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

जलभृत प्रबंधन योजना

Aquifer Management Plan

मेसकौर और निकटवर्ती प्रखण्ड, नवादा जिला, बिहार

Meskaur and adjacent Blocks, Nawada District, Bihar

मध्य-पूर्वी क्षेत्र, पटना

Mid-Eastern Region, Patna

2024

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Meskaur and adjacent Blocks, Nawada District, Bihar

प्राथमिकता प्रकार: जल संकटग्रस्त क्षेत्र
Priority Type: Water Stressed Area

मध्य-पूर्वी क्षेत्र, पटना
Mid-Eastern Region, Patna

2024

Report on
Aquifer Management Plan in Meskaur and adjacent Blocks, Nawada District, Bihar
AAP: 2023-24

Contributors Page

Under the Guidance of

Shri Rajeev Ranjan Shukla
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Composition of the Team

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Dr. Sunil Kumar Ambast
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सत्यमेव जयते

भारत सरकार
जल शक्ति मंत्रालय
जल संसाधन,
नदी विकास और गंगा संरक्षण विभाग
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Government of India
Ministry of Jal Shakti
Department of Water Resources,
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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.

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श्री एन वरदराज
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Department of Water Resources, River Development and Ganga Rejuvenation
Central Ground Water Board

Message

A realistic evaluation of the availability and utilization of a natural resource is imperative for formulating strategies to ensure its sustainable development and its management. This significance is heightened, especially in the context of groundwater in the Country, which faces escalating stress due to its extraction for diverse purposes. The consequence of this situation is a decline in groundwater levels, the desaturation of aquifers, and the deterioration of water quality, among other issues. Groundwater needs to be used and managed in a sustainable way to ensure its long-term sustainability.

The NAQUIM 2.0 study has involved meticulous fieldwork, detailed analysis, and comprehensive interpretation to ensure that our findings are both accurate and informative. The study covers various aspects, including availability, and potential for future development. The data and recommendations outlined after this study will be instrumental in guiding strategic decisions and supporting sustainable management of groundwater resources. The findings obtained after this study are of great importance not only to policymakers and stakeholders but also to the public. Understanding the status and potential of our groundwater resources is crucial for informed decision-making and fostering community engagement.

The report, titled "Aquifer Management Plan, Parts of Nawada District, Bihar" embodies water level behavior, ground water exploration, geophysical exploration, geochemical analysis, hydrometeorological aspects, in parts of Nawada District of Bihar state. This is the first attempt to synthesize the entire set of related data, analyze and interpret them and to present the findings on micro level in a format that appeal to the academicians, administrators and all the stakeholders in ground water.

The commendable endeavors undertaken by the Central Ground Water Board, Mid-Eastern Region in the preparation of the "Aquifer Management Plan, Parts of Nawada District, Bihar" report deserve praise. I am confident that this report will offer substantial benefits to all stakeholders, academicians, administrators and the public alike and will go a long way in the planning and management of the ground water resources for the state of Bihar.

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Member (East)

राजीव रंजन शुक्ला, क्षेत्रीय निदेशक
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सत्यमेव जयते

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Foreword

Ground water is a vital resource that support agriculture and is the most dependable resource in rural India due to its extensive availability, dependability, and affordability. It has played a crucial role in driving India's economic growth and promoting socio-economic advancement. But as the dependability on ground water increases, understanding and managing this precious resource has become more crucial. In the southern part of Bihar, where the marginal alluvium is underlain by hard rocks of Chhotanagpur system. In these areas, there is scarcity of ground water coupled with quality concerns.

NAQUIM 2.0 initiated by Central Ground Water Board, is designed to provide detailed information to support ground water management decisions at ground level. Aquifer Mapping and management plan under NAQUIM 2.0 was undertaken for water stressed areas of Meskaur and adjacent blocks of Nawada District, Bihar. The main objective was demarcation of Aquifer Disposition, identification & demarcation of potential zone of ground water aquifer, identification of recharge-area, types of feasible Artificial Recharge structure and providing management plan for sustainability of ground water resources.

With appreciation for the dedication of the team led by Shri Pankaj Kumar, Scientist-D (Hydrogeology) along with Mrs. Siperna Nayak, Assistant Hydrogeologist, Sh. Astik Panja, STA (Hydrogeology), Dr. Suresh Kumar, Assistant Chemist and Sh. Ritik Das, Scientist-B (Geophysics), the report present here will prove to be a valuable resource. Despite the logistic challenges, the major one was shortage of field worthy vehicle along with other simultaneous time bound assignments, the team has completed the task, which is commendable.

राजीव रंजन शुक्ला

(Rajeev Ranjan Shukla)
Regional Director

Executive Summary

Aquifer mapping is a scientific method used to assess ground water quantity, quality, and sustainability through geological, geophysical, hydrological, and chemical analyses. The National Aquifer Mapping and Management Programme, led by the Central Ground Water Board (CGWB), mapped 32 lakh square kilometers of India from 2012 to 2023 at a 1:50,000 scale, providing critical data for groundwater management. By March 2023, mapping of Bihar was completed. In 2023, the CGWB launched NAQUIM 2.0 to map aquifers at a more localized level (village or gram panchayat), focusing on water-stressed and contaminated areas, urban zones, and industrial regions for more detailed mapping and the development of targeted management plans.

The present study focuses on conducting a detailed analysis in the water-stressed areas of the Meskaur block and adjacent blocks of Narhat, Hisua, and Sirdala in Nawada District, Bihar, India.

The study focuses on mapping the aquifer by analyzing subsurface lithology using CGWB and other state agency well data, along with geophysical surveys. It determines aquifer depth, thickness, and potential zones through geological and geophysical interpretations, creating a Depth to Bedrock map and 3D models using Rockworks software. The study includes hydrogeological survey by establishment of 123 key wells and conducting pumping test. Geophysical survey including 42 Transient Electromagnetic Surveys (TEM) & 27 Vertical Electrical Soundings (VES) were conducted in the study area. Water levels during pre-monsoon and post-monsoon periods were monitored and depth to water level map & contour maps prepared. Ground water quality is studied by collecting and analysing 104 pre-monsoon and 108 post-monsoon ground water samples.

Meskaur and nearby blocks in Nawada District, Bihar, are identified as "Water Stressed Areas" under the NAQUIM 2.0 project, requiring an artificial recharge strategy for sustainable ground water management. Suitable areas for recharge are those with post-monsoon water levels greater than 3 m bgl. Proposed measures include gully plugs for steep slopes and percolation tanks, check dams, and Nala Bunds for moderate slopes. CGWB and Ministry of Jal Shakti follow a Standard Operating Procedure (SOP) for risk assessment in ground water dependent villages, involving geotagging, data collection on village infrastructure, aquifer type, water source reliability, and annual assessments to ensure sustainable water supply systems.

The study reveals that the area has two aquifer systems: Aquifer I (shallow), formed by alluvium and weathered rock, and Aquifer II (deeper), from fractured hard rock. Aquifer I has limited development potential and is accessed by shallow wells, while Aquifer II, is tapped by deep borewells, developed through fracture. The depth to bedrock ranges from 2.0 m to 60.0 m bgl. Water levels in Aquifer I range from 2.75 to 20.15 m bgl, while in Aquifer II, they range from 4.8 to 36.5 m bgl. Fluoride levels in ground water are generally suitable for drinking, though some areas, especially in the southern parts, have fluoride concentration greater than permissible limit.

The study highlights the importance of identifying recharge areas for ground water management. The southern part of the study area is identified as a potential recharge zone. To protect these areas, water management practices such as regulations, conservation, and restoration are recommended. In the study area, 216 villages are at risk, and 39 are in the high-risk category for sustainable drinking water supply, particularly in the southern (Sirdala Block) and hilly regions (Meskaur Block). The study suggests focusing on water conservation and artificial recharge in alluvial and weathered zones. It estimates the construction of 96 percolation tanks, 106 check dams, and 217 nala bunds to enhance recharge, along with de-silting tanks, renovating the Ahar Pyne system, and implementing rooftop rainwater harvesting in government buildings for improved water sustainability.

The outcome of the study will help the state government and relevant departments make informed decisions and implement effective strategies at the local level. The findings will guide the development of policies and actions to improve ground water management and ensure sustainability in the region.

कार्यकारी सारांश

जलभृत मानचित्रण एक वैज्ञानिक विधि है जिसका उपयोग भूवैज्ञानिक, भूभौतिकी, जल विज्ञान और रासायनिक विश्लेषण के माध्यम से भूजल की मात्रा, गुणवत्ता और स्थिरता का आकलन करने के लिए किया जाता है। केंद्रीय भू जल बोर्ड (सीजीडब्ल्यूबी) ने राष्ट्रीय जलभृत मानचित्रण और प्रबंधन कार्यक्रम द्वारा 2012 से 2023 तक 1:50,000 scale पर भारत के 32 लाख वर्ग किलोमीटर का मानचित्रण किया, जिससे भूजल प्रबंधन के लिए महत्वपूर्ण आँकड़े संग्रहीत हुए। बिहार के समस्त जिलों का जलभृत मानचित्रण मार्च 2023 तक सम्पूर्ण कर लिया गया है। वार्षिक कार्य योजना 2023-24 से , CGWB ने अधिक विस्तृत मानचित्रण और लक्षित प्रबंधन योजनाओं के विकास के लिए water stressed areas और भू जल प्रदूषित क्षेत्रों, शहरी क्षेत्रों और औद्योगिक क्षेत्रों पर ध्यान केंद्रित करते हुए, अधिक स्थानीय स्तर (गांव या ग्राम पंचायत) पर जलभृतों के मानचित्रण के लिए NAQUIM 2.0 को प्रारंभ किया गया है।

वर्तमान अध्ययन बिहार के नवादा जिले के मेसकौर ब्लॉक और निकटवर्ती नरहट, हिसुआ और सिरदला ब्लॉकों के water stressed areas में विस्तृत विश्लेषण करने पर केंद्रित है।

यह अध्ययन सीजीडब्ल्यूबी और अन्य राज्य एजेंसी के निर्मित कूपों के आंकड़ों का उपयोग करके subsurface lithology के साथ-साथ भूभौतिकीय सर्वेक्षणों के विश्लेषण द्वारा जलभृत के मानचित्रण पर केंद्रित है। यह भूवैज्ञानिक और भूभौतिकीय सर्वेक्षणों द्वारा से जलभृत के विन्यास (गहराई एवं मोटाई) और भू जल उपलब्धता की दृष्टि से potential zones की पहचान करता है। Rockworks सॉफ्टवेयर का उपयोग करके "सतह से शैलआधार" (Depth to Bedrock) मानचित्र और 3D मॉडल तैयार करता है। इस अध्ययन में 123 Key wells की स्थापना और पंपिंग परीक्षण द्वारा हाइड्रोजियोलॉजिकल सर्वेक्षण किए गए। अध्ययन क्षेत्र में 42 TEM और 27 VES सहित भूभौतिकीय सर्वेक्षण आयोजित किए गए। प्री-मॉनसून और पोस्ट-मॉनसून अवधि के दौरान भू जल स्तर की निगरानी की गई और भू जल स्तर मानचित्र और contour map भी तैयार किया गया। भूजल गुणवत्ता का अध्ययन के लिए 104 मानसून पूर्व और 108 मॉनसून पश्चात भू जल नमूनों को एकत्रित और विश्लेषण किया गया है।

बिहार के नवादा जिले में मेसकौर और आसपास के ब्लॉकों को NAQUIM 2.0 परियोजना के तहत " water stressed areas " के रूप में अध्ययन किया गया, जिसके स्थायी भूजल प्रबंधन के लिए एक कृत्रिम पुनर्भरण रणनीति की आवश्यकता है। पुनर्भरण के लिए उपयुक्त क्षेत्र वे हैं जहां मानसून के बाद का जल स्तर 3 mbgl से अधिक है। प्रस्तावित उपायों में खड़ी ढलानों के लिए गली प्लग और मध्यम ढलानों के लिए percolation tanks, check dams, and

Nala Bunds शामिल हैं। सीजीडब्ल्यूबी और जल शक्ति मंत्रालय विभिन्न आवश्यकताओ के लिए भूजल पर निर्भर गांवों में risk assessment के लिए मानक संचालन प्रक्रिया (SOP) का पालन करते हैं, जिसमें sustainable जल आपूर्ति प्रणालियों को सुनिश्चित करने के लिए geotagging, गांव के बुनियादी ढांचे का डेटा संग्रह, जलभृत प्रकार, जल स्रोत की reliability और वार्षिक मूल्यांकन शामिल हैं।

अध्ययन से पता चलता है कि इस क्षेत्र में दो जलभृत प्रणालियाँ हैं: जलोढ़ (alluvium) और अपक्षयित (weathered) चट्टान से निर्मित जलभृत-I (उथला), और fractured कठोर चट्टान से निर्मित जलभृत-II (गहरा)। जलभृत-I में विकास की सीमित क्षमता है और उथले कुओं द्वारा उस तक पहुंच बनाई जाती है, जबकि जलभृत-II, गहरे बोरवेलों द्वारा उपयोग किया जाता है, जो फ्रैक्चर के माध्यम से विकसित होता है। सतह से शैल आधार (depth to bedrock) की गहराई 2.0 मीटर से 60.0 मीटर bgl तक है। जलभृत-I में जल स्तर 2.75 से 20.15 m bgl तक है, जबकि जलभृत-II में 4.8 से 36.5 m bgl तक है। भूजल में फ्लोराइड का सांद्रण आमतौर पर पीने के लिए उपयुक्त है, हालांकि कुछ क्षेत्रों में, विशेष रूप से दक्षिणी भागों में, फ्लोराइड का सांद्रण मानक (permissible) सीमा से अधिक है।

यह अध्ययन भूजल प्रबंधन के लिए पुनर्भरण क्षेत्रों की पहचान करने के महत्व पर प्रकाश डालता है। अध्ययन क्षेत्र के दक्षिणी भाग को संभावित पुनर्भरण क्षेत्र के रूप में पहचाना गया है। इन क्षेत्रों की सुरक्षा के लिए नियमन, संरक्षण और पुनर्स्थापन जैसी जल प्रबंधन कार्यों की अनुशंसा की जाती है। अध्ययन क्षेत्र में sustainable drinking water supply की दृष्टिकोण से 216 गाँव 39 गाँव क्रमश risk और high risk श्रेणी में आते हैं, विशेष रूप से दक्षिणी (सिरदला ब्लॉक) और पहाड़ी क्षेत्रों (मेसकौर ब्लॉक) में। अध्ययन में जलोड़िय और अपक्षयित क्षेत्रों में जल संरक्षण और कृत्रिम पुनर्भरण पर ध्यान केंद्रित करने का सुझाव दिया गया है। इसमें पुनर्भरण को बढ़ाने के लिए 96 percolation tanks, 106 चेक डैम और 217 नाला बंड के निर्माण प्रस्तावित है, साथ ही टैंकों से गाद निकालने, अहार पाइन प्रणाली का नवीनीकरण करने और बेहतर water sustainability के लिए सरकारी भवनों में roof top वर्षा जल संचयन को लागू करने का भी सुझाव है।

अध्ययन के नतीजे से राज्य सरकार और संबंधित विभागों को बेहतर निर्णय लेने और स्थानीय स्तर पर प्रभावी रणनीतियों को लागू करने में मदद मिलेगी। इसका निष्कर्ष भूजल प्रबंधन में सुधार और क्षेत्र में sustainability सुनिश्चित करने के लिए नीतियों और कार्यों के विकास का मार्गदर्शन करेंगे।

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Chapter 1
Introduction

Aquifer mapping is a scientific process, wherein a combination of geologic, geophysical, hydrologic and chemical field and laboratory analyses are applied to characterize the quantity, quality and sustainability of ground water in aquifers. Systematic aquifer mapping is expected to improve our understanding of the geologic framework of aquifers, their hydrologic characteristics, water levels in the aquifers and how they change over time, and the occurrence of natural and anthropogenic contaminants that affect the portability of ground water. Aquifer mapping at the appropriate scale can help prepare, implement and monitor the efficacy of various management interventions aimed at long-term sustainability of our precious ground water resources, which, in turn, will help achieve drinking water security, improved irrigation facilities and sustainability in water resources development in the country as a whole. Various on-going activities of Central Ground Water Board, such as ground water monitoring, ground water resource assessment, artificial recharge and ground water exploration in drought, water scarcity and vulnerable areas can also be integrated in the aquifer mapping project.

The National Aquifer Mapping and Management Programme undertaken by the Central Ground Water Board has mapped 32 lakh sq. km area of the entire country at a 1:50,000 scale, in 2012-23. This programme has provided aquifer geometry, parameters, and groundwater quality data. Management plans have been proposed based on the data generated from this study. Under this programme, entire state of Bihar has been covered till March, 2023.

As a part further down the scale to micro level, NAQUIM 2.0 has been taken by CGWB from 2023, so that the recommendations of the study can be brought down to gram panchayat or village level. The NAQUIM 2.0 has identified 11 priority areas for clubbing the different studies in different parts of the country viz. Water Stressed areas, ground water contamination, urban agglomerates, and industrial areas for further detailed mapping and specific management plan formulation.

The present study investigates the further detailed study in water stressed areas of Meskaur block along with adjoining blocks of Narhat, Hisua and Sirdala of Nawada District

Chapter 2
About the Study Area

Nawada district, with a geographical area of 2487 sq.km and covering 14 blocks, falls in Survey of India Degree Sheet No. 72 H and 72 G. The district is bounded in north by Nalanda and Sheikhpura districts, in east by Jamui district, in west by Gaya district, and south by Koderma&Giridih districts of Jharkhand state. The index map of the study area is given in Figure 2.1.

Under NAQUIM 2.0, water stressed block of Meskaur and adjoining blocks – Hisua, Narhatand Sirdala has been taken up for detailed study, on the suggestion of GoB. The total study area of the 04 blocks is 627.77 sq. km.

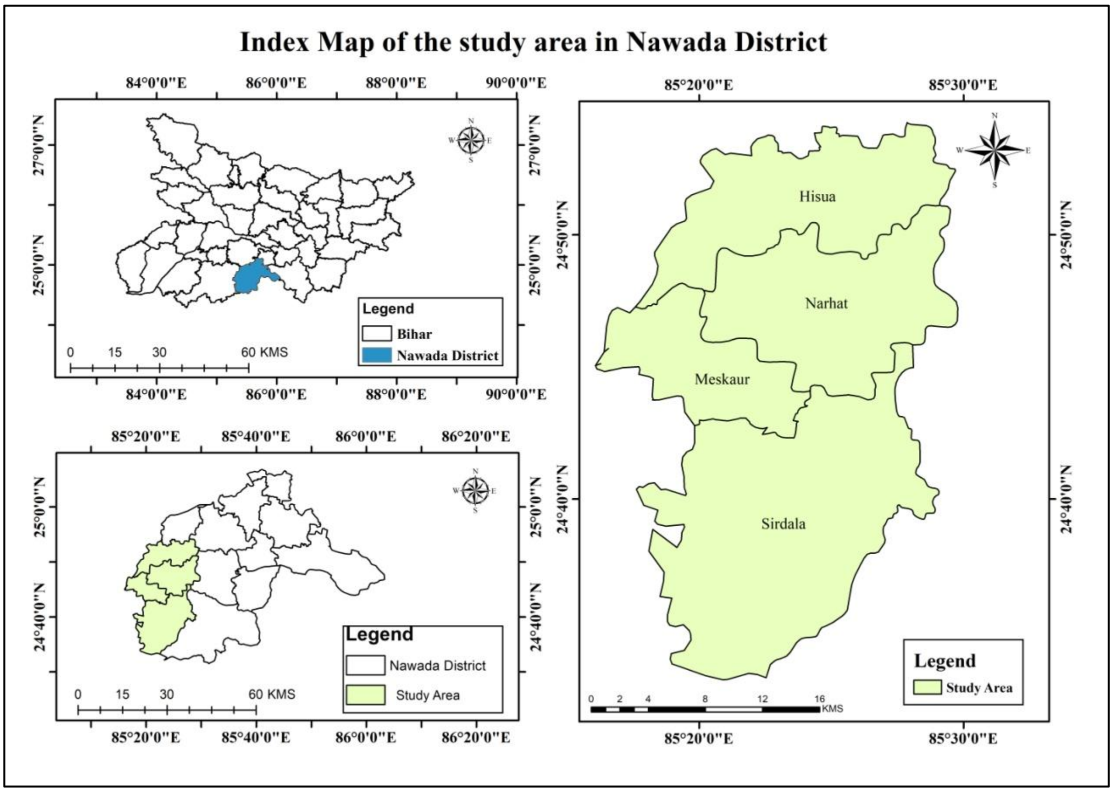


Figure 2.1 Index Map of Nawada District

2.1 Geology

Geologically, the blocks are covered by Quaternary alluvium, along with patches of granite/migmatite gneissic/schistose rocks of Chotanagpur complex in some area. Majority of the study area is consisting of older alluvium except the southern part which is covered by Precambrian rocks. Hydrogeologically the area is underlain by older alluvium of depth varies from 15m to 40m, followed by weathered basement. However, Hisua block is having greater depth of alluvium. TDS of the ground water of NHS wells varies from 206 to 595 mg/L.

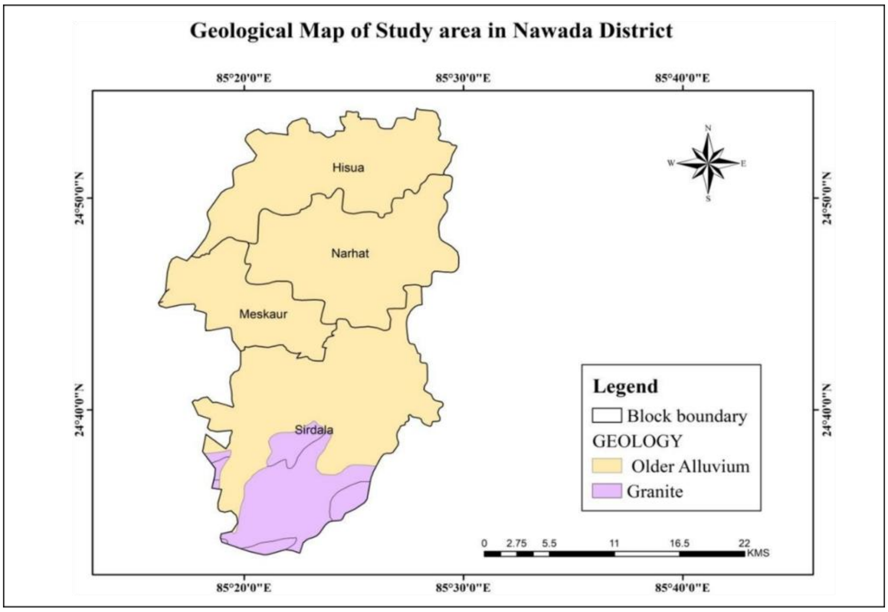


Figure 2.2 Geological Map of the Study Area

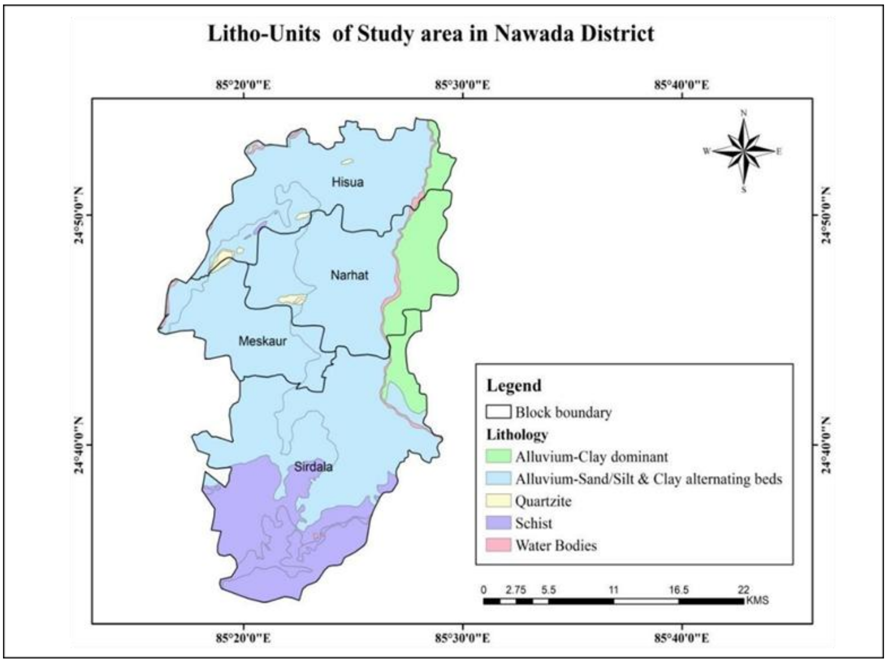


Figure 2.3 Litho-units of Study area

2.2 Geomorphology

Geomorphologically, the study area can be divided into the northern alluvial plain, and southern dissected hills and plateau parts. The district is drained by river Dhanarjya and Tilaiya. In the western part of the study area some granite outcrops can be observed at Meskaur block.

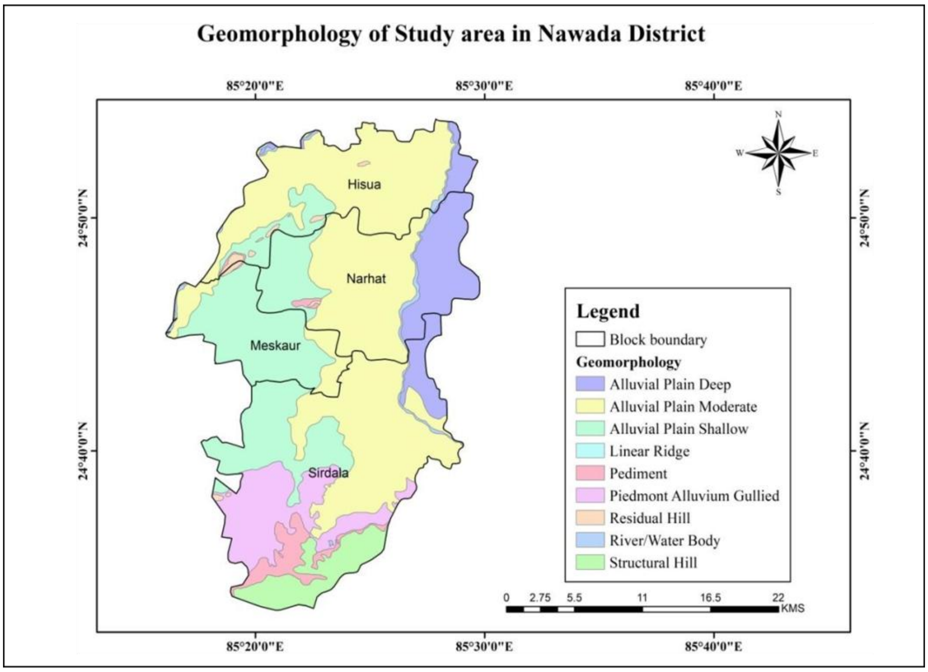


Figure 2.4: Geomorphological Map of the Study Area

2.3 Rainfall

The average annual rainfall in the study area is 831.8 mm, distributed over 201 rainy days. The normal annual rainfall varies from 725 mm in Meskaur block to 1030 mm in Sirdala block. The rainfall details of the four blocks—Meskaur, Hisua, Narhat, and Sirdala are shown in the Table No. 2.1.

Table 2.1 Rainfall of the area

Sl No	Block	Area (sq km)	Normal Annual Rainfall (mm)	No. Of Rainy Days
1	**Meskaur**	181.83	725.10	51
2	**Hisua**	122.70	830.60	48
3	**Narhat**	76.39	756.50	50
4	**Sirdala**	246.85	1030.10	52

2.4 Demography

The study area covers an area of 627.77 Km^2 with a total population of 558,531. There are 45 Panchayats and 320 villages across these blocks. The population in the study area varies from 94358 at Meskaur to 178472 at Sirdala.

The area is falling in Agro Ecological Zone Type IIIB. The temperature of the region varies from 46°C in summer to 4°C in winter. Some of the details of the study area are given block wise in succeeding tables.

2.5 Land Use and Land Cover

Land use pattern of an area has an intrinsic relationship to geology and lithology of the area. Water demand of an area depends on the utility of the land for various purposes. From district agricultural records it has been found that the total gross cropped area of the study area is 44580 hectares out of which 21390 hectares area is net sown area and average cropping intensity stands at 162.5%. The block wise breakdown of land use patterns are shown in the table No.2.3.The majority of the geographical area across the four blocks consists of agricultural land and fallow land, with only a small portion being built-up areas. The southern section of the study area features shrub land and deciduous broadleaf forest. Figure No. 2.5 illustrates the land use and land cover patterns in the study area.

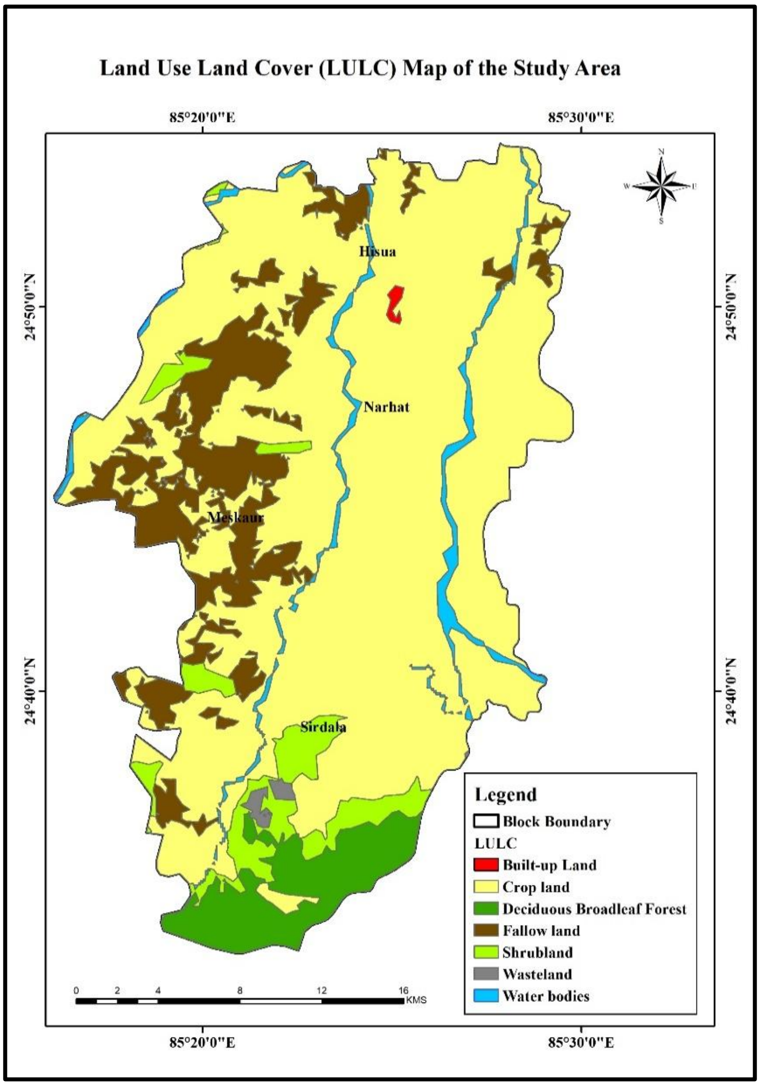


Figure 2.5: Land Use and Land Cover map of the study area.

Table 2.2 Land Use pattern of the area (in ha)

Sl No	Block	Gross Cropped Area	Net Sown Area	Cropping Intensity (%)	Area under Forest	Area under Wasteland	Area under other uses
1	**Meskaur**	11449	4627	164	106	105	817
2	**Hisua**	10587	4903	161	93	404	1001
3	**Narhat**	6865	4607	165	0	0	827
4	**Sirdala**	15679	7253	160	6622	959	1414

2.6 Irrigation

Across all blocks, the total area includes 34,698 hectares of Gross Irrigated Area, 11,997 hectares of Rainfed Area, 463 hectares of partially irrigated land, and 22,238 hectares of un-irrigated land. Table 2.4 details the irrigated and rainfed areas, as well as the irrigation status for the blocks of Meskaur, Hisua, Narhat, and Sirdala.

Table 2.3 Irrigated and Rainfed Area (in ha)

Sl No	Block	Irrigated Area		Rainfed Area	
		Gross Irrigated Area	Net Irrigated Area	Partially Irrigated	Unirrigated
1	**Meskaur**	7597	1846	41	5710
2	**Hisua**	7878	3282	74	4522
3	**Narhat**	7592	1752	95	5745
4	**Sirdala**	11631	5117	253	6261

2.7 Cropping Pattern

The cropping calendar in the study area spans from July to June of the following year, covering three main agricultural seasons: Kharif, Rabi, and Zaid. Kharif crops are typically reliant on monsoon rainfall, though due to low rainfall in the area, there is a growing dependency on groundwater for irrigation. Both Rabi and Kharif crops are heavily dependent on groundwater. The primary crops for each season are:

- **Kharif (July to October):** Paddy
- **Rabi (October to February/March):** Wheat, Mustard, Oilseeds, and Vegetables
- **Zaid (March to June):** Moong, Chana, and Millet

Figure 2.6: Crops grown in the study area

Chapter 3
Priority Types

Based on the experience of NAQUIM studies, CGWB has initiated the studies under the NAQUIM 2.0 at varied finer scale in eleven types of identified priority areas. These areas have been identified based on ground water related issues/criticality of groundwater situations like water stressed areas, urban agglomerates, coastal areas, industrial cluster & mining areas, areas with spring as the principle sources, areas with deeper aquifers, ground water contamination, auto flow zones, canal command areas, areas with poor ground water quality etc.

By now it has become necessary to pay much more attention to ground water resources in our country. This is because the groundwater recharge rate has been in decline, particularly during the drought years. This is supplemented by the changing precipitation and temperature conditions. Progressive climate change means that this set of problems is likely to escalate. Planning at regional level can designate priority and restricted areas for the conservation of groundwater and thus the NAQUIM 2.0 study.

The present study involving the Meskaur and adjacent blocks of Nawada district is Water stressed areas. Ground water potential of the area is restricted owing to the limited overburden thickness of alluvium and/ or weathered residuum together with nature of secondary porosity developed in the hard rock below.

Chapter 4
Previous Studies

In the field of geology, the systematic geological mapping of the area was carried out way back in early 40’s, before independence and systematic hydrogeological studies were carried out in late 60’s. Previous studies are summarised below.

- The district has been covered under systematic geological mapping by L A N Iyer (1939-44), Dunn (1942), Eahadovan & Haithain (1967), A K Ghosal (1981-82), B K Bisaria (1982) under the aegis of Geological Survey of India.

- Earlier systematic hydrogeological studies carried out in the district include groundwater investigation by A. Mukherjee (GSI) during 1966 followed by reappraisal hydrogeological survey by S J Prasad during 1987-88 under the aegis of CGWB.

- Studies regarding mineral resources characterization of mica pegmatites of Nawada and Hazaribagh districts have been done by R C Chattopadhay & R N Mukherjee (1979-80, 1986-87), B P Bhattacharya &A S Banerjee (1984).

- Special studies titled “Quaternary geology and geomorphology of parts of the Son-Ganga alluvial belt Gaya, Nalanda, Nawada, Hazaribagh, Giridih districts, bihar” has been done by D Bhaduri& S S Bose (1984-85) of Geological Survey of India.

- Regional Geochemical Mapping of the district has been carried out by R N Ravi das & R Awungshi (2015) of GSI as part of their ‘National Geochemical Mapping’ programme.

- Central Groundwater Board (then Geological Survey of India) started groundwater exploration studies in the district in collaboration with state Public Health Engineering Department during 1966-67 in the drought affected areas of the district. During 1977-79, the State Tube Well Corporation, Govt. of Bihar constructed high yielding irrigation tube wells in Nawada, Warisaliganj, Pakribarwan blocks. During 1992-93, CGWB has constructed 13 exploratory wells in Nawada district.

- During 2019-20, NAQUIM study have been completed in the district for an area of 2487 sq km covering 14 blocks of the district.

- During AAP 2020-’21, one exploratory well and one observation well has been constructed in Pakribarwan through outsourcing work.

- Groundwater monitoring in the district has been done through the existing Network Hydrograph Stations.

Chapter 5
Objectives of the Study

Identifying and assessing aquifers and their potential will assist water supply agencies, stakeholders and decision makers in determining the volume of water available. A strong and actionable groundwater management plan will serve as a "Road Map" for systematically managing groundwater resources to ensure equitable distribution across all sectors. To achieve the stated goal, the following objectives have been identified as the most crucial in the context of this study.

- ✓ Existing Water supply and Supply gap identification
- ✓ Plan for Source sustainability and possibility of replenishment
- ✓ Identification and demarcation of potential zone of ground water aquifer.
- ✓ Alternate source identification and conjunctive use
- ✓ Management of GW based water supply
- ✓ Mitigation/ suggestive measures e.g. Additional wells to be constructed, or decrease in Ground Water pumping depending upon the scenario.
- ✓ Preparation of overburden thickness maps
- ✓ Identification of recharge- area, types of feasible AR structure and cost estimation

Chapter 6
Deliverables of the Study

With the aforementioned objective in mind, the study aims to generate the following outputs within the study area keeping in view the deliverables as per NAQUIM toolkit.

- ✓ Aquifer Dispositions
- ✓ Aquifer-wise ground water levels
- ✓ Delineation of Recharge Areas
- ✓ Estimation/Refinement of parameters used for resource assessment
- ✓ Assessment of ground water resources
- ✓ Ground Water Quality
- ✓ Areas showing signs of subsidence
- ✓ Ground Water Quality Management Interventions including demarcation of safer aquifers
- ✓ Artificial Recharge Plan
- ✓ Other measures
- ✓ Identification of potential aquifers for drinking water supply
- ✓ A plan for drinking water source sustainability
- ✓ Identification of potential aquifers for irrigation.

Chapter 7
Data Generation in the Study Area

In the Study Area, the existing data of water level, water quality, exploratory wells, and geophysical studies was very limited and there was strong need to generate additional data. This was achieved by carrying out different activities in the field of geophysical surveys, exploratory drilling & pumping test, hydro-geochemical analysis of ground water samples besides hydrogeological surveys.

There were only 05 NHS wells in the study area for monitoring depth to water level. These NHS wells represent the shallow aquifer. 87 key wells have been established during the study. There were no existing monitoring wells for the deeper aquifer initially, during the study 31 key wells were established, resulting in a total of 31 wells for monitoring the deeper aquifer. For information about sub-surface lithological data and aquifer characteristics, 04 new exploratory wells were constructed. This was in addition to the existing 04 exploratory wells. Pumping tests were also carried out at 06 farmer borewells in the field to assess behaviour of shallow aquifers. Soil infiltration tests were conducted at 07 different locations to evaluate soil infiltration rates. Additionally, 35 Farmers feedback forms were filled, as per NAQUIM 2.0 toolkit during the study, providing valuable insights on depth of wells constructed for irrigation, depth of encountering of fracture, crop types & rotation, and pumping data. Other secondary data were also collected from various departments to supplement the study. Rainfall data was obtained from the Directorate of Economics and Statistics, Government of Bihar, while lithological data and discharge information were collected from the Public Health Engineering Department (PHED), Government of Bihar.

In terms of water quality, data has been collected for both the shallow and deeper aquifers. For the shallow aquifer, 77 ground water samples were collected during pre-monsoon and post-monsoon. For the deeper aquifer, initial data collection was limited, with no existing data points. However, 26 pre-monsoon and 36 post-monsoon sample locations were added during the present study.

Geophysical studies have been carried out in the study area to supplement the hydrogeological data to decipher the aquifer geometry. There was existing Vertical Electrical Sounding (VES) data from 15 locations. During the course of the study 12 VES and 42 Transient Electromagnetic (TEM) at 14 locations were conducted. These data also helped in preparation of depth to Bed Rock map.

Overall, this study has significantly expanded the data available on water levels, quality, exploratory wells, and geophysical studies, providing a comprehensive overview of the study area. The existing data and data generated during the study is given in table 7.1 and is represented in the map given as Figure 7.1.

Table 7.1: Existing data and new data generated in the study area

<table>
<tr><th colspan="2">Data</th><th>Existing number of data points in the Study Area</th><th colspan="2">Additional data generated</th><th>Total</th></tr>
<tr><td colspan="2">Water Level (Shallow Aquifer)</td><td>5 NHS wells</td><td colspan="2">87 key wells</td><td>92 wells</td></tr>
<tr><td colspan="2">Water Level (Deeper Aquifer)</td><td>Nil</td><td colspan="2">31 key wells</td><td>31 wells</td></tr>
<tr><td colspan="2" rowspan="2">Water Quality (Shallow Aquifer)</td><td rowspan="2">5</td><td>Pre</td><td>72</td><td>77</td></tr>
<tr><td>Post</td><td>72</td><td>77</td></tr>
<tr><td colspan="2" rowspan="2">Water Quality (Deeper Aquifer)</td><td rowspan="2">0</td><td>Pre</td><td>26</td><td>26</td></tr>
<tr><td>Post</td><td>36</td><td>36</td></tr>
<tr><td colspan="2">Exploratory Well</td><td>4</td><td colspan="2">4</td><td>8</td></tr>
<tr><td rowspan="2">Geophysical Studies</td><td>VES</td><td>15</td><td colspan="2">12</td><td>27</td></tr>
<tr><td>TEM</td><td>0</td><td colspan="2">42</td><td>42</td></tr>
<tr><td colspan="2">Pumping Test</td><td>0</td><td colspan="2">6</td><td>6</td></tr>
<tr><td colspan="2">Soil Infiltration Test</td><td>0</td><td colspan="2">7</td><td>7</td></tr>
</table>

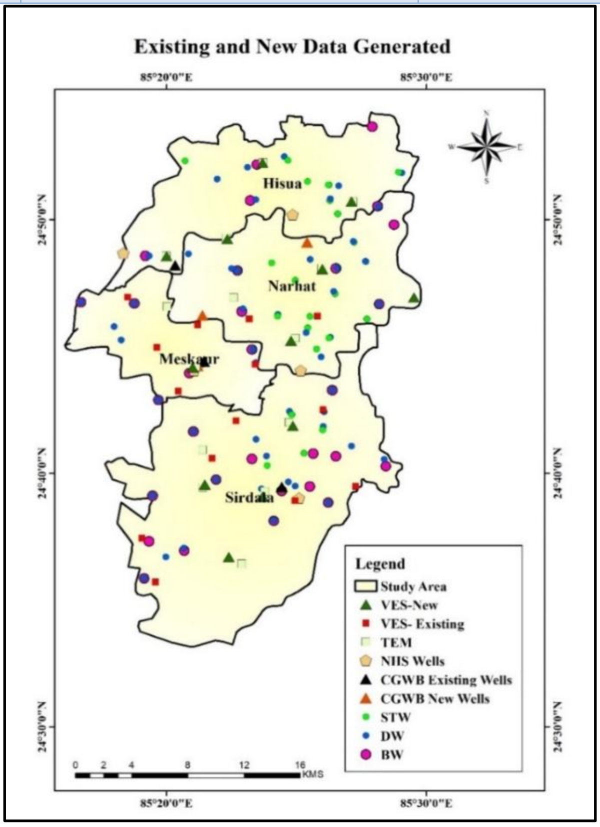


Figure 7.1: Map showing existing and new data in the study area.

Chapter 8
Aquifer Disposition

8.1 Objectives

The objective of the present chapter is to delineate aquifer disposition of the study area, which includes deciphering the number of aquifer system present in the study area down to the explored depth, depth to aquifer top and depth to aquifer bottom, thickness of the aquifer, potential aquifer zones using geological and geophysical interpretations.

8.2 Methodology

The subsurface lithology was obtained from existing and newly drilled CGWB exploratory wells (EW). The subsurface lithology was also studied from state Govt. well data (PHED). Geophysical investigations were carried out covering the four blocks as part of the study. The geological and geophysical data were correlated to interpret the subsurface lithology. Depth to Bed rock map was prepared on the basis of CGWB exploratory well data, PHED well data and information collected from farmers' feedback form. Cross-section prepared in Rockworks 20.0 software. 3D model-Cross sections/ block diagrams were prepared in rockworks format.

A total of 42 TEM (Transient Electromagnetic Survey) at 14 locations and 27 VES (12 under AAP 2023-24 and 15 existing).

8.3 Results and Discussions

8.3.1 Hydrogeological Interpretation

There were 4 existing exploratory wells in the study area and 4 new wells were drilled during the present study in AAP 2023-24. The details of 40 state govt. wells (PHED wells) were used to infer depth to bed rock. A total of 12 representative wells including CGWB EWs and PHED wells spread across the study area were used to prepare the section lines, which are used to prepare the lithological and stratigraphic cross-sections (Figure 8.1). Aquifer parameters and water quality including lithological characteristics, as inferred from the analysis of existing and data generated during the study are summarized aquifer wise in the following table.

