केंद्रीय भूमि जल बोर्ड

जल संसाधन, नदी विकास और गंगा संरक्षण

विभाग, जल शक्ति मंत्रालय

भारत सरकार

Central Ground Water Board

Department of Water Resources, River Development and Ganga Rejuvenation, Ministry of Jal Shakti

Government of India

AQUIFER MAPPING AND MANAGEMENT OF GROUND WATER RESOURCES

KABIRDHAM DISTRICT, CHHATTISGARH

उत्तर मध्य छत्तीसगढ़ क्षेत्र, रायपुर

North Central Chhattisgarh Region, Raipur

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 & Ganga Rejuvenation
केन्द्रीय भूमि जल बोर्ड
CENTRAL GROUND WATER BOARD

जलभृत नक्शा एवं भूजल प्रबंधन कबीरधाम जिला, छत्तीसगढ़

Aquifer Maps and Ground Water Management Plan of Kabirdham District, Chhattisgarh

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2022

FOREWORD

Groundwater resources are being developed over years in order to meet domestic, irrigation and industrial requirements. The spatial distribution of availability of ground water resources however, is uneven and is being indiscriminately exploited by various users thereby creating relentless pressure. On the other hand, rapid urbanization, industrialization and land use changes has resulted decline of water levels in many parts of the country.

There is an urgent need for scientific approach for proper management of the available ground water resources for sustainability of this precious natural resource for present and future generation.

Central Ground Water Board has been in the forefront of activities for occurrence, development, and management of this resource through various scientific studies and techniques. Over the last four decades CGWB, NCCR, Raipur has gathered a huge amount of data regarding ground water resources of Chhattisgarh. Based on this experience aquifer mapping of Kabirdham district was prepared with the vast amount of data generated and available with North Central Chhattisgarh Region. The report embodies all the features of ground water and related aspects of the study area including physiography, meteorological conditions, hydrology, drainage, geomorphology, geology, hydrogeology, ground water resources, hydrochemistry, geophysics, ground water problems etc.

The report titled "AQUIFER MAPS AND GROUNDWATER MANAGEMENT PLAN OF KABIRDHAM DISTRICT, CHHATTISGARH" is prepared by Sh Uddeshya Kumar, Scientist-B under supervision of Sh. A.K.Biswal, Scientist-E. I appreciate the concerted efforts put by the author to make it possible to bring the report in its present shape. I hope this report will be useful and worthy for the benefit of Kabirdham district and would be a useful document for academicians, administrators, planners and all the stakeholders in ground water.

Though utmost care has been taken to minimize the errors, some errors may have inadvertently crept in. It is expected that these mistakes will be taken in the proper spirit.

Dr. P. K. Naik
(REGIONAL DIRECTOR)

कार्यकारी सारांश

एक्वीफर मैपिंग एक बहु-विषयक वैज्ञानिक प्रक्रिया है जिसमें भूगर्भीय, जल-भूवैज्ञानिक, भूभौतिकीय, जल विज्ञान और गुणवत्ता डेटा के संयोजन को एक्वीफर्स में भूजल की मात्रा, गुणवत्ता और गति को चिह्नित करने के लिए एकीकृत किया जाता है। हालांकि, पिछले एक दशक में विकास से भूजल प्रबंधन पर ध्यान केंद्रित करने के कारण, स्थानीय स्तर पर भूजल संसाधनों के न्यायसंगत और टिकाऊ प्रबंधन के लिए बड़े पैमाने पर अधिक विश्वसनीय और व्यापक जलभृत मानचित्रों की आवश्यकता महसूस की गई है। भूजल मात्रा का सटीक आकलन एवं भविष्य में भूजल के विकास और प्रबंधन के लिए रणनीति जलभृत मानचित्रण के प्राथमिक उद्देश्य हैं।

जलभृत मानचित्रण कार्यक्रम के तहत कबीरधाम जिले के सभी विकास खंडों (कवर्धा, पंडरिया, सहसपुर लोहारा और बोड़ला) को अध्ययन के लिए लिया गया था। यह क्षेत्र सर्वे ऑफ इंडिया की डिग्री शीट नंबर 64 बी, सी, एफ और जी में आता है और अक्षांश 21° 42' 1.5" से 22° 31' 37" उत्तर और देशांतर 80° 49' 48" से 81° 33' 20" पूर्व तक घिरा है। यह उत्तर और पश्चिम में मध्य प्रदेश, पूर्व में मुंगेली जिले, दक्षिण-पूर्व में बेमेतरा जिले और दक्षिण में राजनांदगांव जिले से घिरा हुआ है। यह लगभग 4447 वर्ग किलोमीटर के क्षेत्र को कवर करता है। जिले के 1812 वर्ग किमी जो की कुल भौगोलिक क्षेत्र का लगभग 40% वन से आच्छादित है। जिले में अच्छी तरह से विकसित सड़क नेटवर्क है और जिला मुख्यालय कवर्धा सड़क (एनएच 30) के माध्यम से जुड़ा हुआ है और राज्य की राजधानी रायपुर से 120 किमी दूर है।

2011 की जनगणना के अनुसार जिले की कुल जनसंख्या 822526 है जिसमें से पुरुष जनसंख्या 412058 है जबकि महिला जनसंख्या 410468 है और जनसंख्या घनत्व 185 प्रति वर्ग किमी है।

कबीरधाम जिला उपोष्णकटिबंधीय जलवायु का क्षेत्र है। अध्ययन क्षेत्र में औसत वार्षिक वर्षा लगभग 911 मिमी है। भौगोलिक दृष्टि से, जिले को दो अलग-अलग भागों में विभाजित किया जा सकता है; (1) पश्चिम का पहाड़ी भाग और (2) पूर्व का मैदानी भाग। मैकाल और मंगटा पर्वतमाला जिले के पश्चिमी भाग में फैली हुई है। जिले की ऊंचाई 300 से 931 m amsl तक है। जिला ज्यादातर सिवनाथ उप बेसिन का एक हिस्सा है एवं पश्चिमी भाग में बंजारा उप-बेसिन का हिस्सा है।

शुद्ध बुवाई क्षेत्र 189182 हेक्टेयर है, जबकि दोहरी फसल क्षेत्र 116271 हेक्टेयर है। सकल सिंचित क्षेत्र जिला 149927 हेक्टेयर है जहां भूजल का योगदान केवल 120407 हेक्टेयर है। सकल सिंचित क्षेत्र की तुलना में भूजल द्वारा सिंचित क्षेत्र का प्रतिशत 80.31 प्रतिशत है।

ब्लॉकों के लिए उत्पन्न अन्वेषणात्मक ड्रिलिंग डेटा के आधार पर, क्षेत्र में मौजूदा एक्वीफर सिस्टम को फेरटिक और फ्रैक्चर्ड एक्विफर में विभाजित किया गया है। प्रमुख जलभृतों में शेल, चूना पत्थर, ग्रेनाइट, नीस, शिस्ट, बेसाल्ट और लेटराइट शामिल हैं। जिले में कुल 18 अन्वेषक बोर ड्रिल किए गए, जहां

डिस्चार्ज 0-14.5 एलपीएस है और ड्रॉडाउन रेंज 4.24 से 21.32 मीटर है। औसत आवरण मोटाई 16.45 मीटर है। पहचान किए गए अधिकांश जल संभावित क्षेत्र 100 मीटर की गहराई के भीतर हैं।

भूजल संसाधन अनुमान 2020 के अनुसार जिले में भूजल निष्कर्षण का चरण 72.98% है। कवर्धा और पंडरिया ब्लॉक को "क्रिटिकल" और सहसपुर लोहारा को "सेमी क्रिटिकल" के रूप में वर्गीकृत किया गया है, जबकि बोडला ब्लॉक केवल सुरक्षित वर्गीकरण के अंतर्गत आता है। कुल भूजल निष्कर्षण में सिंचाई निकासी का योगदान 93.41% है।

अध्ययन क्षेत्र में सर्वेक्षण के दौरान पहचाने गए प्रमुख भूजल मुद्दे इस प्रकार हैं: (i) सिंचाई के लिए बोरवेल की बढ़ती संख्या के परिणामस्वरूप भूजल स्तर में गिरावट और कम उपलब्ध भूजल संसाधन। (ii) गर्मी के दिनों में जिले के मध्य और पूर्वी हिस्से में खोदे गए कुएं सूख जाते हैं। (iii) अंतर्निहित भूवैज्ञानिक विशेषताओं के कारण जिले के उत्तरी और पश्चिमी भाग में डिस्चार्ज कम है। (iii) यह देखा गया है कि फील्डवर्क के दौरान निजी कुएं और सार्वजनिक जल आपूर्ति प्रणाली के माध्यम से भूजल की भारी बर्बादी होती है। (iv) कुछ क्षेत्रों में मानसून के बाद की अवधि के दौरान जल स्तर 3 मीटर से नीचे रहता है, जिस पर कृत्रिम पुनर्भरण करने की आवश्यकता होती है। (vi) भूजल गुणवत्ता के मुद्दे मुख्य रूप से जिले के कुछ हिस्सों में आयरन और नाइट्रेट के हैं। हालांकि 0.03 मिलीग्राम/लीटर से अधिक यूरेनियम सांद्रता भी 03 स्थानों पर दर्ज की गई है।

जहां तक भूजल उपलब्धता के लिए प्रबंधन रणनीतियों का संबंध है, कृत्रिम रिचार्ज संरचनाओं का निर्माण उपयुक्त स्थानों पर किया जा सकता है, विशेषकर उन क्षेत्रों में जहां जल स्तर मानसून के बाद की अवधि में 3 मीटर से अधिक गहरा रहता है। बोडला ब्लॉक में भूजल निकासी के 70% चरण को प्राप्त करने के लिए, उपयुक्त भूजल निकासी संरचनाओं के निर्माण के द्वारा भूजल विकास किया जा सकता है। जिले के उत्तरी और पश्चिमी भाग में ड्रिलिंग के लिए संयोजन रिग का उपयोग करना चाहिए। वर्षा जल के कुशल भंडारण के लिए मौजूदा तालाबों का डी-सिल्टेशन किया जाना है। साथ ही, भूजल पर दबाव को कम करने के लिए गांवों में वर्षा जल संचयन संरचनाओं का निर्माण किया जा सकता है। इसी प्रकार, उच्च लौह सांद्रता वाले गांवों के लिए आयरन फिल्टर का उपयोग किया जा सकता है। ग्राम स्तर पर नियमित भूजल स्तर और गुणवत्ता निगरानी की आवश्यकता है। भूजल संसाधनों के प्रभावी उपयोग और पानी बचाने में सामुदायिक भागीदारी के महत्व के बारे में लोगों को जागरूक करने के लिए व्यापक जागरूकता अभियान आवश्यक हैं।

Executive summary

Aquifer mapping is a multidisciplinary scientific process wherein a combination of geological, hydrogeological, geophysical, hydrological and quality data is integrated to characterize the quantity, quality and movement of ground water in aquifers. However, due to paradigm shift in focus from development to management of ground water in last one decade, the need for more reliable and comprehensive aquifer maps on larger scale has been felt for equitable and sustainable management of the ground water resources at local scale. Volumetric assessment of ground water and strategies for future development and management are the primary objectives of aquifer mapping.

Under the aquifer mapping programme, all the development blocks of Kabirdham District namely Kawardha, Pandariya, Sahaspur Lohara and Bodla was taken up for study covering an area of 4447 Sq. Km. It falls in the Survey of India's Degree Sheet Nos. 64 B, C, F and G and bounded by latitude 21° 42' 1.5" to 22° 31' 37" N and longitude 80° 49' 48" to 81° 33' 20" E. It is surrounded by Madhya Pradesh in the north and west, Mungeli district in the east, Bemetara district in the south-east and Rajnandgaon district in the south. It covers an area of about 4447 Sq Km. Nearly 40 % of the total geographical area 1812 Sq Km of the District is covered by forest. The district has a well-developed road network and district headquarter Kawardha is connected via road (NH 30) and 120 km from state capital Raipur.

The total population of district as per 2011 Census is 822526 out of which male population is 412058 while the female population is 410468 and having population density of 185 per Sq km.

The study area experiences sub-tropical climate. The average annual rainfall for the study area is around 911 mm. Physiographically, the district can be divided into two distinct part; (1) Hilly part of the west and (2) plain region of the east. The Maikal and Mangata ranges have spread in western part of the district. District elevation ranges from 300 to 931 mamsl. The district forms mostly a part of Seonath sub basin, with the area in western part forming part of Banjara sub-basin.

The net sown area is 189182 Ha, while double-cropped area is 116271 Ha. The gross irrigated area district is 149927 Ha where ground water contribution is 120407 Ha only. Percentage of Area Irrigated by ground water with respect to gross irrigated area is 80.31%.

Based on the exploratory drilling data generated for the blocks, the existing aquifer systems in the area divided into phreatic and fractured aquifer. The major aquifers consist of Shale, Limestone, Granite, Gneiss, Schist, Basalt and Laterite. Total 18 exploratory well drilled in district, where discharge varies from 0- 14.5 lps and having drawdown range of 4.24 to 21.32 m. Average casing thickness is 16.45 m. Most of the water bearing potential zone identified are within 100 meter depth.

As per 2020 ground water resource estimation stage of ground water extraction in district is 72.98 %. Kawardha and Pandariya blocks categorizes as "Critical" and Sahaspur Lohara categorizes as "Semi Critical" while Bodla block only falls under safe categorization. Irrigation extraction contributes 93.41 % of total groundwater extraction.

The major ground water issues identified during the survey in the study area are as follows: (i) Increasing number of bore wells for irrigation resulting declination in groundwater level and less available resources. (ii) During summer, dug wells becomes dry at central and eastern part of district. (iii) Due to inherent hydrogeological characteristics, discharge is less in northern and western part of district. (iii) It has been observed during fieldwork, there is colossal wastage of groundwater through private well and public water supply system. (iv) In some areas the water level remains below 3 m during the post-monsoon period in the study area which needs to be attended for intervention. (v) Ground water quality issues mainly is of Iron and Nitrate in part of the district. Although Uranium concentration more than 0.03 mg/l also reported at 03 locations.

So far as Management strategies are concerned for ground water availability, Artificial Recharge structures may be constructed in suitable locations especially in the areas where the water level remains deeper than 3m in the post-monsoon period. In order to achieve 70% stage of ground water withdrawal in Bodla blocks, ground water development may be taken up by construction of suitable abstraction structures. In northern and western part of district combination rig is preferred for drilling. De-siltation of existing ponds to be carried out for efficient storage of rainwater. Also, Rain water harvesting structures may be constructed in villages to reduce stress on groundwater. Similarly, Iron filter may be used for the villages having high Iron concentration. Regular ground water level and quality monitoring is required at village level. Massive awareness campaigns are essential to aware people about the effective utilization of ground water resources and importance of community participation in saving water.

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The author is grateful to Shri Sunil Kumar, Chairman, Central Ground Water Board for giving opportunity for preparation of Aquifer Map and Management Plan of, Kabirdham district of Chhattisgarh state. I express my sincere gratitude to Shri Sateesh Kumar Member (East), CGWB for giving valuable guidance, encouragement and suggestions during the preparation of this report. The author is thankful to Dr. P. K Naik, Regional Director, Central Ground Water Board, NCCR, Raipur for extending valuable guidance and constant encouragement during the preparation of this report. I am extremely grateful to Sh. A.K. Biswal, Scientist-E for his continuous guidance and support during preparation of this report. The author is also thankful to Dr. P. K Naik, Regional Director (Retd.) and Sh A.K. Patre, Sc-D for the guidance and suggestions. I would like to acknowledge the help rendered by Smt Prachi Gupta, Sc-B while preparing aquifer map and 3-d disposition of aquifers. The author is also thankful to Sh Sidhanta Sahu, Sc-B for rendering help and valuable inputs while preparing the report. The author is also thankful to Sh Rakesh Dewangan, Sc-B for the chemical analysis and valuable inputs on quality issues. The author is also thankful to Sh A. K. Sinha, Sc-B for sharing the geophysical studies. The efforts made by Sh. T.S. Chouhan, Draftsman, for digitization of maps are thankfully acknowledged. The author is also thankful to the state agencies for providing the various needful data. The author is thankful to Technical Section, Data Centre, Chemical Section, Report Processing Section and Library of CGWB, NCCR, Raipur for providing the various needful data.

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AQUIFER MAPS AND GROUND WATER MANAGEMENT PLAN
KABIRDHAM DISTRICT, CHHATTISGARH

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ABBREVIATIONS

mamsl	Meter above mean sea level
BDR	Basic Data Report
BW	Borewell
CGWB	Central Ground Water Board
Dia	Diameter
DTW	Depth To Water
DW	Dugwell
EC	Electrical Conductivity
EW	Exploratory Wells
GS	Gabion structures
GW/ gw	Ground Water
ham	Hectare meter
HP	Handpump (Shallow)
lpcd	litres per capita per day
lpm	litres per minute
lps	liters per second
m	meter
m bgl	meter below ground level
m2/day	Square meter/ day
m3/day	cubic meter/day
MCM/mcm	Million Cubic Meter
NCCR	North Central Chhattisgarh Region
NHNS/ NHS	National Hydrograph Network Stations
OW	Observation Well
PZ	Piezometre
Sq km	Square Kilometer
STP	Sewage Treatment Plan
T	Transmissivity
TW	Tubewell

1. Introduction
1.1 Objective

The groundwater is the most valuable resource for the country. However, due to rapid and uneven development, this resource has come under stress in several parts of the country. Central Ground Water Board (CGWB) is, therefore, involved in hydrogeological investigations for Re-appraisal of ground water regime. CGWB has also carried out ground water exploration in different phases with prime objective of demarcating and identifying the potential aquifers in different terrains for evaluating the aquifer parameters and for developing them in future. The reports and maps generated from the studies are mostly based on administrative units such as districts and blocks and depict the subsurface disposition of aquifer on regional scale. However, due to paradigm shift in focus from development to management of ground water in last one decade, the need for more reliable and comprehensive aquifer maps on larger scale has been felt for equitable and sustainable management of the ground water resources at local scale.

1.2 Scope of study

The groundwater management plan includes Ground Water recharge, conservation, harvesting, development options and other protocols of managing groundwater. These protocols will be the real derivatives of the aquifer mapping exercise and will find a place in the output i.e, the aquifer map and management plan. The main activities under NAQUIM are as follows:

a). Identifying the aquifer geometry
b). Aquifer characteristics and their yield potential
c). Quality of water occurring at various depths
d). Assessment of ground water resources
e). Preparation of aquifer maps and
f). Formulate ground water management plan

The demarcation of aquifers and their potential will help the agencies involved in water supply in ascertaining, how much volume of water is under their control. The robust and implementable ground water management plan will provide a “Road Map” to systematically manage the ground water resources for equitable distribution across the spectrum.

1.3 Approach and Methodology

The activities under the aquifer project can be summarized as follows:

i) **Data Compilation & Data Gap Analysis:** One of the important aspects of the aquifer mapping programme was the synthesis of the large volume of data already collected during specific studies carried out by the Central Ground Water Board and various other government organizations with a new set of data generated that broadly describe an aquifer system. The data were compiled, analyzed, synthesized and interpreted from available sources. These sources were predominantly non-computerized data that were converted into computer-based GIS data sets. On the basis of these available data, Data Gaps were identified.

ii) **Data Generation:** It was evident from the data gap that additional data should be generated to fill the data gaps in order to achieve the objective of the aquifer mapping programme. This was done by multiple activities like exploratory drilling, hydrochemical analysis, use of geophysical techniques as well as detail hydrogeological surveys.
iii) **Aquifer map Preparation:** On the basis of integration of data generated through various hydrogeological and geophysical studies, aquifers have been delineated and characterized in terms of quality and potential. Various maps have been prepared bringing out the Characterization of Aquifers. These maps may be termed as Aquifer Maps depicting spatial (lateral and vertical) variation of the aquifers existing within the study area, quality, water level and vulnerability (quality and quantity).
iv) **Aquifer Management Plan:** Based on the integration of these generated, compiled, analysed and interpreted data, the management plan has been prepared for sustainable development of the aquifer existing in the area.

