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

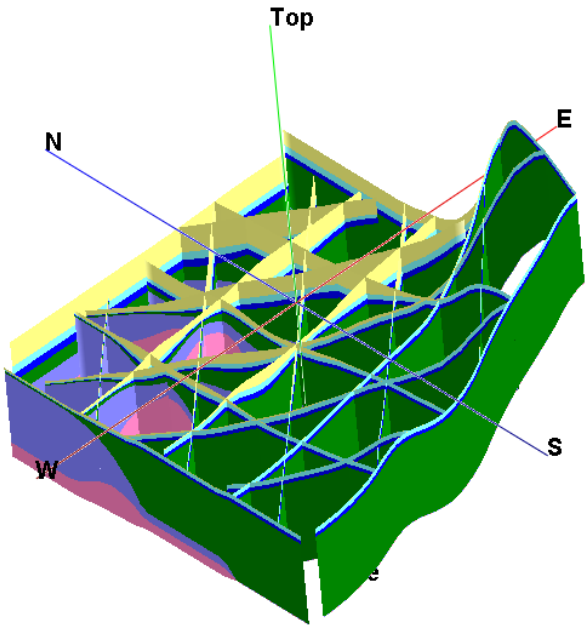
HARDA DISTRICT, MADHYA PRADESH

उत्तर मध्य क्षेत्र, भोपाल
North Central Region, Bhopal

Central Ground Water Board

Department of Water Resources, RD& GR
Ministry of Jal Shakti
Government of India

Aquifer Mapping and Ground Water Management Plan of Harda District, Madhya Pradesh



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SOUTH EASTERN COASTAL REGION
CHENNAI
2022-2023

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PREFACE

'Aquifer mapping' is a holistic approach for aquifer-based groundwater management. It may not be construed as aquifer geometry mapping only. In a broader perspective it can be defined as understanding the aquifers, ascertaining and establishing their quantity and quality sustainability through multi-disciplinary scientific approach integrating the techniques of geology, remote sensing, hydrogeology, geophysics, borehole drilling, hydrochemistry, hydrology, hydrometeorology, mathematical modelling, agriculture and soil science, water treatment and remediation, economics and social and environmental sciences.

Under the project on National Aquifer Mapping (NAQUIM to formulate sustainable aquifer management plan, Central Ground Water Board (CGWB), North Central Region, Bhopal has taken up Harda district to prepare the 3-Dimensional Model and 2-Dimensional Aquifer Maps for the entire district and formulate Block-wise Aquifer Management Plan.

Harda district occupies an area of 3330 Sq.km out of which the ground water recharge worthy area is 2700 sq. km. and the rest is covered by hilly and forest area. The major rivers flowing through the area includes the Narmada and Its tributaries. The major part of the district is covered by the Basalt, Granite and Alluvium. Based on the 4 exploratory / PZ bore wells drilled by CGWB, NCR under its exploratory program, it has been observed that the yield varies from meger to 2 lps. There are two aquifer zone demarcated in the Harda District.

The ground water occurs under unconfined condition and semi confined to confined condition. About 50 % of monitoring wells recorded water level in the range of 5-10 m bgl category, spreading in patches and major pockets in the north-western and eastern part of area. About 30% of monitoring wells recorded water level in the depth range of 10-20 m bgl occurring in broad patches all over the region. Deeper ground water levels ranging >20 m bgl constituting only about 4% of wells in this category, Long term water level trend show declining trend.

As per the Management plan prepared under NAQUIM of all the Block of Harda District, a total number of 212 Percolation Tanks, 741 Recharge Shafts/Tube wells and 847 Nala Bunds/Check Dams and 213 Village pond / Cement Plugs have been proposed and these structures can recharge 159 MCM.

Results of these comprehensive studies will contribute significantly to ground water sustainable management tools. It will not only enhance the long-term aquifer monitoring networks and but would also help in building the conceptual and quantitative regional ground-water-flow models for planners, policy makers and other stakeholders.

I would like to place on record my appreciation for ***G.Vengatajalapathi, Assistant Hydrogeologist*** to compile this report. I fondly hope that this report will serve as a valuable guide for sustainable development of ground water in the Harda District, Madhya Pradesh.

1. Introduction

Groundwater is of paramount importance for an agriculture-based country like India. Being a predominant asset, the use of groundwater, primarily for irrigation and for various development activities over the years, has adversely affected the ground water regime in many parts of the country. This has in turn led to an emergent need for comprehensive and realistic information pertaining to various aspects of groundwater resources available in different hydro-geological settings through a process of systematic data collection, compilation, data generation, analysis and synthesis, which together brings in the concept of an Aquifer Mapping and Management Plan.

a. Objective/Scope of Study

The primary objective of Aquifer Mapping can be specified as "Know your Aquifer, Manage your Aquifer". Systematic mapping of an aquifer incorporates activities such as collection and compilation of available information on aquifer systems, demarcation of their extents and their characterization, analysis of data gaps, generation of additional data for filling the identified data gaps and finally, preparation of aquifer maps at the desired scale.

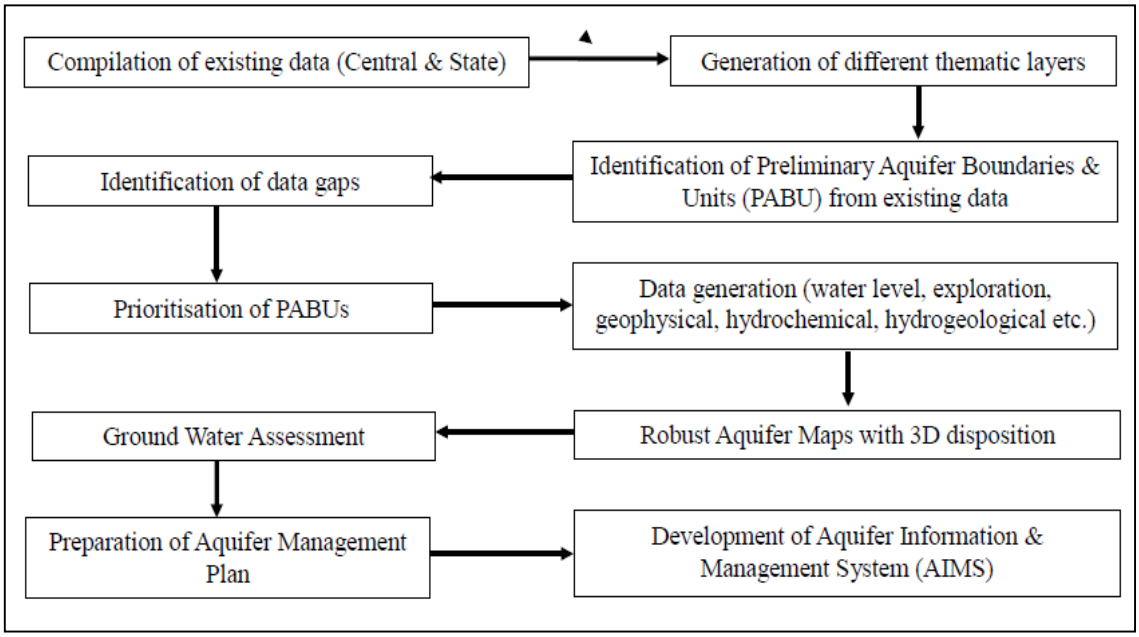
The two major objectives of the aquifer mapping are the delineation of lateral and vertical disposition of aquifers and their characterization at 1: 50,000 scale in general and further detailing up to 1: 10,000 scale in identified priority areas and the quantification of ground water availability and assessment of its quality to formulate aquifer management plans to facilitate sustainable management of ground water resources at appropriate scales through participatory management approach with active involvement of stakeholders.

b. Approach/ Methodology

The aquifer mapping study in this report has been compiled on the basis of existing data that were assembled, analyzed and interpreted from available sources. The collected data was further prepared to generate regional hydro-geological maps, thematic maps, water quality maps, cross-sections, 2-D and 3-D aquifer dispositions and potentiometric maps eventually to define the aquifer geometry, type of aquifers, ground water regime behavior, hydraulic characteristics and geochemistry of multi-layered aquifer systems on 1:50000 scale. To achieve the objectives, the following approach and methods have been adopted and stepwise details have been shown in the Fig 1.

- Data compilation
- Data gap analysis
- Data generation
- Preparation of block-wise aquifer maps and management plan

Figure 1: Aquifer mapping approach and methodology



c. Study area

The area of Harda district is 3330 Sq. Km. Harda district lies between north latitudes 21^0 54' and 22^0 36' and east longitudes 76^0 46' and 77^0 30' in parts of Survey of India toposheet No's, 55 B & F. Harda district has predominantly an agricultural based economy. It is situated in the eastern part of Madhya Pradesh. Prior to 1998-99 District Harda was a part of Hoshangabad District. Harda District was created in 6th July 1998, when it was divided from Hoshangabad District. After the division of the district, the district is bounded by Dewas and Sehore districts in the North, Hoshangabad district in the North east Betul in the south and Khandwa district in the west and south. In Harda district, there are three main rivers namely the Narmada, Ganjaal& the Maachak. Harda is the district headquarters and Khirkiya and Timarni are some of the major towns. Harda lies on Delhi-Mumbai and Kolkata-Mumbai railway routes. State Highway No. 15, linking Bhopal to Khandwa and National Highway No.59 A, linking Indore to Betul, pass through the district. The villages in the district are approachable by fair weather motorable tract. The district is divided into Six Tehsils such as Harda, Handia, Timarni, Rehatgaon, Khirkiya, Sirali and three development Blocks, namely

Harda, Timarni and Khirkiya Blocks, A detailed location map of the study area is shown in the Fig 2.

Figure 2: Location map of Harda district

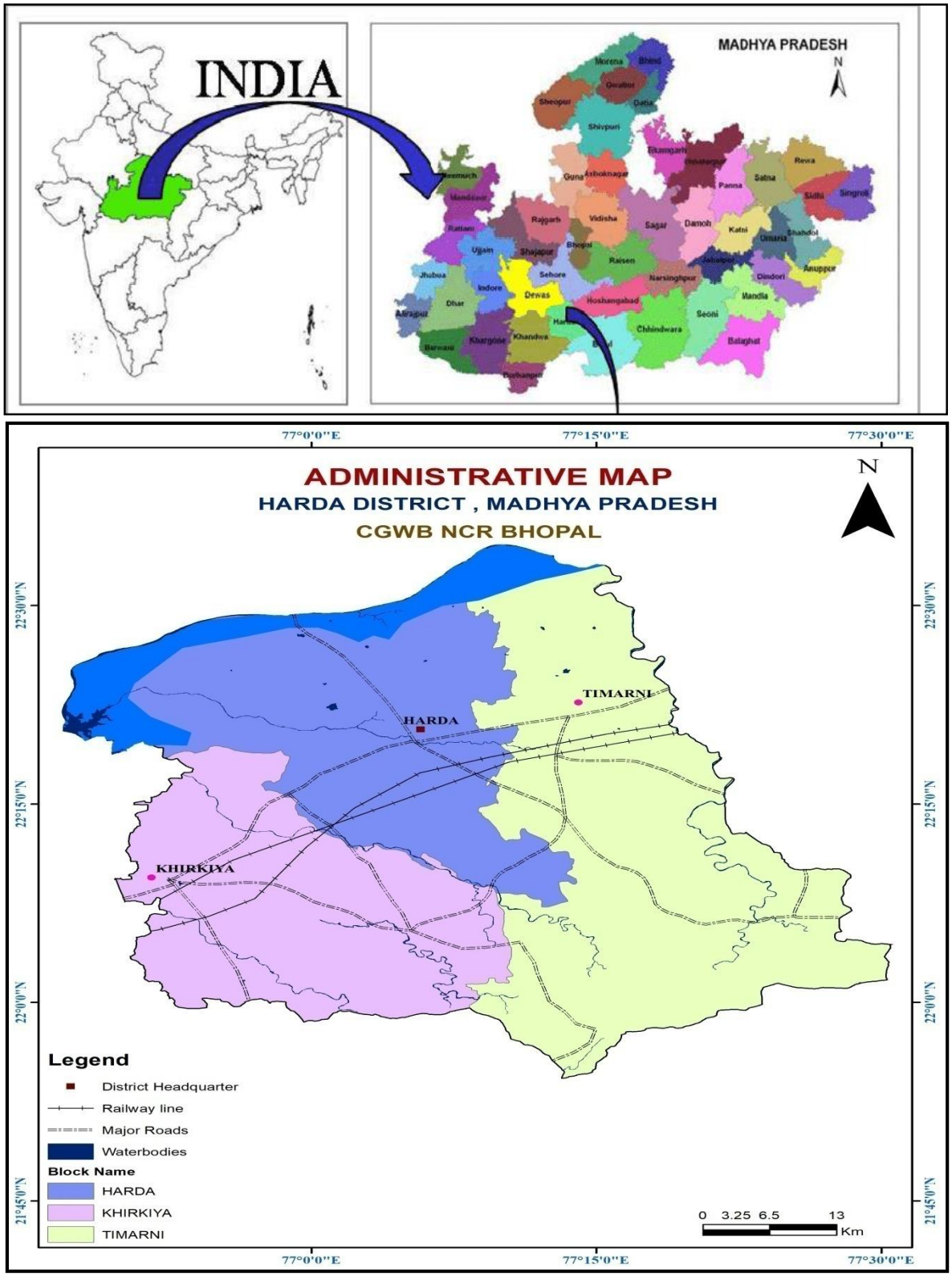


Table-1: DISTRICT AT A GLANCE

S.No	Items	Statistics	
1	General Information		
	i) Geographical Area	3330 Sq.Km	
	District Head Quarter	Harda	
	ii) Administrative Division Number of Tehsil/Block Number of Villages Population (As per census 2011) Normal Annual Rainfall (mm)	 6 Tehsil / 3 Block 571 5,70,465 1374.0	
2.	Geomorphology		
	1. Major Physiographic Units :	1. Satpura range and extension of Malwa Plateau in the south 2. Ridges (equivalent to Aravalli) 3. Alluvial plain in the north-east and central part	
	2. Major Drainage :	Narmada river and its tributaries, Namely Ganjal river, Ajnal river, Sukni nadi, Midkul nadi, Dedra nadi, Machak nadi, Syani nadi and Kalimachak river.	
3.	Land use in ha		
	a) Forest Area	104.8	
	b) Net area sown	180.6	
	c) Cultivable area	182.2	
4.	Major Soil Types	Black soils and ferruginous red lateritic soils, Sandy clay loam, sandy loam and clay loam	
5.	Area Under Principal Crops	Moong Dal, Soya, Wheat, Gram, Pulses, maize	
6.	Irrigation By Different Sources		
	Structures	**Nos.**	**Area (ha)**
	Dug Wells	8140	30.7
	Tube wells/Bore wells	1894	14.2
	Tanks/Ponds	1	01.0
	Canals	1	79.5
	Other sources	12	16.9
	Net irrigated Area	-	141.4
	Gross Irrigated Area	-	141.4
7.	Number of Ground Water Monitoring		
	Wells of CGWB Dug Wells	12	
	No. of Piezometers	2	

Administrative Details

The Harda district has been divided into 3 Blocks. There are 527 villages in the district. Total population of the district is 5, 70,465 (2011 Census). Detailed administrative divisions of the district are given in Table-1 & 2 and Fig.3

Figure 3: Administrative Map

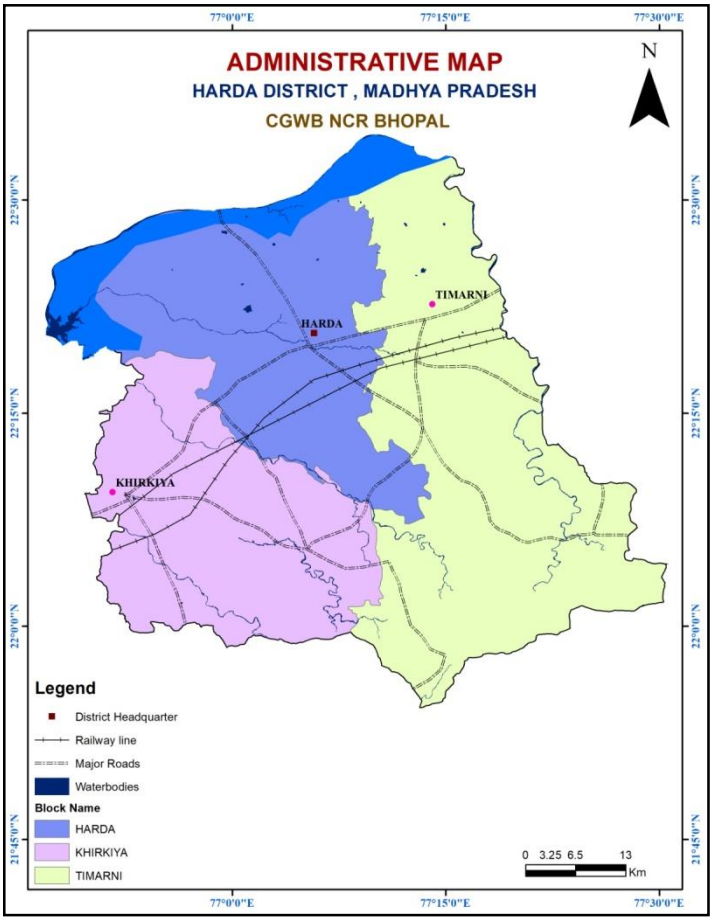


Table 1: Administrative Divisions

Name of Assessment Unit (Block)	Recharge worthy area in Sq.Km	Areal extent (in Sq. Km)			
		Total Geographical Area	Hilly Area	Command Area	Non command
Harda	91650	105000	13350	45650	46000
Khirkia	79440	124000	44560	0	79440
Timarni	99000	104000	5000	33500	65500
Total	**270090**	**333000**	**62910**	**79150**	**190940**

d. Climate and rainfall

The climate of Harda district is characterized by a hot summer and general dryness except during the south west monsoon season. The year may be divided into four seasons. The cold season, December to February is followed by the hot season from March to about the middle of June. The period from the middle of June to September is the southwest monsoon season. October and November form the post monsoon period.

The normal rainfall of Harda district is 1374.5 mm. It receives maximum rainfall during southwest monsoon period. About 90.5% of the annual rainfall is received during monsoon season and only 9.5 % of the annual rainfall takes place during October to May period. The surplus water for groundwater recharge is available only during the southwest monsoon period.

The normal maximum temperature occurs during the month of May i.e. 42.1^{o}C and minimum during the month of January i.e. 11.7^{o}C. The normal annual mean maximum and minimum temperature of Harda district is 32.8^{o}C and 19.8^{o}C respectively. During the southwest monsoon season the relative humidity generally exceeds 91% (August month). Rest of the year is drier. The driest part of the year is the summer season, when relative humidity is less than 33%. April is the driest month of the year. The wind velocity is higher during the pre-monsoon period as compared to post monsoon period. The maximum wind velocity 7.7 km/hr is observed during the month of June and minimum 2.9 km/hr during the month of December. The average normal annual wind velocity of Harda district is 5.0 km/hr., Monthly rainfall is shown in Table 3.

Table 2: Rainfall data of Harda District (Source: IMD)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
2016	2.6	0	1.1	0	4.3	140.5	356.1	392.7	53	45.8	0	0	996.1
2017	0	6	0	0	0	95.8	301.1	111.1	152	9.9	0	0	675.9
2018	0	3.9	0	0	0	120.7	269.1	316.9	63.5	7.1	0	0	781.2
2019	0	10.5	13.2	0.5	0	42.4	446.3	410.3	692.6	67.8	26.7	7.4	1717.7
2020	1.4	1	13	1.6	1.9	233.1	203.3	623.8	99.6	14.1	0	10	1202.8

e. Physiography/ DEM

Physiographically, the district can be divided in three major divisions: -

1. Satpura range and extension of Malwa Plateau in the south,

2. Ridges (equivalent to Aravalli Hills) in the north-west,

3. Alluvial plain in the north-east and central part

The district is bounded by Satpura ranges in south and by Narmada River in the north. The area slopes North West towards the Narmada River. The slope is generally steep at the foothills of Satpura but moderate to gentle towards Narmada River. The land surface attains a maximum altitude of 734 m above mean sea level at Kaoti (77^0 19'30": $22^0$03'00"), and minimum altitude of 240 m above mean sea level at confluence of Machak river with the Narmada ($76^0$46'50": $22^0$19'00"). A large number of north westerly flowing tributaries originating from the Satpura join the Narmada River along the left bank. The area is mainly drained by Narmada River and its tributaries - namely GanjalRiver, AjnalRiver, Sukninadi, Midkulnadi, Dedranadi, Machaknadi, Syaninadi and KalimachakRiver. The DEM and Physiographic Map are shown in Fig.4 and 5 respectively.

