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

PUSAUR BLOCK, RAIGARH DISTRICT, CHHATTISGARH

उत्तर मध्य छत्तीसगढ़ क्षेत्र, रायपुर

North Central Chhattisgarh Region, Raipur

Government of India
Ministry of Jal Shakti
Department of Water Resources, River Development & Ganga Rejuvenation
CENTRAL GROUND WATER BOARD

Aquifer Mapping and Management Plan in Pusaur block, Raigarh District, Chhattisgarh

By
Sh. A K Biswal (Scientist-D)

Type of Study	**Officer engaged**
Data compilation, Data Gap Analysis & Data Generation	Sri R.K.Tripathy, Scientist-B, (AAP:2016-17)
Data Interpretation, Integration, Aquifer Mapping, Management Plan & Report writing	Sri A. K. Biswal, Scientist-D

North Central Chhattisgarh Region
Raipur
2020

BLOCK AT A GLANCE

PUSAUR BLOCK, RAIGARH DISTRICT, CHHATTISGARH

1.	**GENERAL INFORMATION**	
	i) Geographical area (Sq. km)	510.3
	ii) Administrative Divisions (As on 2017)	
	a) Number of Villages	148
	iii) Population as on 2011 Census	139799
	iv) Average Annual Rainfall	1427.8 mm
2.	**GEOMORPHOLOGY**	
	i) Major Geomorphological Units	Structural plain on Proterozoic rocks
	ii) Major Drainages	Mond river and Kelo river flowing southwards
3.	**LAND USE (ha) As on 2016-17**	
	i) Forest Area	246
	ii) Net Area Sown	21252
	iii) Double cropped Area	1330
4.	**MAJOR SOIL TYPES**	Ultisols- Red & Yellow soil
5.	**AREA UNDER PRINCIPAL CROPS, in ha (As on 2016-17)**	Paddy-27101, Wheat-797, Pulses-1619, Tilhans-1301, Fruits and vegetables- 19
6.	**IRRIGATED AREA BY DIFFERENT SOURCES in ha (As on 2016-17)**	
	i) Dug wells	102
	ii) Tube wells/Bore wells	10489
	iii) Canals	0
	iv)Tanks	1589
	v) Other sources	695
	vi) area Irrigated more than once	6141
7.	**NUMBERS OF GROUND WATER MONITORING WELLS OF CGWB (As on March'2019)**	
	i) No of Dug wells	11
	ii) No of Piezometers	0
8.	**PREDOMINANT GEOLOGICAL FORMATIONS**	
	Gunderdih formation (shale)	
	Charmuria formation (Limestone)	

9.	**HYDROGEOLOGY**	
	i) Major Water Bearing Formations	Weathered & fractured shale and limestone
	ii) Pre-monsoon Depth to Water Level	2.01 to 32.6 mbgl
	iii) Post-monsoon Depth to Water Level	0.01 to 16.68 mbgl
	iv) Long Term Water Level Trend for 10 yrs (2008-2017 Vs 2018) in m/yr	Falling trend of 40 cm/year both in pre-monsoon and post monsoon period
10.	**GROUND WATER EXPLORATION BY CGWB (As on March'2019)**	
	i) No of Wells Drilled	EW+OW: 22
	ii) Depth Range (m)	28.71 - 202
	iii) Discharge (litres per second)	Neg to 22.42
11.	**GROUND WATER QUALITY**	
	i) Presence of Chemical Constituents	EC for Shallow aquifer is 223 to 1378 and for deeper aquifer is 140 to 2320 µS/cm at 25℃ , PH- 7 to 8.3, All the chemical constituents are well within permissible limit except sulphate and total hardness at som places.
	ii) Type of Water	Calcium-Magnesium-Bicarbonate (Ca-Mg-HCO_3) and Calcium-Sulphate (Ca-SO_4) type for shallow aquifer & Calcium-Bicarbonate (Ca-HCO_3) type for deeper aquifer respectively.
12.	**DYNAMIC GROUND WATER RESOURCES in Ham (Estimated as on March'2013)**	
	i) Annual Extractable Ground Water Recharge	4371.35
	ii) Total Annual Ground Water Extraction	3359.58
	iii) Ground Water Resources for Future use	955.62
	iv) Stage of Ground Water Development	76.85
	v) Category	Semi-Critical
13.	**AWARENESS AND TRAINING ACTIVITY**	nil
14.	**EFFORTS OF ARTIFICIAL RECHARGE & RAIN WATER HARVESTING**	
	i) Projects Completed by CGWB (No & Amount spent)	Nil
	ii) Projects Under Technical Guidance of CGWB (Numbers)	Nil

16. MAJOR GROUND WATER PROBLEMS AND ISSUES

a. In several regions there is deeper water table due to excessive withdrawal of ground water for irrigation.
b. The bore wells are drilled by the farmers without taking into consideration the spacing criteria between wells. In many instances bore wells drilled are very close to each other.
c. Desilting of the existing tanks for increasing storage capacity and recharge to the ground water.
d. In some areas there is iron contamination in groundwater was recorded.

CONTENTS

ABBREVIATIONS

a msl	above mean sea level
BDR	Basic Data Report
CGWB	Central Ground Water Board
Dia	Diameter
DTW	Depth To Water
EC	Electrical Conductivity
EW	Exploratory Wells
GW/ gw	Ground Water
ham	Hectare meter
lpcd	litres per capita per day
lpm	litres per minute
lps	liters per second
m bgl	meter below ground level
MCM/mcm	Million Cubic Meter
NCCR	North Central Chhattisgarh Region
NHNS/ NHS	National Hydrograph Network Stations
OW	Observation Well
PZ	Piezometre

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 Pusaur block 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 " A REPORT ON AQUIFER MAPPING & MANAGEMENT PLAN IN PUSAUR BLOCK, RAIGARH DISTRICT, CHHATTISGARH" " is prepared by Sh. A.K.Biswal, Scientist-D (CGWB,NCCR,Raipur) and is the result of untiring efforts Sh. R.K.Tripathy, Scientist-B, (CGWB,SER,Bhubaneswar). It was a Herculean job and required hard working. 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 no doubt be useful and worthy for the benefit of Raigarh block 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. Santanu Samanta
(REGIONAL DIRECTOR (I/C))

EXECUTIVE SUMMARY

The Pusaur block covers a geographical area of 510.3 sq. km. It is situated in the eastern central part of the Chhattisgarh lying between 21.68 degree and 21.88 degree North latitudes and 83.237 degree and 83.538 degree East longitudes comprising 81 village panchayats and 148 villages. According to 2011 census record the total population of the block is 139799. About 41.33 % of the net sown area is irrigated by all sources. Ground water contributes more than 81% of the net irrigated area.

Pusaur block experiences Sub-tropical climate characterized by extreme cold in winter and extreme hot in summer. The average annual rainfall is 1427.8 mm (average of last five years i.e 2012-2017). The annual temperature varies from 100C in winter to 460C in summer. The relative humidity varies from 85 % in rainy season to 35-40 % during winter. The block is mainly drained by the rivers-Mond river and Kelo river flowing southwards along with its tributaries as Sanpakhar, Sapna and kurr nala. The drainage system in Kharsia block originates at the northern part and flow in south & south-east direction before joining the Mahanadi river.

Geomorphologically the Lailunga block is characterized by structural plateau on proterozoic rocks. The general elevation of the plain ranges between 210 and 500m amsl. The elevation in case of structural hills ranges from 300 to 800 m amsl. This region has a general slope towards the south. The foothills are characterized by pediments.

Geologically Lailunga block is mainly covered by hard rock belonging to Raigarh formation crystalline represented by Gunderdih shale and Charmuria limestone.

The aquifer material controlling ground water flow in the block can be broadly divided into two major media (1) Porous media (Shallow Aquifer) and (2) Fractured media (Deeper Aquifer). The major aquifer groups in Lailunga block are (i) Gunderdih shale & (ii) Charmuria limestone.

Hydrogeologically, the shallow aquifers both in hard and semi-consolidated rock in the block are wide spread and largely in use. The shallow aquifers are being tapped through dug wells, dug cum bore wells or shallow bore wells drilled to a depth of 60 m. The weathered mantle and shallow fractures mainly constitute the shallow aquifers. The thickness of weathered mantle varies from 5 to 25m bgl. The average yield of Gunderdih shale is 6.41 lps with avg transmissivity of 14.58 m²/day & average drawdown is 13.91 m. One to three sets of potential fracture zone mostly lie within 100 m depth in Gunderdih shale. The average yield of Charmuria limestone is 9 lps with avg transmissivity of 17.855 m²/day & average drawdown is 19.63 m. One to two sets of potential fracture zone mostly lie within 100 m depth in Charmuria Limestone.

*22 nos. of observation wells were established and monitored in pre & post monsoon period to access the ground water regime of the block including the national hydrograph stations. The water level analysis data indicates that the ground water level of phreatic aquifer during pre monsoon period ranges from 2.01 to 32.60 mbgl and during post-monsoon period it is from 0.01 to 16.68 mbgl. The fluctuation ranges from 0.60 to 16.68 m with an average fluctuation of 5.25 m. The average weathered thickness of the phreatic aquifer is around 17.17 m. The long term ground water level trend indicates that there is appreciable change in ground water level with a falling trend of 40 cm/year both in pre-monsoon and post monsoon period (GWE report-2017) and is categorized as “**Semi-Critical**” block.*

The regional ground water flow direction is towards south. It may also be seen that the flow of ground water is mostly towards the major drainage suggesting that the base flow is towards the drainage system.

As per resource estimation March 2017, the Net Annual Extractable Ground Water Recharge (Ham) in Pusaur block is 4371.35 ham. The Net Ground Water Availability for future use is 406.13 ham. Current Annual Ground Water Extraction for all purposes is 3359.58 ham out of which 3009.6 ham is for irrigation. The overall Stage of Ground Water Extraction in the block is 76.85 %. The Annual GW Allocation for domestic Use as on 2025 is 406.13 ham.

As per the NAQUIM study in the block , since the stage of ground water extraction for Pusaur block is 76.85 % and is categorized as Semi-Critical,, the water stressed condition of the block can be improved by change in cropping pattern from paddy in Rabi season to maize can lead to improvement of stage of ground water extraction to 36.41 from 76.85%.

Similarly to sustain the ground water resources in a long term basis, 40 nos. of Percolation tank, 133 nos of Nala bunding cement plug/ check dam, 320 nos. of recharge shaft and 238 nos. of Gully plugs /Gabbion structures may be constructed throughout the block that can recharge 17.43 mcm water to underground.

The quality of ground water in the phreatic zone is well within permissible limit of BIS standards and is suitable for drinking, irrigation and industrial purposes. The ground water of Pusaur block in overall is calcium-magnesium-bicarbonate (Ca-Mg-HCO3) and calcium-sulphate (Ca-SO4) type for shallow aquifer & calcium-bicarbonate (Ca-HCO3) type for deeper aquifer respectively.