1.4 Area Details

Under the aquifer mapping programme, all the 04 development blocks namely Kawardha, Pandariya, Sahaspur Lohara and Bodla of Kabirdham district have been covered and aquifer map and management plan prepared for all the blocks. Kabirdham district is located in the western part of Chhattisgarh. It falls in the Survey of India's Degree Sheet Nos. 64 B, C, F and G and bounded by latitude 21° 42' 1.5" to 22° 31' 37" N and longitude 80° 49' 48" to 81° 33' 20" E. It is surrounded by Madhya Pradesh in the north and west, Mungeli district in the east, Bemetara district in the south-east and Rajnandgaon district in the south. It covers an area of about 4447 Sq Km. Nearly 40 % of the total geographical area 1812 Sq Km of the district is covered by forest.
The total population of district as per 2011 Census is 822526 out of which male population is 412058 while the female population is 410468 and having population density of 185 per sq km. In the district rural population is 735131 while the urban population is 87395.

1.4.1 Administrative Division

Kabirdham district has 1004 villages and 468 Gram Panchayat, for administrative convenience these villages are grouped into 04 development blocks. Kawardha is the districts headquarter. The block headquarters are at Kawardha, Pandariya, Bodla and Lohara. The administrative map for the Kabirdham district is given in Figure 1.

Table 1: Details of area covered under NAQUIM in Kabirdham district

Sl No	Block	Area (Sq. Km.)	No. of Villages
1	Bodla	1722.64	341
2	Kawardha	531.43	182
3	Pandariya	1217.78	284
4	Sahaspur Lohara	975.20	197
Kabirdham District (Total)		4447.05	1004

Source: District Statistical Book-2019-20

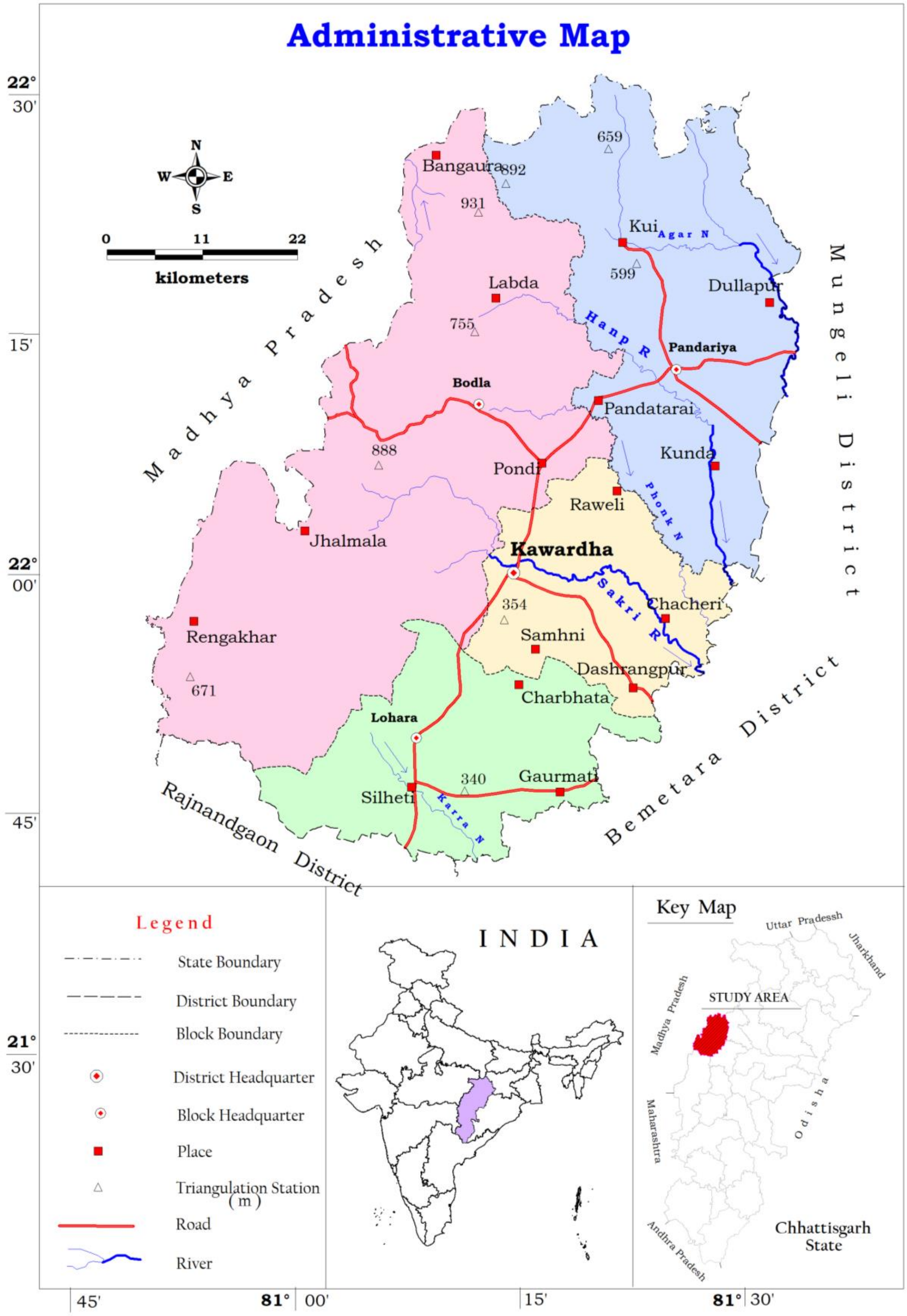

Figure 1: Administrative Map of Kabirdham District

1.5 Data Availability, Data Adequacy and Data gap Analysis

The hydrogeological data already available includes NHNS data, VES, exploration data, and chemical data. All the data has been analyzed and depending upon the hydrogeological conditions data gap has been identified for all the blocks.

Ground Water exploration in Kabirdham district was first taken up during 1998-99 by deploying DTH/SHM-88/66 rig. Till March 1999, a total of 6 Exploratory bore wells and 3 observations wells were drilled. 12 numbers of exploratory borewells were drilled through outsourcing in 2001-2002 for providing drinking water to the rural population of district under the 'accelerated exploration drilling programme' during AAP 2001- 2002. So far 21 bore wells (18 EW and 3 OW) under exploratory drilling programme and 5 piezometers under Hydrology Project have been drilled Geophysical study to unravel the hidden sub-surface hydrogeological conditions was also carried out. Total 72 VES was carried out distributed in all the blocks.

For ground water monitoring of Phreatic and fractured aquifer in district, 19 dugwell and 09 piezometer are regularly monitored 04 times every year. The existing network provides information on ground water regime with fair degree of accuracy. During Groundwater monitoring of premonsoon season groundwater samples has been collected and analyzed. At 16 locations of district water sample has been analyzed.

1.5.1 Data Gap Analysis

Based on the NHNS data, exploratory data, VES data and chemical data available in the study area, the data gap analysis has been prepared to ascertain the data gap in the Kabirdham district and presented in summary in Table 2.

Table 2: Data gap analysis in Kabirdham district

Activity	Required	Available	Gap
Exploratory Well (EW)	45	18	17
GW Monitoring (Unconfined aquifer)	34	19	15
GW Monitoring (Fractured aquifer)	48	9	39
Quality monitoring	66	16	50
VES	97	72	25

1.6 Rainfall-spatial, temporal and secular distribution

The Kabirdham district receives rainfall mainly from south-west monsoon. About 87% of the annual rainfall is received during June to September, July and August are the months of maximum precipitation, some rainfall is received in June, mostly in the form of thunder showers and during the cold season in association with passing western disturbances. There are on an average 70 to 80 rainy days in a year in the District. The average annual rainfall for the Kabirdham district is around 911.37 mm (Average of the last five years) which is presented below in **Table 3**.

Table 3: Annual Rainfall (mm) in Kabirdham district for the years (2015-16 to 2019-20)

Year	2015-16	2016-17	2017-18	2018-19	2019-20
Kabirdham	852.90	885.80	887.25	841.90	1089.00

Source: District Statistical Book-2019-20

1.7 Geomorphology

Physiographically, the district can be divided into two distinct part; (1) Hilly part of the west and (2) plain region of the east. The Maikal and Mangata ranges are spread in western part of the district. The general slope of the district is towards the east. The central and southern parts of district exhibit landforms of structural hills, valleys and plains with denudational plateaux, pediment/pediplain and flood plains (including in-filled river beds). The northern part of district exhibits landforms of pediment/pediplain with denudational plateaux and slope and region of high level and middle level plateaux of extrusive origin. The district forms mostly a part of Seonath sub basin, with the area in western part forming part of Banjara sub-basin. The tributaries of Seonath and Banjara rivers constitute the surface drainage system of the area. The general gradient in most of the area is towards southeast direction with the south western most part bearing Banjara sub-basin showing gradient towards north direction. The northen and western parts are surrounded by Maikal mountain ranges of Satpura. The highest peak is Kesmarda in Maikal mountain which is 931 m above mean sea level as recorded in the northwestern part while the minimum elevation of 300 m above mean sea level in the southeastern part. Figure 2 shows the Geomorphology in the study area.

1.8 Land use

Total area of the district is 4447.05 Sq Km out of which 1812.12 Sq Km is forest area. Maximum double cropped area is in Kawardha block. Details are presented in Table 4.

Table 4: Land Use Pattern (Ha)

Sl. No	Blocks	Revenue Forest Area	Area not available for cultivation	Non agricultural & Fallow land	Agricultural fallow land	Net sown area	Double cropped area	Gross cropped area
1	Kawardha	0	3533	3956	1581	44073	33848	77921
2	Bodla	11715	7396	13103	4564	40518	19465	59983
3	Sahaspur Lohara	1238	6820	3655	1589	48177	35153	83330
4	Pandariya	12666	8796	8359	2754	56414	27805	84219
Total (District)		25619	26545	29073	10488	189182	116271	305453

1.9 Soil

About 70 % of the district area, is covered by black soils (Inceptisols and vertisols). Red-yellow soils (Ultisols) and red soils (Alfisols) combinedly cover nearly 30% area. Northern part of Pandariya block have the Ultisols in the form of laterites. Kawardha, Sahaspur Lohara and southern half of Pandariya block is covered by vertisols (medium black soil). In general, the water holding capacity of alfisol and ultisols are poor though they have good infiltration capacity. Similarly the black soils have moderate infiltration capacity and moderate water holding capacity. Figure 3 shows the soil map of the area.

1.10 Hydrology and Drainage

Kabirdham district forms a part of Mahanadi basin with rivers viz. Hanp, Phonk and Sakri as well as Narmada basin. The Mahanadi basin covers 85 % of the area however the remaining area is drained by the Narmada basin. The drainage pattern in the District is dendritic to sub-dendritic and the drainage density is high in north and west parts. The main rivers of the district originate generally from Maikal mountain range. Hanp, Phonk and Sakri rivers after emerging from north-west of the district flow towards south-east and in the end after going in Shivnath river. Phen, Halon, Banjar and Jamunia rivers flowing towards west fall in river Narmada. There is no all weather rivulet except Saliha Nala in the district.The district forms mostly a part of Shivnath sub basin, with the area in western part forming part of Banjara sub-basin. The tributaries of Shivnath and Banjara rivers constitute the surface drainage system of the area. The general gradient in most of the area is towards southeast direction with the south western most part bearing Banjara sub-basin showing gradient towards west. Figure 4 shows the drainage map of the area.

