

# REPORT

# HYDROGEOLOGY

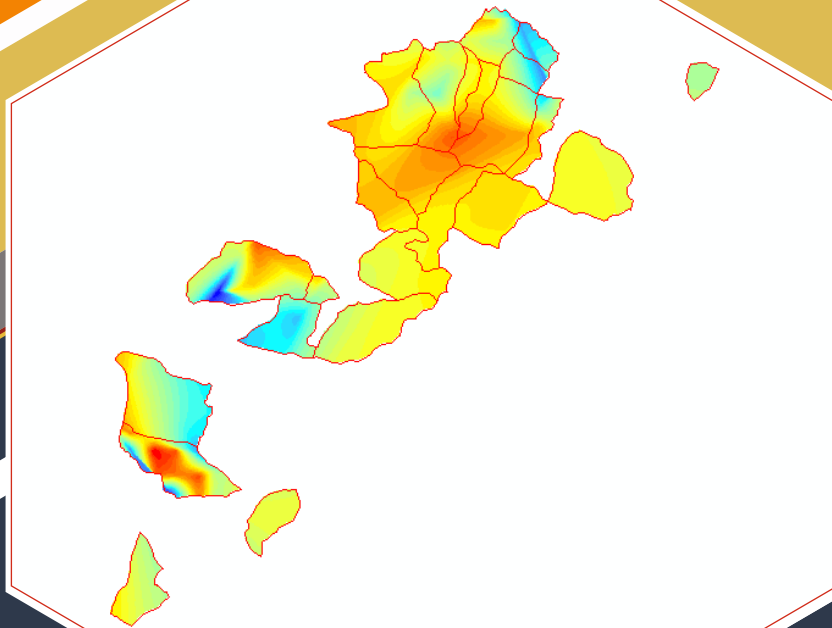
GROUNDWATER ASSESSMENT REPORT

## INTEGRATED HYDROGEOLOGICAL AQUIFER MAPPING AND GROUNDWATER RESOURCE FEASIBILITY ASSESSMENT FOR CLIMATE-RESILIENT WATER SECURITY IN DEOGHAR (PALOJORI), DHANBAD (TUNDI), DUMKA (JAMA), EAST SINGHBHUM (GURABANDA, DALBHUMGARH), HAZARIBAGH (CHURCHU, DADI), AND KHUNTI (MURHU) DISTRICTS OF JHARKHAND, INDIA

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- AQUIFER MAPPING
- PRECAMBRIAN CRYSTALLINE BASEMENT
- RUNOFF MODELLING
- GEOPHYSICAL INVESTIGATION
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**2026**

**HYDROGEOLOGICAL REPORT**  
**INTEGRATED HYDROGEOPHYSICAL AQUIFER MAPPING AND GROUNDWATER**  
**RESOURCE FEASIBILITY ASSESSMENT FOR CLIMATE-RESILIENT WATER SECURITY**  
**IN DEOGHAR (PALOJORI), DHANBAD (TUNDI), DUMKA (JAMA), EAST**  
**SINGHBHUM (GURABANDA, DALBHUMGARH), HAZARIBAGH (CHURCHU, DADI),**  
**AND KHUNTI (MURHU) DISTRICTS OF JHARKHAND, INDIA**

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**Submitted to**



**Collectives for Integrated Livelihood Initiatives**

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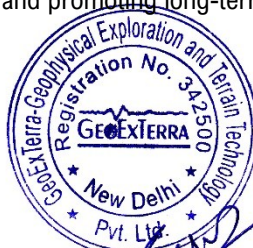
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### FOREWORD

The present represents a comprehensive scientific effort to evaluate and strengthen groundwater resources across 161 villages covering approximately 37,535.6 hectares in Deoghar (Palojori), Dhanbad (Tundi), Dumka (Jama), East Singhbhum (Gurabanda and Dalbhumgarh), Hazaribagh (Churchu and Dadi), and Khunti (Murhu) districts of Jharkhand. This study has been undertaken in response to the growing challenges of water scarcity, climate variability, declining groundwater levels, and increasing dependence on fragile rainfed agricultural systems in hard rock terrains of the Chotanagpur Plateau. The project adopts an integrated and multidisciplinary approach, combining hydrogeological investigations, geophysical surveys, remote sensing, soil and land resource analysis, water quality assessment, and hydrological modeling to generate a robust understanding of aquifer systems and their dynamic behavior. The findings reveal that groundwater occurrence in the region is primarily governed by weathered and fractured crystalline formations, characterized by low storativity and highly variable transmissivity, necessitating site-specific and scientifically informed groundwater development strategies. The study highlights that despite receiving substantial annual rainfall, a significant portion is lost to evapotranspiration and runoff, thereby limiting effective groundwater recharge. Through detailed analysis, the report identifies substantial opportunities for augmenting groundwater resources through strategically planned water conservation interventions, including check dams, recharge shafts, bunding, and desiltation measures, capable of conserving over 9300 TCM of runoff and significantly enhancing aquifer recharge. Furthermore, the integration of hydrogeophysical data with terrain, soil, drainage, and land use characteristics has enabled the delineation of recharge-priority zones and the formulation of targeted intervention strategies that are both technically sound and economically viable. The projected outcomes, including improved groundwater levels, enhanced soil moisture availability, increased cropping intensity, and strengthened drought resilience, underscore the critical importance of adopting an integrated watershed-based approach for sustainable water resource management. This report is intended to serve as a decision-support document for planners, implementing agencies, and stakeholders, providing a scientifically validated framework for groundwater development, recharge planning, and climate-resilient water security interventions. It is expected that the recommendations and strategies outlined herein will contribute significantly to improving rural livelihoods, ensuring reliable water supply for domestic and agricultural use, and promoting long-term sustainability of groundwater resources in the project area.



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## EXECUTIVE SUMMARY

The present study provides a comprehensive and integrated hydrogeophysical evaluation of groundwater resources, recharge potential, and water management strategies across 161 villages covering ~37,535.6 ha in Deoghar (Palojori), Dhanbad (Tundi), Dumka (Jama), East Singhbhum (Gurabanda and Dalbhumgarh), Hazaribagh (Churchu and Dadi), and Khunti (Murhu) districts of Jharkhand. The region, situated within the hard rock terrain of the Chotanagpur Plateau, is characterized by gently undulating topography, elevation ranging from ~57 m to 723 m amsl, and a dendritic drainage system controlled by the Damodar and Subarnarekha river basins, which collectively influence groundwater occurrence, recharge, and movement. Hydrogeologically, the area is dominated by weathered and fractured crystalline aquifers with secondary porosity, where aquifer thickness varies from ~8.5 m to 82.8 m and groundwater availability extends up to ~83.6 m depth, indicating moderate to favorable aquifer potential. Pumping test analysis confirms a heterogeneous aquifer system with transmissivity ranging from ~10 to 113 m<sup>2</sup>/day and low storativity (0.0003–0.0025), reflecting semi-confined to confined conditions governed by fracture connectivity. Hydrological assessment reveals that out of 637561.3 TCM annual rainfall (2025), only 21.7% contributes to natural recharge, while 64.7% is lost to evapotranspiration and 13.6% as runoff, highlighting substantial scope for water harvesting. The study identifies that approximately 9321.7 TCM of runoff (~10.7% of recharge potential) can be conserved through 422 proposed water augmentation structures, including check dams, recharge shafts, gabions, and bund rehabilitation, with an estimated investment of ₹1750.42 million, where desiltation and repair of existing structures contribute the highest volumetric gains. These interventions are strongly controlled by terrain, soil hydro-physical properties, drainage density, and lineament distribution, with low permeability zones favoring surface storage structures and permeable zones supporting subsurface recharge systems. The projected hydrological impact includes groundwater level rise of ~1–2.7 m, enhancement of soil moisture (40–45%), extension of moisture availability by ~56 days, and increased groundwater retention by ~8–9 days, thereby improving resilience during dry periods. From an agricultural perspective, the additional conserved water has the potential to bring ~1864.4 ha under second cropping, with irrigation requirements ranging from 3000–6000 m<sup>3</sup>/ha annually, depending on soil and terrain conditions. Overall, the integrated analysis demonstrates that groundwater occurrence, recharge, and sustainability in the project area are controlled by a complex interplay of physiography, geology, soil characteristics, land use, and climatic variability, and that systematic implementation of targeted runoff harvesting and recharge interventions can significantly enhance groundwater storage, stabilize water levels, improve agricultural productivity, and ensure long-term climate-resilient water security across the region.

## 1. BACKGROUND

The present has been conceptualized against the backdrop of increasing stress on groundwater resources in hard rock terrains, where water availability is inherently constrained by geological controls and further aggravated by climate variability, erratic rainfall patterns, and rising anthropogenic demand. The project has been commissioned by Collectives for Integrated Livelihood Initiatives (CInI) as part of its broader mandate to strengthen rural livelihoods, enhance water security, and promote sustainable natural resource management in tribal and rural landscapes through scientifically informed and community-oriented interventions. Jharkhand, being predominantly underlain by Precambrian crystalline formations such as granite gneiss and phyllite, exhibits groundwater occurrence primarily within weathered zones and fracture networks, resulting in highly heterogeneous and localized aquifer systems with limited storage capacity and variable transmissivity. In such hydrogeological settings, conventional approaches to groundwater development often lead to sub-optimal outcomes due to inadequate understanding of subsurface conditions, thereby necessitating an integrated and multidisciplinary investigation framework. To address these challenges, GeoExTerra® Geophysical Exploration and Terrain Technology Private Limited, New Delhi, has been engaged to undertake detailed hydrological and hydrogeological investigations incorporating advanced geoscientific tools and methodologies. The scope of work includes systematic field surveys, geophysical exploration using techniques such as electrical resistivity tomography and vertical electrical sounding, aquifer characterization through pumping test analysis, groundwater potential assessment, and spatial delineation of aquifer systems using GIS-based mapping and modelling approaches. The integration of hydrogeophysical data with field observations enables precise identification of fracture zones, aquifer geometry, and recharge potential, thereby facilitating evidence-based planning for sustainable groundwater development. This study is particularly significant in the context of climate-resilient water security, as it aims to generate scientifically robust datasets and actionable insights for optimizing groundwater extraction, enhancing recharge through suitable water conservation structures, and supporting decentralized water management strategies. By bridging the gap between scientific assessment and field-level implementation, the project contributes to long-term sustainability of water resources while aligning with broader goals of livelihood enhancement, environmental conservation, and resilience building in vulnerable rural regions of Jharkhand.

## 2. INTRODUCTION

The present project is designed to address the critical challenge of sustainable groundwater management in hard rock terrains, where water availability is intrinsically controlled by complex geological and structural conditions. Jharkhand is predominantly underlain by Precambrian crystalline formations such as granite gneiss and phyllite, where groundwater occurs mainly within weathered mantles and fracture systems, resulting in highly heterogeneous aquifer characteristics with limited storage and localized productivity. In recent years, increasing pressure on groundwater resources due to population growth, agricultural expansion, and climate variability has led to declining water levels, reduced well yields, and growing vulnerability of rural communities, particularly in tribal-dominated regions. The study area spans multiple districts and blocks with varying geomorphological, hydrological, and geological settings, necessitating a comprehensive and integrated approach to understand

aquifer behavior and groundwater potential. In this context, the project adopts a multidisciplinary hydrogeophysical framework that integrates surface and subsurface investigations, including geological mapping, hydrogeological surveys, geophysical exploration (such as electrical resistivity methods), and pumping test analysis, to delineate aquifer systems and evaluate their hydraulic properties. Furthermore, the study incorporates spatial analysis using Geographic Information Systems (GIS) to generate aquifer maps, groundwater potential zonation, and site-specific recommendations for water resource development. The integration of these methodologies facilitates a more accurate identification of productive zones, fracture networks, and recharge areas, thereby reducing uncertainties in groundwater exploration and development. The primary objective of this investigation is to develop a scientifically robust understanding of aquifer systems and to translate this knowledge into actionable strategies for climate-resilient water security. By combining hydrogeological insights with geophysical data, the project aims to optimize groundwater extraction, enhance recharge through suitable water conservation measures, and support decentralized water management practices tailored to local conditions. The outcomes of this study are expected to provide a strong technical foundation for planning sustainable groundwater interventions, improving water availability for domestic and agricultural use, and strengthening the resilience of rural communities against climate-induced water stress. Overall, the project represents a critical step towards integrated water resource management in Jharkhand, aligning scientific assessment with practical implementation to ensure long-term sustainability and equitable access to groundwater resources.

### 3. SCOPE OF WORK

The aquifer mapping project aims to interpret the hydrogeological properties and groundwater conditions in the subsurface to identify suitable zones for groundwater recharge through appropriate and area-specific water conservation structures aiming for the elevation of the groundwater table and mitigation of vulnerability imposed by salinity ingress and climate change. To characterize the subsurface geometries and their hydrogeological characteristics following steps listed below were taken by the GeoExTerra®.

- i. Site visits to familiarize with the project area.
- ii. To obtain, study, and synthesize background information, including the area's geology, hydrology, and hydrogeology.
- iii. To carry out geophysical investigations at selected sites, concerning the subsurface investigation.
- iv. Geophysical data analysis and its hydrogeological interpretation related to the local hydrogeological regime and its behavior concerning aquifer geometries, groundwater recharge, availability, and safe yield.
- v. Recommendations, including proposing sites suitable for water harvesting and groundwater recharge structures.

### 4. PROCEDURE/METHODOLOGY

The field survey and all measurements were taken from 11th November 2025 to 15th January 2026. Following procedure/methods adopted to attend the objectives of the study.

## 4.1 Transect Walk

To understand terrain topography, soils, drainage, geology, hydrogeology, and geomorphology, and to design the field survey the entire study area is traversed. Several hydrogeological and related parameters, i.e., structural settings, drainages, lithology, water bodies, slope, and land cover patterns were studied. Also, during the transect walk, various thematic layers and areas with hydrogeological problems and prospecting including soil loss were identified and validated for field reality. Further, if modeled data was reported to have a deviation from field observed data, then essential corrections were made to generate field-realistic models.

## 4.2 GIS and Satellite Remote Sensing

Applications of satellite remote sensing with GIS modeling to water resource studies entail delineation and mapping of different geological, hydrogeological, lithological, structural, geomorphological, land cover, and surface hydrology units. The surface expression of geological structures such as fractures (faults, joints, dykes, and veins), shear zones, and foliations, and often displayed or represented in the form of lineaments in remote sensing data for groundwater studies. While in hydrology satellite data facilities, identifying boundary conditions, drainage pattern recognition, vegetation classification and estimation of precipitation, surface runoff, stream discharge, evapotranspiration, etc. These are some advanced characteristics that have made satellite data an effective tool for water resource investigation.

### 4.2.1 Preparation of Thematic Maps

Using high-resolution satellite data Digital Elevation Map (DEM) of Advanced Land Observing Satellite – Phased Array Type L-Band Synthetic Aperture Radar (ALSO – PALSAR), Satellite Imageries of IRS-R2A-L4FX, hydro-climatological data by combination of the Modern-Era Retrospective analysis for Research and Applications version 2 (MERRA-2) data and Climate Hazards Group InfraRed Precipitation with Station (CHIRPS) were used to generate various thematic maps i.e., drainage, drainage density, lineament, lineament density, slope/contour, geomorphology, geology, soils, land cover, evapotranspiration, rainfall and used to understand the characteristic signatures of the area. These thematic maps were used to identify areas having hydrogeological prospects and problems related to water conservation, runoff management, enhancing baseflow for groundwater and soil moisture development, and prevention of runoff-based soil loss issues that impair crop productivity due to nutrient leach out and lack of humus. All the parameterized databases used were discretized into  $10 \times 10$  m grid cells to produce uniform pixel data onto spatial geometry for the generation of all maps and models.

## 4.3 Geological and Hydrological Studies

Geological settings of hilly and rocky terrain play an important role in controlling geohydrological characteristics responsible for runoff infiltration, groundwater recharge/movement, and maintaining baseflow discharge. To study

the geology of area structural mapping for fracture/dykes/joints dispositions, lava flow mapping, soils, water level, water quality, lithology, rocks settings, and pumping tests were done.

#### 4.4 Geophysical Investigation

The sustainability of watershed development is highly dependent on the knowledge of subsurface characteristics. Thereby geophysical techniques are used to characterize the geological settings of the subsurface, the disposition of geological formations, subsurface fracture/lineaments, and their hydrogeological characteristics. Therefore, locating the fractures and their orientation, understanding the lineament/fracture/conduits and thickness of various rock layers i.e., soil, weathered, fractured zones, including aquifer mapping and assessing hydrological properties, are of primary concern for the design and construction of recharge structures for the sustainable development of the watershed. Geophysical data analysis and its hydrogeological interpretation will reveal the local hydrogeological regime and its behavior in the subjected area. Using geophysical resistivity techniques i.e., vertical electrical sounding subsurface geometries of aquifers and rocks settings, including flow dynamics of groundwater, location, and, distribution of recharge zone for optimized and enhanced infiltration were mapped and potential/problematic zones have been identified.

The vertical electrical sounding technique uses direct current which is interposed into the ground through a pair of current electrodes and the resulting potential difference between two other intermediate points is measured using non-polarized electrodes. The apparent resistivities obtained from the field measurement were plotted against half-current electrode ( $AB/2$ ) separation of apparent resistivity on a log-log graph to a get geoelectric depth model (Maury and Balaji, 2014, 2015; Maury et al., 2016). The Schlumberger array configuration will be used to measure apparent resistivities. The apparent resistivity ( $\rho_a$ ) for the Schlumberger electrode array is expressed below

$$\rho_a = G \cdot \frac{\Delta V}{I}$$

$G$  is a geometric factor which is given by:

$$G = \frac{\pi}{2} \cdot \frac{\left(\frac{AB}{2}\right)^2 - \left(\frac{MN}{2}\right)^2}{\left(\frac{MN}{2}\right)}$$

Where  $V$  voltage,  $I$  current,  $AB$  the distance between the current electrodes, and  $MN$  is the distance between the potential electrodes.

#### 4.5 Soil Hydro-physical Investigation

Soil hydraulic conductivities were estimated using a mini-disk infiltrometer following the Van Genuchten method by preparing soil infiltration vs square root of the time curve. Whereas soil volumetric water content (soil moisture

percentage), soil electric conductivity, and soil temperature were obtained using the time-domain refractometry method.

#### 4.6 Data Integration and Interpretation

To understand the hydrological response in the area the integration of terrain surface hydrology and subsurface hydrogeology is essential. Hence, joint interpretation of terrain factors i.e., drainage, drainage density, runoff, slope, soils, geomorphology, geohydrology, patterns of surface runoff, the role of the subsurface in controlling infiltration and baseflow, and local agro-geo-climatic (land cover, rainfall pattern, evapotranspiration) made to draw a decision on planning and selection of site-specific water conservation activities. Necessary upscaling and downscaling were also performed in the hydrological models to optimize interpretation and ease up decision-making for efficient infiltration/recharge prospects to be created for enhanced groundwater availability, the baseflow retention period for a longer duration, and arresting groundwater salinization for the sustainable growth of agriculture of the area.

### 5. BACKGROUND OF THE PROJECT AREA

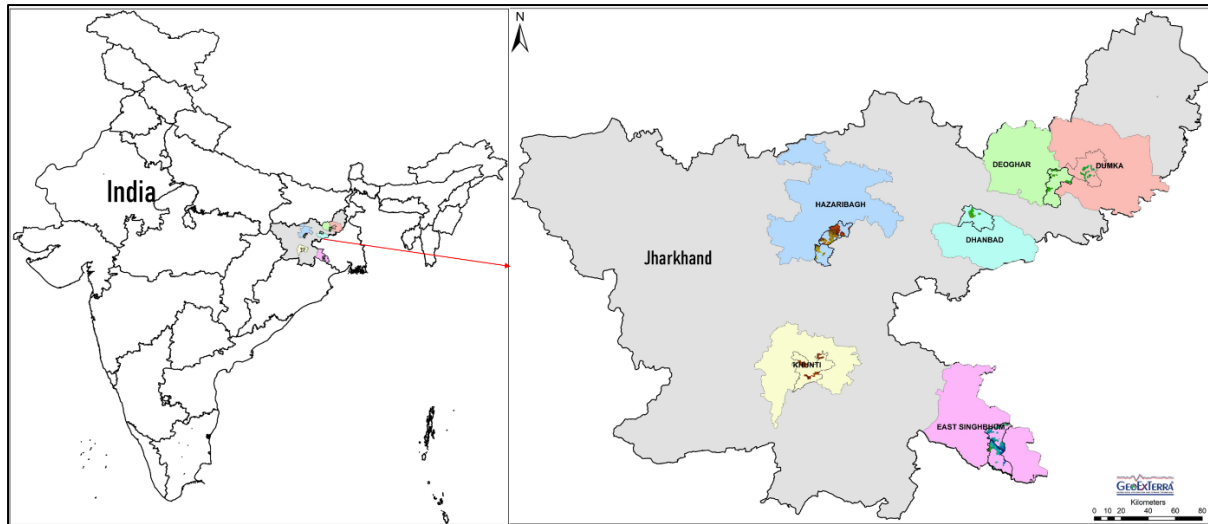
#### 5.1 Problem and Constraints

The project area encompassing Deoghar (Palojori), Dhanbad (Tundi), Dumka (Jama), East Singhbhum (Gurabanda and Dalbhumgarh), Hazaribagh (Churchu and Dadi), and Khunti (Murhu) districts of Jharkhand is characterized by a complex interplay of geological, hydrological, and socio-economic constraints that collectively limit the availability and sustainability of groundwater resources. The region is predominantly underlain by hard rock formations of the Precambrian Basement Complex, including granite gneiss and phyllite, where groundwater occurrence is restricted to secondary porosity zones such as weathered mantles, joints, fractures, and lineaments. These aquifers are inherently discontinuous, anisotropic, and spatially heterogeneous, resulting in highly variable well yields and limited storage capacity. One of the primary challenges in the area is the low storativity of aquifers, which leads to rapid depletion of groundwater under pumping conditions and poor sustenance during dry periods. This is further exacerbated by moderate to low transmissivity in several locations, as evidenced by pumping test results, indicating restricted groundwater movement and weak hydraulic connectivity, particularly in areas like Tundi and Churchu. Climatically, the region experiences monsoonal rainfall with high temporal variability and short-duration intense precipitation events, which result in significant surface runoff and limited infiltration. The undulating terrain, coupled with shallow soil cover and poor soil moisture retention capacity, further reduces effective groundwater recharge. In addition, the absence or inadequate maintenance of water conservation structures such as check dams, percolation tanks, and recharge pits limits the natural replenishment of aquifers. Anthropogenic pressures, including increasing dependence on groundwater for domestic and agricultural needs, unregulated abstraction, and lack of scientific well siting, have contributed to declining groundwater levels and reduced well performance in several parts of the study area. Tribal and rural communities in these regions often face acute seasonal water scarcity, particularly during pre-monsoon months, affecting drinking water availability and agricultural productivity.

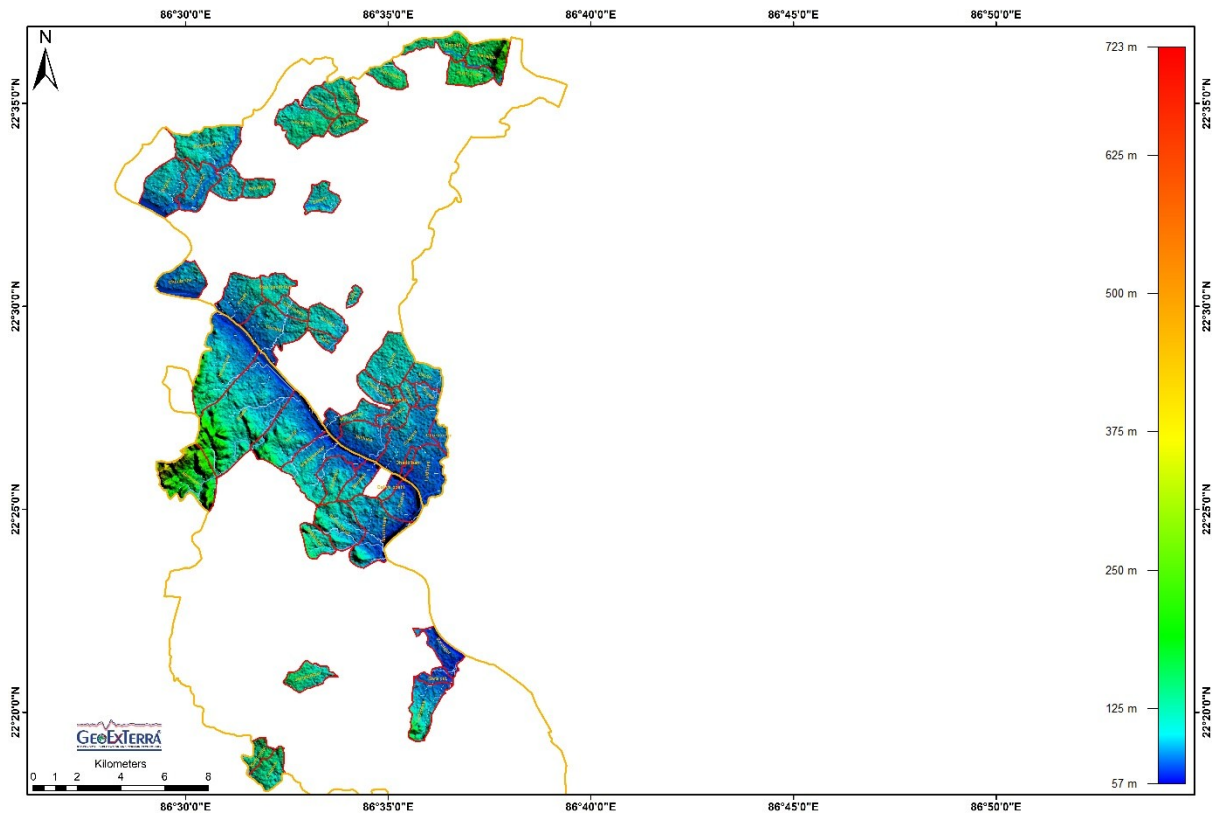
Another significant constraint is the limited availability of reliable subsurface data, which hampers accurate delineation of aquifer geometry and fracture systems. Conventional groundwater exploration methods, without integration of geophysical techniques, often fail to identify productive zones, leading to high failure rates of wells. Furthermore, the presence of localized structural controls, such as faults and fracture intersections, governs groundwater occurrence but remains inadequately mapped in many areas. The combination of geological complexity, climatic variability, inadequate recharge, and increasing water demand creates a fragile hydrogeological regime that is highly vulnerable to climate change impacts. Therefore, the project area faces critical challenges in achieving sustainable groundwater development, necessitating an integrated hydrogeophysical approach for precise aquifer mapping, identification of recharge zones, and formulation of site-specific water management strategies to overcome these constraints and ensure long-term water security.

## 5.2 Location and Physiography

The project area is geographically located in the eastern part of India, encompassing multiple administrative blocks across Jharkhand State. The study region covers an extensive area of approximately 37,535.6 hectares, distributed across 161 villages, including 22 villages in Palojori (Deoghar), 22 in Tundi (Dhanbad), 19 in Jama (Dumka), 18 in Gurabanda and 35 in Dalbhumgarh (East Singhbhum), 20 in Churchu and 4 in Dadi (Hazaribagh), and 21 in Murhu (Khunti). These villages form a spatially discontinuous yet hydrogeologically interconnected cluster of predominantly rural settlements, where livelihoods are largely dependent on agriculture and groundwater resources for domestic and irrigation purposes. Geographically, the study area extends between 85°11'10.839" to 87°13'26.497" East longitudes and 22°16'28.003" to 24°21'8.683" North latitudes, placing it within the central-eastern sector of the Indian peninsular shield (Fig. 1). The spatial distribution of villages across multiple districts reflects a diverse terrain setting with localized variations in topography, drainage, and land use, necessitating a block-wise and site-specific hydrogeological assessment approach. Physiographically, the region is characterized by a predominantly plain to gently undulating topography, typical of hard rock terrains of the Chotanagpur Plateau. The elevation across the project area varies from approximately 57 m to 723 m above mean sea level, with relatively lower elevations occurring along river valleys, seasonal streams, and drainage corridors, while higher elevations correspond to residual uplands, dissected plateaus, and isolated hillocks (Figs. 2 to 6). The gentle slopes and subdued relief conditions facilitate moderate surface runoff and appreciable infiltration, which are critical factors governing groundwater recharge in the area (Figs 7 to 11). The drainage system is primarily influenced by major river basins such as the Damodar and Subarnarekha river systems, along with their tributaries, forming a dendritic to sub-dendritic drainage pattern controlled by lithology and structural features. Seasonal streams and nalas play a significant role in local recharge, especially during the monsoon period, although their ephemeral nature limits sustained recharge. The physiographic setting, combined with the underlying fractured crystalline geology, exerts a strong control on groundwater occurrence, movement, and storage. Variations in slope, elevation, and drainage density across different blocks result in differential recharge potential, making certain zones more favorable for groundwater accumulation than others. Overall, the location and physiographic characteristics of the study area highlight the importance of integrating terrain analysis with hydrogeophysical investigations to accurately delineate aquifer systems and identify suitable zones for sustainable groundwater development.



**Fig. 1 Location Map of the Project Area.**



**Fig. 2 Physiological Map of the Project Villages of East Singhbhum.**

**Table 1. List of Districts, Blocks and Project Villages of Jharkhand.**

Sl. No.	District	Block	Village	Area (ha)
1	Deoghar	Palojori	Ghorparha	135.7
2			Phuljori	41.2
3			Nawadih Nunurai	114
4			Nand Kura	63.6

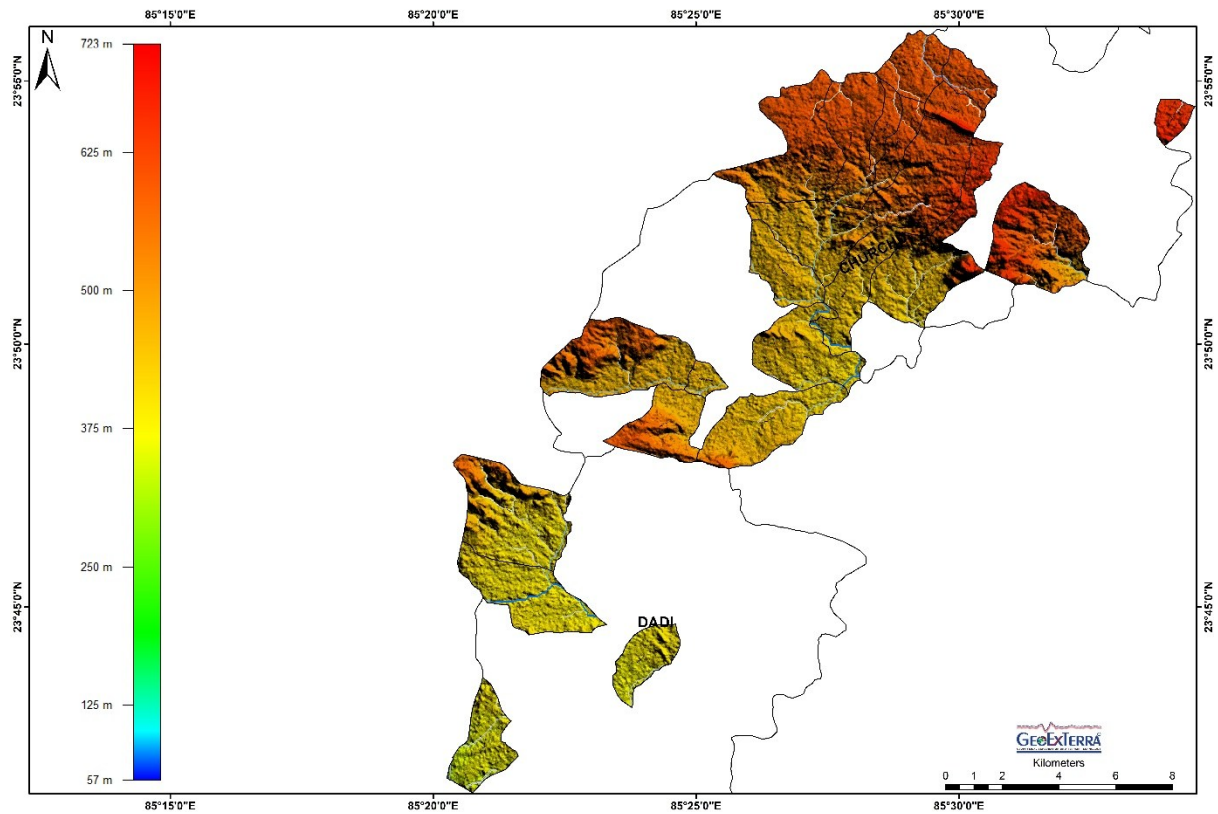
5			Lusio	24.4
6			Belmi	83.2
7			Kolgi	159.7
8			Baghmara Harladangal	174
9			Bedganwa Nawadih	106.3
10			Mohanpur	79.5
11			Damadih	68.4
12			Basmata	81.5
13			Tengdhoya	97.3
14			Bedia	205.7
15			Khairwa	130.6
16			Sirsia	160.8
17			Sonatanr	213.5
18			Kanki	271.5
19			Simla	80.6
20			Phuljori	59.7
21			Chhaglajor	279.6
22			Mashanjor	235
23	Dhanbad	Tundi	Nayabahal	15.1
24			Kolhar	245.2
25			Alkushia	26.4
26			Karmatanr	155.6
27			Bhuski	100.3
28			Dalugura	149.9
29			Karampura	90.9
30			Madhopur	124.4
31			Bishunpur	154.1
32			Nawatanr	42.1
33			Chakamanpur	87.7
34			Jamkol	122.9
35			Jhinaki	135.3
36			Murhara	43.9
37			Kadwara	77.4
38			Chainpur	96.8
39			Chinapahari	118.9
40			Patrobad	40.8
41			Baghmara	96.9
42			Naro	128.6
43			Jatakhati	298.5
44			Chakghaskari	7.7
45	Dumka	Jama	Asanbani	127
46			Amgachhi	104.6
47			Dandodumria	102.5
48			Gaibathan	206.8
49			Bhotokauria	310.5
50			Chundoba	79.7
51			Sampur	133.7
52			Pachkathia	140.6
53			Birajpur	150.3
54			Kalipurranga	123.6
55			Chatra	162
56			Madhuban	313.5
57			Baramasia	225.9
58			Jarjokha	187.2
59			Khapchua	113.3
60			Upar Balram	142.4

61			Bigai Bandh	203.1
62			Lakhanpur	113.7
63			Kulhoria	169.3
64	East Singhbhum	Gurabanda	Khejurdari	146.6
65			Dumurbandi	311.9
66			Asanbani	206.3
67			Murakati	148.8
68			Baliya Poshi	53.3
69			Reruya	211.3
70			Murathkura	447
71			Kananluka	677.3
72			Bhalki	1133.2
73			Sunrgi	537.9
74			Madhbhandar	420.1
75			Namulepa	453.4
76			Jayghantpur	166
77			Kumrashol	98.8
78			Laupara	166.6
79			Paraspur	168.5
80			Bera pal	74
81			Larkabasa	267.8
82		Dalbhumgarh	Swargachhinra	147.5
83			Uparsholl	286.6
84			Raghunathdi	404.7
85			Chirugora	148.5
86			Bagula	344.6
87			Pentuldanga	247.9
88			Bhaduya	101.7
89			Ulda	37.8
90			Derang	391.1
91			Kanas	300
92			Chhabisha	250
93			Bihinda	278.1
94			Dhadkibani	41.3
95			Laldhuya	298.2
96			Noyadi	88.4
97			Ekghariya	24.4
98			Maholishol	189.1
99			Duliya Para	107.5
100			Kokpara	381.9
101			Ghoratoriya	66
102			Jamuya	62
103	Ektal		65.6	
104	Jorshol		171.8	
105	Choirra		326.9	
106	Chatro		129.3	
107	Kharbanda		129	
108	Shirishbani		87.4	
109	Swargachhinra		137.5	
110	Sarbila	142.4		
111	Karuakata	135		
112	Dudh pushi	163.6		
113	Haildajuri	153.6		
114	Jar pojara	103.1		
115	Babaida	174.8		
116		Basajhor	231.1	

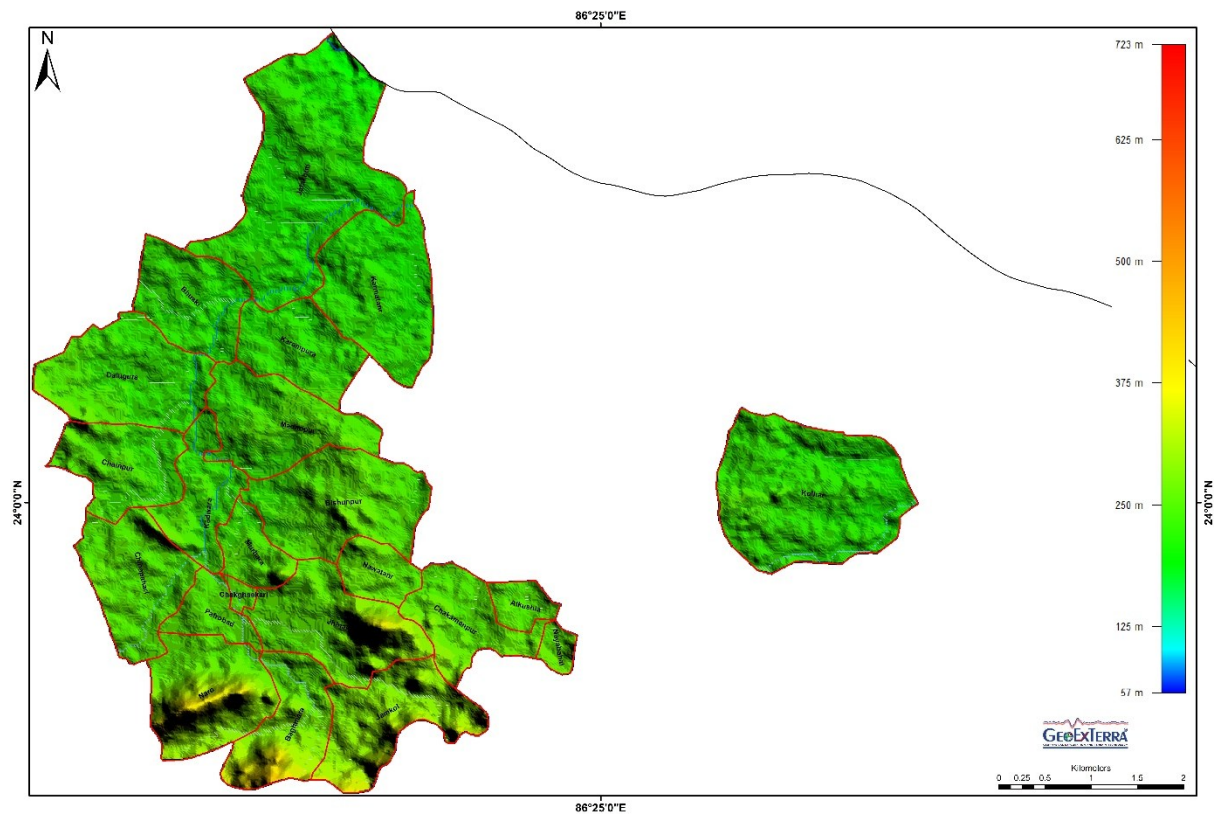
117	Hazaribagh	Churchu	Lara	354.7		
118			Tasnalo	191.4		
119			Rahamdaga	131.6		
120			Chichi kalan	904.6		
121			Chichikhurd	619.4		
122			Belgara	153.2		
123			Jordag	223.8		
124			Dumar	206.9		
125			Bodra	239.2		
126			Bali	791.4		
127			Kargi	875		
128			Kajri	682.7		
129			Bahera	525.9		
130			Chanaro	647.4		
131			Charhi (CT)	387.4		
132			Harhad	476.9		
133			Karu Khap	103		
134			Hendegara	943.3		
135			Indra	639.5		
136			Daso Khap	728.4		
137			Dadi	Kura	959.2	
138				Rikba	696.5	
139				Kanki	325.1	
140			Khunti	Murhu	Kurkuta	429.2
141					Kundibartoli	208.3
142					Chendagutu	173.1
143					Damriay	133
144					Simbua	97.9
145					Dekla	316
146					Murud	201.1
147					Siyankel	267.5
148					Bamarda	156.6
149					Gumpuru	304.4
150					Hesel	179.2
151					Sardula	87.3
152					Mahil	471
153					Perka	165.8
154	Hansa	431				
155	Gaigaon	538				
156	Katingkel	131.7				
157	Bhursa	79.6				
158	Saprum	127.7				
159	Saedba	312.2				
160	Mailburu	154				
161		Digri	392.4			
<b>Total Area (ha)</b>			<b>37535.6</b>			

### 5.3 Rainfall and Climate

The climate of the project area is characterized by a tropical monsoonal regime with distinct seasonal variability, exerting a dominant control on groundwater recharge, surface runoff, and overall hydrological balance. Analysis of the provided daily rainfall dataset indicates that precipitation is highly episodic and concentrated within a limited monsoon window, with negligible or zero rainfall observed during a significant portion of the year (January to Mid



**Fig. 3 Physiographical Map of the Project Villages of Hazaribagh.**



**Fig. 4 Physiographical Map of the Project Villages of Dhanbad.**

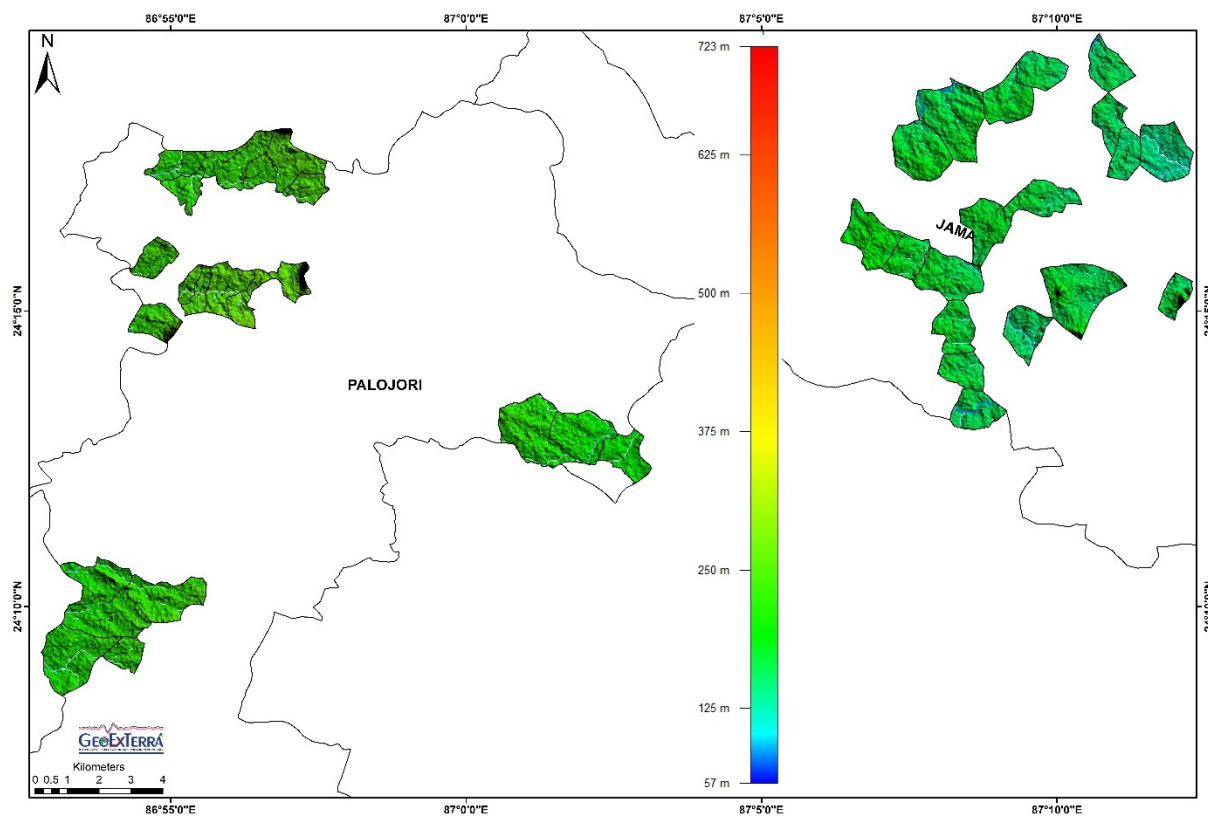


Fig. 5 Physiographical Map of the Project Villages of Deoghar and Dumka.