Figure 4: Digital Elevation Model

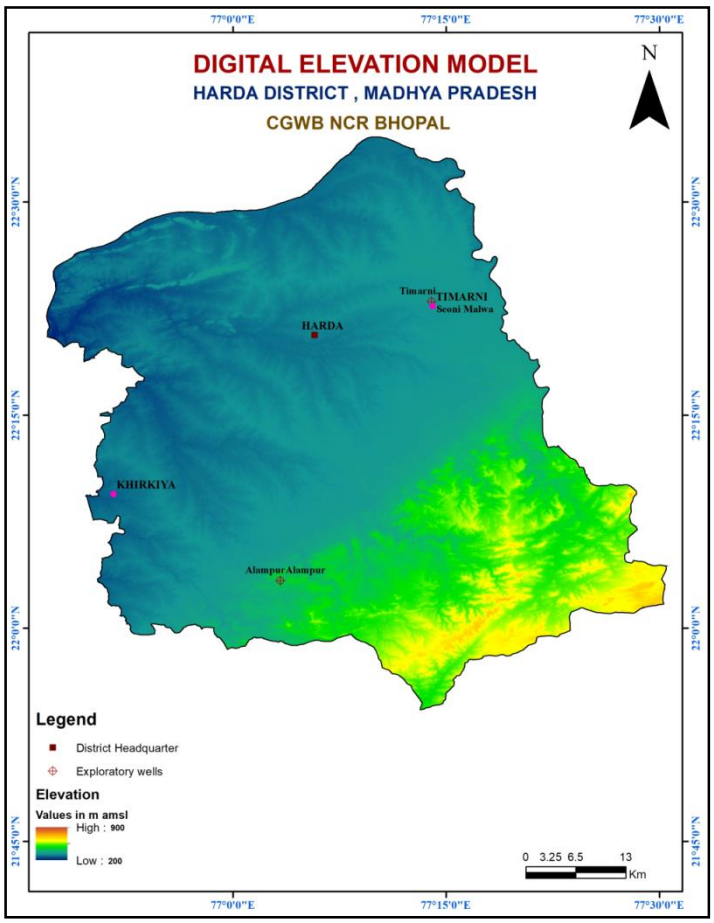
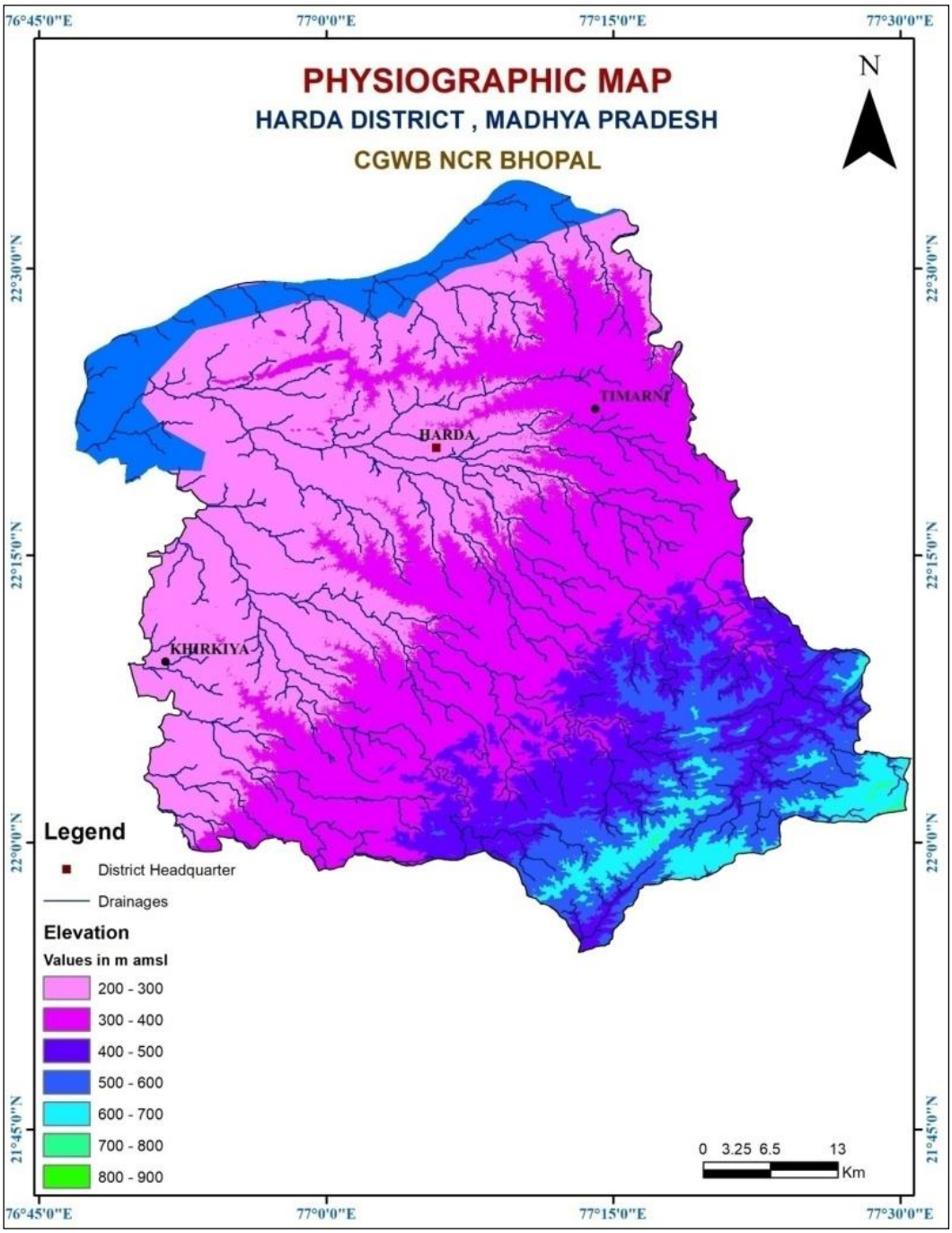


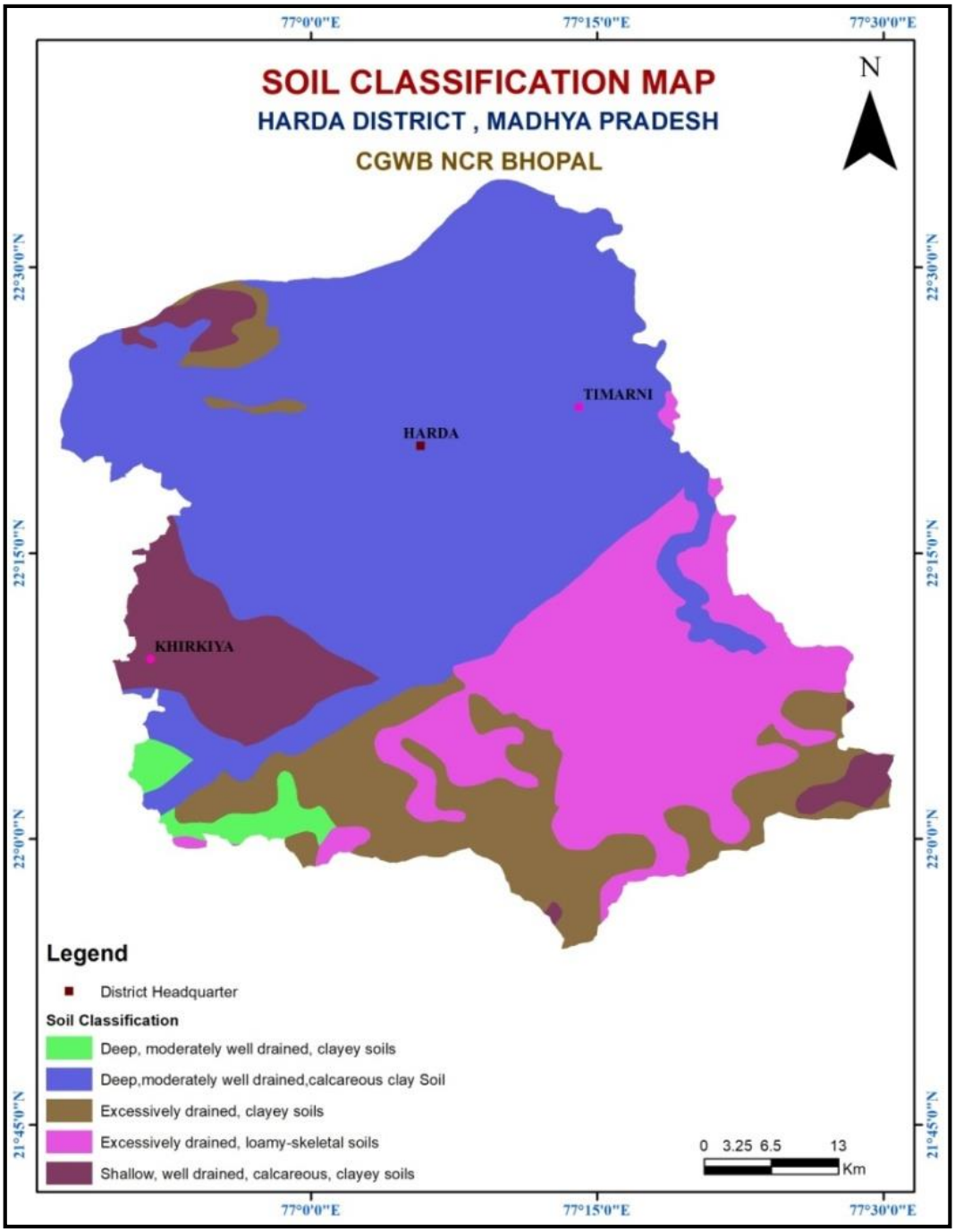
Figure 5: Physiographic Map



f. Soil

The nature & Characteristics of soils is dependent primarily on Relief of the area which influences the variation in soil formation. The soils of Harda district are classified on medium black soils under the broad classification of soil of India & are low fertility soils. There are alluvial deposits constituting gravel sand; silt or clay sized unconsolidated alluvium found along the narrow strips of rivers. A map showing Soil types is presented in the Fig.6

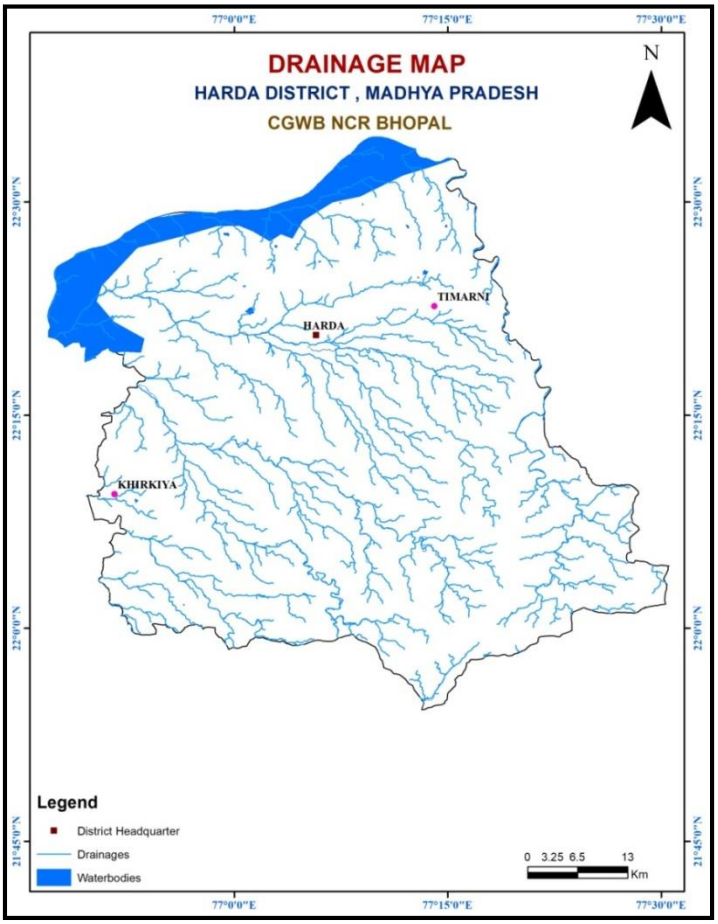
Figure.6: **Soil Map**



g. Drainage

The entire district is drained by Narmada River and its tributaries. Thus the area falls in the Narmada Basin. The river Narmada flows along the northern boundary of the district. The Ganjal River is the major tributary of the Narmada River and flows from south to north along the western boundary of Harda district before merging into the Narmada River. The other major tributary of the Narmada river draining the district are Ajnal river, Sukninadi, Midkulnadi, Dedranadi, Machaknadi, Syaninadi and Kalimachak river. The drainage map is shown in Fig.7

Figure 6: Drainage Map



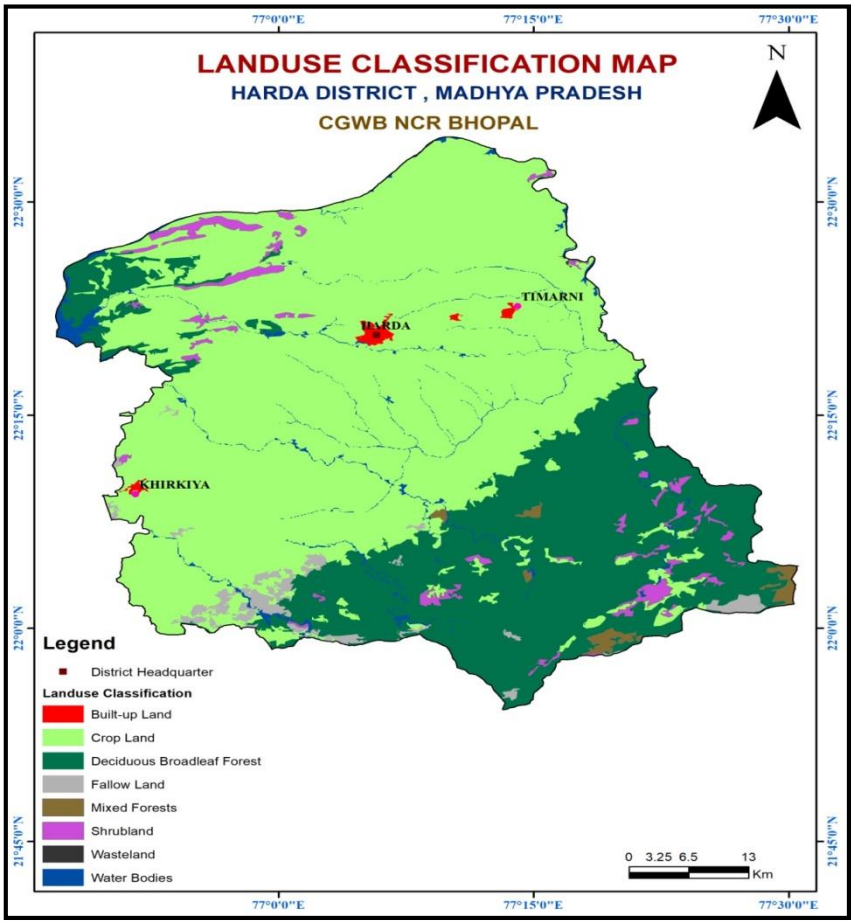
h. Land use pattern

Agriculture cropland and deciduous forest are the prominent land use aspects in the district and forms 52 % and 35 % of total area respectively followed by the shrub land and water bodies. The spatial distribution of land use is presented in Fig.8 and Table.4

Table 3: Landuse Classification in Harda district

Land use Classes	Area in Sq.Km	%
Built-up Land	6.57	0.20
Deciduous Broadleaf Forest	1189.19	35.70
Mixed Forests	10.29	0.31
Crop Land	1732.46	52.01
Fallow Land	226.90	6.81
Shrub land	93.44	2.81
Wasteland	1.70	0.05
Water Bodies	70.33	2.11

Figure 7: Land Use Land Cover Map



i. Cropping pattern

District is very rich in the field of agriculture due to good sources of irrigation and fertile alluvial and black cotton soil. Wheat and gram are the main crops grown during Rabi season. Moong, Soyabean, Wheat, Mustard, Til and Groundnut are the main oilseeds produced here. The farmers have started the production of Sunflowers. (Table 5&6)

Table 4: Land use pattern in Harda District (Area in ha)

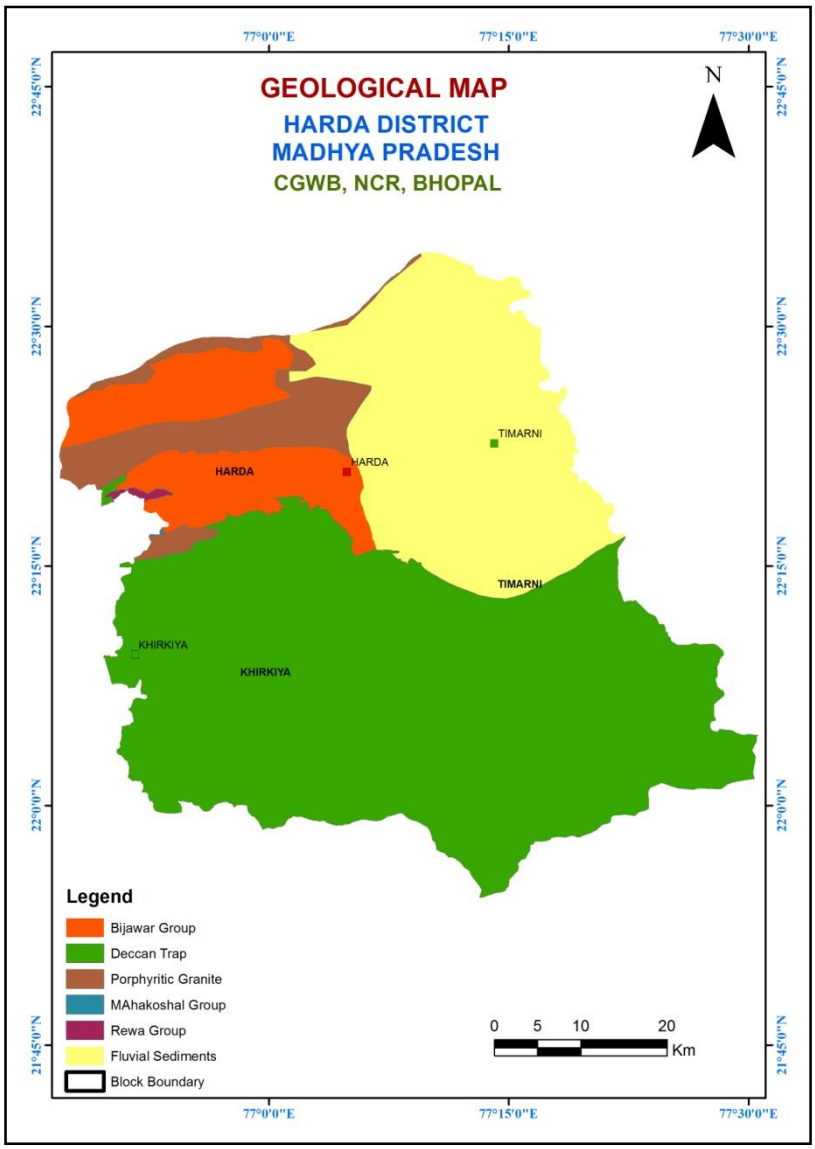
Name of District	Geographical area	Cultivable area	Forest area	Land under non-agricultural use	Permanent pastures	Cultivable wasteland	Land under Misc. tree crops and grove	Barren and uncultivable land	Current fallows	Other fallows
Harda	330.6	182.2	104.8	8.7	13.7	5.10	0.4	15.7	0.1	1.5

Table 5: Crop-wise Irrigation Status in Harda

	Kharif (Area in ha)			Rabi (Area in ha)			Summer crop (Area in ha)			Total (Area in ha)			Horticulture & Plantation (Area in Ha)		
Crop type	**Irrigated**	**Rainfed**	**Total**	**Irrigated**	**Rainfed**	**Total**	**Irrigated**	**Rainfed**	**Total**	**Irrigated**	**Rainfed**	**Total**	**Irrigated**	**Rainfed**	**Total**
A)Cereals	0	9100	9100	139260	0	139260	0	0	0	139260	9100	148360			
B)Coarse Cereals	0	200	200	0	0	0	0	0	0	0	200	200			
C)Pulses	0	3350	3350	12168	28075	40243	27000	0	27000	12168	31425	43593			
D)Oil seeds	0	165200	165200	0	0	0	0	0	0	0	165200	165200			
E)Fiber	0	330	330	0	0	0	0	0	0	0	330	330			
F) Any other crops…	0	0	0	497	0	497	0	0	0	497	0	497			
													5840	1376	7216
total	0	178180	178180	151925	28075	180000	27000	0	27000	151925	206255	358180	5840	1376	7216

j. Geology

The rocks occurring in the district range in age from Palaeo proterozoic to Quaternary. About 40 % of the district, in the eastern, central and northern (adjoining the Narmada river) part, is covered with alluvium, The Archaean Group of rocks, comprising granite, phyllite, dolomite, quartzite, chert breccia etcis exposed in the north-western part and is faulted near the Narmada River. Weathered and fractured Granite forms a potential aquifer in the area, Deccan traps, which make for about 50% of the entire district, occur as lava flows in the western and southern part of the district, the alluvial aquifer system in the district is highly potential. Two to three granular zones and at places more number of potential granular zones comprising of fine to medium to coarse grained sand, gravel and pebbles and Laterite are encountered in alluvium, illustrated in Fig.9



2. Data Collection and Generation

The basic concept of aquifer mapping stands on these four major pillars. The aquifer mapping and management plan of Harda district is broadly carried out in following steps:

a. **Data compilation:** The previous studies carried out by Central Ground Water Board and various Government organizations were collected. The Basic data reports of exploratory wells/Observation wells/ Piezometers drilled by CGWB, details of wells drilled by State Public Health and Engineering Department (PHED) and district brochures published by CGWB was compiled and integrated for aquifer mapping. The Dynamic Ground Water Resource (2020) of CGWB and figures from the Water Resource Department were used for preparation of management plan.

b. **Data adequacy:** The data compiled has been collected from the CGWB/ State departments. Thus, the adequacy of the data is supposed to be high and reliable for the specific study of aquifer mapping and management plan.

c. **Data gap analysis:** The identification of data gap was done after the detailed analysis, examination, synthesis and interpretation from available sources. This process incorporated the conversion of analog data in the form of digital data that could be processed readily on GIS platform.

