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

केंद्रीय भूमि जल बोर्ड
Central Ground Water Board

NAQUIM 2.0

उज्जैन औद्योगिक क्षेत्र की राष्ट्रीय जलभृत मानचित्रण और प्रबंधन योजना
मध्य प्रदेश

NATIONAL AQUIFER MAPPING AND MANAGEMENT PLAN OF UJJAIN INDUSTRAIL CLUSTER
MADHYA PRADESH

North Central Region
Bhopal 2024

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

सत्यमेव जयते

भारत सरकार
जल शक्ति मंत्रालय
जल संसाधन,
नदी विकास और गंगा संरक्षण विभाग
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Message

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

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

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

(Dr. Sunil Kumar Ambast)

Chairman, CGWB

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ए. के. बिस्वाल
क्षेत्रीय निदेशक
A.K. Biswal
Regional Director

सत्यमेव जयते

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

FOREWARD

The state of Madhya Pradesh is in the process of an accelerated development in the fields of irrigation and industrial activities and ground water occupies a key position in the developmental activities of the state. Although, ground water is a replenishable resource, over extraction of ground water, recurrent droughts, varied monsoon pattern etc., are leading to situation on which several blocks of the state have been categorized as over exploited to Semi- critical.

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

Under the National Project on Aquifer Mapping 2.0 (NAQUIM 2.0), Central Ground Water Board (CGWB), North Central Region, Bhopal has taken up Industrial Cluster in Ujjain district to prepare the aquifer maps in 1:10000 scale and formulate the focused interventions for aquifer management. Groundwater contamination in industrial areas stems from various sources such as leakage from storage tanks, improper disposal of hazardous materials, and runoff from industrial sites. Chemicals like heavy metals, solvents, and petroleum products seep into the groundwater, posing serious health risks to nearby communities and ecosystems. Contaminated groundwater can lead to long-term health issues including cancer, organ damage, and neurological disorders. This study presents a comprehensive analysis of aquifer mapping in industrial clusters in and around Ujjain City focusing on the delineation of aquifer boundaries, characterization of hydrogeological parameters, recharge and discharge zones and assessment of ground water quality and accordingly suitable management plan.

Geographical area of Ujjain industrial cluster along with its buffer zone is 478sq.km in parts of Ujjain and Ghatiya blocks. The area is mainly occupied by Deccan Trap Basalt. As per the Dynamic Ground Water Resources Assessment Report (2023), both the blocks falls under over-exploited category.

I would like to place on record, my appreciation of the efforts of Mrs. Anakha Ajai, Scientist- C, Sh. Sumanta Kumar Mohanta, Scientist-C, Sh. Pradip Roy, Scientist-B and Sh. Jitendra Kumar, STA (chemical) for carrying out the study in Ujjain industrial cluster. Mrs. Anakha Ajai, Scientist-C deserves immeasurable debt for commendation for carrying extensive exercises and converging into report.

I sincerely hope that this report will serve as a valuable guide for sustainable development of groundwater in Ujjain Industrial Cluster, Madhya Pradesh.

Water is elixir of life

(Ashok Kumar Biswal)
Regional Director

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The authors would like to take an opportunity to thank **Dr. Sunil Kumar Ambast**, Chairman CGWB for providing opportunity and the necessary facilities to carry out this NAQUIM 2.0 study.

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The authors would like to take an opportunity to thank WRD, Govt. of Madhya Pradesh and Ujjain for their support and co-operation throughout the study.

EXECUTIVE SUMMARY

Groundwater pollution in industrial clusters presents a complex environmental challenge with far-reaching implications. Industrial activities within these clusters often involve the use and disposal of various chemicals and contaminants, leading to the potential contamination of groundwater sources. Factors contributing to groundwater pollution in industrial clusters include improper waste management practices, accidental spills, leaks from storage tanks, and inadequate treatment of wastewater. The proximity of multiple industrial facilities within a cluster exacerbates the risk of groundwater pollution due to the cumulative impact of pollutant discharge. Contaminants such as heavy metals, solvents, pesticides, and petroleum hydrocarbons can infiltrate groundwater, posing serious risks to human health and the environment.

The consequences of groundwater pollution in industrial clusters extend beyond immediate health hazards. Contaminated groundwater can spread over large areas, affecting drinking water supplies, agricultural productivity, and ecosystem health. Additionally, it can lead to long-term remediation challenges and economic burdens for affected communities and industries.

The aim of the groundwater contamination study in the industrial cluster is to evaluate the extent and sources of groundwater pollution resulting from industrial activities. The study focuses on identifying contaminants, their concentrations, and their pathways into the groundwater system. It assesses the impact of contamination on water quality, public health, and ecosystem sustainability. By mapping contamination sources and analyzing their effects, the study aims to develop effective strategies for contamination mitigation and groundwater management. The ultimate objective is to safeguard water resources, protect community health, and promote sustainable industrial practices.

Central Ground Water Board, North Central Region, Bhopal taken up NAQUIM 2.0 studies in an area of 478sq.km in and around industrial cluster, Ujjain City under AAP 2023-24. Total geographical area of the district is 6130.23 km^2 and recharge worthy area is 5939.33 km^2. Methodologies used for the study includes direct and in-direct methods of groundwater exploration, establishment of key observation wells, periodic water level monitoring, both manual as well as DWLR, farmer's feedback, water sample collection and analysis, analysis and presentation of data using different software etc.

The study provides a thorough examination of aquifer mapping, with particular attention to crop productivity, ground water level and quality scenarios, hydrogeological parameter characterisation, and aquifer boundary delineation. The report goes into great depth about artificial recharge plans, which include building agricultural ponds and recharge shafts, potential quality management interventions in urban areas, and extra steps for sustainable groundwater management.

AT A GLANCE

Si No	Item Description	Results/Remarks
1	Area Covered	478 km^2
2	Priority Type	Industrial Cluster
3	Study Area	Ujjain Industrial Cluster
4	Latitude	23.089N to 23.374N
5	Longitude	75.697E to 75.933E
6	Block	Ujjain, Ghatiya
7	District	Ujjain
8	Categorization as per GWRA 2023	Over-exploited
9	Principle Aquifer	Deccan Trap Basalt
10	Major Aquifer	Weathered/Vesicular/Fractured Basalt
11	Yield of Aquifer	0.2 to 7 lps
12	Average Water Level (mbgl)	Pre-Monsoon 1.2 to 17 Post monsoon 0.6 to 25
13	Population (Urban)	628800
14	Demand (For Domestic)	184.43 MLD (135 LPCD)
15	Surface Water Supply (For Domestic)	122.78 MLD (Gambhir dam, Undasa Tank and Dhabla Rehwari (Sahabkheri) Irrigation Tank
16	Demand (For Industrial)	573 KLD
17	GAP in Supply	60.64 MLD (For Urban Area). Rural population is dependent on GW for drinking/domestic and Irrigation other than villages in vicinity to the river.
18	Issues Identified	• Contamination f surface water and groundwater sources • Low groundwater sustainability and deeper water levels • Issues related to crop health and yield
19	Management strategies	• Water quality management interventions • Artificial recharge plan

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CHAPTER-1
INTRODUCTION

1.1 Background of the study

Aquifer mapping studies under NAQUIM was carried out in the year 2015-16 in Ujjain district by Central Groundwater Board. It covered the preparation of block wise aquifer maps and management plan for sustainable groundwater management in 1:50000 scale. In 2018, Central Ground Water Board, Bhopal in convergence with MGNERGA, taken up implementation of management plan under NAQUIM in water stressed Badnagar block of Ujjain district under which, approximately 400 artificial recharge structures were constructed during 2018-2022. As per the inferences from NAQUIM and GWRA 2023, the district falls in Malwa area of Madhya Pradesh which is covered by deccan trap basalts. Despite being potential aquifers, the district is reeling under water scarcity due to over exploitation of groundwater resources for irrigation. Further, the developing industrial areas in Ujjain and Nagda areas are causing groundwater contamination (Special Study in Nagda industrial area by CGWB, 2021).

Hon'ble National Green Tribunal Central Zonal Bench New Delhi, in the matter of original application no. 673/2018 (News Item Published in the "Hindu" authored by Shri Jacob Koshy titled" More river stretches are now critically polluted: CPCB") passed an order on 20/09/2018 regarding the rejuvenation of 72km polluted stretch of Kanh river which is originating in Indore and flowing through major urban and industrial area in Sanwer of Indore district. The same river is merging with Kshipra river in Ujjain district at Triveni Ghat near Pipaliyaragho village in Ujjain block resulting in contamination of Kshipra River. Most of the villages in downstream of Kshipra river is dependent on the river for irrigation.

Kumbh Mela is a program occurs one in 12 years at Ujjain Mahakaleshwar Temple in which approx 10 million pilgrims visits the temple during months of April, May. Before the Simhastha in 2016, Water Resources Department, Ujjain as directed by the district administration, prepared a DPR for diverting Khan River through underground pipes to avoid mixing of contaminated water Kshipra river in 17km urban stretch from Pipaliyaragho to Sulyakhedi. The project viz. Khan diversion Canal Project **Fig-1.1(a) & 1.1 (b)** was executed in 2016. The upcoming Simhastha is in 2028 and a feasible action plan for tackling contamination of Kshipra river is not formulated yet which is adversely affecting both the agricultural revenue and pilgrimage tourism in the district. In additional to these issues, an industrial area with 4.5Sq.km **(Fig-1.1-a)** is located at Vikram Udyogpuri Ujjain. As the area is located near the urban habitat of Ujjain city, which causes it more difficult to manage the waste water treatment generated in the area. As the industrial effluent and sewage water from urban area are potential sources of groundwater contamination, the urban habitat is 100% dependent on Surface water supply for drinking and domestic purposes. The major source of water supply are (Gambhir dam, Undasa Tank and Dhabla Rehwari (Sahabkheri) Irrigation Tank and total water supply is 122.78 MLD. As reported by the Ujjain municipal corporation under Amrit-2.0, the total demand – supply gap in Ujjain urban area is 60.64 MLD.

This is matter of great concern raised state administration during State Ground Water Co-ordination Committee meeting held on **19.04.2023** and **17.08.2023** under the chairmanship of Additional chief Secretary, Water Resource Department, Government of Madhya Pradesh. Accordingly, CGWB Bhopal took up a study to analyze the groundwater level, groundwater quality and groundwater resource conditions in the industrial cluster of Ujjain and prepare a feasible management plan for better groundwater management .

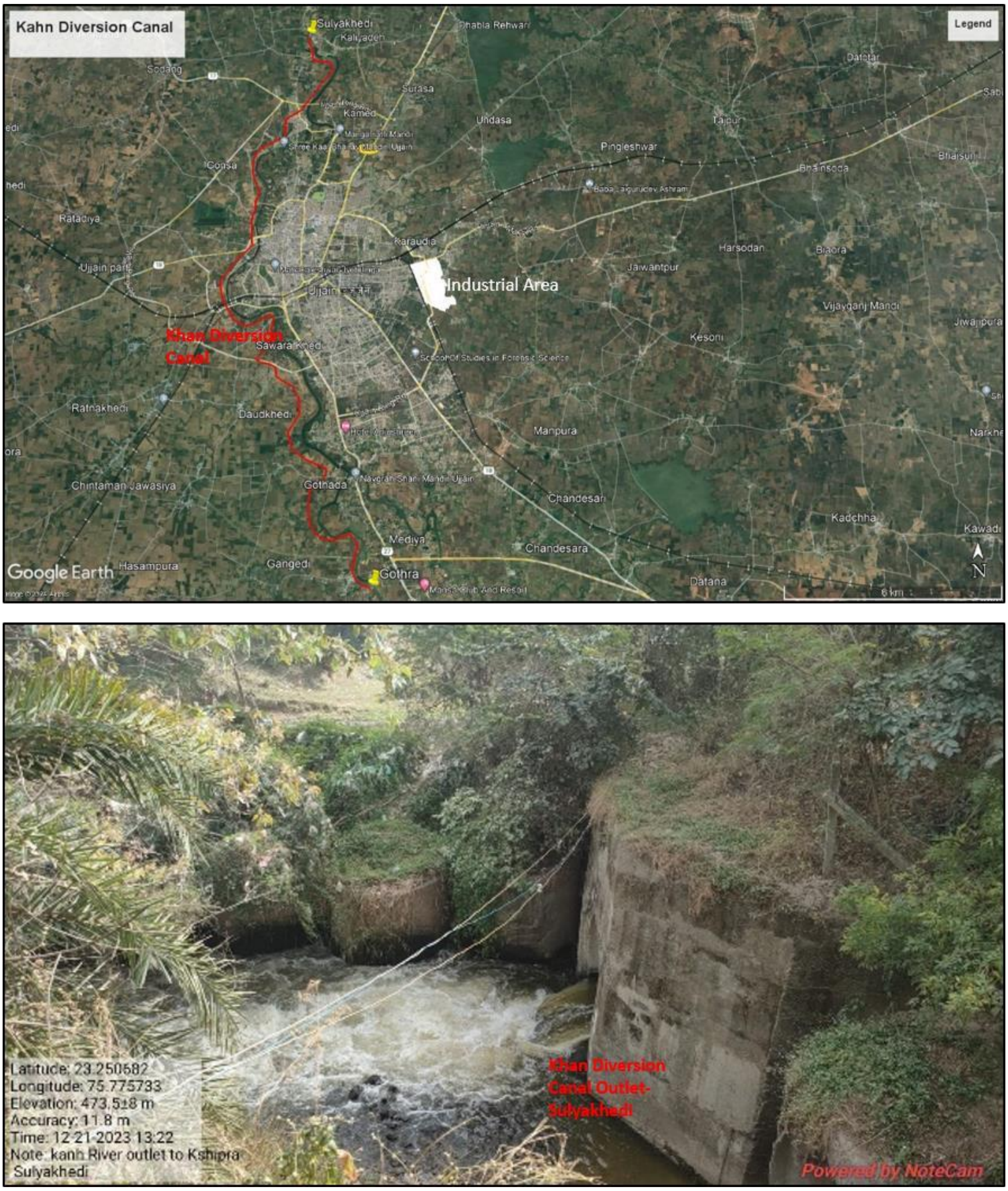


Fig. 1.1-(a): Khan Diversion Canal

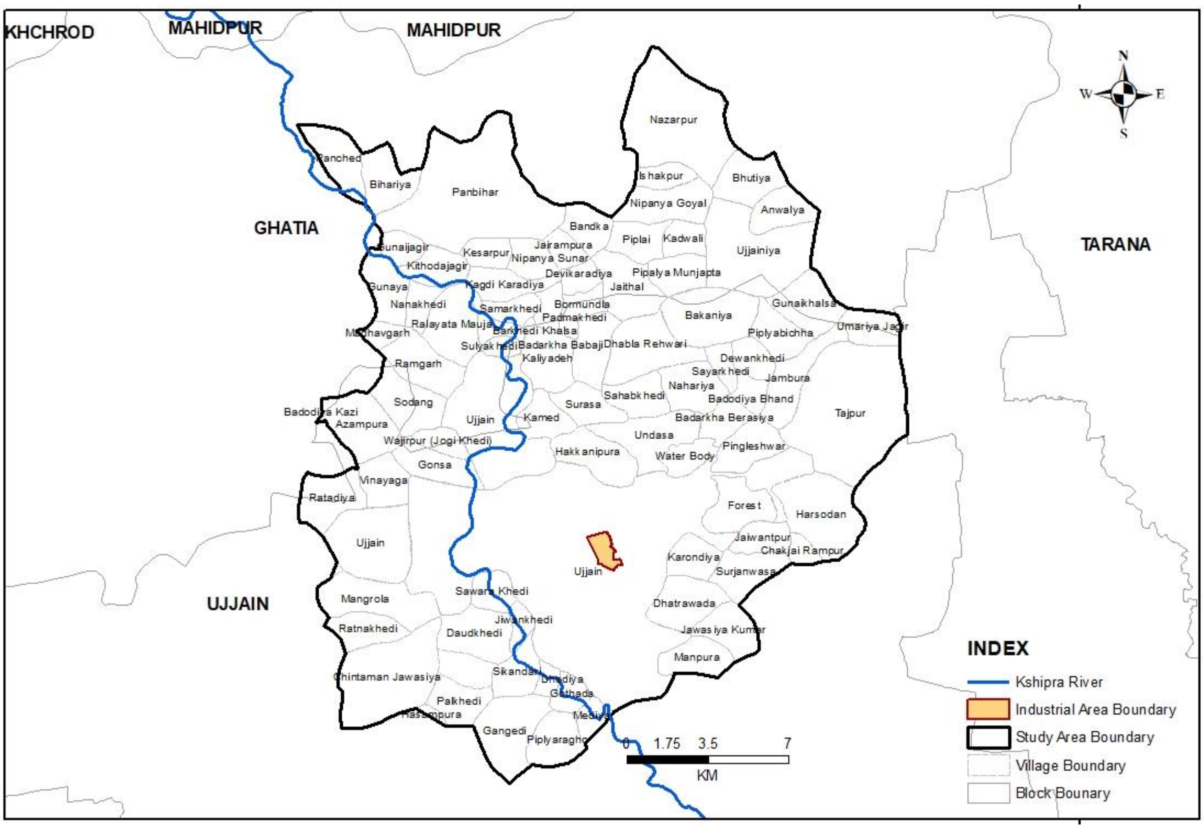


Fig. 1.1-(b): Khan Diversion Canal with industrial area

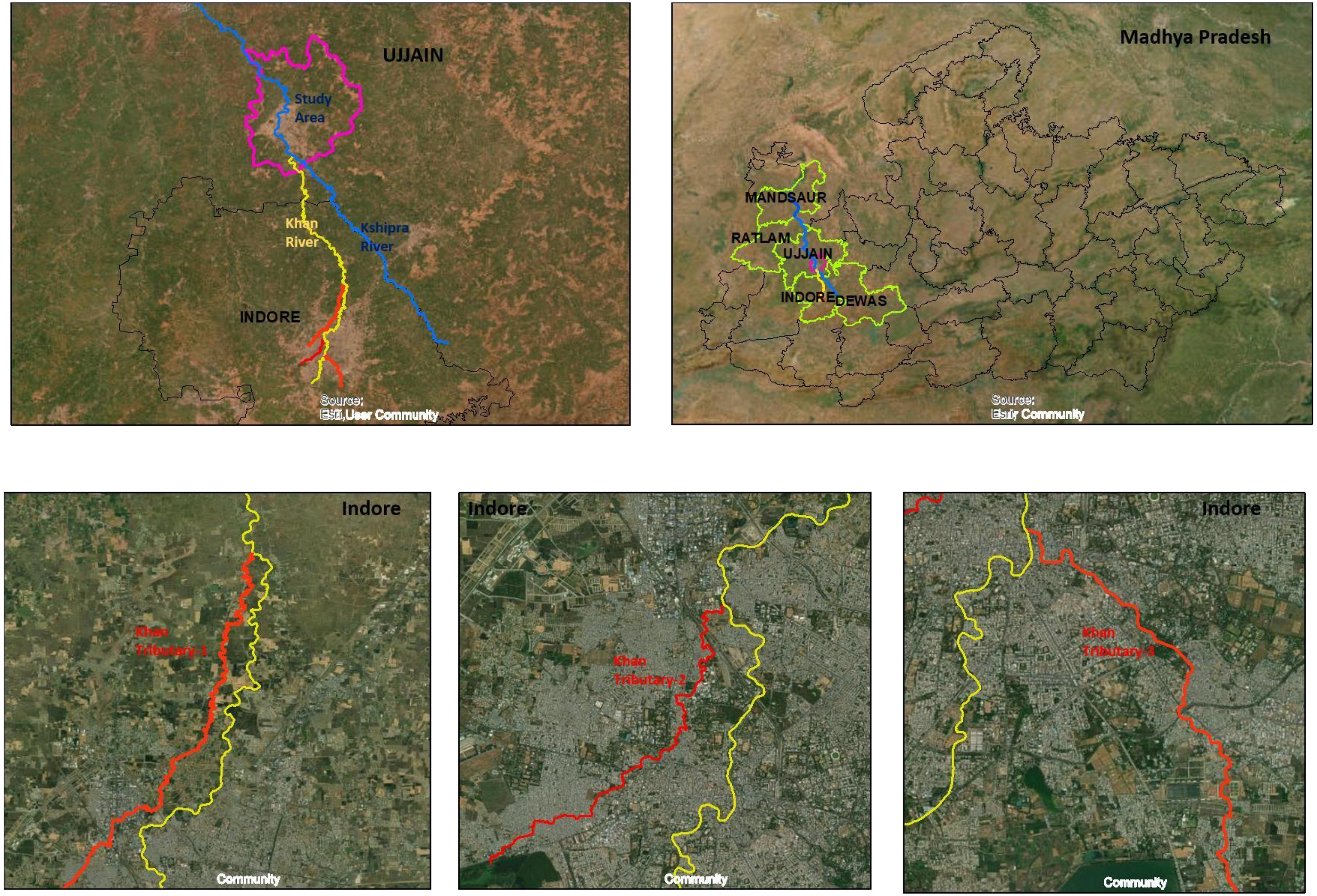


Fig. 1.1 -(c): Khan River and its meeting point at Ujjain district

1.2 Priority Type

Ujjain is a rapidly developing district in Madhya Pradesh with 3 industrial clusters marked by Madhya Pradesh Industrial Development Corporation (MPIDC) viz. Tajpur, Vikram Udyogpuri and Nagda industrial Area. The present study area **{Fig- 1.1(b)}** covers Tajpur and Vikram Udyogpuri which are falling in Ghatiya and Ujjain blocks of the district, categorized as an industrial cluster of which area specific issue have to be identified and area specific groundwater management strategies are to be formulated. The major types of industries can be broadly classified into food products and food processing industries, Pharmaceuticals, Steel and Engineering Products, Petroleum products and explosives manufacturing **(Annexure-1).** Each of these industries produces effluents which can contaminate the aquifers surrounding them.

1.3 Objectives of the study

- Generated data **(Flow chart-fig-1.3)** to prepare lithological models, cross sections etc. in large scale for deciphering aquifer disposition.
- Observation of aquifer wise groundwater levels and influence of existing industries to the ground water.
- Detailed analysis of groundwater quality in the area and proposing possible remedies.

- Determine the primary sources and pathways of groundwater pollutants linked to industrial activities.
- Measure the concentration and distribution of contaminants in the groundwater to evaluate the severity of pollution.
- Analyze the potential impact of groundwater contamination on public health and local ecosystems.
- Propose effective measures to reduce or eliminate contamination, including remediation techniques and changes in industrial practices.

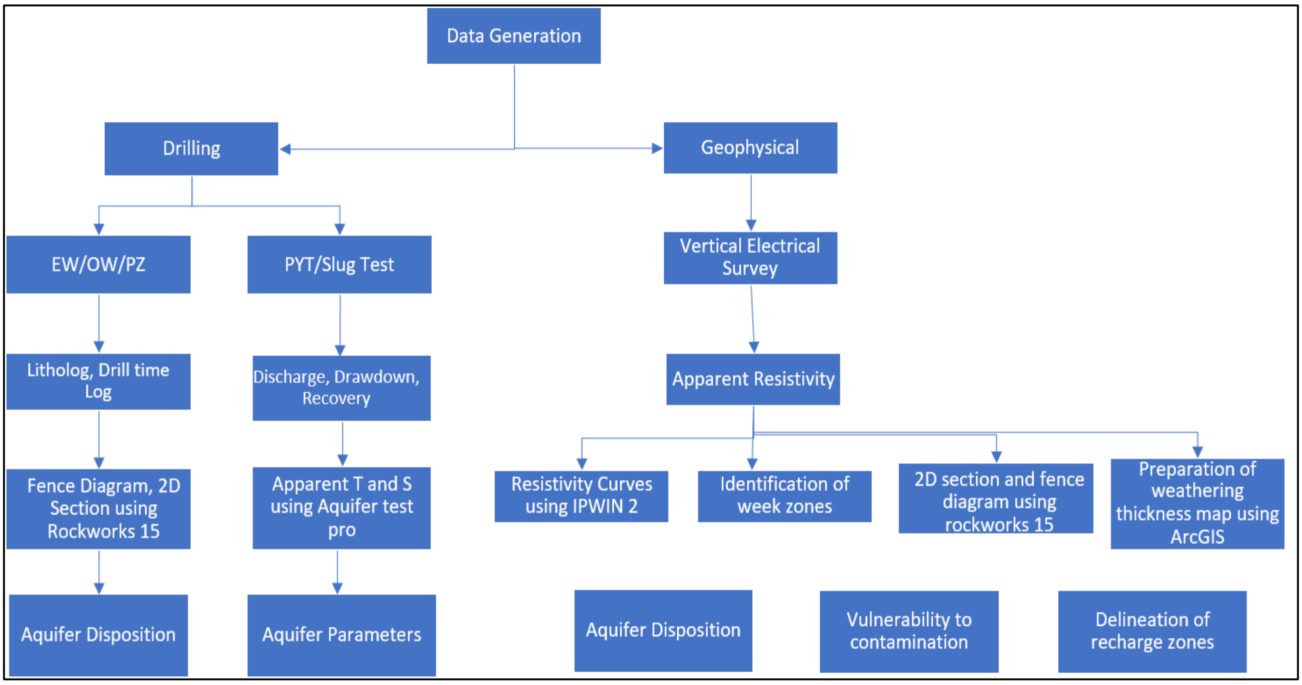


Fig. 1.3: Flow chart showing methodology used in aquifer disposition.

CHAPTER -2
STUDY AREA

2.1 Location, Extend and Accessibility

Ujjain district is situated towards the western part of Madhya Pradesh extending between the North latitudes 22° 49' 4″ and 23° 45' 10″ and between the East longitudes 75° 08' 27″ and 76° 15' 17″. The Survey of India Topo Sheet No. 46M (parts of 46M/3,7.8.10.11.12.14,15,16) 46N (parts of 46N/5) and 55A (parts of 55A/2,3,4) projects Ujjain district. Total geographical area of the district is 6130.23 sq.km and recharge worthy area is 5939.33 sq.km.

The study area benefits from excellent connectivity via air, rail, and road networks. Ujjain, served by the Western Railway zone with station code UJN, ensures convenient rail access. The nearest airport, Devi Ahilyabai Holkar Airport in Indore, located just 53 km away, further enhances transportation accessibility.

The present study area is a part of Ujjain district which includes the industrial cluster and a part of urban area in Ghatia and Ujjain blocks of the district with an area extend 478 sq.km extending between the North latitudes 23° 6′ 30″ and 23° 19′ 40’’ and East longitudes 75°42′34″ and 75° 55′ 37″. Location map of the study area is given in **Fig-2.1.**

The Ujjain Industrial Cluster is a significant industrial zone contributing to the region's economic development. It encompasses a diverse range of industries, including manufacturing, textiles, and chemicals. This cluster is strategically positioned to leverage Ujjain's infrastructure and connectivity, facilitating robust industrial activity and growth.

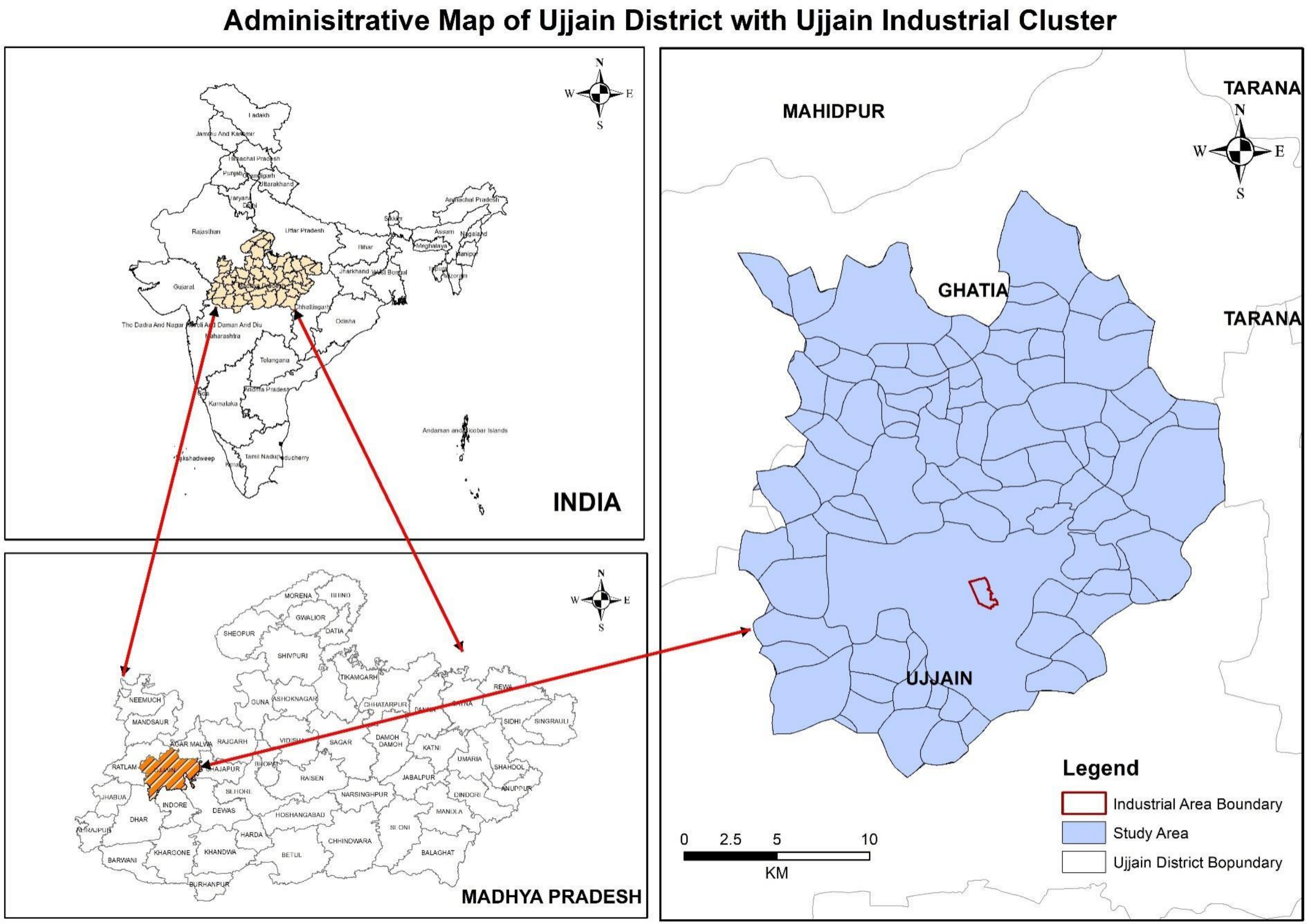


Fig. 2.1: Study area of Ujjain district with Ujjain Industrial Cluster

2.2 Land use, Irrigation and cropping pattern

2.2.1 Land use

The land use pattern in the study area reflects a diverse mix of agricultural, urban, and industrial activities, shaped by its geographical, economic, and socio-cultural characteristics.

Agriculture area 401.02 km^2 which is 83.9 % of total area dominates the land use with a significant portion of the land dedicated to various crops. The fertile alluvial soil and favourable climatic conditions support the cultivation of crops such as wheat, rice, onion, garlic, pulses and oilseeds. The majority of rural land is utilized for farming, making agriculture the backbone of the district's economy and a major source of livelihood for its residents.

Build up area 66.62 km^2 which was increased about 25% since 2017 is primarily concentrated around the city of Ujjain, which is a significant urban centre and a major pilgrimage site. The city's land use includes residential, commercial, and institutional areas. The urban sprawl is characterized by expanding infrastructure, including roads, markets, and public services, to accommodate the growing population and economic activities.

Industrial land use is relatively limited but growing in the Ujjain Industrial Cluster. This area hosts various industries, including manufacturing and processing units. The industrial growth is geared towards leveraging the region's strategic location and resources to boost economic development.

Water bodies and **wastelands** also feature in the land use pattern, although their proportion is relatively minor compared to agricultural and urban areas. Sustainable management of these resources is essential for maintaining environmental health and supporting the district's overall land use balance.

Land use pattern, cropping pattern, change in land use pattern over the years etc are given in **Table-2.2.1, and Fig. 2.2.1-a and 2.2.1-b.**

Table No.2.2.1 Land use and cropping pattern of Ujjain industrial cluster

SI NO.	TYPE	AREA IN km^2
1	CROPPED AREA	401.02
2	FALLOW/BARREN/RANGE LAND	2.94
3	BUILT UP AREA	62.12
4	INDUSTRIAL AREA	4.5
5	VEGETATION	0.01
6	WATER BODY	7.44

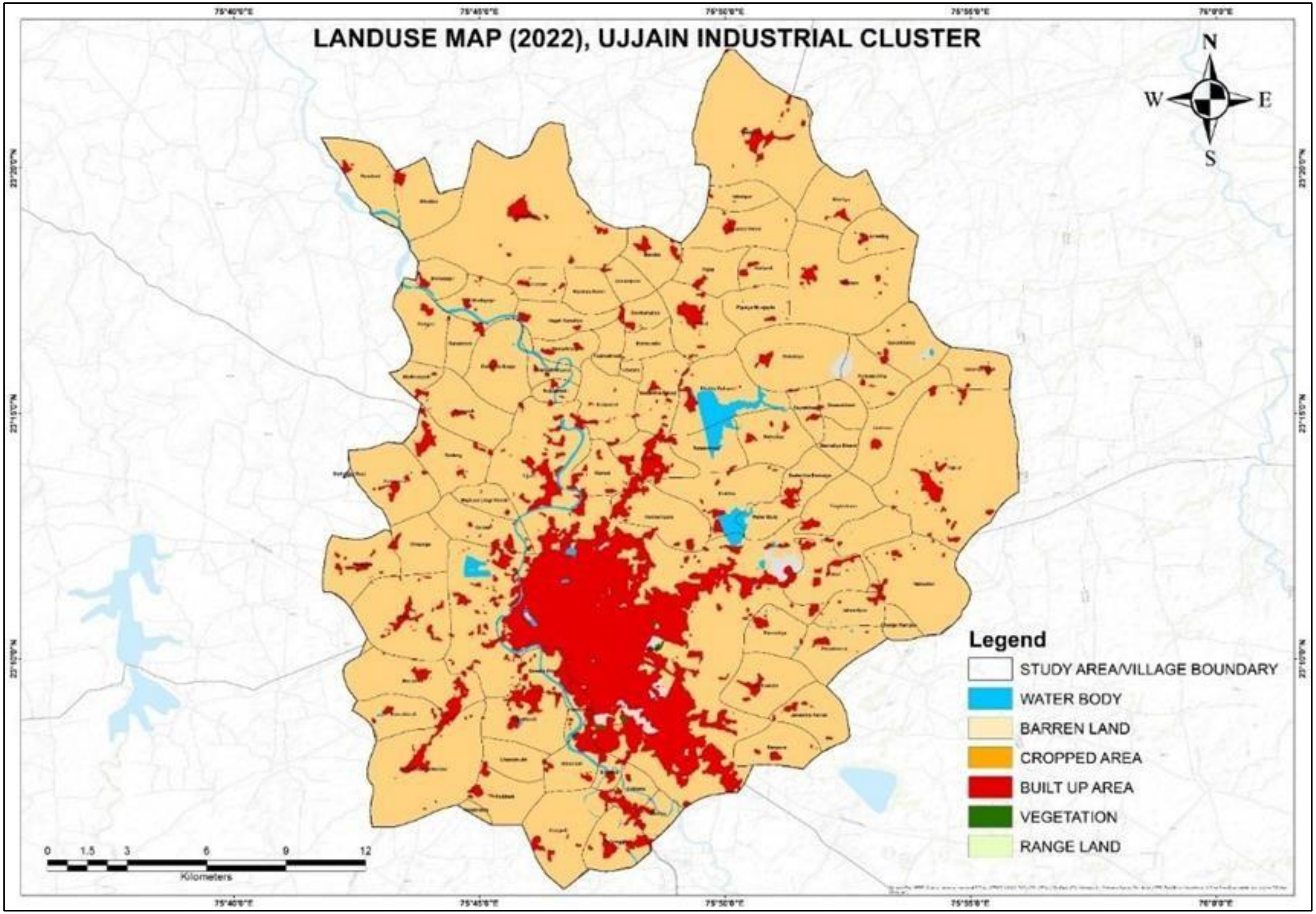
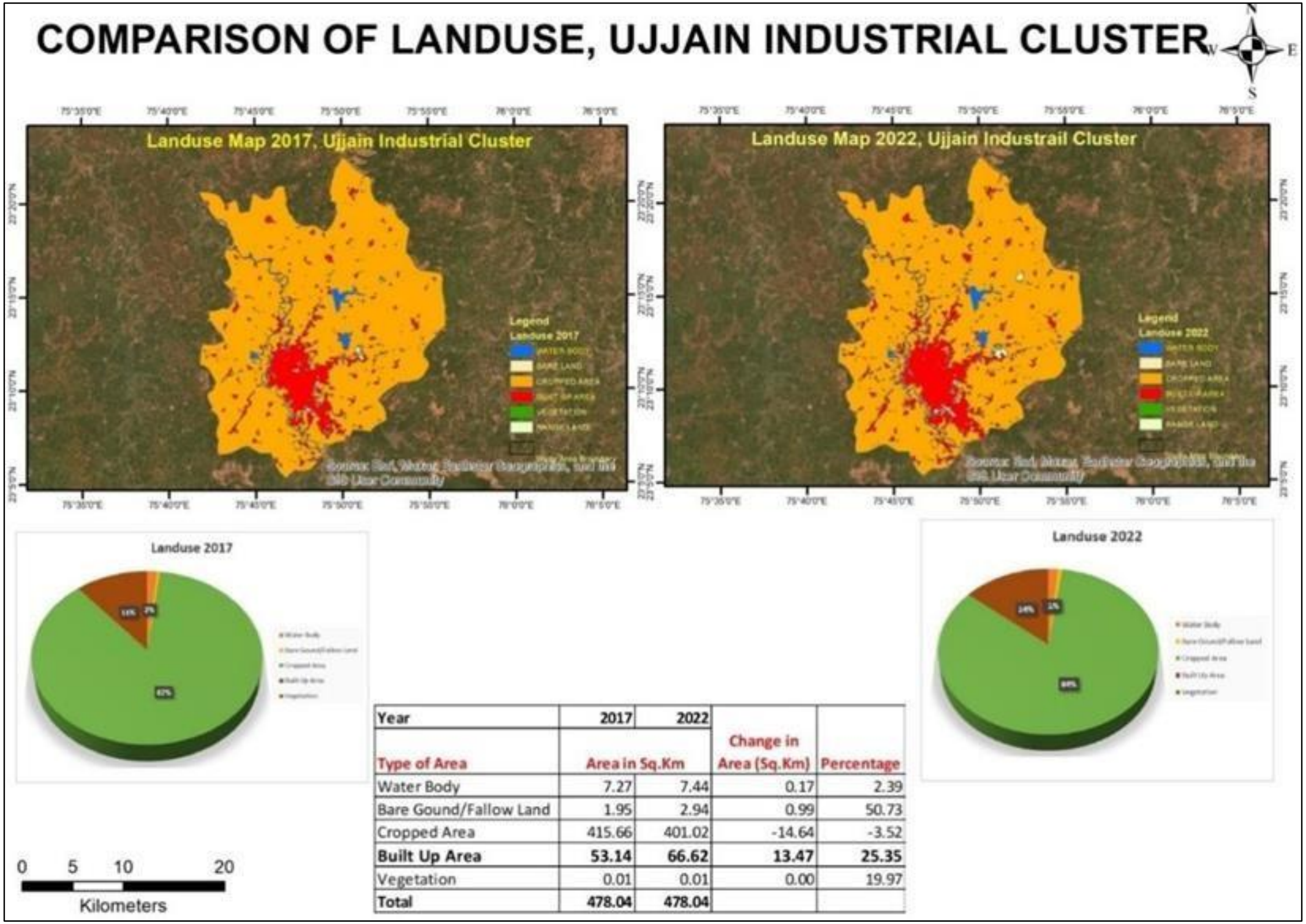


Fig. 2.2.1: (a) LULC Map of Ujjain Industrial Cluster



Year	2017	2022	Change in Area (Sq.Km)	Percentage
Type of Area	Area in Sq.Km			
Water Body	7.27	7.44	0.17	2.39
Bare Gound/Fallow Land	1.95	2.94	0.99	50.73
Cropped Area	415.66	401.02	-14.64	-3.52
Built Up Area	**53.14**	**66.62**	**13.47**	**25.35**
Vegetation	0.01	0.01	0.00	19.97
Total	**478.04**	**478.04**		

Fig. 2.2.1: (b) Change in LULC of Ujjain Industrial Cluster

2.2.2 Irrigation

The irrigation facilities in Ujjain district are moderate. Surface water irrigation in the district is in the developing stage. Groundwater is the main source of irrigation in the district.

2.2.3 Agriculture & cropping patterns

Ujjain district is mainly agriculture-based district and its cropping pattern is diversified. The main crops in kharif season are Soybean, Maize, Rice, Jawar & Bajra, Groundnut while in the Rabi crops are Wheat, Gram, Onion, Garlic etc.

2.3 Urban Area, Industry and Mining activities: -

Ujjain urban area covers 194.21 km². As per 2011 census, In total 779,213 people live in urban areas of which males are 399,936 and females are 379,277.

Ujjain Industrial sector also known as DMIC Vikram Udyogpuri Ltd is a joint venture company incorporated between Government of India represented by NICDIT and State Govt. represented by MP Trade and Investment Facilitation Corporation Ltd (MPTRIFAC). The site is located about 14 km from Ujjain and 18 km from Dewas. On the Dewas-Ujjain Road near Narwar Village in Ujjain district and has a total are of 443.79 Ha.

The major types of industries can be broadly classified into food products and food processing industries, Pharmaceuticals, Steel and Engineering Products, Petroleum products and explosives manufacturing.