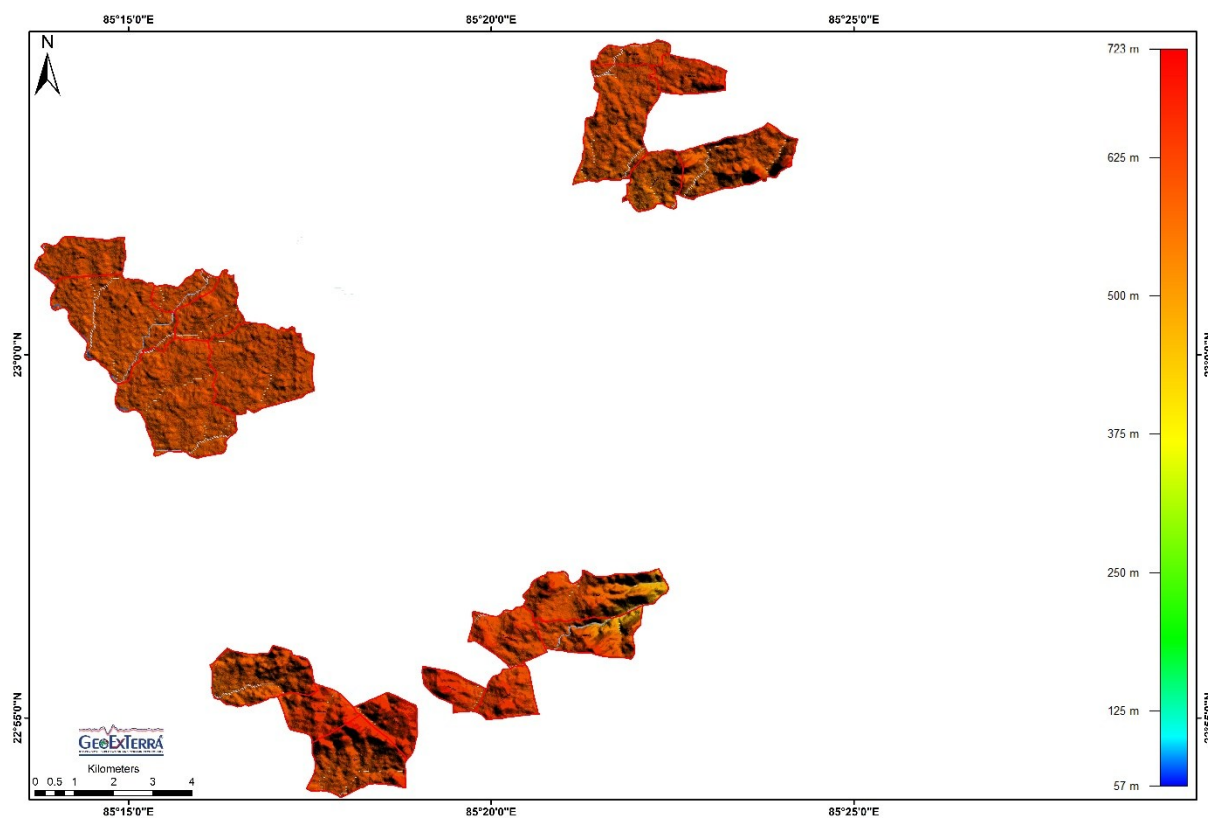


Fig. 6 Physiographical Map of the Project Villages of Khunti.

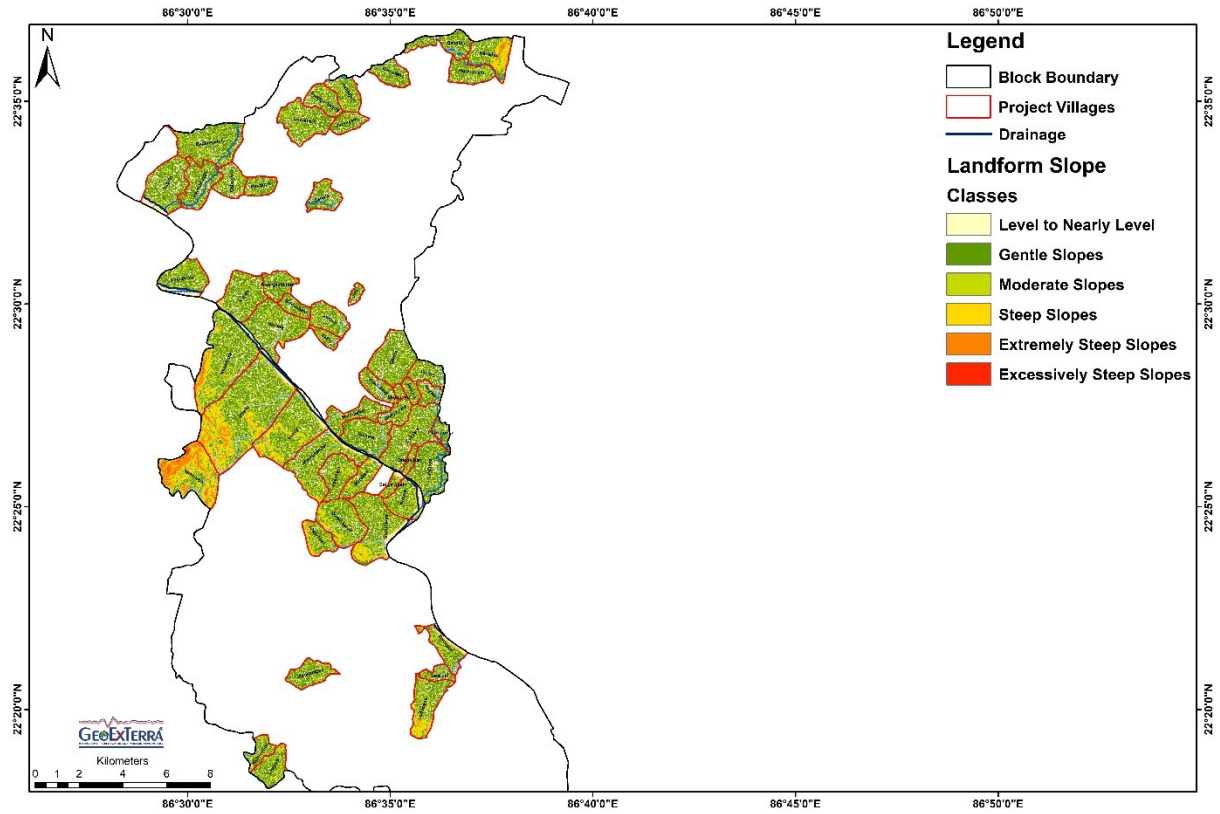


Fig. 7 Slope Map of the Project Villages of East Singhbhum.

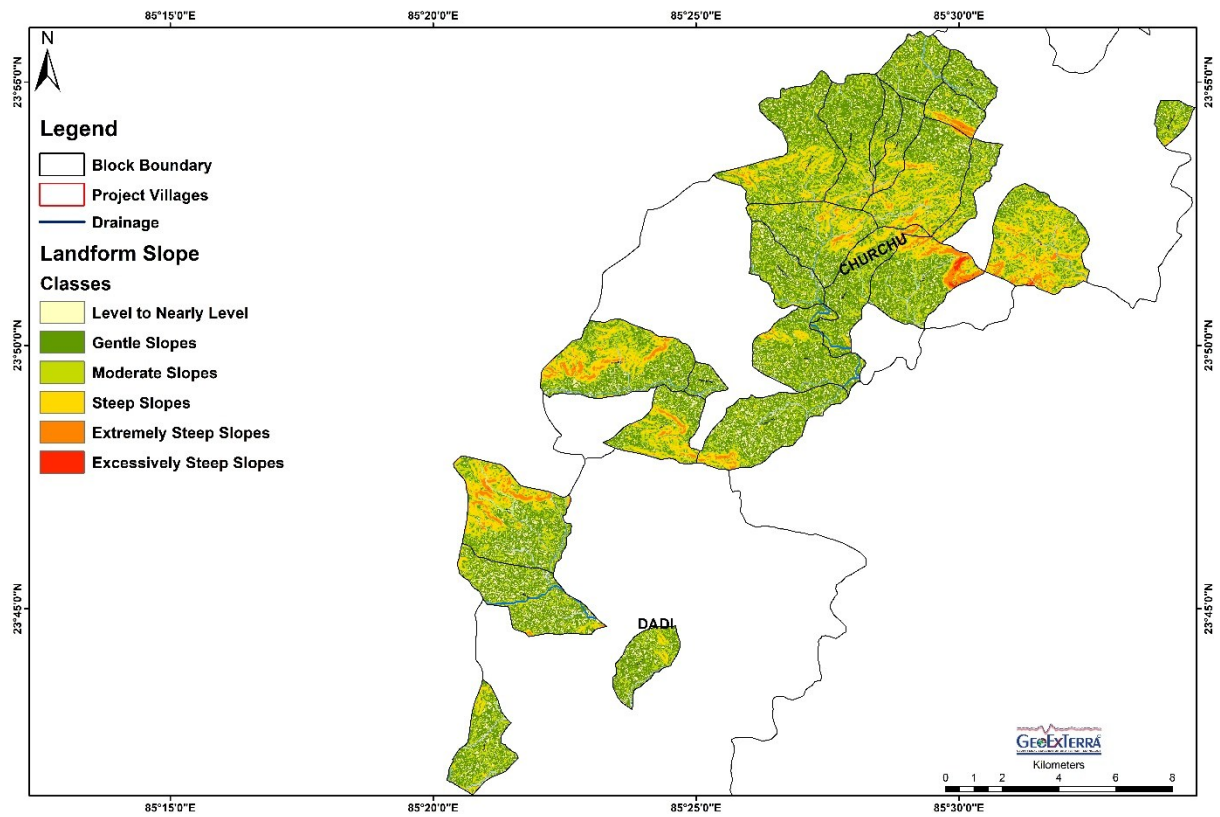


Fig. 8 Slope Map of the Project Villages of Hazaribagh.

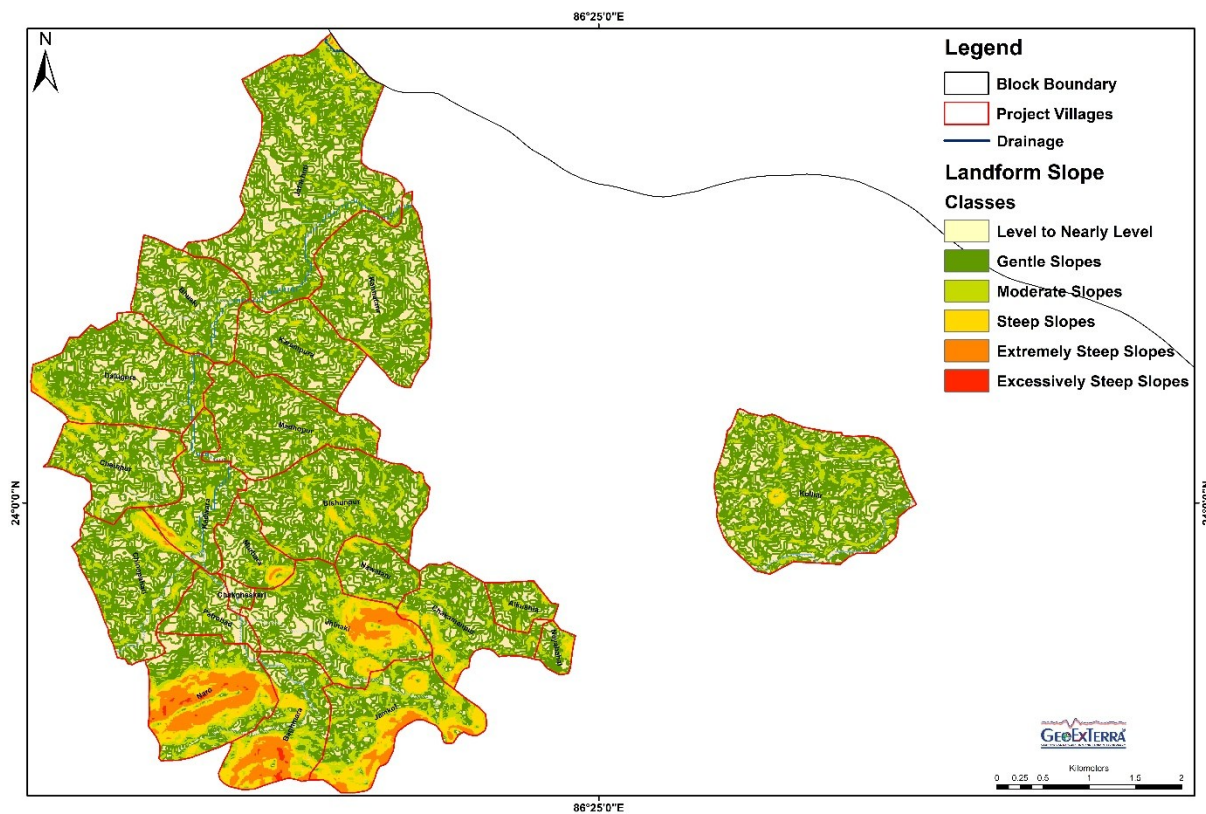


Fig. 9 Slope Map of the Project Villages of Dhanbad.

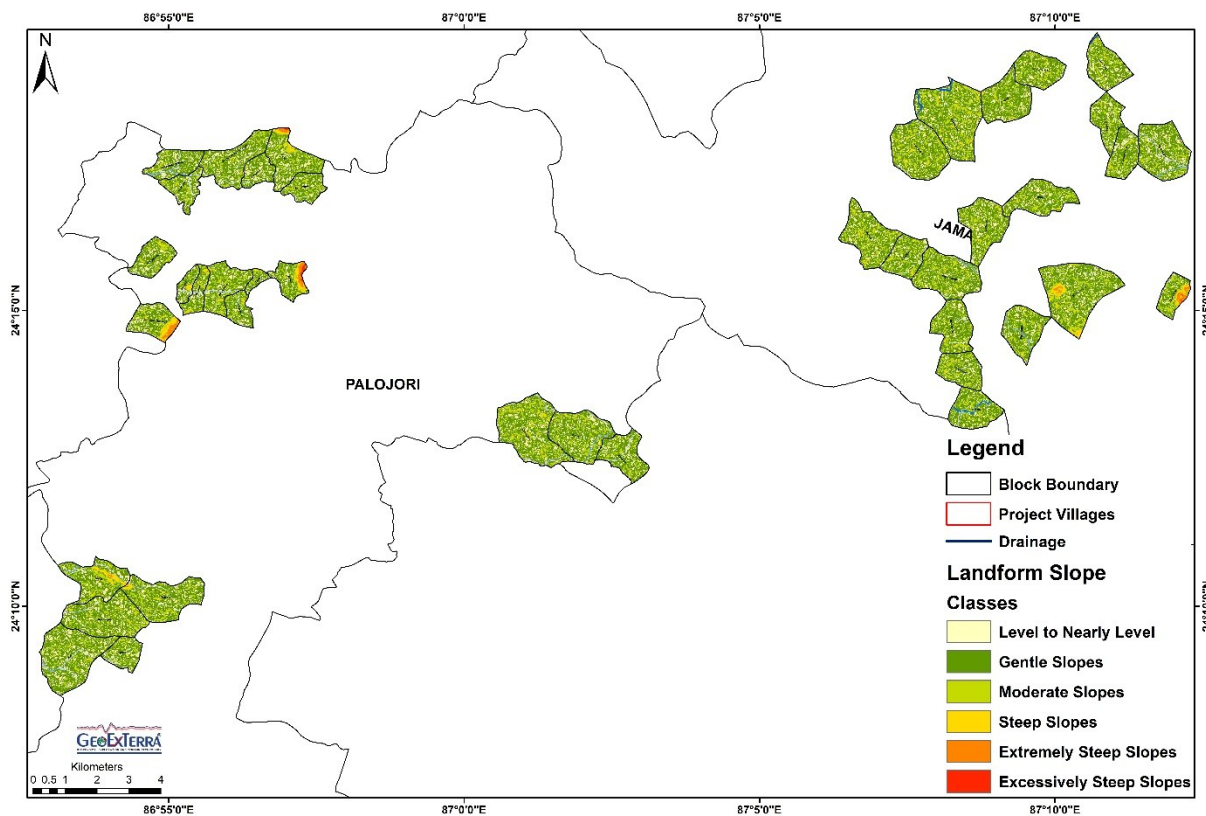
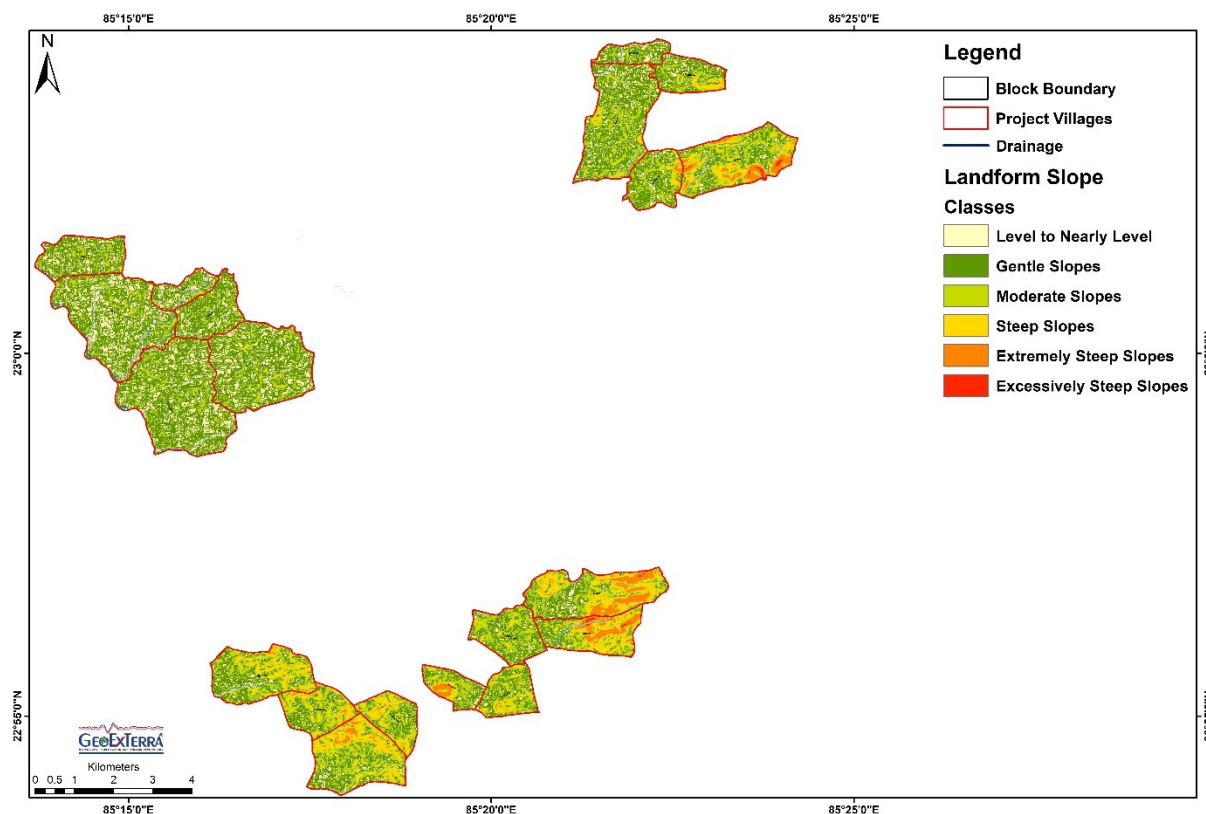


Fig. 10 Slope Map of the Project Villages of Deoghar and Dumka.



**Fig. 11 Slope Map of the Project Villages of Khunti.**

February and October to December), clearly reflecting prolonged dry periods typical of peninsular hard rock terrains. The onset of rainfall begins around mid February with scattered pre-monsoon showers, followed by a gradual intensification culminating in peak monsoon activity between Day Mid June to November, during which multiple high-intensity rainfall events are recorded across all blocks. Notably, extreme rainfall events exceeding 100 mm/day are observed, particularly in Murhu (~155.8 mm), Gurabanda–Dalbhumgarh (~144.5 mm), and Churchu–Dadi (~77 mm), indicating the occurrence of short-duration, high-intensity storms that contribute significantly to surface runoff rather than effective infiltration. Spatial analysis from the rainfall maps further reveals that the annual rainfall distribution varies from approximately 1,388 mm to over 2,198 mm, with higher rainfall zones concentrated in the southern and eastern parts (notably Murhu and parts of East Singhbhum), while relatively moderate rainfall (1,400–1,800 mm) dominates the central and northern blocks such as Churchu, Dadi, and Palojori (Figs. 12 to 16). The drainage network, as depicted in the maps, shows a well-developed dendritic to sub-dendritic pattern, which, in conjunction with moderate slopes, facilitates rapid runoff during intense rainfall events, thereby limiting infiltration opportunities in areas with low soil thickness and exposed hard rock. From a hydrogeological perspective, despite the seemingly adequate annual rainfall, the effective groundwater recharge remains constrained due to the combined influence of high rainfall intensity, short duration of precipitation, and the fractured crystalline aquifer system with limited primary porosity. The temporal distribution of rainfall indicates that the majority of recharge potential is confined to a narrow monsoon period, beyond which evapotranspiration losses and lack of sustained precipitation lead to declining groundwater levels. Additionally, the variability in rainfall across blocks introduces spatial heterogeneity in recharge conditions, with high rainfall zones not necessarily translating

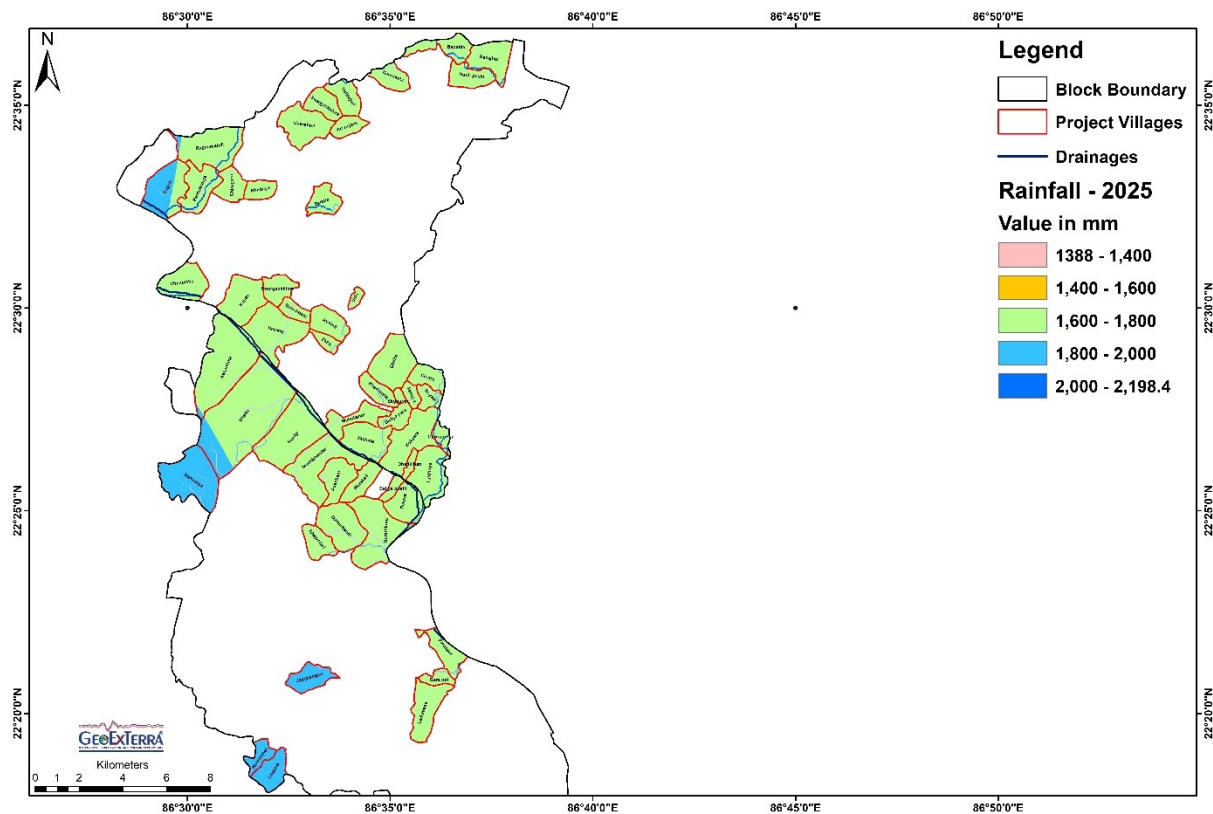


Fig. 12 Distribution of Rainfall During 2025 in the Project Villages of East Singhbhum.

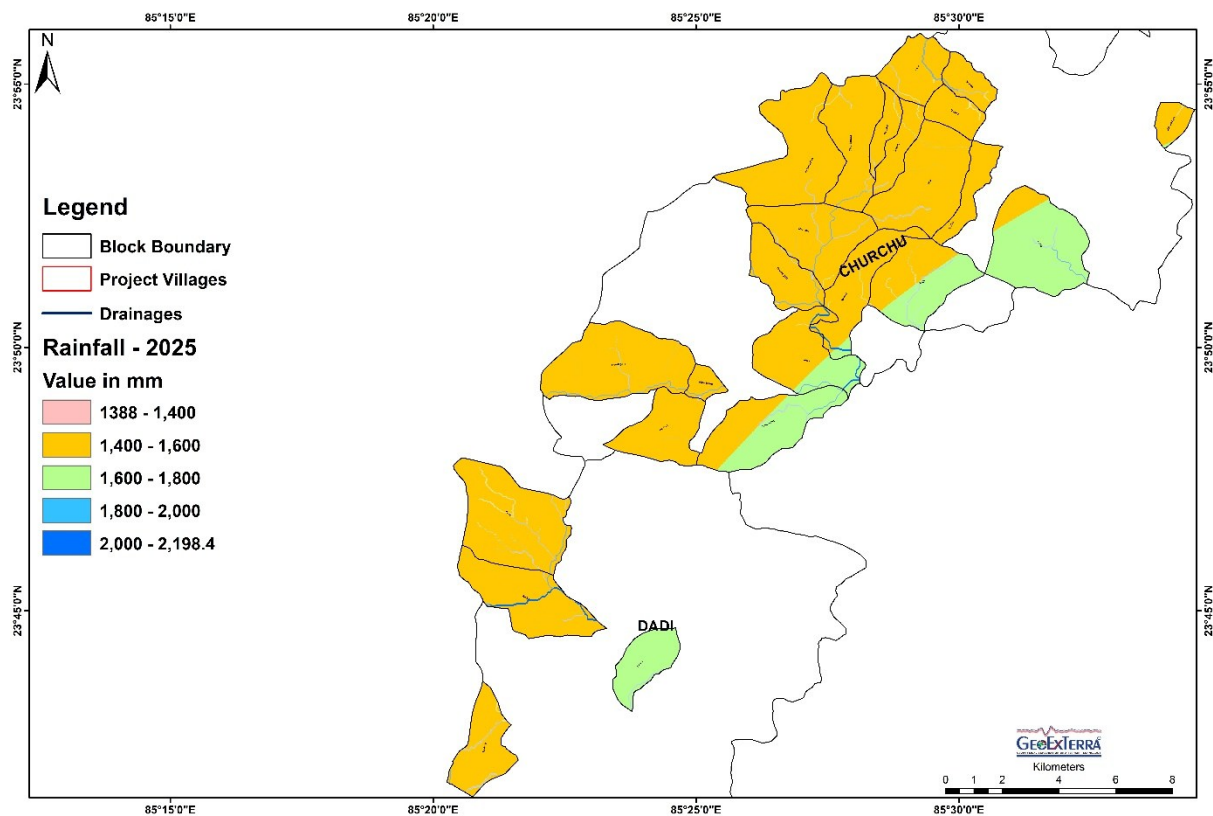
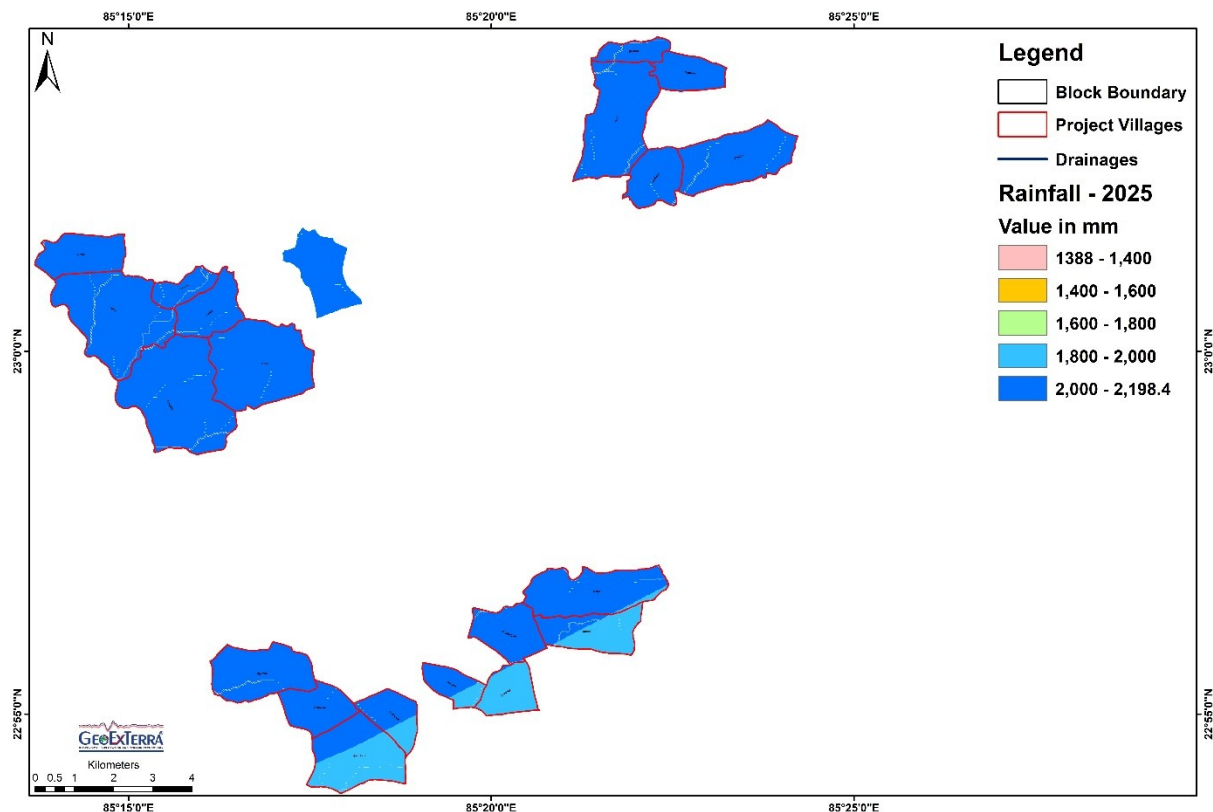


Fig. 13 Distribution of Rainfall During 2025 in the Project Villages of Hazaribagh.





**Fig. 16 Distribution of Rainfall During 2025 in the Project Villages of Khunti.**

into high groundwater availability due to runoff dominance and structural controls of the aquifer. The climate is further characterized by hot summers (March–June), a humid monsoon season (June–September), and a mild to cool winter (October–February), with temperature extremes enhancing evapotranspiration and reducing effective recharge. Overall, the rainfall and climatic regime of the study area underscores a paradox of moderate to high annual rainfall but limited groundwater sustainability, emphasizing the need for scientifically planned water conservation measures such as recharge structures, drainage line treatment, and fracture zone targeting to enhance infiltration and ensure climate-resilient water security across the region.

