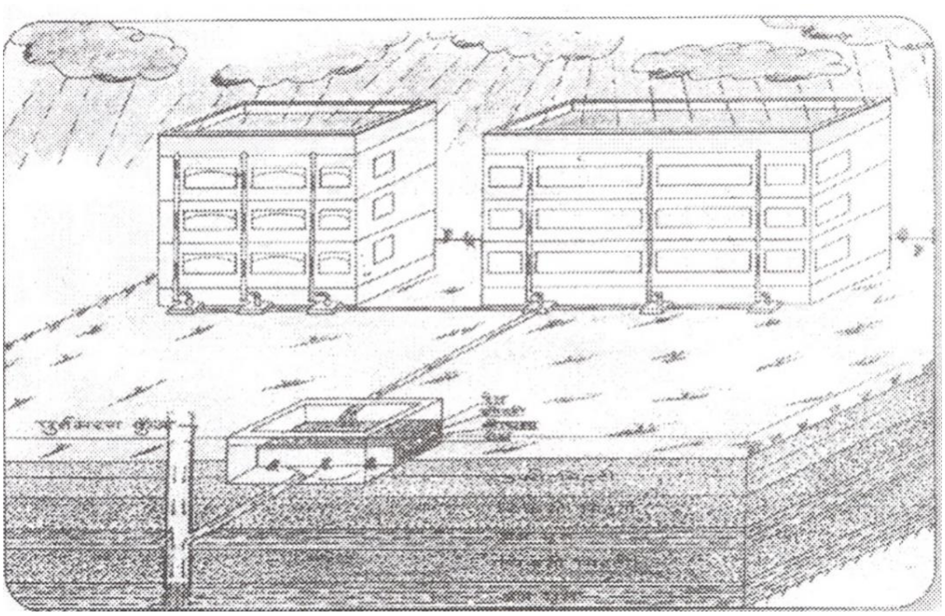


Fig. 9.3: depicting Roof top rainwater harvesting with recharge of aquifer system (Source-CGWB)

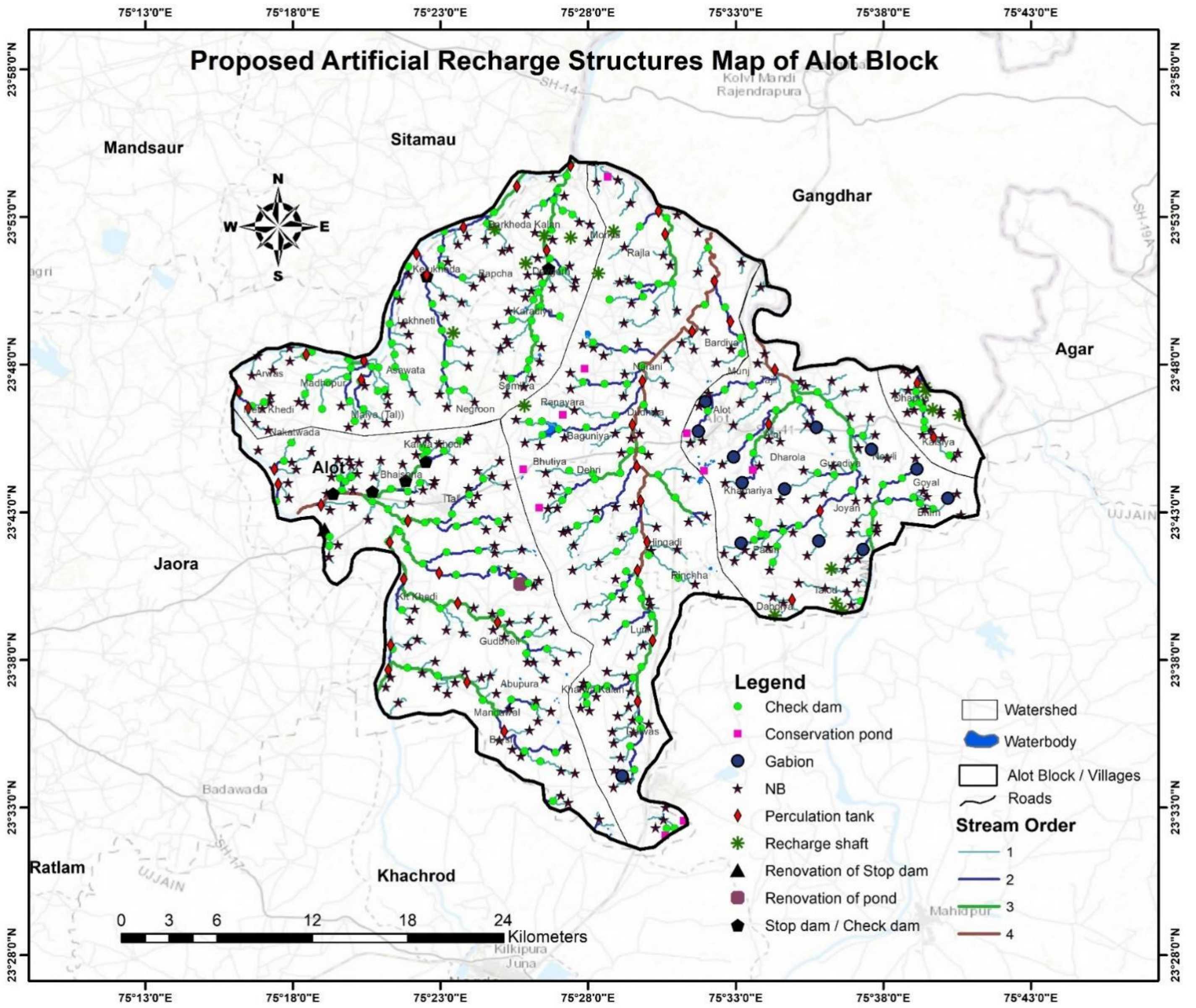


Fig. 9.4: Proposed Watershed-wise Artificial Recharge Structures

9.1.3.6 CASE STUDY ON THE VILLAGE NIPANIYA LEELA

During the field study, the village of Nipaniya Leela was selected as a model site for assessing source sustainability and proposing artificial recharge structures. These structures were recommended based on field observations, including the water levels of shallow and deep aquifers, weathering thickness, transmissivity, slope, aquifer thickness, and drainage patterns of the village. A summary of the village's key characteristics is presented in Table 9.6, with its location depicted in Figure 9.5. To inform the water management plan for Nipaniya Leela, a slug test was conducted, and observations from the recovery of water levels and borewell discharge were recorded (detailed in Table 9.7). Based on these findings, appropriate recharge structures were proposed, as outlined in Table 9.8.

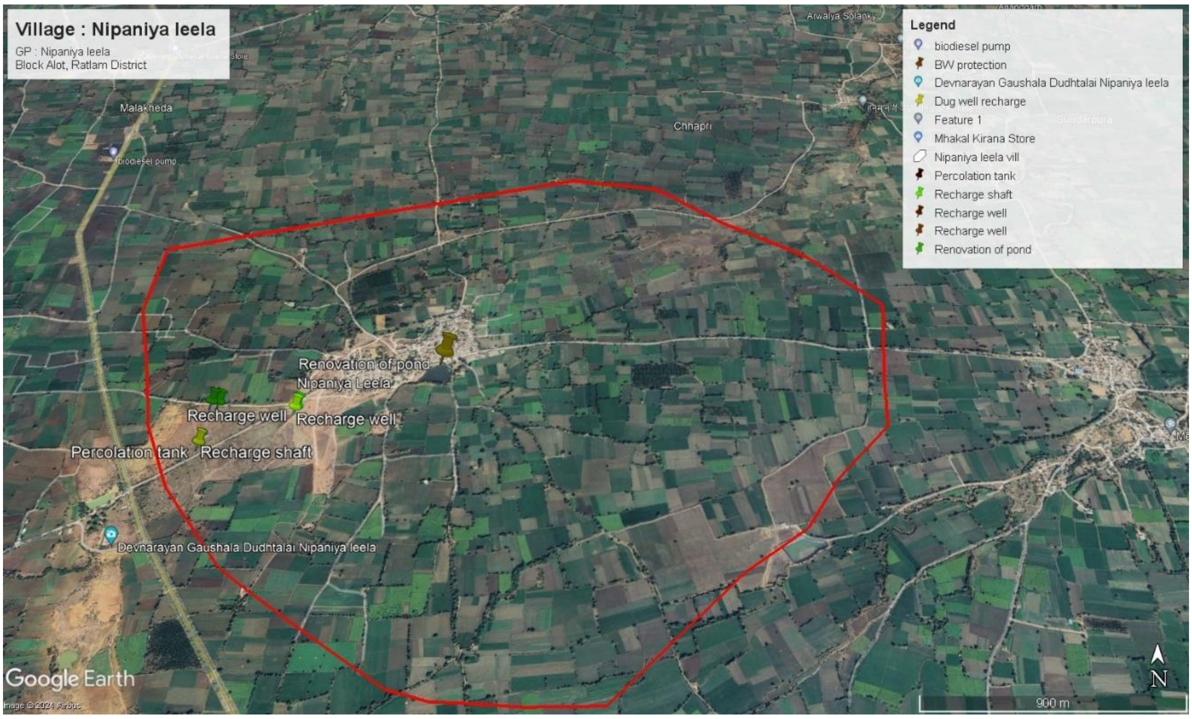


Fig. 9.5: Location map of Nipaniya Leela village

Table 9.6: Sailent details of Nipaniya Leela village

Source for Water Supply	Mainly deeper and also Shallow Aquifer (DW and BW)
Source Coordinate	N 23.65807,
	E 75.4584
Weathered thickness	18 m
Water Level	18 m dry during pre and post monsoon
Major Aquifer	Laterite, Basalt

Table 9.7: Sailent details of bore well and type of recharge structures proposed

Suitable recharge structures and sustainability measures	Percolation tank, Dug well recharge, Recharge shafts, Renovation of pond, Abondoned wells used as recharge wells
Major source	BW
Discharge	280 lpm

Table 9.8: Sailent details of proposed recharge structures

S No	Village	Latitude	Longitude	Type	Remarks
1	Nipaniya leela	23.65806	75.458691	Dug well recharge	Channnelise the run off water for dug well recharge
2	Nipaniya leela	23.65609	75.458415	Percolation tank	
3	Nipaniya leela	23.65609	75.458415	Recharge shaft	Upto 25m
4	Nipaniya leela	23.65807	75.458398	BW protection	Protection of source
5	Nipaniyaleela	23.66053	75.467826	Renovation of pond	Cleaning and deepening of pond
6	Nipaniyaleela	23.65786	75.461977	Recharge well	Abondoned well taken as recharge well
7	Nipaniyaleela	23.65779	75.461901	Recharge well	Abondoned well taken as recharge well

9.2 GROUNDWATER QUALITY MANAGEMENT INTERVENTIONS

9.2.1 Objective

The primary aim of this chapter is to develop a management plan to address groundwater quality challenges, specifically focusing on mitigating issues related to nitrate contamination and high electrical conductivity in both shallow and deeper aquifers.

9.2.2 Methodology

Groundwater quality issues were evaluated through the analysis of 224 samples taken from both shallow and deep aquifers during the pre-monsoon and post-monsoon periods. The analysis adhered to standard procedures outlined in the 23rd edition of the American Public Health Association (APHA) manual. Contamination sources were identified during field investigations. The management plan was subsequently formulated based on the issues identified.

9.2.3 Result and Discussion

9.2.3.1 Issue: Nitrate Contamination in Shallow and Deep Aquifer

Groundwater quality study in Alot study area detected nitrate levels exceeding the BIS permissible limit (>45 mg/l) in 50 key wells representing the shallow aquifer and 48 key wells representing the deeper aquifer. After the Post monsoon analysis it is observed that almost all wells showing the nitrate contamination in shallow aquifer i.e., nearly 46 wells and 29 wells showing the contamination in deeper aquifer. Highest nitrate is reported in the water sample collected from Shallow aquifer of Thuriya village (139 mg/l) and for deeper aquifer Patan village (201 mg/l) in pre monsoon

9.2.3.2 Issue: High Value of Electrical conductivity in shallow and deep aquifer:

The samples collected all over the study area for groundwater quality revealed the high values of EC observed in shallow and mainly in deep aquifer. It is observed that values more than 2000 µs/cm is observed in 26 key wells of shallow aquifer and 45 key wells in deeper aquifer. After Post monsoon analysis values more than 2000 µs/cm is observed in 15 key wells of shallow aquifer and 13 key wells in deeper aquifer, it was observed that the during pre-monsoon, EC ranged from 595 to 5025 (Avg 1730) µS at 25°C and 647 to 4311 (Avg 1746) µS at 25°C whereas from 550 to 7391 (Avg 1940) µS at 25°C and 540 to 3862 (Avg 2052) µS at 25°C during post-monsoon in shallow & deeper aquifer respectively.

9.2.3.3 Recommendation for Nitrate Contamination in Shallow and Deep Aquifer:

The primary source of nitrate contamination in the study area is attributed to excessive use of fertilizers during irrigation practises. Further, Human anthropogenic activities are the main causative agents in the increase of nutrients like nitrate, phosphates, chlorides, and calcium and ultimately lead to eutrophication (Shekhar et al, 2008). So the management would be efficient use of fertilizers will be promoted and recharge through rain water will dilute the concentration of nitrate in ground water.

9.2.3.4 Recommendation for High Value of Electrical conductivity in shallow and deep aquifer

To mitigate high electrical conductivity in groundwater within the study area Alot block, as shown in the issue map **(Fig 7.4)** one of the main source is irrigation along the chambal river these may be due to upstream Nagda industrial area dumping the solid matter into the chambal river so it is recommended to avoid irrigation through polluted Chambal river and implementing artificial recharge techniques, such as check dams and rainwater harvesting, to dilute salinity levels which are proposed. Regulating groundwater extraction and promoting sustainable agricultural practices, including the use of low-salinity irrigation methods, are essential.

9.3 DEMARCATION OF AQUIFERS SUITABLE FOR DRINKING WATER SUPPLY

9.3.1 Objective

The primary aim is to identify aquifers that meet the safety standards for drinking water quality.

9.3.2 Materials and methods

Water Quality Index (WQI) is a metric used to assess the overall quality of water based on multiple parameters. The WQI provides a single value representing the combined influence of various water quality parameters, allowing for a more straightforward interpretation and comparison. The method used for the calculation of the WQI was adapted from Sharma et al. 17 parameters (TDS, F^-, Cl^-, NO_3^-, SO_4^{2-}, HCO_3^-, Ca^{2+}, Mg^{2+}, total hardness, Zn, Cr, Uranium, Cu, Fe, Mn, Arsenic, and Lead) were considered to calculate the Water Quality Index. Following four equations has been used for WQI. (Reference: Sahu and Sikdar, 2008). 224 ground water samples were collected for each basic parameters and heavy metal analysis from shallow aquifer and deep aquifer during Pre monsoon and 133 samples are collected during post monsoon 2023.

$W_i = w_i / \sum_{i=1}^{n} w_i$ __________(1) $q_i = \left(\frac{C_i}{S_i}\right) \times 100$ _________(2) $SI_i = W_i \times q_i$ __________(3) $WQI = \sum_{i=1}^{n} SI_i$ __________(4)	Where: C_i- Observed concentration for i^{th} parameter Wi- Relative weight of i^{th} parameter w_i- Definite weight for i^{th} parameter S_i-recommended standard limit for i^{th} parameter q_i- Quality rating scale i^{th} parameter Sl_i- Sub-Index i^{th} parameter

Each parameter was assigned a definite weight (w_i) according to its relative importance on the overall quality of water, ranging from 1 to 5, where 5 was considered most significant while 1 was least significant. In the second step, the relative weight (W_i) was computed using equation (1). In the next step, the quality rating scale (qi) calculated by comparing the concentration of each parameter in the sample with its respective acceptable limit value, as suggested in the IS 10500:2012. Sub-indices (SI) were calculated to compute the WQI in the next step using equation (3). In final step, the WQI was calculated using equation (4)**.**

9.3.3 Results and Discussion

The WQI in shallow aquifer during pre-monsoon and post-monsoon of water stress Alot block of Ratlam district are ranged 29.04 to 257.74 and 33.68 to 142.16 respectively whereas in deeper aquifer ranged 25.39 to 195.14 and 30.4 to 116.5. The minimum, maximum and mean value of WQI is given below in Table 9.9; WQI of shallow and deeper aquifer is presented in **Annexure-XIII** respectively.

Sample Calculation has been shown in Table 9.9 for WQI calculation for Ground Water of Pipliya Tukur village collected during pre-monsoon sampling in study area. The water quality index for DW48 has been calculated 257.74, comes under very poor water category as per Yenugu et al. 2020 classification.

In the study area 93.23% in pre-monsoon and 96.51% in post-monsoon of shallow aquifer are found excellent to good water quality in terms of water quality index; whereas in deeper aquifer is found 93.18% in pre-monsoon and 93.33% excellent to good water quality. The WQI value more than 100 indicates the ground water under poor water category. In deeper aquifer, the WQI of all water is less than 100 value, its shows that the water is excellent to good category. The water quality index classification for shallow and deeper aquifer are given in Table 9.10**.**

Table 9.9: The Minimum, Maximum and Mean value of WQI in Shallow and Deeper Aquifer.

Water Quality	Shallow Aquifer		Deeper Aquifer	
	Pre-Monsoon	Post-Monsoon	Pre-Monsoon	Post-Monsoon
No. of Samples	133	86	88	45
Minimum Value	29.04	33.68	25.39	30.40
Maximum Value	257.74	142.16	195.14	116.51
Mean value	64.80	63.46	64.18	63.57

Table 9.10: Calculation of WQI for Ground Water Samples collected during pre-monsoon of Alot block

Water quality Index status	Water quality Index classification	Shallow Aquifer		Deeper Aquifer	
		Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon
Excellent	< 50	25.56	24.42	27.27	28.89
Good	50–100	67.67	72.09	65.91	64.44
Poor water	101–200	6.02	3.49	6.82	6.67
Very poor	201–300	0.75	0	0	0
Water unsuitable for drinking	> 300	0	0	0	0

9.3.4 Conclusion

Ground water quality of shallow and deeper aquifer of study area has been found excellent to good category as per as per Yenugu et al. 2020 classification. No major change has been found in WQI of study area after monsoon. During Pre-monsoon season only one location out of 133 nos of Ground water samples collected from shallow aquifer (Pipliyatukur) locations was assigned to marginal category drinking water having WQI between (WQI 201 to 300) due to High Mn concentration. Water Quality Index maps of shallow and deep aquifer for pre and post-monsoon are given in **Fig. 9.6, Fig. 9.7, Fig. 9.8 and Fig. 9.9.**

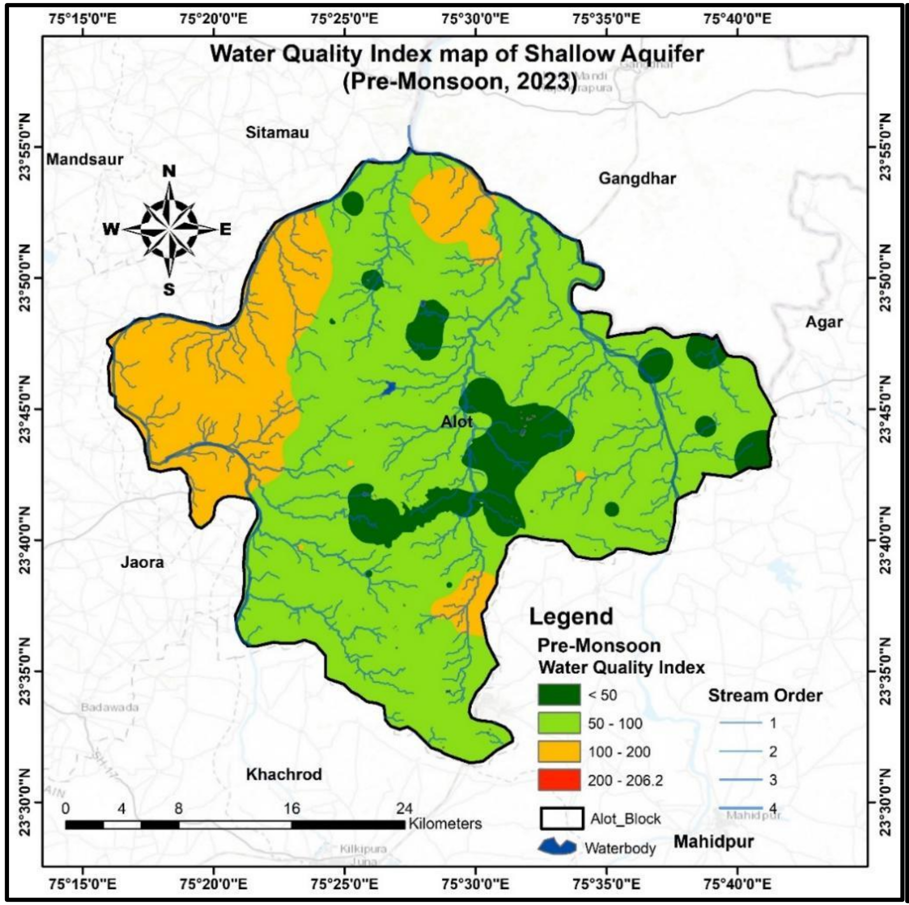


Fig. 9.6: Water Quality Index Map of Shallow aquifer for Pre-monsoon (2023)

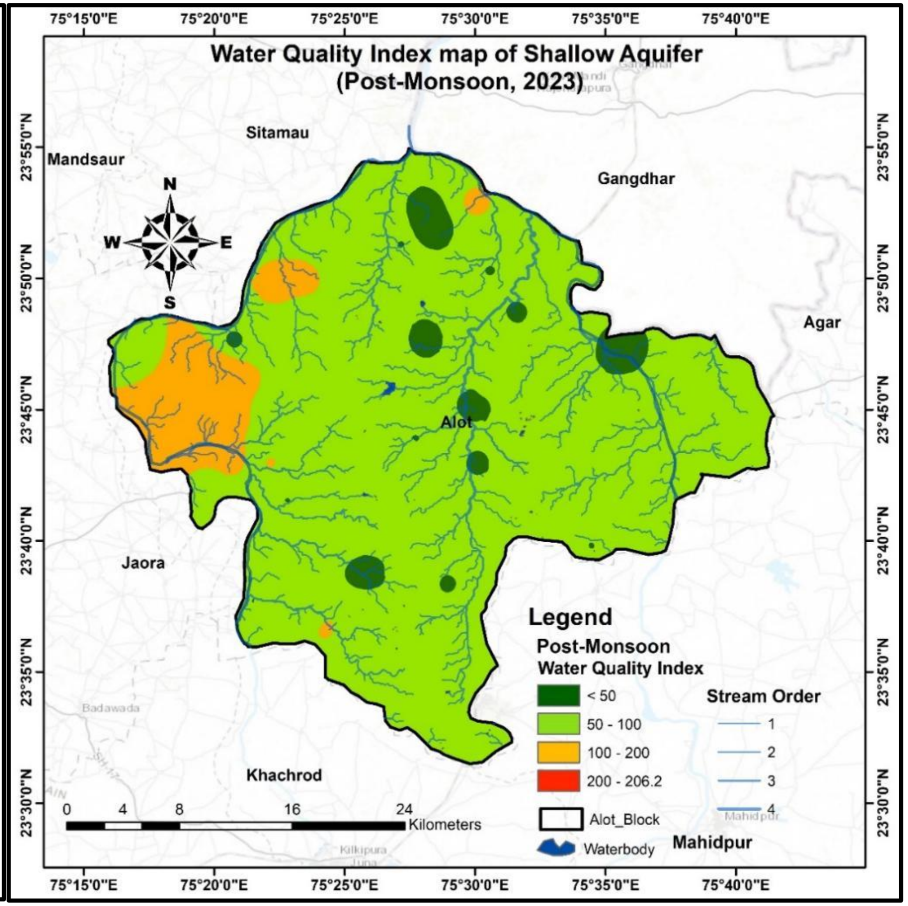


Fig. 9.7: Water Quality Index Map of Shallow aquifer for Post-monsoon (2023)

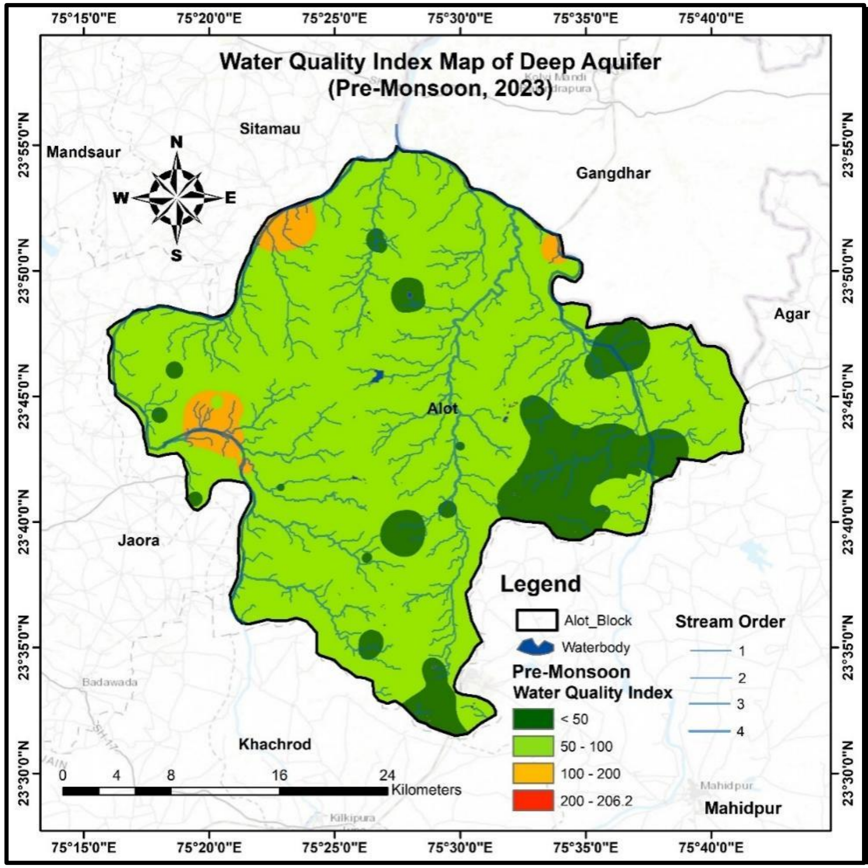


Fig. 9.8: Water Quality Index Map of Deep aquifer for Pre-monsoon (2023)

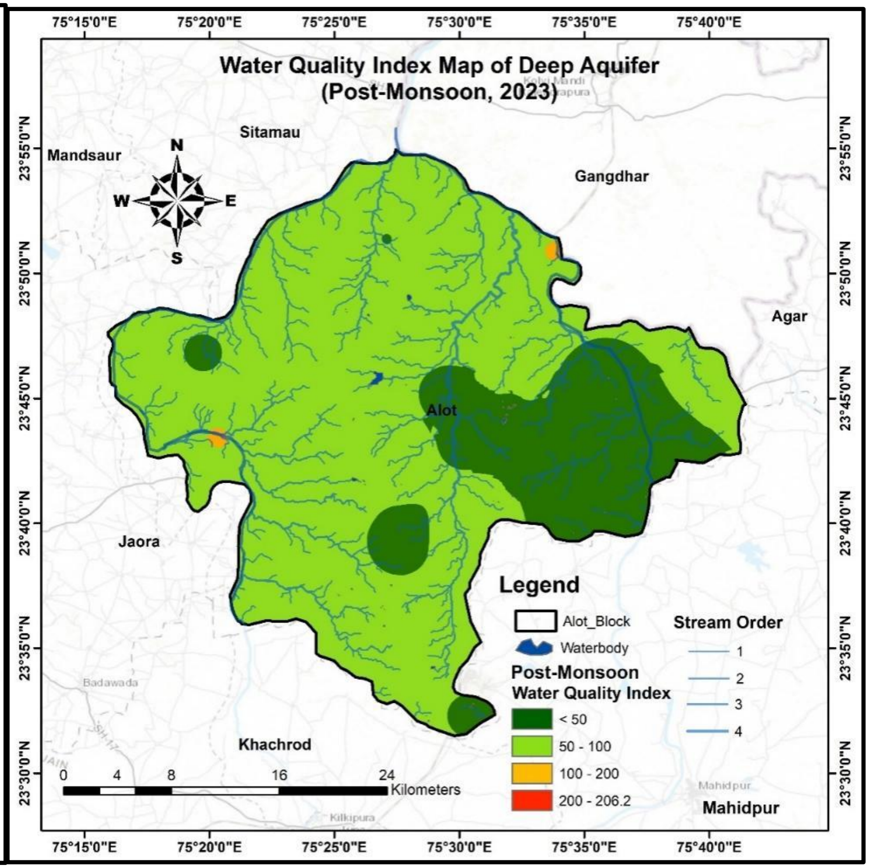


Fig. 9.9: Water Quality Index Map of Deep aquifer for Post-monsoon (2023)

9.4 IDENTIFICATION OF GROUNDWATER POTENTIAL AQUIFER FOR DRINKING WATER SUPPLY

9.4.1 Objective

The main objective of this chapter is to demarcate groundwater potential zones for drinking water supply within the study area.