The mining activities (**Fig-2.3.1**) are located near village- Gunai Khalsa, Tehsil- Ujjain having an area of 7.00 Ha. The mining plan with progressive mine closure plan has been prepared for the proposed production of 200000 cu.m per annum of Stone (Gitti) and submitted to competent authority. The same is being approved by Regional Head Department of Geology & Mining, Madhya Pradesh Indore, vide its letter No. 468/M. plan/Na. Kra./2022, dated 24.03.2022.

Fig. 2.3.1: Showing the mining activities in the study area

2.4 Climate and Rainfall

Ujjain has a humid subtropical climate with mild dry winters, hot summer and humid monsoon season. Average annual maximum temperature is 32.50C and average annual minimum temp is 17.40C. Mean maximum temperature of hottest months which is May is 40.50C and mean maximum temperature of coldest month January is 26.4 0C and mean minimum temperature of coldest month is 8.8 0C. Ever recorded maximum temperature was 460C on 22th May 2010 and ever recorded minimum temperature was 0.00C on 22nd Jan 1962. Average annual rainfall is 94.2 cm and average annual rainy days are 43. Mean monthly highest rainfall observed in august is 29.3 cm and mean monthly lowest rainfall observed in April is 0.4cm. Ever recorded heaviest rainfall in 24 hrs is 30.1 cm on 10th august 2006. Rainfall during south west monsoon season is about 91% of annual rainfall. Values of relative humidity are about 70% to 90% in the morning and 42 to 76% in the afternoon during the south west monsoon season. During the southwest monsoon season the skies are generally overclouded to overcast. In the post monsoon season and latter part of summer clouding is moderate. Rest of the year skies are clear or lightly clouded. During summer season occasional thunderstorms occur and rain during southwest monsoon season often associated with winter. Wind speed highest during the southwest monsoon season and it ranges from 6.8kmph to 12.4kmph. during the winter season wind speed varies between 3.7kmph to 4.5kmph. Rainfall during south west monsoon season of three consecutive years (2021, 2022 and 2023) are shown in figure 1. A spatiotemporal variability is observed in the rainfall. Ghatia block received more rainfall as compared to Ujjain Block in the Year 2021 however, in the next two respective years its in opposite (figure 1). Seasonal variability in rainfall of the Year 2023 is shown in **Fig 2.4.1**. In both the blocks rainfall variability is more in august months (cv 2.92 Ghatia and 3.63 Ujjain) and less in the months of July (cv 1.52 Ghatia and 1.92 Ujjain). This write up is prepared on the basis of India Meteorological Department data and report. The rainfall data is depicted in **Fig 2.4.1.**

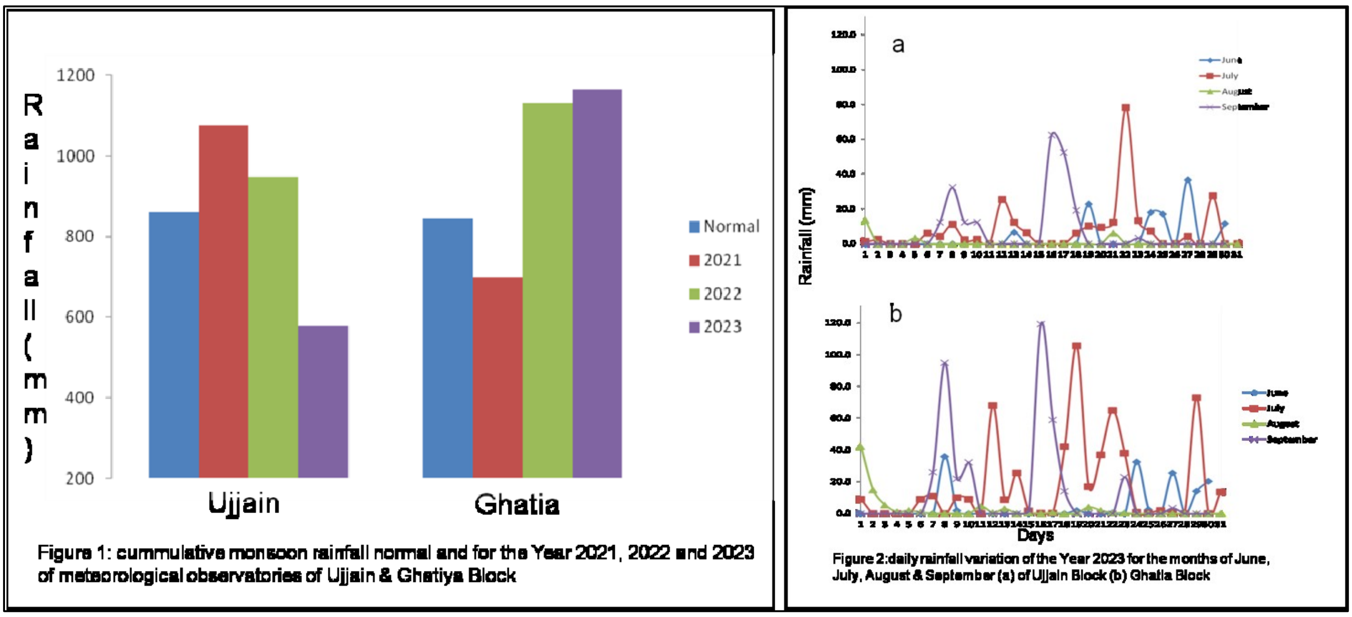


Fig. 2.4.1: Showing the Rainfall Graphs

2.5 Geology

Deccan Trap basaltic rock occupies the entire study area. The different flows of basaltic rock are mostly of “Aa” type but pahoehoe and intermediate type are also present. The soft amygdaloidal varieties usually occupy the flanks and valley floors. Geodes with chalcedony, zeolites, agate and calcite are found in amygdaloidal trap. At time basalts are porphyritic and exhibits lath shaped phenocrysts of feldspar. The traps are invariably jointed. Vertical and inclined joints are also present. The trends of major joints are approximately NW-SE and NE-SW. The low knolls, elongated mounds erected ridges as seen from Marooda to Kanchankheri via Khachrod around Gopalpur, Dhanoria to Nagpura (Mahidpur block) appear to be formed by dykes.Weathering of basalt in initial stage has given rise to pale brown fragmented material with admixture of brownish yellow or pale yellow soil but with intensive weathering yellowish brown and black cotton soil. Usually the “Red bole” and vesicular basalt are prone to weathering and give rise extensive black cotton soil. These black cotton soil vary in thickness from a few centimetres to as much as 60 to 90 centimetres and are normally underlain with “Kankar”.The various flows of basalts are at times inter bedded with fossiliferous inter-trappean. At places alluvium is found in the valley and stream course of Kshipra and Chambal Rivers. Geological Survey of India has mapped these lava flows are presented in **Table.2.5.1.** Geological map of the study area is given in **Fig. 2.5.1**

Table.2.5.1: Elevation of basaltic lava Flows in Ujjain district

Flow No.	Elevation above mean sea level	Thickness of flow (m)	Occurrence and characteristic
5	534.84	-	Top weathered and under lying by red bole. Exposed near Barra Dhoulagiri, Umaria etc. Weathered zeolotic zone act as an aquifer.
4	503.0-534.84	31.84	Flow 4-cover maximum area of the district. It is amygdaloidal in nature and filled with secondary Minerals and at bottom of this flow shows columnar joints.
3	457.73-483.0	25.27	Characterized by weathered vesicular basalt, vesicle filled with zeolites and calcite. Shows spheroidal weathering and are found as scattered hills exposed along Kshipra. Joints form the aquifer.
2	430.0-457.0	27.00	Big boulder on its top and boulder are vesicular and jointed. This flow has very promising water bearing zone, seen on Tarana-Ghosla road and hillock near tukrol village.
1	450-423	27.00	Out crops exposed at elevation between 480 and 423 m a.m.s.l and weathered to the extent of 10 m.

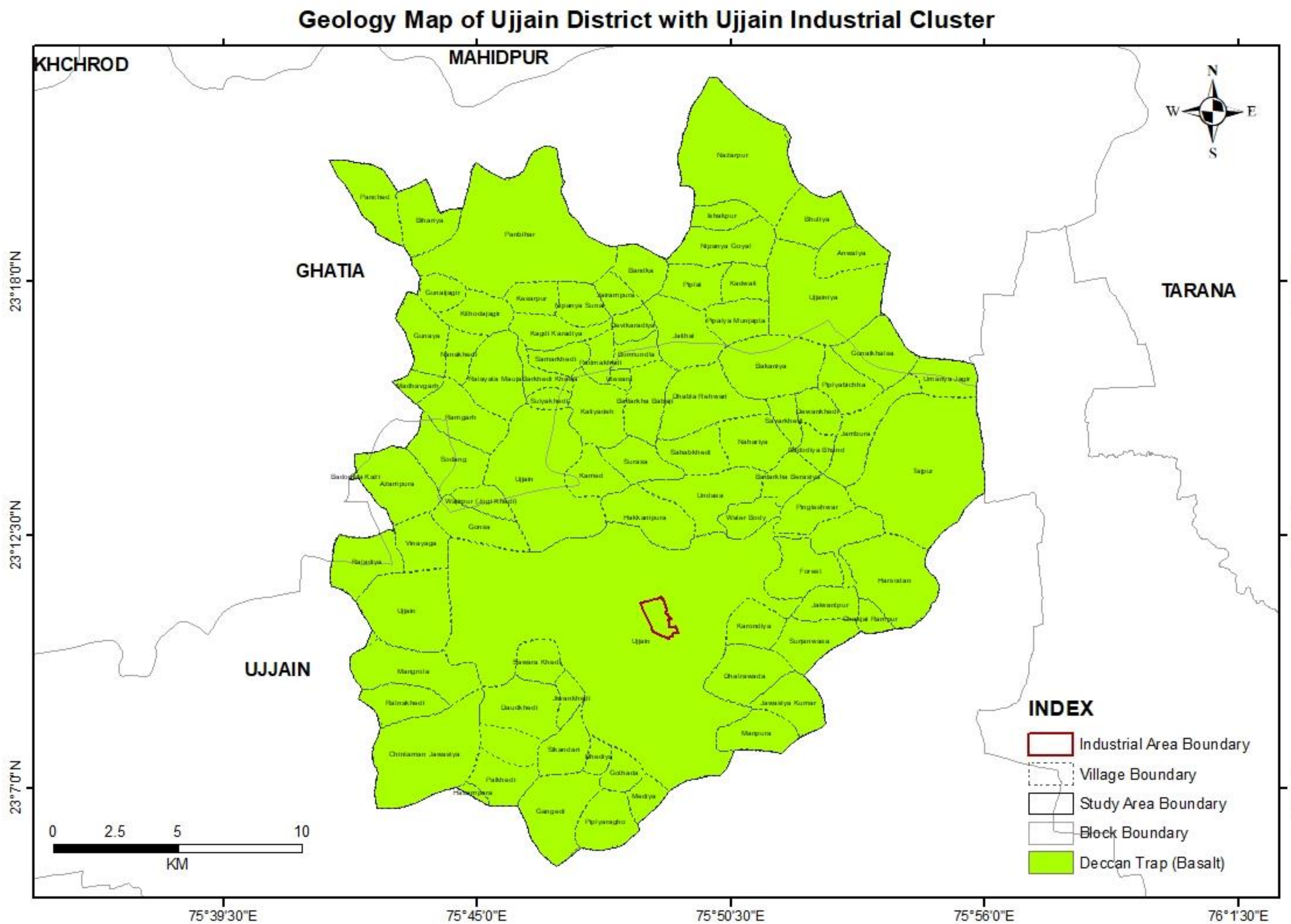


Fig. 2.5.1: Geological Map of Ujjain Industrial Cluster

2.6 GEOMORPHOLOGY, DEM AND DRAINAGE

2.6.1 Geomorphology

The geomorphology **(Fig- 2.6.1)** of the Ujjain Industrial Cluster in Madhya Pradesh is characterized by a diverse and dynamic landscape shaped by a combination of geological processes and human activities. Understanding the geomorphology of this region is crucial for assessing its suitability for industrial development, managing environmental impacts, and implementing effective land-use planning.

Geological Setting:

The Ujjain Industrial Cluster is situated in the Malwa Plateau region, which is part of the larger Deccan Plateau undergone extensive geological processes, including weathering and erosion, leading to the development of various landforms.

Geomorphological Features:

Alluvial Plains: The Ujjain Industrial Cluster is situated on a significant alluvial plain formed by sediment deposition from the Kshipra River. These plains are flat and fertile, providing an ideal setting for both agriculture and industrial infrastructure.

Pediments and Piedmonts: The region features pediments, which are gently sloping rock surfaces found at the base of hills or ridges. These landforms are often covered with a thin layer of sediment and are important for understanding erosion patterns and soil distribution.

Ridge and Valley Systems: The landscape includes low ridges and valleys, which influence local drainage patterns and the distribution of land use. These features are remnants of ancient geomorphological processes and contribute to the region's natural variability.

Human Impact:

Human activities, including industrialization, urbanization, and agriculture, have significantly altered the natural geomorphological features of the Ujjain Industrial Cluster. The construction of infrastructure such as roads, buildings, and industrial facilities has led to changes in landforms, soil erosion, and alterations in drainage patterns. Additionally, industrial activities have the potential to impact soil and water quality, necessitating careful management and remediation efforts.

Environmental Considerations:

Understanding the geomorphology of the Ujjain Industrial Cluster is essential for mitigating environmental impacts associated with industrial activities. Effective land-use planning and environmental management practices are crucial to address issues such as soil erosion, water contamination, and the preservation of natural landforms.

In summary, the geomorphology of the Ujjain Industrial Cluster is characterized by its flat to gently undulating terrain, alluvial plains, and underlying Precambrian rock formations. The landscape’s suitability for industrial development is influenced by its geological and topographical features, which must be carefully managed to balance development with environmental sustainability.

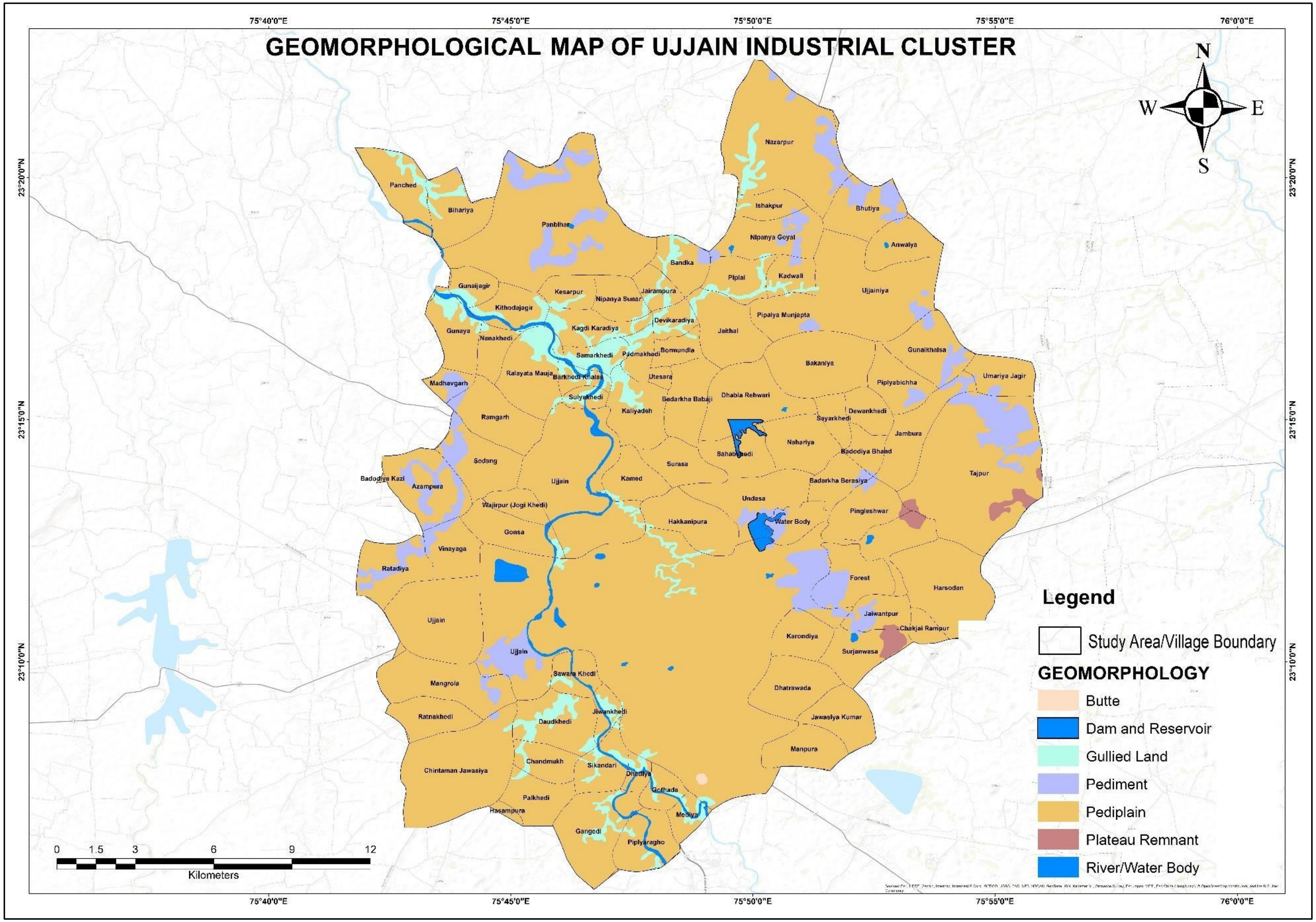


Fig. 2.6.1: Geomorphological map of Ujjain Industrial Cluster

2.6.2 Digital Elevation Model (DEM)

The Digital Elevation Model (DEM) **(Fig-2.6.2)** of the Ujjain Industrial Cluster provides a detailed, high-resolution representation of the area's topography. The DEM is created using remote sensing technologies, such as LiDAR (Light Detection and Ranging) or satellite imagery, to capture elevation data with precise accuracy.

Features of the DEM:

1. **Elevation Details:** The DEM reveals the variation in elevation across the industrial cluster, highlighting the gentle slope of the alluvial plains and the subtle topographical changes. This information is crucial for infrastructure planning, as it helps in determining the most suitable locations for construction and identifying areas prone to flooding or erosion.

2. **Hydrogeological Analysis:** By analysing the DEM, planners can understand the natural drainage patterns and potential water flow paths. This is important for managing water resources, mitigating flood risks, and designing effective drainage systems to prevent waterlogging in industrial areas.

3. **Environmental Impact Assessment:** The DEM assists in evaluating the potential environmental impacts of industrial activities. It helps in identifying sensitive areas that may be affected by construction and industrial processes, such as changes in land cover and soil erosion.

Applications and Implications

The topographic and DEM data of the Ujjain Industrial Cluster are essential for several applications:

- **Urban and Industrial Planning:** Accurate elevation data supports the design and development of industrial infrastructure, including roads, factories, and utilities. It aids in optimizing land use and minimizing construction challenges.

- **Flood Risk Management:** Understanding the topography and elevation variations helps in assessing flood risks and designing appropriate flood mitigation measures.

- **Environmental Management:** The DEM provides insights into the potential environmental impacts of industrial activities, allowing for better management of natural resources and mitigation of adverse effects.

In summary, the topography of the Ujjain Industrial Cluster features flat to gently undulating terrain with fertile alluvial plains, while the Digital Elevation Model offers detailed elevation data crucial for planning and managing industrial and environmental aspects. Both tools are integral to ensuring sustainable development and efficient land use in the region.

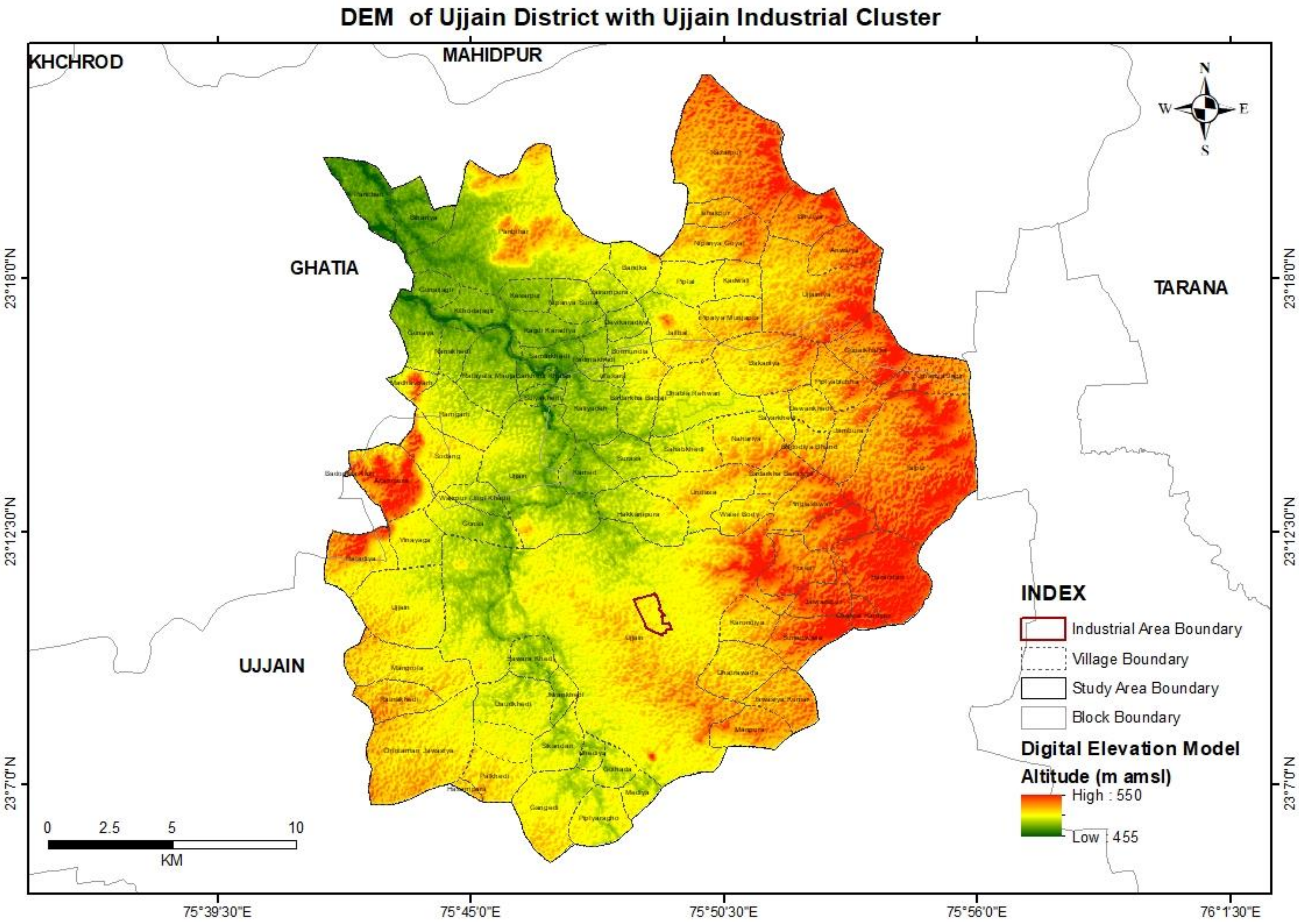


Fig.2.6.2: Digital Elevation Map of Ujjain Industrial Cluster

2.6.3 Drainage: -

The area forms part of Chambal sub basin (Ganga basin). The study area is mainly drained by Kshipra River and its tributaries. Drainage Map of the study area is given in **Fig 2.6.3.** The drainage system of the Ujjain Industrial Cluster, located in Madhya Pradesh, is primarily influenced by its geographical setting and hydrological features. The area's drainage pattern is dominated by the Kshipra River, which is a major river flowing through Ujjain city and significantly affects the regional hydrology.

Major Drainage Features:

Kshipra River: The Kshipra River is the central drainage feature of the Ujjain Industrial Cluster. It originates from the Vindhyan ranges and flows towards the northwest, creating a broad alluvial plain through the Ujjain region. The river plays a crucial role in the regional drainage system by collecting and channeling water from various tributaries and smaller streams. Its flow influences local groundwater recharge and surface water distribution.

Tributaries and Streams: Several minor tributaries and seasonal streams feed into the Kshipra River, contributing to its flow. These smaller watercourses form a network of natural drainage channels that manage runoff and surface water across the industrial cluster. Their patterns are shaped by the region's topography and seasonal rainfall.

Alluvial Plains: The region's alluvial plains, formed by sediment deposition from the Kshipra River and its tributaries, feature relatively flat terrain with gentle slopes. These plains facilitate the flow of surface water towards the river, reducing the likelihood of severe flooding but necessitating effective drainage management to prevent waterlogging, especially in industrial areas.

Man-made Drainage: In response to industrialization and urban development, man-made drainage systems have been implemented to manage storm water runoff and prevent flooding. These systems include drains, culverts, and retention basins designed to direct excess water away from industrial and residential areas.

Hydrological Considerations:

The drainage of the Ujjain Industrial Cluster is crucial for managing water resources, mitigating flood risks, and maintaining environmental health. Effective drainage management is essential to address challenges such as waterlogging, pollution, and the impact of industrial activities on water quality. By integrating natural and engineered drainage solutions, the region can balance industrial development with sustainable water management practices.

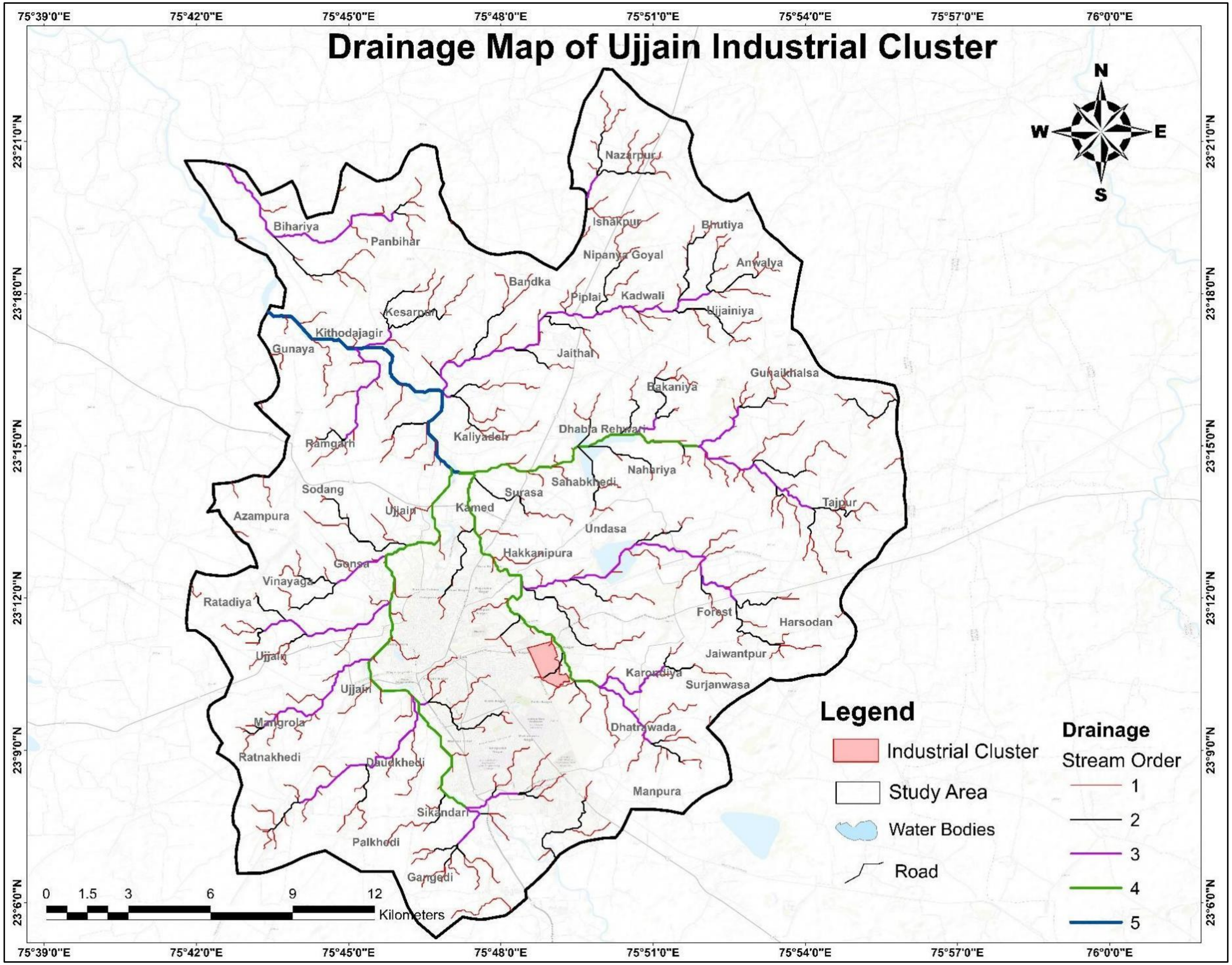


Fig. 2.6.3: Drainage Map of Ujjain Industrial Cluster

2.7 PREVIOUS STUDIES

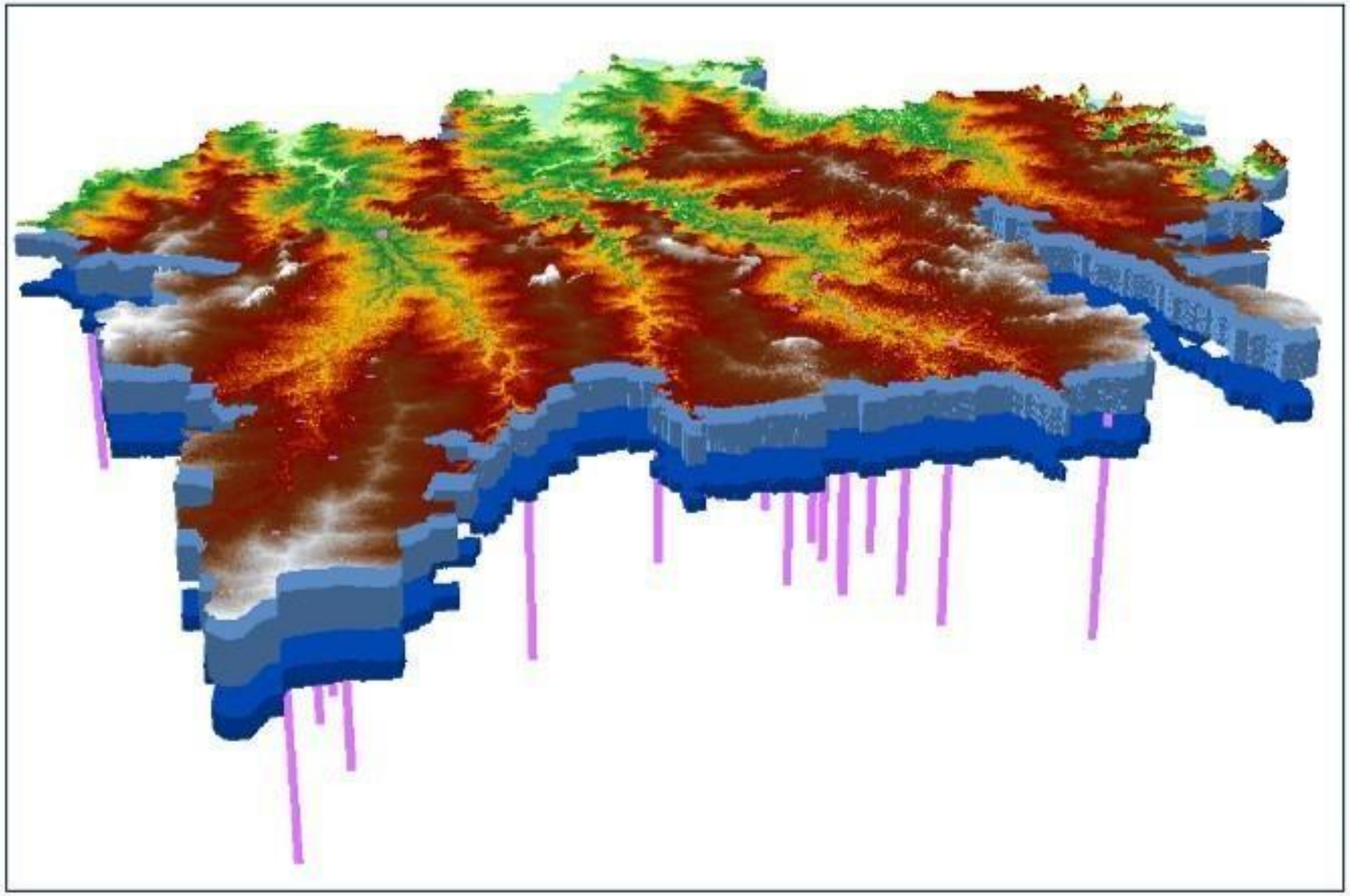
Previous studies and reports in the area are:

1. Reappraisal hydrogeological surveys during 1995-96
2. Aquifer Mapping & Management Plan for Ujjain District, Madhya Pradesh carried out during 2015-16
3. District Groundwater Brochure of Ujjain District
4. Groundwater Resource Assessment using GEC-15 during 2017, 2020 and 2022

FINDINGS OF AQUIFER MAPPING AND MANAGEMENT PROGRAMME-I

As per GWRA 2023, three blocks in the district falls under semi-critical and three blocks under over-exploited category. As a part of aquifer management plan under NAQUIM, additional groundwater recharge is proposed through construction of artificial recharge structures in all blocks in the district for sustainable development of groundwater. As the area is covered with hard rocks, the thickness of the aquifers is limited. The weathered basalt generally from the shallow aquifer, which are extends maximum up to the depth of 30m. The fractured/jointed massive/vesicular basalt forms the deeper aquifer. The disposition of Aquifer-I and Aquifer-II and other geological units can be observed in the 3D model **(fig 2.7.1)** shows that the region is dominantly occupied by basalt.

Aquifer	Shallow	Deep
Formation	Weathered/fractured	Deep fracture & inter flow contact with vesicular basalt
Thickness(m)	3-30	30-200
DTW (mbgl)	7-20 mbgl	11-32
Yield(m3?day)	20-40	65-324



Source- NAQUIM Report (Ujjain District)

Fig.2.7.1: 3D aquifer model, Ujjain district

CHAPTER-3
AQUIFER DISPOSITION

3.1 Objectives

The objectives of aquifer disposition involve

- Delineating the horizontal and vertical extension of aquifer boundaries
- Demarcation of various aquifers
- Determination of Aquifer Characteristics
- Evaluation of vulnerability to contamination
- Delineation of recharge zone

3.2 Methodology

Aquifer disposition can be effectively managed using data compiled from hydrogeological surveys, which include exploratory drilling to obtain direct information on water depth, quality, and quantity. Additionally, pumping tests are conducted to evaluate aquifer properties, such as transmissivity and storage capacity. Geophysical techniques, such as electrical resistivity and seismic refraction, are employed to map subsurface structures and identify water-bearing formations. The methods followed to decipher aquifer disposition in the study area are described as follows:

I. Direct Methods

Under Direct methods, 6 Exploratory Wells, 1 Observation Well and 7 Piezometers were constructed in and around the study area. Locations of the wells are shown in **Fig. 3.2.1** and status of exploration is tabulated as **Table-3.2.1.** Lithologs were prepared from the drill cuttings at every 3m interval to identify depth wise occurrence and thickness of aquifer. Existing Lithologs of wells constructed during NAQUIM studies were also utilized **(Annexure-2).** Using Rockworks 15 software, prepared 2-dimensional aquifer sections and fence diagram to identify the lateral extend and connectivity of each aquifer.

Zone wise discharge from each well the was measured during the time of drilling. Preliminary yield test conducted in 2 exploratory wells and 1 piezometer. Drawdown and recovery and recovery data were plotted using Aquifer test pro software.

II. Indirect Methods

Under Indirect methods, 48 number of vertical electrical survey were carried out in the study area **(Fig-3.2.1).** Data were acquired using Aquameter CRM Auto C. The maximum spreading (AB/2) was 300 m, and the obtained apparent resistivity values were plotted against AB/2 in double logarithmic paper of moduli 62.5 mm. The data were interpreted using the software IPI2WIN. Equivalence of layer parameters were kept in mind during interpretation and final models for each sounding was selected such that it satisfies local hydro- geological conditions. An attempt was made to identify the directions of fractured or weak zones from perpendicular VES in seven locations. These seven locations are selected near two reservoirs (i.e Undasa & Dabla Rehwari) located in the Study Area. The main objective is to find out whether water is being recharged from these two reservoirs.

Table-3.2.1 The details of Exploration wells constructed by CGWB in the study area during 2023-24

SI No.	District	Block	Site	Latitude	Long	Type (EW/OW/PZ)	Total Depth	Discharge (lps)	Water Bearing Zones (mbgl)	Principal Aquifer	Major Aquifer	Aquifer Type (Phreatic/Semiconfined/Confined)
1	Ujjain	Ghatiya	Jairampura Pz	23.29773	75.79798	PZ	100.6	Negligible	7.90-10.90 and 83.30-86.30	Basalt	Vesicular basalt	Phreatic & Confined
2	Ujjain	Ujjain	Ratadiya EW	23.19878	75.71205	EW	202.3	1.38	14.0 -17.0 and 62.0-65.0	Basalt	Weathered Basalt, Fractutred Basalt	Phreatic & Confined
3	Ujjain	Ghatiya	Jaithaltek EW	23.2816	75.82153	EW	202.3	4.5	52.80-55.90 and 101.60 - 104.70	Basalt	Vesicular basalt	Semiconfined & Confined
4	Ujjain	Ghatiya	Jaithaltek OW	23.2816	75.82153	OW	202.3	0.76	71.10-74.20 and 120.0-123.0	Basalt	Vesicular basalt	Semiconfined & Confined
5	Ujjain	Ujjain	WRD Office PZ	23.17544	75.80797	PZ	101.6	0.76	17.0-20.10	Basalt	Weathered Basalt	Phreatic
6	Ujjain	Ujjain	New Thehsil Office (Collectorate) Pz	23.16603	75.80618	PZ	101.6	0.8	49.80-52.80	Basalt	Vesicular Basalt	Semi Confined
7	Ujjain	Ghatiya	Bakaniya EW 1	23.27092	75.84883	EW	110.8	3.3	50.60-53.60	Basalt	Vesicular Basalt	Semi Confined
8	Ujjain	Ghatiya	Bakaniya EW 2	23.27092	75.84883	EW	114	7.8	53.00-59.00	Basalt	Vesicular Basalt	Semi Confined

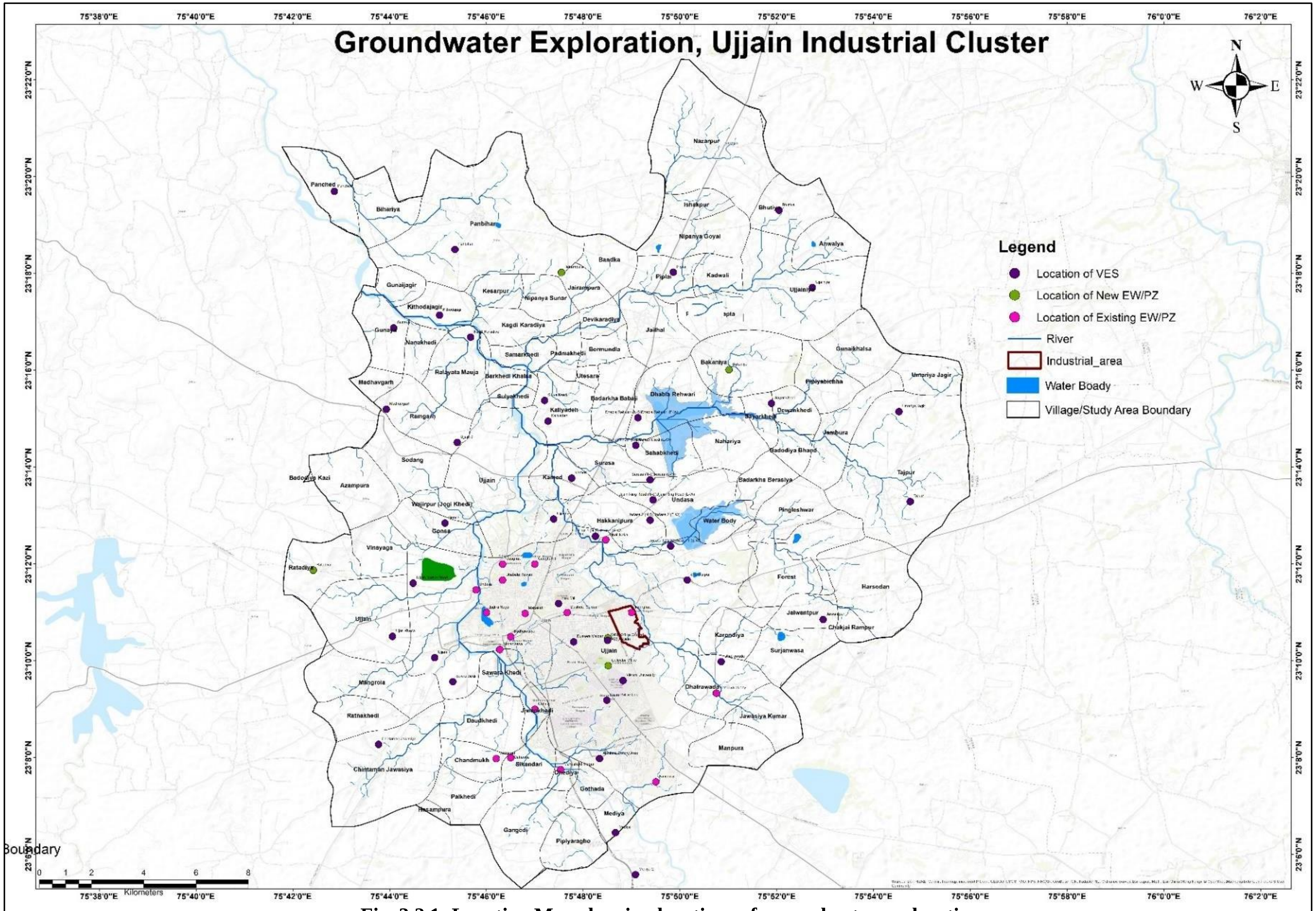


Fig. 3.2.1: Location Map showing locations of groundwater exploration

3.3 Results and Discussion

3.3.1 Ground Water Exploration

Two numbers of 2-Dimensional aquifer sections were prepared to identify the lateral extend and connectivity of aquifers.