#### 5.4 Geomorphology

The geomorphological framework of the project area is predominantly governed by denudational and structural landform assemblages typical of the Precambrian crystalline terrain of the Chotanagpur Plateau, as interpreted from the attached thematic maps. The study area is largely characterized by the extensive development of Denudational Origin Pediment–Pediplain Complex, which forms the dominant geomorphic unit across most of the villages, indicating prolonged weathering, erosion, and planation processes that have reduced the terrain into gently sloping surfaces with thin to moderate soil cover overlying weathered and fractured bedrock. These pediplain surfaces are interspersed with Denudational Origin Moderately Dissected Hills and Valleys, particularly prominent in parts of Churchu–Dadi, Murhu, and localized pockets in Gurabanda and Dalbhumgarh, where differential erosion and structural control have resulted in undulating topography with residual hills, shallow valleys,

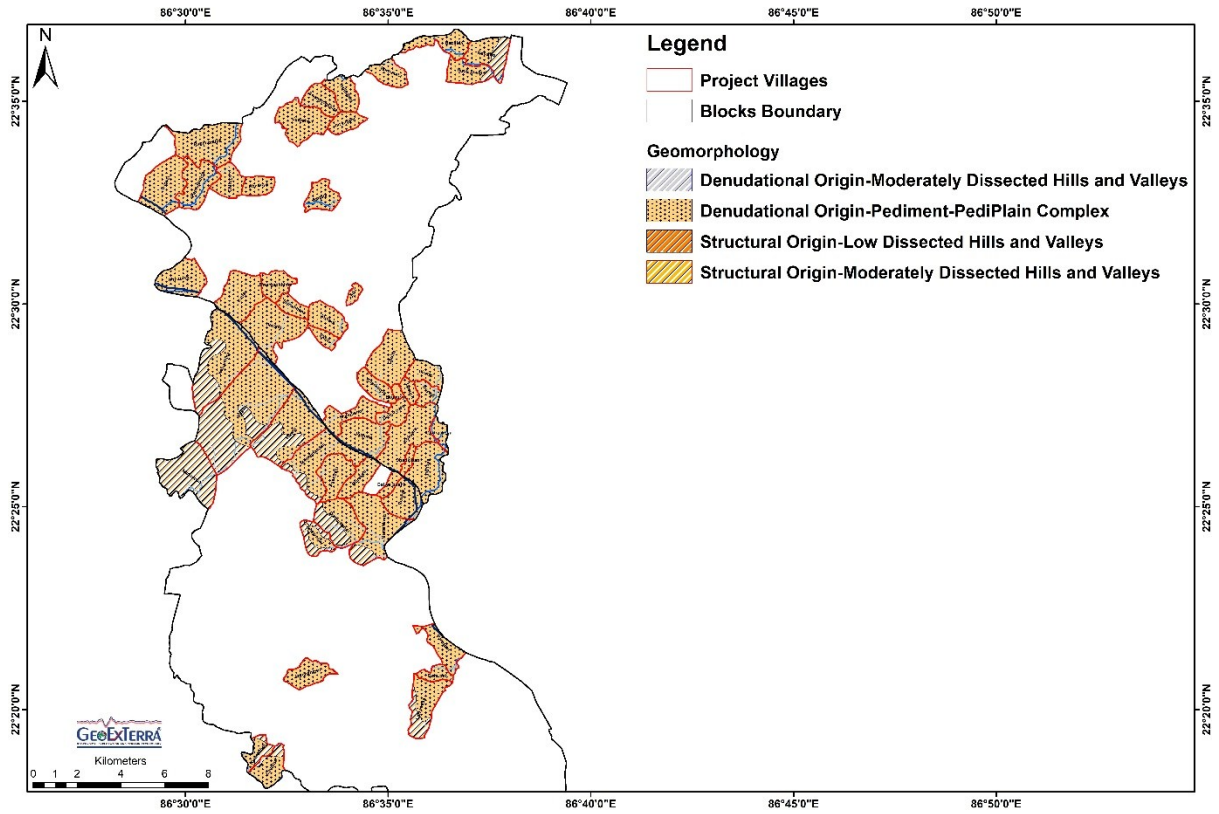


Fig. 17 Geomorphology of the Project Villages of East Singhbhum.

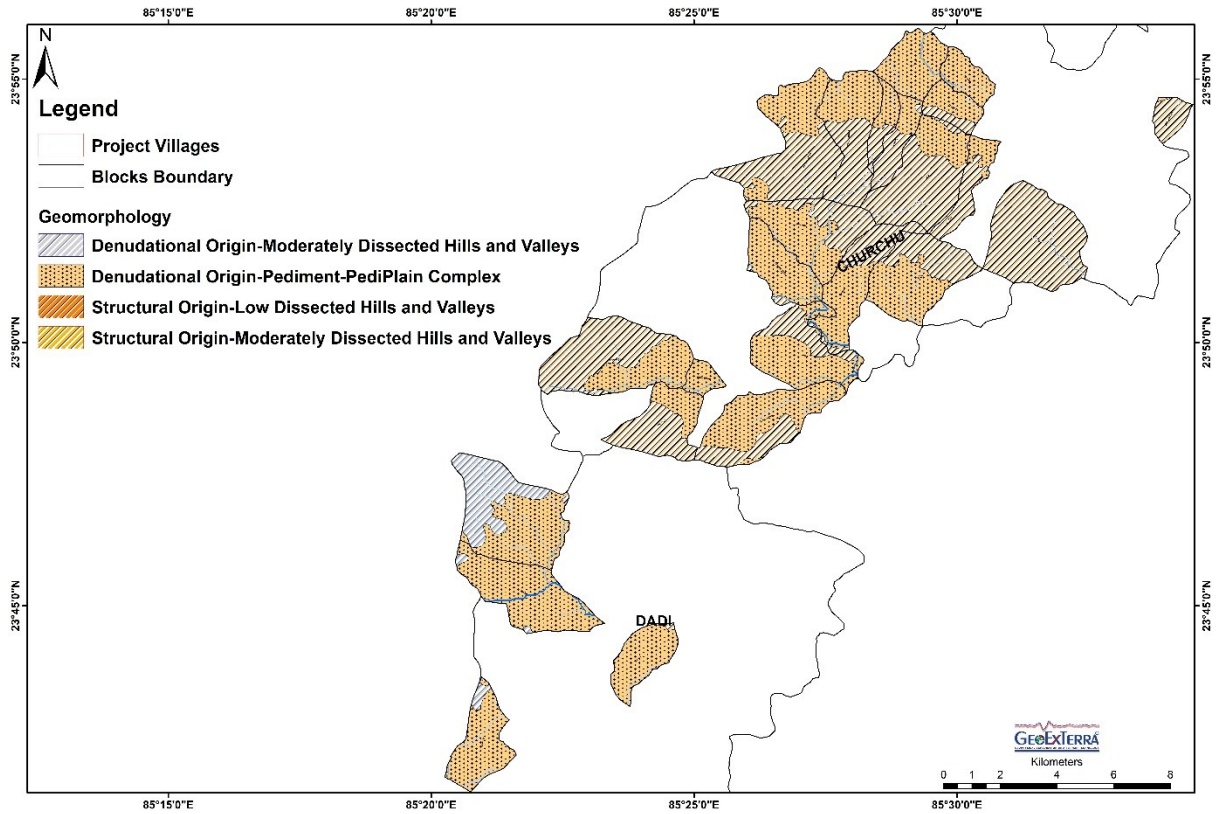


Fig. 18 Geomorphology of the Project Villages of Hazaribagh.

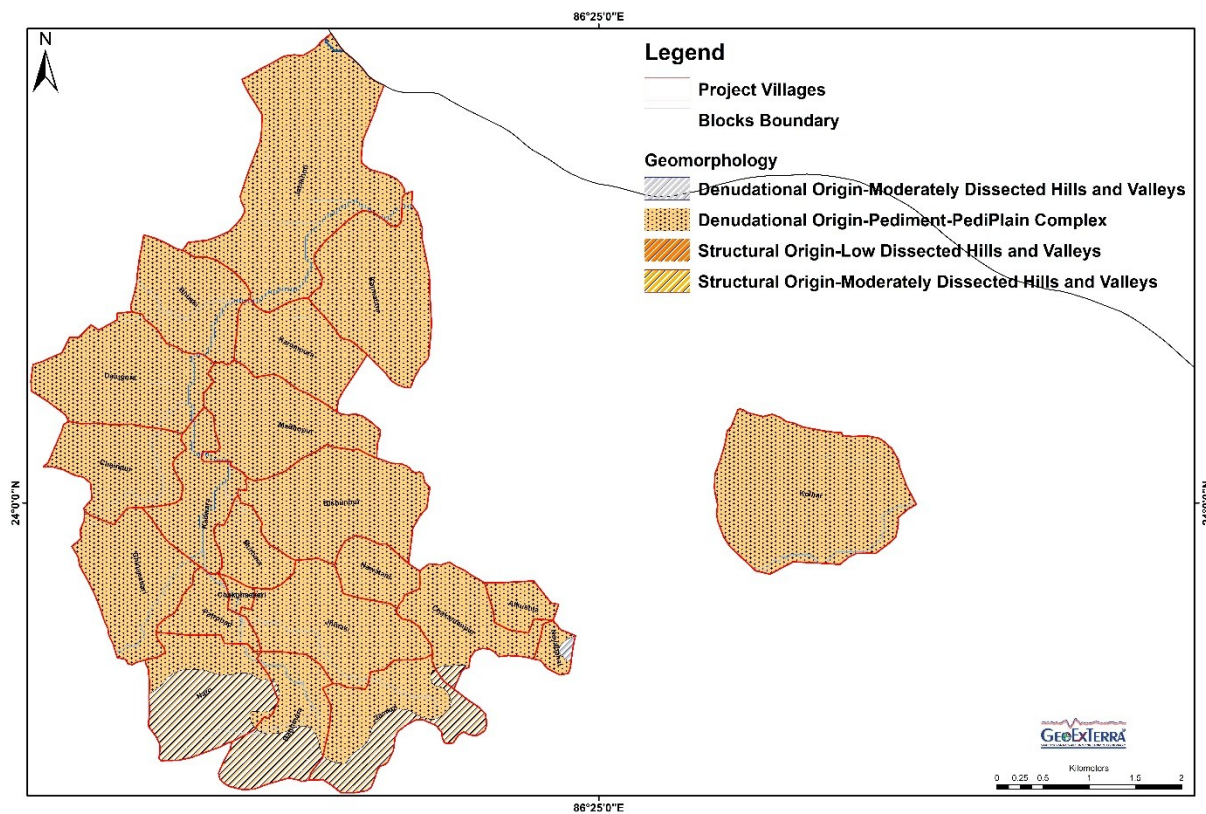


Fig. 19 Geomorphology of the Project Villages of Dhanbad.

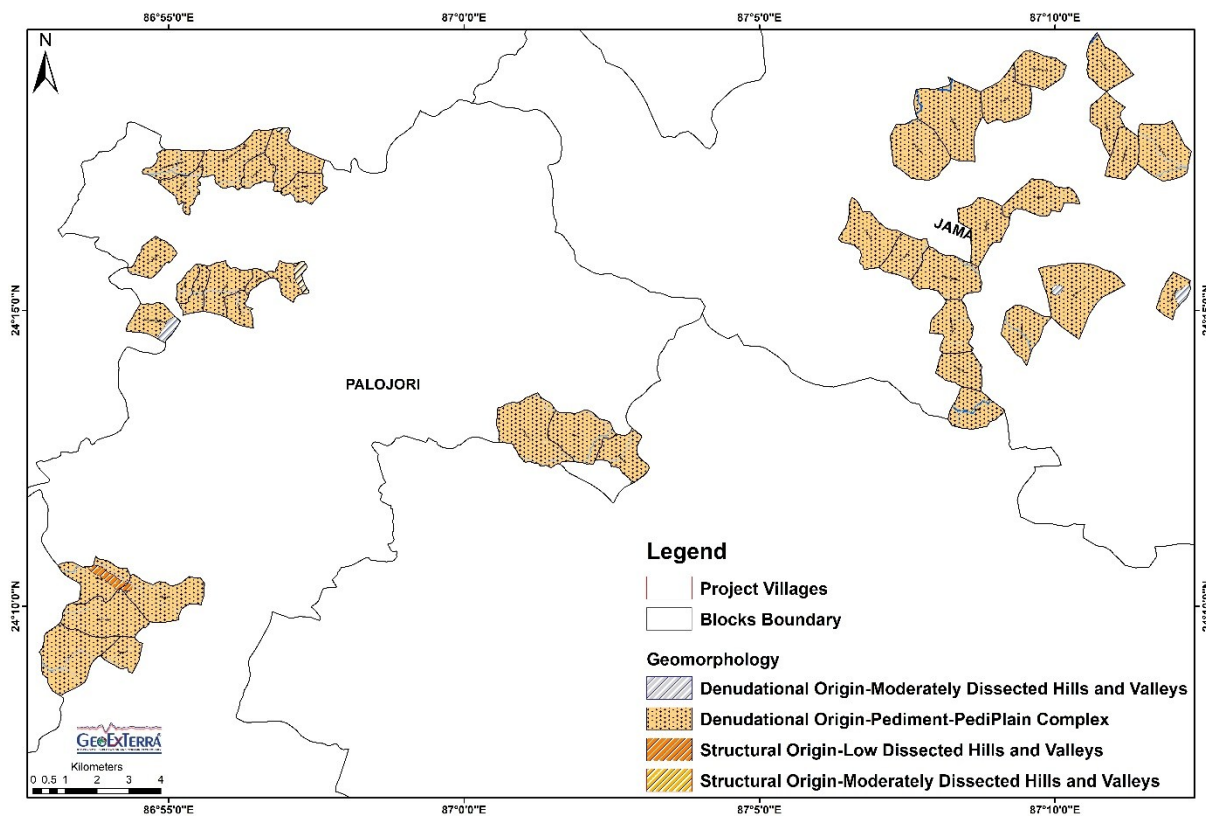
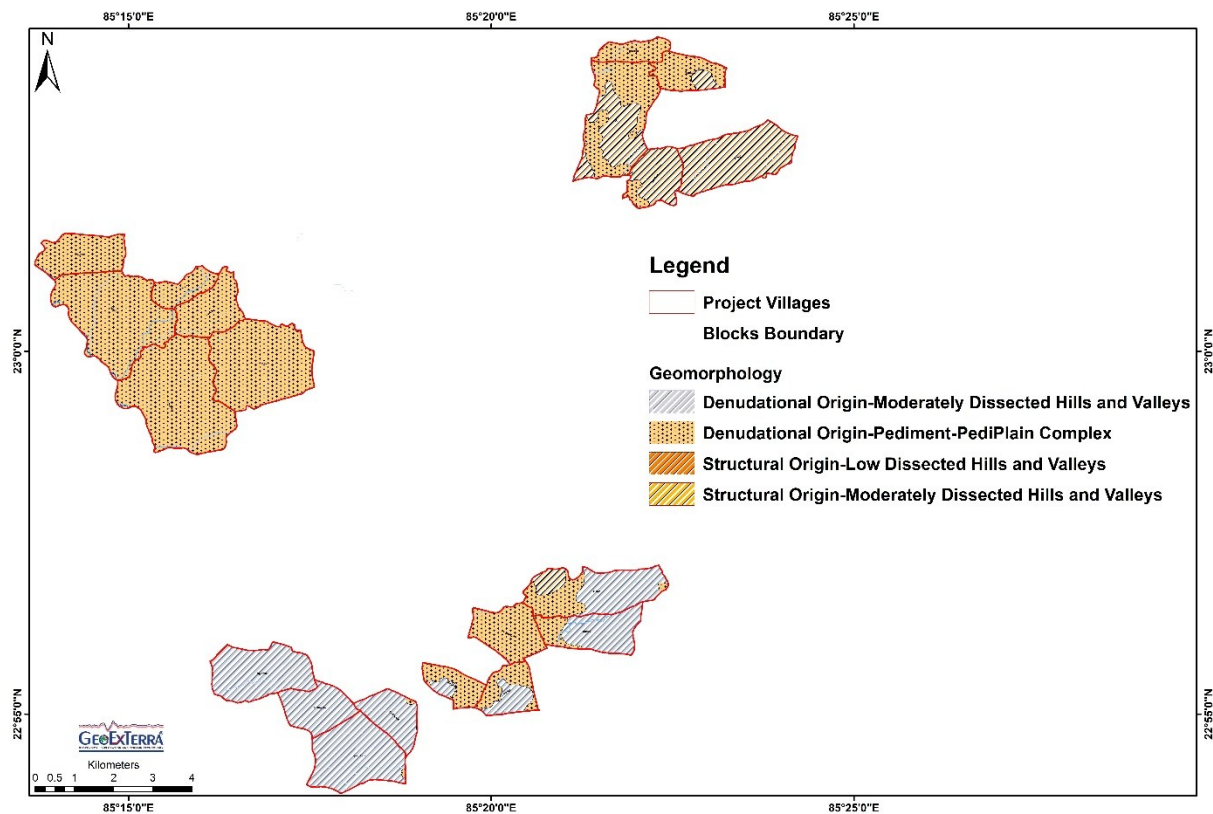


Fig. 20 Geomorphology of the Project Villages of Deoghar and Dumka.



**Fig. 21 Geomorphology of the Project Villages of Khunti.**

and moderate relief (Figs. 17 to 21). Additionally, Structural Origin Low to Moderately Dissected Hills and Valleys are observed in select zones, especially along lineament-controlled regions and lithological contacts, reflecting the influence of tectonic features, jointing, and foliation patterns in shaping the landscape. These structural hills often exhibit higher slopes and reduced soil thickness, thereby limiting infiltration and enhancing surface runoff. Hydrogeomorphologically, the pediment–pediplain complexes represent moderately favorable zones for groundwater occurrence, as they are associated with weathered mantle development and interconnected fracture systems that facilitate storage and movement of groundwater, although the overall yield remains controlled by fracture density and depth of weathering. In contrast, the moderately dissected denudational and structural hills act largely as runoff zones with limited groundwater potential, except in valley fills and fracture intersections where localized recharge and storage may occur. The transition zones between pediplains and valley systems are particularly significant, as they function as recharge interfaces, where runoff from elevated terrains accumulates and infiltrates into the subsurface through weathered and fractured horizons. The drainage pattern, closely aligned with geomorphic features, further reinforces this relationship, with streams preferentially occupying structurally weak zones and valley depressions. Overall, the geomorphology of the area reflects a complex interplay of lithology, structure, and long-term denudational processes, resulting in a heterogeneous aquifer system where groundwater occurrence is highly localized and controlled by secondary porosity. The predominance of pediplain complexes suggests moderate recharge potential under favorable conditions, whereas the dissected hill regions impose constraints on groundwater development. Therefore, effective groundwater resource management in the region requires geomorphology-driven planning, focusing on pediplain zones for well development, valley segments for

recharge interventions, and structurally controlled zones for targeted exploration, thereby ensuring sustainable and climate-resilient water resource utilization.

### 5.5 Soils

The soil characteristics across the project area exhibit a distinct spatial variability in both soil texture and topsoil thickness, which are closely interlinked with geomorphology, drainage patterns, and underlying lithology, as interpreted from the provided thematic maps. The soil texture is dominantly categorized into fine-textured soils (loamy clay, clay, sandy clay, silty clay, and sandy clay mixtures), which extensively cover the majority of the project villages, particularly in Tundi, Jama, Palojori, and large parts of Gurabanda–Dalbhumgarh and Murhu blocks. These fine-textured soils are typically characterized by low permeability and high water retention capacity, resulting in reduced infiltration rates but enhanced moisture availability for agriculture. In contrast, coarse-textured soils (loamy sand and sand) are observed primarily along drainage courses and valley fills, notably in Churchu and parts of Dadi, where fluvial processes have deposited relatively permeable materials that facilitate higher infiltration and groundwater recharge. Additionally, rocky and non-soil surfaces are identified in localized patches, particularly in structurally controlled upland and hill regions, indicating shallow or absent soil cover and limited potential for soil moisture storage or recharge. The analysis of topsoil depth reveals that the majority of the area is characterized by moderately shallow to moderate soil thickness ranging between 0.6–0.75 m and 0.75–1.0 m, which corresponds well with the pediplain and gently undulating terrains where weathering has produced a relatively consistent soil

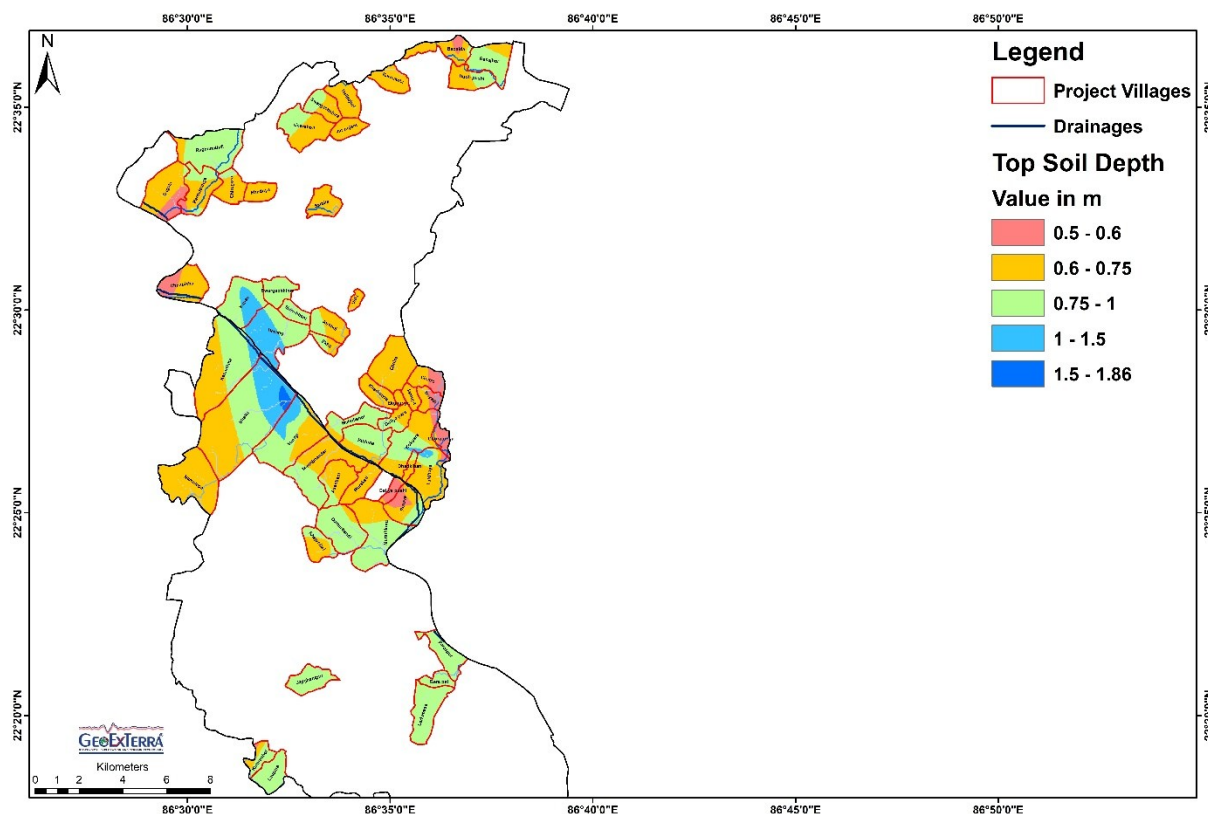


Fig. 22 Soil Thickness Map of the Project Villages of East Singhbhum.

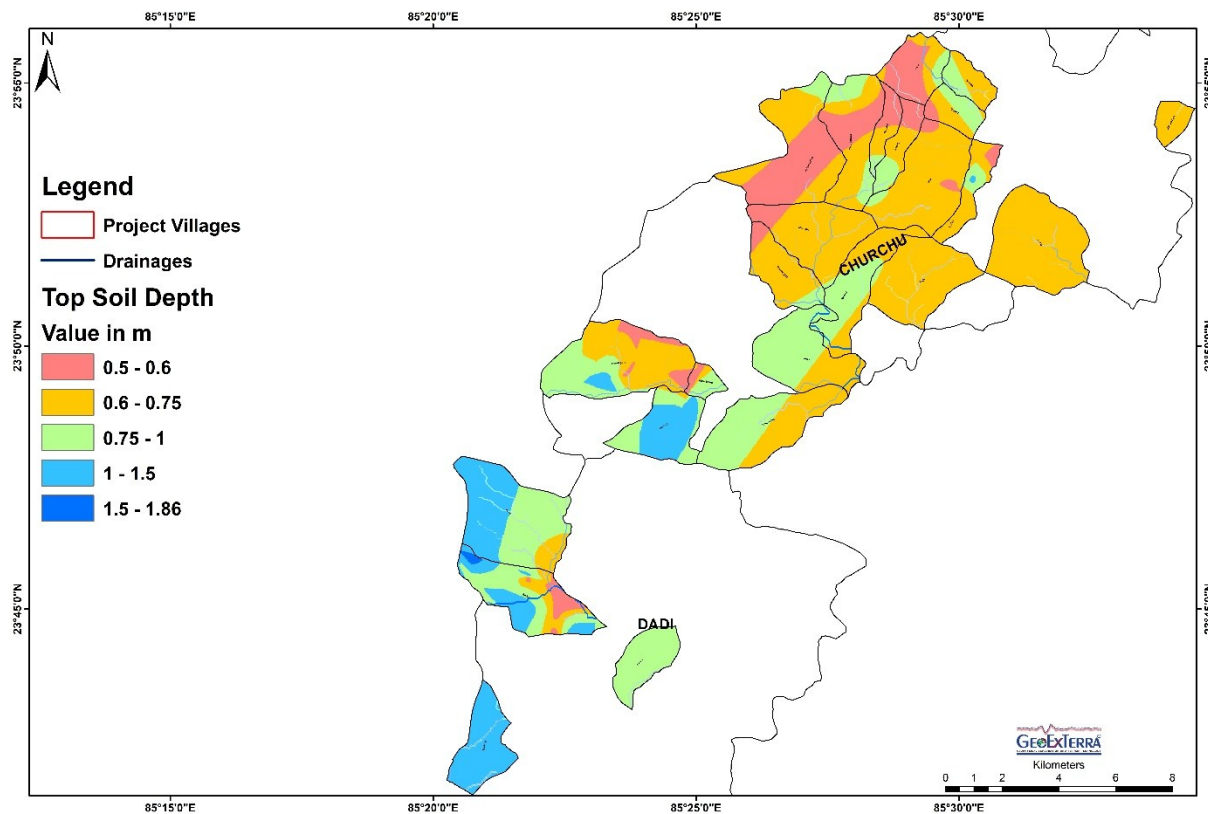


Fig. 23 Soil Thickness Map of the Project Villages of Hazaribagh.

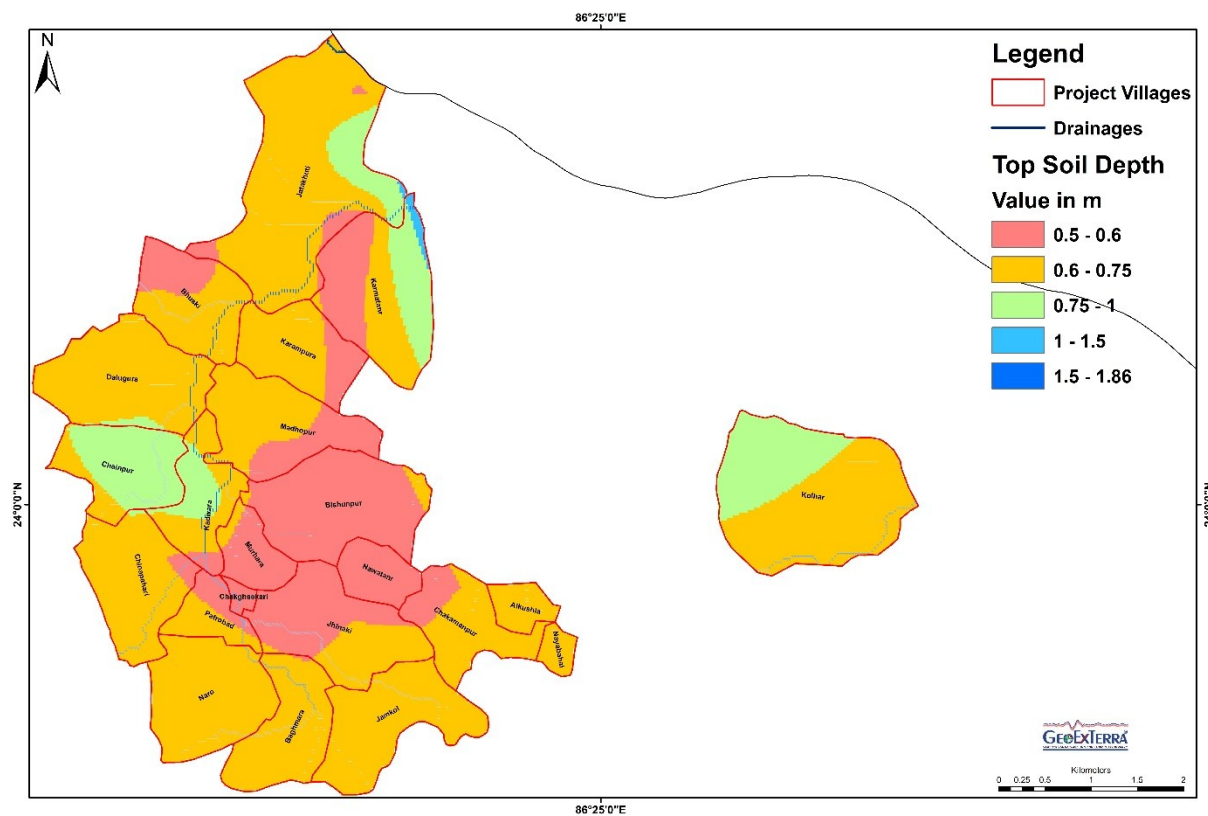


Fig. 24 Soil Thickness Map of the Project Villages of Dhanbad.

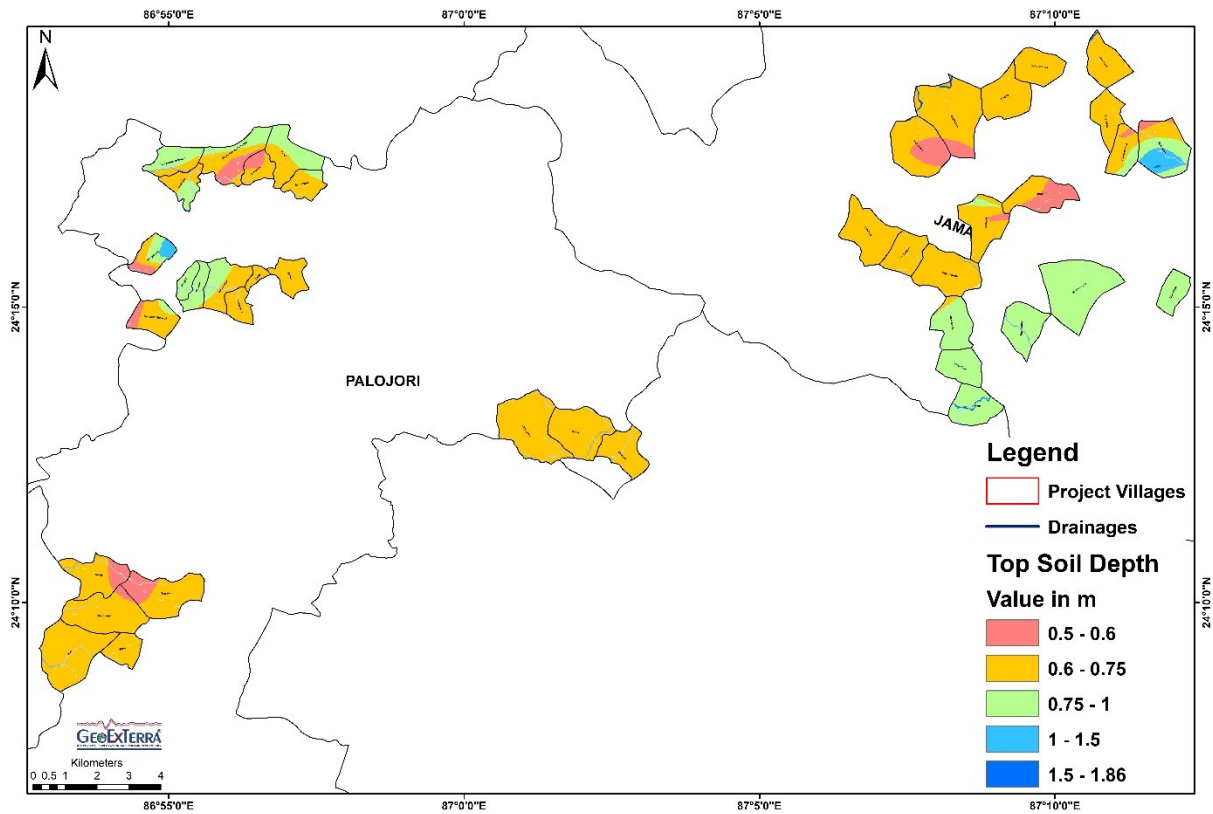


Fig. 25 Soil Thickness Map of the Project Villages of Deoghar and Dumka.

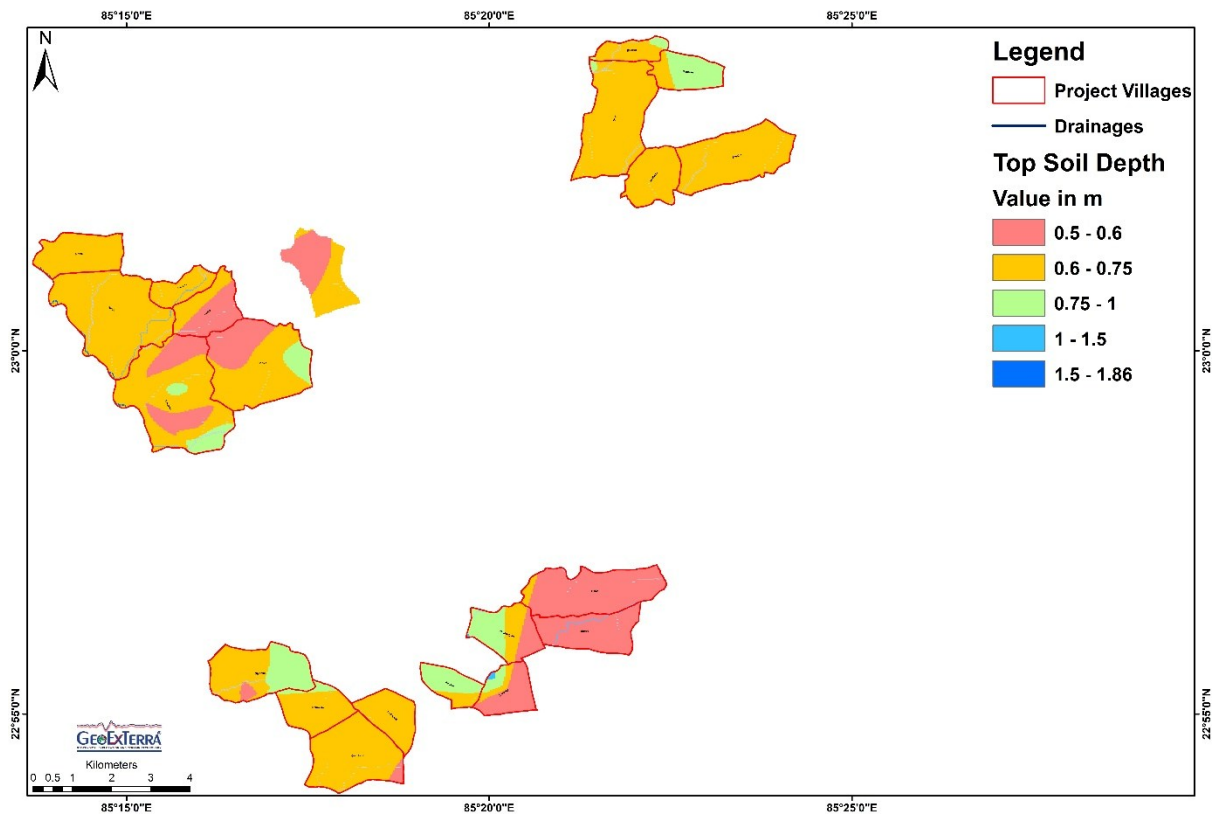


Fig. 26 Soil Thickness Map of the Project Villages of Khunti.

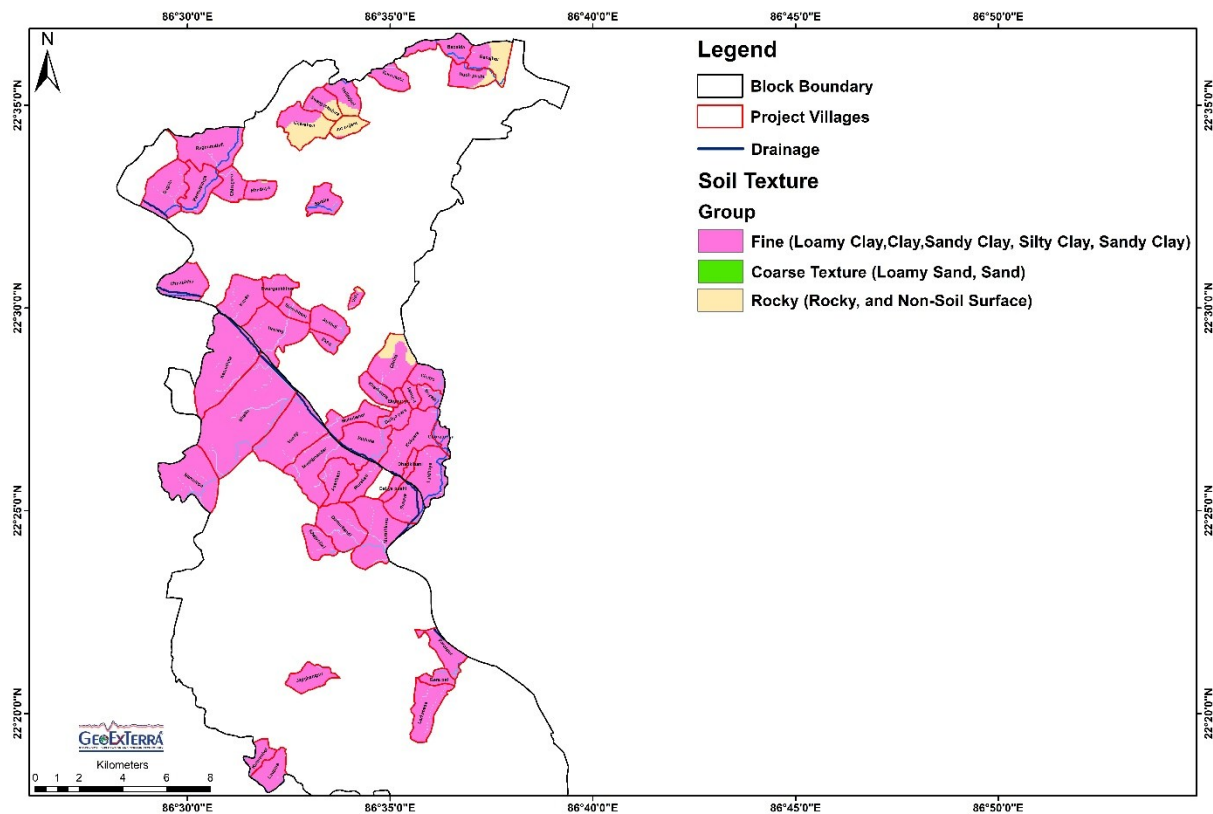


Fig. 27 Distribution of Soil Texture in the Project Villages of East Singhbhum.