ACKNOWLEDGEMENT

The author is grateful to Shri G C Pati, Chairman, Central Ground Water Board for giving opportunity for preparation of the National Aquifer Mapping & Management report of Pusaur block, Raigarh district, Chhattisgarh. I express my sincere gratitude to Shri G.L.Meena, Member (WQ & WTT) & Sh. S.Marwaha, Member (Scientific), CGWB for giving valuable guidance, encouragement and suggestions during the preparation of this report. The author is thankful to Dr. S.K.Samanta, Head of the Office, Central Ground Water Board, NCCR, Raipur extending valuable guidance and constant encouragement during the preparation of this report. The author is also thankful to Sh. A.K.Patre, Sc.D; Sh. J.R.Verma, Sc.D; Smt.Priyanka Sonbarse , Sc-B; Sh.R.K.Dewangan, Sc-B & Sh. Uddeshya Kumar, Sc-B and other officers and officials of all the sections of the office for the help rendered & for providing the needful data during the preparation of this report on "AQUIFER MAPPING & MANAGEMENT PLAN IN PUSAUR BLOCK, RAIGARH DISTRICT, CHHATTISGARH".

A.K.Biswal

Scientist-D

AQUIFER MAPPING AND MANAGEMENT PLANS IN PUSAUR BLOCK, DISTRICT-RAIGARH, CHHATTISGARH

CHAPTER-1
INTRODUCTION

1.1 Objectives:

The groundwater is the most valuable resource for the country. The demand for ground water for various types of use is increasing day by day; consequently indiscriminate development of ground water has taken place and the ground water resource has come under stress in several parts of the country. On the other hand, there are also areas where adequate development of ground water resources has not taken place. These facts underscore the need for micro-level study of the aquifer systems of the country. Central Ground Water Board (CGWB) is involved in hydrogeological investigations covering major part of the country and as per requirement; the reappraisal of ground water regime is being taken up in priority areas to generate the background data on regional scale. 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 also 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. Volumetric assessment of ground water and strategies for future development and management are the primary objective of aquifer mapping.

1.2 Scope of the study:

The aquifer maps are the maps depicting aquifer disposition, giving lateral and vertical extension. The maps will also provide information on the quantity and quality. 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.

It explains the components of the Aquifer Classification System, outlines the assumptions underlying the map information presented and also summarizes the content of an aquifer classification map. The goal is to help the map users understand the strengths and limitations of the information contained on the aquifer classification maps so that they can apply that information appropriately to their particular water and land management needs. The system and maps are designed to be used together and in conjunction with other available information as a screening tool for setting groundwater management priorities. They provide a way of comparing aquifers within a consistent hydrogeological context and prioritizing future actions at various planning levels. The maps may provide some background information for site-specific projects. However, the maps are not to be used for making site-specific decisions. The classification of an aquifer reflects the aquifer as a whole and at a specific time.

Groundwater conditions, such as the degree of vulnerability and water quality, can vary locally and over time respectively. This variability in the data sometimes requires subjective decision-making and generalising of information for an entire aquifer. As such the Pusaur block was studied under NAQUIM program in 2016-17.

1.3 Methodology:

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

i) Data Compilation & Data Gap Analysis: One of the important aspect 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, analysed, synthesized and interpreted from available sources. These sources were predominantly non-computerised 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, hydro-chemical analysis, use of geophysical techniques as well as detail hydrogeological surveys. About 5 nos. of exploratory wells & observation wells were drilled by CGWB and through outsourcing in various periods in different formation, 28 nos of key observation wells (dug wells, hand pumps and piezometers) established during the survey and 33 nos of ground water samples from different sources representing shallow as well as deeper aquifers were studied carefully and analysed before preparing the aquifer map and management plan.

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 Salient Information:

Pusaur block is situated in the central part of Raigarh district of Chhattisgarh and is bounded on the north by Raigarh block, in the west by Janjgir Champa district, in the south by Baramkela block and in the east by state Odisha. The area lies between 21.68 degree and 21.88 degree N latitudes and 83.237 degree and 83.538 degree E longitudes. The geographical extension of the study area is 510.3 sq.km representing around 7.5 % of the district's geographical area. Administrative map of the block is shown in **map-1**. Mond river and Kelo river flowing southwards along with its tributaries as Sanpakhar, Sapna and kurr nala forms the major drainage system of the block. Mahanadi river flows east – west in the southern boundary of Pusaur before entering to Odisha state. The drainage system of the block is a part of Mahanadi basin. Drainage map is shown in **map-2**.

1.5 Population:

The total population of Pusaur block as per 2011 Census is 139799 out of which rural population is 135055 living in 148 nos of villages while the urban population is 4744. The decadal growth rate of the block is 22.79 as per 2011 census. The population detail is given in table-1 below –

Table- 1: Population Break Up

Block	Total population	Rural population	Urban population	Nos of Villages/ village panchayats
Pusaur	139799	135055	4744	148/81

Source: CG Census, 2011

1.6 Rainfall:

The study area receives rainfall mainly from south-west monsoon. It sets in third/fourth week of June and continues till mid-August/September with heaviest showers in the months of July and August. The months of July and August are the heaviest rainfall months and nearly 95% of the annual rainfall is received during June to September months. Average annual rainfall in the study area is (Average of the last five years i.e. 2012 to 2017) 1099.62 mm with 50 to 60 rainy days. The rainfall detail is presented in table-2.

Table-2: Annual Rainfall (mm) in Pusaur block for the years (2012-2017)

Block	Rainfall in mm				
	2012-13	2013-14	2014-15	2015-16	2016-17
Pussaur	1139.5	1469.8	1048	1696.9	1784.8
Average	1427.8				

Source: Land and Revenue Department, Raigarh district

1.7 Agriculture and Irrigation:

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 dug wells, Bore wells /tube wells. The principal crops in the block are Paddy, Wheat and pulses.

In some areas, double cropping is also practiced. The landuse (agricultural) pattern, cropping pattern and details of area irrigated in Pusaur block is given in Table 3 (A, B, C, D).

Table-3 (A): Land use pattern in Pusaur block during the year 2016-17(in ha)

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
Pussaur	246	5924	3136	3620	21252	1330	33138

Source: District Statistical Book-2017

Table-3 (B): Cropping pattern in Pusaur block during the year 2016-17(in ha)

Blocks	Kharif	Rabi	Cereal				Pulses	Tilhan	Fruits /Vegetables	Mirch Masala	Sugar-cane
			Rice	Wheat	Jowar & Maize	Others					
Pussaur	26878	6260	27101	797	20	315	1619	1301	19	187	90

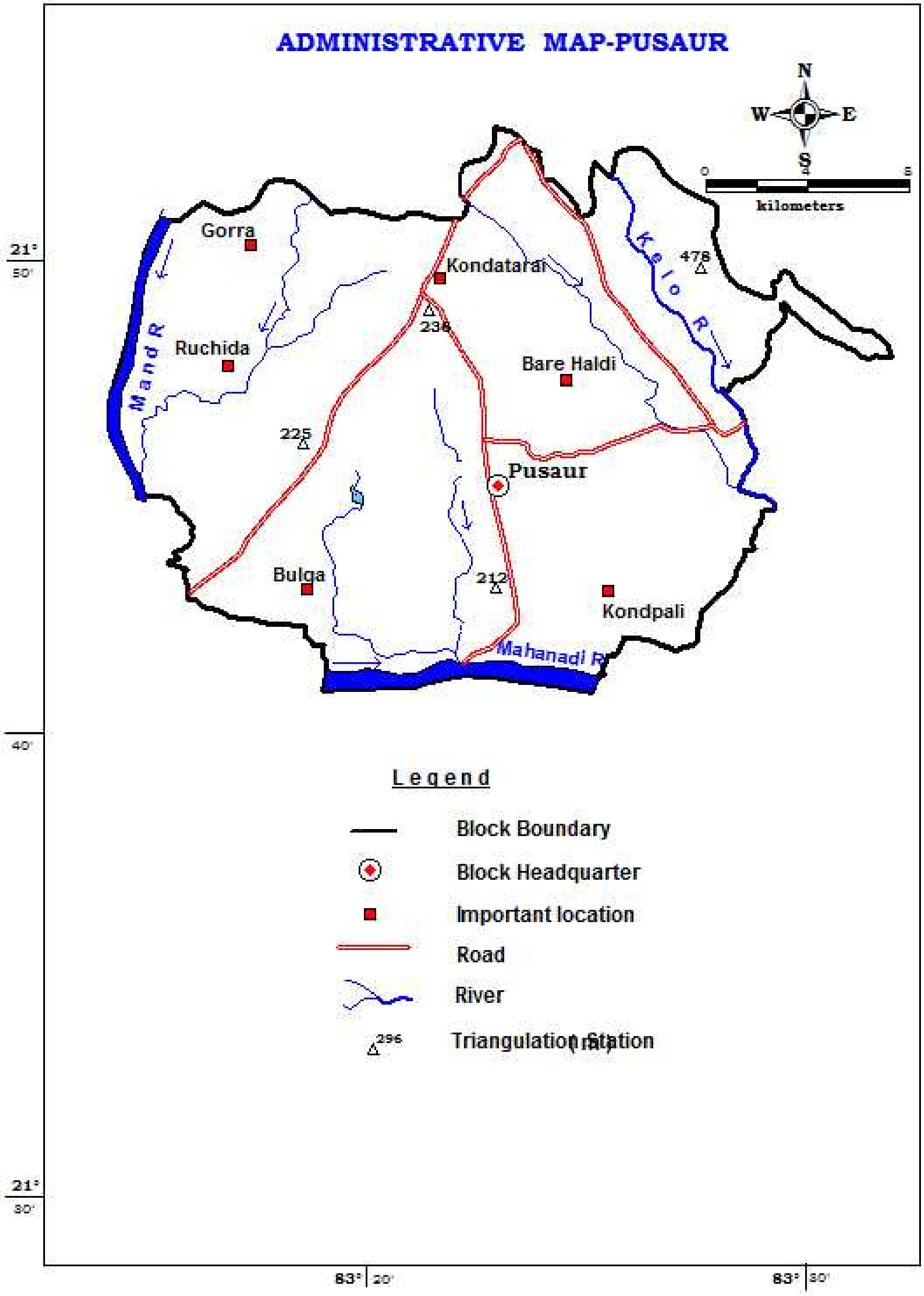
Table-3 (C): Area irrigated by various sources in Pusaur block during the year 2016-17(in ha)

Blocks	Canal (private and Govt.)		Bore wells/ Tube wells		Dug wells		Talabs		Irrigated area by other sources	Irrigated area by GW sources	Net Irri-gated area	Irrigated area more than once	Gross irrigated area	% of Net irrigated area to. Net area sown
	Nos	Irrigated area (ha)	Nos	Irrigated area	Nos	Irrigated area	Nos	Irrigated area						
Pussaur	0	0	3014	10489	309	102	516	1589	695	10591	12980	6141	13697	41.33