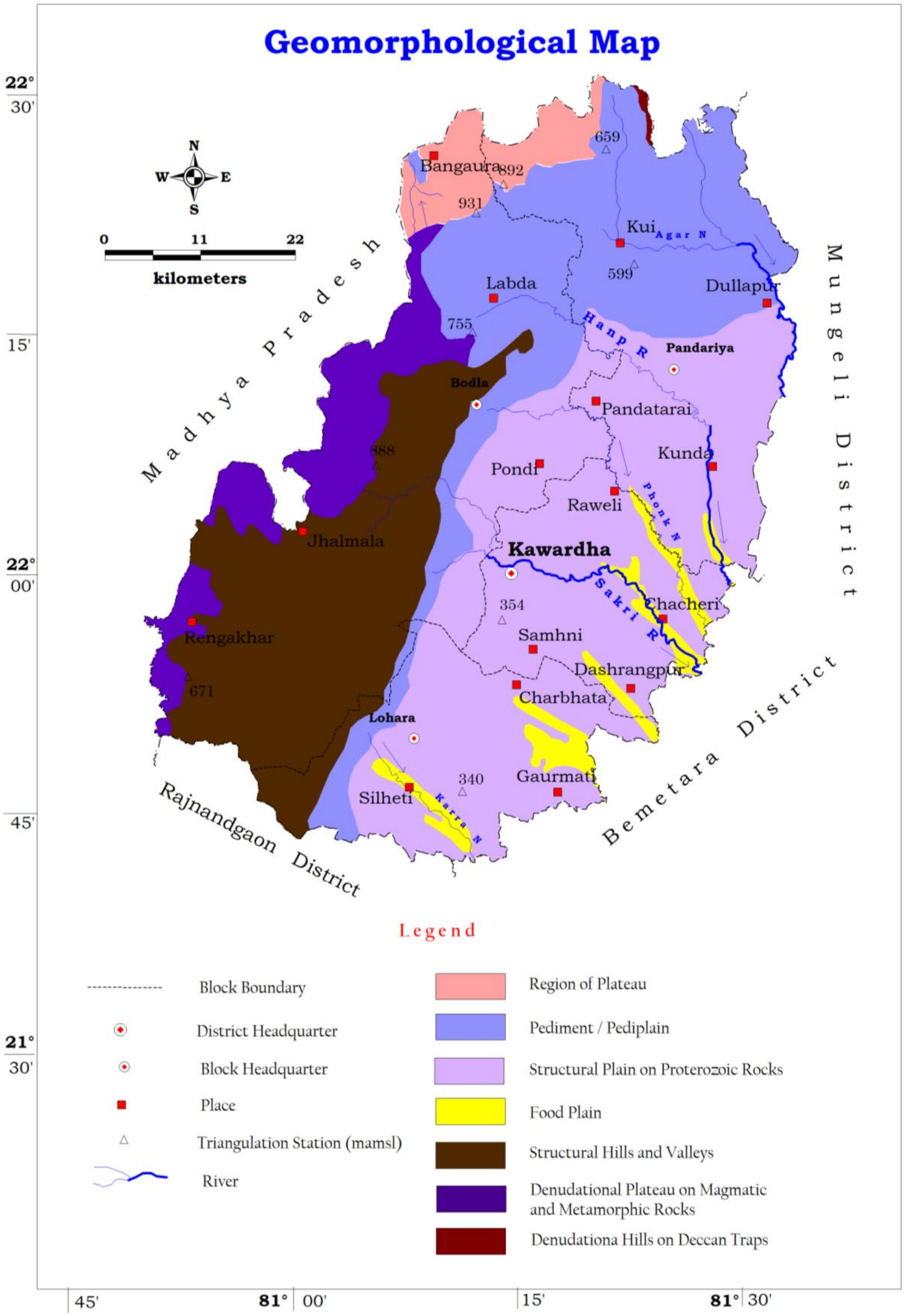

Figure 2: Geomorphological Map of Kabirdham District

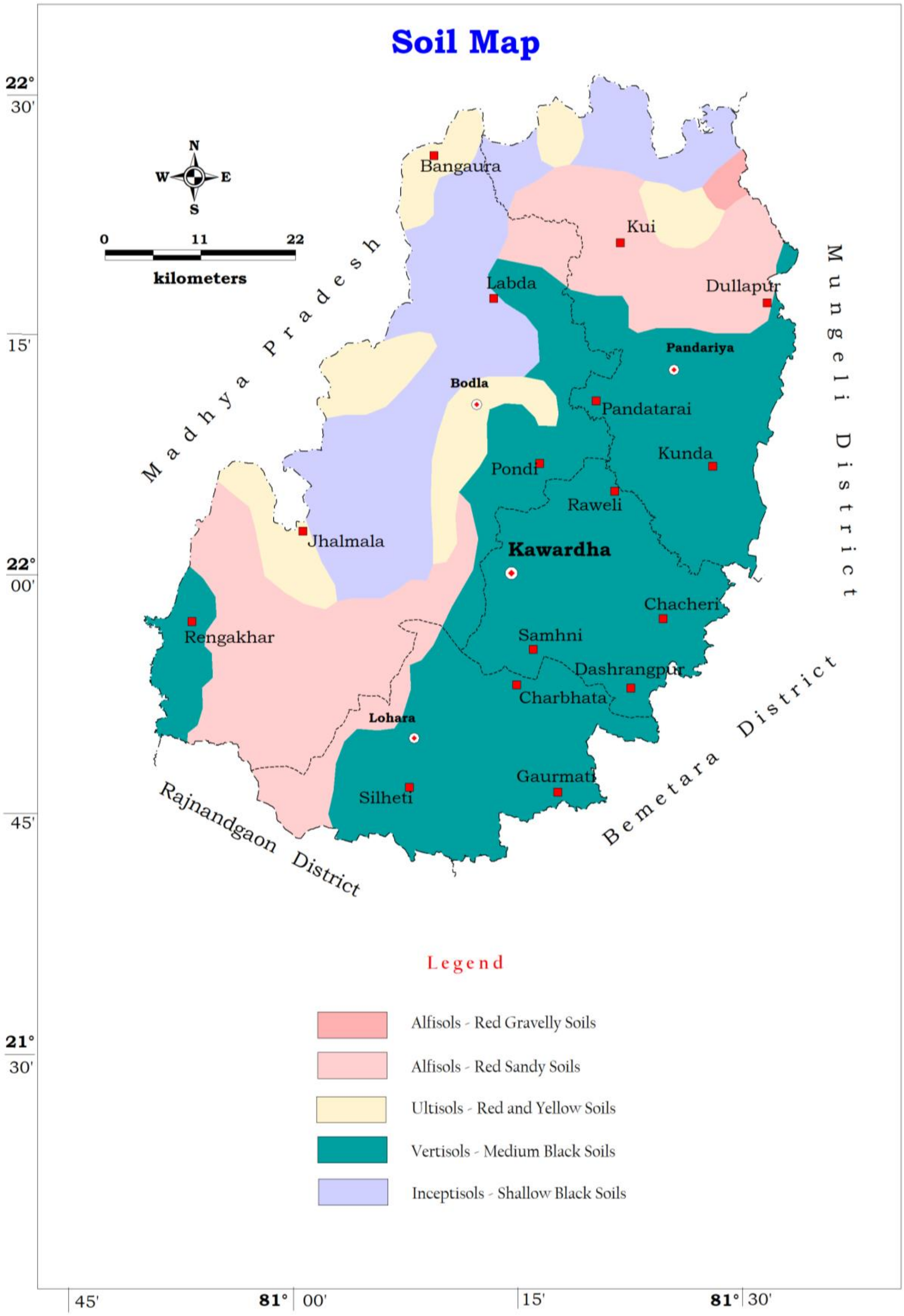

Figure 3: Soil Map of Kabirdham District

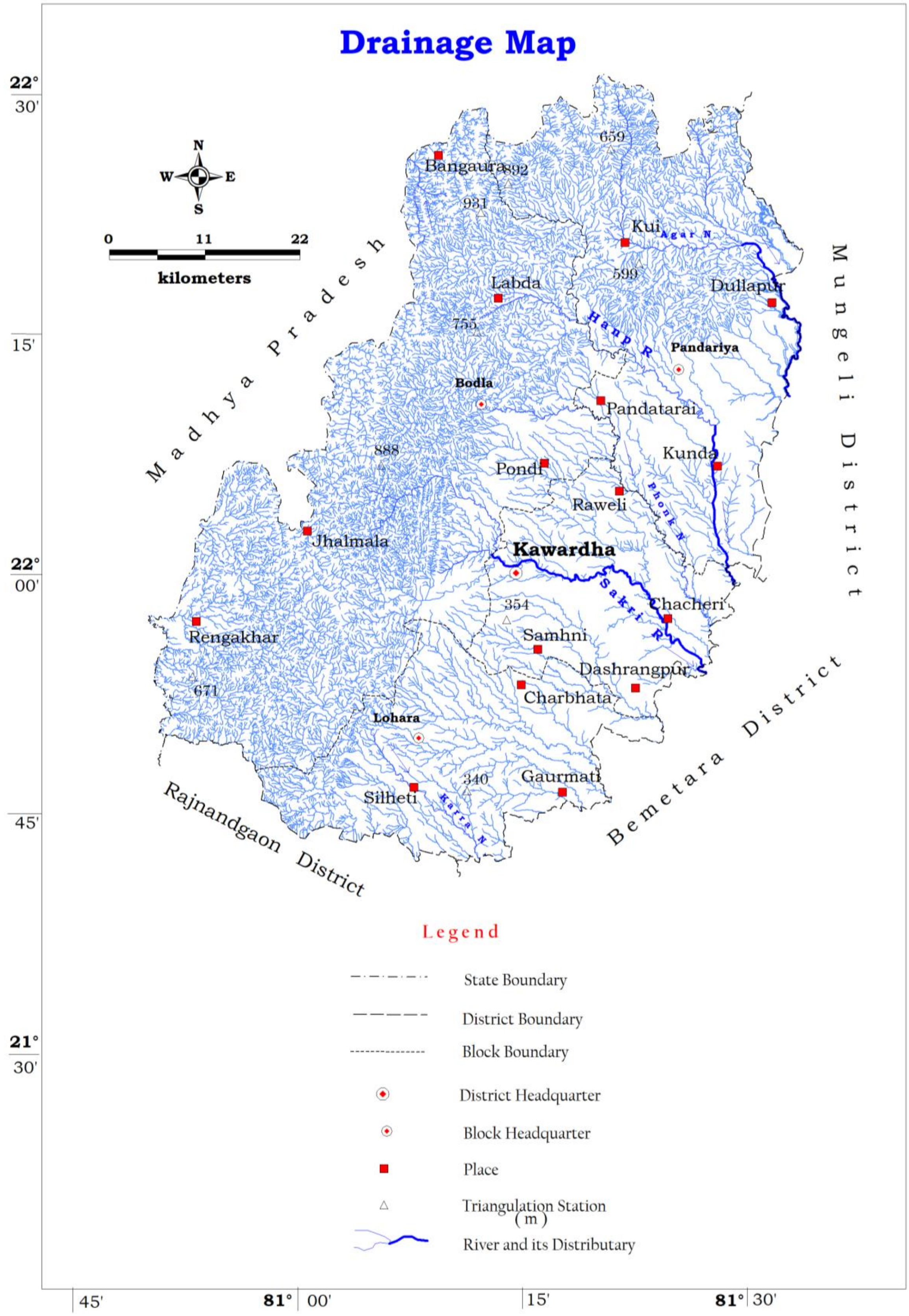

Figure 4: Drainage Map of Kabirdham District

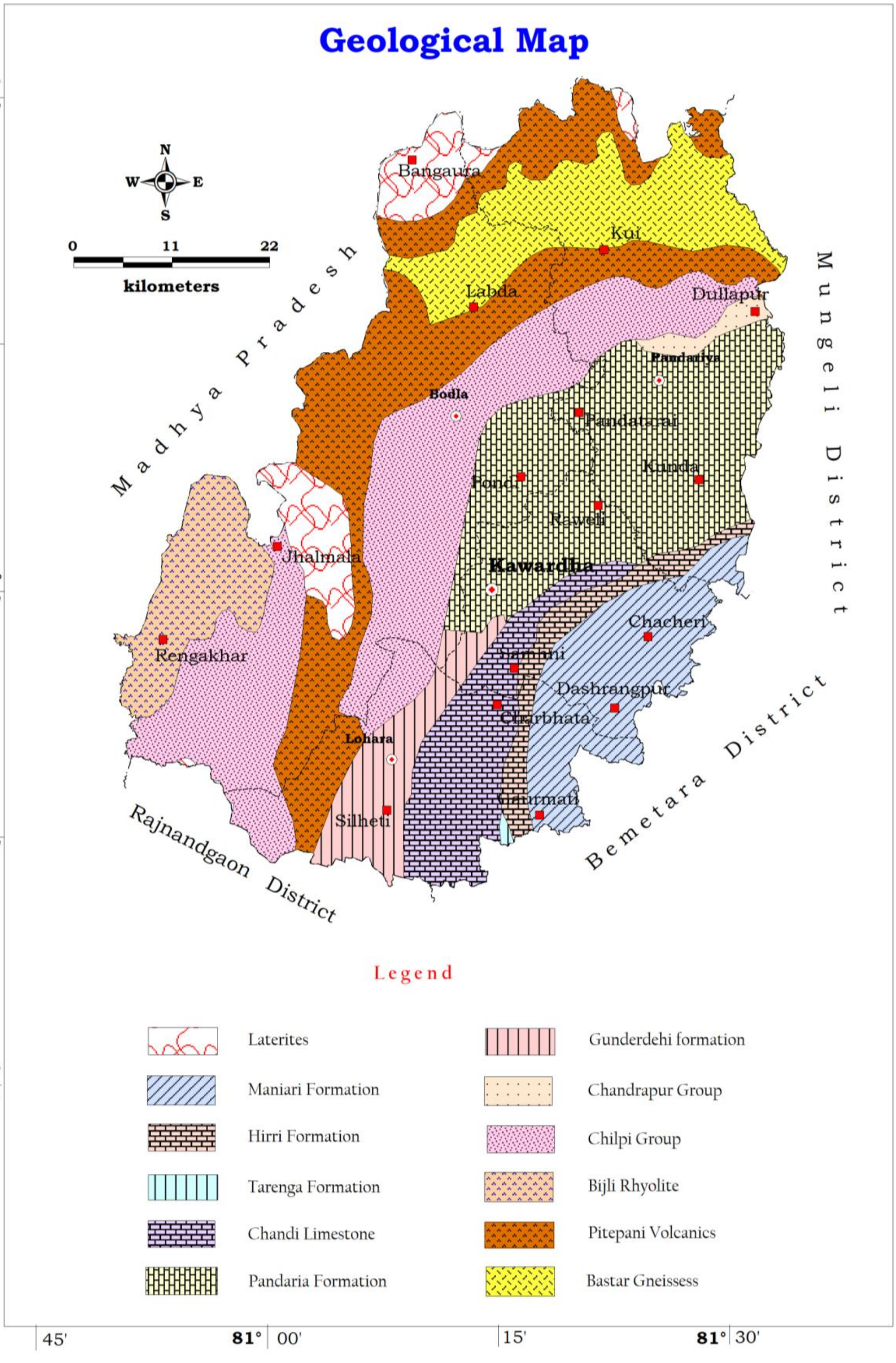

Figure 5: Geological Map of Kabirdham District

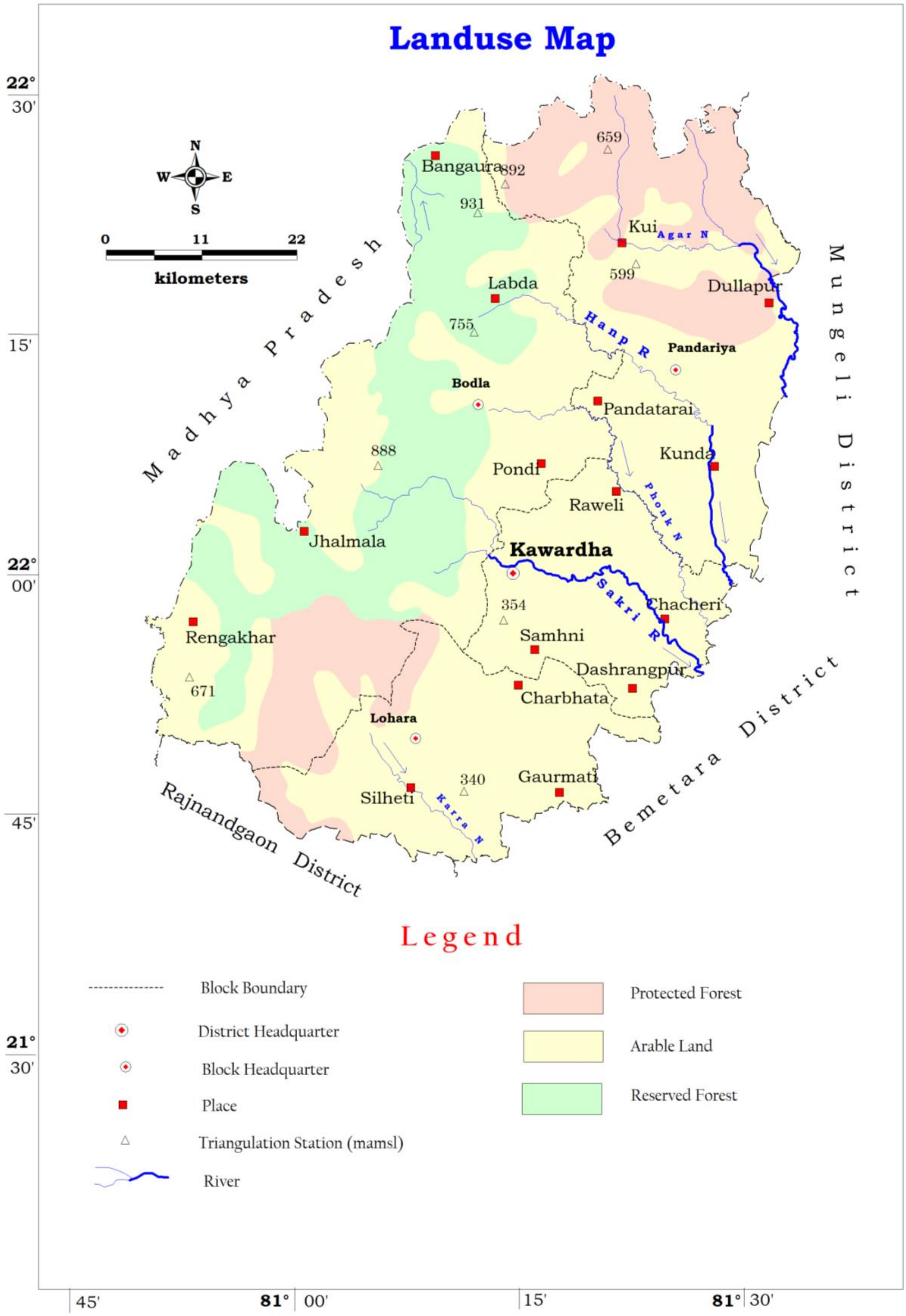

Figure 6: Landuse Map of Kabirdham District

1.11 Geology and Hydrogeology

Rock formations ranging in the age from Archaean to Cainozoic are exposed in the district. The oldest rocks in the area are represented by Bilaspur-Raigarh-Surguja Group of Archaean age (4000-2500 m.y.) and are equivalent to Bengpal Group. They are exposed in the northern part and comprise granite and gneiss with enclaves of mica schist, chlorite-mica schist, sillimanite-talc-chlorite-mica schist, hornblende schist and conglomerate. The geological map of Kawardha district is shown in figure 5.

Nandgaon Group of Palaeo to Meso Proterozoic age (2500-1600 m.y.) comprises meta-basalt is exposed in the southwestern part of district. Malanjkhand Granitoids is also exposed in the southwestern part of the district. It ranges in composition from granodiorite to quartz diorite with porphyritic biotite granite at places.

Quartz diorite, granite porphyry and basic dykes of Meso Proterozoic age (2000-1600 m.y.) intruded the Bilaspur-Raigarh-Surguja Group. The Chilpi Group of rocks is exposed in the western part of district. It comprises slate, shale, phyllite, sandstone, quartzite and conglomerate. Intrusions of quartz reefs/veins are seen in the Bilaspur- Raigarh-Surguja, Nandgaon and Chilpi group of rocks.

Undeformed and unmetamorphosed sedimentary sequence of rocks belonging to Chhattisgarh Supergroup of Meso to Neo Proterozoic age (2000-900 m.y.) occupy the southeastern and east central part of the district. Chhattisgarh Supergroup is represented by Chandrapur and Raipur groups. Chandrapur Group comprises mostly arenite with ferruginous sandstone and polymictic conglomerate at places. Ferruginous sandstone shows shale partings. Raipur Group is classified into Gunderdehi, Chandi, Tarenga, Hirri and Miniari formations. Gunderdehi Formation is dominantly a calcareous- argillite distinct facies. It comprises calcareous, highly friable, purple shale associated with impersistent stromatolitic limestone bands and intra-formational conglomerate lenses in the upper part. Chandi Formation is mostly a calcareous facies with intra-formational arenite. It comprises of stromatolitic limestone and dolomitic limestone with intercalations of ferruginous and galuconitic sandstone. Tarenga Formation is dominantly a calc-argillite facies. It comprises dolomitic argillite with chert intercalations, claystone and shale. Hirri Formation comprises mostly a dark grey, bedded dolomite associated with light grey laminated argillaceous dolomite. Miniari Formation is the closing phase of Chhattisgarh basin and comprises of siltstone and shale with lenses of dolomite, dolomitic limestone and gypsum.

Deccan Trap of Cretaceous to Palaeogene age (65-60 m.y.) occurs in the western and northern part of the district. The Deccan Trap is represented by unclassified basalt in major part of the area. However, the basalts exposed at few places in the west central part of the area are grouped under Linga Formation. Linga Formation comprises mostly non-porpohyritic basaltic lava flows. The high level plateaus of Deccan Trap are often capped by laterite of Cainozoic age. The laterite shows variation in colour from dark grey to yellowish brown. It is spongy and pisolitic in nature with calcareous concretions at places. Laterite occurring in the northern part of area contains irregular tabular lensoid bodies of bauxite.

The occurrence of ground water and its movement are usually controlled by the thickness of weathered mantle, fracture and joint system in the country rock. Archaean granites occurring in the western and northern parts of the district are generally hard and massive and posses negligible primary porosity. The occurrence of ground water is restricted to the weathered mantle lying over hard and massive granites.

The sedimentary rocks consist of limestone and shale is spread in the eastern part of the district. Stromatolitic limestone and dolomitic limestone in the area form the potential aquifers. Ground water occurs along joints, fractures and bedding planes under phreatic conditions. These rocks show secondary porosity due to solution effect along joints, fractures and bedding planes. The hydraulic conductivity of these rocks varies in vertical and lateral directions. In limestone, the solution openings are more widespread so as to form natural interconnected openings. The karstification is controlled by major joint pattern trending in NW-SE direction.

The joints and bedding planes of shale constitute the phreatic aquifer, which is tapped by open well in the area. Since the joints and fractures are not continuous in the area the ground water yield from the aquifer is generally poor. In Maniyari formation, ground water moves laterally and in channels to create maximum dissolution of the gypsum and carbonate rock. This results in interconnected cavernous zones to act as master conduit system confirming the ground water under pressure conditions.

Ground water potential is variable with average drill time discharges of the borewells ranging from 0 to 15 lps Rocks belonging to Chhattisgarh Supergroup are relatively better aquifers and are exposed in the eastern part. Transmissivity of shale and limestone ranges from 29 to 107 m^2/day. Storativity values of these formations range from $5.69x10^{-5}$ to 1.02×10^{-3} . One well drilled in the metasediments has yielded nearly 11 lps. Transmissivity value in this well has been estimated to be 993 m^2/day and the storativity has been estimated as $2.25x\ 10^{-5}$. In Chilpi formation , two exploratory borewells have been drilled to a maximum depth of 150 m bgl, a discharge of more than 3 lps has been recorded. From the exploratory drilling it is revealed that the water bearing fractures are very common between the depth of 30 and 70 m bgl and these fractures have very good potential.

1.12 Agriculture, Irrigation, Cropping Pattern

Agriculture is practiced in the area during Kharif and Rabi season every year. During the Kharif, cultivation is done through rainfall while during the Rabi season, it is done through ground water as well as partly through surface water like canals and other sources. The groundwater abstraction structures are generally Borewells /tubewells. The crops in general shown are paddy, wheat, kodo, kutki, sugarcane, pulses, maize, oil seeds and vegetables.

In some areas, double cropping is also practiced. The agricultural pattern, cropping pattern and area irrigated data of Kabirdham districtis given in Table 5, 6 and 7.

Table 5: Cropping pattern (in ha)

Sl	Blocks	Kharif	Rabi	Cereal				Pulses	Oil seeds	Fruits/ Vegetables	Sugarc ane
				Wheat	Rice	Kodo Kutki	Othe rs				
1	Kawardha	43312	34609	1805	31448	225	16	33215	4958	1192	5062
2	Bodla	39940	20043	1110	27993	2235	940	19582	2938	649	4517
3	Sahaspur Lohara	46056	37274	1803	32557	58	16	36418	10945	1164	140
4	Pandariya	52613	31606	2455	40957	1882	497	29439	1000	655	7286
Total (District)		181921	123532	7173	132955	4400	1469	118654	19841	3660	17005

Source: District Statistical Book-2019-20

Table 6: Area irrigated by various sources (in ha)

Sl	Blocks	No. of canals (private and Govt.)	Irrigated area	No. of bore wells/ Tube wells	Irrigated area	Net Irrigated area	Gross irrigated area	% of irrigated area wrt. Net sown area
1	Kawardha	10	4164	7676	41814	28333	45978	64.28
2	Bodla	9	6090	2771	23385	18516	29475	45.69
3	Sahaspur Lohara	16	8257	4885	22657	19823	30914	41.15
4	Pandariya	11	11009	3260	32551	31109	43560	55.14
Total (District)		46	29520	18592	120407	97781	149927	51.69

Source: District Statistical Book-2019-20

Table 7: Statistics showing Agricultural land Irrigated (in ha)

Sl	Blocks	Gross Irrigated Area	Gross Irrigated Area by ground water	Percentage of Area Irrigated by ground water
1	Kawardha	45978	41814	90.94%
2	Bodla	29475	23385	79.34%
3	Sahaspur Lohara	30914	22657	73.29%
4	Pandariya	43560	32551	74.73%
Total (District)		149927	120407	80.31%

2.0 Data Collection and Generation

2.1 Hydrogeological Data

Keeping in view of the diverse hydrogeology of the Kabirdham district additional 15 key well has been established in Phreatic aquifer and 39 key well in Fractured aquifer for monitoring of water level and other hydrogeological information. A total of 55 key well (**Table 8**) has been established and monitored in pre monsoon and post monsoon period.

Table 8: Details of monitoring well (Key well)

Aquifer	Kawardha	Bodla	Sahaspur Lohara	Pandariya
Existing Monitoring Key Well (NHNS)				
Phreatic Aquifer	2	12	4	3
Fractured Aquifer	3	3	2	1
Generated Monitoring Key Wells (NAQUIM)				
Phreatic Aquifer	2	8	3	2
Fractured Aquifer	8	12	7	12

2.2 Hydrochemical Data

To know the hydro chemical behaviour of the ground water in the study area, 50 nos. of ground water samples were collected and analysed in the chemical laboratory of Central Ground Water Board, NCCR, Raipur for determination of various chemical parameters. 16 ground water samples were collected and analysed under NHNS monitoring.

Table 9: Details of Block wise groundwater sample

Block	Kawardha	Bodla	Sahaspur Lohara	Pandariya
Sample Analyzed (NHNS)	5	2	5	3
Sample Analyzed (NAQUIM)	5	20	15	11

2.3 Geophysical Data

To delineate the disposition of the existing aquifer system 72 VES already carried out by CGWB. Additional 25 VES proposed through outsourcing.