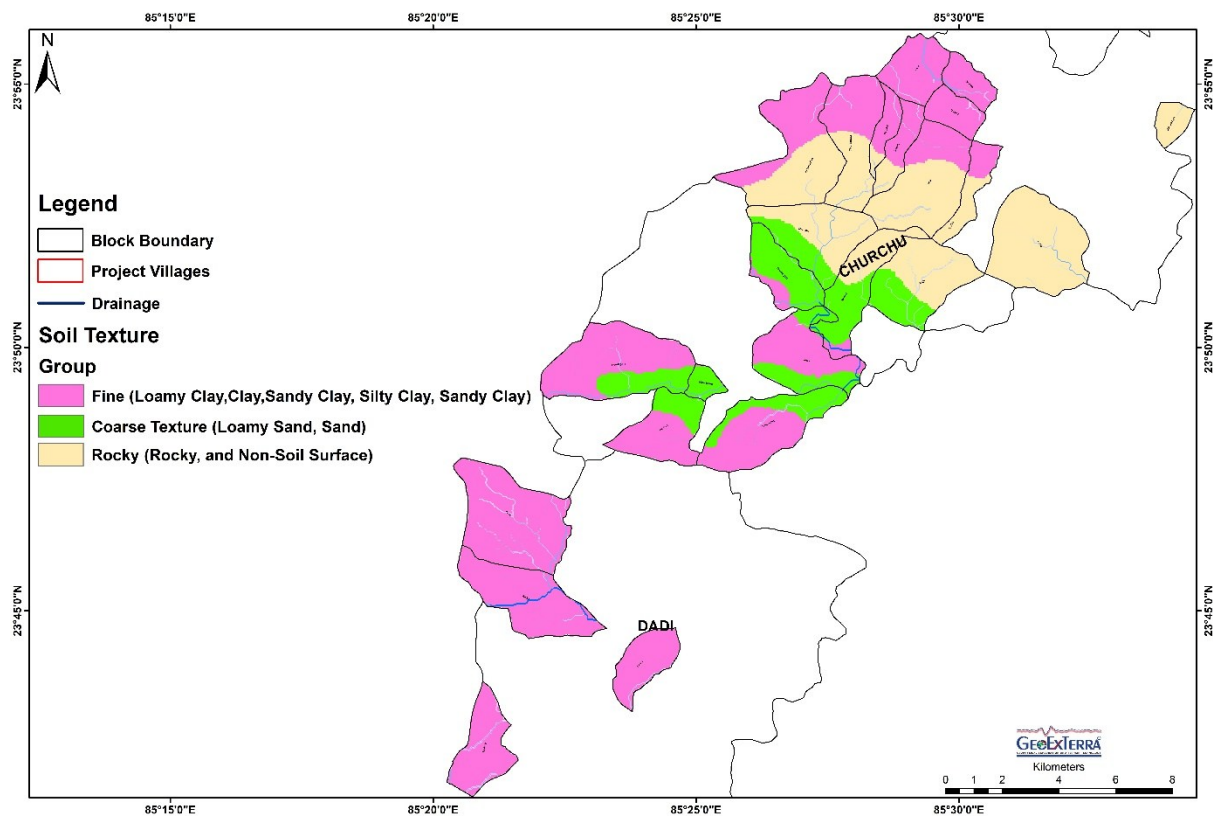


Fig. 28 Distribution of Soil Texture in the Project Villages of Hazaribagh.

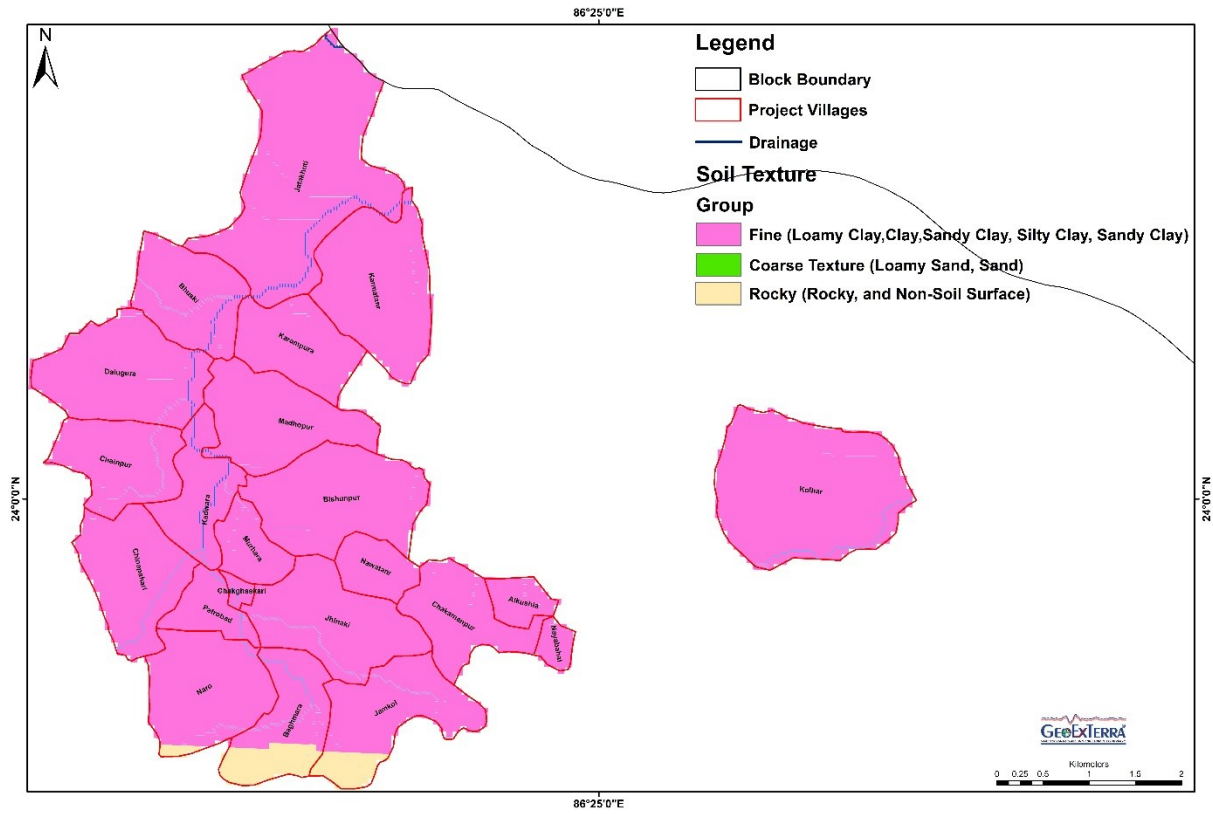


Fig. 29 Distribution of Soil Texture in the Project Villages of Dhanbad.

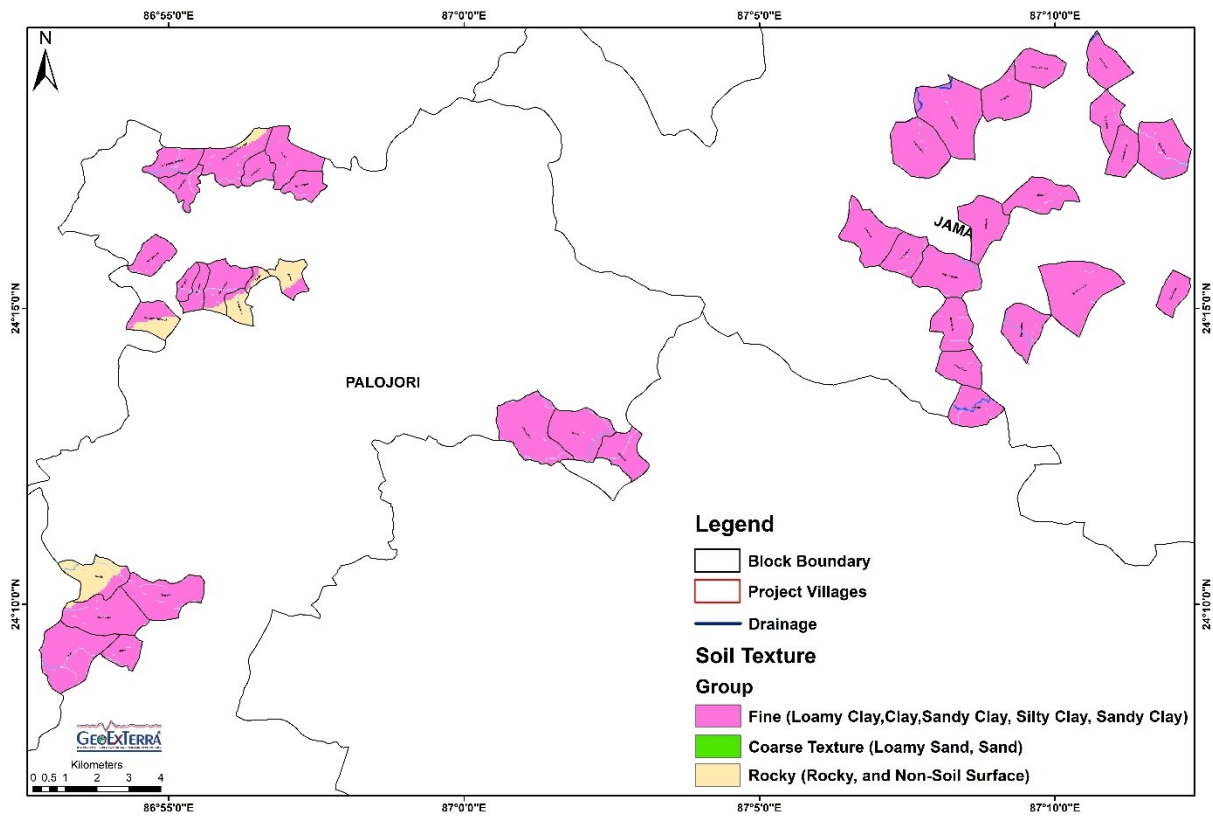
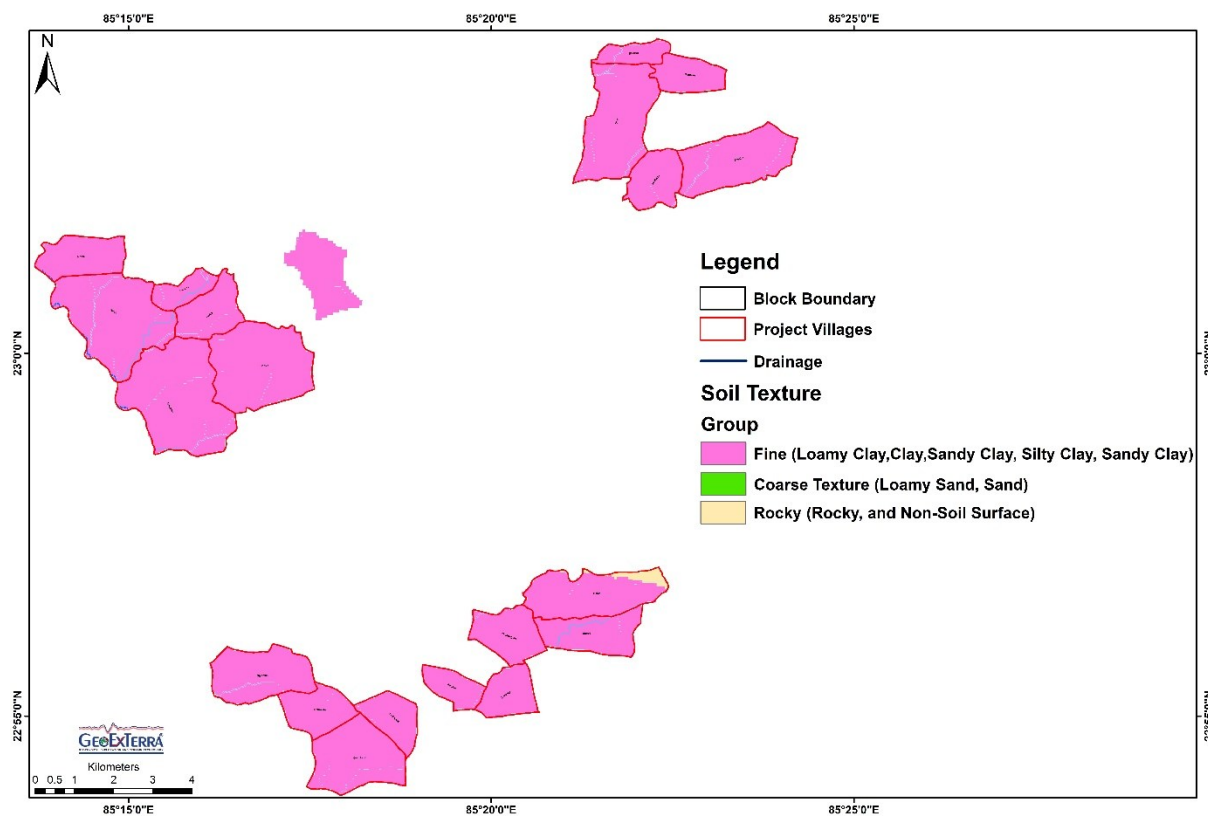


Fig. 30 Distribution of Soil Texture in the Project Villages of Deoghar and Dumka.



**Fig. 31 Distribution of Soil Texture in the Project Villages of Khunti.**

mantle (Figs. 22 to 26). Deeper soil profiles ranging from 1.0–1.5 m and up to 1.86 m are predominantly confined to valley zones and drainage-aligned areas, especially in Churchu and adjoining regions, indicating zones of sediment accumulation and enhanced infiltration potential. Conversely, shallow soils (0.5–0.6 m) are observed in upland and dissected terrains, particularly in parts of Tundi and Jama, reflecting active erosion, limited weathering depth, and exposure of bedrock. A strong correlation between soil texture and thickness is evident across the study area, wherein fine-textured soils are generally associated with moderate thickness zones, contributing to higher water retention but limited percolation, thereby favoring surface storage and agricultural usage rather than deep aquifer recharge. On the other hand, coarse-textured soils coincide with deeper soil profiles along drainage corridors, forming critical groundwater recharge zones due to their higher permeability and storage capacity (Fig. 27 to 31). The rocky terrains, with negligible soil thickness, act as runoff zones with minimal infiltration. From a hydrogeological perspective, this heterogeneity implies that groundwater occurrence is largely controlled by the interplay between soil properties and subsurface fracture systems. Therefore, for climate-resilient water resource management, valley-fill zones with coarse texture and greater soil thickness should be prioritized for artificial recharge structures such as check dams, percolation tanks, and recharge trenches, while fine-textured pediplain areas are better suited for moisture conservation practices like farm ponds and contour bunding. The integration of soil texture and thickness analysis thus provides a critical basis for delineating recharge potential zones and optimizing groundwater development strategies across the diverse hydrogeomorphic settings of the project area.

## 5.6 Geology and Hydrogeology

The geological and hydrogeological framework of the project area encompassing is predominantly controlled by a complex assemblage of Precambrian crystalline basement rocks and localized Gondwana sedimentary formations, as interpreted from the provided geology and lineament-integrated maps, which collectively govern the occurrence, movement, and storage of groundwater. The Basement Gneissic Complex constitutes the most extensive lithological unit across the study area, particularly dominating Murhu, Palojori, Jama, and large parts of Tundi and Gurabanda–Dalbhumgarh blocks, where it occurs as hard, compact, and poorly porous crystalline rock (Figs 32 to 36). Hydrogeologically, this formation behaves as a low primary porosity aquifer, with groundwater occurrence restricted to the weathered mantle (generally 5–20 m thick) and deeper fractured zones, thereby making the aquifer system highly discontinuous and dependent on secondary porosity. The presence of lineaments and fracture systems, clearly observed in the maps especially in Tundi, Churchu, and parts of Dalbhumgarh, plays a critical role in enhancing permeability by acting as conduits for groundwater movement and storage; intersections of such lineaments represent high-potential groundwater zones suitable for borewell development and artificial recharge interventions. In contrast, Gondwana formations comprising sandstone interbedded with shale and coal seams, prominently observed in Churchu–Dadi blocks, form relatively moderate to good aquifers due to their higher primary porosity and permeability, particularly within the sandstone horizons. These formations support semi-confined to confined aquifer conditions, where groundwater occurs in stratified layers, and the interbedded shale units act as aquitards, locally restricting vertical movement. Additionally, occurrences of phyllite, quartzite, schist, and undifferentiated metasedimentary rocks across parts of Tundi and adjoining areas exhibit variable hydrogeological behavior; phyllites and schists, due to their foliated nature, allow groundwater movement along

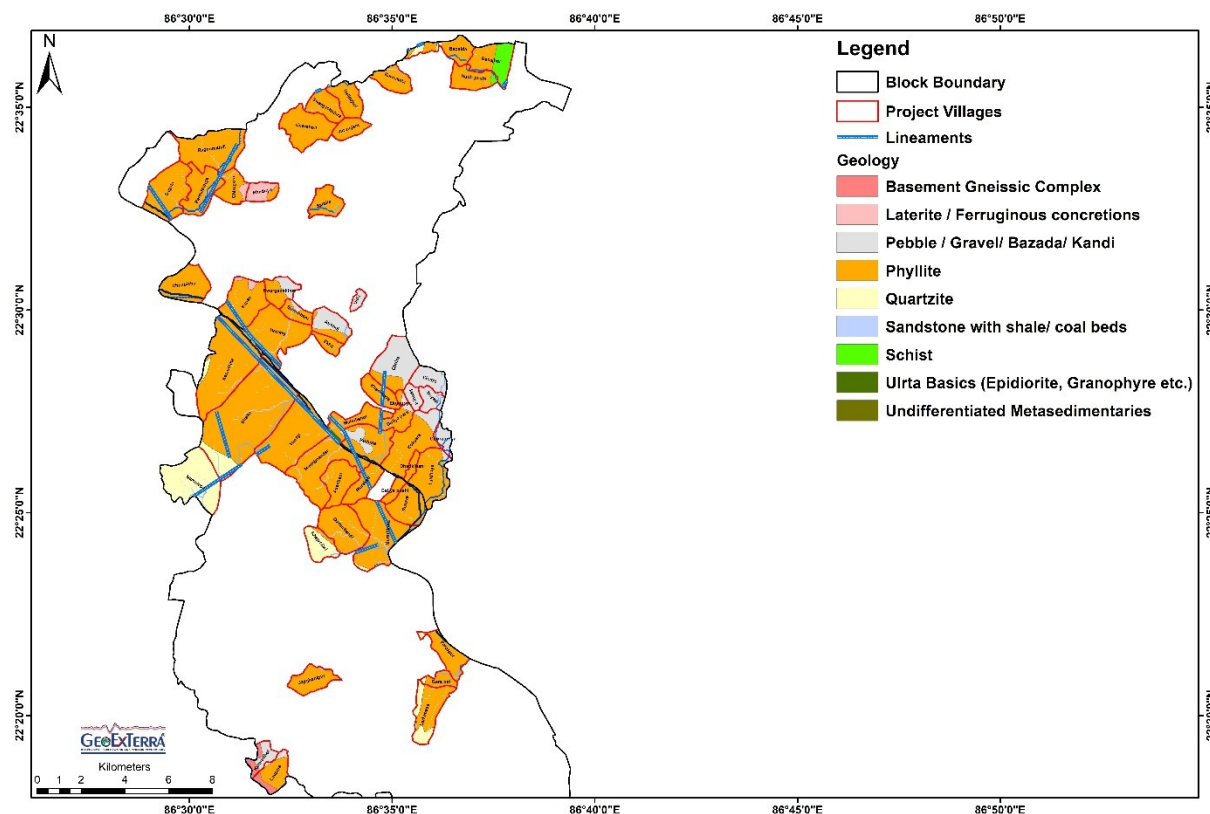


Fig. 32 Geological Map of the Project Villages of East Singhbhum.

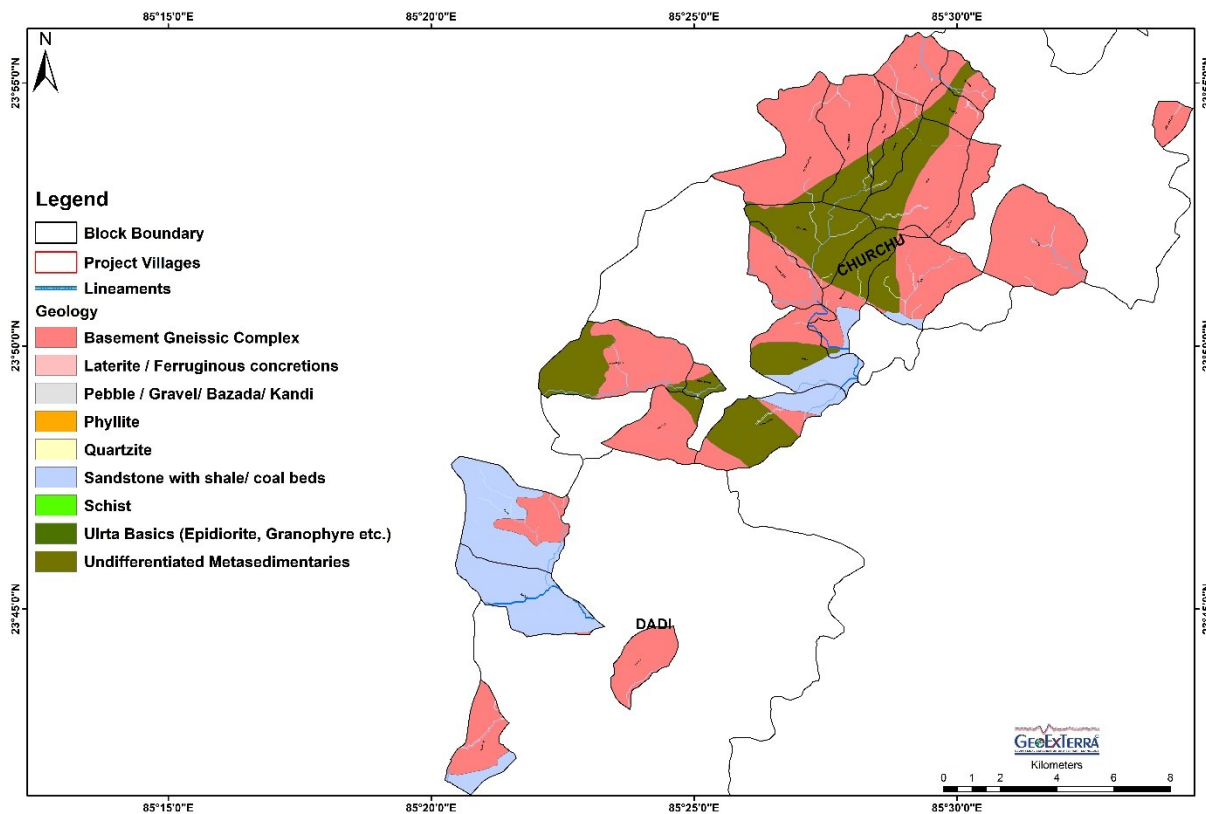


Fig. 33 Geological Map of the Project Villages of Hazaribagh.

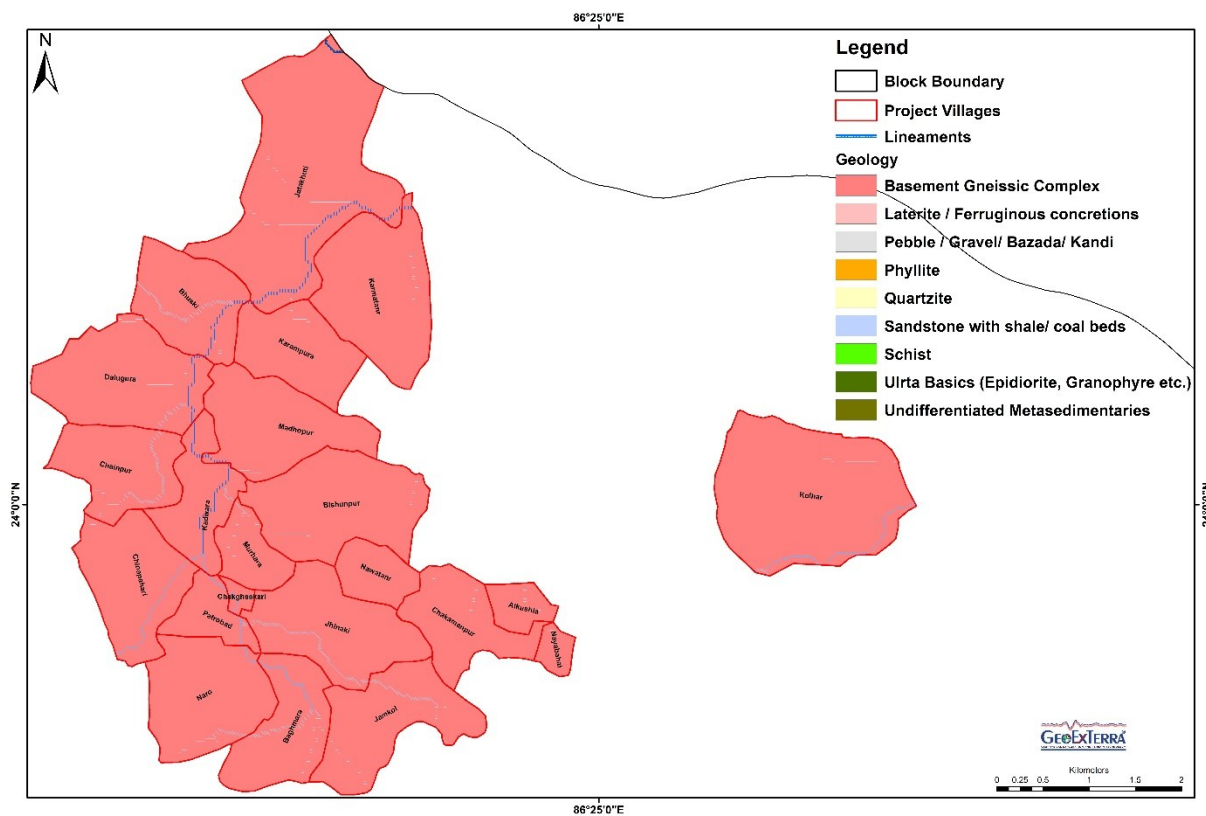


Fig. 34 Geological Map of the Project Villages of Dhanbad.

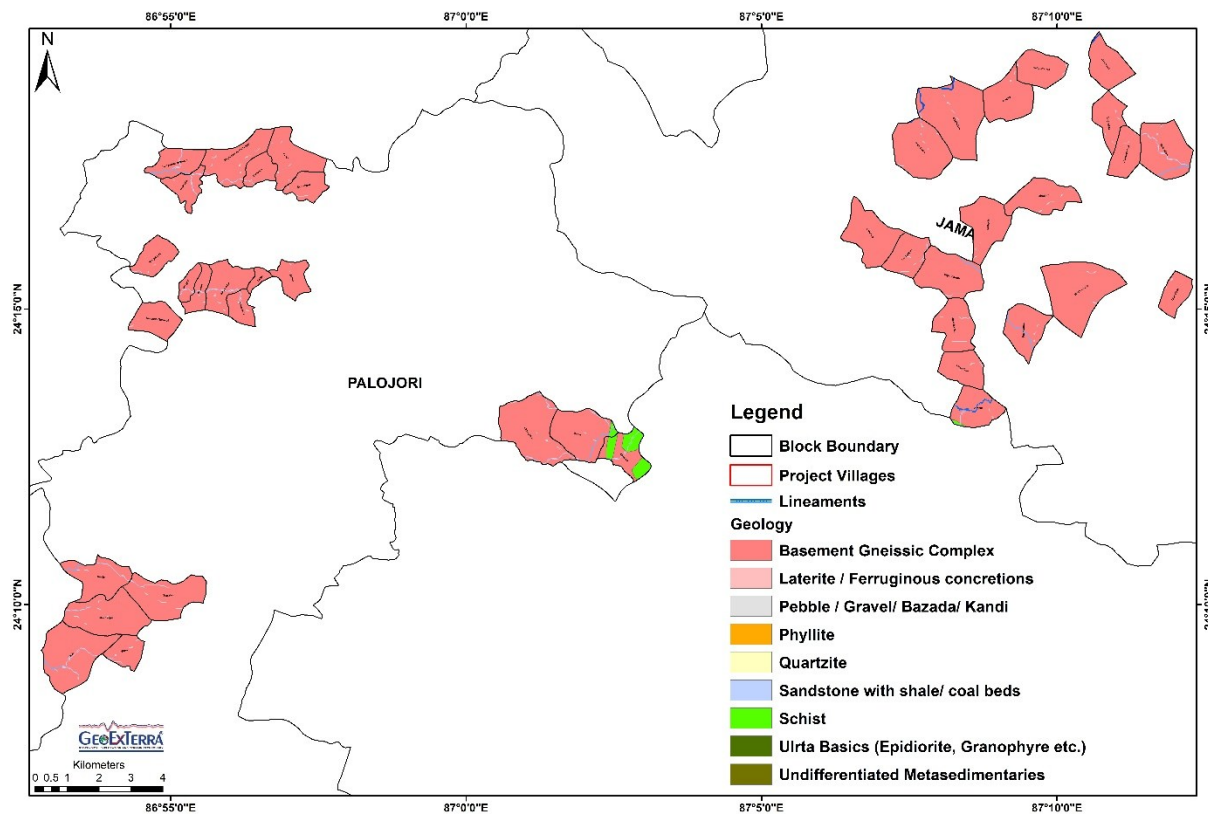


Fig. 35 Geological Map of the Project Villages of Deoghar and Dumka.

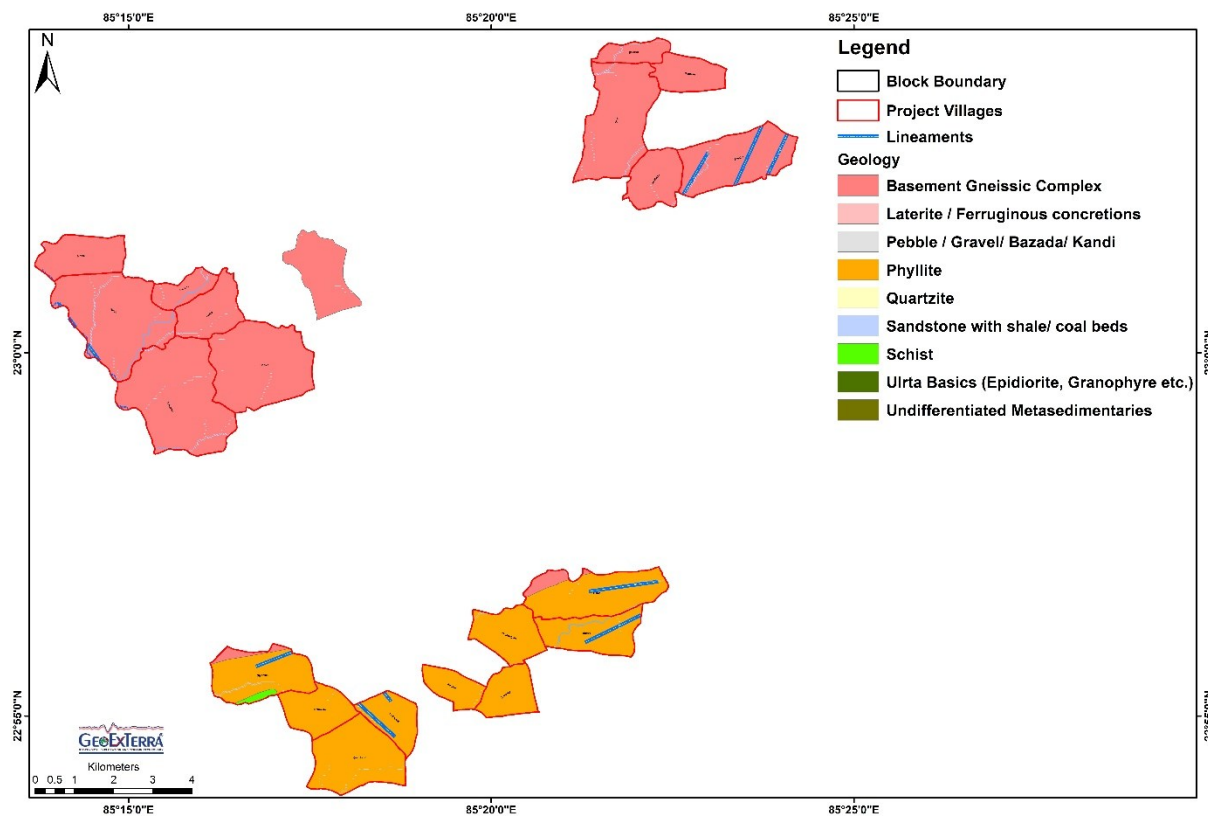


Fig. 36 Geological Map of the Project Villages of Khunti.

planes of weakness, while quartzites generally act as poor aquifers unless fractured. The presence of ultrabasic intrusives (epidiorite, granophyre, etc.) in localized zones contributes to heterogeneous aquifer characteristics, often forming hard, compact bodies with limited storage but occasionally hosting fractures that can store groundwater. Surface and near-surface formations such as laterite and ferruginous concretions, as well as pebble-gravel (bajada/kandi) deposits, though limited in spatial extent, significantly influence recharge dynamics by providing high infiltration zones where present. The integration of geology with geomorphology and soil data indicates that valley-fill deposits and structurally controlled zones within sedimentary terrains exhibit the highest groundwater potential, while elevated pediplains and rocky uplands underlain by crystalline rocks show comparatively low potential unless intersected by major fractures. The drainage pattern, often structurally controlled and aligned with major lineaments, further supports the role of tectonic features in guiding groundwater flow. From a hydrogeological perspective, the study area can thus be categorized into (i) weathered–fractured hard rock aquifers (gneissic and metamorphic terrains), (ii) porous and semi-confined sedimentary aquifers (Gondwana formations), and (iii) localized alluvial or colluvial recharge zones, each requiring distinct groundwater development strategies. Sustainable groundwater exploitation in this region necessitates a targeted approach focusing on lineament intersection zones, weathered thickness enhancement areas, and valley-fill sediments, combined with artificial recharge structures aligned along drainage channels and fracture zones. This integrated geological and hydrogeological understanding provides a robust basis for delineating groundwater potential zones and ensuring climate-resilient water security across the diverse lithological and structural settings of the project area.

## 6. RESULTS AND FINDINGS

### 6.1 Satellite Remote Sensing and GIS Mapping/Modelling

Satellite data was used to prepare various thematic maps and their interpretation was made using GIS techniques.

#### 6.1.1 Drainage Analysis

The drainage analysis of the project area reveals a predominantly dendritic to sub-dendritic drainage pattern with localized structural control, as interpreted from the drainage density maps and stream network distribution. The computed drainage density values range from 0.4 to 5.8 km/km<sup>2</sup>, indicating significant spatial variability in runoff characteristics, infiltration capacity, and subsurface permeability across different litho-geomorphic units (Figs. 37 to 41). A major proportion of the study area, particularly in Murhu, Palojori, and parts of Jama and Gurabanda–Dalbhumgarh, falls under the low drainage density category (0.4–0.5 km/km<sup>2</sup>), which is indicative of relatively permeable subsurface conditions, thicker weathered zones, gentle slopes, and higher infiltration rates, thereby favoring groundwater recharge. These zones are typically associated with pediplains and weathered crystalline terrains where surface runoff is limited and infiltration dominates the hydrological regime. Moderate drainage density zones (0.5–1.5 km/km<sup>2</sup>), observed intermittently across all blocks, particularly in transition zones between uplands and valleys, reflect balanced hydrological conditions, where both runoff and infiltration processes coexist. Such areas are hydrogeologically significant as they support seasonal recharge through stream–aquifer interaction,

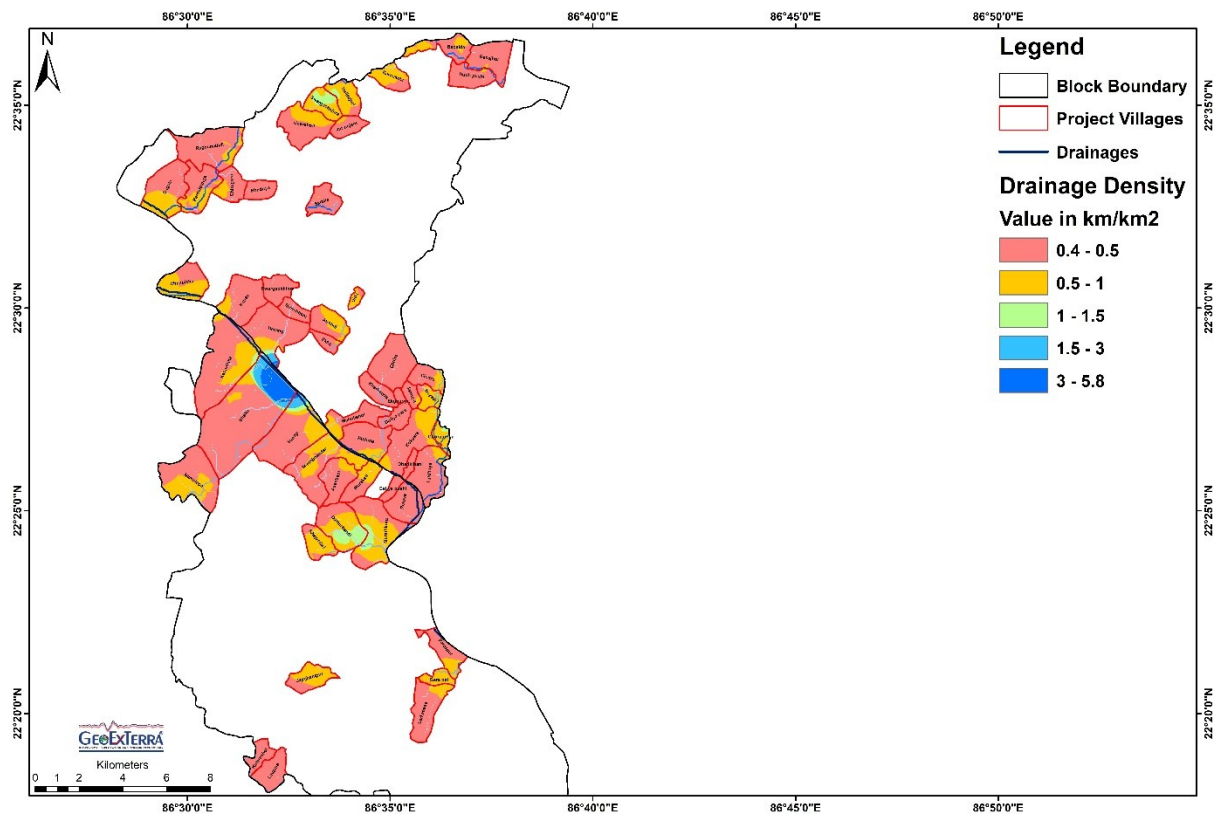


Fig. 37 Drainage Density of the Project Villages of East Singhbhum.