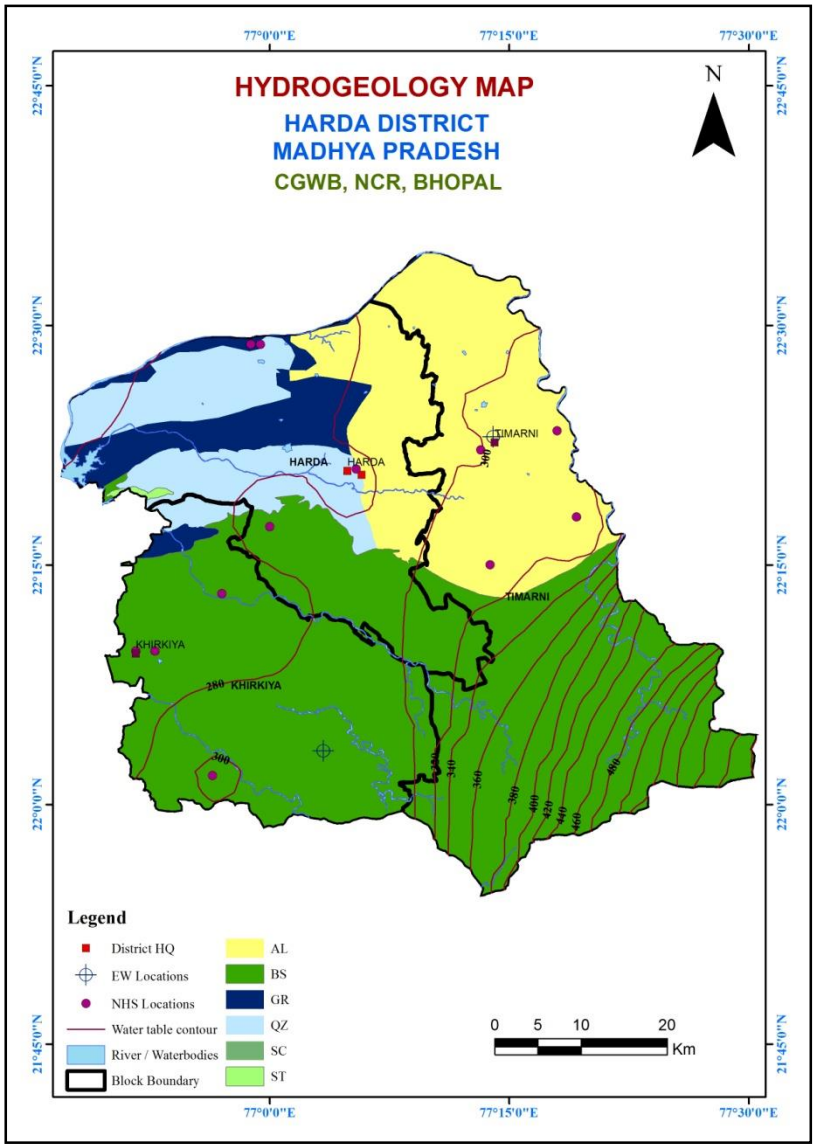
d. **Data Generation:** The study of Harda district concentrated on the existing data; thus, no new data was generated The Data gap analysis for 16exploratory wellsand 50 VES proposed for data generation.

a. Hydrogeology

Aquifer System and Aquifer Parameters

The rocks occurring in the district range in age from Palaeoproterozoic to Quaternary. About 40 % of the district, in the eastern, central and northern (adjoining the Narmada river) part, is covered with alluvium. Ground water occurs under phreatic as well as confined conditions. The water bearing properties of different hydrogeological units occurring in Harda District are described below. Hydrogeology of the district is shown in Fig.10

Figure 8: Hydrogeology of Harda District, M.P



Archaeans and Metamorphic rocks equivalent to Aravallis

The Archaean Group of rocks, comprising granite, phyllite, dolomite, quartzite, chert breccia etc is exposed in the north-western part and is faulted near the Narmada River. Weathered and fractured Granite forms a potential aquifer in the area.

Deccan Trap

Deccan traps, which make for about 50% of the entire district, occur as lava flows in the western and southern part of the district. The phreatic aquifer in weathered / vesicular basalt is tapped by dug wells while the deeper confined aquifers are tapped by drilling tube wells. The yield of dug wells ranges from 120 to 180 liters per minute, but in the canal command area, due to substantial recharge from canal seepage, sustains a good discharge.

Alluvium

The alluvial aquifer system in the district is highly potential. Two to three granular zones and at places more number of potential granular zones comprising of fine to medium to coarse

grained sand, gravel and pebbles and Laterite are encountered in alluvium. The top phreatic aquifer range in thickness from 2 to 10m and is encountered in the depth range of 4 to 20 mbgl.

It appears that all the alluvial aquifer zones constitute a single aquifer system - the unconfined aquifer and a number of deeper aquifer zones separated by thick clay zones. The deeper aquifers are of semi-confined to confined nature with varying potentiometric heads. The yield of alluvial aquifers ranges from 180 to 900 liters per minute.

Depth to Water levels

Pre-monsoon water level (May 2022)

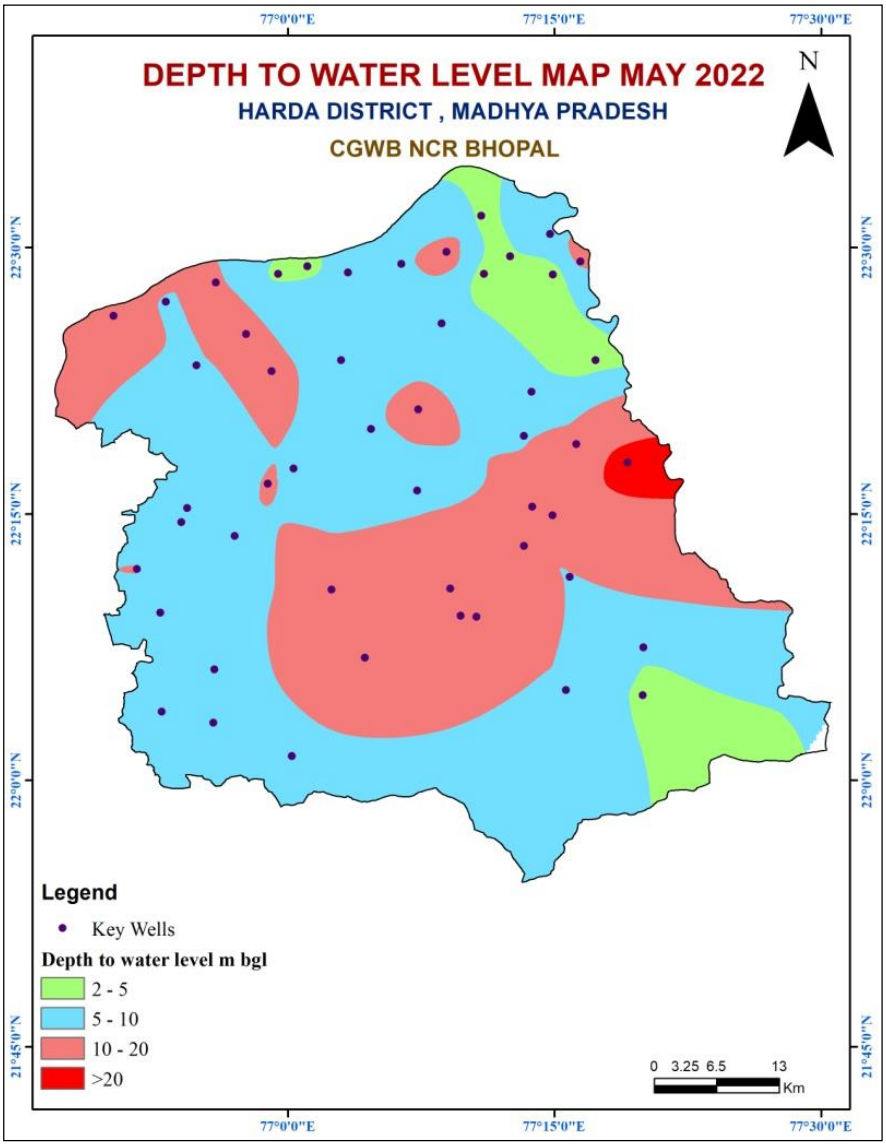
The pre-monsoon depth to Water levels ranges from a minimum of 2.48 meters below ground level (mbgl) at Bajaniain Timarni block to a maximum of 24.51 m bgl at TemagavTimarni block of Harda district. About 16% very shallow water levels up to 2-5m bgl have been recorded in a small patch in part of district. About 50 % of monitoring wells recorded water level in the range of 5-10 m bgl category, spreading in patches and major pockets in the north-western and eastern part of area. About 30% of monitoring wells recorded water level in the depth range of 10-20 m bgl occurring in broad patches all over the region. Deeper ground water levels ranging >20 m bgl constituting only about 4% of wells in this category have been observed only in small pocket in the northern and south-western part of Harda district. Ground water levels of more than 20 m bgl have been recorded in the eastern part of the area. The pre-monsoon Depth to Water Level map has been shown in the Fig. 11. Key well location and Depth to water level in Harda District shown in Table.7

Table 6. Pre-monsoon Depth to Water Level in Harda District

S.No	Block	Location	Type	Lat	Long	MP	Depth m	Dia m	WL mamp	DTW mbgl
1	Harda	Handia	DW	22.475261	76.991094	0.7	8.7	3.73	4.53	3.83
2	Harda	Bhamori	DW	22.482329	77.018423	0	4.83	3.3	4.6	4.6
3	Harda	Adampur	DW	22.476654	77.056767	0.4	6.3	2.2	6.1	5.7
4	Harda	Nandra	DW	22.484745	77.106797	0.5	9.3	3.3	9.1	8.6
5	Harda	Sonkhedi	DW	22.428839	77.144342	0.8	11.3	1.1	8.28	7.48
6	Timarni	Kartana	DW	22.475238	77.184178	0.7	8.1	2.5	3.58	2.88
7	Timarni	Rundlay	DW	22.495893	77.148868	0.7	15	3.8	14.7	14.03
8	Timarni	Tajpura	DW	22.529805	77.181693	0.2	14	1.4	3.61	3.41
9	Timarni	Godri	DW	22.491846	77.208585	0.1	5.3	1.7	4.38	4.28
10	Timarni	Nayagaon	DW	22.51293	77.246183	1	12.1	1.8	10.3	9.28
11	Timarni	Gadrapur	DW	22.487033	77.274642	0.8	15	1.8	12.1	11.3
12	Timarni	Bajania	DW	22.474812	77.248855	0	15	4.8	2.48	2.48
13	Harda	Udda	DW	22.348268	77.122518	0.7	13.1	1.8	12.2	11.54
14	Timarni	Chidgaon	DW	22.394398	77.288907	0.7	9	3.1	4.08	3.38

S.No	Block	Location	Type	Lat	Long	MP	Depth m	Dia m	WL mamp	DTW mbgl
15	Timarni	Bhayili	DW	22.364658	77.228848	1.8	8.4	2.3	7.83	6.03
16	Timarni	Sodalpur	DW	22.323157	77.221507	0.8	10.9	3.2	10.4	9.62
17	Timarni	Sirkumba	DW	22.315361	77.270619	1.1	16	3.2	13.4	12.27
18	Timarni	Temagav	DW	22.298467	77.318931	0.5	26	4.2	25	24.51
19	Timarni	Mohanpur	DW	22.25663	77.229247	1	15	2.8	12.9	11.93
20	Timarni	Rajabarari	DW	22.24866	77.248573	0.7	16.5	3.3	14	13.26
21	Timarni	Kasarni	DW	22.219792	77.221532	0	16.5	3.5	9.92	9.92
22	Harda	Barkhedi	DW	22.179755	77.152485	0.4	21	3.1	16.8	16.43
23	Harda	Magardha	DW	22.154415	77.16207	0.9	15	8.9	10.6	9.67
24	Harda	Jhiri	DW	22.153358	77.176973	0.5	22.5	3.7	20.5	20.03
25	Harda	Balagaon	DW	22.271792	77.121451	0.5	10.5	2.5	8.92	8.42
26	Harda	Gosala	DW	22.329745	77.07825	1	15	2.7	10.3	9.32
27	Harda	Masangaon	DW	22.292624	77.005488	1.2	10.8	2.7	10.4	9.18
28	Harda	Kakaria	DW	22.278423	76.981328	0.6	11.5	4.2	11	10.42
29	Khirkiya	Mandia	DW	22.229352	76.950295	0.2	10	4.1	9.44	9.24
30	Khirkiya	Dhanwad	DW	22.255542	76.905723	0.6	11.8	6.2	5.76	5.16
31	Khirkiya	Sarangpur	DW	22.242077	76.900298	0.4	12.3	6.5	6.85	6.45
32	Khirkiya	Choukdi	DW	22.198307	76.858535	0.5	11.8	2	10.7	10.22
33	Khirkiya	Chippabad	DW	22.157353	76.880568	0.3	9.8	3.5	8.34	8.04
34	Khirkiya	Temalabari	DW	22.064275	76.881787	0.5	8.5	5.3	6.74	6.24
35	Khirkiya	Rhunjan	DW	22.053835	76.930333	0.3	12.8	6.1	9.82	9.52
36	Khirkiya	Sarsud	DW	22.104122	76.931378	0.5	12.5	4.4	9.47	8.97
37	Khirkiya	Bhimpura	DW	22.02262	77.003965	0.4	9.3	4.7	8.7	8.3
38	Khirkiya	Khudia	DW	22.115057	77.07232	0.3	15.9	5.5	13.6	13.26
39	Khirkiya	Bhatpura	DW	22.1789	77.0412	0.8	19.6	3.5	11.8	11
40	Timarni	Banspani	DW	22.084582	77.2609	0.3	8.5	5.5	8.1	7.8
41	Timarni	Chandrakhal	DW	22.079753	77.332878	0.5	9.5	5	4.83	4.33
42	Timarni	Gorakhal	DW	22.124796	77.333703	0.8	8.5	4.5	6.2	5.4
43	Timarni	Balwarni	DW	22.190948	77.264467	0.8	11.6	4.8	10.4	9.61
44	Harda	Atarsama	DW	22.394403	77.05015	0.9	9	2.4	8.75	7.85
45	Harda	Relwa	DW	22.383832	76.984932	0.5	12	2.5	11.8	11.3
46	Harda	Pachola	DW	22.389417	76.914382	0.8	12	3	10.1	9.3
47	Harda	Kheda	DW	22.418753	76.960948	0.7	17	5.1	13.7	13.02
48	Harda	Nayapura	DW	22.44913	76.88572	0.5	11	3.5	10.2	9.7
49	Harda	Saliyakhedi	DW	22.435925	76.836785	0.2	12.8	2.8	11.7	11.53
50	Harda	Mangrul	DW	22.467153	76.932602	0.5	12	4	11.5	11

Figure 9: Premonsoon Depth to Water Level Map (2022)



Post-monsoon water level (Nov2022)

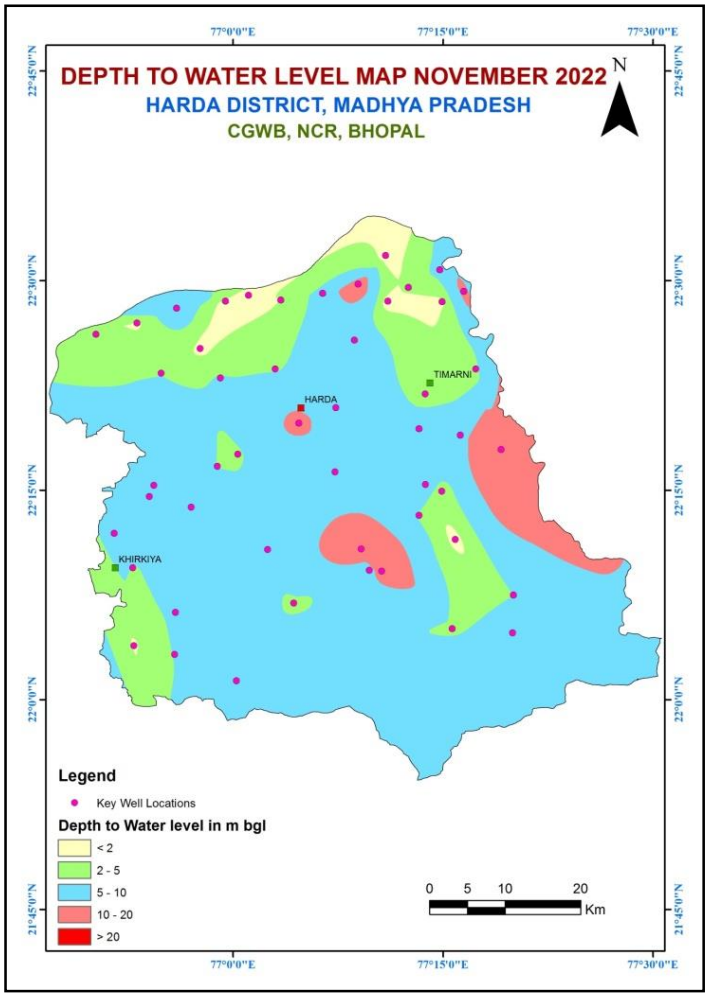
The pre-monsoon depth to Water levels ranges from a minimum of 0.1 meters below ground level (mbgl) at Tajpura in Timarni block to a maximum of 18.15 m bgl at Temagav Timarni block of Harda district. About 18% very shallow water levels up to 0-2m bgl have been recorded in a small patch in part of district. About 30 % of monitoring wells recorded water level in the range of 2-5 m bgl category, spreading in patches and major pockets in the north-western and eastern part of area. About 40 % of monitoring wells recorded water level in the depth range of 5-10 m bgl occurring in broad patches all over the region. Deeper ground water levels ranging 10-20 m bgl constituting only about 12% of wells in this category have been observed only in small pocket in the northern and south-western part of Harda district. The Post-monsoon Depth to Water Level map has been shown in the Fig. 12, Key well location and Depth to water level in Harda District shown in Table.8