9.4.2 Methodology

Groundwater potential zones of the study area have been demarcated using Vertical Electrical Sounding (VES) data. Transverse Resistance & Longitudinal Conductance has been calculated from interpreted VES results.

It can be envisaged that the VES stations with low to moderate S value and high T represents freshwater region. Increasing T values indicate high transmissivity of aquifers (Gupta G, 2015).

The Transverse Resistance (T) and Longitudinal Conductance (S) values are effectively useful for demarcating groundwater potential (Narendra, 2007). Ayolabi, (2005) stated that from the geo-electric parameters such as longitudinal conductance and transverse resistance the coefficient of anisotropy of the overburden material can be determined. Singh, (2003) stated that the transverse resistance (T) and longitudinal conductance (S) are used for better resolution of thin layers of both resistive and conductive properties. The transverse resistance (T) values can be calculated from VES results. The equation is as follows.

$$T = h1 \times \rho 1 + h2 \times \rho 2 \ldots\ldots\ldots + hn \times \rho n \quad in\ ohm.m^2$$

Where, T=Transverse Resistance, h=layer thickness, ρ = layer resistivity.

The Longitudinal conductance (S) values can be derived from VES results. The equation is as follows.

$$S = \frac{h1}{\rho 1} + \frac{h2}{\rho 2} \ldots\ldots\ldots \frac{hn}{\rho n} \quad in\ \text{mhos}$$

Where, S= Longitudinal Conductance, h=layer thickness, ρ = layer resistivity.

9.4.3 Result and Discussion

In the study area, regions characterized by high transverse resistivity (T) and low longitudinal conductivity (S) have been identified predominantly in the north-eastern, north-western, Southern, South-eastern & central sectors. In north-western region Chamble river & in northeastern region Kshipra river flows. Due to these rivers ground water potential in these regions is high. An average transverse resistivity value of 50000 ohm-m2 and an average longitudinal conductivity value of 5 mho have been considered. Groundwater potential zones have been delineated based on these criteria, with the identified areas exhibiting high T and low S indicative of favourable groundwater potential. Conversely, the remaining portions of the study area exhibit lower groundwater potential. The validity of the data is supported by the exploration details obtained from 8 exploratory wells. These wells, having low discharge rates, are situated within regions identified as having low groundwater potential. This confirmation reinforces the accuracy of the assessment, highlighting the consistency of findings across areas characterized by limited groundwater resources. Transverse resistivity, longitudinal conductivity and Groundwater potential zone maps are presented below in **Fig. 9.10, 9.11** and **9.12** respectively**.** The Groundwater Potential zone lie on the North-western and North Eastern parts along Chambal and Kshipra and some portion in Southern part of the study area.

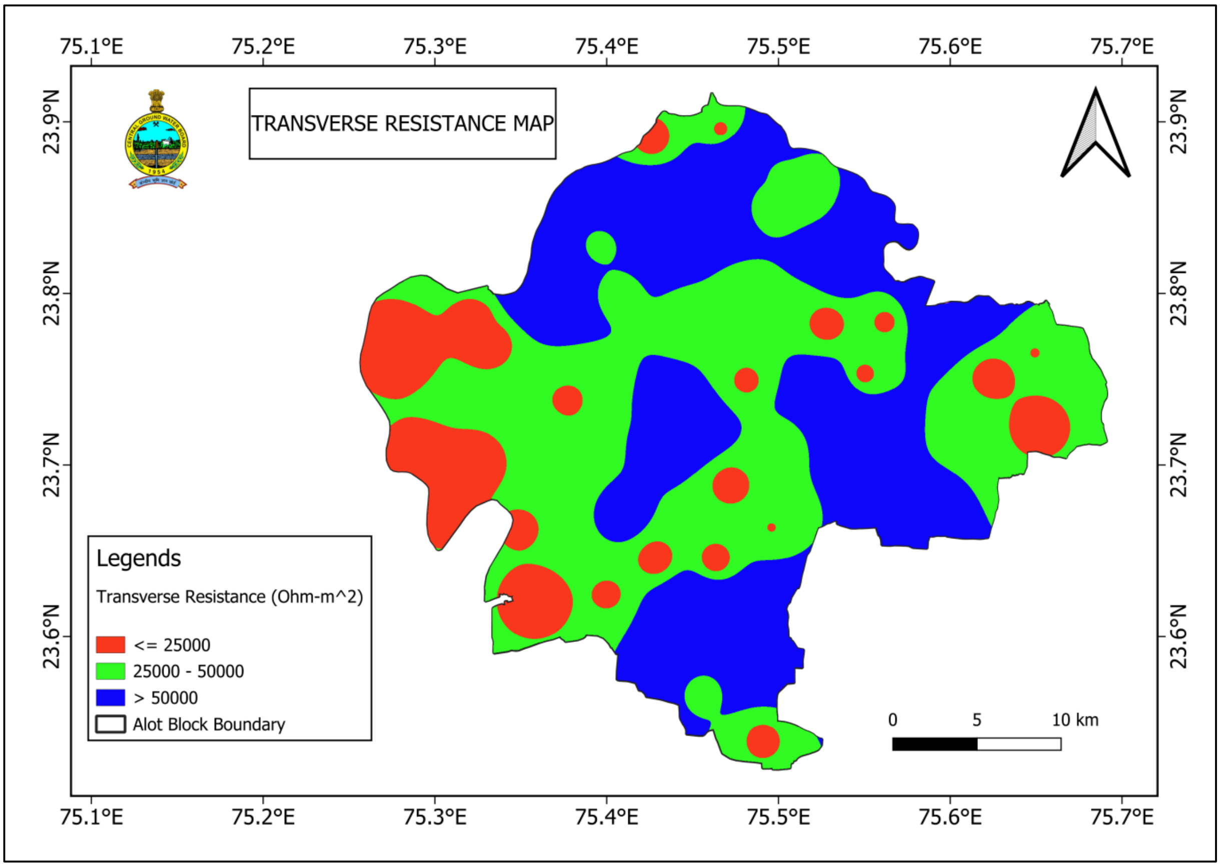


Fig. 9.10: Map of Transverse Resistance

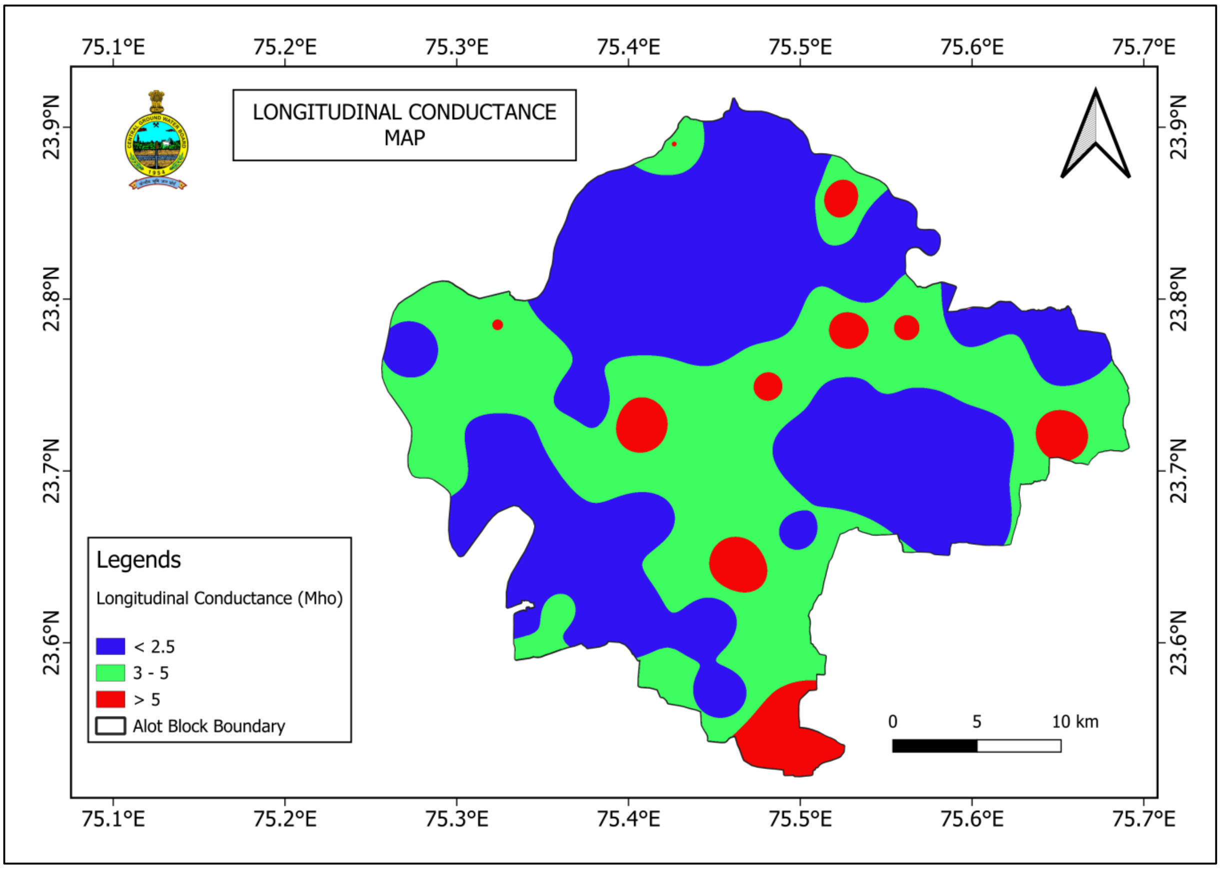


Fig. 9.11: Map of Longitudinal Conductance

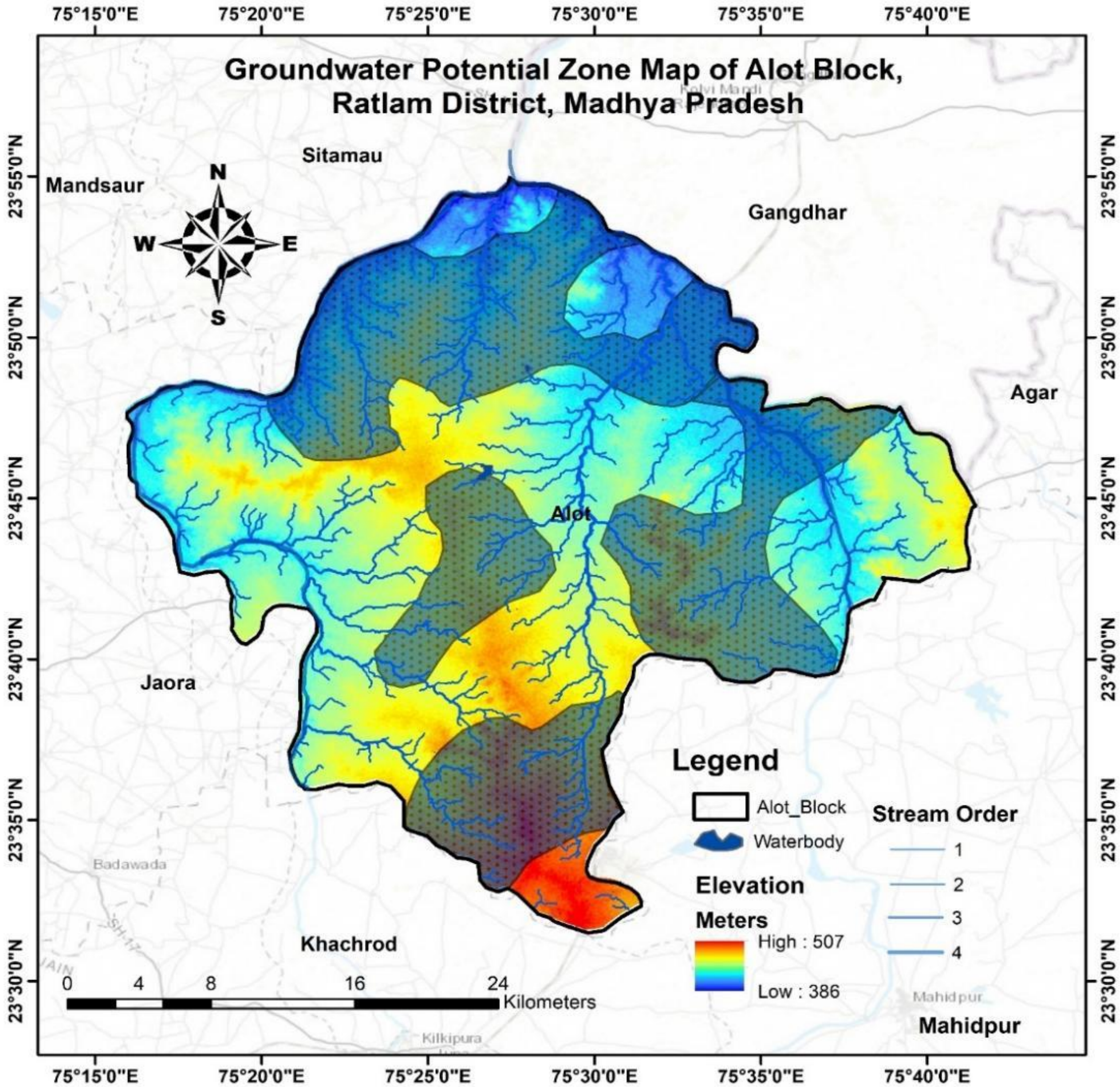


Fig. 9.12: Groundwater Potential zone map

9.5 MANAGEMENT PLAN FOR ENSURING LONG TERM SUSTAINABILITY OF BORE WELLS

9.5.1 Objective

The primary objective of this chapter is to provide an optimal design for borewells that ensures their long-term sustainability.

9.5.2 Methodology

This involves identifying areas with collapsible formations by analysing litholog data obtained from field observation wells and drilling of exploratory wells within the study area.

9.5.3 Result and Discussion

In regions characterized by hard rock formations, casing is typically installed up to a certain depth to penetrate the weathered zone. However, in the study area which is underlain by Deccan Trap basalt and Vindhyan formations, there are inter-trappean beds, specifically red bole in basaltic areas and contact zone between Deccan trap basalt and Vindhyan Sandstone are collapsible in nature. These collapsible layers pose significant challenges to the stability and sustainability of wells. In red bole areas, caving can occur, sealing off the aquifer zone. According to drilling data of CGWB, locations such as Nipaniya leela, Karwakhedi, Kalsiya, Pipliya maru, Pipliya sisodiya, Khajuria Solanki etc having deeper collapsible zones consisting of red bole/ contact zone.

Management plan involves to provide the proper well design. The design of water wells requires careful scientific consideration. To prevent collapse and maintain well stability, casing must be precisely installed against these collapsible zones specifically against red bole in Deccan trap area. It is also noted that contact zone between Deccan trap basalt and Vindhyan Sandstone acts as an aquifer, Hence, slotted pipes should be installed against these zones. This approach is essential for safeguarding the aquifer and ensuring the structural integrity of the well. The design of the well is provided for reference **(Fig. 9.13).**

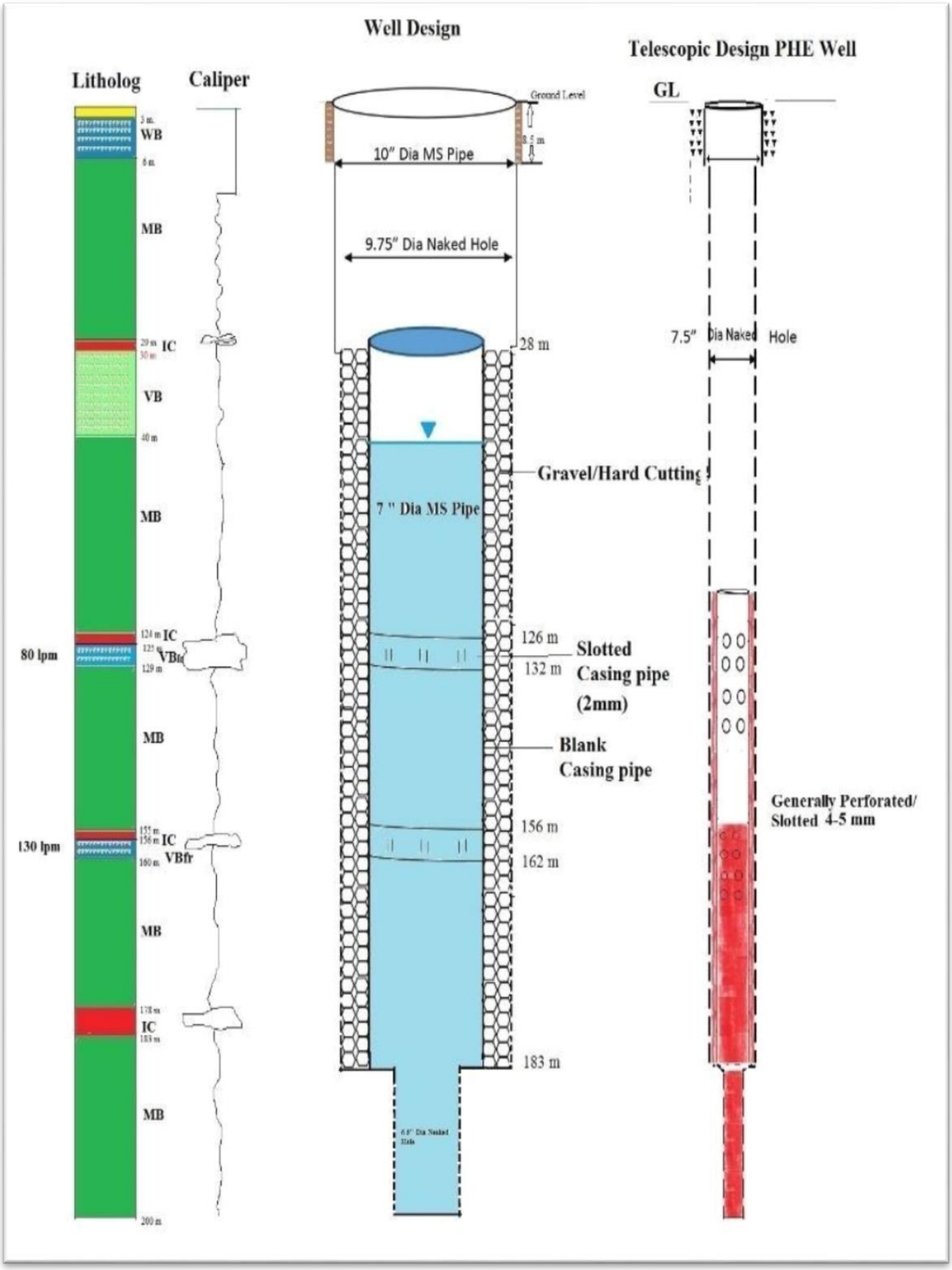


Fig. 9.13: Recommended Well Design in areas having collapsible formation.

9.6 MANAGEMENT PLAN FOR AREA HAVING LIMITED SHALLOW AQUIFER THICKNESS

9.6.1 Objective

To identify the areas having limited aquifer thickness and to suggest proper management plan to overcome this issue.

9.6.2 Methodology

Exploration details like aquifer thickness, aquifer zones, yield of aquifer are employed to delineate the area having limited aquifer thickness.

9.6.3 Result and Discussion

The study area is dominated by hard rock terrain, consisting of Deccan Trap basalt and massive Vindhyan Sandstone. Deeper aquifers in this region are mainly formed by joints and fractures within the hard rock. However, these aquifers have limited regional extent and thickness, which poses a significant challenge for groundwater availability. From key wells data during the field study and exploratory drilling by the Central Groundwater Board (CGWB) has revealed the limited thickness of the shallow aquifers. Areas with restricted aquifer thickness have been mapped which includes villages Patan, Hingadi, Talod, Karadiya, Bapchha, Negroon, Ranayara, Daulatganj, Baguniya, Rajla Dhapna, Goyal, Bhim etc .

Management Plan:

Implementing water conservation structures, such as check dams, percolation tanks, and recharge pits, serves as an alternative management strategy for areas with limited shallow aquifer thickness. These structures enhance groundwater recharge by slowing surface runoff and promoting infiltration, thereby stabilizing the water table. This approach mitigates the stress on overexploited aquifers, sustains groundwater levels, and ensures long-term water availability for agricultural and domestic use in regions with constrained aquifer resources To optimize well productivity, hydrofracturing is a viable technique to enhance yield. The process involves lowering a rubber packer to the target depth within the well and expanding it to isolate a specific section. Pressurized water is then injected into this sealed segment, generating hydraulic pressure that forces water into the borewell walls. This pressure can open or expand small joints and fractures, linking them with adjacent fractures, thereby improving borewell yield. Hydrofracturing can be strategically implemented in the areas delineated on the map.

9.7 MANAGEMENT PLAN FOR AREAS OF LAND SUBSIDENCE

9.7.1 Objective

The objective is to identify the areas having land subsidence and mitigate through sustainable groundwater management, monitoring, and land-use planning, ensuring long-term stability.

9.7.2 Methodology

The methodology for identifying land subsidence areas integrates exploration drilling, borehole camera inspections, and community feedback. Exploration drilling provides detailed subsurface stratigraphy, revealing compressible soil layers susceptible to subsidence. Borehole cameras offer visual confirmation of voids, fractures, and structural deformations within these layers. Feedback from local villagers, who observe surface changes over time, adds valuable qualitative data, helping to pinpoint areas of concern. By synthesizing these data sources, a comprehensive understanding of subsidence-prone areas is achieved, allowing for accurate mapping and informed decision-making for mitigation and land management strategies. This multidisciplinary approach ensures thorough site assessment.

9.7.3 Result and Discussion

The study area, characterized by hard rock terrain, is predominantly composed of Deccan Trap basalt interbedded with intertrappean clays, such as red boles, and massive Vindhyan Sandstone. Overexploitation of groundwater, coupled with the proliferation of water extraction structures, has led to the erosion and flushing away of intertrappean clays. This process has resulted in the formation of dry fractures and voids within the basalt and sandstone layers. Over time, these structural gaps have contributed to land subsidence, compromising the stability of the terrain and highlighting the need for sustainable groundwater management and monitoring in the region. During the field study and exploratory drilling by the Central Groundwater Board (CGWB) has revealed the areas of land subsidence. Areas with land subsidence have been mapped and shown in the Fig. 9.13 and 9.14 which includes Karwakhedi, Bhaisana, Negroon, Khejriya Sondia and Semliya.

9.7.4 Management Plan:

A comprehensive management plan to mitigate land subsidence in the study area should focus on enhancing groundwater recharge through rainwater harvesting and runoff management. Given the hard rock terrain and susceptibility to subsidence due to the loss of intertrappean clays, the plan proposes the use of rainwater from rooftops and surface runoff to create subsurface reservoirs and theses these locations have been marked in Fig. 9.15. Roof rainwater harvesting systems can be installed to collect and channel water into strategically located recharge pits or injection wells. This method ensures direct infiltration into deeper aquifers, aiding in the replenishment of groundwater levels. Additionally, surface runoff can be efficiently captured and diverted into depressions or excavated trenches, lined with permeable materials, to maximize infiltration. These locations should be carefully selected based on geological surveys, targeting areas where voids and dry fractures are prevalent. The infiltration of water into these subsurface reservoirs can rehydrate the surrounding rock formations, reducing the risk of further subsidence. Regular monitoring of groundwater levels and subsidence rates should accompany these measures, using a combination of geophysical surveys, GPS, and remote sensing technologies. Implementing these strategies will stabilize the terrain over time, preserving the structural integrity of the region and ensuring sustainable water resource management.