Table 10: Block wise distributions of surface geophysical activities in Kabirdham district

S. No.	Block	No. of VES	No. of WRP (line kms)	Radial Sounding
1	Bodla	14	-	-
2	Kawardha	14	-	-
3	Pandaria	38	2 (0.41)	1
4	Sahaspur Lohara	6	-	-
Total		72	2 (0.41)	1

2.4 Exploratory Data

A total of 18 exploratory wells (EW) and 03 observation well (OW) exist in the Kabirdham district before the NAQUIM study. Additional 17 EW construction proposed through outsourcing. Table 11 summarizes the status of exploratory wells in the study area.

Table 11: Block wise distributions of Exploration in Kabirdham district

Well Type	Kawardha	Bodla	Sahaspur Lohara	Pandariya
EW	6	1	5	6
OW	2	2	0	0

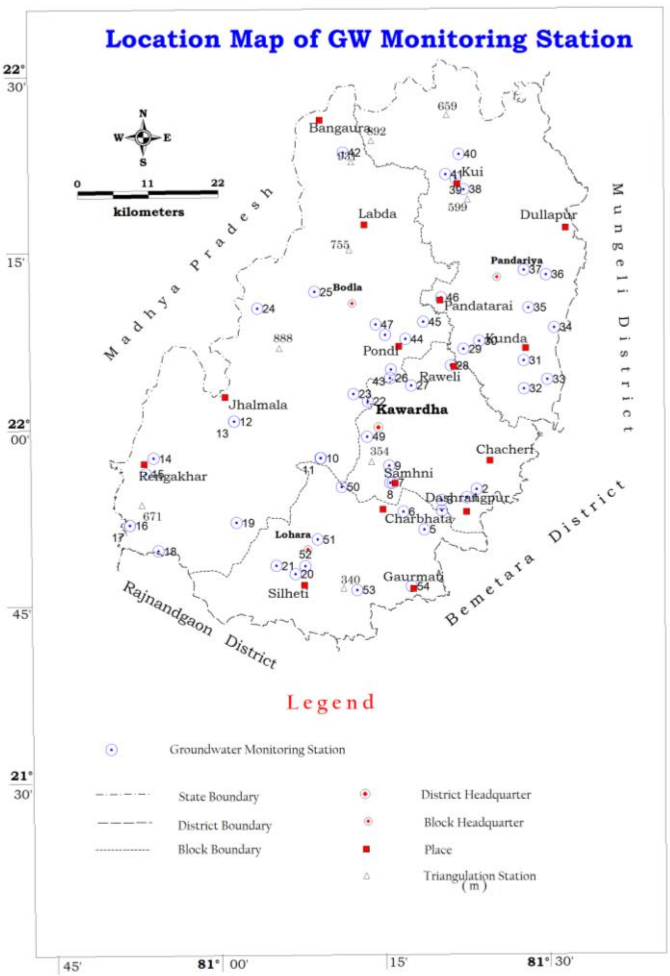

Figure 7: Location Map of GW Monitoring station

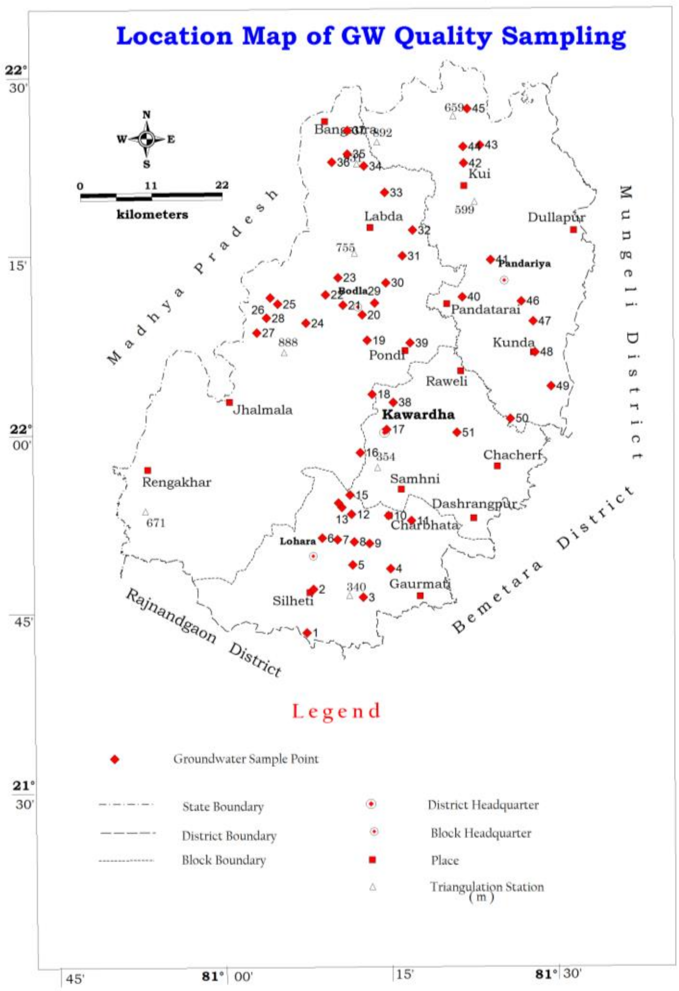

Figure 8: Location Map of GW Sampling Point

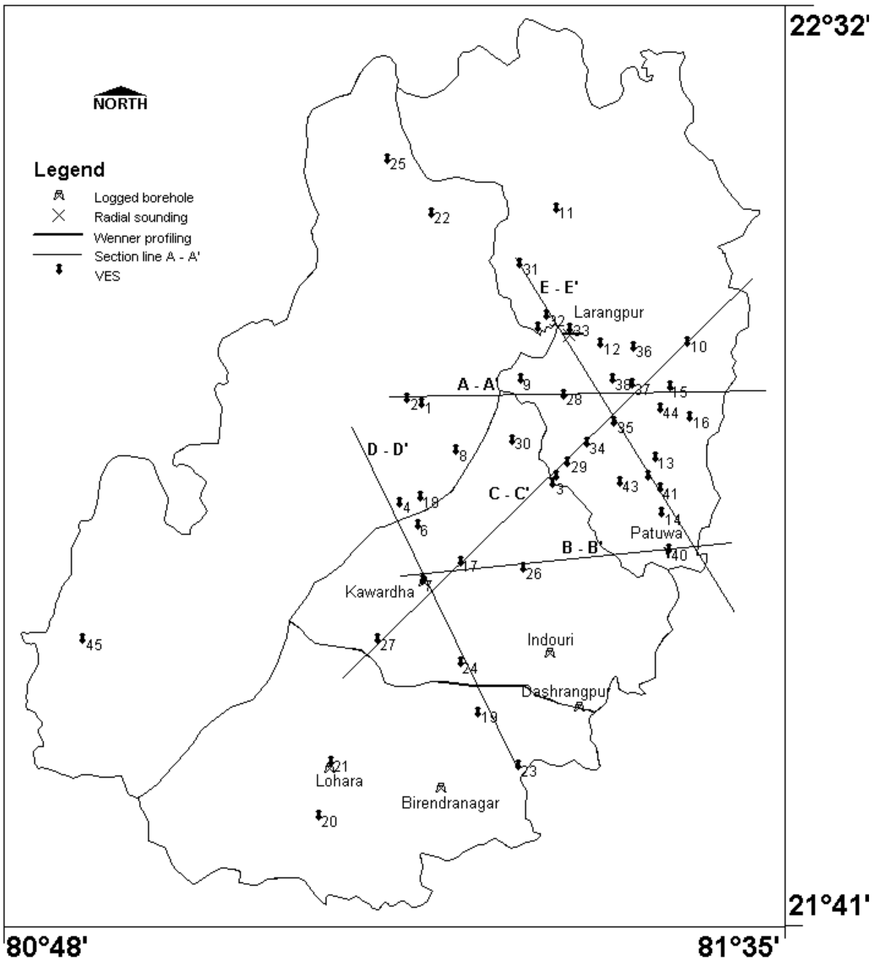

Figure 9: Location of Geophysical Activities in Kabirdham District

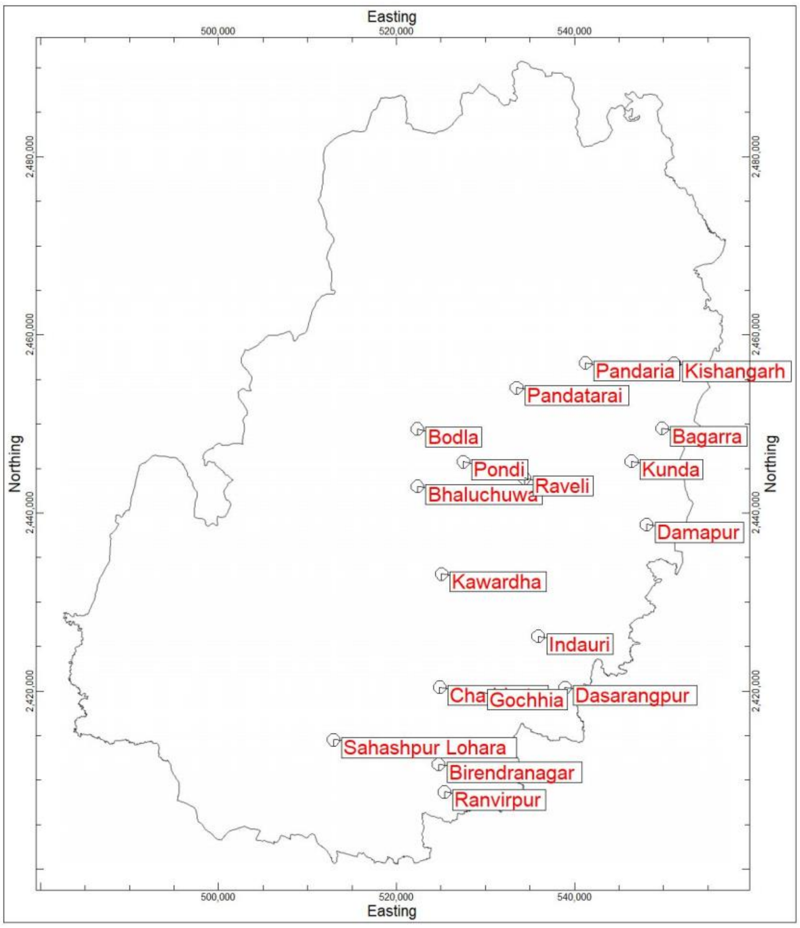

Figure 10: Location of Exploratory Wells in Kabirdham District

3. Data Interpretation, Integration and Aquifer Mapping

3.1 Hydrogeological Data

Based on the depth to water level periodical monitoring data of the key wells established in the study area, pre-monsoon and post-monsoon depth to water level maps as well as seasonal fluctuation maps have been prepared.

Water Level Behavior:

(i) Premonsoon Water Levels

Water Levels in Phreatic aquifer (Figure 11) of district varies from 5.29 to 10.0m below ground level with average of 7.50m bgl whereas in fracture aquifer (Figure 14) it varies from 8 to 19 mbgl.

(ii) Post Monsoon Water Levels

Water Levels in Phreatic aquifer (Figure 12) of district varies from 2.55 to 9.95m below ground level with average of 5.01m bgl wheras in deeper fracture aquifer (Figure 15) it varies from 2.5 to 44.1m bgl with average of 8.90m bgl. Maximum post monsoon water level observed at Daladali plateau area.

(iii) Seasonal water level fluctuation: The water level fluctuation data indicates that in study area, water level fluctuation in phreatic aquifer (Figure 13) varies from 0.18m at Marajpur village of Bodla to 4.14m at Chilpi village with an average fluctuation of 2.73m.

The long term water level trend (Figure 16) indicates that there is decline in pre-monsoon water level in Kawardha, southern part of Pandariya block and Sahaspur Lohara block. Increasing number of borewells for irrigation is major reason for long term declination in water level. In other parts of the Kabirdham district there is no significant decline in water level.

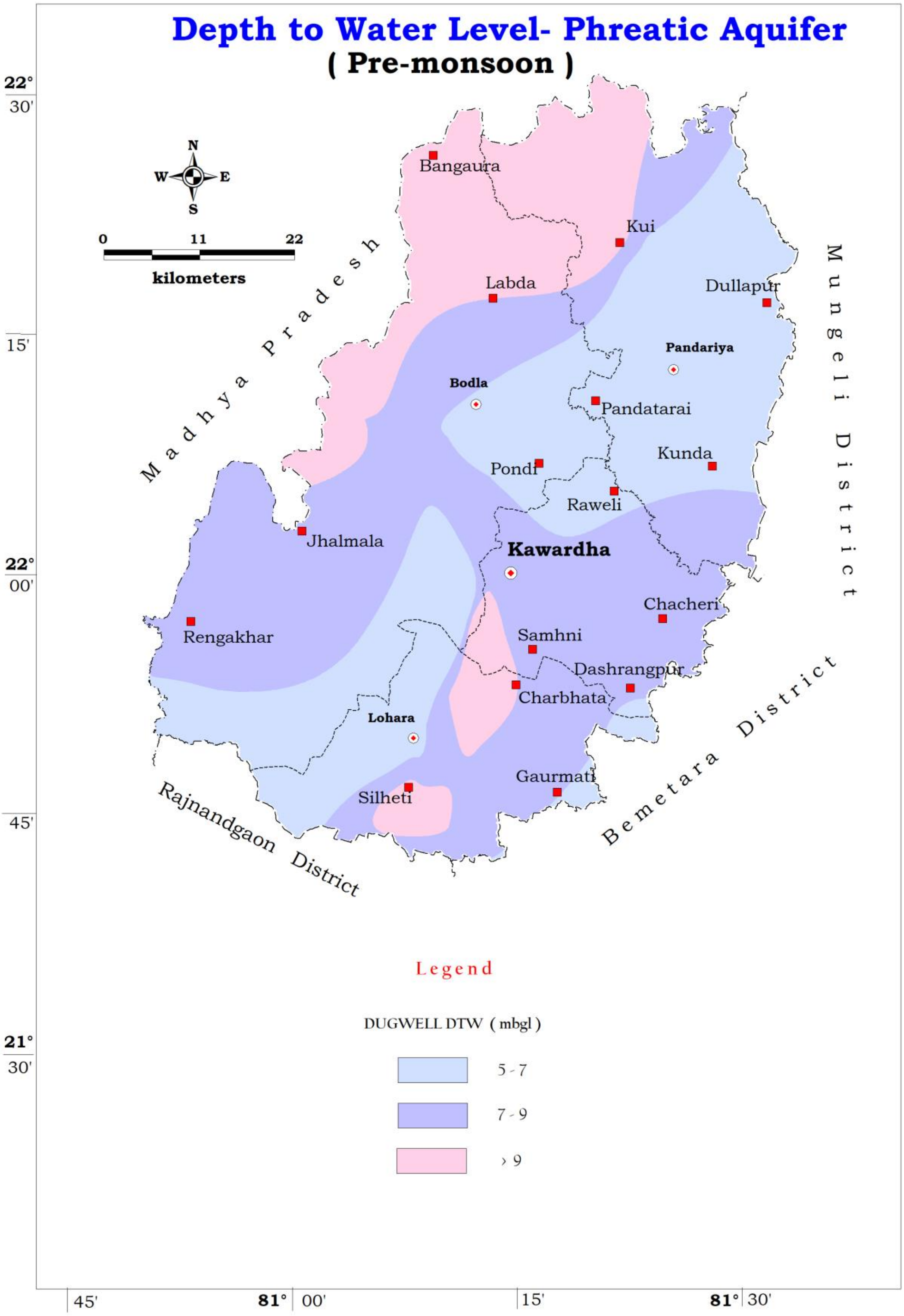

Figure 11: Depth to water level map Phreatic Aquifer (Pre-monsoon)

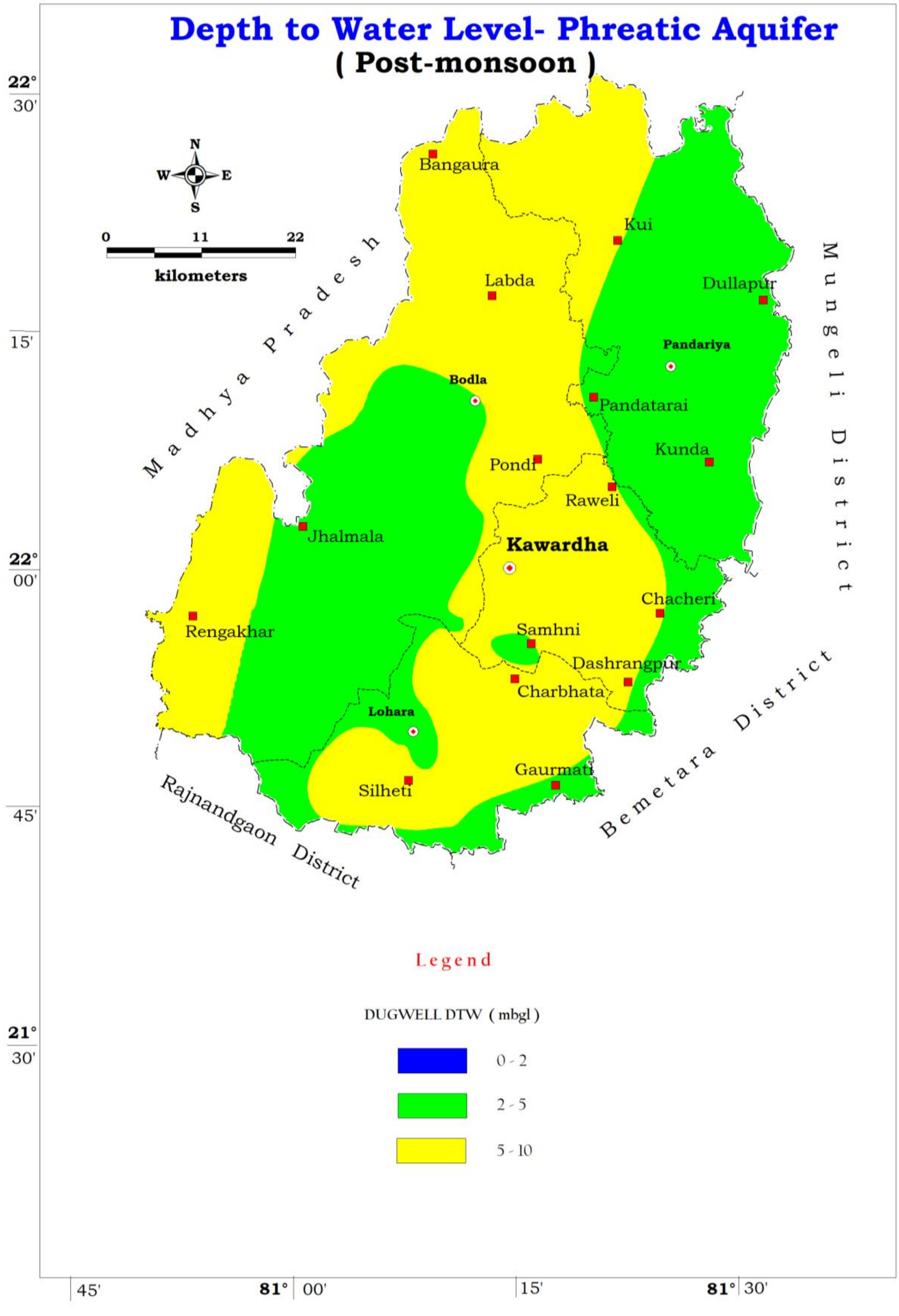

Figure 12: Depth to water level map Phreatic Aquifer (Post-monsoon)