Table 8.1: Aquifer characterization and disposition

Stratigraphy	Principal Aquifer	Major Aquifer	Lithological Characteristics	Nature of Aquifer	Depth of occurrence Aquifer (mbgl)	Thickness Range (m)	Water Level (mbgl) Range (mbgl)	Type of Abstraction Structure	Quality F Range (mg/l)	Quality (TDS) Range (mg/l)	Discharge Range lps	Transmissivity Range m2/day
Quaternary	Alluvium (Alluvial Aquifer)	Alluvium [AL01/AL 03]	Older Alluvium with Sand fine to coarse, clay, silt with Kankar, gravel Greyish to brownish grey .[AL03]	Unconfined Aquifer/ Weathered Aquifer	0-50	1.5-50	Pre- 3.1-18.05 Post- 0.9 - 20.15	Dugwell and Shallow Tube Well	0.33-4.6	260-1628	1.36- 3.35	1.46 - 418.16
Archean - Mesoproterozoic	Granitic Gneiss (Fractured Aquifer)	Granitic Gneiss [GN 01]	Quartzite, phyllite, biotite gneiss, granite gneiss [GN01]	Fractured Aquifer	1.5 - 200	3 - 200	Pre- 6 - 36.5 Post- 2 - 31.3	Deep Bore Wells	0.63 - 4.01	212 - 1484	0.828 - 18	149 - 395

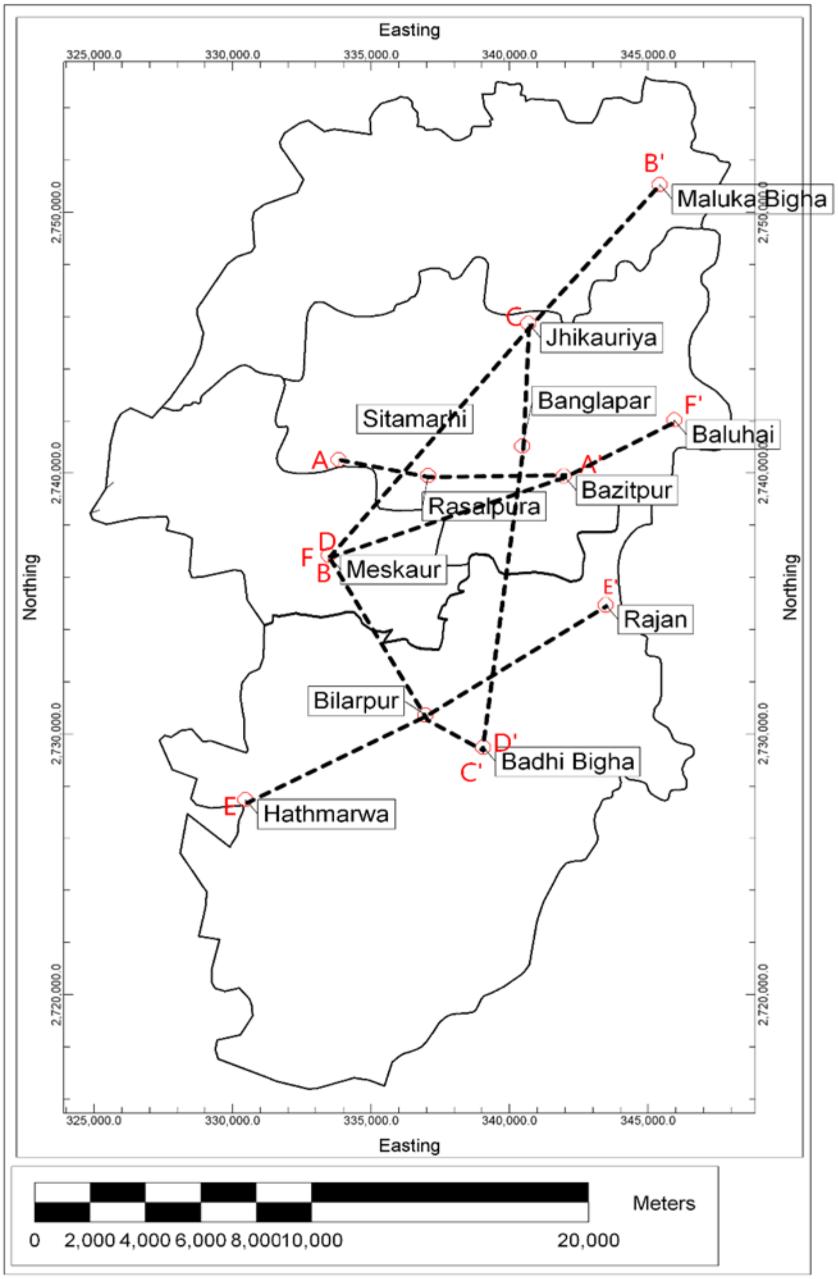
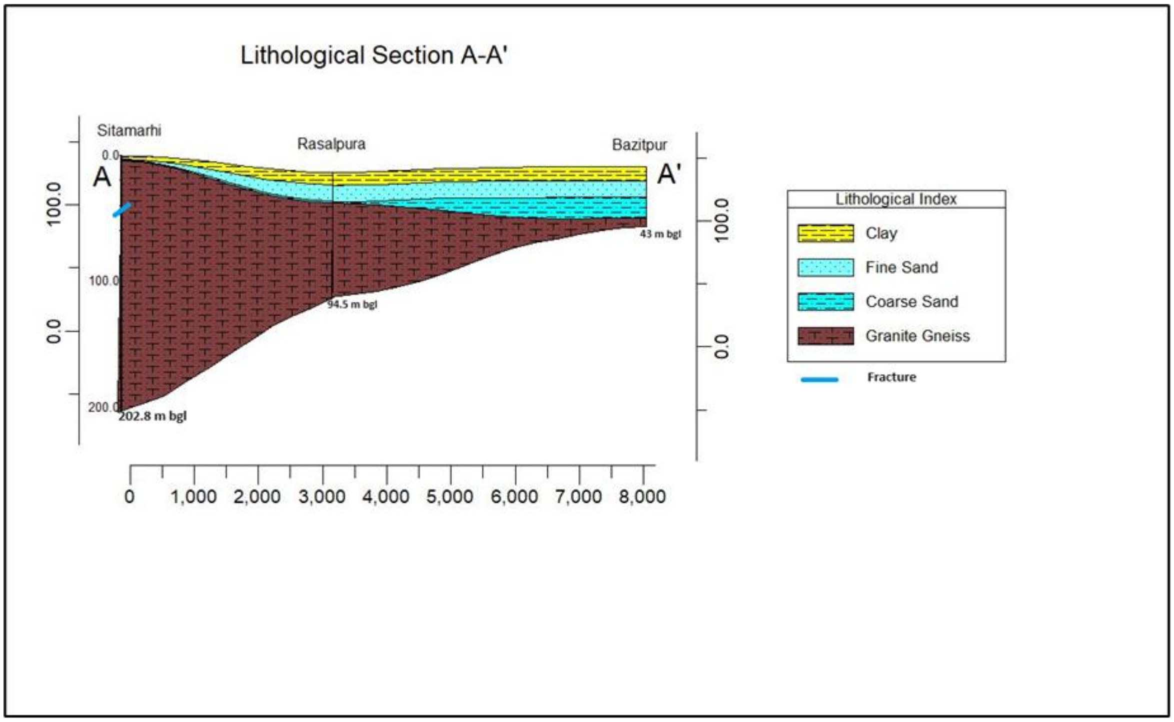


Figure 8.1: Profile for cross section

Cross-section AA’ is between Sitamarhi-Rasalpura-Bazitpur. Sitamrahi is CGWB EW drilled during the present study having a depth of 202.8 m bgl. A fracture is encountered at a depth of 41.2-44.2 m bgl. Rasalpura and Bazitpur are PHED wells having depth of 94.5 m bgl and 43 m bgl, respectively.



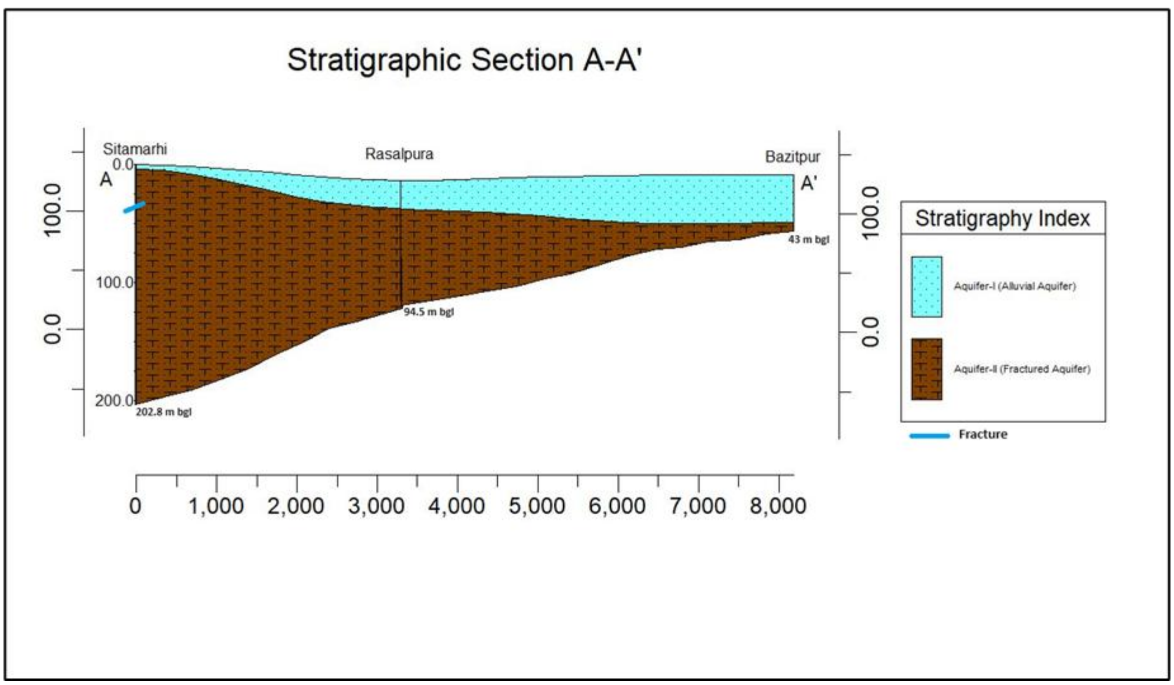


Figure 8.2: Lithological section and Stratigraphic section along AA’

Cross-section BB’ is between Meskaur-Jhikauriya-Maluka Bigha. Meskaur and Jhikauriya are CGWB EW drilled during the present study. The EW at Meskaur has a depth of 200.8 m bgl. Two sets of fractures are encountered in this well, one at a depth of 56.4-59.5 m bgl and the other one at 59.5-62.5 m bgl. The EW at Jhikauriya is also drilled upto a depth of 200.8 m bgl. Two sets of fractures are encountered in this well also. The first one at a depth of 50.3-53.4 m bgl and the second one at a depth of 102.2-105.2 m bgl. Malukia Bigha is a PHED well having a depth of 50 m bgl.

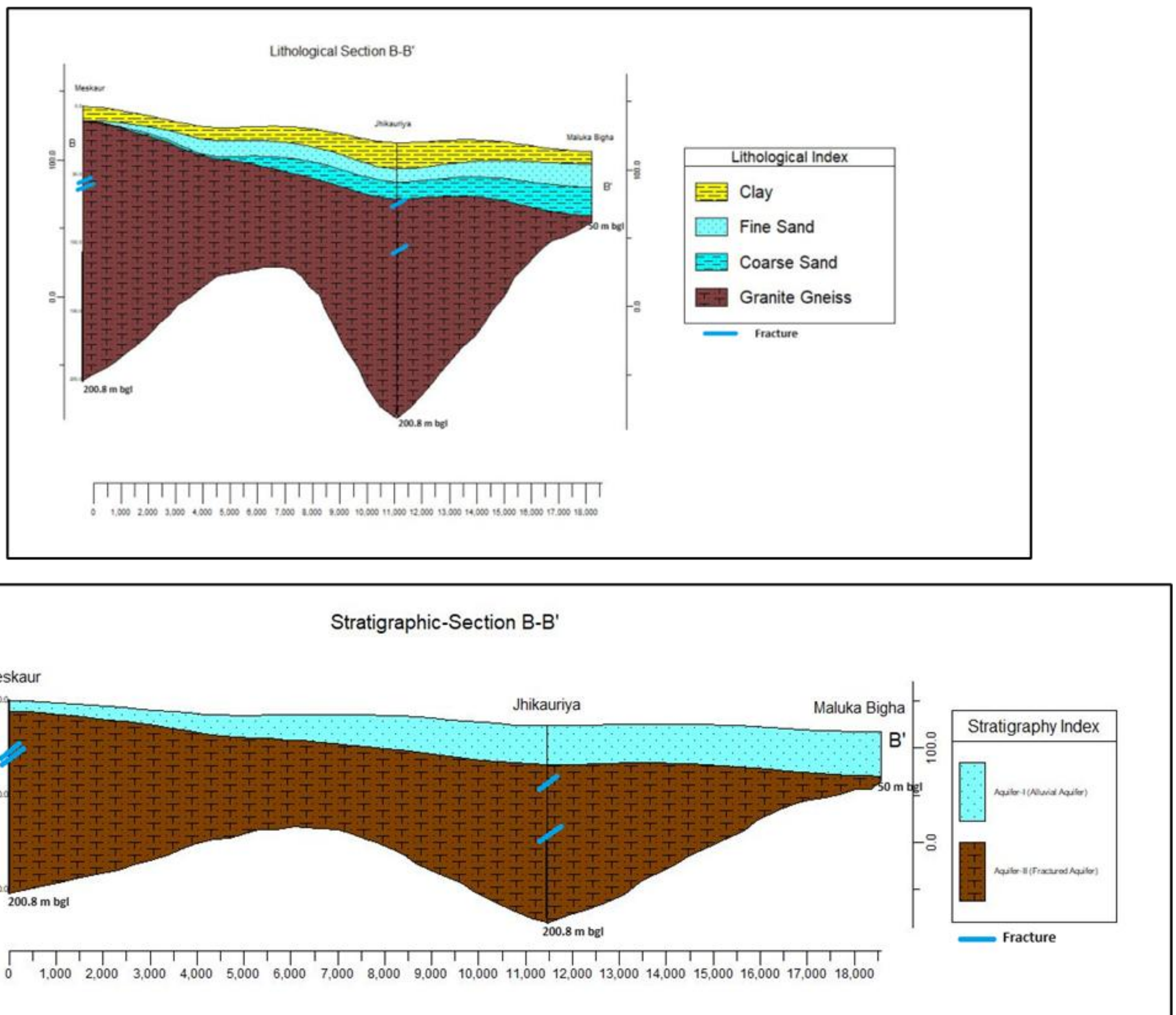


Figure 8.3: Lithological section and Stratigraphic section along BB’

Cross-section CC’ is between Jhikauriya- Banglapar-Badhi Bigha. Jhikauriya is CGWB EW drilled during the present study having a depth of 200.8 m bgl. Two sets of fracture are encountered in this well, at depths of 50.3-53.4 m bgl and 102.2-105.2 m bgl, respectively. Banglapar and Badhi Bigha are PHED wells having depth of 49 m bgl and 98 m bgl, respectively.

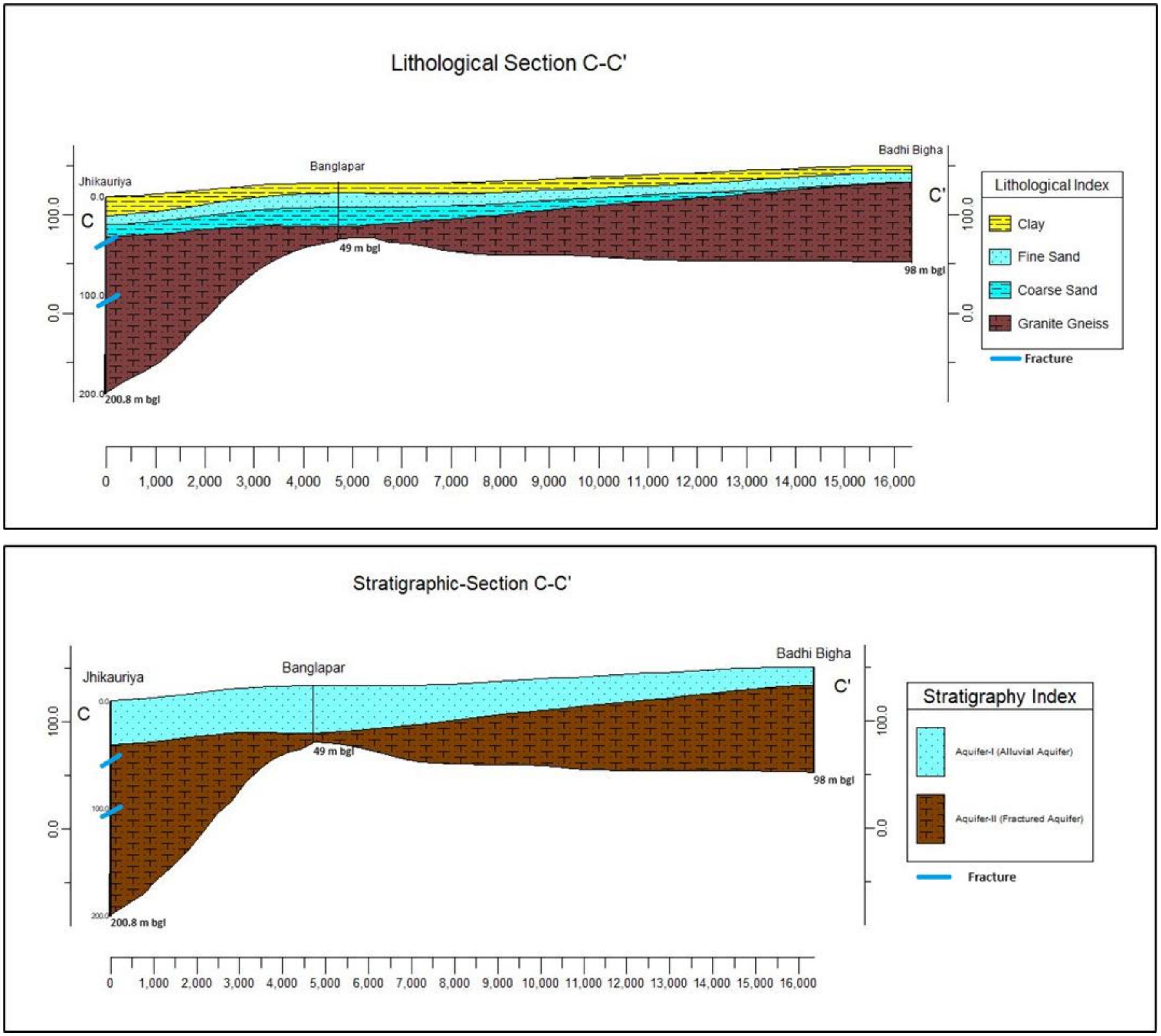
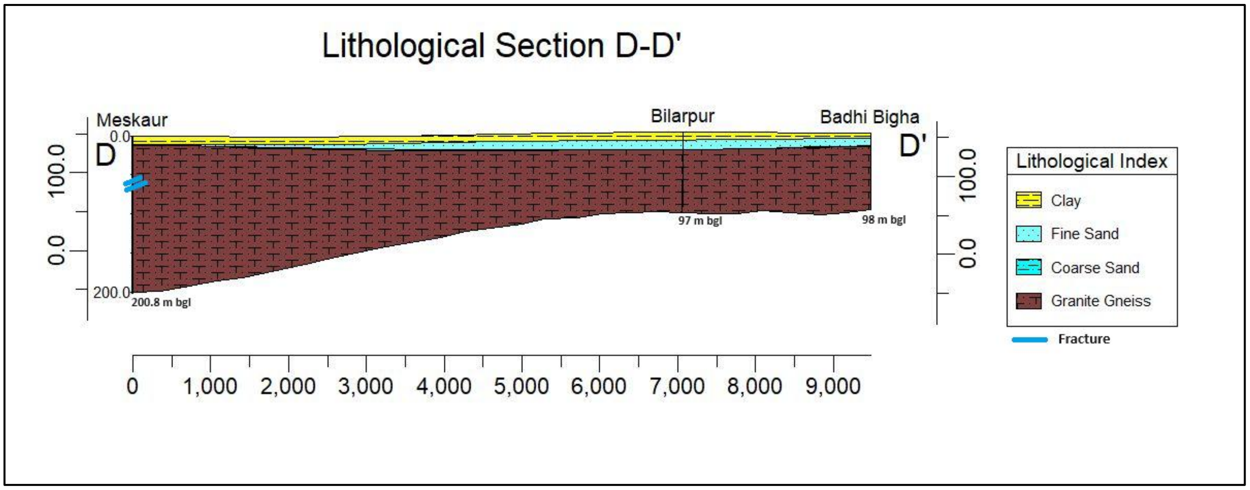


Figure 8.4: Lithological section and Stratigraphic section along CC’

Cross-section DD' is between Meskaur-Bilarpur-Badhi Bigha. Meskaur is CGWB EW drilled during the present study uto the depth of 200.8 m bgl, having fractures at 56.4-59.5 m bgl and 59.5-62.5 m bgl depths. Bilarpur and Badhi Bigha are PHED well having depth 97m bgl and 98 m bgl, respectively.



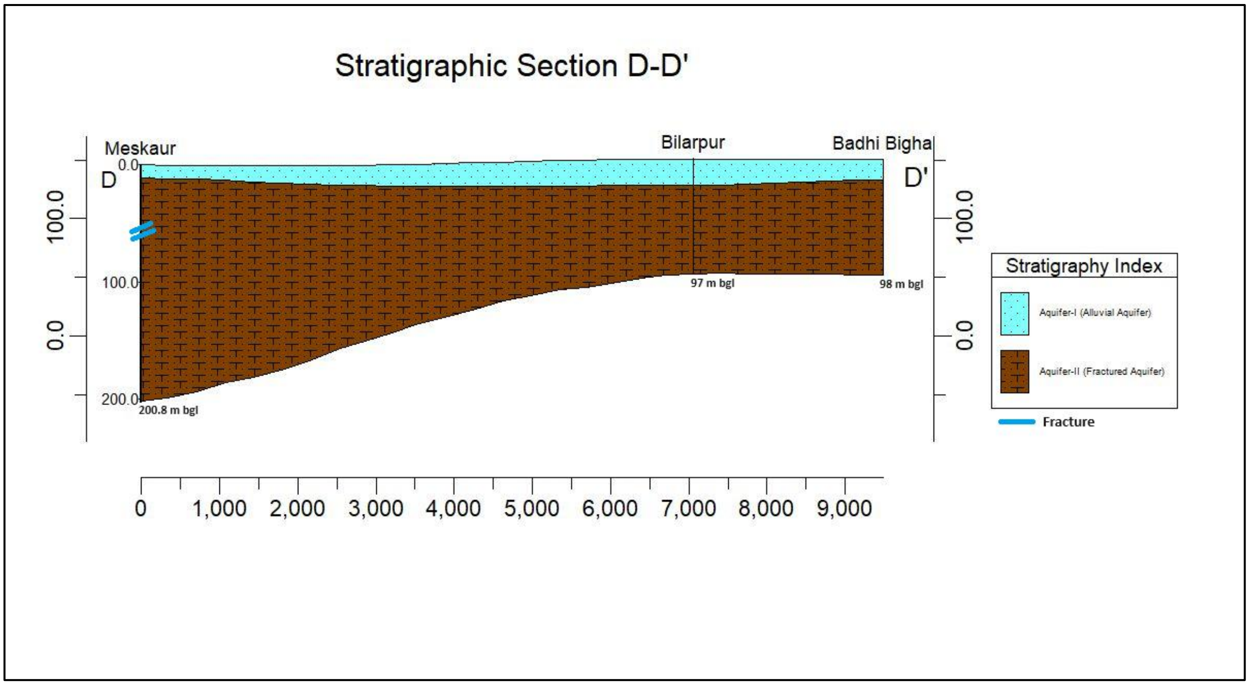


Figure 8.5: Lithological section and Stratigraphic section along DD'

Cross-Section EE' is between Hathmarwa-Bilarpur-Rajan. All the wells are PHED wells. The well at Hathmarwa has a depth of 103 m bgl. The well at Bilarpur has a depth upto 97 m bgl and the well at Rajan has a depth of 37 m bgl. No fractures are encountered in these wells as per PHED data.

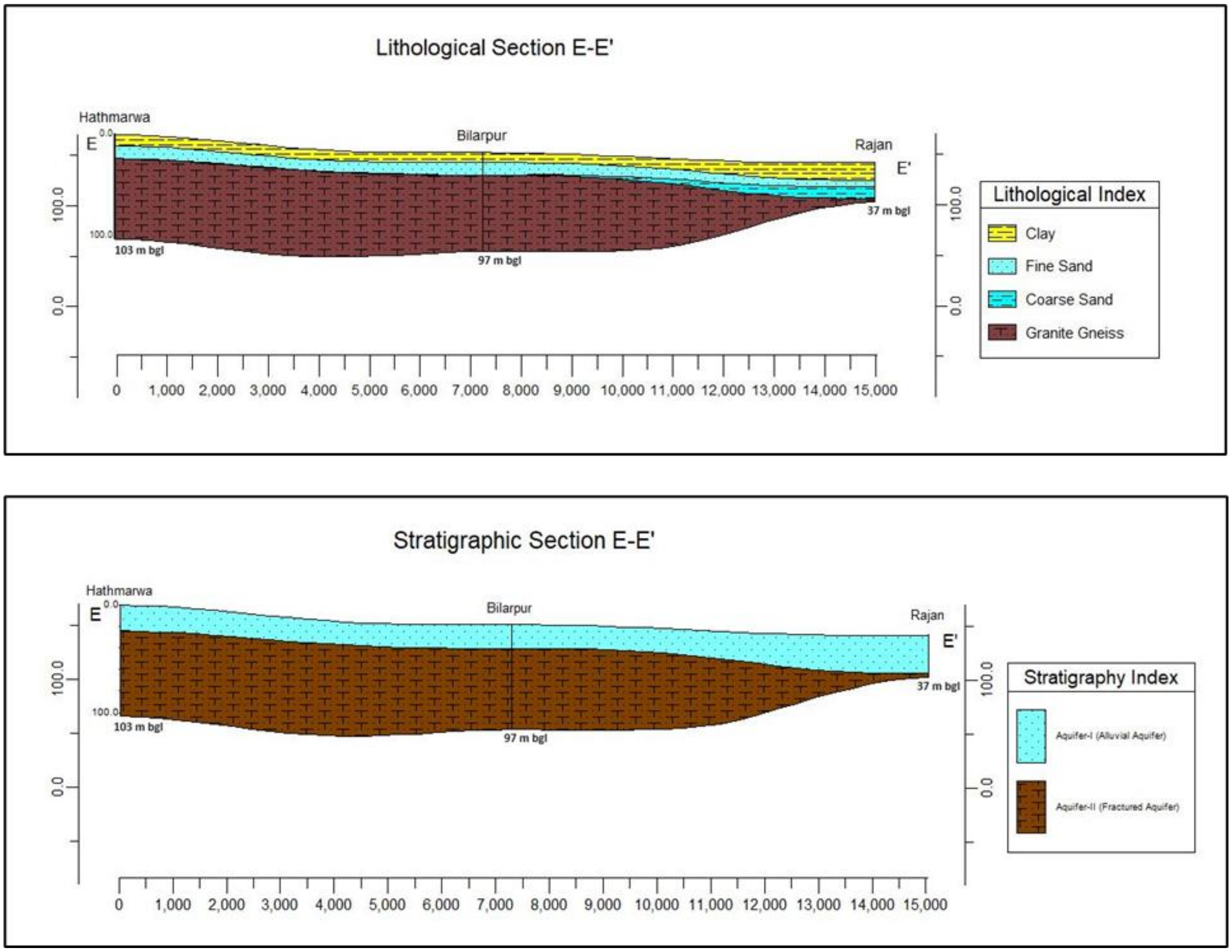
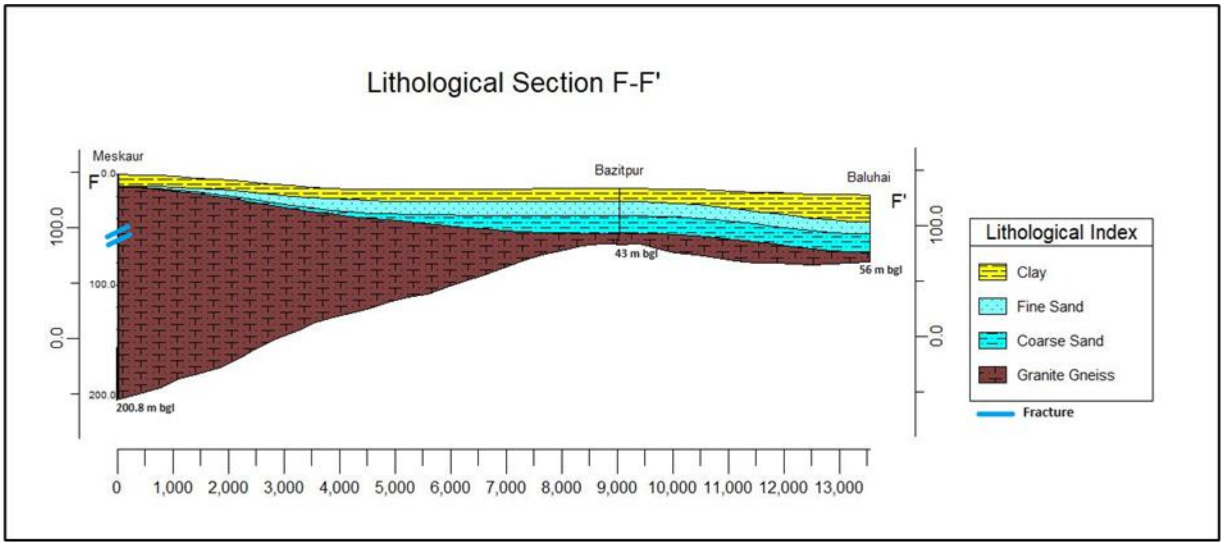


Figure 8.6: Lithological section and Stratigraphic section along EE'

Cross-section FF' is between Meskaur-Bazitpur-Baluhai. The details of EW at Meskaur is already discussed in the above sections. The wells at Bazitpur and Baluhai are PHED wells having depth of 43 m bgl and 56 m bgl, respectively.



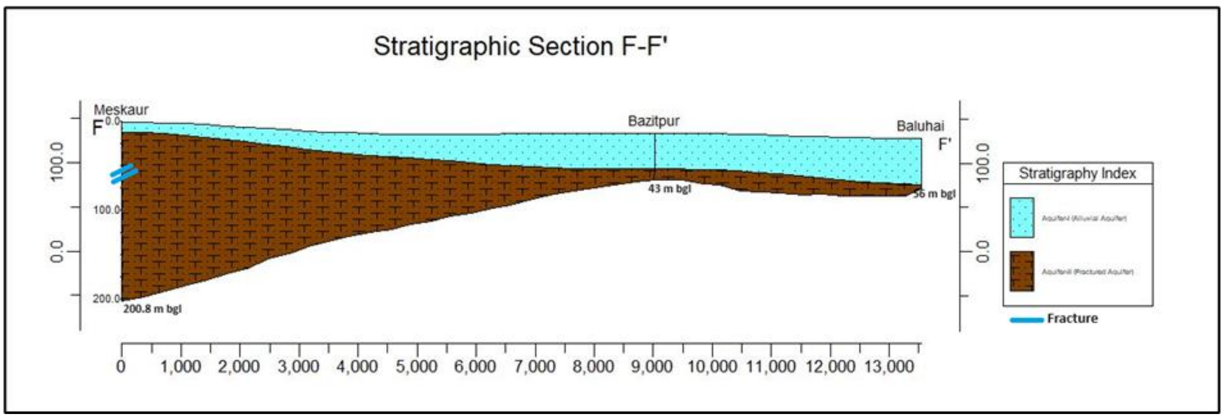


Figure 8.7: Lithological section and Stratigraphic section along FF’

The subsurface stratigraphic sections shows that there are two major aquifers in the study area: Aquifer-I (Alluvial aquifers) and Aquifer-II (Fractured aquifers).

Aquifer-I is the alluvial aquifer of Quaternary age lithologically made up of clay, fine to coarse sand, with kankars and grayish to brownish gravels. The depth of aquifer-I ranges from the surface upto 50 m bgl. The thickness of this aquifer varies from 1.5 m to 50 m. The pre-monsoon water level varies from 3.1 m bgl to 18.05 m bgl and the post-monsoon water level ranges from 0.9 m bgl to 20.15 m bgl in aquifer-I. The water from this aquifer is mainly tapped using dug wells and shallow tube wells and at some places shallow borewells. The discharge of this aquifer ranges from 1.36 lps to 3.35 lps and transmissivity varies from 1.46 m^2/day to 418.16 m^2/day. The TDS value of water samples collected from aquifer-I ranges between 260-1628 mg/L and the Fluoride concentration ranges from as low as 0.33 mg/L to as high as 4.6 mg/L.

Aquifer-II is the fractured aquifer where the fractures occur in Granitic gneiss of Archean age. The depth of aquifer-II ranges from1.5 m bgl to 200 m bgl as per the drilling data. The thickness of the aquifer thus, varies from 3 m to 200 m. The pre-monsoon depth to water level ranges from 6 m bgl to 36.5 m bgl and the post monsoon depth to water level varies from 2 m bgl to 31.3 m bgl in aquifer-II. The water from this aquifer is tapped using deeper bore wells. The discharge of this aquifer ranges from 0.828 lps to 18 lps and transmissivity varies from 149 m^2/day to 395 m^2/day. The TDS value of water samples collected from aquifer-II ranges between 212-1484 mg/L and the Fluoride concentration ranges from as low as 0.63 mg/L to as high as 4.01 mg/L.

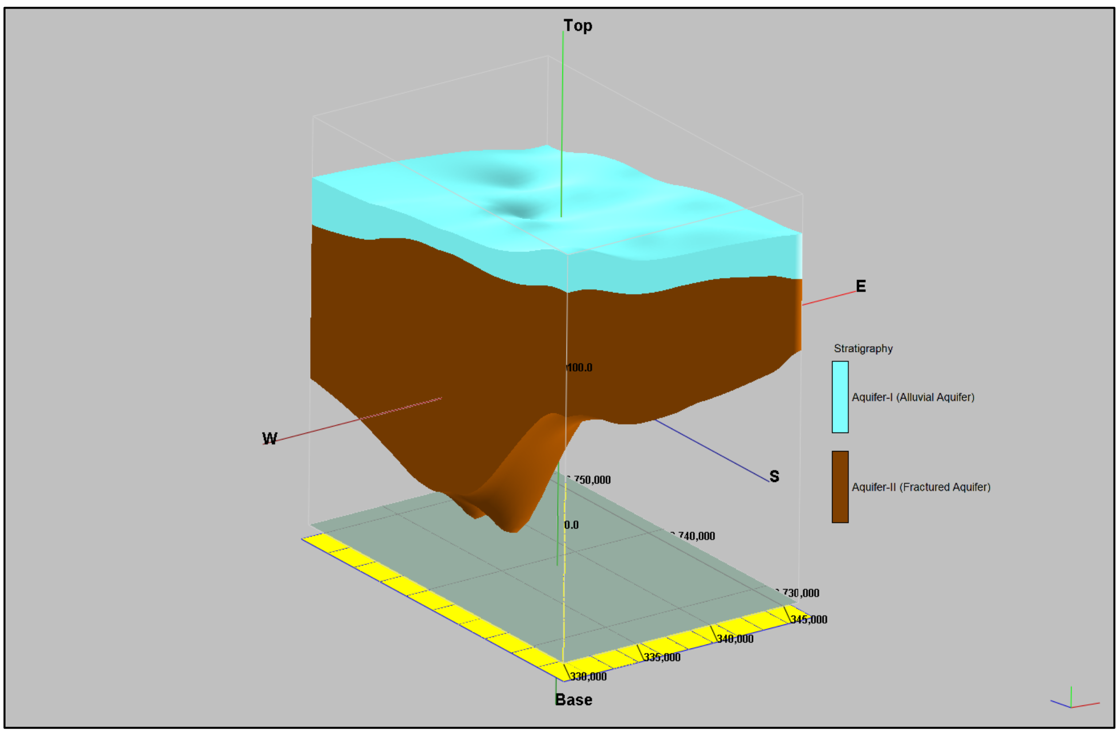


Figure 8.8: 3D model of the aquifer disposition in the study area

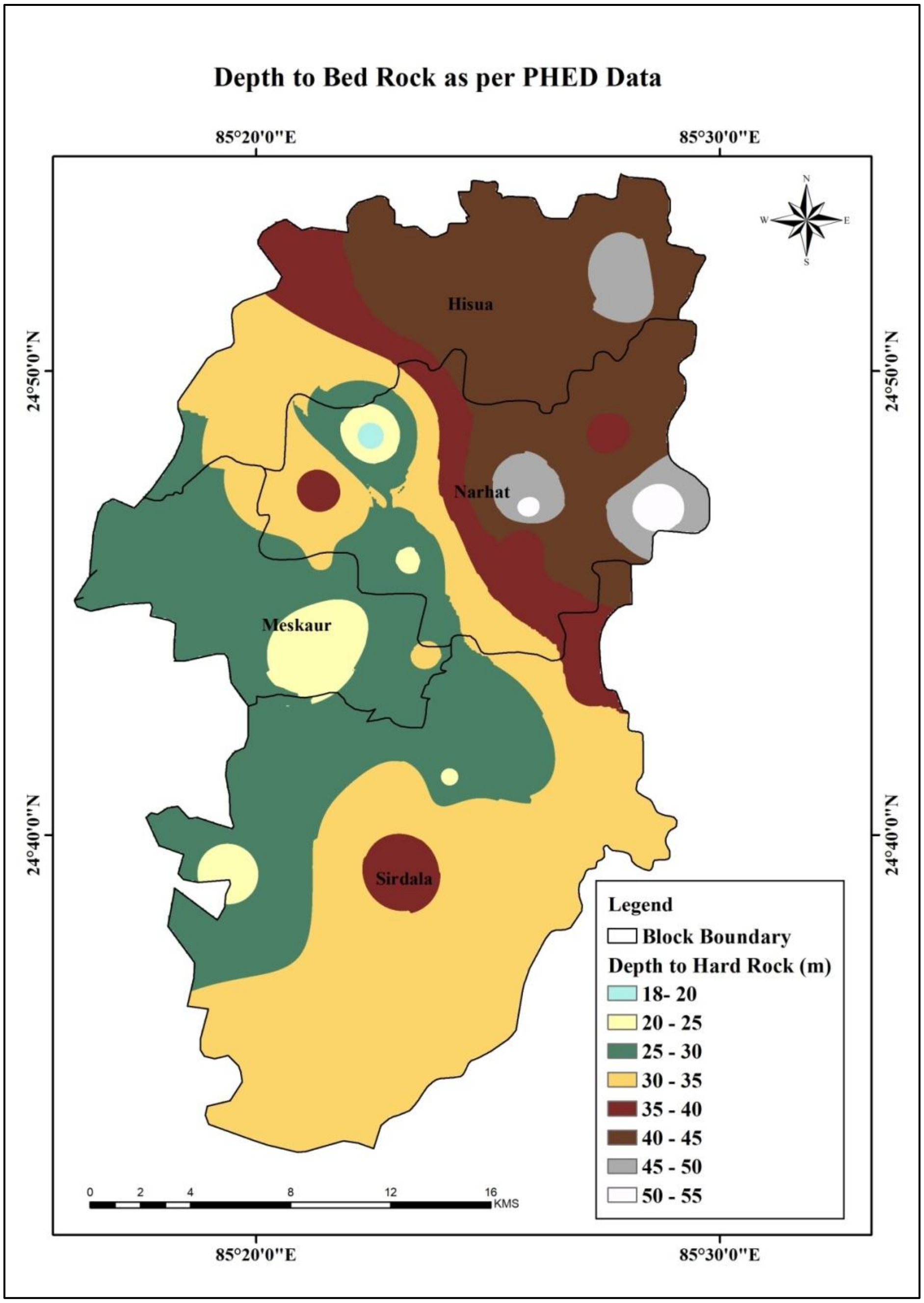


Figure 8.9: Depth to bed rock map as per PHED Well data

8.3.2 Geophysical Investigation and Interpretation

Vertical Electrical Sounding (VES) and Ground Transient Electromagnetic Survey (TEM) have been carried out in the study area to decipher the aquifer geometry and identification of suitable fracture encountered depth. A total of 27 VES (including existing VES conducted in the area) and 42 TEM (in 14 locations) have been conducted. The location points are presented in the following map.

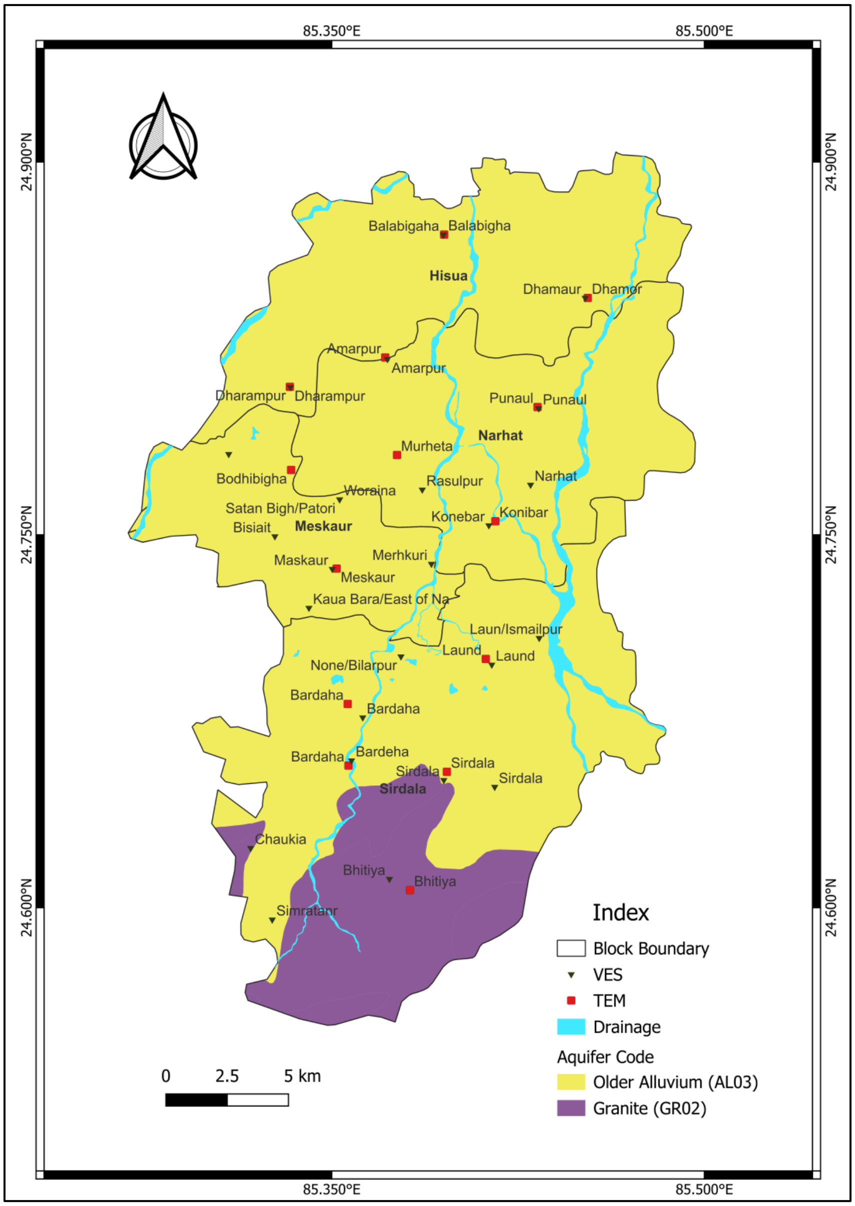


Figure 8.10: Map showing location of Geophysical survey

8.3.2.1 **VES Survey in parts of Nawada District**:

A total of 27 VES were conducted spanning the whole study area. Out of 27 VES, 12 VES were carried out in AAP 2023-24. The data were acquired using the instrument *Aquameter CRM Auto C*. The maximum spreading (AB/2) was 400.0 m, and the obtained apparent resistivity values were plotted against AB/2 in double logarithmic paper of moduli 62.5 mm. The data were interpreted using the software *IX1d.* Equivalence of layer parameters were kept in mind during interpretation and final models for each sounding was selected such that it satisfies local hydrogeological conditions. An attempt was made to identify the probable fracture zones with the help of curve break technique. A few representative VES curves along with interpreted models are shown below. The interpreted results of VES survey are attached in Annexure.

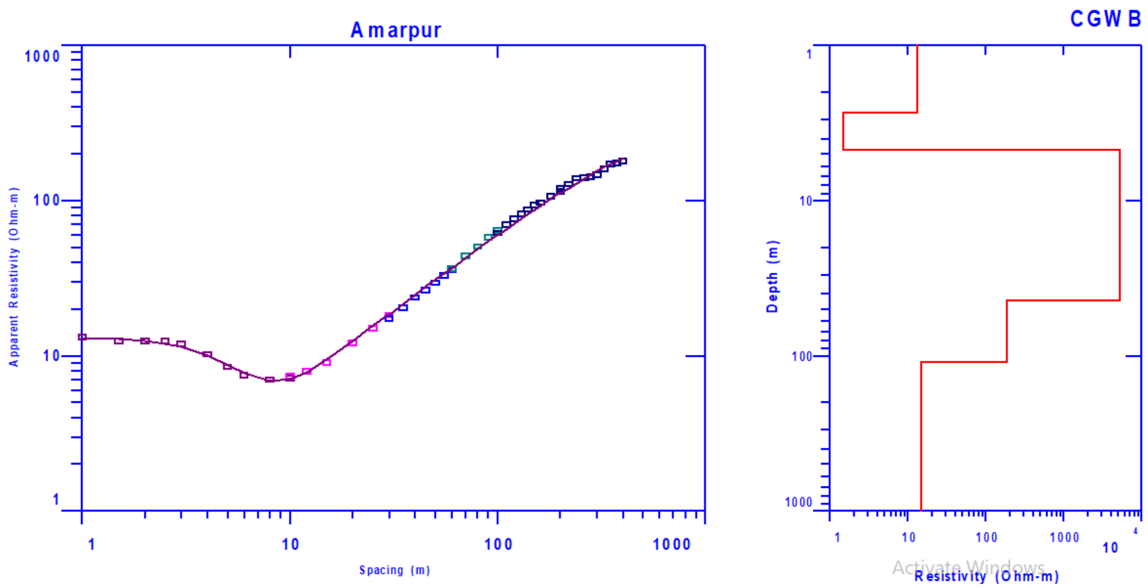


Figure 8.11: VES Curve and interpreted layer parameters at Amarpur, Nawada

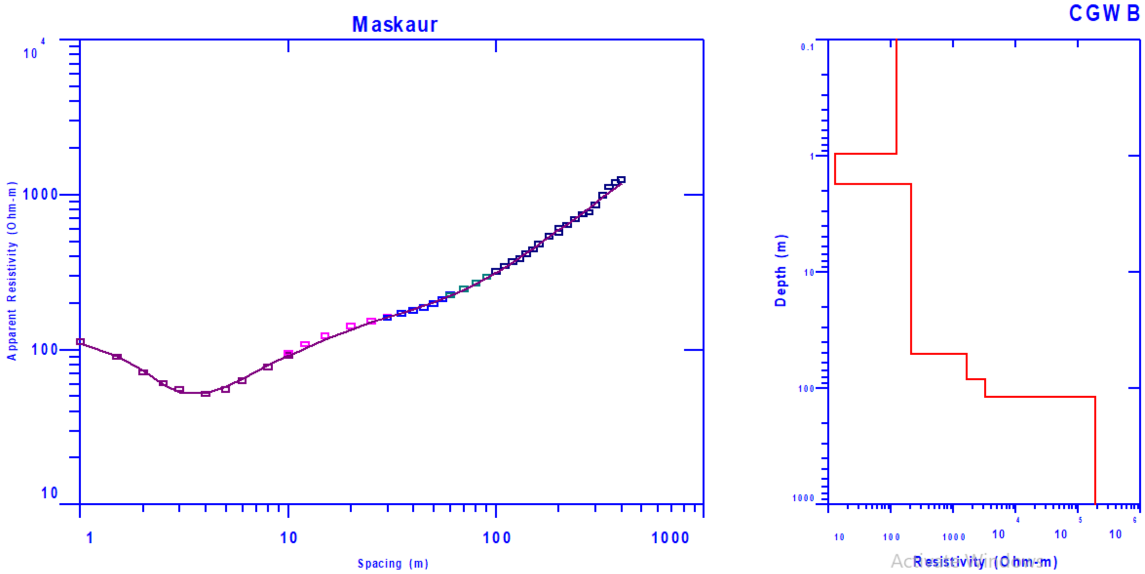


Figure 8.12: VES Curve and interpreted layer parameters at Meskaur, Nawada

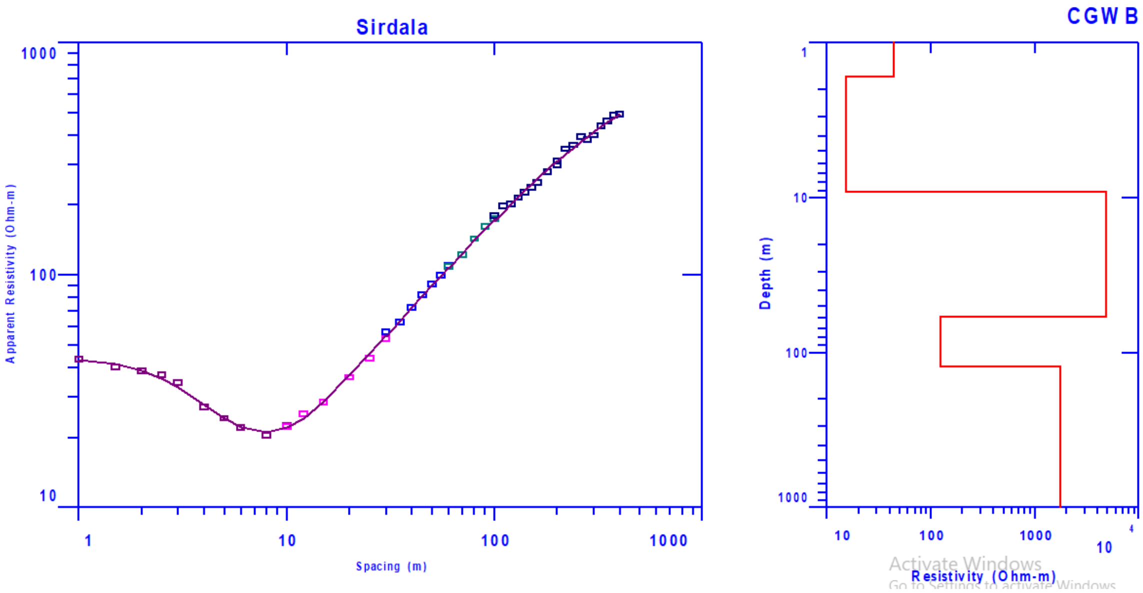


Figure 8.13: VES Curve and interpreted layer parameters at Sirdala, Nawada

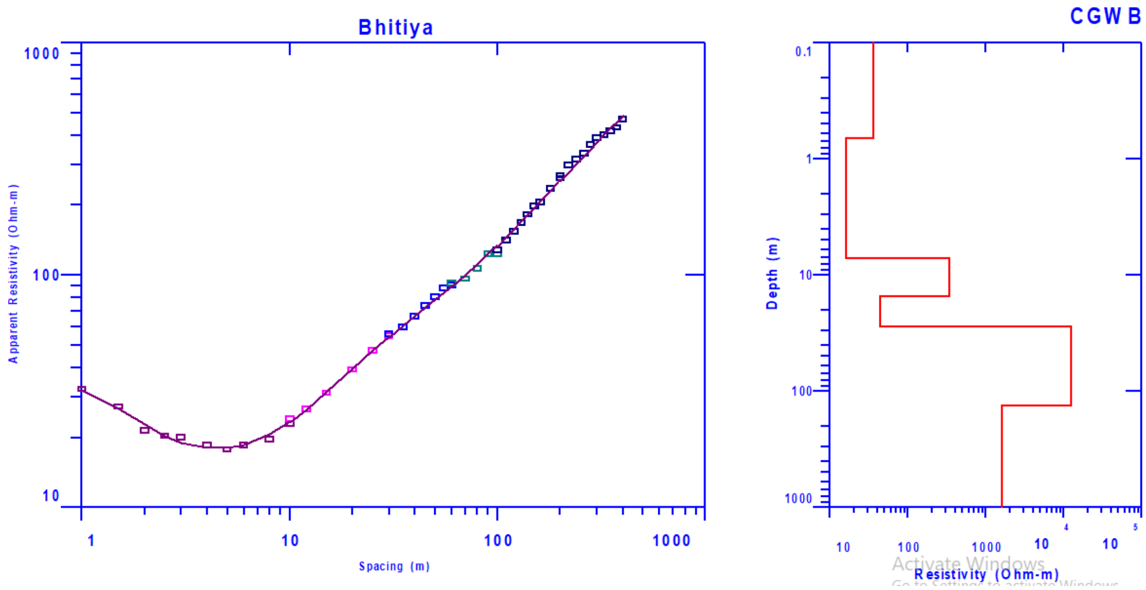


Figure 8.14: VES Curve and interpreted layer parameters at Bhitiya, Nawada

8.3.2.2 TEM Survey in parts of Nawada District: -

42TEM soundings at 14 locations were carried out using the instrument MonexGeoscope. Coincident loop configuration was used to acquire the data. The dimension of both transmission and receiver loop was set to be 40 x 40 m^2. Utmost care was taken during acquisition of data and potential sources of noise such as transmission line, heavy electrical accessories, and anthropogenic structures were avoided, and the obtained data was inverted using the software Terra Tem Plot. Final interpretation was carried out using the software IX1d. Equivalence of layer parameters is an observed phenomenon in TEM interpretation. Local hydrogeological conditions were kept in mind during the interpretation process.