2-D Section-1 from Ratadiya-Nimanwasa-Collector Office-Kendriya Colony (N-S) **(Fig 3.3.1-a)** reveals that the first aquifer, weathered basalt occurring at an elevation of 490-500m amsl is present in all four wells and connected to each other. Average thickness of this layer is 5m. The second aquifer is also weathered basalt which is extended from Ratadiya to Kendriya Colony occurring at an elevation of 483m amsl. Similarly vesicular basalt at elevation of 500-493m amsl, 452-444m amsl are connected to each other. These are the two potential aquifers in the area with a lateral extent of approximately 7.2km. Average thickness of massive basalt in between two consecutive flows observed is 15m and total flows identified up to 200m depth is six. Collapsible red bole formation of average thickness is observed at elevation of 471-467m amsl with a lateral extent of approximately 2.5km towards collector office, Sethi Nagar.

2-D Section-2 from Jaithaltek-Ratadiya-Gaughat-Bakaniya (E-W) (**Fig-3.3.1-b)** reveals that there is no significant connectivity in between potential aquifers other than weathered basalt at an elevation of 360m amsl and vesicular basalt at an elevation of 354m amsl. Average thickness of massive basalt observed in between consecutive flows is 17m. Total lateral extent of the aquifer is approximately 6km.

Fence diagram **(Fig 3.3.1-c)** reveals that in the industrial area, there are total seven consecutive basaltic flows in the study area up to a thickness of 200m. Average thickness of each flow is 30m. Occurrence of thin layer of red bole with average thickness of 2.5m is observed at two elevations 471-467m amsl and 435 to 432m amsl. Weathered basalt forms the shallow aquifer which is interconnected with good lateral extend. The deeper aquifers include fractured basalt and vesicular basalt occurring at different elevations exhibit no continuity throughout the study area. These aquifers are pinching out in between flows. Therefore, the chances groundwater contamination is more in shallow aquifer. No significant vertical connectivity is observed in between the aquifers. Therefore, it is inferred that zone of recharge to the deeper aquifers are not present in the study area.

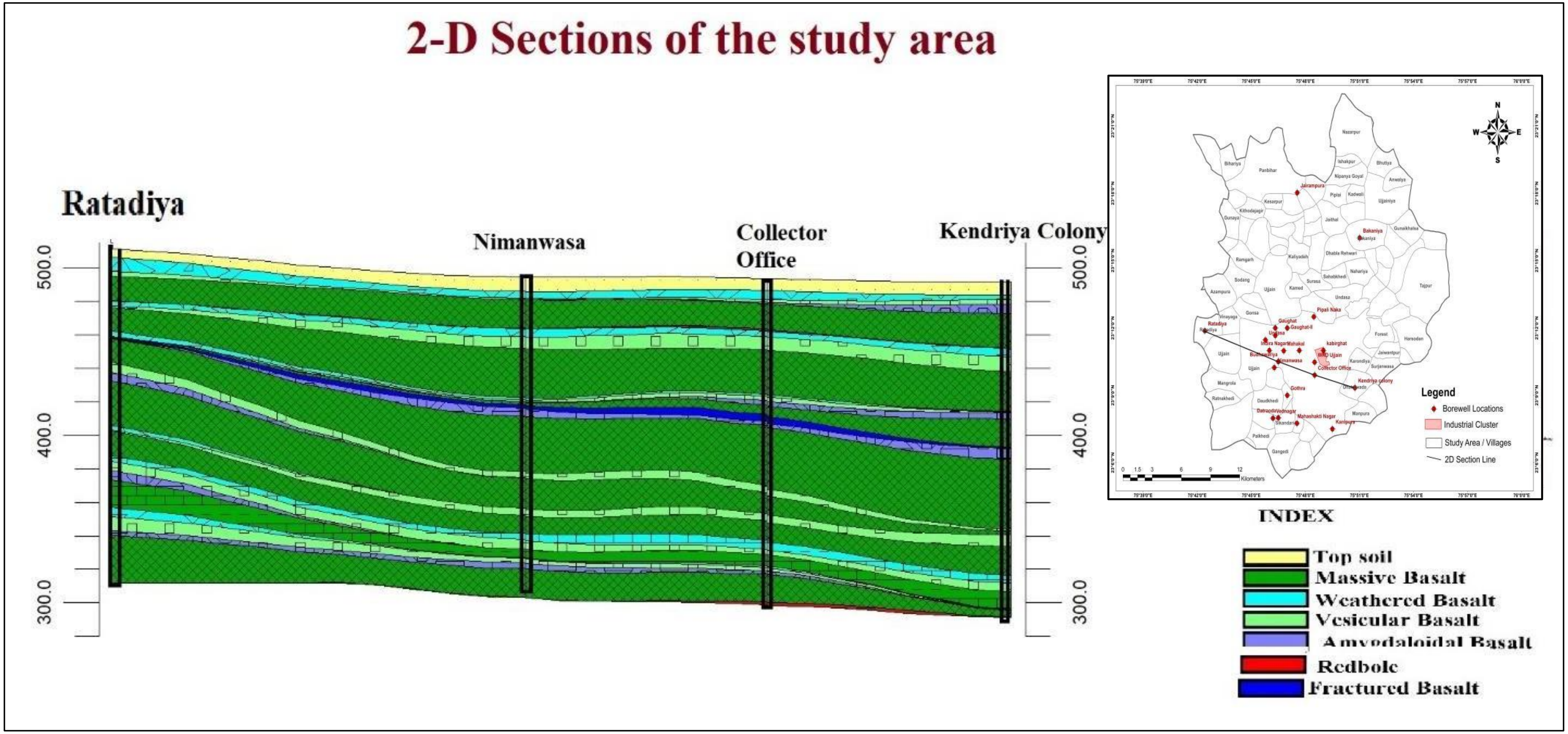


Fig. 3.3.1-a: 2-D Section-1 from Ratadiya-Nimanwasa-Collector Office-Kendriya Colony (N-S)

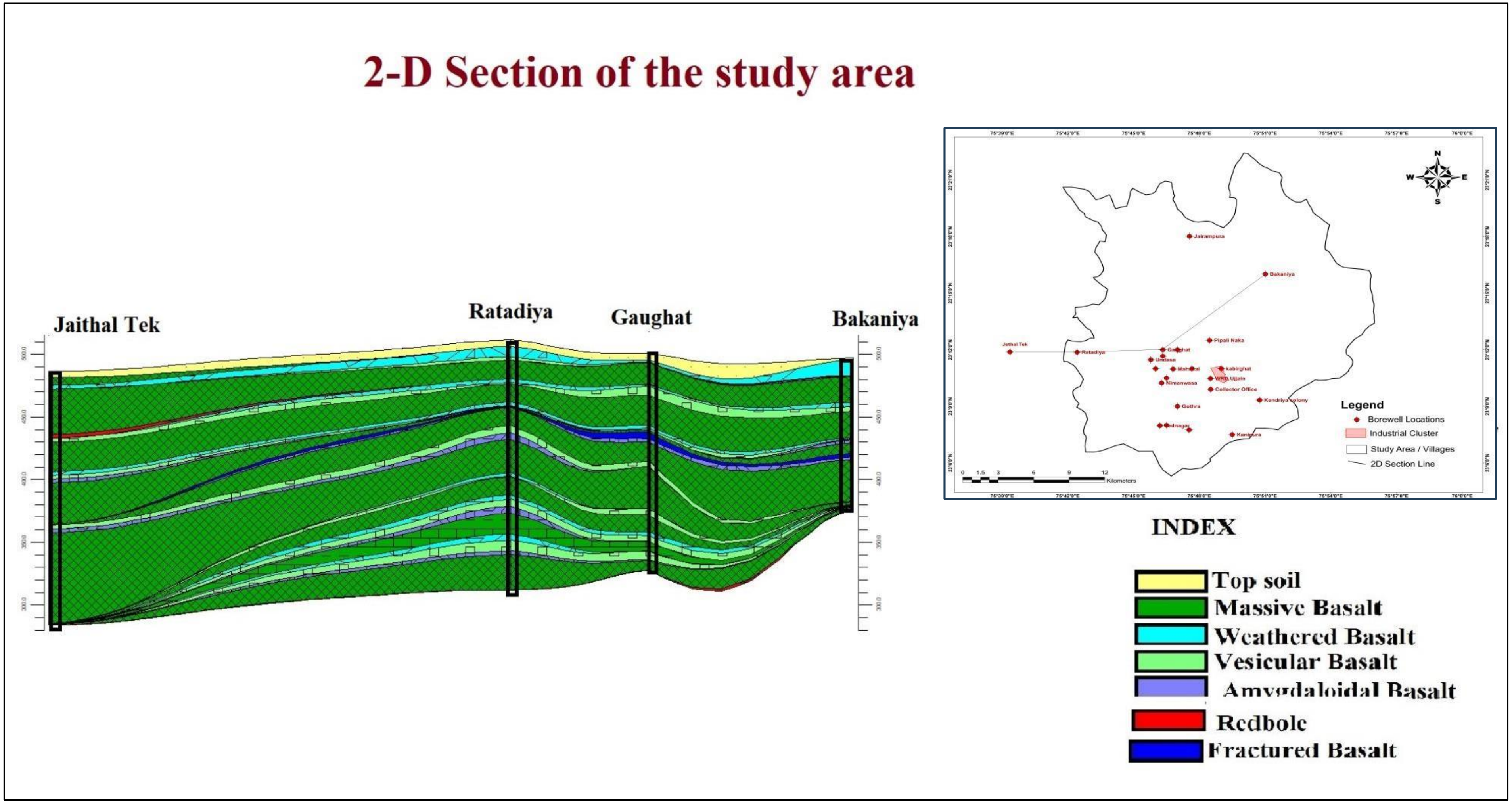


Fig. 3.3.1-b: 2-D Section-2 from Jaithaltek-Ratadiya-Gaughat-Bakaniya (E-W)

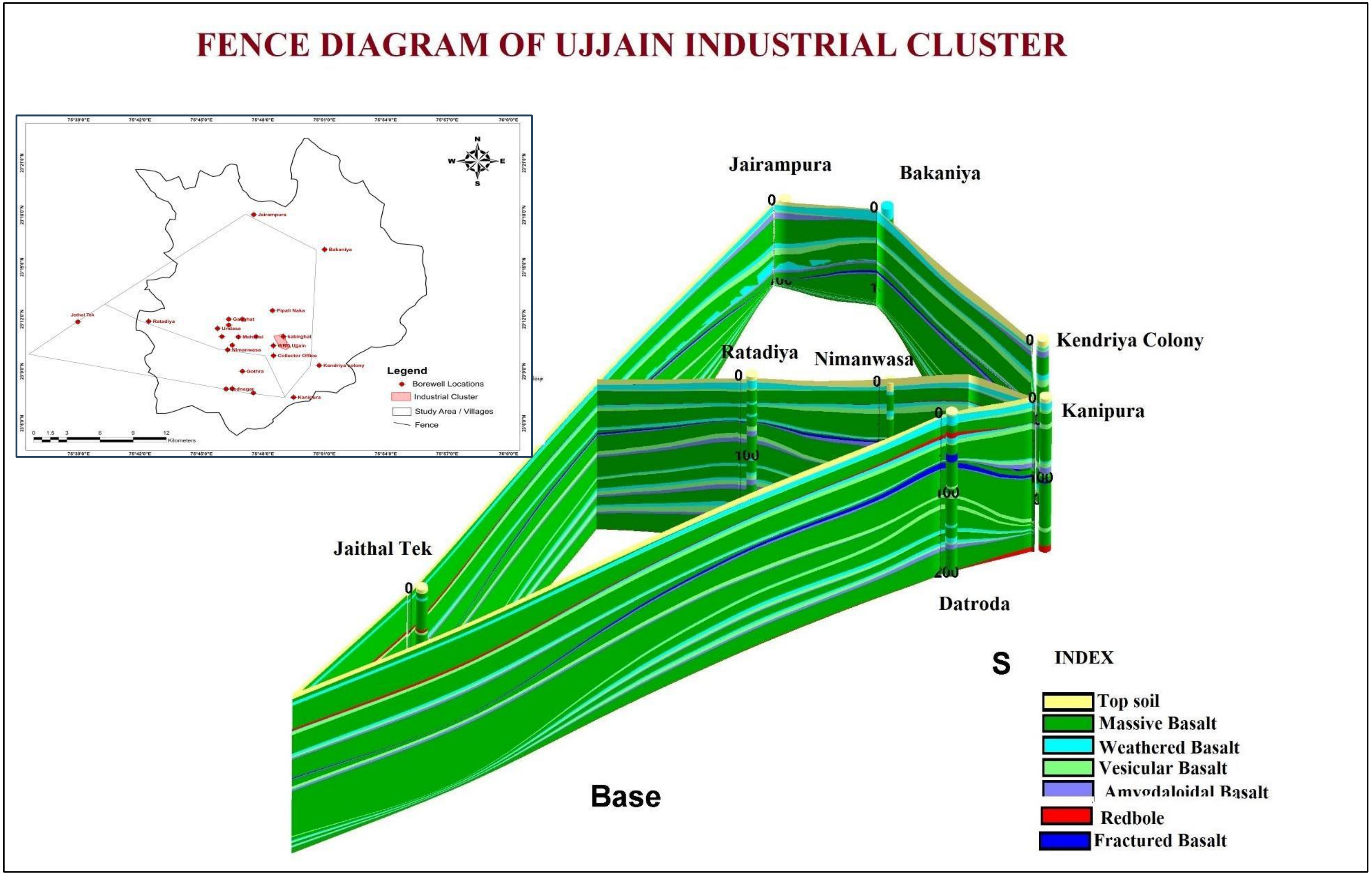


Fig. 3.3.1-c: 3-D Fence Diagram, Ujjain Industrial Cluster

3.3.2 Geophysical Exploration

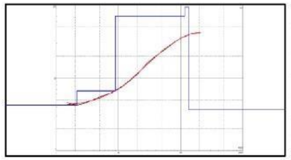
From interpreted results of 48 VES **(Fig-3.3.2a, 3.3.2b, 3.3.2c &3.3.2d)** carried out in & around Ujjain Industrial Cluster area six to seven geo-electrical layers have been identified. The geology of the study area is Deccan Trap Basalt. It comprises of several basaltic flows in geological past forming successive layers of Massive & Vesicular Basalts. The Weathered Basalt, highly Fractured Basalt, Vesicular Basalt have capabilities to form potential aquifers. From interpreted VES results the Top Soil, Weathered Zone, Fractured Zone, Massive Zone and Vesicular Zones have been identified. VES Results revel Aquifer Disposition very well. From the local geological setup >60 ohm-m resistivity is taken as Massive Formation, 10 – 30 ohm-m resistivity is taken as weathered formation, 40 – 60 ohm-m resistivity is taken as fractured formation & low resistivity in between two high resistivities of Massive Formation is taken as Vesicular Formation. From interpreted VES Results Weathering Thickness Map of the study area is prepared. From Weathering Thickness Map, **(Fig-3.3.2-e)** it is seen that the maximum portion of the Study Area falls under weathering thickness 10 – 20 meters. Some patches of area in North – West & South portion of the study area contains weathering thickness 5 – 10 meters. The areas where the weathering thickness are more than 10 m form potential shallow aquifers. The area having weathering thickness more than 10 m is suitable for Artificial Recharge.

Two Cross Sections are prepared from interpreted VES Results named A – A‟‟ Section **(Fig-3.3.2-f)** & B – B‟‟ Section **(Fig- 3.3.2-g)**. A-A‟‟ Section is drawn in North – South Direction & B – B‟‟ Section is drawn in SW – NE Direction.

VES conducted within the Urban Area of Ujjain City show shallow Depth of Investigation due to non-availability of spreading. From Section A – A‟‟ it is clear that the Massive Basalt is thicker and the weathering zone is less thick in Southern portion of the Study Area as compared to Northern portion. The Section B – B‟‟ also shows that in North – East portion the Massive Basalt is thicker compared to South – West portion of the Study Area.

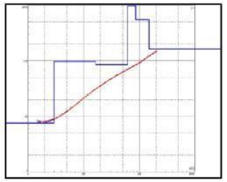
An attempt is made for identifying the direction of fractured / weak zones from perpendicular VES at seven locations **(Fig- 3.3.2-h)**. The locations were taken near two reservoirs located in the study area with the aim to know whether water is being recharged from these two reservoirs or not. From the interpreted results of perpendicular VES directions of weak zones have been identified and shown in the following map.

Perpendicular VES was carried out at seven locations (i.e. VES NO. 16,18,23,22,27,25,19 in **fig. 3.3.2-h**. From interpreted results at six locations weak zones are found except at location 27. From direction of weak zones it can be inferred that water is being recharged to the aquifer or discharged from aquifer based on hydraulic head near Dabla Rehwari Reservoir located in the North but it is not the case for Undasa Reservoir located in the South.



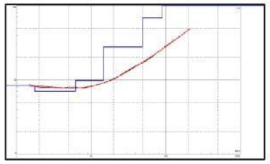
N	ρ	h	d	Alt
1	4.26	2.15	2.15	-2.148
2	6.69	6.86	9	-9.004
3	70.9	107	116	-116.3
4	94.5	20	136	-136.3
5	3.68			

(I) Abhilasha Colony



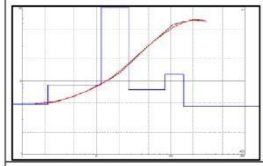
N	ρ	h	d	Alt
1	7.63	2.93	2.93	-2.929
2	97.1	13.4	16.3	-16.29
3	86	46	62.3	-62.29
4	1332	24.7	87	-87.01
5	552	62.2	149	-149.2
6	163			

(II) Bhutiya



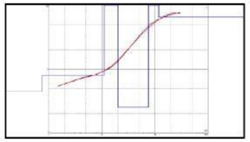
N	ρ	h	d	Alt
1	8.34	1.75	1.75	-1.748
2	7	4.41	6.16	-6.162
3	9.88	8.42	14.6	-14.58
4	27.7	33.8	48.4	-48.41
5	68.3	41.5	89.9	-89.92
6	188			

(III) Chintaman Jawasiya



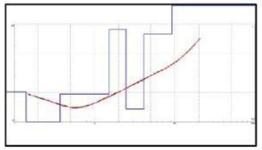
N	ρ	h	d	Alt
1	4.8	2.23	2.23	-2.232
2	8.82	9.37	11.6	-11.6
3	1071	15.6	27.2	-27.16
4	7.65	56.4	83.6	-83.6
5	12.3	65.8	149	-149.4
6	4.5			

(IV) Dabla Rehwari (E – W)



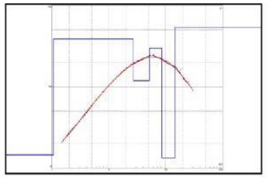
N	ρ	h	d	Alt
1	4.45	0.75	0.75	-0.75
2	8.06	10.3	11.1	-11.09
3	2145	9.01	20.1	-20.11
4	2.54	54.6	74.7	-74.75
5	500	43	118	-117.7
6	65.3			

(V) Dabla Rehwari (N – S)



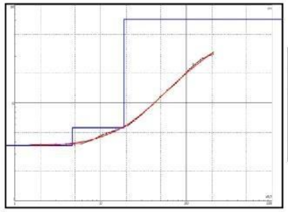
N	ρ	h	d	Alt
1	20.3	1.41	1.41	-1.407
2	9.99	2.33	3.74	-3.738
3	19.3	11.5	15.3	-15.28
4	00.7	9.47	24.0	-24.75
5	13.5	16.4	41.2	-41.17
6	80	50.5	91.6	-91.63
7	3761			

(VI) Dhatrawada



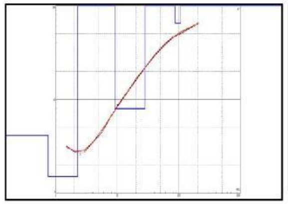
N	ρ	h	d	Alt
1	14.4	1.06	1.06	-1.061
2	383	25.7	26.8	-26.79
3	118	24.6	51.4	-51.39
4	296	33.7	85.1	-85.12
5	13.3	59.7	145	-144.9
6	537			

(VII) Dussera Maidan



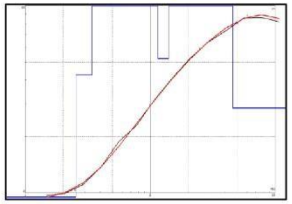
N	ρ	h	d	Alt
1	3.7	4.65	4.65	-4.649
2	5.6	14	18.7	-18.68
3	70.9			

(VIII) Gonsa



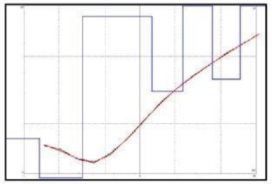
N	ρ	h	d	Alt
1	4.14	0.75	0.75	-0.75
2	1.52	1.52	2.27	-2.267
3	835	6.83	9.1	-9.099
4	7.99	19	28.1	-28.13
5	174	58.5	86.6	-86.59
6	64.9	20.5	107	-107.1
7	721			

(IX) Gunaya



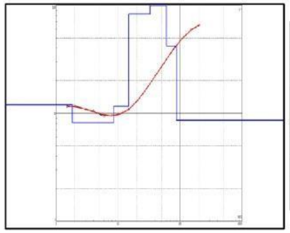
N	ρ	h	d	Alt
1	9.09	2.54	2.54	-2.538
2	42.7	0.876	3.41	-3.413
3	236	8.1	11.5	-11.51
4	52	2.56	14.1	-14.08
5	150	31.8	45.9	-45.89
6	28.4			

(X) Hira Mill



N	ρ	h	d	Alt
1	16.3	1.37	1.37	-1.369
2	5.71	1.84	3.2	-3.205
3	86.4	9.47	12.7	-12.67
4	30.9	10.7	23.4	-23.4
5	186	18.6	42	-42.04
6	36.5	31	73.1	-73.07
7	230			

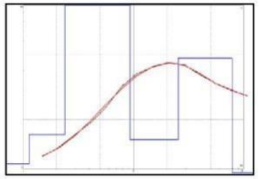
(XI) Jawaintpur



N	ρ	h	d	Alt
1	11.9	1.83	1.83	-1.835
2	8.2	6.68	8.51	-8.512
3	11.7	6.46	15	-14.97
4	82.7	17.8	32.8	-32.76
5	576	27.5	60.3	-60.27
6	42.1	27.7	87.9	-87.95
7	8.6			

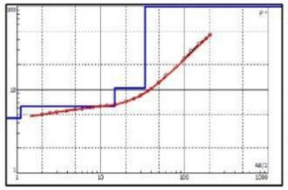
(XII) Kagdi Karadiya

Fig-3.3.2-a VES Locations carried out in the study area



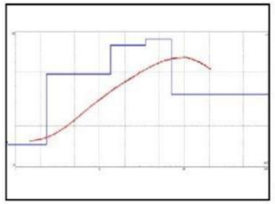
N	ρ	h	d	Alt
1	10.7	1.13	1.13	-1.133
2	16.2	1.25	2.39	-2.387
3	110	6.94	9.33	-9.33
4	15.1	16.2	25.5	-25.52
5	47.4	53.1	78.6	-78.63
6	3.08			

(XIII) Kaliyadeh



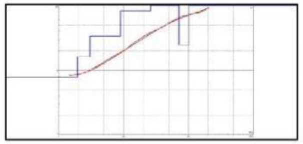
N	ρ	h	d	Alt
1	4.58	1.11	1.11	-1.112
2	6.27	13.6	14.7	-14.74
3	10.5	19.1	33.8	-33.84
4	1810	56.3	90.1	-90.14
5	253			

(XIV) Kamed



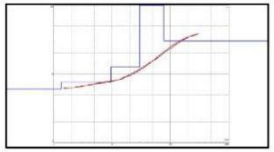
N	ρ	h	d	Alt
1	15.2	0.816	0.816	-0.8162
2	14.6	1.54	2.35	-2.354
3	48.6	11.2	13.6	-13.56
4	79.5	21.4	35	-34.96
5	88.2	36.6	71.6	-71.58
6	34.3			

(XV) Kithodajagir



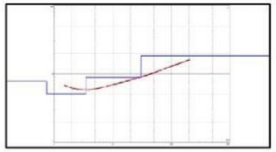
N	ρ	h	d	Alt
1	7.88	1.95	1.95	-1.95
2	16.2	1.1	3.05	-3.05
3	33.6	5.95	9	-8.999
4	81.7	17	26	-26
5	106	45.5	71.5	-71.55
6	24.6	31.7	103	-103.2
7	1075			

(XVI) Madhavgarh



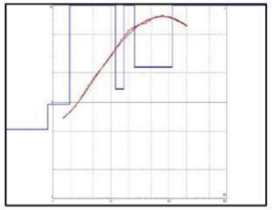
N	ρ	h	d	Alt
1	6.01	1.34	1.34	-1.34
2	7.55	8.23	9.57	-9.574
3	12.6	20.3	29.9	-29.87
4	103	47.8	77.7	-77.67
5	30.4			

(XVII) Mediya



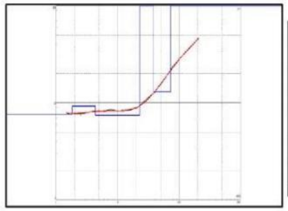
N	ρ	h	d	Alt
1	7.8	0.75	0.75	-0.75
2	5.11	2.77	3.52	-3.523
3	8.92	26.8	30.4	-30.37
4	18.4			

(XVIII) Mediya 2



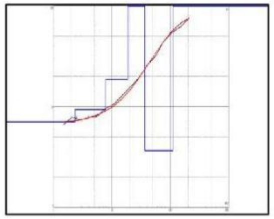
N	ρ	h	d	Alt
1	5.19	0.811	0.811	-0.8112
2	9.39	1.13	1.94	-1.941
3	203	10.1	12	-12.04
4	13.6	4.69	16.7	-16.73
5	521	8.75	25.5	-25.48
6	22.9	89.9	115	-115.4
7	135			

(XIX) Panbihar



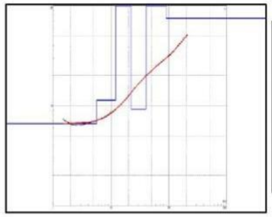
N	ρ	h	d	Alt
1	7.63	1.83	1.83	-1.826
2	9.23	2.48	4.31	-4.309
3	7.46	18.6	22.9	-22.94
4	593	15.3	38.2	-38.2
5	13	34.5	72.7	-72.67
6	1137			

(XX) Panched



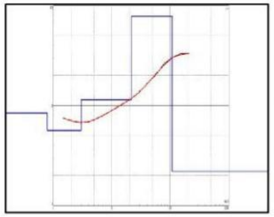
N	ρ	h	d	Alt
1	7.06	2.32	2.32	-2.324
2	9.38	5.47	7.79	-7.794
3	18.6	11	18.8	-18.79
4	1133	17.8	36.6	-36.64
5	3.67	74.3	111	-110.9
6	251			

(XXI) Piplai



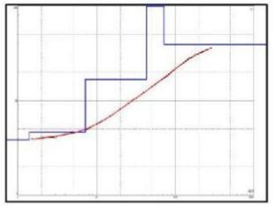
N	ρ	h	d	Alt
1	6.61	5.66	5.66	-5.655
2	11.4	6.44	12.1	-12.1
3	111	9.86	22	-21.96
4	9.2	18.3	40.3	-40.27
5	840	48.7	89	-89.01
6	74.7			

(XXII) Sahabkhedi (E – W)



N	ρ	h	d	Alt
1	8.39	0.793	0.793	-0.793
2	5.65	2.2	2.99	-2.994
3	11.5	18.7	21.7	-21.7
4	77.8	86.1	108	-107.8
5	2.2			

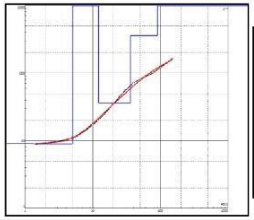
(XXIII) Sahabkhedi (N – S)



N	ρ	h	d	Alt
1	3.84	1.4	1.4	-1.395
2	4.65	5.82	7.22	-7.216
3	16.7	36.2	43.4	-43.43
4	141	28.5	71.9	-71.92
5	39.2			

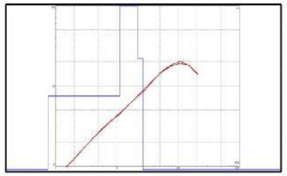
(XXIV) Sawrakhedi

Fig-3.3.2-b VES Locations carried out in the study area



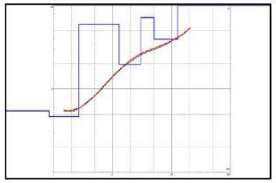
N	ρ	h	d	Alt
1	9.07	1.33	1.33	-1.325
2	8.94	3.67	4.99	-4.993
3	2750	7.18	12.2	-12.17
4	36.3	23.7	35.8	-35.84
5	359	54.6	90.4	-90.42
6	1632			

(XXV) Sayarkhedi



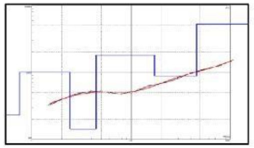
N	ρ	h	d	Alt
1	5.37	0.75	0.75	-0.75
2	74.6	10.3	11.1	-11.09
3	2192	10.5	21.6	-21.57
4	220	4.74	26.3	-26.31
5	6.87	50.3	76.6	-76.56
6	3.78			

(XXVI) Shankargarh



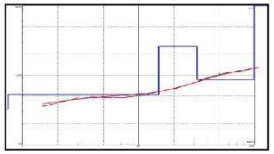
N	ρ	h	d	Alt
1	5.5	0.835	0.835	-0.8352
2	4.7	1.85	2.68	-2.683
3	59.2	10.3	13	-12.96
4	19.6	17	29.9	-29.95
5	71.6	20.7	50.6	-50.65
6	39.5	77.9	129	-128.5
7	453			

(XXVII) Suliyakhedi



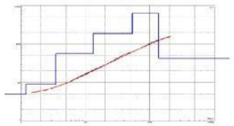
N	ρ	h	d	Alt
1	22.8	0.75	0.75	-0.75
2	101	1.66	2.41	-2.413
3	14.1	2.05	4.46	-4.46
4	179	12.8	17.2	-17.24
5	88	28.4	45.6	-45.6
6	527			

(XXVIII) Surasa (E – W)



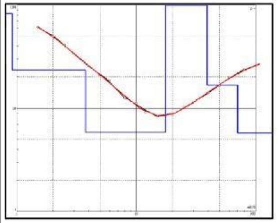
N	ρ	h	d	Alt
1	32.6	0.75	0.75	-0.75
2	52.5	14.2	15	-14.97
3	259	16.9	31.9	-31.89
4	85.8	66.5	98.4	-98.35
5	4403			

(XXIX) Surasa (N – S)



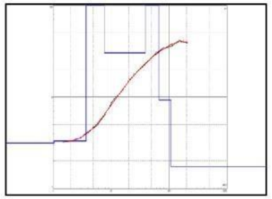
N	ρ	h	d	Alt
1	4.93	1.19	1.19	-1.192
2	8.92	2.29	3.48	-3.478
3	56.3	9.62	13.1	-13.1
4	188	39.9	53	-53.01
5	633	83.5	137	-136.5
6	42.6			

(XXX) Tajpur



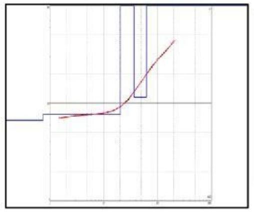
N	ρ	h	d	Alt
1	82.5	0.919	0.919	-0.9186
2	23.3	2.85	3.77	-3.769
3	5.85	13.8	17.6	-17.58
4	201	21.5	39.1	-39.06
5	16.7	31.5	70.5	-70.55
6	5.76			

(XXXI) Ujadkheda



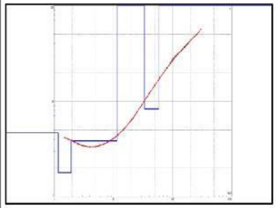
N	ρ	h	d	Alt
1	3.14	1.03	1.03	-1.033
2	3.3	2.71	3.75	-3.748
3	226	3.9	7.65	-7.653
4	30.5	31.9	39.5	-39.51
5	221	27	66.5	-66.51
6	9.27	41.2	108	-107.7
7	1.74			

(XXXII) Ujjain 1



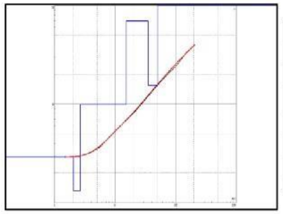
N	ρ	h	d	Alt
1	6.68	0.75	0.75	-0.75
2	7.7	19.6	20.4	-20.4
3	266	16	36.4	-36.37
4	11.5	26.4	62.8	-62.8
5	166	33.5	96.3	-96.27
6	433			

(XXXIII) Ujjain 2



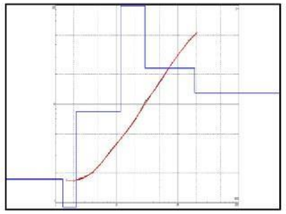
N	ρ	h	d	Alt
1	4.67	1.17	1.17	-1.172
2	1.79	0.764	1.94	-1.936
3	3.83	9.58	11.5	-11.51
4	489	21.9	33.4	-33.39
5	8.28	24.9	58.3	-58.32
6	486			

(XXXIV) Ujjain 3



N	ρ	h	d	Alt
1	2.9	2.04	2.04	-2.043
2	1.32	0.61	2.65	-2.653
3	9.96	12.6	15.2	-15.23
4	69.6	20	35.2	-35.23
5	15.6	15.1	50.3	-50.28
6	101			

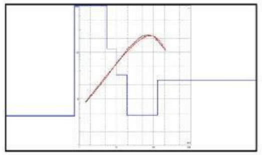
(XXXV) Ujjain 4 (E – W)



N	ρ	h	d	Alt
1	1.73	1.32	1.32	-1.321
2	0.86	0.869	2.19	-2.19
3	8.4	9.49	11.7	-11.68
4	1627	17.6	29.2	-29.24
5	23.2	60.6	89.8	-89.84
6	12.9			

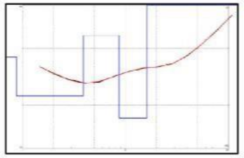
(XXXVI) Ujjain 4 (N – S)

Fig-3.3.2-c VES Locations carried out in the study area



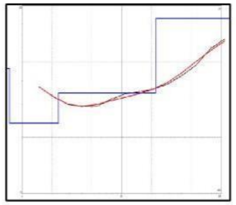
N	ρ	h	d	Alt
1	4.4	0.75	0.75	-0.75
2	4262	4.89	5.64	-5.64
3	119	4.34	9.98	-9.976
4	32.8	9.53	19.5	-19.5
5	4.53	108	127	-127.3
6	25.2			

(XXXVII) Ujjain Police Line



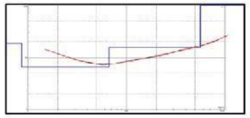
N	ρ	h	d	Alt
1	43.5	0.881	0.881	-0.8814
2	23.3	3.03	3.91	-3.91
3	61.3	4.81	8.72	-8.716
4	16.3	7.4	16.1	-16.12
5	107	69	85.1	-85.1
6	1724			

(XXXVIII) Ujjain Ring Road(E – W)



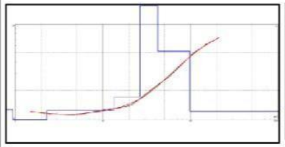
N	ρ	h	d	Alt
1	46.3	0.75	0.75	-0.75
2	23.7	1.56	2.31	-2.314
3	34.4	19.7	22.1	-22.05
4	85.2			

(XXXIX) Ujjain Ring Road(N – S)



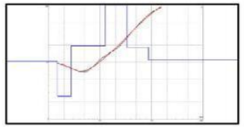
N	ρ	h	d	Alt
1	18.8	0.865	0.865	-0.8654
2	6.58	5.77	6.64	-6.636
3	15.6	49.5	56.1	-56.1
4	1992			

(XXXX) Ujjain Sadval Road



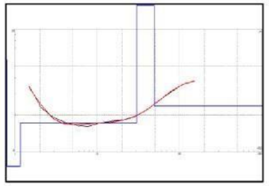
N	ρ	h	d	Alt
1	12.7	0.934	0.934	-0.9342
2	9.86	1.35	2.29	-2.285
3	12.5	11.1	13.4	-13.38
4	17.2	13.1	26.5	-26.49
5	1516	15.6	42.1	-42.07
6	51.7	55.6	97.7	-97.66
7	12.2			

(XXXXI)Ujjaniya



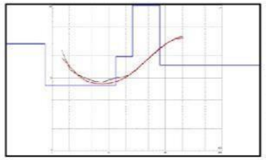
N	ρ	h	d	Alt
1	10.5	1.49	1.49	-1.49
2	2.55	1.26	2.75	-2.751
3	19.3	9.93	12.7	-12.68
4	1710	20.5	33.2	-33.16
5	18.3	54	87.2	-87.17
6	10.9			

(XXXXII)Umaria Jagir



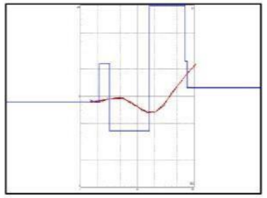
N	ρ	h	d	Alt
1	56	0.75	0.75	-0.75
2	7.6	0.41	1.16	-1.16
3	17.1	28.9	30.1	-30.06
4	180	19.2	49.3	-49.26
5	23.5			

(XXXXIII)Undasa 1 (E – W)



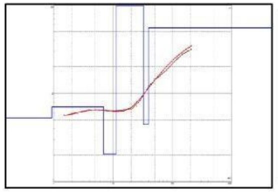
N	ρ	h	d	Alt
1	29.5	0.75	0.75	-0.75
2	7.89	12.6	13.4	-13.35
3	19.6	13.1	26.5	-26.45
4	106	53.3	79.8	-79.76
5	15			

(XXXXIV)Undasa 1 (N – S)



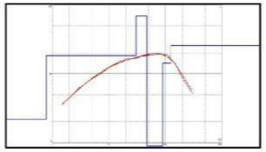
N	ρ	h	d	Alt
1	8.57	2.14	2.14	-2.143
2	22.9	1.1	3.25	-3.247
3	4.12	13	16.3	-16.25
4	116	53.7	70	-69.99
5	24.2	4.99	75	-74.98
6	12.4			

(XXXXV)Undasa 2 (E – W)



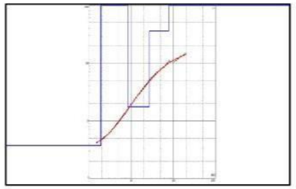
N	ρ	h	d	Alt
1	5.25	0.926	0.926	-0.9261
2	7.06	5.95	6.87	-6.873
3	2.05	4.3	11.2	-11.18
4	201	21.6	32.8	-32.78
5	4.44	6.98	39.8	-39.76
6	55.5			

(XXXXVI)Undasa 2 (N – S)



N	ρ	h	d	Alt
1	21.8	0.79	0.79	-0.7899
2	185	29.4	30.2	-30.18
3	694	17.5	47.7	-47.72
4	6.5	41.9	89.6	-89.62
5	143	36.3	126	-125.9
6	259			

(XXXXVII)Vikram University



N	ρ	h	d	Alt
1	3.72	1.89	1.89	-1.887
2	1756	6.38	8.27	-8.271
3	17.4	18.7	26.9	-26.92
4	357	50.6	77.5	-77.53
5	2080			