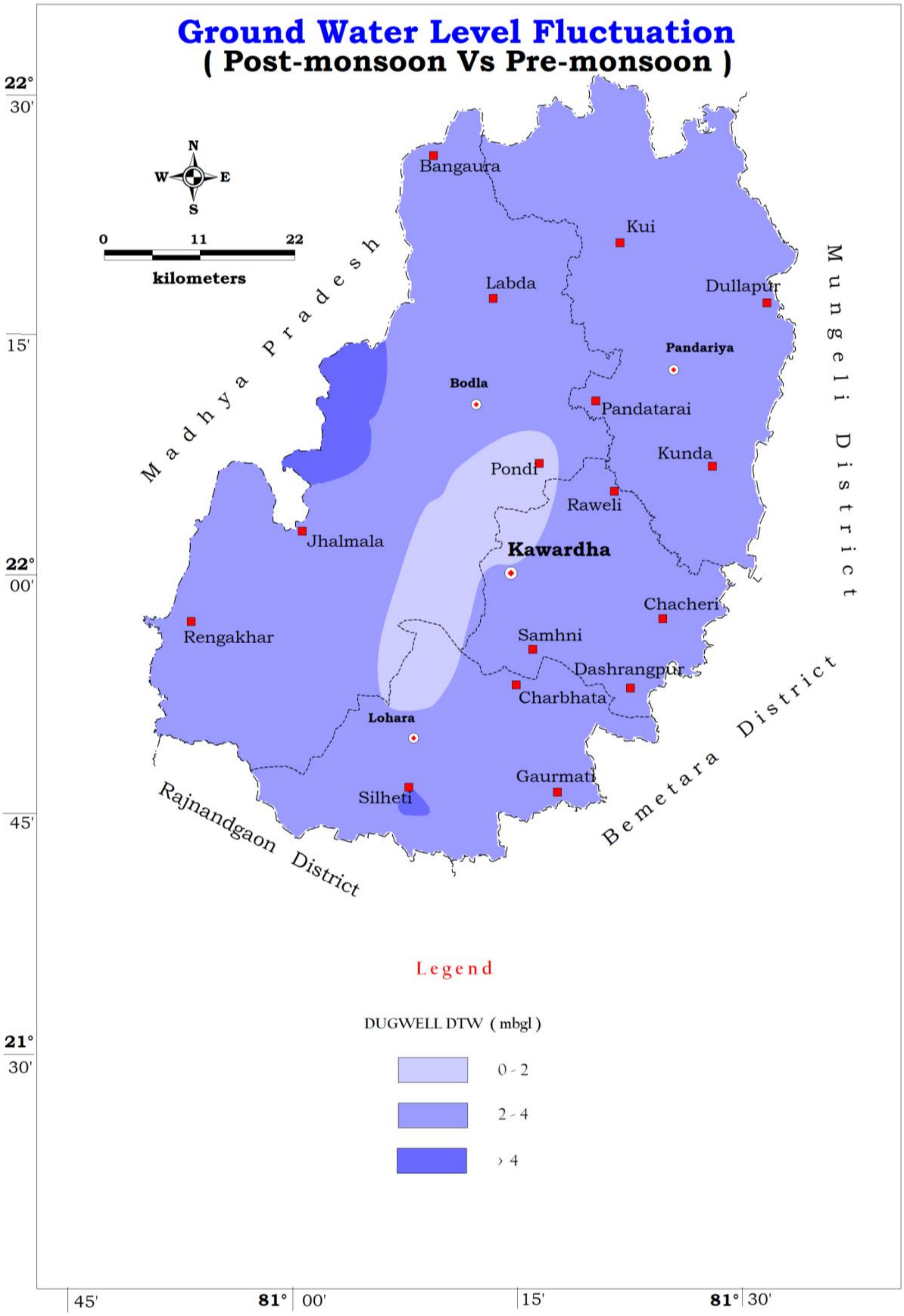

Figure 13: Depth to water level fluctuation map of Phreatic Aquifer

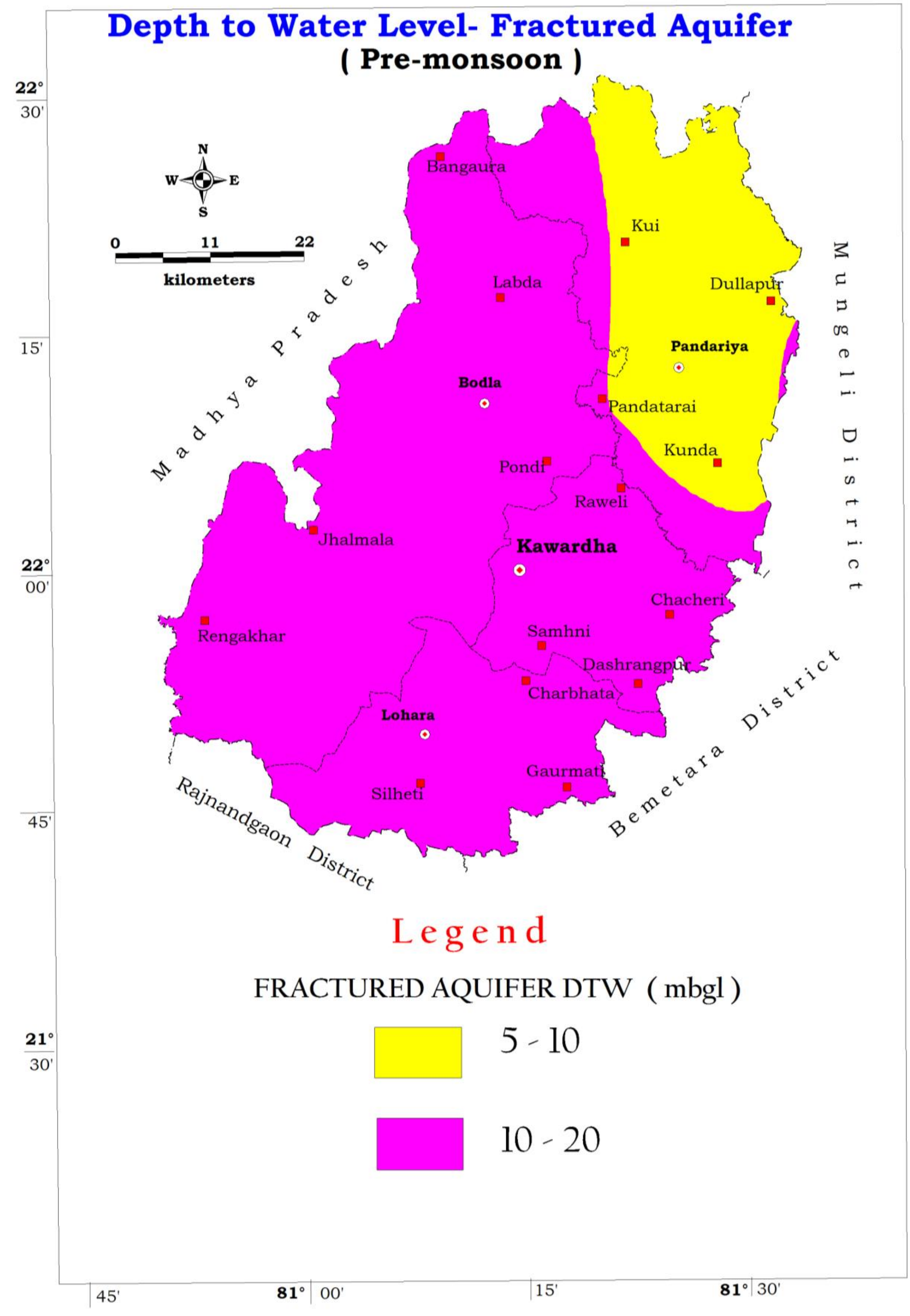

Figure 14: Depth to water level map Fractured Aquifer (Pre-monsoon)

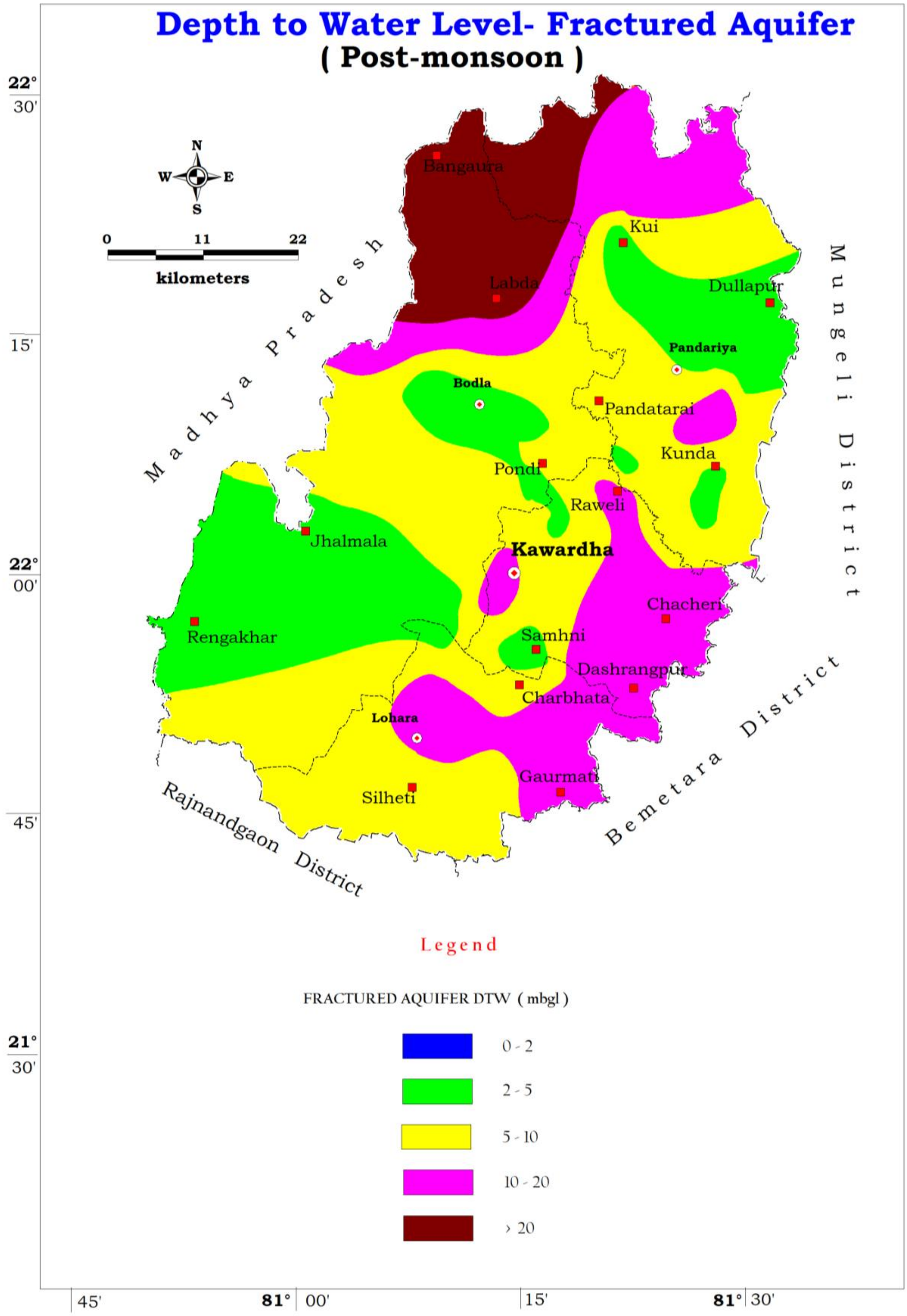

Figure 15: Depth to water level map Fractured Aquifer (Post-monsoon)

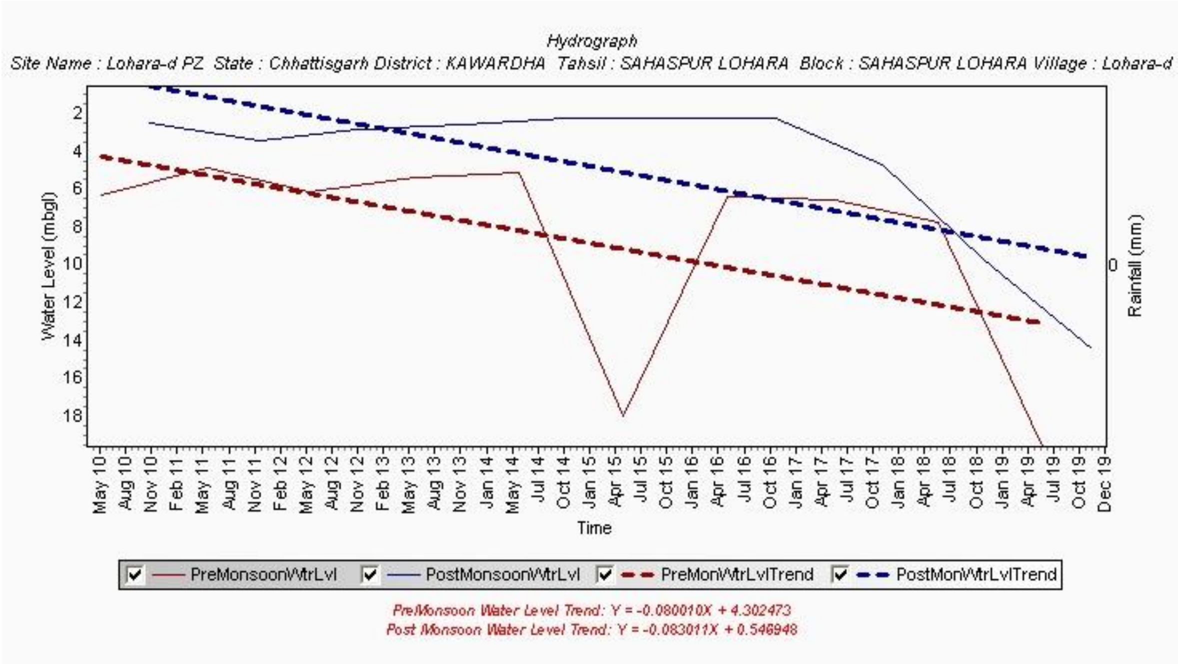

Figure 16 a: Hydrograph of Lohara Piezometer (Deep), Kabirdham dsitrict

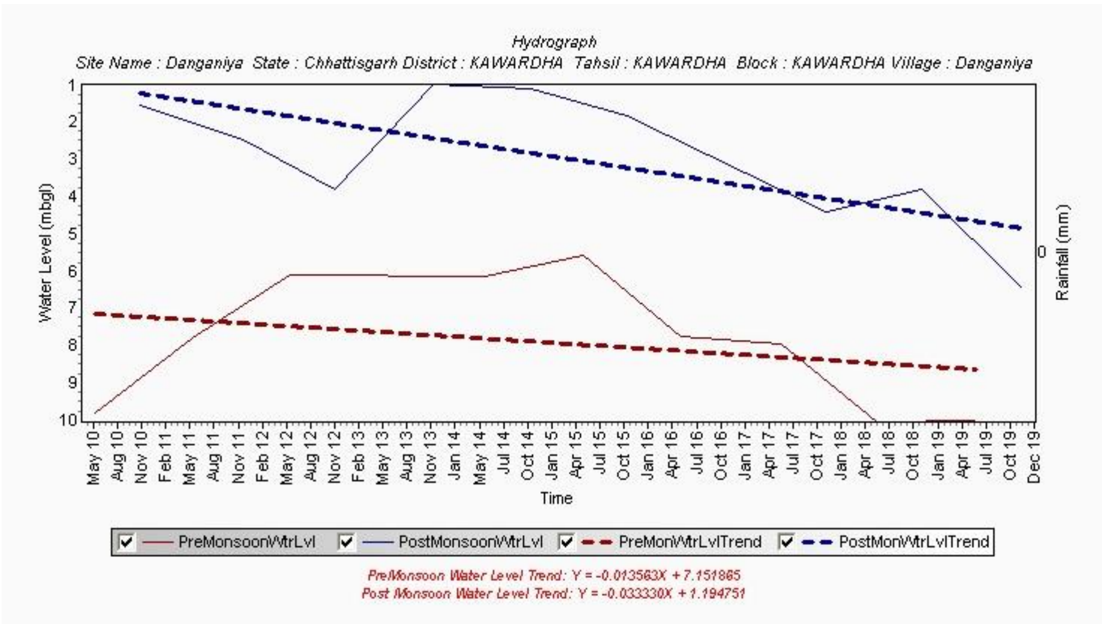

Figure 16 b: Hydrograph of Danganiya village, Kawardha block

3.2 Hydrochemical Data

Drinking water quality: A total 52 nos. of ground water samples were collected in Kabirdham district. The pH value varies from 7.45 to 8.3 with an average value of 7.85 and water is neutral in nature. The electrical conductivity varies from 69 to 2131 µS/cm at 25° C with an average of 606.1 µS/cm. The bicarbonate ranges from 36.6 to 640.5 mg/l with an average of 235 mg/l. The concentrations of bicarbonate, chloride varies from 7.1 to 337.2 mg/l with average concentration of 52 mg/l. The sulphate concentration varies from 1.7 to 101.0 with average concentration of 22.33 mg/l. Nitrate is main water quality problem in this area the highest concentration was recorded 78 mg/l. High nitrate > 45 mg/l, recorded at Dania Khurd, Charbatha, Gochhiya, Kodar, Charbhata, Polmi, Putputa, Dullarpur and Saihamalgi. The fluoride concentration ranges from 0.04 to 1.6 mg/l with an average value of 0.54 mg/l in the district. High concentration 1.6 mg/l was recorded at Navagaon village.

The value of total hardness observed from 40.0 to 1500 mg/l with an average of 212.94 mg/l.

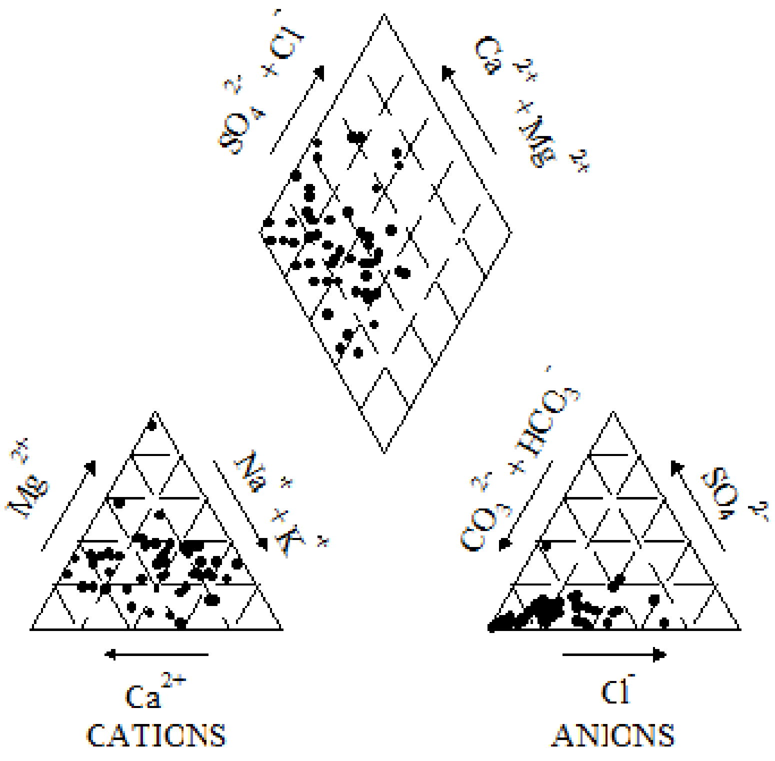

Figure 17: Piper Diagram for Kabirdham District

The concentrations of calcium, magnesium, sodium and potassium vary from 8.0 to 108.0 mg/l, 2.4 to 350.14 mg/l, 1.6 to 341 mg/l and 0.3 to 41.0 mg/l respectively. The iron concentration recorded upto 1.82 mg/l. High Iron concentration recorded at Bija Bairangi village (1.82mg/l), Sahaspur lohara (0.31mg/l), Uriakhurd (0.32mg/l), Banjari village (0.61 mg/l) and Chilpi (0.40mg/l). No arsenic was detected in ground water of the district. As per the drinking water standards in most of the area groundwater is portable. However at few locations ground water quality problem is observed.