Findings: -The findings of TEM survey at few locations are shown below.

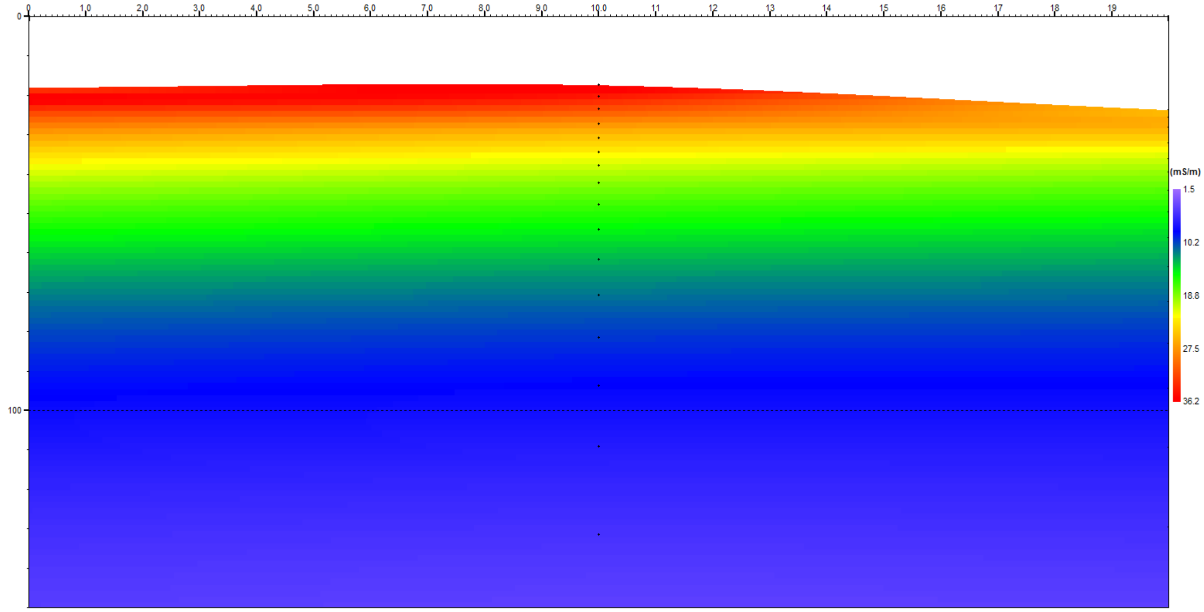


Figure 8.15: Apparent Conductivity Pseudo Section of Bhitiya, Sirdala block, Nawada

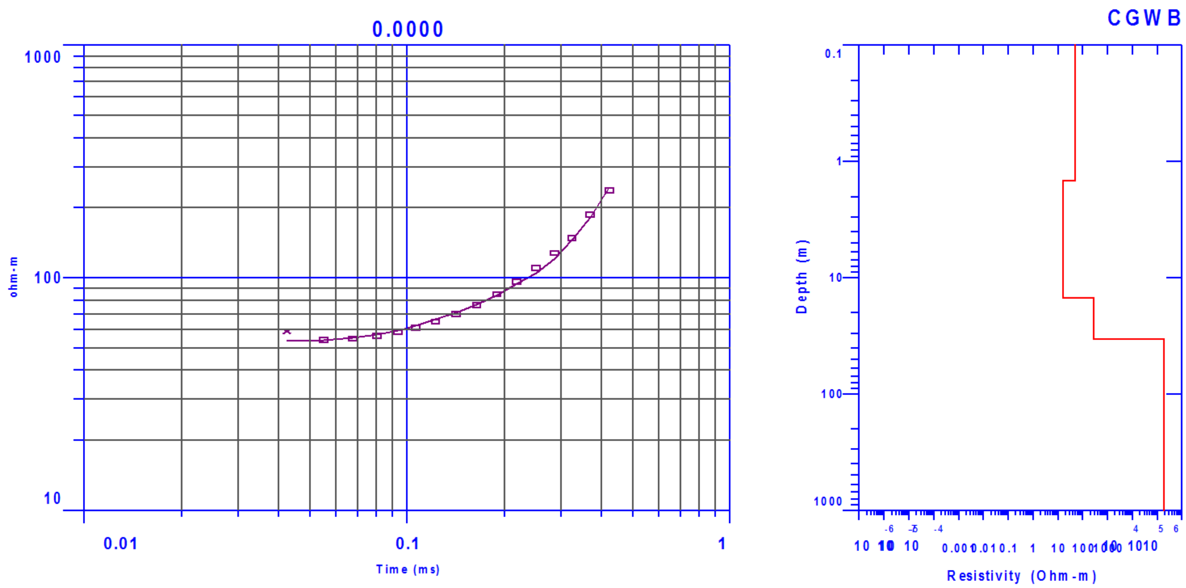


Figure 8.16 Decay curve of TEM survey and interpreted layer parameters at Bhitiya, Sirdala,

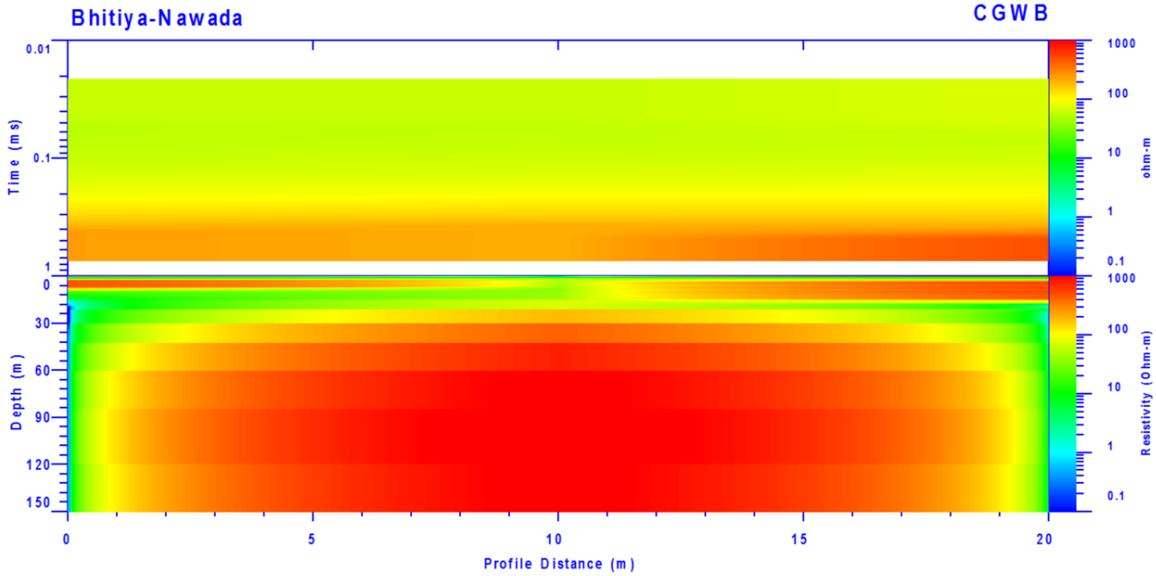


Figure 8.17: Profile showing Interpreted resistivity model at Bhitiya, Sirdala, Nawada

Fig 8.15 - Fig 8.17 shows the inferred geoelectrical properties at Bhitiya of Sirdala block, Nawada district. Fig 8.15 indicates that apparent conductivity decreases as one move downwards. True resistivity profile (Fig 8.17) also depicts the same indicating presence of massive bedrock at a depth of 35.0 mbgl.

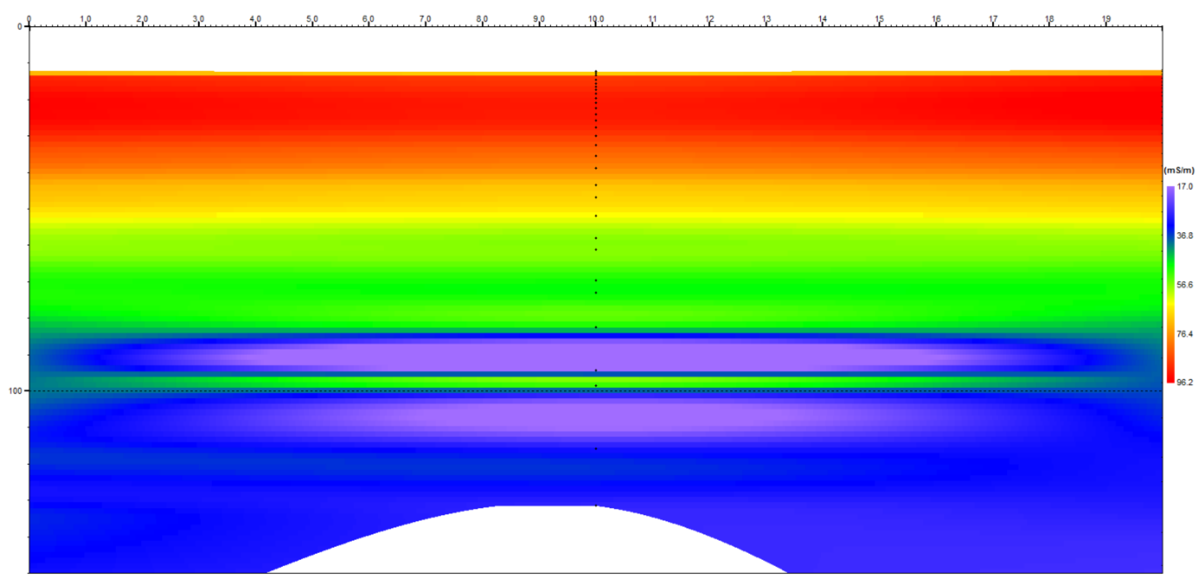


Figure 8.18 Apparent Conductivity Pseudo Section of Dhamor, Hisua block, Nawada

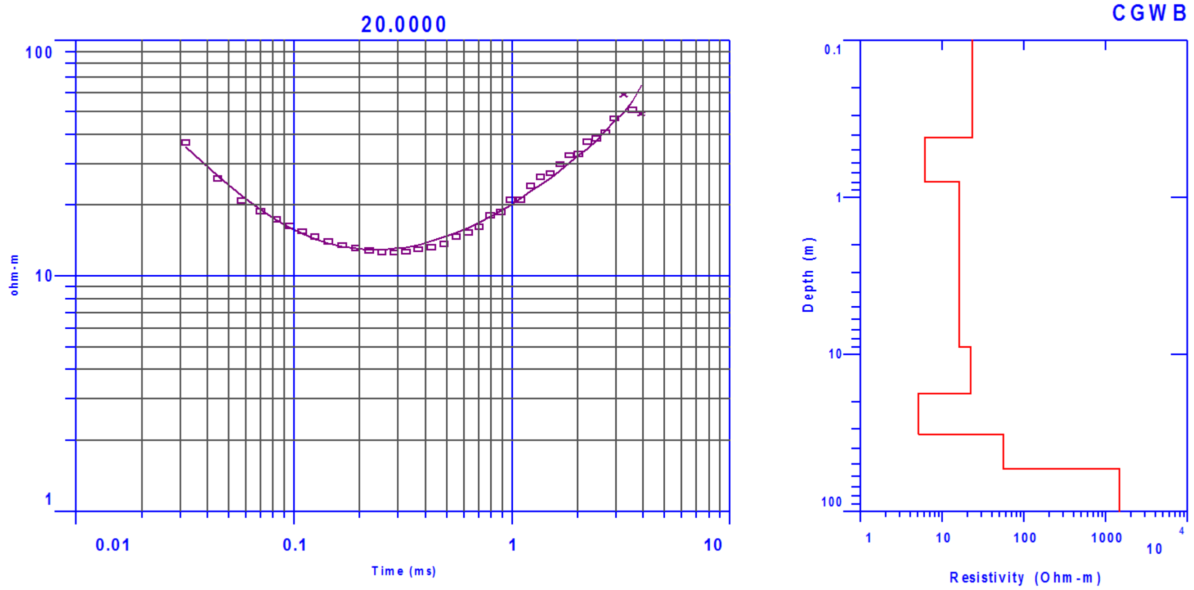


Figure 8.19: Decay curve of TEM survey and interpreted layer parameters at Dhamor, Hisua, Nawada

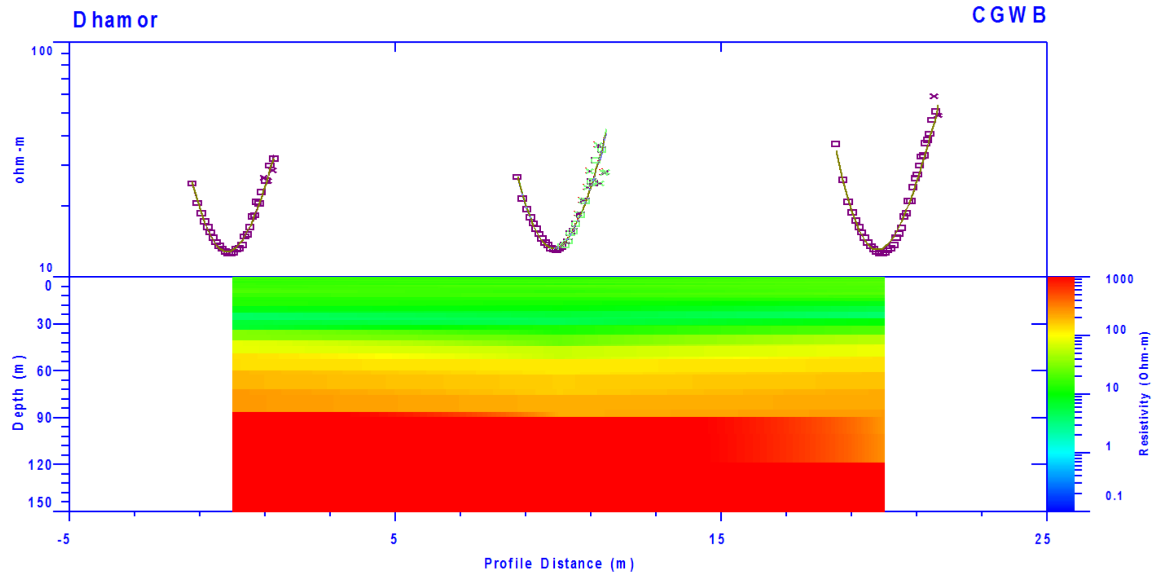


Figure 8.20: Profile showing Interpreted resistivity model at Dhamor, Hisua, Nawada

Fig 8.18 - Fig 8.20 depicts presence of massive formation at a depth of 60.0mbgl. The bedrock is overlaid by geoelectrical layers with subsequently increasing resistivity which indicates that grain size increases with depth.

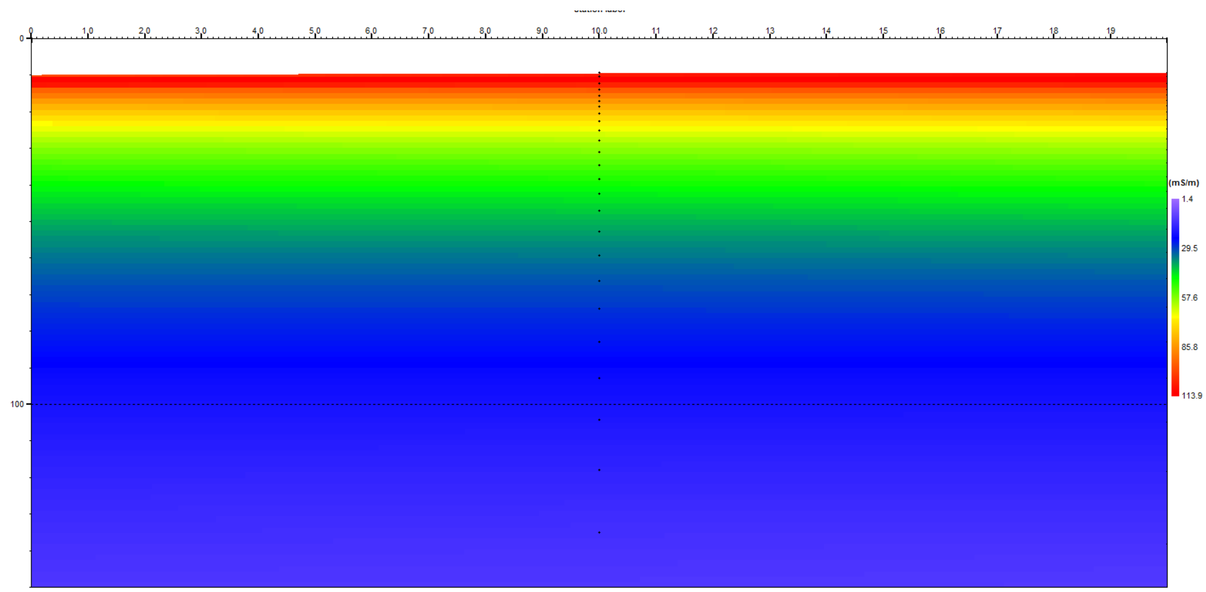


Figure 8.21: Apparent Conductivity Pseudo Section of Murheita, Narhat block, Nawada

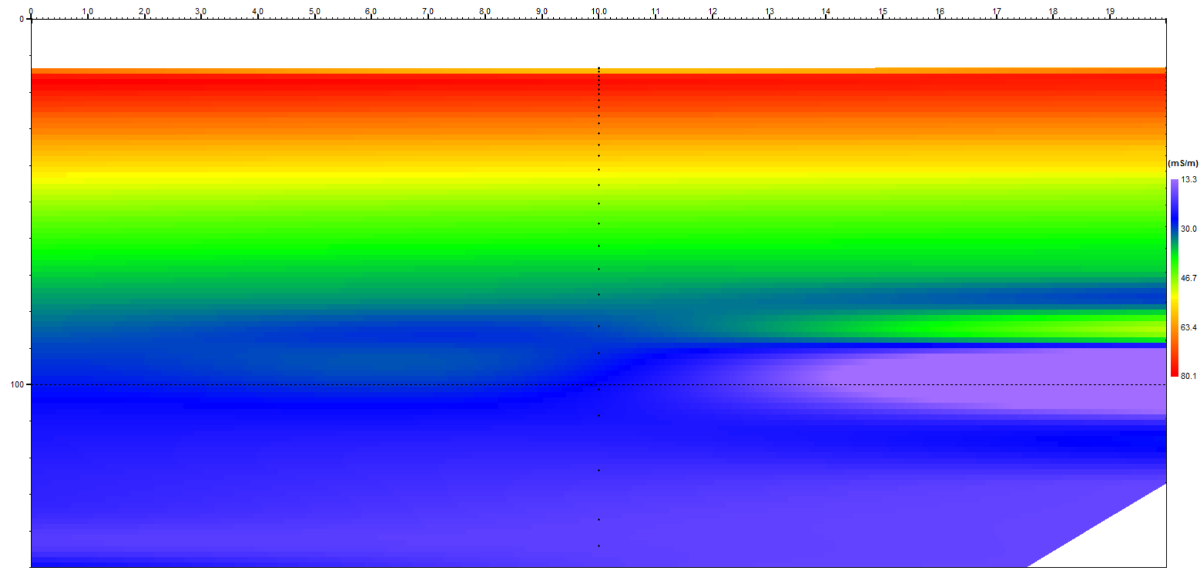


Figure 8.22: Apparent Conductivity Pseudo Section of Punaul, Narhat block, Nawada

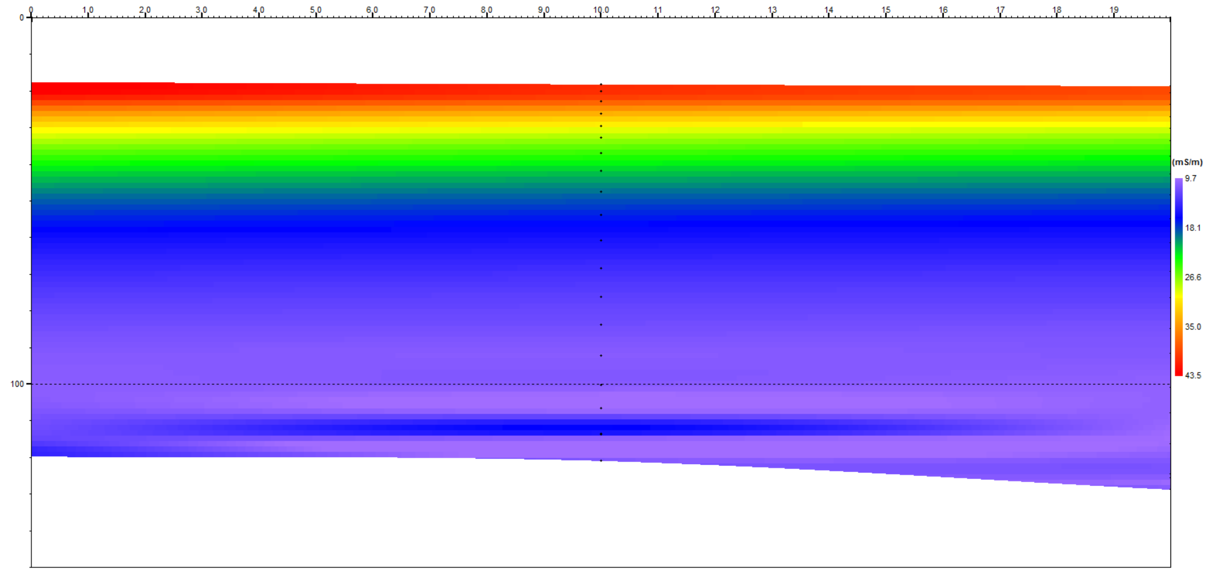


Figure 8.23: Apparent Conductivity Pseudo Section of Bodhibigaha, Meskaur block, Nawada

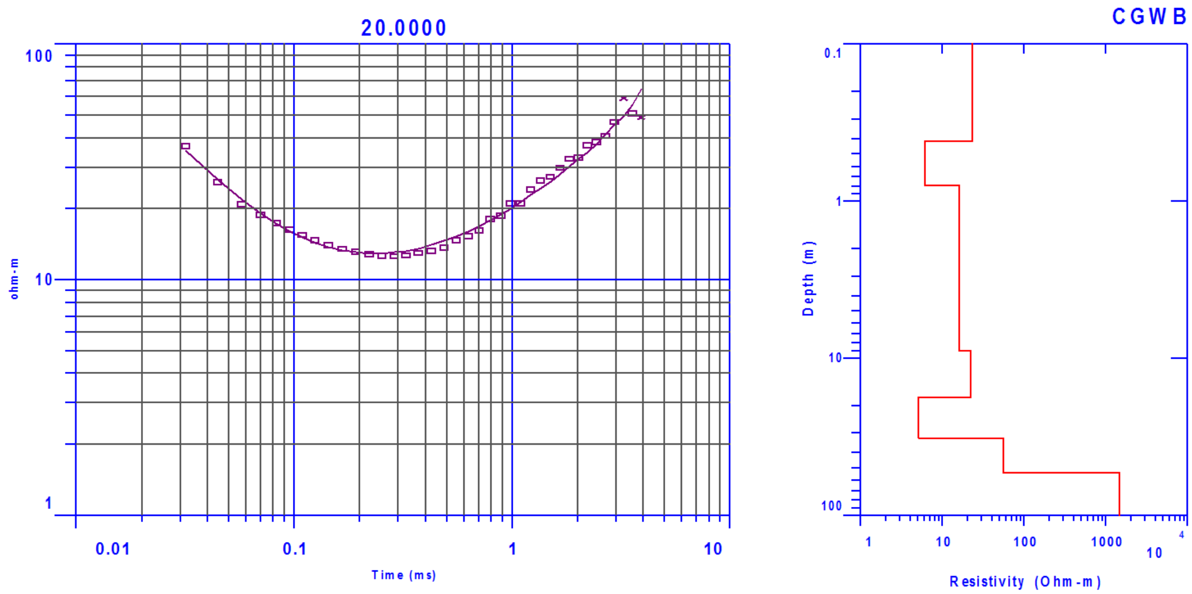


Figure 8.24: Decay curve of TEM survey and interpreted layer parameters at Bodhibigha, Meskaur, Nawada

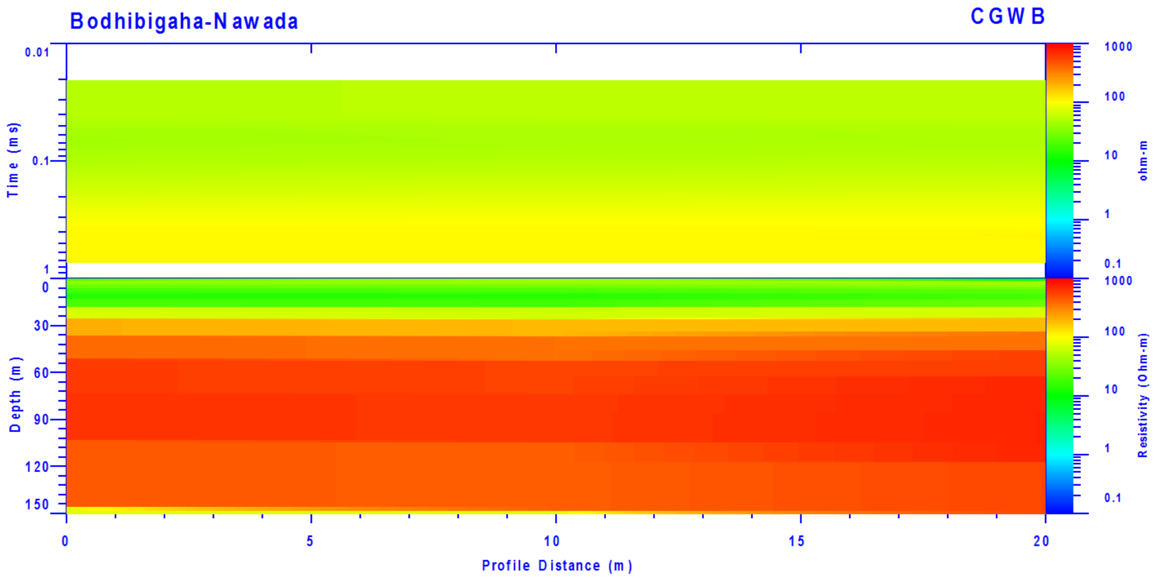


Figure 8.25: Profile showing Interpreted resistivity model at Bodhibigha, Meskaur, Nawada

8.3.2.3 VES-TEM-BH correlation: -

An EW was constructed in Narhat block uptothe depth of 200.0 mbgl. 01 VES and 03 TEM soundings were carried out at Punaul of Narhat block which is situated around 1.25 km SE from the borewell. Therefore, an attempt was made to correlate the interpreted layer parameters with local lithology.

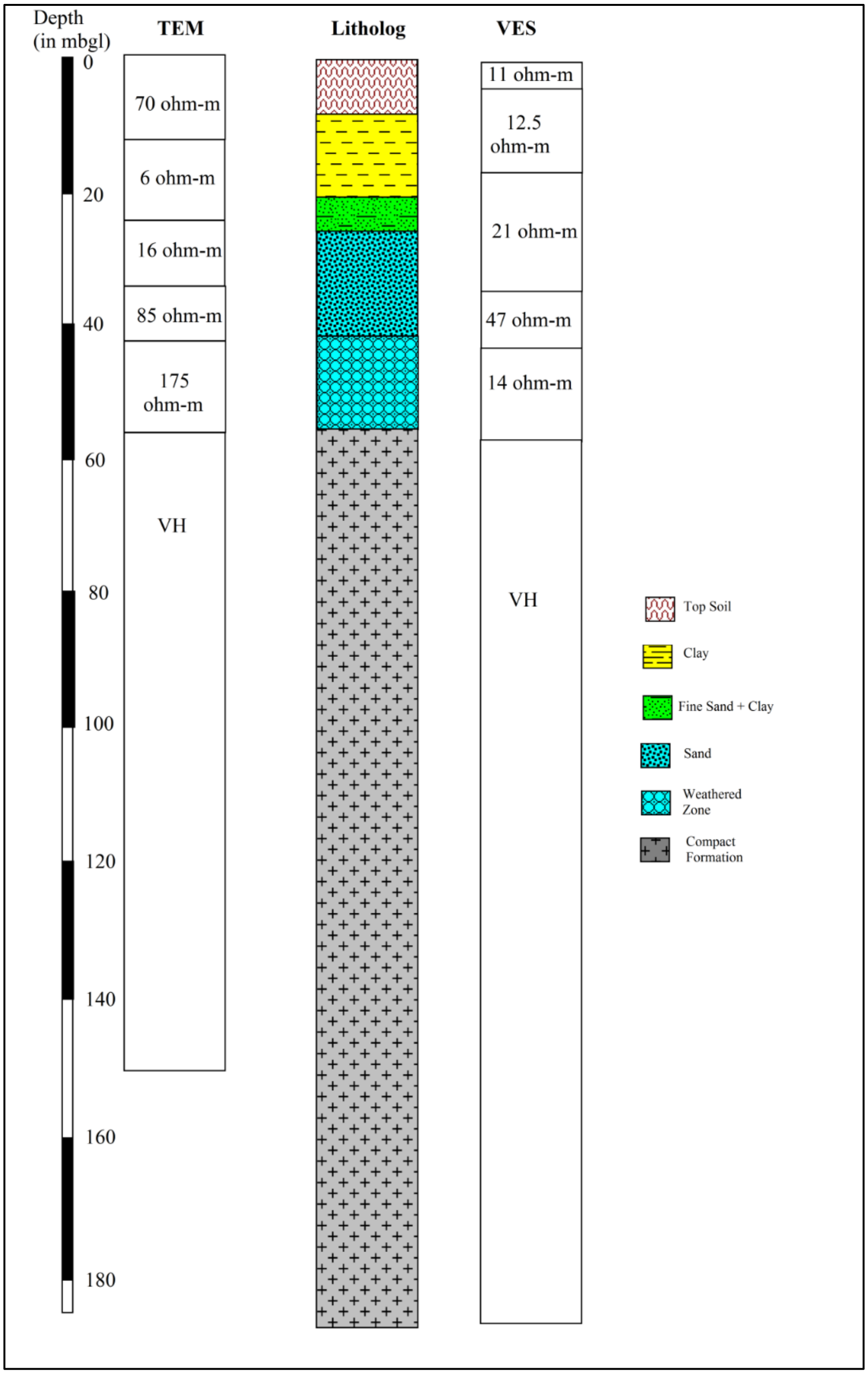


Figure 8.26: Diagram depicting correlation of VES, TEM and Borehole at Narhat block, Nawada District.

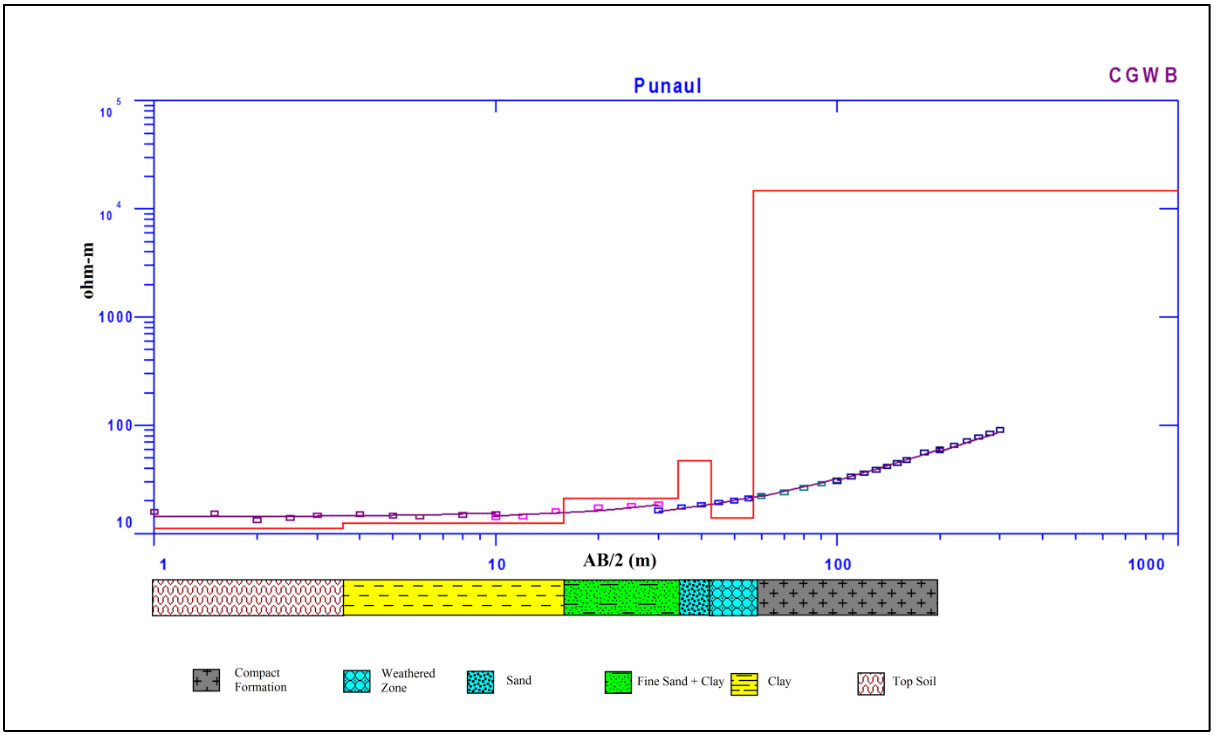


Figure 8.27: Interpreted VES data at Punaul, Nawadaalong with inferred lithology.

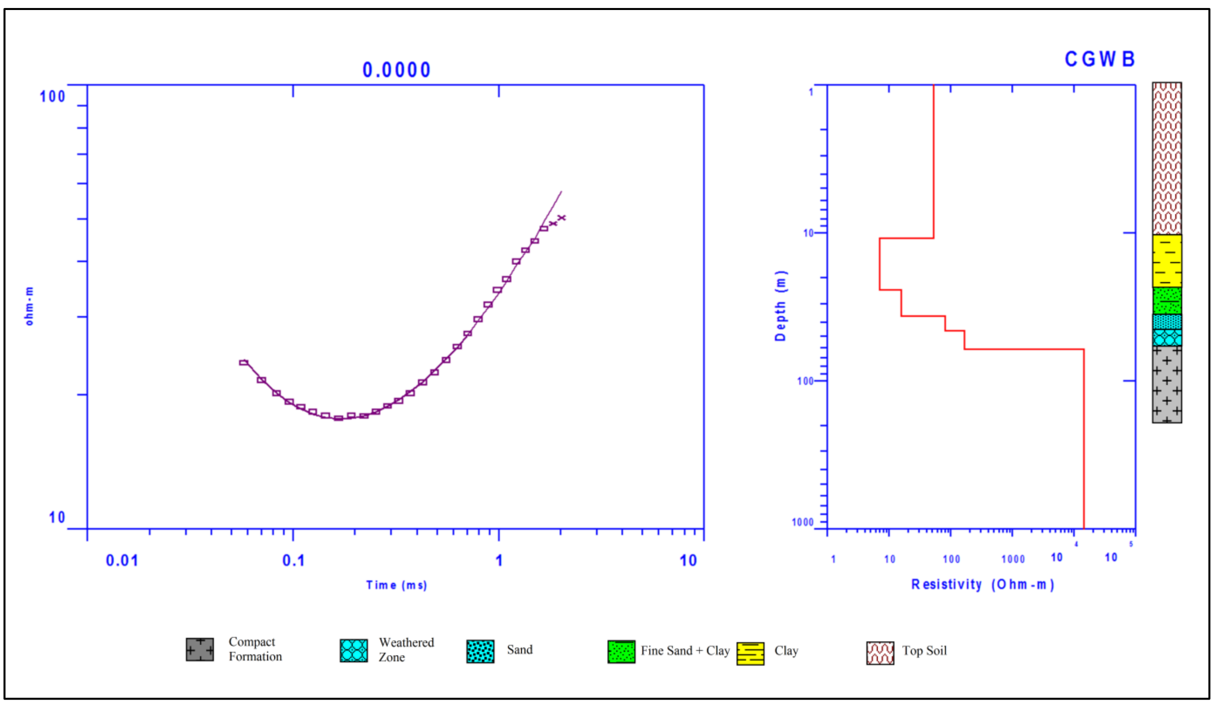


Figure 8.28: Interpreted TEM data at Punaul, Nawada along with inferred lithology.

Figure 8.26 shows the correlation diagram of EW, VES and TEM. The compact formation was encountered at a depth of 56.4 mbgl in the BW. The overburden contains top soil from 0 to 7.6

mbgl, a clay layer of thickness 12.2 m from 7.6mbgl to 19.8 mbgl, a layer comprising of sandy clay from 19.8 mbgl to 25.9 mbgl, followed by a layer having mixture of sand and gravel of thickness 15.3 m which is underlined by the weathered zone from 41.2 mbgl to 56.4 mbgl. Interpretation of TEM soundings at Punaul gave 6 geoelectric layers having resistivities 70 Ω-m, 6 Ω-m, 16 Ω-m, 85 Ω-m, 175 Ω-m, VH (Very high) and thicknesses 12.8 m, 11.2 m, 9.6 m, 8.7 m and 13.9 mrespectively. Similarly, interpretation of VES curve gave 6 geoelectric layers with resistivities 11 Ω-m, 12.5 Ω-m, 21 Ω-m, 47 Ω-m, 14 Ω-m, VH (Very High) and thicknesses 3.6 m, 12.2 m, 18.4 m, 8.6 m, 14.0 m respectively.

Based on the above correlation, following standardization of resistivity ranges for different lithounits have been fixed for the study area.

Table 8.2 Correlation of Resistivity range with lithology

Resistivity Range (ohm-m)	Inferred Lithology
5-15	Clay
15-28	Fine Sand + Clay
28-150	Sand
150-400	Weathered Rock
>400	Compact Formation

8.3.2.4 Geoelectrical Cross Section: -

Based on the inferred lithology, two geoelectrical cross sections were prepared to get a regional picture of aquifer disposition in the study area. The section A-A' extends from Dhamour in Hisua block to Bhitiya in Sirdala block traversing NE-SW direction. The section B-B' extends from Dharampur of Hisua block to Bhitiya of Sirdala block traversing NW-SE direction.

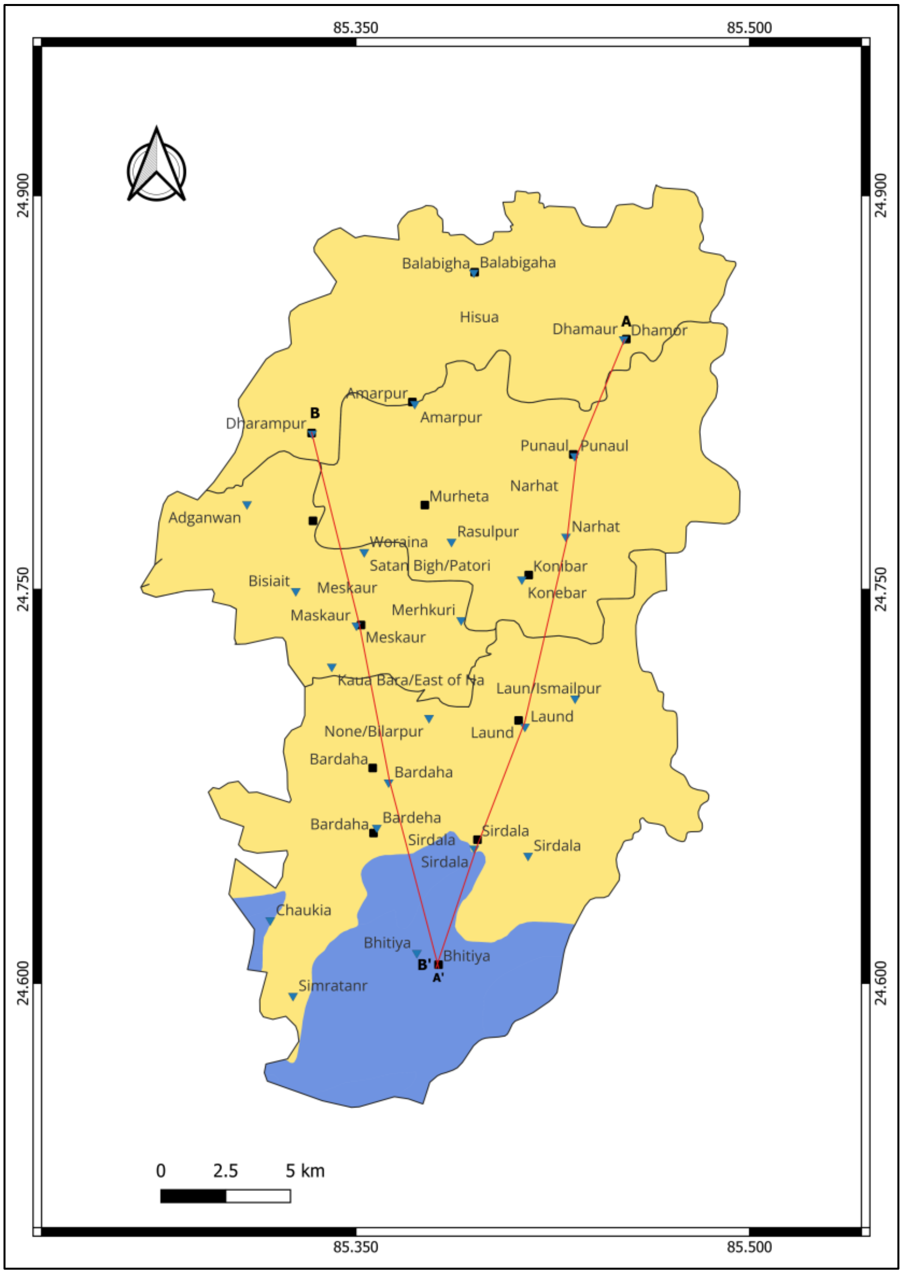


Figure 8.29: Map showing profiles AA' and BB'

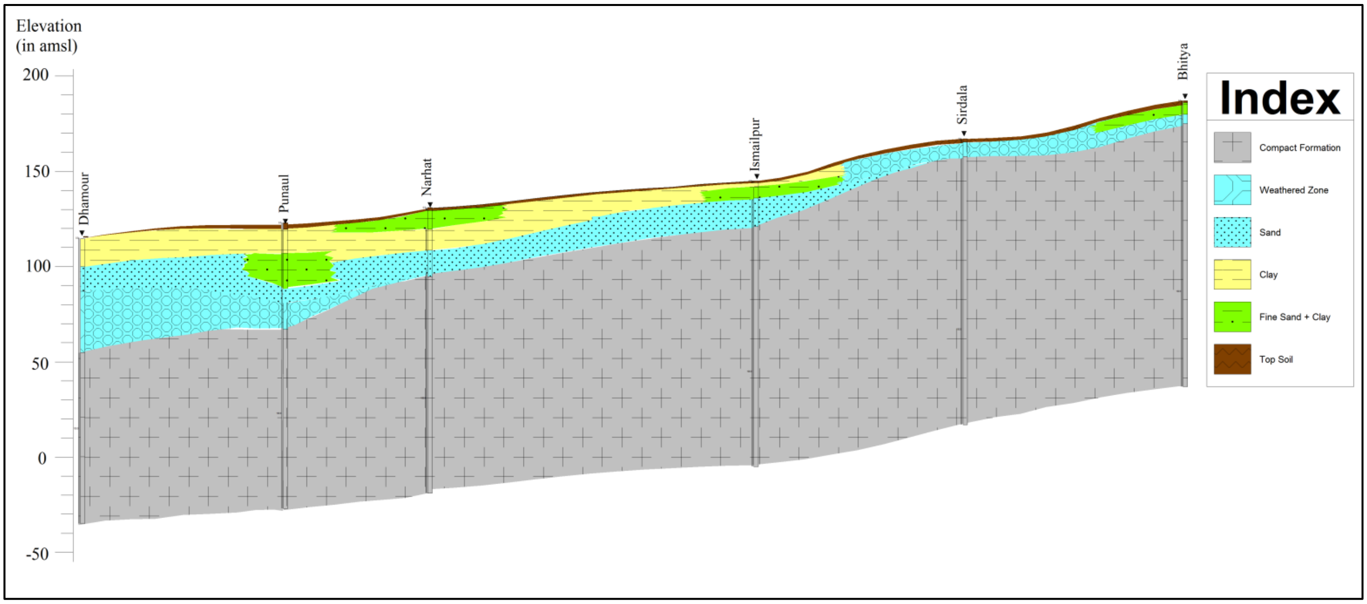


Figure 8.30: Geoelectrical Section A-A'

The section A-A' depicts dipping of bedrock towards southern side of the study area as one traverse from northern part. The maximum depth to bed rock has been inferred to be 60.0mbgl at Dhamour whereas the shallowest depth was inferred to be 11.3mbgl at Bhitiya. A clay layer of varying thickness has been inferred at Dhamour, Punaul, Narhat and Ismailpurarea, however, it could not be inferred in Sirdala and Bhitiya area. The prominent sand zone along with the weathered zone in all the locations may act as shallow aquifer.