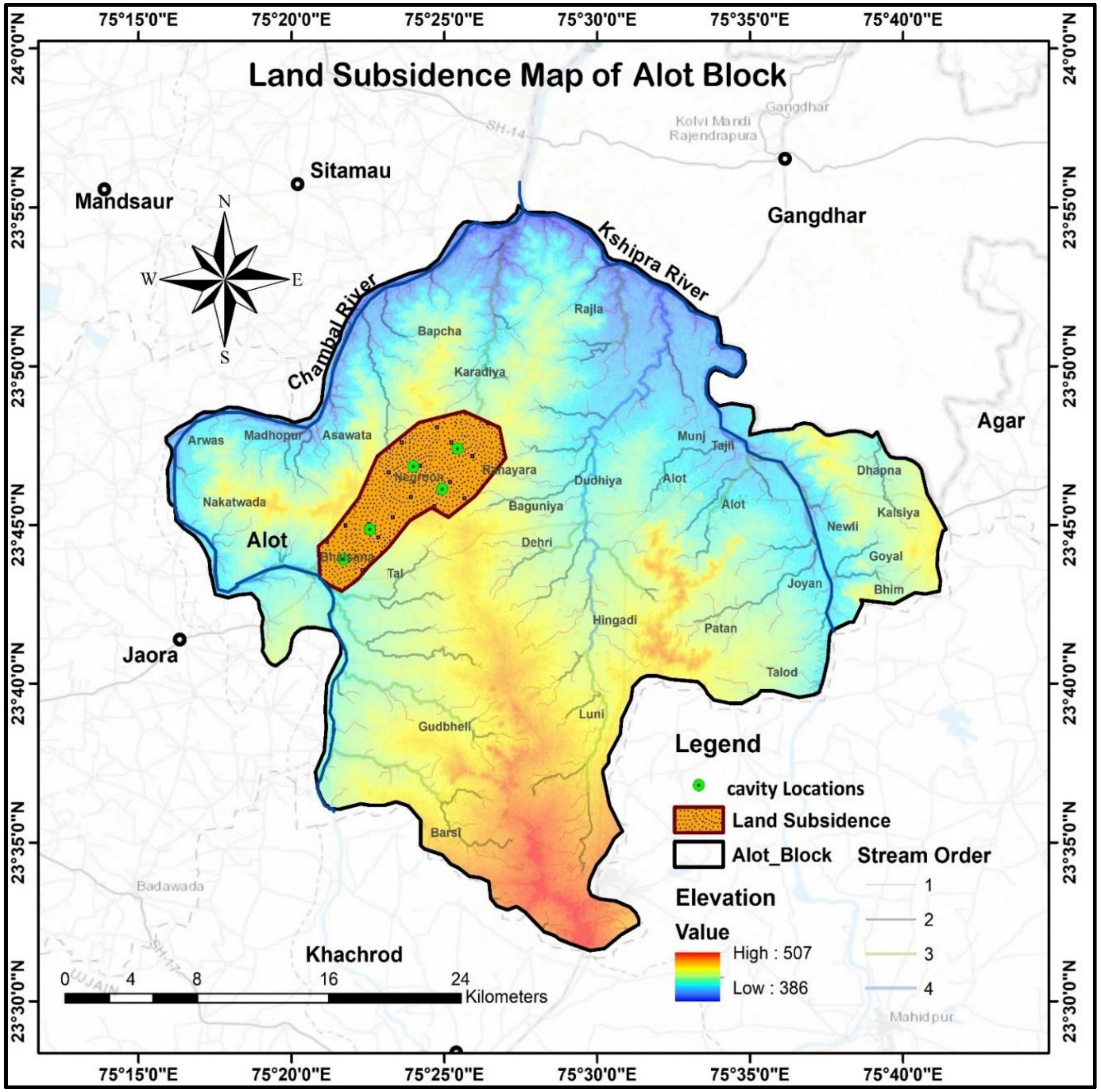


Fig. 9.14: Land Subsidence Map of Alot Block

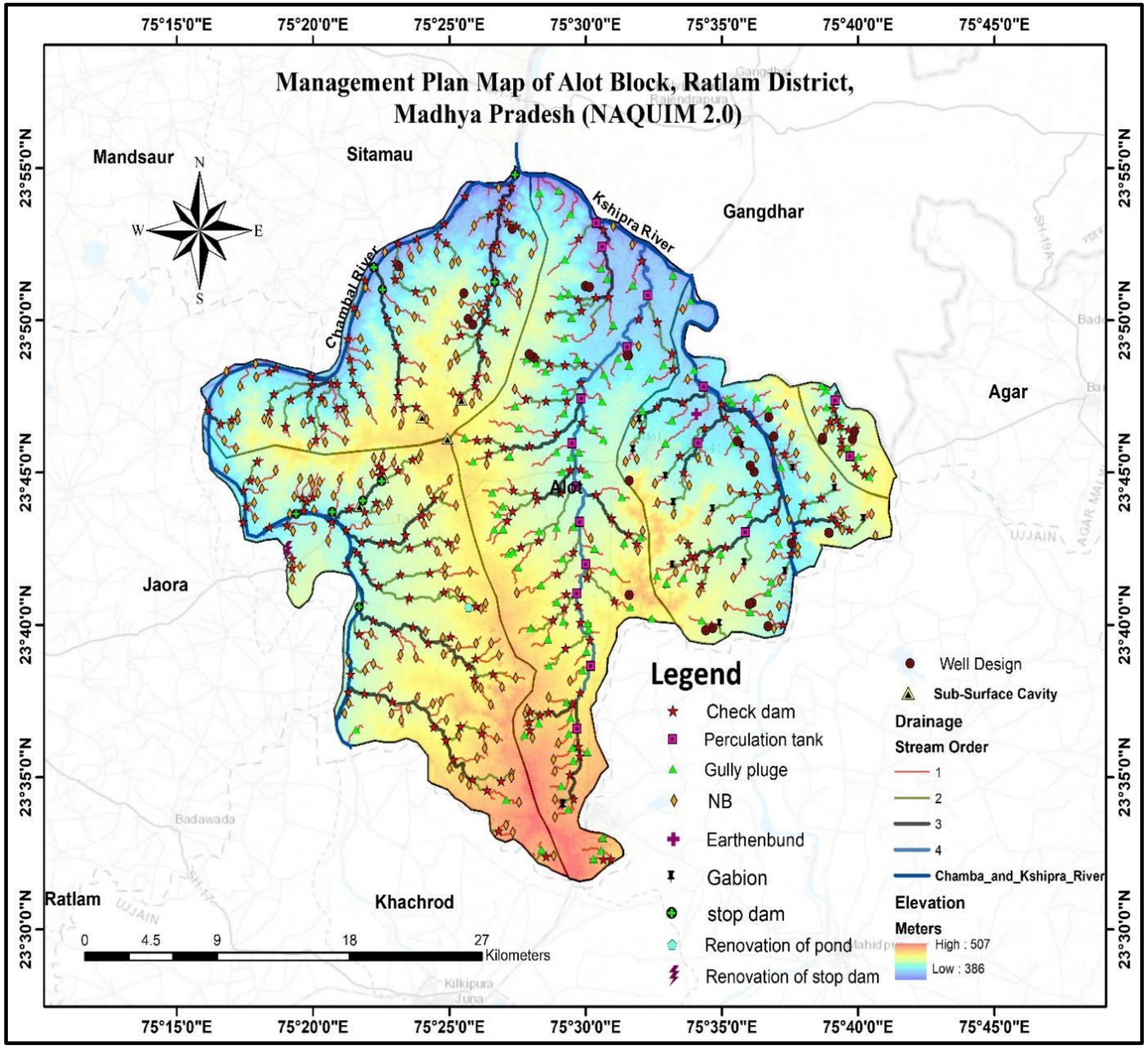


Fig. 9.15: Management Plan Map of Alot Block, Ratlam District, Madhya Pradesh

CHAPTER 10

CONCLUSIONS AND RECOMMENDATIONS

- Study area taken under NAQUIM 2.0 is water stressed Alot block extending over an area of 945 Sq. Km of Ratlam District. Alot block comprises of 91 gram panchayats which includes 191 villages. Chambal, Kshipra and Luni are the major rivers of the study area with Chambal along western to North western part, Kshipra along North eastern to Eastern part and Luni along the central part of the block.

- The study area mainly comprises of two hydrogeological units namely Deccan trap basalt and Vindhyan Sandstone and Shales and some portion of Marginal alluvium along the rivers. With the help of exploration drilling, field observations and data collected from key wells detailed aquifer mapping at a 1:10,000 scale has delineated both horizontal and vertical extents of aquifers within the study area reveals that along the Chambal and Kshipra rivers the contact of basalt and sandstone is relatively at shallow depth ranging from 500-700 ft mbgl and while towards the central part the contact zone become more deeper ranging from 900-1100 ft mbgl is observed. The shallow/unconfined aquifers are mainly Weathered basalts whereas vesicular/fractured basalt and fractured/jointed sandstone form semi-confined or confined aquifers. In the study area limited aquifer thickness is a major issue, to address this alternate water conservation structures are proposed to handle water crisis. hydrofracturing is recommended to open up the small joints and fractures thereby improving their yield.

- Three aquifer systems have been demarcated, Weathered Basalt and Marginal Alluvium being Aquifer I ranging from 3-30 m, vesicular/fractured basalt being Aquifer II ranging from 30 - 212 m, contact zone of Vindhyan Sandstone and Deccan basalt being Aquifer III ranging from 212-303 m Discharge ranging from 0.5 to 1 lps, 0.8 – 2 lps and 1-17.75 lps in Aquifer I, Aquifer II and Aquifer III respectively.

- During pre-monsoon, the depth to Water levels in Aquifer I ranges from 4.55 mbgl to 26.2 m bgl, 75% of the study area falls between 10 to 20 mbgl. In post-monsoon, the depth to Water levels ranges from 2.71 m bgl to 18.22 m bgl, 56% of the study area falls between 5 to 10 mbgl. In Aquifer II and Aquifer III, 53% of the study area falls between 30 to 90 mbgl during post-monsoon. After analysing groundwater level behaviour, the fluctuations of shallow aquifer whose range from 0 to 2 m, indicating good storage capacity of unconfined aquifer.

- Refinement in Ground Water Resource Assessment have been carried out. For the irrigation purposes and declining and deeper water levels, ground water abstraction structures have been increased over the years and it is one of the major variable in assessment of ground water resources. As per the field study and data from various district authorities, stage of ground water development is around 155% To reduce reliance on groundwater, artificial recharge structures is proposed. In areas within the study that are not suitable for groundwater recharge, it is advised to install a water conservation structures and roof top water harvesting structures are recommended.

- Based on the SOP, drinking water source sustainability study has been caried out in 55 villages it is observed 38 gram panchayats i.e, 69% falls in the High risk category, 8 gram panchayats i.e, (14.5%) in the At Risk category and remaining 9 gram panchayats i.e, (16.3%) falls in the Safe category

- Groundwater samples collected for quality analysis and to evaluate its suitability for drinking purposes. The analysis revealed high electrical conductivity and nitrate contamination in the shallow aquifer and deep aquifer is observed during pre and post monsoon analysis, high electrical conductivity more than 2000 μs/cm has been observed in shallow aquifer mainly may be due to irrigation through polluted water from rivers or may be due to water extraction from very deep depths will increase the temperature and increase the solubility of water. Nitrate contamination was detected all over the study area, attributed by excessive use of fertilizers during irrigation and contaminating both shallow and deep aquifers. The safer aquifer for drinking water has been identified using the Water Quality Index (WQI), it has been observed that shallow and deeper aquifer of study area has been found excellent to good category as per as per Yenugu et al. 2020 classification. No major change has been found in WQI of study area after monsoon. The Gibbs diagram indicates that the groundwater quality in shallow aquifers is primarily influenced by the evaporation-crystallization process, resulting in groundwater that is suitable for drinking

- To determine the effect of monsoon on groundwater quality, paired t-test analysis was conducted which indicates that the monsoon significantly affects certain groundwater quality parameter such as temperature, pH, electrical conductivity, bio-carbonate, sulphate, nitrate, total hardness, calcium, magnesium, sodium, potassium, arsenic and lead has been changed significantly. While parameter like chloride, fluoride, iron, manganese, copper, zinc, chromium and uranium remained unchanged after monsoon in shallow aquifer. For deeper aquifer parameter such as temperature, pH, electrical conductivity, chloride, sulphate, nitrate, total hardness, calcium, potassium, lead and uranium has been changed significantly. While parameter like bio-carbonate, fluoride, magnesium, sodium, iron, manganese, copper, zinc, arsenic and chromium remained unchanged after monsoon.
- All the surface water are having fluoride concentration is within the permissible limit of 1.5 mg/l as per BIS (IS 10500:2012). The maximum of fluoride concentration has been observed at Kshipra river during post-monsoon i.e. 0.55 mg/l The nitrate concentration is within the acceptable limit of 45 mg/l during both season. The highest concentration of nitrate is reported in the surface water sample Chambal river during pre-monsoon (11 mg/l). The Piper diagram shows that the surface water samples are Calcium Bi-carbonate type (temporary hardness) of water. The US Salinity Diagram shows that the ground water samples of both river samples fall in C3-S1 Class (Medium Salinity & Low Sodium) Class of water may be used for irrigation purpose for most of the crops.
- Areas undergoing land subsidence due to flushing of clays has been demarcated.To mitigate these recharge has to be enhanced through roof top rain water harvesting or channelising the rain water into these locations to create sub surface reservoirs to minimise the land subsidence.

- A total number of 44 Percolation Tanks, 217 Check Dams with Recharge Shafts, 342 Nalla bund, 10 conservation ponds, 13 gabions, 6 Stop dams and 1 renovation of Stop dam have been envisaged in the study area to recharge about 20.18 MCM. The locations of the recharge structures has been ground verified in many villages during the field study with the assistance of watershed and MGNREGA departments. These interventions may enhance the drinking water supply and well sustainability in the study area.

ANNEXURE-I

LITHOLOG OF EXPLORATORY WELLS

S. No	Site Name	Depth from (mbgl)	Depth to (mbgl)	Litholog
Exploratory wells under NAQUIM 2.0 within the study area				
1	Rinchha	0	2	Weathered Basalt
	Rinchha	2	14.2	Massive Basalt
	Rinchha	14.2	26.4	Vesicular Basalt
	Rinchha	26.4	99.6	Massive Basalt
	Rinchha	99.6	102.6	Fractured Basalt
	Rinchha	102.6	120.9	Vesicular Basalt
	Rinchha	120.9	136.2	Vesicular Basalt
	Rinchha	136.2	200.2	Massive Basalt
2	Mundla Kalan	0	1	Top soil
	Mundla Kalan	1	8.1	Weathered Basalt
	Mundla Kalan	8.1	11.1	Seepage zone
	Mundla Kalan	11.1	26.4	Massive Basalt
	Mundla Kalan	26.4	32.5	Vesicular Basalt
	Mundla Kalan	32.5	35.5	Plastic clay (grey bole?)
	Mundla Kalan	35.5	105.7	Massive Basalt
3	Aakya Kalan	0	2	Top soil
	Aakya Kalan	2	20.3	Weathered basalt
	Aakya Kalan	20.3	35.5	Vesicular basalt, Massive
	Aakya Kalan	35.5	38.6	Fractured vesicular basalt
	Aakya Kalan	38.6	188	Massive basalt
	Aakya Kalan	188	192	Weathered Vindhyan sandstone
	Aakya Kalan	192	200.2	Massive Vindhyan sandstone
4	Kamla khedi	0	2	Top soil
	Kamla khedi	2	5	Weathered basalt
	Kamla khedi	5	11.1	Massive basalt
	Kamla khedi	11.1	14.2	Red bole
	Kamla khedi	14.2	23.5	Amygdoidal Basalt/Vesicular Basalt
	Kamla khedi	23.5	69.1	Massive basalt
	Kamla khedi	69.1	75.2	Vindhyan Weathered sandstone
	Kamla khedi	75.2	96.5	Vindhyan Massive sandstone
	Kamla khedi	96.5	108.7	Vindhyan shale,
	Kamla khedi	108.7	136.2	Vindhyan Massive sandstone
	Kamla khedi	136.2	200.2	Vindhyan shale,
5	Pipliya maru	0	11.1	Weathered basalt
	Pipliya maru	11.1	35.5	Massive basalt
	Pipliya maru	35.5	50.8	Vesicular basalt
	Pipliya maru	50.8	81.3	Massive basalt
	Pipliya maru	81.3	117.9	Vesicular basalt

S. No	Site Name	Depth from (mbgl)	Depth to (mbgl)	Litholog
	Pipliya maru	117.9	127	Massive basalt
	Pipliya maru	127	133.1	Amygdoidal Basalt
	Pipliya maru	133.1	148.4	Massive basalt
	Pipliya maru	148.4	163.6	Vesicular basalt
	Pipliya maru	163.6	200.2	Massive basalt
6	Kolu khedi	0	2	Weathered basalt
	Kolu khedi	2	14.2	Massive basalt
	Kolu khedi	14.2	15	Red bole
	Kolu khedi	15	17.2	Vesicular basalt
	Kolu khedi	17.2	54	Massive basalt
	Kolu khedi	54	55	Red bole
	Kolu khedi	55	60	Vesicular basalt
	Kolu khedi	60	66	Massive basalt
	Kolu khedi	66	68	Red bole
	Kolu khedi	68	72	Amygdoidal Basalt
	Kolu khedi	72	81.31	Massive basalt

ANNEXURE-II

VERTICAL ELECTRICAL SOUNDING DATA IN AND AROUND STUDY AREA

S. No.	Location	Rho 1 (Ohm-m)	Rho 2 (Ohm-m)	Rho 3 (Ohm-m)	Rho 4 (Ohm-m)	Rho 5 (Ohm-m)	Rho 6 (Ohm-m)	h1 (m)	h2 (m)	h3 (m)	h4 (m)	h5 (m)	h6 (m)
1	Alot	7.56	5.06	22.8	1662	9.38	68.2	0.75	3.74	17.1	5.53	26.1	101
2	Garda	6.41	8.33	7.27	482	3.63	125	1.76	5.14	14	25.5	16.2	128
3	Gulbalod	5.72	8.97	482	13.4	52.9	8.67	1.06	24.4	23.3	29.4	52.7	
4	Sherpur Buzurg	38	722	4.41	359	5.57	13.7	3	12.1	9.15	20.1	72.3	
5	Sukha Kheda	5.01	39.3	4642	7.36	1188	593	0.75	1.61	6.85	3.28	29.8	134
6	Pipal Khedi	45.4	150	12.4	259	51	1106	0.8	1.02	1.17	16.1	7.63	34.6
7	Maliya Tal	8.06	11.2	647	9.63	284	23.8	0.75	1.88	6.48	24.2	16	36.6
8	Barkheda Kalan	5.51	10.7	5.71	223	8.79	75.3	1.35	2.18	8.14	12.8	24.1	26.8
9	Rupri	7.36	9.77	20.9	1353	33	4.38	1.4	2.88	11.8	14.4	26	
10	Joyan	18.8	42	345	44.2	1335	186	3.25	3.1	5.67	17.9	19.6	26.1
11	Bhoja Khedi	5.82	9.9	114	11.9	68.2	203	2.37	13.1	18.7	27	48.9	10.9
12	Borkhedi	3.56	14.3	38.2	9404	186	663	1.1	2.08	4.4	16.1	47.2	60
13	Bhikramgarh	3.18	6.48	31.9	3.85	102	13.1	0.75	8.68	5.65	8.35	15.9	45.6
14	Bhim	11.9	5.15	20.7	9.47	185	14.3	1.47	1.28	3.37	24.8	31.8	52.3
15	Badagaon	23.2	50	582	159	485	498	0.7	5.2	10.3	30.5	27.7	
16	Tal	5.32	10.8	1975	25.7	74.3	18.5	3.62	10.5	12.6	25.3	50	
17	Nipaniya Leela	5.51	5.61	2.3	524	21.5		1.03	7.25	18	15.8		
18	Luni	7	2.57	76.2	8.34	101	267	0.9	1.69	4.33	5.98	5.33	87.3
19	Palasiya	10.7	2.72	8.68	332	3082	627	0.9	6.1	17.8	14.8	72.2	
20	Melu Khedi	36.5	21.3	18.7	167	12.5	307	1.15	0.9	8	9.71	20.4	8.21
21	Madhabpur	21.9	11.4	7.17	81.3	24	303	0.86	2.43	13	7.3	69.3	22.7
22	Mindli	14	7.3	4.62	390	17.1	302	0.9	1.72	10.6	13	24.8	22

S. No.	Location	Rho 1 (Ohm-m)	Rho 2 (Ohm-m)	Rho 3 (Ohm-m)	Rho 4 (Ohm-m)	Rho 5 (Ohm-m)	Rho 6 (Ohm-m)	h1 (m)	h2 (m)	h3 (m)	h4 (m)	h5 (m)	h6 (m)
23	Nimba Khedi	9.34	21.9	131	25.8	124	9.53	0.75	1.57	6.1	10.9	16	17.3
24	Thumb Guradiya	17.7	3.45	10.6	22.8	193	2119	0.93	3.42	11.9	18.3	23.8	
25	Saranga Kheda	34.5	6.9	11.3	1220	44.1		0.75	8.96	29.6	104		
26	Khedi Tal	6.72	3.35	18.2	1260	7.16	167	0.75	2.14	14.5	29.8	51.2	65.9
27	Ranayara	203	23.9	573	1081	26.1	676	0.75	0.55	19.6	7.78	12.3	27.7
28	Baman Khedi	40.6	150	12.8	303	48	732	0.75	1	1.2	10.2	4.1	51.6
29	Asawata	10.4	14.9	1695	36.9	478	11008	1.23	1.71	3.41	10.6	3.66	14.3
30	Arjala	42.3	10.1	123	209	48.3	217	1.19	2.21	2.8	9.85	5.86	66.4
31	Gudbheli	23.3	3.49	7.04	128	24.8	1560	1.05	6.32	2.41	10.8	59.1	
32	Alot	27.5	7.65	503	9.29	271	144	1.25	1.54	3.98	20	26.6	46.9
33	Nipaniya Tal	35.4	4.26	638	33.5	125	181	0.9	1.52	15.6	11.1	68.3	
34	Moriya	37.7	9.05	495	23.8	163	2257	1.83	2.44	10.3	4.26	8.02	46.8
35	Sherpur Khurd	256	165	49.6	451	53.8	302	0.9	3.6	2.1	8.2	3.45	72.3
36	Kalakhedi (Rajla)	86.5	2456	41821				0.75	19				
37	Alakheda	114	371	589	530	911		1.07	7.57	34.9	28.6		
38	Hariya Kheda	123	313	544	59.3	996	483	1.41	8.19	10.5	2.1	17.4	86.5
39	Arwaliya Bhama	188	23.4	1002	69.2	978	475	0.75	0.7	6.6	6.2	12.1	166
40	Baradiya	134	545	294	1401	51.1	967	1.98	6.55	10.9	9.35	8.66	49.4
41	Pipaliya Maru	206	32.7	740	52.3	545	50.3	0.75	0.8	16.5	6.09	45.8	91.5
42	Talod	151	1136	50.3	3065	40.3	826	2.26	7.32	5.01	9.3	49	25.3
43	Khamariya	363	687	2899	361	1398	527	1.11	12.3	3.17	17.5	17.7	26.5
44	Jeevangarh	285	526	705	1297	507		1.09	7.14	69.7	97.4		
45	Bhesola	123	34.4	2285	15.4	814	50.4	1.36	3.48	7.69	3.39	23.5	36.2
46	Kharwa Kalan	97.5	2275	50.2	3909	115	2168	1.94	7.1	6.2	10.3	16.3	58.1
47	Panth Piploda	256	57.5	1777	143	4638	187	0.9	1.33	6.5	11.2	10.8	44

S. No.	Location	Rho 1 (Ohm-m)	Rho 2 (Ohm-m)	Rho 3 (Ohm-m)	Rho 4 (Ohm-m)	Rho 5 (Ohm-m)	Rho 6 (Ohm-m)	h1 (m)	h2 (m)	h3 (m)	h4 (m)	h5 (m)	h6 (m)
48	Barkheda	103	270	142	283			1.55	22.7	83.9			
49	Bhaisana	145	34	154	198	521		2.66	2.51	3.8	70.2		
50	Mundala Kalan	50.3	385	590				0.43	39.2				

ANNEXURE-III

LIST OF KEY WELLS ESTABLISHED IN STUDY AREA

S no	Village	Latitude	Longitude	Type	Depth of well (mbgl)
1	Mermiya kheda	23.68903	75.38002	DW	16.4
2	Mermiya kheda	23.69135	75.37999	HP	91
3	Mermiya kheda	23.6896	75.3807	BW	91
4	Kitkhedi	23.66147	75.3721	DW	13.4
5	Kitkhedi	23.6657	75.3731	HP	197
6	Kitkhedi	23.66504	75.3731	BW	212
7	Lasudiya surajmal	23.62834	75.35887	DW	16.5
8	Lasudiya surajmal	23.6277	75.36019	HP	212
9	Lasudiya surajmal	23.627	75.36217	BW	303
10	Kothdi Karwa	23.61093	75.40554	DW	24.9
11	Kothdi Karwa	23.61664	75.39897	HP	91
12	Mandawal	23.6086	75.4152	DW	21
13	Mandawal	23.60968	75.41558	HP	78
14	Mandawal	23.60784	75.41328	BW	91
15	Pant piploda	23.66352	75.40997	DW	12.82
16	Pant piploda	23.6601	75.41067	HP	136
17	Pant piploda	23.65889	75.41097	BW	212
18	Tajkheda	23.64911	75.39226	DW	22.1
19	Tajkheda	23.65014	75.3907	BW	272
20	Daulatganj	23.63604	75.43414	DW	22.7
21	Daulatganj	23.63126	75.44499	BW	303

S no	Village	Latitude	Longitude	Type	Depth of well (mbgl)
22	Khetakhedi	23.6451	75.43152	DW	17
23	Gudbeli	23.64546	75.42375	HP	91
24	Khetakhedi	23.64248	75.438	BW	181
25	Bersi	23.5845	75.4223	DW	13.4
26	Bersi	23.5847	75.4232	HP	121
27	Bersi	23.58472	75.42226	BW	290
28	Gurukhedi	23.5807	75.438	HP	121
29	Gurukhedi	23.58472	75.44018	BW	115
30	Bensola	23.57081	75.46012	BW	303
31	Kesari chouhan	23.50932	75.4808	HP	121
32	Kesari chouhan	23.56935	75.48086	BW	303
33	Minawada	23.55085	75.4978	DW	7.5
34	Minawada	23.53587	75.47981	HP	121
35	Minawada	23.53661	75.47891	BW	242
36	Kollu khedi	23.54092	75.50554	BW	133
37	Kollu khedi	23.541	75.5044	BW	303
38	Delwas	23.59381	75.49158	DW	14.98
39	Delwas	23.59298	75.49209	HP	106
40	Delwas	23.59206	75.49348	BW	227
41	Karwa kalan	23.61216	75.48151	DW	25
42	Karwa kalan	23.61124	75.48058	BW	212
43	Luni	23.63772	75.48335	DW	24.5
44	Luni	23.65811	75.49634	BW	151
45	Luni	23.65933	75.49645	BW	272
46	Pipliya tukur	23.62894	75.4915	DW	15.5
47	Pipliya tukur	23.62838	75.49141	HP	121
48	Pipliya tukur	23.628	75.49108	BW	242
49	Sanga kheda	23.71518	75.41964	DW	14.92

S no	Village	Latitude	Longitude	Type	Depth of well (mbgl)
50	Sanga kheda	23.71428	75.41564	HP	136
51	Sanga kheda	23.71428	75.41564	BW	303
52	Kishangarh	23.67557	75.42852	DW	25.2
53	Kishangarh	23.67699	75.43075	HP	121
54	Kishangarh	23.67818	75.43021	BW	212
55	Nipani leela	23.65883	75.46329	BW	45
56	Nipani leela	23.65875	75.46337	BW	291
57	Chapri	23.67649	75.49115	DW	21
58	Arvalya solanki	23.68487	75.49236	HP	136
59	Sala khedi	23.67321	75.49236	BW	181
60	Rinchha	23.67971	75.51783	DW	19
61	Rinchha	23.68247	75.32422	BW	121
62	Hingodi	23.70591	75.49938	DW	19.2
63	Hingodi	23.70624	75.49859	BW	228
64	Sherpur Khurd	23.71633	75.50128	DW	21.1
65	Sherpur Khurd	23.71693	75.5	BW	228
66	Thamb guradiya	23.6928	75.4619	BW	242
67	Kharwa Khurd	23.69566	75.4275	DW	12
68	Kharwa Khurd	23.69475	75.43459	HP	60
69	Kharwa Khurd	23.69193	75.42977	BW	152
70	Kachhaliya	23.73101	75.46144	DW	28
71	Kachhaliya	23.7289	75.45995	HP	121
72	Kachhaliya	23.72921	75.48634	BW	182
73	Gulbalod	23.75579	75.48634	DW	16
74	Gulbalod	23.763	75.4891	BW	257
75	Gulbalod	23.75401	75.4887	BW	121
76	Kaspura	23.75334	75.4973	DW	21.1
77	Maukhedi	23.74047	75.5006	DW	14.95