(XXXXVIII)WRD Office

Fig-3.3.2-d VES Locations carried out in the study area

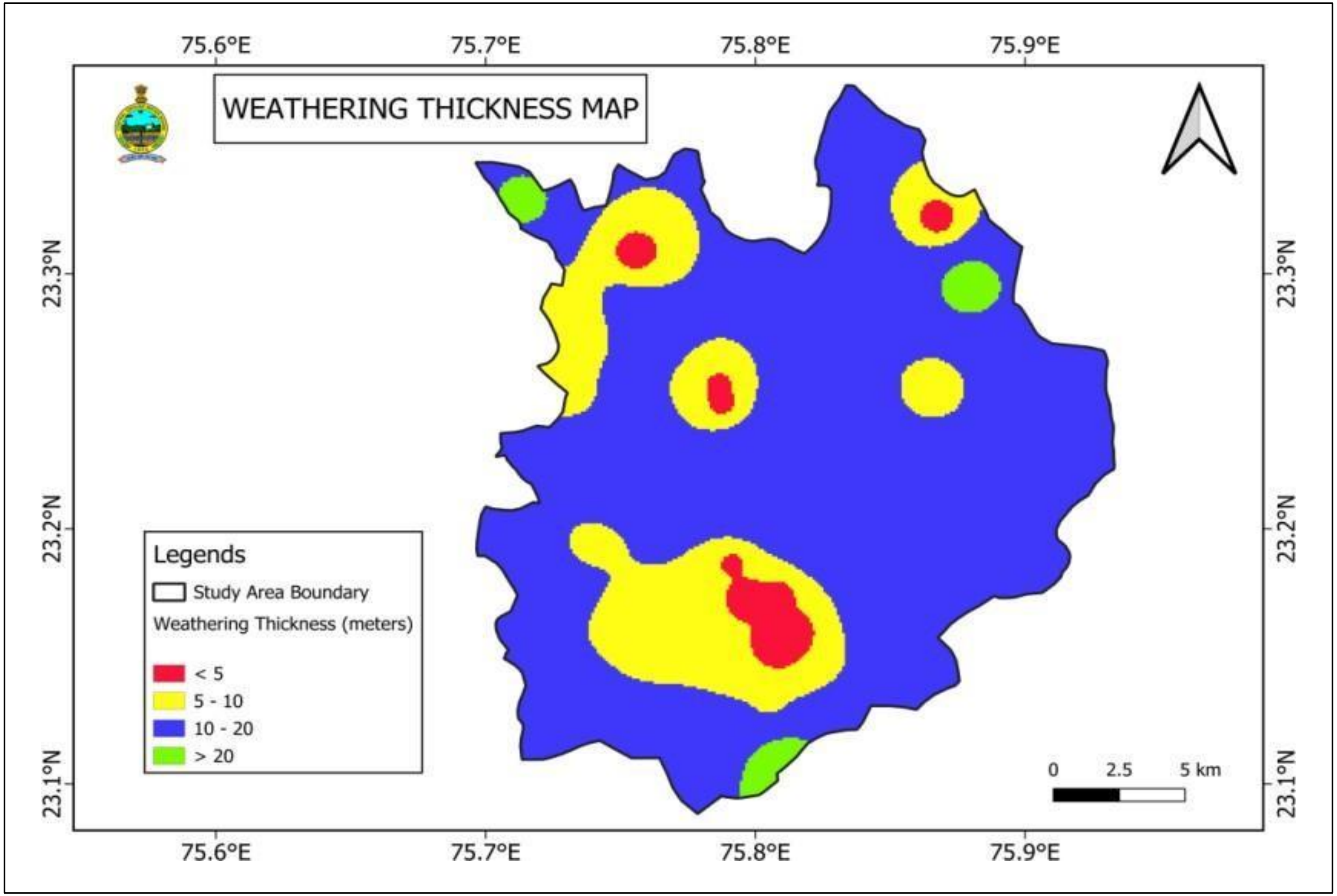


Fig. 3.3.2-e: Weathering Thickness Map, Ujjain Industrial

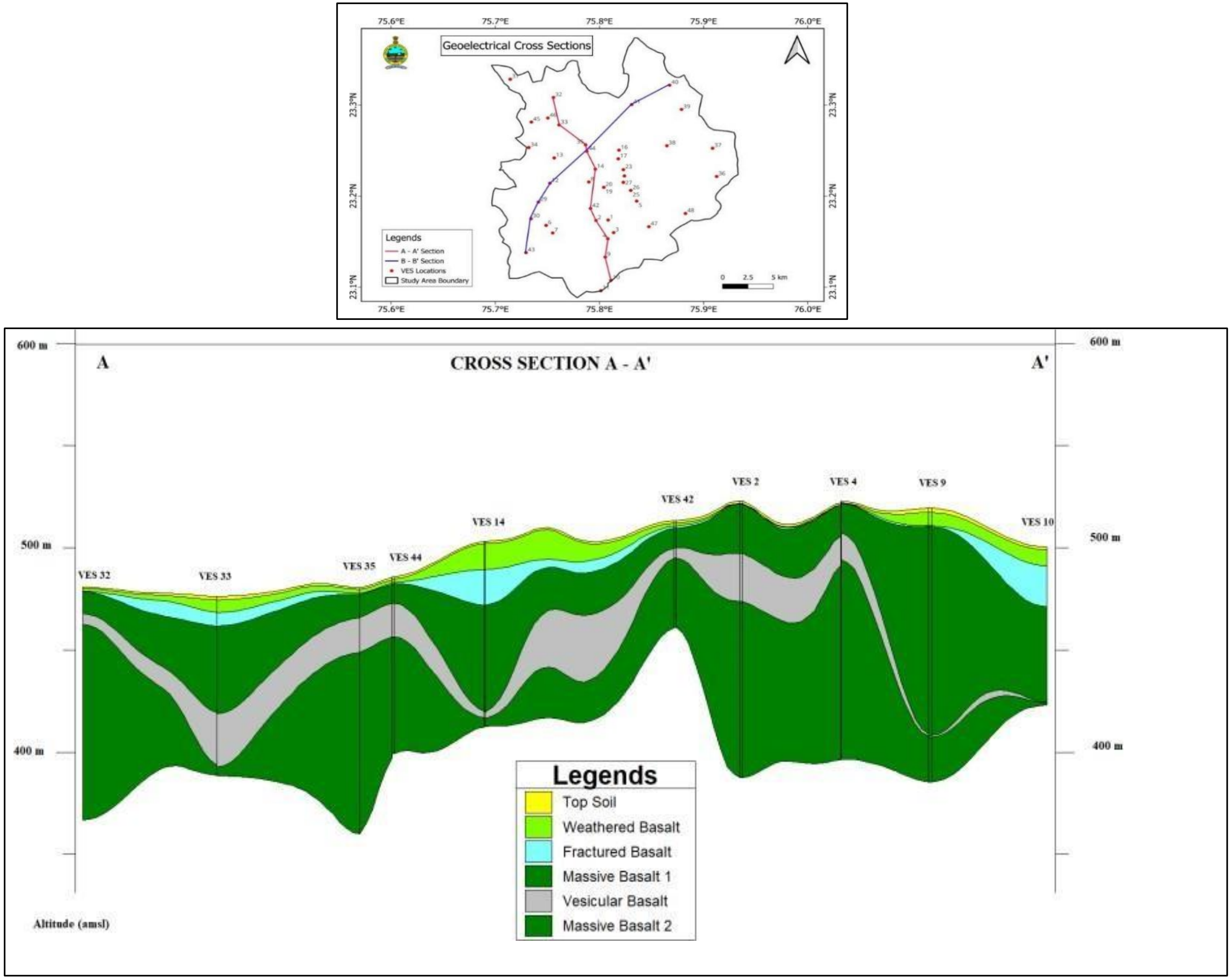
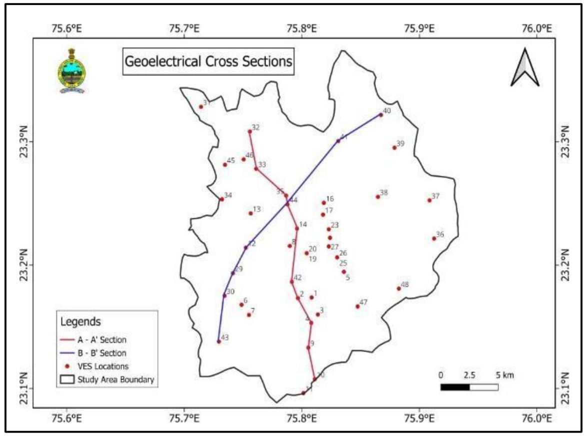


Fig. 3.3.2-f: Cross Section Along A-A'



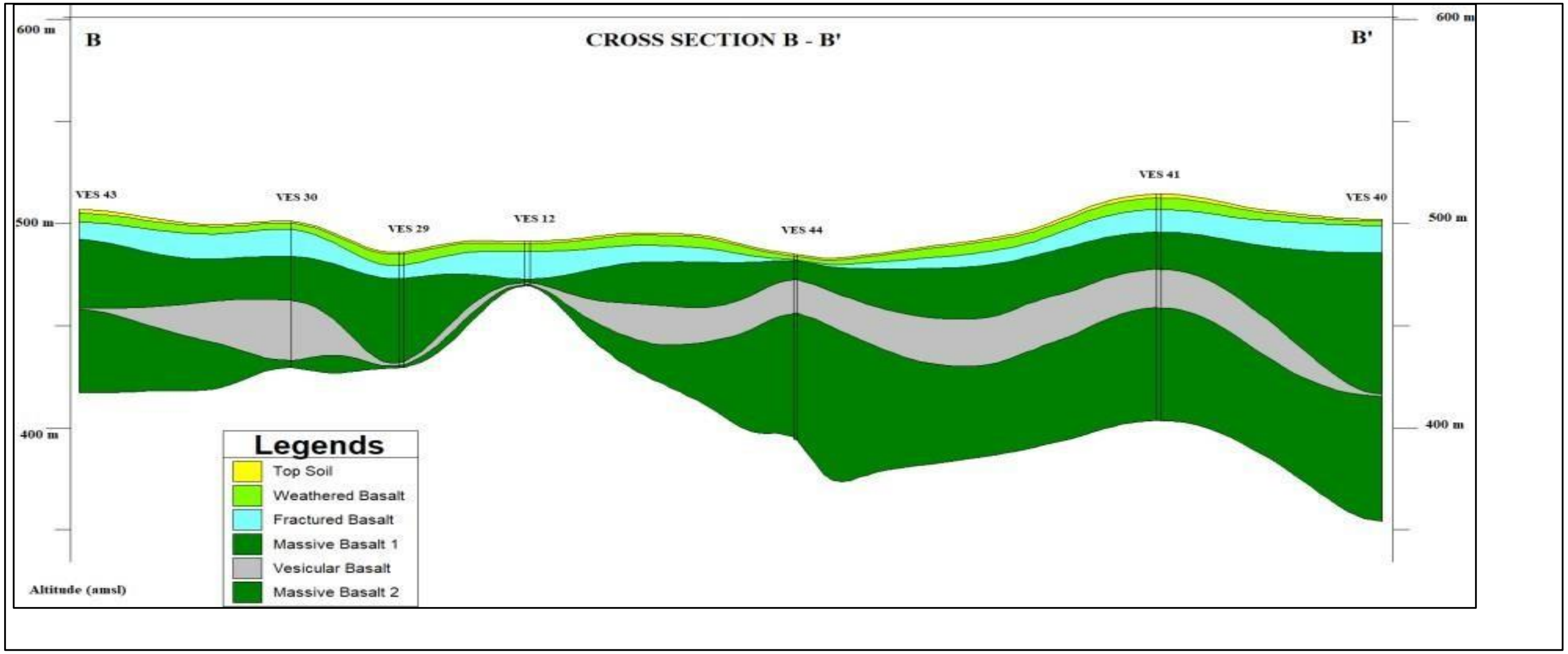


Fig. 3.3.2-g: Cross Section Along B-B'

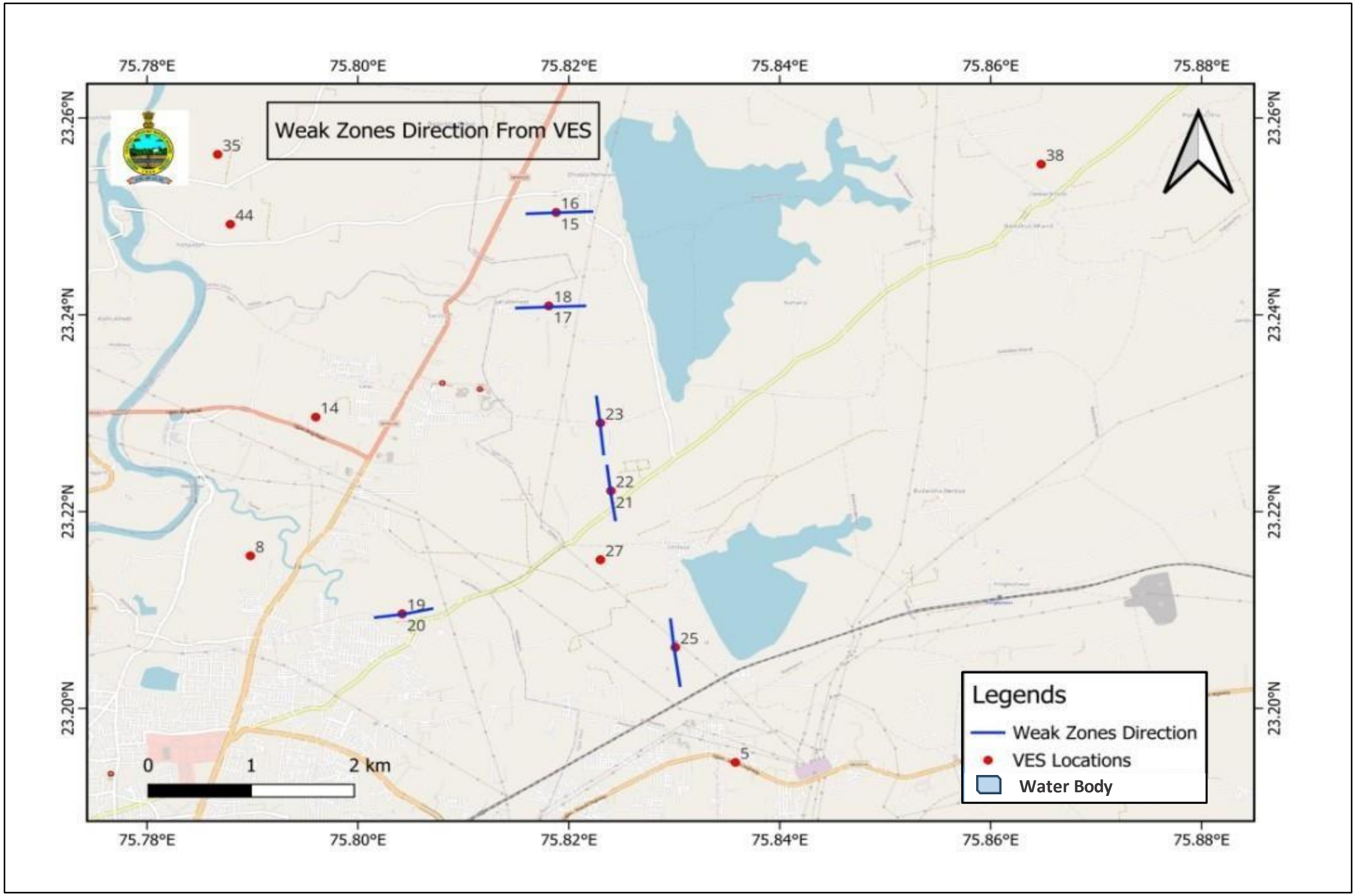


Fig: 3.3.2-h Map showing directions of weak zones from perpendicular VES

CHAPTER-4
GROUND WATER REGIME

4.1 Objectives

The objectives to monitor the aquifer wise ground water level is to assessing seasonal fluctuations, understanding recharge patterns and evaluating sustainability.

4.2 Methodology

Aquifer wise ground Water level was deciphered by monitoring of 97 key observation wells **(fig-4.2.1 & Annexure-3)** during pre and post monsoon from 2 aquifer levels in order to study the groundwater dynamics in the study area. The Depth to Water Level maps for shallow and deep aquifers have been prepared for 2 times **(Pre and Post)** using ArcGIS.

4.3 Result and Discussion

4.3.1 Occurrence of groundwater

Groundwater occurs in weathered rocks along fractures, joints and vesicles and it shows vide spatial and temporal variation due to large difference in the hydrogeological environment. Amygdaloidal nature of flow number 4 and filling of calcite, agate and chalcedony not only control the occurrence of phreatic groundwater but also hydrodynamic response input and discharge as output by way of fluctuation in water level during the pre and post monsoon seasons. The depth to water level maps of shallow aquifer **(Fig-4.3.1)** reveals that water level ranges from 5-10 m in shallow aquifer in most parts of the study area during pre-monsoon. Minimum water level observed is 1.2 m and maximum water level observed is 17m **(Table-4.3.1)**. During post monsoon, water levels ranges between 5-10 m in shallow aquifer in most parts of the study area. Minimum water level observed is 0.66 m and maximum water level observed is 25m. No significant change is observed in water level ranges during pre and post monsoon indicating low rate of recharge from rainfall. This may be due to lack of connectivity of aquifer or lack of significant recharge areas.

In deeper aquifer, pre monsoon water level ranges between 10-20m in most part of the study area. Minimum water level observed is 4.88m and maximum water level observed is 50m. During post monsoon, the same scenario prevails except for patches of shallow water level rage between 5-10m towards the southwestern part of study area.

This confirms the connectivity of deeper aquifers towards the southwestern parts of study area as discussed in **chapter 3**.

Groundwater levels observed during monitoring of Key observation wells are tabulated in **table. 4.3.1.**

Table No.4.3.1: WL distribution in Ujjain industrial cluster

SI NO.	MONTH	WL DISTRIBUTION (mbgl)			
		Shallow		Deep	
		MIN.	MAX.	MIN.	MAX.
1	MAY (PRE-MONSOON)	1.2	17	4.88	50
3	NOVEMBER (POST-MONSOON)	0.66	25.55	0.36	69

Water table contour maps were prepared during pre-monsoon **(Fig-4.3.2)** and post-monsoon **(Fig-4.3.3)** periods. During both periods, the groundwater flow direction was towards Kshipra River. This indicates that groundwater is recharging the river in other words; the river is in effluent condition.

From farmer's feedback, it is inferred that maximum continuous pumping hours during pre-monsoon period is 1-2 hours for domestic purposes and during post monsoon period is 5-6 hours for irrigation.

It is inferred from the water table contour maps that the continuous pumping is not causing the river to change its condition from effluent to influent conditions. If excessive pumping will occur in the area, it may cause reversal of river condition. As the river is mostly contaminated from various effluents, sewage and khan diversion canal towards the downstream from Sulyakhedi village, this may cause groundwater contamination.

Based on the findings detailed above, the hydrogeological map of the study area has been prepared and is depicted in **Fig- 4.3.4**.

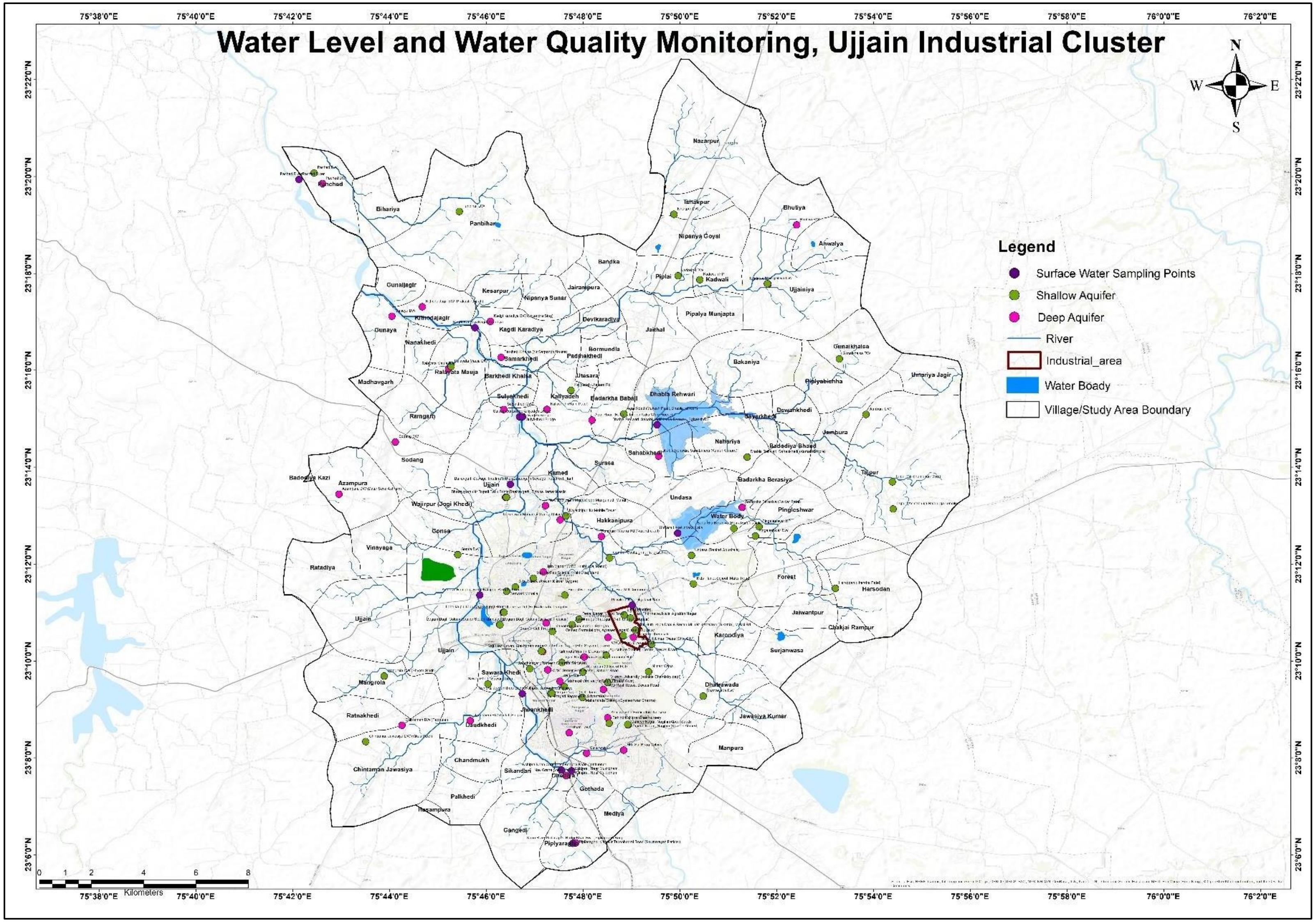


Fig. 4.2.1: Map showing locations of water level and water quality monitoring in Ujjain Industrial Cluster.

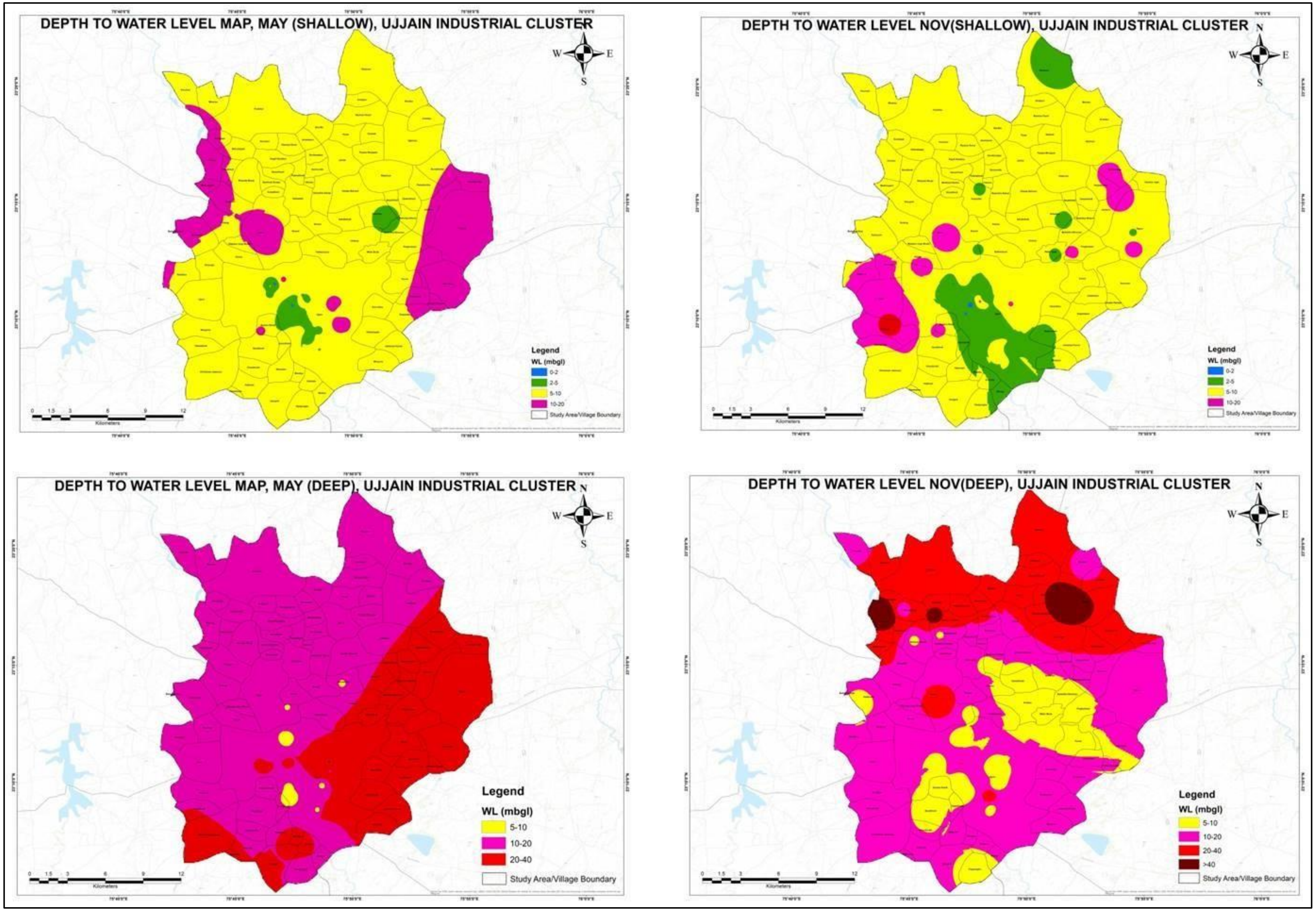


Fig. 4.3.1: Maps showing the Depth to Water Level Map of Deep and Shallow Aquifer during pre (May) and Post (November) Monsoon

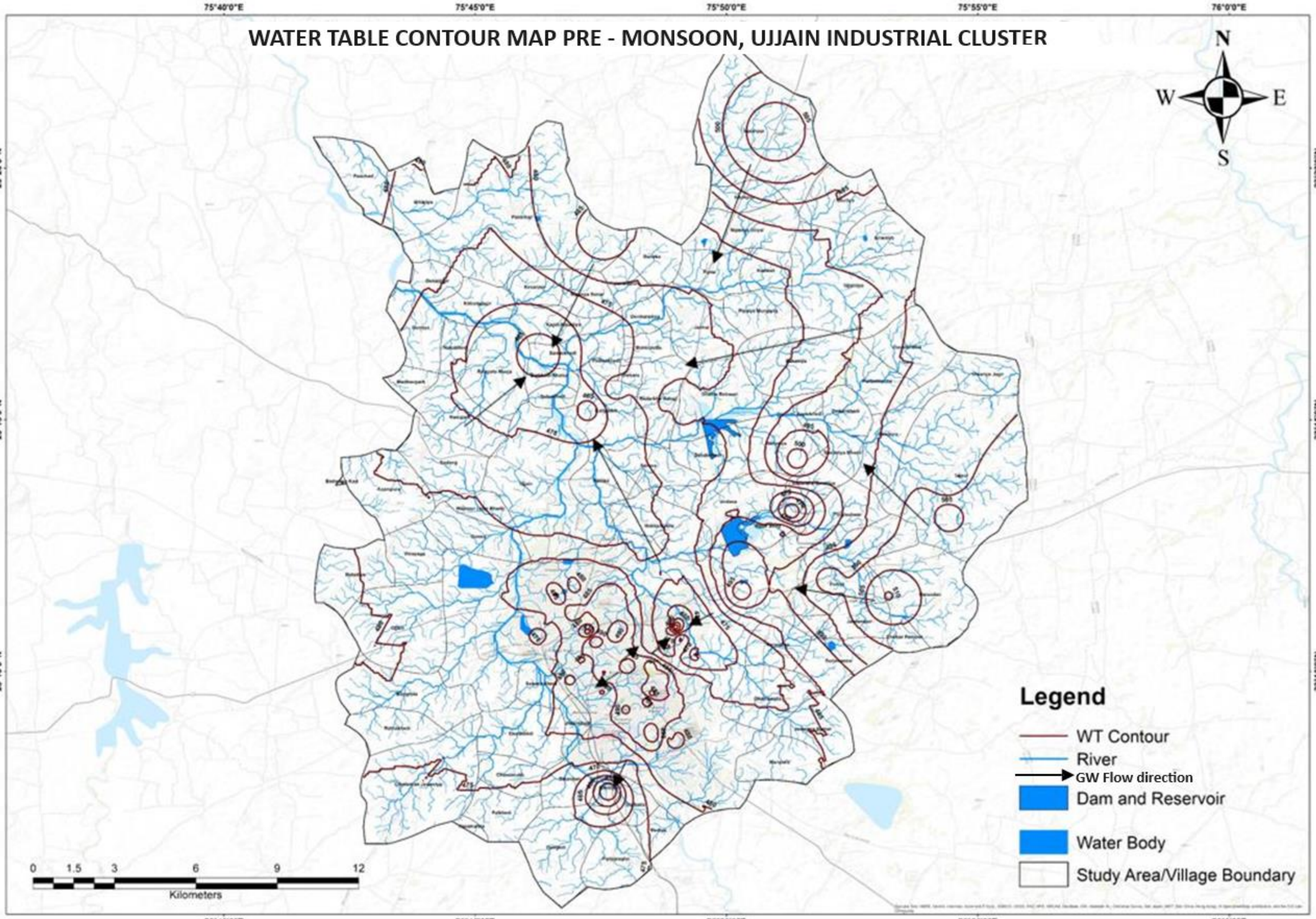


Fig. 4.3.2: Water Table Contour Map during pre-Monsoon

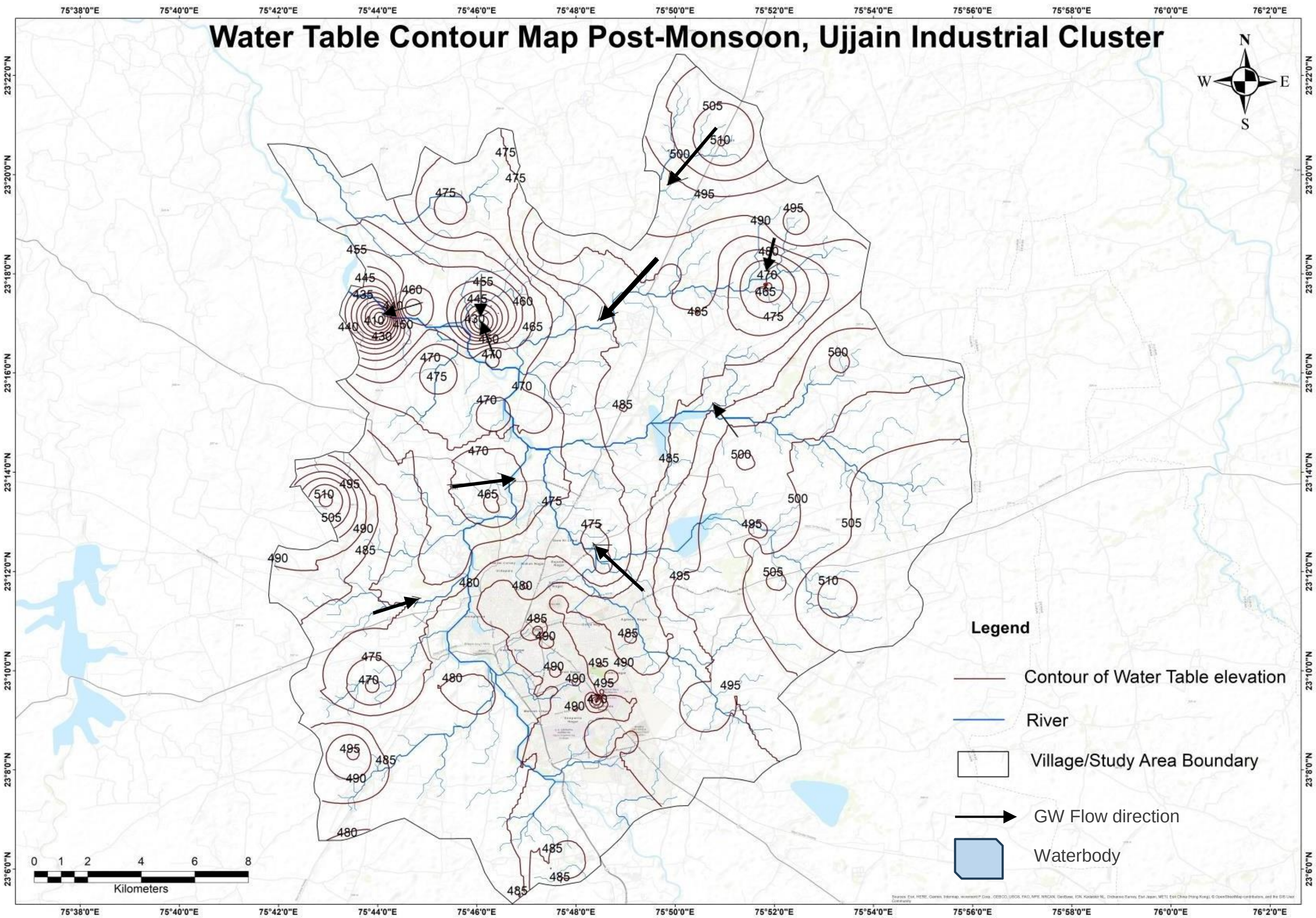


Fig. 4.3.3: Water Table Contour Map during Post-Monsoon

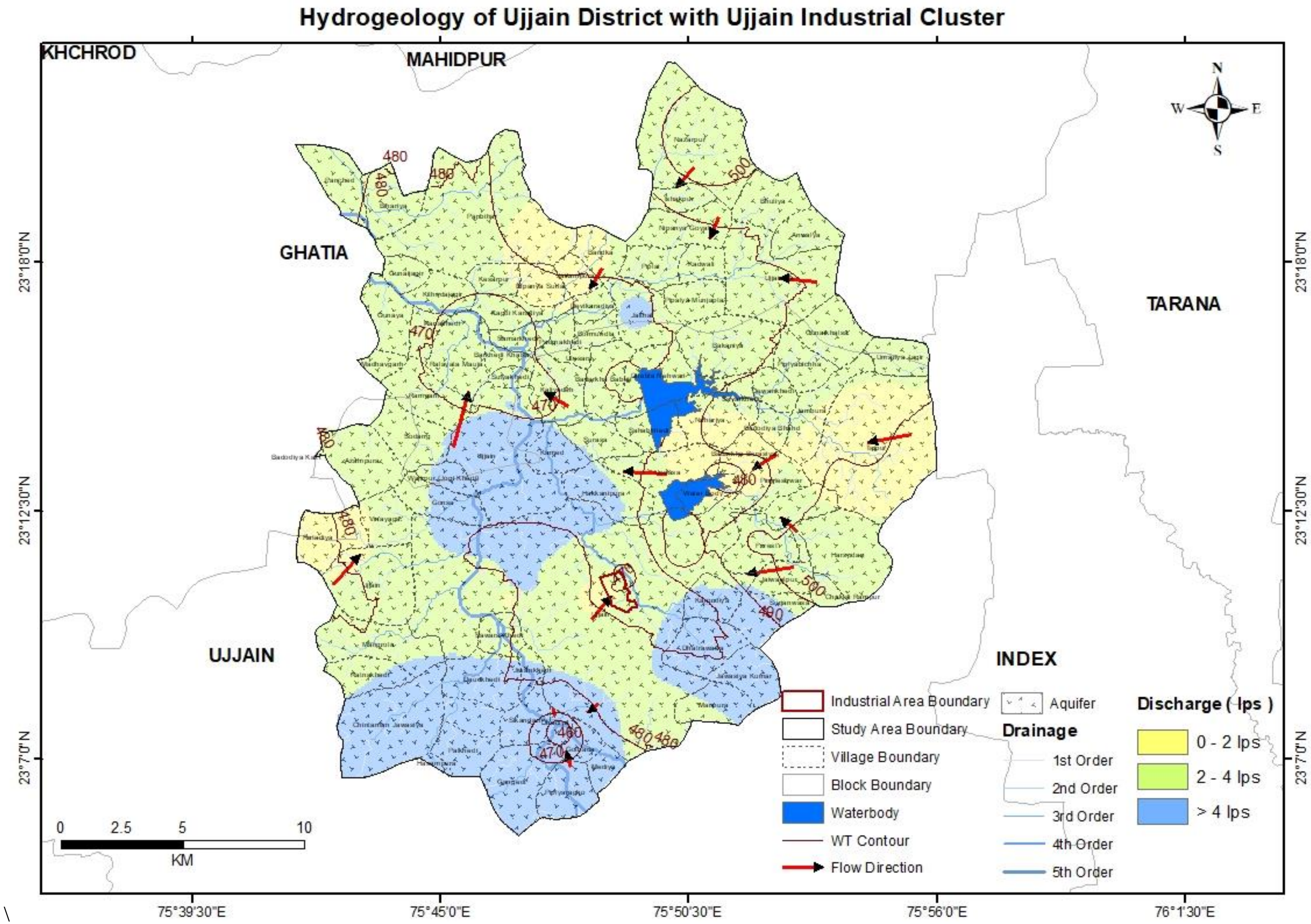


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Fig. 4.3.4: Hydrogeological map of Ujjain Industrial Cluster

CHAPTER-5
GROUND WATER QUALITY

5.1 Objectives

The main objective of hydro chemical study is to identify the sources, and extent of groundwater contamination, their potential impacts on groundwater resources and demarcation of safer aquifer for drinking.

5.2 Methodology

The ground water samples were collected in clean double stopper polyethylene bottles from 99 different locations of dug well, hand pump and bore wells for basic parameters and heavy metals analysis during pre-monsoon and post-monsoon period, list is given in **Annexure-4**. The ground water samples were analyzed for following water quality parameters: pH, Electrical Conductivity (EC), Total hardness (TH), Calcium, Magnesium, Sodium, Potassium, Carbonate, Bi-carbonate, Chloride, Fluoride, Nitrate, Sulphate, Phosphate, Silica and selective trace/ heavy metals viz. Iron, Manganese, Copper, Zinc, Arsenic, Lead, Chromium and Uranium. The results of basic water quality parameter, Heavy/Trace Metal analysis results and statistical summary of results have been given in annexures.

5.3 Results and Discussion

5.3.1 General Chemical Characteristics of Ground Water

(a) The pH of water indicates whether the water is acidic or alkaline. The measurement scale of pH ranges from 1 to 14 with a pH of 7 indicating as neutral condition (neither acid nor alkaline). The value of pH is lower than 7 indicate acidic and more than 7 indicate alkaline. IS 10500:2012 has set pH limit for drinking purpose 6.5 to 8.5. The pH of ground water of study area ranges in between 7.04 to 8.15 and 7.15 to 8.19 with a mean value of 7.42 and 7.52 for Pre-monsoon and Post-Monsoon respectively. As per BIS recommendation, all water samples are within the acceptable limit. The ground water of the study area can be assessed as slightly acidic to neutral in nature.

(b) Electrical Conductance (EC) is ability of water to conduct electric current and it depends on the concentration of ions, type of ions, and temperature. Bureau of Indian Standard (BIS) has recommended desirable limit for Total Dissolved Solid (TDS) as 500 mg/L corresponding to EC value approximately as 750 µS/cm at 25°C, which is extendable to permissible limit as 2000 mg/L TDS corresponding to EC value is about 3000 µS/cm at 25°C in absence of alternate source of water. The water having EC more than 3000 µS/cm at 25°C are not considered suitable for drinking purpose and causes a gastrointestinal irritation. The electrical conductivity of ground water in study area ranges in between 560 to 3851 µS/cm at 25°C for Shallow and Deeper Aquifer based on Pre and Post Monsoon data. Percent distribution and spatial distribution of electrical conductivity is being given in **Table 5.3.1(b)** and **Fig.5.3.1 (b)** respectively. The ground water of approximately 90% locations falls under moderately mineralized water i.e. between

750- 2250 µS/cm range. DW24, BW17, BW28, BW25, DW08, DW07, DW35, BW20, DW28 and DW38 water has been found in slightly mineralized category with EC Value between 2250-3000 µS/cm. Electrical Conductivity of DW34(Shri Gurukripa Daal & Besan Mill,Maksi Rd) and BW11(Ralayata Mauja) water has been found above 3000 µS/cm and can be assessed as highly mineralized water.

Based on electrical conductivity, the ground water of study area belongs to moderate to slightly mineralized water.

Table 5.3.1(b): Percent Distribution of Electrical Conductivity in Ground Water of Study Area

	Shallow Aquifer		Deeper Aquifer	
	Pre-Monsoon	Post- Monsoon	Pre-Monsoon	Post-Monsoon
No. of Samples	37	48	32	33
Min. Value	560	712	849	850
Max. Value	3851	3345	2715	3311
Mean Value	1451	1415	1652	1641
< 750 µS/cm	2.7 %	2.1%	Nil	Nil
750- 1500 µS/cm	59.5 %	68.8%	37.5%	39.4%
1500-2250 µS/cm	29.7%	18.8%	56.3%	51.5%
2250-3000 µS/cm	5.4%	8.3%	6.3%	6.1%
> 3000 µS/cm	2.7%	e2.1%	Nil	3.0%

(c) Chloride (Cl^-) is present in all-natural waters, mostly at low concentrations. It is highly soluble in water and moves freely with water through soil and rock. In ground water the chloride content is mostly below 250 mg/L except in cases where inland salinity is prevalent and in coastal areas. BIS (Bureau of Indian Standard) have recommended a desirable limit of 250 mg /L of chloride in drinking water; this concentration limit can be extended to 1000 mg/L of chloride in case no alternative source of water with desirable concentration is available. However, ground water having concentration of chloride more than 1000 mg /L are not suitable for drinking purposes. Based on pre-monsoon and post-monsoon data, study area has a chloride concentration between 17-805 mg/L for shallow aquifer and 35-535 mg/l for a deeper aquifer. DW 34, located in Shri Gurukripa Daal & Besan Mill on Maksi Road, ground water has a maximum chloride concentration i.e. 805 mg/L during pre-monsoon. Shallow aquifer has high variance in chloride concentration rather than deeper aquifer. Percent distribution of chloride is being given in **Table 5.3.1(c).** Approximately 80% and 60% of Samples have a chloride concentration within acceptable limit and 20% and 40% of samples have a chloride content within permissible limit in shallow and deeper aquifer respectively. No sample has a chloride above permissible limit in study area.