Table 7:Post-monsoon Depth to Water Level in Harda District

S.No	Block	Location	Type	Lat	Long	MP	Depth m	Dia m	WL mamp	WL mbgl
1	Harda	Handia	DW	22.475261	76.991094	0.7	8.7	3.73	1.59	0.89
2	Harda	Bhamori	DW	22.482329	77.018423	0	4.83	3.3	0.4	0.4
3	Harda	Adampur	DW	22.476654	77.056767	0.4	6.3	2.2	2.42	2.02
4	Harda	Nandra	DW	22.484745	77.106797	0.5	9.3	3.3	6.94	6.44
5	Harda	Sonkhedi	DW	22.428839	77.144342	0.8	11.3	1.1	10.08	9.28
6	Timarni	Kartana	DW	22.475238	77.184178	0.7	8.1	2.5	1	0.3
7	Timarni	Rundlay	DW	22.495893	77.148868	0.7	15	3.8	15.67	14.97
8	Timarni	Tajpura	DW	22.529805	77.181693	0.2	14	1.4	0.3	0.1
9	Timarni	Godri	DW	22.491846	77.208585	0.1	5.3	1.7	3.01	2.91
10	Timarni	Nayagaon	DW	22.51293	77.246183	1	12.1	1.8	7.2	6.2
11	Timarni	Gadrapur	DW	22.487033	77.274642	0.8	15	1.8	12.3	11.5
12	Timarni	Bajania	DW	22.474812	77.248855	0	15	4.8	1.4	1.4
13	Harda	Udda	DW	22.348268	77.122518	0.7	13.1	1.8	6.45	5.75
14	Timarni	Chidgaon	DW	22.394398	77.288907	0.7	9	3.1	3.46	2.76
15	Timarni	Bhayili	DW	22.364658	77.228848	1.8	8.4	2.3	5.32	3.52
16	Timarni	Sodalpur	DW	22.323157	77.221507	0.8	10.9	3.2	8.15	7.35
17	Timarni	Sirkumba	DW	22.315361	77.270619	1.1	16	3.2	9.24	8.14
18	Timarni	Temagav	DW	22.298467	77.318931	0.5	26	4.2	18.65	18.15
19	Timarni	Mohanpur	DW	22.25663	77.229247	1	15	2.8	9.12	8.12
20	Timarni	Rajabarari	DW	22.24866	77.248573	0.7	16.5	3.3	3.64	2.94
21	Timarni	Kasarni	DW	22.219792	77.221532	0	16.5	3.5	4.57	4.57
22	Harda	Barkhedi	DW	22.179755	77.152485	0.4	21	3.1	16.24	15.84
23	Harda	Magardha	DW	22.154415	77.16207	0.9	15	8.9	6.32	5.42
24	Harda	Jhiri	DW	22.153358	77.176973	0.5	22.5	3.7	16.64	16.14
25	Harda	Balagaon	DW	22.271792	77.121451	0.5	10.5	2.5	5.64	5.14
26	Harda	Gosala	DW	22.329745	77.07825	1	15	2.7	13.31	12.31
27	Harda	Masangaon	DW	22.292624	77.005488	1.2	10.8	2.7	5.72	4.52
28	Harda	Kakaria	DW	22.278423	76.981328	0.6	11.5	4.2	5.53	4.93
29	Khirkiya	Mandia	DW	22.229352	76.950295	0.2	10	4.1	6.77	6.57
30	Khirkiya	Dhanwad	DW	22.255542	76.905723	0.6	11.8	6.2	8.7	8.1
31	Khirkiya	Sarangpur	DW	22.242077	76.900298	0.4	12.3	6.5	8.18	7.78
32	Khirkiya	Choukdi	DW	22.198307	76.858535	0.5	11.8	2	8.42	7.92
33	Khirkiya	Chippabad	DW	22.157353	76.880568	0.3	9.8	3.5	5.08	4.78
34	Khirkiya	Temalabari	DW	22.064275	76.881787	0.5	8.5	5.3	2.1	1.6
35	Khirkiya	Rhunjan	DW	22.053835	76.930333	0.3	12.8	6.1	5.52	5.22
36	Khirkiya	Sarsud	DW	22.104122	76.931378	0.5	12.5	4.4	6.5	6
37	Khirkiya	Bhimpura	DW	22.02262	77.003965	0.4	9.3	4.7	8.64	8.24

S.No	Block	Location	Type	Lat	Long	MP	Depth m	Dia m	WL mamp	WL mbgl
38	Khirkiya	Khudia	DW	22.115057	77.07232	0.3	15.9	5.5	4.76	4.46
39	Khirkiya	Bhatpura	DW	22.1789	77.0412	0.8	19.6	3.5	7.61	6.81
40	Timarni	Banspani	DW	22.084582	77.2609	0.3	8.5	5.5	4.56	4.26
41	Timarni	Chandrakhal	DW	22.079753	77.332878	0.5	9.5	5	7.75	7.25
42	Timarni	Gorakhal	DW	22.124796	77.333703	0.8	8.5	4.5	5.76	4.96
43	Timarni	Balwarni	DW	22.190948	77.264467	0.8	11.6	4.8	1.75	0.95
44	Harda	Atarsama	DW	22.394403	77.05015	0.9	9	2.4	5.54	4.64
45	Harda	Relwa	DW	22.383832	76.984932	0.5	12	2.5	5.74	5.24
46	Harda	Pachola	DW	22.389417	76.914382	0.8	12	3	5.73	4.93
47	Harda	Kheda	DW	22.418753	76.960948	0.7	17	5.1	1.62	0.92
48	Harda	Nayapura	DW	22.44913	76.88572	0.5	11	3.5	1.78	1.28
49	Harda	Saliyakhedi	DW	22.435925	76.836785	0.2	12.8	2.8	3.74	3.54
50	Harda	Mangrul	DW	22.467153	76.932602	0.5	12	4	9.54	9.04

Figure 10: Post-monsoon Depth to Water Level Map



b. Hydrochemistry

The water samples were collected from Key wells in clean double stopper poly ethylene bottles from 50 different locations of Harda district during May 2022 and selective wells samples has been collected during November 2022. All the collected water Samples are submitted to Chemical lab NCR, for analysis

Quality of Ground Water for Drinking Purpose:

The ground water samples collected from Harda district having pH range from 6.41 to 7.78. As per BIS (IS10500:2012) recommendation, almost all the water sample shave pH recorded within the permissible limits of 6.5 to 8.5, except Nayapura village shows 6.41, the maximum pH recorded in the water sample of Handia (7.78). The ground water of the study area can be assessed as neutral to slightly alkaline. The electrical conductivity of ground water samples in Harda district varies from 248 to 2200 µS/cm at 25°C. In the 50 nos. of water samples 34 shows electrical conductivity less than 1000µS/cm; in 9 nos. of samples EC in between 1000 to 1500 µS/cm and remaining 7 samples is more than 1500 µS/cm. So, overall ground water quality in Harda district is good. The maximum electrical conductivity has been observed in the water sample of Tajpura village i.e. 2200µS/cm at 25 °C.

The fluoride concentration in Harda district lies in between 0.1 to 2.69 mg/l, which represent that almost all the samples are within the permissible limit i.e.1.5 mg/l as per BIS (IS 10500: 2012) except Jhiri, Nayapura, Mangrul and Tajpura village i.e. 2.12 to 2.69 mg/l. Nitrate in ground water samples of Harda district fall within limits of 2 to 43 mg/l. It is observed that 100% samples have Nitrate concentration less than the acceptable limit i.e. 45 mg/l. highest nitrate is reported in the water sample of Bajania (43mg/l). High nitrate in ground water samples may be due to anthropogenicactivities or excessive use of fertilizers. The range of Total Hardness (as $CaCO_3$) in groundwater samples of study area is 59 to 579 mg/l. In all locations, total hardness concentrations are within the permissible limit of 600 mg/l. The maximum concentration of total hardness observed in the village of Rundlay (579mg/l).

Piper diagram has three parts: a Cation triangle, an Anion triangle, and a Central diamond-shaped field. In Cation triangle, the relative percentages of the major cations (Ca^{2+},Mg^{2+}, Na^{+}, K^{+}) are plotted. In Anion triangle the major anions (HCO_3^{-}+CO_3^{2-}, SO_4^{2-}, Cl^{-}) are plotted. These points are then projected to the central diamond shaped field. The piper diagram of Harda district shows the ground water samples are Calcium-Bicarbonate type; hence show temporary hardness; Calcium Chloride type (permanent hardness); Mixed type and Sodium Chloride(saline) types.

Quality of Ground Water for Irrigation Purpose:

In classification of water for irrigation purpose, it is assumed that the water will be used for irrigation purpose based upon its soil texture, infiltration rate, drainage and climate. The chemical data of all the water samples from Harda district is plotted on U.S. Salinity Laboratory diagram.

It is clear that approx.42% samples shows that the ground water are

C_2-S_1 Class (Medium Salinity & Low Sodium); 50% samples of study area are observed under C_3-S_1Class (High Salinity & Low Sodium) and 8% samples of study area are observed under C_3-S_2 Class (High Salinity & Medium Sodium) which means that these waters can be used for Irrigation purpose for most of the crops, Water from these areas can be used for irrigation, considering the salinity content of the ground water.

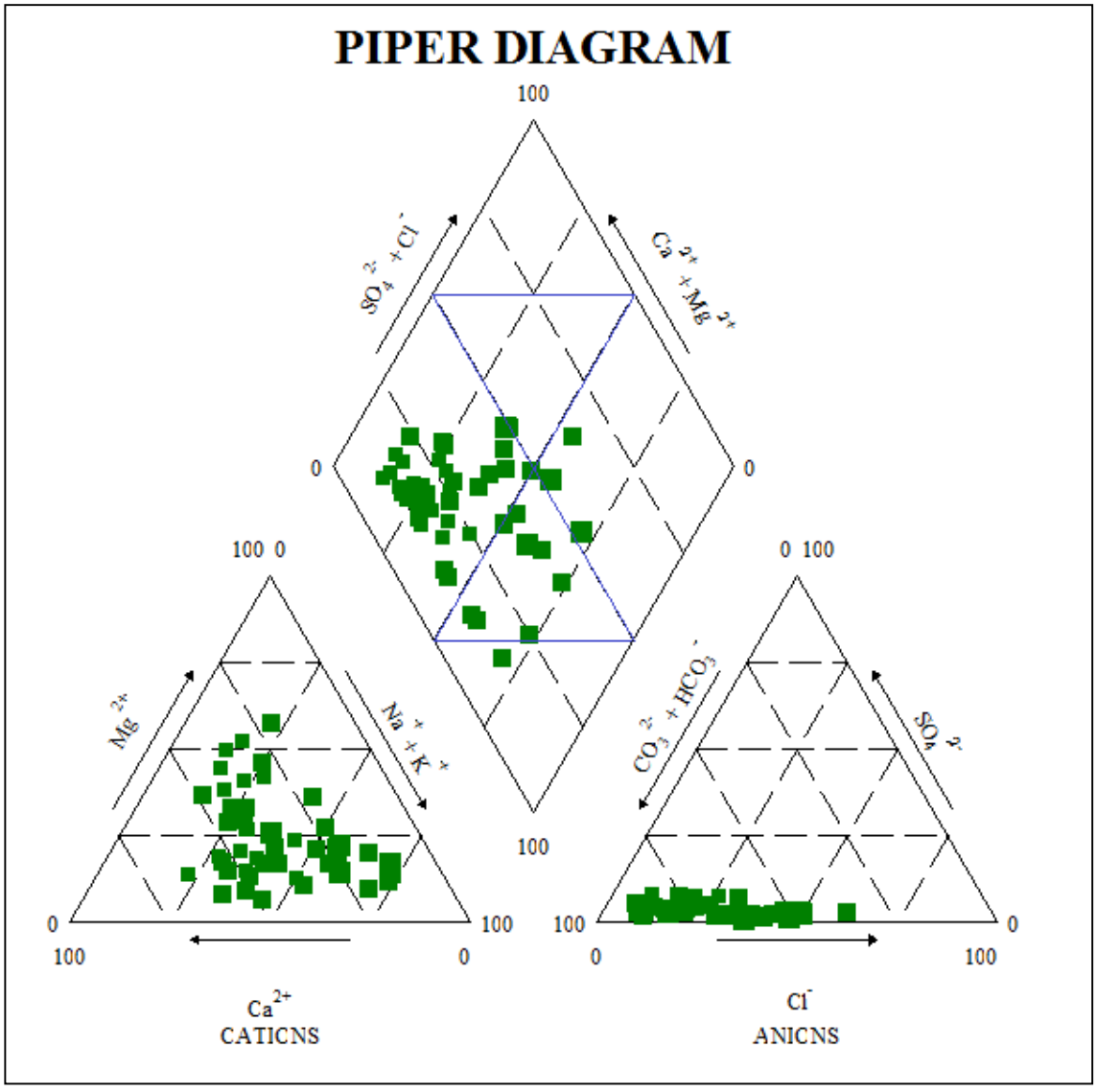


Figure 13: Hill Piper Diagram representing classification of water samples collected from Key wells of Harda District, Madhya Pradesh

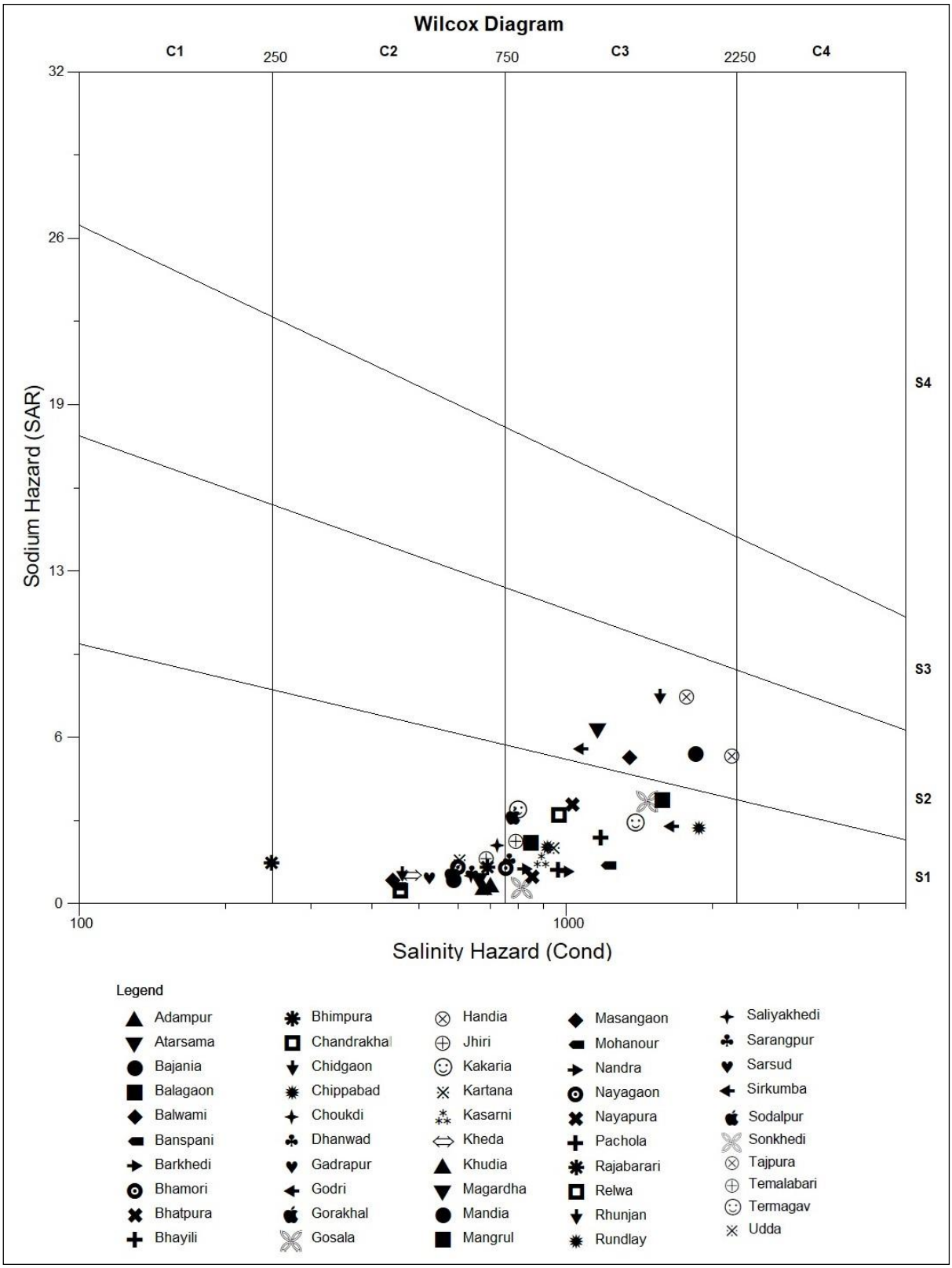


Figure.14 .US Salinity Diagram for water samples collected from National Hydrograph Stations of Harda District, Madhya Pradesh

c. Ground Water Exploration and aquifer parameters & Geophysical

CGWB under its exploration program drilled 4 bore wells (Fig. 13). On the basis of samples collected during exploration, and from the field observation litho logs have been prepared. The aquifer parameters are calculated on the basis of pumping tests. The salient details of the some of the drilled bore wells and piezometer are given in Table No 9. 16 EW and 47 VES have been proposed in Harda district. Fig.13 illustrates the locations of existing EW details are shownTable.9

Fig 15: Map showing locations of Existing Exploratory Wells & Proposed EW & VES

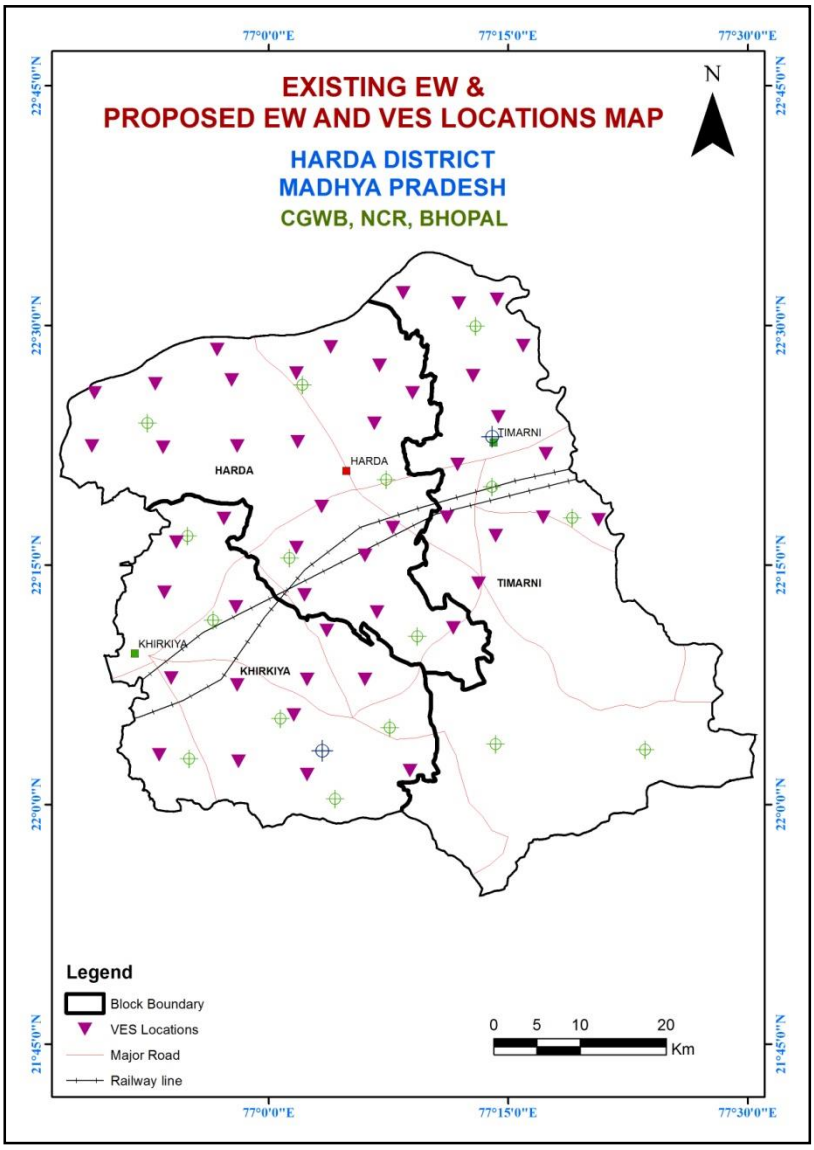


Table 8: Salient Hydrogeological Details of Exploratory Wells of Harda District.

S.No	Location	Latitude	Longitude	Year of Drilling	Depth drilled (mbgl)	Depth constructed (mbgl)	Lithology	Aquifer zones tapped (mbgl)	SWL (mbgl) /Date	Discharge (lps)	Draw down (m)	T (m^2/day)	S
1	Timarni	22°23' 00”	77°14' 55	1997-2000	32.61	32.61	0-28.35 Alluvium Basalt at 28.35	-	-	-	-	-	-
2	Handia	22°29'02"	76°59'10"	1997-2000	36.86	36.86	0-14 Alluvium Granite at 14.0	14.43-17.86 23.86-30.86	9.43	1.0	-	-	-
3	Harda	22°20'29"	77°05'27"	1997-2000	57.5	57.5	-	-	10.46	-	-	-	-
4	Khirkiya	22°09'45"	76°51'34"	1997-2000	98.45	98.45	0-0.6 Soil Basalt at 0.6	8.5-12.19	4.58	-	-	-	-

3. Data Interpretation , Integration and Aquifer Mapping

a. Hydro-chemical data interpretation

Almost all the water samples have pH recorded within the permissible limits of 6.5 to 8.5, except Nayapura village shows 6.41, the maximum pH recorded in the water sample of Handia (7.78). The ground water of the study area can be assessed as neutral to slightly alkaline. Overall ground water quality in Harda district is good. The maximum electrical conductivity has been observed in the water sample of Tajpura village i.e. 2200 µS/cm at 25 °C. The fluoride concentration in Harda district lies in between 0.1 to 2.69 mg/l, which represent that almost all the samples are within the permissible limiti.e.1.5mg/l as per BIS (IS 10500: 2012) except Jhiri, Nayapura, Mangrul and Tajpuravillage i.e. 2.12 to 2.69 mg/l.

The piper diagram of Harda district shows the ground water samples are Calcium-Bicarbonate type; hence show temporary hardness; Calcium Chloride type (permanent hardness); Mixed type and Sodium Chloride(saline) types. It is clear that approx.42% samples shows that the ground water are C_2-S_1Class(Medium Salinity & Low Sodium); 50% samples of study area are observed under C_3-S_1Class (High Salinity & Low Sodium) and 8% samples of study area are observed under C_3-S_2Class (High Salinity & Medium Sodium) which means that these waters can be used for Irrigation purpose for most of the crops

b. Aquifer Disposition – 2D (maps) / 3D (Fence/ Rockworks)

The Lithological data collected from CGWB Bore wells, Piezometers and State Ground Water Piezometers were studied, compiled and integrated as per Rockworks software format to prepare the 3-Dimensional Stratigraphic model, 2-Dimensional Cross section and Fence diagrams. The sub-surface lithology of the Harda district as inferred from the 3-D Model, 2-DSection and Fence diagram is presented below.