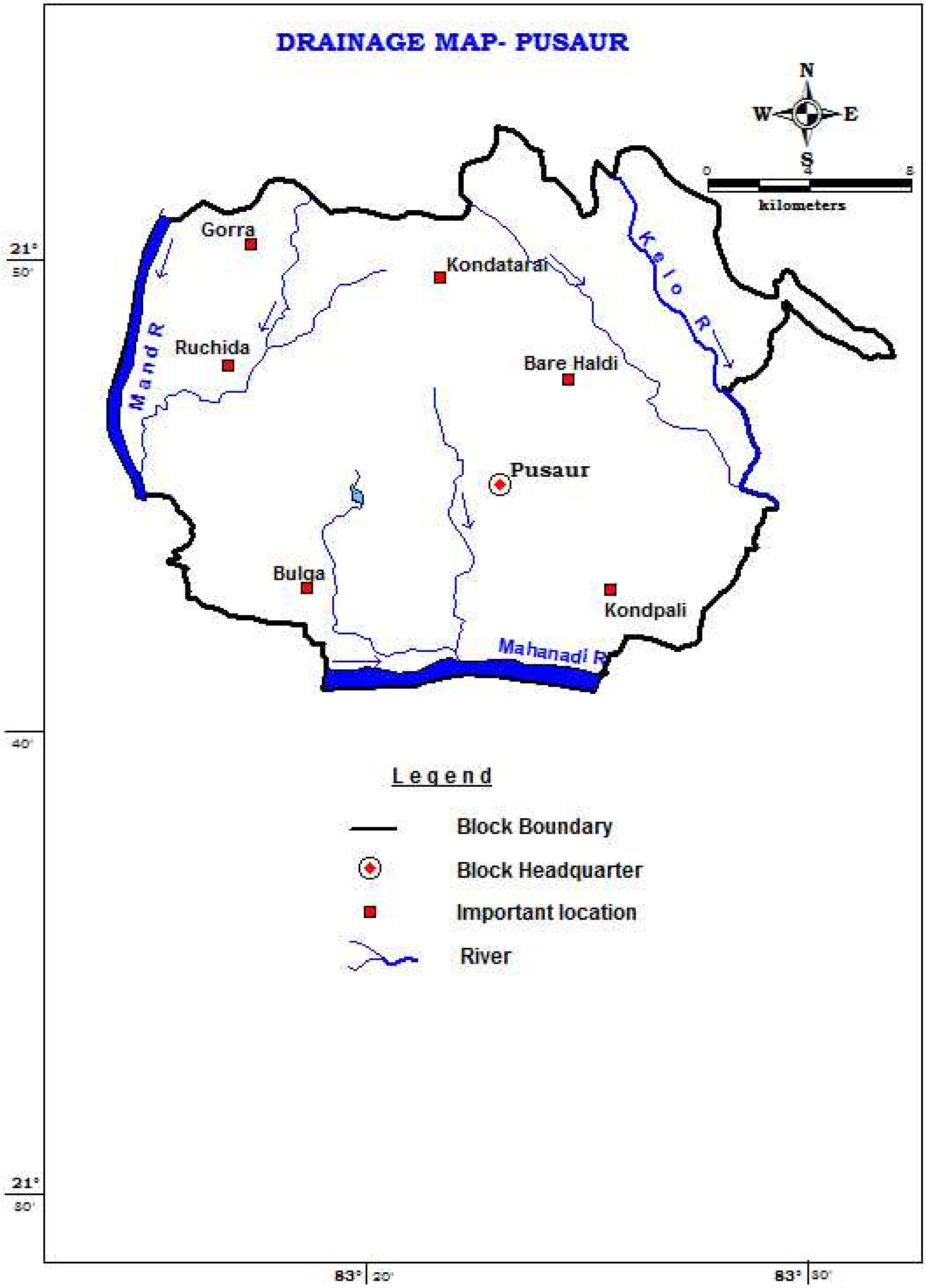
Table 3 (D): Statistics showing Agricultural land Irrigated

Block	Net Irrigated Area	Net Irrigated Area by ground water	Percentage of Area Irrigated by ground water
Pusaur	12980	10591	81.6

Map-1: Administrative map of Pusaur



Map-2: Drainage map of Pusaur block



CHAPTER-2

DATA COLLECTION & GENERATION

2.1 Introduction:

About 22 nos. of exploratory wells (EW & OW) drilled by CGWB and through outsourcing in various periods in different formation (table-4), 22 nos of key observation wells (dug wells, hand pumps and piezometers) established during the survey and 32 nos of ground water samples collected from different sources representing shallow as well as deeper aquifers were studied carefully and analysed before preparing the aquifer map and management plan of Pusaur block.

Table-4: Status of exploration (EW) in Pusaur block (formation wise)

Block	Gondwana formation	Gunderdih Shale	Charmuria Limestone	ChandrapurSandstone	Crystallines	Total
Pusaur	-	14	3	-	-	17

2.2 Exploration data:

Hard and soft rocks need separate well design. Since Pusaur block is mostly covered by hard rock, so well construction is relatively an easy job. With the help of high capacity DTH rigs, 200 m deep wells can be constructed within 10-12 hrs in hard rock areas. In these wells of hard rock, casing the initial weathered thickness is a bit time taking. Once the weathered zone is sealed with casing, drilling through massive formation is just a matter of time. The penetration rates (depth drilled per minute) are high in general. During the exploration, cutting materials are collected in every 3 m interval of depth and kept in a wooden box prepared for the sample collection. These rock cutting materials are observed carefully and accordingly a litholog is prepared which represents the depth wise rock type at that point. The aquifer parameter of various shallow and deeper aquifers were calculated based on long term (1000 minutes) pumping tests, preliminary yield test and slug test of bore/tube wells during exploratory drilling. The details of the exploratory well is given in **Annexure-I.**

2.2.1 Well design:

Hard and soft rocks need separate well design. Since Pusaur block is mostly covered by hard rock, so well construction is relatively an easy job. With the help of high capacity DTH rigs, 200 m deep wells can be constructed within 10-12 hrs in hard rock areas. In these wells of hard rock, casing the initial weathered thickness is a bit time taking. Once the weathered zone is sealed with casing, drilling through massive formation is just a matter of time. The penetration rates (depth drilled per minute) are high in general. PVC casing is preferred where ever ferric oxide problem persist in ground water of hard rock **(Fig-1**).

In these wells protective casing of 4” to 6” diameter and length varying from 9 m to 36 m is required for the weathered and collapsible zone (**Fig. 2**). The cavernous limestone/dolomite sometimes cause drilling problem even after the top weathered zone is cased, due to filling of sticky clay. Sometimes this zone needs casing to complete the drilling operation successfully. Alluvium covered hard rock need combination rig, so that the upper alluvium can be drilled through rotary rig to construct a gravel pack well followed by DTH drilled uncased hole. In soft rock, gravel pack wells drilled by Rotary rigs are the best. Filter point wells are preferred in very shallow alluvial cover area. Though it is easy as well as economical to construct filter point wells, normally they have short life span (less than 5 years).

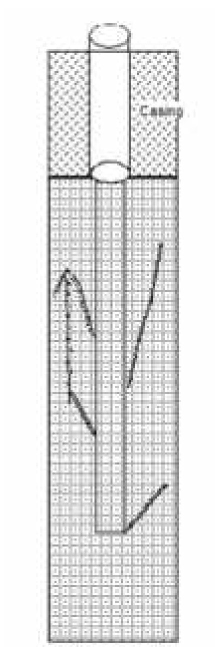


Fig-1: Bore well design

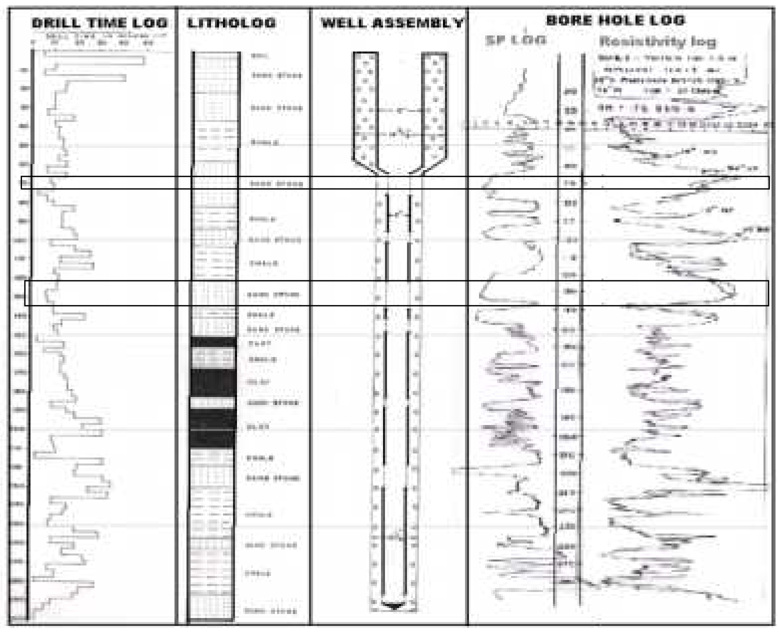


Fig. 2: Design of Kotrimal Bore well and relation with Drill Time

2.3 <u>Water Level data</u>:

Ground water is a dynamic system. It always remains under the influence of time dependant recharging and discharging factors. Due to this continuous influence, water level of the aquifer system fluctuates and the range depends on the period of influence. The recharge to the ground water system is controlled by many factors such as rainfall, seepage from reservoirs, lakes, ponds, rivers and irrigation, etc. The output from the ground water system includes ground water withdrawal, natural seepage to rivers and sea, evaporation from shallow water table and transpiration through vegetation. To study the ground water behavior, CGWB has established some dug wells and piezometers as observation wells known as national Hydrograph station (NHS) which are monitored regularly with respect to static water level and quality from 1969 onwards. The density of observation wells was increased year after year. During the present survey 22 nos of observation wells including NHS were monitored. The NHS are monitored four times in a year and the newly established key observation wells were monitored two times (Pre-monsoon & Post-monsoon). The time period of monitoring is as follows:

May -	20th to 30th of the month - represents Pre-monsoon water level
August -	20th to 30th of the month - represents peak monsoon water level.
November -	1st to 10th of the month- represents water level of Post-monsoon period.
January -	1st to 10th of the month- represents the recession stage of water level.

The water samples from these wells were collected in pre-monsoon period and were analysed to ascertain the chemical quality. Ground water levels, observed over a period, provides valuable information on the behavior of ground water regime, which is constantly subjected to changes due to recharge and discharge. The difference between these two factors results in the decline or rise in the ground water storage. When the recharge exceeds discharge there will be rise in the ground water storage whereas decline in the storage will be observed when recharge is less than discharge. The response of these factors is ultimately reflected on the water level of the area and their fluctuation. The phreatic water table of an area is the subdued replica of surface topography, which is regionally controlled by the major river basins and locally controlled by the watersheds. This is termed as phreatic aquifer in the report which represents the weathered formation of the area. Since all the developmental activities are listed by administrative unit in the state hence the block wise water level data is needed for planning developmental activity. On the basis of analysis of water level data, the changes in the ground water regime have been discussed. For every set of measurement the data was analyzed and maps like Pre and post-monsoon depth to water level, Water level fluctuation and Long term (decadal) water level trend have been prepared. The historical water level data available were analyzed to have long-term trend in water level behavior of all the basins within the state. The water level trends were analyzed to understand the ground water regime variation in long-term basis. The details of the water level data is given in **Annexure-II**.