Table 5.3.1(c): Percent Distribution of Chloride in Ground Water of Study Area

	Shallow Aquifer		Deeper Aquifer	
	Pre-Monsoon	Post- Monsoon	Pre-Monsoon	Post-Monsoon
Min. Value	17	25	35	35
Max. Value	805	648	465	535
Mean Value	183	175	214	231
<250 mg/L	81.1%	79.2%	62.5%	57.6%
250-1000 mg/L	18.9%	20.8%	37.5%	42.4%
>1000 mg/L	Nil	Nil	Nil	Nil

(d) Fluorine (F^-) is a common element but it does not occur in the elemental state in nature because of its high reactivity. Fluorine is the most electronegative and reactive of all elements that occur naturally within many types of rock. It exists in the form of fluorides in a number of minerals of which fluorspar; cryolite, fluorite and fluorapatite are the most common. Fluorite (CaF2) is a common fluoride mineral. Most of the fluoride found in groundwater is naturally occurring from the breakdown of rocks and soils or weathering and deposition of atmospheric particles. Most of the fluorides are sparingly soluble and are present in ground water in small amounts. The type of rocks, climatic conditions, nature of hydrogeological strata and time of contact between rock and the circulating ground water affects the occurrence of fluoride in natural water. Presence of other ions, particularly bicarbonate and calcium ions also affect the concentration of fluoride in ground water. It is well known that small amounts of fluoride (less than 1.0 mg/L) have proven to be beneficial in reducing tooth decay. Community water supplies commonly are treated with NaF or fluorosilicates to maintain fluoride levels ranging from 0.8 to 1.2 mg/L to reduce the incidence of dental carries. However, high concentrations such as 1.5 mg/L of F and above have resulted in staining of tooth enamel while at still higher levels of fluoride ranging between 5.0 and 10 mg/L, further pathological changes such as stiffness of the back and difficulty in performing natural movements may take place.

BIS has recommended an upper desirable limit of 1.0 mg/L of F- as desirable concentration of fluoride in drinking water, which can be extended to 1.5 mg/L of F in case no alternative source of water is available. Water having fluoride concentration of more than 1.5 mg/L are not suitable for drinking purposes. Pre and post monsoon data of fluoride concentration in ground water reveals that in shallow aquifer fluoride ranges between BDL to 1.32 mg/L and for deeper aquifer it is found between BDL to1.21 mg/L. Percent distribution fluoride is being given in **Table 5.3.1(d).** Percent distribution table of fluoride reveals that almost all samples of shallow and deeper aquifer comes under acceptable limit as per IS 10500:2012 and no sample has a fluoride concentration above permissible limit. During pre-monsoon DW09 (Sawarakhedi), DW41 (Prajapat Nagar), DW43 (Tajpur), BW19 (Alakhdham Nagar) and BW 22 (Begam Bagh Colony) have fluoride value 1.32 mg/L, 1.23 mg/L, 1.02 mg/L,1.12mg/L and 1.21mg/L respectively. After Monsoon only DW42 (Prajapat Nagar) has fluoride content 1.01 mg/L. All these values are above acceptable limit but within permissible limit.

Table 5.3.1(d): Percent Distribution of Fluoride in Ground Water of Study Area

	Shallow Aquifer		Deeper Aquifer	
	Pre-Monsoon	Post-Monsoon	Pre-Monsoon	Post-Monsoon
No. of Samples	37	48	32	33
Min. Value	0.14	BDL	0.14	BDL
Max. Value	1.32	1.01	1.21	0.95
Mean Value	0.56	0.41	0.59	0.43
<1.0 mg/L	91.9%	97.9%	93.8%	100.0%
1-1.5 mg/L	8.1%	2.1%	6.3%	Nil
>1.5 mg/L	Nil	Nil	Nil	Nil

(e) Nitrate (NO_3) is a naturally occurring compound that is formed in the soil when nitrogen and oxygen combine. The primary source of all nitrates is atmospheric nitrogen gas. This is converted into organic nitrogen by some plants by a process called nitrogen fixation. Dissolved Nitrogen in the form of Nitrate is the most common contaminant of ground water. Nitrate in groundwater generally originates from non-point sources such as leaching of chemical fertilizers & animal manure, groundwater pollution from septic and sewage discharges etc. It is difficult to identify the natural and man-made sources of nitrogen contamination of ground water. Some chemical and microbiological processes such as nitrification and denitrification also influence the nitrate concentration in ground water.

As per the BIS Standard for drinking water, the maximum desirable limit of Nitrate concentration in ground water is 45 mg/L with no relaxation. However, Nitrate is considered relatively non-toxic; a high nitrate concentration in drinking water is an environmental health concern arising from increased risks of methemoglobinemia particularly to infants. Adults can tolerate little higher concentrations. The specified limits are not to be exceeded in public water supply. If the limit is exceeded, water is considered unfit for human consumption

Nitrate concentration in shallow aquifer ranges from 2 to 175 mg/L and 4 to 289 mg/L in pre-monsoon and post-monsoon samples respectively, while in deeper aquifer nitrate found between 1 to 174 mg/L and 6 to 310 mg/L in pre-monsoon and post-monsoon samples respectively. Analysis data reveals that in both the aquifer pre- monsoon mean nitrate concentration is almost same i.e. 30 mg/L for shallow aquifer and 33 mg/L for deeper aquifer. After monsoon, mean value of nitrate increases from 30 mg/L to 58 mg/L for shallow aquifer and 33 mg/L to 79 mg/L for deeper aquifer. BW11 (Ralayata Mauja) and DW35 (Mangrola) have nitrate concentration near 300 mg/L i.e. 310 mg/L and 289 mg/L respectively in Post Monsoon Samples. Percent distribution and spatial distribution of fluoride is being given in **Table 5.3.1(e)** and **Fig 5.3.1(e)** respectively.

In shallow as well as in deeper aquifer percentage of samples, which have nitrate more than permissible limit increased significantly during monsoon period i.e. 19 % to 44 % and 25% to 67 % for shallow and deeper aquifer respectively.

Table 5.3.1(e): Percent Distribution of Nitrate in Ground Water of Study Area

	Shallow Aquifer		Deeper Aquifer	
	Pre-Monsoon	Post- Monsoon	Pre-Monsoon	Post-Monsoon
Min. Value	2	4	1	6
Max. Value	175	289	174	310
Mean Value	30	58	33	79
<45 mg/L	81%	56%	75%	33%
>45 mg/L	19%	44%	25%	67%

(f) Hardness can be defined as the capacity of water to precipitate soap caused by presence of calcium and magnesium-bicarbonate, sulfate and chloride ions. Hardness causes a variety of problems with complex formation with these ions. Hard water leaves scales after dry on the surface of cooking appliances called water spots. When hard water is heated, CaCO3 precipitates which clogs pipes and industrial boilers. As per Bureau of Indian Standard (BIS): 10500-2012 (Drinking Water), the acceptable limit for total hardness is 200 mg/l and permissible limit is 600 mg/l in absence of alternate sources.

Around 75% ground water samples collected from shallow and deeper aquifer of study area during pre-monsoon and post-monsoon have total hardness value within permissible limit i.e. 200-600 mg/L as CaCO3. On an average less than 10% samples from both the aquifers falls within acceptable limit and 10 -20 % samples have the total hardness value more than permissible limit. Percent distribution and spatial distribution of total hardness is being given in **Table 5.3.1(f)** and **Fig 5.3.1(f)** respectively.

Table 5.3.1(f): Percent Distribution of Total Hardness in Ground Water of Study Area

	Shallow Aquifer		Deeper Aquifer	
	Pre-Monsoon	Post- Monsoon	Pre-Monsoon	Post-Monsoon
Min. Value	178	190	158	140
Max. Value	1218	1040	765	955
Mean Value	460	401	450	442
<200 mg/L as $CaCO_3$	2.7 %	2.1%	6.3%	9.1%
200-600 mg/L as $CaCO_3$	81.1%	87.5%	71.9%	75.8%
>600 mg/L as $CaCO_3$	16.2%	10.4%	21.9%	15.2

For shallow aquifer, total hardness ranges between 178 to 1218 mg/L as CaCO3 during pre and post- monsoon period, whereas for deeper aquifer total hardness value varies from 140 to 955 mg/L. Ground Water Sample collected from DW 34 located in Shri Gurukripa Daal & Besan Mill on Maksi Road has maximum value for total hardness in pre-monsoon and post-monsoon sample analysis i.e.1218 mg/L and 1040 mg/L as CaCO3 respectively.

(g) Iron (Fe) is a common constituent in soil and ground water. It is present in water as either soluble ferrous iron or the insoluble ferric iron. Water containing ferrous iron is clear and colorless because the iron is completely dissolved. When exposed to air, the water turns cloudy due to oxidation of ferrous iron into reddish brown ferric oxide. The concentration of iron in natural water is controlled by both physico- chemical and microbiological factors. It is contributed to groundwater mainly from weathering of ferruginous minerals of igneous rocks such as hematite, magnetite and sulphide ores of sedimentary and metamorphic rocks. The acceptable iron concentration in ground water is up to 1.0 mg/L as per the BIS Standard for drinking water and no relaxation has been given in absence of alternate source i.e. permissible limit.

In study area, all the ground water samples collected from shallow and deeper aquifer has the iron concentration within acceptable limit during pre and post monsoon sample analysis. For shallow aquifer iron concentration found between BDL to 0.602 and for deeper aquifer, it has been found between BDL to 0.478. Maximum iron concertation 0.602 mg/L has been found in HP06 sample (Navgrah Shani mandir, Dhediya) during post-monsoon in shallow aquifer. In deeper aquifer maximum iron concentration 0.478 mg/L has been found in BW12 (Sawarakhedi) during post-monsoon.. Percent distribution of Iron is being given below in **Table 5.3.1(g).**

Table 5.3.1(g): Percent Distribution of Iron in Ground Water of Study Area

	Shallow Aquifer		Deeper Aquifer	
	Pre Monsoon	Post Monsoon	Pre Monsoon	Post Monsoon
Min. Value	BDL	BDL	BDL	BDL
Max. Value	0.409	0.602	0.164	0.478
Mean Value	0.06	0.07	0.03	0.07
<1.0 mg/L	100 %	100 %	100 %	100 %
>1.0 mg/L	Nil	Nil	Nil	Nil

(h) Manganese (Mn) is an essential trace element for human health. The BIS has set health-based desirable and permissible guideline values for manganese in drinking water as 0.1 mg/l and 0.3 mg/l respectively to ensure protection against manganese toxicity. Water Sample collected from BW36 (Lohe Ka Pul) in Pre-Monsoon, DW43 (Tajpur) in Pre-Monsoon and DW41 (Prajapat Nagar) in Post-Monsoon have the manganese concentration above permissible limit i.e.0.997 mg/L, 0.569 mg/L and 0.423 mg/L respectively. More than 80% samples have manganese concentration within acceptable limit. Concisely 147 samples out of 150 collected during Pre-Monsoon and Post-Monsoon period have Manganese value within acceptable range. Percentage distribution of Manganese is being given below in **Table 5.3.1(h).**

Table 5.3.1(h): Percent Distribution of Manganese in Ground Water of Study Area

	Shallow Aquifer		Deeper Aquifer	
	Pre Monsoon	Post Monsoon	Pre Monsoon	Post Monsoon
<0.1 mg/L	81.1%	91.7%	90.6%	100.0%
0.1-0.3 mg/L	16.2%	6.3%	6.3%	Nil
>0.3 mg/L	2.7%	2.1%	3.1%	Nil

(i) Copper (Cu) concentrations less than 0.5 mg/l in water has been set by BIS as acceptable limit and 1.5 mg/l as permissible limit in case of no alternate source is available.100% samples from study area falls under acceptable limit of IS 10500:2012 for copper concentration. Ground water sample collected from BW43 (Sinhel Enterprises) has maximum concentration 0.025mg/L for copper during Post-Monsoon. 147 samples out of 150 collected during study period have Copper concentration below 0.01mg/L.

(j) Zinc (Zn) is essential and beneficial element in human metabolism. Zinc imparts astringent taste to water above 5 mg/L. Acceptable and permissible limit for zinc is 5mg/l and 15 mg/L respectively as per IS 10500:2012. BW 22 (Begambagh Colony, Senior Steel Fabrication) water has a maximum concentration of zinc i.e. 1.759 mg/L and 0.892 mg/L for pre-monsoon and post monsoon respectively. 149 samples out of 150 collected during study period have Zinc concentration below 1 mg/L.

(k) Arsenic (As) is a naturally occurring trace element found in rocks, soils and the water in contact with them. Arsenic has been recognized as a toxic element and is considered a human health hazard.IS 10500:2012 (Drinking Water Specification) allow less than 10 µg/L (0.010 mg/L) of arsenic as acceptable limit. In study area arsenic concentration, ranges from BDL to 9.3 µg/L during study period. Maximum concentration of arsenic 9.3 µg/L has been found in BW36 (Lohe Ka Pul) water in pre-monsoon sample. 100% of samples falls within acceptable limit for arsenic concentration.

(l) lead (Pb) and chromium (Cr) ranged between BDL to 4.6 µg/L and BDL to 0.9 µg/L respectively in study area. 100% samples from study area has a lead and chromium concentration within acceptable limit i.e. 10 µg/L for lead and 50 µg/L for chromium as published in IS 10500:2012. Maximum concentration of lead and chromium i.e. 4.6 µg/L and 0.9 µg/L respectively has been found in BW 32 (Hira Industries) water.

(m) Uranium (U) occurs naturally in groundwater and surface water. Being a radioactive mineral, high uranium concentration can cause impact on water, soil and health. Uranium has both natural and anthropogenic source that could lead to the aquifer. These sources include leaching from natural deposits, release in mill tailings and emissions from the nuclear industry, combustion of coal and other fuels and the use of phosphate fertilizers that contains uranium and contribute to ground water pollution. Uranium enters in human tissues mainly through drinking water, food, air and other occupational and accidental exposures. Intake of uranium through air and water is normally low, but in circumstances in which uranium is present in a drinking water source, the majority of intake can be through drinking water.

Water with uranium concentration above the recommended maximum permissible concentration of 30 ppb (BIS, 10500:2012) is not safe for drinking purposes as it can cause damage to internal organs, on continuous intake. Elevated uranium concentrations in drinking water have been associated with many epidemiological studies such as urinary track cancer as well as kidney toxicity. A recent study, found a strong correlation between uranium concentration in drinking water and uranium in bone, suggesting that bones are good indicators of uranium exposed via ingestion of drinking water. Therefore, such studies trigger further assessment of uranium's adverse health effects on humans and/or the environment for countries where elevated uranium concentration in drinking water has been observed. Hence, it becomes important to study the level of uranium in drinking water for health risk assessment.

Uranium concentration in the shallow ground water varies primarily due to recharge and discharge, which would have dissolved or leached the uranium from the weathered soil to groundwater zone. High uranium concentrations observed in groundwater may be due to local geology, anthropogenic activities, urbanization and use of phosphate fertilizers in huge quantity for agriculture purpose. Studies have shown that phosphate fertilizer possess uranium concentration ranging from 1 mg/kg to 68.5 mg/kg (Brindha K et al., 2011). Hence, the phosphate fertilizers manufactured from phosphate rocks may also contribute uranium to ground water in agriculture region.

In study area, uranium concentration ranged between BDL to 7.9 μg/L. Maximum concentration of uranium has been found in BW 33 water located in Gopal Yadav agricultural land on Indore Road during pre-monsoon sampling. 100 % water samples collected from shallow and deeper aquifer of study area has been found within acceptable.

5.3.2 Hydro-chemical facies and Water Chemistry Controlling Factors for Ground Water of Study Area (Piper Diagram)

In 1994, Arthur M. Piper, proposed an effective graphic procedure to segregate relevant analytical data to understand the sources of the dissolved constituents in water. This procedure was born under the statement that most natural waters contain cations and anions in chemical equilibrium. It is assumed that the most abundant cations are two "alkaline earths" calcium (Ca) and magnesium (Mg) and one "Alkali" sodium (Na). The most common anions are one "weak acid" bicarbonate (HCO3) and two "strong acids" Sulphate (SO4) and chloride (Cl).To create a graph with the major water constituents, Piper (1994) suggested drawing two triangles corresponding with the cations and anions, respectively, and one diamond that summarize both triangles. According to the location of the sample in that diamond, the hydro chemical facies can be identified. Said facies are the diagnostic chemical aspect of water solutions occurring in hydrologic systems and are explained in the following **Table 5.3.2a** and **fig 5.3.2a**:

Table 5.3.2a: General characteristics of water in each zone of the Piper trilinear diagram.

Zone	Characteristics of water (Hydro-chemical facies)
1	Calcium-Chloride type water (Permanent Hardness)
2	Mixed Type (Ca-Mg-Cl-SO4)
3	Mixed Type (Ca-Na-HCO3)
4	Calcium-Bicarbonate type (Temporary Hardness)
5	Sodium- Chloride type (Saline)
6	Alkali Bi-carbonate (Na-HCO3)
7	Alkaline earths exceed alkalis (Ca+Mg >Na+K)
8	Alkalis exceed alkaline earths (Na+K> Ca+Mg)
9	Weak acids exceed strong acids (CO3+HCO3>Cl+SO4)
10	Strong acids exceed weak acids (Cl+SO4>CO3+HCO3)

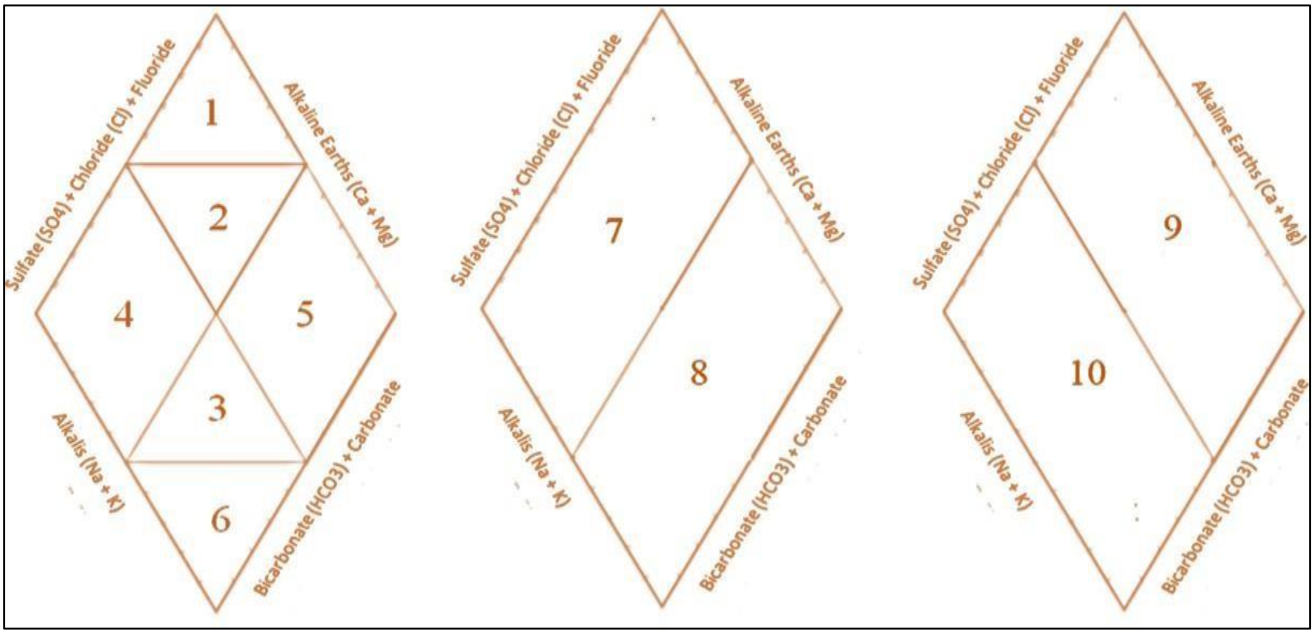


Fig.5.3.2a: Piper Diagram

In the study area, piper diagram and percent distribution table depicts **(Fig 5.3.2b and Table 5.3.2b)** ground water samples of shallow aquifer belongs to zone 4, 2, 3 and 5 of piper diagram and follows the order of Ca-Mg-HCO3 type > Mixed type > Na-Cl type hydro-chemical characteristics i.e. Temporary hardeness is prevalent in shallow aquifer. Ground water samples collected from DW 08 (Ralayata Mauja), DW26 (Hira Mill compound), DW35 (Mangrola), DW36 (Krishi Upaj Mandi), HP05 (Nanakheda) and HP06 (Shani Mandir, Dhediya) are saline nature.

Table 5.3.2b: Percent Distribution of ground water samples based on Piper Diagram

	Shallow Aquifer		Deeper Aquifer	
	Pre-Monsoon	Post-Monsoon	Pre-Monsoon	Post-Monsoon
Mixed Type	35.1%	25.0%	50.0%	45.5%
Ca-Mg-HCO3 Type	62.2%	62.5%	28.1%	27.3%
Ca-Cl-SO4 Type	Nil	Nil	3.1%	Nil
Na-Cl Type	2.7%	12.5%	18.8%	27.3%
Na-HCO3	Nil	Nil	Nil	Nil

Deeper aquifer of study area also falls in zone 4, 2, 3 and 5 of piper diagram, but around 50 % of samples shows the properties of zone 2 and 3 i.e. Ca-Mg-Cl-SO4 and Ca-Na-HCO3 type (Mixed Type) and follow the characteristics order of Mixed type> Ca-Mg-HCO3 type ≥ NaCl type. Sample collected from BW20 (Alchemy Chemicals) is found under permanent hardness category due to high Sulphate concentration.

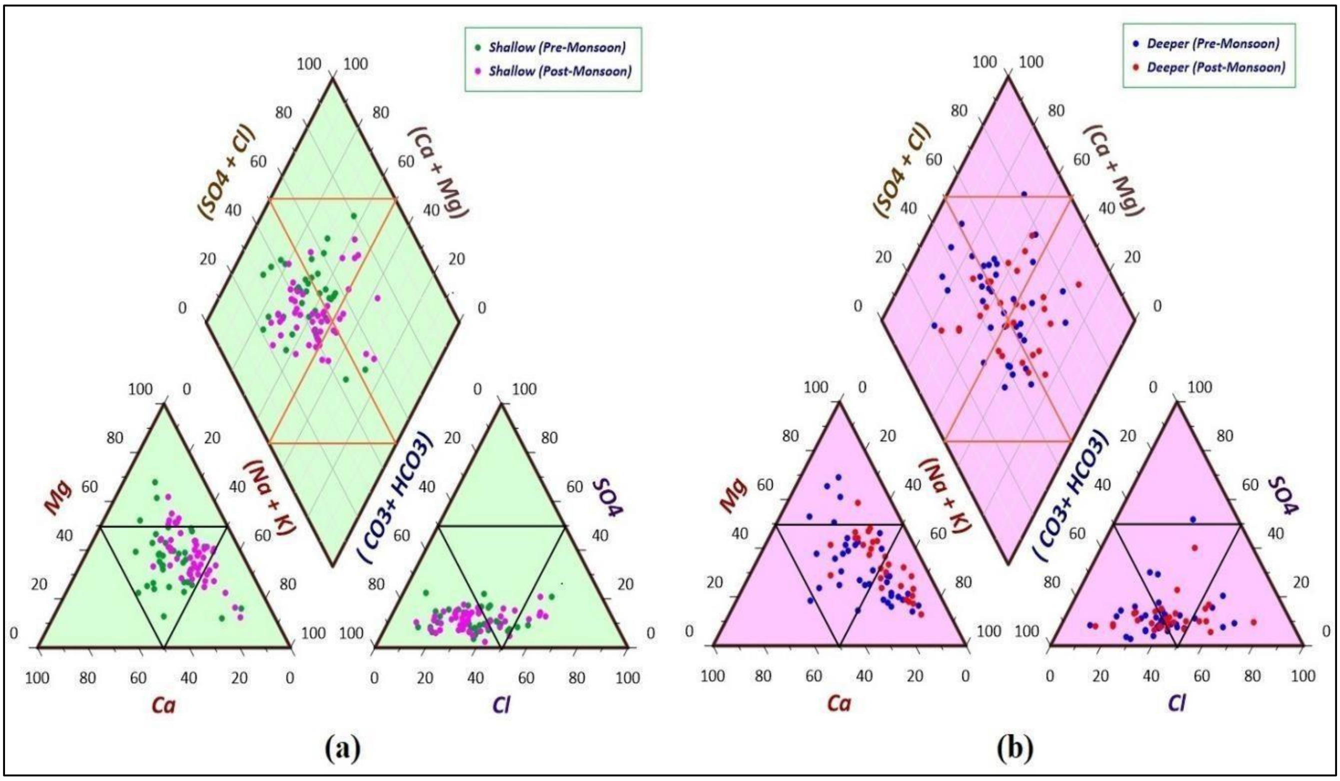


Fig. 5.3.2b: (a) Piper Diagram for Shallow Aquifer Samples during Pre-Monsoon and Post Monsoon (b) Piper Diagram for Deeper Aquifer Samples during Pre-Monsoon and Post Monsoon

In shallow aquifer samples, precipitation/recharge water is the key factor and for deeper aquifer samples ion exchange phenomenon is the key controlling factor for water chemistry.

5.3.3 Ground Water Assessment for agricultural use (Based on USSL Diagram)

USSL Diagrams (Figure 5.3.3(a) and (b)) have been plotted to understand the class of water for agricultural use. USSL diagrams reveals that more than 75% locations of ground water from shallow and deeper aquifer falls under C3S1 Category of USSL Diagram; high electrical conductivity and low sodium water. Percent distribution of samples based on USSL Diagram is being given below in **table 5.3.3;**

Table 5.3.3: Percent Distribution of Ground Water of Study Area (based on USSL Classes)

	Shallow Aquifer		Deeper Aquifer	
USSL Class	Pre-Monsoon	Post-Monsoon	Pre-Monsoon	Post-Monsoon
C2S1	2.7%	2.1%	Nil	Nil
C3S1	83.8%	83.3%	81.3%	75.8%
C3S2	5.4%	4.2%	12.5%	15.2%
C4S1	2.7%	Nil	3.1%	Nil
C4S2	5.4%	10.4%	3.1%	9.1%

Water from both the aquifer may not be used on soils with restricted drainage, even with adequate drainage, special management for salinity control may be required and plants/ crops with good salt tolerance may be selected.

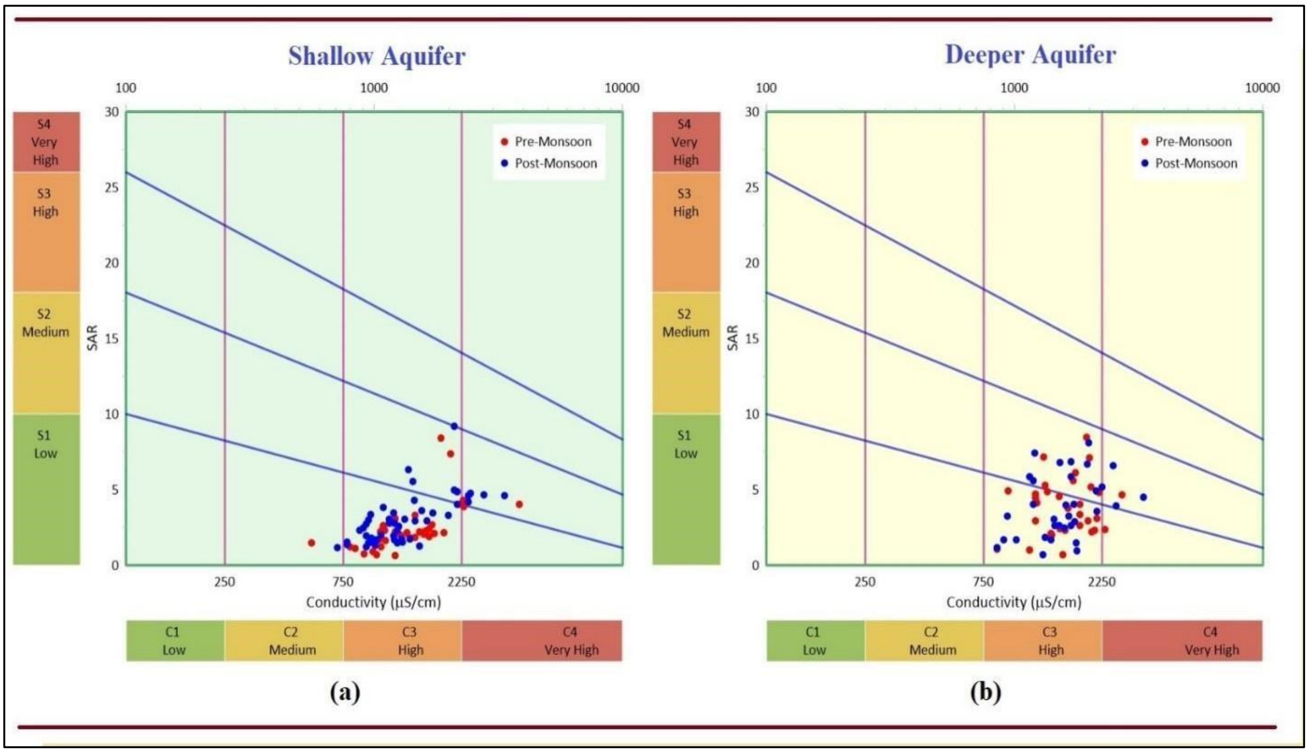


Fig. 5.3.3: (a) USSL Diagram for Shallow Aquifer Samples during Pre-Monsoon and Post Monsoon (b) USSL Diagram for Deeper Aquifer Samples during Pre-Monsoon and Post Monsoon

5.3.4 Surface Water Chemistry and its Assessment for Agriculture Use

For evaluation of surface water of study area a total 13 samples has been collected during study from percolation tanks, river and from nala. The water samples were analysed for following water quality parameters: pH, Electrical Conductivity (EC), Total hardness (TH), Calcium, Magnesium, Sodium, Potassium, Carbonate, Bi-carbonate, Chloride, Fluoride, Nitrate, Sulphate, Phosphate, Silica and selective trace/ heavy metals viz. Iron, Manganese, Copper, Zinc, Arsenic, Lead, Chromium and Uranium.

pH of surface water has been found between 7.23 to 8.03. Electrical conductivity ranges between 514 to 4526 µS/cm at 25°C with an average of 1504 µS/cm at 25°C. In surface water major cations follows the order of Na>Ca>Mg>K with percent distribution of 48%, 26%,23% and 2% respectively. While in anions follows the order of HCO3>Cl>SO4>NO3 with percent distribution of 47%, 39%, 10% and 4%.

In surface water samples, sodium adsorption ratio has been found between 0.8 to 10. and residual sodium carbonate has been found below 1.25. Permeability index of all the surface water samples has been found above 59 %. Based on SAR, RSC and PI surface water comes under Excellent, suitable and good category respectively. All the surface water samples has Kelly ratio below 1 and comes under suitable category for agriculture except Kaliyadeh bridge river water (R2), Bhairavgarh stp (N1) and Piliyakhal nala (R10).Sample from R10 has highest KR value of 1.80.

Based on USSL diagram, Nine samples of surface water falls under C3S1 category of USSL diagram, two samples falls under C2S1 category and one-one samples belongs to C4S2 (N1) and C4S3 (R10) category of USSL diagram.

5.3.5 Comparison of Ground Water Chemistry (Pre-Monsoon Vs Post-Monsoon)

To examine the effect of monsoon on ground water quality a paired t-test employed on 51 Number of samples. These 51 Nos. of samples collected from the same sample source during pre and post-monsoon. A t-test is a statistical hypothesis test that is used to determine whether there is a significant difference between the means of two groups. It helps you assess whether any observed differences between the groups are likely to have occurred by chance or if they are statistically significant.

At 95 % confidence level and with a degree of freedom 50, outcome of t-test reveals that, mean value of parameter such as pH, Electrical conductivity, sulphate, nitrate, fluoride, total hardness, magnesium, sodium, potassium, arsenic and lead has been changed significantly. Percent variation in mean value of significantly changed parameter after monsoon Percent distribution of nitrate in shallow and deeper Aquifer is being given in **figure 5.3.5 (a) & (b).**

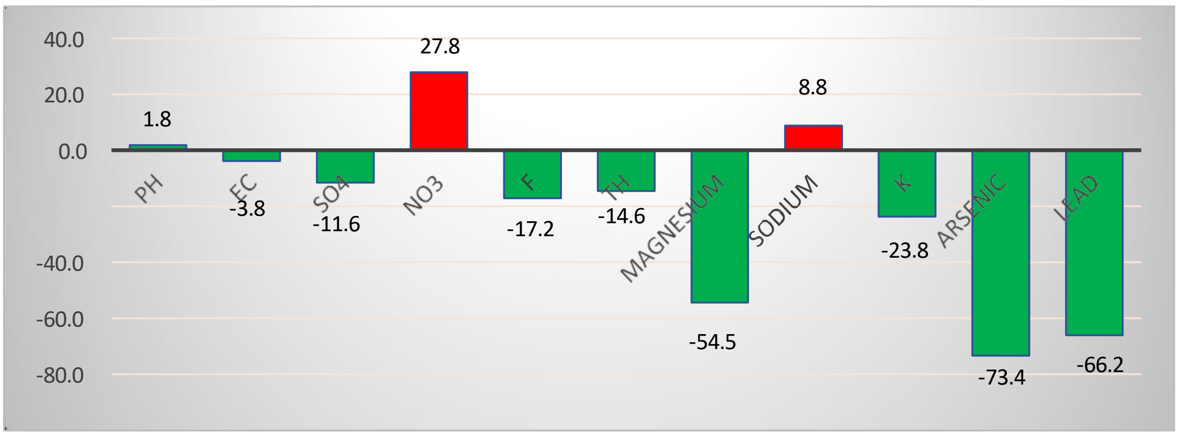


Fig. 5.3.5: (a) Percent variation in mean value of significantly changed parameter after monsoon.

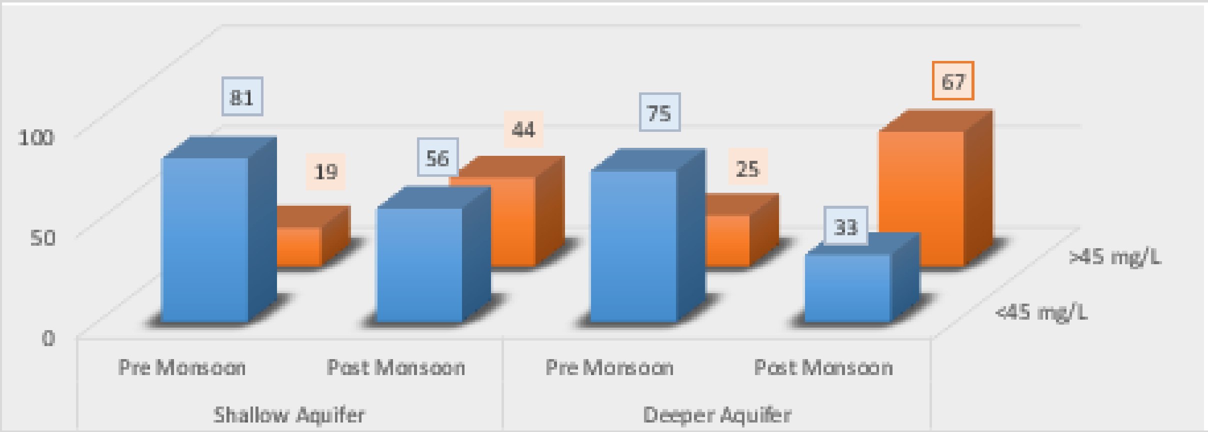


Fig. 5.3.5: (b) Percent distribution of nitrate in shallow and deeper Aquifer (Pre-Monsoon vs Post-Monsoon)

While parameter like bi-carbonate, chloride, calcium, iron, manganese, copper, zinc, chromium and uranium remained unchanged after monsoon. Parameters, which are changed significantly after monsoon, have negative percent change in mean value except nitrate and sodium. The mean value of nitrate and sodium increased 27.8 % and 8.8 % respectively after monsoon.

Both aquifer shows uptrend value for nitrate concentration after monsoon due to anthropogenic activities in study area i.e. use of agriculture fertilizer, municipal waste leaching etc. Rest of the parameters shows downtrend value after monsoon due to recharge of aquifers.

5.3.6 Water Quality Index of Ground Water of Study Area

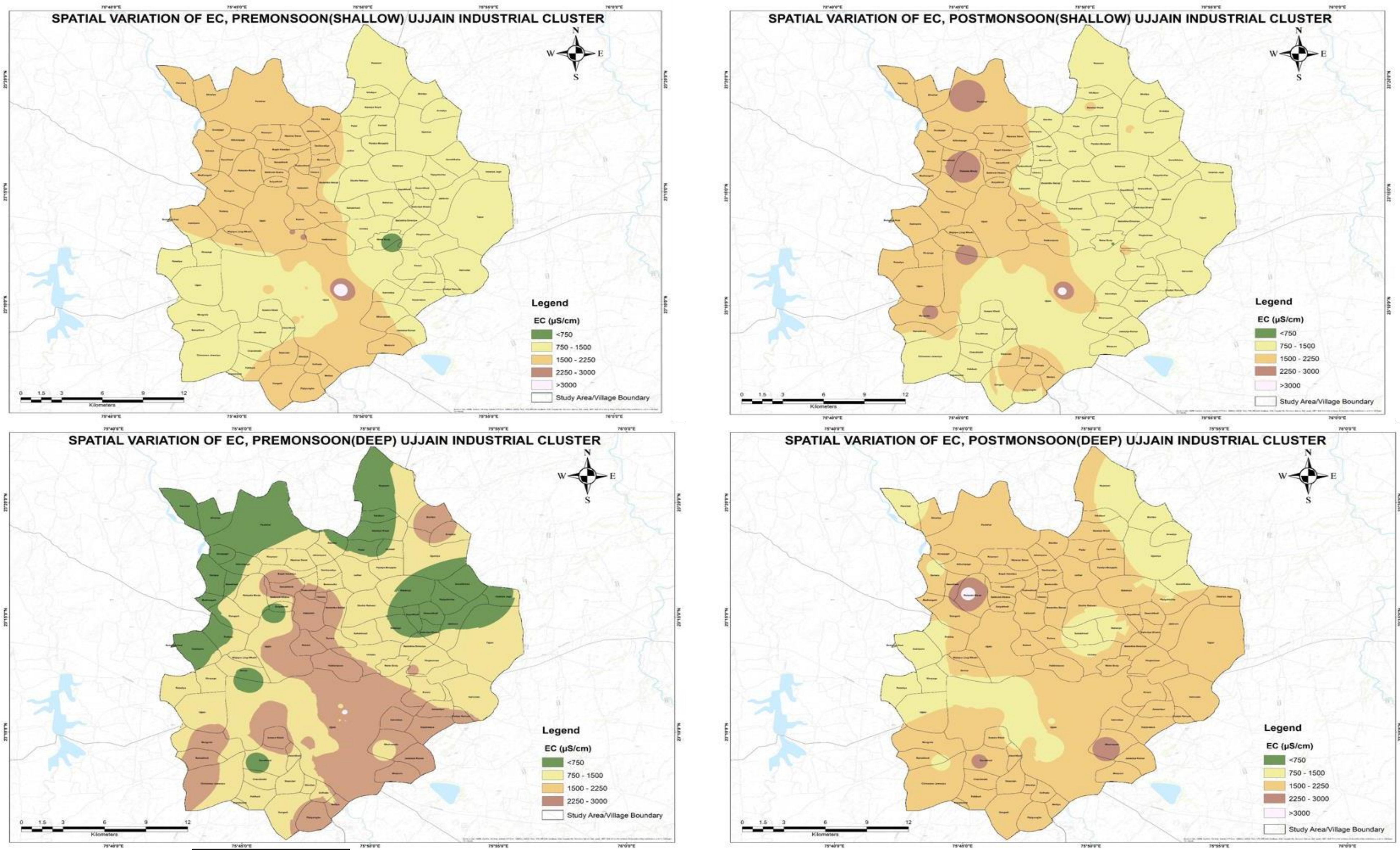
Water Quality Index (WQI) is a metric used to assess the overall quality of water based on multiple parameters. The WQI provides a single value representing the combined influence of various water quality parameters, allowing for a more straightforward interpretation and comparison. The method used for the calculation of the WQI was adapted from Sharma et al.

In shallow aquifer and deeper aquifer of study area, the WQI value ranged from 26 to 131 and 28 to 137 respectively. Percent distribution (WQI) of Ground water samples is being given below in **table 5.3.6.**

Table 5.3.6: Percent Distribution of water samples in shallow and deeper aquifer Based on Yenugu et al. WQI classification.

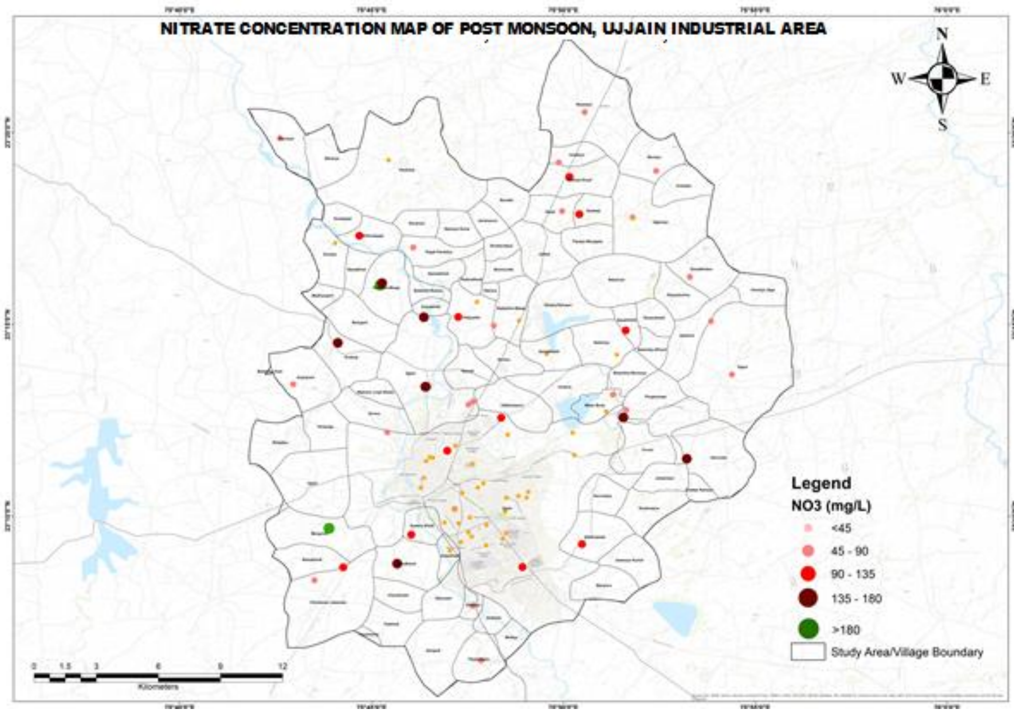
Classification range based on Yenugu et al. 2020	Water Quality	Shallow Aquifer		Deeper Aquifer	
		Pre-Monsoon	Post-Monsoon	Pre-Monsoon	Post-Monsoon
< 50	Excellent	40.5%	54.2%	25.0%	24.2%
50–100	Good	56.8%	41.7%	71.9%	72.7%
101–200	Poor water	2.7%	4.2%	3.1%	3.0
201–300	Very poor	Nil	Nil	Nil	Nil
> 300	Unsuitable	Nil	Nil	Nil	Nil

Almost 95 % samples of shallow and deeper aquifer of study area are found excellent to good water quality in terms of water quality index. In Pre-monsoon ground water from DW 34 (Makshi Road) of Shallow, aquifer and BW 36 (Lohe Ka Pul) of deeper aquifer have WQI value 131 and 126 respectively and comes under poor water category. While in post –monsoon ground water from DW 34 (Makshi Road) and DW 35 (Mangrola) for shallow aquifer and BW 11 (Ralayata Mauja) of deeper aquifer have WQI value 124, 107 and 137 respectively.