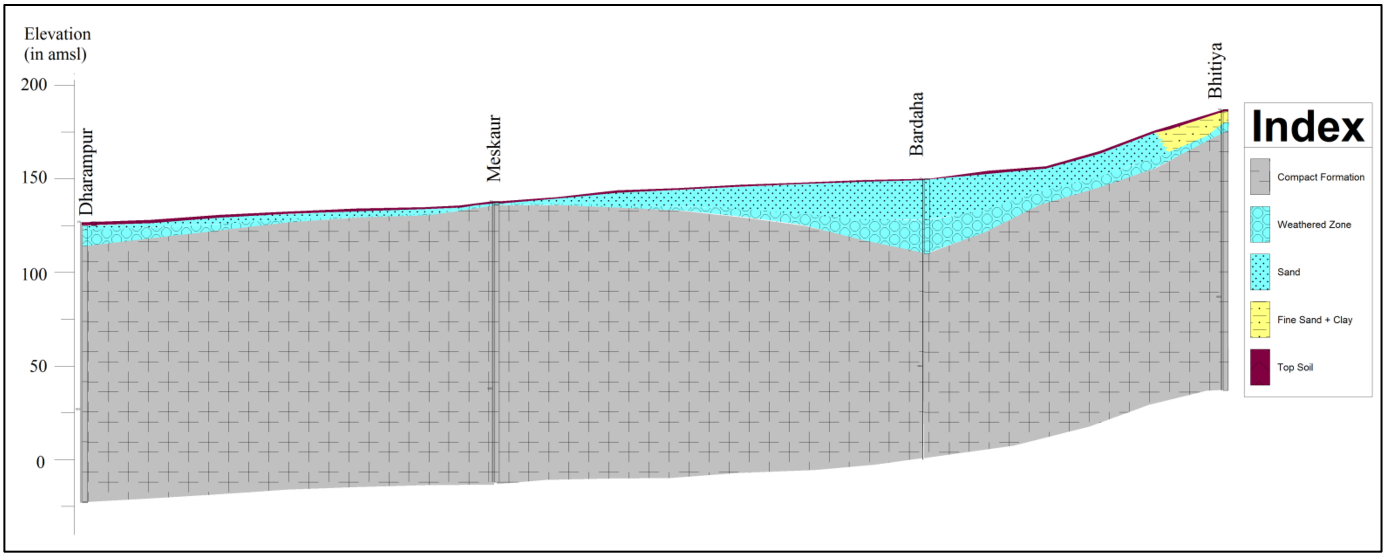


Figure 8.31: Geoelectrical Section B-B'

8.3.2.5 Depth to Bedrock (Based on Geophysical Investigation): -

Based on the results obtained from Geophysical studies, an attempt was made to prepare the depth to bedrock map of the study area (Fig 8.32).

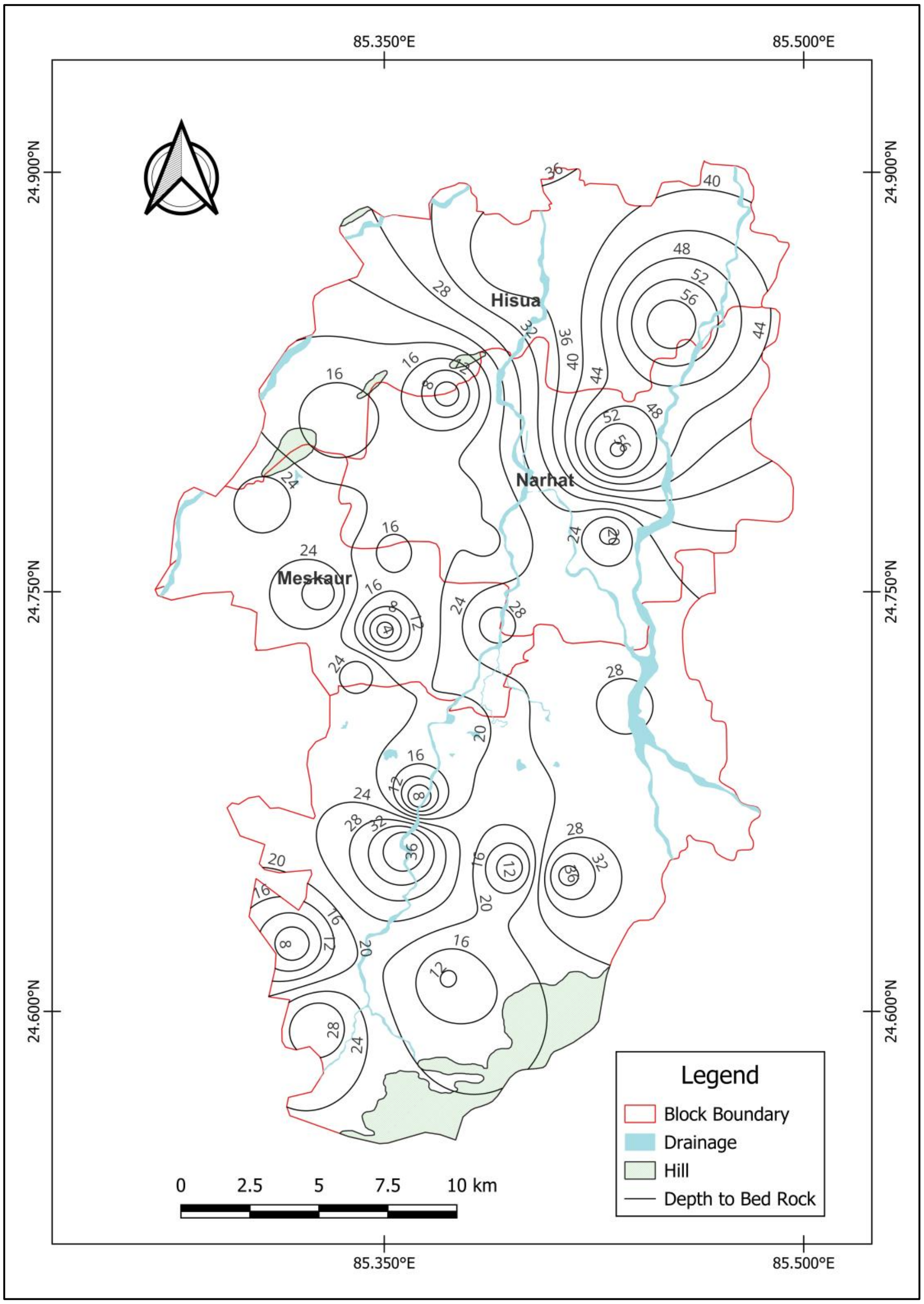


Figure 8.32 Depth to Bedrock map of parts of Nawada District, Bihar

From the figure, it can be seen that the north eastern part of the study area has comparatively thicker alluvium capping. The depth to bedrock is shallower towards the Western and South-Western part of the district. The maximum value of depth to bedrock has been found to be 60.0 mbgl at Dhamor whereas the minimum value has been inferred to be 2.0 mbgl at Meskaur.

Table 8.3 Depth to bedrock (Based on Geophysical Investigation)

S. No	Location	Block	Longitude	Latitude	Depth to Bed Rock (m)
1	Balabigha	Hisua	85.39525	24.87081	40
2	Bardaha	Sirdala	85.35672	24.65719	40
3	Bodhibigha	Meskaur	85.33364	24.77611	23
4	Dhamor	Hisua	85.45306	24.84533	57
5	Dharampur	Hisua	85.33314	24.80956	12
6	Konibar	Narhat	85.41586	24.75547	25
7	Laund	Sirdala	85.412	24.70008	25
8	Punaul	Narhat	85.43283	24.80142	56
9	Murheta	Narhat	85.37628	24.78213	18
10	Bhitiya	Sirdala	85.3815	24.60706	15
11	Balabigaha	Hisua	85.39494	24.87069	37
12	Bardaha 2	Sirdala	85.36248	24.6765	4
13	Bardaha	Sirdala	85.35796	24.65922	40
14	Bhitiya	Sirdala	85.37323	24.61154	11.3
15	Dhamour	Hisua	85.45203	24.84531	60
16	Dharampur	Hisua	85.33336	24.80939	13
17	Konibar	Narhat	85.41325	24.75379	24
18	Laund	Sirdala	85.41442	24.69773	24
19	Punaul	Narhat	85.43331	24.80083	57
20	Sirdala	Sirdala	85.39512	24.65131	9.2
21	Meskaur	Maskaur	85.3502	24.73625	2
22	Amarpur	Hishua	85.37242	24.82067	6
23	Satan Bigh/Patori	Meskaur	85.35317	24.76423	19.2
24	Woraina	Meskaur	85.35317	24.76423	10.3
25	Merhkuri	Meskaur	85.39012	24.73829	30.7
26	Kaua Bara/East of Na	Meskaur	85.34081	24.72058	26.1
27	Bisiait	Meskaur	85.3271	24.74937	31
28	Adganwan	Meskaur	85.30851	24.78246	26.17
29	Laun/Ismailpur	Sirdala	85.43352	24.70847	30.6
30	None/Bilarpur	Sirdala	85.37786	24.70105	16.5

S. No	Location	Block	Longitude	Latitude	Depth to Bed Rock (m)
31	Chaukia	Sirdala	85.31737	24.62399	5.4
32	Sirdala	Sirdala	85.41561	24.64856	37.4
33	Simratanr	Sirdala	85.32604	24.59518	31.5
34	Majhila	Sirdala	85.50852	24.63236	29
35	Rasulpur	Narhat	85.38643	24.76816	18.9
36	Narhat	Narhat	85.43004	24.7701	19

Table 8.4 Aquifer Resistivity Characteristics of parts of Nawada district, Bihar

Location	Aquifer Resistivity Characteristics			Qualitative Indicators for Possible Presence of Thin Fractured Zone Aquifer (in mbgl)
	Weathered Zone or Alluvial Capping			
	Resistivity (ohm-m)	Depth Range (m)	Lithological Predominance	
Satan BighPatori	29	10-19	Sand	50, 75
Woraina	30	1-10	Sand	50
Merhkuri	111	9-31	Sand or Weathered Zone	80, 140
Kaua Bara	44-130	2-26	Sand and Weathered Zone	35, 110
Bisiait	52	3-31	Sand	90, 100-120
Adganwan	39	16-26	Sand & Clay	40, 65
Rasulpur	15	6-19	Sand & Clay	55, 75, 90, 130
Narhat	57	22-37	Clay & Sand	65, 100
Majhila	36	2-9	Sand	80, 110
	13	9-29	Clay or highly weathered	
Amawan	39	16-26	Sand	80, 100, 130
LaunIsmailpur	48	25-31	Sand	75, 100-110
None Bilalpur	25	0.4-9	Sand & Clay	60
	64	9-11	Sand	
	11	11-16	Clay or highly weathered	
Bardaha	-	-		100

Chapter 9
Aquifer Wise Ground Water Levels

9.1 Objectives

The main objective of the present chapter is to discuss aquifer wise depth to water levels, aquifer-wise contours of water table/ piezometric surface elevations and flow lines, water level trends in the study area and to delineate areas showing long term water level changes.

9.2 Methodology

The depth to water level were measured during pre-monsoon (May 2023) and post-monsoon (November 2023) from dug wells, shallow bore wells and deeper bore wells. The aquifer wise depth to water level maps and contour maps were prepared using spatial analyst tool and interpolation (IDW) method in ArcGIS platform. The long term water level trend (Hydrographs) are prepared using the historical water level data and the data collected during present study.

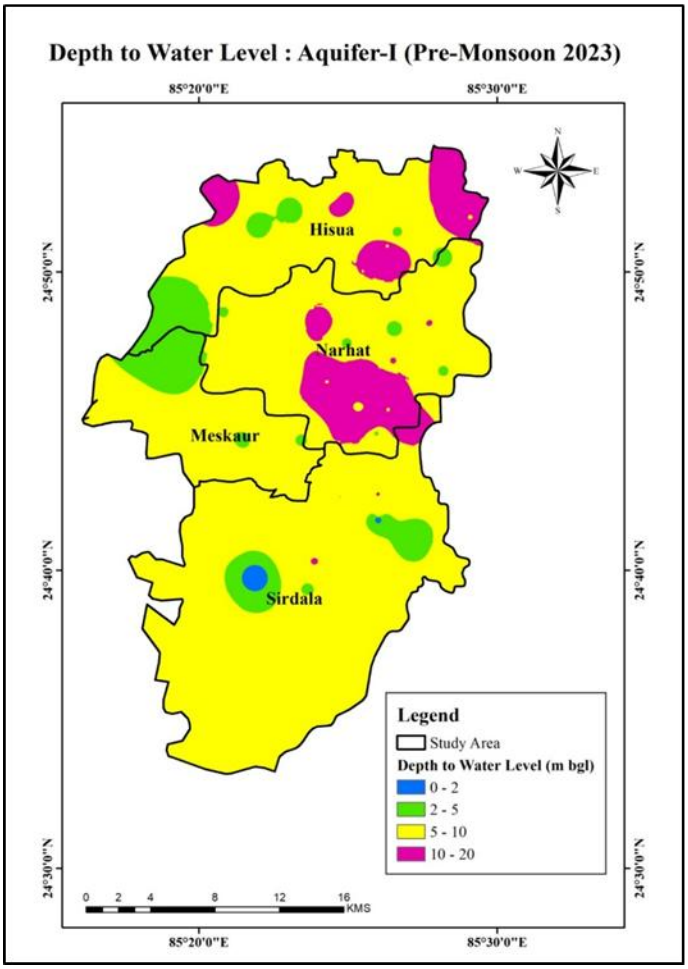
9.3 Results and Discussions

9.3.1 Aquifer-I (Alluvium Aquifer)

A total of 87 monitoring stations were established during the study to measure the depth to water level, which includes 58 Dug wells (DW) and 29 Shallow Tube Wells (STW). Water level measurements were taken during pre-monsoon (May 2023) and post- monsoon (November 2023)to study the changes in water level in this aquifer.

9.3.1.1 Depth to Water level of Aquifer-I

The pre-monsoon water level ranges from 2.75 m bgl in Karamchak of Hisua Block to 18.05 mbgl in Chandra Shekhar Nagar of Hisua Block. During pre-monsoon, the water level in majority of the area ranges from 5 to 10 m bgl (Figure 9.1). The post-monsoon water level ranges from as shallow as 0.9 m bgl in Karamchak of Hisua Block to as deep as 20.15 m bgl in Khanwan of Narhat Block, in the alluvium aquifer. The water level in North-Western and South-Eastern parts of the study area is within the range of 2 to 5 m bgl, while the central and northern part of the area are having water level within the range of 5 to 10 mbgl (Figure 9.1).



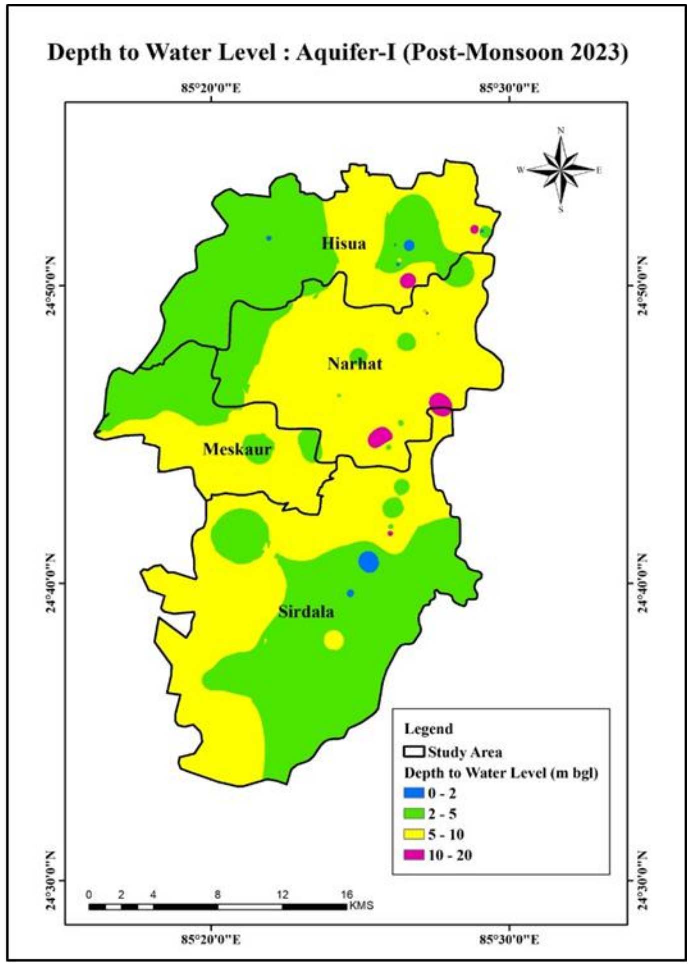


Figure 9.1: Depth to water level map of Aquifer I (Pre-monsoon and Post-monsoon)

9.3.1.2 Seasonal Ground Water Fluctuation

The shallow aquifer seasonal ground water level fluctuation (between pre-monsoon and post-monsoon season) ranges between maximum fall of 6.25 m to maximum rise of 15.45 m. 77% of the wells show rise in groundwater level during post-monsoon and majority of wells show rise in the range of 0-2 m.

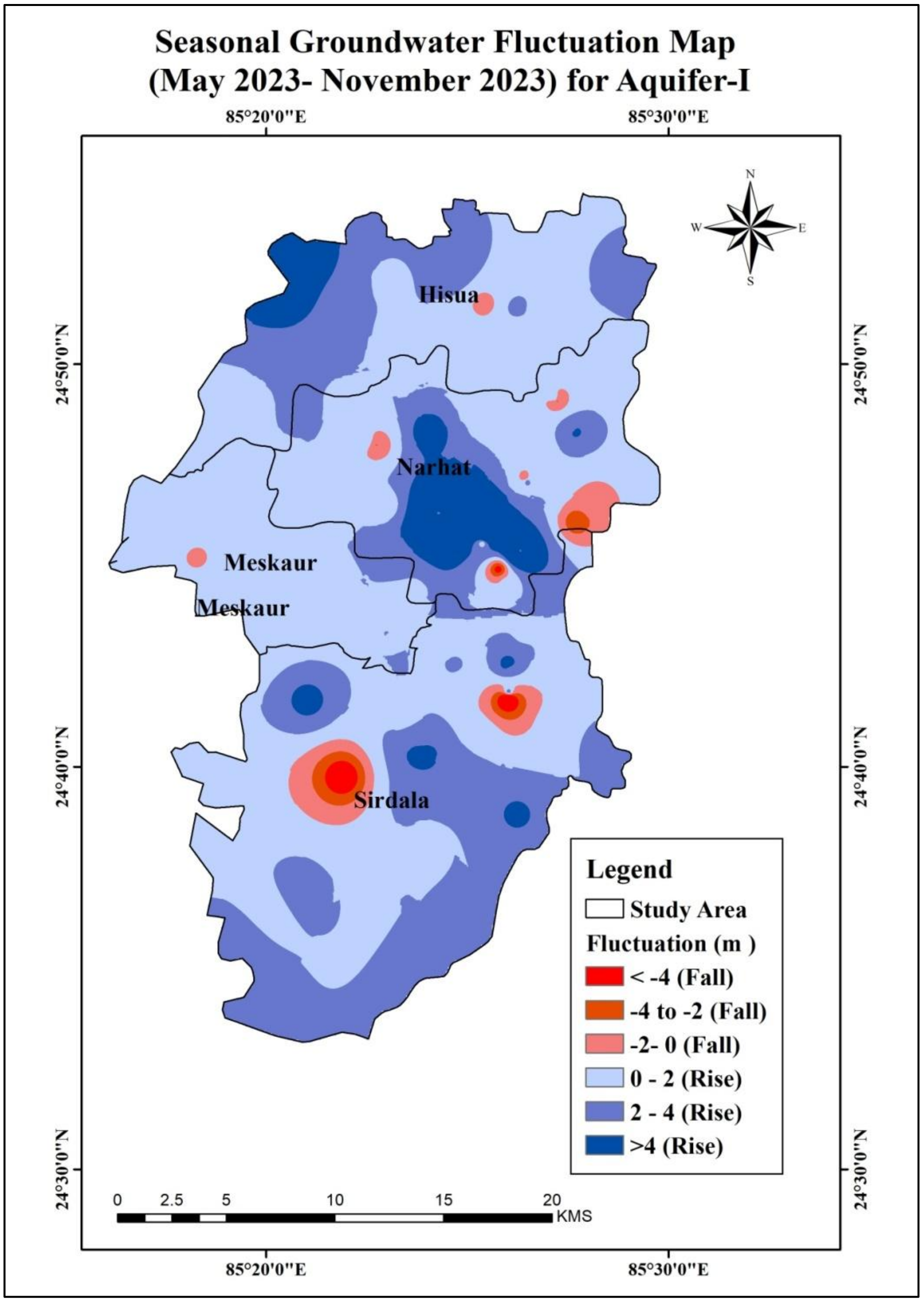


Figure 9.2: Seasonal Water level fluctuation map (May 2023 to November 2023) of Aquifer I

9.3.1.3 Water Table and Flow Direction in Aquifer-I

The water table contour maps of Aquifer-I (shallow aquifer) both during pre-monsoon and post-monsoon seasons shows a general flow direction of groundwater from southwest to north east.

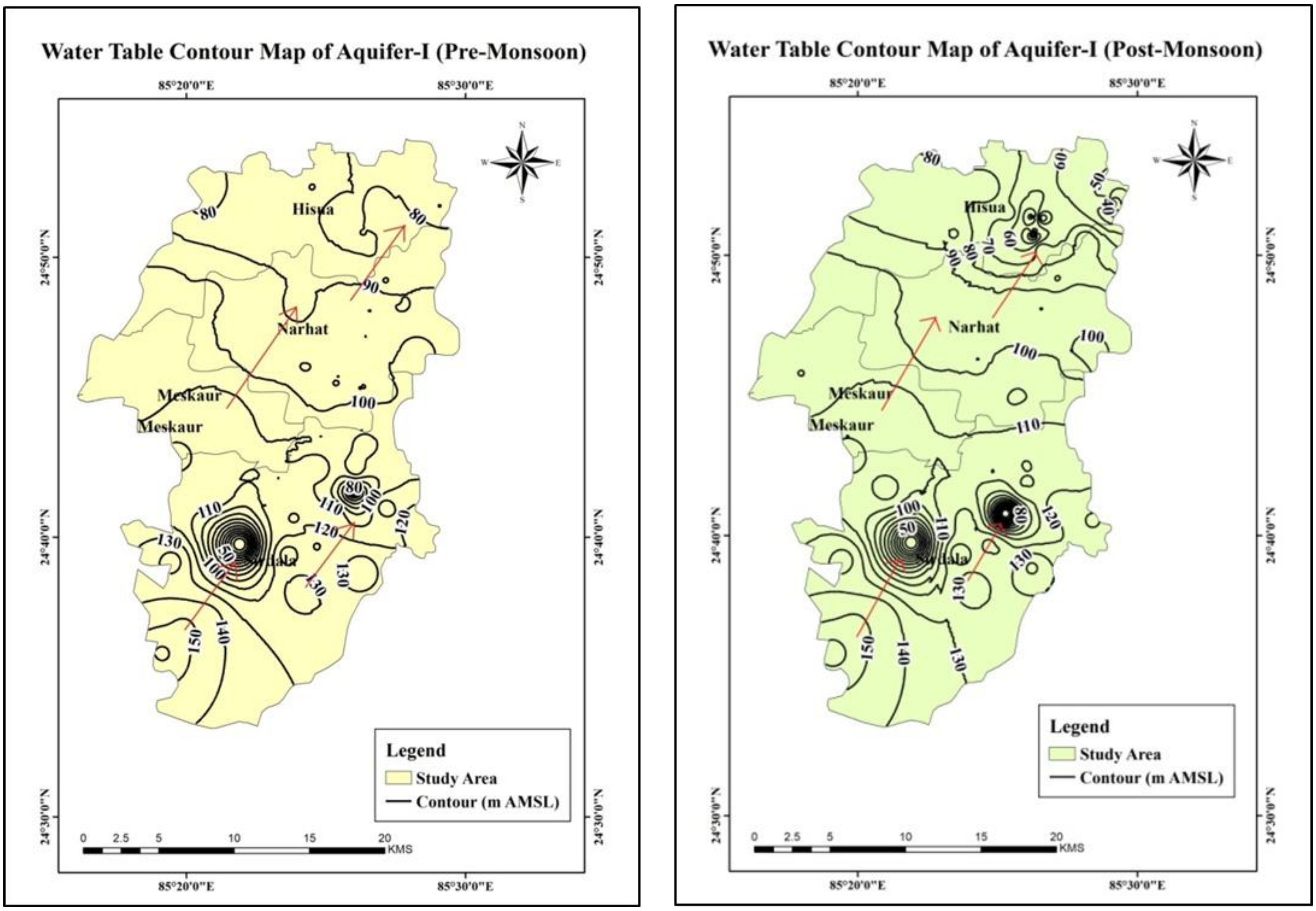


Figure 9.3: Water table contour map of Aquifer I during pre-monsoon.

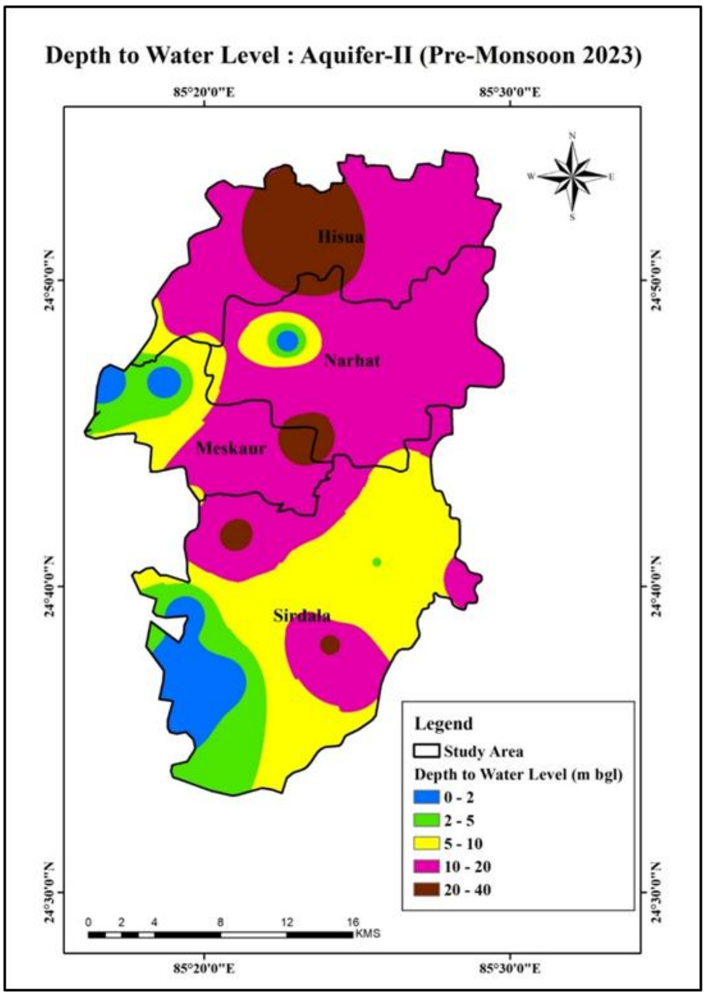
9.3.2 Aquifer-II (Fractured Aquifer)

A total of 31 wells (Deeper Bore wells, mainly wells constructed by PHED under HarGharNalYojna) were established and monitored to measure the variations in water level of Aquifer-II.To study the changes in water level in the deeper (fractured) aquifer, water-level measurements were taken during pre-monsoon (May 2023) and post- monsoon (November 2023) season.

9.3.2.1 Depth to Water level of Aquifer-II

The pre-monsoon water level ranges from 4.8 m bgl in Bhiwalpur of Sirdala Block to 36.5 mbgl in Kaithir of Hisua Block. The water level in majority of the area ranges from 10 to 20 m bgl and > 20 mbgl during pre-monsoon (Figure 9.4).

The post-monsoon water level ranges from as shallow as 2 m bgl in Dhiraundh of Sirdala Block to as deep as 31.3 m bgl in Kaithir of Hisua Block. The water level in majority of the study area is within 10 mbgl during post-monsoon, mainly confined to the central and eastern parts of the study area (Figure 9.4).



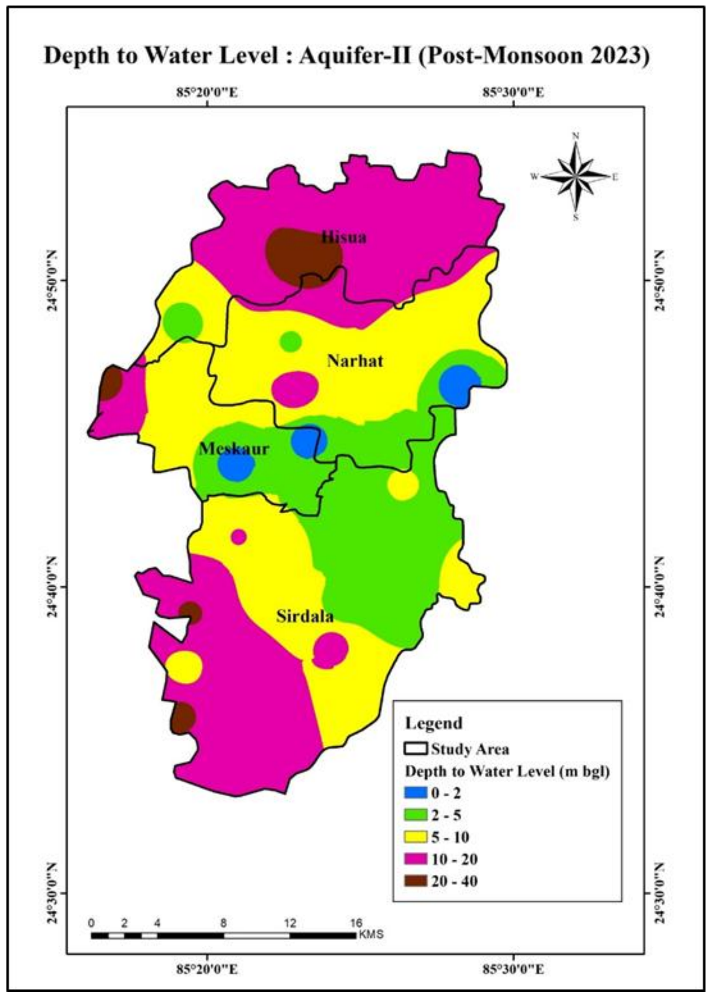


Figure 9.4: Depth to water level map of Aquifer II (Pre-monsoon &Post-monsoon 2023)

9.3.2.2 Seasonal Groundwater Fluctuation

In the deeper aquifer, seasonal ground water level fluctuation (between pre-monsoon and post-monsoon season), 100% of the wells show rise in groundwater level during post-monsoon and majority of wells show rise of more than 4 m.

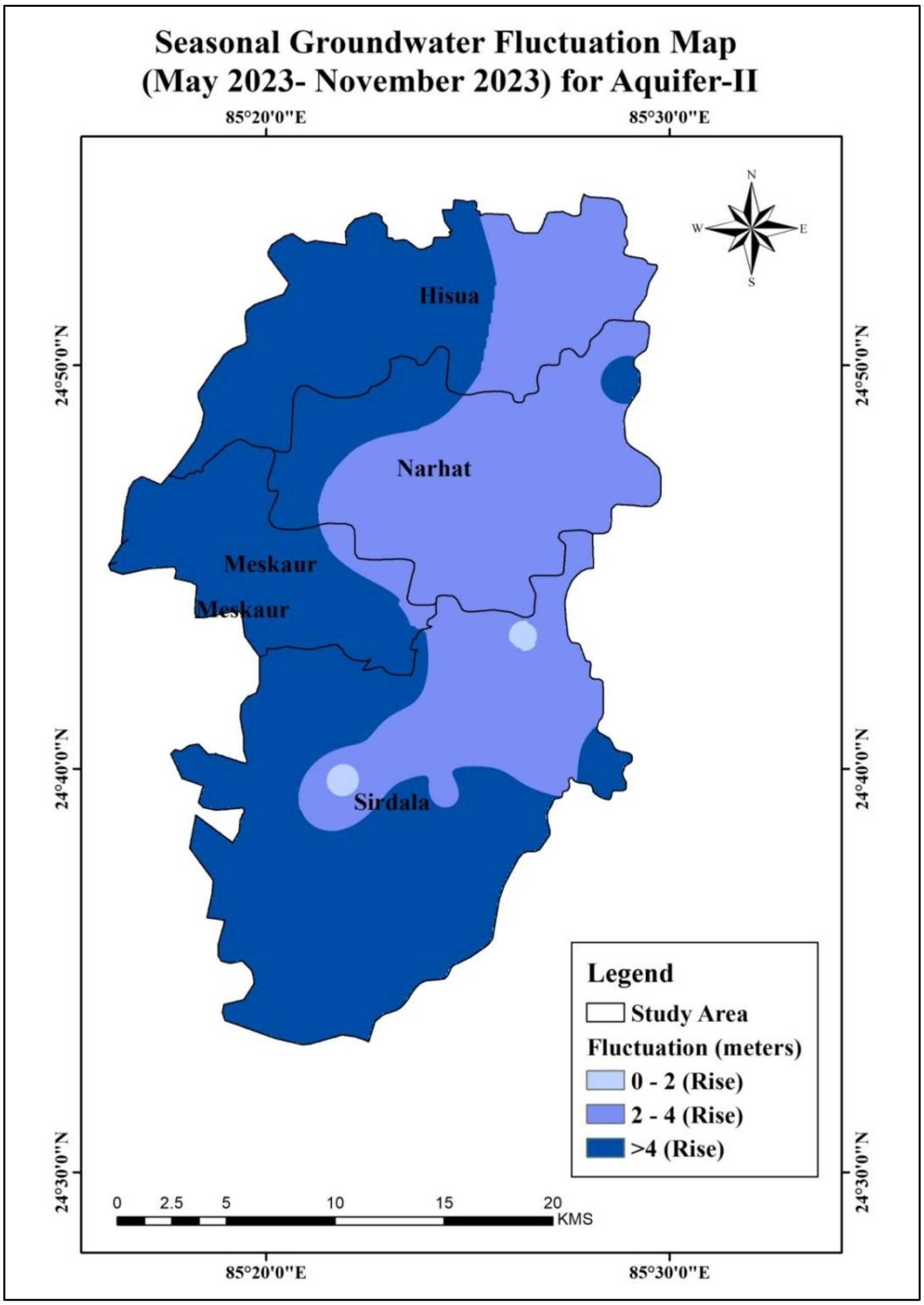
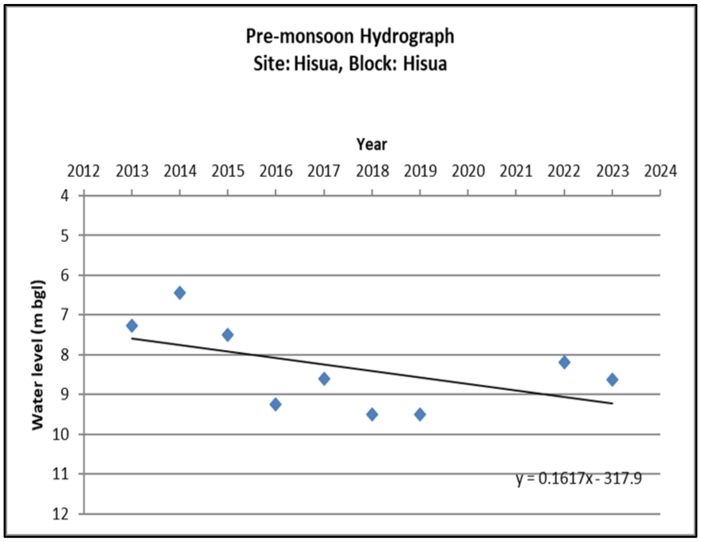


Figure 9.5: Seasonal Water level fluctuation map (May 2023 to November 2023) of Aquifer II

9.4 Hydrographs with trend

The long-term trend analysis of five NHS dugwells was conducted to observe water level behaviour across the study area. The hydrograph for Hisua indicates a falling trend, while Khanwa (Narhat block) shows a rising trend in both pre-monsoon and post-monsoon periods. Meskaur and Nawabganj (Sirdala block) hydrographs display a falling trend during the pre-monsoon and a rising trend in the post-monsoon. Conversely, Tungi (Hisua block) exhibits a rising trend in the pre-monsoon and a falling trend in the post-monsoon.

The rate of decline ranges from 0.09 m/year to 0.16 m/year in the pre-monsoon and from 0.15 m/year to 0.21 m/year in the post-monsoon. The rate of rise varies from 0.02 m/year to 0.34 m/year in the pre-monsoon and from 0.02 m/year to 0.09 m/year in the post-monsoon.



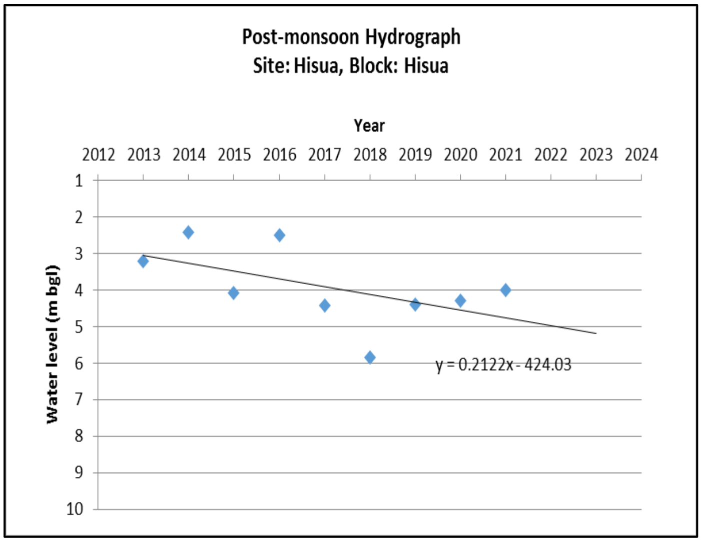


Figure 9.6: Hydrograph of Hisua (Block-Hisua)

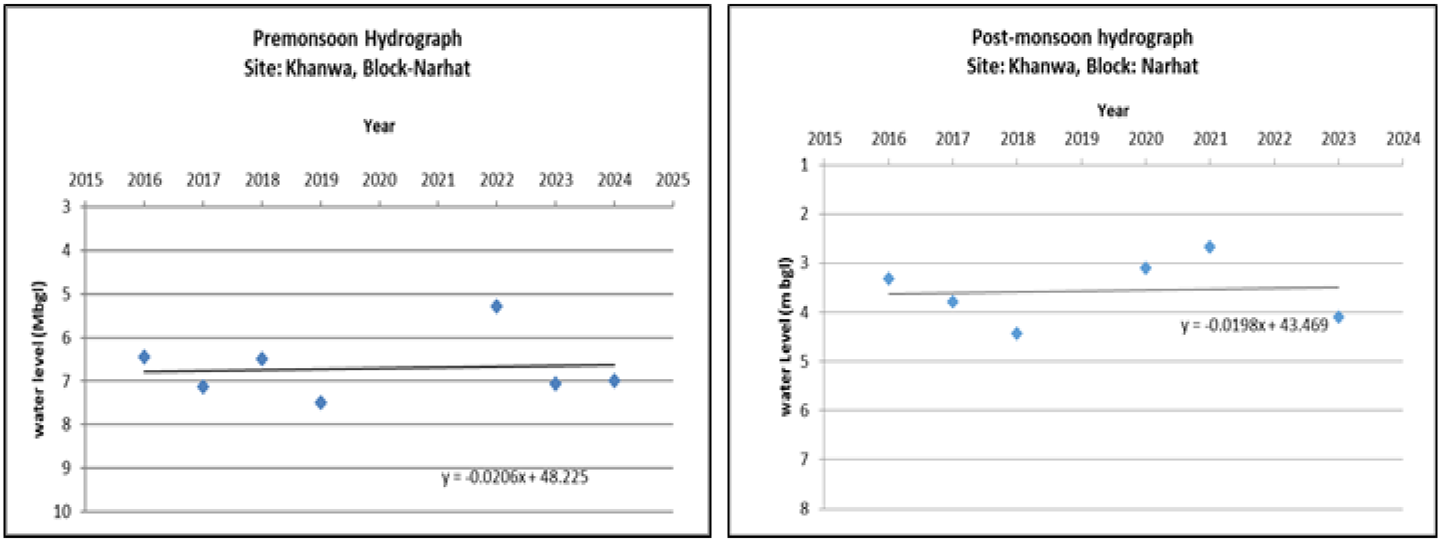


Figure 9.7: Hydrograph of Khanwa (Block-Narhat)

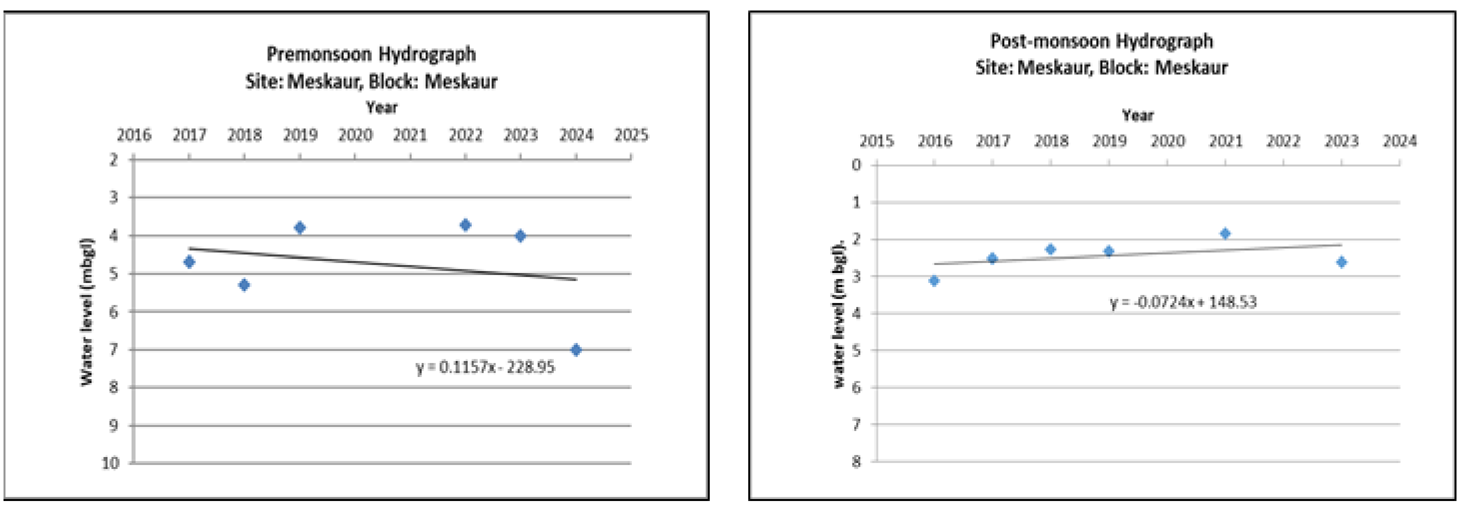
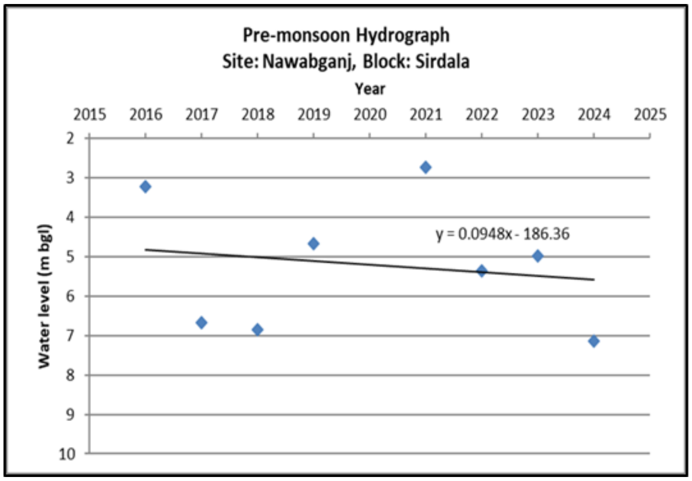


Figure 9.8: Hydrograph of Meskaur (Block-Meskaur)



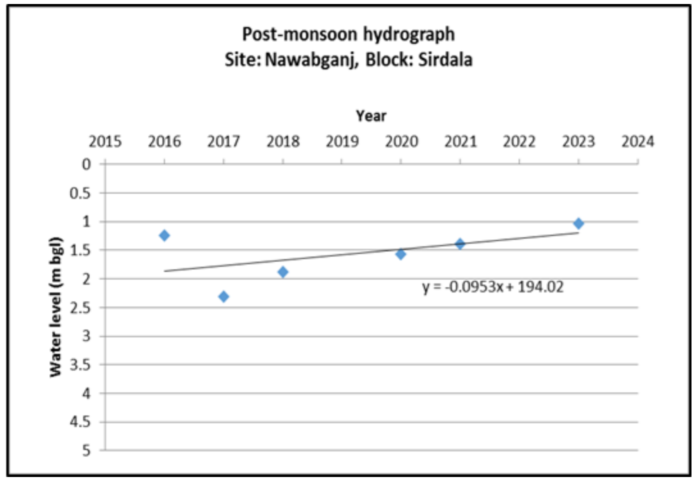
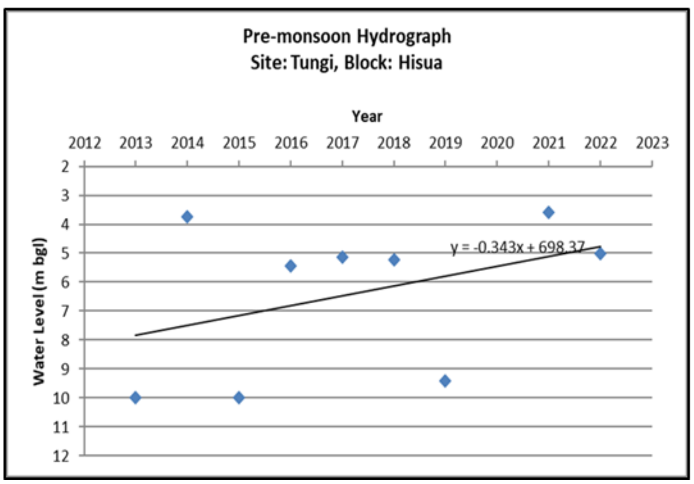


Figure 9.9: Hydrograph of Nawabganj (Block-Sirdala)



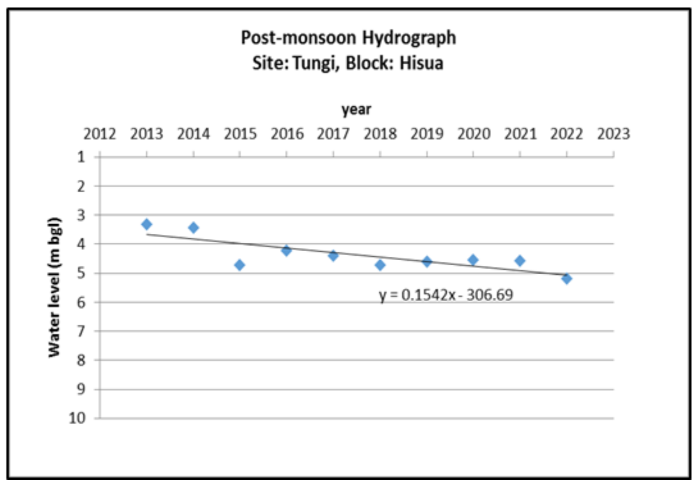


Figure 9.10: Hydrograph of Tungi (Block-Hisua)

Chapter 10
Delineation of Recharge Areas

In ground water management, delineation of recharge areas is an important step. Recharge areas are those areas, where the water recharge the ground water and replenishes the aquifers. Elevation and slope data have been used to prepare the recharge area map within the study area. Surface water flows pattern indicate the potential recharge areas. Within the boundary of the study area, it is indicated that southern part may be considered as recharge areas.