2.4 Hydrochemical data:

The hydrochemical analysis of the ground water of the block was based mostly on the analysis of 32 ground water samples collected during the survey and exploration from key observation wells as well as exploratory wells (**Annexure-III A & B**). The parameters analysed were EC, pH, Ca^+, Mg^+, Na^+, K^+, CO_3^{--}, HCO_3^-, Cl^-, SO_4^{--}, NO_3^- and F^-. During the year 2016, ground water samples from ground water monitoring wells of CGWB in Pusaur block were analysed for Arsenic. Further, a special study has been taken up by CGWB to assess the Uranium contamination in ground water in the year 2019 where ground water samples were analysed in the chemical laboratory of CGWB, Chandigarh.

All the chemical analyses presented here have been carried out in the laboratory of CGWB, NCCR, Raipur. EC and pH were analysed using EC and pH meters respectively. Ca, Fe, CO3, HCO3 and Cl were analysed using titrimetric methods. K and Na were analysed by flame photometer, SO4 and F by Spectrophotometer, NO3 by UV Spectrophotometer and Arsenic was analyzed by AAS. The samples which were analyzed for major cation and anion species are balanced electrochemically within +10 percent. The obtained results give the overall existing scenario of the ground water hydrochemistry of Pusaur block. With respect to the results the suitability of ground water for drinking, agriculture and industrial purposes has been described. The result of the chemical analysis of ground water samples was compared with IS 10500 BIS: 2012 for the drinking purposes. The BIS standard mentions the acceptable limit and indicates its background. It recommends implementing the acceptable limit. Values in excess of those mentioned as “acceptable” render the water is not acceptable, but still may be tolerated in the absence of an alternative source but upto the limits indicates under “permissible limit” in the absence of alternate source, above which the sources will have to be rejected.

2.5 Achievement:

To understand the regional hydrogeological behavior of Pusaur block, this complex aquifer setup has been classified into aquifer system on the basis of their lithology and age. The aquifer characteristics, its extent and the ground water quality are analyzed on the basis of these broad classifications. However, for better delineation of the aquifer characteristics, the lithologs and pumping test results of same formation but in neighboring blocks are taken into consideration. Ground water flow pattern, long and short term dynamics is also studied block wise. Finally the Aquifer maps were prepared and accordingly Aquifer Management Plan has been formulated for Pusaur block.

CHAPTER-3

AQUIFER DISPOSITION

3.1 Principal & Major aquifer groups:

The aquifer material controlling ground water flow in Pusaur block can be broadly divided into two major media (1) Porous media (Phreatic Aquifer) and (2) Fractured media (Deeper Aquifer). The phreatic aquifer both in hard and soft rocks in the block is wide spread and largely in use. This aquifer is being tapped mainly through dug well upto a depth of 20 m broadly. The weathered mantle and shallow fractures mainly constitute the shallow aquifers. The thickness of weathered mantle varies from 5 to 20m bgl. Nearly 90% of dug wells are in the depth range between 5 and 15 mbgl. The hand pumps installed by PHED for drinking water taps the shallow fracture zone down to 60 m bgl. The deeper aquifers have been identified in both hard and soft rocks. From the data collected, the characteristic of different aquifers in the block are deciphered.

Geologically, The Raipur Group is represented by Raigarh Formation in the block. The Chandrapur sandstones are overlain by argillo-calcareous rocks representing Raigarh Formation in Baradwar sub basin. This formation occupies low lying area. The Raigarh Formation is equivalent of Charmuria and Gunderdih Formation of Hirri sub basin. The Raigarh Formation is mainly composed of shale-limestone-dolomite. These are generally horizontally bedded, unmetamorphosed, thinly laminated intruded by series of dolerite dyke. The major aquifer groups in Pusaur block are (**Map-3**):

(i) Gunderdih Shale
(ii) Charmuria Limestone

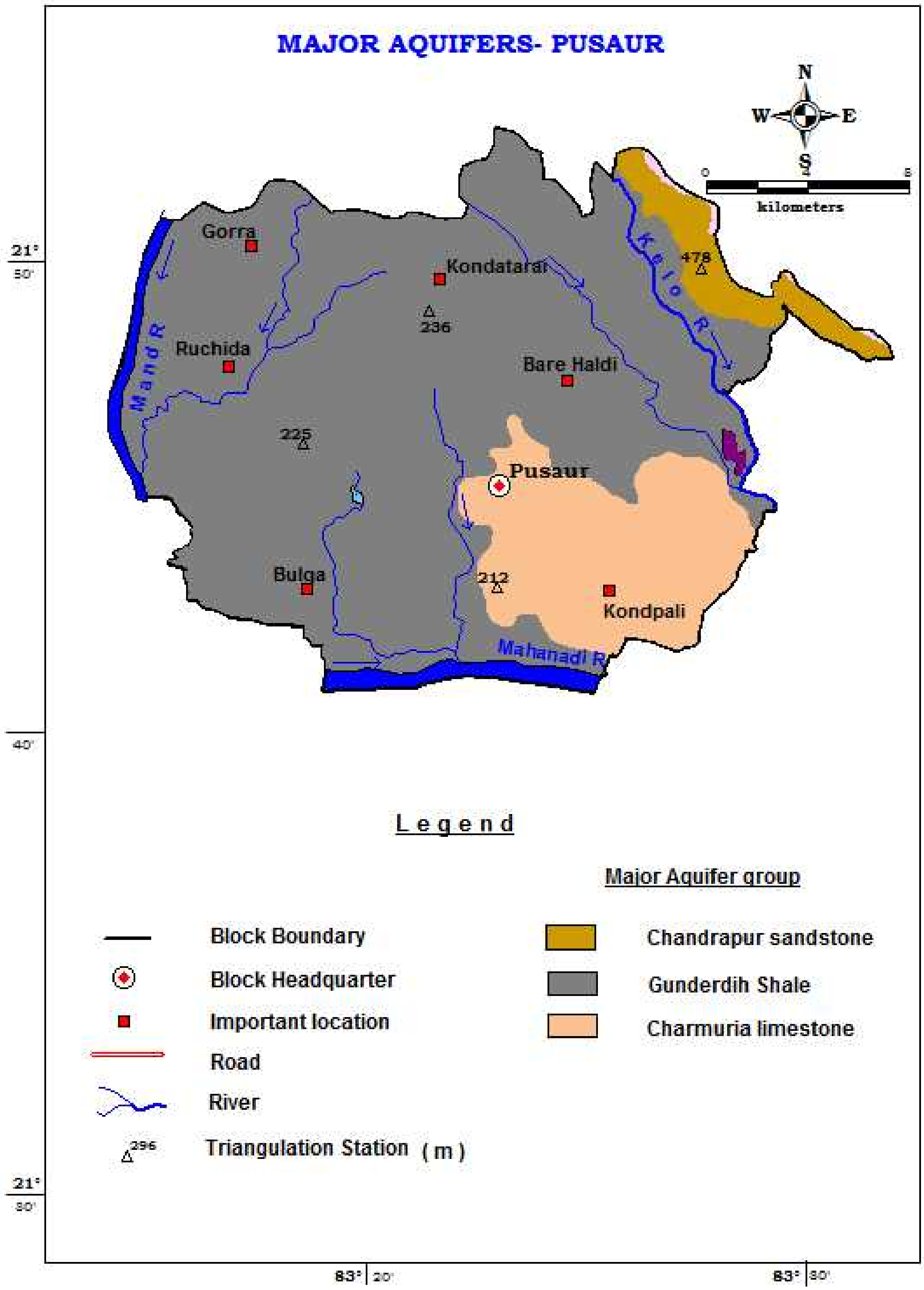
(i) Gunderdih Shale: The Gunderdih shale is calcareous in subsurface and many times gypsiferous, having good secondary porosity in parts of Raigarh, Pusaur and Kharsia blocks. The shally part of Raigarh Formation is represented by Gunderdih shale in Kharsia, Pusaur, Raigarh, Baramkela and Sarangarh blocks. The fracture zones are encountered in the depth range of 60 to 120 mbgl. However the potential fractures are mostly confined to within the depth of 100 m. The casing depth varies from 6 to 35.5 mbgl. The casing length also indicates thickness of the weathered formation. The discharge obtained from the wells drilled in the Gunderdih shale varies from 0.5 to 22.42 lps. The highest discharge of 22.42 lps was obtained at aurda village in Pusaur block.

(ii) Charmuria Limestone : The Charmuria formation in Pusaur block is predominantly dolomite having cavernous zones and is good repository of ground water. Seasonal weak auto flow conditions exist at few places within Raigarh Formation like Gotma village. The fracture zones are encountered in the depth range of 60 to 120 mbgl. However the potential fractures are mostly confined to within the depth of 100 m. Depth to a water level in bore wells varies from 4 to 17 mbgl. The casing depth varies from 6 to 30.56 mbgl. The casing length also indicates thickness of the weathered formation. The discharge obtained from the wells drilled in the Charmuria limestone varies from 0.5 to 19.5 lps.