The modified piper diagram of the district was given in Figure 17 which shows the ground water of Kabirdham district is found calcium-bicarbonate (Ca-HCO3) type. However in few locations it is found sodium-bicarbonate (Na-HCO3) in nature.

Irrigation water quality: The ground water in the district is suitable for irrigation uses except Kawardha, where the high value of SAR, SSP and KI were obtained. The US Salinity diagram plotted between SAR and EC value explains that most of the ground water samples fall in C1S1, C2S2, C1S3 category and quality of water is suitable for irrigation purposes and presented in Figure 18. At few location it is fall in C3S2 category and suitable for restricted crop.

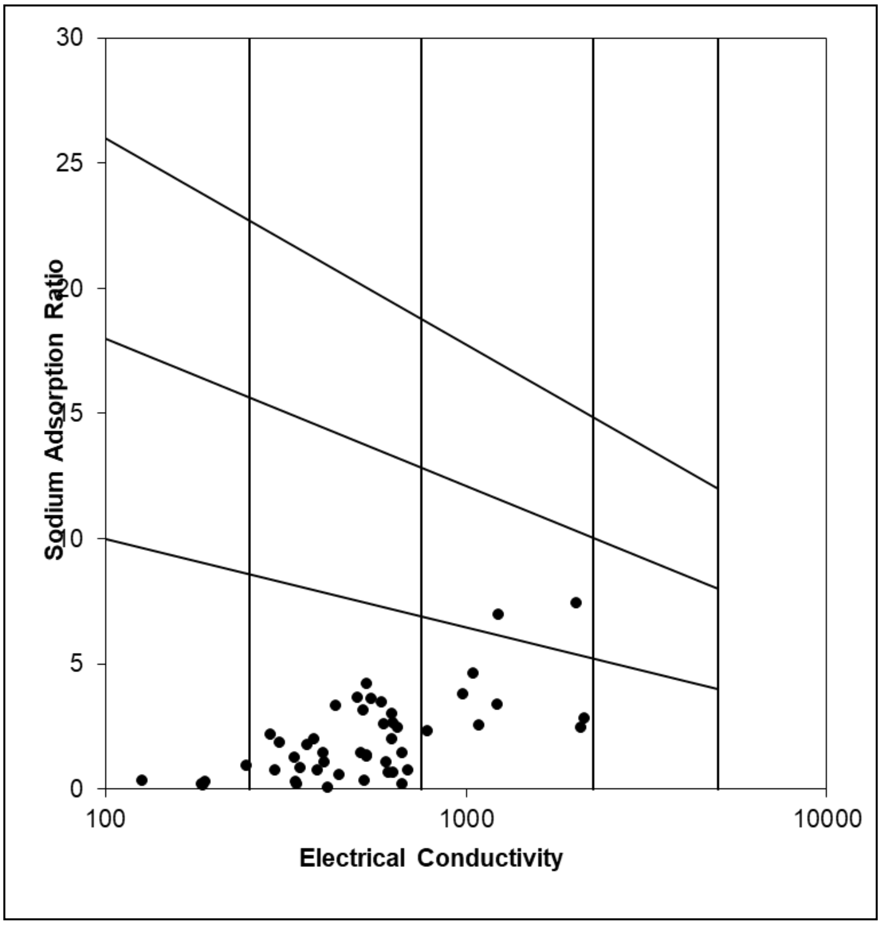

Figure 18: US Salinity Plot for Kabirdham District

Industrial water quality: All the ground water of Kawardha is non corrosive and suitable for industrial uses except one location is Sahaspur lohara where ground water was found less suitable for industrial purposes.

3.3 Geophysical Data

A total number of forty five (45) VES has been selected as representative sounding curves for describing the Kawardha district mainly the area occupied by Chhattisgarh Super Group. The interpreted layer parameters of VES curves are given in Table 12**.** The central area of the district i.e. central east part of Bodla block, western part of Kawardha block and southern part of Pandaria block is having high ground water potentiality. The maximum depth of bedrock about 60m at village Borla, 58m at Rajnawa and about 45m at Newari isencountered in the district. The southern and extreme eastern part of the district is having poor ground water potentiality. The depth of bedrock about 7.5m at village Gochia, 14.5m at Mahali and about 26m at Patuwa is encountered in the district. The area occupied by limestone formation having low S.P. and resistance indicates the occurrence of zones within the overall high resistive limestone formation and is interpreted to be zones occupied by secondary porosity and suitable for development of ground water.

Table 12: Interpreted layer parameters of VES observed in Kabirdham district

VES No.	Location	Respective Resistivity (ohm-m)					Respective layer Depth (m)			
		ρ_1	ρ_2	ρ_3	ρ_4	ρ_5	D_1	D_2	D_3	D_4
1	Bodla	34	16	30	360	1000	1.2	3.5	25	60
2	Bandhatola	37	25	45	1200	-	0.9	5.5	42	-
3	Raweli	9	5.5	200	1000	-	1.8	9.3	15	-
4	Rajnawa	40	160	20	70	1500	0.5	2.5	20	58
5	Sodha	9	27	100	1200	-	14	20	28	-
6	Rengakharkhurd	95	135	25	200	-	0.6	5.5	22	-
7	Kawardha	95	26	1500	-	-	4.5	41	-	-
8	Pondi	8	21	1500	-	-	4	15	-	-
9	Pandatarai	28	9	100	1500	-	4	10	32	-
10	Kishangarh	4	18	170	1500	-	1.8	7	15	-
11	Kui	42	32	2000	-	-	2.7	22	-	-
12	Pandaria	6.8	42	127	1500	-	5	21	35	-
13	Kunda	12	375	-	-	-	15	-	-	-
14	Damapur	6	1300	-	-	-	5.2	-	-	-
15	Mahali	18	40	500	-	-	3.5	14.5	-	-
16	Bagharra	21	100	300	-	-	2	19	-	-
17	Newari	6.5	30	800	-	-	6	45	-	-
18	Bhaluchuwa	5	85	-	-	-	6.5	-	-	-
19	Gochia	6.5	265	-	-	-	7.5	-	-	-
20	Silhati	9	1500	-	-	-	10	-	-	-
21	Sahaspurlohara	13	9	1500	-	-	0.7	10	-	-
22	Taregaon	31	54	2500	-	-	1.5	12.5	-	-
23	Thathapur	15	200	-	-	-	15	-	-	-
24	Bamhani	60	20	700	-	-	0.9	37	-	-
25	Daldali	1100	3500	950	50	-	1	7	30	-
26	Manikchouri	5	57	1500	-	-	3	32	-	-
27	Maharajpur	4	47	11	1200	-	1	3.5	20	-
28	Plansari	4.5	110	1200	-	-	11	22	-	-
29	Ruse	4.5	18	1200	-	-	4.5	18.5	-	-

VES No.	Location	Respective Resistivity (ohm-m)					Respective layer Depth (m)			
		ρ_1	ρ_2	ρ_3	ρ_4	ρ_5	D_1	D_2	D_3	D_4
30	Sarangpur	2.8	1200	-	-	-	4.2	-	-	-
31	Devsara	40	70	630	-	-	1.8	32	-	-
32	Biranpur	6	22	1200	-	-	15	30	-	-
33	Larangpur	6.5	35	750	-	-	6	37	-	-
34	Jangalpur	6.5	36	1500	-	-	14	39	-	-
35	Bortara	7	40	1500	-	-	18	26	-	-
36	Tenduwadih	5.5	15	200	-	-	2	8	-	-
37	Sirmaguda	6	12	600	-	-	5	18	-	-
38	Dhogbhati	40	22	2000	-	-	8	33	-	-
39	Chhanta	8	28	9	2000	-	1.5	10.5	40	-
40	Patuwa	5	9	1500	-	-	6	26	-	-
41	Dullipar	10	22	600	-	-	1.5	9	-	-
42	Kheltukari	6.5	36	400	-	-	10	35	-	-
43	Kolegaon	5	200	-	-	-	11	-	-	-
44	Gunjheta	8	1500	-	-	-	9	-	-	-
45	Rengakhar	38.5	115	390	-	-	4.8	31	-	-

3.4 Exploratory Data

The status of exploratory borewells drilled in each formation and their depth range, zone encountered and discharge variation is tabulated in **Table 13.** The area explored formed eastern part of the district which falls under Kawardha,Pandaria and Lohara blocks. The depth of exploration of ground water through drilling was down to depth of 300 mbgl. Most of the wells drilled ended either in Maniyari formation or Pandariya formation. The yield of these exploratory wells range between 1.0 to 10.85 litres per second for a drawdown ranging between 4.2 and 15 mts, static water level ranged between 2.00 to 8.00 mbgl.

District is underlain by Volcanic rocks of Nandgaon group, Dondargarh granite,Chipi formation belonging to middle proterozoic age, overlain unconformably by Chattisgarh Super group belonging to upper proterozoic age. Recent to subrecent age alluvial deposits comprising gravel, sand, clay and laterite also occur at places in the area. The status of exploratory borewells drilled in each formation and their depth range, zone encountered and discharge variation is tabulated in Table 13.

Table 13: Formation wise status of the exploratory borewells in Kabirdham district

Formation	No.of borewells drilled	Depth range	Casing piped lowered	Zone encountered	Discharge (lps) in number of wells					Draw down	Transmissivity	S
		m bgl	m	m bgl	<1	1-3	3-5	5-10	>10	m	m^2/day	
Maniyari fm	4	250-300	9-30	22-30,46-49,60-65,	1	2	1	1		19	33	0.00006
Hirri fm /Tarenga fm	1	120	14	20-25,30-32	1					19		
Chandi	1	140	12	20-25,40-45,60-62				1		15		
Gunderdehi	1	297	12	27-30		1						
Pandaria fm	9	21-137	12-25	30-35,45-50,63-65,70-71,97-98			2	6	1	15	8-21	
Chilpi/cryataline / Andesite	2	150	14	30-35,45-50,63-65,70-71				1	1	35	1-14	

Chilpi Formation: 2 exploratory borewells have been drilled to a maximum depth of 150 m bgl, a discharge of more than 3 lps has been recorded. Through exploratory drilling it is revealed that the water bearing fractures are very common between the depth of 30 and 70 m bgl and these fractures have very good potential.

Pandaria Formation**:** This formation covers an area of about 765 sq.kms developed in central part of the district. This formation represents the cale-argillite facies overlying the Chanderpur arenites and is characterized by predominance of purple coloured calcarious shale with lenses and pockets of bedded flaggy limestone, stromatolitic limestone and dolomite. Pandaria formation represents lateral facies variation of charmuria (bedded) limestone, Gunderdehi shale, Chandi (Stromatalitic) Limestone and Tarenga argillites, which are directly developed in southern part of the Hirri sub basin but are inter mixed in northern part of Hirri sub basin to form this formation. From ground water point of view this formation is highly potential. Central Ground Water Board has drilled 9 number of exploratory borewells in the area maximum down to a depth of 137 m bgl. The wells have yielded water in the range of 3 and 14 lps. The transmissivity of the formation was measured to be 107 m^2/day. Due to the collapsible nature and high discharge of the formation drilling of deep borewell is a difficult job. Deep borewells can be constructed only by using telescopic method by gradually decreasing the diameter of borewell and lowering slotted sections against the collapsitble strata.

Chandi Formation: This formation comprises a dominant stromatolitic limestone sequence is eastern part of . It covers a maximum area of 280 sq.km.In all 1 nos of bore wells down to 140 m have been drilled in Chandi formation. Potential zones recorded down to 62 m bgl has yielded water upto 3 lps. Transmissvity of the formation varies from1 to 15 m^2/day.

Hirri and Tarenga Formation*:* This formation covers an area of about 120 sq.km is southern part of the district. It comprises predominantly argillite- dolomite sequence over lying Chandi formation Central Ground Water Board has drilled 1 borewells in this formation

Maniary Formation:.Maniary formation is gypsyferous shale. Ground Water is restricted within the secondary porosity developed as fractur/caverns in the formation down to 127 meters.Central Ground Water Board has drilled 4 borewells down to 300 meter mbgl piercing Hirri formation. Wells have given the discharge in the range of 1 to 10 lps. Transmissivity of the formation ranges between 33 m^2/day and Storativity is 0.00006 (Table 13).

3.5 Aquifer Geometry and Characterization

On the basis underneath geology and hydrogeological characteristics multiple aquifer system have been identified. Although most part are covered by Limestone, Shale and Gneiss aquifer system. All the aquifer system has the shallow aquifer and deeper aquifer which occurs in phreatic and fractured condition respectively.

Limestone Aquifer System: This formation represents the calc-argillite facies overlying the Chandrapur arenites and is characterized by predominance of purple colored calcareous shale with lenses and pockets of bedded flaggy limestone, stromatolitic limestone and dolomite. Pandaria formation represents lateral facies variation of Charmuria (bedded) limestone, Gunderdehi shale, Chandi (Stromatolitic) Limestone and Tarenga argillite, which are directly developed in southern part of the Hirri sub basin but are inter mixed in northern part of Hirri sub basin to form this formation. The area represents plain but slightly elevated terrain sloping towards south. From ground water point of view this formation is highly potential and is well developed by construction of bore wells for irrigation of Crops like Sugarcane and paddy twice a year, which requires comparatively more water. The wells have yielded water in the range of 7 and 14 lps. The transmissivity of the formation was ranges 2 to 145 m^2 /day. Due to the collapsible nature and high ground water potential of the formation drilling of deep bore well is a difficult job. Deep bore wells can be constructed only by using telescopic method by gradually decreasing the diameter of bore well and lowering slotted sections against the collapsible strata.

Shale Aquifer System: Shale aquifer system mainly consist of Maniyari Formation which shows oval shape out crop in the center of the Hirri sub-basin. It represents closing phase of deposition of Chhattisgarh basin and consist of lower gypsiferous grey silt stone and shale and followed upward by reddish brown calcareous and non-calcareous shale with limestone and dolomite. The red shale is less fissile. The laminated grey shale is composed of clay and silt. The alternate clay and silt define the laminated character. The terrain is generally gently sloping plain terrain with an elevation ranging between 300 and 275 m amsl. The formation is highly cavernous and highly potential. Presence of gypsum veins within the formation has given rise to the salinity in ground water due to high sulphate contents. All the high yielding wells are within the depth range of 200 mbgl. Generally the caverns, developed due to the dissolution of gypsum veins do not occur below 200 m bgl. Hence the maximum discharge is obtained within 200 m deep well. The value of transmissivity ranges between upto 600m^2 /day. Studies carried out by Central Ground Water Board reveals that because gypsum veins does not occur at any particular depth of direction high sulphate areas cannot be predicted.

Laterite Aquifer System: Laterite is developed as 2 to 20 m thick capping on most of the basaltic terrains. At places it is being tapped in dug wells as aquifer but ground water in this formation sustain for only a short period. About 40–50 m. thick Laterite is reported by PHE Department which is being tapped in tube wells. This formation is reported to have enough potential and sustainability to fulfill the domestic and drinking water requirements of the area.

Granite, Gneiss and Schist Aquifer System: Based on the field observation it can be inferred that the weathered thickness varies from few meters to 25 meters. Weathered mantle is the main aquifer which holds considerable potential of ground water. Generally the weathered zone is immediately followed by a fracture. However deep-seated fractures zone have also been encountered at places down to 150 m depth. In granite and gneisses the yield of well depends upon structure, lithology and landform, structure controlled by lineament plays a major role in controlling the yield. Generally the site located along the lineaments or in close vicinity of lineaments have given high yields whereas sites away from the lineaments have yielded poorly.

Basalt Aquifer System: Ground water occurs in weathered zone, joints and fracture and vesicular zones under both phreatic and semi-confined conditions. Semi confined conditions are observed in interflow zones at shallow depths, whereas confined conditions are observed in the interflow zones at deeper depth. It is observed that ground water in Basalt occur in

(i). Weathered loose morrum like material in upper weathered zone.
(ii). Weathered ambygadaliodal basalts in each flow.
(iii). Exfoliated weathered zones covered by flows with columnar joints.
(iv). Fractured massive basalt, dykes etc.

The shallow aquifers are tapped by open wells of depth range of 8 to 25 mbgl. in which depth to water level range from1.5 to 21.0 mbgl. The borewells tapping interflow zones between 60 to 100 mbgl have piezometric head ranges from 15 to 25 mbgl. The yield of shallow/ deep boreholes depends on the thickness of vesicular and jointed horizons 1 to 9 lps.