S no	Village	Latitude	Longitude	Type	Depth of well (mbgl)
78	Maukhedi	23.74136	75.50196	BW	91
79	Jeevangarh	23.75008	75.51643	BW	253
80	Chaplakhedi	23.66016	75.38827	DW	14.82
81	Chaplakhedi	23.6609	75.38835	HP	33
82	Chaplakhedi	23.66079	75.38851	BW	182
83	Jahanabad	23.71862	75.52116	DW	17.5
84	Jahanabad	23.72343	75.52276	BW	182
85	Jahanabad	23.72208	75.51988	BW	272
86	Kanthariya	23.6894	75.5404	DW	12.58
87	Kanthariya	23.67863	75.53915	BW	206
88	Dabdiya	23.66558	75.57811	DW	13.95
89	Dabdiya	23.66378	75.57477	HP	166
90	Dabdiya	23.66484	75.57719	BW	275
91	Talod	23.6867	75.58687	DW	18.4
92	Talod	23.67763	75.59969	BW	121
93	Talod	23.67557	75.59759	BW	182
94	Patan	23.70689	75.56708	HP	91
95	Patan	23.70427	75.56433	BW	242
96	Nipaniya Rajguru	23.69962	75.59962	DW	14.75
97	Nipaniya Rajguru	23.69766	75.59506	BW	176
98	Guradiya	23.74983	75.62806	DW	22.73
99	Guradiya	23.7479	75.60513	BW	121
100	Sathikheda	23.7258	75.62806	DW	14.62
101	Rawatkheda	23.71807	75.63801	BW	151
102	Kamla khedi	23.7422	75.6329	HP	167
103	Goyal	23.7392	75.6448	DW	10.3
104	Goyal	23.7416	75.64295	BW	121
105	Inderpur	23.72156	75.68049	DW	12.95

S no	Village	Latitude	Longitude	Type	Depth of well (mbgl)
106	Bhim	23.72156	75.68049	BW	183
107	Kalsiya	23.76423	75.67431	DW	18.8
108	Hampura	23.71644	75.36908	DW	10.4
109	Hampura	23.7152	75.3666	BW	182
110	Fatehpur	23.70354	75.35813	BW	76
111	Bisalkheda	23.72073	75.35813	DW	16.2
112	Bisalkheda	23.72384	75.34437	HP	42
113	Bisalkheda	23.72388	75.33958	BW	52
114	Bisalkheda	23.72417	75.33982	BW	122
115	Mandla kalan	23.70219	75.33083	DW	28
116	Mandla kalan	23.7055	75.33045	BW	227
117	Aakyakalan	23.7438	75.3373	DW	21.5
118	Aakyakalan	23.7438	75.3373	BW	240
119	Kothadi	23.7382	75.3032	DW	18.2
120	Kothadi	23.7367	75.305	HP	90
121	Kothadi	23.7374	75.301	BW	76
122	Arwas	23.7874	75.2791	DW	9.5
123	Arwas	23.7899	75.28	HP	76
124	Arwas	23.7877	75.2834	BW	76
125	Madhopur	23.7918	75.3088	DW	18
126	Madhopur	23.7891	75.3101	HP	90
127	Madhopur	23.7669	75.3107	BW	182
128	Malya	23.7746	75.3369	DW	16.5
129	Malya	23.7744	75.3345	HP	106
130	Malya	23.7774	75.33	BW	113
131	Karwakhedi	23.7479	75.3698	DW	13.2
132	Karwakhedi	23.7423	75.3762	HP	61
133	Karwakhedi	23.7472	75.3758	BW	212

S no	Village	Latitude	Longitude	Type	Depth of well (mbgl)
134	Bhaisana	23.7298	75.3601	DW	14.8
135	Bhaisana	23.7318	75.3604	HP	121
136	Bhaisana	23.7319	75.3572	BW	137
137	Asawata	23.7936	75.3459	DW	16.5
138	Asawata	23.806	75.3649	BW	303
139	Kelukheda	23.8488	75.3684	DW	9
140	Kelukheda	23.8515	75.3729	HP	121
141	Surjana	23.8626	75.3857	DW	13.2
142	Surjana	23.8626	75.3857	BW	150
143	Barkhera kalan	23.8764	75.4233	DW	16.7
144	Barkhera kalan	23.8808	75.4214	HP	76
145	Barkhera kalan	23.8783	75.4184	BW	152
146	Karadiya	23.8318	75.4324	DW	14.6
147	Karadiya	23.8318	75.4324	HP	182
148	Negroon	23.7797	75.3976	DW	11.9
149	Negroon	23.7821	75.3965	BW	167
150	Bamankhedi	23.8060	75.4095	DW	17.6
151	Bamankhedi	23.8071	75.4109	HP	91
152	Barkherakhurd	23.8140	75.3903	DW	13.1
153	Barkherakhurd	23.8141	75.388	HP	121
154	Pipalkhedi	23.8298	75.3825	DW	18
155	Pipalkhedi	23.8304	75.3875	HP	76
156	Pipalkhedi	23.8299	75.3934	BW	182
157	Semliya	23.7919	75.4212	DW	16.6
158	Semliya	23.7919	75.4212	BW	179
159	Jamuniya shankar	23.8061	75.4376	DW	10.1
160	Jamuniya shankar	23.8048	75.4359	BW	100
161	Lasudiya khedi	23.7501	75.4132	DW	11.3

S no	Village	Latitude	Longitude	Type	Depth of well (mbgl)
162	Lasudiya khedi	23.7495	75.4147	HP	106
163	Bhutiya	23.7436	75.4385	DW	15.6
164	Bhutiya	23.7442	75.4381	HP	106
165	Bhutiya	23.7443	75.4386	BW	182
166	Manuniya	23.7647	75.4312	DW	17.2
167	Manuniya	23.766	75.4342	BW	303
168	Ranayara	23.7776	75.4450	DW	19.1
169	Ranayara	23.7776	75. 4450	BW	212
170	Pipalya sisodiya	23.8133	75.4771	DW	14.8
171	Pipalya sisodiya	23.8146	75.4653	BW	242
172	Pipalya Pitha	23.8174	75.4807	DW	21.3
173	Pipalya Pitha	23.8177	75.481	BW	182
174	Pipliya Maru	23.7935	75.4676	DW	22.2
175	Pipliya Maru	23.7955	75.4688	BW	137
176	Malhargarh	23.7944	75.5033	DW	14.2
177	Malhargarh	23.7941	75.5053	HP	121
178	Shisakhedi	23.8197	75.5152	DW	18.2
179	Shisakhedi	23.8128	75.5182	BW	152
180	Khajuri Devada	23.8391	75.5095	DW	27
181	Khajuri Devada	23.8447	75.5083	HP	61
182	Majanpur	23.8811	75.5000	DW	12
183	Majanpur	23.8797	75.4999	BW	91
184	Rajla	23.8670	75.4763	DW	13.1
185	Rajla	23.8643	75.4802	BW	124
186	Moriya	23.8772	75.4714	DW	20
187	Moriya	23.8765	75.4668	BW	106
188	Himmatkhedi	23.8546	75.4518	DW	14.7
189	Himmatkhedi	23.8564	75.4517	BW	151

S no	Village	Latitude	Longitude	Type	Depth of well (mbgl)
190	Devgarh	23.8532	75.4476	DW	17.9
191	Devgarh	23.8544	75.4457	BW	151
192	Munj	23.7941	75.5465	DW	23.9
193	Munj	23.7935	75.5511	HP	106
194	Bardiya Rathor	23.8120	75.5266	DW	14.3
195	Bardiya Rathor	23.8150	75.5287	BW	121
196	Kandiya	23.8535	75.5440	DW	28.7
197	Kandiya	23.8588	75.5408	BW	151
198	Arwalya Bama	23.8367	75.5358	DW	17.5
199	Thuriya	23.8471	75.5621	DW	15.7
200	Thuriya	23.8485	75.5626	BW	110
201	Aakya	23.8088	75.5596	DW	15
202	Dudhiya	23.7618	75.5048	DW	18.5
203	Dudhiya	23.7733	75.4968	BW	167
204	Baguniya	23.7564	75.4637	DW	12.5
205	Baguniya	23.7596	75.4641	BW	212
206	Borkhedi	23.7881	75.5927	DW	14.6
207	Borkhedi	23.7877	75.5926	HP	121
208	Bhojakhedi	23.7760	75.6123	DW	15.1
209	Bhojakhedi	23.7810	75.6085	BW	121
210	Kalsya	23.7656	75.6596	DW	14.5
211	Kalsya	23.7661	75.66	BW	115
212	Thapna	23.7841	75.6499	DW	22.3
213	Khajuriya Solanki	23.7608	75.5889	DW	17.5
214	Khajuriya Solanki	23.7684	75.5934	BW	212
215	Alot (Vikramgarh)	23.7776	75.5716	DW	20.8
216	Tal	23.7223	75.3870	DW	15.3
217	Khamriya	23.7360	75.5512	DW	18.6

S no	Village	Latitude	Longitude	Type	Depth of well (mbgl)
218	Khamriya	23.7390	75.552	BW	121
219	Dharola	23.7523	75.5659	DW	15.8
220	Dharola	23.7537	75.5657	BW	64
221	Joyan	23.7274	75.6020	DW	13.5
222	Joyan	23.7228	75.6027	BW	121
223	Dehari	23.7456	75.4534	DW	15.9
224	Hampura	23.7219	75.3621	DW	17.7

ANNEXURE-IV

PRE AND POST-MONSOON GROUNDWATER LEVEL AND FLUCTUATION OF ALOT BLOCK 2023

S no	Village	Pre monsoon WL (mbgl)	Post monsoon WL (mbgl)	Fluctuation (m)
1	Aakya	11.8	9.05	2.75
2	Aakyakalan	15.7	7.08	8.62
3	Alot (Vikramgarh)	8.1	2.71	5.39
4	Arwalya Bama	16.1	13.51	2.59
5	Arwas	8.1	7.75	0.35
6	Asawata	13.2	3.82	9.38
7	Baguniya	9.5	7.22	2.28
8	Bamankhedi	17	8.48	8.52
9	Bardiya Rathor	13.5	6.85	6.65
10	Barkhera kalan	15.7	11.22	4.48
11	Barkherakhurd	12.5	10.41	2.09
12	Bersi	9.42	5.81	3.61
13	Bhaisana	8.9	3.22	5.68
14	Bhojakhedi	12.3	4.18	8.12
15	Bhutiya	13.8	8.05	5.75
16	Bisalkheda	12.6	5.51	7.09
17	Borkhedi	9.5	5.24	4.26
18	Chaplakhedi	10.1	8.68	1.42
19	Chapri	17.5	8.25	9.25
20	Dabdiya	13.42	12.1	1.32
21	Daulatganj	16.3	4.82	11.48
22	Dehari	10.9	4.32	6.58
23	Delwas	9.4	3.98	5.42
24	Devgarh	14.2	8.03	6.17
25	Dharola	15.1	6.75	8.35
26	Dudhiya	18.3	16.85	1.45
27	Goyal	9.2	7.45	1.75
28	Gulbalod	15.7	11.96	3.74
29	Guradiya	16.55	9.05	7.5
30	Hampura	8.41	7.4	1.01
31	Hampura	11.9	6.56	5.34
32	Himmatkhedi	12.5	6.48	6.02
33	Hingodi	17.6	10.42	7.18
34	Inderpur	10.22	9.95	0.27
35	Jahanabad	13.28	6.84	6.44
36	Jamuniya shankar	8.7	3.48	5.22
37	Joyan	11.3	5.68	5.62
38	Kachhaliya	18.5	8.72	9.78
39	Kalsiya	10.9	3.68	7.22

S no	Village	Pre monsoon WL (mbgl)	Post monsoon WL (mbgl)	Fluctuation (m)
40	Kalsya	13.8	10.45	3.35
41	Kandiya	15.4	12.61	2.79
42	Kanthariya	11.98	7.52	4.46
43	Karadiya	12.3	7.42	4.88
44	Karwa kalan	20.2	12.05	8.15
45	Karwakhedi	10.9	3.64	7.26
46	Kaspura	17.3	7.62	9.68
47	Kelukheda	7.6	3.75	3.85
48	Khajuri Devada	16	6.52	9.48
49	Khajuriya Solanki	11.9	5.42	6.48
50	Khamriya	16.7	5.72	10.98
51	Kharwa Khurd	4.55	3.15	1.4
52	Khetakhedi	16.1	6.33	9.77
53	Kishangarh	19.35	12.52	6.83
54	Kitkhedi	9.97	5.25	4.72
55	Kothadi	8.8	6.52	2.28
56	Kothdi Karwa	13.72	7.95	5.77
57	Lasudiya khedi	7.6	3.85	3.75
58	Lasudiya surajmal	8.65	3.72	4.93
59	Luni	19.4	18.22	1.18
60	Madhopur	14.9	5.92	8.98
61	Majanpur	8.1	4.92	3.18
62	Malhargarh	9.7	3.68	6.02
63	Malya	14	5.45	8.55
64	Mandawal	15.2	5.74	9.46
65	Mandla kalan	18.1	10.36	7.74
66	Manuniya	8.5	5.08	3.42
67	Maukhedi	12.75	4.68	8.07
68	Mermiya kheda	14.32	7.05	7.27
69	Minawada	6.85	3.38	3.47
70	Moriya	15.4	6.12	9.28
71	Munj	17.5	7.92	9.58
72	Negroon	10.6	6.41	4.19
73	Nipaniya leela	16.4	15.26	1.14
74	Nipaniya Rajguru	14.6	13.61	0.99
75	Pant piploda	10.52	4.32	6.2
76	Pipalkhedi	11.2	10.52	0.68
77	Pipalya Pitha	17.1	5.75	11.35
78	Pipalya sisodiya	14.1	4.84	9.26
79	Pipliya Maru	12.4	7.98	4.42
80	Pipliya tukur	13.6	12.86	0.74
81	Rajla	14.98	11.1	3.88
82	Ranayara	16.3	14.75	1.55
83	Rinchha	16.8	8.58	8.22

S no	Village	Pre monsoon WL (mbgl)	Post monsoon WL (mbgl)	Fluctuation (m)
84	Sanga kheda	7.22	2.93	4.29
85	Sathikheda	9.55	4.92	4.63
86	Semliya	12.8	3.58	9.22
87	Sherpur Khurd	17.1	8.56	8.54
88	Shisakhedi	12.8	8.35	4.45
89	Surjana	11.5	5.22	6.28
90	Tajkheda	15.2	8.98	6.22
91	Tal	11.1	6.79	4.31
92	Talod	16.1	6.56	9.54
93	Thapna	17.7	9.75	7.95
94	Thuriya	13	6.25	6.75

ANNEXURE-V

GROUND WATER QUALITY RESULTS OF PHREATIC AQUIFER (DUG WELLS), HAND PUMPS AND BORE WELLS OF WATER STRESS ALOT BLOCK OF RATLAM DISTRICT UNDER NAQUIM 2.0 (PRE-MONSOON-2023)

S.No	District	Block	Location	Source	pH	EC	CO_3	HCO_3	Cl	SO_4	NO_3	F	PO_4	SiO_2	TH	Ca	Mg	Na	K	TDS
1	Ratlam	Alot	Aakyakalan	BW	7.16	3076	0	647	387	367	39	0.19	BDL	32	624	173	47	413	9.4	1999
2	Ratlam	Alot	Asawata	BW	8.03	1215	0	240	205	73	37	0.32	0.14	28	287	59	34	143	3.8	790
3	Ratlam	Alot	Baguniya	BW	7.71	1546	0	209	357	69	10	1.60	0.14	34	248	64	21	236	5.1	1005
4	Ratlam	Alot	Bardiya Rathor	BW	7.42	1327	0	191	277	83	21	1.35	BDL	28	257	72	19	182	3.6	863
5	Ratlam	Alot	Barkherakalan	BW	7.65	3560	0	351	920	96	64	0.67	BDL	24	475	100	55	598	4.6	2314
6	Ratlam	Alot	Bensola	BW	7.46	3224	0	339	861	46	34	1.42	BDL	28	302	61	36	594	9.8	2096
7	Ratlam	Alot	Bersi	BW	7.46	1830	0	290	416	52	15	1.43	BDL	22	168	50	11	337	7.7	1190
8	Ratlam	Alot	Bhaisana	BW	7.23	3780	0	450	952	97	43	0.36	BDL	25	540	112	63	615	6.4	2457
9	Ratlam	Alot	Bhim	BW	7.52	1895	0	240	460	54	23	0.72	BDL	19	272	95	8	305	4.8	1232
10	Ratlam	Alot	Bhojakhedi	BW	7.11	905	0	394	52	17	32	0.11	0.1	28	312	82	26	61	3.3	588
11	Ratlam	Alot	Bhutiya	BW	7.21	2242	0	222	497	165	45	0.31	0.14	31	426	108	38	308	18.6	1457
12	Ratlam	Alot	Bisalkheda	BW	7.82	2369	0	795	270	75	56	0.70	0.15	74	797	162	95	174	1.1	1540
13	Ratlam	Alot	Bisalkheda	BW	7.66	3950	0	893	738	102	62	0.82	BDL	80	931	230	87	477	1.2	2568
14	Ratlam	Alot	Chaplakhedi	BW	6.89	2044	0	444	394	44	43	0.81	0.17	70	455	91	55	255	5.5	1329
15	Ratlam	Alot	Dabdiya	BW	7.09	1308	0	376	178	40	46	0.57	0.15	83	317	63	39	148	6.0	850
16	Ratlam	Alot	Daulatganj	BW	7.59	1923	0	259	483	35	10	1.10	BDL	21	282	57	34	305	10.5	1250
17	Ratlam	Alot	Delwas	BW	7.10	2100	0	259	418	166	59	0.33	BDL	80	391	115	25	291	19.8	1365
18	Ratlam	Alot	Devgarh	BW	7.63	1308	0	166	280	96	3	0.43	0.17	33	243	80	10	185	3.6	850
19	Ratlam	Alot	Dharola	BW	7.07	1733	0	456	277	59	25	0.42	0.15	24	515	106	61	151	13.9	1126
20	Ratlam	Alot	Dudhiya	BW	7.11	1312	0	401	187	29	28	0.43	BDL	31	376	94	34	125	4.6	853
21	Ratlam	Alot	Fatehpur	BW	7.68	2692	0	924	314	69	50	1.17	0.12	92	817	164	99	239	1.2	1750
22	Ratlam	Alot	Goyal	BW	7.30	1884	0	437	351	53	12	0.78	BDL	56	450	93	53	221	3.7	1225

S.No	District	Block	Location	Source	pH	EC	CO_3	HCO_3	Cl	SO_4	NO_3	F	PO_4	SiO_2	TH	Ca	Mg	Na	K	TDS
23	Ratlam	Alot	Gulbalod	BW	7.21	1157	0	357	158	28	22	0.87	0.22	101	228	48	26	155	7.7	752
24	Ratlam	Alot	Gulbalod	BW	7.01	1468	0	573	121	34	44	0.58	0.17	98	475	97	57	112	5.9	954
25	Ratlam	Alot	Guradiya	BW	7.50	1881	0	339	376	74	40	0.39	BDL	31	391	91	40	249	2.3	1223
26	Ratlam	Alot	Gurukhedi	BW	7.56	1272	0	283	220	57	18	0.96	0.14	44	129	30	13	229	4.5	827
27	Ratlam	Alot	Hampura	BW	7.22	3912	0	437	1037	73	23	0.47	BDL	31	401	97	39	713	1.1	2543
28	Ratlam	Alot	Himmatkhedi	BW	7.58	1435	0	203	277	100	53	1.28	0.21	42	267	88	12	201	9.1	933
29	Ratlam	Alot	Hingodi	BW	7.29	1302	0	444	158	33	21	0.62	0.12	74	416	85	49	101	10.0	846
30	Ratlam	Alot	Jahanabad	BW	6.91	1277	0	407	156	32	37	0.88	0.11	58	327	119	7	133	10.7	830
31	Ratlam	Alot	Jahanabad	BW	6.92	1966	0	481	351	49	23	1.00	0.13	43	421	87	49	252	5.2	1278
32	Ratlam	Alot	Jamuniyashankar	BW	7.33	3748	0	203	1017	164	56	0.38	0.11	27	386	76	47	674	12.4	2436
33	Ratlam	Alot	Jeevangarh	BW	7.08	1294	0	314	233	31	16	1.25	BDL	58	307	77	28	150	7.6	841
34	Ratlam	Alot	Joyan	BW	7.55	1303	0	253	255	55	20	1.51	BDL	25	134	28	15	234	5.0	847
35	Ratlam	Alot	Kachhaliya	BW	7.09	1586	0	425	243	42	43	0.25	0.21	82	406	109	33	171	9.4	1031
36	Ratlam	Alot	Kalsya	BW	7.12	2346	0	431	485	59	58	0.25	BDL	28	653	186	46	233	5.8	1525
37	Ratlam	Alot	Kandiya	BW	7.11	1821	0	487	257	58	89	0.78	0.16	26	505	108	57	183	2.9	1184
38	Ratlam	Alot	Kanthariya	BW	7.37	1029	0	314	129	38	22	1.25	BDL	82	218	46	25	129	5.9	669
39	Ratlam	Alot	Karwa kalan	BW	7.47	2033	0	610	260	82	43	1.34	0.15	14	292	63	33	327	7.3	1321
40	Ratlam	Alot	Karwakhedi	BW	7.29	2693	0	444	555	149	14	0.46	0.12	34	530	120	56	368	10.8	1750
41	Ratlam	Alot	Kesari chouhan	BW	7.86	1323	0	314	196	89	20	1.06	0.16	26	178	38	20	218	4.4	860
42	Ratlam	Alot	Khajuriya Solanki	BW	7.36	1184	0	401	132	28	45	0.85	0.13	21	292	60	35	134	4.2	770
43	Ratlam	Alot	Khamriya	BW	7.04	778	0	265	70	35	28	1.55	0.14	48	153	44	11	102	3.9	506
44	Ratlam	Alot	Kharwa Khurd	BW	7.17	2590	0	585	498	60	23	1.28	BDL	75	243	50	29	476	9.4	1684
45	Ratlam	Alot	Khetakhedi	BW	7.17	1185	0	388	124	49	44	0.21	0.22	36	371	81	41	98	2.7	770
46	Ratlam	Alot	Kishangarh	BW	7.41	1242	0	382	156	39	43	1.26	0.14	116	361	75	42	111	13.0	807
47	Ratlam	Alot	Kitkhedi	BW	7.44	1699	0	462	218	76	72	0.59	BDL	29	540	121	58	137	4.7	1104
48	Ratlam	Alot	Kollu khedi	BW	7.19	1459	0	166	270	125	82	0.86	0.11	70	203	53	17	236	5.8	948
49	Ratlam	Alot	Lasudiyasurajmal	BW	7.55	1588	0	357	220	122	43	0.24	BDL	30	470	141	29	143	3.2	1032
50	Ratlam	Alot	Luni	BW	7.44	1802	0	462	203	165	53	0.88	0.1	60	337	87	29	254	8.3	1171

S.No	District	Block	Location	Source	pH	EC	CO_3	HCO_3	Cl	SO_4	NO_3	F	PO_4	SiO_2	TH	Ca	Mg	Na	K	TDS
51	Ratlam	Alot	Luni	BW	7.40	2087	0	518	329	76	57	0.66	0.24	57	510	103	61	236	12.5	1357
52	Ratlam	Alot	Majanpur	BW	7.03	1557	0	357	240	66	73	0.31	BDL	25	381	96	34	178	1.5	1012
53	Ratlam	Alot	Mandawal	BW	7.26	2003	0	536	302	71	43	0.41	BDL	37	559	131	57	196	9.9	1302
54	Ratlam	Alot	Mandla kalan	BW	7.53	2629	0	610	502	62	16	0.21	BDL	19	624	154	58	313	2.4	1709
55	Ratlam	Alot	Manuniya	BW	7.42	2184	0	166	530	155	22	0.17	0.13	21	312	69	34	351	9.2	1420
56	Ratlam	Alot	Maukhedi	BW	6.95	1510	0	419	230	35	40	0.48	0.14	84	421	85	51	148	5.3	982
57	Ratlam	Alot	Mermiyakheda	BW	7.47	1012	0	265	136	38	55	0.54	BDL	38	312	95	18	87	2.5	658
58	Ratlam	Alot	Minawada	BW	7.85	550	0	173	52	15	44	0.34	0.13	62	129	28	14	63	5.0	358
59	Ratlam	Alot	Moriya	BW	7.40	2509	0	425	520	121	25	0.42	BDL	21	510	130	45	338	4.2	1631
60	Ratlam	Alot	Negroon	BW	7.41	2761	0	179	767	105	15	0.51	BDL	39	317	65	38	485	6.6	1795
61	Ratlam	Alot	Nipanileela	BW	7.14	612	0	173	64	26	48	1.32	0.15	82	119	24	14	79	8.7	398
62	Ratlam	Alot	Nipanileela	BW	7.24	1065	0	197	146	80	82	0.23	BDL	93	233	50	26	131	9.0	692
63	Ratlam	Alot	Nipaniya Rajguru	BW	7.42	1277	0	425	139	49	32	0.27	0.11	39	436	89	52	89	0.7	830
64	Ratlam	Alot	Nipaniya Rajguru	BW	7.50	1361	0	444	156	53	31	0.44	0.13	42	446	107	43	105	1.3	885
65	Ratlam	Alot	Pant piploda	BW	7.52	1764	0	530	228	72	30	1.53	BDL	39	460	109	46	188	6.2	1147
66	Ratlam	Alot	Patan	BW	7.35	1180	0	253	215	49	17	0.30	BDL	28	183	46	17	185	1.0	767
67	Ratlam	Alot	Pipalkhedi	BW	8.20	1827	0	234	377	148	11	1.15	BDL	31	312	80	27	271	4.2	1188
68	Ratlam	Alot	PipalyaPitha	BW	7.38	2128	0	160	507	164	20	0.57	0.15	24	248	71	17	371	4.4	1383
69	Ratlam	Alot	Pipalyasisodiya	BW	8.60	758	18	173	82	53	27	1.19	0.14	48	178	37	21	89	2.4	493
70	Ratlam	Alot	Pipliya Maru	BW	7.28	2318	0	277	527	126	26	1.20	0.14	28	347	102	22	369	4.8	1507
71	Ratlam	Alot	Pipliyatukur	BW	7.36	1867	0	314	337	148	25	1.41	0.14	60	391	81	46	242	9.8	1214
72	Ratlam	Alot	Rajla	BW	7.43	2495	0	345	535	105	96	0.84	0.14	28	470	144	27	354	11.2	1622
73	Ratlam	Alot	Ranayara	BW	7.85	2013	0	209	532	49	20	0.56	BDL	31	243	49	29	348	4.2	1308
74	Ratlam	Alot	Rawatkheda	BW	7.55	908	0	296	89	38	39	0.31	0.14	48	272	55	33	79	1.7	590
75	Ratlam	Alot	Rinchha	BW	7.19	926	0	394	47	27	34	1.36	0.11	69	252	55	28	88	9.8	602
76	Ratlam	Alot	Sala khedi	BW	7.03	1454	0	530	119	88	16	0.54	0.18	71	243	51	28	213	11.3	945
77	Ratlam	Alot	Sanga kheda	BW	7.05	2260	0	240	532	113	46	0.47	BDL	70	391	81	46	331	11.9	1469
78	Ratlam	Alot	Semliya	BW	7.17	2340	0	314	512	129	39	0.34	0.14	34	441	96	49	331	6.8	1521