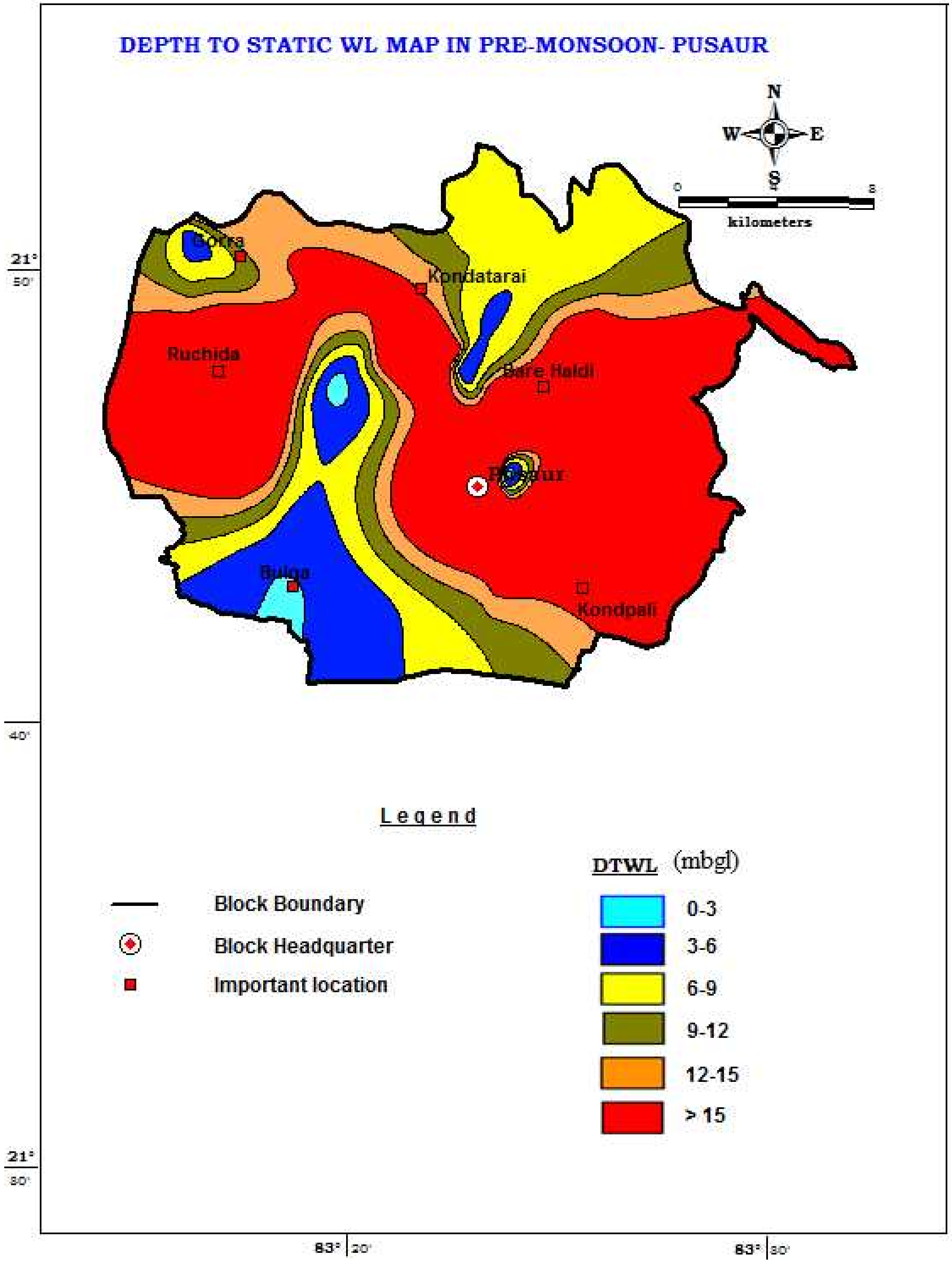
3.2 <u>Ground Water Regime monitoring</u>:

During the study, 22 nos. of wells both dug wells and hand pumps were established and monitored (Annexure-II) both in pre-monsoon and post-monsoon period. The water level analysis data indicates that the ground water level of phreatic aquifer during pre monsoon period ranges from 2.01 to 32.60 mbgl and during post-monsoon period it is from 0.01 to 16.68 mbgl. The fluctuation ranges from 0.60 to 16.68 m with an average fluctuation of 5.25 m. The average weathered thickness of the phreatic aquifer is around 17.17 m. The water level map prepared for the district is presented in (**Map-4 A, B &C**).

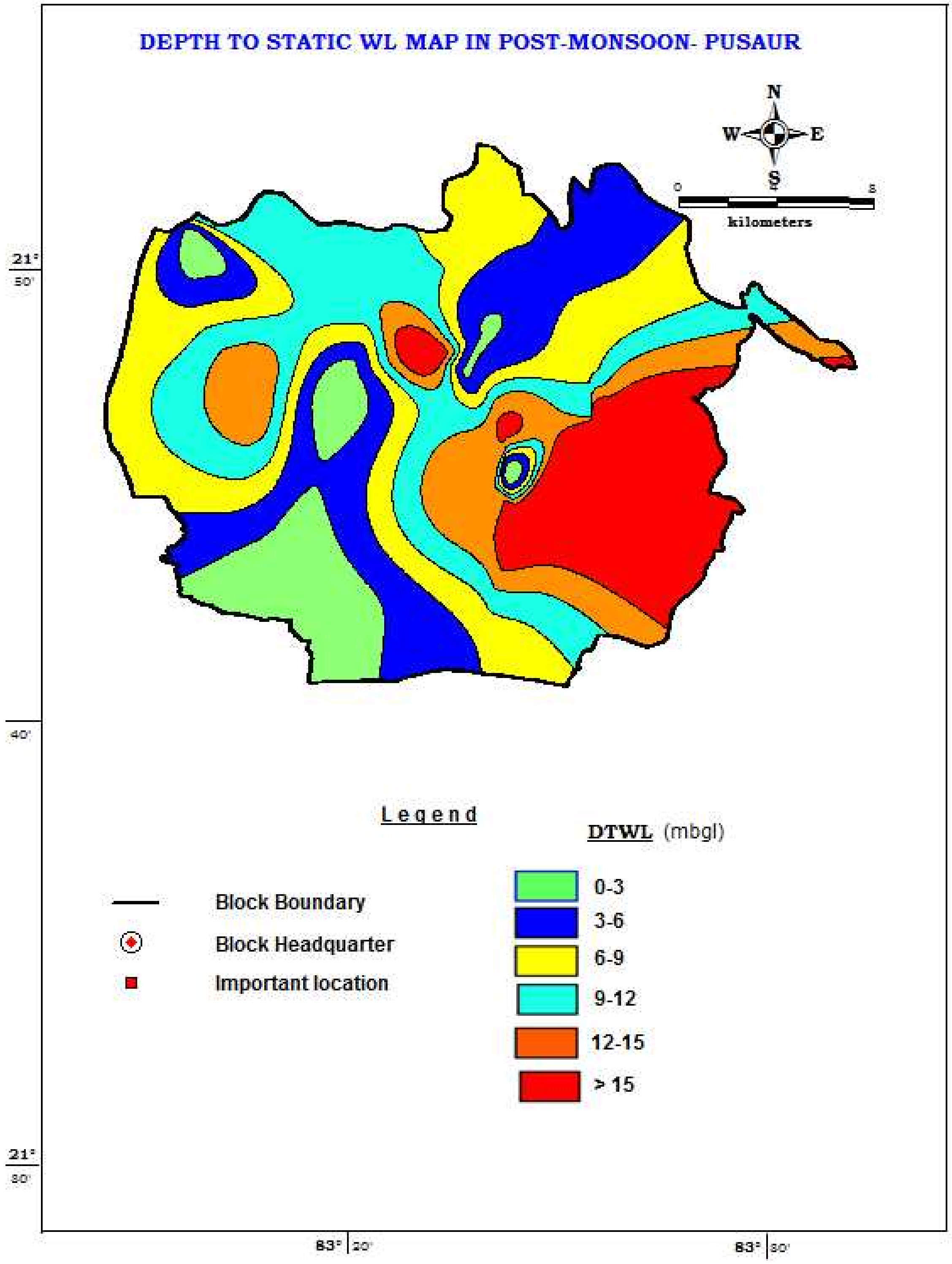
Map-3: Major Aquifer map of Pusaur block



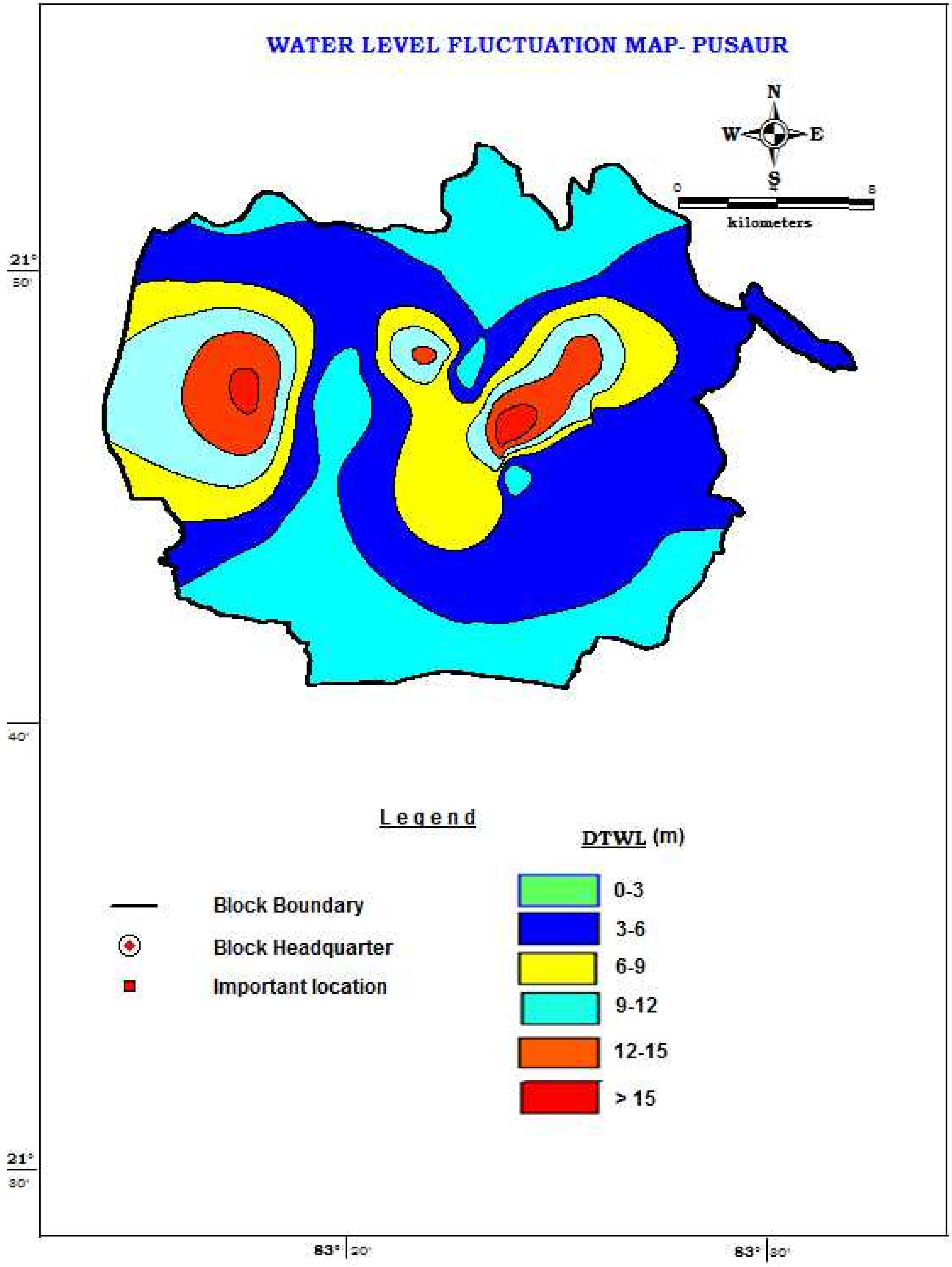
Map-4 (A): Pre-monsoon depth to water level map of Pusaur block



Map-4 (B): Post-monsoon depth to water level map of Pusaur block



Map-4 (C): Water level fluctuation map of Pusaur block



3.2.1 Ground water level trend:

The long term ground water level trend indicates that there is appreciable change in ground water level with a falling trend of 40 cm/year both in pre-monsoon and post monsoon period (GWE report-2017).

3.2.1 Ground Water flow direction:

The regional ground water flow direction is towards west. It may also be seen that the flow of ground water is mostly towards the major drainage suggesting that the base flow is towards the drainage system.