Pre-Monsoon **Post-Monsoon**

Fig. 5.3.1: (b) Spatial Distribution of EC, Ujjain Industrial Cluster



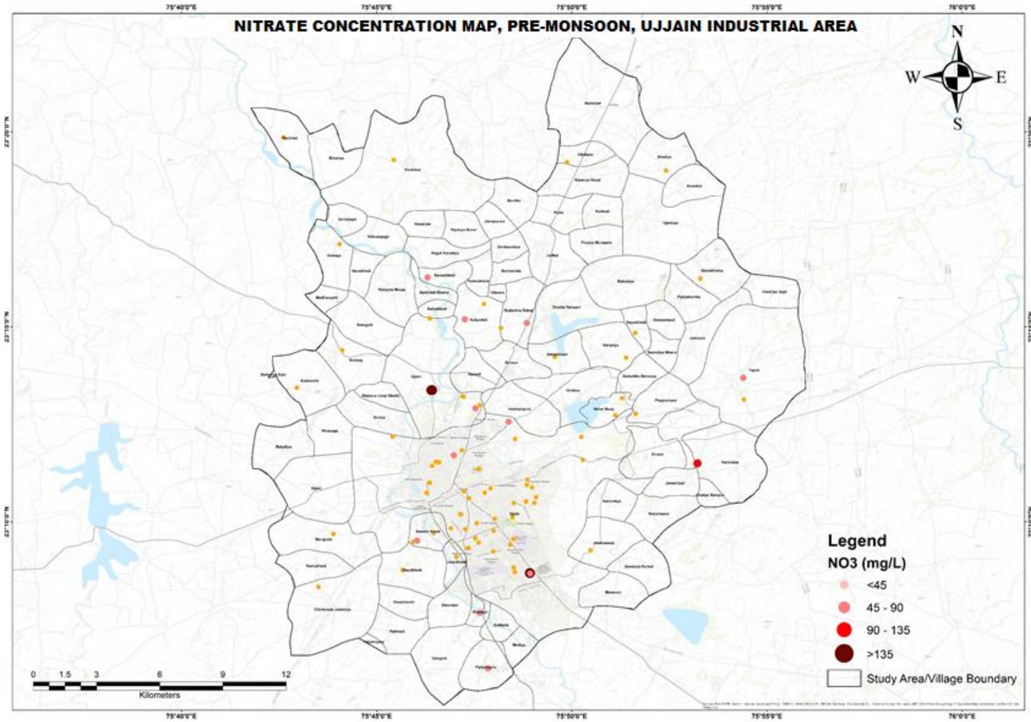


Fig. 5.3.1: (e) Point Values of NO3 Concentration, Ujjain Industrial Cluster

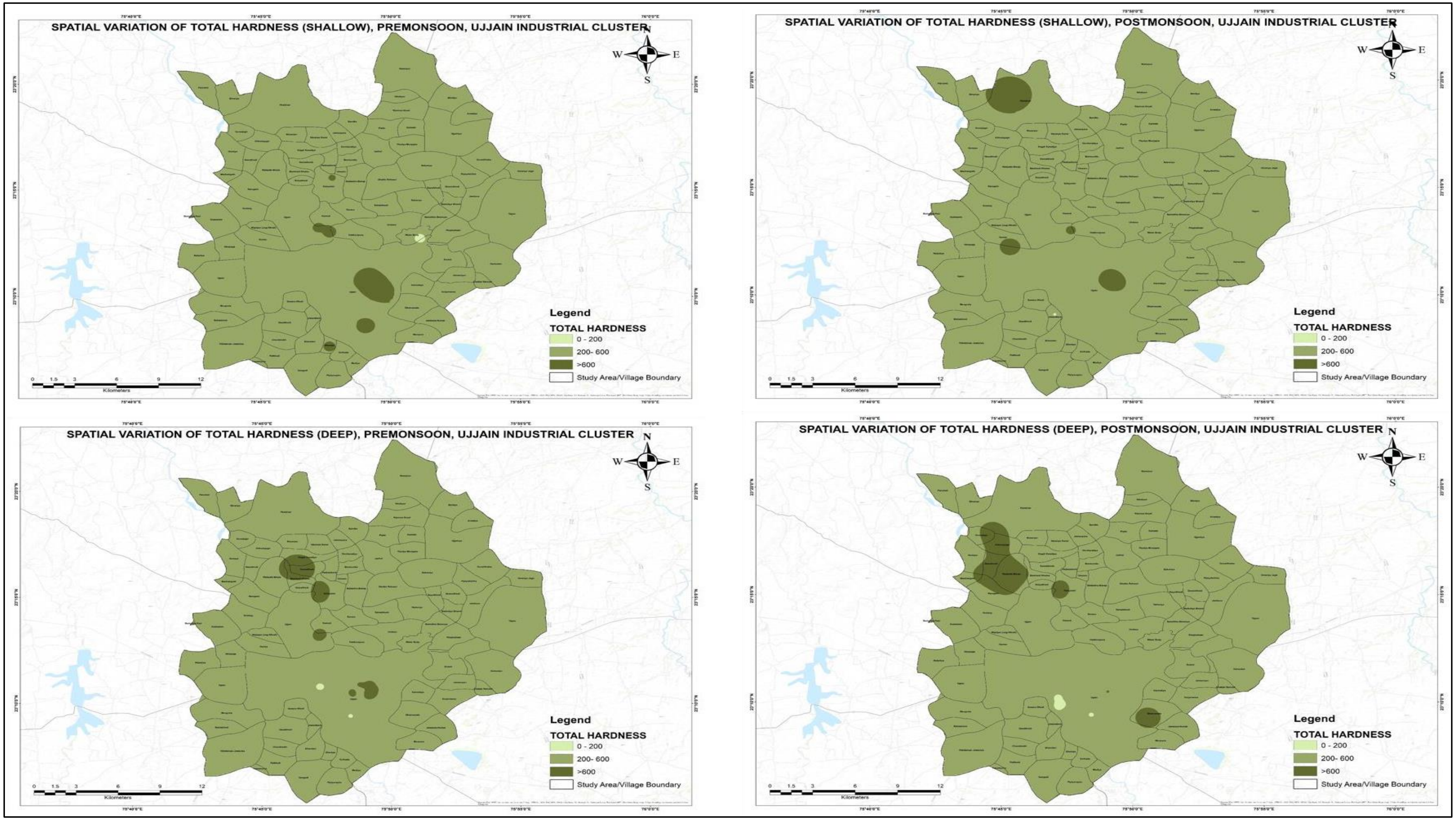


Fig. 5.3.1: (f) Spatial Distribution of Total Hardness, Ujjain Industrial Cluster

CHAPTER-6
Impact of Industrial activities and Vulnerability of Aquifers

6.1 Objectives

Assessing the impact of industrial activities on groundwater quality involves evaluating how various industrial processes and practices affect subterranean water sources. Industrial activities, such as manufacturing and waste disposal, can lead to the release of pollutants, including heavy metals, chemicals, and hydrocarbons, which seep into the groundwater and degrade its quality. This contamination can result in elevated levels of toxic substances, negatively impacting both human health and ecosystems. Comprehensive assessments typically involve monitoring groundwater samples for contaminants, analysing changes in water chemistry over time, and comparing findings against regulatory standards. The goal is to identify pollution sources, assess the extent of contamination, and implement mitigation strategies to protect groundwater resources and ensure safe drinking water supplies.

The objective of this study is to investigate the impact of industrial activities on groundwater quality in the study area by analyzing physical and chemical properties, comparing results with drinking water standards, and identifying key indicators of industrial impact. Additionally, the study aims to examine the distribution of Electrical Conductivity (EC) and Chloride, assess the presence of heavy metals, and evaluate the effects of groundwater contamination on crop productivity, ultimately identifying potential sources of contamination and informing strategies for mitigation and management.

6.2 Methodology

Ground water and surface water samples were collected in clean double stopper polyethylene bottles from 6 different locations close to industrial sector **(Table-6.2.1)** from dug well, hand pump and bore wells during pre-monsoon. The ground water samples were analyzed for following water quality parameters: pH, Electrical Conductivity (EC), Total hardness (TH), Calcium, Magnesium, Sodium, Potassium, Carbonate, Bi-carbonate, Chloride, Fluoride, Nitrate, Sulphate, Phosphate, Silica and selective trace/ heavy metals viz. Iron, Manganese, Copper, Zinc, Arsenic, Lead, Chromium and Uranium. Chemical analysis results has been compared against drinking water standard. We assumed Electrical Conductivity, chloride, sulphate, manganese, copper, zinc, lead, and chromium as key indicators for impact assessment of industrial activity on ground water quality. Sample Locations with source ID and results of Heavy Metals analysis are being given below in **Table 6.2.1 and Table 6.2.2** respectively.

Table-6.2.1 Sampling locations with source ID

Sl. No.	Source ID	Location Detail	pH	EC (µS/cm)	Cl (mg/L)	SO4 (mg/L)
1	DW34	Shri Guru Kripa Daal & Besan Mill (Near Mahavir Tolkanta), Maksi Rd	7.29	3851	805	378
2	BW17	Prad Pharmaceuticals, Agrasen Nagar	7.34	2715	375	127
3	BW18	Shaba Cylinders, Agrasen Nagar	7.29	1150	75	61
4	BW20	Alchemy Chemicals	7.39	2305	225	522
5	BW32	Hira Industries	7.26	1978	225	122
6	BW43	Sinhal Enterprise	7.48	1523	125	208

Table-6.2.2 Heavy metal analysis results

Sl. No.	Source ID	Mn	Cu	Zn	Pb	Cr
		mg/L			µg/L	
1	DW34	0.112	BDL	0.001	BDL	BDL
2	BW17	0.006	0.004	0.069	1.3	BDL
3	BW18	0.126	0.003	0.023	1.1	0.6
4	BW20	0.004	0.001	0.003	1.4	BDL

5	BW32	0.003	0.003	0.004	4.6	0.9
6	BW43	0.001	0.01	0.011	1.8	0.6

Effluents from the industrial cluster are processed at the Sadawal treatment plant before being released into the Khsipra river, while certain areas within the urban region necessitate maintenance of the sewage network.

6.3 Result and Discussions

6.3.1 Distribution of EC and Chloride in Industrial area.

pH in industrial area samples has been found between 7.29 to 7.48 **(Table-6.2.1)** and as per BIS recommendation, all water samples are within the **acceptable limit**. The ground water of the industrial area can be assessed as slightly acidic to neutral in nature. The electrical conductivity of ground water in industrial area ranges in between **1150 to 3851** µS/cm at 25°C. Electrical Conductivity of DW34 (Shri Gurukripa Daal & Besan Mill, Maksi Rd) has been found above permissible limit of IS 10500:2012 i.e. more than 3000 **(µS/cm)** at 25°C.The Chloride concentration in ground water of industrial area has been found between 75 to 805 mg/L. DW 34, located in Shri Gurukripa Daal & Besan Mill on Maksi Road, ground water has a maximum chloride concentration i.e. 805 mg/L. The distribution of EC and point value map of chloridefor study area are being given below in figure xx and figure xx respectively. The Ground water of alchemy chemicals has sulphate concentration 522 mg/L i.e. above permissible limit set by drinking waterstandard. The Concentration of Mn, Cu, Zn, Pb and Cr has been found within acceptable limit **(Table-6.2.2)** in all the ground water samples of Industrial area. The distribution of EC and Chloride is illustrated in the **fig-6.3.1.**

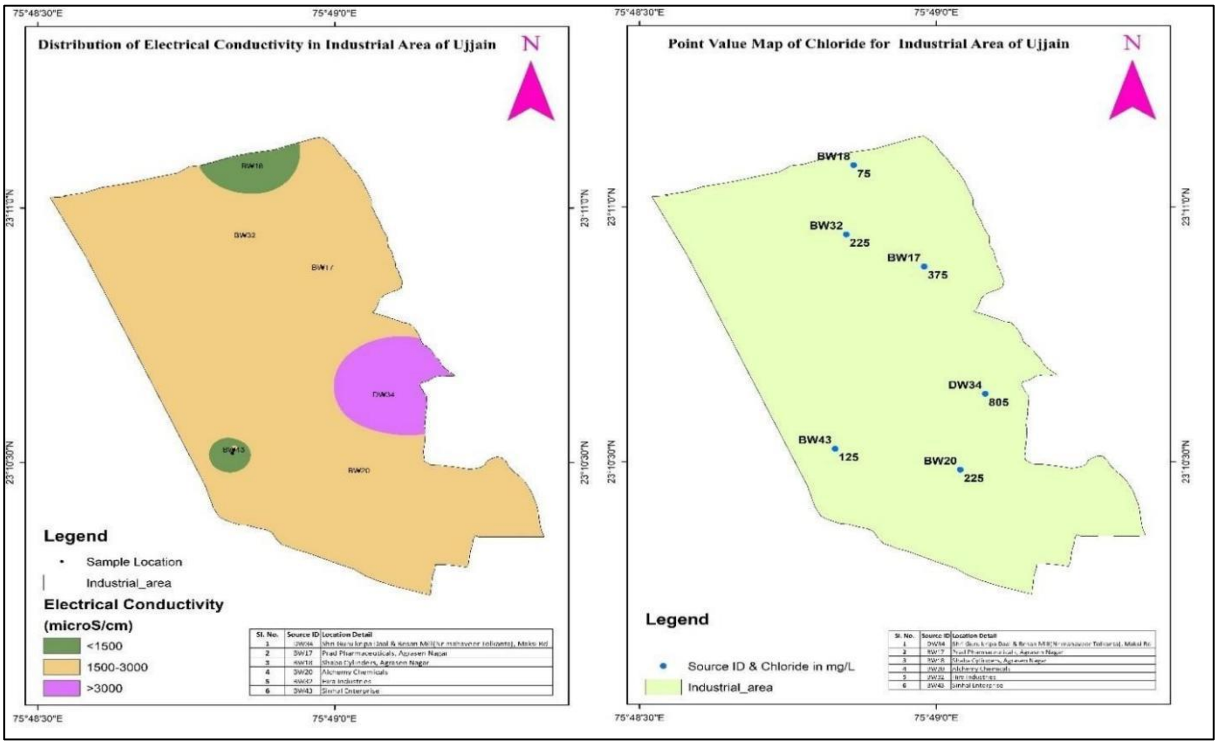


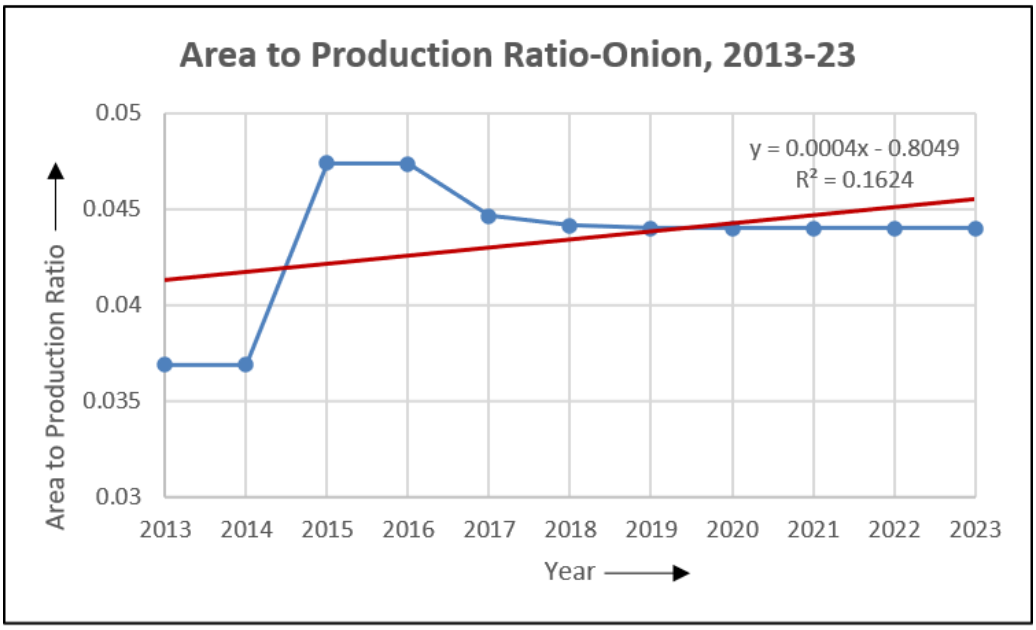
Fig-6.3.1: Distribution of EC & Chloride in industrial area

The chemical analysis results of ground water samples reveal no sign of heavy metal pollution in industrial area of our study area. Some point source is there nearby Shri Guru Kripa Daal & Besan Mill that is contaminating ground water of DW 34 and Deeper Aquifer sample near alchemy chemicals has high Sulphate concentration indicating some source of sulphate is there and requires further study for source identification.

Furthermore, it was observed that groundwater and surface water contamination due to effluents from Piliyakhal nala carrying Industrial effluents, Bhairavgarh nala carrying Textile Dyes, Kanh River diversion canal carrying treated water and Industrial effluents from Indore district and Gonsa Nala carrying treated water from Sadawal Sewage Treatment Plant.

6.3.2 Decline in Crop Productivity

Effluents from industries located in Indore district are drained by 72km polluted stretch of Kanh River **(Fig-1.1.b),** merging with Kshipra River near the southern part of study area, affecting the quality of Kshipra River. As inferred from farmer's feedback **(Annexure-5),** since the implementation of the project, the production and health of onion and garlic production are adversely affected in the area**.** Both the crops are either affected by yellowing and rotting of leaves and rotting of roots. Yield of the crops also decreased over the years. Same issue is reported in Sawarakhedi and Daudkhedi villages in the Urban area where the canal is leaking into GW. Inorder to confirm the same, production data of onion and garlic from 2013 to 2023 was collected from Agricultural Directorate, Ujjain district (**Annexure-6**). Results of the data analysis is given in **Fig-6.3.2-a and 6.3.2-b.** Area of each crop (y-axis) is plotted against year (x-axis) in fig. **6.3.2-c and 6.3.2-d**. Area to production ratio of each crop (y-axis) is plotted against year in x-aixs. From figure 6.3.2-a and 6.3.2-c and the data it is evident that there is a sharp increase in area of onion crop in the study area in the year 2015 with a rising trend till 2023 while the area to production ratio of the crop is more or less same. This indicates low yield of onion crop in the area especially since 2017. Similarly, the area to production ratio of garlic is showing declining trend while the area of crop increased over the years. Onion and garlic crops belongs to the genus Allium which are sensitive to the presence of heavy metals and NaOH. Problematic villages coincide with the Kanh diversion canal project and Gonsa Nala. Even though all the parameters exhibited values within the BIS limits, the principle component analysis revealed that these villages shows positive loading related to EC, TDS, SO_4, Cl, TH, Ca, HCO_3 moderate and positive loading related to Pb, Zn, PO_4, Cr, Cu and F. This indicates mixing of heavy metal contaminants from different effluents (**Annexure-7**).



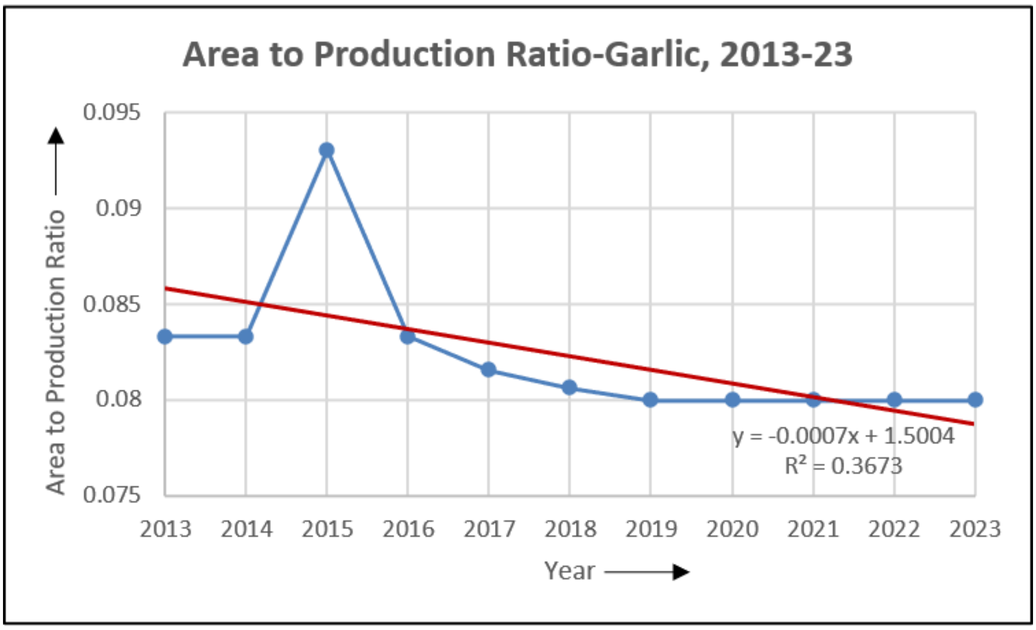
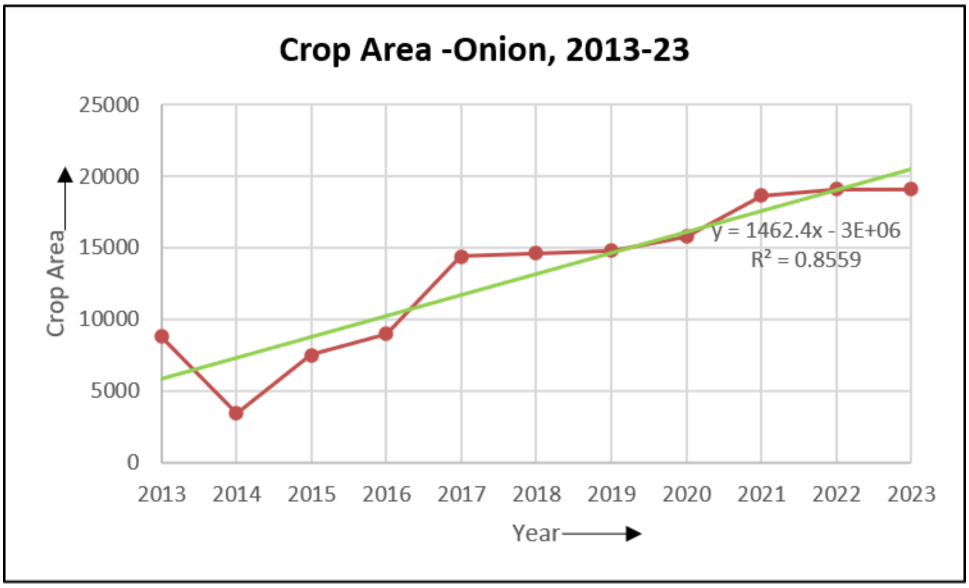


Fig. 6.3.2: (a & b) Crop Productivity of Onion, Garlic in Ujjain Industrial Cluster



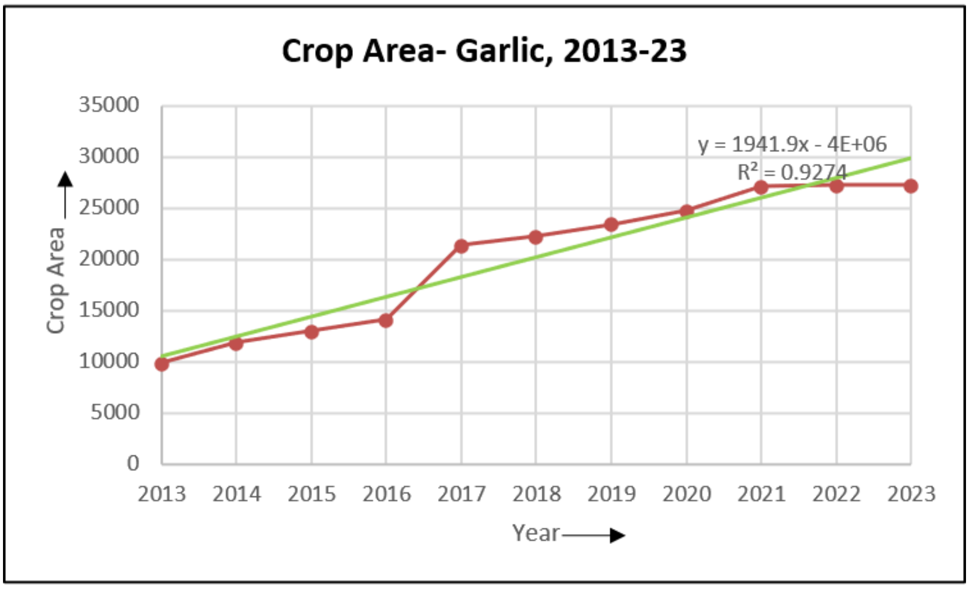


Fig. 6.3.2: (c & d) Crop Area of Onion, Garlic in Ujjain Industrial Cluster

CHAPTER-7
GROUND WATER RELATED ISSUES

The groundwater-related issues identified through the hydrogeological, geophysical, and geochemical studies conducted in the study area are listed below (Fig-7).

7.1 Issue: Low Groundwater Sustainability & Deeper water levels: -

During pre and post monsoon monitoring, it has been observed that massive basalt is exposed at top in villages **(Fig-7)** viz. Panbihar, Nipaniyasunar, Bandka, Gunaikhalsa etc. Due to the same, rate of natural recharge is low in these areas leading to low groundwater sustainability. Further, villages Jambura, Umariya, Tajpur, Badodiyabhand etc. have deeper water levels leading to are low groundwater sustainability (Inferred from farmers feedback). This causes demand-supply gap for irrigation in the villages as the major crop cultivated in the area is wheat.

7.2 Issue: Low Groundwater sustainability and prone to contamination: -

In villages towards the W, SW parts of study area **(Fig-7)** Azampura, Vinayaga, Ratadiya, Ujjain, Mangrola, Ratankhedi, Chintaman Jawasiya, Chandmukh, Palkhdei, Hasampura, low groundwater sustainability is observed due to over exploitation for irrigation. Further, these villages are close to the sources of surface water contamination in the study area including Gonsa Nala. Further, in villages like Sodang, water from river is used for irrigation through pipelines. The return flow from this irrigation is contaminating groundwater. Therefore, the above-mentioned villages are prone to contamination. However, ensuring source sustainability is necessary for agriculture and drinking/domestic purposes in this area.

7.3 Issue: Groundwater and surface water contamination due to various sources

- **Piliyakhal Nala**

  Piliyakhal Nala Carrying Industrial Effluents – starting from the industrial area, the piliyakhal drain carries industrial effluent from Vikram Udyogpuri and drains through the study area to meet Kshipra River near Mangalnath Ghat.

- **Bhairavgarh Nala**

  Bhairavgarh Nala Carrying Textile Dyes – starting from the Bhairavgarh textile area, the drain carrying textile dyes especially indigo colour drains through the study area to get collected at treatment plant near Bhairavgarh. As the plant is not operational, the effluent gets mixed with Kshipra River near bridge at Ujjain-Nagda ring road.

- **Kanh River Diversion Canal**

  The diversion canal carrying treated water and Industrial effluents from Indore district flows through 17km closed duct underground diversion canal and meets Kshipra river at Sulyakhedi village. This water is being mixed with fresh water in Kshipra river without any treatment causing contamination of Kshipra river.

- **Gonsa Nala**

  Gonsa Nala carrying treated water from Sadawal Sewage Treatment Plant- The treated water effluent from Sadawal treatment plant carries Na and OH used for sewage treatment and meets Kshipra river near Shri Vikrant Bhairav Temple.

- **Nitrate contamination-**

  Nitrate Contamination is observed in shallow aquifer in urban area in Alkadham Nagar, Gandhinagar, Nagjhiri, Kshipra Vihar, Vyas Nagar and Krishi Upaj Mandi. This is due to the leakage of sewage water into groundwater.

7.4 Low Yield/Productivity of Onion and Garlic (Fig-6.3.2a)

Low productivity of Onion and Garlic and health issues of Onion and Garlic Crops in villages due to irrigation from Surface Water - Sulyakhedi, Padmakhedi, Kadgi Karadia, Kithodajagir, Sawarakhedi, Sodang and Panched.

From the **Fig-7** it is observed that the crop yield issues found was coinciding with the Kanh diversion canal project. Special management for salinity control may be required including soil treatment. Plants/ crops with good salt tolerance should be selected (Cereals, Leafy vegetables, Chickpea, Indian Mustard, Sugar beet etc.) instead of Garlic/Onion.

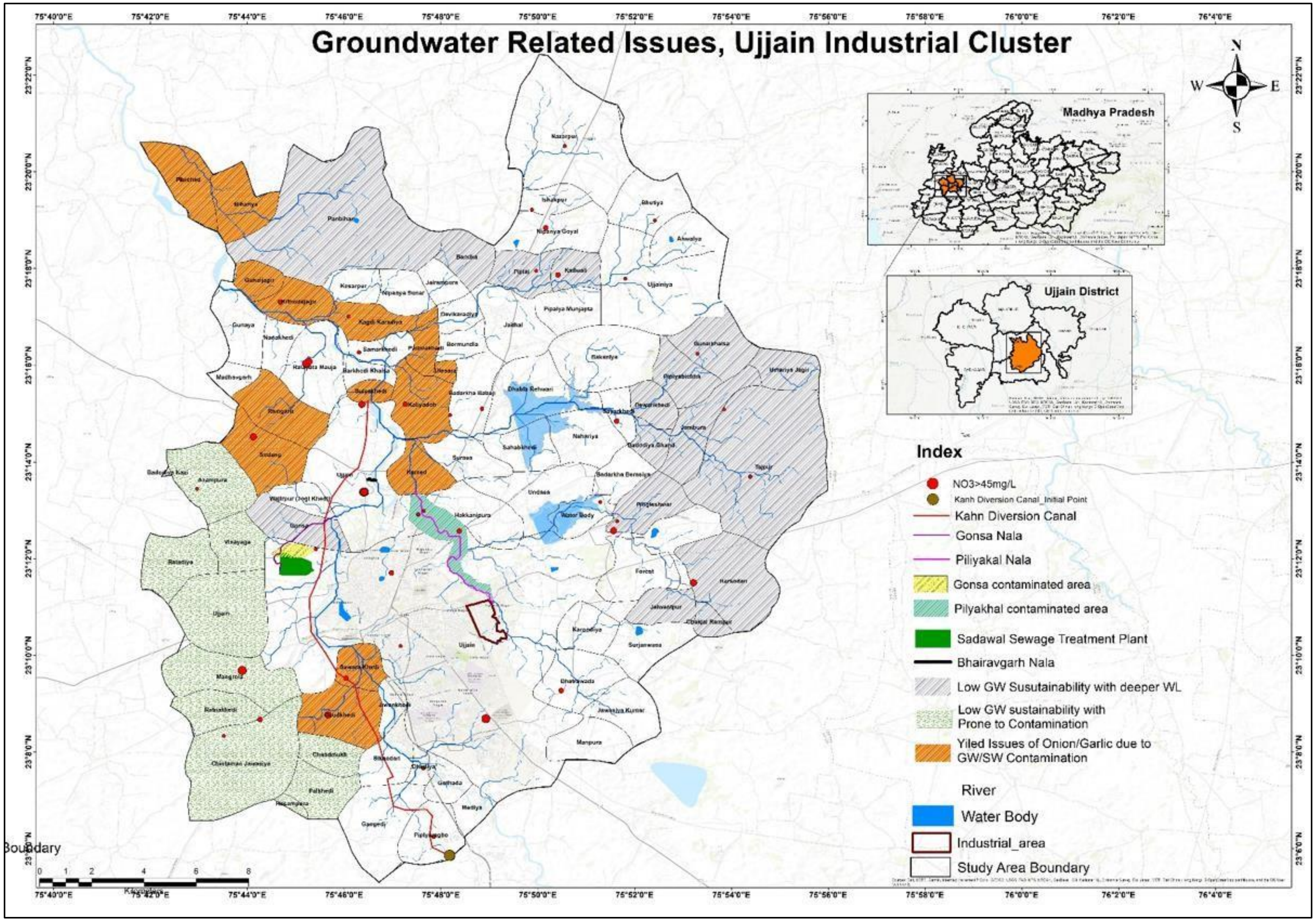


Fig-7 Showing ground water related issues

GROUNDWATER MANAGEMENT PLAN

CHAPTER-8
MANAGEMENT PLAN

8.1 Objectives

Groundwater management interventions encompass a range of strategies aimed at safeguarding and improving the quality and availability of groundwater resources.
One crucial aspect of our study involves the demarcation of safer aquifers, which entails identifying and delineating aquifers with minimal contamination risks and ensuring their sustainable utilization. Another part emphasize the significance of artificial recharge in over-exploited areas covered by hand and massive Deccan Traps Basalt, aiming at groundwater replenishment, mitigating water scarcity, and enhancing water quality.

8.1 Methodology

Understanding of groundwater related issues are very crucial before suggesting management interventions. For identification of issues, extensive field work had been carried out in the study area during the period of April 2023 to March 2024. During the visits, filed mapping of aquifers, identification and mapping of sources of contamination, water sample collection and quality monitoring, well inventory and water level monitoring were carried out and farmers feedback were collected. Issue based management plan was formulated **(Fig-8.3.1 and Table-8.3.1 and 8.3.2).**

8.2 Results and Discussion

8.2.1 Issue: Low Groundwater Sustainability & Deeper water levels

Management Plan - Low Groundwater Sustainability & Deeper water levels
In order to ensure sustainability, artificial recharge to groundwater is recommended in the area. As massive basalt is exposed in some the above villages, construction of recharge shaft up to a depth of 1st available aquifer (weathered/vesicular) recommended. Total 16 recharge shafts are recommended up to maximum depth of 35m with a diameter of 200mm.

8.2.2 Issue: Low Groundwater sustainability and prone to contamination

Management Plan - Low Groundwater Sustainability & Deeper water levels

In order to ensure sustainability, artificial recharge to groundwater is recommended in the area **(Fig-8.3.1).** As weathering thickness is available, construction of farm ponds up to a depth of 3.5m is recommended in this area. As this area is prone to contamination, periodical groundwater quality monitoring is also recommended in this area. Total number of farm ponds recommended is 11.

8.2.3 Issue: Groundwater and surface water contamination due to various sources

During field study, various sources of groundwater and surface water contamination were identified in the study area as discussed;

a. **Issue: Piliyakhal Nala**

   Management Plan: Liquid effluent from all industries shall be collected and transported to a common point. The drain that carries industrial effluents to the treatment plant should be properly lined in order to avoid leakage into ground.
   The effluent shall then be treated by constructing a common ETP (Location marked in the map). Operational charges of the ETP can be charged from the industries based on quantity of effluent generated.
   Treated water (grey water) can be used for various purposes including supply to hotels, public utility centers for flushing. The solid waste can be transported to nearest fertilizer industry. The same method is being adopted by various industrial zones under MPIDC like Mandideep, Sanwer, Meghnagar, Pithampur etc.

b. **Issue: Bhairavgarh Nala Carrying Textile Dyes**

   Management Plan: Treatment Plant near Bhairavgarh was found to be not operational during the visits in May, September, November 2023 and January 2024. As the textile industry is cottage industry in the area, maximum effluent is generated during January to mid-May and mid-September to December. District administration shall carryout the necessary maintenance of the plant and make it fully operational during the above-mentioned periods. Further, the drain that carries industrial effluents to the treatment plant should be properly lined in order to avoid leakage into ground.

c. **Issue: Kanh River Diversion Canal**

   Management Plan: Before diverting the water from Kanh river to the diversion canal at Gothra, it should be treated properly. If not possible, district administration shall take up collaborative project district administration, Indore as the major sources of contamination of Kanh river is situated in Indore district. Action plan for Rejuvenation of Kanh river by MPPCB, Indore is enclosed for reference.

d. **Issue: Gonsa Nala**

   Management Plan: The STP shall be utilized to its full capacity of 87MLD. Further, treated water (grey water) can be used for various purposes including recharge to groundwater through irrigation tanks after quality testing. The treated water can also be supplied to hotels, public utility centers etc. for flushing. Solid waste can be transported to nearest organic fertilizer industry.

e. **Issue: Nitrate contamination**

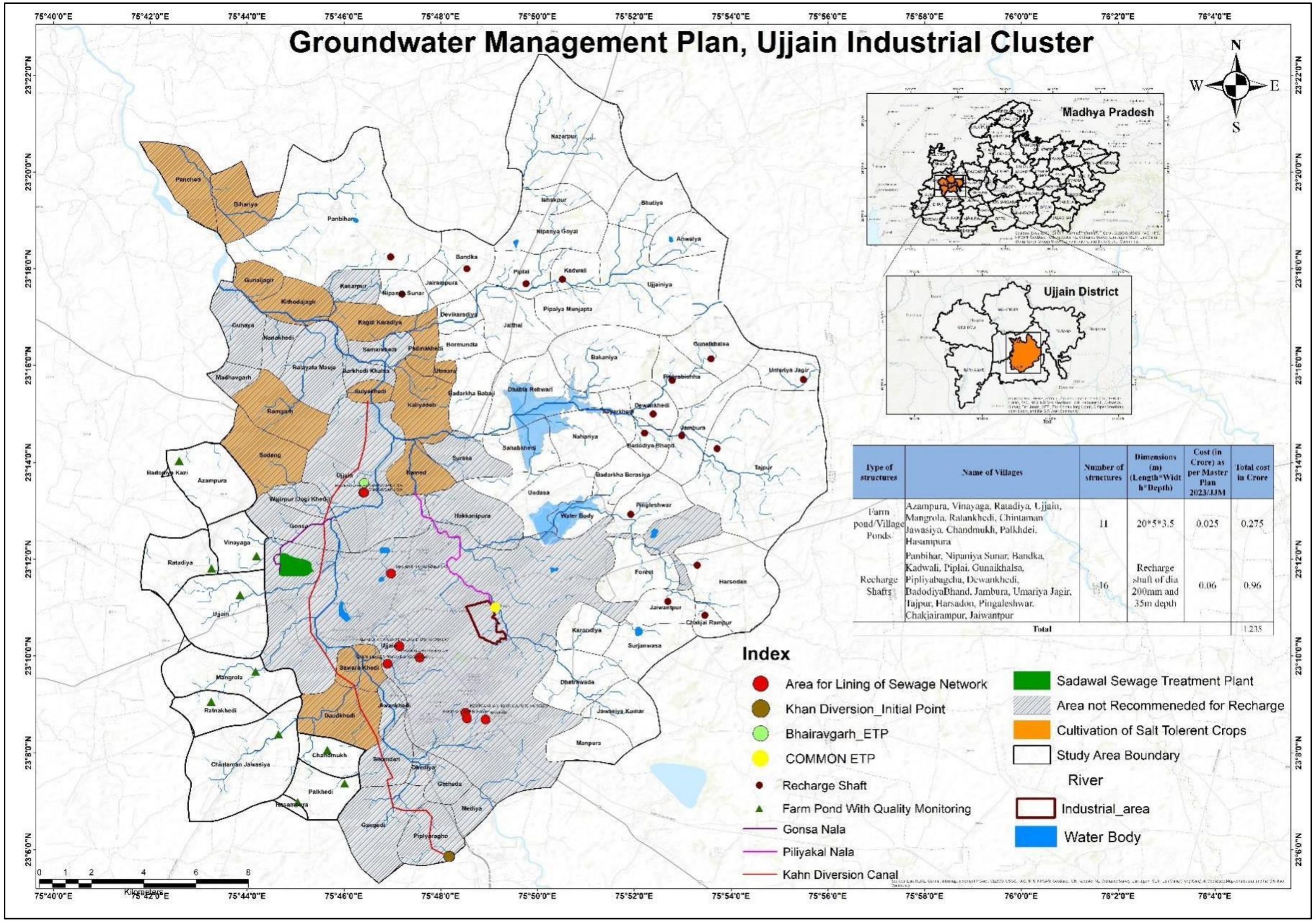
Management Plan: In order to avoid this, the sewage pipelines/drains shall be properly maintained and lined with leak proof material.

f. **Issue: Low Yield/Productivity and health issues of Onion and Garlic**

Management Plan: Onion and garlic belong to genus Allium which are sensitive to heavy metal and OH contamination. In the above-mentioned villages, irrigation is carried out either directly from Kshipra River or through private pipelines by farmers. It was observed that productivity of onion and garlic had significantly reduced in these villages since 2016. In Sawarakhedi village, the Kanh diversion canal is leaking into the groundwater which is causing similar productivity issue in onion and garlic. As a management strategy, it is recommended to cultivate Plants/ crops with good salt tolerance instead of Garlic/Onion. Eg:- Cereals, Leafy vegetables, Chickpea, Indian Mustard, Sugar beet etc. The district administration shall take the necessary steps to increase the MSP of such crops in consultation with KVK, Ujjain. Further, the maintenance of Kanh diversion canal should also be carried out. DPR on Khan Diversion Canal Project by WRD, Ujjain is attached for reference.