3-D Lithological models

A 3-Dimensional Lithological model was prepared for the Harda district, Madhya Pradesh after detailed analysis of the pre-existing and available bore-log data collected from the Basic Data Reports of CGWB (Fig 14). A comprehensive analysis was made as perlithologyandstratigraphyofthearea.ThelocationdetailswithRLvaluesandtheircorrespondingstratigraphicdetailsaspertheRockworksformatisprovidedintheAnnexures- I and II.

The 3-D Model results showed that the region is dominantly occupied by Basalt, Alluvium Sandstone, Quartzite and Granite respectively. The sub-surface lithology has been broadly classified into Top soil/Unsaturated zone / Alluvium, underlain by Weathered

Basalt and which has been considered as shallow aquifer (up to a depth of 30 mts). Massive Basalt was encountered in few bore wells mainly occupying the southern region of Harda. This over lies the Fractured Basalt Sandstone that forms the deeper aquifer (from 30-200 mts). The fractured aquifer lies between Vesicular Basalt and predominantly Massive Basalt.

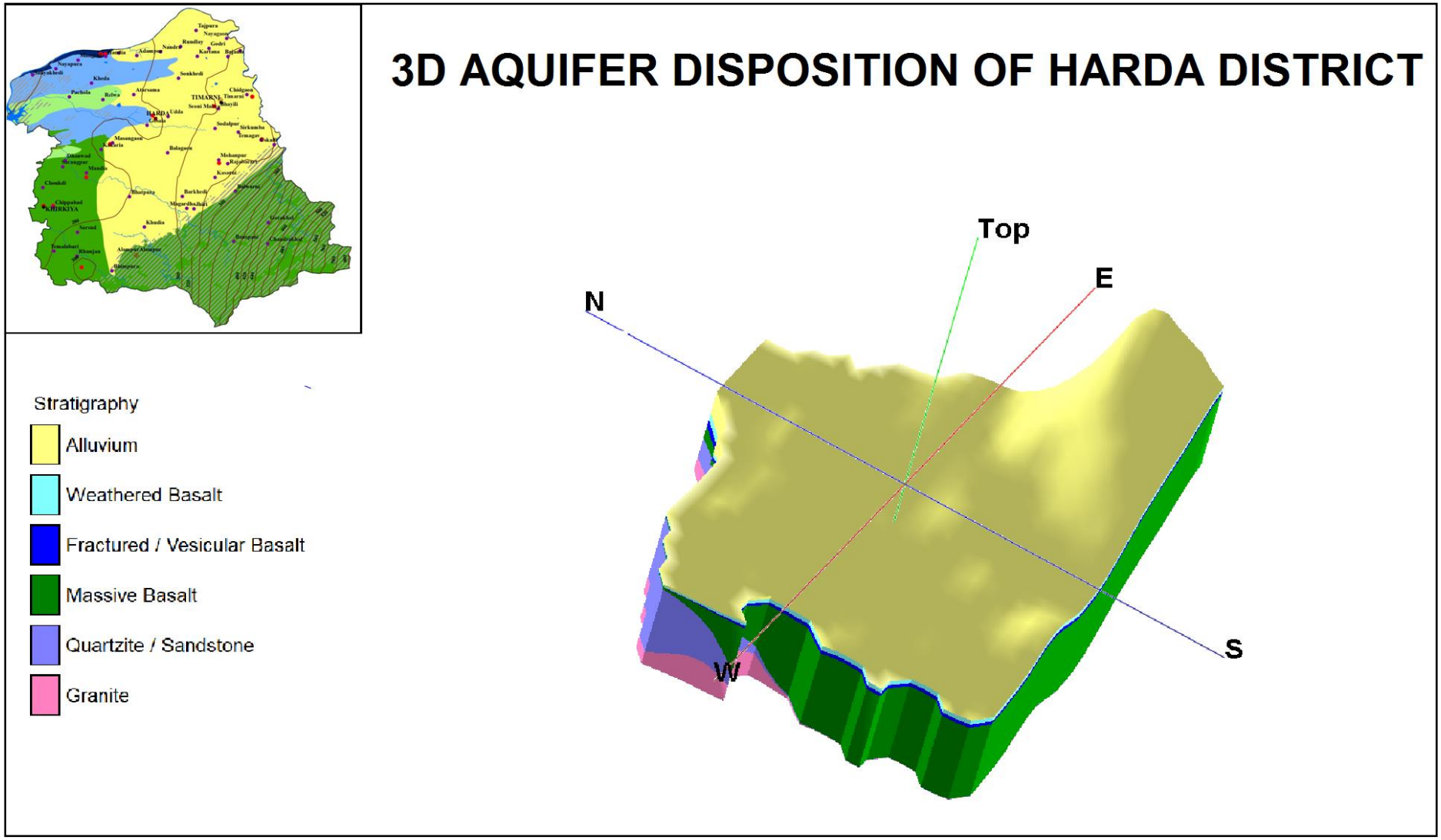
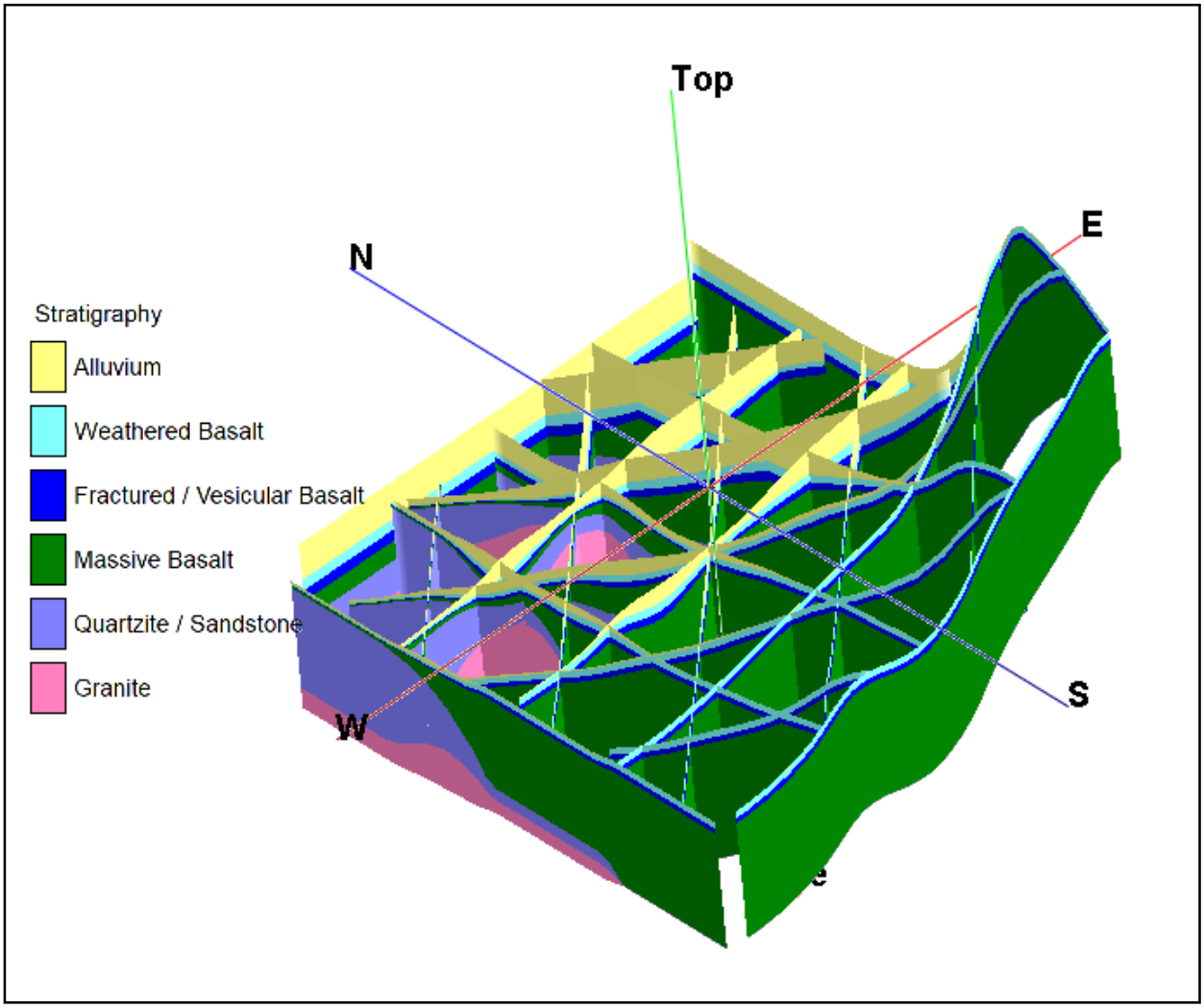


Figure 16:3-DLithologicalModelofHardaDistrict, Madhya Pradesh

Fence Diagram

The Fence diagram was also prepared using the Rockworks software (Fig. 15). The pattern for the Fence was chosen as such to cover the maximum portion of the region to represent the enhanced picture of the sub-surface as deciphered from the 3-D stratigraphic model. It has also been interpreted from the diagram that the shallow and deeper aquifers are not in connection to each other.

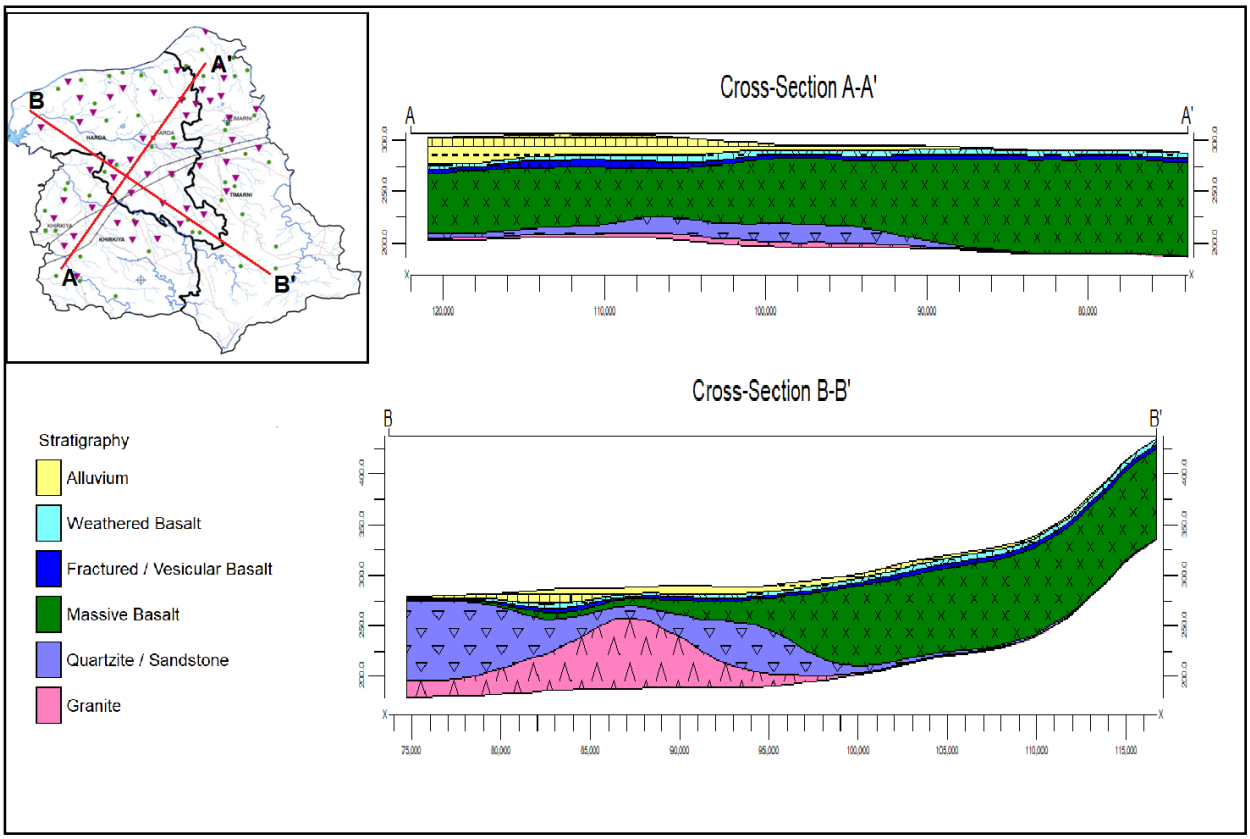
Figure 17: Fence Diagram, Harda District Madhya Pradesh



2-D Cross Section

2-Dimensional cross-section along the section line A-A' (SW-NE), B-B' has been prepared using Rockworks and later refined in Mapinfo (Fig.16). The cross-section shows that the shallow aquifer is not continuing for the whole region and occurs as narrow pinches in the western portion of Harda. The deeper aquifers whereas, occurs throughout the section line and can be encountered at depth where fractures are present.

Figure 118: 2-D Cross section along A-A' (SW-NE), B-B' Harda District, Madhya Pradesh



4. Ground Water Resources

a. Dynamic Ground Water Resource (2022)

Harda district is characterized by alluvial formations and Deccan trap basaltic lava flow. Dynamic ground water resources of the district have been estimated for base year - 2021-22 on block-wise basis. Out of 333000 ha of geographical area, 270090 ha (81%) is ground water recharge worthy area and 62910 ha (19%) is hilly area. There are three numbers of assessment units in the district which fall under command (29%) and non-command (71%) categories sub units. All blocks of the district are categorized as safe blocks, with highest stage of ground water development of 68.65% in Khirkiya block. The annual extractable ground water resource in the district 42913 ham and ground water extraction for all uses is Dynamic Ground Water Resource of Madhya Pradesh - 2022 108 15645 ham, making Stage of Ground water extraction 36.46 (34.03% in 2019-20) as a whole for district. After making allocation for future domestic supply for year 2025, balance available ground water for future use would be 1331 ham (Table 10).

Table 9: Dynamic Ground Water Resources (2022)

Assessment Unit Name	Ground Water Extraction for Irrigation Use (Ham)	Ground Water Extraction for Industrial Use (Ham)	Ground Water Extraction for Domestic Use (Ham)	Total Extraction (Ham)	Annual GW Allocation for for Domestic Use as on 2025 (Ham)	Net Ground Water Availability for future use (Ham)	Stage of Ground Water Extraction (%)	Categorization
TIMARNI	5920.56	0.00	420.96	6341.53	457.79	5517.10	53.31	safe
KHIRKIYA	4082.40	0.00	400.09	4482.49	435.10	2011.71	68.65	safe
HARDA	4402.08	16.17	402.72	4820.97	437.96	19631.80	19.69	safe
DISTRICT TOTAL	**14405.04**	**16.17**	**1223.77**	**15644.99**	**1330.85**	**27160.61**	**36.46**	safe

b. In storage

The Ground Water Resource of Harda district has been calculated block-wise considering the variable lithology and their associated aquifer parameters like specific yield. The In-storage resource for the shallow aquifer below zone of fluctuation (up to 30 mbgl) is computed to be around 729.61 mcm. The static resource for the deeper aquifer (30-200 mbgl) is computed as 183 mcm. The block-wise detail of ground water resources and draft as an outcome of NAQUIM is presented in the Table No.11

Block	Harda	Khirkiya	Timarni
Shallow Aquifer			
Dynamic Resources (MCM)	118.9546	65.2921	244.8801
In storage Resources(MCM)	98.848	107.027	94.611
Total Resources(MCM)	**217.80**	**172.32**	**339.49**
Irrigation	59.2056	40.824	44.02
Domestic + Industries	4.21	4.00	4.19
Deeper Aquifer			
Static Resources(MCM)	50.34	54.78	78.59
GW Draft(MCM	63.42	44.82	48.21
Total GW Resources(MCM)	268.14	227.10	418.09
Gross Ground Water Draft(MCM)	126.83	89.65	96.42

Table 10: Ground Water Resources (Outcome of NAQUIM)

5. Ground Water Related Issues

a. Ground Water Decline

The long-term water level trend analysis indicates mixed results. During pre-monsoon season, out of 14 Hydrograph Stations, 9 are showing declining trend (Fig. 17). Similarly, during post-monsoon season, out of 14 stations 6 stations are showing falling trend in the district and all stations of Harda blocks are showing depletion of water levels in the area.

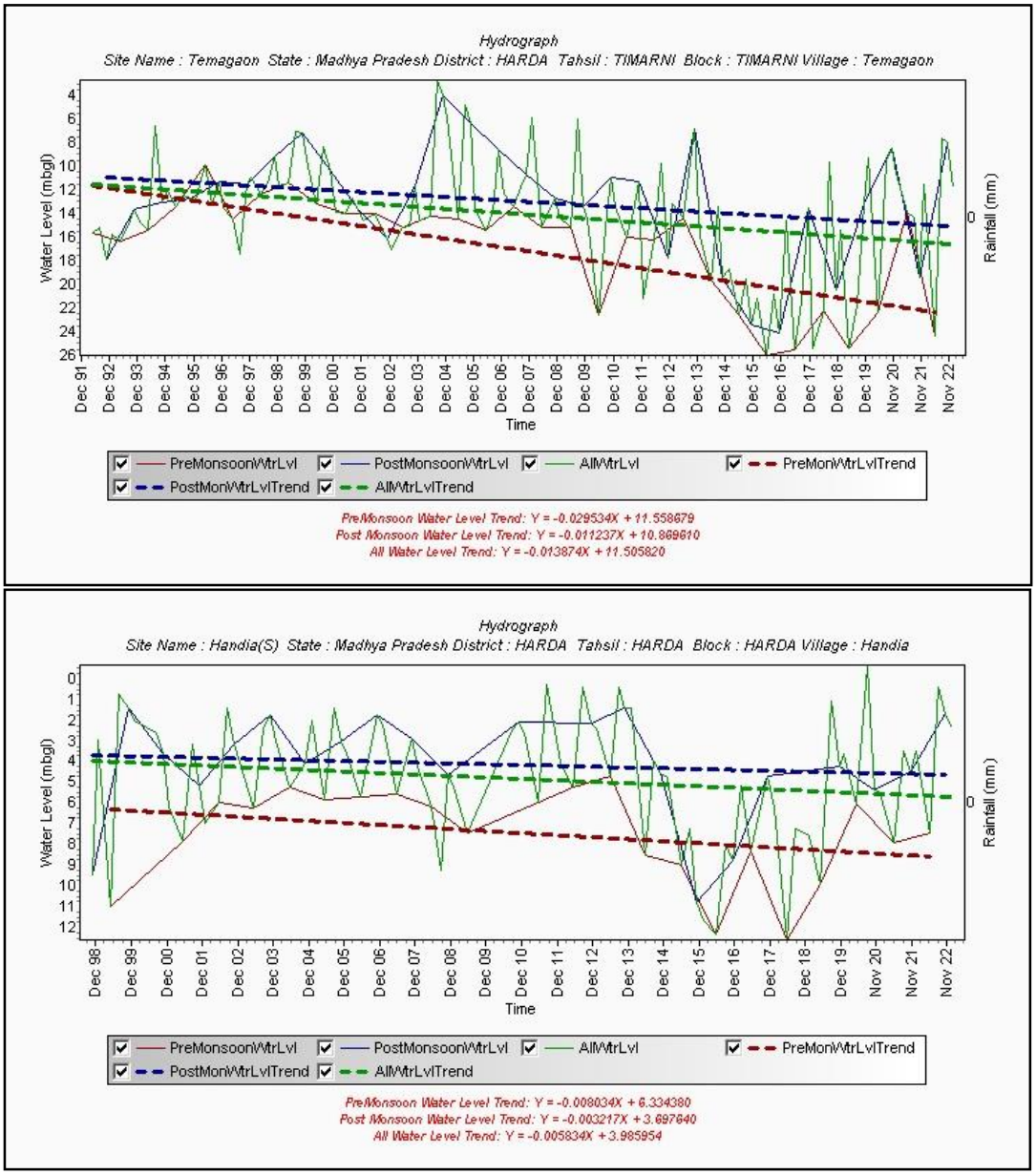


Figure 129: Hydrographs showing declining water level trend during Pre-monsoon and Post-Monsoon at **sites Temagaon and Handia,** Harda District, Madhya Pradesh

b. Ground Water Contamination

The fluoride concentration in Harda district lies in between 0.1 to 2.69 mg/l, which represent that almost all the samples are within the permissible limit i.e.1.5 mg/l as per BIS (IS 10500: 2012) except Jhiri, Nayapura, Mangrul and Tajpura village i.e. 2.12 to 2.69 mg/l.