3.3 Ground Water Resources:

The ground water Resources of Pusaur block has been estimated on the basis of revised methodology GEC 2015. Ground water resources have two components – Replenishable ground water resources or Dynamic ground water resources and Static resources.

3.3.1 Replenishable ground water resources or Dynamic ground water resources:

As per resource estimation March 2017, the Net Annual Extractable Ground Water Recharge (Ham) in Pusaur block is 4371.35 ham. The Net Ground Water Availability for future use is 955.62 ham. Current Annual Ground Water Extraction for all purposes is 3359.58 ham out of which 3009.6 ham is for irrigation. The overall Stage of Ground Water Extraction in the block is 76.85 % and categoised as Semi-Critical as there is a significant falling in the water level trend during pre& post monsoon period to the tune of 40 cm per year (GWE report-2017). The declining trend in post-monsoon period indicates the declining trend in ground water recharge which may be attributed to the declining trend in rainfall as well as reducing trend in the area for ground water of recharge. The Annual GW Allocation for domestic Use as on 2025 is 406.13 ham. The block wise resource is presented in table 5.

Table-5: Resources as estimated in 2017 of Pusaur block

Block	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	Stage of Ground Water Extraction (%)	Categorization (OE/Critical/ Semi critical/ Safe)	Does the water Level Trend during Pre and Post Monsoon show a significant falling trend (Yes /No)	
		Irrigation use	*Industrial use*	*Domestic use*	*Total Extraction*					Yes/No	If Yes Value (cm/yr)
Pusaur	4371.35	3009.6	0	349.98	3359.58	406.13	955.62	76.85	Semi-Critical	Yes	40

3.3.2 <u>Static Ground Water Resources:</u>

An attempt has been made to assess the Static Ground Water Resources Pusaur block which is the resource that remains available below the dynamic zone of water table fluctuation. This is not replenished every year and extracting this water is ground water mining. The quantum of ground water available for development is usually restricted to long term average recharge or dynamic resources. For sustainable ground water development, it is necessary to restrict it to the dynamic resources. Static or in-storage ground water resources could be considered for development during exigencies that also for drinking water purposes. It is also recommended that no irrigation development schemes based on static or in-storage ground water resources be taken up at this stage. The following table-6 presents the ground water resources of Raigarh block.

Table-6: Ground water Resources of Pusaur block

Block	Recharge worthy Area (Ha)	Stage of Extraction in %	Static Resource in Ham	Dynamic Resource in Ham
Pusaure	51030	76.85	423.753	4371.350

The table shows that the total static ground water resource of Pusaur block is 423.753 Ham beside the dynamic ground water resource of 4371.35 ham.

3.4 <u>Ground Water Quality</u>:

Ground water quality of shallow aquifer as well as deeper aquifer in Pusaur block for drinking, irrigation and industrial purposes is assessed on the basis of analysis of ground water samples collected from 24 nos. of observation wells for shallow aquifer & 8 exploratory wells for deeper aquifer (**Annexure-III A & B**). Apart from these, water samples were also analysed to assess the arsenic and uranium contamination respectively.

3.4.1 <u>Water quality for all purposes:</u> The concentrations of various parameters for both shallow & deeper aquifers are presented in the following table-7.

Table-7: Ground water quality data for shallow & deeper aquifer

Sl. No	Parameters (in ppm)	Shallow Aquifer		Deeper Aquifer	
		Min	Max	Min	Max
1	pH	7	7.56	7.2	8.2
2	EC(in µS/cm at 25° C)	223	1378	140	2320
3	Total Alkalinity	45.08	350	14.75	185
4	HCO_3	55	427	18	225.7
5	Cl	7	75	7	35
6	SO_4	4	442.6	0	126.51
7	F	0	0.52	0.02	0.56
8	TH	65	510	30	995
9	Ca	6	144	4	364
10	Mg	3.6	68	5	47
11	Na	8.1	109	18	125
12	K	0.6	37	1	4

The above table-7 indicates that the EC & sulphate content of ground water for shallow aquifer and EC, total hardness for deeper aquifer are more than permissible limit at some places. However in overall, the ground water of Pusaur block is was found suitable for drinking purposes, irrigation as well as industrial purposes.

3.4.2 Arsenic contamination: No arsenic contamination in ground water is found in any ground water sample collected in Pusaur block.

3.4.3 Uranium contamination: The maximum uranium content in ground water in Pusaur block is found at Semra which is about 0.00927 mg/l. However the ground water in Raigarh block is safe from Uranium contamination point of view.

3.4.4 Type of Ground Water: The ground water of Pusaur block is calcium-magnesium-bicarbonate (Ca-Mg-HCO_3) and calcium-sulphate (Ca-SO_4) type for shallow aquifer & calcium-bicarbonate (Ca-HCO_3) type for deeper aquifer respectively.

3.5 Ground Water Issues:

i. In several regions there is deeper water table due to excessive withdrawal of ground water for irrigation.
ii. The bore wells are drilled by the farmers without taking into consideration the spacing criteria between wells. In many instances bore wells drilled are very close to each other.
iii. Desilting of the existing tanks for increasing storage capacity and recharge to the ground water.
iv. In some areas there is iron contamination in groundwater was recorded.

CHAPTER-IV

AQUIFER MAPPING & MANAGEMENT PLAN

4.1 Aquifer Map:

Finally on the basis of above studies such as the aquifer characteristic of various aquifer groups & ground water level behavior in various seasons, the following maps for Pusaur block were prepared:

(i) Aquifer map 2-dimensionsl, (**Map-5)**

(ii) Aquifer map 3-dimensionsl (**Map-6)**

(iii) Ground water Development Potential & Artificial Recharge Prospect (**Map-7)**

4.2 Status of Ground Water Development Plan:

(i) The ground water development in the block is being done by dug wells and tube well/ bore wells. The dug well depth varies from 5 to 20 m and the diameter varies from 1 to 4 m. The bore wells drilled in the area are 60 to 150 m deep with diameter of 100 to 150 mm. Diesel or electric operated pumps of 1 to 5 HP or traditional tenda is used to lift the water from dug wells for irrigation purposes. The submersible electrical pumps of 3 to 5 HP are used for irrigation purpose in case of bore wells in the area. The bore wells in the area can irrigate an area of 0.5 to 2.5 ha for paddy.

(ii) The stage of ground water development for Pusaur block is 76.85 % and is categorized under **Semi-Critical**, there is need for artificial recharge structures in a long term basis to arrest the non-committed run-off to augment the ground water storage in the block. The details of artificial recharge structures to enhance ground water resource are presented in the table-8.

Table-8: Details of AR structures in Pusaur block

Block	Percolation tank recharge capacity 0.2192 mcm	Nalas bunding cement plug/ check dam recharge capacity 0.0326 mcm	Recharge shaft recharge capacity 0.00816mcm	Gully plugs Gabbion structures recharge capacity 0.0073 mcm	Total recharge in mcm
Pusaur	40	133	320	238	17.43

From the table 8, it is depicted that 40 nos. of percolation tank, 133 nos. of nala bunding/cement plug/check dams , 320 nos. of recharge shafts and 238 nos. of gully plug/gabion structures may be constructed at suitable locations that can enhance the ground water source to 17.43 mcm more.

(iii) The stage of ground water extraction in the block is 76.85 %. So there is needed to improve the ground water stressed condition to safe side that is to maintain the stage of ground water extraction less than 60%. Hence from the demand side of ground water management, change in cropping pattern from paddy to maize in Rabi season is an important aspect that can lead to improvement of stage of ground water extraction to 58.55% from 76.85% if at least 2000 ha cultivated for paddy in Rabi season is cultivated for maize as explained in table-10.

Table-8: Details of change in cropping pattern in Pusaur block

Paddy culti vation area in Rabi season	Water requirement (m) per ha		Difference (m per ha)	Total saving of water (ham)	Existing gross ground water extraction for all uses in ham	Improved status of ground water extraction
	Paddy	Maize				
2000	0.9	0.5	0.4	800	3359.58	58.55

(iv) Field to field irrigation (flooding method) should be replaced with channel irrigation in command area as there is about 30-40% conveyance loss in field irrigation. Same amount of water can be saved through channel irrigation.

(v) Information, education and Communication (IEC) activities such as mass awareness programs to be organized to sensitize people on the issues of depleting groundwater resource, spacing criteria between ells, shifting from summer rice to Maize/ Ragi, to save ground water for future generation, advantages of taking such crops, crop methodology and its related aspects.

(vi) In command or non-command area wherever ground water has been used for field irrigation should be replaced immediately with micro irrigation methods such as sprinklers, drip irrigation etc.

(vii) Government should provide attractive incentives and subsidies to encourage farmers to take up alternative crops to paddy, which are equally profitable and adopt micro-irrigation practices such as drip and sprinkler irrigation.

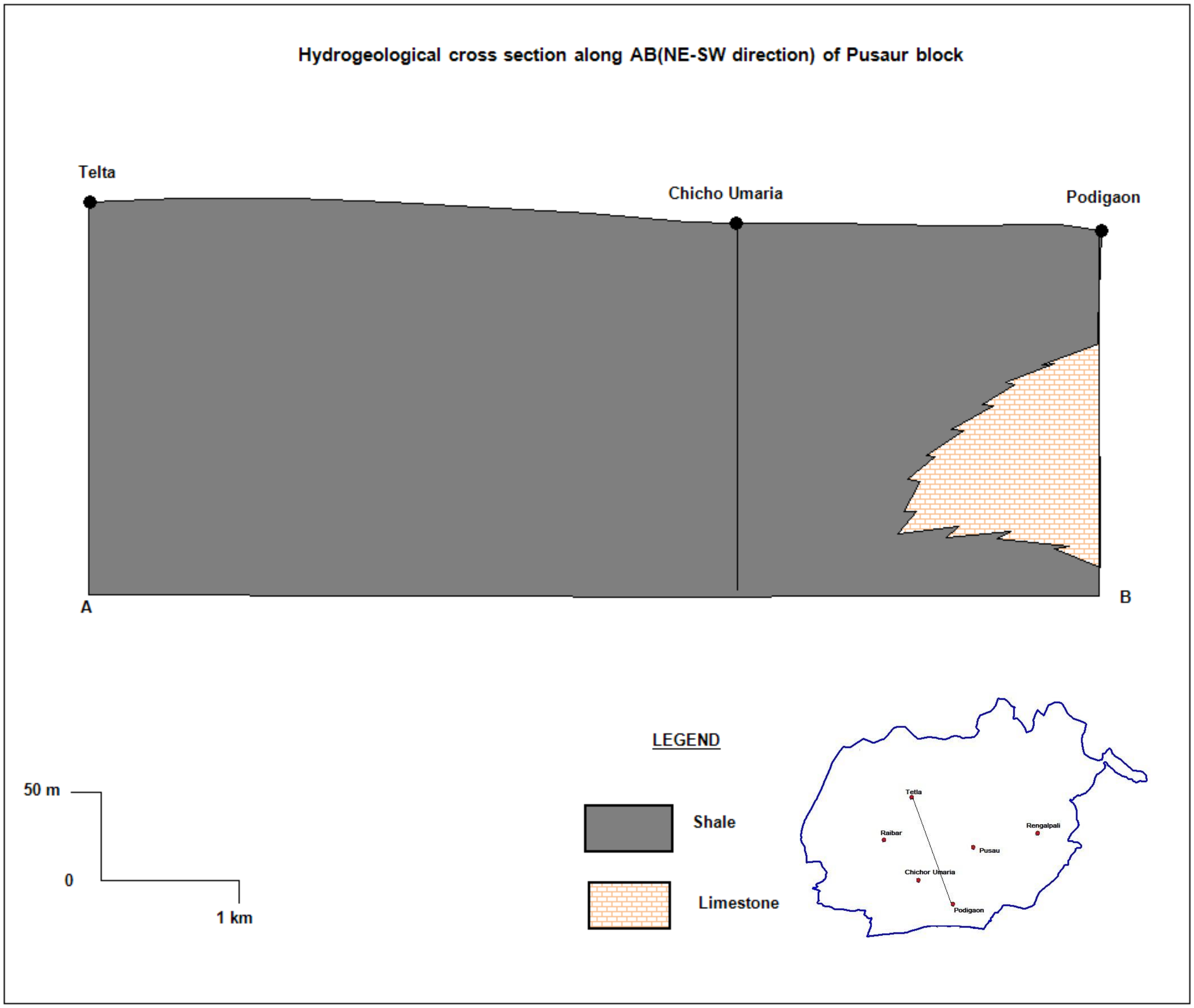
(ix) The practice of providing free electricity to operate irrigation bore wells should be strictly monitored and put to an end in case of overconsumption.