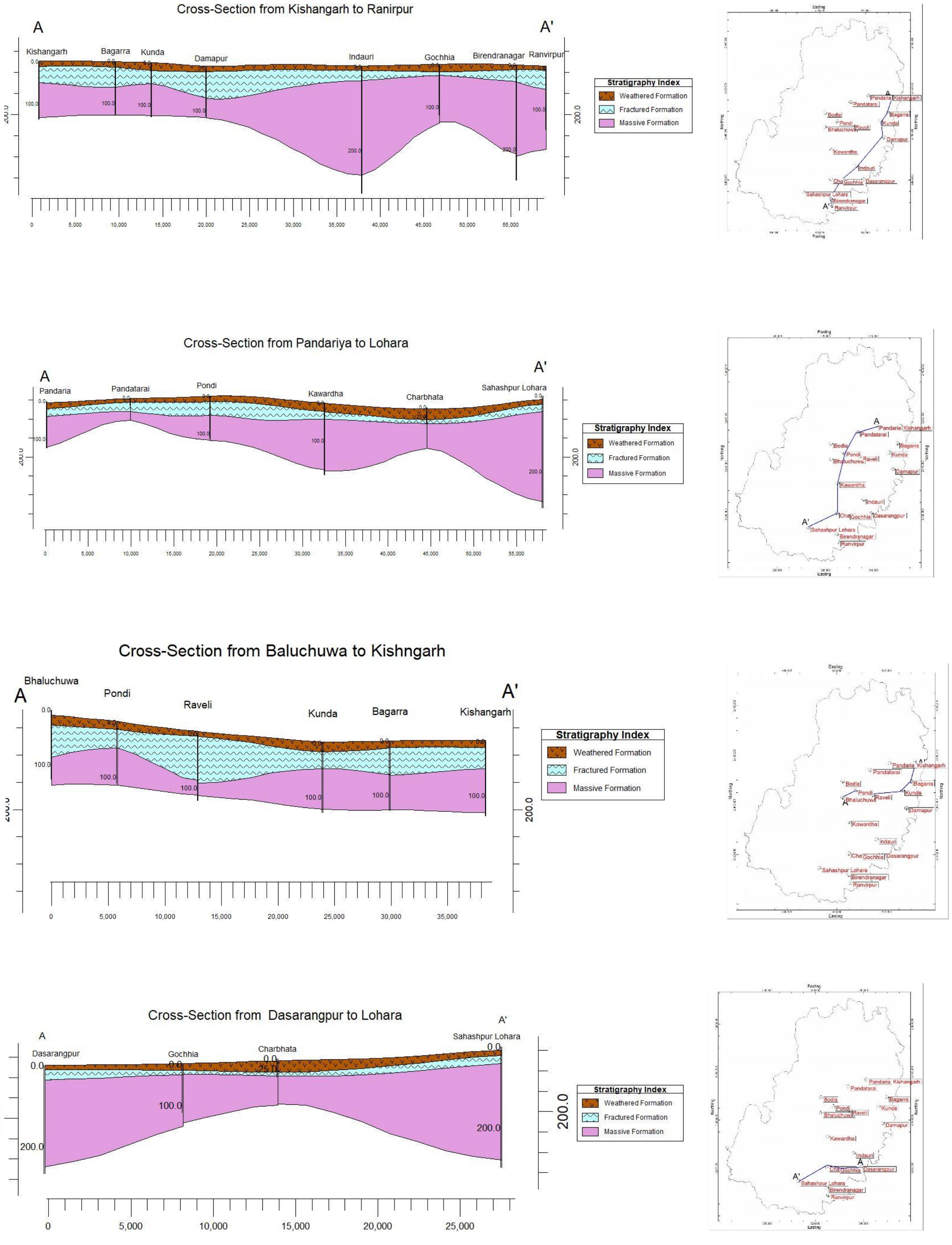

Figure 19: Two Dimensional (2-D) Aquifer Disposition of Kabirdham district

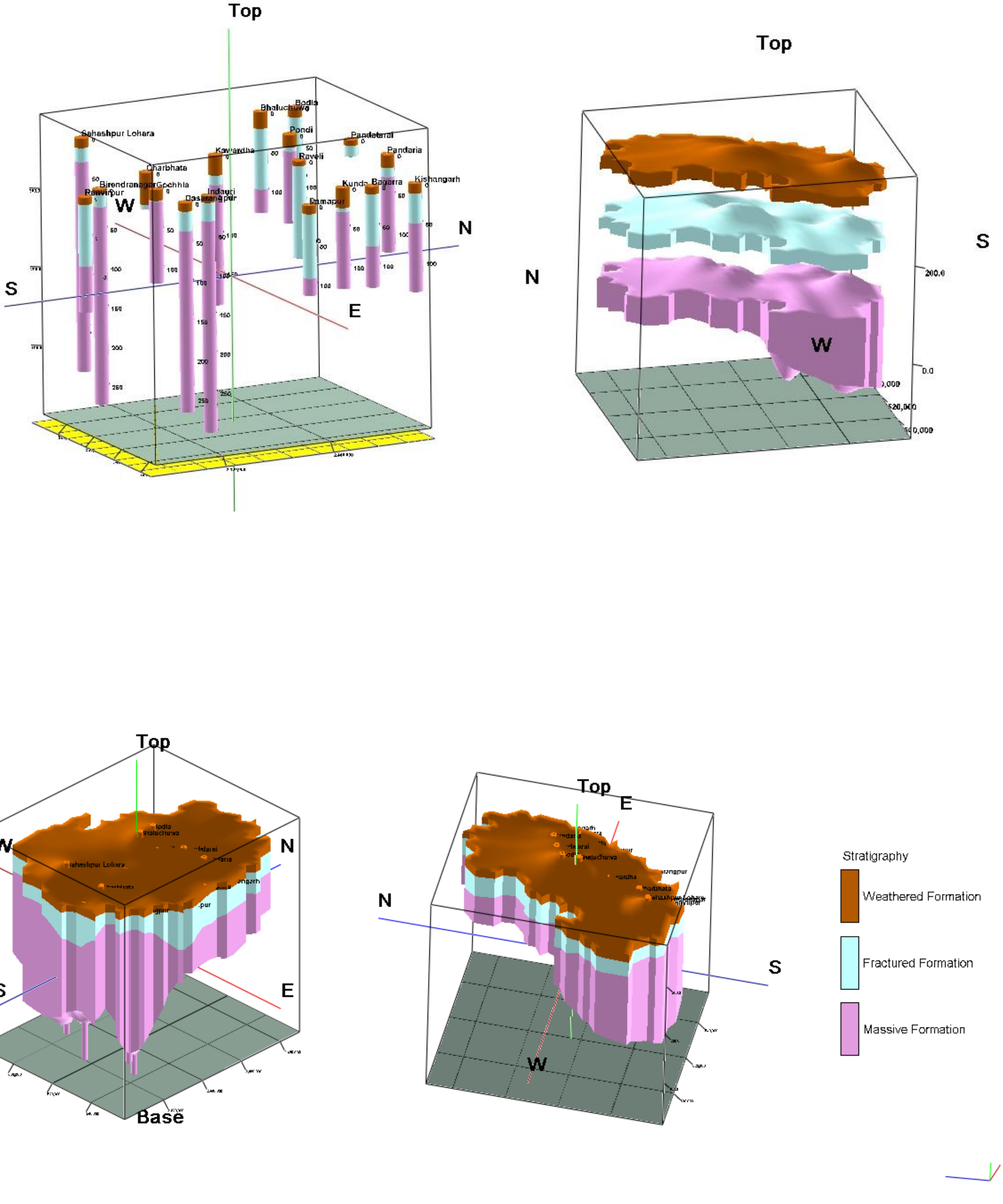

Figure 20: Three Dimensional (3-D) Aquifer Disposition of Kabirdham district

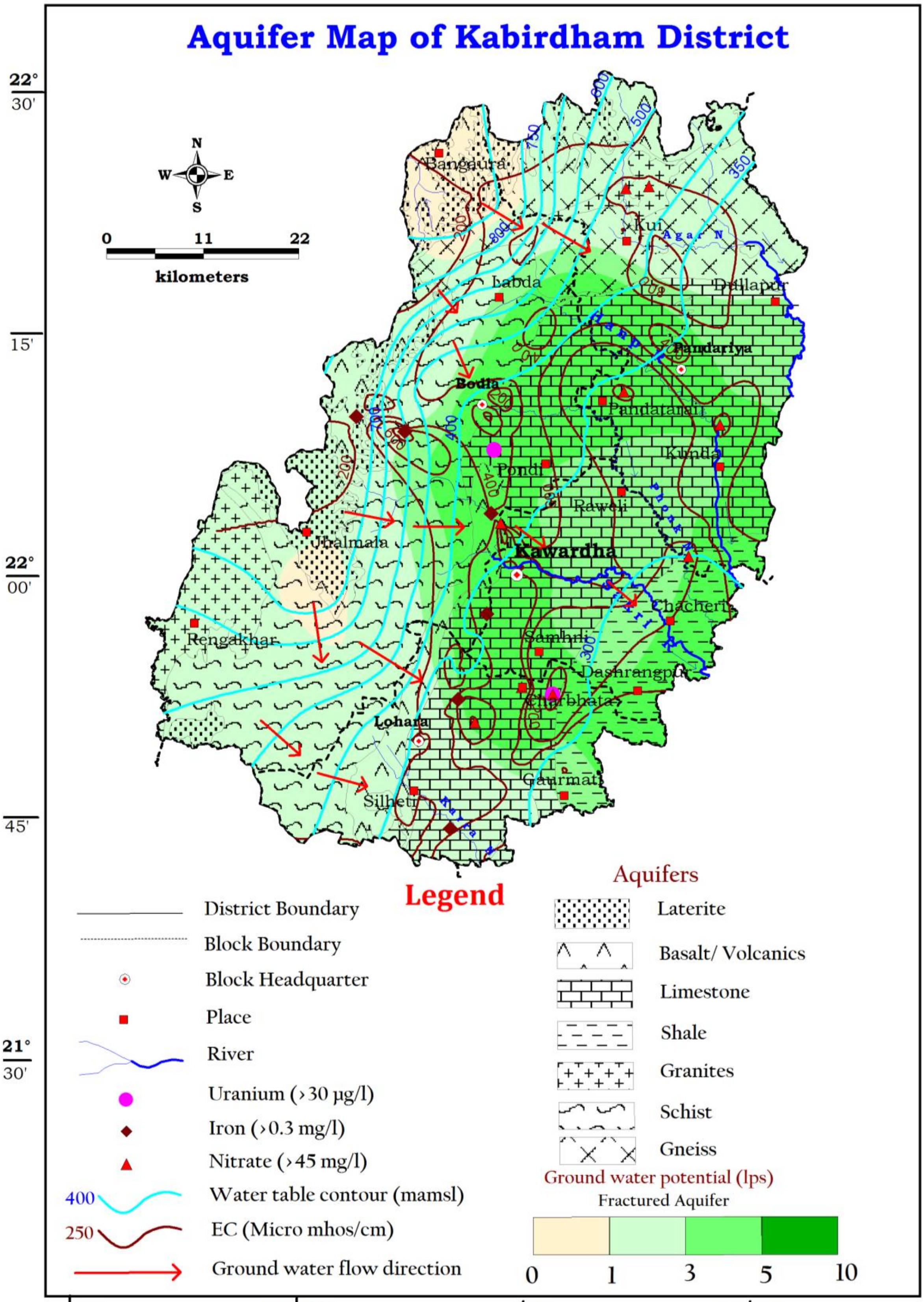

Figure 21: Aquifer Map of Kabirdham District

4. GROUND WATER RESOURCES

Groundwater Resource Availability and Extraction: Based on the resource assessment made, the resource availability in Kabirdham district upto 200 m depth is given in the table 14 & 15.

Table 14: Ground Water Recharge of Kabirdham district in Ham

Block/ District	Ground Water Recharge (Ham)				Total Annual Ground Water (Ham) Recharge	Total Natural Discharges (Ham)
	Monsoon Season		Non-monsoon season			
	Recharge from Rainfall	Recharge from Other Sources	Recharge from Rainfall	Recharge from Other Sources		
Bodla	11803.07	2083.04	1640.89	2474.85	18001.85	1119.42
Kawardha	5268.57	1001.06	741.34	3403.45	10414.42	1041.44
Pandariya	9148.20	660.66	1228.32	2062.98	13100.16	1310.02
Sahaspur Lohara	7649.57	1012.66	1276.87	1638.13	11577.23	677.39
Total (District)	33869.41	4757.42	4887.42	9579.41	53093.66	4148.27

Table 15: Ground Water Resources of Kabirdham district in Ham

Block/District	Dynamic Resource Phreatic Aquifer	Dynamic Resource Fractured Aquifer	Total Static Resources Phreatic Aquifer	In storage Resource Fractured Aquifer	Total Resource	Stage of Extraction (%)	Categorization
Bodla	16882.43	241.63	3788.09	7473.32	28385.47	39.20	Safe
Kawardha	9372.98	105.24	1320.07	2405.46	13203.76	96.10	Critical
Pandariya	11790.14	230.16	3010.35	5002.73	20033.38	93.59	Critical
Sahaspur Lohara	10899.84	175.27	1973.80	4360.48	17409.39	83.12	Semi Critical
Total (District)	48945.39	752.3	10092.31	19241.99	79032	72.98	

Existing and Future Water Demand (2025): The existing groundwater extraction for irrigation in the area is 33365.73 Ham, for domestic extraction is 2347.60 Ham. To meet the future demand for ground water, a total quantity of 12735.54 ham of ground water is available for future use.

Table 16: Ground Water Existing and Future Water Demand (2025)

Block/ District	Annual Extractable Ground Water Recharge (Ham)	Current Annual Ground Water Extraction (Ham)				Annual GW Allocation for Domestic Use as on 2025	Net Ground Water Availability for future use
		Irrigation Use	Industrial Use	Domestic Use	Total Extraction		
Bodla	16882.43	6107.52	3.36	507.65	6618.54	591.36	10180.18

Kawardha	9372.98	8346.00	0.14	661.27	9007.41	797.18	229.66
Pandariya	11790.14	10315.91	1.23	717.30	11034.43	852.50	620.50
Sahaspur Lohara	10899.84	8596.30	2.15	461.38	9059.83	596.18	1705.21
Total (Dist)	48945.39	33365.73	6.89	2347.60	35720.21	2837.22	12735.54

5. GROUND WATER RELATED ISSUES

(i) Kabirdham district have more than 80% of irrigated area is dependent on groundwater. District current annuall ground water extraction for irrigation contributes more than 93 % of total extraction. In Kawardha block more than 90 % of gross cropped area has been irrigated by groundwater and Irrigation extraction contributes 92.65 % out of the total extraction for all uses. Similarly, in Pandariya block more than 74 % of gross cropped area irrigated by groundwater and irrigation extraction contributes 93.48 % out of the total extraction for all uses. Irrigation extraction is the main factor for critical categorization of Kawardha and Pandariya blocks, and Semi critical categorization for Sahaspur Lohara block.

(ii) At several places of Kawardha and southern part of Pandariya and Sahaspur Lohara blocks phreatic aquifer i.e. zone of dugwells dried up in summer due to large number of shallow borewells in the area.

(iii) In Granite/Gneiss/Schist aquifer system potential zone for ground water is related with occurrence of fracture, so drilling a high yield well is always a challenge. Proper scientific study coupled with geophysical investigation may minimize the failure of well.

(iv) Problems in Tube well / Bore well construction in areas underlain by collapsible formation where drilling becomes difficult. When portable rotary rigs are deployed for drilling, the drilling operations become very slow and the pore spaces in fine grained layers are invaded by drilling fluid as a result the discharges tend to be poor. Proper well development is seldom carried out by private drillers and as a result fine grains deposited in the bore. Sometimes caving of wells are commonly reported where DTH rigs also not successful. So combination rig may be preferred for drilling in such areas.

(v) Groundwater quality issues mainly is of Iron and Nitrate in part of the district. Although Uranium concentration more than 0.03 mg/l also reported at 03 locations.

6. GROUND WATER MANAGEMENT PLAN

(i) It has been observed during fieldwork, there is colossal wastage of groundwater through private well and public water supply system. So, Information, Education and Communication (IEC) activities need to be organized to sensitize people on the issues of depleting groundwater resource. Massive awareness campaigns are essential to aware people about the importance of community participation in saving water.

(ii) Desiltation of existing Tanks and Talabs to be carried out for efficient storage of rainwater. Rain water harvesting structures may be constructed in villages to reduce stress on groundwater.

(iii) It has been observed that the demand of ground water is increasing for irrigation uses. Hence, microirrigation should be promoted for irrigation. Details of groundwater saved through microirrigation is depicted in table 19.

(iv) At locations where water level is declining, we have to go for artificial recharge on a long-term sustainability basis. Artificial Recharge structures may be constructed at suitable locations (figure 22) especially in the areas where the water level remains more than 3m in the post-monsoon period in this block to arrest the huge non-committed run-off and augment the ground water storage in the area. The different types of artificial structures feasible in the block are described in table 17. Abandoned tube well and dug well may be used for the recharge through shaft especially in urban and water stressed areas.

Table 17: Types of Artificial Recharge structures feasible in district

Block/District	Area Feasible for recharge (sq.km)	Volume of Sub Surface Potential for Artificial recharge (MCM)	Types of Structures Feasible and their Numbers			
			Percolation tank	Nalas bunding/ cement plug/ check dam	Gravity head /Dug well/ tube well/Recharge shaft	Gully plugs/ Gabion structures
Recharge Capacity - (MCM)/structure			0.2	0.03	0.008	0.007
Bodla	76.92	4.046	13	45	101	77
Kawardha	136.85	21.93	73	243	547	417
Pandariya	190.72	11.14	37	123	278	212
Sahaspur Lohara	140.51	5.259	17	58	131	100
Total (District)	545	42.375	140	469	1057	806

(v) Iron filter plant may be installed in the villages having higher value of contaminants.

(vi) In urban areas STP may be installed for the treatment of sewage water in proper numbers to avoid contamination of ground water. Treatment of sewage water in village through soak pit for the individual houses and Seechewal model or similar model for community level may be adopted to avoid contamination of ground water. Treated water may also be reused for irrigation and other industrial purposes.

(vii) Since the stage of development in the Bodla block is 39.20 %. There is scope of utilizing more ground water for future irrigation purpose. Additional number of Ground water abstraction structure (figure 22) may be developed for the effective utilization of ground water resources in the block. Yield potential for the district has been shown in Aquifer map (figure 21). Sites for wells need to be selected only after proper scientific investigation. The ground water quality also needs to be ascertained and the wells used for water supply should be first checked for Iron, Fluoride and other pollutants.

Table 18: Potential of Additional GW abstraction structure

Block	Surplus ground water at present Stage of Development (ham)	Number of TW Recommended in each block (Assuming unit draft as 1.6 ham/structure/year)	Number of DW Recommended in each block (Assuming unit draft as 0.72 ham/structure/year)	Additional Irrigation potential creation for Maize/ wheat in winter season in Ha (Assuming 500 mm water requirement)	Additional Irrigation potential creation for Paddy in Ha (Assuming 900 mm water requirement)
Bodla	3510.92	1317	1951	7021.836	3159.8262

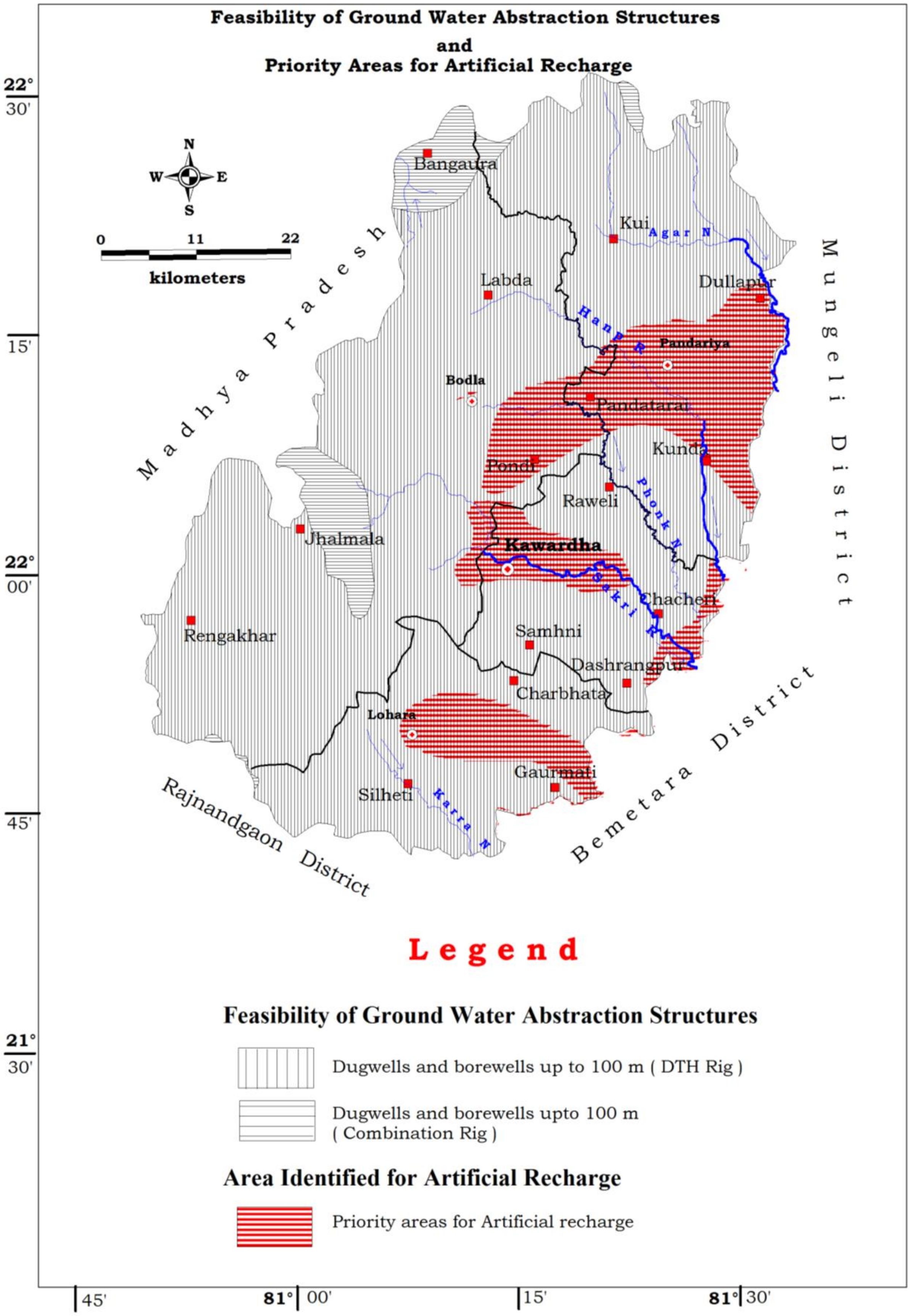

Figure 22: Feasibility of GW Abstraction and Area Identified for Artificial Recharge Map

7. CONCLUSION:

For effective utilization of Ground water existing draft for irrigation may be coupled with micro irrigation system. Change in irrigation pattern, optimum use of available resource, use of ground water potential created after artificial recharge can lead to groundwater savings and increase in gross cropped area of the district (Table 19).