6. Ground Water Management Strategies and Aquifer Management Plan

Groundwater has been contributing more to agricultural wealth than surface irrigation since ages. Tube wells are now the largest source of irrigation in the country. Since this sector has almost no dependence on the government, it is growing at a rapid rate and it is estimated that one million wells are added every year (Shah and Deb, 2004). Being an individually managed source, ground water irrigation is also a more efficient form of irrigation, with crop yields per cubic meter of water being 1.2 to 3 times higher than surface irrigation. However, since this sector has grown through investment by individual farmers, with little state involvement compared to canal irrigation, government support for understanding this sector and improving its performance is negligible. The major issues for the future growth of ground water irrigation is declining resource base, demand driven growth, and a lack of policy and regulatory framework. Since groundwater extraction is primarily driven by the needs of the population and the density of farmer population and not the quality of resource, ground water irrigation is scaling up even in such hard rock areas causing irreversible depletion of the resource base (ShahandDeb, 2004).To warrant the current situation effective ground water management strategies needs to be evolved.

District Ground Water Management Plan (Outcome of NAQUIM)

Harda district has been facing problems of ground water exploitation which in turn are depleting the ground water resources in the non-command area. This has led to evolve sustainable water conservation and management practices through an integrated approach. The ground water management plan for Harda district has been made keepingin view the area specific details and includes the strategies like enhancing the ground water resources through construction of artificial recharge structures such as percolation tanks, check dams/ Nala bunds, recharge shafts, etc. and ensuring water use efficiency throughmaintenance/ renovation of existing water bodies/water conservation structures. Also, adoption of micro-irrigation techniques such as sprinkler irrigation has been proposed, that would not only conserve ground water resources by reducing the draft, but would also increase the net cropping area

thereby augmenting the agricultural economy of the district.

Supply Side Management

Artificial recharge to ground water is one of the most efficient, scientificallyproven and cost-effective technology to mitigate the problems of over exploitation of ground water resources. The artificial recharge techniques simultaneously rejuvenate the depleted ground water storage, reduce the ground water quality problems and also improve the sustainability of wells in the affected areas.

The supply side management plan for Harda district has been formulated using the basic concepts of hydrogeology. Sub-surface storage is calculated by multiplying the total area with the respective specific yield (considering the variable lithology) and the unsaturated zone thickness obtained by subtracting 3 mts from the post-monsoon water level. The volume of ground water recharge generated through pre-existing rain water harvesting/water conservation structures is subtracted from the sub-surface storage to assess the available storage potential. Thus, the surface water requirement to completely saturate the sub-surface storage is obtained by multiplying a factor of 1.33 to available storage potential. A runoff coefficient factor of 0.23 has been considered for Harda district to calculate the total surface water runoff, 30% of which accounts to the non-committed runoff which is available to sustain the proposed artificial recharge structures. Further, the number of structures has been calculated by allotting 35%, 35% and 20% of non-committed runoff to Percolationtanks, Recharge shafts/Tube wells and Nala bunds/Check dams/Cement Plugs respectively. The remaining 10 % runoff is considered to restore the pre-existing village tanks, ponds and water conservation structures. A detailed calculation of the proposed artificial recharge structures is presented in the Table No.12

A financial outlay plan has also been chalked out, assuming the cost for the artificial recharge structures to be Rs. 20 lakhs each for percolation tanks, Rs. 10 lakhs each for Nala bunds/Check Dams/Cement Plugs, Rs. 5 lakhs each for Recharge shafts/Tube wells and Rs. 2 lakhs each for renovation of Village tanks/ponds/WCS. This accounts to a total of Rs. 168.45 Crores to successfully implement the supply side management strategy. Table No. 13 represents the complete financial outlay plan for the district.

Demand Side Management

Micro irrigation technologies such as drip and sprinkler systems are beingincreasingly promoted as technological solutions for achieving water conservation. Micro- irrigation

comprises two technologies-drip and sprinkler irrigation. Both saves conveyance losses and improve water application efficiency by applying water near the root-zone of the plant some benefits of the micro-irrigation have been listed below:

The increase in yield for different crops ranges from 27 per cent to 88 per cent and water saving ranges from 36 per cent to 68 per cent vis-à-vis conventional flow irrigation systems (Phansalker and Verma, 2005).

It enables farmers to grow crops which would not be possible under conventional systems since it can irrigate adequately with lower water quantities.

It saves costs of hired labour and other inputs like fertilizer.

It reduces the energy needs for pumping, thus reducing energy per ha of irrigation because of its reduced water needs. However, overall energy needs of the agriculture sector may not get reduced because most farmers use the increased water efficiency to bring more area under irrigation.

Adoption of Sprinkler irrigation techniques in 50% of the area irrigated by ground water has been suggested for the Harda district Also, the 60% of additional recharge created by construction of artificial recharge structures can be utilized to increase the total cropping area, thereby enhancing the productivity and economy of the district.

Table 11: Ground Water Management–Supply Side, Harda District, Madhya Pradesh

Block	Area (Sq.Km)	Area suitable for recharge (Non-command) (Sq.Km)	Rainfall (m)	Average post-monsoon water level(m)	Un saturated zone(m)	Average SP Yield (%)	Sub-surface storage(MCM)	GW Recharge through RWH Structures Constructed (MCM)
	1	2	3	4	5	6	7	8
Harda	1050	916.5	1.38	5.9335	2.93	0.015/ 0.10	53.77	53.77
Khirkiya	1240	794.4	1.38	6.134545	3.13	0.0200	49.80	49.8
Timarni	1040	990	1.38	5.807895	2.81	0.02/0.10	55.60	55.60
DistrictTotal	3330	2700.9	1.38	2.55	1.11	0.02/0.15	159.17	159.17

Table 12: Financial Outlay Plan-Supply Side Management, Harda District, MadhyaPradesh

Block	Area Suitable for AR	Volume of Surface Water available for AR (MCM)	Volume of Water required for recharge (MCM)	Percolation Tanks		NB/CP		CP/Recharge shaft		Renovation of Village Ponds		Total Cost of ARS in crores
				structure	cost	structure	cost	structure	cost	structure	cost	
				Nos.	(crores)	Nos.	(crores)	Nos.	(crores)	Nos.	(crores)	
Harda	916.5	53.77	71.52	72	14.40	286	28.60	250	12.50	73	1.46	56.96
Khirkiya	794.4	49.80	66.24	66	13.25	265	26.50	232	11.60	67	1.34	52.69
Timarni	990	55.60	73.94	74	14.79	296	29.60	259	12.95	73	1.46	58.80
TOTAL	2700.9	159.17	211.69	212	42.44	847	84.7	741	37.05	213	4.26	168.45

Post-Intervention

The expected outcome of the proposed interventions from both supply side and demand side has been described in Table No 14. It can been revised that the Stage of groundwater development for the entire Harda district, would increase to 36.46 % as compared to the present stage of ground water development of 42.06%after implying and successful implementation of proposed interventions.

Table 13:Post-Intervention Impact, Harda District, Madhya Pradesh (inMCM)

Block	Net GW Availability	GW Draft for Irrigation	GW Draft for Domestic & Industrial	Gross Draft	Stage of Development (%)	Saving by MI in mcm	Additional recharge created by AR	After intervention of AR Structure Net GW availability	After intervention of AR Structure & utilization of 60% of additional GW Created	Draft after sprinkler & additional area created for agriculture	Stage of Development W/O GW use for additional Area Irrigation	Additional area irrigated by GW after intervention
Harda	118.9546	59.21	4.210	63.415	**53.31**	6.34	53.77	172.7257	32.2626	89.34	**51.72**	8066
Khirkiya	65.2921	40.82	4.001	44.825	**68.65**	4.48	49.80	115.09	29.8810	70.22	**61.01**	7470
Timarni	244.8801	44.02	4.189	48.210	**19.69**	4.82	55.60	300.48	44.48	87.87	**29.24**	11119
Total	429.1268	144.05	44.361	156.450	36.46	15.64	159.17	588.29	349.0387	247.36	**42.06**	26655

Table 14: Block wise Management Plan

Block wise Management Plan

Block	Harda
Geographical area	1050
Basin/Sub Basin	Narmada Basin
Principal Aquifer System	Granite Gneiss / Alluvium
Major Aquifer System	Alluvium / Fractured Gneiss
Normal Annual Rainfall	1374.5
Aquifer Disposition	Two Types of Aquifer System
	Shallow Aquifer system (Aquifer-I): Depth range from 3 to 30 m, Weathered Granite Gneiss / Alluvium
	Deeper Aquifer System (Aquifer-II): Depth range from 30-180m)
	Fractured Gneiss /sandstone
Status of GW Exploration	Piezometer - 2
Aquifer Characteristic	Aquifer I : Depth of Occurrence (m bgl): 3 to 30, Thickness average (m):15
	DTWL (m bgl): 2-15
	Yield (lps): 1 to 6.5
	Specific yield :0.015/0.10
	Aquifer II : Depth of Occurrence (m bgl): 30 m to 180 m, Thickness average (m): 0.5 to 6
	DTWL (m bgl): 11 - 28
	Yield (lps): Meager to 12
	T (m2/day), Specific yield :0.015
Ground water Monitoring Status	NHS: DW - 3, PZ-1
Groundwater Quality	Generally shallow and Deeper Aquifer Ground water Quality potable
Aquifer potential	Mainly aquifer potential in weathered / Fracture Granite Gneiss and in Alluvium
Groundwater Resource	GW Availability 11895.46 GW Draft 6341.53 ham
	Stage of GW Development 53.31 %
Existing and Future water Demand	Present Demand for All usage 6341.53 ham Future
	Demand for Domestic and Industrial Use 457.79 ham

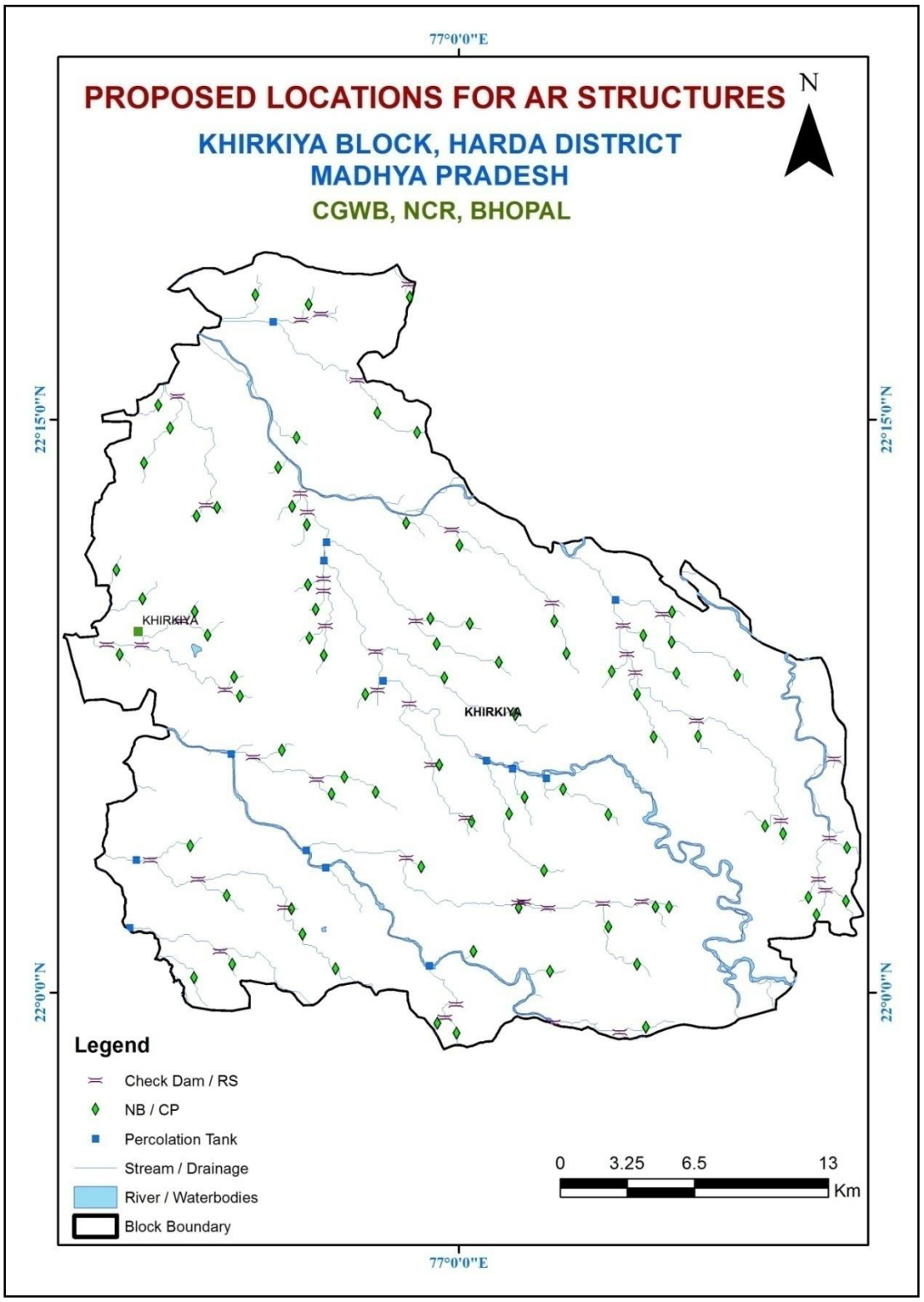
Block	Khirkiya
Geographical area	1240
Basin/Sub Basin	Narmada Basin
Principal Aquifer System	Basalt
Major Aquifer System	Fractured Basalt
Normal Annual Rainfall	1374.5
Aquifer Disposition	Two Types of Aquifer System
	Shallow Aquifer system (Aquifer-I): Depth range from 3 to 30m, Weathered Basalt
	Deeper Aquifer System (Aquifer-II): Depth range from 30-170m,
	Fractured Basalt
Status of GW Exploration	Exploratory Well- 1
Aquifer Characteristic	Aquifer I : Depth of Occurrence (m bgl): 3 to 30, Thickness average (m):15
	DTWL (m bgl): 3-14
	Yield (lps): 1 to 4.5
	Specific yield :0.02
	Aquifer II : Depth of Occurrence (m bgl): 30 m to 180 m, Thickness average (m): 0.5 to 6
	DTWL (m bgl): 11 - 28
	Yield (lps): Meager to 7
	T (m2/day), Specific yield :0.020
Ground water Monitoring Status	NHS: DW - 5, PZ-1
Groundwater Quality	Generally shallow and Deeper Aquifer Ground water Quality potable
Aquifer potential	Mainly aquifer potential in weathered / Fracture Basalt
Groundwater Resource	GW Availability 6529.21 GW Draft 4482.49 ham
	Stage of GW Development 68.65%
Existing and Future water Demand	Present Demand for All usage 4482.49 ham Future
	Demand for Domestic and Industrial Use 435.1 ham

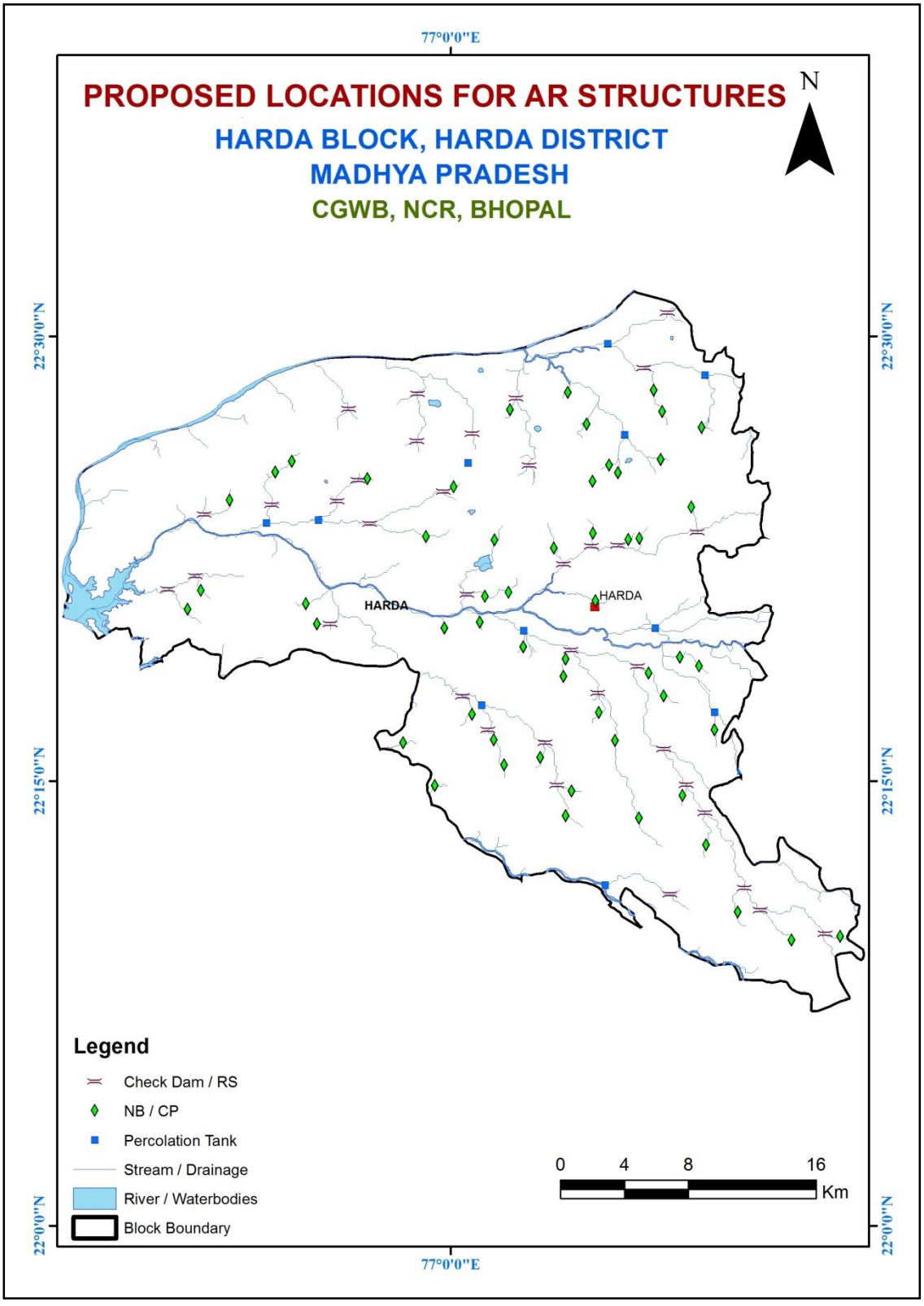
Block	Timarni
Geographical area	1040
Basin/Sub Basin	Narmada Basin
Principal Aquifer System	Basalt / Alluvium
Major Aquifer System	Fractured Basalt / Alluvium
Normal Annual Rainfall	1374.5
Aquifer Disposition	Two Types of Aquifer System
	Shallow Aquifer system (Aquifer-I): Depth range from 2 to 30m, Weathered Basalt / Alluvium
	Deeper Aquifer System (Aquifer-II): Depth range from 30-180 m,
	Fractured Basalt
Status of GW Exploration	Piezometer - 1
Aquifer Characteristic	Aquifer I : Depth of Occurrence (m bgl): 2 to 30, Thickness average (m):13
	DTWL (m bgl): 2-14
	Yield (lps): 1 to 4.5
	Specific yield :0.02/0.10
	Aquifer II : Depth of Occurrence (m bgl): 30 m to 180 m, Thickness average (m): 0.5 to 6
	DTWL (m bgl): 11 - 28
	Yield (lps): Meager to 12
	T (m2/day), Specific yield :0.020
Ground water Monitoring Status	NHS: DW - 4
Groundwater Quality	Generally shallow and Deeper Aquifer Ground water Quality potable
Aquifer potential	Mainly aquifer potential in weathered / Fracture Basalt and in Alluvium
Groundwater Resource	GW Availability 24488.01 GW Draft 4820.97 ham
	Stage of GW Development 19.69%
Existing and Future water Demand	Present Demand for All usage 4820.97 ham Future
	Demand for Domestic and Industrial Use 437.96 ham

Table 15: Block wise Proposed AR Structure and Cost Estimation

TYPE OF STRUCTURE:	Harda	Khirkiya	Timarni	Total No. of Structures	Total Est. Cost in Cr.
Percolation Tanks (Rs20 Lakh Per Structure)	72	66	74	212	42.44
NB /CP (Rs10 Lakh Per Structure)	286	265	296	847	84.70
CD /Recharge Shaft (Rs5 Lakh Per Structure)	250	232	259	741	37.05
Renovation of Village Ponds / Farm Ponds (Rs2 Lakh Per Structure)	73	67	73	213	4.26
Total Cost in Cr.					**168.45**

Figure 13. Block wise Proposed AR Locations for Khirkiya, Harda, Timarni Blocks




77°0'0"E
PROPOSED LOCATIONS FOR AR STRUCTURES
HARDA BLOCK, HARDA DISTRICT
MADHYA PRADESH
CGWB, NCR, BHOPAL
N
22°30'0"N
22°15'0"N
22°0'0"N
HARDA
HARDA
Legend
Check Dam / RS
NB / CP
Percolation Tank
Stream / Drainage
River / Waterbodies
Block Boundary
0 4 8 16
Km