(x) Even if farmers use solar pump or other method of ground water irrigation for summer paddy, it should not be flooding method. Proper pipes are to be used to transfer water from one plot to another.

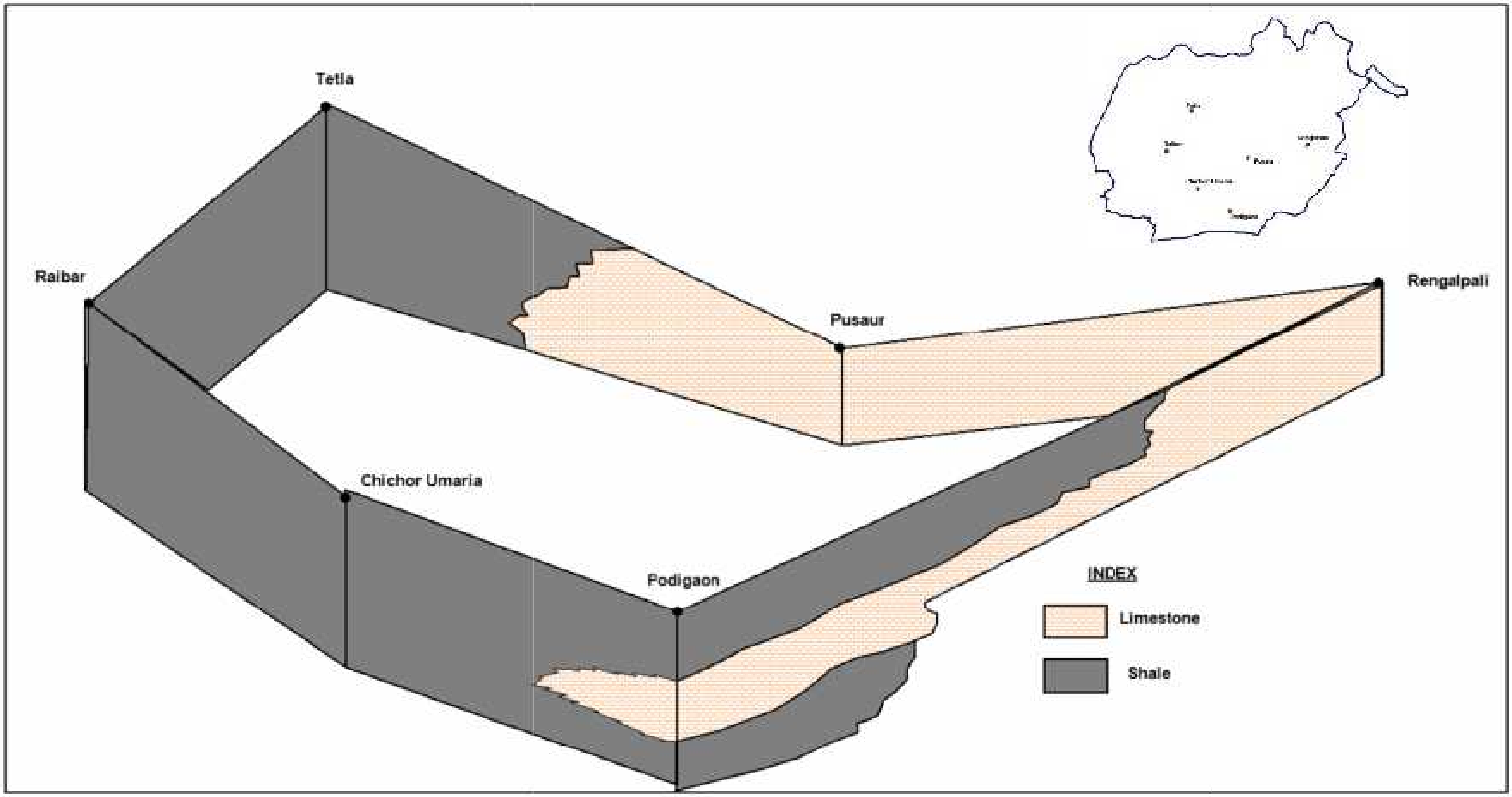
(xi) Govt. may set up network of grids to purchase electricity generated from solar panels. This will encourage the farmers not to waste electricity by extracting groundwater unnecessarily and also provide alternative income.

(xii) Furthermore, in order to strike a balance between the ground water draft and the available resource, suitable artificial structures at appropriate locations be constructed through successive phases after tentatively every 20nos of groundwater abstraction structures become operative.

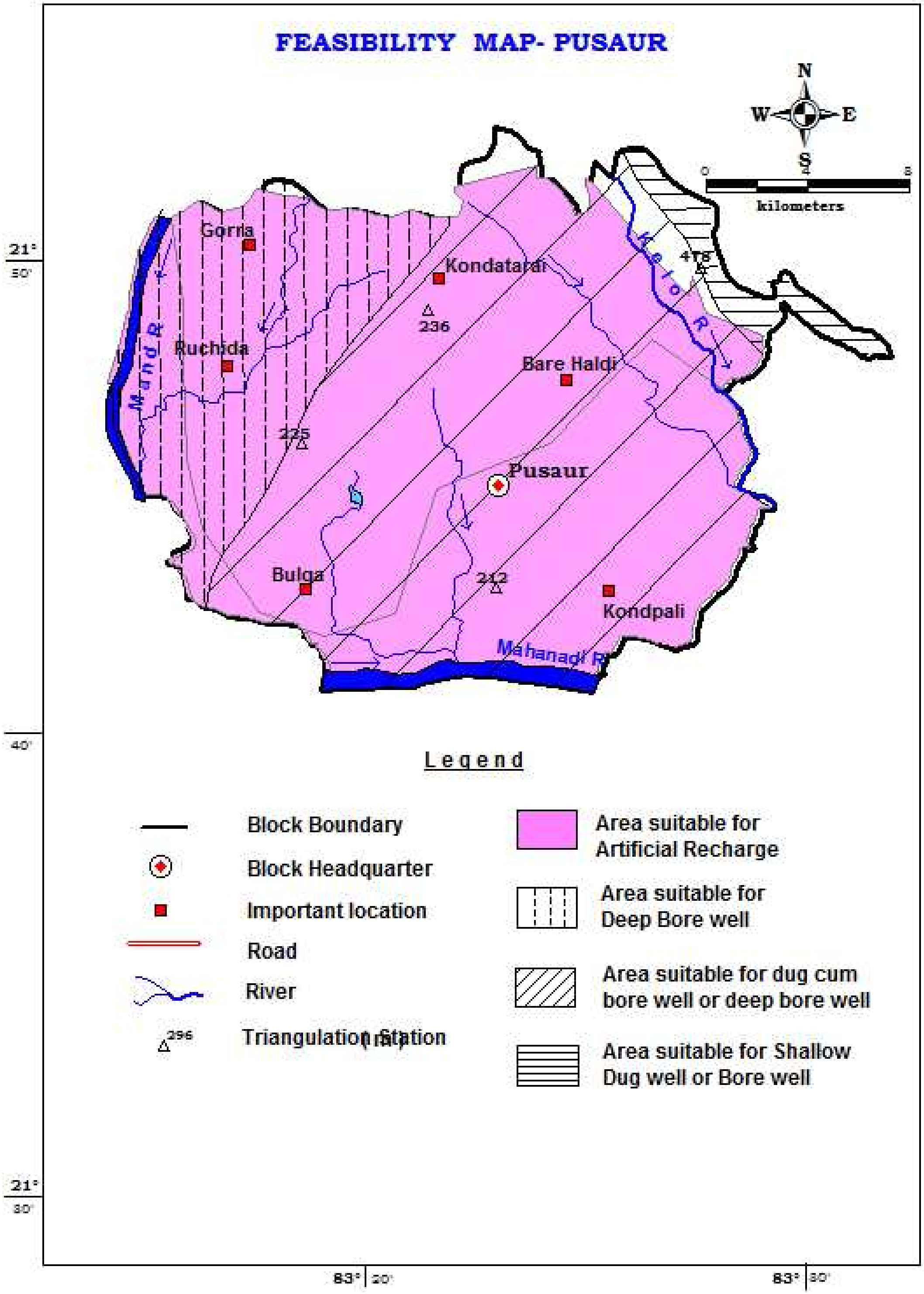
Map-5: Hydrogeological cross section in NE-SW direction, Pusaur block



Map-6: Aquifer disposition in 3-dimension in Pusaur block



Map-7: Ground Water Development & prospect map of Pusaur block



CHAPTER-V

SUM UP

5.1 Conclusions:

Area: 510.3 sq.km taken for study having a total Annual Extractable Ground Water Recharge of 4371.35 ham and present stage of ground water extraction is 76.85 % and is under semi-critical category. 86.22 % of the total irrigated area is irrigated by groundwater. The Principal aquifer system in Pusaur block is Raipur group both in phreatic and fractured condition and the major aquifer groups are (i) Gunderdih Shale (ii) Charmuria Limestone.

The average ground water level of phreatic aquifer during pre monsoon period is 13.71 mbgl and during post-monsoon period it is 8.45 mbgl. The average fluctuation ranges is 5.25 m. The long term ground water level trend indicates that there is appreciable change in ground water level with a falling trend of 40 cm/year both in pre-monsoon and post monsoon period. The average weathered thickness of the phreatic aquifer is around 17.17 m.