Table 8.3.1: Artificial Recharge Plan, Ujjain Industrial Cluster

Type of structures	Name of Villages	Number of structures	Dimensions (m) (Length*Width*Depth)	Cost (in Crore) as per Master Plan 2023/JJM	Total cost in Crore
Farm pond/Village Ponds	Azampura, Vinayaga, Ratadiya, Ujjain, Mangrola, Ratankhedi, Chintaman Jawasiya, Chandmukh, Palkhdei, Hasampura	11	20*5*3.5	0.025	0.275
Recharge Shafts	Panbihar, Nipaniya Sunar, Bandka, Kadwali, Piplai, Gunaikhalsa, Pipliyabagcha, Dewankhedi, BadodiyaBhand, Jambura, Umariya Jagir, Tajpur, Harsadon, Pingaleshwar, Chakjairampur, Jaiwantpur	16	Recharge shaft of dia 200mm and 35m depth	0.06	0.96
Total					1.235



Type of structures	Name of Villages	Number of structures	Dimensions (m) (Length*Width*Depth)	Cost (in Crore) as per Master Plan 2023/JJM	Total cost in Crore
Farm pond/Village Ponds	Azampura, Vinayaga, Ratadiya, Ujjain, Mangrola, Ratankhedi, Chintaman Jawasiya, Chandmukh, Palkhdei, Hasampura	11	20*5*3.5	0.025	0.275
Recharge Shafts	Panbihar, Nipaniya Sunar, Bandka, Kadwali, Piplai, Gunaikhalsa, Pipliyabagcha, Dewankhedi, BadodiyaBhand, Jambura, Umariya Jagir, Tajpur, Harsadon, Pingaleshwar, Chakjairampur, Jaiwantpur	16	Recharge shaft of dia 200mm and 35m depth	0.06	0.96
Total					1.235

Fig. 8.3.1: Proposed Groundwater Management Plan, Ujjain Industrial Cluster

CHAPTER-9
Conclusion and Recommendation

- The study area, spanning **478 km², ** is part of the industrial cluster in Ujjain city, specifically within the **Ghatia and Ujjain blocks**. The predominant industries in this region include food products and food processing, pharmaceuticals, steel and engineering products, petroleum products, and explosives manufacturing.

- The land use pattern in the study area is a mixture of **Agriculture area** 401.02 km^2 which is 83.9 %, **Build up area** 66.62 km^2, **Industrial area (**DMIC Vikram Udyogpuri**)** 4.5 km^2, **Water body** 7.44 km^2 and **barren land** 2.94 km^2.

- The aim of the study was to determine whether effluent from the industrial sector contaminates groundwater. To achieve this, geological, geophysical, and geochemical studies were conducted. A total of **97 key observation wells** were established and 4 exploratory wells (EWs), **1 observation well (OW),** and **3 piezometers (PZs)** were constructed. Additionally, **48 vertical electrical soundings (VES)** were performed across the study area to investigate groundwater dynamics. All exploratory data were compiled for analysis and the construction of 2-D and 3-D section.

- All maps were prepared for the study. The geological map indicates that the area is covered by **Deccan basalt.** The water table map reveals that deeper water levels are found in the northern and north eastern parts of the study area. The drainage map shows that the stream is in an effluent condition during both pre-monsoon and post-monsoon seasons.
- From the exploratory drilling, it was observed there are 3 types of aquifer is present in the study area (1st aquifer ranges from **0.00-20.00mbgl**, 2nd aquifer from **50.00-80.00** mbgl and 3rd aquifer below **100 mbgl**).

- The geochemical study revealed that all three types of aquifers—shallow, intermediate, and deeper—were free of contamination, as no river recharge **(Effluent stream)** had occurred. However, surface water was found to be contaminated where industrial effluent mixed with river water, which negatively impacts crop production.
- In addition, in areas such as **Sawarakhedi and Daudkhedi** villages within the urban area, canal leakage into groundwater has been observed. These problematic villages are situated near the Kanh Diversion Canal project and Gonsa Nala, where onion and garlic production has gradually declined following the implementation of the **Kanh Diversion project.**

- The groundwater-related issues identified includes **Low sustainability and deeper water levels** due to exposure of massive basalt, surface water contaminated due to industrial effluent, groundwater contaminated due to leakage of sewage pipelines, leakage of khan diversion canal, areas affected by contamination due to return flow recharge from irrigation from contaminated surface water.

- **Low Yield/Productivity** and health issues of Onion and Garlic Crops in villages due to irrigation from Surface Water - Sulyakhedi, Padmakhedi, Kadgi Karadia, Kithodajagir, Sawarakhedi, Sodang and Panched.
- **Nitrate contamination** is observed in shallow aquifer in urban area in Alkadham Nagar, Gandhinagar, Nagjhiri, Kshipra Vihar, Vyas Nagar and Krishi Upaj Mandi. This is due to the leakage of sewage water into groundwater.

- In order to ensure sustainability, **artificial recharge** to groundwater is recommended in the villages Panbihar, Nipaniyasunar, Bandka, Gunaikhalsa, Jambura, Umariya, Tajpur, Badodiyabhand etc.
- The villages Azampura, Vinayaga, Ratadiya, Ujjain, Mangrola, Ratankhedi, Chintaman Jawasiya, Chandmukh, Palkhdei, Hasampura prone to contamination recommended to construct farm ponds up to a depth of 3.5m as weathering thickness is available.
- For industrial contamination, the liquid effluent shall be collected and transported to a common ETP for the treatment and the treated water (grey water) can be used for various purposes including supply to hotels, public utility centers for flushing plant and operational charges of the ETP can be charged from the industries based on quantity of effluent generated. The solid waste can be transported to nearest fertilizer industry. The same method is being adopted by various industrial zones under MPIDC like Mandideep, Sanwer, Meghnagar, Pithampur etc.

- Treatment Plant near Bhairavgarh was found to be not operational during the visits in May, September, November 2023 and January 2024. District administration shall carryout the necessary maintenance of the plant and make it fully operational.
- Before diverting the water from Kanh river to the diversion canal at Gothra, it should be treated properly.

- The sewage pipelines/drains shall be properly maintained and lined with leak proof material in areas of Nitrate contamination like Alkadham Nagar, Gandhinagar, Nagjhiri, Kshipra Vihar, Vyas Nagar and Krishi Upaj Mandi.
- A management strategy is recommended in areas where onion and garlic production has been decreases to cultivate Plants/ crops with good salt tolerance instead of Garlic/Onion. Eg:- Cereals, Leafy vegetables, Chickpea, Indian Mustard, Sugar beet etc.

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Annexure-1

SI No.	Application Type	Project Name	Application Category Description	Latitude	Longitude
1	Industrial	New Era Switchgear Pvt Ltd	Steel Fabrication Industry	23.183413	75.814943
2	Industrial	Ariba Foods Pvt. Ltd	Food Processing Industry	23.46188	75.850399
3	Industrial	Unique Industries	Plastic	23.1902	75.8138
4	Industrial	Prad Pharma Products	Pharmaceuticals	23.1813	75.8163
5	Industrial	Vyanktesh Plastic & Packaging Pvt Ltd	Corrugated boxes	23.1811	75.80997
6	Industrial	Shree Packers Mp Pvt Ltd Unit-2	Corrugated boxes	23.1806	75.8104
7	Industrial	Vyanktesh Corrugators Pvt Ltd	Corrugated boxes	23.1838	75.81581
8	Industrial	Vyanktesh Corrugators Pvt Ltd	Corrugated boxes	23.1838	75.8158
9	Industrial	Shree Packers Mp Pvt. Ltd	Corrugated boxes	23.1808	75.8109
10	Industrial	Padma Polytex	Plastic	23.18315	75.809856
11	Industrial	Shree Packers Mp Pvt Ltd	Corrugated boxes	23.18189	75.811276
12	Industrial	Divis Pharma Chem	Bulk Drug	23.1765	75.7885
13	Industrial	India Phosphate	Bulk Drug	23.1765	75.7885
14	Industrial	Pioneer Engineering Industries	Foundary Operation	23.1765	75.7885
15	Industrial	Hira Industries	Agro Base Food Products	23.18	75.81
16	Industrial	Heavy Machines	Engineering Goods Products	23.1793	75.784912
17	Industrial	Osmed Formulations Pvt. Ltd.	Pharmaceuticals	23.175021	75.814063
18	Industrial	Kush Enterprises	Explosive Manufacturing	23.25314	75.91342
19	Industrial	Tara Flour Mill	Food Processing Industry	23.25654	75.90752
20	Industrial	Uk Engineering	Steel Fabrication Industry	23.25337	75.9134
21	Industrial	R M Enterprises	Petroleum Products	23.1765	75.7885
22	Industrial	Shaba Cylinder Pvt. Ltd.	Steel Fabrication Industry	23.18445	75.814412
23	Industrial	Sonam Industries	Packaged Drinking Water	23.17919	75.784248
24	Industrial	Alimco Auxiliary Production Center	Steel Fabrication Industry	23.1332167	75.8326194

SI No.	Application Type	Project Name	Application Category Description	Latitude	Longitude
25	Industrial	Ujjain Bottling Plant Indian Oil Corporation Limited	Petroleum Products	23.35969	75.855588
26	Industrial	Clinker Grinding Unit J.K. Cement	Cement Industry	23.2586	75.7636
27	Industrial	Shriji Polymers (India) Limited	Pharmaceutical Packaging	23.179567	75.788732
28	Industrial	Shriji Polymers (India) Limited	Pharmaceutical Packaging	23.179567	75.788732
29	Industrial	Ujjain Bottling Plant Indian Oil Corporation Limited	Petroleum Products	23.35969	75.855588

Annexure-2

Site Name	Depth to Top (m)	Depth to Base (m)	Stratigraphy
Ratadiya	0	4.8	Top Soil
Ratadiya	4.8	4.8	MB1
Ratadiya	4.8	14	WB1
Ratadiya	14	17	VB1
Ratadiya	17	17	AB1
Ratadiya	17	31.5	MB2
Ratadiya	31.5	31.5	Redbole1
Ratadiya	31.5	34.5	WB2
Ratadiya	34.5	34.5	VB2
Ratadiya	34.5	46.7	MB3
Ratadiya	46.7	49.8	WB3
Ratadiya	49.8	49.8	VB3
Ratadiya	49.8	49.8	AB2
Ratadiya	49.8	49.8	MB4
Ratadiya	49.8	49.8	FB1
Ratadiya	49.8	49.8	AB3
Ratadiya	49.8	62	MB5
Ratadiya	**62**	**68.1**	**VB4**
Ratadiya	68.1	74.2	AB4
Ratadiya	74.2	101.6	MB6
Ratadiya	101.6	104.7	WB4
Ratadiya	104.7	104.7	VB5
Ratadiya	104.7	119.9	MB7
Ratadiya	119.9	123	WB5
Ratadiya	123	129.1	VB6
Ratadiya	129.1	135.2	AB5
Ratadiya	135.2	153.5	MB8
Ratadiya	153.5	159.6	WB6
Ratadiya	159.6	168.7	VB7
Ratadiya	168.7	171.8	AB6
Ratadiya	171.8	202.3	MB9
Ratadiya	202.3	202.3	Redbole2
Dhabala Rewar	0	2	Top Soil
Dhabala Rewar	2	2	MB1
Dhabala Rewar	2	2	WB1
Dhabala Rewar	2	2	VB1
Dhabala Rewar	2	2	AB1
Dhabala Rewar	2	21.2	MB2
Dhabala Rewar	21.2	21.2	Redbole1

Site Name	Depth to Top (m)	Depth to Base (m)	Stratigraphy
Dhabala Rewar	21.2	21.2	WB2
Dhabala Rewar	21.2	26.2	VB2
Dhabala Rewar	26.2	48.6	MB3
Dhabala Rewar	48.6	51.7	WB3
Dhabala Rewar	51.7	51.7	VB3
Dhabala Rewar	51.7	51.7	AB2
Dhabala Rewar	51.7	51.7	MB4
Dhabala Rewar	51.7	58.8	FB1
Dhabala Rewar	58.8	62.8	AB3
Dhabala Rewar	62.8	67.9	MB5
Dhabala Rewar	**67.9**	**71**	**VB4**
Dhabala Rewar	71	71	AB4
Dhabala Rewar	71	110.5	MB6
Dhabala Rewar	110.5	110.5	WB4
Dhabala Rewar	110.5	116.7	VB5
Dhabala Rewar	116.7	136.5	MB7
Dhabala Rewar	136.5	136.5	WB5
Dhabala Rewar	136.5	142.1	VB6
Dhabala Rewar	142.1	142.1	AB5
Dhabala Rewar	142.1	151.3	MB8
Dhabala Rewar	151.3	151.3	WB6
Dhabala Rewar	151.3	160.4	VB7
Dhabala Rewar	160.4	160.4	AB6
Dhabala Rewar	160.4	160.4	MB9
Dhabala Rewar	160.4	160.4	Redbole2
Datraoda	0	1.8	Top Soil
Datraoda	1.8	1.8	MB1
Datraoda	1.8	14	WB1
Datraoda	14	14	VB1
Datraoda	14	14	AB1
Datraoda	14	23.2	MB2
Datraoda	23.2	29.3	Redbole1
Datraoda	29.3	35.4	WB2
Datraoda	35.4	38.4	VB2
Datraoda	38.4	50.6	MB3
Datraoda	50.6	50.6	WB3
Datraoda	50.6	50.6	VB3
Datraoda	50.6	50.6	AB2
Datraoda	50.6	50.6	MB4
Datraoda	50.6	59.8	FB1

Site Name	Depth to Top (m)	Depth to Base (m)	Stratigraphy
Datraoda	59.8	59.8	AB3
Datraoda	59.8	90.3	MB5
Datraoda	**90.3**	**93.3**	**VB4**
Datraoda	93.3	93.3	AB4
Datraoda	93.3	99.4	MB6
Datraoda	99.4	99.4	WB4
Datraoda	99.4	105.5	VB5
Datraoda	105.5	139	MB7
Datraoda	139	142	WB5
Datraoda	142	142	VB6
Datraoda	142	142	AB5
Datraoda	142	155	MB8
Datraoda	155	160	WB6
Datraoda	160	163	VB7
Datraoda	163	169	AB6
Datraoda	169	203	MB9
Datraoda	203	203	Redbole2
WRD	4	4.8	Top Soil
WRD	4.8	4.8	MB1
WRD	4.8	7.9	WB1
WRD	7.9	10.9	VB1
WRD	10.9	10.9	AB1
WRD	10.9	17	MB2
WRD	17	17	Redbole1
WRD	17	23	WB2
WRD	23	29.5	VB2
WRD	29.5	49.8	MB3
WRD	49.8	49.8	WB3
WRD	49.8	49.8	VB3
WRD	49.8	49.8	AB2
WRD	49.8	49.8	MB4
WRD	49.8	52.8	FB1
WRD	52.8	52.8	AB3
WRD	52.8	101	MB5
WRD	101	101	**VB4**
WRD	101	101	AB4
WRD	101	101	MB6
WRD	101	101	WB4
WRD	101	101	VB5
WRD	101	101	MB7

Site Name	Depth to Top (m)	Depth to Base (m)	Stratigraphy
WRD	101	101	WB5
WRD	101	101	VB6
WRD	101	101	AB5
WRD	101	101	MB8
WRD	101	101	WB6
WRD	101	101	VB7
WRD	101	101	AB6
WRD	101	101	MB9
WRD	101	101	Redbole2
Gaughat-I	0	22	Top Soil
Gaughat-I	22	22	MB1
Gaughat-I	22	22	WB1
Gaughat-I	22	22	VB1
Gaughat-I	22	22	AB1
Gaughat-I	22	30	MB2
Gaughat-I	30	30	Redbole1
Gaughat-I	30	30	WB2
Gaughat-I	30	44	VB2
Gaughat-I	44	67	MB3
Gaughat-I	67	67	WB3
Gaughat-I	67	67	VB3
Gaughat-I	67	67	AB2
Gaughat-I	67	67	MB4
Gaughat-I	67	72	FB1
Gaughat-I	72	72	AB3
Gaughat-I	72	79	MB5
Gaughat-I	79	83	**VB4**
Gaughat-I	83	83	AB4
Gaughat-I	83	93	MB6
Gaughat-I	93	93	WB4
Gaughat-I	93	97	VB5
Gaughat-I	97	127	MB7
Gaughat-I	127	127	WB5
Gaughat-I	127	129	VB6
Gaughat-I	129	129	AB5
Gaughat-I	129	140.12	MB8
Gaughat-I	140.12	140.12	WB6
Gaughat-I	140.12	140.12	VB7
Gaughat-I	140.12	140.12	AB6
Gaughat-I	140.12	140.12	MB9

Site Name	Depth to Top (m)	Depth to Base (m)	Stratigraphy
Gaughat-I	140.12	140.12	Redbole2
Mahakal	0	7.9	Top Soil
Mahakal	7.9	7.9	MB1
Mahakal	7.9	14	WB1
Mahakal	14	17	VB1
Mahakal	17	17	AB1
Mahakal	17	28	MB2
Mahakal	28	28	Redbole1
Mahakal	28	34	WB2
Mahakal	34	44	VB2
Mahakal	44	68	MB3
Mahakal	68	72	WB3
Mahakal	72	72	VB3
Mahakal	72	72	AB2
Mahakal	72	72	MB4
Mahakal	72	72	FB1
Mahakal	72	72	AB3
Mahakal	68	84	MB5
Mahakal	84	92	**VB4**
Mahakal	92	92	AB4
Mahakal	92	147	MB6
Mahakal	147	147	WB4
Mahakal	147	147	VB5
Mahakal	147	147	MB7
Mahakal	147	147	WB5
Mahakal	147	147	VB6
Mahakal	147	147	AB5
Mahakal	147	147	MB8
Mahakal	147	147	WB6
Mahakal	147	155	VB7
Mahakal	155	155	AB6
Mahakal	155	180.9	MB9
Mahakal	180.9	180.9	Redbole2
Collector Office	0	0	Top Soil
Collector Office	0	0	MB1
Collector Office	0	4.8	WB1
Collector Office	4.8	7.9	VB1
Collector Office	7.9	14	AB1
Collector Office	14	23.1	MB2
Collector Office	23.1	26.2	Redbole1

Site Name	Depth to Top (m)	Depth to Base (m)	Stratigraphy
Collector Office	26.2	32.3	WB2
Collector Office	32.3	35.3	VB2
Collector Office	35.3	50.6	MB3
Collector Office	50.6	50.6	WB3
Collector Office	50.6	53.6	VB3
Collector Office	53.6	53.6	AB2
Collector Office	53.6	77.2	MB4
Collector Office	77.2	77.2	FB1
Collector Office	77.2	80.3	AB3
Collector Office	80.3	110.8	MB5
Collector Office	110.8	110.8	**VB4**
Collector Office	110.8	110.8	AB4
Collector Office	110.8	110.8	MB6
Collector Office	110.8	110.8	WB4
Collector Office	110.8	110.8	VB5
Collector Office	110.8	110.8	MB7
Collector Office	110.8	110.8	WB5
Collector Office	110.8	110.8	VB6
Collector Office	110.8	110.8	AB5
Collector Office	110.8	110.8	MB8
Collector Office	110.8	110.8	WB6
Collector Office	110.8	110.8	VB7
Collector Office	110.8	110.8	AB6
Collector Office	110.8	110.8	MB9
Collector Office	110.8	110.8	Redbole2
Bakaniya	0	0	Top Soil
Bakaniya	0	0	MB1
Bakaniya	0	14	WB1
Bakaniya	14	14	VB1
Bakaniya	14	14	AB1
Bakaniya	14	34.5	MB2
Bakaniya	34.5	34.5	Redbole1
Bakaniya	34.5	37.6	WB2
Bakaniya	37.6	40.6	VB2
Bakaniya	40.6	62	MB3
Bakaniya	62	62	WB3
Bakaniya	62	62	VB3
Bakaniya	62	65	AB2
Bakaniya	65	74.2	MB4
Bakaniya	74.2	77.2	FB1

Site Name	Depth to Top (m)	Depth to Base (m)	Stratigraphy
Bakaniya	77.2	79	AB3
Bakaniya	79	114	MB5
Bakaniya	114	114	**VB4**
Bakaniya	114	114	AB4
Bakaniya	114	114	MB6
Bakaniya	114	114	WB4
Bakaniya	114	114	VB5
Bakaniya	114	114	MB7
Bakaniya	114	114	WB5
Bakaniya	114	114	VB6
Bakaniya	114	114	AB5
Bakaniya	114	114	MB8
Bakaniya	114	114	WB6
Bakaniya	114	114	VB7
Bakaniya	114	114	AB6
Bakaniya	114	114	MB9
Bakaniya	114	114	Redbole2
Dashera Maidan	0	9	Top Soil
Dashera Maidan	9	9	MB1
Dashera Maidan	9	9	WB1
Dashera Maidan	9	9	VB1
Dashera Maidan	9	9	AB1
Dashera Maidan	9	26	MB2
Dashera Maidan	26	26	Redbole1
Dashera Maidan	26	26	WB2
Dashera Maidan	26	46	VB2
Dashera Maidan	46	69	MB3
Dashera Maidan	69	69	WB3
Dashera Maidan	69	78	VB3

Site Name	Depth to Top (m)	Depth to Base (m)	Stratigraphy
Dashera Maidan	78	78	AB2
Dashera Maidan	78	94	MB4
Dashera Maidan	94	103	FB1
Dashera Maidan	103	103	AB3
Dashera Maidan	103	117	MB5
Dashera Maidan	117	129	**VB4**
Dashera Maidan	129	129	AB4
Dashera Maidan	129	148	MB6
Dashera Maidan	148	148	WB4
Dashera Maidan	148	158	VB5
Dashera Maidan	158	158	MB7
Dashera Maidan	158	183	WB5
Dashera Maidan	183	185	VB6
Dashera Maidan	185	185	AB5
Dashera Maidan	185	198	MB8
Dashera Maidan	198	198	WB6
Dashera Maidan	198	198	VB7
Dashera Maidan	198	200	AB6
Dashera Maidan	200	200	MB9
Dashera Maidan	200	200	Redbole2

Site Name	Depth to Top (m)	Depth to Base (m)	Stratigraphy
Kendriya colony	0	8	Top Soil
Kendriya colony	8	8	MB1
Kendriya colony	8	10	WB1
Kendriya colony	10	13	VB1
Kendriya colony	13	20	AB1
Kendriya colony	20	42	MB2
Kendriya colony	42	42	Redbole1
Kendriya colony	42	48	WB2
Kendriya colony	48	57	VB2
Kendriya colony	57	79	MB3
Kendriya colony	79	79	WB3
Kendriya colony	79	79	VB3
Kendriya colony	79	82	AB2
Kendriya colony	82	102	MB4
Kendriya colony	102	102	FB1
Kendriya colony	102	110	AB3
Kendriya colony	110	152	MB5
Kendriya colony	152	152	**VB4**
Kendriya colony	152	152	AB4
Kendriya colony	152	152	MB6

Site Name	Depth to Top (m)	Depth to Base (m)	Stratigraphy
Kendriya colony	152	152	WB4
Kendriya colony	152	160	VB5
Kendriya colony	160	180	MB7
Kendriya colony	180	185	WB5
Kendriya colony	185	191	VB6
Kendriya colony	191	191	AB5
Kendriya colony	191	203	MB8
Kendriya colony	203	203	WB6
Kendriya colony	203	203	VB7
Kendriya colony	203	203	AB6
Kendriya colony	203	203	MB9
Kendriya colony	203	203	Redbole2
Nimanwasa	0	11	Top Soil
Nimanwasa	11	11	MB1
Nimanwasa	11	15	WB1
Nimanwasa	15	15	VB1
Nimanwasa	15	15	AB1
Nimanwasa	15	35	MB2
Nimanwasa	35	35	Redbole1
Nimanwasa	35	42	WB2
Nimanwasa	42	46	VB2
Nimanwasa	46	82	MB3
Nimanwasa	82	82	WB3
Nimanwasa	82	82	VB3
Nimanwasa	82	82	AB2
Nimanwasa	82	82	MB4
Nimanwasa	82	82	FB1
Nimanwasa	82	92	AB3
Nimanwasa	92	142	MB5

Site Name	Depth to Top (m)	Depth to Base (m)	Stratigraphy
Nimanwasa	142	142	**VB4**
Nimanwasa	142	142	AB4
Nimanwasa	142	142	MB6
Nimanwasa	142	142	WB4
Nimanwasa	142	146	VB5
Nimanwasa	146	160	MB7
Nimanwasa	160	162	WB5
Nimanwasa	162	171	VB6
Nimanwasa	171	171	AB5
Nimanwasa	171	175	MB8
Nimanwasa	175	175	WB6
Nimanwasa	175	175	VB7
Nimanwasa	175	181	AB6
Nimanwasa	181	200	MB9
Nimanwasa	200	200	Redbole2
Pipali Naka	0	21	Top Soil
Pipali Naka	21	21	MB1
Pipali Naka	21	24	WB1
Pipali Naka	24	24	VB1
Pipali Naka	24	24	AB1
Pipali Naka	24	38	MB2
Pipali Naka	38	38	Redbole1
Pipali Naka	38	38	WB2
Pipali Naka	38	42	VB2
Pipali Naka	42	78	MB3
Pipali Naka	78	80	WB3
Pipali Naka	80	84	VB3
Pipali Naka	84	84	AB2
Pipali Naka	84	84	MB4
Pipali Naka	84	84	FB1
Pipali Naka	84	90	AB3
Pipali Naka	90	160	MB5
Pipali Naka	160	160	**VB4**
Pipali Naka	160	160	AB4
Pipali Naka	160	160	MB6
Pipali Naka	160	160	WB4
Pipali Naka	160	160	VB5
Pipali Naka	160	160	MB7
Pipali Naka	160	160	WB5
Pipali Naka	160	168	VB6

Site Name	Depth to Top (m)	Depth to Base (m)	Stratigraphy
Pipali Naka	168	168	AB5
Pipali Naka	168	168	MB8
Pipali Naka	168	168	WB6
Pipali Naka	168	168	VB7
Pipali Naka	168	168	AB6
Pipali Naka	168	195	MB9
Pipali Naka	195	200	Redbole2
Kanipura	0	5.1	Top Soil
Kanipura	5.1	5.1	MB1
Kanipura	5.1	13	WB1
Kanipura	13	18.1	VB1
Kanipura	18.1	18.1	AB1
Kanipura	18.1	31.3	MB2
Kanipura	31.3	31.3	Redbole1
Kanipura	31.3	31.3	WB2
Kanipura	31.3	37.4	VB2
Kanipura	37.4	78	MB3
Kanipura	78	80.1	WB3
Kanipura	80.1	86.2	VB3
Kanipura	86.2	93.3	AB2
Kanipura	97.4	102.5	MB4
Kanipura	102.5	105.5	FB1
Kanipura	105.5	105.5	AB3
Kanipura	105.5	161.4	MB5
Kanipura	161.4	166.4	**VB4**
Kanipura	166.4	166.4	AB4
Kanipura	166.4	166.4	MB6
Kanipura	166.4	166.4	WB4
Kanipura	166.4	166.4	VB5
Kanipura	166.4	166.4	MB7
Kanipura	166.4	166.4	WB5
Kanipura	166.4	166.4	VB6
Kanipura	166.4	166.4	AB5
Kanipura	166.4	166.4	MB8
Kanipura	166.4	166.4	WB6
Kanipura	166.4	166.4	VB7
Kanipura	166.4	166.4	AB6
Kanipura	166.4	184.5	MB9
Kanipura	184.5	191.9	Redbole2
Jaithal Tek	0	4.8	Top Soil

Site Name	Depth to Top (m)	Depth to Base (m)	Stratigraphy
Jaithal Tek	4.8	10.9	MB1
Jaithal Tek	10.9	14	WB1
Jaithal Tek	14	14	VB1
Jaithal Tek	14	14	AB1
Jaithal Tek	14	50.6	MB2
Jaithal Tek	50.6	53.6	Redbole1
Jaithal Tek	53.6	53.6	WB2
Jaithal Tek	53.6	56.7	VB2
Jaithal Tek	56.7	80.3	MB3
Jaithal Tek	80.3	83.3	WB3
Jaithal Tek	83.3	86.4	VB3
Jaithal Tek	86.4	89.4	AB2
Jaithal Tek	89.4	123	MB4
Jaithal Tek	123	123	FB1
Jaithal Tek	123	123	AB3
Jaithal Tek	123	123	MB5
Jaithal Tek	123	126	**VB4**
Jaithal Tek	126	129.1	AB4
Jaithal Tek	129.1	202.3	MB6
Jaithal Tek	202.3	202.3	WB4
Jaithal Tek	202.3	202.3	VB5
Jaithal Tek	202.3	202.3	MB7
Jaithal Tek	202.3	202.3	WB5
Jaithal Tek	202.3	202.3	VB6
Jaithal Tek	202.3	202.3	AB5
Jaithal Tek	202.3	202.3	MB8
Jaithal Tek	202.3	202.3	WB6
Jaithal Tek	202.3	202.3	VB7
Jaithal Tek	202.3	202.3	AB6
Jaithal Tek	202.3	202.3	MB9
Jaithal Tek	202.3	202.3	Redbole2
Jairampura	0	4.8	Top Soil
Jairampura	4.8	4.8	MB1
Jairampura	4.8	10.9	WB1
Jairampura	10.9	14	VB1
Jairampura	14	23.1	AB1
Jairampura	23.1	55.9	MB2
Jairampura	55.9	55.9	Redbole1
Jairampura	55.9	62	WB2
Jairampura	62	71.1	VB2

Site Name	Depth to Top (m)	Depth to Base (m)	Stratigraphy
Jairampura	71.1	89.3	MB3
Jairampura	74.2	89.3	WB3
Jairampura	89.3	89.4	VB3
Jairampura	89.4	92.5	AB2
Jairampura	92.5	100.6	MB4
Jairampura	100.6	100.6	FB1
Jairampura	100.6	100.6	AB3
Jairampura	100.6	100.6	MB5
Jairampura	100.6	100.6	**VB4**
Jairampura	100.6	100.6	AB4
Jairampura	100.6	100.6	MB6

Annexure 3

SI NO.	DISTRICT	VILLAGE	Source (Dugwell/Bore Well)	Static Water Level (Pre-monsoon)mbgl	Static Water Level (Post-Monsoon) mbgl
1	Ujjain	Bachhukhera	Dug Well	8.83	6.1
2	Ujjain	Chakrawada Grid	Dug Well	14.1	6.6
3	Ujjain	Chhoti Ghadsod	Dug Well	16.33	3.3
4	Ujjain	Chhoti Ghadsod New	Dug Well	13.67	12
5	Ujjain	Dabla Rehwari	Dug Well	8.25	7
6	Ujjain	Dablahardu	Dug Well	10.76	5
7	Ujjain	Delchi buzurg	Dug Well	14.36	4.7
8	Ujjain	Ghosla	Dug Well	6.01	10.2
9	Ujjain	Jharda	Dug Well	8.47	2
10	Ujjain	Kachord New	Dug Well	9.46	5.4
11	Ujjain	Kaiytha	Dug Well	10.99	3.5
12	Ujjain	Khachrod	Dug Well	8.66	5.9
13	Ujjain	Khakri Sultan	Dug Well	8.17	0.7
14	Ujjain	Kharotia	Dug Well	7.53	3.9
15	Ujjain	Kharotia New	Dug Well	9.41	2.6
16	Ujjain	Khera khajuria	Dug Well	7.83	3.8
17	Ujjain	Mahidpurroad	Dug Well	7.42	1.5
18	Ujjain	Mahidpurtown	Dug Well	10.97	2
19	Ujjain	Makdon	Dug Well	6.97	2.2
20	Ujjain	Naikhedi	Dug Well	12.12	2.1
21	Ujjain	Narwar	Dug Well	13.57	7.8
22	Ujjain	Nazarpur	Dug Well	7.4	8
23	Ujjain	Palkhanda	Dug Well	6.68	2.6
24	Ujjain	Patpala	Dug Well	9.38	2.6
25	Ujjain	Raghvi	Dug Well	11.65	5.1
26	Ujjain	Ruie	Dug Well	15.06	5.3
27	Ujjain	Ruie New	Dug Well	3.12	3.4
28	Ujjain	Rupakhedi	Dug Well	11.77	6.2
29	Ujjain	Sumra Kheda	Dug Well	13.3	4.1
30	Ujjain	Tarana	Dug Well	11.22	2.6
31	Ujjain	Ujjain Nagar Palika	Dug Well	6.33	2.6
32	Ujjain	Unhel	Dug Well	12.19	4
33	Ujjain	Vijayganj Mandi	Dug Well	11.75	3.4
34	Ujjain	Vikram University (outside Chemistry	Dug Well	4.27	4.7
35	Ujjain	Agriculture Training Centre, Dewas R	Dug Well	6.46	3.6
36	Ujjain	Kids Planet School, Maksi Road	Dug Well	9.9	4.4
37	Ujjain	Bhairavgarh, Chhipa Jamat Masjid	Dug Well	17	9.8
38	Ujjain	Bharatpuri (Office of FCI)	Dug Well	4.6	13.8
39	Ujjain	Mahananda Colony (Gyaneshwar Sha	Dug Well	4.3	3.3
40	Ujjain	Badarkha Berasiya (BharatSingh's fiel	Dug Well	7.75	4.8

SI NO.	DISTRICT	VILLAGE	Source (Dugwell/Bore Well)	Static Water Level (Pre-monsoon)mbgl	Static Water Level (Post-Monsoon) mbgl
41	Ujjain	Dhabla Rehwari, Sahabkhedi (Kamal K	Dug Well	2.7	2
42	Ujjain	Undasa (Behind Goushala)	Dug Well	7	4
43	Ujjain	Harsodan (Jitendra Patel)	Dug Well	11.7	7.1
44	Ujjain	Tajpur (Ashtabhuja Navdurga Temple	Dug Well	12.38	9.1
45	Ujjain	Tajpur (Nr Shamshan Ghat)	Dug Well	15.3	11.9
46	Ujjain	Sawarakhedi	Dug Well	11	4.3
47	Ujjain	Mahakal Vanijya (Nr Begin Fitness Gy	Dug Well	6.43	11.2
48	Ujjain	Pragati Nagar (B.K. Srivastava)	Dug Well	5.92	11.3
49	Ujjain	Gandhinagar (Ramesh Chandra Sarve	Dug Well	3.96	3.5
50	Ujjain	Vyas Nagar Vikas Samiti Community H	Dug Well	4.2	3.3
51	Ujjain	Ganesh Nagar, Nagjhiri(Abdul Saed)	Dug Well	6	2.9
52	Ujjain	Behind Kshipra Vihar Nursery	Dug Well	4.95	2.4
53	Ujjain	Gita Colony (Pawan Kumar Jaggee)	Dug Well	1.2	4.4
54	Ujjain	MadhavRao Scindia Krishi Upaj Mand	Dug Well	11.4	7.3
55	Ujjain	Hirdeshwar mahadev mandir,Hira Mil	Dug Well	5.1	1.9
56	Ujjain	Desai Nagar, Maksi Road	Dug Well	4.1	8.6
57	Ujjain	Kalyanmal Jain mandir, Freeganj	Dug Well	1.64	2.7
58	Ujjain	Alakhdham Nagar (Shri Shyam Library	Dug Well	3.35	11.2
59	Ujjain	Begam Bagh Colony (Dr Sajid Hussain	Dug Well	9.45	2.2
60	Ujjain	Lohe ka Pul (Retiwale baba Dargah)	Dug Well	4	1.2
61	Ujjain	New Bholenath Mandir(opp Mangaln	Dug Well	7.77	1.9
62	Ujjain	Khilachipur, Nr Mobile Tower	Dug Well	8.25	3.5
63	Ujjain	Kaliyadeh-Utesara Rd	Dug Well	6.52	4.6
64	Ujjain	Agar Road (Mukesh Patel, Dhabla reh	Dug Well	9.06	4.6
65	Ujjain	Garima Krushi farm, Prajapat Nagar	Dug Well	5.2	6.2
66	Ujjain	Shri Guru kripa Daal & Besan Mill (Nr	Dug Well	12.7	7
67	Ujjain	Liman Wasa (Shiv City)	Dug Well	9.07	10.4
68	Ujjain	Niman Wasa	Dug Well	13.5	10
69	Ujjain	Seswani Mohalla	Dug Well	5.1	7
70	Ujjain	Ashok nagar, Freeganj (Nr Hanuman	Dug Well	6.7	10.6
71	Ujjain	Ambodia Npz	Bore	6.29	15.2
72	Ujjain	Badnagar Npz	Bore	12.77	5.9
73	Ujjain	Badnagar(deep)	Bore	13.08	11.4
74	Ujjain	Chibdi	Bore	15.22	8
75	Ujjain	Dhanodiya	Bore	131.45	6.6
76	Ujjain	Gogapur Npz	Bore	7.04	8.8
77	Ujjain	Hasmpura Npz	Bore	42.78	6
78	Ujjain	Ingoria Npz	Bore	22.58	22
79	Ujjain	Jhirniya	Bore	23.37	7.4

SI NO.	DISTRICT	VILLAGE	Source (Dugwell/Bore Well)	Static Water Level (Pre-monsoon)mbgl	Static Water Level (Post-Monsoon) mbgl
80	Ujjain	Kaitha Npz	Bore	9.73	25.6
81	Ujjain	Khachrod Npz	Bore	11.3	4.3
82	Ujjain	Mahidpur Town Npz	Bore	4.88	11.7
83	Ujjain	Mahidpur town(deep)	Bore	7.76	3.1
84	Ujjain	Makdon Npz	Bore	5.74	2.1
85	Ujjain	Nagda Npz	Bore	4.97	3.2
86	Ujjain	Narwar(deep)	Bore	39.91	5.3
87	Ujjain	Pat Npz	Bore	5.15	49.2
88	Ujjain	Raghvi(deep)	Bore	6.9	3.6
89	Ujjain	Runija(deep)	Bore	27.29	18.5
90	Ujjain	Runija(shallow)	Bore	15.28	2.2
91	Ujjain	Sandawada Ow	Bore	38.5	16.8
92	Ujjain	Tarana Npz	Bore	12.65	7.3
93	Ujjain	Tarana(deep)	Bore	46.12	5.2
94	Ujjain	Ujjain(deep)	Bore	8.48	0.7
95	Ujjain	Ujjain(shallow)	Bore	6.1	1.1
96	Ujjain	Unhel Npz	Bore	24.33	2
97	Ujjain	PWD Rest House, Dewas Road	Bore	19	3.2
98	Ujjain	Kirti mata Mandir, Dewas Road	Bore	19.2	8.7
99	Ujjain	WRD Office, Dewas Road	Bore	21.95	1.7
100	Ujjain	Pipliaragho, Mahavir Tapobhoomi Ro	Bore	18.2	1.4
101	Ujjain	Bhairavgarh (Nr Rupali Batik Prints)	Bore	17.4	0.3
102	Ujjain	Barkhedi Khalsa (Nr Sarpanch House)	Bore	17.1	0.8
103	Ujjain	Prad Pharmaceuticals, Agrasen Nagar	Bore	45.7	10.9
104	Ujjain	Osmed Formulations, Agrasen Nagar	Bore	38.1	3.6
105	Ujjain	Sinhal Enterprise	Bore	14.4	6.3
106	Ujjain	Hira Industries	Bore	20.2	3.3
107	Ujjain	Alchemy Chemicals	Bore	17.5	2.7
108	Ujjain	Badarkha Berasiya (Sardar Patel)	Bore	35.5	4.1
109	Ujjain	Dhabla Rehwari, Sahabkhedi (Kamal K	Bore	9.7	33.8
110	Ujjain	Sawarakhedi	Bore	15.5	15.5
111	Ujjain	4R Udyan	Bore	9.92	6.4
112	Ujjain	Pragati Nagar (S.K. Jain)	Bore	5.1	7.8
113	Ujjain	SC/ST Senior Boys Hostel, Sanwer Ro	Bore	8.3	32.6
114	Ujjain	Ganesh Nagar, Nagjhiri (Khaleel Ahm	Bore	40	8
115	Ujjain	Kshipra ViharHorticulture Nursery	Bore	8	9.8
116	Ujjain	Jain Mandir (MRS Krishi upaj Mandi)	Bore	5.58	4.6
117	Ujjain	Grand Hotel, Freeganj	Bore	23.08	4.2
118	Ujjain	Yajurved Udyan, Alakhdham nagar	Bore	11.14	5.5
119	Ujjain	Begam Bagh Colony (Senior Steel Fab	Bore	26.57	7.4

SI NO.	DISTRICT	VILLAGE	Source (Dugwell/Bore Well)	Static Water Level (Pre-monsoon)mbgl	Static Water Level (Post-Monsoon) mbgl
120	Ujjain	Lohe ka pul (opp Dayal Guest House)	Bore	17.5	17.9
121	Ujjain	New Bholenath Mandir(opp Mangaln	Bore	9.5	5
122	Ujjain	Upkeshwar Mahadev Mandir,Khilachi	Bore	12.5	7.2
123	Ujjain	Kaliyadeh (Rafiq Patel)	Bore	18.6	20.3
124	Ujjain	Agar Road (Raes Patel,opp Kaka Ware	Bore	12.1	7.4
125	Ujjain	Kanipura-Tarana Rd (Narendra Jat)	Bore	10.03	8.3
126	Ujjain	Upan Lawn	Bore	11.04	8.2
127	Ujjain	Nav Graha Shani Mandir	Bore	33.46	16.5
128	Ujjain	Sakarwasa	Bore	18.7	8.3
129	Ujjain	Shri Sai Bhag Colony	Bore	11.04	10.4
130	Ujjain	Shiv city	Bore	37.6	12.4
131	Ujjain	Ralayata Mauja BW	Bore		7.7
132	Ujjain	Gunaya BW	Bore		69
133	Ujjain	Bhutiya BW	Bore		13.6
134	Ujjain	Ujjainiya BW	Bore		61
135	Ujjain	Chintaman BW (Pappulal)	Bore		15.9
136	Ujjain	Pached BW	Bore		16.8
137	Ujjain	Kadgi Karadiya BW (Lokendra Sing)	Bore		50.5
138	Ujjain	Daudkhedi BW (Gulab Singh)	Bore		6.3
139	Ujjain	Kithoda Jagir BW (Prakash Gujrati)	Bore		11.8
140	Ujjain	Sodang BW	Bore		19.8
141	Ujjain	Azampura BW (Datar Seva Ashram)	Bore		6.7