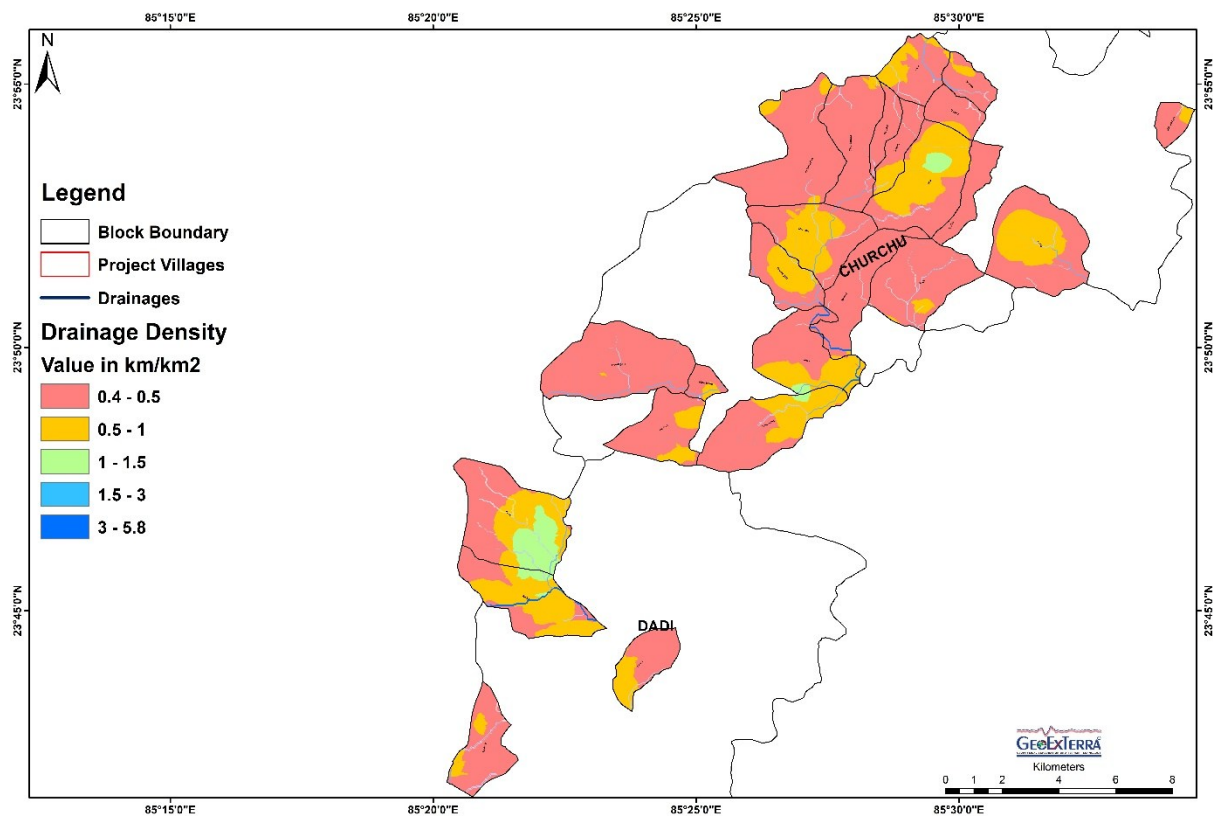


Fig. 38 Drainage Density of the Project Villages of Hazaribagh.

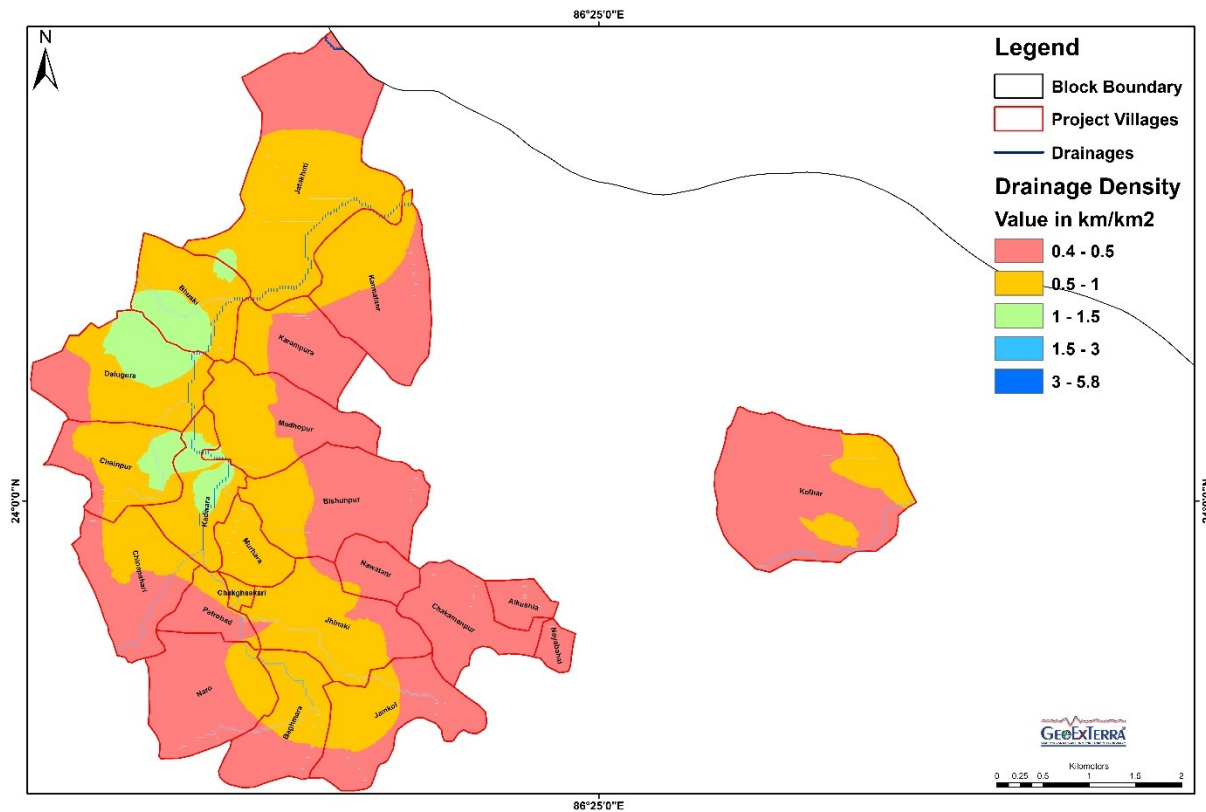


Fig. 39 Drainage Density of the Project Villages of Dhanbad.

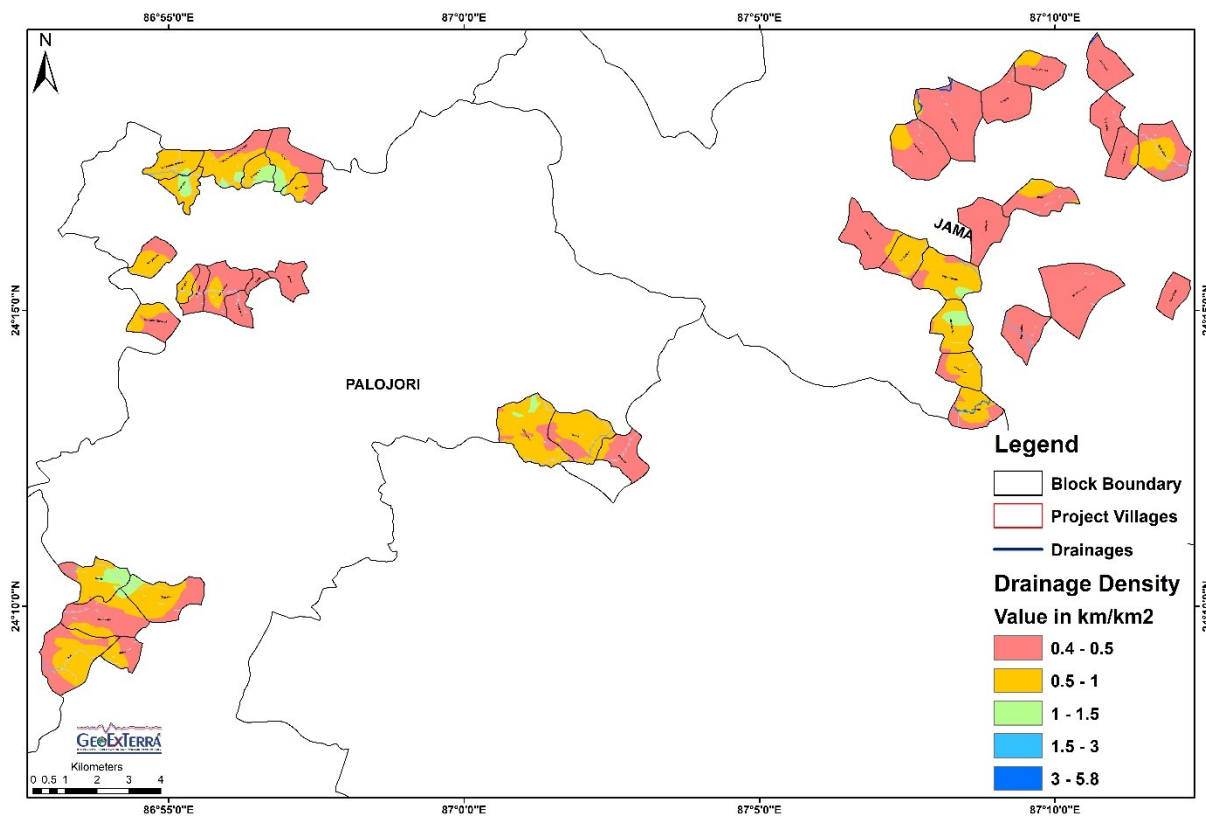
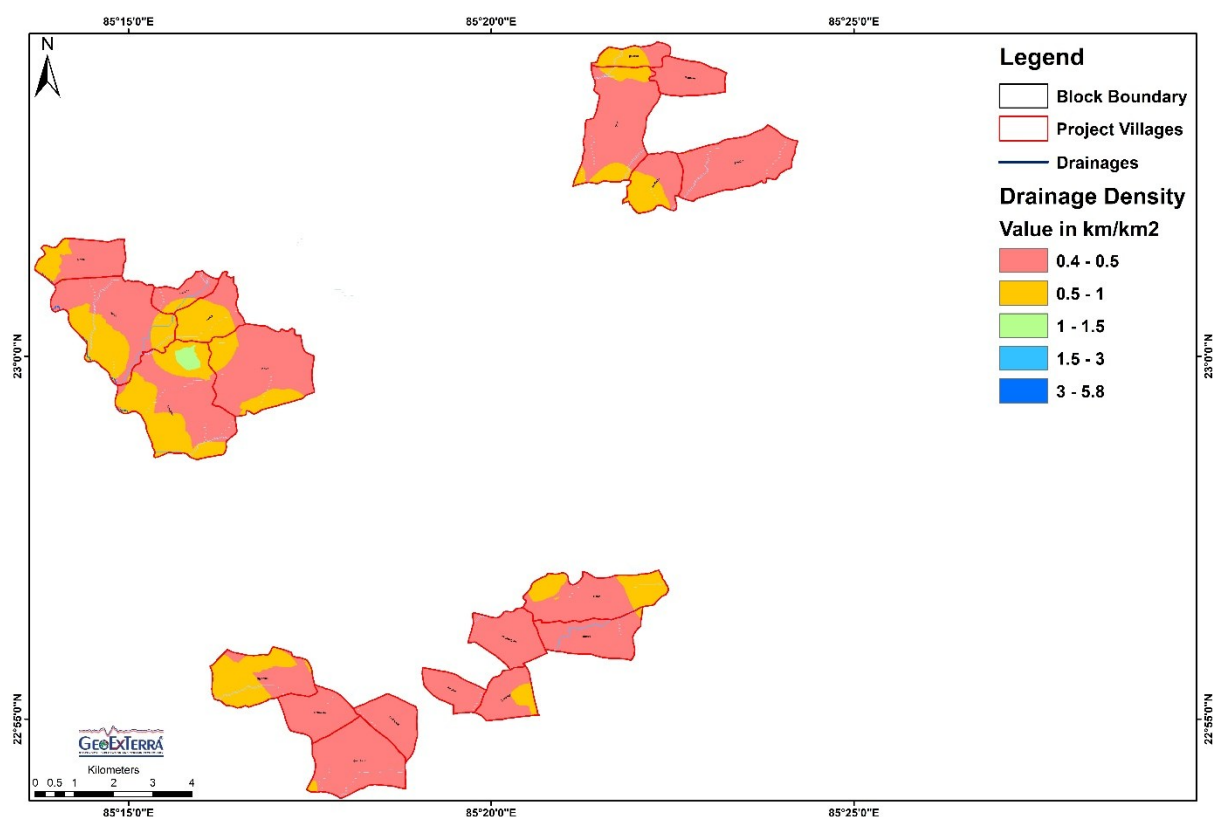


Fig. 40 Drainage Density of the Project Villages of Deoghar and Dumka.



**Fig. 41 Drainage Density of the Project Villages of Khunti.**

especially along first- and second-order streams. In contrast, high drainage density zones ( $1.5\text{--}3\text{ km/km}^2$  and locally up to  $3\text{--}5.8\text{ km/km}^2$ ) are prominently developed in parts of Tundi and Churchu blocks, where closely spaced stream networks and linear drainage segments correspond with structurally controlled terrains and relatively impermeable lithologies such as compact basement rocks or shale-dominated sequences. These areas exhibit higher surface runoff, reduced infiltration, and quicker hydrological response to rainfall, making them prone to erosion but less favorable for direct groundwater recharge unless structural features such as fractures and lineaments enhance permeability. The spatial coincidence of higher drainage density zones with lineament corridors and valley alignments suggests that tectonic features significantly influence drainage evolution and groundwater movement in the region. In particular, the central and southwestern parts of Tundi and the northern segments of Churchu show elongated drainage patterns aligned along major lineaments, indicating structurally guided flow paths that can serve as potential groundwater conduits when intersected by recharge structures. Furthermore, localized patches of moderate to high drainage density in otherwise low-density regions highlight zones of topographic convergence and localized runoff concentration, which are suitable for constructing water harvesting structures such as check dams, percolation tanks, and recharge trenches. From a watershed management perspective, the drainage analysis clearly delineates three hydro-functional zones: (i) low-density recharge-dominated zones suitable for infiltration-based interventions, (ii) moderate-density transition zones ideal for conjunctive recharge and storage structures, and (iii) high-density runoff-dominated zones requiring runoff harvesting and erosion control measures. The integration of drainage density with geology, geomorphology, and soil characteristics indicates that optimal groundwater development potential exists in low to moderate drainage

density areas intersected by lineaments and underlain by weathered/fractured formations, while high-density zones require engineered interventions to enhance recharge. Overall, the drainage characteristics of the study area provide a critical framework for designing climate-resilient water resource strategies, emphasizing decentralized recharge, runoff management, and structural targeting of hydrogeologically favorable zones.

### 6.1.2 Lineament Analysis

Lineaments are the linear or curvilinear surface manifestations of structurally controlled features such as faults, fractures, joints, rock contacts, etc. It depicts the weaker zone of bedrock developing generally due to stress and strain, providing an important clue on surface features. Lineaments are also responsible for the development of secondary permeability and porosity in rocks, influencing weathering, soil water, and groundwater movements. The fracture zone forms an interlaced network of high transmissivity and serves as groundwater conduits in rocks. The lineament analysis of the project area reveals a structurally controlled hydrogeological framework characterized by a well-developed network of fractures, faults, and shear zones, as interpreted from satellite-derived lineament density maps. The mapped lineament density varies from 0.4 to 3.6 km/km<sup>2</sup>, indicating heterogeneous structural deformation and differential secondary porosity development across the terrain (Figs. 42 to 46). A significant portion of the area, particularly in Murhu, Palojori, and peripheral zones of Jama and Gurabanda, exhibits low lineament density (0.4–0.5 km/km<sup>2</sup>), suggesting relatively massive, less fractured basement conditions with limited groundwater movement restricted primarily to weathered horizons. In contrast, moderate lineament density zones

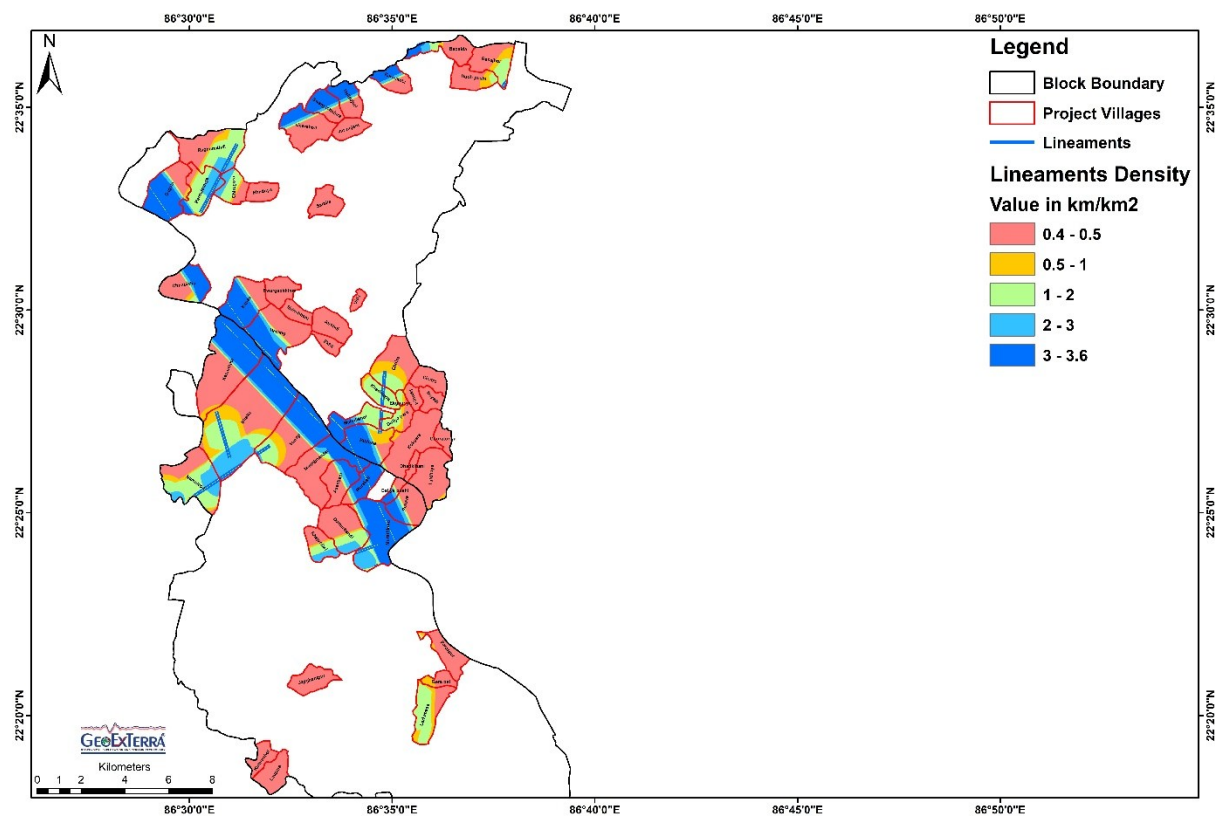


Fig. 42 Lineament Density of the Project Villages of East Singhbhum.

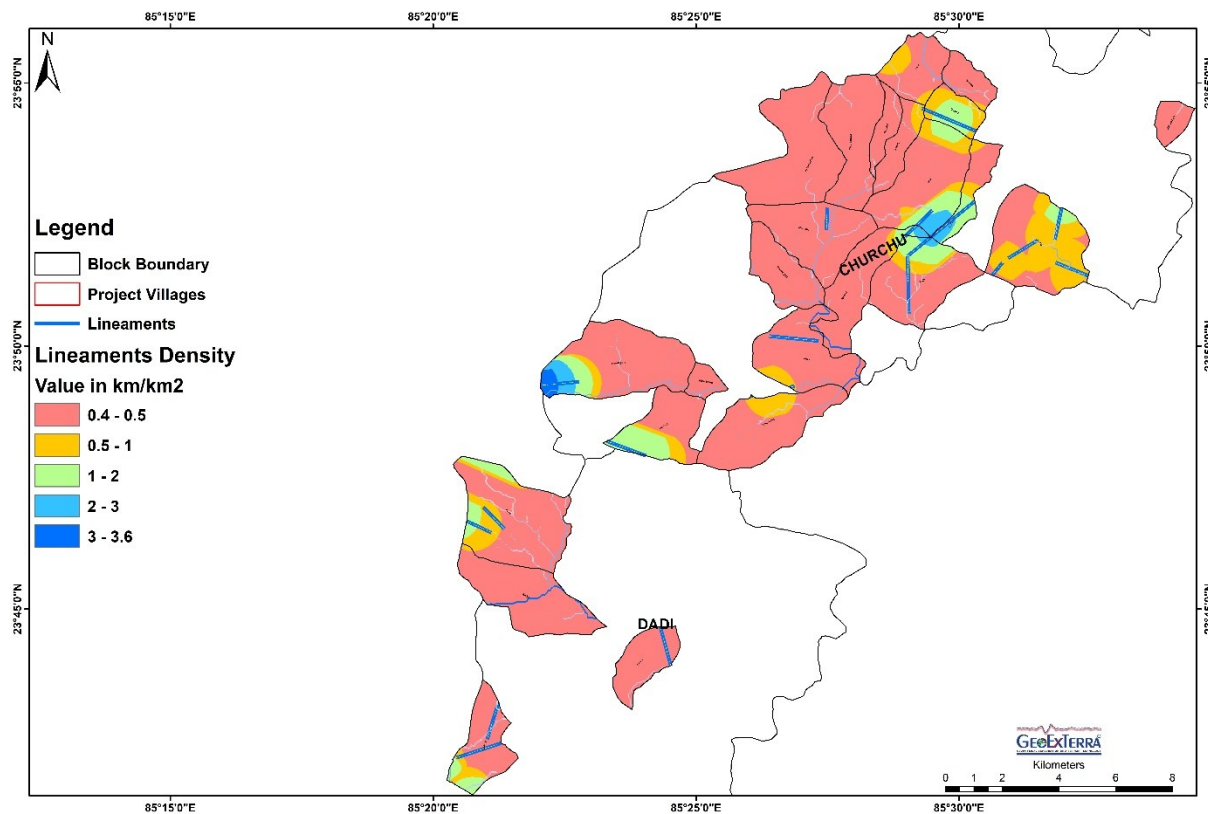


Fig. 43 Lineament Density of the Project Villages of Hazaribagh.

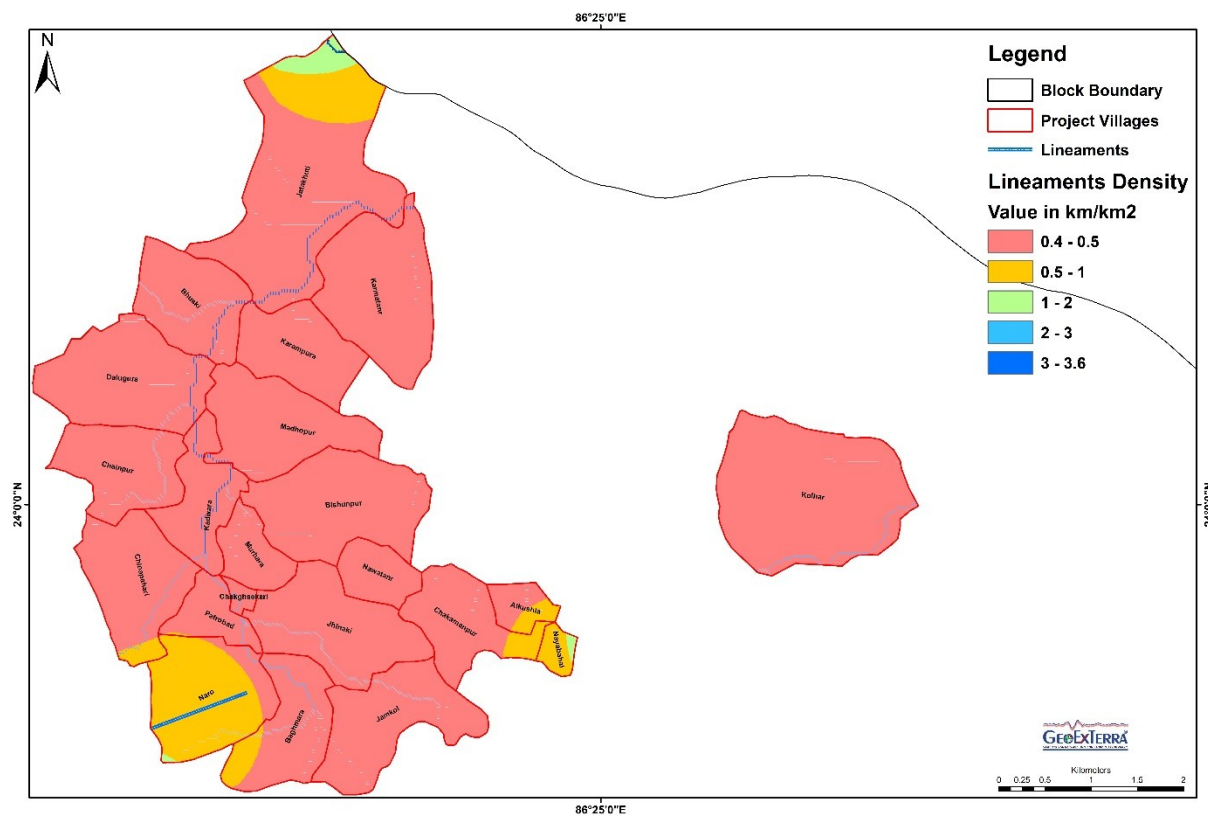


Fig. 44 Lineament Density of the Project Villages of Dhanbad.

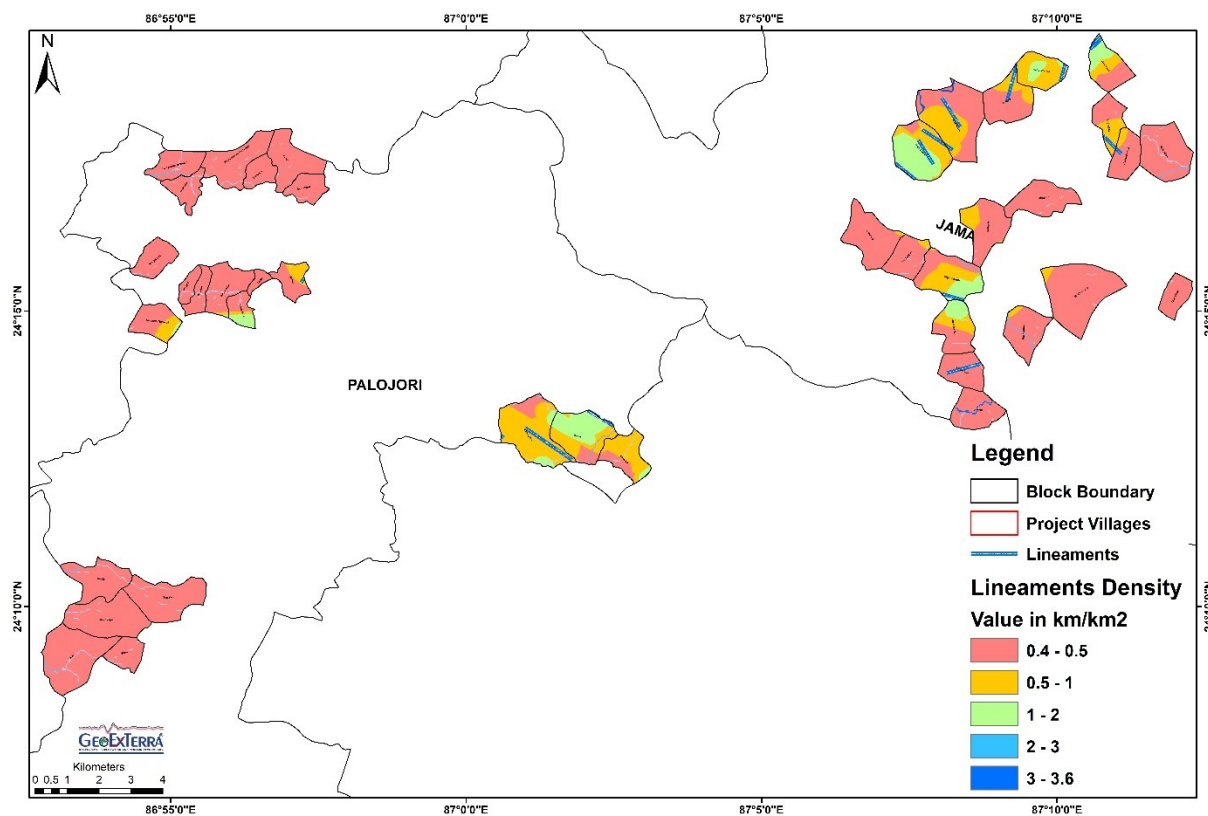


Fig. 45 Lineament Density of the Project Villages of Deoghar and Dumka.

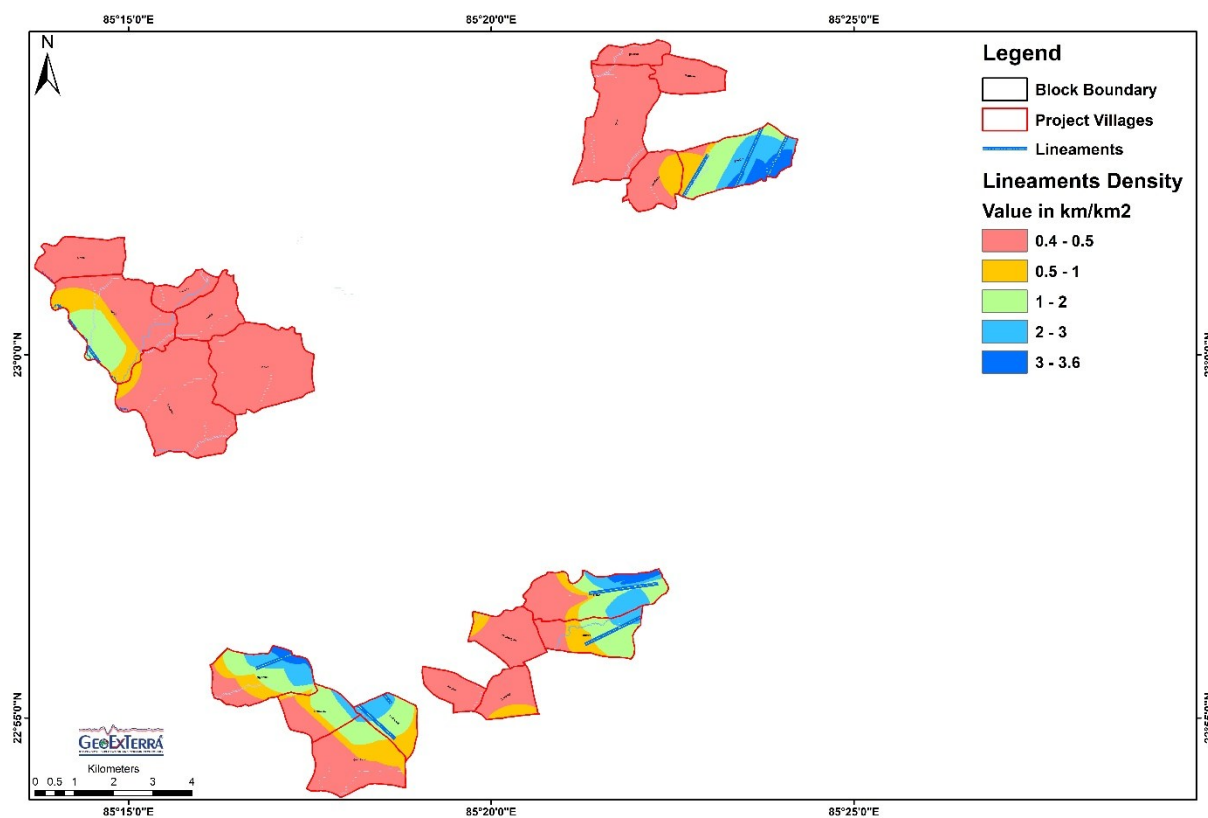


Fig. 46 Lineament Density of the Project Villages of Khunti.

(0.5–2 km/km<sup>2</sup>) are widely distributed across transition zones and pediplains, where fractured crystalline rocks provide moderate permeability and storage potential, making these areas suitable for decentralized groundwater development through shallow to intermediate depth wells. The most hydrogeologically significant zones are represented by high to very high lineament density areas (2–3 km/km<sup>2</sup> and 3–3.6 km/km<sup>2</sup>), prominently observed in Tundi, parts of Jama, and localized corridors within Churchu and Gurabanda–Dalbhumgarh blocks. These zones are characterized by closely spaced, intersecting lineaments forming fracture corridors, which enhance secondary porosity and permeability, thereby acting as preferential pathways for groundwater recharge, storage, and movement. Notably, the alignment of these lineaments exhibits dominant NW–SE, NE–SW, and locally E–W trends, reflecting regional tectonic controls and reactivation of pre-existing structural fabrics within the Chotanagpur Gneissic Complex and associated meta-sedimentary sequences. The coincidence of high lineament density zones with drainage alignments and valley features further substantiates the role of structural controls in guiding surface and subsurface hydrological processes. Spatial analysis indicates that lineament intersections and zones of lineament convergence are particularly prominent in central Tundi and parts of Jama and Churchu blocks, where multiple fracture sets intersect, creating highly transmissive aquifer zones. These intersection zones are of paramount importance for groundwater exploration, as they offer enhanced well yields and sustained discharge due to interconnected fracture networks. Conversely, areas with sparse and isolated lineaments are likely to exhibit limited groundwater potential and rapid depletion under abstraction stress. Additionally, the presence of linear features extending across multiple villages suggests regional-scale fracture systems, which can facilitate long-distance groundwater movement and recharge propagation, especially during monsoonal recharge events. From a groundwater management perspective, the integration of lineament density with drainage density and geological formations delineates priority zones for groundwater development and artificial recharge interventions. High lineament density corridors, particularly where coinciding with moderate drainage density and weathered zones, are ideal for borewell siting, recharge shaft construction, and fracture-controlled aquifer tapping, while low-density areas require surface water harvesting and soil moisture conservation measures to augment recharge. Overall, the lineament analysis underscores the critical role of structural controls in governing aquifer geometry and productivity in the hard rock terrain of Jharkhand, providing a robust scientific basis for targeted, climate-resilient groundwater resource development and sustainable water security planning in the project area.

## 6.2 Well Observatory and Water Quality

The comprehensive well inventory and groundwater quality assessment conducted across the project villages during January 2026 provides a robust evaluation of the hydrogeological regime, aquifer behavior, and potable water suitability in the hard rock terrain of Jharkhand. Analysis of observed groundwater levels indicates a wide spatial variability ranging from ~0.55 m to 9.35 m below ground level (mbgl), reflecting strong control of lithology, weathering thickness, topography, and structural features (Figs. 47 to 51, Table 2). Shallow water levels (0.6–3 mbgl), prominently observed in parts of Gurabanda, Murhu, and localized pockets of Tundi and Jama, indicate good recharge conditions and proximity to unconfined aquifers, particularly along drainage courses and fracture zones, whereas moderate depths (3–5 mbgl) dominate large parts of Churchu, Palojori, and Dalbhumgarh, representing stable phreatic conditions with moderate storage potential. Deeper water levels (5–9.1 mbgl),

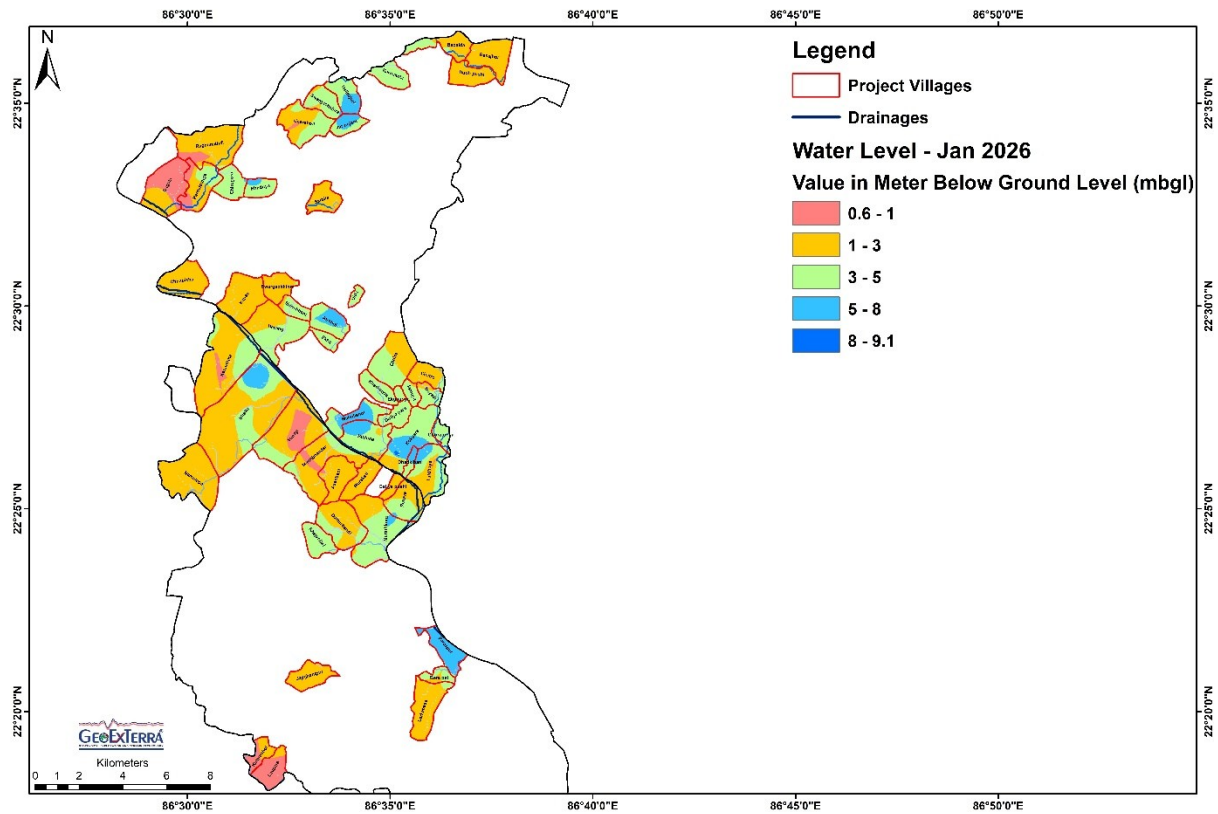


Fig. 47 Depth of Water Level During Jan 2026 in the Project Villages of East Singhbhum.