The average yield of Gunderdih shale is 6.41 lps with avg transmissivity of 14.58 m^2/day & average drawdown is 13.91 m. One to three sets of potential fracture zone mostly lie within 100 m depth in Gunderdih shale. The average yield of Charmuria limestone is 9 lps with avg transmissivity of 17.855 m^2/day & average drawdown is 19.63 m. One to two sets of potential fracture zone mostly lie within 100 m depth in Charmuria Limestone.

The major ground water issues are: (i) In several regions there is deeper water table due to excessive withdrawal for irrigation, (ii) No proper spacing criteria between wells (iii) Silting of the existing tanks. In terms of Demand side management, change in cropping pattern from paddy in Rabi season to maize can lead to improvement of stage of ground water extraction to 36.41 from 76.85%. . In terms of Supply side management, by constructing artificial recharge structure such as Percolation Tank (40) , Nala bund & Check dam (133), Recharge shafts (320) and gully plug/gabion structures (238), the ground water resource can be increased to 17.43 mcm more.

5.2 Recommendations:

- In terms of Demand side management, change in cropping pattern from paddy in Rabi season to maize can lead to improvement of stage of ground water extraction to 36.41 from 76.85%.

- In terms of Supply side management, we have to go for artificial recharge, particularly to recharge the area of deeper water level. As such 17.43 mcm water can be recharged to the underground by constructing Percolation Tank (40), nala bund / Check dam (133), Recharge shafts (320) and gully plug/gabion structures (238).

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ANNEXURE-I: Exploration details in Pusaur block

SL. NO	LOCATION	LAT	LONG	DEPTH (m)	CASING (m)	FORMATION	ZONE ENCOUNTERED (m)	YIELD (lps)	DRAWDOWN (m)	TRANSMISSIVITY (m^2/sec)	STORATIVITY
1	Chikhli	21.773	83.319	68	18.2	Raigarh Fm.-Shale	28-30, 65-68	8.68	12.22		
2	Chhichorumaria	21.735	83.351	130		Raigarh Fm.	32-32.5,75-75.5, 99-99.5	7	17.34	46	
3	Rengalpali	21.76	83.45	105	32.5	Raigarh Fm.	32-32.5,99-99.5	9	19.95	11.8	
4	Kondatarai	21.827	83.358	123	14.5	Raigarh Fm.-Shale	60,90,117	3.5	5.66	15.8	0.00178
5	Pusaur	21.751	83.395	91.5	18.5	Raigarh Fm.-Shale	28-29, 56, 59, 90-91.5	6	24.47	32.71	- -
6	Aurda	21.805	83.358	72	20.5	Raigarh Fm.-Shale	22-23,44-47,51-54, 69-71	22.42	3.41	4.43	- -
7	Podigaon (EW)	21.704	83.389	202	12	Fractured Dark colour claystone	73.9-76.9, 101.3-104.4, 131.3-134.9	7	7.1		
8	Umaria (EW)	21.730	83.346	202	12	Raigarh Fm.-Shale	43.4-46.4, 70.8-73.9, 83-86.1,168.4-170.6	6			
9	Barbhavna	21.794	83.313	28.71	6	Gunderdih shale					
10	Nandgaon	21.79	83.313	202	13.5	Gunderdih shale		1			
11	Raibar	21.77	83.31	202	12.1	Gunderdih shale		0.5			
12	Tetla	21.8	83.33	202	12	Gunderdih shale		3			
13	Basanpali	21.79	83.41	202	35.5	Gunderdih shale		5			
14	Tilgi	21.758	83.308	101.5	22	Fracture and Shaly L.St.	26, 82,90	15	6.81		
15	Tadola	21.791	83.711	115	18.3	Shale	26, 82	10	7.7		
16	Pedigaon	21.680	83.383	115	13.75	Shale	32, 82	5	16.83		
17	Bhatanpail	21.8	83.429	113.5	18.1	Shale	32, 49, 57	11.5	13.5		
18	Chhichorumaria	21.735	83.351	136	12.5	Raigarh Fm.-Shale	41-41.5,111-111.5	5.6			
19	Chhichorumaria	21.735	83.351	50	12	Raigarh Fm.-Shale	32.-32.5	1.5			
20	Podigaon (OW)	21.703	83.389	141	12	Raigarh Fm.-Shale	40.3-4.4, 98.3-101, 113.5-116.6	10			
21	Umaria (OW)	21.73	83.346	165	6	Raigarh Fm.-Shale	89.1-92.2, 153.2-156.2	10			
22	Kondatarai	21.827	83.358	122.00		Raigarh Fm.-Shale					

ANNEXURE-II: Static Ground Water level details in Pusaur block

S.No	Village	Long	Lat	Source	Pre-Monsoon SWL (mbgl)	Post-Monsoon SWL (mbgl)	Fluctation (m)
1	Aurda	83.38838	21.81203	DW	5.85	2.85	3
2	Bonda	83.3042	21.7194	DW	3	1.42	1.58
3	Surajgarh	83.3853	21.6925	DW	8.8	6	2.8
4	Tadola	83.3806	21.7958	DW	4	3	1
5	Tetla	83.3292	21.7917	DW	2.6	1.9	0.7
6	Baghadola(Maldipa)	83.398	21.759	DW	2.2	0.3	1.9
7	Loharsingha	83.343	21.828	DW	2.3	0.3	2
8	Teka	83.271	21.846	DW	4.57	0.82	3.75
9	Tadola	83.3806	21.7958	DW	3.3	2.3	1
10	Tetla	83.3292	21.7917	DW	2.01	0.01	2
11	Jharmunda	83.366	21.802	HP	31.4	18.8	12.6
12	Kusmunda	83.396	21.774	HP	32.6	15.92	16.68
13	Ghutkupali	83.432	21.774	HP	24	20.52	3.48
14	Riyapali	83.43	21.782	HP	21	10.39	10.61
15	Pusaur	83.391	21.753	HP	20.8	12.93	7.87
16	Odekera	83.402	21.74	HP	23.7	19.66	4.04
17	Garh umaria	83.401	21.849	HP	7	6.4	0.6
18	Darramuda	83.423	21.838	HP	6.53	5.3	1.23
19	Jhalmala(Dipapara)	83.43	21.803	HP	21	7.82	13.18
20	Tarapur	83.268	21.858	HP	14.3	12	2.3
21	Loharsingha	83.343	21.828	HP	30.4	22.7	7.7
22	Kensara	83.294	21.79	HP	30.2	14.63	15.57

ANNEXURE-III (A): Chemical Quality details of Shallow aquifer in Pusaur block

S.NO.	Location	pH	TDS	EC	CO3	HCO3	Total Alkalinity	Cl	F	SO4	Ca	Mg	Na	K	TH	PO4	SiO2	Fe
1	Jharmunda	7.45	249.6	416	0	98	80.33	21	0.46	100	12	17	59	1.2	100	0.00	8	0.128
2	Kusmunda	7.42	310.8	518	0	122	100.00	21	0.45	120	38	22	37	4.3	185	0.00	14	0.19
3	Baghdola	7.24	468.6	781	0	220	180.33	14	0.44	150	82	12	53	2.3	250	0.00	12	0.19
4	Ghuterpali	7.5	176.4	294	0	73	59.84	14	0.42	46	14	11	33	1.6	80	0.00	11	0.222
5	Pusaur	7.27	676.8	1128	0	390	319.67	35	0.44	144	138	22	51	25	435	0.00	10	
6	Odekora	7.47	184.2	307	0	98	80.33	21	0.48	54	12	12	37	4.6	80	0.00	15	0.19
7	Darramuda	7.56	158.4	264	0	98	80.33	21	0.40	26	6	12	23	7.8	80	0.00	14	0.096
8	Bathanpali	7.33	143.4	239	0	73	59.84	7	0.52	58	10	3.6	22	4.6	65	0.00	15	**3.79**
9	Jhalmala	7.32	133.8	223	0	92	75.41	14	0.47	4	20	6	8.1	7.8	75	0.00	14	0.128
10	Tarapur	7.42	456	760	0	98	80.33	28	0.40	130	88	11	39	3.5	265	0.00	10	0.316
11	Pacheda	7.26	826.8	1378	0	427	350.00	35	0.43	70	90	68	109	1.95	510	0.00	12	0.128
12	Teka	7.39	190.2	317	0	79	64.75	11	0.47	68	23	13	17	1.56	120	0.00	12	0.034
13	Loharsunga	7.3	508.8	848	0	183	150.00	21	0.50	150	60	31	62	37	230	0.00	12	0.159
14	Kensara	7.34	364.2	607	0	134	109.84	28	0.44	130	50	14	55	16	185	0.00	10	0.096
15	Bonda	7.1	312	520	0	177	145.08	53	0.3	30.3	24	37.2	10.8	1.5	215	0.11	6.9	
16	Surajgarh	7.3	256.2	427	0	153	125.41	50	0.1	11.3	30	13.2	31.7	0.6	130	0.11	6.1	
17	Kondatarai	7	513.6	856	0	128	104.92	46	0.2	194	58	28.8	65.9	1.6	265	0.12	12.1	
18	Nawrangpur	7.2	688.2	1147	0	85	69.67	14	0.2	442.6	118	31.2	57.8	1.9	425	0.15	8.7	
19	Tadola	7.4	307.2	512	0	256	209.84	18	0.1	27	46	20.4	30.2	1.4	200	0.11	14	
20	Tetla	7.3	628.2	1047	0	165	135.25	21	0	318	102	25.2	81.5	2	360	0.15	11.4	
21	Kathali	7.2	628.8	1048	0	55	45.08	50	0	394.2	104	38.4	59.2	2.5	420	0.05	8	
22	Aurda	7.3	384	640	0	232	190.16	75	0.1	28.5	50	24	44.8	1.1	225	0.1	4	
23	Koshmunda	7.4	409.2	682	0	262	214.75	21	0.2	109.8	42	37.2	42.9	1.5	260	0.2	13.8	
24	Rengalpali	7.3	657	1095	0	171	140.16	46	0	341	144	25.2	37.7	7.7	465	0.14	12.4	

ANNEXURE-III (B): Chemical Quality details of deeper aquifer in Pusaur block

S.NO.	Location	pH	TDS	EC	CO_3	HCO_3	Total Alkalinity	Cl	F	SO_4	Ca	Mg	Na	K	TH	PO_4	SiO_2	Fe
1	Rengalpali	8	390	650	0	146	119.67	7		0	66	13	50	1.6	220			0
2	Tilga	7.9	84	140	0	18	14.75	7		0	4	5	18	1	30			0
3	Bhatanpail	8.2	240.6	401	0	159	130.33	14			26	16			130			
4	Nandeli	7.7	481.2	802	0	177	145.08	14			100	13			305			
5	Kusmura	8	1023	1705	0	67	54.92	35			262	47			50			
6	Nandagoan	7.2	1392	2320	0	225.7	185.00	31.9	0.0	126.5	364	20.4	125	4	995	0.2		
7	Nandagoan	7.45	220.2	367	0	183	150.00	21.3	0.5	20.2	20	13.2	41.2	3.3	105	0.1		
8	Podigaon	7.45	211.2	352	0	219.6	180.00	7.1	0.6	6.1	22	10.8	44.6	1.1	100	0.1		

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