S.No	District	Block	Location	Source	pH	EC	CO_3	HCO_3	Cl	SO_4	NO_3	F	PO_4	SiO_2	TH	Ca	Mg	Na	K	TDS
79	Ratlam	Alot	Sherpur Khurd	BW	6.90	1211	0	456	109	27	46	0.22	0.15	82	431	115	35	75	6.9	787
80	Ratlam	Alot	Shisakhedi	BW	7.47	1692	0	542	190	83	40	0.35	BDL	33	480	100	56	165	2.7	1100
81	Ratlam	Alot	Surjana	BW	7.48	7391	0	407	2187	149	37	0.40	0.21	42	609	124	73	1409	8.6	4804
82	Ratlam	Alot	Tajkheda	BW	7.33	1685	0	388	280	48	70	0.98	0.14	28	441	127	30	181	3.5	1095
83	Ratlam	Alot	Talod	BW	7.01	1090	0	320	161	24	17	1.47	0.1	86	213	53	19	146	5.1	709
84	Ratlam	Alot	Talod	BW	6.80	1464	0	425	200	42	53	0.22	0.24	104	446	103	46	127	5.5	952
85	Ratlam	Alot	Thambguradiya	BW	7.22	2047	0	357	438	75	12	0.46	BDL	55	416	131	22	268	14.1	1331
86	Ratlam	Alot	Thuriya	BW	7.01	3150	0	832	492	75	118	0.50	0.13	35	881	178	106	313	6.8	2048
87	Ratlam	Alot	Aakya Kalan	BW	7.40	4848	0	647	1238	76	10	0.72	BDL	76	1748	451	150	303	3.8	3151
88	Ratlam	Alot	Arwas	BW	7.62	1964	0	191	495	88	25	1.37	0	45	272	57	31	323	2.0	1277
89	Ratlam	Alot	Kothati	BW	8.11	1328	0	222	260	91	8	0.88	BDL	38	267	71	22	175	7.0	863
90	Ratlam	Alot	Malya	BW	7.53	2288	0	92	693	51	14	1.45	BDL	29	262	71	20	398	2.1	1487
91	Ratlam	Alot	Mathopur	BW	7.99	1339	0	117	334	72	11	1.32	BDL	39	178	38	20	221	1.6	870
92	Ratlam	Alot	Aakya	DW	7.08	1572	0	518	172	45	72	0.39	0.11	22	480	90	62	138	3.3	1022
93	Ratlam	Alot	Aakyakalan	DW	7.09	1945	0	290	327	143	129	0.09	0.15	28	505	120	50	212	5.3	1264
94	Ratlam	Alot	Alot (Vikramgarh)	DW	7.19	1511	0	425	232	39	32	0.29	BDL	27	416	96	43	153	2.7	982
95	Ratlam	Alot	Arwalya Bama	DW	7.29	1831	0	489	277	39	77	0.56	0.17	32	530	134	47	174	3.1	1190
96	Ratlam	Alot	Arwas	DW	7.35	2510	0	647	382	109	43	0.36	BDL	39	688	155	73	256	3.6	1632
97	Ratlam	Alot	Asawata	DW	7.33	1051	0	320	97	68	51	0.23	0.1	32	307	65	35	97	3.6	683
98	Ratlam	Alot	Baguniya	DW	7.15	1647	0	228	380	56	27	0.24	BDL	28	327	70	37	224	3.2	1071
99	Ratlam	Alot	Bamankhedi	DW	8.00	797	0	259	65	58	29	1.43	0.16	26	208	43	24	83	5.0	518
100	Ratlam	Alot	Bardiya Rathor	DW	7.08	1155	0	320	135	58	61	0.23	0.14	44	371	84	39	90	2.8	751
101	Ratlam	Alot	Barkherakalan	DW	7.37	1237	0	216	230	61	40	1.44	0.22	36	243	53	27	168	3.8	804
102	Ratlam	Alot	Barkherakhurd	DW	7.75	707	0	228	57	42	45	0.69	BDL	28	243	49	29	50	2.6	460
103	Ratlam	Alot	Bersi	DW	7.43	1828	0	518	280	45	28	1.23	0.17	42	505	105	59	177	13.4	1188
104	Ratlam	Alot	Bhaisana	DW	7.07	2982	0	524	545	180	89	0.74	BDL	31	703	141	85	352	16.0	1938
105	Ratlam	Alot	Bhojakhedi	DW	7.15	853	0	364	55	12	35	0.14	0.24	31	317	84	26	47	3.0	554
106	Ratlam	Alot	Bhutiya	DW	7.21	2290	0	437	400	136	66	0.42	BDL	25	475	110	49	269	65.0	1489

S.No	District	Block	Location	Source	pH	EC	CO_3	HCO_3	Cl	SO_4	NO_3	F	PO_4	SiO_2	TH	Ca	Mg	Na	K	TDS
107	Ratlam	Alot	Bisalkheda	DW	7.44	2016	0	678	220	84	39	0.45	0.14	64	673	152	71	151	1.1	1310
108	Ratlam	Alot	Borkhedi	DW	6.90	1142	0	376	127	27	55	0.26	0.15	29	396	106	32	78	3.1	742
109	Ratlam	Alot	Chaplakhedi	DW	7.09	1756	0	474	262	52	53	0.91	BDL	84	505	105	59	165	5.2	1141
110	Ratlam	Alot	Chapri	DW	6.91	1829	0	524	213	133	28	0.71	0.11	55	480	97	58	193	9.0	1189
111	Ratlam	Alot	Dabdiya	DW	6.92	1560	0	425	233	42	47	0.31	BDL	95	446	103	46	148	6.4	1014
112	Ratlam	Alot	Daulatganj	DW	7.13	1093	0	462	74	36	13	0.42	BDL	44	391	101	34	68	4.0	710
113	Ratlam	Alot	Dehari	DW	7.29	2264	0	382	487	68	37	0.52	BDL	19	460	96	54	304	3.8	1472
114	Ratlam	Alot	Delwas	DW	6.80	1855	0	364	252	164	88	0.56	BDL	77	530	109	63	175	7.6	1206
115	Ratlam	Alot	Devgarh	DW	7.11	1603	0	345	230	68	136	0.21	0.22	36	450	92	54	157	6.8	1042
116	Ratlam	Alot	Dharola	DW	6.99	1369	0	339	222	49	33	0.39	BDL	41	312	64	37	165	6.3	890
117	Ratlam	Alot	Dudhiya	DW	7.14	1050	0	302	145	25	46	0.25	BDL	29	356	86	34	74	3.3	683
118	Ratlam	Alot	Goyal	DW	7.43	1073	0	277	151	51	36	0.16	0.15	24	312	71	33	100	1.5	697
119	Ratlam	Alot	Guradiya	DW	6.97	2181	0	425	394	92	82	0.64	BDL	27	520	156	31	258	1.7	1418
120	Ratlam	Alot	Hampura	DW	7.25	2006	0	413	405	45	35	0.17	0.2	20	342	72	39	299	4.3	1304
121	Ratlam	Alot	Hampura	DW	7.28	4843	0	622	1233	88	31	0.56	BDL	27	653	147	70	807	2.1	3148
122	Ratlam	Alot	Himmatkhedi	DW	7.23	1232	0	320	157	52	76	0.14	0.16	29	371	88	37	105	3.5	801
123	Ratlam	Alot	Hingodi	DW	6.98	1405	0	499	141	54	27	0.33	BDL	81	475	97	57	97	8.7	913
124	Ratlam	Alot	Inderpur	DW	7.10	595	0	209	32	35	44	1.23	BDL	20	238	57	23	26	0.5	387
125	Ratlam	Alot	Jahanabad	DW	7.04	865	0	290	104	25	15	1.41	BDL	55	153	34	17	123	5.7	562
126	Ratlam	Alot	Jamuniyashanka r	DW	7.54	1448	0	271	197	156	43	0.47	0.15	29	411	86	47	135	10.0	941
127	Ratlam	Alot	Joyan	DW	6.96	1576	0	407	245	44	58	0.58	BDL	22	436	100	45	158	3.0	1024
128	Ratlam	Alot	Kachhaliya	DW	6.92	1648	0	271	349	41	55	0.32	BDL	93	312	75	30	228	7.4	1071
129	Ratlam	Alot	Kalsiya	DW	7.19	2353	0	407	540	35	20	0.14	0.2	20	406	97	40	351	1.1	1529
130	Ratlam	Alot	Kalsya	DW	7.00	2358	0	462	472	48	68	0.30	BDL	25	673	178	56	224	4.9	1533
131	Ratlam	Alot	Kandiya	DW	7.28	1167	0	468	72	41	52	0.69	BDL	39	465	96	55	49	4.8	759
132	Ratlam	Alot	Kanthariya	DW	6.89	1438	0	474	139	57	71	0.17	BDL	70	490	101	58	95	13.4	935
133	Ratlam	Alot	Karadiya	DW	7.45	633	0	222	42	48	23	1.05	BDL	22	223	71	11	38	7.6	411
134	Ratlam	Alot	Karwa kalan	DW	7.29	3090	0	733	384	298	65	0.65	0.14	82	599	127	69	429	9.7	2009

S.No	District	Block	Location	Source	pH	EC	CO_3	HCO_3	Cl	SO_4	NO_3	F	PO_4	SiO_2	TH	Ca	Mg	Na	K	TDS
135	Ratlam	Alot	Karwakhedi	DW	7.13	2196	0	444	382	110	54	0.65	0.11	31	574	133	59	234	4.8	1427
136	Ratlam	Alot	Kaspura	DW	6.93	1117	0	407	101	25	52	0.30	BDL	81	396	81	47	69	5.4	726
137	Ratlam	Alot	Kelukheda	DW	7.31	918	0	327	75	45	35	1.43	BDL	32	307	65	35	66	3.2	597
138	Ratlam	Alot	KhajuriDevada	DW	7.15	1493	0	407	207	48	72	0.22	0.12	29	500	106	57	111	1.5	970
139	Ratlam	Alot	Khajuriya Solanki	DW	6.96	2256	0	487	440	59	34	0.65	0.11	25	530	136	46	261	18.6	1466
140	Ratlam	Alot	Khamriya	DW	6.85	775	0	320	42	27	32	0.11	0.12	34	228	76	9	70	2.5	504
141	Ratlam	Alot	Kharwa Khurd	DW	7.18	820	0	259	106	28	9	0.27	0.1	57	248	57	25	69	7.8	533
142	Ratlam	Alot	Khetakhedi	DW	7.38	1105	0	339	114	54	51	0.33	0.16	38	366	77	42	82	3.5	718
143	Ratlam	Alot	Kishangarh	DW	7.20	737	0	308	42	35	11	0.38	BDL	55	257	53	30	44	8.2	479
144	Ratlam	Alot	Kitkhedi	DW	7.40	1552	0	468	158	75	82	0.51	0.14	45	540	143	45	104	3.4	1009
145	Ratlam	Alot	Kothadi	DW	7.18	1293	0	265	155	146	48	0.39	0.11	38	272	63	28	169	3.5	840
146	Ratlam	Alot	Kothdi Karwa	DW	7.64	1753	0	345	290	84	96	0.55	BDL	26	257	65	23	281	4.8	1139
147	Ratlam	Alot	Lasudiyakhedi	DW	7.26	2826	0	345	642	125	71	0.57	0.24	31	356	71	44	482	4.4	1837
148	Ratlam	Alot	Lasudiyasurajm al	DW	7.46	1509	0	357	193	116	58	0.31	BDL	32	480	129	39	123	1.9	981
149	Ratlam	Alot	Luni	DW	7.30	881	0	191	114	49	78	1.45	0.11	55	104	22	12	150	6.4	573
150	Ratlam	Alot	Madhopur	DW	7.38	1515	0	327	250	84	38	0.23	BDL	32	396	80	47	163	2.8	985
151	Ratlam	Alot	Majanpur	DW	7.07	1458	0	333	207	69	92	0.40	0.15	22	475	118	44	113	1.3	948
152	Ratlam	Alot	Malhargarh	DW	7.55	2436	0	388	537	59	63	0.45	0.18	30	797	214	64	191	1.6	1583
153	Ratlam	Alot	Malya	DW	7.11	1068	0	333	102	56	56	1.41	0.18	30	371	76	44	70	2.8	694
154	Ratlam	Alot	Mandawal	DW	7.73	1515	0	376	215	69	62	0.92	BDL	33	327	71	36	192	3.6	985
155	Ratlam	Alot	Mandla kalan	DW	7.47	2773	0	690	498	60	30	0.90	BDL	25	653	160	61	335	1.0	1802
156	Ratlam	Alot	Manuniya	DW	7.27	1397	0	179	220	143	88	0.45	0.11	25	312	67	35	173	3.0	908
157	Ratlam	Alot	Maukhedi	DW	7.04	1354	0	382	210	27	27	0.42	BDL	72	371	75	45	135	6.3	880
158	Ratlam	Alot	Mermiyakheda	DW	7.45	1432	0	407	181	72	42	0.55	BDL	28	530	156	34	82	4.1	931
159	Ratlam	Alot	Minawada	DW	6.91	1692	0	136	324	213	43	0.74	0.17	59	391	91	40	205	4.2	1100
160	Ratlam	Alot	Moriya	DW	7.70	741	0	197	70	45	65	0.18	BDL	32	262	54	31	45	1.9	482
161	Ratlam	Alot	Munj	DW	7.10	1239	0	302	157	68	77	0.19	BDL	24	356	78	39	106	3.0	805
162	Ratlam	Alot	Negroon	DW	7.22	3053	0	635	590	99	32	0.36	BDL	28	569	141	53	423	26.6	1984

S.No	District	Block	Location	Source	pH	EC	CO_3	HCO_3	Cl	SO_4	NO_3	F	PO_4	SiO_2	TH	Ca	Mg	Na	K	TDS
163	Ratlam	Alot	Nipaniya Rajguru	DW	7.38	2236	0	561	379	77	21	0.95	0.14	31	550	111	66	257	2.1	1453
164	Ratlam	Alot	Pant piploda	DW	7.51	1733	0	548	208	68	36	0.25	0.15	50	550	154	40	141	5.7	1126
165	Ratlam	Alot	Pipalkhedi	DW	7.35	1074	0	333	80	101	41	0.68	0.11	22	262	53	32	122	3.2	698
166	Ratlam	Alot	PipalyaPitha	DW	6.97	1866	0	425	330	62	42	0.21	BDL	41	460	92	56	214	3.4	1213
167	Ratlam	Alot	Pipalyasisodiya	DW	7.50	689	0	234	47	48	31	1.49	0.12	34	203	47	21	61	2.6	448
168	Ratlam	Alot	Pipliya Maru	DW	7.56	1096	0	197	150	106	61	0.34	0.11	9	188	45	18	162	3.4	712
169	Ratlam	Alot	Pipliyatukur	DW	7.13	2399	0	524	361	167	66	0.51	BDL	48	589	127	66	269	14.3	1559
170	Ratlam	Alot	Rajla	DW	7.48	761	0	216	75	41	59	0.28	0.1	32	248	62	23	53	1.5	495
171	Ratlam	Alot	Ranayara	DW	7.09	2240	0	253	562	42	66	0.79	BDL	27	292	65	32	367	20.6	1456
172	Ratlam	Alot	Rinchha	DW	7.12	935	0	437	42	24	12	0.47	0.21	88	262	53	31	86	9.2	608
173	Ratlam	Alot	Sanga kheda	DW	7.13	3789	0	573	780	217	47	0.45	0.11	92	693	141	83	492	94.2	2463
174	Ratlam	Alot	Sathikheda	DW	7.10	1471	0	437	151	65	92	0.63	0.12	34	510	117	53	100	1.4	956
175	Ratlam	Alot	Semliya	DW	6.91	2807	0	425	585	145	45	1.05	BDL	28	564	114	68	372	20.4	1825
176	Ratlam	Alot	Sherpur Khurd	DW	6.94	1143	0	425	99	26	55	0.24	BDL	89	401	119	25	72	7.0	743
177	Ratlam	Alot	Shisakhedi	DW	7.37	1525	0	487	157	67	58	0.59	0.11	31	406	84	48	160	1.2	991
178	Ratlam	Alot	Surjana	DW	7.07	2103	0	481	377	69	33	1.34	0.16	29	490	155	25	254	4.0	1367
179	Ratlam	Alot	Tajkheda	DW	7.49	1864	0	487	275	59	68	0.61	0.1	42	530	123	54	179	6.6	1212
180	Ratlam	Alot	Tal	DW	6.88	2016	0	444	385	42	41	0.25	BDL	31	530	132	49	213	3.2	1310
181	Ratlam	Alot	Talod	DW	7.06	1062	0	493	45	16	42	0.72	0.11	95	292	63	33	106	5.1	690
182	Ratlam	Alot	Thapna	DW	7.37	740	0	302	47	13	43	0.31	0.14	31	287	62	32	36	3.0	481
183	Ratlam	Alot	Thuriya	DW	7.36	2340	0	659	312	58	139	0.52	BDL	28	767	162	88	182	3.9	1521
184	Ratlam	Alot	Aakya Kalan	DW	7.81	2896	0	585	545	149	17	0.33	BDL	28	663	182	51	355	1.6	1882
185	Ratlam	Alot	Chambal River	DW	7.60	1962	0	425	342	112	11	0.31	BDL	32	475	107	51	227	2.8	1275
186	Ratlam	Alot	Kshipra River	DW	7.80	1164	0	327	183	38	3	0.51	BDL	28	267	75	19	137	8.8	757
187	Ratlam	Alot	Arvalyasolanki	HP	7.47	1036	0	364	92	57	21	0.52	0.14	82	252	55	28	114	9.1	673
188	Ratlam	Alot	Arwas	HP	6.90	1834	0	462	260	115	35	0.36	BDL	29	520	133	45	178	4.6	1192
189	Ratlam	Alot	Bamankhedi	HP	7.21	1547	0	419	220	74	31	1.08	0.17	32	416	84	50	161	3.4	1006
190	Ratlam	Alot	Barkherakalan	HP	7.27	1192	0	222	205	72	45	0.24	0.17	33	228	45	28	166	4.4	775

S.No	District	Block	Location	Source	pH	EC	CO_3	HCO_3	Cl	SO_4	NO_3	F	PO_4	SiO_2	TH	Ca	Mg	Na	K	TDS
191	Ratlam	Alot	Barkherakhurd	HP	7.20	3077	0	216	815	125	55	0.38	0.13	35	411	84	49	507	12.2	2000
192	Ratlam	Alot	Bersi	HP	7.17	1197	0	253	218	48	21	1.30	BDL	24	153	36	16	198	4.4	778
193	Ratlam	Alot	Bhaisana	HP	7.01	4447	0	573	1075	144	33	0.51	0.15	22	634	129	75	709	33.8	2891
194	Ratlam	Alot	Bhutiya	HP	6.96	2813	0	548	507	149	59	0.21	BDL	28	599	125	69	329	68.3	1828
195	Ratlam	Alot	Bisalkheda	HP	7.58	2482	0	887	250	92	44	0.77	BDL	85	866	176	104	168	1.2	1613
196	Ratlam	Alot	Borkhedi	HP	7.04	1194	0	401	132	28	46	0.19	0.11	27	401	112	29	85	3.6	776
197	Ratlam	Alot	Chaplakhedi	HP	6.84	3630	0	887	574	158	87	0.80	0.16	87	1025	206	124	356	7.2	2360
198	Ratlam	Alot	Dabdiya	HP	6.94	1468	0	413	205	45	49	0.87	0.14	91	371	73	46	161	5.5	954
199	Ratlam	Alot	Delwas	HP	7.04	3066	0	598	540	172	76	0.58	BDL	79	777	164	89	339	10.0	1993
200	Ratlam	Alot	Gudbeli	HP	7.44	1110	0	364	106	51	48	0.42	0.21	42	361	75	42	85	2.6	722
201	Ratlam	Alot	Kachhaliya	HP	6.94	1315	0	407	166	32	56	0.19	0.16	96	396	125	20	113	6.6	855
202	Ratlam	Alot	Kamla khedi	HP	7.58	1393	0	277	287	25	23	0.57	BDL	41	252	57	26	197	8.2	905
203	Ratlam	Alot	Karadiya	HP	7.07	1392	0	320	215	91	21	0.23	0.14	44	366	96	31	143	10.8	905
204	Ratlam	Alot	Karwakhedi	HP	6.88	3161	0	610	600	178	12	0.51	BDL	33	723	145	88	392	3.6	2055
205	Ratlam	Alot	Kelukheda	HP	7.16	1103	0	351	120	57	30	1.33	BDL	21	332	82	31	98	3.2	717
206	Ratlam	Alot	Kesari chouhan	HP	7.72	1129	0	327	153	36	27	1.12	BDL	39	119	32	10	199	4.5	734
207	Ratlam	Alot	KhajuriDevada	HP	7.21	1750	0	487	235	65	69	0.23	BDL	31	569	146	50	135	7.6	1138
208	Ratlam	Alot	Kharwa Khurd	HP	7.16	1398	0	530	97	92	15	1.04	0.14	83	312	67	35	169	5.9	909
209	Ratlam	Alot	Kishangarh	HP	7.26	997	0	437	57	36	9	0.56	0.12	114	371	77	43	52	7.8	648
210	Ratlam	Alot	Kitkhedi	HP	7.31	1554	0	481	156	74	80	0.56	BDL	39	535	152	37	108	2.0	1010
211	Ratlam	Alot	Kothadi	HP	7.70	1706	0	277	277	159	55	0.27	0.14	45	376	82	41	216	3.8	1109
212	Ratlam	Alot	Kothdi Karwa	HP	7.49	1450	0	425	176	59	56	0.40	0.11	31	470	113	46	114	2.4	943
213	Ratlam	Alot	Lasudiyakhedi	HP	6.97	2830	0	425	607	134	41	0.32	0.1	28	520	104	63	409	3.6	1840
214	Ratlam	Alot	Lasudiyasurajmal	HP	7.38	1518	0	339	210	114	55	0.30	BDL	28	460	125	36	134	1.9	987
215	Ratlam	Alot	Madhopur	HP	7.58	5025	0	308	1395	167	54	0.25	0.14	28	540	129	53	899	5.8	3266
216	Ratlam	Alot	Malhargarh	HP	7.31	1953	0	437	367	42	51	0.38	0.21	42	649	158	62	149	0.8	1269
217	Ratlam	Alot	Malya	HP	8.10	935	0	259	112	68	11	0.27	0.21	26	153	35	16	140	3.8	608
218	Ratlam	Alot	Mandawal	HP	7.30	1340	0	382	168	49	66	0.32	0.12	34	416	99	41	113	2.9	871

S.No	District	Block	Location	Source	pH	EC	CO_3	HCO_3	Cl	SO_4	NO_3	F	PO_4	SiO_2	TH	Ca	Mg	Na	K	TDS
219	Ratlam	Alot	Mermiyakheda	HP	7.28	1616	0	450	213	51	78	0.50	BDL	32	500	152	29	138	4.0	1050
220	Ratlam	Alot	Minawada	HP	7.47	1532	0	364	218	98	42	0.54	BDL	56	446	95	51	142	5.9	996
221	Ratlam	Alot	Munj	HP	7.01	1683	0	357	237	96	119	0.13	BDL	36	460	102	50	171	20.1	1094
222	Ratlam	Alot	Patan	HP	6.74	2371	0	592	290	95	201	0.54	BDL	110	693	141	83	208	27.0	1541
223	Ratlam	Alot	Pipalkhedi	HP	7.99	1696	0	179	350	167	18	0.74	BDL	29	282	76	22	256	3.8	1102
224	Ratlam	Alot	Pipliyatukur	HP	7.43	2091	0	382	351	156	52	0.50	BDL	55	550	113	65	220	10.3	1359
225	Ratlam	Alot	Sanga kheda	HP	7.52	2228	0	370	441	65	51	0.58	0.13	74	411	83	49	290	11.5	1448
226	Ratlam	Alot	Nimbakhedi	HP	7.10	1832	0	259	403	109	5	0.31	0.11	31	332	69	39	265	2.7	1191

ANNEXURE-VI

STRANGE TABLE TO DETERMINE SURFACE RUNOFF COEFFICIENT

Total Monsoon rainfall (inches)	Total Monsoon rainfall (mm)	Percentage of Runoff to rainfall: Good catchment	Average catchment	Bad catchment	Total Monsoon rainfall (inches)	Total Monsoon rainfall (mm)	Percentage of Runoff to rainfall: Good catchment	Average catchment	Bad catchment
1.0	25.4	0.1	0.1	0.1	31.0	787.4	27.4	20.5	13.7
2.0	50.8	0.2	0.2	0.1	32.0	812.8	28.5	21.3	14.2
3.0	76.2	0.4	0.3	0.2	33.0	838.2	29.6	22.2	14.8
4.0	101.6	0.7	0.5	0.3	34.0	863.6	30.8	23.1	15.4
5.0	127.0	1.0	0.7	0.5	35.0	889.0	31.9	23.9	15.9
6.0	152.4	1.5	1.1	0.7	36.0	914.4	33.0	24.7	16.5
7.0	177.8	2.1	1.5	1.0	37.0	939.8	34.1	25.5	17.0
8.0	203.2	2.8	2.1	1.4	38.0	965.2	35.3	26.4	17.6
9.0	228.6	3.5	2.6	1.7	39.0	990.6	36.4	27.3	18.2
10.0	254.0	4.3	3.2	2.1	40.0	1016.0	37.5	28.1	18.7
11.0	279.4	5.2	3.9	2.6	41.0	1 041.4	38.6	28.9	19.3
12.0	304.8	6.2	4.6	3.1	42.0	1066.8	39.8	29.8	19.9
13.0	330.2	7.2	5.4	3.6	43.0	1092.2	40.9	30.6	20.4
14.0	355.6	8.3	6.2	4.1	44.0	1117.6	42.0	31.5	21.0
15.0	381.0	9.4	7.0	4.7	45.0	1143.0	43.1	32.3	21.5
16.0	406.4	10.5	7.8	5.2	46.0	1168.4	44.3	33.2	22.1
17.0	431.8	11.6	8.7	5.8	47.0	1193.8	45.4	34.0	22.7
18.0	457.2	12.8	9.6	6.4	48.0	1219.2	46.5	34.8	23.2
19.0	482.6	13.9	10.4	6.9	49.0	1244.6	47.6	35.7	23.8
20.0	508.0	15.0	11.3	7.5	50.0	1270.0	48.8	36.6	24.4
21.0	533.4	16.1	12.0	8.0	51.0	1295.4	49.9	37.4	24.9
22.0	558.8	17.3	12.9	8.6	52.0	1320.8	51.0	38.2	25.5
23.0	584.2	18.4	13.8	9.2	53.0	1346.2	52.1	39.0	26.0
24.0	609.6	19.5	14.6	9.7	54.0	1371.6	53.3	39.9	26.6
25.0	635.0	20.6	15.4	10.3	55.0	1397.0	54.4	40.8	27.2
26.0	660.4	21.8	16.3	10.9	56.0	1422.4	55.5	41.6	27.7
27.0	685.8	22.9	17.1	11.4	57.0	1447.8	56.6	42.4	28.3
28.0	711.2	24.0	18.0	12.0	58.0	1473.2	57.8	43.3	28.9
29.0	736.6	25.1	18.8	12.5	59.0	1498.6	58.9	44.4	29.41
30.0	762.0	26.3	19.7	13.1	60.0	1524.0	60.0	45.0	30.0