Annexure 4 Chemical Quality Data, Ujjain Industrail Cluster

District	Block	Location	LAB ID	pH	EC	CO3	HCO3	Cl	SO4	NO3	F	PO4	SiO2	TH	Ca	Mg	Na	K	TDS
Ujjain	Ghatia	Kaliyadeh-Utesara Rd	DW04	7.45	1745	0	370	342	78	2	0.58	0.4	30	604	123	72	118	8.8	1134
Ujjain	Ujjain	Agricultural Training Center	DW11	8.15	990	0	333	120	37	8	0.88	0.1	31	402	78	50	42	3.4	644
Ujjain	Ujjain	Kids Planet School	DW29	7.47	909	0	302	85	59	27	0.31	0.1	27	373	110	24	34	0.4	591
Ujjain	Ujjain	Maksi Road	DW34	7.29	3851	0	456	805	378	14	0.43	0.2	43	1218	297	116	323	2.7	2503
Ujjain	Ujjain	Kshipra Vihar Nursery	DW30	7.52	1658	0	462	265	77	2	0.49	0.1	30	594	75	99	107	5.2	1078
Ujjain	Ujjain	Vikram University	DW45	7.42	1276	0	308	237	51	9	0.55	0.1	12	451	90	55	98	1.1	829
Ujjain	Ujjain	Bharatpuri	DW17	7.27	1023	0	388	77	75	9	0.58	0.2	34	431	106	41	32	2.2	665
Ujjain	Ujjain	Harsodan	DW25	7.28	1209	0	425	70	64	114	0.18	0.1	42	535	166	29	35	1.3	786
Ujjain	Ujjain	Gandhi Nagar Dw	DW22	7.21	1456	0	499	187	36	23	0.27	0.3	24	515	111	58	95	1.6	946
Ujjain	Ujjain	Freeganj Hp	HP03	7.27	1586	0	487	210	72	2	0.77	0.2	44	545	119	60	109	2.3	1031
Ujjain	Ujjain	Pragati Nagar Dw	DW40	7.26	1602	0	487	225	53	21	0.82	0.2	36	554	87	82	122	0.9	1041
Ujjain	Ghatia	Dhabla Rehwari	DW01	7.46	1402	0	456	167	50	46	0.44	0.3	41	495	107	55	92	2.8	911
Ujjain	Ujjain	Mahakal Vanijya	DW32	7.31	1526	0	444	210	79	2	0.76	0.4	36	535	107	65	117	3.6	992
Ujjain	Ujjain	Nagjhiri	DW37	7.04	1904	0	530	210	71	175	0.28	1.6	38	653	127	82	127	40.9	1238
Ujjain	Ujjain	Nanakheda	HP05	7.41	1460	0	382	247	46	23	0.25	0.2	43	402	122	24	152	1.3	949
Ujjain	Ujjain	Navgrah Shani Mandir, Dhediya	HP06	7.19	2187	0	536	357	77	89	0.27	0.1	48	618	137	67	231	1.5	1422
Ujjain	Ujjain	Khilachipur	DW28	7.78	2289	0	641	340	119	20	0.71	0.2	24	644	59	120	225	4.4	1488
Ujjain	Ujjain	Vyas Nagar	DW46	7.51	1356	0	468	152	61	10	0.2	0.8	32	446	107	43	102	5	881
Ujjain	Ujjain	Hira Mill Compound	DW26	7.05	1089	0	283	157	48	3	0.36	0.3	27	307	71	31	106	11.5	708
Ujjain	Ujjain	Alakhdham Nagar Dw	DW12	7.45	1045	0	345	107	65	6	0.88	0.2	22	376	55	58	75	2.1	679
Ujjain	Ujjain	Gita Colony Dw	DW23	7.34	1100	0	290	135	85	12	0.39	1.2	26	337	79	34	98	11.2	715
Ujjain	Ujjain	Freeganj Dw	DW21	7.59	1054	0	314	125	85	5	0.41	0.8	23	327	83	29	92	6.5	685
Ujjain	Ujjain	Begambagh Colony Dw	DW15	7.19	1705	0	561	190	59	42	0.25	0.3	34	525	87	75	142	26.6	1108
Ujjain	Ghatia	Sawarakhedi Dw	DW09	7.93	1210	0	425	155	21	33	1.32	7.8	37	317	63	39	126	16.3	787
Ujjain	Ujjain	New Bholenath Mandir Dw	DW38	7.25	2285	0	702	302	105	7	0.52	0.2	33	624	107	87	246	3.9	1485
Ujjain	Ujjain	Bhairavgarh Dw	DW16	7.38	1663	0	382	155	146	173	0.42	0.1	38	559	82	86	132	1.9	1081
Ujjain	Ujjain	Undasa	DW44	7.57	800	0	320	52	38	4	0.57	0.3	24	277	75	22	46	1.8	520

District	Block	Location	LAB ID	pH	EC	CO3	HCO3	Cl	SO4	NO3	F	PO4	SiO2	TH	Ca	Mg	Na	K	TDS
Ujjain	Ujjain	Mahananda Colony	DW33	7.21	1066	0	444	62	39	20	0.25	0.3	27	402	98	38	56	1.5	693
Ujjain	Ujjain	Lohe Ka Pul Dw	DW31	7.27	1210	0	407	100	85	10	0.14	1	46	337	67	41	92	65.9	787
Ujjain	Ujjain	Desai Nagar	DW19	7.39	1078	0	351	105	87	3	0.96	0.4	31	327	79	31	98	7.3	701
Ujjain	Ujjain	Seswani Mohalla	HP08	7.46	1205	0	407	125	59	22	0.63	0.2	41	347	67	43	122	9.1	783
Ujjain	Ujjain	Tajpur Dw 2	DW43	7.53	1350	0	592	90	41	5	1.02	5.9	52	416	127	24	102	19.8	878
Ujjain	Ujjain	Prajapat Nagar	DW41	7.43	2032	0	715	272	63	2	1.23	0.6	25	347	51	53	315	9.2	1321
Ujjain	Ujjain	Tajpur Dw 1	DW42	7.47	1112	0	437	62	74	65	0.48	0.2	51	406	99	39	76	2.9	723
Ujjain	Ujjain	Dhabla Rehwari, Sahabkhedi Dw	DW20	7.42	838	0	388	37	32	14	0.69	0.3	34	332	75	35	47	1.6	545
Ujjain	Ujjain	Mrs Krishi Upaj Mandi Dw	DW36	7.48	1855	0	481	220	133	87	0.92	0.5	41	257	59	26	308	3.4	1206
Ujjain	Ujjain	Badarkha Berasia Dw	DW13	7.64	560	0	222	17	57	13	0.47	0.2	46	178	55	10	46	1.6	364
Ujjain	Ghatia	Agar Road	BW01	7.51	1756	0	604	205	50	32	0.49	0.2	36	327	71	36	253	2.6	1141
Ujjain	Ghatia	Barkhedi Khalsa	BW03	7.26	2100	0	628	280	75	77	0.3	0.1	33	725	98	117	142	1.9	1365
Ujjain	Ghatia	Kaliyadeh	BW08	7.2	2043	0	567	252	132	73	0.57	0.3	35	723	75	130	135	2.9	1328
Ujjain	Ghatia	Sawarakhedi Bw	BW12	7.94	1832	0	444	290	58	66	0.58	0.5	47	495	95	63	206	1.8	1191
Ujjain	Ujjain	4r Udyan	BW15	7.46	1723	0	499	262	71	4	0.98	0.2	38	347	71	41	240	2	1120
Ujjain	Ujjain	Agrasen Nagar 1	BW16	7.43	1410	0	339	127	182	24	0.37	0.2	35	471	114	45	99	3.3	917
Ujjain	Ujjain	Agrasen Nagar 2	BW17	7.34	2715	0	813	375	127	28	0.81	0.1	38	706	212	43	285	2.6	1765
Ujjain	Ujjain	Agrasen Nagar 3	BW18	7.29	1150	0	437	75	61	26	0.23	0.1	37	451	137	26	50	1.4	748
Ujjain	Ujjain	Alakhdham Nagar Bw	BW19	7.54	1210	0	339	137	98	8	1.12	0.3	32	267	48	36	167	2.9	787
Ujjain	Ujjain	Alchemy Chemicals	BW20	7.39	2305	0	228	225	522	10	0.46	0.2	38	765	157	91	151	4.3	1498
Ujjain	Ujjain	Badarkha Berasia Bw	BW21	7.56	1330	0	530	97	93	27	0.7	0.2	21	257	44	36	195	4.1	865
Ujjain	Ujjain	Begambagh Colony Bw	BW22	7.35	2000	0	265	465	85	16	1.21	0.2	18	356	79	39	309	4.6	1300
Ujjain	Ujjain	Bhairavgarh Bw	BW23	7.49	2025	0	536	250	112	174	0.47	0.1	42	480	122	43	262	2.7	1316
Ujjain	Ujjain	Dewas Road	BW26	7.64	1232	0	333	192	51	6	0.62	0.2	38	275	71	24	158	1.6	801
Ujjain	Ujjain	Dhabla Rehwari, Sahabkhedi Bw	BW27	7.52	849	0	419	35	34	7	0.71	0.2	39	347	67	43	44	1.2	552
Ujjain	Ujjain	Freeganj Bw	BW29	7.63	942	0	296	125	38	1	0.47	0.2	22	158	40	14	142	4.6	612
Ujjain	Ujjain	Gandhi Nagar Bw	BW30	7.41	1510	0	314	252	76	67	0.47	0.2	43	337	79	34	192	4.3	982
Ujjain	Ujjain	Gita Colony Bw	BW31	7.62	1210	0	419	125	63	10	0.69	0.2	33	248	44	34	172	2.3	787
Ujjain	Ujjain	Hira Industries	BW32	7.26	1978	0	690	225	122	22	0.33	0.2	38	676	180	55	175	1.9	1286

District	Block	Location	LAB ID	pH	EC	CO3	HCO3	Cl	SO4	NO3	F	PO4	SiO2	TH	Ca	Mg	Na	K	TDS
Ujjain	Ujjain	Indore Road	BW33	7.39	2185	0	715	285	125	36	0.78	0.2	27	578	67	100	265	0.4	1420
Ujjain	Ujjain	Kanipura-Tarana Road	BW34	7.59	1945	0	604	247	68	65	0.56	0.3	38	277	55	34	325	3.1	1264
Ujjain	Ujjain	Kshipra Vihar Horti Culture Nursery	BW35	7.44	1645	0	277	322	121	12	0.32	0.1	39	436	103	43	181	2.7	1069
Ujjain	Ujjain	Lohe Ka Pul Bw	BW36	7.15	1825	0	739	177	31	5	0.14	5.1	55	475	95	58	167	72.7	1186
Ujjain	Ujjain	Mrs Krishi Upaj Mandi Bw	BW37	7.43	1210	0	394	100	85	36	0.84	0.2	42	347	67	43	125	3	787
Ujjain	Ujjain	New Bholenath Mandir Bw	BW38	7.25	2142	0	610	302	58	20	0.66	0.2	31	673	107	99	184	2.8	1392
Ujjain	Ujjain	Pipliaragho	BW39	7.09	1600	0	370	225	84	67	0.39	0.1	48	500	118	50	118	1.1	1040
Ujjain	Ujjain	Pragati Nagar Bw	BW40	7.35	1402	0	437	185	47	15	0.62	0.3	37	475	107	51	105	1.4	911
Ujjain	Ujjain	Pwd Rest House	BW41	7.72	1308	0	216	290	47	7	0.95	0.2	35	176	43	17	219	1.1	850
Ujjain	Ujjain	Sanwer Road	BW42	7.32	1356	0	481	162	42	1	0.4	0.4	31	277	59	31	185	1.5	881
Ujjain	Ujjain	Sinhal Enterprise	BW43	7.48	1523	0	401	125	208	25	0.46	0.2	41	490	125	43	123	1.7	990
Ujjain	Ujjain	Wrd Office	BW44	7.2	1565	0	444	207	89	26	0.21	0.1	44	686	165	67	42	0.5	1017
Ujjain	Ujjain	Khilachipur Bw	BW45	7.27	1826	0	536	237	82	66	0.83	0.3	30	584	111	75	147	2.7	1187
Ujjain	Ghatia	Dhabla Rehwari	DW01	7.32	1387	0	489	141	48	32	0.31	0	46	475	138	32	86	4.4	
Ujjain	Ghatia	Ishakpur	DW02	7.57	1008	0	320	77	64	71	0.34	0.1	44	370	102	28	59	4	
Ujjain	Ghatia	Kadawali Dw	DW03	7.23	945	0	350	64	28	75	0.11	0	46	340	64	44	62	4.5	
Ujjain	Ghatia	Kaliyadeh-Utesara Rd	DW04	7.54	1300	0	314	210	26	44	0.42	0	22	460	112	44	75	4.8	
Ujjain	Ghatia	Nazarpur Dw	DW05	7.28	1206	0	368	116	56	90	0.37	0	48	425	124	28	79	5.1	
Ujjain	Ghatia	Pached Dw	DW06	8.19	1523	0	489	218	16	63	0.6	0	44	610	190	33	73	0.75	
Ujjain	Ghatia	Panbihar Dw	DW07	7.42	2389	0	417	500	156	29	0.41	0	44	640	190	40	242	6.5	
Ujjain	Ghatia	Ralayata Mauja Dw	DW08	7.31	2442	0	568	324	132	178	0.05	0.3	48	585	136	60	265	58.1	
Ujjain	Ghatia	Ujjainiya Dw	DW10	7.21	1555	0	519	144	84	67	0	0	54	410	106	35	167	4.1	
Ujjain	Ujjain	Agricultural Training Center	DW11	7.41	775	0	284	77	26	15	0.66	0.4	30	260	62	26	57	4.3	
Ujjain	Ujjain	Alakhdham Nagar Dw	DW12	7.71	871	0	314	89	59	13	0.74	0	15	260	66	23	85	0.5	
Ujjain	Ujjain	Badarkha Berasia Dw	DW13	7.78	712	0	278	40	40	33	0.29	0	32	265	64	26	43	2.2	
Ujjain	Ujjain	Badodiya Bhand	DW14	7.3	1290	0	477	84	54	94	0.05	0	46	460	138	28	86	3.8	
Ujjain	Ujjain	Bhairavgarh Dw	DW16	7.54	1725	0	417	153	106	162	0.92	0	44	470	118	43	172	3.4	
Ujjain	Ujjain	Bharatpuri	DW17	7.49	1198	0	471	139	46	7	0.69	0	34	400	112	29	89	2.7	

District	Block	Location	LAB ID	pH	EC	CO3	HCO3	Cl	SO4	NO3	F	PO4	SiO2	TH	Ca	Mg	Na	K	TDS
Ujjain	Ujjain	Chintaman Jawasiya	DW18	7.51	1256	0	236	228	66	62	0.23	0	56	360	106	23	112	0.75	
Ujjain	Ujjain	Desai Nagar	DW19	7.76	945	0	356	87	56	9	0.82	0.2	26	265	62	27	112	4.5	
Ujjain	Ujjain	Dhabla Rehwari, Sahabkhedi Dw	DW20	7.61	930	0	387	54	32	21	0.42	0.1	42	350	104	22	53	4.2	
Ujjain	Ujjain	Freeganj Dw	DW21	7.61	925	0	326	97	65	9	0.55	0.4	22	245	52	28	98	2.5	
Ujjain	Ujjain	Gandhi Nagar Dw	DW22	7.62	1084	0	374	124	32	21	0.21	0.1	25	225	56	21	132	1.75	
Ujjain	Ujjain	Gita Colony Dw	DW23	7.68	905	0	278	92	59	19	0.19	0.8	24	235	52	26	87	6.5	
Ujjain	Ujjain	Gonsa	DW24	7.32	2772	0	441	601	174	53	0.35	0	26	730	224	41	289	1.25	
Ujjain	Ujjain	Harsodan	DW25	7.27	1235	0	350	101	66	140	0.2	0	46	460	130	33	73	2.7	
Ujjain	Ujjain	Hira Mill Compound	DW26	7.69	1425	0	242	299	102	11	0.52	0.2	32	270	66	26	210	2.25	
Ujjain	Ujjain	Jambura	DW27	7.35	777	0	302	25	32	83	0.32	0	44	265	64	26	52	5.5	
Ujjain	Ujjain	Khilachipur	DW28	7.69	2156	0	658	314	116	68	0.64	0.1	28	630	144	66	232	2	
Ujjain	Ujjain	Kids Planet School	DW29	7.59	972	0	302	82	75	39	0.27	0.3	26	340	82	33	75	0.5	
Ujjain	Ujjain	Lohe Ka Pul Dw	DW31	7.47	1241	0	477	106	68	26	0.2	0.7	50	340	84	32	98	56.5	
Ujjain	Ujjain	Mahakal Vanijya	DW32	7.53	1453	0	501	228	77	9	0.46	2.6	30	365	106	24	188	8.5	
Ujjain	Ujjain	Mahananda Colony	DW33	7.57	1145	0	380	116	48	33	0.32	0.1	26	300	84	22	122	0.5	
Ujjain	Ujjain	Maksi Road	DW34	7.3	3345	0	489	648	330	36	0.44	0	42	1040	302	69	342	1.25	
Ujjain	Ujjain	Mangrola Dw (Shyam Singh)	DW35	7.6	2389	0	429	322	140	289	0.38	0	37	570	178	30	252	7.75	
Ujjain	Ujjain	Mrs Krishi Upaj Mandi Dw	DW36	7.72	2106	0	501	304	155	122	0.88	0.2	38	270	52	34	347	2	
Ujjain	Ujjain	Pingaleshwar Dw	DW39	7.5	1988	0	538	203	118	167	0.61	0.5	56	525	130	49	175	73.5	
Ujjain	Ujjain	Pragati Nagar Dw	DW40	7.8	1205	0	374	153	36	39	0.62	0.1	25	360	72	44	122	2.5	
Ujjain	Ujjain	Prajapat Nagar	DW41	7.58	2098	0	628	287	82	9	1.01	0.1	30	520	138	43	262	1.25	
Ujjain	Ujjain	Tajpur Dw 1	DW42	7.74	1063	0	332	77	60	88	0.31	0	50	345	72	40	85	3.1	
Ujjain	Ujjain	Undasa	DW44	7.56	1025	0	465	77	30	7	0.43	0.2	26	340	82	33	72	3.1	
Ujjain	Ujjain	Vikram University	DW45	7.59	1145	0	393	139	28	15	0.42	0	40	310	84	24	112	2.2	
Ujjain	Ujjain	Vyas Nagar	DW46	8.1	1198	0	471	136	64	6	0.2	0.4	30	315	102	15	142	1.25	
Ujjain	Ghatia	Nipaniay Goyal Hp	HP01	7.3	1625	0	477	151	88	135	0.46	0	54	485	142	32	148	4.5	
Ujjain	Ghatia	Ujjainiya Hp	HP02	7.25	1462	0	598	87	74	43	0.1	0	56	425	118	32	139	4.5	
Ujjain	Ujjain	Freeganj Hp	HP03	7.32	1323	0	405	153	86	4	0.56	0.1	40	370	104	27	135	0.75	
Ujjain	Ujjain	Gunaikhalsa	HP04	7.48	930	0	338	59	60	48	0.08	0	54	295	68	30	76	4	
Ujjain	Ujjain	Nanakheda	HP05	7.56	1371	0	338	210	68	23	0.38	0.1	42	190	42	21	202	1.5	

District	Block	Location	LAB ID	pH	EC	CO3	HCO3	Cl	SO4	NO3	F	PO4	SiO2	TH	Ca	Mg	Na	K	TDS
Ujjain	Ujjain	Navgrah Shani Mandir, Dhediya	HP06	7.28	2156	0	538	302	77	85	0.24	0	46	520	130	47	256	1.5	
Ujjain	Ujjain	Pingaleshwar Hp	HP07	7.39	971	0	314	74	60	66	0.12	0	36	340	86	30	65	5.5	
Ujjain	Ujjain	Seswani Mohalla	HP08	7.57	968	0	380	104	45	22	0.61	0.1	40	230	50	26	118	8	
Ujjain	Ghatia	Pached Bw	BW10	7.76	1303	0	393	153	22	56	0.39	0	41	570	170	35	37	0.75	847
Ujjain	Ghatia	Kithoda Jagir	BW09	7.46	1785	0	682	178	22	122	0.37	0	36	755	246	34	61	1.25	1160
Ujjain	Ghatia	Kaliyadeh	BW08	7.26	1764	0	531	233	86	95	0.39	0.2	34	685	178	58	89	3.5	1147
Ujjain	Ghatia	Gunaya	BW05	7.6	1329	0	362	210	46	14	0.2	0	20	460	118	40	91	6.7	864
Ujjain	Ujjain	Dhatrawada Bw	BW28	7.58	2556	0	308	475	228	105	0.32	0	34	685	222	32	237	2.75	1661
Ujjain	Ujjain	Pipliaragho	BW39	7.51	1586	0	513	255	59	68	0.38	0	44	565	152	45	135	0.5	1031
Ujjain	Ujjain	Khilachipur Bw	BW45	7.29	1688	0	525	257	83	71	0.65	0	28	595	162	46	146	1	1097
Ujjain	Ghatia	Ralayata Mauja Bw	BW11	7.26	3311	0	495	535	226	310	0.01	0	52	955	264	72	320	9.2	2152
Ujjain	Ghatia	Sodang Bw	BW13	7.29	1405	0	387	144	52	153	0.44	0	51	505	164	23	88	1.5	913
Ujjain	Ujjain	Sinhal Enterprise	BW43	7.38	1745	0	429	252	201	20	0.7	0	42	555	172	30	156	1.5	1134
Ujjain	Ghatia	Sulyakhedi Bw	BW14	7.47	1655	0	302	260	66	171	0.18	0	46	470	124	39	162	4.6	1076
Ujjain	Ghatia	Kadgi Karadiya Bw	BW07	7.81	1989	0	169	500	88	58	0.21	0	62	290	68	29	316	3	1293
Ujjain	Ghatia	Sawarakhedi Bw	BW12	7.33	1733	0	417	275	52	106	0.55	0	40	425	124	28	192	1.25	1126
Ujjain	Ujjain	Pwd Rest House	BW41	7.67	1188	0	242	252	32	11	0.72	0.1	22	190	54	13	177	3.4	772
Ujjain	Ujjain	Chintaman Bw	BW24	7.15	1450	0	453	178	42	92	0.9	0	42	440	118	35	126	1.25	943
Ujjain	Ujjain	Wrd Office	BW44	7.64	1440	0	411	191	72	43	0.38	0.1	40	410	124	24	142	2.2	936
Ujjain	Ujjain	Begambagh Colony Bw	BW22	7.76	1685	0	314	309	76	34	0.95	0.1	35	325	84	28	242	1.75	1095
Ujjain	Ujjain	Alchemy Chemicals	BW20	7.58	2145	0	272	252	372	42	0.21	0.1	32	610	178	40	202	1.25	1394
Ujjain	Ujjain	Daudkhedi	BW25	7.58	2485	0	429	426	164	146	0.24	0	46	510	162	26	342	1.75	1615
Ujjain	Ujjain	Kanipura-Tarana Road	BW34	7.16	2245	0	495	337	95	123	0.42	0.1	30	530	136	46	275	3.25	1459
Ujjain	Ujjain	Badarkha Berasia Bw	BW21	7.34	1510	0	507	129	88	56	0.22	0.1	36	475	144	28	132	2.6	982
Ujjain	Ujjain	Dhabla Rehwari, Sahabkhedi Bw	BW27	7.47	1012	0	417	69	40	16	0.52	0.1	38	340	58	47	71	4.2	658
Ujjain	Ujjain	Bhairavgarh Bw	BW23	7.51	2132	0	544	235	136	169	0.35	0	46	505	142	36	254	4	1386
Ujjain	Ghatia	Kadawali Bw	BW06	7.23	1612	0	441	171	94	124	0	0	54	405	104	35	185	7.3	1048
Ujjain	Ujjain	Sanwer Road	BW42	7.8	1202	0	338	186	56	6	0.65	0.2	34	140	30	16	203	1	781

District	Block	Location	LAB ID	pH	EC	CO3	HCO3	Cl	SO4	NO3	F	PO4	SiO2	TH	Ca	Mg	Na	K	TDS
Ujjain	Ghatia	Azampura	BW02	7.54	901	0	368	62	32	63	0.32	0	58	310	86	23	68	2	586
Ujjain	Ghatia	Agar Road	BW01	7.53	1962	0	592	257	66	52	0.32	0.1	31	350	112	17	287	3.3	1275
Ujjain	Ujjain	Gita Colony Bw	BW31	7.76	932	0	350	99	48	7	0.53	0.1	15	225	52	23	112	2.5	606
Ujjain	Ujjain	Gandhi Nagar Bw	BW30	7.69	1521	0	380	215	90	91	0.54	0	42	245	64	21	245	2.25	989
Ujjain	Ujjain	4r Udyan	BW15	7.67	1685	0	465	235	89	7	0.91	0.1	40	290	66	30	268	1.5	1095
Ujjain	Ujjain	Alakhdham Nagar Bw	BW19	7.75	1145	0	326	141	39	55	0.23	0.1	26	185	42	19	182	1.25	744
Ujjain	Ghatia	Bhutiya	BW04	7.5	850	0	344	35	28	74	0.12	0	56	315	70	34	48	3.7	553
Ujjain	Ujjain	Mrs Krishi Upaj Mandi Bw	BW37	7.77	1189	0	387	101	70	40	0.95	0	40	275	58	32	154	1.5	773
Ujjain	Ghatia	Kagdi Karadiya River	R1	7.58	1250	0	394	177	46	6	1.1	5.6	25	353	75	41	112	16.9	813
Ujjain	Ghatia	Kaliyadeh Bridge	R2	7.79	1420	0	456	227	32	9	0.54	2.7	8	343	63	45	170	13.9	923
Ujjain	Ghatia	Pached River	R3	7.58	1255	0	362	149	52	111	0.37	4.6	30	370	92	34	120	10.25	816
Ujjain	Ghatia	Sulyakhedi Bridge	R4	7.41	1320	0	447	156	46	22	0.47	5.6	36	340	64	44	139	12.7	858
Ujjain	Ujjain	Bhairavgarh Stp	N1	8.03	2823	0	758	465	183	39	0.75	4.8	75	696	78	122	356	19.8	1835
Ujjain	Ujjain	Dhabla Rehwari Percolation Tank	PT1	7.33	514	0	222	25	33	16	0.36	0.2	23	208	55	17	28	5.1	334
Ujjain	Ujjain	Khan River Pipliaragho Bridge	R5	7.62	1211	0	444	147	40	22	1.18	9.3	34	333	78	33	128	11.8	787
Ujjain	Ujjain	Kshipra , Near Muktidham	R6	7.56	1250	0	370	157	45	34	0.97	5.4	30	314	90	21	123	12.1	813
Ujjain	Ujjain	Kshipra, Jeevankhedi Bridge	R7	7.92	1075	0	388	107	51	25	0.88	5.1	27	324	86	26	92	9	699
Ujjain	Ujjain	Kshipra, Ramghat Bridge	R8	7.94	1150	0	314	160	47	62	0.61	3.8	26	333	67	41	108	7.2	748
Ujjain	Ujjain	Kshipra-Khan Confluence	R9	7.59	1175	0	370	160	40	29	1.05	0.5	31	304	78	26	125	13.8	764
Ujjain	Ujjain	Piliyakhal Nala	R10	7.6	4526	0	900	707	324	42	1.23	8	30	775	165	88	642	31.7	2942
Ujjain	Ujjain	Undasa Lake	PT2	7.23	588	0	216	52	22	8	0.55	0.1	15	178	51	12	45	5.2	382

Farmer Feedback Form

Photograph

Name	SEVARAM Ji	
Village	pached	
Block	Ujjain	
District	Ujjain	
Address	.	
Mobile Number (optional)	.	
Type and number of structures		
Type	BW	DW
Number	01	01
(coordinates of the structures are to be obtained by the field officer)	-	-
Drill time discharge (lps)	1 lps	-
Depth of installation of pump	20 mtr.	-
Casing depth (Bore wells) HR	30 mtr.	-
Fracture encountered depth-HR	25-30 mtr.	-
Slotted pipe depths (TW) SR	-	-
Average water levels – pre-monsoon	16.83 mtr	7.20 mtr
Average water levels – post-monsoon	10.20 mtr.	3.20.
The well is used for	Domestic & Irrigation	DOmestic.
Is water available throughout the year	yes	WL goes down during summer.
If not for how many months water is available	-	-

Pumping Duration

	Number of days pump is operated (days) of each well	What is the average pumping duration (in hours) of each well	Instantaneous Discharge Measurement (to be carried out by the field officer) in lps
Rabi (no of months to be specified)	4-5	10 hrs.	1 lps.

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Kharif (no of months to be specified)	NO	NO	NO
Others (no of months to be specified)	.	-	.
Area Irrigated			
	Area Irrigated	Type of crop taken	Remarks
Rabi (no of months to be specified)	4 Acre.	Onion, Garlic.	
Khariff (no of months to be specified)	4 Acre.	Soya, Rice	
Others (no of months to be specified)	-	-	
Cropping patterns (past and present) in the village (Not Change yet)			
Traditional Cropping pattern in the village	Kharif	Rabi	Other
Type of Crop	NA	NA	NA
Area under crop			
Prevailing Cropping pattern in the village	Kharif	Rabi	Other
Type of Crop	Soya, Rice.	Onion, Garlic	
Area under crop			
Reasons for change in cropping pattern in last 20 years.	NA	NA.	
If the cropping pattern is to be changed, which are the suitable crops that can be grown	Onion and garlic production gradually decreases, Suggest to adopt Salt tolerance crops		
Available Market for the crop	Ujjain Govt. Krishi Upaj Mandi		
Average unit cost of production	-	-	-
Average unit cost of selling			
Existing MSP and other related information	Crop wise details are to be collected		
Other subsidies, facilities, restrictions.	-		
Source of Energy			
Solar	○ Is it connected to grid Yes ○ If yes how much incentive do you get per month on an average for feeding electricity to the grid (Rs per month) unable to explain by the farmer.		
Electric	○ Do you get free electricity for irrigation? NO ○ Do you pay a fixed charge ○ If a fixed charge is paid, what is the per month charge ○ If unit-based charges are paid what is the average monthly charges in rupees ○ During kharif---- ○ During Rabi-----		
Diesel	○ Average consumption of diesel (liters) per month ○ During Kharif ○ During Rabi		

Water Market*	o Do you share the pumped water with other farmers NO o If yes o For how many days do you share pumped water in Kharif o For how many days do you share pumped water in Rabi Period o On an average how much do you charge per annum (in Rs)
	o Do you receive additional water from boreholes of nearby farmers NO. o If yes o For how many days do you receive pumped water in Kharif o For how many days do you receive pumped water in Rabi Period o On an average how much do you pay per annum (in Rs)
Other issues/Remarks	e.g. common problems in drilling of wells, common health issues in the area etc
- Feedback of the local users will form an important input for problem identification and characterization. Feedbacks are to be obtained in case of Urban areas, Industrial clusters also. Feedbacks on drinking water availability, dependence on ground water etc are also to be obtained. The above feedback form can be customized to the type of priority area and objective of the study.	

Annexure-6

Production of Onion and garlic in Ujjain Industrial Area 2013-2023.

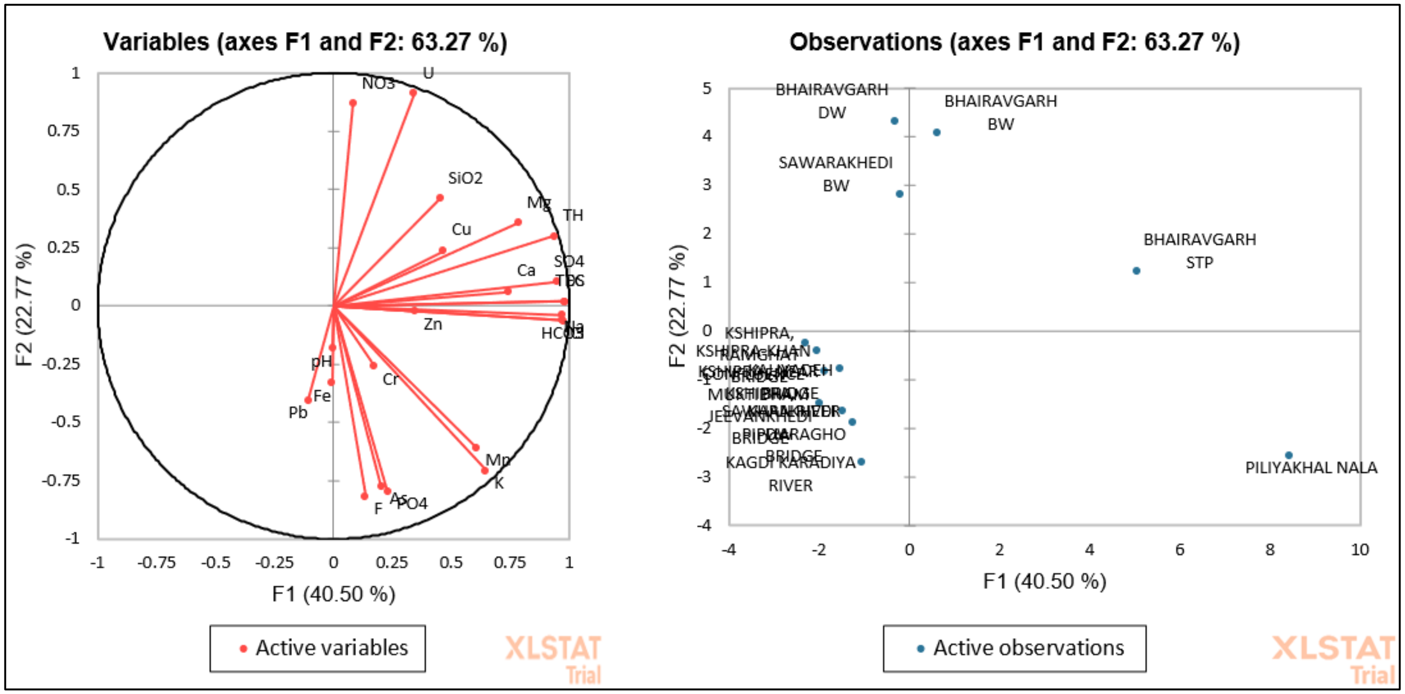
Onion											
Year	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Area	8838	3478	7527	9022	14440	14645	14820	15786	18635	19082	19082
Production	239429	94254	158827	190545	323445	331856	336847	358816	423573	433734	433734
Garlic											
Year	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Area	9848	11884	13013	14086	21369	22224	23447	24711	27100	27200	27200
Production	118176	142608	139890	169032	261984	275575	293082	308886	338750	340000	340000

Source: Directorate of Agriculture, Ujjain

Annexure-7:

Pearson Correlation Matrix & PCA of chemical parameters in water samples from villages with yield issue of onion and Garlic

Variables	pH	EC	HCO3	Cl	SO4	NO3	F	PO4	SiO2	TH	Ca	Mg	Na	K	TDS	Fe	Mn	Cu	Zn	As	Pb	Cr	U
pH	**1**	-0.3	-0.2	-0.1	-0.4	-0.3	0.2	-0.3	0.3	-0.2	-0.2	-0.3	-0.1	-0.3	-0.3	-0.4	-0.1	0.1	-0.3	0.5	-0.5	-0.1	-0.5
EC	-0.3	**1**	0.1	**0.9**	**0.9**	-0.1	-0.3	-0.1	0	0.3	0.3	0	**0.8**	0.1	**1**	-0.1	-0.2	0	0.4	-0.4	0.2	0	-0.1
HCO3	-0.2	0.1	**1**	-0.3	-0.1	0.1	0.4	0.3	-0.4	**0.9**	**0.9**	0.2	-0.4	-0.3	0.1	0	-0.1	0.5	0.3	0	0.2	**0.7**	0
Cl	-0.1	**0.9**	-0.3	**1**	**0.9**	-0.4	-0.4	-0.2	0.1	0	0	0	**0.9**	0.2	**0.9**	-0.2	-0.1	-0.2	0.2	-0.3	0.1	-0.3	-0.1
SO4	-0.4	**0.9**	-0.1	**0.9**	**1**	-0.1	-0.4	0	0	0.2	0.1	0.1	**0.8**	0.3	**0.9**	-0.1	-0.2	-0.2	0.4	**-0.6**	0.3	-0.3	0
NO3	-0.3	-0.1	0.1	-0.4	-0.1	**1**	-0.3	0	0.3	-0.1	0	-0.3	0	-0.2	-0.1	0.3	-0.3	0	0.4	-0.3	0	0.2	0.4
F	0.2	-0.3	0.4	-0.4	-0.4	-0.3	**1**	0	-0.3	0.3	0.3	0	-0.5	-0.3	-0.3	0.4	0.1	-0.1	-0.2	0.4	0	0	-0.1
PO4	-0.3	-0.1	0.3	-0.2	0	0	0	**1**	-0.2	0.3	0.1	**0.7**	-0.2	0.2	-0.1	-0.1	-0.1	0	-0.2	-0.4	**0.7**	-0.1	0.5
SiO2	0.3	0	-0.4	0.1	0	0.3	-0.3	-0.2	**1**	-0.6	-0.4	**-0.6**	0.3	0	0	0.1	**-0.7**	-0.2	-0.1	-0.2	-0.2	-0.1	0.1
TH	-0.2	0.3	**0.9**	0	0.2	-0.1	0.3	0.3	-0.6	**1**	**1**	0.5	-0.3	-0.1	0.3	-0.3	0	0.5	0.3	0.1	0.3	0.5	0
Ca	-0.2	0.3	**0.9**	0	0.1	0	0.3	0.1	-0.4	**1**	**1**	0.2	-0.2	-0.3	0.3	-0.2	-0.1	0.5	0.5	0.1	0.2	0.5	0
Mg	-0.3	0	0.2	0	0.1	-0.3	0	**0.7**	**-0.6**	0.5	0.2	**1**	-0.3	0.5	0	-0.4	0.3	0	-0.4	-0.2	0.4	-0.1	0.3
Na	-0.1	**0.8**	-0.4	**0.9**	**0.8**	0	-0.5	-0.2	0.3	-0.3	-0.2	-0.3	**1**	0.2	**0.8**	0	-0.2	-0.3	0.3	-0.5	0	-0.3	-0.1
K	-0.3	0.1	-0.3	0.2	0.3	-0.2	-0.3	0.2	0	-0.1	-0.3	0.5	0.2	**1**	0.1	-0.1	0.2	-0.5	-0.4	-0.4	-0.2	-0.2	0.2
TDS	-0.3	**1**	0.1	**0.9**	**0.9**	-0.1	-0.3	-0.1	0	0.3	0.3	0	**0.8**	0.1	**1**	-0.1	-0.2	0	0.4	-0.4	0.2	0	-0.1
Fe	-0.4	-0.1	0	-0.2	-0.1	0.3	0.4	-0.1	0.1	-0.3	-0.2	-0.4	0	-0.1	-0.1	**1**	-0.2	-0.3	-0.1	-0.3	0	0	0.2
Mn	-0.1	-0.2	-0.1	-0.1	-0.2	-0.3	0.1	-0.1	**-0.7**	0	-0.1	0.3	-0.2	0.2	-0.2	-0.2	**1**	-0.1	0	0.5	-0.1	0.1	-0.2
Cu	0.1	0	0.5	-0.2	-0.2	0	-0.1	0	-0.2	0.5	0.5	0	-0.3	-0.5	0	-0.3	-0.1	**1**	0.2	0.2	0.1	0.5	-0.4
Zn	-0.3	0.4	0.3	0.2	0.4	0.4	-0.2	-0.2	-0.1	0.3	0.5	-0.4	0.3	-0.4	0.4	-0.1	0	0.2	**1**	0	0.3	0.3	0
As	0.5	-0.4	0	-0.3	**-0.6**	-0.3	0.4	-0.4	-0.2	0.1	0.1	-0.2	-0.5	-0.4	-0.4	-0.3	0.5	0.2	0	**1**	-0.2	0.3	-0.2
Pb	-0.5	0.2	0.2	0.1	0.3	0	0	**0.7**	-0.2	0.3	0.2	0.4	0	-0.2	0.2	0	-0.1	0.1	0.3	-0.2	**1**	-0.2	0.4
Cr	-0.1	0	**0.7**	-0.3	-0.3	0.2	0	-0.1	-0.1	0.5	0.5	-0.1	-0.3	-0.2	0	0	0.1	0.5	0.3	0.3	-0.2	**1**	-0.1
U	-0.5	-0.1	0	-0.1	0	0.4	-0.1	0.5	0.1	0	0	0.3	-0.1	0.2	-0.1	0.2	-0.2	-0.4	0	-0.2	0.4	-0.1	**1**


Variables (axes F1 and F2: 63.27 %)
F1 (40.50 %)
F2 (22.77 %)
NO3
U
SiO2
Mg
TH
Cu
Ca
SO4
TDS
Zn
HCO3
Na
pH
Fe
Pb
Cr
Mn
K
As
PO4
F
Active variables
Observations (axes F1 and F2: 63.27 %)
BHAIRAVGARH DW
BHAIRAVGARH BW
SAWARAKHEDI BW
BHAIRAVGARH STP
PILIYAKHAL NALA
KAGDI KARADIYA RIVER
Active observations

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