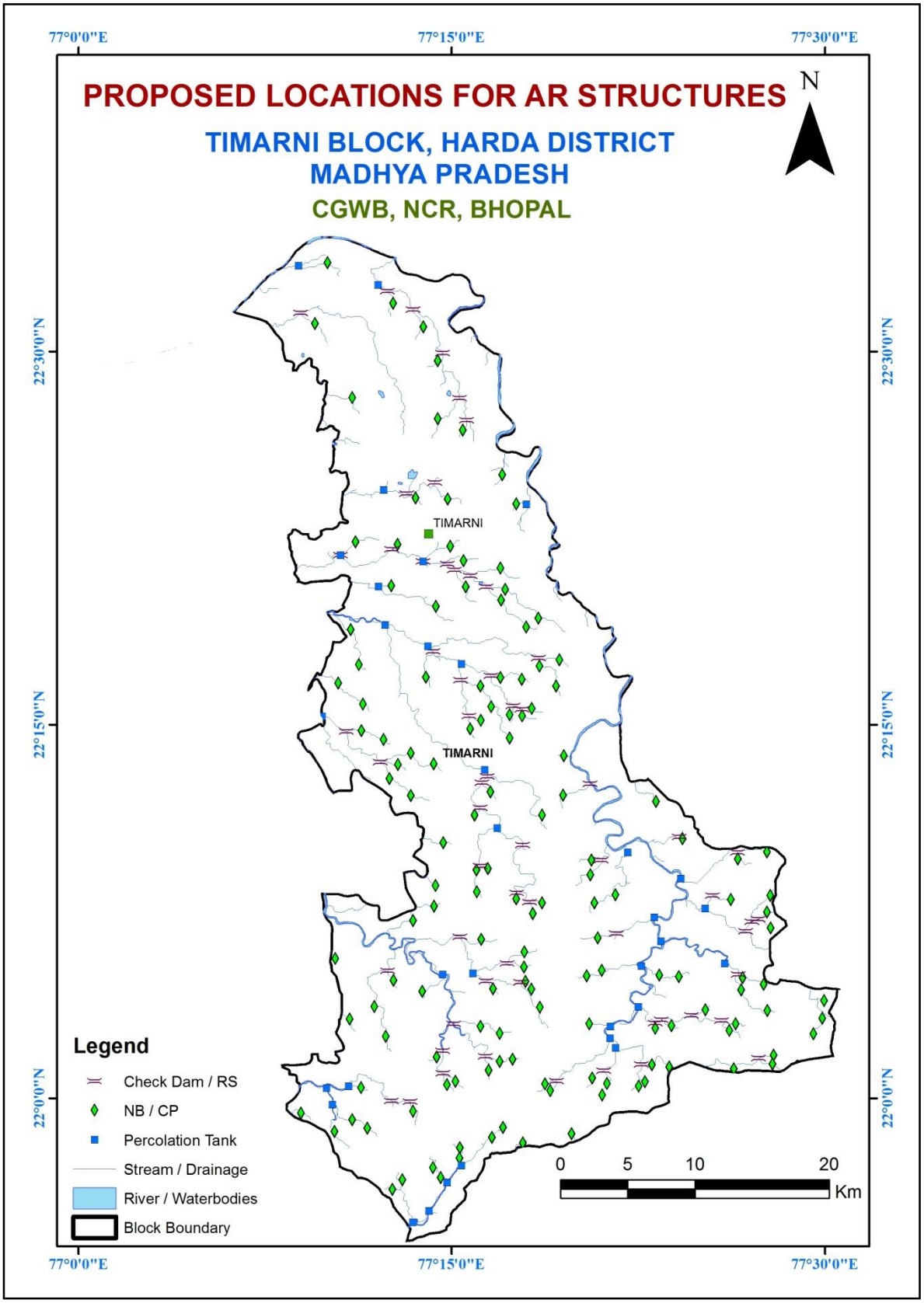

PROPOSED LOCATIONS FOR AR STRUCTURES
TIMARNI BLOCK, HARDA DISTRICT
MADHYA PRADESH
CGWB, NCR, BHOPAL
N
77°0'0"E
77°15'0"E
77°30'0"E
22°30'0"N
22°15'0"N
22°0'0"N
TIMARNI
TIMARNI
Legend
Check Dam / RS
NB / CP
Percolation Tank
Stream / Drainage
River / Waterbodies
Block Boundary
0 5 10 20
Km

Table.17. Proposed ARS Locations Block wise in Harda District

S.No	Dist	Block	Internvention	Lat	long
1	Harda	Harda	Check Dam / RS	22.39444	76.95444
2	Harda	Harda	Check Dam / RS	22.18611	77.12333
3	Harda	Harda	Check Dam / RS	22.24750	77.05972
4	Harda	Harda	Check Dam / RS	22.27139	77.05306
5	Harda	Harda	Check Dam / RS	22.27861	77.02083
6	Harda	Harda	Check Dam / RS	22.29750	77.00667
7	Harda	Harda	Check Dam / RS	22.33806	76.93222
8	Harda	Harda	Check Dam / RS	22.41250	76.99583
9	Harda	Harda	Check Dam / RS	22.41889	76.94778
10	Harda	Harda	Check Dam / RS	22.42722	77.04417
11	Harda	Harda	Check Dam / RS	22.46500	77.03667
12	Harda	Harda	Check Dam / RS	22.44083	76.98083
13	Harda	Harda	Check Dam / RS	22.46753	76.98138
14	Harda	Harda	Check Dam / RS	22.44500	77.01194
15	Harda	Harda	Check Dam / RS	22.45889	76.94250
16	Harda	Harda	Check Dam / RS	22.40715	76.93617
17	Harda	Harda	Check Dam / RS	22.40500	76.89917
18	Harda	Harda	Check Dam / RS	22.39972	76.86139
19	Harda	Harda	Check Dam / RS	22.36500	76.85639
20	Harda	Harda	Check Dam / RS	22.35750	76.84083
21	Harda	Harda	Check Dam / RS	22.48194	77.10861
22	Harda	Harda	Check Dam / RS	22.51306	77.12194
23	Harda	Harda	Check Dam / RS	22.38972	77.13861
24	Harda	Harda	Check Dam / RS	22.38222	77.09389
25	Harda	Harda	Check Dam / RS	22.38194	77.07917
26	Harda	Harda	Check Dam / RS	22.37167	77.06333
27	Harda	Harda	Check Dam / RS	22.35472	77.00917
28	Harda	Harda	Check Dam / RS	22.32333	77.06750
29	Harda	Harda	Check Dam / RS	22.29944	77.08278
30	Harda	Harda	Check Dam / RS	22.31417	77.10500
31	Harda	Harda	Check Dam / RS	22.26778	77.11972
32	Harda	Harda	Check Dam / RS	22.23194	77.14306
33	Harda	Harda	Check Dam / RS	22.24778	77.13250
34	Harda	Harda	Check Dam / RS	22.17722	77.17417
35	Harda	Harda	Check Dam / RS	22.16389	77.21056
36	Harda	Harda	Check Dam / RS	22.18972	77.16528
37	Harda	Harda	NB / CP	22.41825	77.07978
38	Harda	Harda	NB / CP	22.16056	77.19167
39	Harda	Harda	NB / CP	22.17611	77.16139
40	Harda	Harda	NB / CP	22.27139	76.97333
41	Harda	Harda	NB / CP	22.24722	76.99111

S.No	Dist	Block	Internvention	Lat	long
42	Harda	Harda	NB / CP	22.34639	76.85194
43	Harda	Harda	NB / CP	22.35694	76.85944
44	Harda	Harda	NB / CP	22.34944	76.91861
45	Harda	Harda	NB / CP	22.33806	76.92472
46	Harda	Harda	NB / CP	22.33583	76.99639
47	Harda	Harda	NB / CP	22.33917	77.01639
48	Harda	Harda	NB / CP	22.28722	77.01194
49	Harda	Harda	NB / CP	22.25889	77.03000
50	Harda	Harda	NB / CP	22.27306	77.02417
51	Harda	Harda	NB / CP	22.26306	77.05028
52	Harda	Harda	NB / CP	22.24417	77.06806
53	Harda	Harda	NB / CP	22.30861	77.06333
54	Harda	Harda	NB / CP	22.31833	77.06472
55	Harda	Harda	NB / CP	22.32528	77.04083
56	Harda	Harda	NB / CP	22.28833	77.08333
57	Harda	Harda	NB / CP	22.23028	77.06472
58	Harda	Harda	NB / CP	22.22917	77.10583
59	Harda	Harda	NB / CP	22.27250	77.09250
60	Harda	Harda	NB / CP	22.21389	77.14361
61	Harda	Harda	NB / CP	22.24167	77.13028
62	Harda	Harda	NB / CP	22.16250	77.21917
63	Harda	Harda	NB / CP	22.31444	77.13972
64	Harda	Harda	NB / CP	22.31944	77.12889
65	Harda	Harda	NB / CP	22.29778	77.11972
66	Harda	Harda	NB / CP	22.31056	77.11139
67	Harda	Harda	NB / CP	22.27861	77.14833
68	Harda	Harda	NB / CP	22.38611	77.10611
69	Harda	Harda	NB / CP	22.38556	77.10000
70	Harda	Harda	NB / CP	22.38917	77.08000
71	Harda	Harda	NB / CP	22.38083	77.05806
72	Harda	Harda	NB / CP	22.35583	77.03250
73	Harda	Harda	NB / CP	22.35361	77.01917
74	Harda	Harda	NB / CP	22.38528	77.02472
75	Harda	Harda	NB / CP	22.35111	77.08139
76	Harda	Harda	NB / CP	22.40389	77.13528
77	Harda	Harda	NB / CP	22.38722	76.98611
78	Harda	Harda	NB / CP	22.41528	77.00167
79	Harda	Harda	NB / CP	22.41972	76.95306
80	Harda	Harda	NB / CP	22.42944	76.91056
81	Harda	Harda	NB / CP	22.42361	76.90139
82	Harda	Harda	NB / CP	22.40778	76.87556
83	Harda	Harda	NB / CP	22.45056	77.07639
84	Harda	Harda	NB / CP	22.46833	77.06583

S.No	Dist	Block	Internvention	Lat	long
85	Harda	Harda	NB / CP	22.45861	77.03333
86	Harda	Harda	NB / CP	22.43056	77.11806
87	Harda	Harda	NB / CP	22.42306	77.09417
88	Harda	Harda	NB / CP	22.42750	77.08917
89	Harda	Harda	NB / CP	22.46944	77.11417
90	Harda	Harda	NB / CP	22.45750	77.11889
91	Harda	Harda	NB / CP	22.44861	77.14111
92	Harda	Harda	Percolation Tank	22.42870	77.00974
93	Harda	Harda	Percolation Tank	22.19139	77.08694
94	Harda	Harda	Percolation Tank	22.29250	77.01750
95	Harda	Harda	Percolation Tank	22.33444	77.04111
96	Harda	Harda	Percolation Tank	22.28861	77.14833
97	Harda	Harda	Percolation Tank	22.33583	77.11500
98	Harda	Harda	Percolation Tank	22.39667	76.92556
99	Harda	Harda	Percolation Tank	22.39500	76.89639
100	Harda	Harda	Percolation Tank	22.44444	77.09778
101	Harda	Harda	Percolation Tank	22.47806	77.14306
102	Harda	Harda	Percolation Tank	22.49556	77.08833
103	Harda	Khirkiya	Check Dam / RS	22.01778	76.89583
104	Harda	Khirkiya	Check Dam / RS	22.04917	76.88611
105	Harda	Khirkiya	Check Dam / RS	22.05750	76.86528
106	Harda	Khirkiya	Check Dam / RS	22.03694	76.92389
107	Harda	Khirkiya	Check Dam / RS	21.98889	76.99389
108	Harda	Khirkiya	Check Dam / RS	21.99472	76.99861
109	Harda	Khirkiya	Check Dam / RS	21.98667	77.04111
110	Harda	Khirkiya	Check Dam / RS	21.98250	77.07028
111	Harda	Khirkiya	Check Dam / RS	22.03861	77.06278
112	Harda	Khirkiya	Check Dam / RS	22.03944	77.07972
113	Harda	Khirkiya	Check Dam / RS	22.03889	77.02611
114	Harda	Khirkiya	Check Dam / RS	22.03667	77.03889
115	Harda	Khirkiya	Check Dam / RS	22.03944	77.02833
116	Harda	Khirkiya	Check Dam / RS	22.07611	77.00306
117	Harda	Khirkiya	Check Dam / RS	22.05861	76.97694
118	Harda	Khirkiya	Check Dam / RS	22.09278	76.93778
119	Harda	Khirkiya	Check Dam / RS	22.10250	76.91028
120	Harda	Khirkiya	Check Dam / RS	22.09917	76.98806
121	Harda	Khirkiya	Check Dam / RS	22.13167	76.96444
122	Harda	Khirkiya	Check Dam / RS	22.13194	76.89806
123	Harda	Khirkiya	Check Dam / RS	22.12583	76.97833
124	Harda	Khirkiya	Check Dam / RS	22.15972	76.94167
125	Harda	Khirkiya	Check Dam / RS	22.17500	76.94083
126	Harda	Khirkiya	Check Dam / RS	22.18028	76.94082
127	Harda	Khirkiya	Check Dam / RS	22.16194	76.87917

S.No	Dist	Block	Internvention	Lat	long
128	Harda	Khirkiya	Check Dam / RS	22.15139	76.86167
129	Harda	Khirkiya	Check Dam / RS	22.15167	76.84639
130	Harda	Khirkiya	Check Dam / RS	22.04444	77.16000
131	Harda	Khirkiya	Check Dam / RS	22.04917	77.15694
132	Harda	Khirkiya	Check Dam / RS	22.06722	77.16167
133	Harda	Khirkiya	Check Dam / RS	22.10167	77.16361
134	Harda	Khirkiya	Check Dam / RS	22.07472	77.14056
135	Harda	Khirkiya	Check Dam / RS	22.11833	77.10361
136	Harda	Khirkiya	Check Dam / RS	22.13944	77.07694
137	Harda	Khirkiya	Check Dam / RS	22.14750	77.07333
138	Harda	Khirkiya	Check Dam / RS	22.16500	77.08889
139	Harda	Khirkiya	Check Dam / RS	22.16000	77.07167
140	Harda	Khirkiya	Check Dam / RS	22.16972	77.04056
141	Harda	Khirkiya	Check Dam / RS	22.16194	76.98111
142	Harda	Khirkiya	Check Dam / RS	22.14861	76.96361
143	Harda	Khirkiya	Check Dam / RS	22.20167	76.99694
144	Harda	Khirkiya	Check Dam / RS	22.20944	76.93389
145	Harda	Khirkiya	Check Dam / RS	22.21750	76.93083
146	Harda	Khirkiya	Check Dam / RS	22.26694	76.95556
147	Harda	Khirkiya	Check Dam / RS	22.21250	76.88972
148	Harda	Khirkiya	Check Dam / RS	22.26000	76.87722
149	Harda	Khirkiya	Check Dam / RS	22.29333	76.93111
150	Harda	Khirkiya	Check Dam / RS	22.29583	76.93972
151	Harda	Khirkiya	Check Dam / RS	22.30889	76.97806
152	Harda	Khirkiya	NB / CP	22.06306	77.16944
153	Harda	Khirkiya	NB / CP	22.04139	77.15250
154	Harda	Khirkiya	NB / CP	22.03389	77.15611
155	Harda	Khirkiya	NB / CP	22.03972	77.16889
156	Harda	Khirkiya	NB / CP	22.01222	77.07778
157	Harda	Khirkiya	NB / CP	22.02861	77.06528
158	Harda	Khirkiya	NB / CP	22.03722	77.08583
159	Harda	Khirkiya	NB / CP	22.03722	77.09167
160	Harda	Khirkiya	NB / CP	22.00917	77.03972
161	Harda	Khirkiya	NB / CP	21.98222	76.99889
162	Harda	Khirkiya	NB / CP	21.98647	76.99062
163	Harda	Khirkiya	NB / CP	21.98472	77.08167
164	Harda	Khirkiya	NB / CP	22.05306	77.03722
165	Harda	Khirkiya	NB / CP	22.07778	77.02194
166	Harda	Khirkiya	NB / CP	22.08500	77.02861
167	Harda	Khirkiya	NB / CP	22.07750	77.06528
168	Harda	Khirkiya	NB / CP	22.08861	77.04556
169	Harda	Khirkiya	NB / CP	22.08722	76.96361
170	Harda	Khirkiya	NB / CP	22.09389	76.95000

S.No	Dist	Block	Internvention	Lat	long
171	Harda	Khirkiya	NB / CP	22.08639	76.94444
172	Harda	Khirkiya	NB / CP	22.04222	76.89861
173	Harda	Khirkiya	NB / CP	22.06389	76.88278
174	Harda	Khirkiya	NB / CP	22.01222	76.90111
175	Harda	Khirkiya	NB / CP	22.00639	76.88444
176	Harda	Khirkiya	NB / CP	22.01028	76.94611
177	Harda	Khirkiya	NB / CP	22.02528	76.93167
178	Harda	Khirkiya	NB / CP	22.10556	76.92278
179	Harda	Khirkiya	NB / CP	22.13750	76.90194
180	Harda	Khirkiya	NB / CP	22.12917	76.90444
181	Harda	Khirkiya	NB / CP	22.15583	76.89028
182	Harda	Khirkiya	NB / CP	22.16611	76.88472
183	Harda	Khirkiya	NB / CP	22.17167	76.86194
184	Harda	Khirkiya	NB / CP	22.18417	76.85056
185	Harda	Khirkiya	NB / CP	22.14722	76.85194
186	Harda	Khirkiya	NB / CP	22.17778	76.93417
187	Harda	Khirkiya	NB / CP	22.16694	76.93750
188	Harda	Khirkiya	NB / CP	22.15444	76.93472
189	Harda	Khirkiya	NB / CP	22.14694	76.94111
190	Harda	Khirkiya	NB / CP	22.20389	76.93361
191	Harda	Khirkiya	NB / CP	22.21194	76.92722
192	Harda	Khirkiya	NB / CP	22.21139	76.89444
193	Harda	Khirkiya	NB / CP	22.20778	76.88556
194	Harda	Khirkiya	NB / CP	22.23083	76.86250
195	Harda	Khirkiya	NB / CP	22.24611	76.87389
196	Harda	Khirkiya	NB / CP	22.25611	76.86889
197	Harda	Khirkiya	NB / CP	22.22889	76.92111
198	Harda	Khirkiya	NB / CP	22.24194	76.92917
199	Harda	Khirkiya	NB / CP	22.25278	76.96444
200	Harda	Khirkiya	NB / CP	22.24417	76.98187
201	Harda	Khirkiya	NB / CP	22.30000	76.93444
202	Harda	Khirkiya	NB / CP	22.30417	76.91111
203	Harda	Khirkiya	NB / CP	22.30333	76.97861
204	Harda	Khirkiya	NB / CP	22.13000	76.95917
205	Harda	Khirkiya	NB / CP	22.16083	77.00472
206	Harda	Khirkiya	NB / CP	22.16306	76.98750
207	Harda	Khirkiya	NB / CP	22.14389	77.01750
208	Harda	Khirkiya	NB / CP	22.15194	76.99028
209	Harda	Khirkiya	NB / CP	22.12111	77.02472
210	Harda	Khirkiya	NB / CP	22.13722	76.99361
211	Harda	Khirkiya	NB / CP	22.07444	77.00556
212	Harda	Khirkiya	NB / CP	22.09917	76.99139
213	Harda	Khirkiya	NB / CP	22.11167	77.10444