ANNEXURE-VII

NORMS RECOMMENDED FOR SPECIFIC YIELD

S. No	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
1	Alluvium	AL01	Younger Alluvium (Clay/Silt/Sand/ Calcareous concretions)	Quaternary	10	8	12
2	Alluvium	AL02	Pebble / Gravel/ Bazada/ Kandi	Quaternary	16	12	20
3	Alluvium	AL03	Older Alluvium (Silt/Sand/Gravel/Lithomargic clay)	Quaternary	6	4	8
4	Alluvium	AL04	Aeolian Alluvium (Silt/ Sand)	Quaternary	16	12	20
5	Alluvium	AL05	Coastal Alluvium (Sand/Silt/Clay)	Quaternary	10	8	12
6	Alluvium	AL06	Valley Fills	Quaternary	16	12	20
7	Alluvium	AL07	Glacial Deposits	Quaternary	16	12	20
8	Laterite	LT01	Laterite / Ferruginous concretions	Quaternary	2.5	2	3
9	Basalt	BS01	Basic Rocks (Basalt) - Weathered, Vesicular or Jointed	Mesozoic to Cenozoic	2	1	3
10	Basalt	BS01	Basic Rocks (Basalt) - Massive Poorly Jointed	Mesozoic to Cenozoic	0.35	0.2	0.5
11	Basalt	BS02	Ultra Basic - Weathered, Vesicular or Jointed	Mesozoic to Cenozoic	2	1	3
12	Basalt	BS02	Ultra Basic - Massive Poorly Jointed	Mesozoic to Cenozoic	0.35	0.2	0.5
13	Sandstone	ST01	Sandstone/Conglomerate	Upper Palaeozoic to Cenozoic	3	1	5
14	Sandstone	ST02	Sandstone with Shale	Upper Palaeozoic	3	1	5

S. No	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
				to Cenozoic			
15	Sandstone	ST03	Sandstone with shale/ coal beds	Upper Palaeozoic to Cenozoic	3	1	5
16	Sandstone	ST04	Sandstone with Clay	Upper Palaeozoic to Cenozoic	3	1	5
17	Sandstone	ST05	Sandstone/Conglomerate	Proterozoic to Cenozoic	3	1	5
18	Sandstone	ST06	Sandstone with Shale	Proterozoic to Cenozoic	3	1	5
19	Shale	SH01	Shale with limestone	Upper Palaeozoic to Cenozoic	1.5	1	2
20	Shale	SH02	Shale with Sandstone	Upper Palaeozoic to Cenozoic	1.5	1	2
21	Shale	SH03	Shale, limestone and sandstone	Upper Palaeozoic to Cenozoic	1.5	1	2
22	Shale	SH04	Shale	Upper Palaeozoic to Cenozoic	1.5	1	2
23	Shale	SH05	Shale/Shale with Sandstone	Proterozoic to Cenozoic	1.5	1	2
24	Shale	SH06	Shale with Limestone	Proterozoic to Cenozoic	1.5	1	2
25	Limestone	LS01	Miliolitic Limestone	Quarternary	2	1	3
26	Limestone	LS01	KarstifiedMiliolitic Limestone	Quarternary	10	5	15
27	Limestone	LS02	Limestone / Dolomite	Upper Palaeozoic to Cenozoic	2	1	3
28	Limestone	LS02	KarstifiedLimestone / Dolomite	Upper Palaeozoic to Cenozoic	10	5	15

S. No	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
29	Limestone	LS03	Limestone/Dolomite	Proterozoic	2	1	3
30	Limestone	LS03	Karstified Limestone/Dolomite	Proterozoic	10	5	15
31	Limestone	LS04	Limestone with Shale	Proterozoic	2	1	3
32	Limestone	LS04	Karstified Limestone with Shale	Proterozoic	10	5	15
33	Limestone	LS05	Marble	Azoic to Proterozoic	2	1	3
34	Limestone	LS05	Karstified Marble	Azoic to Proterozoic	10	5	15
35	Granite	GR01	Acidic Rocks (Granite, Syenite, Rhyolite etc.) - Weathered, Jointed	Mesozoic to Cenozoic	1.5	1	2
36	Granite	GR01	Acidic Rocks (Granite, Syenite, Rhyolite etc.)- Massive or Poorly Fractured	Mesozoic to Cenozoic	0.35	0.2	0.5
37	Granite	GR02	Acidic Rocks (Pegmatite, Granite, Syenite, Rhyolite etc.) - Weathered, Jointed	Proterozoic to Cenozoic	3	2	4
38	Granite	GR02	Acidic Rocks (Pegmatite, Granite, Syenite, Rhyolite etc.) - Massive, Poorly Fractured	Proterozoic to Cenozoic	0.35	0.2	0.5
39	Schist	SC01	Schist - Weathered, Jointed	Azoic to Proterozoic	1.5	1	2
40	Schist	SC01	Schist - Massive, Poorly Fractured	Azoic to Proterozoic	0.35	0.2	0.5
41	Schist	SC02	Phyllite	Azoic to Proterozoic	1.5	1	2
42	Schist	SC03	Slate	Azoic to Proterozoic	1.5	1	2
43	Quartzite	QZ01	Quartzite - Weathered, Jointed	Proterozoic to Cenozoic	1.5	1	2

S. No	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
44	Quartzite	QZ01	Quartzite - Massive, Poorly Fractured	Proterozoic to Cenozoic	0.3	0.2	0.4
45	Quartzite	QZ02	Quartzite - Weathered, Jointed	Azoic to Proterozoic	1.5	1	2
46	Quartzite	QZ02	Quartzite- Massive, Poorly Fractured	Azoic to Proterozoic	0.3	0.2	0.4
47	Charnockite	CK01	Charnockite - Weathered, Jointed	Azoic	3	2	4
48	Charnockite	CK01	Charnockite - Massive, Poorly Fractured	Azoic	0.3	0.2	0.4
49	Khondalite	KH01	Khondalites, Granulites - Weathered, Jointed	Azoic	1.5	1	2
50	Khondalite	KH01	Khondalites, Granulites - Mssive, Poorly Fractured	Azoic	0.3	0.2	0.4
51	Banded Gneissic Complex	BG01	Banded Gneissic Complex - Weathered, Jointed	Azoic	1.5	1	2
52	Banded Gneissic Complex	BG01	Banded Gneissic Complex - Massive, Poorly Fractured	Azoic	0.3	0.2	0.4
53	Gneiss	GN01	Undifferentiated metasedimentaries/ Undifferentiated metamorphic - Weathered, Jointed	Azoic to Proterozoic	1.5	1	2
54	Gneiss	GN01	Undifferentiated metasedimentaries/ Undifferentiated metamorphic - Massive, Poorly Fractured	Azoic to Proterozoic	0.3	0.2	0.4
55	Gneiss	GN02	Gneiss -Weathered, Jointed	Azoic to Proterozoic	3	2	4

S. No	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
56	Gneiss	GN02	Gneiss-Massive, Poorly Fractured	Azoic to Proterozoic	0.3	0.2	0.4
57	Gneiss	GN03	Migmatitic Gneiss - Weathered, Jointed	Azoic	1.5	1	2
58	Gneiss	GN03	Migmatitic Gneiss - Massive, Poorly Fractured	Azoic	0.3	0.2	0.4
59	Intrusive	IN01	Basic Rocks (Dolerite, Anorthosite etc.) - Weathered, Jointed	Proterozoic to Cenozoic	2	1	3
60	Intrusive	IN01	Basic Rocks (Dolerite, Anorthosite etc.) - Massive, Poorly Fractured	Proterozoic to Cenozoic	0.35	0.2	0.5
61	Intrusive	IN02	Ultrabasics (Epidiorite, Granophyre etc.) - Weathered, Jointed	Proterozoic to Cenozoic	2	1	3
62	Intrusive	IN02	Ultrabasics (Epidiorite, Granophyre etc.) - Massive, Poorly Fractured	Proterozoic to Cenozoic	0.35	0.2	0.5

ANNEXURE-VIII

PROPOSED ARTIFICIAL RECHARGE STRUCTURES OF RAWATKHEDA WATERSHED

S. no.	Village name	Latitude	Longitude	Structure type
1	Kalsiya	23.7488	75.670658	Check dam
2	Kalsiya	23.76391	75.656467	Check dam
3	Kalsiya	23.768208	75.656414	Check dam
4	Dhapna	23.775317	75.655732	Check dam
5	Dhapna	23.778067	75.649418	Check dam
6	Dhapna	23.77875	75.653629	Check dam
7	Dhapna	23.784786	75.651809	Check dam
8	Kalsiya	23.747638	75.673231	NB
9	Kalsiya	23.750408	75.67548	NB
10	Kalsiya	23.758754	75.666745	NB
11	Kalsiya	23.760587	75.655547	NB
12	Kalsiya	23.763389	75.660105	NB
13	Dhapna	23.772418	75.665714	NB
14	Dhapna	23.773039	75.646868	NB
15	Dhapna	23.774504	75.650848	NB
16	Dhapna	23.774597	75.665642	NB
17	Dhapna	23.779179	75.655947	NB
18	Dhapna	23.783452	75.639943	NB
19	Dhapna	23.785736	75.647416	NB
20	Dhapna	23.794997	75.64701	NB
21	Kalsiya	23.758918	75.661629	Percolation tank
22	Dhapna	23.789577	75.652483	Percolation tank
23	Kalsiya	23.771624	75.67622	Recharge shaft
24	Dhapna	23.774523	75.661289	Recharge shaft
25	Dhapna	23.784854	75.657375	Recharge shaft
26	Dhapna	23.787328	75.656994	Recharge shaft

ANNEXURE-IX

PROPOSED ARTIFICIAL RECHARGE STRUCTURES OF KSHIPRA WATERSHED

S. no.	Village name	Latitude	Longitude	Structure type
1	Talod	23.66669	75.620716	Check dam
2	Patan	23.688512	75.570995	Check dam
3	Patan	23.697422	75.573294	Check dam
4	Patan	23.701097	75.560374	Check dam
5	Patan	23.704029	75.567102	Check dam
6	Patan	23.70431	75.564252	Check dam
7	Isampur	23.705681	75.625649	Check dam
8	Patan	23.706032	75.576646	Check dam
9	Pratappura	23.709259	75.585508	Check dam
10	Patan	23.710762	75.562815	Check dam
11	Joyan	23.716271	75.627684	Check dam
12	Bhim	23.718584	75.661409	Check dam
13	Bhim	23.721911	75.653963	Check dam
14	Kamla Khedi	23.722887	75.636017	Check dam
15	Goyal	23.72514	75.650297	Check dam
16	Joyan	23.729126	75.615451	Check dam
17	Kamla Khedi	23.732213	75.633083	Check dam
18	Kamla Khedi	23.735903	75.643859	Check dam
19	Guradiya	23.737896	75.605688	Check dam
20	Dudhawati	23.738993	75.596166	Check dam
21	Guradiya	23.742291	75.616546	Check dam
22	Khedi (Alot)	23.750042	75.5599	Check dam
23	Alot	23.759135	75.55782	Check dam
24	Bhoja Khedi	23.759982	75.62167	Check dam
25	Laxmipura	23.762196	75.614909	Check dam
26	Alot	23.773969	75.534217	Check dam
27	Alot	23.774316	75.572773	Check dam
28	Bhavgarh	23.777302	75.602636	Check dam
29	Palnagara	23.780166	75.585623	Check dam
30	Bor Khedi (Alot)	23.784622	75.596226	Check dam
31	Bor Khedi (Alot)	23.785831	75.543692	Check dam
32	Palnagara	23.787491	75.583372	Check dam
33	Tajli	23.788244	75.559254	Check dam
34	Jeevangarh	23.740182	75.532117	Conservation pond
35	Khamariya	23.740645	75.559576	Conservation pond
36	Jeevangarh	23.7613	75.522373	Conservation pond
37	Isampur	23.695719	75.621759	Gabion
38	Patan	23.699172	75.552973	Gabion
39	Nipaniya Rajguru	23.700442	75.596847	Gabion
40	Goyal	23.724607	75.669721	Gabion

S. no.	Village name	Latitude	Longitude	Structure type
41	Badnawara	23.729815	75.57754	Gabion
42	Khamariya	23.733359	75.553624	Gabion
43	Goyal	23.740993	75.65215	Gabion
44	Alot	23.747814	75.548833	Gabion
45	Newli	23.752093	75.626662	Gabion
46	Khajuri Solanki	23.762435	75.528875	Gabion
47	Khajuri Solanki	23.764577	75.595474	Gabion
48	Khajuri Solanki	23.779056	75.532888	Gabion
49	Talod	23.664558	75.6152	NB
50	Dabdiya	23.665735	75.577071	NB
51	Dabdiya	23.669041	75.570998	NB
52	Talod	23.671641	75.612875	NB
53	Talod	23.673877	75.60061	NB
54	Talod	23.676871	75.585642	NB
55	Talod	23.676884	75.618355	NB
56	Patan	23.684188	75.569193	NB
57	Talod	23.684402	75.61158	NB
58	Dayalpura	23.689324	75.549319	NB
59	Isampur	23.690369	75.613424	NB
60	Isampur	23.690414	75.61898	NB
61	Patan	23.692393	75.559777	NB
62	Nipaniya Rajguru	23.692417	75.59049	NB
63	Patan	23.693557	75.543401	NB
64	Patan	23.695563	75.555165	NB
65	Patan	23.696967	75.568419	NB
66	Isampur	23.705264	75.61521	NB
67	Patan	23.705431	75.582376	NB
68	Isampur	23.70568	75.629551	NB
69	Patan	23.708638	75.576155	NB
70	Isampur	23.70912	75.629879	NB
71	Joyan	23.710769	75.618298	NB
72	Patan	23.71335	75.557765	NB
73	Indarpura	23.715405	75.677241	NB
74	Bhim	23.718361	75.657034	NB
75	Joyan	23.723182	75.617862	NB
76	Badnawara	23.723764	75.575124	NB
77	Joyan	23.724273	75.624509	NB
78	Badnawara	23.724277	75.589759	NB
79	Goyal	23.725708	75.65817	NB
80	Khamariya	23.727111	75.553796	NB
81	Kabriya Khedi	23.727129	75.675002	NB
82	Dudhawati	23.727511	75.599737	NB
83	Goyal	23.728666	75.655911	NB
84	Khamariya	23.733418	75.544088	NB
85	Guradiya	23.734995	75.62328	NB

S. no.	Village name	Latitude	Longitude	Structure type
86	Badnawara	23.740509	75.588366	NB
87	Guradiya	23.742833	75.605199	NB
88	Khedi (Alot)	23.742991	75.563441	NB
89	Alot	23.74388	75.542456	NB
90	Kalsiya	23.747187	75.65148	NB
91	Newli	23.747363	75.635439	NB
92	Laxmipura	23.753123	75.619371	NB
93	Jeevangarh	23.756021	75.524521	NB
94	Alot	23.756792	75.575172	NB
95	Jeevangarh	23.757144	75.531419	NB
96	Alot	23.75807	75.56879	NB
97	Laxmipura	23.758256	75.604605	NB
98	Bhoja Khedi	23.760482	75.628814	NB
99	Bhoja Khedi	23.766122	75.548815	NB
100	Khajuri Solanki	23.766445	75.590372	NB
101	Bhoja Khedi	23.770291	75.626005	NB
102	Bhoja Khedi	23.770753	75.614724	NB
103	Palnagara	23.774055	75.592754	NB
104	Palnagara	23.776737	75.529317	NB
105	Palnagara	23.778587	75.552744	NB
106	Bhoja Khedi	23.781898	75.567813	NB
107	Bhoja Khedi	23.783841	75.534735	NB
108	Bhoja Khedi	23.784746	75.611643	NB
109	Bhoja Khedi	23.787033	75.622408	NB
110	Bor Khedi (Alot)	23.788148	75.589469	NB
111	Bor Khedi (Alot)	23.790554	75.586685	NB
112	Bor Khedi (Alot)	23.791006	75.604312	NB
113	Akya (Alot)	23.800866	75.562529	NB
114	Akya (Alot)	23.806196	75.566266	NB
115	Thuriya	23.843915	75.564067	NB
116	Dabdiya	23.667157	75.581858	Percolation tank
117	Joyan	23.717519	75.597592	Percolation tank
118	Alot	23.766433	75.568628	Percolation tank
119	Tajli	23.797076	75.572048	Percolation tank
120	Dabdiya	23.658579	75.572094	Recharge shaft
121	Talod	23.661553	75.609808	Recharge shaft
122	Talod	23.665439	75.60664	Recharge shaft
123	Talod	23.684903	75.603927	Recharge shaft

ANNEXURE-X

PROPOSED ARTIFICIAL RECHARGE STRUCTURES OF LUNI WATERSHED

S. no.	Village name	Latitude	Longitude	Structure type
1	Kolu Khedi	23.538293	75.510965	Check dam
2	Kolu Khedi	23.538352	75.515504	Check dam
3	Chapala Khedi	23.57138	75.492757	Check dam
4	Delwas	23.584728	75.49042	Check dam
5	Delwas	23.594855	75.496467	Check dam
6	Palasiya	23.599974	75.495438	Check dam
7	Bilawali	23.608874	75.465946	Check dam
8	Kharwa Kalan	23.613672	75.465493	Check dam
9	Kharwa Kalan	23.617217	75.472069	Check dam
10	Kharwa Kalan	23.61865	75.477289	Check dam
11	Kharwa Kalan	23.618941	75.466176	Check dam
12	Pipapliya Tukhar	23.623312	75.491903	Check dam
13	Pipapliya Tukhar	23.629558	75.49677	Check dam
14	Luni	23.653776	75.487817	Check dam
15	Luni	23.658324	75.502581	Check dam
16	Salakhedi	23.667979	75.49686	Check dam
17	Nipaniya Leela	23.669176	75.480161	Check dam
18	Chhapri	23.675724	75.486937	Check dam
19	Sundarpura	23.67701	75.495368	Check dam
20	Rinchha	23.679668	75.517604	Check dam
21	Arwalya Solanky	23.683294	75.488291	Check dam
22	Anandgarh	23.692529	75.500781	Check dam
23	Dhutakhedi	23.69441	75.482737	Check dam
24	Sherpur Khurd	23.706569	75.492633	Check dam
25	Rachhaliya	23.709241	75.460573	Check dam
26	Rachhaliya	23.712652	75.47136	Check dam
27	Saranga Kheda	23.723671	75.452051	Check dam
28	Beti Khedi	23.724994	75.515927	Check dam
29	Kachhaliya	23.728775	75.455479	Check dam
30	Dehri	23.735334	75.47044	Check dam
31	Mau Khedi	23.737925	75.506238	Check dam
32	Dehri	23.738545	75.469131	Check dam
33	Jhangariya	23.738851	75.484793	Check dam
34	Bhutiya	23.740159	75.456053	Check dam
35	Gulbalod	23.751496	75.490652	Check dam
36	Gulbalod	23.751898	75.497019	Check dam
37	Kalyanpura	23.760409	75.440845	Check dam
38	Manuniya	23.763592	75.450028	Check dam
39	Baguniya	23.764526	75.465608	Check dam
40	Manuniya	23.767715	75.433489	Check dam

S. no.	Village name	Latitude	Longitude	Structure type
41	Manuniya	23.768044	75.440529	Check dam
42	Dudhiya	23.771412	75.482196	Check dam
43	Dudhiya	23.777289	75.497887	Check dam
44	Pipalya Maru	23.789088	75.475832	Check dam
45	Pipalya Sisodiya	23.78911	75.488585	Check dam
46	Ranayara	23.790191	75.46364	Check dam
47	Narani	23.798972	75.497097	Check dam
48	Munj	23.80646	75.553373	Check dam
49	Pipalya Sisodiya	23.808653	75.487451	Check dam
50	Pipalya Sisodiya	23.81258	75.4694	Check dam
51	Bardiya	23.815288	75.552855	Check dam
52	Arwalya Bhama	23.832339	75.544039	Check dam
53	Bajpur	23.833973	75.532498	Check dam
54	Hanumantya	23.836615	75.478824	Check dam
55	Hanumantya	23.838447	75.497563	Check dam
56	Alakheda	23.844671	75.495531	Check dam
57	Khajuri Devada	23.845759	75.506269	Check dam
58	Khajuri Devada	23.84602	75.514288	Check dam
59	Garda	23.865908	75.534376	Check dam
60	Bagli	23.878017	75.495873	Check dam
61	Majanpur	23.882843	75.510907	Check dam
62	Kolu Khedi	23.534364	75.510148	Conservation pond
63	Kolu Khedi	23.542633	75.520558	Conservation pond
64	Saranga Kheda	23.719343	75.438985	Conservation pond
65	Lasudiya Khedi	23.740996	75.429943	Conservation pond
66	Ranayara	23.771881	75.452357	Conservation pond
67	Pipalya Maru	23.797723	75.464683	Conservation pond
68	Sipawra	23.906119	75.477644	Conservation pond
69	Kasari Harod	23.567844	75.485876	Gabion
70	Kolu Khedi	23.538719	75.504814	NB
71	Kolu Khedi	23.543159	75.509389	NB
72	Kolu Khedi	23.550113	75.510366	NB
73	Kasari Harod	23.561423	75.481158	NB
74	Kasari Harod	23.565757	75.489262	NB
75	Kasari Harod	23.571191	75.481323	NB
76	Kasari Harod	23.578458	75.485083	NB
77	Kasari Harod	23.586444	75.481169	NB
78	Delwas	23.592389	75.492483	NB
79	Kasari Harod	23.592903	75.480376	NB
80	Delwas	23.597202	75.500929	NB
81	Palasiya	23.599501	75.491926	NB
82	Kharwa Kalan	23.601864	75.483384	NB
83	Bilawali	23.604713	75.467554	NB
84	Bilawali	23.606283	75.462451	NB
85	Palasiya	23.606977	75.489555	NB

S. no.	Village name	Latitude	Longitude	Structure type
86	Kharwa Kalan	23.612734	75.471338	NB
87	Pipapliya Tukhar	23.615653	75.490644	NB
88	Kharwa Kalan	23.618057	75.463175	NB
89	Kharwa Kalan	23.620659	75.464196	NB
90	Pipapliya Tukhar	23.624546	75.488388	NB
91	Kharwa Kalan	23.626895	75.477341	NB
92	Kamma Khedi	23.635997	75.490601	NB
93	Luni	23.641782	75.497856	NB
94	Luni	23.6443	75.47745	NB
95	Luni	23.65211	75.500424	NB
96	Nipaniya Leela	23.658816	75.476905	NB
97	Luni	23.664226	75.501844	NB
98	Nipaniya Leela	23.664708	75.466215	NB
99	Salakhedi	23.667579	75.501191	NB
100	Nipaniya Leela	23.668396	75.486268	NB
101	Kanthariya	23.670079	75.540465	NB
102	Rinchha	23.676251	75.5272	NB
103	Arwalya Solanky	23.679226	75.482202	NB
104	Thamguradiya	23.684171	75.45797	NB
105	Thamguradiya	23.688464	75.472589	NB
106	Hingadi	23.695332	75.502317	NB
107	Hingadi	23.695816	75.516947	NB
108	Thamguradiya	23.698192	75.458634	NB
109	Dhutakhedi	23.702747	75.485792	NB
110	Thamguradiya	23.705564	75.45267	NB
111	Thamguradiya	23.706541	75.455533	NB
112	Sherpur Khurd	23.708444	75.505317	NB
113	Jahanabad	23.71145	75.523478	NB
114	Jahanabad	23.71471	75.533664	NB
115	Rachhaliya	23.717888	75.471538	NB
116	Saranga Kheda	23.718816	75.444101	NB
117	Saranga Kheda	23.719082	75.449377	NB
118	Rachhaliya	23.719829	75.482153	NB
119	Sherpur Khurd	23.720548	75.4928	NB
120	Kajakhedi	23.727178	75.446107	NB
121	Kajakhedi	23.731643	75.449237	NB
122	Mau Khedi	23.736518	75.522213	NB
123	Bhutiya	23.739169	75.442919	NB
124	Khaspura	23.749126	75.500748	NB
125	Gulbalod	23.750352	75.485481	NB
126	Kalyanpura	23.754509	75.439539	NB
127	Kalyanpura	23.756113	75.431031	NB
128	Gulbalod	23.758414	75.490916	NB
129	Baguniya	23.759016	75.453445	NB
130	Gulbalod	23.761182	75.495837	NB

S. no.	Village name	Latitude	Longitude	Structure type
131	Baguniya	23.761341	75.482057	NB
132	Dudhiya	23.768045	75.510814	NB
133	Manuniya	23.769078	75.426018	NB
134	Dudhiya	23.773591	75.504895	NB
135	Ranayara	23.774443	75.459012	NB
136	Pipalya Maru	23.782317	75.486724	NB
137	Ranayara	23.786508	75.456893	NB
138	Malhargarh	23.789057	75.510051	NB
139	Pipalya Sisodiya	23.794769	75.487397	NB
140	Jamuniya Shankar	23.795506	75.456765	NB
141	Narayangarh	23.801314	75.539215	NB
142	Jalodiya	23.803461	75.511099	NB
143	Pipalya Sisodiya	23.805274	75.475519	NB
144	Shisakhedi	23.808639	75.526427	NB
145	Bardiya	23.808816	75.547608	NB
146	Pipalya Sisodiya	23.809642	75.469686	NB
147	Pipalya Sisodiya	23.811835	75.463694	NB
148	Pipalya Pitha	23.812189	75.49484	NB
149	Shisakhedi	23.812402	75.519592	NB
150	Shisakhedi	23.81909	75.532491	NB
151	Pipalya Pitha	23.82358	75.486927	NB
152	Khajuri Devada	23.830386	75.504685	NB
153	Khajuri Devada	23.830735	75.516902	NB
154	Hanumantya	23.834764	75.491297	NB
155	Alakheda	23.846589	75.48461	NB
156	Alakheda	23.848008	75.489707	NB
157	Bajpur	23.852547	75.528779	NB
158	Mina Khedi	23.856176	75.513131	NB
159	Kandiya	23.857927	75.553244	NB
160	Mina Khedi	23.861928	75.509252	NB
161	Rajla	23.86654	75.487247	NB
162	Mithangarh	23.874682	75.52858	NB
163	Majanpur	23.884787	75.517011	NB
164	Kalakhedi	23.891364	75.490638	NB
165	Ismailganj	23.903176	75.471461	NB
166	Sipawra	23.904363	75.483591	NB
167	Palasiya	23.609881	75.494597	Percolation tank
168	Luni	23.644365	75.503067	Percolation tank
169	Anandgarh	23.683959	75.494516	Percolation tank
170	Hingadi	23.699948	75.500033	Percolation tank
171	Sherpur Khurd	23.723082	75.496325	Percolation tank
172	Jhangariya	23.742354	75.494161	Percolation tank
173	Gulbalod	23.766079	75.491672	Percolation tank
174	Arniya (Alot)	23.790649	75.497213	Percolation tank
175	Shisakhedi	23.818679	75.525354	Percolation tank

S. no.	Village name	Latitude	Longitude	Structure type
176	Bardiya	23.824354	75.547016	Percolation tank
177	Bajpur	23.847055	75.537985	Percolation tank
178	Majanpur	23.873711	75.5102	Percolation tank
179	Ralayata	23.886705	75.506502	Percolation tank
180	Semliya	23.776843	75.430787	Recharge shaft
181	Himmat Khedi	23.851525	75.47249	Recharge shaft
182	Moriya	23.87532	75.481056	Recharge shaft