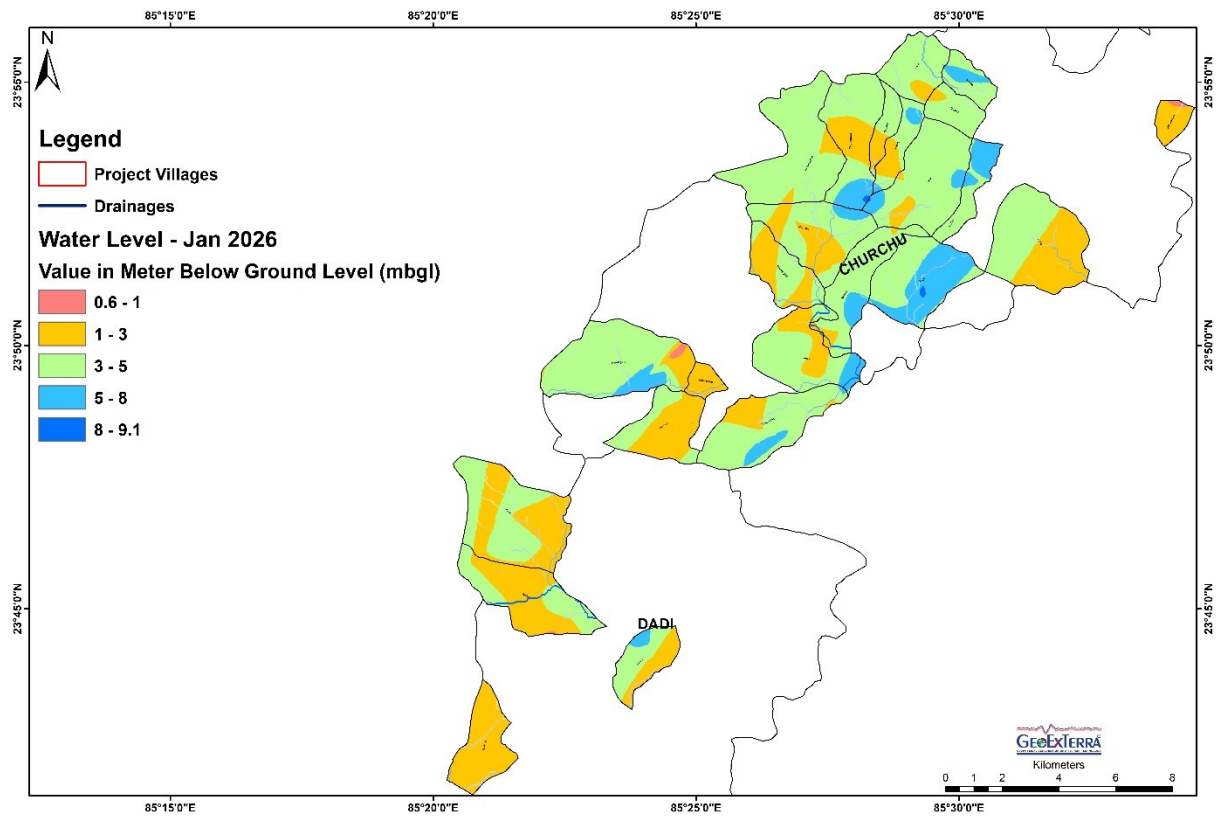


Fig. 48 Depth of Water Level During Jan 2026 in the Project Villages of Hazaribagh.

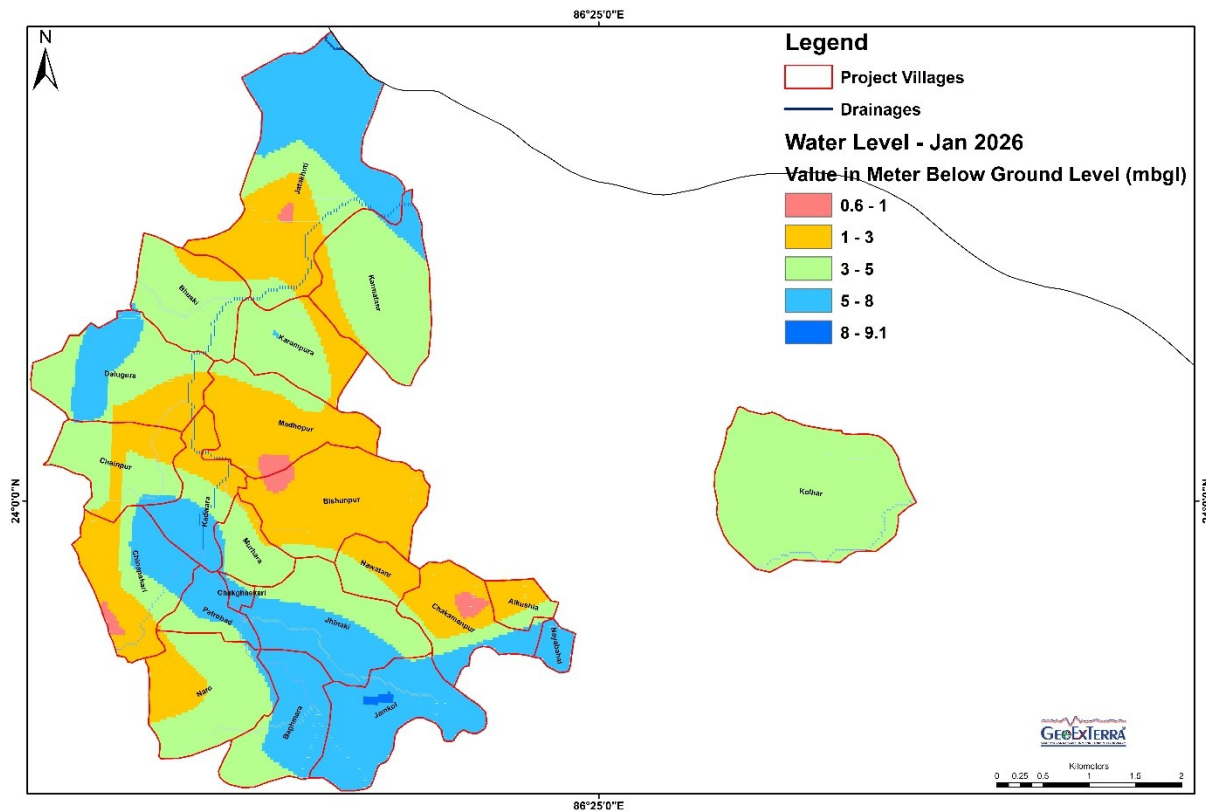


Fig. 49 Depth of Water Level During Jan 2026 in the Project Villages of Dhanbad.

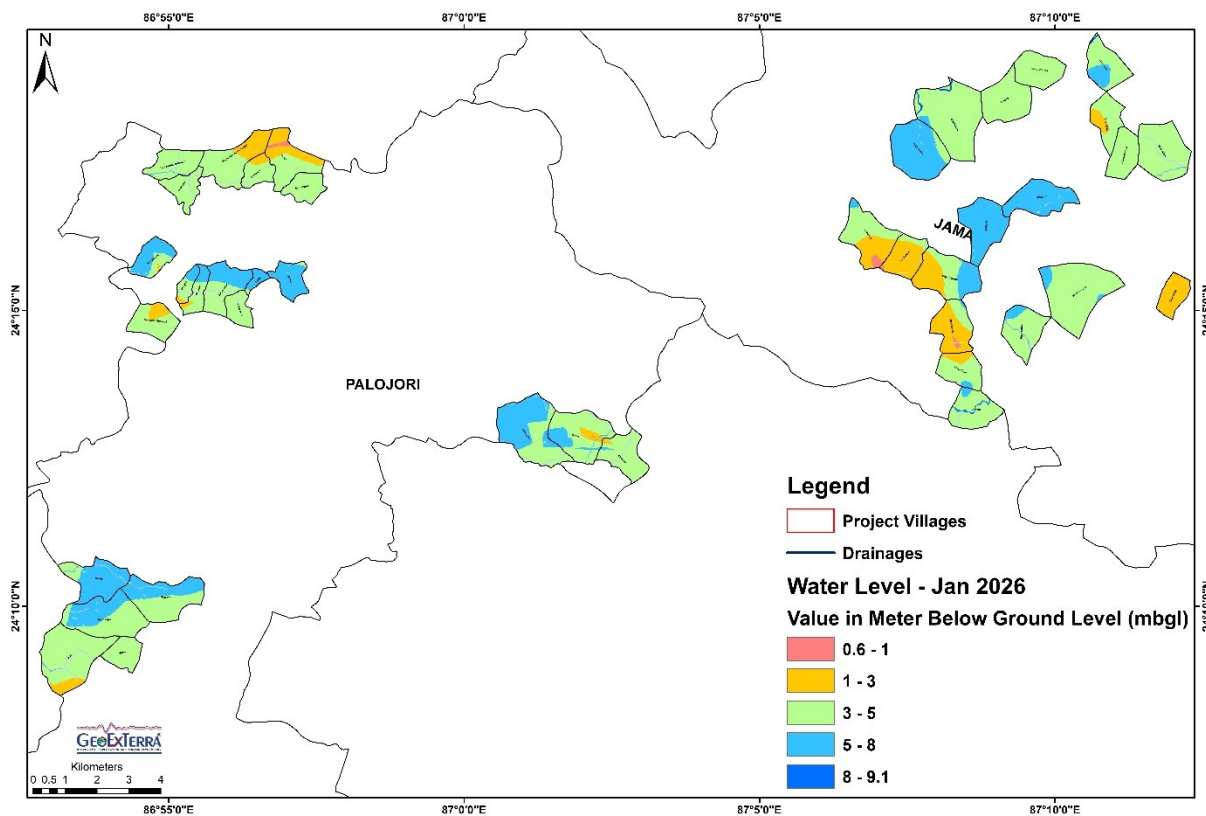
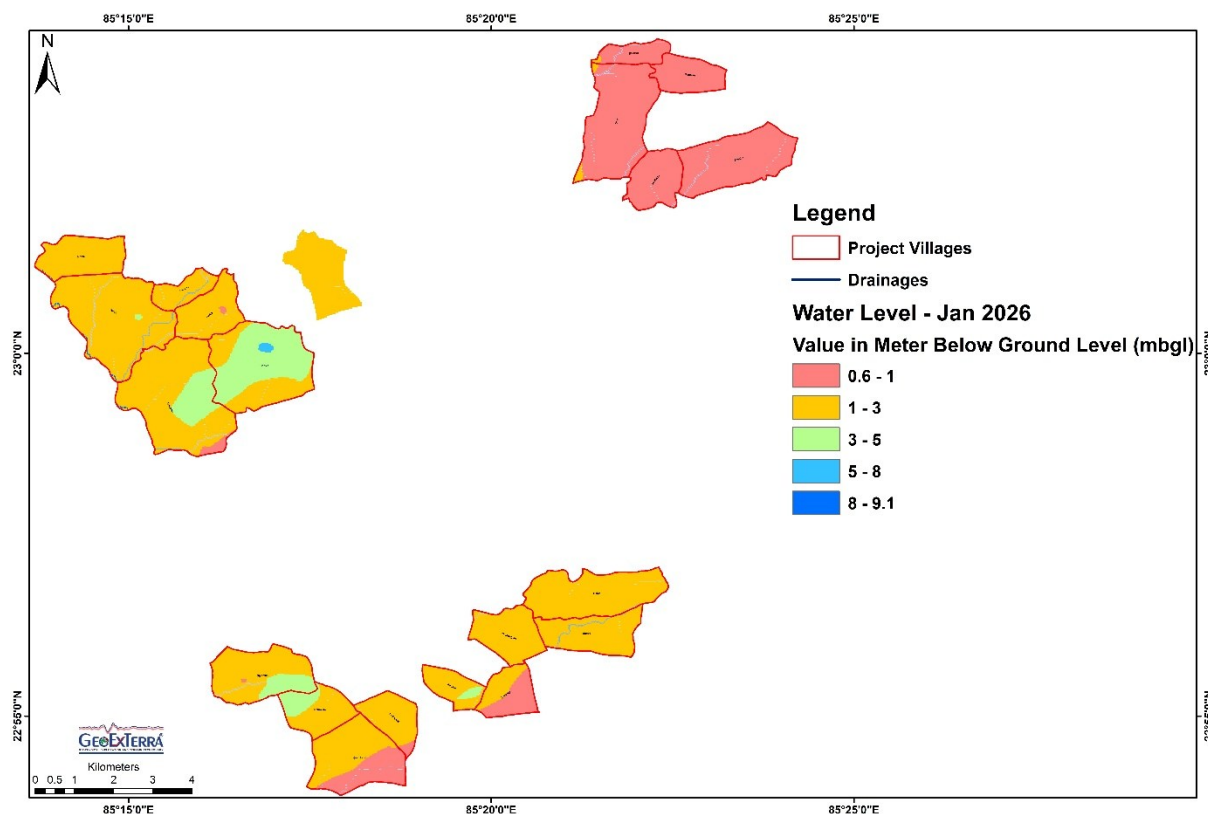


Fig. 50 Depth of Water Level During Jan 2026 in the Project Villages of Deoghar and Dumka.



**Fig. 51 Depth of Water Level During Jan 2026 in the Project Villages of Khunti.**

especially in isolated zones of Tundi, Dadi, and portions of Jama, suggest limited recharge, thicker unsaturated zones, or structurally controlled deeper aquifer systems, often associated with compact bedrock and lower primary porosity. The spatial correlation of groundwater levels with drainage networks clearly demonstrates hydraulic connectivity between surface water and subsurface aquifers, where shallow water table zones align with drainage channels and valley fills, indicating active recharge and higher groundwater sustainability. Conversely, elevated terrains and structurally less fractured zones exhibit deeper water levels, implying recharge constraints and localized groundwater stress conditions. Water quality assessment based on pH, Total Dissolved Solids (TDS), and Electrical Conductivity (EC) reveals that groundwater in the project area is predominantly neutral to slightly alkaline in nature, with pH values ranging from 6.5 to 8.5, falling well within the acceptable limits prescribed by Bureau of Indian Standards (BIS 10500:2012/2015) (acceptable range: 6.5–8.5). The majority of samples cluster within 7.0–7.5, indicating chemically stable groundwater with minimal acidity or alkalinity-related hazards (Figs. 52 to 56). Isolated occurrences of slightly alkaline water (pH up to 8.5), particularly in parts of Bali, Bhalki, and select villages of Churchu and Murhu, are likely associated with rock-water interaction processes involving feldspar weathering and bicarbonate enrichment, but remain within permissible limits. The TDS values across the dataset range from ~60 mg/l to ~640 mg/l, with the majority of samples falling below 500 mg/l, indicating freshwater conditions and low mineralization, suitable for drinking without significant treatment (Figs. 57 to 61, Table 2). Only a few localized pockets (e.g., Swargachhinra, Phuljori, Khejurdari, Kurkuta) exhibit relatively higher TDS (500–640 mg/l), which still lie within the permissible limit of 2000 mg/l (BIS) but may impart mild taste or scaling characteristics. Electrical Conductivity values ranging from ~110 to 640  $\mu\text{S}/\text{cm}$  further corroborate the low to moderate ionic concentration

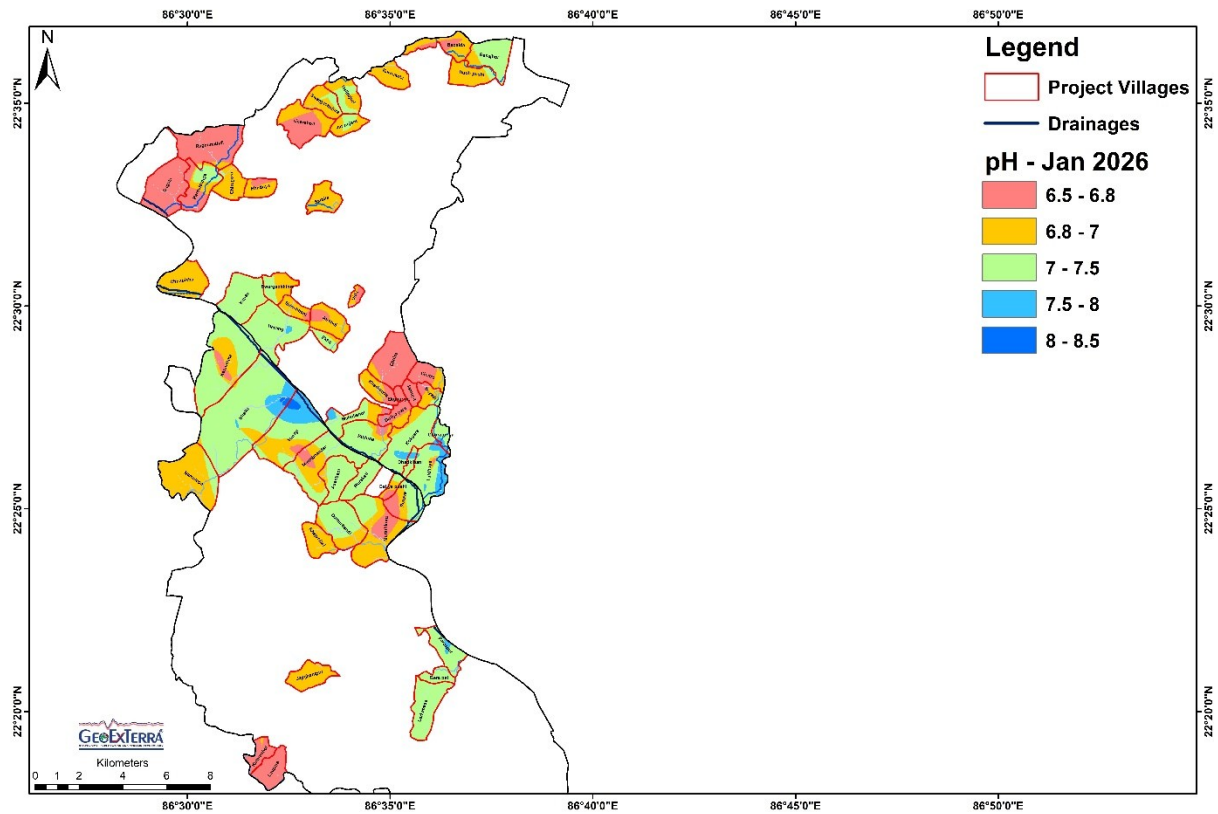


Fig. 52 pH of Groundwater During Jan 2026 in the Project Villages of East Singhbhum.

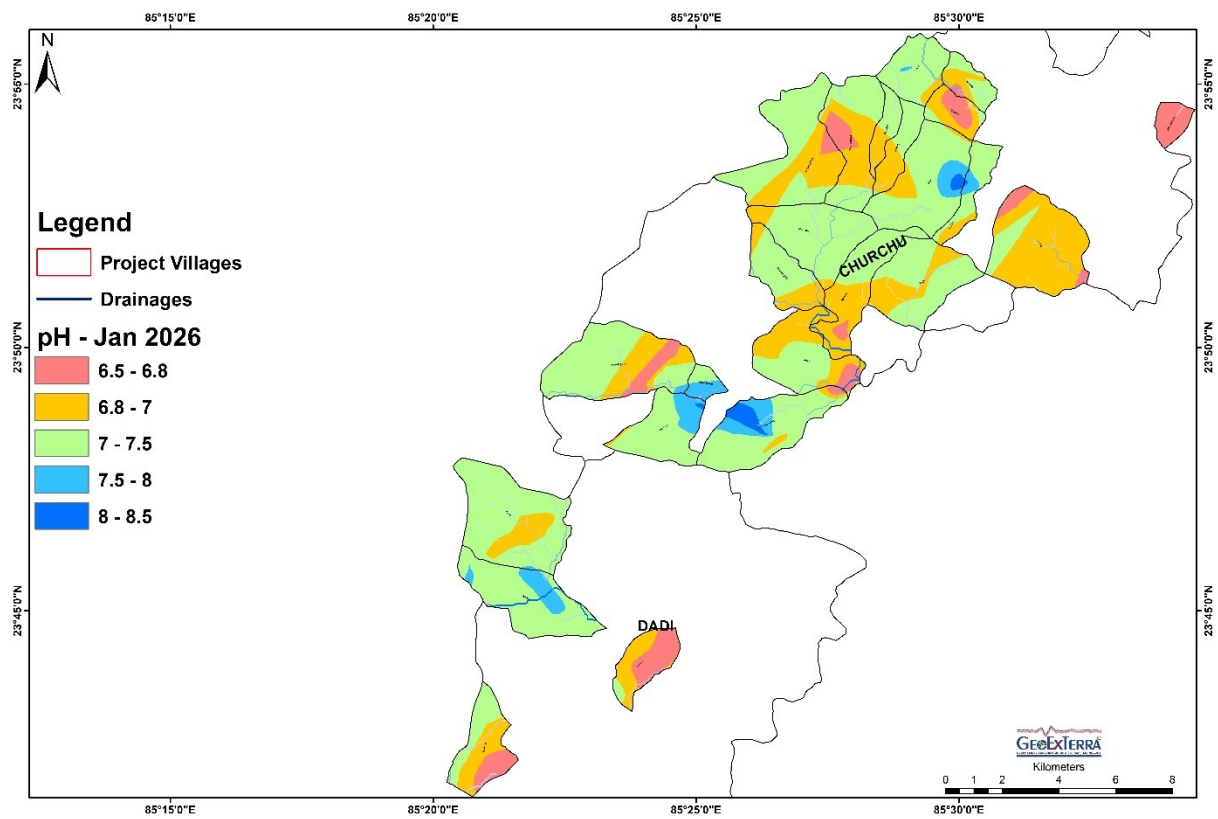


Fig. 53 pH of Groundwater During Jan 2026 in the Project Villages of Hazaribagh.

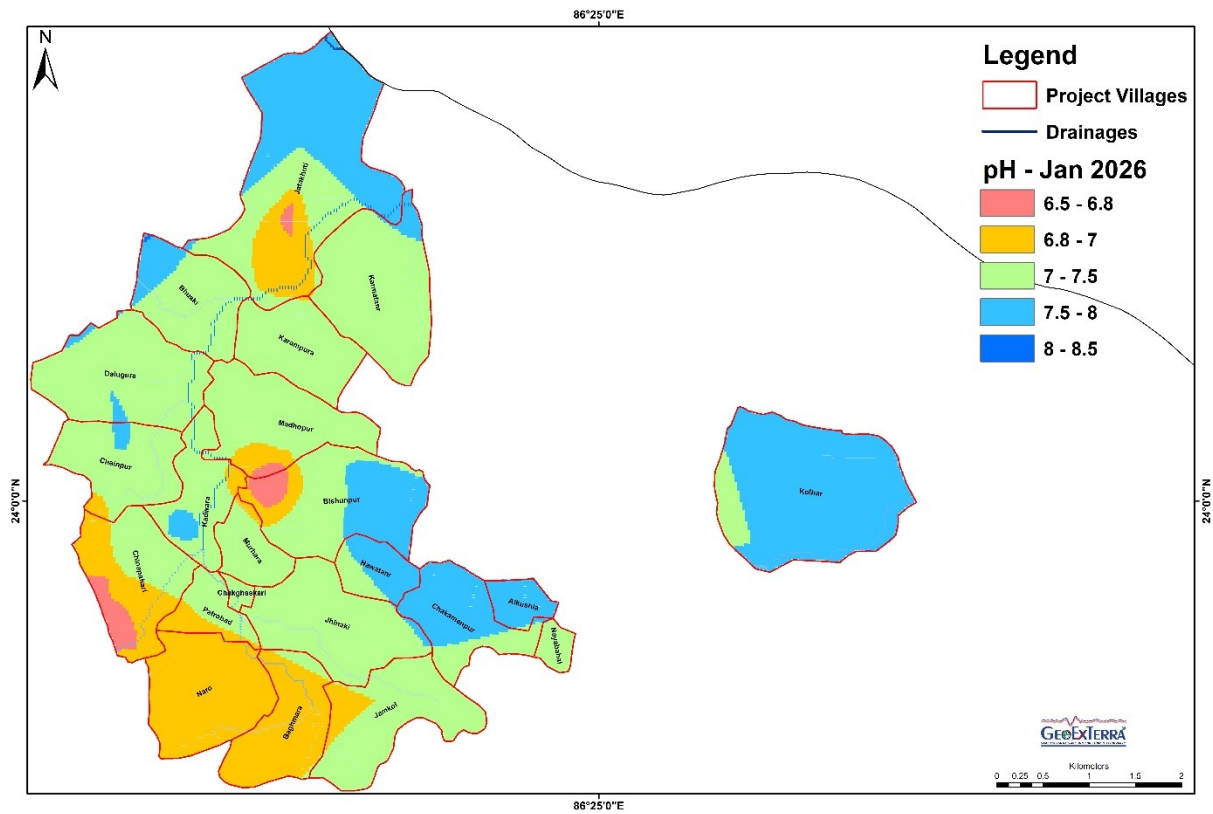


Fig. 54 pH of Groundwater During Jan 2026 in the Project Villages of Dhanbad.

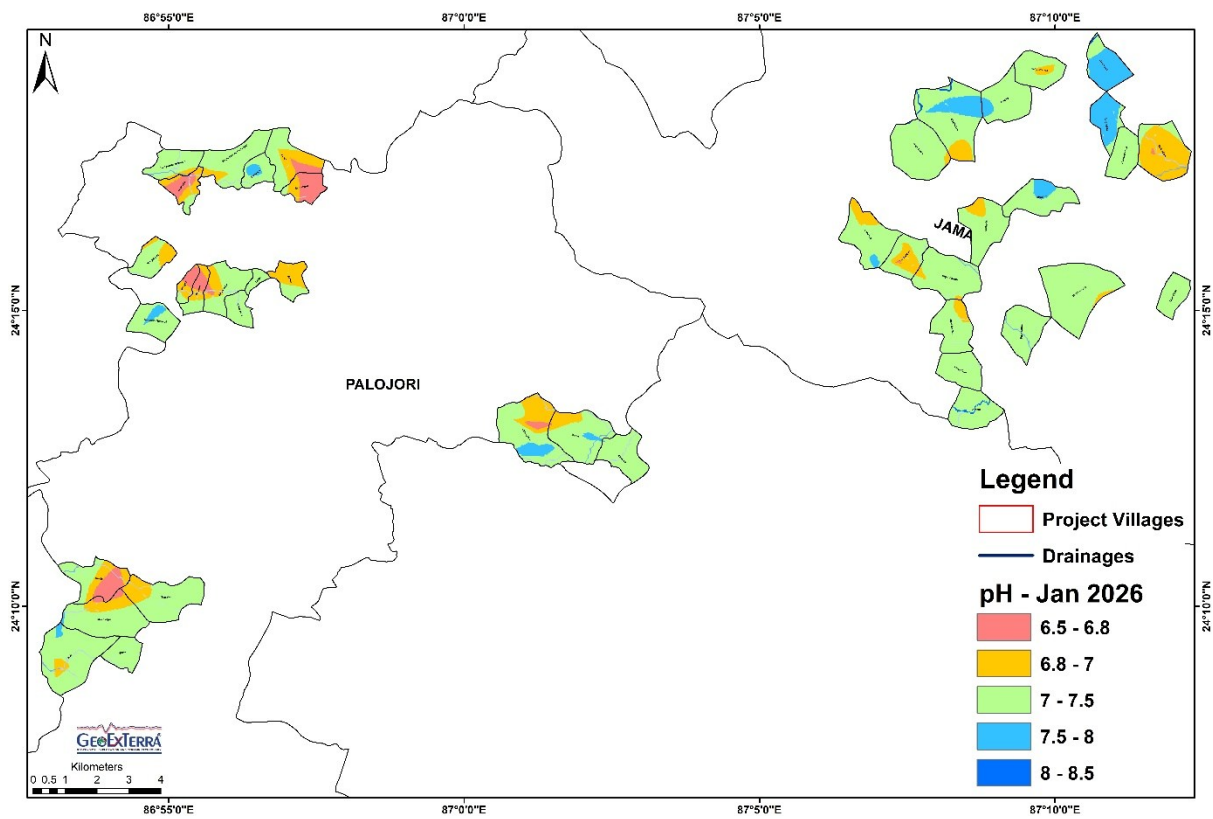


Fig. 55 pH of Groundwater During Jan 2026 in the Project Villages of Deoghar and Dumka.

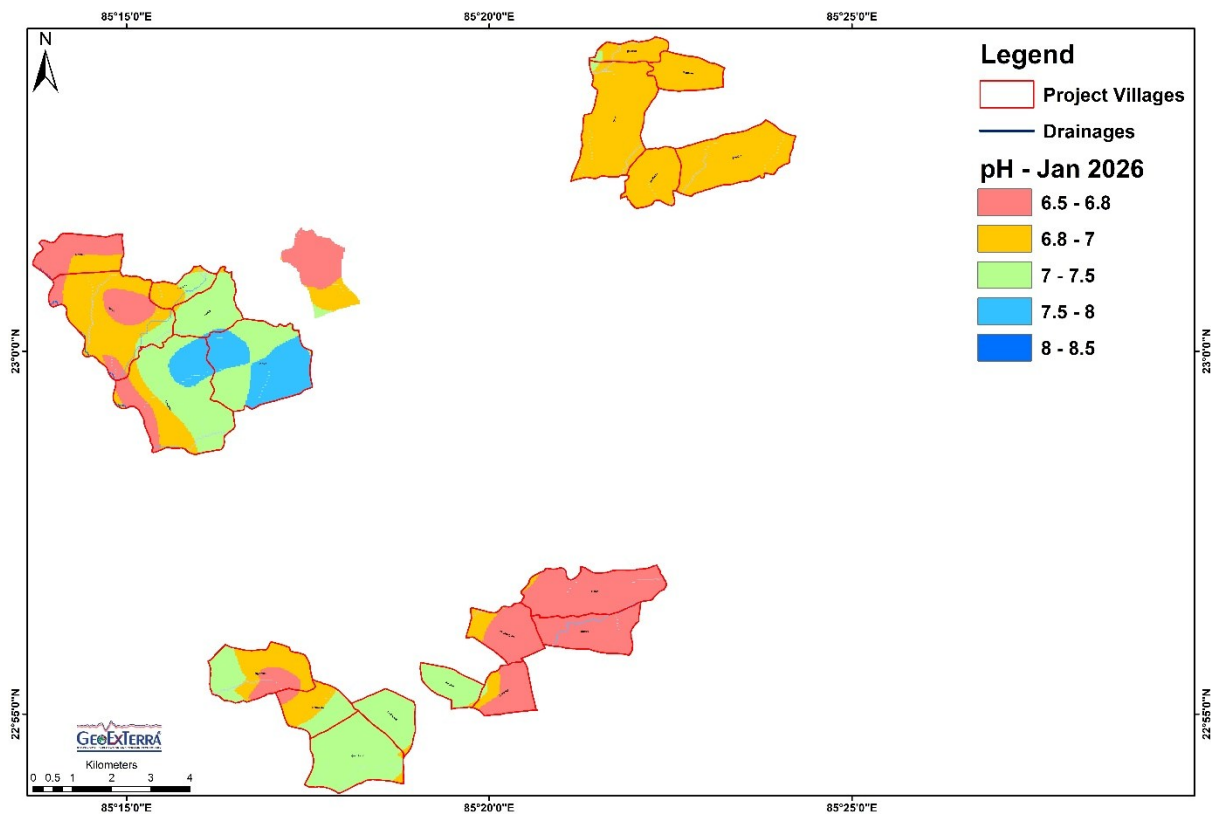


Fig. 56 pH of Groundwater During Jan 2026 in the Project Villages of Khunti.

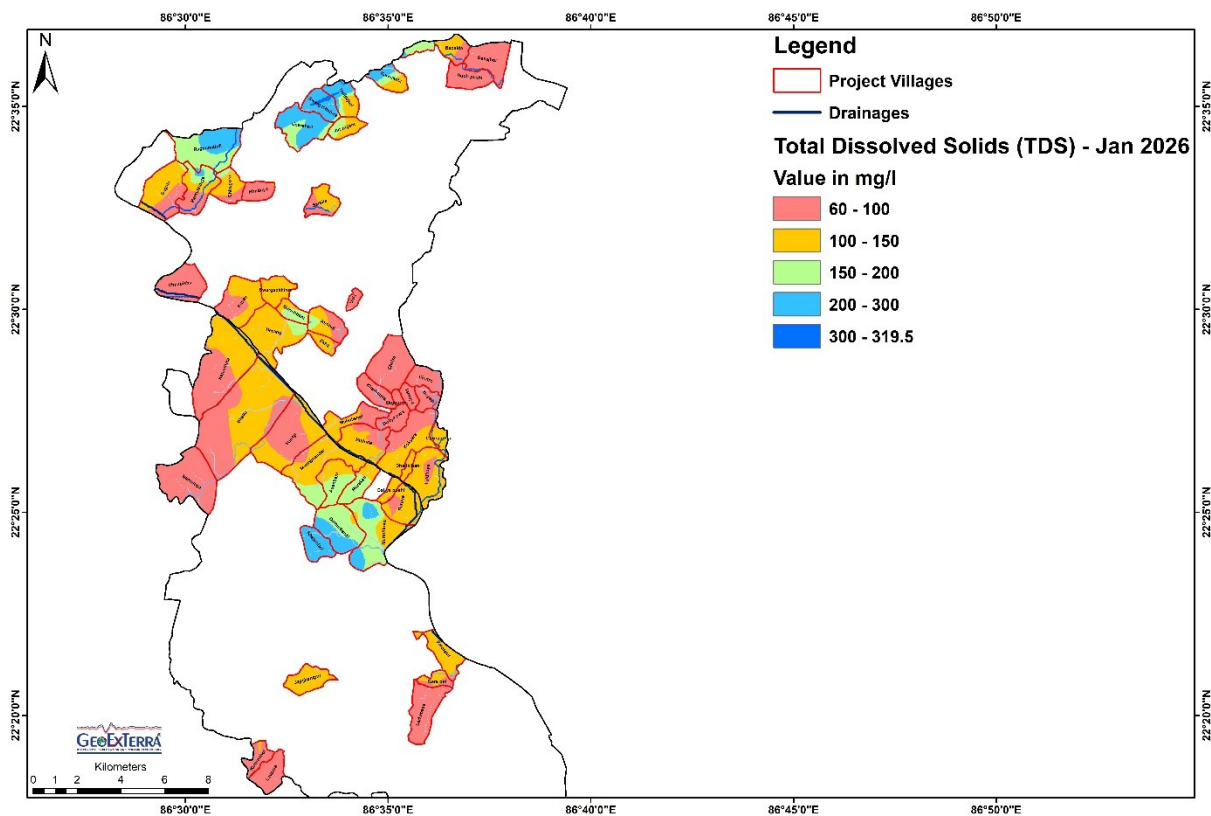


Fig. 57 Total Dissolved Solids (TDS) of Groundwater During Jan 2026 in the Project Villages of East Singhbhum.

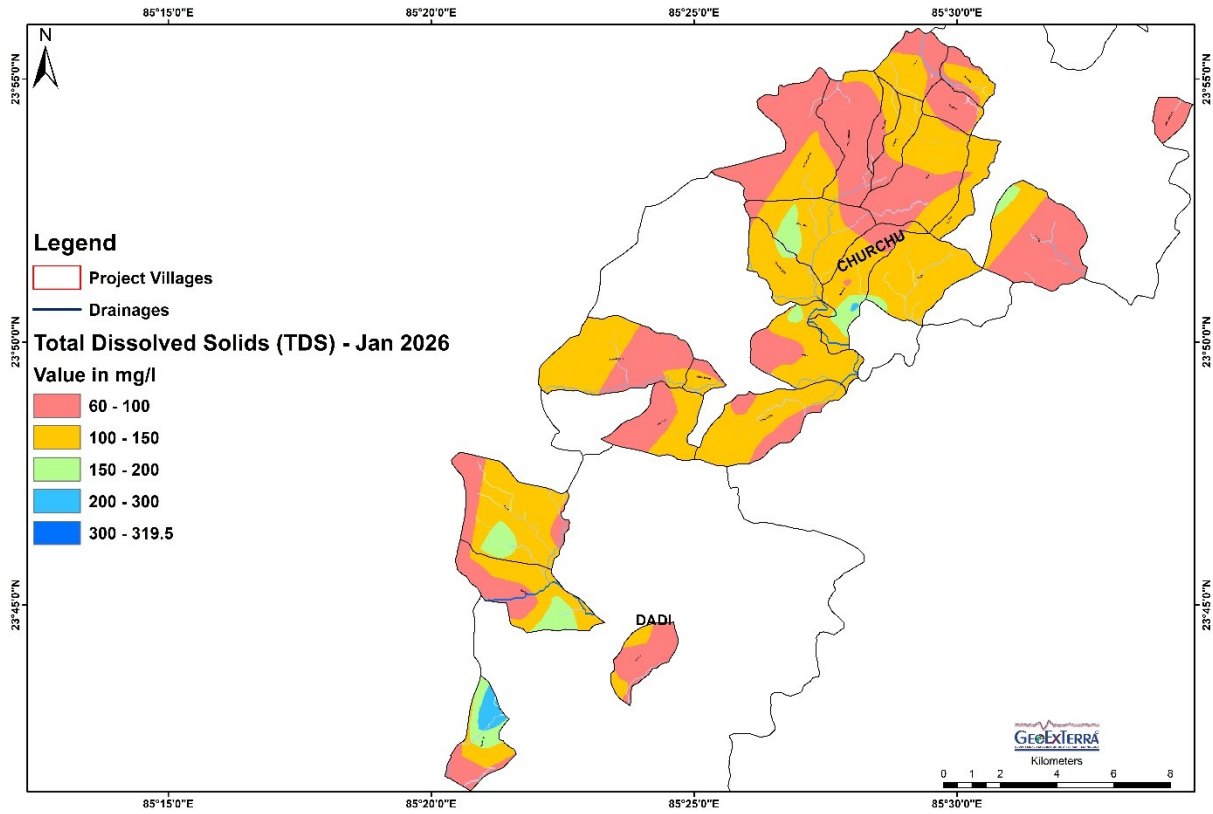


Fig. 58 Total Dissolved Solids (TDS) of Groundwater During Jan 2026 in the Project Villages of Hazaribagh.