S.No	Dist	Block	Internvention	Lat	long
214	Harda	Khirkiya	NB / CP	22.11139	77.08500
215	Harda	Khirkiya	NB / CP	22.13000	77.07778
216	Harda	Khirkiya	NB / CP	22.13988	77.06675
217	Harda	Khirkiya	NB / CP	22.07250	77.13361
218	Harda	Khirkiya	NB / CP	22.06917	77.14139
219	Harda	Khirkiya	NB / CP	22.13917	77.09500
220	Harda	Khirkiya	NB / CP	22.15556	77.08056
221	Harda	Khirkiya	NB / CP	22.13833	77.12139
222	Harda	Khirkiya	NB / CP	22.15278	77.09278
223	Harda	Khirkiya	NB / CP	22.16583	77.09306
224	Harda	Khirkiya	NB / CP	22.19500	77.00028
225	Harda	Khirkiya	NB / CP	22.20472	76.97694
226	Harda	Khirkiya	NB / CP	22.14778	77.04694
227	Harda	Khirkiya	NB / CP	22.16194	77.04167
228	Harda	Khirkiya	NB / CP	22.05472	76.98361
229	Harda	Khirkiya	NB / CP	22.01778	77.00639
230	Harda	Khirkiya	NB / CP	22.03639	76.92694
231	Harda	Khirkiya	NB / CP	22.03694	77.02611
232	Harda	Khirkiya	Percolation Tank	22.02806	76.85639
233	Harda	Khirkiya	Percolation Tank	22.05778	76.85917
234	Harda	Khirkiya	Percolation Tank	22.06183	76.93328
235	Harda	Khirkiya	Percolation Tank	22.05434	76.94188
236	Harda	Khirkiya	Percolation Tank	22.01152	76.98703
237	Harda	Khirkiya	Percolation Tank	22.10389	76.90056
238	Harda	Khirkiya	Percolation Tank	22.13583	76.96694
239	Harda	Khirkiya	Percolation Tank	22.18833	76.94111
240	Harda	Khirkiya	Percolation Tank	22.19639	76.94222
241	Harda	Khirkiya	Percolation Tank	22.10111	77.01194
242	Harda	Khirkiya	Percolation Tank	22.09750	77.02333
243	Harda	Khirkiya	Percolation Tank	22.09333	77.03806
244	Harda	Khirkiya	Percolation Tank	22.17111	77.06833
245	Harda	Khirkiya	Percolation Tank	22.29250	76.91889
246	Harda	Timarni	Check Dam / RS	21.99806	77.20972
247	Harda	Timarni	Check Dam / RS	21.99750	77.22222
248	Harda	Timarni	Check Dam / RS	22.01667	77.24417
249	Harda	Timarni	Check Dam / RS	22.02806	77.27250
250	Harda	Timarni	Check Dam / RS	22.04978	77.25140
251	Harda	Timarni	Check Dam / RS	22.03167	77.24389
252	Harda	Timarni	Check Dam / RS	22.01139	77.32028
253	Harda	Timarni	Check Dam / RS	22.08528	77.20722
254	Harda	Timarni	Check Dam / RS	22.07750	77.29639
255	Harda	Timarni	Check Dam / RS	22.07833	77.27306
256	Harda	Timarni	Check Dam / RS	22.09028	77.28722

S.No	Dist	Block	Internvention	Lat	long
257	Harda	Timarni	Check Dam / RS	22.01833	77.35194
258	Harda	Timarni	Check Dam / RS	22.02250	77.37694
259	Harda	Timarni	Check Dam / RS	22.05028	77.38639
260	Harda	Timarni	Check Dam / RS	22.05250	77.39028
261	Harda	Timarni	Check Dam / RS	22.05528	77.41056
262	Harda	Timarni	Check Dam / RS	22.05194	77.43083
263	Harda	Timarni	Check Dam / RS	22.02667	77.45556
264	Harda	Timarni	Check Dam / RS	22.08278	77.44194
265	Harda	Timarni	Check Dam / RS	22.11028	77.36028
266	Harda	Timarni	Check Dam / RS	22.11972	77.45528
267	Harda	Timarni	Check Dam / RS	22.11806	77.45111
268	Harda	Timarni	Check Dam / RS	22.11167	77.44694
269	Harda	Timarni	Check Dam / RS	22.13556	77.42472
270	Harda	Timarni	Check Dam / RS	22.16444	77.44139
271	Harda	Timarni	Check Dam / RS	22.17472	77.40250
272	Harda	Timarni	Check Dam / RS	22.15939	77.35020
273	Harda	Timarni	Check Dam / RS	22.13111	77.30222
274	Harda	Timarni	Check Dam / RS	22.13722	77.29361
275	Harda	Timarni	Check Dam / RS	22.15528	77.26917
276	Harda	Timarni	Check Dam / RS	22.19444	77.26917
277	Harda	Timarni	Check Dam / RS	22.21111	77.27028
278	Harda	Timarni	Check Dam / RS	22.21028	77.34278
279	Harda	Timarni	Check Dam / RS	22.10806	77.25556
280	Harda	Timarni	Check Dam / RS	22.52556	77.14889
281	Harda	Timarni	Check Dam / RS	22.54028	77.20694
282	Harda	Timarni	Check Dam / RS	22.52778	77.22417
283	Harda	Timarni	Check Dam / RS	22.49861	77.24389
284	Harda	Timarni	Check Dam / RS	22.46861	77.25528
285	Harda	Timarni	Check Dam / RS	22.45389	77.26000
286	Harda	Timarni	Check Dam / RS	22.40472	77.22000
287	Harda	Timarni	Check Dam / RS	22.41194	77.23889
288	Harda	Timarni	Check Dam / RS	22.36333	77.17556
289	Harda	Timarni	Check Dam / RS	22.36750	77.21000
290	Harda	Timarni	Check Dam / RS	22.35917	77.23083
291	Harda	Timarni	Check Dam / RS	22.35750	77.24722
292	Harda	Timarni	Check Dam / RS	22.35361	77.25194
293	Harda	Timarni	Check Dam / RS	22.34972	77.26250
294	Harda	Timarni	Check Dam / RS	22.34222	77.27306
295	Harda	Timarni	Check Dam / RS	22.22500	77.20222
296	Harda	Timarni	Check Dam / RS	22.16944	77.29750
297	Harda	Timarni	Check Dam / RS	22.21528	77.27389
298	Harda	Timarni	Check Dam / RS	22.25583	77.26167
299	Harda	Timarni	Check Dam / RS	22.27972	77.25611

S.No	Dist	Block	Internvention	Lat	long
300	Harda	Timarni	Check Dam / RS	22.29889	77.23750
301	Harda	Timarni	Check Dam / RS	22.28278	77.27639
302	Harda	Timarni	Check Dam / RS	22.29444	77.30806
303	Harda	Timarni	Check Dam / RS	22.26028	77.29694
304	Harda	Timarni	Check Dam / RS	22.26250	77.29111
305	Harda	Timarni	Check Dam / RS	22.24556	77.17944
306	Harda	Timarni	NB / CP	22.06083	77.30917
307	Harda	Timarni	NB / CP	22.07281	77.30344
308	Harda	Timarni	NB / CP	22.07806	77.29944
309	Harda	Timarni	NB / CP	22.08758	77.29861
310	Harda	Timarni	NB / CP	22.09778	77.29889
311	Harda	Timarni	NB / CP	22.07311	77.27781
312	Harda	Timarni	NB / CP	22.04333	77.28222
313	Harda	Timarni	NB / CP	22.04806	77.26944
314	Harda	Timarni	NB / CP	21.96667	77.25556
315	Harda	Timarni	NB / CP	21.95972	77.25528
316	Harda	Timarni	NB / CP	21.95333	77.23750
317	Harda	Timarni	NB / CP	21.94667	77.24278
318	Harda	Timarni	NB / CP	21.94528	77.21694
319	Harda	Timarni	NB / CP	21.93889	77.21028
320	Harda	Timarni	NB / CP	21.97972	77.19361
321	Harda	Timarni	NB / CP	21.98556	77.18361
322	Harda	Timarni	NB / CP	21.97750	77.17167
323	Harda	Timarni	NB / CP	21.99111	77.22417
324	Harda	Timarni	NB / CP	22.00889	77.24694
325	Harda	Timarni	NB / CP	22.01111	77.25250
326	Harda	Timarni	NB / CP	22.01861	77.27472
327	Harda	Timarni	NB / CP	22.02611	77.29083
328	Harda	Timarni	NB / CP	22.02444	77.28222
329	Harda	Timarni	NB / CP	22.02750	77.24000
330	Harda	Timarni	NB / CP	22.00694	77.18944
331	Harda	Timarni	NB / CP	22.00944	77.31250
332	Harda	Timarni	NB / CP	21.97000	77.29778
333	Harda	Timarni	NB / CP	21.98028	77.28444
334	Harda	Timarni	NB / CP	21.97361	77.27694
335	Harda	Timarni	NB / CP	21.97611	77.33028
336	Harda	Timarni	NB / CP	22.00500	77.31611
337	Harda	Timarni	NB / CP	22.01333	77.34417
338	Harda	Timarni	NB / CP	22.00194	77.35083
339	Harda	Timarni	NB / CP	22.00972	77.35417
340	Harda	Timarni	NB / CP	22.00806	77.37528
341	Harda	Timarni	NB / CP	22.01083	77.37944
342	Harda	Timarni	NB / CP	22.04972	77.34222

S.No	Dist	Block	Internvention	Lat	long
343	Harda	Timarni	NB / CP	22.02083	77.39583
344	Harda	Timarni	NB / CP	22.02222	77.38417
345	Harda	Timarni	NB / CP	22.04667	77.38639
346	Harda	Timarni	NB / CP	22.04833	77.39722
347	Harda	Timarni	NB / CP	22.08167	77.34056
348	Harda	Timarni	NB / CP	22.08556	77.35056
349	Harda	Timarni	NB / CP	22.02861	77.46556
350	Harda	Timarni	NB / CP	22.02278	77.46500
351	Harda	Timarni	NB / CP	22.01956	77.43895
352	Harda	Timarni	NB / CP	22.04528	77.43611
353	Harda	Timarni	NB / CP	22.04972	77.44028
354	Harda	Timarni	NB / CP	22.05917	77.42000
355	Harda	Timarni	NB / CP	22.08139	77.40222
356	Harda	Timarni	NB / CP	22.08222	77.38917
357	Harda	Timarni	NB / CP	22.05861	77.46139
358	Harda	Timarni	NB / CP	22.07250	77.44389
359	Harda	Timarni	NB / CP	22.07611	77.45889
360	Harda	Timarni	NB / CP	22.08058	77.44483
361	Harda	Timarni	NB / CP	22.04306	77.49222
362	Harda	Timarni	NB / CP	22.05333	77.49833
363	Harda	Timarni	NB / CP	22.06528	77.49944
364	Harda	Timarni	NB / CP	22.10722	77.34778
365	Harda	Timarni	NB / CP	22.11389	77.46361
366	Harda	Timarni	NB / CP	22.12444	77.46111
367	Harda	Timarni	NB / CP	22.13556	77.46333
368	Harda	Timarni	NB / CP	22.13278	77.43694
369	Harda	Timarni	NB / CP	22.16472	77.46111
370	Harda	Timarni	NB / CP	22.16000	77.44167
371	Harda	Timarni	NB / CP	22.17361	77.40472
372	Harda	Timarni	NB / CP	22.13056	77.34556
373	Harda	Timarni	NB / CP	22.13611	77.35972
374	Harda	Timarni	NB / CP	22.14944	77.34306
375	Harda	Timarni	NB / CP	22.15917	77.34361
376	Harda	Timarni	NB / CP	22.10611	77.27000
377	Harda	Timarni	NB / CP	22.07139	77.23028
378	Harda	Timarni	NB / CP	22.07889	77.21111
379	Harda	Timarni	NB / CP	22.06139	77.19833
380	Harda	Timarni	NB / CP	22.04139	77.20583
381	Harda	Timarni	NB / CP	21.99000	77.14917
382	Harda	Timarni	NB / CP	22.05278	77.18167
383	Harda	Timarni	NB / CP	22.09333	77.17222
384	Harda	Timarni	NB / CP	22.12833	77.23833
385	Harda	Timarni	NB / CP	22.11889	77.22417

S.No	Dist	Block	Internvention	Lat	long
386	Harda	Timarni	NB / CP	22.14222	77.23917
387	Harda	Timarni	NB / CP	22.13806	77.26694
388	Harda	Timarni	NB / CP	22.15250	77.26667
389	Harda	Timarni	NB / CP	22.15361	77.27444
390	Harda	Timarni	NB / CP	22.13333	77.29333
391	Harda	Timarni	NB / CP	22.13056	77.31056
392	Harda	Timarni	NB / CP	22.12361	77.30444
393	Harda	Timarni	NB / CP	22.18944	77.26556
394	Harda	Timarni	NB / CP	22.18944	77.31056
395	Harda	Timarni	NB / CP	22.20500	77.27611
396	Harda	Timarni	NB / CP	22.20278	77.32472
397	Harda	Timarni	NB / CP	22.20250	77.22278
398	Harda	Timarni	NB / CP	22.21389	77.20833
399	Harda	Timarni	NB / CP	22.22361	77.23806
400	Harda	Timarni	NB / CP	22.23083	77.22278
401	Harda	Timarni	NB / CP	22.22333	77.21417
402	Harda	Timarni	NB / CP	22.24000	77.20444
403	Harda	Timarni	NB / CP	22.24583	77.18972
404	Harda	Timarni	NB / CP	22.26361	77.19056
405	Harda	Timarni	NB / CP	22.27778	77.17417
406	Harda	Timarni	NB / CP	22.29000	77.18806
407	Harda	Timarni	NB / CP	22.31361	77.18250
408	Harda	Timarni	NB / CP	22.24722	77.26250
409	Harda	Timarni	NB / CP	22.25278	77.26972
410	Harda	Timarni	NB / CP	22.24111	77.28889
411	Harda	Timarni	NB / CP	22.26194	77.27667
412	Harda	Timarni	NB / CP	22.27583	77.26944
413	Harda	Timarni	NB / CP	22.25667	77.28889
414	Harda	Timarni	NB / CP	22.25583	77.29722
415	Harda	Timarni	NB / CP	22.26083	77.30361
416	Harda	Timarni	NB / CP	22.28028	77.29694
417	Harda	Timarni	NB / CP	22.28139	77.28278
418	Harda	Timarni	NB / CP	22.27583	77.32000
419	Harda	Timarni	NB / CP	22.28917	77.30889
420	Harda	Timarni	NB / CP	22.29333	77.32222
421	Harda	Timarni	NB / CP	22.22917	77.32528
422	Harda	Timarni	NB / CP	22.17083	77.24444
423	Harda	Timarni	NB / CP	22.19861	77.38694
424	Harda	Timarni	NB / CP	22.28167	77.23278
425	Harda	Timarni	NB / CP	22.32917	77.23944
426	Harda	Timarni	NB / CP	22.34306	77.20972
427	Harda	Timarni	NB / CP	22.37222	77.18583
428	Harda	Timarni	NB / CP	22.36944	77.24917

S.No	Dist	Block	Internvention	Lat	long
429	Harda	Timarni	NB / CP	22.34222	77.25944
430	Harda	Timarni	NB / CP	22.35972	77.25806
431	Harda	Timarni	NB / CP	22.35472	77.28278
432	Harda	Timarni	NB / CP	22.32111	77.30806
433	Harda	Timarni	NB / CP	22.34056	77.28583
434	Harda	Timarni	NB / CP	22.33333	77.28333
435	Harda	Timarni	NB / CP	22.45472	77.24083
436	Harda	Timarni	NB / CP	22.44722	77.25750
437	Harda	Timarni	NB / CP	22.49361	77.24083
438	Harda	Timarni	NB / CP	22.51611	77.23111
439	Harda	Timarni	NB / CP	22.53194	77.21083
440	Harda	Timarni	NB / CP	22.51833	77.15861
441	Harda	Timarni	NB / CP	22.55917	77.16694
442	Harda	Timarni	NB / CP	22.41722	77.28389
443	Harda	Timarni	NB / CP	22.46889	77.18361
444	Harda	Timarni	NB / CP	22.37056	77.21389
445	Harda	Timarni	NB / CP	22.40083	77.24750
446	Harda	Timarni	NB / CP	22.40167	77.22583
447	Harda	Timarni	NB / CP	22.39778	77.29333
448	Harda	Timarni	NB / CP	22.31528	77.30000
449	Harda	Timarni	Percolation Tank	21.99572	77.17019
450	Harda	Timarni	Percolation Tank	22.00806	77.18111
451	Harda	Timarni	Percolation Tank	21.95500	77.25667
452	Harda	Timarni	Percolation Tank	21.91696	77.22407
453	Harda	Timarni	Percolation Tank	21.92461	77.23478
454	Harda	Timarni	Percolation Tank	21.94359	77.24687
455	Harda	Timarni	Percolation Tank	22.04000	77.35611
456	Harda	Timarni	Percolation Tank	22.03361	77.35972
457	Harda	Timarni	Percolation Tank	22.04806	77.35639
458	Harda	Timarni	Percolation Tank	22.06092	77.37508
459	Harda	Timarni	Percolation Tank	22.08833	77.37694
460	Harda	Timarni	Percolation Tank	22.12105	77.38564
461	Harda	Timarni	Percolation Tank	22.10500	77.39000
462	Harda	Timarni	Percolation Tank	22.08361	77.26417
463	Harda	Timarni	Percolation Tank	22.08280	77.24409
464	Harda	Timarni	Percolation Tank	22.00664	77.16610
465	Harda	Timarni	Percolation Tank	22.25556	77.16333
466	Harda	Timarni	Percolation Tank	22.12694	77.41972
467	Harda	Timarni	Percolation Tank	22.09009	77.43290
468	Harda	Timarni	Percolation Tank	22.14702	77.40347
469	Harda	Timarni	Percolation Tank	22.16444	77.36778
470	Harda	Timarni	Percolation Tank	22.18083	77.28056
471	Harda	Timarni	Percolation Tank	22.21972	77.27222

S.No	Dist	Block	Internvention	Lat	long
472	Harda	Timarni	Percolation Tank	22.29056	77.25667
473	Harda	Timarni	Percolation Tank	22.30250	77.23417
474	Harda	Timarni	Percolation Tank	22.31667	77.20556
475	Harda	Timarni	Percolation Tank	22.34250	77.20111
476	Harda	Timarni	Percolation Tank	22.54444	77.20083
477	Harda	Timarni	Percolation Tank	22.55722	77.14750
478	Harda	Timarni	Percolation Tank	22.40722	77.20444
479	Harda	Timarni	Percolation Tank	22.39750	77.30000
480	Harda	Timarni	Percolation Tank	22.36333	77.17556
481	Harda	Timarni	Percolation Tank	22.35917	77.23083

7. Conclusion and Recommendation

On the basis of NAQUIM studied in the area, the following conclusions are drawn. The studied area occupies an area of 3330 Sq. Km. The district is divided into Six Tehsils such as Harda, Handia, Timarni, Rehatgaon, Khirkiya, Sirali and three development Blocks, namely Harda, Timarni and Khirkiya Blocks.

The slope is generally steep at the foothills of Satpura but moderate to gentle towards Narmada River. The land surface attains a maximum altitude of 734 m above mean sea level at Kaoti (77^0 19'30": $22^0$03'00"), and minimum altitude of 240 m above mean sea level at confluence of Machak river with the Narmada.

A large number of north westerly flowing tributaries originating from the Satpura join the Narmada River along the left bank. The area is mainly drained by Narmada River and its tributaries - namely Ganjal River, Ajnal River, Sukninadi, Midkulnadi, Dedranadi, Machaknadi, Syaninadi and Kalimachak River.

Harda district is underlain by various geological formations, forming different types of aquifers in the area. Main geological; units of the area are Archaean, Vindhyan, Deccan traps and Alluvium.

The pre-monsoon depth to Water levels ranges from a minimum of 2.48 meters below ground level (mbgl) at Bajania in Timarni block to a maximum of 24.51 m bgl at Temagav Timarni block of Harda district. About 16% very shallow water levels up to 2-5m bgl have been recorded in a small patch in part of district. About 50 % of monitoring wells recorded water level in the range of 5-10 m bgl category, spreading in patches and major pockets in the north-western and eastern part of area. About 30% of monitoring wells recorded water level in the depth range

of 10-20 m bgl occurring in broad patches all over the region. Deeper ground water levels ranging >20 m bgl constituting only about 4% of wells in this category

The post-monsoon depth to Water levels ranges from a minimum of 0.1 meters below ground level (mbgl) at Tajpura in Timarni block to a maximum of 18.15 m bgl at TemagavTimarni block of Harda district. About 18% very shallow water levels up to 0-2m bgl have been recorded in a small patch in part of district. About 30 % of monitoring wells recorded water level in the range of 2-5 m bgl category, spreading in patches and major pockets in the north-western and eastern part of area. About 40 % of monitoring wells recorded water level in the depth range of 5-10 m bgl occurring in broad patches all over the region. Deeper ground water levels ranging 10-20 m bgl constituting only about 12% of wells in this category

Dynamic ground water resources of the district have been estimated for base year - 2021-22 on block-wise basis. Out of 333000 ha of geographical area, 270090 ha (81%) is ground water recharge worthy area and 62910 ha (19%) is hilly area. There are three numbers of assessment units in the district which fall under command (29%) and non-command (71%) categories sub units. All blocks of the district are categorized as safe blocks, with highest stage of ground water development of 68.65% in Khirkiya block.

Long term water level trend show declining in the district

Under the prevailing hydrogeological conditions, Aquifer Mapping and Characterization, the following recommendations are made for the development & management of ground water.

As per the Management plan prepared under NAQUIM of all the Block of Harda District, a total number of 212 Percolation Tanks, 741 Recharge Shafts/Tube wells and 847 Nala Bunds/Check Dams and 213 Village pond / Cement Plugs have been proposed and these structures can recharge 159 MCM.

Financial expenditure is expected to be Rs 168.45 Crores in Harda District for sustainable development and management of ground water resources.

The number of artificial recharge structure and financial estimation has been proposed based on the CGWB Master plan 2020. It may be differ from the field condition as well as changes in dynamic Ground water resources.

After the implemented of project interventions in the report, the stage of ground water extraction is expected to increase by 8 % i.e. from 36 % to 42 % for the Harda district and additional area for the irrigation will be266.55Sq.Km

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