Water management practices may be used to protect the recharge areas, which include regulations, conservation practices and restoration activities.

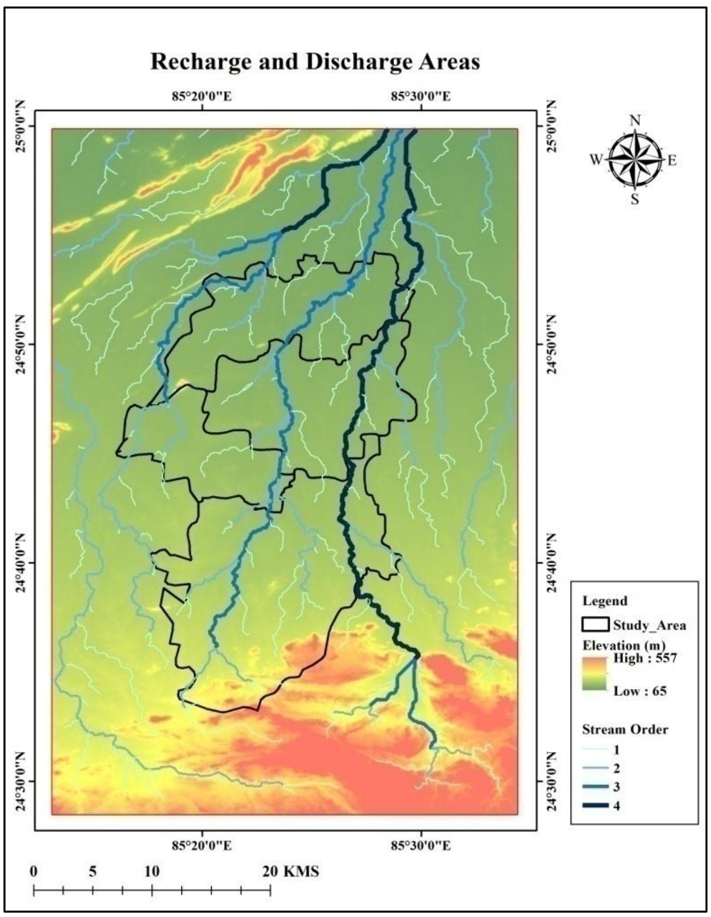


Figure 10.1: Recharge and Discharge areas

Chapter 11
Ground Water Resource Assessment (GWRA)

Ground Water Resource of the area has been estimated block wise based on for base year as on 2023. In the present report GEC 2015 methodology has been used and based on the assessment has been made using appropriate assumptions. This methodology recommends aquifer wise ground water resource assessment of both the Ground water resources components, i.e., Replenishable ground water resources or Dynamic Ground Water Resources and In-storage Resources or Static Resources. The assessment of ground water includes assessment of dynamic and in-storage ground water resources, but the development planning should mainly depend on dynamic resource only as it gets replenished every year. Such resources may not be replenishable annually and may be allowed to be extracted only during exigencies with proper recharge planning in the succeeding excess rainfall years.

The methodology for ground water resources estimation is based on the principle of water balance as given below

Inflow – Outflow = Change in Storage (of an aquifer)

The equation can be further elaborated as

$$\Delta S = RRF+RSTR+RC+RSWI+RGWI+RTP+RWCS \pm VF \pm LF - GE - T - E - B$$

Where, ΔS – Change is storage, RRF – Rainfall recharge, RSTR- Recharge from stream channels RC – Recharge from canals, RSWI – Recharge from surface water irrigation RGWI- Recharge from ground water irrigation, RTP- Recharge from Tanks & Ponds RWCS – Recharge from water conservation structures, VF – Vertical flow across the aquifer system, LF- Lateral flow along the aquifer system (through flow), GE-Ground Water Extraction, T- Transpiration, E- Evaporation, B-Baseflow.

The dynamic Ground Water Resources has been assessed by CGWB, MER, Patna in association with Minor Water Resources Department, Government of Bihar based on GEC, Methodology 2015.

The table provides an overview of groundwater statistics for four blocks, including total annual groundwater recharge, natural discharges, the amount of groundwater that can be extracted annually, and the annual groundwater draft for various uses (irrigation, industrial, and domestic). It also outlines the planned groundwater allocation for domestic use by 2025, the availability of groundwater for future use, the percentage of groundwater extraction, and the status categorization of each block's groundwater (Over-Exploited, Critical, Semi-Critical, or Safe).The salient features of Dynamic Ground Water Resources of the four blocks of the study area is given in table below and described in succeeding paragraphs.

Table 11.1 Ground Water Resource Estimation 2023

Block	Total Annual Ground Water (Ham) Recharge	Total Natural Discharges (Ham)	Annual Extractable Ground Water Resource (Ham)	ANNUAL GROUND WATER DRAFT (Ham)				Annual GW Allocation for Domestic Use as on 2025 (Ham)	Net Ground Water Availability for future use (Ham)	Stage of Ground Water Extraction (%)	Categorization (OE/Critical/Semi critical/ Safe)
				Irrigation Use (Ham)	Industrial Use (Ham)	Domestic Use (Ham)	Total Extraction (Ham)				
Hisua	3680.66	368.07	3312.59	2447.55	0.9	419.5025	2867.95	448.43	415.71	86.57727035	Semi critical
Meskaur	1198.3	119.83	1078.47	589.95	0	292.1438	882.1	312.29	176.22	81.79179764	Semi critical
Sirdala	5254.46	525.44	4729.02	1191.24	0	432.6995	1623.94	462.54	3075.24	34.33988437	Safe
Narhat	2450.9	245.1	2205.8	1497.15	7.5	270.9118	1775.56	289.59	411.56	80.49505848	Semi critical

- **Hisua:** This block has an annual groundwater recharge of 3680.66 Ham, with 368.07 Ham being naturally discharged. The extractable groundwater resource is 3312.59 Ham, and total groundwater extraction amounts to 2867.95 Ham. The block is categorized as Semi-Critical, with a groundwater extraction rate of 86.58%.

- **Meskaur:** With an annual recharge of 1198.3 Ham and natural discharges of 119.83 Ham, the extractable resource is 1078.47 Ham. Total groundwater extraction is 882.1 Ham, and the block is classified as Semi-Critical, having an extraction rate of 81.79%.

- **Sirdala:** The block has an annual recharge of 5254.46 Ham, with natural discharges of 525.44 Ham. The extractable groundwater resource is 4729.02 Ham, and total extraction is 1623.94 Ham. This block is considered Safe, with a 34.34% groundwater extraction rate.

- **Narhat:** The block shows an annual recharge of 2450.9 Ham and natural discharges of 245.1 Ham. The extractable groundwater resource is 2205.8 Ham, with total extraction reaching 1775.56 Ham. It is classified as Semi-Critical, with an extraction rate of 80.50%.

Chapter 12
Ground Water Quality

12.1 Introduction

Groundwater is an essential factor for human survival. As claimed by the 2021 World Water Development Report (UNESCO), the global use of freshwater has increased six-fold in the past 100 years. According to this report it has been growing by about 1% per year since the1980s. With the increase of water consumption, water quality is facing severe challenges. Increasing industrialization, agricultural activities, and urban life have brought about the degradation of the surrounding environment, ultimately adversely affecting the water bodies indispensable for life.

Most often groundwater is naturally of good quality. Generally industrial and municipal wastewater is discharged into the environment without any prior treatment. The quality of drinking water in developing countries is worrying. This practice is common in the least developed countries, where sanitation and wastewater treatment facilities are extremely poor. This leads to several anthropogenic contaminants to water bodies. Geogenic contaminants range from comparatively benign elements, such as iron, to lethal substances, such as arsenic and fluoride. Virtually any activity whereby chemicals or wastes may be released to the environment, either intentionally or accidentally, has the potential to pollute ground water.

The pressure on ground water is substantial in the present study area to meet household water requirements as well as the irrigation requirements. It is therefore need of the hour to conserve the existing groundwater resources of the present study area and ensure their sustainability so that the water crisis could be dealt with better management.

12.2 Methodology

One hundred four ground water samples in pre-monsoon and one hundred eight ground water samples were collected in post-monsoon from shallow and deep wells respectively, for estimation of major ions. Fifty water samples were collected in pre-monsoon season for estimation of trace metals separately. Ground water samples were collected in high density polyethylene bottle (HDPE) which was rinsed twice with distilled water before collection of water samples. For sampling of trace metal analysis, It was ensured that nitric acid was added to each sample to bring down pH to <2. This was done to avoid adsorption and precipitation on the sample bottle wall (APHA, 2005). The coordinates of sampling points were also recorded. All the chemical parameters were estimated using standard procedure as given by American Public Health Association. The following standard methods (Table-12-1) have been adopted for the chemical analysis of different constituents in water samples. Ultrapure distilled water was used for making all standards. Class A glassware was used for all the estimations. The analytical precision of data was ensured by screening water samples having ionic charge balance beyond ±10%. The Quality control was achieved by using duplicate sub-samples and standard materials.

Table 12.1: Method used for Chemical Analysis of Ground Water Samples

Sl. No.	Constituents	Method Used
1.	pH	pH Meter
2.	EC	EC Meter
3.	Carbonate & Bi-carbonate	Titrimetric method
5.	Chloride	Mohr's method
6.	Total Hardness	EDTA Titrimetric method
7.	Calcium	-do-
8.	Magnesium	Evaluation from TH and Ca
9.	Sodium	Flame emission photometric method
10.	Potassium	-do-
11.	Nitrate	Spectrophotometer UV range
12.	Sulphate	Spectrophotometer Visible range
13.	Phosphate	Spectrophotometer Visible range
14.	**Fluoride**	Spectrophotometer Visible range
15.	Trace Metals	ICP-MS

Estimation of Fe, Mn, Zn, As, Cr, Pb, Cu and U was done by using inductively coupled plasma mass-spectroscopy at CGWB, Chemical lab of NR, Lucknow. National Institute of Standard and Technology (NIST) standard 1640a was used as a reference material for validation. "Cetripur" multi element ICP-MS reference material procured was used during calibration. Replicate analysis of this reference material produced excellent accuracy with a relative standard deviation of ≤ 3%. Accuracy of calibration curve was checked by analyzing standards after every 10 samples.

12.3 Drinking Water Evaluation

Drinking water quality varies from place to place, depending on the condition of the source water from which it is drawn and the treatment it receives. .

Table 12.2: The Indian Bureau of Standards guidelines for contaminants levels in drinking water

Indian Bureau of Standards Guidelines			
Analyte	**Requirement (Acceptable Limit)**	**Permissible Limit in Absence Of Alternative Source**	**Health effects**
pH	**6.5-8.5**	**None**	Corrosion of pipes
TDS	**500**	**2000**	Anesthetic effect
Cl(mg/L)	**250**	**1000**	Eye/nose irritation; stomach discomfort
TH (as $CaCO_3$) mg/L	**200**	**600**	Can cause scaly deposits to form in pipes and water tanks
TA (as $CaCO_3$) mg/L	**200**	**600**	No known harmfull effect
F (mg/L)	**1**	**1.5**	Bone disease (pain and tenderness of the bones); children may get mottled teeth
Fe(mg/L)	**0.1**	**No relaxation**	Anesthetic effect, promotes iron bacteria
Nitrate(mg/L)	**45**	**No relaxation**	High nitrate levels in drinking water can cause bluebaby syndrome
Sulfate(mg/L)	**200**	**400**	very high levels might cause a laxative effect

As(μg/L)	**10**	**No relaxation**	Skin damage, increased risk of cancer
U (μg/L) Mn(mg/L) Cu (mg/L) Zn (mg/L) Cr (mg/L) Pb(μg/L)	30 0.1 0.05 5 0.05 10	No relaxation 0.3 1.5 15 No relaxation No relaxation	Increased risk of cancer, kidney toxicity Neorotoxicant Anaesthetic effect It causes astringent taste Allergic dermatitis Delays in mental development

The presence of certain contaminants in our water can lead to health issues, including gastrointestinal illness, reproductive problems, and neurological disorders. Safe drinking-water, as defined by the Guidelines, does not represent any significant risk to health over a lifetime of consumption, including different sensitivities that may occur between life stages. The World Health Organization (WHO) provides guideline values for "chemicals that areof health significance in drinking-water. Many countries enforce their own drinking water standards that are at least as protective as WHO standards. The Bureau of Indian Standards issued its own set of water standards in 2012 (Table – 12.2).

Table 12.3: Statistical summary of season wise chemical composition of collected groundwater samples.

Chemical Constituent	Pre-monsoon			Post –monsoon			Desirable limit	Permissible Limit
	Min	Max	% of the sample below permissible limits	Min	Max	% of the sample below permissible limits		
pH (Units)	6.95	8.41	100%	6.83	8.49	100%	6.5-8.5	No relaxation

TDS(mg/L)	212.5	1627.5	100%	295.7	1352.7	100%	500	2000
Ca (mg/L)	22	124	100%	25	172	100%	75	200
Mg (mg/L)	1.215	77.76	100%	2.43	89.91	100%	30	100
SO_4 (mg/L)	0.46	142.7	100%	7.67	106.45	100%	200	400
TA as $CaCO_3$	130	570	100%	130	570	98.26%	200	600
TH(mg/L)	90	505	100%	135	630	99%	200	600
NO_3 (mg/L)	BDL	32.97	100%	0.53	49.73	98%	45	No relaxation
Cl (mg/L)	14.18	446.17	100%	17.25	347.41	100%	250	1000
F(mg/L)	0.34	4.62	82%	0.11	3.69	88.5%	1	1.5
Fe(mg/L)	BDL	5.64	27%				0.1	No relaxation
Cr(mg/L)	BDL	0.055	88%				0.05	No relaxation
Mn(mg/L)	BDL	1.18	88%				0.1	0.3
Cu(mg/L)	BDL	0.63	100%				0.05	1.5
Zn(mg/L)	BDL	5.64	100%				5	15
As(µg/L)	BDL	4	100%				10	No relaxation
U(µg/L)	BDL	121	88%				30	No relaxation

The statistical parameters like minimum, maximum and % of groundwater samples below permissible limit asper BIS,2012 for various chemical constituent in pre and post monsoon are presented in Table 12.3. In pre-monsoon and post both seasons all the groundwater samples are within permissible limit for calcium and magnesium ions. The means of NO_3, Cl and SO_4 in pre-monsoon are 31.93 mg/L,74.98 mg/L and 55.81 mg/L respectively whereas, in post monsoon the respective values are 17.54 mg/L, 84.25mg/L and 30.85 mg/L. About 5% groundwater samples in pre-monsoon and 4 % in post-monsoon exceed the required acceptable limit of 250 mg/L chloride. Higher chloride values have been noticed in shallow aquifer water samples in comparison to deeper groundwater samples. High evaporation and local contaminants may have been contributing to elevated chloride concentration in shallow aquifers. In pre-monsoon, all the samples exhibit nitrate concentration below permissible limit. In post monsoon, two samples have nitrate concentration more than permissible limit of 45 mg/L. Both of these sample pertain to shallow depth. Anthropogenic sources of pollution may be the reason for higher nitrate concentration in the shallow aquifer groundwater samples as there is no evidence of geogenic origin of nitrate in the study region.

The HCO_3^- concentration ranges between 159 and 701 mg/L with an average value of 317 mg/L in pre-monsoon. After precipitation, the HCO_3^- concentration ranges between 221 and 836 mg/L with an average value of 336.4 mg/L. It has been observed that enriched fluoride concentration in groundwater is generally associated with high bicarbonate values. 91% of water samples have Total alkalinity (as $CaCO_3$) values more than the acceptable limit of 200 mg/L in post monsoon while only 2% water samples exceeded the permissible limit of 600 for total alkalinity as per BIS,10500. In pre-monsoon all the water samples exhibited TA values below permissible limit of 600.

Fluoride concentration ranges from 0.33mg/L to 4.62 mg/L with a mean of 0.875 mg/L. While in post-monsoon, fluoride concentration ranges from 0.118 mg/L to 3.69 mg/L with a mean of 0.91 mg/L (Fig. 12.1). Weathering and dissolution of fluorine bearing minerals might have enriched fluoride concentration in the groundwater resources of the present study area. A total of 18% and 12% groundwater samples exceeds the permissible limit of 1.5mg/L in pre- and post-monsoon respectively (Fig. 12.2). After precipitation, among 12 samples with fluoride concentration more than permissible limit, 11 belong to deeper aquifer. In pre-monsoon, among 19 samples with fluoride concentration more than permissible limit, 14 belong to deeper aquifer. Spatial distribution of F in the study area has been presented in Figure 12.3.

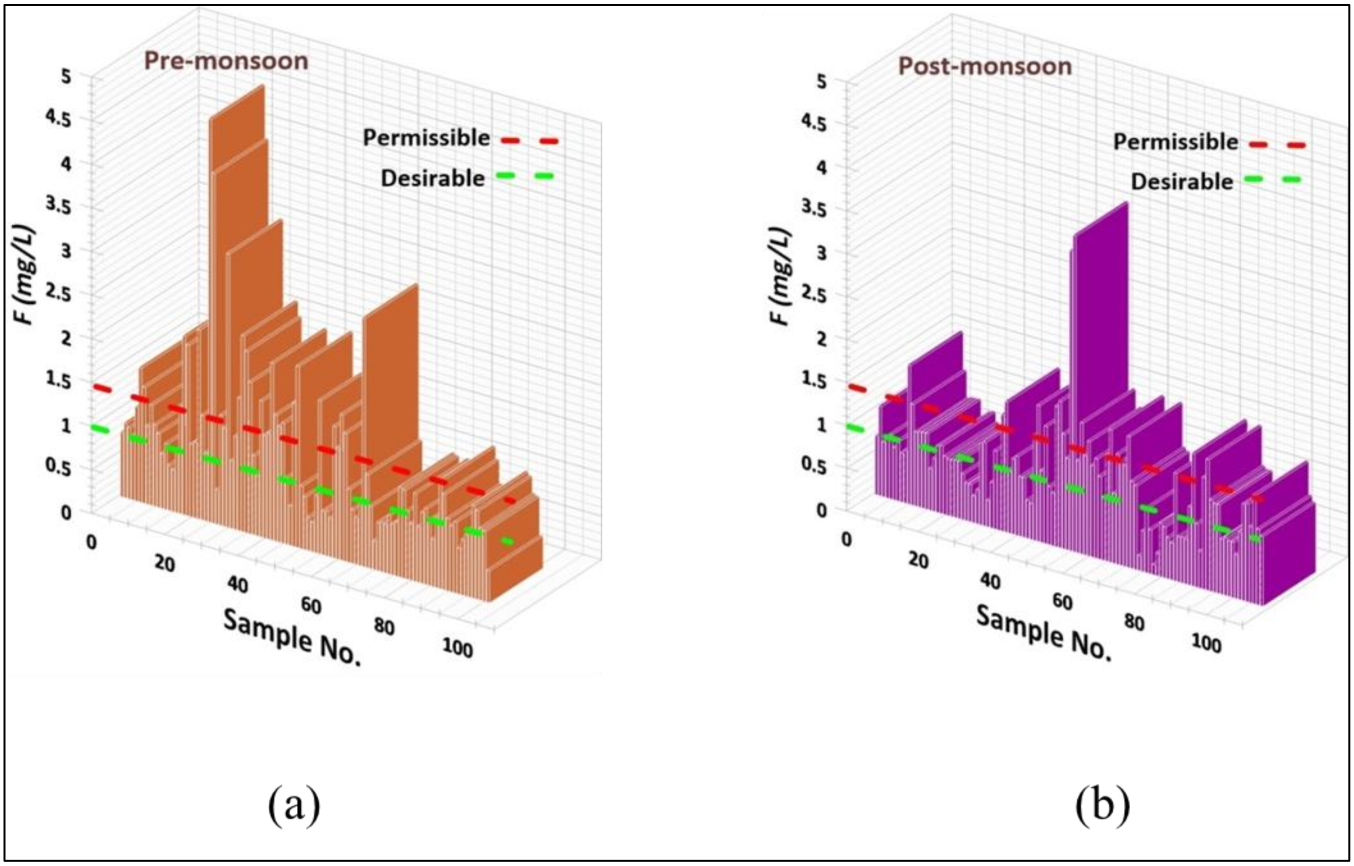


Figure 12.1: Groundwater samples exceeding acceptable and permissible limit of Fluoride as per BIS, 10500 (2012) in pre and post monsoon.

In the Northern part of the study area comprising of Hisua Block all the water samples has F concentration within the permissible limit of 1.5 mg/L as per BIS, 10500. In Meskaur and Narhat Block, six water samples exceed permissible limit of 1.5 mg/L. In the Southern part of the study area, in Sirdala Block excessive fluoride water is widely distributed and 13 water samples exceed the permissible limit of fluoride concentration as per BIS, 10500.

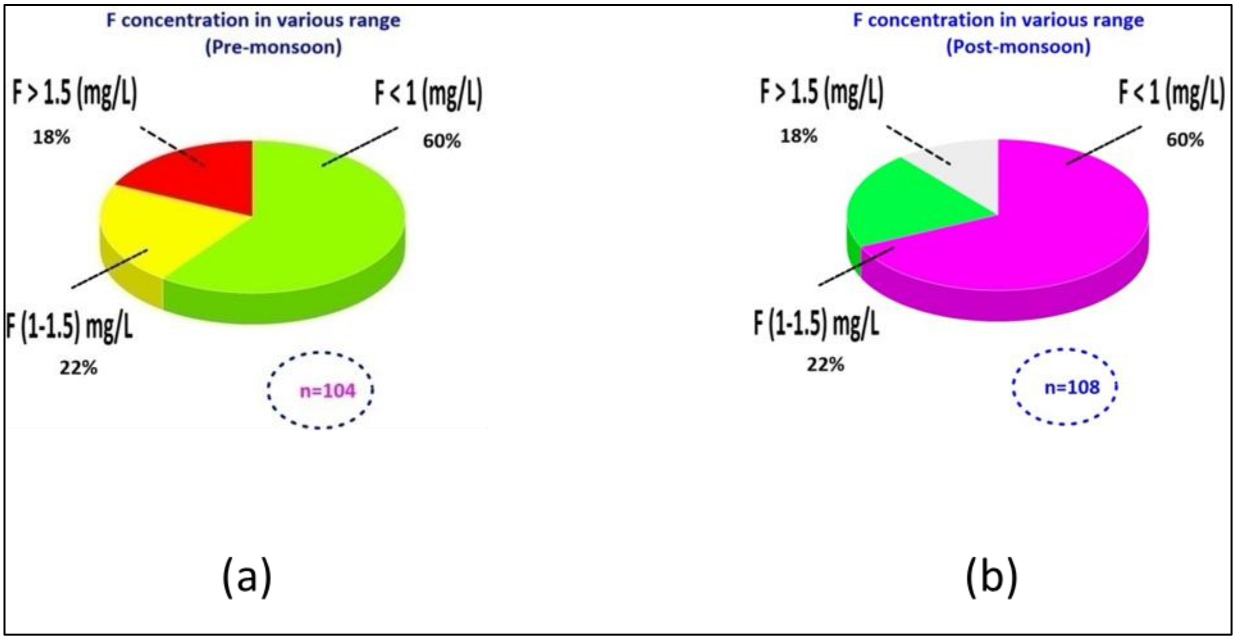


Figure 12.2: Pie chart exhibiting fluoride concentration in the study area in various range.

The hardness results from the divalent metallic ions of which the calcium and magnesium are the most abundant ions in ground water. These ions react with soap to form precipitates, and with certain anions present in water form scales. In some agricultural areas where lime and fertilizers are applied to the land, excessive hardness may indicate the presence of other chemicals such as nitrate. Some types of hardness can be removed by boiling. Water treatment methods such as reverse osmosis, ion exchange or oxidizing filters can be used to reduce other types of water hardness. With the ion exchange process, water is pumped through a tank containing a resin that causes calcium and magnesium ions to be exchanged for sodium or potassium ions.

The degree of hardness in water can be judged from the classification presented below in Table 12.4.

Table 12.4 : Water class as depicted by different TH range

Total Hardness as $CaCO_3$ (mg/L)	Water Class
<75	Soft
75 – 150	Moderately hard
151-300	Hard
301-600	Very hard
>600	Extremely Hard

In pre-monsoon, 17% samples have TH value more than acceptable limit of 300 mg/L, while not a single sample exceeds the permissible limit of 600 mg/L. In post-monsoon, 38% samples have TH value more than acceptable limit of 300 mg/L, and one single sample exceeds the permissible limit of 600 mg/L. The higher TH values observed in some of the water samples are ascribed to the product of ion exchange, high evaporation conditions and agriculture activity.

Heavy metals are now a days, considered as a severe environmental problem due to their release in drinking water by various natural geochemical processes and different anthropogenic sources. In the present study, eight toxic heavy metals like Fe, Zn, Mn, U, Pb, Cu, Cr and. As have been estimated from the water samples of fifty locations. To a much extent, heavy metal concentration and distribution in the ground water relies on degree of weathering and mobility of these elements.

The heavy metals reach into environment by lithogenic as well as anthropogenic processes. The lithogenic process of accumulation of heavy metals in environment is volcanism and bedrock erosion whereas anthropogenic activities include mining and mineral processing, electroplating, metal smelting and chemical industries.

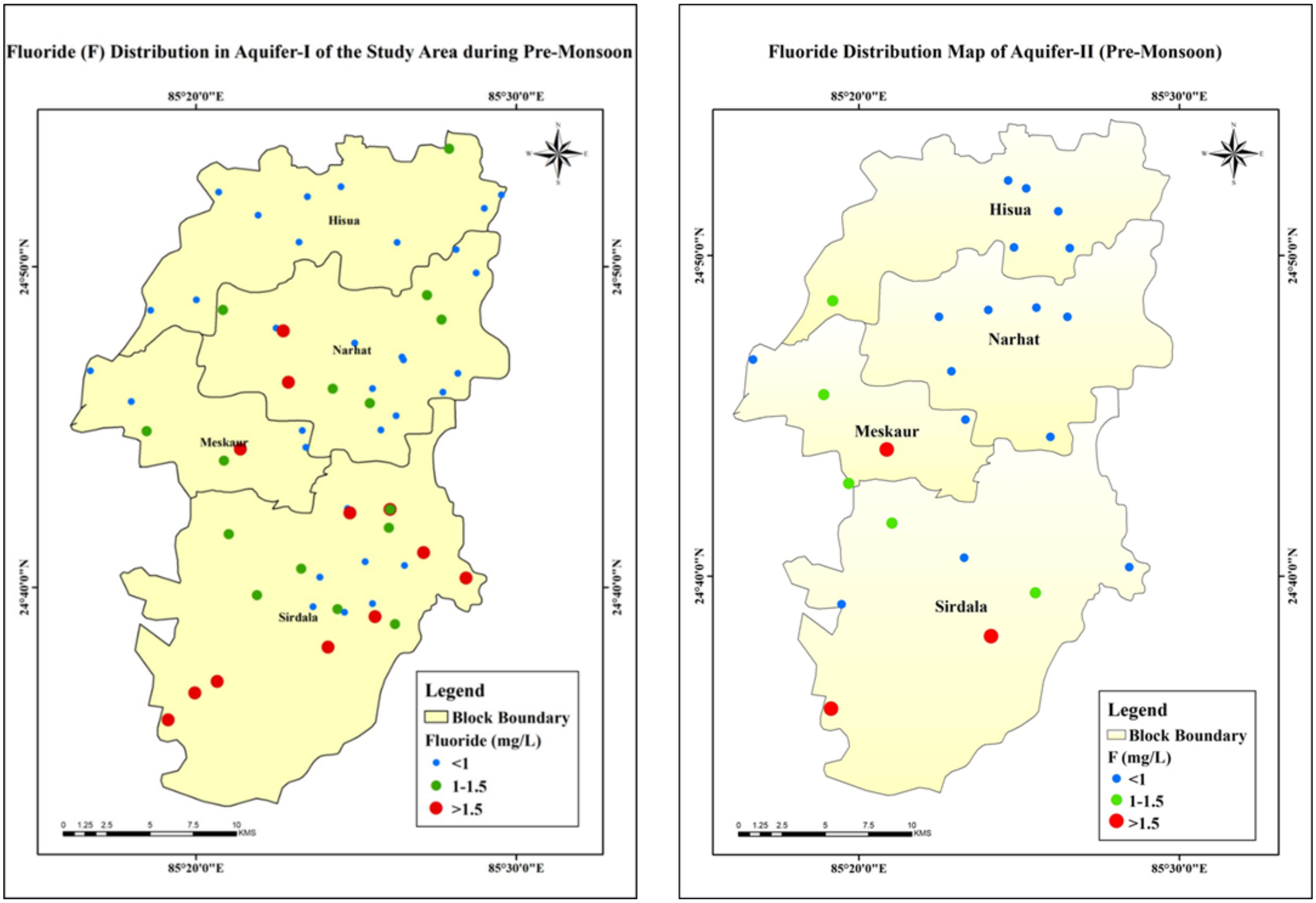


Figure 12.3 Distribution of Fluoride in the study area during pre-monsoon.

A comparison of heavy metal concentrations was made with the water quality guidelines as prescribed in Indian standards (BIS2012) in Table 12.2. It is evident from the table that the measured concentration of heavy metals in the study area decrease in the following order Fe > Zn Mn> U >Pb> Cu > Cr > As. Concentration of Fe varies from BDL to 5.64 (mg/L) with a mean value of 0.686 (mg/L). Fe concentration was found beyond permissible limit in 73% samples in the study area. In Northern part of the study area comprising Hisua Block all the water samples are below acceptable and permissible limit as per BIS,10500. Weathering of rocks is considered as prominent source for the accumulation of iron in water. Spatial distribution of Fe in the study area has been presented in Figure 12.5.

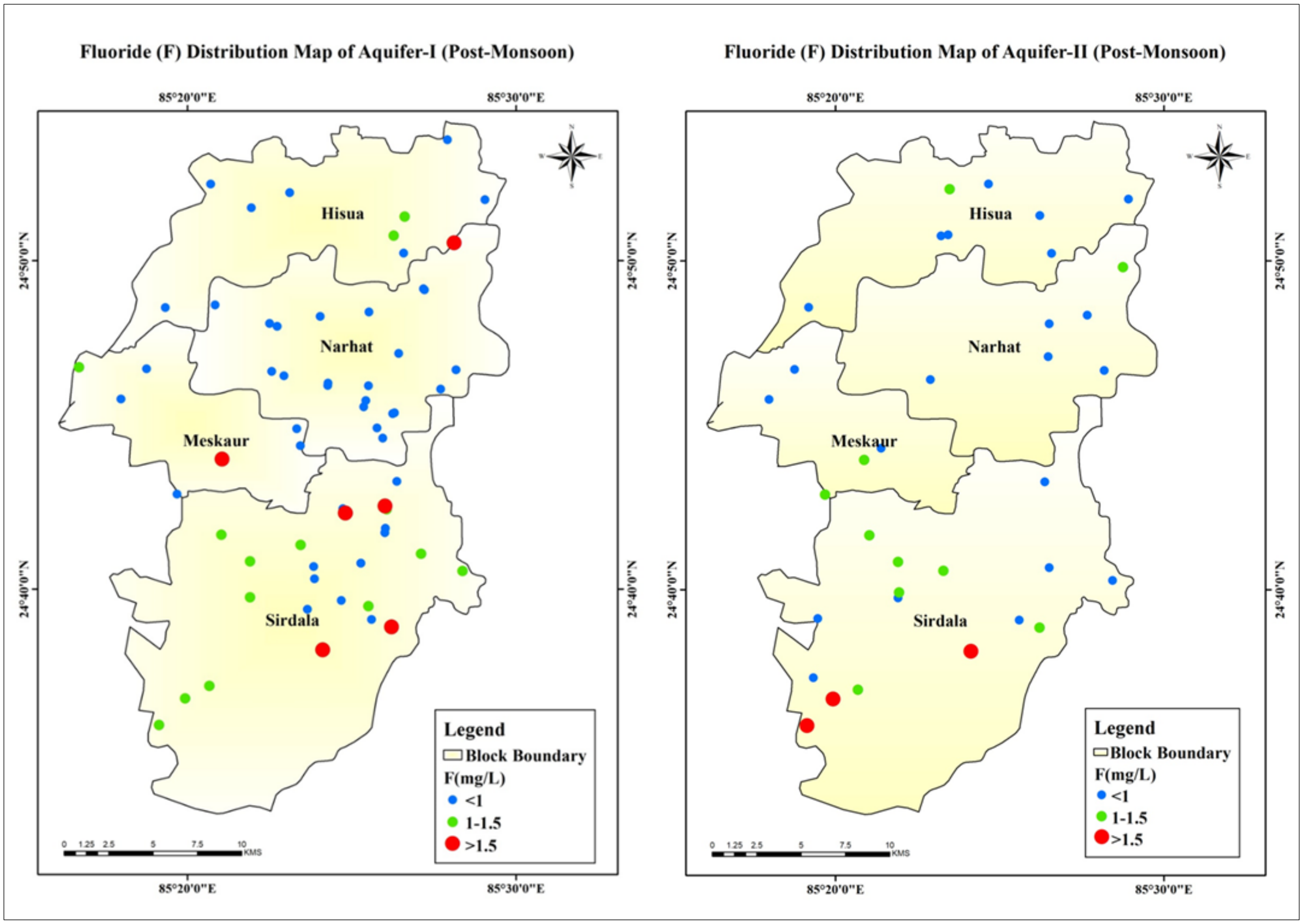


Figure 12.4 Spatial Distribution of Fluoride in the study area during post-monsoon.

The range of Mn concentration ranges was BDL-1.18(mg/L) with a mean value of 0.107 (mg/L). In 10% water samples level of Manganese was found to be more than the permissible limit of 0.3 (mg/L) as per BIS, 2012. In Northern part of the study area comprising Hisua Block all the water samples are below acceptable and permissible limit as per BIS, 10500. Concentration of Zn, Cu and As are well below the permissible limit in every sample as per BIS, 2012.

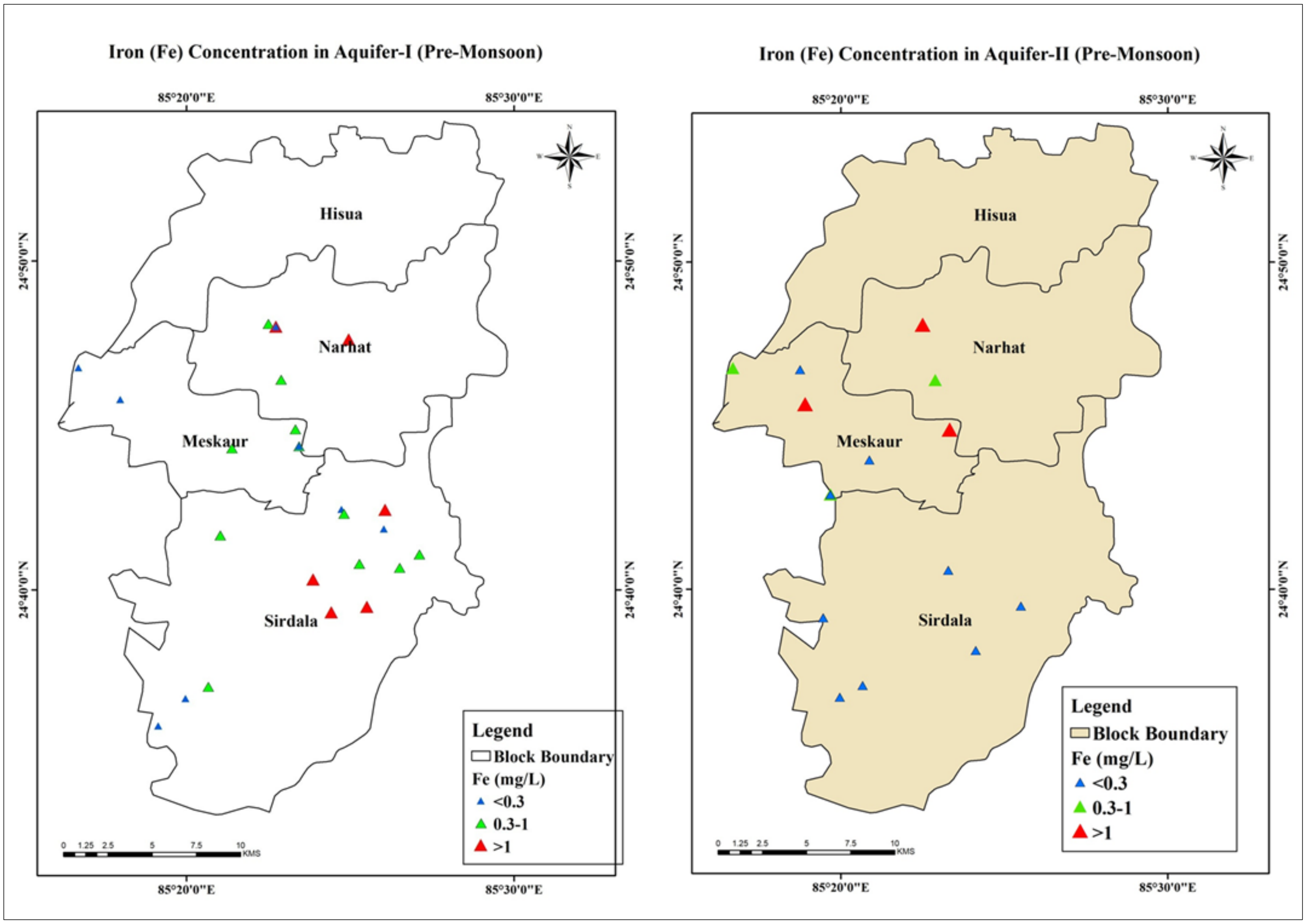


Figure 12.5 Spatial Distribution of Fe in the study area.

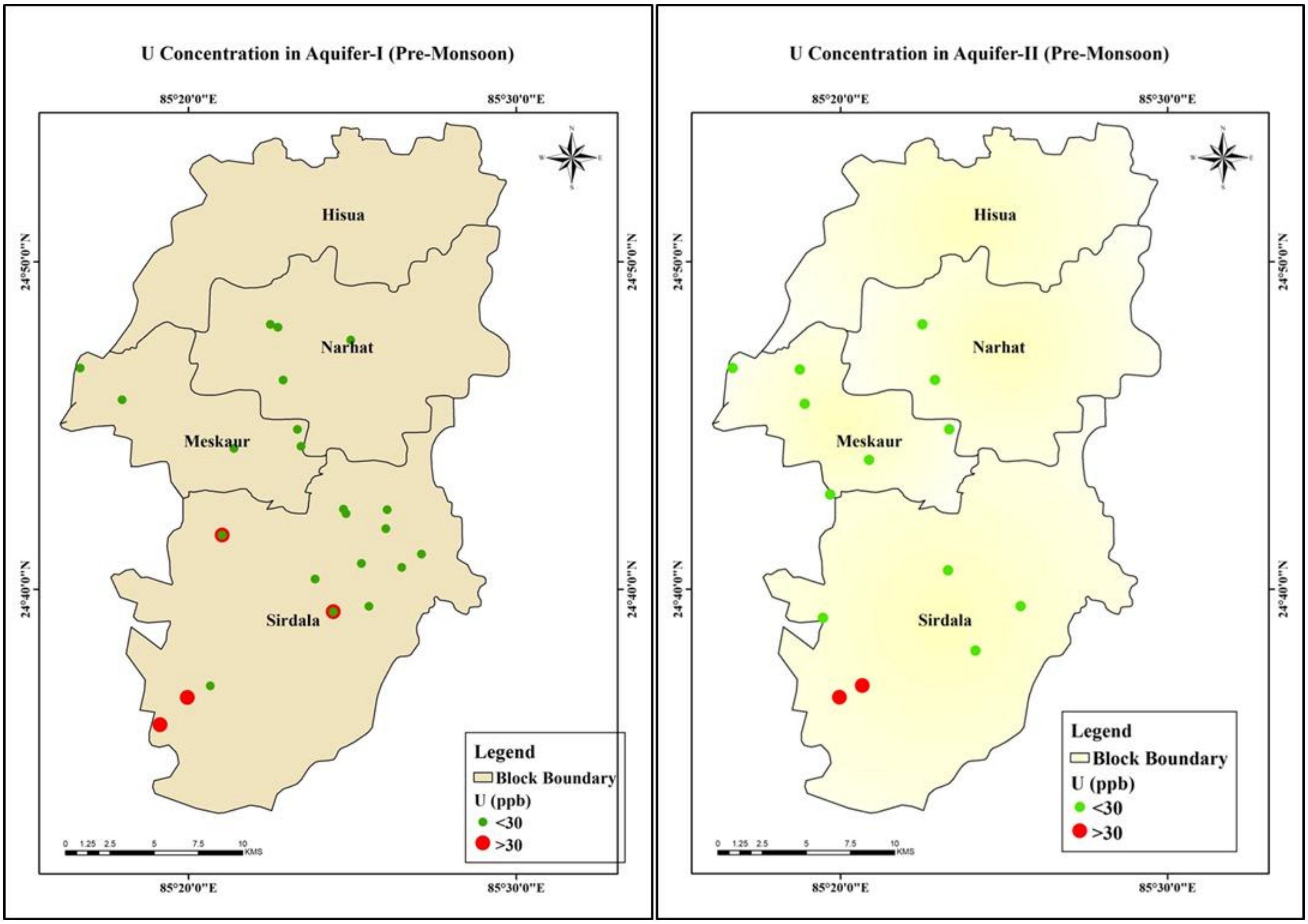


Figure 12.6 Spatial Distribution of U in the study area.

Uranium concentration of more than permissible limit of 30 ppb has been found in water samples of Sirdala Block. Spatial distribution of U in the study area has been presented in Fig.7. In Sirdala Block, about 21% samples exhibited Uranium values more than permissible limit of 30 ppb. Water samples collected from Dhiraundh, Chaukiya, Abdul and SanrhMajhagagan Panchayats have alarming U concentration (Fig.12.6).

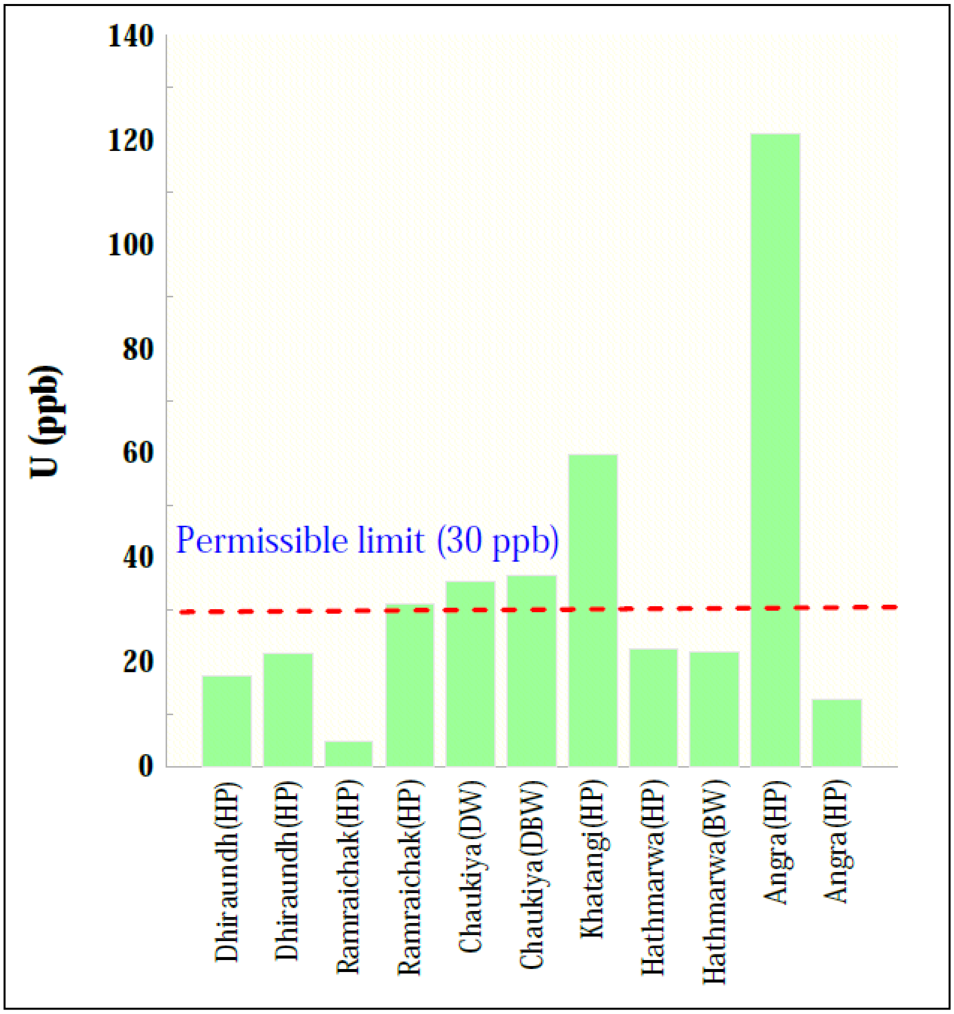


Figure 12.7 Uranium concentration in groundwater samples of Dhiraundh, Chaukiya, Abdul and Sanrh Majhagagan Panchayats.