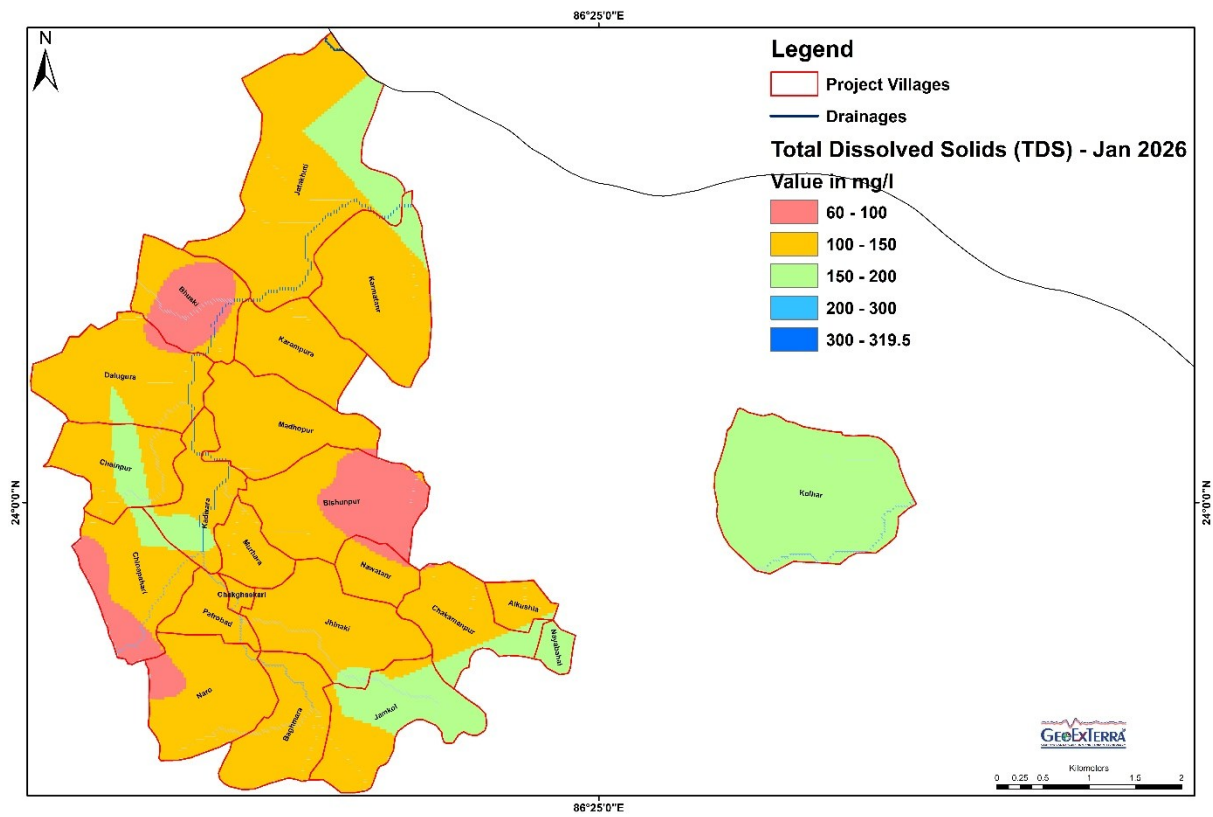
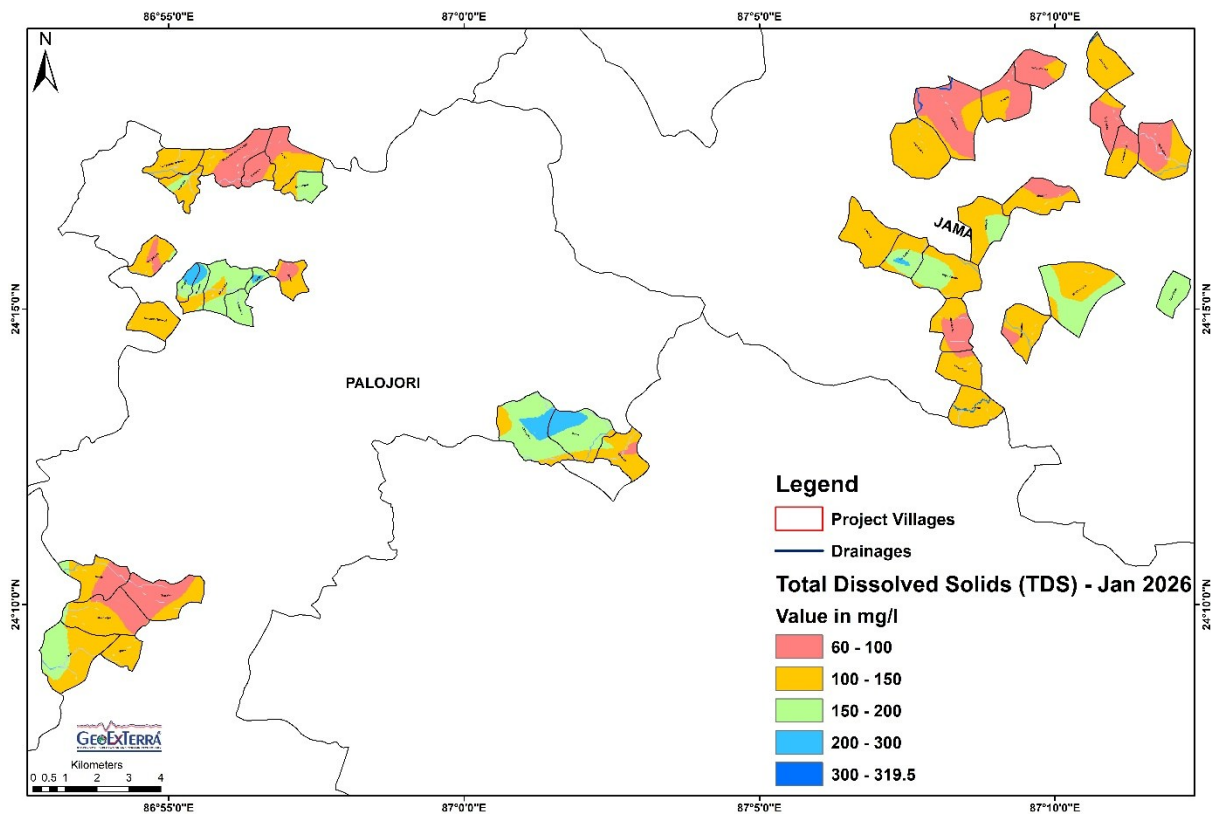
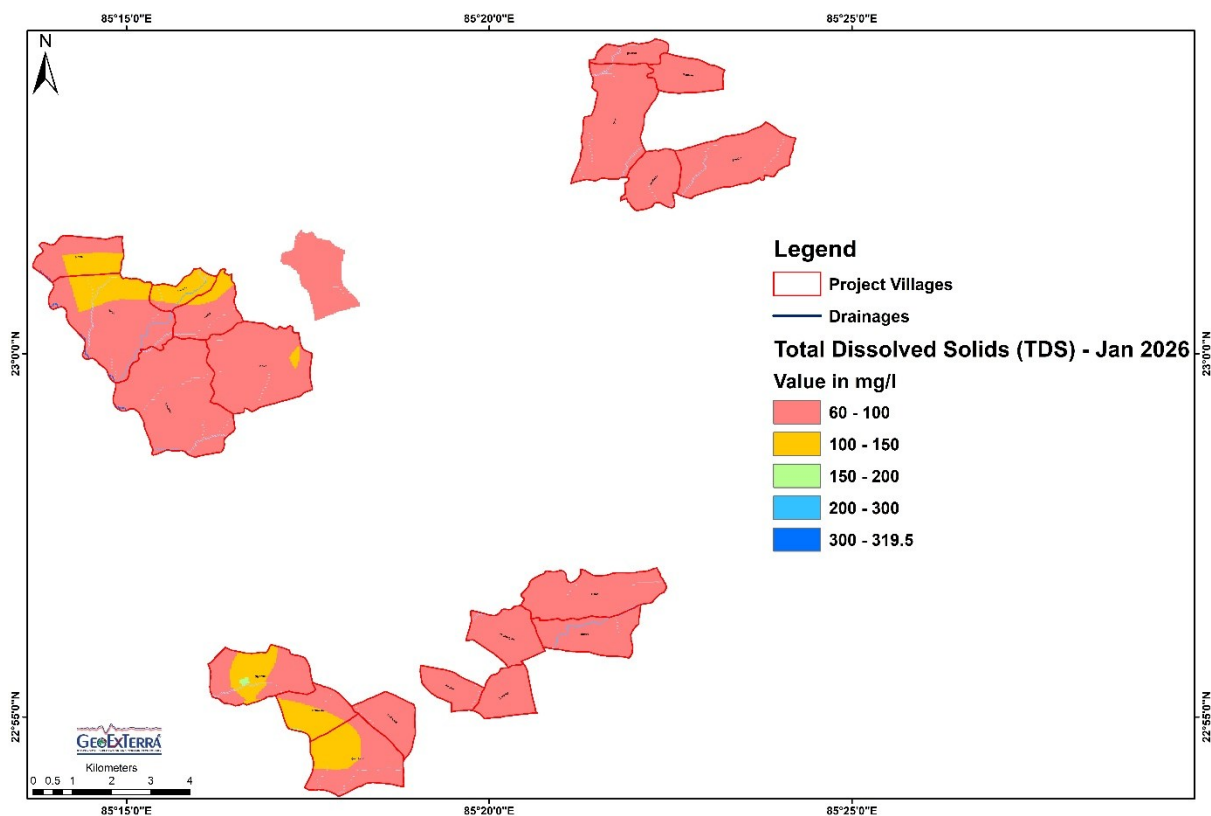


Fig. 59 Total Dissolved Solids (TDS) of Groundwater During Jan 2026 in the Project Villages of Dhanbad.



**Fig. 60 Total Dissolved Solids (TDS) of Groundwater During Jan 2026 in the Project Villages of Deoghar and Dumka.**



**Fig. 61 Total Dissolved Solids (TDS) of Groundwater During Jan 2026 in the Project Villages of Khunti.**

in groundwater, confirming good hydrochemical quality and limited salinity hazard (Figs. 62 to 66). The observed temperature range (~16°C to 28°C) is consistent with shallow to intermediate groundwater circulation and does not indicate any thermal anomaly or deep geothermal influence (Figs. 67 to 71). From a hydrogeochemical perspective, the overall groundwater quality is governed by silicate weathering of crystalline rocks (granites, gneisses, schists), resulting in low dissolved ion concentrations and stable pH conditions. The absence of extreme EC and TDS values indicates minimal anthropogenic contamination and limited evaporative concentration, suggesting that recharge is predominantly from direct rainfall infiltration and surface runoff percolation. Based on the integrated analysis of groundwater levels and water quality parameters, it is conclusively established that groundwater across the project area is largely suitable for drinking purposes as per BIS 10500:2012/2015 standards, with most samples falling within acceptable limits for pH, TDS, and EC. Only localized areas with relatively higher TDS or slightly elevated alkalinity may require basic treatment such as filtration or blending, but do not pose significant health risks. Furthermore, the moderate mineralization and near-neutral pH also make the water suitable for irrigation, with low salinity hazard and minimal risk to soil productivity. In summary, the well observatory data highlights a hydrogeologically favorable regime characterized by shallow to moderate groundwater levels, good recharge conditions in structurally controlled zones, and overall potable water quality, thereby supporting sustainable groundwater development. However, spatial variability in water levels and localized quality variations necessitate site-specific groundwater management strategies, including recharge enhancement in deeper water level zones and periodic water quality monitoring to ensure long-term climate-resilient water security in the project districts.

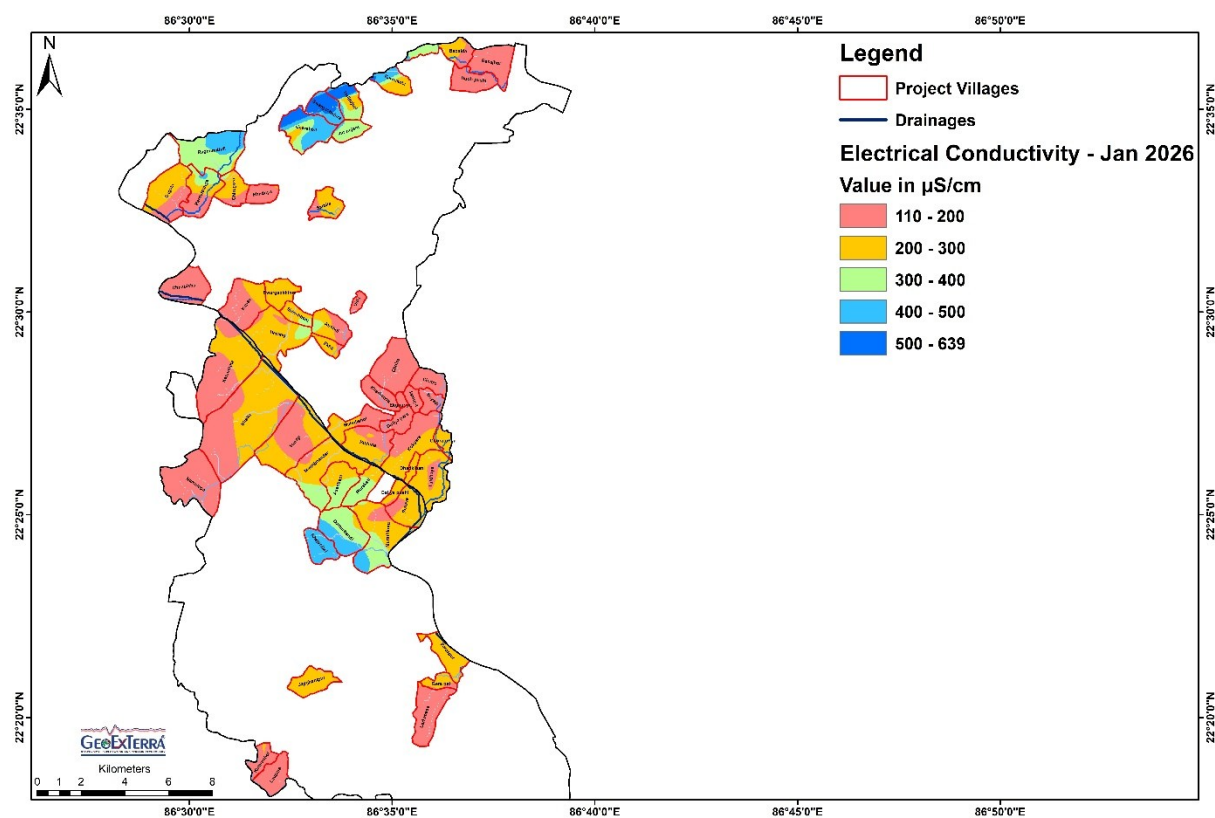


Fig. 62 Electrical Conductivity (EC) of Groundwater During Jan 2026 in the Project Villages of East Singhbhum.

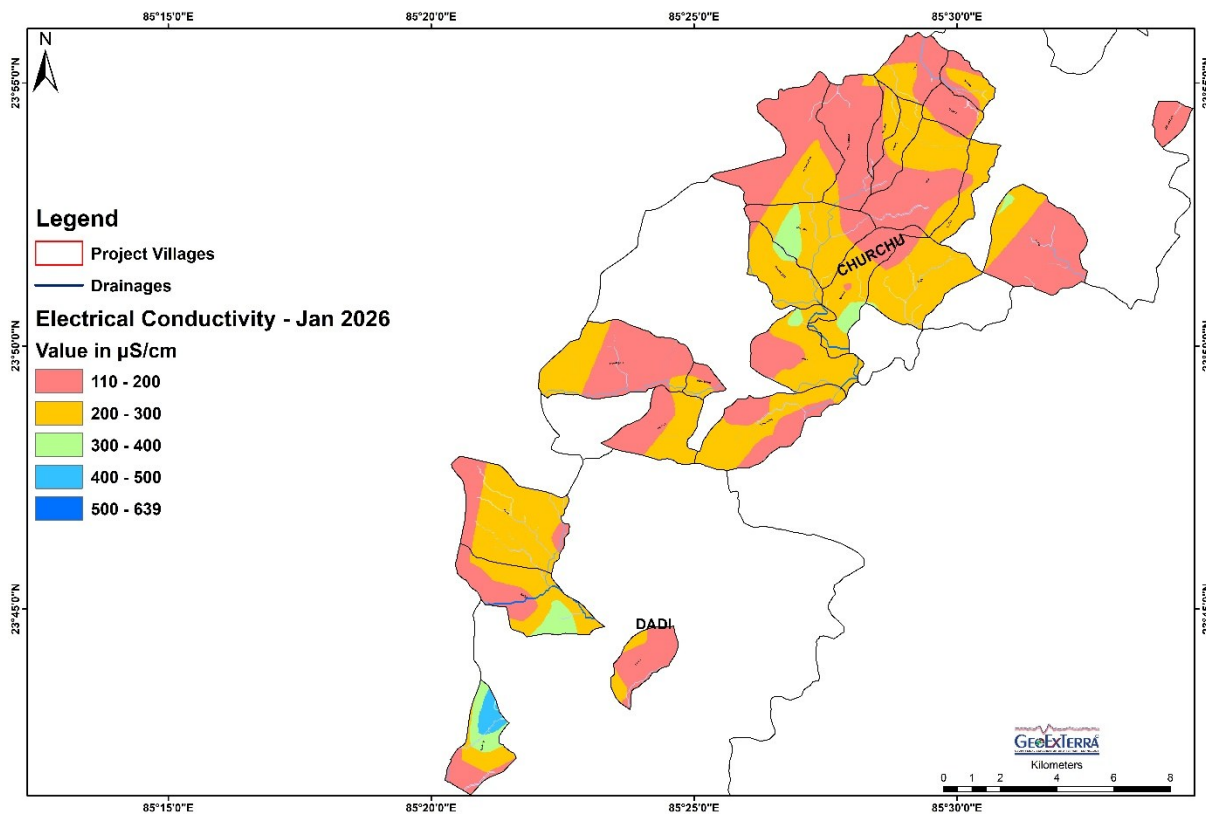


Fig. 63 Electrical Conductivity (EC) of Groundwater During Jan 2026 in the Project Villages of Hazaribagh.

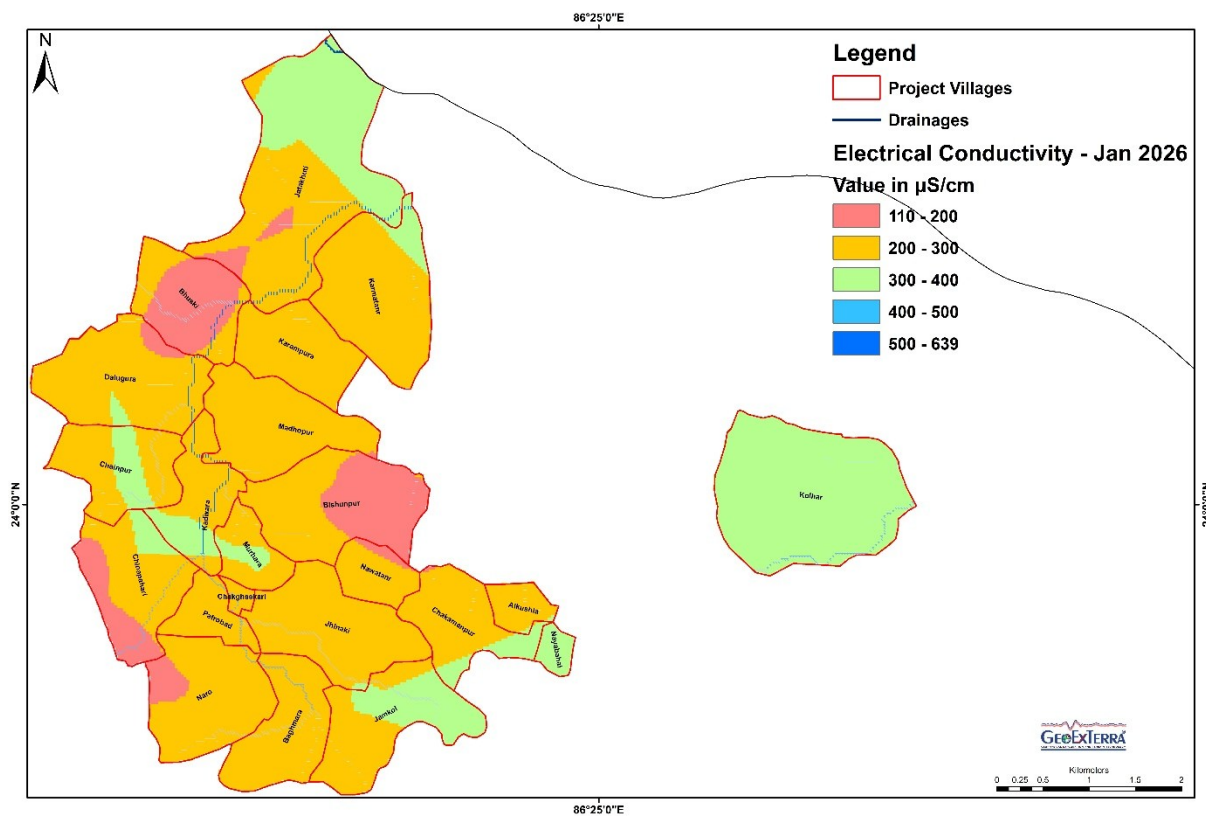
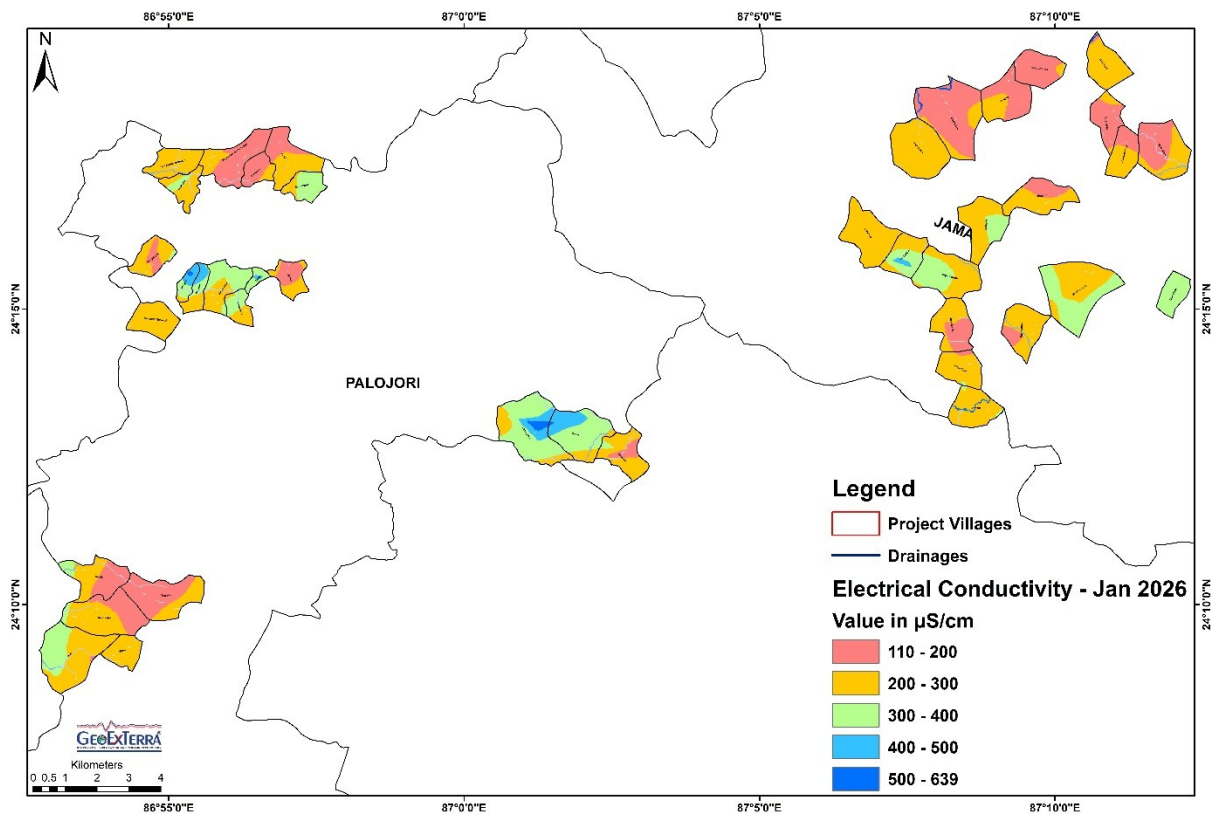
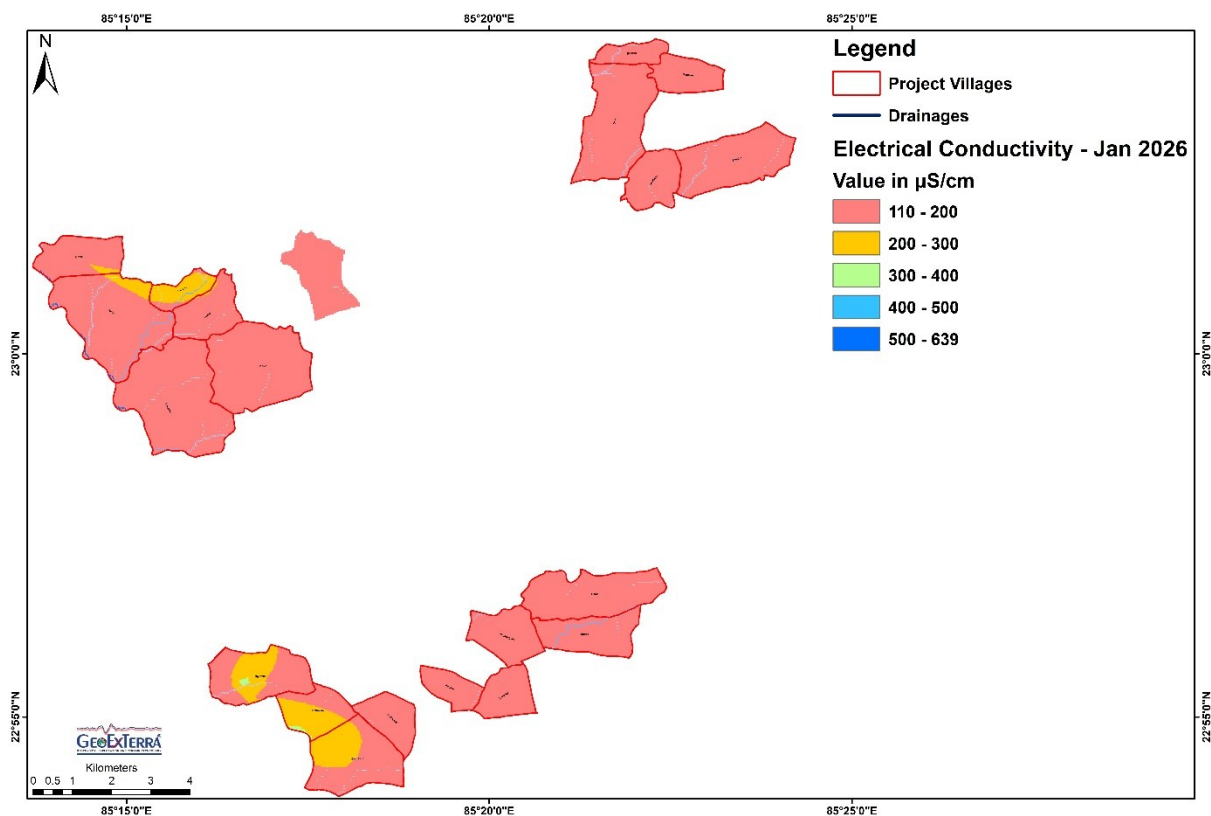


Fig. 64 Electrical Conductivity (EC) of Groundwater During Jan 2026 in the Project Villages of Dhanbad.



**Fig. 65 Electrical Conductivity (EC) of Groundwater During Jan 2026 in the Project Villages of Deoghar and Dumka.**



**Fig. 66 Electrical Conductivity (EC) of Groundwater During Jan 2026 in the Project Villages of Khunti.**

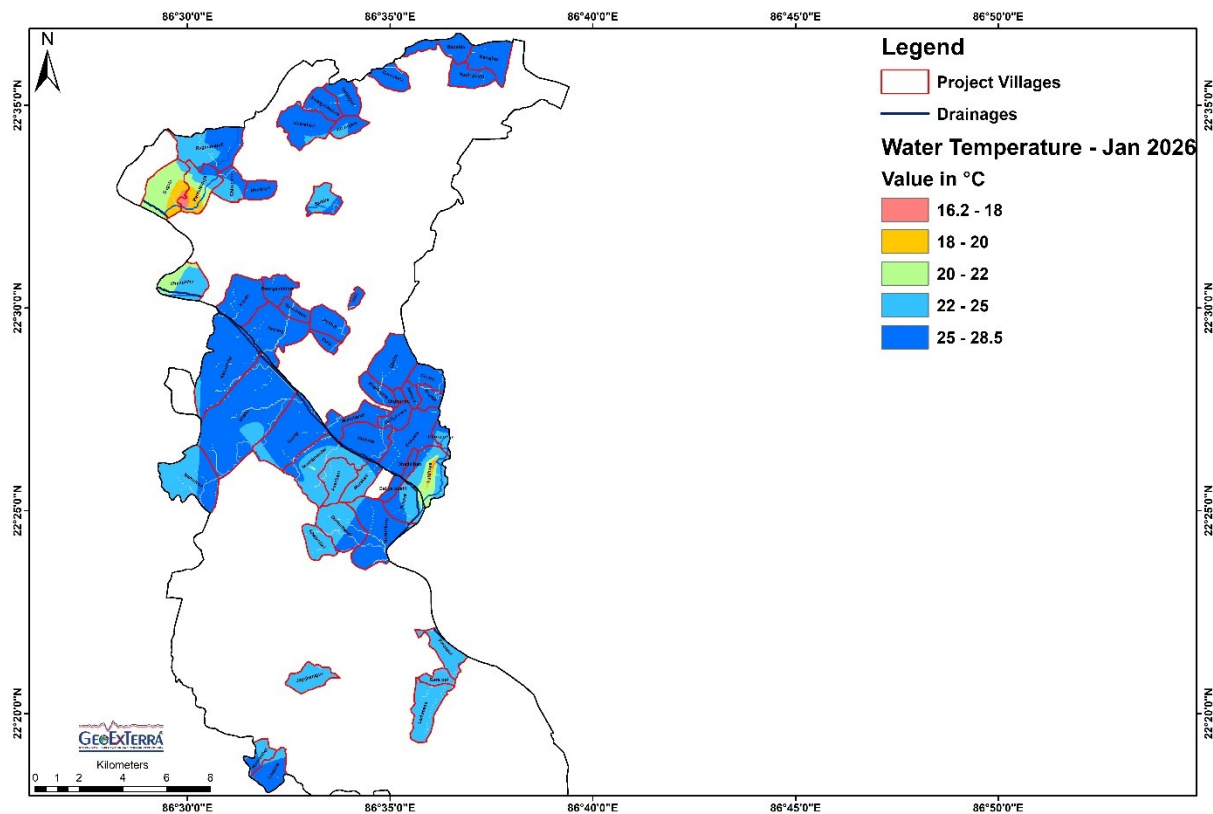


Fig. 67 Temperature of Groundwater During Jan 2026 in the Project Villages of East Singhbhum.

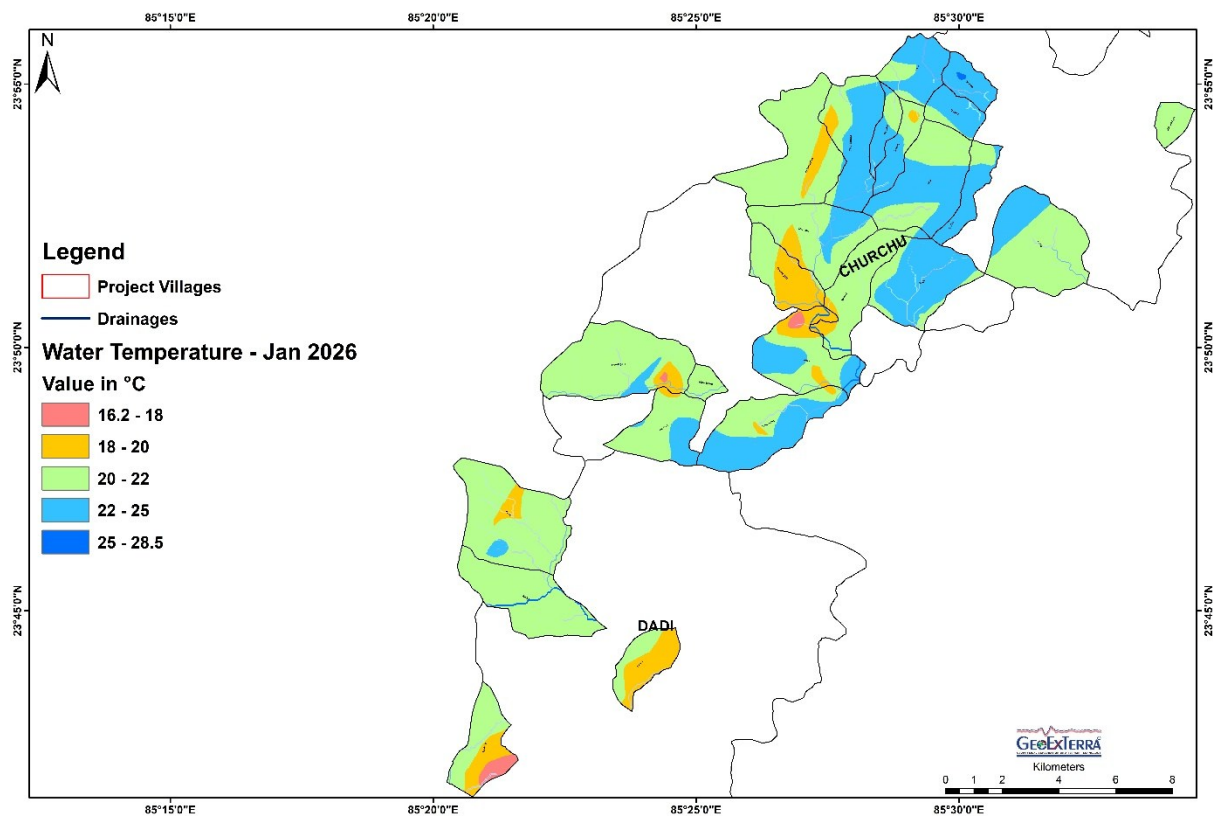


Fig. 68 Temperature of Groundwater During Jan 2026 in the Project Villages of Hazaribagh.



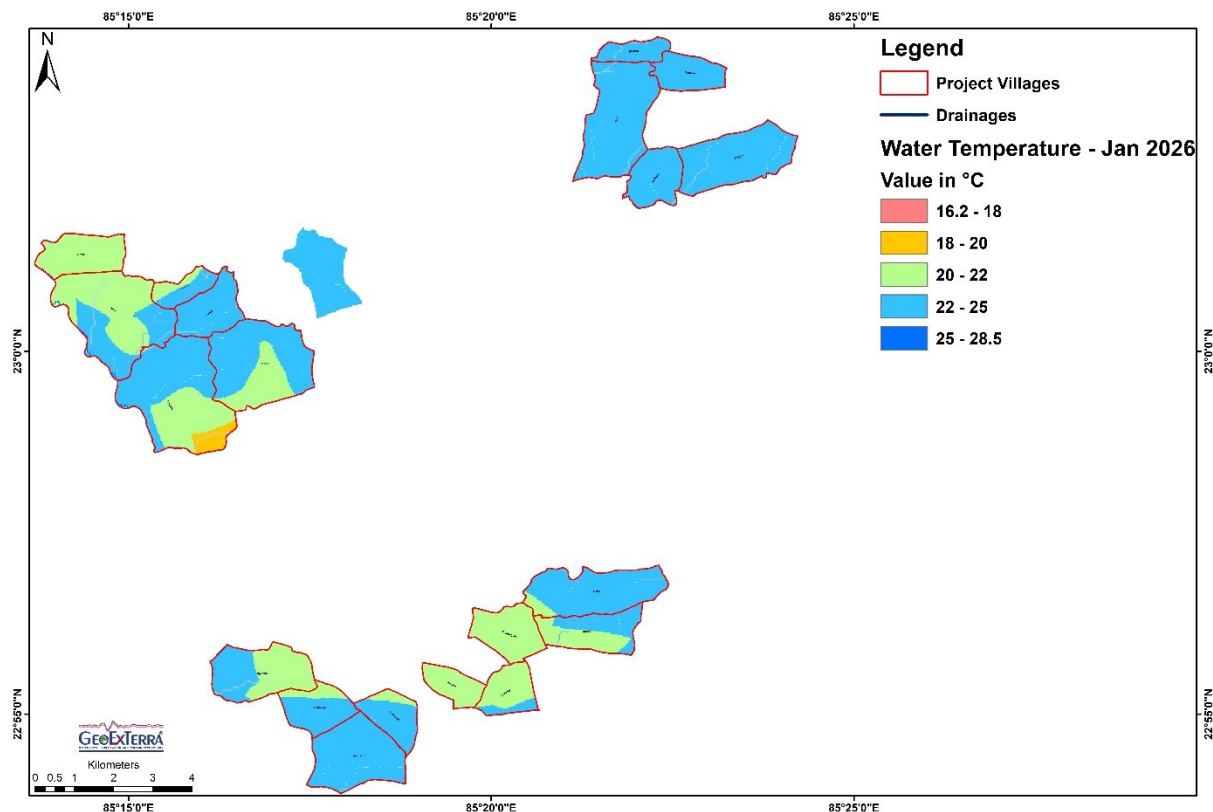


Fig. 71 Temperature of Groundwater During Jan 2026 in the Project Villages of Khunti.

Table 2 Water Level and Water Quality Parameters - Jan 2026.