Table 19: Detail of groundwater saved through microirrigation and other interventions

Block/ District	Existing Gross Ground Water Draft for Irrigation in Ham	Additional Saving of GW after using Micro Irrigation methods in Ham(Assuming 30 % saving)	GW Potential created after Artificial recharge structure in Ham	Total GW Resource Enhancement	Stage of Ground Water Extraction (%) As per 2020 GWRE	Expected Stage of Ground Water Extraction (%) after intervention
Bodla	6107.52	1832.26	404.60	2236.86	39.20	34.62
Kawardha	8346.00	2503.80	2193.00	4696.80	96.10	64.02
Pandariya	10315.91	3094.77	1114.00	4208.77	93.59	68.97
Sahaspur Lohara	8596.30	2578.89	525.90	3104.79	83.12	64.69
Total (District)	33365.73	10009.72	4237.50	14247.22	72.98	56.53

Annexure I Details of Groundwater Monitoring Key Well

Sl	Location	Block	LAT	LONG	Lithology	Aquifer Type	Post-monsoon WL (mbgl)
1	Paneka	Kawardha	21.9064	81.3717	Shale with Limestone	Fractured	14.80
2	Biranpur	Kawardha	21.9181	81.3869	Shale with Limestone	Fractured	16.30
3	Chorbhatti	Kawardha	21.9024	81.3336	Shale with Limestone	Fractured	16.60
4	Kaudiya	Sahaspur Lohara	21.8874	81.3338	Shale with Limestone	Fractured	12.50
5	Danichatoli	Sahaspur Lohara	21.8608	81.3075	Shale with Limestone	Fractured	14.10
6	Gochiya	Sahaspur Lohara	21.8856	81.2756	Dolomite/Limestone	Unconfined	6.35
7	Bamhani	Kawardha	21.9267	81.2592	Dolomite/Limestone	Unconfined	3.60
8	Bamhani	Kawardha	21.9265	81.2553	Dolomite/Limestone	Fractured	3.25
9	Dhamki	Kawardha	21.9509	81.2540	Dolomite/Limestone	Unconfined	9.95
10	Kapa	Bodla	21.9613	81.1496	Basic Rock	Fractured	2.50
11	Kapa	Bodla	21.9612	81.1490	Basic Rock	Unconfined	4.80
12	Jamunpani	Bodla	22.0129	81.0177	Laterite/Ferruginous conccretions	Fractured	2.73
13	Jamunpani	Bodla	22.0129	81.0177	Laterite/Ferruginous conccretions	Unconfined	3.67
14	Advar	Bodla	21.9603	80.8948	Acid Rocks (Granite,Pegmatite,S yenite,Rhyolite etc.	Unconfined	6.05
15	Khamharia	Bodla	21.9385	80.8830	Acid Rocks (Granite,Pegmatite,S yenite,Rhyolite etc.	Unconfined	2.55
16	Newaspur	Bodla	21.8655	80.8587	Phyllite	Unconfined	5.00
17	Newaspur	Bodla	21.8655	80.8587	Phyllite	Fractured	5.20
18	Chhitpuri Khurd	Bodla	21.8293	80.9023	Phyllite	Unconfined	3.55
19	Telitola	Bodla	21.8697	81.0215	Phyllite	Unconfined	2.85
20	Khajari kala	Sahaspur Lohara	21.7973	81.1113	Basic Rock	Unconfined	8.60
21	Pipertola Chhote	Sahaspur Lohara	21.8088	81.0820	Basic Rock	Unconfined	6.90
22	Amaldiha	Kawardha	22.0419	81.2210	Basic Rock	Fractured	9.50
23	Rauchand	Bodla	22.0523	81.1990	Basic Rock	Unconfined	4.15
24	Chilphi	Bodla	22.1730	81.0525	Basic Rock(Basalt)	Fractured	9.20
25	Bairakh	Bodla	22.1967	81.1397	Phyllite	Fractured	3.30
26	Chhapra	Bodla	22.0748	81.2550	Limestone with Shale	Fractured	8.90
27	Daujiri	Kawardha	22.0644	81.2874	Limestone with Shale	Fractured	4.50
28	Raweli	Kawardha	22.0928	81.3476	Limestone with Shale	Fractured	10.90
29	Ruse	Pandariya	22.1163	81.3670	Limestone with Shale	Fractured	3.35
30	Jangalpur	Pandariya	22.1275	81.3906	Limestone with Shale	Fractured	8.70
31	Makri	Pandariya	22.1003	81.4586	Limestone with Shale	Fractured	4.30
32	Ataria	Pandariya	22.0605	81.4588	Dolomite/Limestone	Fractured	4.80

Sl	Location	Block	LAT	LONG	Lithology	Aquifer Type	Post-monsoon WL (mbgl)
33	Gidhari Kapa	Pandariya	22.0738	81.4944	Dolomite/Limestone	Fractured	9.10
34	Mahaka	Pandariya	22.1473	81.5050	Limestone with Shale	Fractured	6.90
35	Mohli	Pandariya	22.1751	81.4655	Limestone with Shale	Fractured	12.90
36	Kisungarh	Pandariya	22.2221	81.4924	Limestone with Shale	Fractured	4.00
37	Sirmadabri	Pandariya	22.2285	81.4584	Limestone with Shale	Fractured	4.50
38	Patouha	Pandariya	22.3424	81.3667	Basement Gneissic Complex	Unconfined	4.35
39	Kukdur	Pandariya	22.3578	81.3546	Basement Gneissic Complex	Fractured	3.60
40	Lokham	Pandariya	22.3922	81.3594	Charnockite	Fractured	11.70
41	Amera	Pandariya	22.3636	81.3392	Basement Gneissic Complex	Unconfined	6.20
42	Daldali	Bodla	22.3940	81.1829	Laterite/Ferruginous conccretions	Fractured	44.10
43	Ranhepur kala	Bodla	22.0868	81.2562	Limestone with Shale	Fractured	3.70
44	Silhati	Bodla	22.1302	81.2785	Limestone with Shale	Fractured	6.00
45	Khadaudha Kalan	Bodla	22.1544	81.3054	Limestone with Shale	Fractured	6.60
46	Pandatarai	Pandariya	22.1891	81.3324	Limestone with Shale	Fractured	6.80
47	Mudiya Para	Bodla	22.1506	81.2331	Limestone with Shale	Fractured	3.80
48	Lenjakhar	Bodla	22.1359	81.2472	Limestone with Shale	Fractured	5.80
49	Ramnagar	Kawardha	21.9918	81.2201	Dolomite/Limestone	Fractured	12.50
50	Nawagaon	Sahaspur Lohara	21.9206	81.1812	Dolomite/Limestone	Fractured	6.70
51	Relai	Sahaspur Lohara	21.8462	81.1449	Dolomite/Limestone	Fractured	13.50
52	Bhimpuri	Sahaspur Lohara	21.8084	81.1263	Dolomite/Limestone	Fractured	9.50
53	Ranjitpur	Sahaspur Lohara	21.7748	81.2053	Dolomite/Limestone	Fractured	8.15
54	Gaurmati	Sahaspur Lohara	21.7802	81.2880	Shale with Limestone	Fractured	12.15

Annexure II Suitability of water for drinking purpose and basic statistics of the groundwater quality data

Sl	Village	Block	pH	EC	TH	Ca	Mg	Na	K	CO3	HCO3	Cl	SO4	NO3	F
				µ S/cm	mg/l										
1	NAROUDHI	SAHASPUR LOHARA	7.88	380	150	20	24.4	56.4	4.5	0	244	7.1	8.3	5.5	0.57
2	SILHATI	SAHASPUR LOHARA	7.91	521	120	18	18.3	78.9	0.88	0	305	14.2	13.1	7.4	0.65
3	RANJITPUR	SAHASPUR LOHARA	7.8	405	150	26	20.74	30.6	0.6	0	189.1	24.85	14.8	17.2	0.55
4	BIRENDRA NAGAR	SAHASPUR LOHARA	7.72	1047	230	36	34.16	161.5	1	0	445.3	81.65	53.5	17.3	1.07
5	SABARTOLA	SAHASPUR LOHARA	7.82	647	180	20	31.72	76	1.6	0	244	46.15	35.8	4.7	0.39
6	IRIBAKSA	SAHASPUR LOHARA	8.3	547	80	10	13.42	74	1.1	3	268.4	10.65	12.9	15.8	0.98
7	BIRANPUR KALA	SAHASPUR LOHARA	7.9	593	140	20	21.96	70	1	0	250.1	53.25	20.2	16.4	0.68
8	DANIA KHURD	SAHASPUR LOHARA	7.45	2080	500	90	67.1	126.5	3.5	0	262.3	337.25	101	70.1	0.57
9	KHAPRI	SAHASPUR LOHARA	7.75	780	240	32	39.04	82	1.1	0	347.7	71	25.9	4.03	0.78
10	CHARBATHA	SAHASPUR LOHARA	7.68	691	255	60	25.62	27.9	0.31	0	103.7	71	49.5	71.9	0.47
11	GOCHHIYA	SAHASPUR LOHARA	7.45	2131	310	108	9.76	113.7	3.3	0	152.5	7.1	78.7	78.4	1.33
12	CHILAN KHODRA	SAHASPUR LOHARA	8.1	585	145	54	2.44	96.2	0.3	0	225.7	31.95	27	7.7	0.65
13	SALIHA	SAHASPUR LOHARA	7.92	288	165	24	25.62	64.1	0.8	0	219.6	63.9	29	29.6	0.38
14	CHANDAINI	SAHASPUR LOHARA	8	364	130	18	20.74	45.8	0.7	0	158.6	14.2	13.4	20.1	0.34
15	GALALPUR	SAHASPUR LOHARA	7.81	510	165	26	24.4	42.7	1.4	0	170.8	21.3	24	24.9	0.44
16	JEODAN KALAN	KAWARDHA	7.52	664	260	40	39.04	7.7	2.4	0	225.7	71	30.4	19.1	0.44
17	KAWARDHA	KAWARDHA	7.7	1223	300	56	39.04	133.9	41	0	366	106.5	78.1	17.2	1.3
18	KODAR	KAWARDHA	7.77	436	170	32	21.96	100	2	0	225.7	35.5	21.9	72.4	0.21
19	KHAIRA BANA	BODLA	7.84	339	1500	26	350.14	18.9	0.89	0	189.1	35.5	11.6	7.2	0.38
20	BANDHA TOLA	BODLA	7.76	627	265	82	14.64	24.2	0.6	0	134.2	81.65	48.9	34.7	0.38
21	AMLIDIH	BODLA	8.22	305	75	20	6.1	37	0.73	0	122	14.2	12.2	2.1	0.38
22	BAIRAKH	BODLA	8.2	445	220	54	20.74	18.5	1.9	0	274.5	10.65	13.1	0.99	0.4
23	DHORA TOLA	BODLA	8.06	532	150	32	17.08	38.2	1.1	0	231.8	24.85	19.9	7.3	0.41
24	PALAK BANJARI	BODLA	8.09	296	130	24	17.08	19.2	0.6	0	152.5	17.75	12.6	1.2	0.29
25	SARODHADADAR	BODLA	7.9	127	45	14	2.44	5.2	0.8	0	73.2	7.1	4.1	0.51	0.15
26	DULDULA	BODLA	7.75	247	70	24	2.4	17.9	1.3	0	67.1	42.6	10.5	0.22	0.32
27	NASAL GUDA	BODLA	7.8	190	85	20	8.54	5.8	0.44	0	115.9	17.75	4.3	22.2	0.3
28	BHOTHI	BODLA	7.75	185	75	20	6.1	4.1	0.43	0	79.3	7.1	2.9	28	0.42
29	BHONDA	BODLA	7.9	69	255	76	15.86	1.92	2.7	0	219.6	81.65	31.2	35.9	0.51
30	KHARIA	BODLA	7.86	525	220	58	18.3	10.9	0.68	0	146.4	24.85	17.2	5.08	0.55
31	DHAURA TOLA	BODLA	7.95	347	135	26	17.08	22.5	0.6	0	152.5	10.65	4	6.9	0.75
32	PACHRAHI	BODLA	7.98	415	200	54	15.86	1.6	1.6	0	512.4	14.2	10.5	9.7	0.38
33	TAREGAON	BODLA	7.85	608	240	66	18.3	23.9	2.4	0	433.1	60.35	30.8	10.2	0.32

Sl	Village	Block	pH	EC	TH	Ca	Mg	Na	K	CO3	HCO3	Cl	SO4	NO3	F
				µ S/cm	mg/l										
34	KOTNA PANI	BODLA	8.14	529	190	50	15.86	40.5	6.1	0	542.9	24.85	21	0	0.37
35	DALDALI	BODLA	8	186	95	24	8.54	3.3	0.4	0	481.9	7.1	2.3	0	0.31
36	MUKAM	BODLA	7.75	76	40	10	3.66	2.2	0.4	0	36.6	7.1	1.7	13.1	0.37
37	RABDA	BODLA	7.8	337	120	38	6.1	7.5	0.6	0	219.6	10.65	2.9	0.16	0.35
38	SINGHANPURI	KAWARDHA	7.99	402	130	26	15.86	38.2	0.7	0	213.5	17.75	8.6	14.8	0.34
39	SILHATI	BODLA	8	602	235	28	40.26	37.2	0.5	0	231.8	42.6	26.7	37.8	0.81
40	CHARBHATA	PANDARIYA	8.2	2030	400	100	36.6	341	1.5	0	640.5	273.35	83.4	62.8	0.61
41	BIRKONA	PANDARIYA	7.94	334	135	26	17.08	33.5	3.12	0	164.7	17.75	19.2	9.2	0.53
42	LAKHANPUR	PANDARIYA	7.68	622	205	50	19.52	99.5	5.7	0	231.8	74.55	9	0	0.48
43	POLMI (KORRAPARA)	PANDARIYA	7.6	622	210	50	20.74	65.5	1.9	0	189.1	49.7	36.6	66.8	0.89
44	PUTPUTA	PANDARIYA	7.6	630	150	52	4.88	73.5	4.5	0	115.9	67.45	14.7	66.2	0.32
45	BHAKUR	PANDARIYA	8.03	388	180	34	23.18	22.9	0.5	0	207.4	7.1	3.2	14	0.4
46	NAWAGAON	PANDARIYA	7.76	532	105	26	9.76	99.4	2.1	0	256.2	46.15	5.7	6.3	1.6
47	DULLAPUR	PANDARIYA	7.61	1090	340	78	35.38	108.6	2.3	0	115.9	163.3	7.4	73.8	0.31
48	KUNDA	PANDARIYA	7.61	668	280	84	17.08	54.7	2	0	207.4	78.1	3.5	34.1	0.04
49	DEVKHARIYA	PANDARIYA	7.87	501	150	14	28.06	102.7	2.01	0	305	10.65	3.1	3.2	0.51
50	SAIHAMALGI	PANDARIYA	7.62	1234	260	8	58.56	258	1.9	0	323.3	170.4	13	66.9	0.58
51	GANGPUR	KAWARDHA	7.69	982	280	50	37.82	145	2.4	0	195.2	71	5.7	25.6	1
		Mean	**7.85**	**606**	**213**	**40**	**28**	**62**	**2**	**0**	**235**	**52**	**22**	**23**	**0.54**
		Min	**7.45**	**69**	**40**	**8**	**2**	**2**	**0**	**0**	**37**	**7**	**2**	**0**	**0.04**
		Max	**8.30**	**2131**	**1500**	**108**	**350**	**341**	**41**	**3**	**641**	**337**	**101**	**78**	**1.60**
	Standard Deviation		**0.20**	**455**	**205**	**25**	**48**	**65**	**6**	**0**	**125**	**64**	**23**	**24**	**0.31**
	Coefficient of variation		**2.50**	**75**	**96**	**62**	**174**	**104**	**235**	**714**	**53**	**122**	**101**	**106**	**56.54**
		BIS DWS - MDL	8.50	750	300	75	30	NR	NR	NR	500	250	200	45	1.00
	% of samples with MDL														
		BIS DWS - MPL	NR	3000	600	200	100	NR	NR	NR	1000	1000	400	45	1.5
	% of samples with MPL														
		BIS DWS	Bureau of Indian Standards Dinking Water Standards									NR	NR		
		MPL	Maximum Permissible Limit												

Annexure III Exploratory details of Kabirdham district

Sl No	location	Y	X	Depth (m)	casing (m)	Formation	Zone encountered (m)	SWL (mbgl)	Discharge (lps)	Drawdown (m)	Transmissivity (m^2/day)	Storativity
1	Birendranagar	21.82	81.18	274.02	6	Chandi Lst & Gunderdehi Sh	22.5	5.07	1		28.66	
2	Charbhata	21.88	81.23	46.2	40.85	Chilpi metasediment	0-25.85 -7"BP 25.85-26.85-4"BP 26.85-39.85-4"SP	8.97	10.85	4.24	933.14	2.25×10^{-5}
3	Charbhata OW	21.88	81.23	43.5	42.51	Chilpi metasediment	0-11.65 -6"BP 11.65-24.16 -6"BP 24.16-42.51-6"SP					
4	Dasarangpur	21.85	81.38	266.59	10.7	Maniari Shale	29.9-31,35-36	9.1	7.4	15.17	33.6	5.69×10^{-5}
5	Dasarangpur OW	21.85	81.38	254.01	9.6	Maniari Shale	21-23,46-49,60-65	8.76	9.31			
6	Indauri	21.95	81.37	300.57	8.15	Maniari Shale	32	2.1				
7	Kawardha	22.03	81.22	190.6	25.6	Chandi Lst & Gunderdehi Sh	37.52 - 37.8	12.94	6.4		107	1.02×10^{-3}
8	Kawardha OW	22.03	81.22	53.72	19.32		33--40		23			
9	Sahashpur Lohara	21.83	81.13	297.02	12	Gunderdihi Sh, Charmuria Lst & Chandrapur Sst	27--30	24.5	1			
10	Ranvirpur	21.83	81.18	146.6	9.15	Chandi Lst	13-17, 87.88	2.13	2.6	19		
11	Pondi	22.12	81.27	112.89	15.78	Chandi Lst	20-21	6.28	5.76	11.25		
12	Kishangarh	22.22	81.50	137.4	12.2	Pandaria Fm- Lst & Sh	30-40, 48.50	4.45	3.5			
13	Pandaria	22.22	81.40	123.8	16.37	Pandaria Fm- Lst & Sh	18-18.5, 22.5-28	5.4	8.7	13.15		
14	Kunda	22.12	81.45	128.2	25.05	Pandaria Fm- Lst & Sh	28-30	6.8	3.5	23.7		
15	Damapur	22.05	81.40	114.4	10.35	Pandaria Fm- Lst & Sh	33.5-34.5, 46.49, 81.00- 81.5, 90-92.40	4.15	5.8	14.6		
16	Bagarra	22.15	81.48	128.2	9.24	Maniyari Sh	26-30, 39-42,75-76	2.4	7.14	18.28		

Sl No	location	Y	X	Depth (m)	casing (m)	Formation	Zone encountered (m)	SWL (mbgl)	Discharge (lps)	Drawdown (m)	Transmissivity (m^2/day)	Storativity
17	Pandatarai	22.19	81.33	21	20.43	Pandaria Fm- Lst & Sh	16.4-21	4	14.5			
18	Bodla	22.15	81.22	123.6	12.42	Pandaria Fm- Lst & Sh	15.6-17, 30-31, 43-44, 63-65	1.83	14.5	8.77		
19	Raveli	22.10	81.33	123.6	6.04	Hirri dolomite		8	0.2			
20	Bhaluchuwa	22.09	81.22	128.2	20.07	Pandaria Fm- Lst & Sh	49-56, 68-70, 97-98	2.53	7.14	21.32		
21	Gochhia	21.88	81.28	119	13.81	Maniyari Sh		10	Negligible			

Lst- Limestone, Sh- Shale

स्वच्छ जल - स्वच्छ भारत

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