The Pearson's correlation coefficient matrices for the analyzed parameters are shown in Table 12.5. According to correlation analysis, there is a strong positive correlation between Cu and Pb (0.94),Cu and Zn (0.78), Pb and Zn advocating common source for them.

From observation it was found that Fe is exhibiting significant positive correlation with Cu (0.82), Zn (0.84), and Pb (0.82) and poor relationship with As, Mn and U.

Table 12.5: Correlation matrix between heavy metal elements.

	Cr	*Fe*	*Mn*	*Cu*	*Zn*	*As*	*Pb*	*U*
Cr	1							
Fe	0.187	1						
Mn	-0.042	0.165	1					
Cu	0.364	0.825	0.044	1				
Zn	0.185	0.848	0.132	0.782	1			
As	-0.004	-0.101	-0.098	-0.062	-0.042	1		
Pb	0.157	0.820	0.013	0.949	0.722	-0.083	1	
U	-0.170	-0.029	0.038	-0.070	-0.045	-0.153	-0.115	1

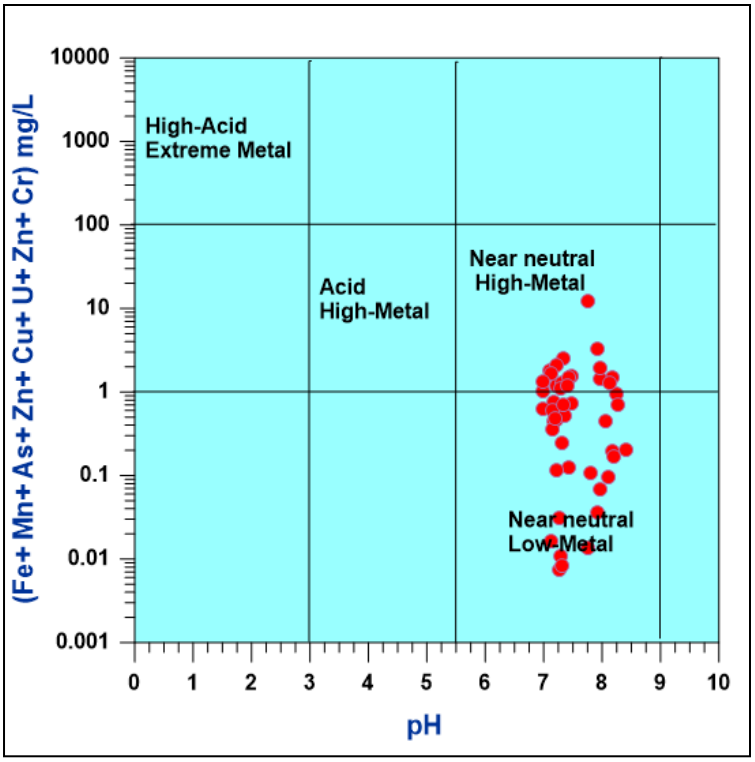


Figure 12.8 Taxonomy of groundwater samples plotted on the basis of Trace metal load and pH after Caboi et al.(1999).

This strong relation advocates that apart from lithogenic sources, Fe concentration is also being enriched due to agricultural and other anthropogenic activities. This also owes addition of Pb, Zn and Cu in water resources to anthropogenic activities, as there is not any geogenic source of these three metals in the study area.

The bond between pH values and trace metal load ((Fe+ Mn+ As+ Zn+ Cu+ U+ Zn+ Cr) have been studied by applying Caboi diagram, (Caboi et al., 1999) in Fig 8. It is obvious from the Caboi diagram that water samples are clustered in near neutral high metal region and low neutral low metal region.

12.4 Hydro geochemistry regulating groundwater quality in the study area

The major ion chemistry of the aquatic system was mainly controlled by weathering of rock forming minerals with minor contribution from atmospheric and anthropogenic source. The abundance of various ions can be modeled in terms of weathering of various rock forming minerals. The bicarbonates are derived mainly from the soil zone CO_2 and weathering of parent minerals. The soil zone in the subsurface contains elevated CO_2 pressure (produced by decay of organic matter and root respiration), which in turn combines with rainwater to form bicarbonate.

$CO_2 + H_2O = H_2CO_3$

$$H_2CO_3 = H^+ + HCO_3$$

The HCO_3 may also be derived from the dissolution of silicate minerals, Orthoclase, Hornblende, Olivine and Biotite of country rocks of the area by carbonic acid. A general reaction for the weathering of silicate rocks with carbonic acid is as follows:

(Cations) silicates + H_2CO_3 =H_4SiO_4+ HCO_3+Cations +solid products (mostly clay minerals)

Binary plots of (Ca+Mg) versus (HCO_3+SO_4) were examined to study the importance of ion exchange and different weathering processes. If Ca, Mg, SO_4 and HCO_3 are derived from a simple dissolution of Calcite, Dolomite and Gypsum a 1:1 stoichiometry of (Ca+Mg) and (HCO_3+SO_4) should exist.

In Ca^{2+} + Mg^{2+} versus HCO_3^- + SO_4^{2-} scatter diagram (Figure 9) almost every groundwater samples in pre-monsoon and post-monsoon show (HCO_3^- + SO_4^{2-}) dominance over (Ca^{2+} + Mg^{2+}), indicating that silicate weathering and ion exchange reactions govern the chemistry of the groundwater samples in different location of study area.

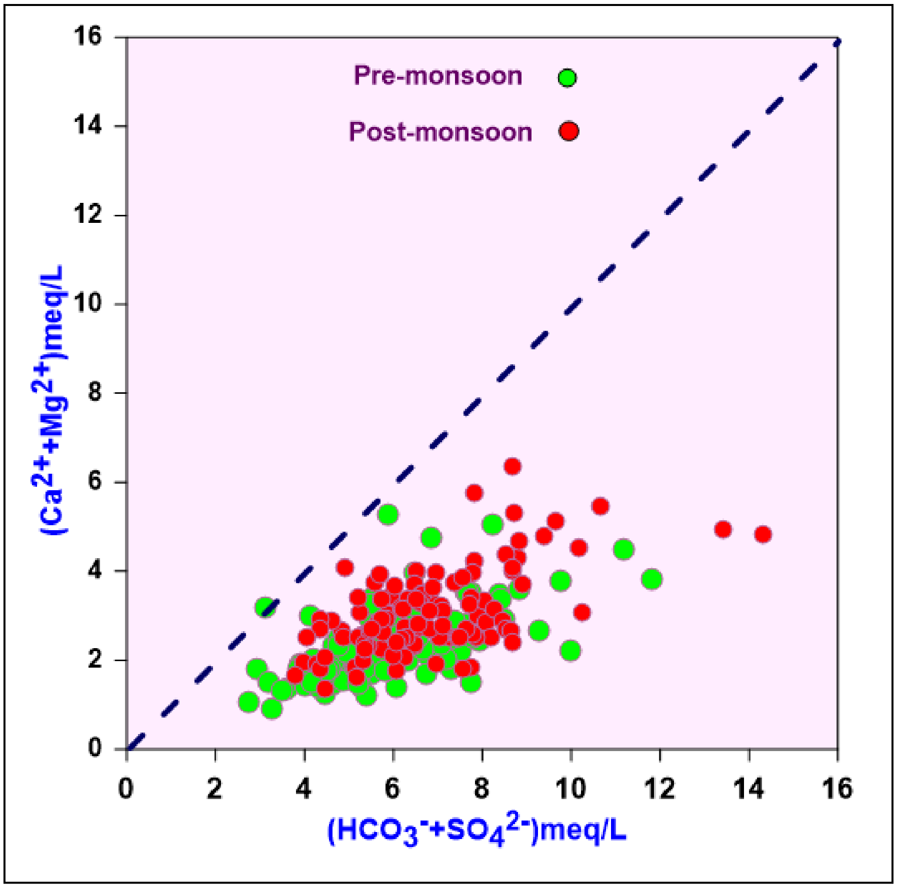


Figure 12.9 Bivariant plot of a (Ca^{2+}+Mg^{2+}) versus (HCO_3- + SO42-).

If halite dissolution is responsible for the sodium, the Na^+/Cl^- ratio is approximately one, whereas a ratio greater than one is typically interpretated as Na^+ released from Silicate weathering reaction. In both seasons, some water samples fall along the equilline in the Na^+/Cl^- plot, indicating common source of halite for both the ions. Na^+/Cl^- ratio greater than one is typically interpretated as Na^+ released from Silicate weathering reaction. It is evident from Figure 10, that 81% samples in pre-monsoon and 75% water samples in post-monsoon have fallen below the 1:1 equiline. Thus, it can be concluded that the apart from halite Na^+ is also getting added in aquifer solution by silicate weathering and ion exchange process.

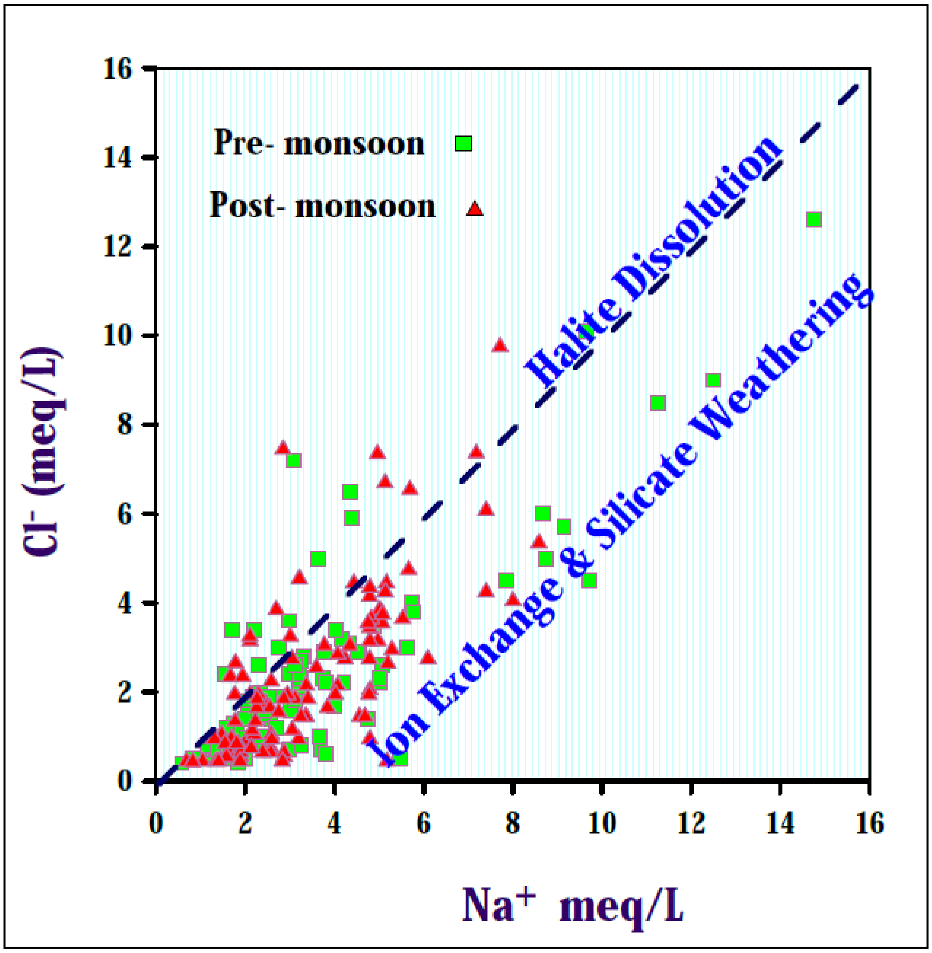


Figure 12.10 Bivariant plot of Sodium vs Chloride.

It is where Na montmorillonite clay reacts with calcium and magnesium and releases sodium (sometimes called natural softening).

$2Na^{+} – clay + Ca^{2+} = Ca^{2+} – clay + Na^{+}$

Since, there is no evidence of groundwater interaction with connate seawater in the study area, the observed $Na^{+}/Cl^{-} < 1$ in some water samples could be attributed to either Cl^{-} enrichment from anthropogenic sources such as irrigation return flows or domestic waste disposal, or it could be due to Na+ depletion as a result of reverse cation exchange. Reverse ion exchange acts as a sink for sodium:

$$2Na^{+} + Ca - clay = Na_2 – clay + Ca^{2+}$$

Most of the fluoride contaminated waters are Na^+ - HCO_3^- type of water.

Stiff diagram of Fluoride contaminated sample of Badhi and Ramraichak village (Figure 12.11) also shows abundance of Na^+ and HCO_3^- ions.

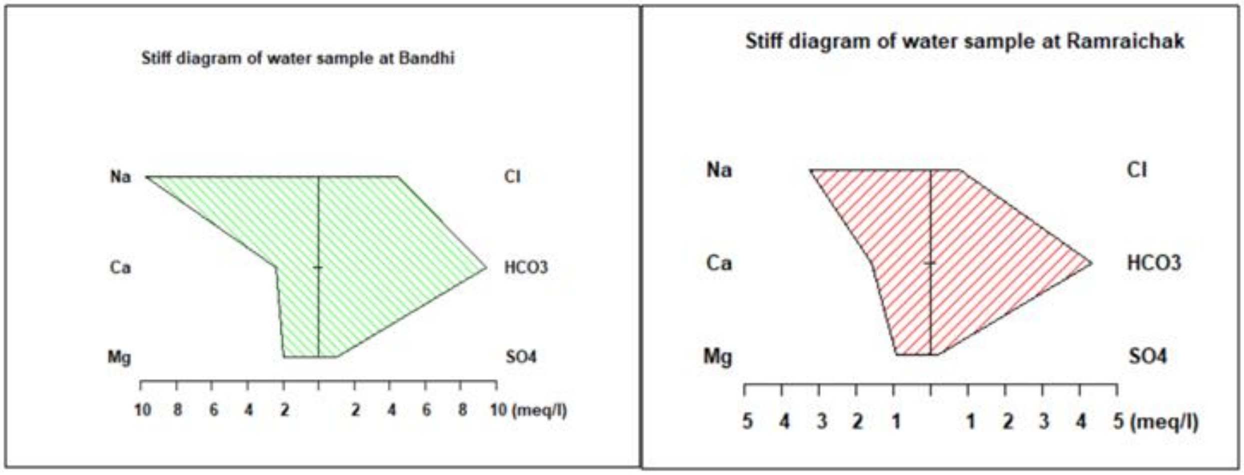


Figure 12.11 Stiff Diagram of the fluoride contaminated water sample from Badhi and Ramraichak village, Sirdala Block

Earlier also so many researchers have advocated that, $Na-HCO_3$ type water provides favourable condition for dissolution of fluorite:

$$CaF_2 + Na_2CO_3 \rightarrow CaCO_3 + 2Na^+ + 2F^- \ldots \quad (1)$$

$$CaF_2 + 2NaHCO_3 \rightarrow CaCO_3 + 2Na^+ + 2F^- + H_2O + CO_2 \ldots \quad (2)$$

pH value of aquifer solution between 5-6.5 leads to adsorption of F^- on clay minerals. The reverse is the situation in alkaline conditions having pH value more than 7.

In these circumstances, OH^- group replaces the exchangeable F^- of clay minerals (biotite, muscovite, apatite, hornblende, and amphiboles), as both of these contain almost identical ionic radius (0.136 nm), consequently resulting in enhanced F− concentration in aquifer. The exchange of F- from OH^- of clay minerals such as biotite, muscovite, apatite, hornblende, and amphiboles take place in following manners:

Fluorite (Eq.3)

$$CaF_2 + 2HCO_3 \rightarrow CaCO_3 + 2F^- + H_2O + CO_2 \ldots \ldots \quad (3)$$

Biotite (Eq.4)

$$KMg_3[AlSi_3O_{10}]F_2 + 2OH^- \rightarrow KMg[AlSi_3O_{10}]OH_2 + 2F^- \ldots \ldots \quad (4)$$

Hornblende (Eq.5)

$$Ca_5Mg_5[Si_6Al_2O_{22}]F_2 + 2OH^- \rightarrow Ca_5Mg_5[Si_6Al_2O_{22}]OH_2 + 2F^- \ldots \ldots \quad (5)$$

Apatite (Eq.6)

$$Ca_{10}\,(PO_4)F_2 + 2OH^- \rightarrow Ca_{10}(PO_4)_6OH_2 + 2F^- \ldots \ldots \quad (6)$$

Muscovite (Eq.7)

$$KAl_2[AlSi_3O_{10}]F_2 + 2OH^- \rightarrow KAl_2[AlSi_3O_{10}]F_2 + 2OH^- \ldots \ldots \quad (7)$$

Along with these factors, humid climate of study area also promotes weathering of host rocks. This leads to formation of weathered overburden material over fluoride bearing rocks. As negatively charged F^- is a common constituent in these overburdens weathered materials, it easily gets added to the aquifer solution in favourable conditions during prolonged rock water interaction.

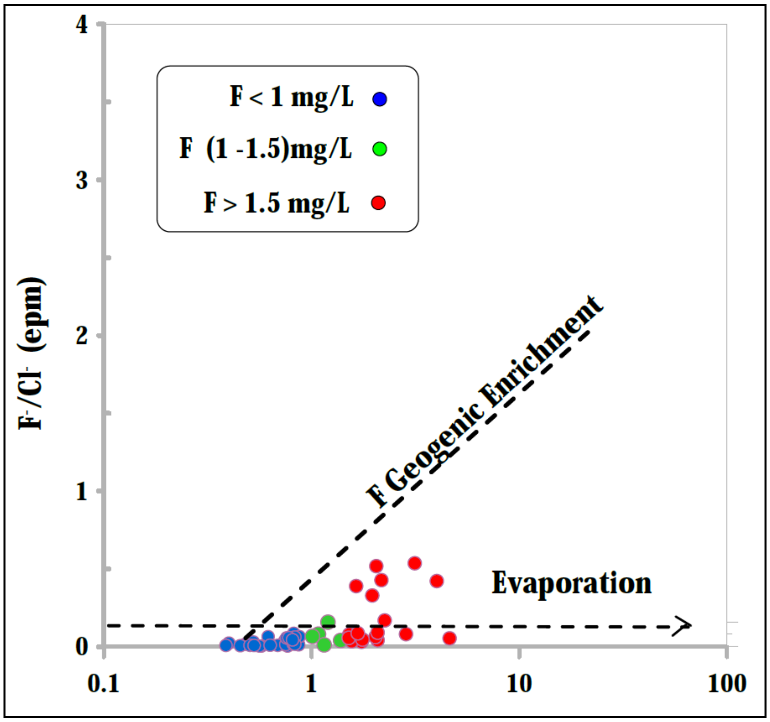


Figure 12.12 Correlation of F− concentration of waters samples in logarithmic scale versus plot of F−/Cl

Chlorine can replace hydroxide in common rock forming minerals such as biotite and amphibole, although concentrations are generally scanty and most rocks liberate very little Cl^- into circulating water. Its circulation through the hydrologic cycle is determined by physical rather than chemical processes. Thus, evaporation should concentrate Cl^- and F^- equally.

In the F^-/Cl^-vs F^- plot in Figure 12, two processes can be deduced: the evaporation line (high F, constantly low F^-/Cl^- ratio) and geogenic enrichment (both, F^- and thus F^-/Cl^- ratio increase since Cl^- does not change). The high F^-/Cl^- ratios points out that enrichment of fluoride are independent of evaporation in groundwater. On the other hand, low F− concentrations in some groundwater could be due to the short residence time of the groundwater limiting water–rock interaction.

12.5 Hydrochemical facies and evolution of groundwater types

Piper diagram (Piper 1944) describes the process responsible for the evolution of hydrogeochemical parameter in groundwater. Piper plot can help us to understand water type, precipitation, mixing and ion exchange involved in aquifer geochemistry. Based on the major cation and major anion content in the water samples and plotting them in the trillinear diagram, hydrochemical facies could be identified. Piper diagrams are a combination of anion and cation triangles that lie on a common baseline. Adjacent sides of the two triangles are then 60^0 apart. A diamond shape between them is used to re plot the analyses. The position of analysis of a water sample placed on a Piper plot can be helpful to reach a tentative conclusion as to origin of groundwater.

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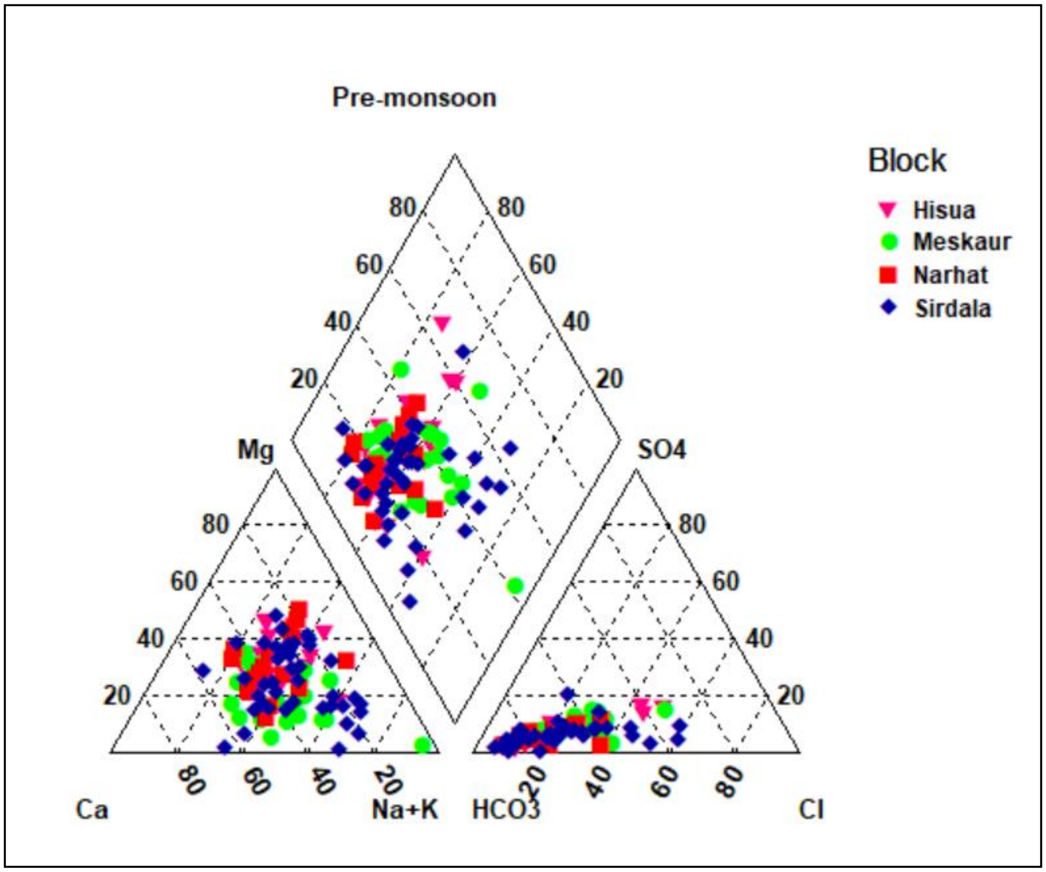


Figure 12.13 Distribution of water samples of various hydro chemical facies in Piper's diagram (Pre-monsoon).

It is obvious from Fig. 12.13 & 12.14 that there exist five water types in the study area: Na^+-HCO_3, Na^+-Cl^- type, Ca-HCO_3, Mg-HCO_3 and mixed type. The hydrochemical types of high fluoride groundwater were characterized by Na^+- HCO_3 and Na^+-Cl^- type influenced by granitoids and metamorphic rocks. The groundwater with a higher concentration HCO_3 generally had higher concentration of groundwater fluoride, which is related to the precipitation of carbonate minerals. Elevation of groundwater HCO_3 potentially causes the decrease in groundwater Ca under the solubility restriction of calcite and dolomite. The decrease in groundwater Ca further triggers the dissolution of fluorite, thereby leading to increase in the concentration of groundwater fluoride. Na–Cl water type indicates ancient groundwater with ample residence time with associated overburden and aquifer material.

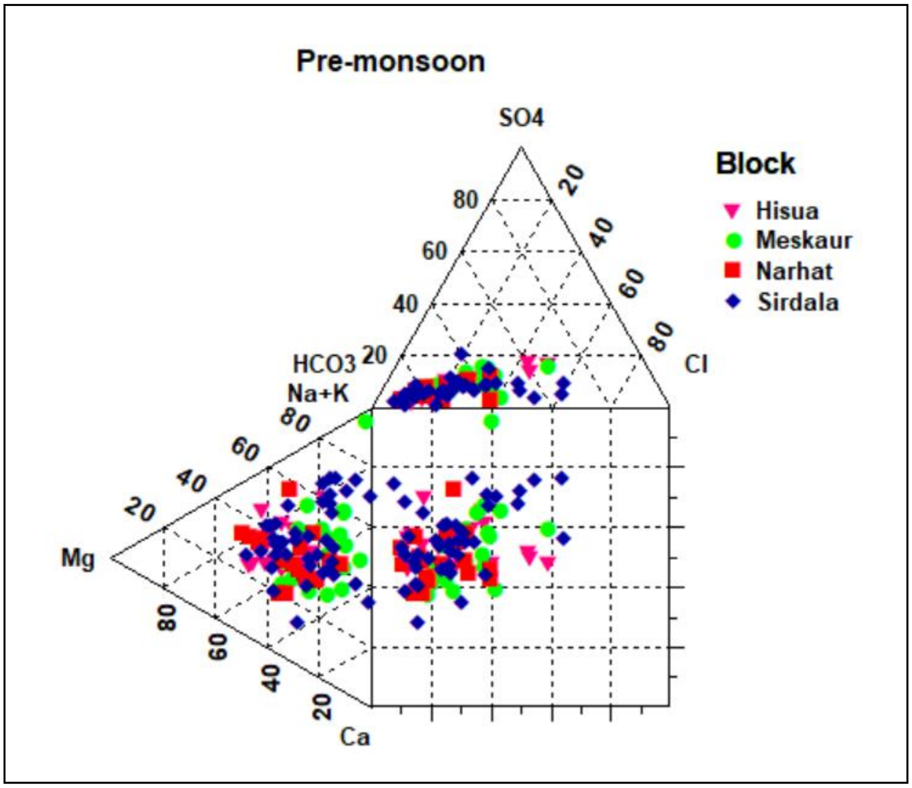


Figure 12.14 Durov plot illustrating hydrochemical processes involved in groundwater in study area.

Pie diagram (Figure 12.15) of average concentration of major ions advocates that cation is dominated by Sodium and anion chemistry is dominated by Bicarbonate.

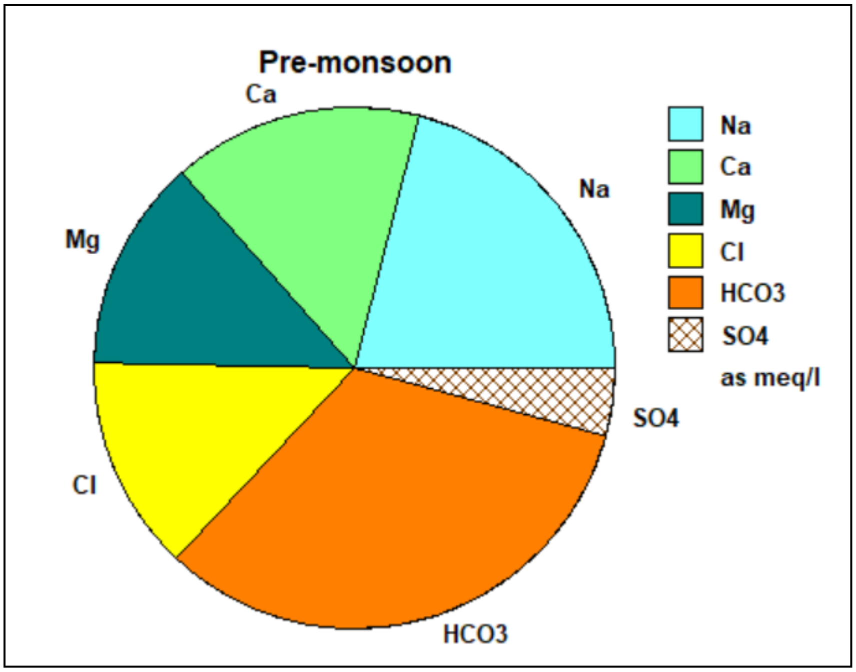


Figure 12.15 Pie Diagram of average concentration of Major ions of groundwater samples.

12.6 Suitability of Groundwater for irrigation purpose

The chemical quality of water is an important factor to be considered in evaluating its usefulness for irrigation purposes. Plants grown by irrigation absorb and transpire water but leave nearly all the salts behind in the soil, where they accumulate and eventually prevent plant growth. Excessive concentrations of solute interfere with the osmotic process by which plant root membranes are able to assimilate water and nutrients. $CaCO_3$ has low solubility, it may precipitate harmlessly but the bulk of residual solutes present may cause a disposal problem that must be solved effectively to maintain productivity of the irrigated soil. In areas where natural drainage is inadequate, the irrigation water infiltrating the root zone will cause water table to rise excessively. In addition to problems caused by excessive concentration of dissolved solids, certain constituents in irrigation water are especially undesirable and some may be damaging even when present in small concentrations. Various parameters viz. Electrical Conductivity (EC), Sodium Adsorption Ratio (SAR), Residual Sodium Carbonate (RSC) and %Na have been evaluated to assess the suitability of ground water for irrigation purposes.

Table 12.6: Criteria of classifying irrigation water quality based on SAR, %Na, RSC, and EC

SAR	EC	Irrigation water quality	%Na	RSC	Irrigation water quality
<10	<250	Excellent Quality	<30	<1.25	Suitable
10-18	250-750	Good Quality	30-60	1.25-2.5	Marginable Suitable
18-26	750-2250	Acceptable Quality	>60	>2.5	Unsuitable
>26	>2250	Unacceptable Quality			

As per Table 12.7 it is obvious that in this region, water samples are observed to lie in C_2 & C_3 class exhibiting medium to high salinity. Such waters can be used for irrigation of most of the soils and crops with little or moderate problem of salinity and without special practices for salinity control.

Table 12.7: Frequency Distribution of E.C. in the study area

%. of samples in various E.C.range (μS/cm at 25° C)							
<250 (low saline, C_1)		250-750 (medium saline, C_2)		751-2250 (high saline, C_3)		> 2250 (very high saline, C_4)	
Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
-	-	62	48	38	52	-	-

The establishment of water-quality classes from the standpoint of the sodium hazard is more complicated than for the salinity hazard. The problem can be approached from the viewpoint of the probable extent to which soil will adsorb sodium from the water and the rate at which such adsorption will occur as the water is applied. Consider the simple case where a nonalkali soil is leached continuously with a high-sodium irrigation water and an increase in concentration of the salts in the solution is prevented by the absence of plant growth and of surface evaporation. Under these conditions, the exchangeable-sodium-percentage (ESP) which the soil will eventually attain when it and the water are in equilibrium can be predicted closely from the sodium-adsorption-ratio (SAR) of the water. The U.S.salinity laboratory has recommended the use of sodium adsorption ratio (SAR) as it is closely related to adsorption of sodium by the soil.

SAR is derived by the following equation

$$\mathbf{SAR = Na / \{(Ca+Mg)/2\}^{1/2}}$$

The water with regard to SAR is classified into four categories (Table12.6).

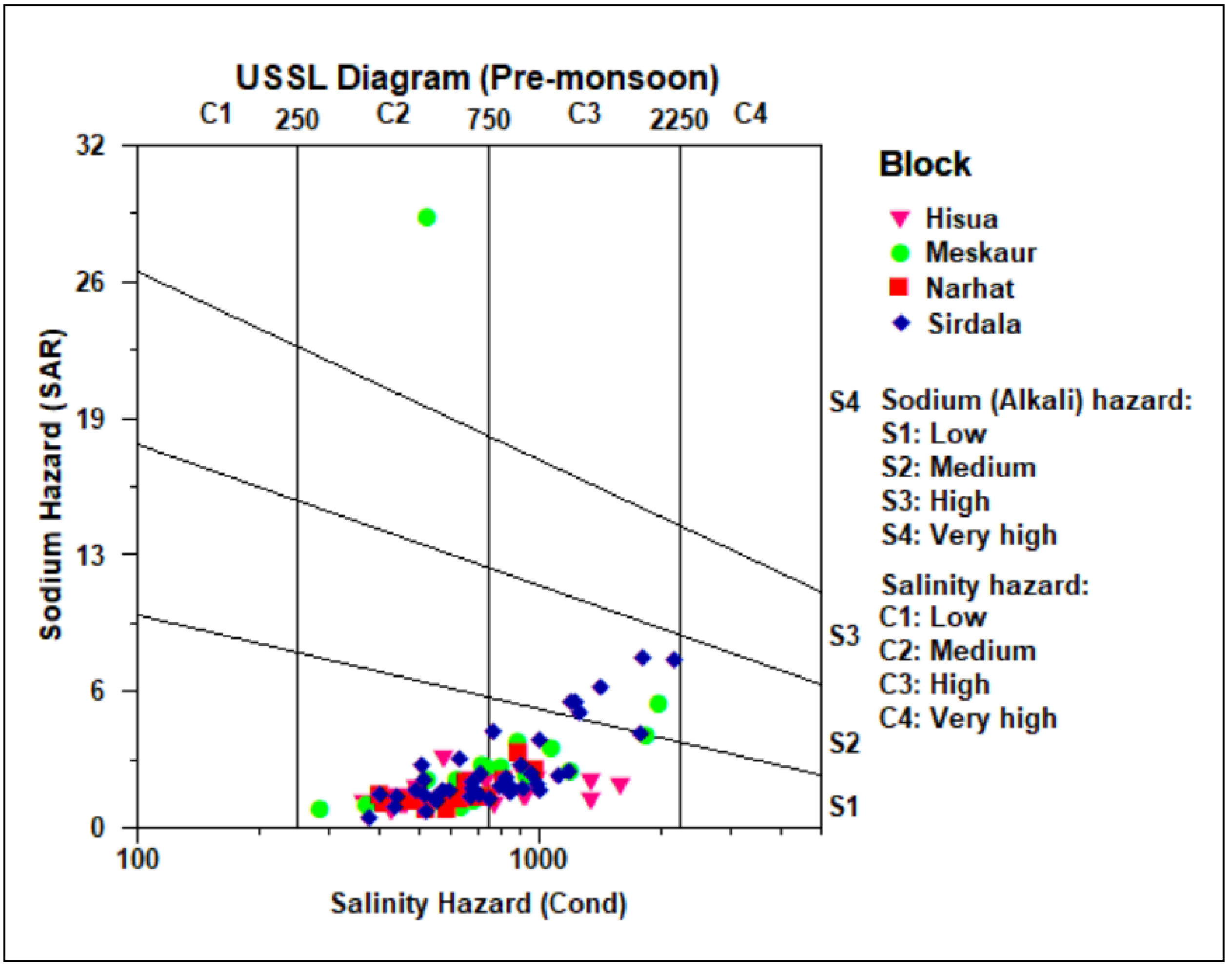


Figure 12.16 US Salinity diagram for assessing water quality (Pre-monsoon).

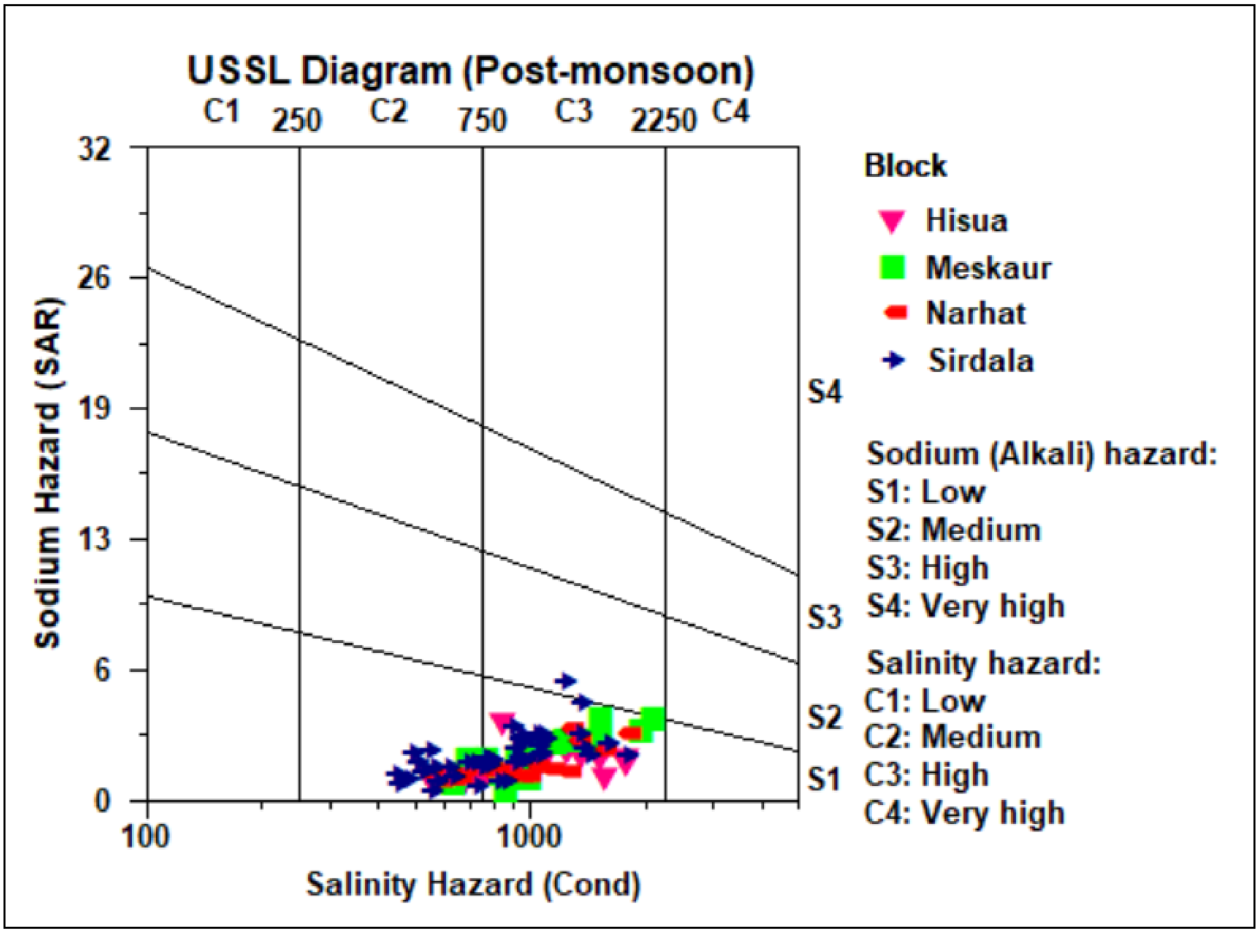


Figure 12.17 US Salinity diagram for assessing water quality (Post-monsoon).

The USSL salinity diagram represents the alkalinity and salinity of irrigation water simultaneously. As shown in Fig.12.16 & 12.17 respectively most of the samples are plotted in C1S1, C2S1 and C3S1 indicating a good to acceptable quality for irrigation in all the regions accept one sample in pre-monsoon which falls in C2S4 region. Water falling in C2S4 region may be improved by the addition of gypsum to the water.

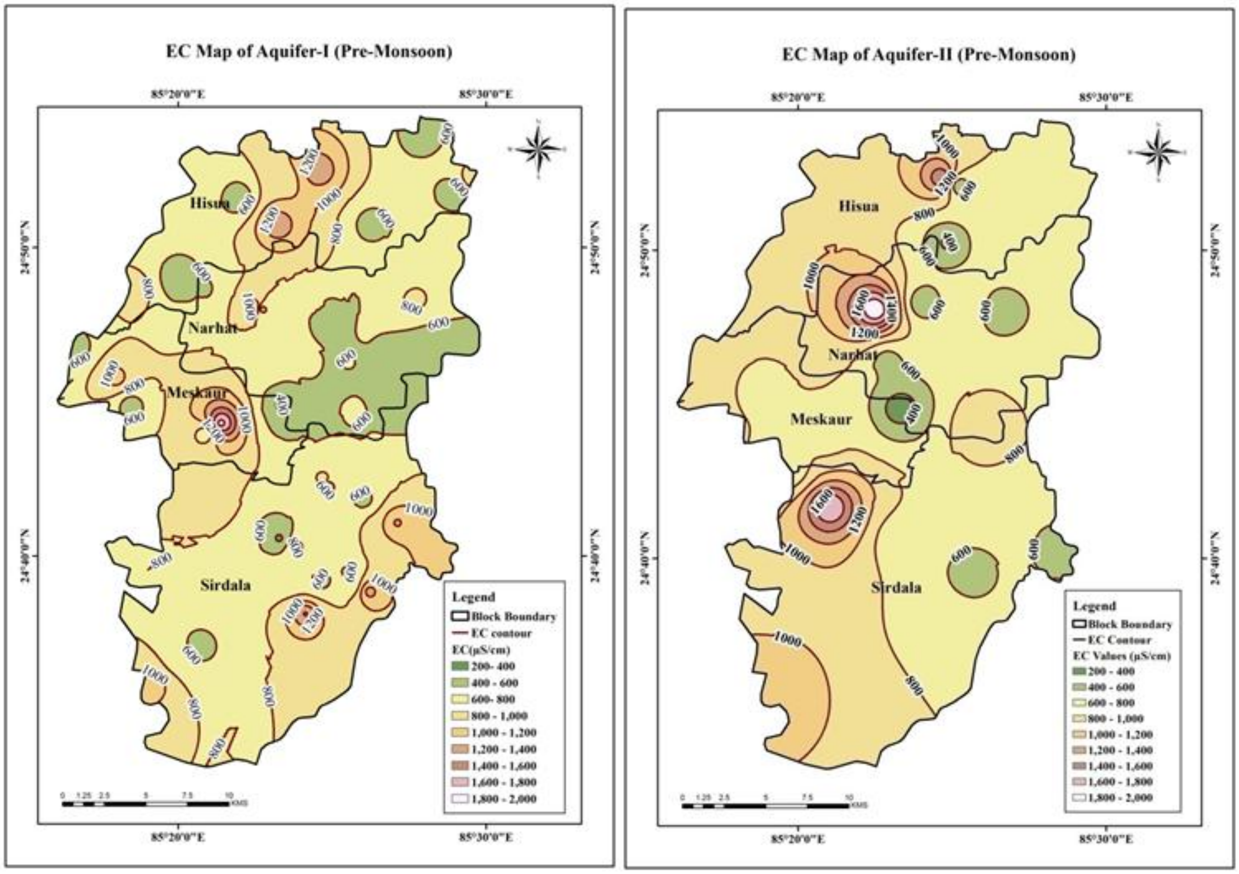


Figure 12.18 EC map of Aquifer I and Aquifer II (Pre-monsoon)

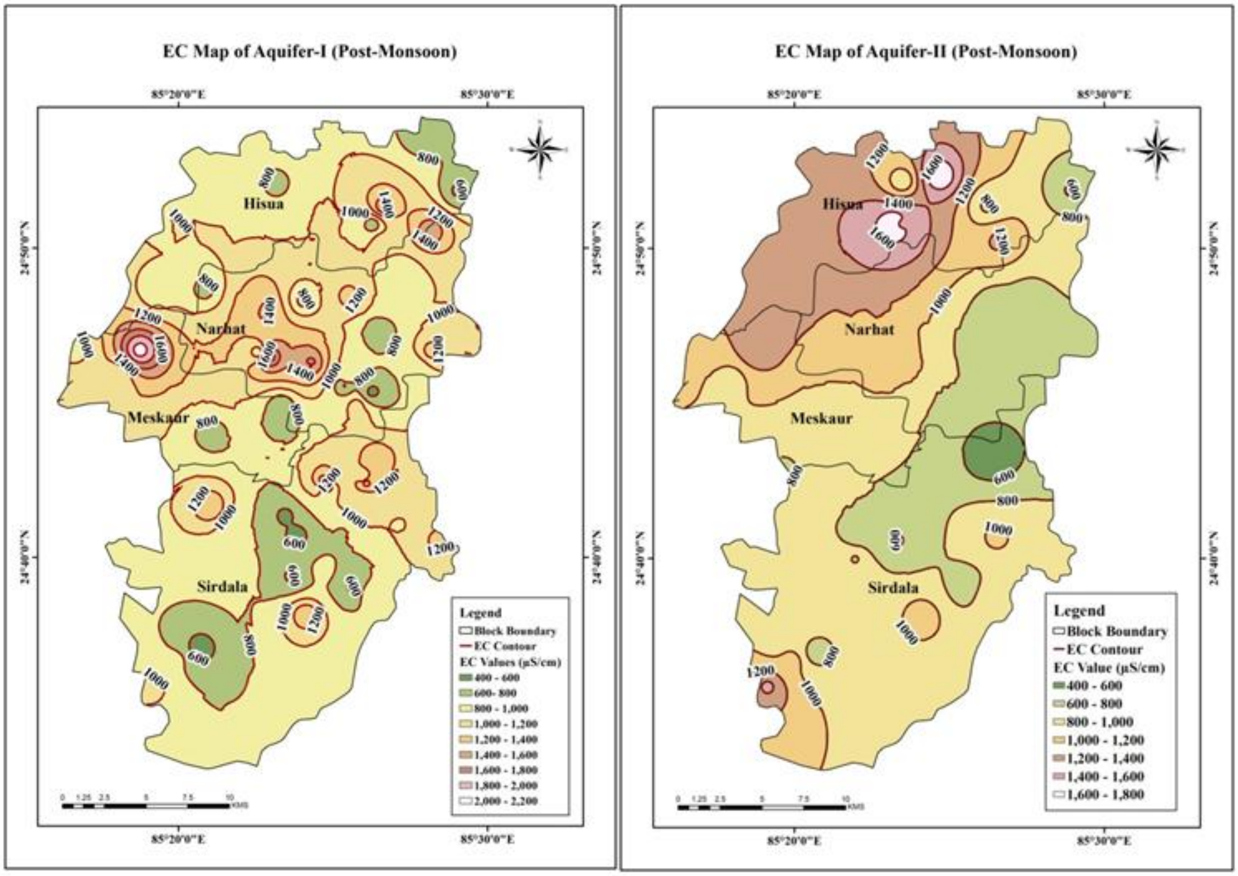


Figure 12.19 EC map of Aquifer I and Aquifer II (Post-monsoon)

When carbonate or bicarbonate concentration in irrigation water is relatively higher than the alkaline earth metals, there is tendency for calcium and magnesium ions to precipitate as carbonates in the soil, thereby reducing the level of calcium and magnesium ions and increasing the relative levels of sodium in the soil. The highly soluble sodium carbonate (black alkali) known as residual sodium carbonate (RSC) is defined as;

$$\mathbf{RSC = (HCO_3 + CO_3) - (Ca + Mg)}$$

Where concentrations are expressed in meq/L.

RSC values range -5.75 to 5.02 in Pre-monsoon and from -5.12 to 4.12 in post monsoon. The perusal of the analysed data in the study area shows that the *most of the Residual Sodium Carbonate (RSC) concentrations are low and continued usage of low-RSC waters will not affect* *the yields of crop.*12% water samples in pre-monsoon and 10% water samples in post-monsoon have RSC values more than 2.5 and are unsuitable for irrigation.