ANNEXURE-XI

PROPOSED ARTIFICIAL RECHARGE STRUCTURES OF LAKHNETI WATERSHED

S. no.	Village name	Latitude	Longitude	Structure type
1	Malya (Tal))	23.768161	75.334967	Check dam
2	Madhopur	23.775016	75.316444	Check dam
3	Malya (Tal)	23.775066	75.339814	Check dam
4	Melu Khedi	23.776684	75.276997	Check dam
5	Melu Khedi	23.778794	75.28362	Check dam
6	Malya (Tal)	23.779382	75.332144	Check dam
7	Madhopur	23.783538	75.30678	Check dam
8	Gondi Shankar	23.784058	75.269425	Check dam
9	Asawata	23.785126	75.347972	Check dam
10	Khejadiya Sondhiyan	23.785238	75.388537	Check dam
11	Asawata	23.785757	75.352073	Check dam
12	Kharawadi	23.785879	75.396456	Check dam
13	Madhopur	23.789907	75.319717	Check dam
14	Malya (Tal))	23.790751	75.338114	Check dam
15	Semliya	23.791941	75.42319	Check dam
16	Kharawadi	23.792012	75.385132	Check dam
17	Madhopur	23.792868	75.309444	Check dam
18	Asawata	23.793079	75.362868	Check dam
19	Madhopur	23.793147	75.330706	Check dam
20	Semliya	23.797508	75.432428	Check dam
21	Madhopur	23.798096	75.332769	Check dam
22	Asawata	23.798393	75.348303	Check dam
23	Asawata	23.798687	75.357715	Check dam
24	Madhopur	23.798867	75.344473	Check dam
25	Kharawadi	23.800292	75.385872	Check dam
26	Jamuniya Shankar	23.802365	75.433375	Check dam
27	Madhopur	23.80266	75.331943	Check dam
28	Ana Khedi	23.805186	75.306681	Check dam
29	Asawata	23.805648	75.357377	Check dam
30	Madhopur	23.807138	75.31066	Check dam
31	Asawata	23.812152	75.355836	Check dam
32	Barkheda Khurd	23.81219	75.388375	Check dam
33	Karadiya	23.815031	75.437015	Check dam
34	Barkheda Khurd	23.819354	75.384048	Check dam
35	Khaikheda	23.823063	75.354611	Check dam
36	Karadiya	23.824839	75.434722	Check dam
37	Karadiya	23.8254	75.423743	Check dam
38	Karadiya	23.827317	75.450681	Check dam
39	Karadiya	23.832879	75.439875	Check dam
40	Shamimabad	23.83414	75.378733	Check dam

S. no.	Village name	Latitude	Longitude	Structure type
41	Karadiya	23.836716	75.435744	Check dam
42	Khajurinag	23.840107	75.358358	Check dam
43	Karadiya	23.840837	75.438535	Check dam
44	Karadiya	23.845942	75.440975	Check dam
45	Kelukheda	23.849113	75.395948	Check dam
46	Devgarh	23.853298	75.45223	Check dam
47	Lasudiya	23.855236	75.365165	Check dam
48	Kelukheda	23.855749	75.383525	Check dam
49	Barkheda Kalan	23.859802	75.445118	Check dam
50	Kelukheda	23.865217	75.383675	Check dam
51	Bhagor	23.87525	75.38542	Check dam
52	Barkheda Kalan	23.875496	75.414659	Check dam
53	Barkheda Kalan	23.876017	75.445899	Check dam
54	Barkheda Kalan	23.879819	75.409544	Check dam
55	Moriya	23.884773	75.457752	Check dam
56	Barkheda Kalan	23.886027	75.413405	Check dam
57	Barkheda Kalan	23.886869	75.452329	Check dam
58	Barkheda Kalan	23.890981	75.441486	Check dam
59	Ismailganj	23.892921	75.447087	Check dam
60	Ismailganj	23.89845	75.449292	Check dam
61	Ismailganj	23.906469	75.454577	Check dam
62	Nakatwada	23.763283	75.286167	NB
63	Malya (Tal))	23.764905	75.331502	NB
64	Malya (Tal))	23.766489	75.34084	NB
65	Malya (Tal))	23.76731	75.352975	NB
66	Melu Khedi	23.767472	75.278984	NB
67	Melu Khedi	23.775208	75.282896	NB
68	Negroon	23.776247	75.387104	NB
69	Madhopur	23.776924	75.327397	NB
70	Madhopur	23.77726	75.306949	NB
71	Malya (Tal))	23.777635	75.353795	NB
72	Melu Khedi	23.778677	75.287149	NB
73	Negroon	23.779015	75.402694	NB
74	Madhopur	23.779131	75.303448	NB
75	Melu Khedi	23.782333	75.287391	NB
76	Asawata	23.782911	75.353406	NB
77	Khejadiya Sondhiyan	23.783427	75.382906	NB
78	Semliya	23.78365	75.420777	NB
79	Asawata	23.784238	75.367392	NB
80	Semliya	23.787789	75.430555	NB
81	Malya (Tal))	23.788156	75.340656	NB
82	Semliya	23.792891	75.435091	NB
83	Semliya	23.79361	75.418971	NB
84	Arwas	23.794	75.276931	NB
85	Arwas	23.797157	75.288755	NB

S. no.	Village name	Latitude	Longitude	Structure type
86	Char Khedi	23.799099	75.39912	NB
87	Jamuniya Shankar	23.801804	75.43942	NB
88	Arwas	23.802109	75.298532	NB
89	Arwas	23.805166	75.280331	NB
90	Barkheda Khurd	23.80739	75.400397	NB
91	Asawata	23.808759	75.366756	NB
92	Baman Khedi	23.809141	75.417284	NB
93	Ana Khedi	23.80947	75.298237	NB
94	Jamuniya Shankar	23.810154	75.440435	NB
95	Iftekharganj	23.81194	75.421678	NB
96	Iftekharganj	23.814332	75.420729	NB
97	Lakhneti	23.817075	75.365411	NB
98	Iftekharganj	23.822508	75.415142	NB
99	Lakhneti	23.82315	75.362262	NB
100	Barkheda Khurd	23.827566	75.385922	NB
101	Karadiya	23.830328	75.421818	NB
102	Pipal Khedi	23.83514	75.395359	NB
103	Lakhneti	23.836596	75.360497	NB
104	Karadiya	23.838119	75.431357	NB
105	Shamimabad	23.838704	75.384981	NB
106	Karadiya	23.841702	75.434719	NB
107	Karadiya	23.842649	75.423977	NB
108	Devgarh	23.843383	75.446765	NB
109	Devgarh	23.843754	75.459071	NB
110	Bapcha	23.844187	75.402115	NB
111	Devgarh	23.847862	75.459657	NB
112	Bapcha	23.849253	75.407034	NB
113	Devgarh	23.85065	75.439696	NB
114	Bapcha	23.850778	75.432539	NB
115	Kelukheda	23.851087	75.365413	NB
116	Devgarh	23.85584	75.456367	NB
117	Kelukheda	23.85812	75.387481	NB
118	Barkheda Kalan	23.860297	75.438367	NB
119	Barkheda Kalan	23.864195	75.418298	NB
120	Barkheda Kalan	23.865567	75.422346	NB
121	Surjana	23.867846	75.393311	NB
122	Moriya	23.869678	75.466859	NB
123	Barkheda Kalan	23.870646	75.446775	NB
124	Barkheda Kalan	23.870673	75.408859	NB
125	Surjana	23.872576	75.398522	NB
126	Barkheda Kalan	23.874731	75.436725	NB
127	Moriya	23.879323	75.46787	NB
128	Moriya	23.880655	75.461715	NB
129	Barkheda Kalan	23.884974	75.431912	NB
130	Ismailganj	23.895468	75.453266	NB

S. no.	Village name	Latitude	Longitude	Structure type
131	Bor Khedi	23.905775	75.446819	NB
132	Melu Khedi	23.775487	75.2749	Perculation tank
133	Gondi Shankar	23.78491	75.269427	Perculation tank
134	Malya (Tal))	23.791486	75.338551	Perculation tank
135	Madhopur	23.80222	75.340096	Perculation tank
136	Ana Khedi	23.805682	75.307465	Perculation tank
137	Kelukheda	23.850661	75.375526	Perculation tank
138	Bhagor	23.862546	75.369815	Perculation tank
139	Barkheda Kalan	23.864418	75.443265	Perculation tank
140	Surjana	23.877539	75.39634	Perculation tank
141	Meriyakhedi	23.900627	75.426494	Perculation tank
142	Tatka	23.912409	75.456754	Perculation tank
143	Barkheda Khurd	23.81783	75.390495	Recharge shaft
144	Barkheda Kalan	23.857233	75.43145	Recharge shaft
145	Hariya Kheda	23.871784	75.456915	Recharge shaft
146	Barkheda Kalan	23.872652	75.44195	Recharge shaft
147	Barkheda Kalan	23.87635	75.413809	Recharge shaft
148	Kelukheda	23.850087	75.375662	Stop dam / Check dam
149	Devgarh	23.854264	75.444366	Stop dam / Check dam

ANNEXURE-XII

PROPOSED ARTIFICIAL RECHARGE STRUCTURES OF BHAISANA WATERSHED

S no	Village name	Latitude	Longitude	Structure type
1	Karondi No.2	23.553782	75.446822	Check dam
2	Gurukhedi	23.576075	75.439684	Check dam
3	Bhensola	23.581077	75.448279	Check dam
4	Gurukhedi	23.581902	75.430756	Check dam
5	Mandawal	23.60352	75.414586	Check dam
6	Napa Kheda(Tal)	23.607002	75.436451	Check dam
7	Kothadi(Kharwa)	23.610674	75.407122	Check dam
8	Mandawal	23.611053	75.42334	Check dam
9	Nimsawadi(Kharwa)	23.62455	75.381717	Check dam
10	Lasudiya Surajmal	23.629015	75.364709	Check dam
11	Gudbheli	23.637172	75.431838	Check dam
12	Lasudiya Surajmal	23.63944	75.356268	Check dam
13	Kheta Khedi	23.639613	75.443364	Check dam
14	Gudbheli	23.648158	75.432787	Check dam
15	Panth Piploda	23.660046	75.417361	Check dam
16	Arnya (Tal)	23.66156	75.361523	Check dam
17	Chapla Khedi (Tal)	23.662573	75.383094	Check dam
18	Kishangarh(Tal)	23.676791	75.432937	Check dam
19	Ankya Khurd	23.681418	75.39212	Check dam
20	Kishangarh(Tal)	23.681709	75.424605	Check dam
21	Tungni	23.68444	75.413326	Check dam
22	Kot Karadiya	23.687678	75.373389	Check dam
23	Marmiya Khedi	23.694238	75.386656	Check dam
24	Mundla Khurd	23.695127	75.404813	Check dam
25	Fatehpur	23.696119	75.364684	Check dam
26	Mundla Kalan	23.697735	75.32057	Check dam
27	Charan Khedi	23.700027	75.353855	Check dam
28	Mundla Kalan	23.702922	75.320607	Check dam
29	Fatehpur	23.705919	75.36008	Check dam
30	Makanpura	23.708834	75.392343	Check dam
31	Makanpura	23.710854	75.374569	Check dam
32	Sanga Kheda	23.711536	75.415946	Check dam
33	Sanga Kheda	23.711632	75.403392	Check dam
34	Fatehpur	23.71167	75.362995	Check dam
35	Makanpura	23.71177	75.381161	Check dam
36	Makanpura	23.715657	75.389849	Check dam
37	Gaddu Khedi	23.718461	75.353632	Check dam
38	Gaddu Khedi	23.722806	75.344753	Check dam
39	Lakhma Khedi	23.722868	75.290473	Check dam
40	Lakhma Khedi	23.72665	75.399522	Check dam

S no	Village name	Latitude	Longitude	Structure type
41	Bhaisana	23.728375	75.36494	Check dam
42	Bisal Kheda	23.729276	75.327659	Check dam
43	Bhaisana	23.729921	75.355275	Check dam
44	Bhaisana	23.733419	75.371835	Check dam
45	Ankya Kalan	23.734243	75.329514	Check dam
46	Khedi Tal	23.735514	75.407332	Check dam
47	Ankya Kalan	23.736006	75.326546	Check dam
48	Ankya Kalan	23.736791	75.333076	Check dam
49	Kothadi (Tal)	23.745678	75.294949	Check dam
50	Karwa Khedi	23.748449	75.374075	Check dam
51	Karwa Khedi	23.751114	75.375851	Check dam
52	Karwa Khedi	23.751276	75.385313	Check dam
53	Karwa Khedi	23.753283	75.373383	Check dam
54	Nakatwada	23.755996	75.299171	Check dam
55	Karwa Khedi	23.757049	75.394125	Check dam
56	Minawada	23.543537	75.473035	NB
57	Karondi No.2	23.552988	75.455498	NB
58	Karondi No.2	23.556977	75.451405	NB
59	Bhensola	23.569514	75.459273	NB
60	Bhensola	23.570854	75.451545	NB
61	Gurukhedi	23.579093	75.428768	NB
62	Barsi	23.582904	75.423913	NB
63	Bhensola	23.58308	75.454673	NB
64	Bhensola	23.585226	75.454613	NB
65	Barsi	23.587992	75.416765	NB
66	Barsi	23.593777	75.43372	NB
67	Napa Kheda(Tal)	23.598998	75.438405	NB
68	Napa Kheda(Tal)	23.604426	75.445789	NB
69	Mandawal	23.605987	75.422478	NB
70	Nimba Khedi	23.609427	75.359612	NB
71	Mandawal	23.610472	75.437346	NB
72	Kesarpura	23.614445	75.387212	NB
73	Abupura	23.614602	75.414887	NB
74	Nimsawadi(Kharwa)	23.618128	75.381346	NB
75	Nimba Khedi	23.618173	75.352619	NB
76	Nimsawadi(Kharwa)	23.620691	75.391574	NB
77	Daulatganj	23.622939	75.4421	NB
78	Kothadi(Kharwa)	23.623454	75.406602	NB
79	Nimba Khedi	23.623674	75.355186	NB
80	Kothadi(Kharwa)	23.624588	75.411469	NB
81	Nimsawadi (Tal)	23.626085	75.373195	NB
82	Nimsawadi(Kharwa)	23.626813	75.39708	NB
83	Daulatganj	23.632133	75.435983	NB
84	Daulatganj	23.63228	75.432624	NB
85	Daulatganj	23.632532	75.448838	NB

S no	Village name	Latitude	Longitude	Structure type
86	Nimsawadi (Tal)	23.632701	75.380408	NB
87	Kheta Khedi	23.637454	75.457299	NB
88	Lasudiya Surajmal	23.64162	75.365133	NB
89	Lasudiya Surajmal	23.645157	75.370202	NB
90	Gudbheli	23.646506	75.419506	NB
91	Tajkheda	23.648721	75.396261	NB
92	Kheta Khedi	23.649887	75.447108	NB
93	Tajkheda	23.650394	75.386771	NB
94	Gudbheli	23.650519	75.413147	NB
95	Panth Piploda	23.654709	75.42233	NB
96	Arnya (Tal)	23.655958	75.366193	NB
97	Panth Piploda	23.656416	75.433003	NB
98	Bhatbardiya	23.656604	75.442305	NB
99	Panth Piploda	23.659458	75.412685	NB
100	Kit Khedi	23.662058	75.36883	NB
101	Panth Piploda	23.662862	75.402155	NB
102	Kishangarh(Tal)	23.675388	75.436096	NB
103	Kishangarh(Tal)	23.678271	75.438934	NB
104	Kishangarh(Tal)	23.685043	75.421586	NB
105	Mundla Kalan	23.691524	75.320446	NB
106	Mundla Khurd	23.693913	75.414067	NB
107	Kharwa Khurd	23.695628	75.429332	NB
108	Mundla Khurd	23.698	75.413924	NB
109	Mundla Kalan	23.698368	75.325424	NB
110	Sanga Kheda	23.706849	75.409179	NB
111	Sanga Kheda	23.708297	75.418338	NB
112	Gaddu Khedi	23.712617	75.342618	NB
113	Sanga Kheda	23.713579	75.421438	NB
114	Dhatrawada	23.717958	75.321072	NB
115	Bisal Kheda	23.720261	75.333927	NB
116	Bisal Kheda	23.72168	75.40122	NB
117	Hampura	23.722547	75.366384	NB
118	Kher Jamuniya	23.724826	75.297746	NB
119	Tal	23.726081	75.404294	NB
120	Dhatrawada	23.727383	75.319189	NB
121	Bisal Kheda	23.729328	75.333981	NB
122	Bhaisana	23.729403	75.373551	NB
123	Tal	23.730324	75.399167	NB
124	Daulatpura	23.731868	75.42077	NB
125	Bhaisana	23.732315	75.379333	NB
126	Kher Jamuniya	23.733364	75.297402	NB
127	Bhaisana	23.734443	75.380098	NB
128	Ankya Kalan	23.736819	75.321901	NB
129	Ankya Kalan	23.737194	75.345784	NB
130	Khedi Tal	23.737196	75.412427	NB

S no	Village name	Latitude	Longitude	Structure type
131	Ankya Kalan	23.738611	75.336403	NB
132	Khedi Tal	23.740241	75.404259	NB
133	Kothadi (Tal)	23.740969	75.302022	NB
134	Ankya Kalan	23.743249	75.33304	NB
135	Bhaisana	23.743888	75.362069	NB
136	Ankya Kalan	23.744769	75.337457	NB
137	Kothadi (Tal)	23.744942	75.299383	NB
138	Lasudiya Khedi	23.745871	75.417011	NB
139	Karwa Khedi	23.746009	75.391051	NB
140	Ankya Kalan	23.746121	75.349736	NB
141	Ankya Kalan	23.746167	75.331905	NB
142	Ankya Kalan	23.746659	75.325416	NB
143	Karwa Khedi	23.749195	75.369678	NB
144	Kothadi (Tal)	23.75099	75.310509	NB
145	Uni	23.7519	75.28049	NB
146	Karwa Khedi	23.755258	75.382644	NB
147	Karwa Khedi	23.757326	75.397793	NB
148	Karwa Khedi	23.758066	75.370482	NB
149	Karwa Khedi	23.758411	75.376	NB
150	Karwa Khedi	23.760062	75.399113	NB
151	Barsi	23.593052	75.4193	Percolation tank
152	Barsi	23.593052	75.4193	Percolation tank
153	Nimsawadi(Kharwa)	23.620907	75.398386	Percolation tank
154	Lasudiya Surajmal	23.627763	75.353781	Percolation tank
155	Lasudiya Surajmal	23.641869	75.355209	Percolation tank
156	Panth Piploda	23.654541	75.41562	Percolation tank
157	Chapla Khedi (Tal)	23.665394	75.393111	Percolation tank
158	Kot Karadiya	23.678958	75.362613	Percolation tank
159	Kot Karadiya	23.682402	75.382529	Percolation tank
160	Charan Khedi	23.699766	75.354673	Percolation tank
161	Fatehpur	23.711872	75.364867	Percolation tank
162	Dhatrawada	23.720688	75.315826	Percolation tank
163	Tamboliya	23.732526	75.29178	Percolation tank
164	Tamboliya	23.74102	75.289638	Percolation tank
165	Kishangarh(Tal)	23.67627	75.42833	Renovation of pond
166	Nagpipalya	23.707189	75.317922	Renovation of Stop dam
167	Dhatrawada	23.727291	75.322787	Stop dam / Check dam
168	Gaddu Khedi	23.728425	75.344926	Stop dam / Check dam
169	Bhaisana	23.73454	75.363633	Stop dam / Check dam
170	Karwa Khedi	23.745309	75.375117	Stop dam / Check dam

ANNEXURE-XIII

GROUND VERIFIED RECHARGE STRUCTURES

Sl no	Gram panchayat	Village	Latitude	Longitude	Type of Structure with tentative location	Remarks (Cost in lakh, Dimensions)
1	Asawta	Asawta	23.8100245	75.363003	Stop dam	15
2	Asawta	Asawta	23.852223	75.334112	Stop dam alighar ghat ke paas	12
3	Asawta	Asawta	23.78836	75.340205	Stop dam amar sing ke kup ke paas	13
4	Asawta	Asawta	23.788142	75.340134	Stop dam middle school ke paas	15
5	Bardiya rathore	Bardiya rathore	23.815125	75.526873	Renovation of pond girit ke pichhe bardiyarathore	15
6	Bardiya rathore	Narayanghar	23.801207	75.525604	Renovation of pond middle schoole ke pichhe narayanghar	12
7	Bardiya rathore	Narayanghar	23.802341	75.524913	Renovation of pond kallu kha ke pichhe narayanghar	10
8	Bardiya rathore	Bardiya rathore	23.81416	75.521109	Check dam shishkhedi raste par bardiyarathore	15
9	Bhensola	Bhensola	23.57174	75.449012	Stop dam palkhanda talai ke paas	10
10	Bhutiya	Kajakhedi	23.73099709	7.54447E+15	Stop dam WITH PULIYA KACHLIYA MARG	15
11	Bhutiya	Kajakhedi	23.72830582	7.54405E+15	Stop dam WITH PULIYA SARANGAKHEDA MARG	15
12	Bhutiya	Bhutiya	23.74539757	75.44355011	Renovation of pond PANCHAYAT BHAWAN KE PASS	15
13	Bhutiya	Bhutiya	23.74160174	75.45008087	Stop dam WITH PULIYA TALAB KE PASS	15
14	Daulatgunj	Bilavali	23.610218	75.468788	Stop dam nai abadi	18
15	Delwas	Chaplakhedi	23.580065	75.492842	Stop dam luni nadi ke paas	25

Sl no	Gram panchayat	Village	Latitude	Longitude	Type of Structure with tentative location	Remarks (Cost in lakh, Dimensions)
16	Himmatkhedi	Himmatkhedi	23.854702	75.455957	Stop dam SASKIY KUP KE PAAS	15
17	Himmatkhedi	Himmatkhedi	23.858157	75.453903	Renovation of pond main Road k paas Himmatkhedi	15
18	Himmatkhedi	Hariyakheda	23.866494	75.455609	Renovation of pond HARIYAKHEDA	15
19	Himmatkhedi	Hariyakheda	23.875345	75.445562	Stop dam HARIYAKHEDA	30
20	Joyan	Joyan	23.723015	75.607192	Stop dam nai abdi joyan	20
21	Joyan	Joyan	23.726251	75.615063	Construction of new pond janglat ke paas joyan	28
22	Kalsiya	Kalsiya	23.774364	75.665667	Stop dam kushal singh ke khet ke paas	12
23	Kalsiya	Kalsiya	23.773677	75.661752	Stop damchatar singh ke khet ke paas	12
24	Kalsiya	Kalsiya	23.77368	75.654757	Stop damchatar govind ke khet ke paas	12
25	Kalsiya	Kalsiya	23.766588	75.655142	Stop damchatar suresh ke khet ke paas	12
26	Kalsiya	Dhapna	23.795285	75.634475	Construction of new pond janglat dhapna kalsiya	20
27	Kalsiya	Kalsiya	23.761149	75643674	Construction of new pond bhim road ke paas kalsiya	20
28	Kandiya	Kandiya	23.51041	75.32262	Stop dam cum puliya luni nadi par kandiya	25
29	Kanthariya	Dayalpura	23.738657	75.499676	Stop dam	12
30	Kanthariya	Kanthariya	23.738346	75.469956	Renovation of pond	10
31	Kanthariya	Dayalpura	23.734545	75.479956	Renovation of pond	10
32	Kanthariya	Napakheda	23.734543	75.489956	Renovation of pond	10
33	Kanthariya	Napakheda	23.734544	75.499655	Renovation of pond	10
34	Kasarichouhan	Kasarichouhan	23.5712	75.482448	Renovation of pond maharaj ji ki kutiya ke paas	15

Sl no	Gram panchayat	Village	Latitude	Longitude	Type of Structure with tentative location	Remarks (Cost in lakh, Dimensions)
35	Khajuri devda	Khajuri devda	23.851983	75.501442	Renovation of pond panchayatbhawan ke paas	15
36	Khajuri solanki	Bhavghar	23.775163	75.590215	Stop dam kalu singh ke ghar ke paas bhavghar	15
37	Khajuri solanki	Bhavghar	23.777527	75.588367	Stop dam puliya ke paas bhavghar	20
38	Khajuri solanki	Khajuri solanki	23.76701	75.59306	Stop dam panchayat bhawan ke paas	15
39	Khamriya	Khamriya	23.735749	75.553632	Stop dam puliya arniya marg pipliypitha	18
40	Khamriya	Khamriya	23.731965	75.539161	Renovation of pond goshal ke paas khamriya	15
41	Khamriya	Khamriya	23.740746	75.537899	Construction of new pond radi wali mata ke raste par khamriya	25
42	Kishanghar	Kishanghar	23.677922	75.43269	Stop dam gov p. school ke paas	15
43	Lasudiya surajmal	Lasudiya surajmal	23.629132	75.36322	Stop dam	19.76
44	Lasudiya surajmal	Lasudiya surajmal	23.635878	75.359539	Renovation of pond	6
45	Lasudiya surajmal	Nibakhedi	23.607931	75.357083	Stop dam hanuman mandir ke paas nibakhedi	20
46	Lasudiya surajmal	Nimbakhedi	23.613095	75.357674	Renovation of pond moti singh ke khaet ke paas	15
47	Lasudiya surajmal	Lasudiya surajmal	23.629132	75.36322	Stop damchatar girit ke paas	15
48	Luni	Luni	23.65384	75.49153	Renovation of pond kharwa raste par new abadi	8
49	Luni	Luni	23.66074	75.492881	Renovation of pond kammakhedi rste par meghpura	15
50	Madhopur	Madhopur	23.793958	75.33081	Stop dam cum puliya amarpura raste par madhopur	20

Sl no	Gram panchayat	Village	Latitude	Longitude	Type of Structure with tentative location	Remarks (Cost in lakh, Dimensions)
51	Malhargarh	Arnya	23.795473	75.491095	Renovation of pond	10 lakhs
52	Malhargarh	Malhargarh	23.792633	75.500214	Check dam	15 lakhs
53	Malhargarh	Arnya	23.795492	75.494034	Check dam arnya	15 lakhs
54	Malhargarh	Arnya	23.795388	75.491263	Renovation of pond	15 lakhs
55	Maukhedi	Maukhedi	23.743065	75.496687	Stop dam	25 lakhs
56	Maukhedi	Maukhedi	23.738627	75.503731	Stop dam	15 lakhs
57	Maukhedi	Maukhedi	23.738659	75.499965	Check dam	12 lakhs
58	Moriya	Kalakhedi	23.906683	75.472164	chek dam	20 lakhs
59	Moriya	Moriya	23.884897	75.459198	Check dam	15 Lakhs
60	Moriya	Moriya	23.875722	75.467185	Renovation of pond	10 lakhs
61	Moriya	Moriya	23.885434	75.458978	construction of new pond	25 lakhs
62	Munj	Akiya	23.810044	75.560477	Stop dam cum talab aakiya	15 lakhs
63	Nipaniya Leela	Nipaniya Leela	23.645301	75.458954	Renovation of pond go shala ke pichhe nipaniyalila	20 lakhs
64	Nipaniya Rajguru	Pratappura	23.710044	75.58562	Check dam	15 lakhs
65	Nipaniya rajguru	Nipaniya raj (Khedi)	23.708669	75.582366	Check dam	15 lakhs
66	Pipliyapitha	Pipliyapitha	23.810685	75.487703	Stop dam puliya arniya marg pipliypitha	18 lakhs
67	Pipliyapitha	Pipliyapitha	23.8184883	75.480297	Renovation of pond hanumantiya road par pipliyapitha	15 lakhs
68	Pipliya Sisodiya	Pipliya Sisodiya	23.81147	75.466858	Stop dam cum puliya mahadev mandir ke paas	20 lakhs
69	Pipliya Sisodiya	Pipliya Sisodiya	23.810762	75.473194	Stop dam cum puliya shanti dham ke paas	25 lakhs
70	Pipliya Sisodiya	Pipliya Sisodiya	23.913822	75.474681	Construction of new pond nai abadi	20 lakhs
71	Pipliya Sisodiya	Pipliya Sisodiya	23.810164	75.477343	Stop dam sagas baw ji ke paas	12 lakhs
72	Pipliyatukhar	Kammakhedi	23.643695	75.501857	Stop dam cum puliya luni nadi par kammakhedi	15 lakhs
73	Piplkhedi	Piplkhedi	23.8295	75.380513	Check dam	10 lakhs