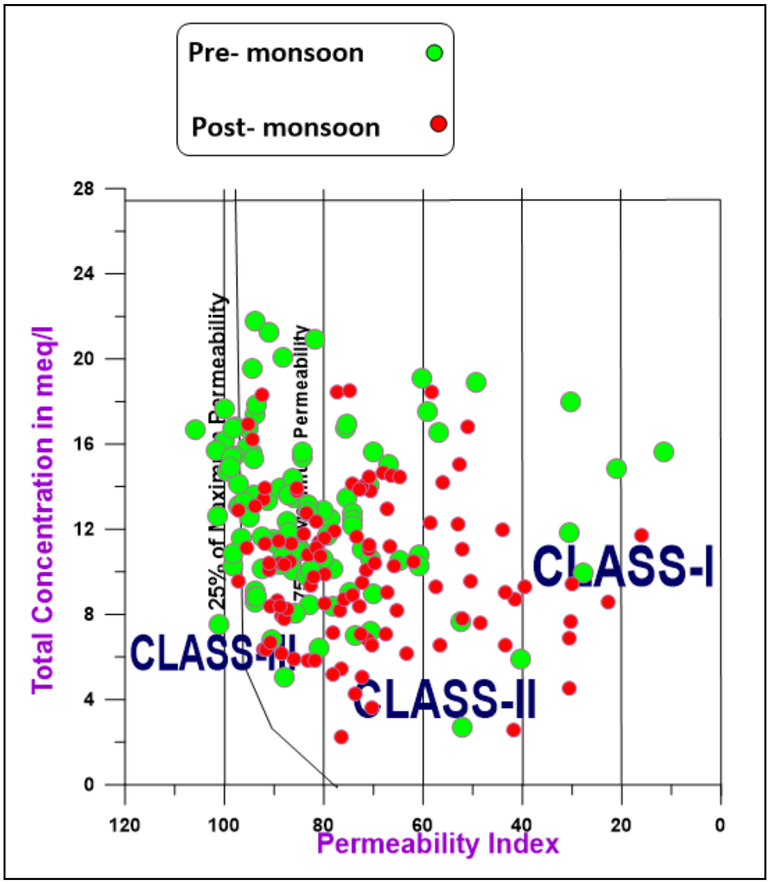


Figure 12.20 Doneen Plot

Chapter 13
Artificial Recharge Plan

13.1 Objective

Meskaur and the adjacent blocks of Hisua, Narhat and Sirdala of Nawada District, Bihar has been classified as "Water Stressed Area" making it one of the 11 priority zones identified by the Central Ground Water Board under NAQUIM 2.0 project. To tackle the risks associated with water scarcity, implementing an artificial recharge strategy is crucial for effective and sustainable groundwater management in the area under study.

13.2 Methodology

Based on the hydrogeological conditions of the study area, an artificial recharge plan of the study area has been formulated. The following methodology has been adopted during preparation of the plan.

i. Areas having Post Monsoon Water Level greater than 3 mbgl are considered to be area suitable for artificial recharge.
ii. Ridge to valley approach has been adopted for efficient use of the run-off water generated during rainfall. The southern part bordering Jharkhand has higher elevation and greater slope. As it comes under Chhotanagpur Granitic formations, higher runoff is generated. Therefore, it is essential to arrest the runoff in the catchment area.
iii. The annual rainfall in the area is less than 1000mm, thus, gully plugs are proposed on 1st and 2nd order streams on steep slopes.
iv. Further, majority of the hilly areas have moderate slope with 2nd and 3rd order streams. Percolation tanks, Check dams and Nala Bunds can be constructed in these hilly part of the study area where the streams are located on fractured and weathered rock.

13.3 Results and Discussions

Given the geological and hydrogeological conditions of the study area, the proposed artificial recharge plan is mainly focused on recharging the Aquifer-I, which is tapped by dug wells and shallow tube wells.

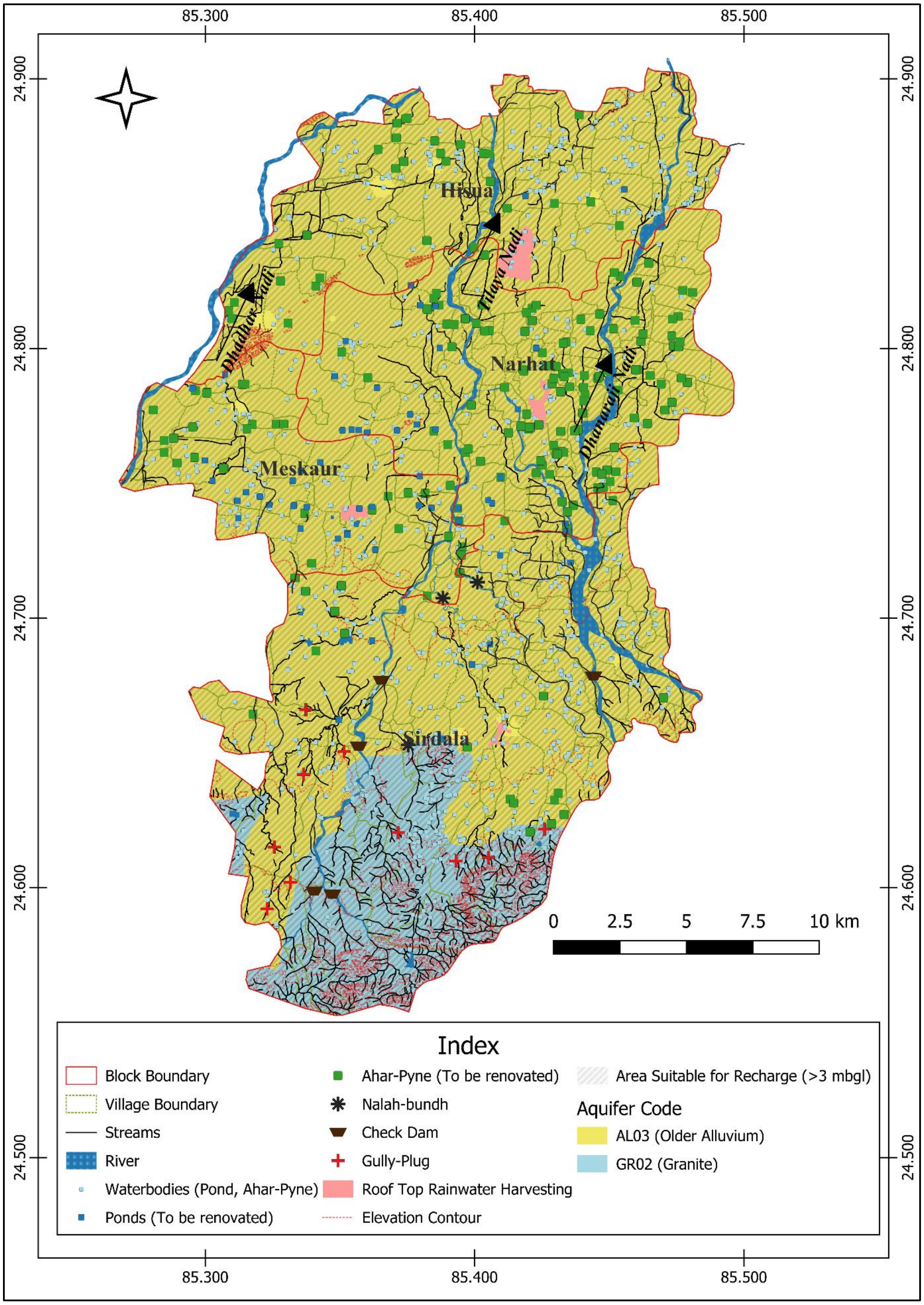


Figure 13.1: Tentative Locations for Water Conservation and Artificial Recharge Structures.

Table 13.1: Estimation of Feasible Runoff available for recharge

Block	Geographical Area (Sq. Km)	Recharge worthy area (Sq. Km)	Post monsoon wl (m bgl)	Available depth for recharge (DTW-3m) unsaturated zone thickness	Sp. Yield	Rainfall (m)	Volume of unsaturated zone available for recharge (MCM)	Available subsurface space for AR (MCM)	Source Water required at 60% efficiency (MCM)	Source water available i.e (Runoff) (MCM)	Total non-committed surplus runoff available (MCM)	Total volume of Available Water for Recharge (MCM)	Feasible runoff available for recharge/ harvested (@ 60%) (MCM)
Hisua	122.7	122.7	6.04	3.04	0.1	0.830	373.01	37.30	61.92	22.42	8.97	8.97	5.38
Meskaur	181.83	181.83	5.60	2.60	0.02	0.683	472.76	9.46	15.70	12.42	4.97	4.97	2.98
Narhat	76.39	76.39	6.84	3.84	0.1	0.623	293.34	29.33	48.69	10.47	4.19	4.19	2.51
Sirdala	246.85	246.85	5.00	2.00	0.1	0.828	493.70	49.37	81.95	44.97	17.99	17.99	10.79
Total	**627.77**						**1632.80**	**125.46**	**208.263**			**36.11**	**21.66**

The total recharge worthy area is 627.77 sq.km and the average post monsoon depth to water level varies from 5-7 m bgl across the four blocks. The annual rainfall is <750 mm in Meskaur and Narhat Blocks and >750mm in Hisua and Sirdala Blocks. As per Dynamic GWRE 2023 of Bihar, the principal aquifer in Hisua, Narhat and Sirdala is alluvium and thus, the specific yield is considered to be 10% and rainfall infiltration factor is 22%. But, in Meskaur the principal aquifer is hard rock and thus, the specific yield is considered to be 2% and rainfall infiltration factor is 10%. The volume of unsaturated zone available for recharge is 1632.80 MCM. Total non-committed surface runoff (volume of water) available for recharge is 36.11 MCM. Considering that only 60% of runoff is feasible, the volume of runoff available for recharge is 21.66 MCM (Table 12.1).

On the basis of available runoff for recharge the number of water conservation and artificial recharge structures that can be constructed in the area has been calculated and their tentative cost has been estimated (Table 12.2). Total 96 percolation tanks, 106 check dams, 217 nala bunds can be constructed in the area. The total cost of construction of these structures will be approximately 38 Crores.

Additionally, de-silting of tanks and ponds can be carried out in the study area which can boost the groundwater health. Traditional Ahar Pyne system of the area can be renovated. Roof Top Rainwater Harvesting can be adopted in the government buildings including government schools etc.

Table 13.2 Number of water conservation structures and tentative cost of construction

	Proposed PT			Proposed CD			Proposed NB			Total Cost
Blocks	**Total volume of Available Water for Recharge through PT (Allocation for PT@60%) (MCM)**	**1. Number of Percolation Tank**	**Cost of PT (lakhs)**	**Total volume of Available Water for Recharge through CD (Allocation for CD@25%) (MCM)**	**2.Number of CD**	**Cost of CD RS (lakhs)**	**Total volume of Available Water for Recharge through NB (MCM) (Allocation for CD@15%) (MCM)**	**3.Number of Nala Bunding**	**Cost of NB (lakhs)**	**In Cr**
Hisua	3.23	24	359	1	26	527	0.81	54	54	9
Meskaur	1.79	13	199	1	15	292	0.45	30	30	5
Narhat	1.51	11	168	1	12	246	0.38	25	25	4
Sirdala	6.48	48	719	3	53	1058	1.62	108	108	19
	13.00	**96**	**1444**	**5**	**106**	**2124**	**3.25**	**217**	**217**	**38**

Chapter 14
Other Measures

It is always essential to address the issue of constraining demand for groundwater abstraction since this will normally contribute more to achieving the groundwater balance.

The concept of real water savings is critical in this regard. The main demand side interventions may be: -

- Modern irrigation practices like drip water irrigation system; sprinklers can be implemented for creating efficiency in irrigation methods applied. Drip irrigation system minimizes water waste and maximizes water use efficiency by reducing evaporation and runoff. It enhances plant growth and yield by providing consistent moisture. Sprinkler irrigation system provides uniform water coverage over large areas.
- Crop choice management and diversification supports groundwater management by balancing water demand, enhancing soil and nutrient management, reducing risks, and promoting sustainable agricultural practices.
- Direct seeding of rice can be done as it reduces water usage compared to traditional transplanting by avoiding continuous flooding, which conserves water and lowers costs.
- Conjunctive use of surface water as well as ground water for irrigation. Conjunctive use of groundwater involves integrating groundwater with surface water resources to optimize water use. By balancing these sources, it enhances overall water availability, reduces reliance on any single source, and improves water management efficiency. This approach helps prevent overexploitation of groundwater, maintains aquifer levels, and supports sustainable water use across different seasons. It also mitigates risks associated with water scarcity and enhances resilience to droughts and climatic variations, leading to more sustainable groundwater management and improved agricultural productivity.
- Special attention should be given towards the already existing structures which have become defunct. These structures unit can be rehabilitated so that it creates a confidence

among the beneficiaries and it can help to boost the overall productivity through multiple cropping pattern.

- Renovating existing ahar and pyne structures—traditional water harvesting systems in India—and addressing defunct structures can significantly enhance groundwater management. By restoring these systems, which capture and direct rainwater to recharge groundwater, efficiency in water storage and distribution is improved. Upgrading or repairing these structures helps maximize rainwater harvesting, reduces surface runoff, and enhances groundwater recharge. This not only improves local water supplies but also mitigates soil erosion and improves agricultural productivity, leading to a more sustainable and resilient groundwater management system.
- De-silting of ponds is beneficial as it helps in removing accumulated silt and sediment to restore their storage capacity and functionality. This process enhances water retention, improves the pond's ability to recharge groundwater. By clearing out silt, de-silting also helps improve water quality.

Chapter 15
Drinking Water Source Sustainability

15.1 Objective:

The study on groundwater sustainability for drinking water sources aims to ensure consistent and long-term access to clean and adequate water for rural communities. The main objective is to improve the "Ease of Living" for rural residents by providing reliable water supplies to households. This goal aligns with the broader mission of delivering drinking water that complies with the Bureau of Indian Standards (BIS10500) for quality and is available in sufficient quantities on a regular and long-term basis.

This initiative is closely linked to the objectives of the Jal Jeevan Mission, a major program by the Ministry of Jal Shakti, Government of India. The Jal Jeevan Mission places a strong focus on empowering communities. It encourages Gram Panchayats (local governance bodies) and rural communities to take charge of planning, implementing, managing, owning, operating, and maintaining their local water supply systems. This community-led approach ensures that water resources are managed sustainably and that local populations play a direct role in securing their water supply.

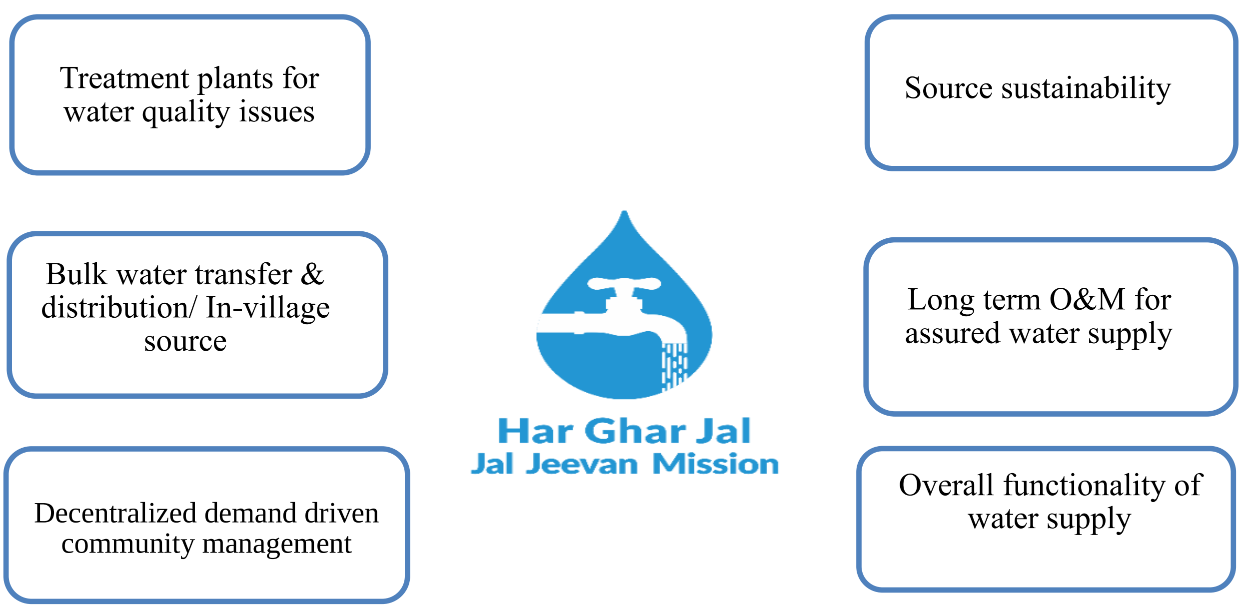


Figure 15.1: Objectives of Jal Jeevan Mission

However, there are several challenges in achieving groundwater sustainability. These include significant variations in rainfall patterns in different seasons and geology across different regions, which affect water availability. The growing population further complicates the situation by decreasing per capita water availability. Moreover, the increasing demand for food, combined with the effects of climate change, places additional strain on water resources, making sustainable management even more critical.

15.2 Methodology:

Maintaining groundwater sources requires extensive water conservation measures and recharge initiatives in villages that rely on groundwater-based water resource schemes. To create a sustainable plan for drinking water sources across different geological terrains, the Standard Operating Procedure (SOP) for Ground Water Source Sustainability, developed by the Central Ground Water Board (CGWB) and the Ministry of Jal Shakti, is followed to conduct a risk assessment of the study area.

15.2.1 Data Collection:

The approach for ensuring the sustainability of water sources starts with gathering essential data, including geotagging, to create a detailed profile of each village's water resources and infrastructure. This process involves recording key details such as the village's name, its precise location (including district, block, and gram panchayat), and its exact geographical coordinates (latitude and longitude). Geotagging these sites allows for precise mapping and continuous monitoring, ensuring data accuracy.

Understanding the geological context is crucial, so information on the village's aquifer type-whether it consists of soft or hard rock is documented. The thickness of the weathered layers or soil, measured in meters, is also noted, as this influences groundwater storage capacity and flow patterns.

The methodology further involves identifying the types of water source structures present in the village, such as dug wells, tube wells, or bore wells. An annual assessment determines the reliability of these water sources throughout the year. Additionally, average daily pumping hours are recorded to help understand water usage patterns, which is vital for evaluating the pressure on water resources.

By applying this methodology, a plan for drinking water source sustainability can be established, ensuring that water supply systems are efficient, resilient, and capable of meeting the long-term needs of the village population.

15.3 Results and Discussions:

15.3.1 Status of Tap Water Supply / "Har Ghar Nal Yojana" (HGNY) Status

The "Har Ghar Nal Yojana" (HGNY) is a key initiative launched by the Government of Bihar with the objective of providing piped drinking water to every rural household. The program is part of a broader effort to ensure that, by 2024, all rural households have access to clean and safe drinking water directly through tap connections. This is based on community participation and the key objective of the scheme is sustainable and efficient water management practices at the local level by providing access to clean and safe drinking water.

The success of "Har Ghar Nal Yojana" is integral to improving the quality of life in rural Bihar by ensuring universal access to clean drinking water, fostering sustainable water use, improving public health, and encouraging community ownership and participation in water resource management.

Table 15.1 Status of Water Supply in Rural Home (As of August 2024)

District	Block	Total No of Households	Household provided with tap water connection through JJM mission	Percentage (%)
Nawada	Hisua	15,462	15,385	99.50%
	Meskaur	14,734	14,395	97.70%
	Narhat	14,434	14,122	97.84%
	Sirdala	27,347	26,975	98.64%

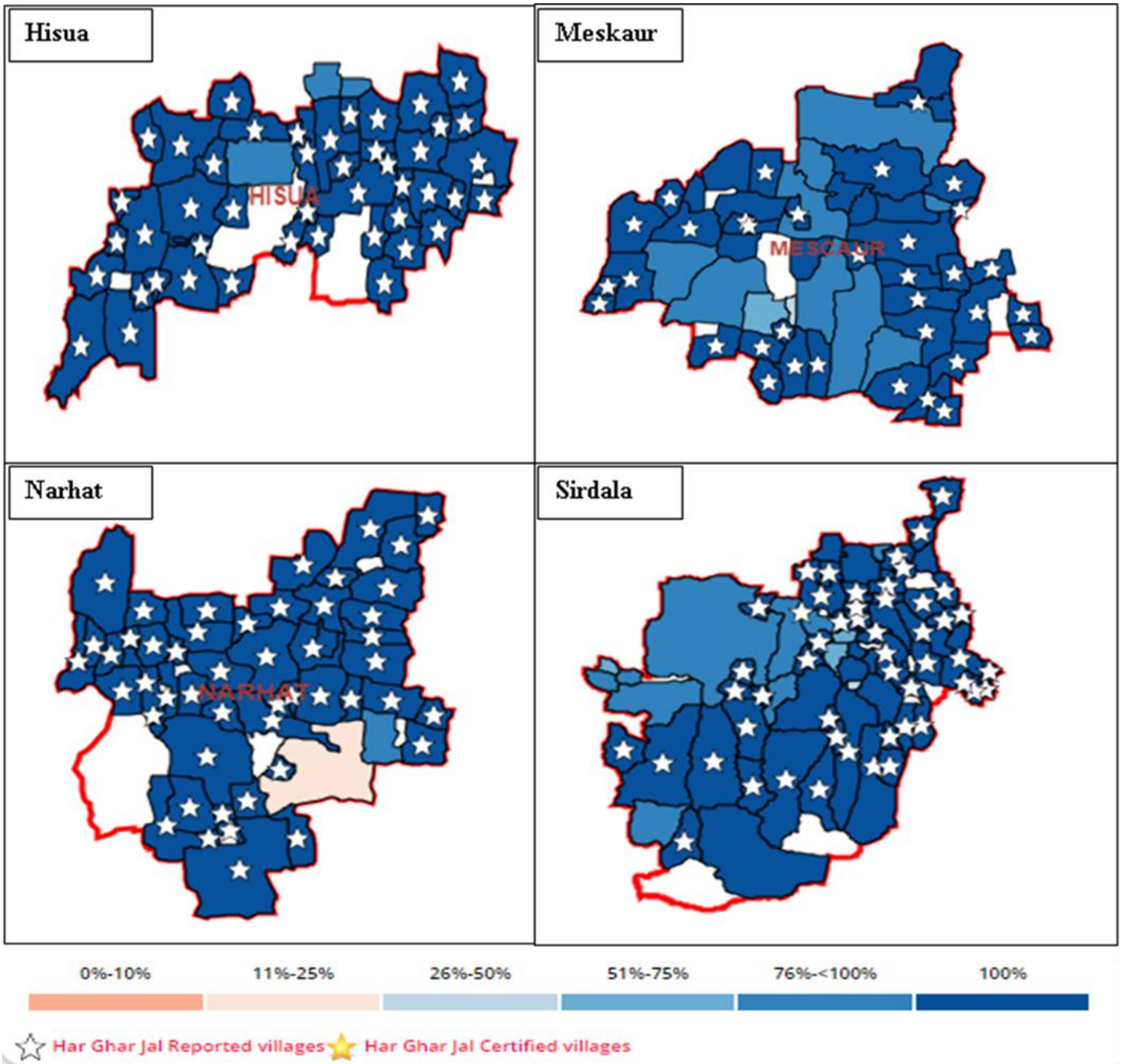


Figure 15.2 Status of tap water supply in rural homes

15.3.2 Risk Assessment

The risk assessment of villages is determined through a series of steps, starting with the analysis of rainfall. The area is categorized based on normal rainfall as being less than 500 mm, 500 – 750 mm and above 750 mm.

If the rainfall is less than 500 mm, the village is categorized as high risk. Rainfall between 500-750 mm or above 750 mm leads to a further evaluation based on the slope of the region. For slope > 20 %, the village is deemed high risk regardless of the rainfall, while slope < 20 % results to further assessment.

Next, well discharge (measured in m3/day) is considered. A well discharge of less than 85 m3/day indicates a high-risk scenario. If the discharge is between 85-250 m3/day or more than 250 m3/day, the assessment moves forward to the consideration of the Depth to Water Level (DTWL).

If there is no data available on DTWL, the village remains in the high-risk category. However, if DTWL data is available, the risk level is further refined. A DTWL greater than 20 meters continues to classify the village as high risk, while a DTWL between 10-20 meters lowers the risk to moderate. Villages with a DTWL of less than 10 meters are considered safe.

This assessment method allows for a layered evaluation, addressing various environmental factors that contribute to the overall risk assessment of villages.

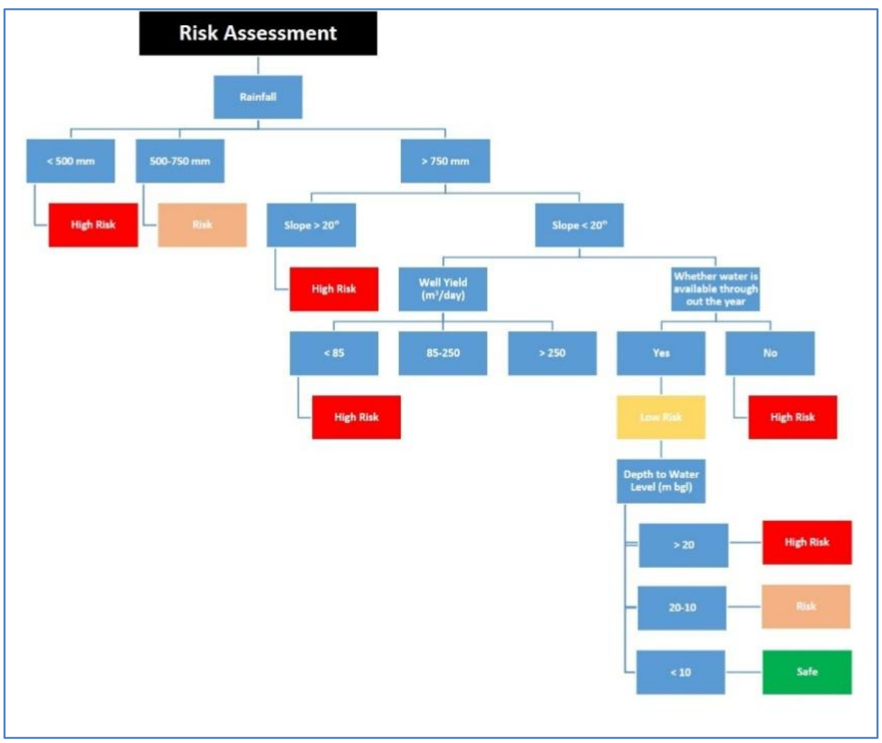


Figure 15.3 Methodology for risk assessment of villages

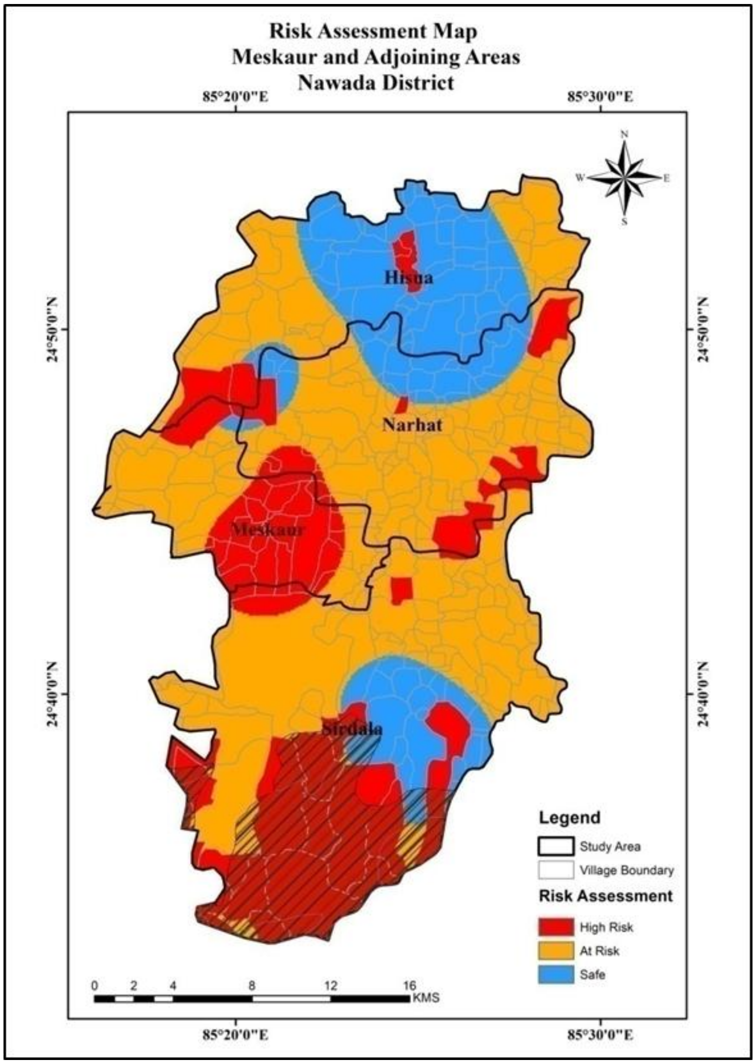


Figure 15.4 Risk Assessment Map of the Study Area

Table 15.2 Risk Assessment and Categorisation of Villages

Category	Villages	Percentage (%)
High Risk	**39**	**(12.19 %)**
Risk	**216**	**(67.5 %)**
Safe	**65**	**(20.31%)**

Based on the SOP for source sustainability of ground water for drinking water sources in the study area, out of 320 villages, 65 villages are in safe category having discharge > 250 m3/day, rainfall>750mm and depth to water level in post-monsoon season less than 10 m bgl.Based on topographic variation, yield of wells, water level behavior in post monsoon and other hydrogeological data from the area, 216 villages are at risk and 39 villages are in high-risk Category for sustainable drinking water supply through ground water.The high risk areas are mainly concentrated in the southern part of the study area (Sirdala Block), bordering the hilly regions and areas with shallow depth to bedrock in major part of Meskaur block.

This study suggests that efforts in water conservation and artificial recharge should target both the alluvial veneer and the underlying weathered zone to ensure the sustainability of the water source in Meskaur and adjoining blocks of Nawada District.

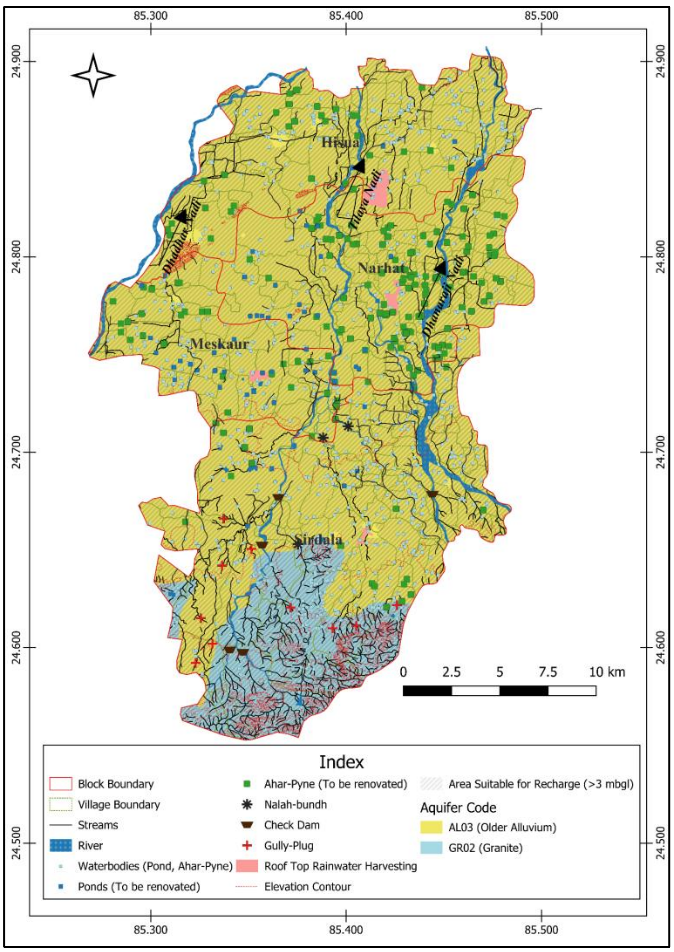


Figure 15.5: Artificial Recharge Plan of the Study Area

Chapter 16
Major findings and Conclusion

- Hydrogeologically, the area is underlain by older alluvium/ weathered residuum, followed by hard rock.
- Hence, two aquifer systems have been demarcated. The alluvium and weathered part of the rock form the Aquifer I (Shallow Aquifer). Thickness of the Aquifer I varies corresponding to the thickness of depth to Bed rock and represented by Dug wells and shallow tube wells. The aquifer is not having much development potential. Fractured Hard rock represent Aquifer II (Deeper Aquifer) and represented by deep borewells, where the secondary porosity is developed and significant. However, fractured aquifers having good ground water potential is very limited in the study area.
- The north eastern part of the study area has comparatively thicker alluvium capping. The depth to bedrock is shallower towards the Western and South-Western part of the district. The maximum value of depth to bedrock has been found to be 60.0 mbgl at Dhamor whereas the minimum value has been inferred to be 2.0 mbgl at Meskaur.
- In Aquifer I, the pre-monsoon water level ranges from 2.75 mbgl in Karamchak of Hisua Block to 18.05 mbgl in Chandra Shekhar Nagar of Hisua Block.The post-monsoon water level ranges from as shallow as 0.9 m bgl in Karamchak of Hisua Block to as deep as 20.15 m bgl in Khanwan of Narhat Block.
- In Aquifer II, the pre-monsoon water level ranges from 4.8 mbgl in Bhiwalpur of Sirdala Block to 36.5 mbgl in Kaithir of Hisua Block. The post-monsoon water level ranges from as shallow as 2 mbgl in Dhiraundh of Sirdala Block to as deep as 31.3 mbgl in Kaithir of Hisua Block.
- Possible presence of thin fractured zone have been noticed from the geophysical prospecting tools ranging in depth from 40 m to 140 mbgl.
- The transmissivity value in Aquifer I is ranging from 1.46 to 418.16 m^2/day, while in Aquifer II, the value is ranging from 149 to 395 m^2/day. These values are based on the pumping test of private irrigation wells and existing CGWB wells.

- In general, the ground water is suitable for drinking purpose. However, the occurrence of fluoride concentration have been noticed in few places. In the Northern part of the study area comprising of Hisua Block all the water samples has F concentration within the permissible limit of 1.5 mg/L as per BIS, 10500. In Meskaur and Narhat Block, six water samples exceed permissible limit of 1.5 mg/L.In the Southern part of the study area, in Sirdala Block excessive fluoride water is widely distributed and13 water samples exceed the permissible limit of fluoride concentration as per BIS, 10500.
- A total of 18% and 12% groundwater samples exceed the permissible limit of 1.5mg/L in pre and post-monsoon respectively. After precipitation, among 12 samples with fluoride concentration more than permissible limit, 11 belong to deeper aquifer. In pre-monsoon, among 19 samples with fluoride concentration more than permissible limit, 14 belong to deeper aquifer. Fluoride concentration ranges from 0.33mg/L to 4.62 mg/L in pre-monsoon. While in post-monsoon, fluoride concentration ranges from 0.118 mg/L to 3.69 mg/L.

Field Photographs

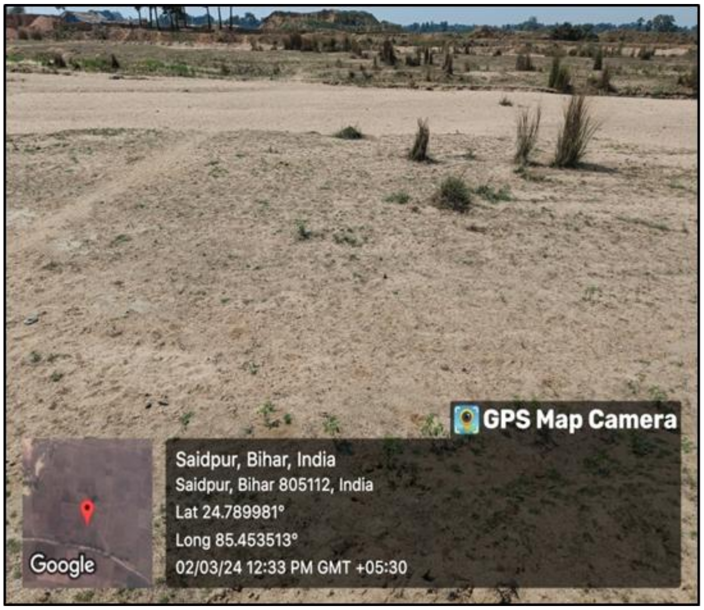
Plate I

Rock Exposures in the Study Area

Plate II

Percolation tank and Pyne structure in the study area

Plate III



River Bed in Meskaur and Adjacent Blocks

Soil Infiltration Test

Plate IV

Pumping test in farmer's borewell

Interaction with farmers

Annexures

Annexure I

Depth to water level (Aquifer I)

Sl.No	Block	Village	Type of Well	Latitude	Longitude	Depth to WL (Pre)	Depth to WL (Post)	Elevation (m)	Water Table (m amsl) Pre	Water Table (m amsl) Post
1	Hisua	Pacharha	DW	24.89558	85.66073	6.4	6.1	88	81.6	81.9
2	Hisua	Chandra Shekhar Nagar	DW	24.86415	85.48417	8.2		89	80.8	
3	Hisua	Chandra Shekhar Nagar	STW	24.86464	85.48198	18.05	14.48	88.9	70.85	74.42
4	Hisua	Sinhin	DW	24.87485	85.4087	7.32	5.04	86.8	79.48	81.76
5	Hisua	Sonsa	STW	24.87229	85.41099	13.5	9.6	96.4	82.9	86.8
6	Hisua	Dona	DW	24.86778	85.38523	3.55	2.1	88	84.45	85.9
7	Hisua	Manjhwe	DW	24.80947	85.32212	3.25	2	107.5	104.25	105.5
8	Hisua	Chitarghati	DW	24.81081	85.34733	4.95	2.45	107.5	102.55	105.05
9	Hisua	Kaithir	DW	24.84643	85.39049	5.2	3.8	94.6	89.4	90.8

Sl.No	Block	Village	Type of Well	Latitude	Longitude	Depth to WL (Pre)	Depth to WL (Post)	Elevation (m)	Water Table (m amsl) Pre	Water Table (m amsl) Post
10	Hisua	Barhauna	DW	24.86005	85.36569	3.97	1.96	89.7	85.73	87.74
11	Hisua	Hadsa	STW	24.87209	85.34514	14	4	87	73	83
12	Hisua	Modi Bigha	DW	24.85616	85.43731	7.25	4.5	86.7	79.45	82.2
13	Hisua	Modi Bigha	STW	24.85621	85.43705	9.2		87.6	78.4	
14	Hisua	Karamchak	STW	25.85569	85.44388	25	12.19	52.6	27.6	40.41
15	Hisua	Karamchak	DW	24.8556	85.44355	2.75	0.9	88.2	85.45	87.3
16	Hisua	Bagodar	STW	24.85845	85.42361	8.3	9.14	84.8	76.5	75.66
17	Hisua	Bagodar	STW	25.85849	85.42548	21		49.7	28.7	
18	Hisua	Baliyari	STW	24.8459	85.43793	21		90.8	69.8	
19	Hisua	Baliyari	DW	24.84709	85.43832	6.9	6.9	91.5	84.6	84.6
20	Hisua	Dhanwan	DW	24.83713	85.44297	5.52	3.74	92.1	86.58	88.36
21	Hisua	Dhanwan	STW	24.83713	85.44297	12.68	13.9	92.1	79.42	78.2
22	Narhat	Bhabnaur	DW	24.84181	85.46902	3.1	3.1	92.3	89.2	89.2
23	Narhat	Punthar	STW	24.8185	85.4535	10.18	13.44	95.8	85.62	82.36

Sl.No	Block	Village	Type of Well	Latitude	Longitude	Depth to WL (Pre)	Depth to WL (Post)	Elevation (m)	Water Table (m amsl) Pre	Water Table (m amsl) Post
24	Narhat	Punthar	DW	24.81904	85.45299	4.2	1.95	97	92.8	95.05
25	Narhat	Milki	STW	24.80576	85.46107	14.7	8.3	99	84.3	90.7
26	Narhat	Milki	DW	24.80606	85.46079	4.45	2.9	99.2	94.75	96.3
27	Narhat	Punaul	DW	24.80156	85.44261	3.5	3.5	103.6	100.1	100.1
28	Narhat	Gangapur	STW	24.78474	85.4413	12	9.14	105.5	93.5	96.36
29	Narhat	Gangapur	DW	24.78619	85.44048	4.9	6.5	105.5	100.6	99
30	Narhat	Chainpura	STW	24.80496	85.40065	12.19	6.76	97	84.81	90.24
31	Narhat	Barauta	STW	24.80617	85.92561	11.75	7.8	132.4	120.65	124.6
32	Narhat	Barauta	DW	24.80715	85.42535	6.7	6.7	98.6	91.9	91.9
33	Narhat	Goasa	DW	24.76803	85.46171	5.3	3.2	110.1	104.8	106.9
34	Narhat	Goasa	STW	24.76803	85.46171	8.72	12.3	110.1	101.38	97.8
35	Narhat	Nawada	DW	24.77782	85.46956	4.5	5.4	109	104.5	103.6
36	Narhat	Walipur	STW	24.7623	85.42379	18	6.65	107.6	89.6	100.95
37	Narhat	Walipur	DW	24.75911	85.42276	6.25	5.4	108.4	102.15	103

Sl.No	Block	Village	Type of Well	Latitude	Longitude	Depth to WL (Pre)	Depth to WL (Post)	Elevation (m)	Water Table (m amsl) Pre	Water Table (m amsl) Post
38	Narhat	Abgil	DW	24.7711	85.40466	5.2	3.7	104.1	98.9	100.4
39	Narhat	Abgil	BW	24.76987	85.40451	24	8.54	106.7	82.7	98.16
40	Narhat	Khanwan	STW	24.74831	85.42944	15	20.15	112.1	97.1	91.95
41	Narhat	Khanwan	DW	24.74317	85.43236	4.3	4	113.6	109.3	109.6
42	Narhat	Narhat	STW	24.76981	85.42518	16.7	8.6	111.6	94.9	103
43	Narhat	Banda Chowk	DW	24.75604	85.43833	4.3	2.4	110.3	106	107.9
44	Narhat	Banda Chowk	STW	24.75565	85.4374	24	8.55	109.2	85.2	100.65
45	Narhat	Jamuara	DW	24.79347	85.41582	4.25	4.25	97	92.75	92.75
46	Narhat	Jamuara	STW	24.79347	85.41582	12	8	97	85	89
47	Sirdala	Berri	DW	24.7213	85.43957	6.4	4.55	122	115.6	117.45
48	Sirdala	Bargawn	DW	24.69747	85.43369	7.02	3.25	128.6	121.58	125.35
49	Sirdala	Bargawn	STW	24.6952	85.43349		12.19	129.3		117.11
50	Sirdala	Ismailpur	DW	24.70707	85.43434	5.9	4.2	124.6	118.7	120.4
51	Sirdala	Ismailpur	STW	24.70868	85.43355	11	4.5	125.3	114.3	120.8

Sl.No	Block	Village	Type of Well	Latitude	Longitude	Depth to WL (Pre)	Depth to WL (Post)	Elevation (m)	Water Table (m amsl) Pre	Water Table (m amsl) Post
52	Sirdala	Sirdala	DW	24.66088	85.41135	5.05	1.8	136.1	131.05	134.3
53	Sirdala	Sonwe	DW	24.67975	85.42133	4.9	3.4	129	124.1	125.6
54	Sirdala	Sonwe	STW	24.67975	85.42133	9		129	120	
55	Sirdala	Akauna	STW	24.67175	85.3978	10.52	4.55	128.8	118.28	124.25
56	Sirdala	Akauna	DW	24.67798	85.39729	7.6	4.4	129	121.4	124.6
57	Sirdala	Bhiwalpur	DW	24.65638	85.39418	4.6	2	141	136.4	139
58	Sirdala	Khanpura	DW	24.68451	85.45186	3.1	2.2	128	124.9	125.8
59	Sirdala	Dhab	DW	24.67579	85.47287	5.7	2.7	134	128.3	131.3
60	Sirdala	Laund	DW	24.70733	85.41216	10.1	7.2	124.8	114.7	117.6
61	Sirdala	Laund	BW	24.70516	85.4135	8	7.2	119.3	111.3	112.1
62	Sirdala	Chaugaon	DW	24.70516	85.4135	4.1	3.5	119.3	115.2	115.8
63	Sirdala	Chaugaon	STW	24.70516	85.4135	8.1	9.96	119.3	111.2	109.34
64	Sirdala	Upardih	DW	24.68897	85.39071	7.5	6.8	125	117.5	118.2
65	Sirdala	Bandhi	DW	24.63568	85.40198	6.8	5.5	144.8	138	139.3

Sl.No	Block	Village	Type of Well	Latitude	Longitude	Depth to WL (Pre)	Depth to WL (Post)	Elevation (m)	Water Table (m amsl) Pre	Water Table (m amsl) Post
66	Sirdala	Dhiraundh	DW	24.65815	85.41579	6	2.4	132.9	126.9	130.5
67	Sirdala	Bairiyatar	DW	24.64734	85.43691	7.15	2.7	144.5	137.35	141.8
68	Sirdala	Ramraichak	DW	24.6175	85.34442	7.8	4.7	152.1	144.3	147.4
69	Sirdala	Nawadih	DW	24.66244	85.36508		6.25	133.2		
70	Sirdala	Chaukiya	DW	24.61155	85.33284	5.6	4.85	159.8	154.2	154.95
71	Sirdala	Khatangi	DW	24.5976	85.31899	9.8	6.8	171.2	161.4	164.4
72	Sirdala	Hathmarwa	DW	24.65194	85.32433	9.2	8.9	152.4	143.2	143.5
73	Sirdala	Angra	DW	24.69415	85.35047	8.5	3.6	128	119.5	124.4
74	Meskaur	Alwan	DW	24.73243	85.35093	8.1	8.1	120.7	112.6	112.6
75	Meskaur	Kaua Bara	DW	24.71477	85.32811	6.5	5.3	130.6	124.1	125.3
76	Meskaur	Barat	DW	24.80133	85.37503	6.6	5.3	103.2	96.6	97.9
77	Meskaur	Barat	STW	24.79989	85.37881	9.5	11.59	98.9	89.4	87.31
78	Meskaur	Shawagpur Sarai	DW	24.79989	85.37881	7.5	6.1	98.9	91.4	92.8
70	Meskaur	Pandey Bigha	STW	24.74803	85.3887	7	3.8	110.2	103.2	106.4

Sl.No	Block	Village	Type of Well	Latitude	Longitude	Depth to WL (Pre)	Depth to WL (Post)	Elevation (m)	Water Table (m amsl) Pre	Water Table (m amsl) Post
80	Meskaur	Pandey Bigha	DW	24.74803	85.3887	5	4.4	110.2	105.2	105.8
81	Meskaur	Merhkuri	DW	24.73934	85.39055	4.6	4.6	112.4	107.8	107.8
82	Meskaur	Rasalpura	DW	24.77485	85.38224	7.5	7.1	103.5	96	96.4
83	Meskaur	Barosar	DW	24.77832	85.31255	2.9	2.2	107.8	104.9	105.6
84	Meskaur	Mirzapur	DW	24.77913	85.27832	5	4.95	113	108	108.05
85	Meskaur	Nimchak	DW	24.76307	85.2996	5.4	4.2	114.4	109	110.2
86	Meskaur	Bisait	DW	24.75423	85.30411	7.1	7.35	112.2	105.1	104.85
87	Meskaur	Meskaur	DW	24.73834	85.35651	4.09	3.5	122.6	118.51	119.1

Annexure II

Depth to Water level (Aquifer II)

Sl.No	Block	Village	Type of Well	Latitude	Longitude	Depth to WL (Pre)	Depth to WL (Post)	Elevation (m)	Water Table (Pre)	Water Table (Post)
1	Hisua	Pacharha	BW	24.89463	85.46512	16.76	14.04	83	66.24	68.96
2	Hisua	BalaBigha	BW	24.86964	85.39127	20.4	15.78	86.5	66.1	70.72
3	Hisua	Manjhwe	BW	24.80966	85.31972	10.55	3.2	105.2	94.65	102
4	Hisua	Kaithir	BW	24.84596	85.38694	36.5	31.3	98	61.5	66.7
5	Narhat	Bhabnaur	BW	24.84221	85.46866	14.15	11.29	94.8	80.65	83.51
6	Narhat	Hasanpur	BW	24.83002	85.47913	12.73	8.35	96.1	83.37	87.75
7	Narhat	Punaul	BW	24.80135	85.44183	12.4	9.2	105	92.6	95.8
8	Narhat	Nawada	BW	24.77778	85.46962	18		109	91	
9	Sirdala	Berri	BW	24.72128	85.43955	7.1	5.25	122	114.9	116.75
10	Sirdala	Sirdala	BW	24.65518	85.40707	6	2.5	138.8	132.8	136.3
11	Sirdala	Bhiwalpur	BW	24.67964	85.42732	4.8	2.7	130.1	125.3	127.4
12	Sirdala	Rajabigha	BW	24.67779	85.44184	5.45	3.3	128	122.55	124.7
13	Sirdala	Khanpura	BW	24.68459	85.95182		21.33	304.5		283.17

Sl.No	Block	Village	Type of Well	Latitude	Longitude	Depth to WL (Pre)	Depth to WL (Post)	Elevation (m)	Water Table (Pre)	Water Table (Post)
14	Sirdala	Dhab	BW	24.67131	85.4739	11.3	6.8	135	123.7	128.2
15	Sirdala	Upardih	BW	24.67619	85.38805	8.15	5	129.3	121.15	124.3
16	Sirdala	Bandhi	BW	24.63536	85.40208	22.5	12.5	146.2	123.7	133.7
17	Sirdala	Dhiraundh	BW	24.65798	85.42516	7.2	2	135.8	128.6	133.8
18	Sirdala	Bairiyatar	BW	24.6473	85.43691	9	4.75	144.3	135.3	139.55
19	Sirdala	Ramraichak	BW	24.61591	85.34474		18.28	152.5		134.22
20	Sirdala	Nawadih	BW	24.66244	85.36508	8.8	7.6	133.2	124.4	125.6
21	Sirdala	Chaukiya	BW	24.62197	85.32206		5.65	149.3		143.65
22	Sirdala	Khatangi	BW	24.5976	85.31899		22.3	171.2		148.9
23	Sirdala	Hathmarwa	BW	24.65194	85.32433		21.8	152.4		130.6
24	Sirdala	Angra	BW	24.69415	85.35047	24	10.32	128	104	117.68
25	Meskaur	Alwan	BW	24.7324	85.34788	14		119.6	105.6	
26	Meskaur	Kaua Bara	BW	24.71477	85.32811	9.3	4.88	130.6	121.3	125.72
27	Meskaur	Shawagpur Sarai	BW	24.79989	85.37881		4.1	98.9		94.8

Sl.No	Block	Village	Type of Well	Latitude	Longitude	Depth to WL (Pre)	Depth to WL (Post)	Elevation (m)	Water Table (Pre)	Water Table (Post)
28	Meskaur	Rasalpura	BW	24.77308	85.38146	16	13.71	107	91	93.29
29	Meskaur	Barosar	BW	24.7783	85.31254		6.15	107.8		101.65
30	Meskaur	Bijubigha	BW	24.74801	85.38805	27.5		110.8	83.3	
31	Meskaur	Mirzapur	BW	24.77913	85.27832		23.3	113		89.7

Annexure III

Chemical analysis of Ground Water samples collected during Pre-Monsoon 2023 (Heavy Metals)

S. No.	Block	Location	Source	Latitude	Longitude	Cr (mg/l)	Fe(mg/l)	Mn(mg/l)	Cu(mg/l)	Zn(mg/l)	As(mg/l)	Pb(mg/l)	U(mg/l)
1	Narhat	Barauta	BW	24.80617	85.42561	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.011
2	Narhat	SaidapurGoasa	BW	24.76803	85.46171	0.055	0.499	0.063	BDL	BDL	BDL	0.002	0.023
3	Narhat	Nawada	HP	24.77778	85.46962	0.002	0.196	0.134	BDL	BDL	BDL	BDL	0.007
4	Narhat	Khanwan	HP	24.74831	85.42944	0.001	BDL	BDL	BDL	BDL	BDL	0.001	0.006
5	Narhat	Narhat	BW	24.76981	85.42518	0.001	0.055	BDL	BDL	BDL	BDL	BDL	0.01
6	Narhat	Banda Chak	BW	24.75565	85.4374	BDL	BDL	BDL	BDL	BDL	BDL	0.001	0.006
7	Narhat	Jamuara	STW	24.79347	85.41582	0.009	6.35	0.307	0.063	5.664	BDL	0.029	0.015
8	Sirdala	Berri	STW	24.7213	85.2341	BDL	0.079	0.057	BDL	0.472	BDL	0.002	BDL
9	Sirdala	Bargawn	DW	24.69747	85.43369	0.001	0.118	BDL	BDL	BDL	BDL	0.002	0.003
10	Sirdala	Ismailpur	HP	24.70707	85.43434	0.002	2.868	BDL	0.049	0.331	BDL	0.028	0.008
11	Sirdala	Sirdala	HP	24.65518	85.40707	BDL	0.623	0.508	BDL	BDL	BDL	BDL	0.048
12	Sirdala	Sirdala	HP	24.65518	85.40707	BDL	1.337	0.186	BDL	BDL	BDL	0.002	0.011
13	Sirdala	Sonwe	HP	24.67975	85.42133	0.002	0.433	BDL	BDL	BDL	BDL	0.001	0.015
14	Sirdala	Sonwe	HP	24.679	85.4213	BDL	0.472	1.179	BDL	0.114	BDL	0.002	0.025

S. No.	Block	Location	Source	Latitude	Longitude	Cr (mg/l)	Fe(mg/l)	Mn(mg/l)	Cu(mg/l)	Zn(mg/l)	As(mg/l)	Pb(mg/l)	U(mg/l)
				75	3								
15	Sirdala	Akauna	HP	24.67175	85.3978	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.011
16	Sirdala	Akauna	HP	24.67175	85.3978	0.003	1.003	BDL	BDL	BDL	BDL	0.003	0.015
17	Sirdala	Bhiwalpur	HP	24.65638	85..39418	BDL	1.182	BDL	BDL	BDL	BDL	0.001	0.004
18	Sirdala	Bhiwalpur	HP	24.65638	85..39419	BDL	1.359	0.7	BDL	0.428	BDL	BDL	0.004
19	Sirdala	Rajabigha	HP	24.67779	85.44184	BDL	0.72	BDL	BDL	BDL	BDL	0.001	0.008
20	Sirdala	Khanpura	HP	24.68451	85.45186	BDL	0.331	0.928	BDL	BDL	BDL	BDL	0.011
21	Sirdala	Khanpura	HP	24.68451	85.45186	BDL	0.749	0.109	BDL	0.085	BDL	0.002	0.021
22	Sirdala	Laund	HP	24.70738	85.41216	0.001	0.234	BDL	BDL	BDL	BDL	0.001	0.008
23	Sirdala	Chaugawan	HP	24.70516	85.4135	0.055	0.891	0.052	0.024	0.461	BDL	0.003	BDL
24	Sirdala	Upardih	BW	24.67619	85.38805	BDL	0.093	BDL	BDL	BDL	0.004	BDL	BDL
25	Sirdala	Bandhi	BW	24.63536	85.40208	BDL	BDL	BDL	BDL	BDL	BDL	0.002	0.015
26	Sirdala	Dhiraundh	HP	24.65798	85.42516	0.005	1.416	0.481	BDL	0.17	BDL	0.003	0.017
27	Sirdala	Dhiraundh	HP	24.65798	85.42516	BDL	0.086	BDL	BDL	BDL	BDL	0.001	0.022
28	Sirdala	Ramraichak	HP	24.6175	85.34442	BDL	0.367	BDL	BDL	0.085	BDL	0.003	0.005
29	Sirdala	Ramraichak	HP	24.6175	85.34442	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.031

S. No.	Block	Location	Source	Latitude	Longitude	Cr (mg/l)	Fe(mg/l)	Mn(mg/l)	Cu(mg/l)	Zn(mg/l)	As(mg/l)	Pb(mg/l)	U(mg/l)
30	Sirdala	Chaukiya	DW	24.61155	85.33284	0.007	0.154	BDL	BDL	BDL	BDL	0.002	0.035
31	Sirdala	Chaukiya	DBW	24.61155	85.33284	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.037
32	Sirdala	Khatangi	HP	24.5976	85.31899	BDL	0.279	BDL	BDL	0.103	BDL	BDL	0.06
33	Sirdala	Hathmarwa	HP	24.65194	85.32433	BDL	0.398	BDL	BDL	0.098	BDL	0.001	0.022
34	Sirdala	Hathmarwa	BW	24.65194	85.32433	BDL	BDL	BDL	BDL	0.091	BDL	0.001	0.022
35	Sirdala	Angra	HP	24.69415	85.35047	BDL	0.974	BDL	BDL	BDL	BDL	BDL	0.121
36	Sirdala	Angra	HP	24.69415	85.35047	BDL	0.996	BDL	BDL	0.675	BDL	0.002	0.013
37	Meskaur	Alwan	HP	24.7324	85.34788	BDL	BDL	BDL	BDL	BDL	BDL	0.001	0.013
38	Meskaur	Kaua Bara	HP	24.71477	85.32811	0.001	0.725	BDL	BDL	BDL	BDL	0.001	0.022
39	Meskaur	Kaua Bara	bw	24.71477	85.32811	BDL	0.052	BDL	BDL	BDL	BDL	0.002	0.016
40	Meskaur	Barat	HP	24.80133	85.37503	0.002	1.118	0.098	BDL	0.108	0.001	0.001	0.019
41	Meskaur	Barat	HP	24.80133	85.37503	0.01	0.303	BDL	BDL	0.304	0.002	0.003	BDL
42	Meskaur	Satiwazpur Sarai	HP	24.79989	85.37881	0.004	1.267	0.074	BDL	0.073	BDL	0.001	0.006
43	Meskaur	Satiwazpur Sarai	BW	24.79989	85.37881	BDL	0.124	0.073	BDL	BDL	BDL	0.001	0.005
44	Meskaur	Pandeybigha	HP	24.74803	85.3887	0.011	1.4	BDL	BDL	0.058	BDL	0.002	BDL
45	Meska	Pandeybigha	BW	24.748	85.3887	0.005	0.35	BDL	BDL	BDL	BDL	0.004	BDL

S. No.	Block	Location	Source	Latitude	Longitude	Cr (mg/l)	Fe(mg/l)	Mn(mg/l)	Cu(mg/l)	Zn(mg/l)	As(mg/l)	Pb(mg/l)	U(mg/l)
	ur			03									
46	Meskaur	Merhkuri	HP	24.73934	85.39055	0.003	0.598	BDL	BDL	BDL	BDL	0.002	0.005
47	Meskaur	Merhkuri	BW	24.73934	85.39055	BDL	BDL	BDL	BDL	BDL	BDL	0.001	0.006
48	Meskaur	Rasalpura	HP	24.77308	85.38146	BDL	0.538	0.067	BDL	0.085	BDL	0.002	0.01
49	Meskaur	Rasalpura	BW	24.77308	85.38146	0.005	0.421	0.268	BDL	BDL	BDL	0.002	0.008
50	Meskaur	Barosar	HP	24.77832	85.31255	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.02
51	Meskaur	Mirzapur	HP	24.77913	85.27832	0.002	1.017	BDL	BDL	0.171	BDL	BDL	0.004
52	Meskaur	Mirzapur	BW	24.77913	85.27832	BDL	BDL	BDL	BDL	BDL	BDL	0.002	0.006
53	Meskaur	Nimchak	HP	24.76307	85.2996	BDL	0.213	0.186	BDL	0.06	BDL	BDL	0.015
54	Meskaur	Laxmanbigha	HP	24.76093	85.31508	0.001	1.572	0.069	BDL	0.252	BDL	0.003	0.009
55	Meskaur	Meskaur	DW	24.73834	85.35651	0.002	0.156	BDL	BDL	BDL	0.001	BDL	0.008
56	Meskaur	Meskaur	HP	24.73834	85.35651	BDL	0.949	BDL	BDL	0.317	BDL	0.003	0.005

Annexure IV

Chemical analysis of Ground Water samples collected during Post-Monsoon 2023 (Heavy Metals)

S. No.	Block	Location	Source	Latitude	Longitude	Cr (mg/l)	Fe(mg/l)	Mn(mg/l)	Cu(mg/l)	Zn(mg/l)	As(mg/l)	Pb(mg/l)	U(mg/l)
1	Hisua	Manjhwe	BW	24.8097	85.3197	0.00149	0.29311	BDL	BDL	BDL	BDL	BDL	0.00582
2	Narhat	Bhabnaur	BW	24.8422	85.4687	0.00385	BDL	BDL	BDL	0.1471	BDL	BDL	0.01587
3	Narhat	Punthar	BW	24.8185	85.4535	0.00161	0.24374	BDL	BDL	0.15806	BDL	0.00114	0.00846
4	Narhat	Milki	BW	24.8058	85.4611	0.00226	0.19899	BDL	BDL	BDL	BDL	BDL	0.00923
5	Narhat	Gangapur	BW	24.7847	85.4413	BDL	0.53346	0.10487	BDL	BDL	0.00591	BDL	BDL
6	Narhat	Chainpura	BW	24.805	85.4007	0.0012	0.10516	BDL	BDL	0.17548	BDL	BDL	0.00782
7	Narhat	Nawada	HP	24.7778	85.4696	BDL	BDL	BDL	BDL	0.07009	BDL	BDL	0.01995
8	Narhat	Abgil	BW	24.7699	85.4045	0.00224	0.06557	BDL	BDL	BDL	BDL	BDL	0.00993
9	Narhat	Banda Chowk	BW	24.7556	85.4374	0.00276	1.81936	0.0548	BDL	BDL	0.00133	0.0054	0.0073
10	Sirdala	Ismailpur	HP	24.7071	85.4343	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
11	Sirdala	Akauna	BW	24.6717	85.3978	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.01081
12	Sirdala	Bhiwalpur	HP	24.6564	85.3942	0.001	0.25031	BDL	BDL	BDL	0.0015	BDL	0.00516
13	Sirdala	Dhab	BW	24.671	85.4739	BDL	0.3896	BDL	BDL	BDL	0.0015	BDL	0.005

S. No.	Block	Location	Source	Latitude	Longitude	Cr (mg/l)	Fe(mg/l)	Mn(mg/l)	Cu(mg/l)	Zn(mg/l)	As(mg/l)	Pb(mg/l)	U(mg/l)
				3			3						56
14	Sirdala	Laund	BW	24.7052	85.4135	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.00358
15	Sirdala	Chaugaon	BW	24.7052	85.4135	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
16	Sirdala	Ramraichak	HP	24.6175	85.3444	0.00153	0.47645	0.05225	BDL	0.10379	BDL	BDL	0.00519
17	Sirdala	Nawadih	BW	24.6624	85.3651	0.00103	BDL	0.15741	BDL	BDL	BDL	BDL	0.01447
18	Sirdala	Hathmarwa	BW	24.6519	85.3243	0.00163	BDL	BDL	BDL	0.1289	BDL	BDL	0.01828
19	Sirdala	Angra	BW	24.6942	85.3505	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.01429
20	Meskaur	Rasalpura	BW	24.7731	85.3815	0.00125	BDL	BDL	BDL	BDL	BDL	BDL	0.0073
21	Meskaur	Meskaur	HP	24.7383	85.3565	0.00444	0.64858	BDL	BDL	0.3298	BDL	BDL	BDL
22	Sirdala	Majhauli	BW	24.6807	85.3651	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
23	Hisua	Pacharha	BW	24.8946	85.4651	0.00721	0.5316	BDL	BDL	BDL	BDL	BDL	0.00723
24	Hisua	Chandra Shekhar Nagar	BW	24.8646	85.482	0.01635	5.92635	0.13315	BDL	BDL	BDL	0.00316	0.00656
25	Hisua	Modi Bigha	BW	24.8562	85.4371	0.00964	BDL	BDL	BDL	BDL	BDL	BDL	0.01088
26	Hisua	Karamchak	DW	24.8556	85.4436	0.00648	0.18424	1.47083	BDL	BDL	0.00129	BDL	0.00804
27	Hisua	Dhanwan	DW	24.8371	85.443	0.0062	BDL	BDL	BDL	BDL	BDL	BDL	0.01191

S. No.	Block	Location	Source	Latitude	Longitude	Cr (mg/l)	Fe(mg/l)	Mn(mg/l)	Cu(mg/l)	Zn(mg/l)	As(mg/l)	Pb(mg/l)	U(mg/l)
28	Hisua	Dhanwan	HP	24.8371	85.443	0.00735	0.90428	BDL	BDL	0.19948	BDL	0.00124	0.01508

Annexure V

Summary of Farmers' Feedback

Sl No.	Block	Village	Latitude	Longitude	Depth of Well (in meters)	Depth of installation of Pump (in meters)	Casing Depth (in meters)	Slotted depth/ Fracture encountered depth (in meters)	Pre monsoon water level(mbgl)	Post monsoon water level (mbgl)	Pumping duration (Rabi)			Pumping duration (Kharif)		
											No. of Days	Hours	Discharge (in lps)	No. of Days	Hrs	Discharge (in lps)
1	Hisua	Pacharha	24.89	85.47		45.72	24.39		22.25	12.20	50	10	0.35			
2	Hisua	Chandra Shekhar Nagar	24.86	85.48		29.00	39.60		18.05	12.20	60	12		40	15	
3	Hisua	Doman Bigha	24.87	85.42		7.70	9.20		8.00	5.50	30	4	0.83	10		
4	Hisua	Hadsa	24.87	85.35		24.40	30.50		12.20	4.50	45	8	1.67	30	6	2.50
5	Hisua	Tungi	24.81	85.31	36.50	24.40	18.30		15.24	9.20	5	20		0	0	0.00
6	Hisua	UmraoBigha	24.81	85.35	61.00	30.00	33.00		16.80	6.10	45	20		10	5	
7	Hisua	Modi Bigha			12.20	4.57	12.20		12.50	7.60	64	6	0.75	16	3	1.25
8	Hisua	Bagodar	25.86	85.43	33.50	22.86	32.00	32-33.5	11.00	4.50	20	14		0	0	
9	Narh	Bhabna	24.8	85.47	39.6	35.05	36.6	36.6-	15.24	6.00	20	8	1.67	0	0	

Sl No.	Block	Village	Latitude	Longitude	Depth of Well (in meters)	Depth of installation of Pump (in meters)	Casing Depth (in meters)	Slotted depth/ Fracture encountered depth (in meters)	Pre monsoon water level(mbgl)	Post monsoon water level (mbgl)	Pumping duration (Rabi)			Pumping duration (Kharif)		
											No. of Days	Hours	Discharge (in lps)	No. of Days	Hrs	Discharge (in lps)
	at	ur	4		0		0	39.6								
10	Narhat	Chatar	24.84	85.49	44.50	42.60	44.00									
11	Narhat	Punthar	24.81	85.45	45.70	80.00	45.70		12.20	4.50	15	20	0.75			
12	Narhat	Gangapur	24.79	85.44	36.50	33.00	36.50	HR after 36.5	15.24	3.70	90	6	0.83	60	3	
13	Narhat	Chainpura	24.80	85.40	21.50	10.67	10.67	HR after 21.5	18.30	9.20	30	3	0.66	20	2	
14	Narhat	Barauta	24.81	85.43	30.50	21.30	21.30		15.24	6.10	90	6		10	1	
15	Narhat	Saidpur Goasa	24.77	85.46			9.20		12.20	4..5	45	20	1.10	90	20	1.60
16	Narhat	Abgil	24.77	85.41	33.50	30.50	18.30	HR after 33.5	27.40	11.00	10	20	5.00	15	5	6.00
17	Narhat	Khanwan	24.75	85.43	30.50	18.30	18.30	HR after 30	15.20	6.10	90	5				
18	Narh	Narhat	24.7	85.43	33.5	24.50		HR	21.30	7.60	45	10		30	5	

Sl No.	Block	Village	Latitude	Longitude	Depth of Well (in meters)	Depth of installation of Pump (in meters)	Casing Depth (in meters)	Slotted depth/ Fracture encountered depth (in meters)	Pre monsoon water level(mbgl)	Post monsoon water level (mbgl)	Pumping duration (Rabi)			Pumping duration (Kharif)		
											No. of Days	Hours	Discharge (in lps)	No. of Days	Hrs	Discharge (in lps)
	at		7		0			after 33.5								
19	Narhat	Jamuara	24.79	85.42	27.00	23.00	26.00	20-26	16.70	12.10	35	7	1.60	25	5	3.20
20	Sirdala	Berri	24.72	85.44	35.00	24.00	30.50	27.4-30.4	18.30	9.10	70	18	1.16	30	11	1.67
21	Sirdala	Bargawn	24.69	85.43	21.00	12.20	20.00	13.7-19.8	12.20	4.60	20	15		12	5	
22	Sirdala	Sonwe	24.68	85.42	18.30	15.00		15-18	12.20	4.60	30	10	1.00	5	5	2.00
23	Sirdala	Akauna	24.67	85.40	23.00	18.00	23.00	16-22	15.20	10.60						
24	Sirdala	Chaugaon	24.71	85.41	18.30	10.67	18.30	12--18	18.30	7.00	60	17	1.34	30	9	1.83
25	Sirdala	Dhiraundh	24.66	85.43	15.24	12.20	15.24	12--15	12.20	3.00	30	16	83.33	10	4	1.33
26	Sirdala	Khatangi	24.60	85.32	12.20	9.10	10.67	8--12	10.67	3.05	70	20	1.00	12	6	1.41
27	Sirdala	Angra	24.69	85.35	85.00	28.00	24.50	No Slot	24.50	12.00	80	15	1.33	15	5	1.60
28	Mes	Alwan	24.7	85.35	42.6	33.50	13.7	No Slot	13.50	3.70	30	5	0.33	10	3	0.66

Sl No.	Block	Village	Latitude	Longitude	Depth of Well (in meters)	Depth of installation of Pump (in meters)	Casing Depth (in meters)	Slotted depth/ Fracture encountered depth (in meters)	Pre monsoon water level(mbgl)	Post monsoon water level (mbgl)	Pumping duration (Rabi)			Pumping duration (Kharif)		
											No. of Days	Hours	Discharge (in lps)	No. of Days	Hrs	Discharge (in lps)
	kaur		3		0		0									
29	Meskaur	Laxman Bigha	24.76	85.32	30.50	20.00	24.40	24.4-30.5			80	20	0.20	70	4	0.33
30	Sirdala	Bargawn	24.70	85.43	21.50	19.50		15-21	9.00	6.00	3	12	1.70	40	10	2.00
31	Narhat	Barauli	24.79	85.43	30.50	6.00			18.20	12.00	4	10		90	15	
32	Narhat	Walipur	24.76	85.42		29.00		23-29	15.00	18.00	4	20		90	20	
33	Meskaur	Alwan	24.73	85.35	61.00	46.00	16.70	No Slot	24.00	9.00	90	5				
34	Hisua	Manjhwe	24.82	85.32			30.50		12.00	6.00	2	20		11	20	
35	Hisua	ChakSinhin	24.87	85.40		30.50	31.00		24.30		30	20		15	24	

Annexure-VI

Depth to Hard Rock (m bgl)

Sl.No.	Block	Village	Latitude	Longitude	Depth to Hard Rock (m)
1	Narhat	Kusha	24.792461	85.427764	47
2	Narhat	Beldariya	24.841622	85.419	44
3	Narhat	Kusha	24.784161	85.431081	53
4	Hisua	MalukaBigha	24.866864	85.469811	41
5	Hisua	Bal KishunBigha	24.868653	85.480989	43
6	Hisua	MalukaBigha	24.866864	85.469811	47
7	Narhat	Ibrahimpur	24.772425	85.429839	37
8	Narhat	Bazitpur	24.765628	85.436828	40
9	Hisua	Dona	24.863161	85.391181	45
10	Hisua	Dona	85.391181	85.391181	45
11	Narhat	Punther	24.808892	85.460764	37
12	Narhat	Taropur	24.79995	85.464864	43
13	Narhat	Santi Nagar	24.866697	85.526117	45
14	Narhat	Baluhai, Hasratpur	24.785344	85.476047	54
15	Narhat	Milki	24.789411	85.356278	40
16	Meskaur	Belwan	24.77626	85.33329	30
17	Meskaur	Medhkuri	24.732883	85.389808	30
18	Meskaur	MedhkuriTola	24.73941	85.3881	25

Sl.No.	Block	Village	Latitude	Longitude	Depth to Hard Rock (m)
19	Meskaur	Tekpur	24.809633	85.374453	18
20	Meskaur	Rasalpura	24.7652	85.3884	24
21	Meskaur	LachhuBigha	24.76829	85.3649	27
22	Meskaur	Sitamarhi	24.769578	85.356608	34
23	Meskaur	Katgara	24.776128	85.357547	35
24	Meskaur	Bodhi Bigha	24.765231	85.3466	27
25	Meskaur	Meskaur (Block side)	24.736842	85.354517	20
26	Sirdala	Meskaur (Eastern Side)	24.741594	85.36286	20
27	Sirdala	Paroriya	24.732433	85.393097	32
28	Sirdala	Sahpur	24.656661	85.386319	40
29	Sirdala	Upardih	24.68235	8538844	43
30	Sirdala	Hajara	24.703458	85.422464	26
31	Sirdala	Bhita	25.30996	85.79003	32
32	Sirdala	BadhiBigha	24.67132	85.40928	33
33	Sirdala	Akauna	24.89603	85.81025	32
34	Sirdala	Khatangi	24.586783	85.331234	33
35	Sirdala	Bilarpur	24.68225	85.38855	33
36	Sirdala	Kendua	24.68732	85.40274	24
37	Sirdala	Laund	24.70054	85.40396	28
38	Sirdala	Hathmarwa	24.65228	85.32468	24

Annexure-VII

Soil Infiltration Rates at various locations in the study area

S.No	Block	Location	Latitude	Longitude	Rate of Infiltration (mm/min)	Type of Soil
1	Narhat	Walipur	24.758367	85.424190	1.85	Clayey with fine sand
2	Sirdala	Bhabninagwa	24.655710	85.403221	1.95	Clay (Kewal Mitti)
3	Meskaur	Gangabara	24.752154	85.350721	5.2	Clay (Kewal Mitti)
4	Hisua	Manjhwe	24.807912	85.326387	5.0	Clayey soil mixed with fine sand
5	Hisua	Sonsa	24.871327	85.414823	3.7	Loamy Soil
6	Narhat	Gangta	24.794385	85.453484	7.3	Fine-Medium Loamy Soil
7	Meskaur	Alwan	24.732808	85.351251	7.35	Fine grained Loamy Soil

Annexure-VIII

Details of EW/OW constructed during previous in-house drilling.

Location	Latitude	Longitude	Depth Drilled (m bgl)	Discharge (m3/hr)	Fracture Encountered Depth (m bgl)	Transmissivity (m2/day)	Storativity
Sirdala	24.6575	85.4072	193	18		395	
Majhwe, Hisua	24.8032	85.3389	117	17.38		149	2.24X10-4
Meskaur EW1	24.7403	85.3573	190	1.5			
Meskaur EW2	24.7403	85.3573	191				

Details of EW/OW constructed during current AAP by in-house drilling.

Location	Latitude	Longitude	Depth Drilled (m bgl)	Discharge (m3/hr)	Fracture Encountered Depth (m bgl)	Casing Depth (m bgl)	Transmissivity (m2/day)
Jhikaruya,Narhat (EW)	24.81831	85.423532	200.8	15.84	50.3-53.4 102.2-105.2	41.2	
Jhikaruya,Narhat (OW)	24.81831	85.423532	123.5	15.84	68.6-71.7 96.0-99.0	38.75	
Meskaur EW	24.737259	85.353246	202.8	0.828	56.4-59.5 59.5-62.5	12.1	
Sitamarhi, Meskaur EW	24.770385	85.356398	202.8	1.692	41.2-44.2	6.05	

Annexure IX

Details of pumping test conducted at farmer's borewells

Block	Village	Latitude	Longitude	Water Level (m bgl)	Discharge (lps)	Drilling Depth (m bgl)	Depth to bed rock Reported (m bgl)	Transmissivity (m^2/day)
Hisua	Manjhwe	24.818127	85.322180	6.5	1.79	24.38	24.38	91.94
Hisua	Sinhin	24.873343	85.395792	9.25	3.35	39.62		61.32
Narhat	Narhat	24.776352	85.426437	9.23	1.36	30.48	33.5	312
Meskaur	Alwan	24.725331	85.348991	9.56	0.625	35.05	10.66	1.46
Sirdala	Bargaon	24.699379	85.434573	6.94	1.87	21.33	21.33	418.16
Sirdala	Parnadabar	24.64571	85.35461	8.19	1.6	12.19		191.02

Annexure X

Litholog used for cross section

Borewell	Latitude	Longitude	Depth (m)		Lithology
			From	To	
Sitamarhi	24.7704	85.3564	0	1.5	Clay
			1.5	1.5	Fine Sand
			1.5	1.5	Coarse Sand
			1.5	202.8	Granite Gneiss
Rasalpura	24.7652	85.3884	0	10	Clay
			10	24	Fine Sand
			24	24	Coarse Sand
			24	94.5	Granite Gneiss
Bazitpur	24.7656	85.4368	0	11	Clay
			11	24	Fine Sand
			24	40	Coarse Sand
			40	43	Granite Gneiss
Meskaur	24.7373	85.3532	0	10.7	Clay
			10.7	10.7	Fine Sand
			10.7	10.7	Coarse Sand
			10.7	200.8	Granite Gneiss
Jhikauriya	24.8183	85.4235	0	19.8	Clay

Borewell	Latitude	Longitude	Depth (m)		Lithology
			From	To	
			19.8	29	Fine Sand
			29	41.2	Coarse Sand
			41.2	200.8	Granite Gneiss
MalukaBigha	24.8669	85.4698	0	9	Clay
			9	26	Fine Sand
			26	47	Coarse Sand
			47	50	Granite Gneiss
Banglapar	24.7758	85.4219	0	10	Clay
			10	25	Fine Sand
			25	46	Coarse Sand
			46	49	Granite Gneiss
BadhiBigha	24.6713	85.4093	0	6	Clay
			6	16	Fine Sand
			16	16	Coarse Sand
			16	98	Granite Gneiss
Bilarpur	24.6823	85.3886	0	10	Clay
			10	23	Fine Sand
			23	23	Coarse Sand
			23	97	Granite Gneiss
Hathmarwa	24.6523	85.3247	0	11	Clay
			11	24	Fine Sand

Borewell	Latitude	Longitude	Depth (m)		Lithology
			From	To	
			24	24	Coarse Sand
			24	103	Granite Gneiss
Rajan	24.7211	85.4523	0	18	Clay
			18	24	Fine Sand
			24	36	Coarse Sand
			36	37	Granite Gneiss
Baluhai	24.7853	85.476	0	25	Clay
			25	36	Fine Sand
			36	53	Coarse Sand
			53	56	Granite Gneiss

Annexure XI

Lithological data from wells of PHED

Sl.No.	Village	ward No.	Block	Latitude	Longitude	Depth Drilled (m)	Depth Constructed (m)	Zones tapped (m)	Discharge (lps)	Litholog		
										Depth (in m)		Type
										From	To	
1	Kusha	14	Narhat	25	85.43	50	46	29-46	3	0	13	Clay
										13	29	Fine Sand
										29	47	Coarse Sand
										47	50	Hard rock (Granite Gneiss)
2	Beldariya	2	Narhat	25	85.42	47	43	26-43	3	0	11	Clay
										11	26	Fine Sand
										26	44	Coarse Sand
										44	47	Hard rock (Granite Gneiss)
3	Kusha	13	Narhat	25	85.43	56	52	32-52	3	0	14	Clay
										14	32	Fine Sand
										32	53	Coarse Sand
										53	56	Hard rock (Granite Gneiss)
4	Anganwari Centre	16	Narhat			43	40	24-40	3.2	0	10	Clay
										10	24	Fine Sand
										24	41	Coarse Sand

Sl.No.	Village	ward No.	Block	Latitude	Longitude	Depth Drilled (m)	Depth Constructed (m)	Zones tapped (m)	Discharge (lps)	Litholog		
										41	43	Hard rock (Granite Gneiss)
5	MalukaBigha	14	Hisua	25	85.47	44	41	23-41	3	0	9	Clay
										9	23	Fine Sand
										23	41`	Coarse Sand
										41	44	Hard rock (Granite Gneiss)
6	Bal KishunBigha	15B	Hisua	25	85.48	47	43	26-43	3	0	8	Clay
										8	26	Fine Sand
										26	44	Coarse Sand
										44	47	Hard rock (Granite Gneiss)
7	MalukaBigha	15A	Hisua	25	85.47	50	47	26-47		0	9	Clay
										9	26	Fine Sand
										26	47	Coarse Sand
										47	50	Hard rock (Granite Gneiss)
8	Manohar Bigha	13	Hisua			44	41	23-41	4	0	8	Clay
										8	23	Fine Sand
										23	41	Coarse Sand
										41	44	Hard rock (Granite Gneiss)
9	Meenapur	3	Narhat			34	31	15-30		0	10	Clay
										10	15	Fine Sand

Sl.No.	Village	ward No.	Block	Latitude	Longitude	Depth Drilled (m)	Depth Constructed (m)	Zones tapped (m)	Discharge (lps)	Litholog		
										15	31	Coarse Sand
										31	34	Hard rock (Granite Gneiss)
10	Mohan Nagar	12	Narhat			49	46	25-43	3	0	12	Clay
										12	25	Fine Sand
										25	46	Coarse Sand
										46	49	Hard rock (Granite Gneiss)
11	Dargahpar	11	Narhat			52	49	28-46	3	0	12	Clay
										12	28	Fine Sand
										28	49	Coarse Sand
										49	52	Hard rock (Granite Gneiss)
12	Banglapar	12	Narhat	25	85.42	49	46	25-43	3	0	10	Clay
										10	25	Fine Sand
										25	46	Coarse Sand
										46	49	Hard rock (Granite Gneiss)
13	Machinepur	13	Narhat			40	37	21-36	3	0	10	Clay
										10	21	Fine Sand
										21	37	Coarse Sand
										37	40	Hard rock (Granite Gneiss)

Sl.No.	Village	ward No.	Block	Latitude	Longitude	Depth Drilled (m)	Depth Constructed (m)	Zones tapped (m)	Discharge (lps)	Litholog		
14	Chandani More	14	Narhat	25	85.43	43	40	24-39	3	0	11	Clay
										11	24	Fine Sand
										24	40	Coarse Sand
										40	43	Hard rock (Granite Gneiss)
15	Madanpur	15	Narhat			40	37	21-36	3	0	10	Clay
										10	21	Fine Sand
										21	37	Coarse Sand
										37	40	Hard rock (Granite Gneiss)
16	Ibrahimpur	16	Narhat	25	85.43	40	37	21-36	3	0	10	Clay
										10	21	Fine Sand
										21	37	Coarse Sand
										37	40	Hard rock (Granite Gneiss)
17	Bazitpur	8	Narhat	25	85.44	43	40	24-39	3	0	11	Clay
										11	24	Fine Sand
										24	40	Coarse Sand
										40	43	Hard rock (Granite Gneiss)
18	Dhergaon	10	Narhat			46	43	27-42	3	0	12	Clay
										12	27	Fine Sand
										27	43	Coarse Sand
										43	46	Hard rock (Granite

Sl.No.	Village	ward No.	Block	Latitude	Longitude	Depth Drilled (m)	Depth Constructed (m)	Zones tapped (m)	Discharge (lps)	Litholog		
												Gneiss)
19	Dona	6	Hisua	25	85.39	48	45	30-45	3.5	0	4	Clay
										4	30	Fine Sand
										30	45	Coarse Sand
										45	48	Hard rock (Granite Gneiss)
20	Dona	1	Hisua	85	85.39	46	43	31-43	3.5	0	4	Clay
										4	31	Fine Sand
										31	43	Coarse Sand
										43	46	Hard rock (Granite Gneiss)
21	Dona	2	Hisua	85	85.39	48	45	30-45	3.5	0	4	Clay
										4	30	Fine Sand
										30	45	Coarse Sand
										45	48	Hard rock (Granite Gneiss)
22	Dona	6	Hisua	85	85.39	48		30-45	3.5	0	4	Clay
										4	30	Fine Sand
										30	45	Coarse Sand
										45	48	Hard rock (Granite Gneiss)
23	Punther	1	Narhat	25	85.46	39	37	22-36	3.2	0	18	Clay
										18	26	Fine Sand

Sl.No.	Village	ward No.	Block	Latitude	Longitude	Depth Drilled (m)	Depth Constructed (m)	Zones tapped (m)	Discharge (lps)	Litholog		
										26	36	Coarse Sand
										36	39	Hard rock (Granite Gneiss)
24	Hamidpur	3	Narhat			51	49	31-49	3.2	0	26	Clay
										26	32	Fine Sand
										32	48	Coarse Sand
										48	51	Hard rock (Granite Gneiss)
25	Hamidpurwara	4A	Narhat			54	52	34-50	3.2	0	24	Clay
										24	33	Fine Sand
										33	50	Coarse Sand
										50	54	Hard rock (Granite Gneiss)
26	KajuBigha	10B	Narhat			48	46	28-45	3	0	25	Clay
										25	33	Fine Sand
										33	45	Coarse Sand
										45	48	Hard rock (Granite Gneiss)
27	Taropur	8	Narhat	25	85.46	42	40	25-39		0	19	Clay
										19	27	Fine Sand
										27	39	Coarse Sand
										39	42	Hard rock (Granite Gneiss)
28	Taropur	9	Narhat	25	85.46	45	43	28-42	3	0	24	Clay

Sl.No.	Village	ward No.	Block	Latitude	Longitude	Depth Drilled (m)	Depth Constructed (m)	Zones tapped (m)	Discharge (lps)	Litholog		
										24	32	Fine Sand
										32	42	Coarse Sand
										42	45	Hard rock (Granite Gneiss)
29	Levar Hasratpur	15A	Narhat			48	46	28-45	3	0	23	Clay
										23	31	Fine Sand
										31	45	Coarse Sand
										45	48	Hard rock (Granite Gneiss)
30	Santi Nagar	10A	Narhat	25	85.53	47	45	27-44	3	0	24	Clay
										24	31	Fine Sand
										31	44	Coarse Sand
										44	47	Hard rock (Granite Gneiss)
31	Baluhai, Hasratpur	15B	Narhat	25	85.48	56	54	33-51	3	0	25	Clay
										25	36	Fine Sand
										36	53	Coarse Sand
										53	56	Hard rock (Granite Gneiss)
32	Milki	6	Narhat	25	85.36	42	40	25-38	3	0	22	Clay
										22	29	Fine Sand
										29	38	Coarse Sand
										38	42	Hard rock (Granite

Sl.No.	Village	ward No.	Block	Latitude	Longitude	Depth Drilled (m)	Depth Constructed (m)	Zones tapped (m)	Discharge (lps)	Litholog		
												Gneiss)
33	Hamidpur Bara	4B	Narhat	25	85.46	45	43	28-41	3	0	24	Clay
										24	31	Fine Sand
										31	41	Coarse Sand
										41	45	Hard rock (Granite Gneiss)
34	Belwan	4	Meskaur	25	85.33	48	30		3.2	0	6	Clay
										6	16	Fine Sand
										16	30	Weathered rock
										30	48	Hard rock
35	Medhkuri		Meskaur	25	85.39	93	30		8	0	12	Clay
										12	24	Fine Sand
										24	30	Weathered rock
										30	93	Hard rock
36	MedhkuriTola		Meskaur	25	85.39	91	25		4.9	0	12	Clay
										12	22	Fine Sand
										22	25	Weathered rock
										25	91	Hard rock
37	Tekpur	10	Meskaur	25	85.37	42	18			0	6	Clay
										6	12	Fine Sand
										12	18	Weathered rock

Sl.No.	Village	ward No.	Block	Latitude	Longitude	Depth Drilled (m)	Depth Constructed (m)	Zones tapped (m)	Discharge (lps)	Litholog		
										18	42	Hard rock
38	Rasalpura	8	Meskaur	25	85.39	94.5	24			0	10	
										10	24	
										24	94.5	Hard rock
39	LachhuBigha	9	Meskaur	25	85.36	93.8	27			0	10	
										10	27	
										27	93.8	Hard rock
40	Sitamarhi	6	Meskaur	25	85.36	64	34		3	0	8	Clay
										2	9	Fine Sand
										9	34	Weathered rock
										34	64	Hard rock
41	Bokhara	8				90.4	21			0	10	
										10	21	
										21	90.4	Hard rock
42	Katgara	1		25	85.36	110	35			0	10	
										10	35	
										35	110	Hard rock
43	Bodhi Bigha	5A	Meskaur	25	85.35	103	27			0	10	
										10	27	
										27	103	Hard rock

Sl.No.	Village	ward No.	Block	Latitude	Longitude	Depth Drilled (m)	Depth Constructed (m)	Zones tapped (m)	Discharge (lps)	Litholog		
44	Lakshmipur	5B				24	15			0	2	Soil
										2	10	Sand
										10	15	Weathered rock
										15	24	Hard rock
45	Meskaur (Block side)		Meskaur	25	85.35	90	20			0	6	Clay
										6	10	Fine Sand
										10	20	Weathered rock
										20	91	Hard rock
46	Meskaur (Eastern Side)		Meskaur	25	85.36	61	20			0	6	Clay
										6	10	Fine Sand
										10	20	Weathered rock
										20	61	Hard rock
47	Paroriya	12	Sirdala	25	85.39	93	32		3.4	0	6	Clay
										6	15	Fine Sand
										15	32	Weathered rock
										32	93	Hard rock
48	Paroriya	13	Sirdala			22	15		3.4	0	6	Clay
										6	10	Fine Sand
										10	15	Weathered rock
										15	22	Hard rock

Sl.No.	Village	ward No.	Block	Latitude	Longitude	Depth Drilled (m)	Depth Constructed (m)	Zones tapped (m)	Discharge (lps)	Litholog		
49	Sahpur	12	Sirdala	25	85.39	90	40			0	10	Clay
										10	22	Fine Sand
										22	40	Weathered rock
										40	90	Hard rock
50	Upardih	8	Sirdala	25	9E+06	134	43			0	15	
										15	43	
										43	134	Hard rock
51	Hajara	1	Sirdala	25	85.42	27	26		4.5	0	2	Soil
										2	20	Fine sand
										20	26	Coarse Sand
										26	27	Hard rock
52	Bhita	3	Sirdala	25	85.79	32	32	26-32	4.45	0	26	Soil and fine sand
										26	32	Coarse Sand
										32	33	Hard rock
53	BadhiBigha	4	Sirdala	25	85.41	98	33		3.2	0	6	Clay
										6	16	Fine Sand
										16	33	Weathered rock
										33	98	Hard rock
54	Bhat Bigha	5	Sirdala			27	26	20-26	4.5	0	20	Soil and fine sand
										20	26	Coarse Sand
										26	27	Hard rock

Sl.No.	Village	ward No.	Block	Latitude	Longitude	Depth Drilled (m)	Depth Constructed (m)	Zones tapped (m)	Discharge (lps)	Litholog		
55	Akauna	8A	Sirdala	25	85.81	32	32	26-32	4.45	0	26	Soil and fine sand
										26	32	Coarse Sand
										32	Onwards	Hard rock
56	Baradih	8B	Sirdala			27	26	20-26	4.5	0	2	Soil
										2	20	Fine sand
										20	26	Coarse Sand
										26	27	Hard rock
57	Khatangi	1	Sirdala	25	85.33	90	33			0	20	
										20	33	
										33	90	Hard rock
58	Gandhi Nagar	12				80	24			0	24	
										24	80	Hard rock
59	Sarai	10				152	42			0	10	
										10	42	
										42	152	Hard rock
60	Mandal	2	Sirdala			17	16	10-16	4.6	0	2	Soil
										2	10	Fine sand
										10	16	Coarse Sand
										16	17	Hard rock
61	Bilarpur	1	Sirdala	25	85.39	97	33		4.6	0	10	Clay

Sl.No.	Village	ward No.	Block	Latitude	Longitude	Depth Drilled (m)	Depth Constructed (m)	Zones tapped (m)	Discharge (lps)	Litholog		
										10	23	Sand
										23	97	Hard rock
62	Baratand	1	Sirdala			103	36		4.7	0	10	Clay
										10	23	Fine Sand
										23	36	Weathered rock
										36	103	Hard rock
63	Kendua	4	Sirdala	25	85.4	80	24		4.8	0	10	Clay
										10	20	Fine Sand
										20	24	Weathered rock
										24	80	Hard rock
64	Laund	10	Sirdala	25	85.4	28	27	15-27		0	2	Soil
										2	15	Fine sand
										15	27	Coarse Sand
										27	28	Hard rock
65	Laund	6	Sirdala			16	15	9-15		0	2	Soil
										2	9	Fine sand
										9	15	Coarse Sand
										15	16	Hard rock
66	Kamal Kurha	5				97	24			0	12	
										12	24	
										24	97	Hard rock

Sl.No.	Village	ward No.	Block	Latitude	Longitude	Depth Drilled (m)	Depth Constructed (m)	Zones tapped (m)	Discharge (lps)	Litholog		
67	BaluKurha	6				90	30			0	15	
										15	30	
										30	90	Hard rock
68	Adeya	1				97	24			0	11	
										11	24	
										24	97	Hard rock
69	Hathmarwa	5	Sirdala	25	85.32	103	24			0	11	
										11	24	
										24	103	Hard rock
70	LaxmiBigha	13				109	36			0	21	
										21	36	
										36	109	Hard rock
71	Karmatand	3				91	30			0	20	
										20	30	
										30	91	Hard rock
72	Rajan	7	Sirdala	25	85.45	37	36	24-36	4.6	0	18	Clay
										18	24	Fine sand
										24	36	Coarse Sand
										36	37	Hard rock
73	Fatehpur	2	Sirdala			42	41	26-41	4.6	0	21	Clay
										21	29	Sand

Sl.No.	Village	ward No.	Block	Latitude	Longitude	Depth Drilled (m)	Depth Constructed (m)	Zones tapped (m)	Discharge (lps)	Litholog		
										29	38	Coarse sand
										38	42	Hard rock
74	Mahmadnagar	9A	Sirdala			33	32	26-32	4.6	0	2	Clay
										2	26	Sand
										26	32	Coarse sand
										32	33	Hard rock
75	Takiya	9B	Sirdala			101	32		3.4	0	6	Clay
										6	15	Fine Sand
										15	32	Weathered rock
										32	101	Hard rock
76	ChhonuBigha	13	Sirdala			101	32		3.4	0	6	Clay
										6	15	Fine Sand
										15	32	Weathered rock
										32	101	Hard rock

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