Sl no	Gram panchayat	Village	Latitude	Longitude	Type of Structure with tentative location	Remarks (Cost in lakh, Dimensions)
74	Piplkhedi	Piplkhedi	23.836692	75.394423	Stop dam puliya bapcha marg piplkhedi	15 lakhs
75	Piplkhedi	Piplkhedi	23.836565	75.394753	Stop dam	15 lakhs
76	Piplkhedi	Lakhaneti	23.823	75.358857	Check dam puliya nag maharaj mandir	15 lakhs
77	Sherpurkhurd	Sherpurkhurd	23.721272	75.497608	Stop dam shantidham ke paas sherpurkhurd	25 lakhs
78	Shishakhedi	Logni	23.820848	75.517581	Stop dam luni nadi par shantidham ke paas	15 lakhs
79	Shishakhedi	Hanumantiya	23.838179	75.486683	Check dam khal par hanumantiya	15 lakhs
80	Talod	Talod	23.676552	75.590224	Renovation of pond	15 lakhs
81	Daulatganj	Daulatganj	23.779424	75.444639	Nala bund	
82	Pipal Khedi	Pipal Khedi	23.83514	75.395359	Nala bund	Length 6m,, height 3 m
83	Pipal Khedi	Pipal Khedi	23.838704	75.384981	Nala bund	Length 10m , height 5 m
84	Pipal Khedi	Pipal Khedi	23.83414	75.378733	Check dam	7m length, 4-5 m height
85	Pipal Khedi	Pipal Khedi	23.817075	75.365411	Nala bund/Cement plug	4m height 5 m length
86	Pipliya Maru	Pipliya Maru	23.780628	75.494078	Stop dam	10 m length, 5 meter height
87	Pipliya Maru	Narayani vill	23.79077	75.491921	Check dam	6 m length 3 m height
88	Pipliya Maru	Narayani vill	23.793898	75.493672	Check dam	10 m length, 4 m height
89	Pipliya Maru	Pipliya Maru	23.790007	75.461661	Nala bund	4 m length, 2.5 height
90	Pipliya Maru	Pipliya Maru	23.788801	75.470599	Check dam	8 m length, 6 m height
91	Pipliya Maru	Pipliya Maru	23.789829	75.481483	Check dam	8 m length, height 6 m
92	Mundla kalan	Mundla kalan	23.707189	75.317922	Renovation of stop dam	Renovation
93	Mundla kalan	Mundla kalan	23.702922	75.320607	Check dam	8 m length,4 m height

Sl no	Gram panchayat	Village	Latitude	Longitude	Type of Structure with tentative location	Remarks (Cost in lakh, Dimensions)
94	Shishakhedi	Shishakhedi	23.823194	75.519896	Check dam	Length 20 m, height 10 m
95	Shishakhedi	Logini	23.831605	75.526587	Check dam	Length 15 m , height 4 m
96	Shishakhedi	Hanumantya	23.836485	75.478811	Nala bund/Cement plug	Length 3 m, height 2 m
97	Shishakhedi	Hanumantya	23.838204	75.486942	Nala bund	Length 5 m height 3 m
98	Shishakhedi	Shishakhedi	23.8159	75.513797	Check dam	Length 12 m, height 5 m
99	Patan	Patan	23.704663	75.56523	Stop dam	Length 10 m , height 4 m
100	Patan	Patan	23.700171	75.565641	Nala bund/Cement plug	Length 3 m , height 2 m
101	Janabad	Janabad	23.709953	75.563281	Nala bund	Length 4 m height 2 m
102	Janabad	Janabad	23.702224	75.563871	Cement plug	Length 6 m , height 4 m
103	Janabad	Janabad	23.718665	75.521184	Check dam	4 m length, height 2.5 m
104	Janabad	Janabad	23.716404	75.524954	Check dam	Length 6 m height 3 m
105	Beti khedi	Beti khedi	23.7276	75.512633	Reenovation of Check dam	
106	Beti khedi	Beti khedi	23.7308	75.497228	Check/Stop dam	Length 7 m, height 4 m
107	Talod vill	Talod vill	23.675495	75.591816	Nala bund	Length 3 m height 2 m
108	Talod vill	Talod vill	23.673998	75.598091	Nala bund	Length 4 m height 1.5 m
109	Dabdiya	Dabdiya	23.667049	75.573934	Nala bund/Cement plug	Length 3 m height 1.5 m width 1 m
110	Dabdiya	Dabdiya	23.667882	75.568051	Nala bund	
111	Bensola	Bensola	23.569514	75.459273	Nala bund/Cement plug	Length 3 m height 1.5 m
112	Ranayara	Ranayara	23.77288	75.466715	Nala bund/Cement plug	Length 6 m , height 3 m
113	Kalsiya	Kalsiya	23.777852	75.654367	Check dam	Length 10 m height 5 m
114	Kalsiya	Dhapna	23.78863	75.652879	Check dam	Length 7 m height 5 m

Sl no	Gram panchayat	Village	Latitude	Longitude	Type of Structure with tentative location	Remarks (Cost in lakh, Dimensions)
115	Kalsiya	Kalsiya	23.766322	75.656688	Check dam	Length 10 m height 5 m
116	Moriya	Moriya	23.884773	75.457752	Check dam	Length 20 m height 6 m
117	Moriya	Moriya	23.880655	75.461715	Nala bund	Length 4 m height 2m
118	Himmatkhedi	Himmatkhedi	23.876017	75.445899	Check dam	Length 15 - 20 m, height 2.5 m
119	Himmatkhedi	Hariya Kheda	23.872378	75.442803	Check dam	Length 20-25 m height 5 m
120	Himmatkhedi	Hariya Kheda	23.870646	75.446775	Nala bund/Cement plug	Length 5 m height 2.5 m
121	Himmatkhedi	Hariya Kheda	23.856171	75.45726	Nala bund	Length 4 m, height 2.5 m
122	Himmatkhedi	Himmatkhedi	23.85489	75.454519	Nala bund	Length 4 m height 1.6 m
123	Himmatkhedi	Himmatkhedi	23.857322	75.449771	Check dam	Length 4m height 2m
124	Himmatkhedi	Himmatkhedi	23.859802	75.445118	Check dam	Length 10m height 4m
125	Moriya	Moriya	23.879323	75.46787	Cement plug	Length 4m , height 1.5m
126	Mandawal	Mandawal	23.614602	75.414887	Nala bund/Cement plug	Length 2 m height 1 m
127	Hingadi	Hingadi	23.705937	75.496714	Check dam	Length 7 m, height 3-4 m
128	Hingadi	Dhatukheda	23.693715	75.481159	Nala bund/Cement plug	Length 4 m height 2m
129	Arvaliya solanki	Arvaliya solanki	23.695515	75.499421	Check dam	Length 9-10 m, height 4-5 m
130	Arvaliya solanki	Anandhgarh	23.692137	75.502811	Check dam	Length 4 m height 2 m
131	Arvaliya solanki	Sala Khedi	23.672882	75.496992	Stop dam	Length 10 m height 5 m
132	Sherpur Khurd	Sherpur Khurd	23.722048	75.496714	Check dam	Length 7 m height 3-4 m
133	Sherpur Khurd	Sherpur Khurd	23.717048	75.496158	Check dam	Length 10 m height 4 m
134	Fatehpur	Fatehpur	23.705919	75.36008	Check dam	Length 4 m height 1.5 m

Sl no	Gram panchayat	Village	Latitude	Longitude	Type of Structure with tentative location	Remarks (Cost in lakh, Dimensions)
135	Fatehpur	Fatehpur	23.696119	75.364684	Check dam	Length 5 -6 m , height 3-4 m
136	Mermiya Kheda	Mermiya Kheda	23.71177	75.381161	Check dam	Length 5-6 m height 2-3 m
137	Chaplakhedi	Chaplakhedi	23.662573	75.383094	Check dam	Length 4-5 m height 1-2 m
138	Chaplakhedi	Nimsawadi kherwa	23.62455	75.381717	Check dam	Length 6m height 3m

ANNEXURE-XIV

FARMERS FEEDBACK

(5)

Annexure -iii

Farmer Feedback Form

Photograph

Name	Sarwan singh s/o Bapu singh
Village	Nipaniya leela
Block	Alot
District	Ratlam
Address	Behind mobile Tower, [illegible]
Mobile Number (optional)	

Type and number of structures

Type	BW	
Number	02	
(coordinates of the structures are to be obtained by the field officer)	23.660602 75.45738	
Drill time discharge (lps)		
Depth of installation of pump	80ft	
Casing depth (Bore wells) HR	90ft	
Fracture encountered depth-HR	90ft	
Slotted pipe depths (TW) SR		
Average water levels – pre-monsoon	150ft	
Average water levels – post-monsoon	90ft	
The well is used for	Irrigation	
Is water available throughout the year	Yes	
If not for how many months water is available		

Pumping Duration

	Number of days pump is operated (days) of each well	What is the average pumping duration (in hours) of each well	Instantaneous Discharge Measurement (to be carried out by the field officer) in lps
Rabi (no of months to be specified)	120 days	05	

23

Kharif (no of months to be specified)	3 months	7 - 8 hrs	
Others (no of months to be specified)			
Area Irrigated			
	Area Irrigated	Type of crop taken	Remarks
Rabi (no of months to be specified)	10 biga	soyabean	
Khariff (no of months to be specified)	10 biga	orchard (Santra) गेहूं, Lasoon	
Others (no of months to be specified)			
Cropping patterns (past and present) in the village			
Traditional Cropping pattern in the village	Kharif	Rabi	Other
Type of Crop	Soyabeen	गेहूं, chana, much	
Area under crop	10 bigs	10 bigs	
Prevailing Cropping pattern in the village	Kharif	Rabi	Other
Type of Crop	Soyabeen	Santra, गेहूं, lason	
Area under crop	10 biga	(5 biga) 3biga 2 bigs	
Reasons for change in cropping pattern in last 20 years.	more profit in Santra crops		
If the cropping pattern is to be changed, which are the suitable crops that can be grown	No chage in 20 years		
Available Market for the crop			
Average unit cost of production	1 quintal = 2000 rs wheat	1 quintal Soyasean 4000 - 5000 rs.	
Average unit cost of selling			
Existing MSP and other related information	Crop wise details are to be collected		
Other subsidies, facilities, restrictions.	No subsidey		
Source of Energy			
Solar	o Is it connected to grid o If yes how much incentive do you get per month on an average for feeding electricity to the grid (Rs per month)		
Electric	o Do you get free electricity for irrigation? o Do you pay a fixed charge o If a fixed charge is paid, what is the per month charge o If unit-based charges are paid what is the average monthly charges in rupees o During kharif---- o During Rabi-----		
Diesel	o Average consumption of diesel (liters) per month o During Kharif o During Rabi		

1 Biga wheat = 15 quintal wheat produced
production cost of 15 quintal wheal = 5000-8000
1 quintal cost of wheat = 2000 rs

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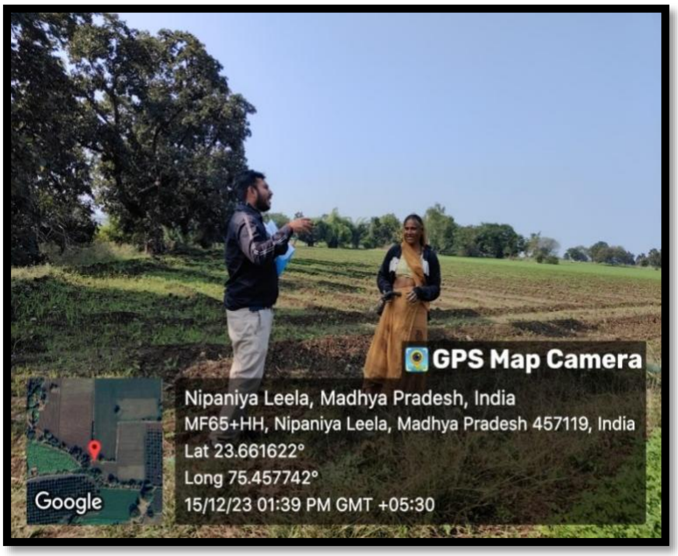
→ For 1 Biga of wheat

Production cost	selling cost
5000 - 8000 rs	30,000 rs

Soyabeam ⇒ 1 biga = 5 quintal produced
1 quintal market cost = 4000 - 5000 rs
5 quintal = 20,000 - 30,000 rs

production cost
1 bige = 2000 rs


GPS Map Camera
Nipaniya Leela, Madhya Pradesh, India
MF65+HH, Nipaniya Leela, Madhya Pradesh 457119, India
Lat 23.661622°
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atganj slug test alot block
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ANNEXURE-XV

GROUND WATER QUALITY RESULTS OF HEAVY METALS OF ALOT BLOCK, RATLAM DISTRICT UNDER NAQUIM 2.0 (PRE-MONSOON-2023)

S.No	Monsoon	District	Block	Location	Source	Source code	Fe (mg/l)	Mn (mg/l)	Cu (mg/l)	Zn (mg/l)	As (ppb)	Pb (ppb)	Cr (ppb)	U (ppb)
1	pre	Ratlam	Alot	Alot (Vikramgarh)	DW	DW60	0.000	0.000	0.000	0.000	0.547	1.499	0.000	3.242
2	pre	Ratlam	Alot	Baguniya	DW	DW61	0.000	0.083	0.000	0.000	0.000	0.993	0.000	0.000
3	pre	Ratlam	Alot	Bamankhedi	DW	DW62	0.000	0.000	0.000	0.000	1.385	2.315	0.000	0.000
4	pre	Ratlam	Alot	Barkhera kalan	DW	DW63	0.000	0.000	0.000	0.000	0.000	1.342	0.000	0.000
5	pre	Ratlam	Alot	Barkherakhurd	DW	DW64	0.000	0.000	0.000	0.000	0.000	3.475	0.000	0.000
6	pre	Ratlam	Alot	Bersi	DW	DW65	0.187	0.000	0.000	0.000	1.042	1.822	0.000	3.654
7	pre	Ratlam	Alot	Bhojakhedi	DW	DW66	0.000	0.000	0.000	0.000	0.000	1.054	0.000	0.000
8	pre	Ratlam	Alot	Bisalkheda	DW	DW67	0.000	0.000	0.000	0.000	0.000	0.712	0.000	3.734
9	pre	Ratlam	Alot	Chapri	DW	DW68	0.164	0.000	0.000	0.000	0.000	0.631	0.000	5.259
10	pre	Ratlam	Alot	Daulatganj	DW	DW69	0.076	0.139	0.000	0.000	0.000	1.367	0.000	0.000
11	pre	Ratlam	Alot	Dharola	DW	DW70	0.240	0.235	0.000	0.000	0.000	1.831	0.000	0.000
12	pre	Ratlam	Alot	Goyal	DW	DW71	0.114	0.000	0.000	0.000	0.000	0.887	0.000	0.000
13	pre	Ratlam	Alot	Hingodi	DW	DW72	0.000	0.000	0.000	0.000	0.000	1.105	0.000	0.000
14	pre	Ratlam	Alot	Inderpur	DW	DW73	0.000	0.000	0.000	0.000	0.000	2.198	0.000	0.000
15	pre	Ratlam	Alot	Jahanabad	DW	DW74	0.000	0.000	0.000	0.000	0.744	1.374	0.000	4.082
16	pre	Ratlam	Alot	Jamuniya shankar	DW	DW75	0.000	0.000	0.000	0.000	0.531	0.969	0.000	0.000
17	pre	Ratlam	Alot	Karadiya	DW	DW76	0.000	0.154	0.000	0.000	1.334	0.681	0.000	0.000
18	pre	Ratlam	Alot	Kelukheda	DW	DW77	0.000	0.000	0.000	0.000	0.000	1.506	0.000	4.365
19	pre	Ratlam	Alot	Khamriya	DW	DW78	0.074	0.000	0.000	0.000	0.000	1.569	0.000	0.000
20	pre	Ratlam	Alot	Kharwa Khurd	DW	DW79	0.000	0.000	0.000	0.000	0.000	0.816	0.000	0.000

S.No	Monsoon	District	Block	Location	Source	Source code	Fe (mg/l)	Mn (mg/l)	Cu (mg/l)	Zn (mg/l)	As (ppb)	Pb (ppb)	Cr (ppb)	U (ppb)
21	pre	Ratlam	Alot	Kishangarh	DW	DW80	0.000	0.000	0.000	0.000	0.000	1.418	0.000	0.000
22	pre	Ratlam	Alot	Madhopur	DW	DW81	0.000	0.000	0.000	0.000	0.000	3.643	0.000	0.000
23	pre	Ratlam	Alot	Maukhedi	DW	DW82	0.000	0.000	0.000	0.000	0.000	1.685	0.000	0.000
24	pre	Ratlam	Alot	Minawada	DW	DW83	0.000	0.000	0.000	0.000	0.000	1.086	0.000	0.000
25	pre	Ratlam	Alot	Pant piploda	DW	DW84	0.050	0.530	0.000	0.000	0.000	1.865	0.000	0.000
26	pre	Ratlam	Alot	Pipalkhedi	DW	DW85	0.000	0.000	0.000	0.000	0.000	0.877	0.000	0.000
27	pre	Ratlam	Alot	Pipalya Pitha	DW	DW86	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
28	pre	Ratlam	Alot	Pipalya sisodiya	DW	DW87	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
29	pre	Ratlam	Alot	Rinchha	DW	DW88	0.000	0.000	0.000	0.000	0.000	1.409	0.000	0.000
30	pre	Ratlam	Alot	Talod	DW	DW89	0.000	0.000	0.000	0.000	0.000	1.127	0.000	3.791
31	pre	Ratlam	Alot	Thapna	DW	DW90	0.000	0.000	0.000	0.000	0.000	1.498	0.000	0.000
32	pre	Ratlam	Alot	Aakya Kalan	DW	DW 91	0.000	0.000	0.000	0.000	0.000	0.000	0.000	3.172
33	pre	Ratlam	Alot	Arvalya solanki	HP	HP27	0.138	0.000	0.127	0.491	0.000	1.365	0.000	0.000
34	pre	Ratlam	Alot	Arwas	HP	HP28	0.731	0.000	0.000	0.288	0.000	1.016	0.000	0.000
35	pre	Ratlam	Alot	Bamankhedi	HP	HP29	0.237	0.000	0.000	0.000	0.000	1.751	0.000	0.000
36	pre	Ratlam	Alot	Barkhera kalan	HP	HP30	0.245	0.000	0.000	0.000	0.000	0.734	0.000	0.000
37	pre	Ratlam	Alot	Bersi	HP	HP31	0.064	0.000	0.000	0.000	0.891	1.754	0.000	0.000
38	pre	Ratlam	Alot	Kamla khedi	HP	HP32	0.000	0.085	0.000	0.000	0.667	0.840	0.000	0.000
39	pre	Ratlam	Alot	Karadiya	HP	HP33	0.468	0.000	0.020	1.101	0.617	4.169	0.000	0.000
40	pre	Ratlam	Alot	Kelukheda	HP	HP34	0.936	0.000	0.021	0.648	0.000	6.724	0.761	0.000
41	pre	Ratlam	Alot	Kesari chouhan	HP	HP35	0.000	0.000	0.000	0.669	0.540	1.910	0.000	0.000
42	pre	Ratlam	Alot	Kharwa Khurd	HP	HP36	0.072	0.000	0.000	0.073	0.000	1.217	0.000	2.648
43	pre	Ratlam	Alot	Kishangarh	HP	HP37	0.103	0.000	0.000	0.053	0.000	5.554	0.000	0.000
44	pre	Ratlam	Alot	Madhopur	HP	HP38	0.000	0.000	0.000	0.000	0.000	2.902	0.000	0.000
45	pre	Ratlam	Alot	Malya	HP	HP39	0.000	0.000	0.000	0.000	2.101	1.080	0.000	0.000
46	pre	Ratlam	Alot	Minawada	HP	HP40	0.137	0.000	0.000	0.259	0.000	1.435	0.000	0.000

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47	pre	Ratlam	Alot	Pipalkhedi	HP	HP41	0.000	0.000	0.000	0.000	0.553	1.710	0.000	0.000
48	pre	Ratlam	Alot	Nimbakhedi	HP	HP 42	0.513	0.000	0.000	1.640	0.000	0.000	0.000	0.000
49	Pre	Ratlam	Alot	Aakyakalan	BW	BW1	0.000	0.000	0.000	0.000	0.000	1.991	0.000	0.000
50	Pre	Ratlam	Alot	Barkhera kalan	BW	BW2	0.000	0.050	0.000	0.000	0.000	0.000	0.000	0.000
51	Pre	Ratlam	Alot	Bhaisana	BW	BW3	0.000	0.059	0.036	0.472	0.000	0.594	0.000	0.000
52	Pre	Ratlam	Alot	Bhutiya	BW	BW4	0.000	0.000	0.000	0.538	0.000	0.000	0.000	0.000
53	Pre	Ratlam	Alot	Bisal Kheda	BW	BW5	0.475	0.000	0.000	0.000	0.000	0.884	6.267	5.794
54	Pre	Ratlam	Alot	Bisalkheda	BW	BW6	0.000	0.000	0.000	0.255	0.000	1.386	0.000	4.843
55	Pre	Ratlam	Alot	Chaplakhedi	BW	BW7	0.423	0.125	0.000	0.000	0.000	0.951	0.000	8.873
56	Pre	Ratlam	Alot	Dabdiya	BW	BW8	0.130	0.000	0.000	0.000	0.000	0.913	0.000	0.000
57	Pre	Ratlam	Alot	Delwas	BW	BW9	0.283	0.000	0.000	0.000	0.000	1.012	0.000	5.725
58	Pre	Ratlam	Alot	Fatehpur	BW	BW10	0.000	0.000	0.000	0.000	0.511	0.578	0.000	12.842
59	Pre	Ratlam	Alot	Gulbalod	BW	BW11	0.000	0.000	0.000	0.000	0.000	1.288	0.000	5.365
60	Pre	Ratlam	Alot	Hampura	BW	BW12	0.109	0.000	0.000	0.000	0.000	0.953	0.000	3.584
61	Pre	Ratlam	Alot	Himmatkhedi	BW	BW13	0.116	0.000	0.000	0.181	0.000	0.722	0.000	0.000
62	Pre	Ratlam	Alot	Jahanabad	BW	BW14	0.098	0.000	0.000	0.000	0.000	1.393	0.000	12.292
63	Pre	Ratlam	Alot	Jamuniya shankar	BW	BW15	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
64	Pre	Ratlam	Alot	Kandiya	BW	BW16	0.000	0.000	0.000	0.000	0.528	0.783	0.000	6.569
65	Pre	Ratlam	Alot	Karwa kalan	BW	BW17	0.000	0.000	0.000	0.000	0.000	1.378	0.000	0.000
66	Pre	Ratlam	Alot	Karwakhedi	BW	BW18	0.086	0.000	0.000	0.000	0.000	1.941	0.000	0.000
67	Pre	Ratlam	Alot	Khajuriya Solanki	BW	BW19	0.000	0.000	0.000	0.000	0.000	0.999	0.000	0.000
68	Pre	Ratlam	Alot	Kharwa Khurd	BW	BW20	0.000	0.000	0.000	0.000	0.000	1.038	0.000	0.000
69	Pre	Ratlam	Alot	Kitkhedi	BW	BW21	0.052	0.000	0.000	0.000	0.000	1.060	2.379	3.078
70	Pre	Ratlam	Alot	Kollu khedi	BW	BW22	0.000	0.000	0.000	0.000	1.212	1.592	0.000	0.000
71	Pre	Ratlam	Alot	Luni_1	BW	BW23	0.000	0.000	0.000	0.000	0.000	1.192	0.000	7.006
72	Pre	Ratlam	Alot	Luni_2	BW	BW24	0.000	0.000	0.000	0.062	0.000	1.374	0.000	4.560

S.No	Monsoon	District	Block	Location	Source	Source code	Fe (mg/l)	Mn (mg/l)	Cu (mg/l)	Zn (mg/l)	As (ppb)	Pb (ppb)	Cr (ppb)	U (ppb)
73	Pre	Ratlam	Alot	Majanpur	BW	BW25	0.125	0.000	0.000	0.000	0.000	0.569	0.000	0.000
74	Pre	Ratlam	Alot	Malya	BW	BW26	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
75	Pre	Ratlam	Alot	Mandawal	BW	BW27	0.000	0.000	0.000	0.000	0.000	1.513	0.000	4.829
76	Pre	Ratlam	Alot	Mandla kalan	BW	BW28	0.000	0.000	0.000	0.000	0.000	0.992	0.000	0.000
77	Pre	Ratlam	Alot	Manuniya	BW	BW29	0.000	0.000	0.000	0.000	0.603	1.565	0.000	0.000
78	Pre	Ratlam	Alot	Moriya	BW	BW30	0.000	0.000	0.000	0.000	0.000	0.776	0.000	0.000
79	Pre	Ratlam	Alot	Negroon	BW	BW31	0.000	0.000	0.000	0.184	0.000	0.000	0.000	0.000
80	Pre	Ratlam	Alot	Nipani leela	BW	BW32	0.241	0.000	0.000	0.000	1.141	1.055	0.000	0.000
81	Pre	Ratlam	Alot	Nipanileela	BW	BW33	0.000	0.000	0.000	0.000	0.583	1.333	0.000	0.000
82	Pre	Ratlam	Alot	Nipaniya Rajguru	BW	BW34	0.000	0.000	0.000	0.000	0.000	0.751	0.000	0.000
83	Pre	Ratlam	Alot	Pipalya Pitha	BW	BW35	0.000	0.000	0.000	0.111	0.000	0.000	0.000	0.000
84	Pre	Ratlam	Alot	Pipliya Maru	BW	BW36	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
85	Pre	Ratlam	Alot	Rajla	BW	BW37	0.175	0.000	0.000	0.000	0.000	0.000	0.000	0.000
86	Pre	Ratlam	Alot	Ranayara	BW	BW38	0.000	0.000	0.000	0.000	4.655	1.130	0.000	0.000
87	Pre	Ratlam	Alot	Sanga kheda	BW	BW39	0.000	0.000	0.000	0.206	0.000	1.290	0.000	0.000
88	Pre	Ratlam	Alot	Semliya	BW	BW40	0.000	0.000	0.000	0.000	0.000	0.909	0.000	0.000
89	Pre	Ratlam	Alot	Sherpur Khurd	BW	BW41	0.000	0.000	0.000	0.000	0.000	0.737	0.000	0.000
90	Pre	Ratlam	Alot	Tajkheda	BW	BW42	0.000	0.000	0.000	0.000	0.000	1.836	0.000	2.715
91	Pre	Ratlam	Alot	Talod01	BW	BW43	0.000	0.000	0.000	0.000	0.000	1.058	0.000	0.000
92	Pre	Ratlam	Alot	Thamb guradiya	BW	BW44	0.125	0.000	0.000	0.000	0.000	0.629	0.000	4.572
93	Pre	Ratlam	Alot	Thuriya	BW	BW45	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

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