ID	Village	Latitude°	Longitude°	Water Level (mbgl)	pH	TDS (mg/l)	Electrical Conductivity (µS/cm)	Temperature (°C)
W16	Outer	22.60995	86.61692	2.4	7.01	80	140	25.6
W40		22.48772	86.50881	3.95	7.16	110	230	26.6
W186		23.81424	85.46071	2.4	7.47	100	190	23.3
W97	Amgachhi	23.02803	85.29137	2.9	6.69	60	120	23.4
W341		24.30375	87.17853	2.25	7.98	70	140	21.9
W29	Asanbani	22.43082	86.55939	1.1	7.1	150	290	23
W342		24.31726	87.18072	6.3	7.63	150	290	21.1
W333		24.32085	87.18249	4	7.96	120	230	19.9
W17	Babaidda	22.60884	86.61082	2.85	6.68	130	260	26.9
W316	Baghmara harladangal	24.28843	86.93305	4.95	6.96	60	120	22.7
W335		24.29320	86.93116	4.1	7.36	110	220	18.4
W18	Bagula	22.54638	86.49830	0.55	6.6	60	120	17
W204	Bahera	23.85175	85.46511	4.5	6.93	90	180	21.3
W208		23.85547	85.46394	3.6	7.14	120	240	20.3
W202		23.84451	85.46733	7.4	6.8	220	380	20.1
W201		23.83735	85.46147	2.8	6.78	140	280	20.4
W238	Bali	23.89519	85.48344	3.75	7.06	120	240	21.6
W239		23.89433	85.49853	4.1	7.34	130	250	20.5
W234		23.88521	85.50017	5.85	8.5	90	150	24.5
W227		23.87876	85.49285	3.1	7.06	100	190	21.8
W226		23.87489	85.47809	2.8	7.19	90	150	20.9
W232	Baramasia	23.88461	85.48303	3.05	6.86	80	160	23.7
W323		24.29188	87.12951	6.05	7.1	130	270	22.7
W324	Barudih	24.29761	87.12072	7.85	7.11	150	300	20.9
W310		24.25347	87.18109	5.6	6.85	170	350	19.3
W334	Basmata	24.28124	86.92193	4.35	7.06	130	250	20.3
W315		24.28688	86.92118	4.7	6.6	160	320	19.8
W287	Bedia	24.21362	87.02656	6.55	7.41	180	350	19.9
W291		24.21879	87.03068	4.2	6.94	220	440	22.2

W292		24.21446	87.03675	0.65	7.72	160	320	21.6
W248	Belgara	23.91553	85.47758	3.1	7.3	110	200	22.3
W302	Belmi	24.25997	86.94840	5.35	6.89	80	150	21.4
W48	Bera pal	22.35068	86.60480	2.9	7.05	130	260	24.5
W21	Bhaduya	22.55162	86.52774	5.5	6.78	90	180	26.3
W9		22.46176	86.54043	1.4	8.39	60	130	25.3
W30		22.44965	86.52120	3.7	6.9	130	250	23.7
W32		22.44970	86.52114	3.6	7.6	130	250	26.6
W33	Bhalki	22.46347	86.53141	3.1	7.36	150	300	25.9
W34		22.46469	86.53761	2.2	7.05	130	260	27
W35		22.46486	86.52036	2.05	7.09	80	170	28.2
W39		22.46921	86.52737	7.9	7.42	130	270	27
W308		24.26007	87.16462	5.4	7.18	170	350	19.4
W309	Bhotokauria	24.25815	87.17195	3.05	7.48	110	210	18.8
W303		24.24695	87.17285	4	7.15	170	340	16.2
W70		23.06723	85.35674	1.2	7.13	60	120	22.3
W71	Bhursa	23.06893	85.36261	0.55	6.85	60	110	24.3
W347		24.02551	86.37263	3.35	8.02	130	250	17
W269	Bhuski	24.01913	86.37676	3.3	7.09	70	130	17.2
W306		24.25995	87.13297	1.95	7.12	180	370	17.4
W307	Bigai bandh	24.25959	87.13984	5.3	7.41	140	280	17.2
W31		22.44811	86.57837	1.8	6.55	60	120	26.3
W53	Bihinda	22.45114	86.57077	7.3	7.03	90	170	26.2
W54		22.44915	86.57535	5	7.2	110	220	26.8
W78	Binda	22.91287	85.28943	2.7	7.03	160	330	25.03
W321	Birajpur	24.28413	87.16227	6.5	7.56	90	180	17
W263		23.99938	86.39511	2.05	7.76	70	140	17.5
W262	Bishunpur	24.00176	86.38486	0.55	6.51	100	200	18.1
W240		23.89436	85.50933	6.2	7.09	140	290	21.3
W235	Bodra	23.88733	85.50509	4.9	7.46	100	200	23.1
W265	Chainpur	24.00632	86.37467	1.1	7.21	110	220	16.8
W260	Chakamanpur	23.98900	86.40409	0.55	7.86	120	240	18.6
W215		23.86889	85.44712	3.5	7.3	170	340	19.5
W223		23.87376	85.44714	3.1	7.18	160	330	20.2
W216	Chanaro	23.86785	85.45560	1.8	7.39	120	240	22
W207		23.86072	85.45835	2.7	7.03	110	220	22.3
W330		24.30538	87.15260	3.7	7.11	100	200	19.2
W329	Chatra	24.30561	87.14760	3.85	7.64	130	240	17
W56	Chatro	22.47400	86.59909	2.35	6.6	60	120	26.7
W74	Chendagutu	22.93399	85.33954	2	6.53	90	180	21.4
W289		24.22001	87.01152	7.2	7.11	140	280	20.5
W290	Chhaglajor	24.21786	87.02007	4.25	6.58	290	590	21.1
W286		24.21098	87.02106	4.55	7.63	170	340	20.1
W241		23.90434	85.45854	2.9	6.6	80	160	18.2
W246		23.91395	85.45971	3.9	7.08	90	160	21.1
W242		23.90438	85.46915	3	6.9	80	160	23
W236	Chichikhurd	23.89933	85.46524	1.8	6.77	80	150	23.3
W225		23.87972	85.47094	8.8	7.1	70	140	23.3
W247		23.91490	85.46548	3.4	7.34	90	190	22.3
W349		23.99585	86.37199	7.05	7.25	150	310	23.2
W350	Chinapahari	23.98927	86.36879	0.8	6.71	90	180	22.1
W57		22.47907	86.58688	2.05	6.68	60	120	26.5
W58	Choiria	22.48028	86.58255	3.35	6.6	60	120	26.9
W311	Chundoba	24.25864	87.20319	1.35	7.14	180	370	18.7
W348		24.01517	86.36864	6.7	7.32	120	240	22.5
W264	Dalugura	24.00786	86.36945	2	7.63	180	350	17.1
W317	Damadih	24.28911	86.94054	3.5	7.67	80	170	19.6
W72	Damriay	22.92114	85.33817	0.55	6.64	80	150	21.6
W326	Dandodumria	24.29341	87.18694	4.2	7.16	110	230	16.2
W192		23.81933	85.46006	4.05	6.6	100	210	18.9
W180		23.80568	85.43902	3.15	8.05	130	250	19.6
W181	Daso khap	23.80451	85.44288	5.6	6.9	90	170	24.2
W184		23.81192	85.43107	1.6	8.29	90	130	20.09
W179		23.80552	85.42515	4.3	7.29	130	250	22.1
W75	Dekla	22.94086	85.34970	1.8	6.76	60	120	22.1
W43		22.49704	86.53497	2.2	7.02	120	230	26.02
W44	Derang	22.49072	86.54235	3.25	7.59	140	290	26.7
W45		22.49712	86.53568	2.35	6.97	110	220	26.2
W46		22.49664	86.53729	2.4	7.25	130	130	25.4

W244	Dumar	23.90590	85.50211	3.7	6.59	60	120	23.2
W25	Dumurbandi	22.40087	86.56565	2.5	6.87	240	480	27.6
W327	Gaibathan	24.29506	87.19410	4.3	6.78	80	160	18.5
W69	Gajgaon	22.99083	85.24890	1.9	6.6	70	190	23.03
W85		22.99585	85.26418	2.9	7.87	80	140	22.3
W86		22.98428	85.26353	3.5	7.06	60	120	21
W87		22.97714	85.26929	0.55	7.06	60	120	18.7
W300		24.26119	86.93258	5.8	7.13	150	310	21.6
W296	Ghorparha	24.25451	86.92942	3.95	6.78	130	250	22.7
W77	Gumpuru	22.90528	85.30840	0.55	7.05	80	150	24.3
W65	Haildajuri	22.58732	86.56157	2.95	7.41	260	270	24.4
W66		22.58668	86.56495	5.5	6.96	120	250	25.5
W79	Hansa	22.98971	85.28321	1.1	7.91	70	120	20.1
W80		22.99253	85.28801	2.7	7.8	80	150	22.5
W81		22.99859	85.28885	3.9	7.85	110	200	23
W82		23.00151	85.28116	5.5	7.34	60	160	21.7
W83		22.99929	85.27216	2.6	7.95	80	140	24.3
W84		22.99231	85.27286	4	7.08	60	120	23
W178	Harhad	23.80880	85.41532	0.95	7.68	120	260	22.5
W183		23.81523	85.41694	2	8.04	140	280	21
W182		23.81407	85.40619	3.15	7.21	70	140	21.5
W190	Hendegara	23.82407	85.40628	5.85	7.33	100	190	17
W189		23.82183	85.39902	6.65	6.6	70	130	23
W196		23.83016	85.40856	0.55	6.78	80	150	20.5
W88	Hesel	23.02303	85.23395	2	6.71	90	120	20.9
W89		23.02056	85.24139	1.4	6.9	150	200	20.01
W200		23.84076	85.44755	2.55	6.83	160	320	17
W193	Indra	23.81998	85.46550	6.75	6.67	130	260	23.9
W199		23.82704	85.45383	1.55	7.44	140	290	19.7
W191		23.82298	85.44631	3.85	7.03	120	240	21.5
W197		23.83419	85.43517	3.45	6.83	60	110	23.4
W198		23.82997	85.44922	4.2	7.2	70	130	24
W257	Jamkol	23.98058	86.39431	8.25	6.99	160	310	20.8
W55	Jamuya	22.46481	86.59286	3.15	6.6	80	160	26.5
W67	Jar pojara	22.57639	86.56605	5.7	7.04	150	360	25
W312	Jarjokha	24.27507	87.11284	4.3	6.96	130	260	16.3
W340		24.26450	87.11607	0.6	7.59	110	220	17.8
W275	Jatakhuti	24.03615	86.38767	5.55	7.69	150	310	17
W273		24.02836	86.38661	0.55	6.72	100	190	16.5
W231		23.89021	85.47413	1.2	6.8	90	170	24.1
W243	Jordag	23.90684	85.48582	6	7.3	120	250	19.2
W237		23.89897	85.48161	3.2	7.05	110	230	22.5
W59	Jorshol	22.49471	86.55167	5	6.6	210	410	25.6
W60		22.49531	86.56140	5.5	6.88	60	120	26.4
W261	Kadwara	23.99759	86.37607	7.3	7.66	160	320	18.7
W205	Kajri	23.84877	85.47909	3.2	6.86	120	240	23.5
W209		23.85726	85.47734	3	7.03	100	200	21.4
W210		23.85724	85.48449	3.6	7.13	110	210	22.8
W206		23.85009	85.48860	8.9	6.95	110	210	24
W203	Kalipurranga	23.84372	85.48885	5.8	7.36	130	260	21.9
W331		24.31692	87.15637	3	7.32	90	180	20.6
W332	24.31838	87.16356	4.2	6.84	100	190	22.2	
W36	Kananluka	22.47103	86.51576	0.8	6.6	70	140	27
W37		22.47194	86.51246	0.55	7.1	60	120	26.4
W38		22.47988	86.51150	0.55	6.69	90	180	27.9
W41	Kanas	22.50825	86.52617	1.45	7.11	120	240	27.2
W42		22.50280	86.52292	1.05	7.08	90	120	25.7
W276	Kanki	24.14203	86.88655	1.9	7.16	120	240	17.9
W345		24.15125	86.89516	3.8	7.1	100	190	18.8
W277		24.15057	86.88493	4.9	6.88	190	350	19.4
W279		24.15874	86.88544	4.45	7.57	160	330	18.6
W150		23.72140	85.39250	3.05	7.1	110	230	20.3
W152		23.73343	85.40255	2.7	6.53	80	130	18.5
W151	Karampura	23.73279	85.39191	4.5	6.93	90	190	20.3
W156		23.74023	85.40111	5.6	6.98	110	210	21.5
W270		24.01628	86.38524	5.15	7.12	140	290	18.4
W229	Kargi	23.87850	85.51630	4.3	6.71	160	310	24.3
W76	Katingkel	22.91880	85.31478	1.7	7.48	60	130	22
W288	Khairwa	24.21090	87.04096	5.4	7.1	170	340	21.1

W346		24.21057	87.04735	3.95	7.26	90	170	21.4	
W294	Khapchua	24.22886	87.14084	5.45	7.42	150	310	20.3	
W26	Khejurdari	22.40316	86.55747	3.5	6.98	250	490	23.1	
W14		22.43629	86.58827	0.85	7.44	120	250	25.4	
W15	Kokpara	22.43912	86.58563	9.35	7.68	110	210	28.6	
W50		22.43746	86.58537	1.2	7.35	120	230	25.9	
W52		22.43531	86.58832	4	7.25	150	310	26.8	
W322	Kolgi	24.29653	86.94591	0.55	7.09	60	120	18.2	
W336		24.29267	86.95101	4.4	6.79	130	250	17.6	
W352	Kolhar	23.99648	86.43066	4.75	7.09	170	330	18.7	
W353		23.99521	86.43177	4.2	7.86	170	340	17.9	
W319	Kulhoria	24.2779	87.14421	5.7	6.88	130	260	19.4	
W320		24.27442	87.14947	5.3	7.11	170	340	20.1	
W2	Kumrashol	22.32058	86.5307	1.75	6.85	120	230	22	
W3		22.3208	86.53168	1.85	6.6	60	120	23	
W96	Kundibartoli	23.01802	85.29428	2	6.6	60	120	24.1	
W168	Kura	23.78071	85.35508	3.55	7.33	130	240	19.5	
W169		23.779	85.36163	2.35	6.93	120	250	20.03	
W166		23.77029	85.37478	1.1	7.05	90	180	21.8	
W165		23.77011	85.36435	4.3	7.01	130	270	21.03	
W164		23.77045	85.35352	4.95	6.89	190	290	22.8	
W149		Kurkuta	23.71533	85.35057	2.7	7.02	250	500	21.2
W146			23.69888	85.34053	1	7.04	60	120	21.3
W147	23.69693		85.35108	2.38	6.6	90	180	16.5	
W305	Lakhanpur	24.26361	87.12201	2.8	6.75	220	440	18.6	
W313		24.26744	87.12576	2.6	6.98	140	280	18.3	
W10	Laldhuya	22.42564	86.59799	1.1	7.55	110	210	20.2	
W11		22.43677	86.59445	6.55	7.47	130	260	26.8	
W12		22.43677	86.602	0.55	6.6	60	120	17	
W13		22.44165	86.60422	4.75	7.66	120	240	24.4	
W253		23.92199	85.48423	3.8	7.55	150	250	21.4	
W249	Lara	23.91191	85.48943	2	6.9	100	180	23	
W254		23.92353	85.49183	4.1	7.15	70	130	23.3	
W47	Larkabasa	22.34049	86.60211	2.3	7.25	70	150	23.8	
W1	Laupara	22.30914	86.52998	0.55	6.6	60	120	25.7	
W314	Lodhna	24.27097	87.14135	5.05	7.66	100	190	17.8	
W301	Lusio	24.25911	86.94286	5.55	7.06	220	430	22.7	
W6	Madhbhandar	22.43472	86.55034	0.55	6.69	120	250	21.6	
W266	Madhopur	24.00548	86.38672	1.15	7.08	140	280	17.2	
W325	Madhuban	24.29689	87.14004	3.5	6.92	90	180	19.8	
W328		24.30742	87.13454	4	7.58	80	150	22	
W90	Mahil	23.00472	85.24111	2	6.93	80	160	22.5	
W91		23.00944	85.23912	2.6	6.91	100	200	22.3	
W92		23.00417	85.24917	2.3	6.93	60	120	21.3	
W93		23.00833	85.25222	3.1	6.6	70	190	22.09	
W51	Maholishol	22.45428	86.56016	4.97	7.55	140	270	26.8	
W280	Mashanjor	24.16302	86.89597	5.35	7.12	130	270	22.5	
W281		24.1599	86.90749	2.95	7.36	90	170	23.8	
W154	Misrain morha	23.74167	85.37129	0.55	7.08	200	390	21.3	
W318	Mohanpur	24.2841	86.95737	3.15	6.6	180	360	19.8	
W28	Murakati	22.42512	86.57188	1.25	7.23	180	370	24	
W23	Murathkura	22.41381	86.58428	5.5	6.6	100	210	27.7	
W24		22.41572	86.57576	1.5	7.15	280	140	28	
W27		22.4136	86.57038	2.8	7.25	130	250	25.4	
W351	Murhara	23.99515	86.38391	3.15	7.18	150	310	18.3	
W337	Nand kura	24.25352	86.93811	4.65	7.47	180	320	23.7	
W256	Naro	23.98315	86.37356	1.35	6.86	90	180	22.5	
W338	Nawadih nunurai	24.24922	86.91392	1.1	7.69	120	240	22.8	
W339		24.24536	86.9089	4.1	7.49	150	290	23.1	
W245	Oreya	23.90812	85.56215	3.6	6.87	60	110	23.9	
W344	Pachkathia	24.2411	87.15494	4.75	7.09	90	170	18.8	
W49	Paraspur	22.35705	86.60654	7.3	7.52	110	230	23.9	
W259	Patrobad	23.99072	86.37805	6.05	7.04	130	260	21.7	
W95	Perka	23.00972	85.27194	0.8	7.24	80	160	24.8	
W299	Phuljori	24.26	86.9227	5.7	6.6	260	530	24.2	
W295		24.25133	86.92049	2.5	7.12	130	260	23.6	
W19	Raghunathdi	22.55919	86.50369	0.7	6.6	180	350	24.6	
W20		22.55643	86.5054	4.8	7.63	240	470	26.1	
W22	Reruya	22.4215	86.58367	2.7	6.6	90	180	26	

W162		23.76203	85.36251	2.3	7.69	140	280	20.04
W161		23.76044	85.35401	1.2	7.04	120	230	21.03
W163		23.76671	85.3461	1.1	7.1	130	260	21.3
W160		23.76251	85.34489	4.3	7.59	60	120	20.6
W157	Rikba	23.75593	85.35034	4.1	7.18	60	140	20.8
W158		23.75119	85.36422	1.6	7.11	60	120	20.3
W153		23.74522	85.3618	2.4	7.04	100	210	20.8
W159		23.7512	85.37251	4.3	7.76	160	320	21.8
W155		23.74965	85.37997	4.1	7.06	140	280	20.3
W293	Sampur	24.22301	87.14282	4.65	7.33	140	280	18
W252	Sanri	23.9115	85.56699	0.7	6.6	60	120	20
W61	Sarbila	22.54967	86.55243	0.9	6.86	100	200	24.5
W94	Sardula	23.0155	85.26743	1.8	7.1	130	220	22.2
W73	Simbua	22.92161	85.32908	3.5	7.26	80	160	21
W278	Simla	24.15113	86.90672	5	7.24	140	280	16.2
W282	Sirsia	24.17044	86.89741	7.55	6.6	80	150	20.9
W98		22.92365	85.2838	3.8	6.6	80	160	20.9
W99	Siyankel	22.92027	85.27773	2.8	6.8	100	200	21.3
W100		22.92482	85.27672	0.8	7.05	170	340	23.05
W101		22.92317	85.27323	1.7	7.1	80	140	24.45
W284	Sonatanr	24.16977	86.91777	5	7.13	90	180	24.2
W283		24.16723	86.90767	3.95	7.02	70	140	21.3
W4		22.44146	86.54278	0.55	6.75	60	160	26.4
W5	Sunrgi	22.43662	86.54265	3.35	7.09	110	250	27.04
W7		22.44101	86.54575	0.65	6.6	60	120	27.3
W8		22.45463	86.55024	0.55	7.73	120	240	25.8
W64	Swargachhinra	22.58688	86.5591	3.95	7.04	320	640	26.8
W255		23.92014	85.49997	6.7	6.88	130	250	25.2
W251	Tasnalo	23.912	85.51032	3.1	7.5	120	240	24.3
W250		23.91296	85.50004	3.3	6.65	70	140	24.6
W304	Tengdhoya	24.26734	86.91242	5.5	7.05	90	180	23.4
W298		24.26282	86.91353	2.8	7.03	80	150	21.4
W343	Upar balram	24.25232	87.14061	5.55	6.91	110	230	19.3
W297		24.24014	87.13897	0.55	7.1	70	150	19
W62	Uparsholl	22.57107	86.5479	3.8	6.6	250	500	25
W63		22.57471	86.54515	0.55	6.6	150	230	26.04

### 6.3 Land Cover

Based on Indian Remote Sensing satellite imagery (IRS-R2A-L4FX) data of January 2026 (Figs. 72 to 76, and Table 3), indicates a dominantly agrarian yet environmentally heterogeneous landscape, directly influencing infiltration, runoff generation, evapotranspiration, and groundwater recharge dynamics. The Land Use/Land Cover (LULC) analysis reveals a dominantly agrarian landscape with significant forest interspersions, characteristic of the undulating hard rock terrain of Jharkhand. Quantitative assessment indicates that rainfed cultivable land constitutes the largest share (14,338.8 ha; 37.0%), followed by irrigated cultivable land (13,273.9 ha; 34.2%), mixed forest/tree/shrub cover (9,802.8 ha; 25.3%), manmade/eroded land (1,135.5 ha; 2.9%), and water bodies (212.4 ha; 0.5%), reflecting a hydro-climatically sensitive system where agriculture is heavily dependent on monsoonal rainfall and limited surface water storage. Spatial interpretation of the maps shows that agricultural land ( $\approx 71.2\%$  combined irrigated and rainfed) is widely distributed across all districts, with irrigated patches concentrated along drainage corridors and low-lying valley fills where groundwater availability is relatively higher, particularly in parts of Tundi, Jama, and Churchu. In contrast, rainfed agriculture dominates upland and plateau regions, especially in Palojori, Murhu, and Gurabanda, where thin soil cover, rapid runoff, and limited groundwater retention restrict irrigation potential, making these areas highly vulnerable to rainfall variability and drought conditions. The forest and shrub cover (25.3%), prominently observed in Churchu, Dadi, and parts of Dalbhumgarh and Murhu, plays a crucial hydro-ecological role by enhancing infiltration, reducing surface runoff, controlling soil erosion, and

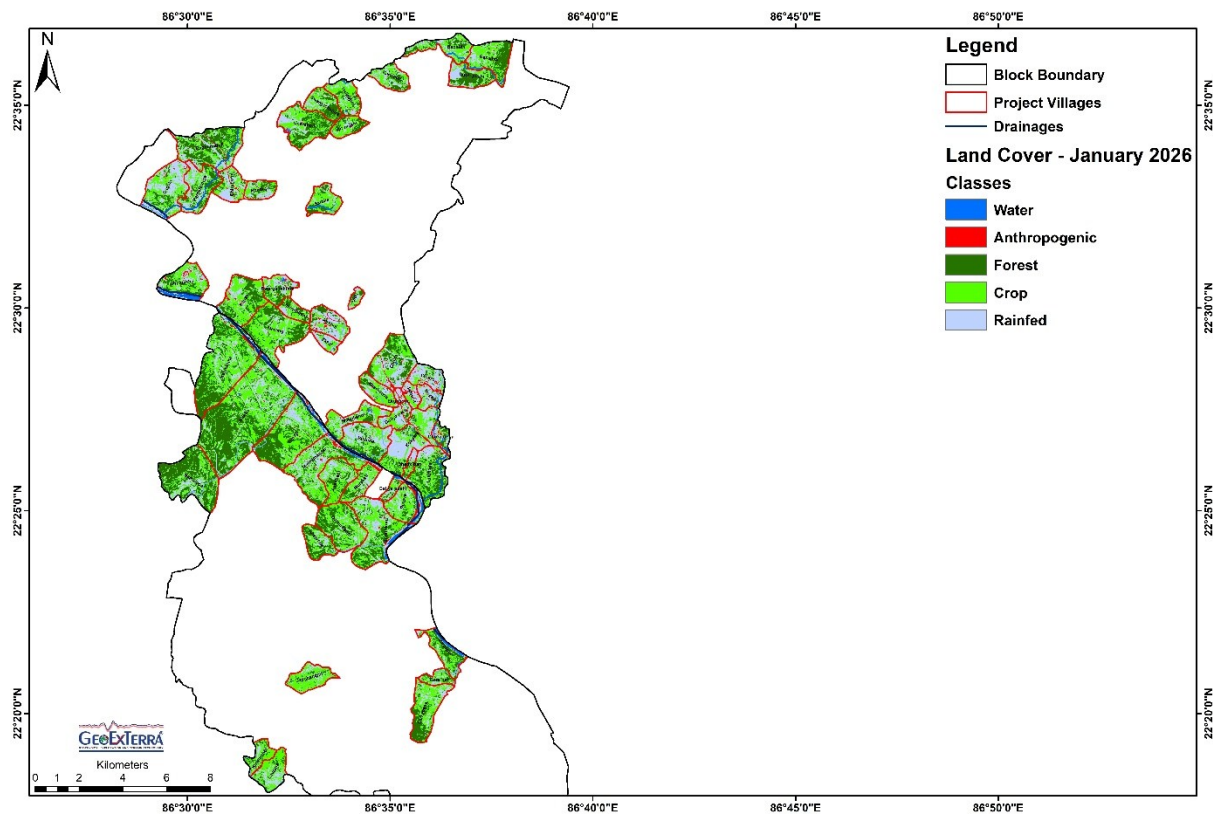


Fig. 72 Land Cover Classes of Project Villages During Jan 2026 - East Singhbhum.

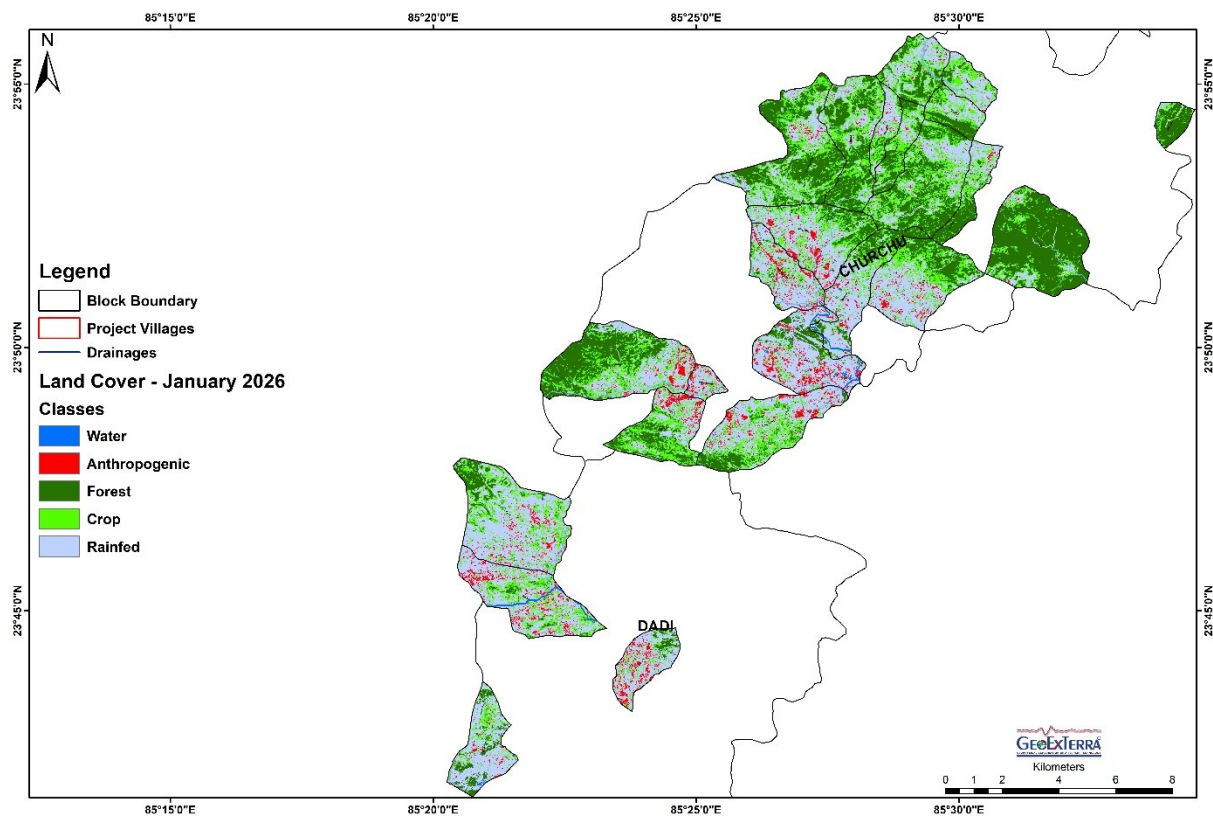


Fig. 73 Land Cover Classes of Project Villages During Jan 2026 - Hazaribagh.

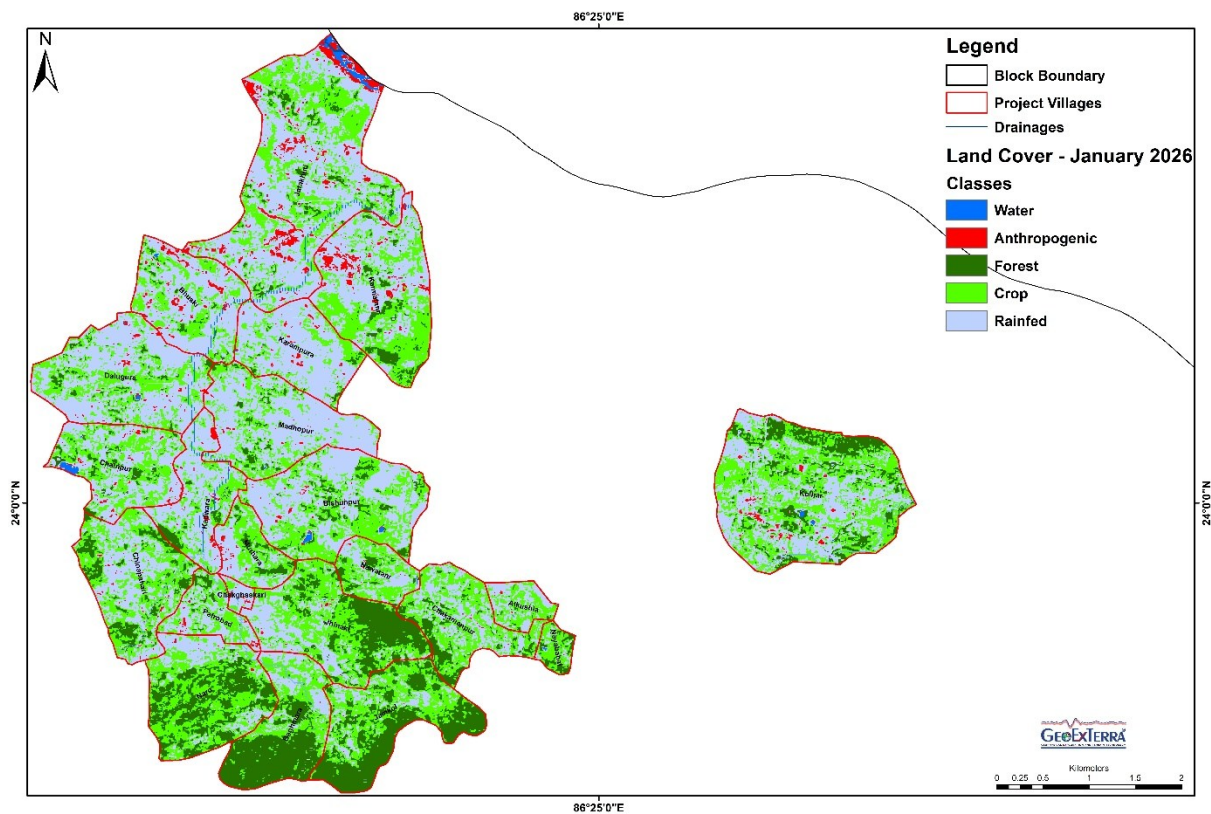


Fig. 74 Land Cover Classes of Project Villages During Jan 2026 - Dhanbad.

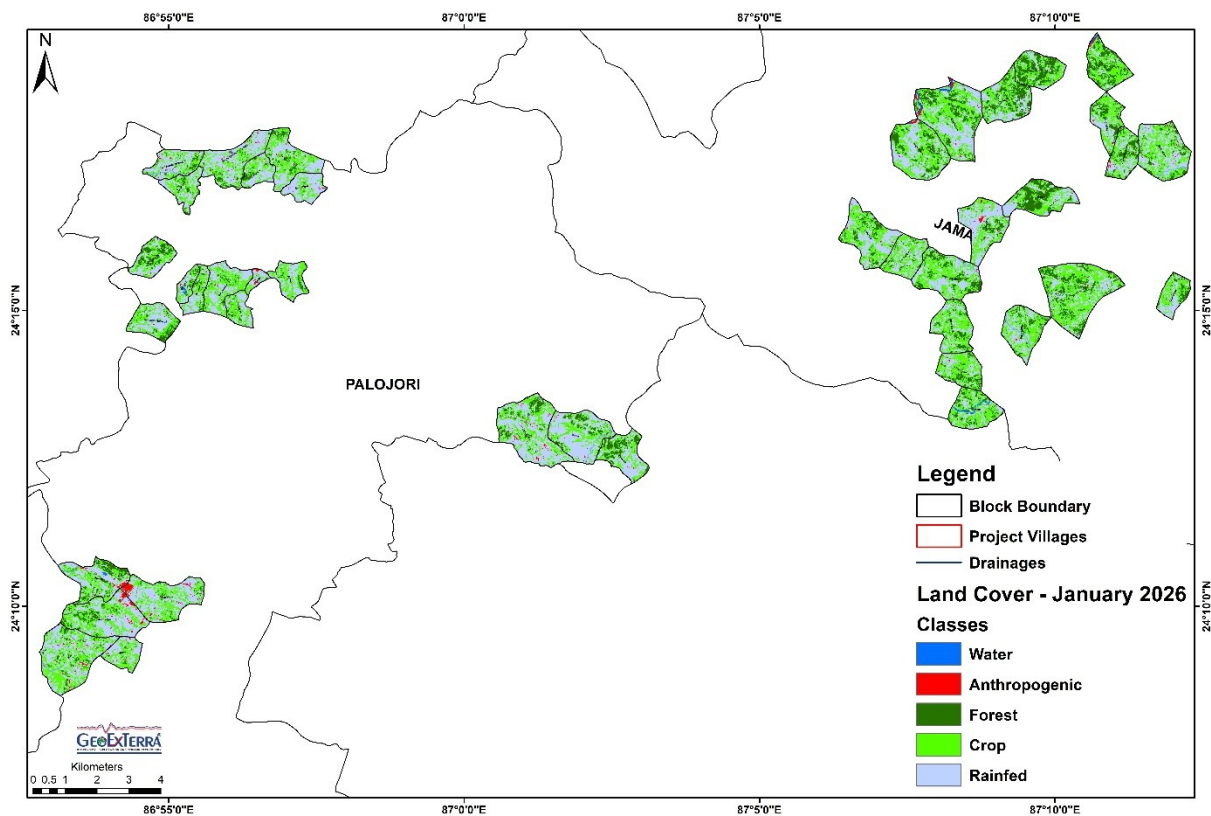
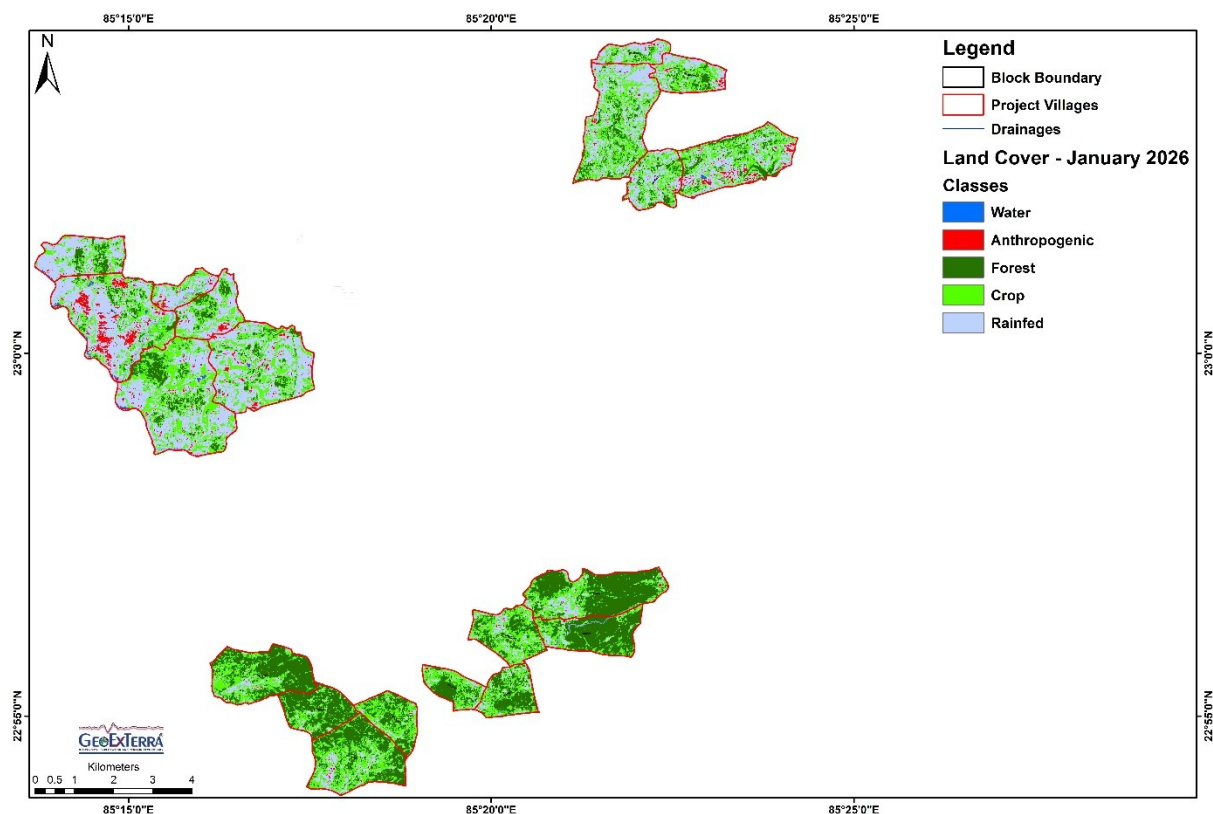


Fig. 75 Land Cover Classes of Project Villages During Jan 2026 - Deoghar and Dumka.



**Fig. 76 Land Cover Classes of Project Villages During Jan 2026 - Khunti.**

supporting groundwater recharge, particularly in structurally controlled terrains with weathered rock development. These zones act as natural recharge buffers, sustaining baseflow in drainage systems and contributing to long-term aquifer replenishment. However, fragmentation of forest patches due to anthropogenic pressures is evident from the scattered distribution of manmade/eroded land (2.9%), which includes settlements, degraded lands, and exposed surfaces. These areas are typically associated with reduced infiltration, increased runoff, and localized groundwater depletion, especially where land degradation and soil erosion are pronounced. The very limited spatial extent of surface water bodies (0.5%) highlights a critical constraint in the regional water resource system, indicating low surface storage capacity and high dependence on groundwater for domestic and agricultural needs. The distribution of water bodies is mostly confined to small ponds, tanks, and localized drainage impoundments, primarily aligned with natural drainage networks. This scarcity underscores the need for enhanced water harvesting and artificial recharge interventions, particularly in rainfed-dominated zones. From a hydrogeological perspective, the LULC pattern exerts a strong control on groundwater occurrence and recharge dynamics. Irrigated areas correlate well with shallow groundwater levels and higher aquifer productivity, often associated with alluvial patches, weathered/fractured zones, and proximity to lineaments and drainage channels. Conversely, rainfed and degraded lands correspond to deeper water levels and lower recharge efficiency, reflecting limited soil moisture retention and rapid surface runoff. Forested areas, despite lower direct water extraction, significantly contribute to sustainable groundwater recharge and aquifer resilience, making them critical zones for conservation. Overall, the LULC analysis indicates a balanced but vulnerable agro-ecological system, where agricultural dominance is counteracted by limited water resources and spatial heterogeneity in recharge conditions. The interplay between

land cover classes clearly demonstrates that groundwater sustainability in the region is highly dependent on land management practices, particularly the preservation of forest cover, expansion of irrigation in suitable hydrogeological zones, and restoration of degraded lands. For climate-resilient water security, the study strongly suggests prioritizing watershed-based interventions, including check dams, percolation tanks, contour bunding, and agroforestry, especially in rainfed and eroded areas, to enhance infiltration, augment groundwater recharge, and stabilize agricultural productivity across the project districts.

**Table 3. Land Cover Classes Jan 2026.**

Land Cover Class	Area (ha)	Area (%) of Total Area
Irrigated - Cultivable	13273.9	34.2
Rainfed - Cultivable (Revenue+Non-Revenue Undifferentiated)	14338.8	37.0
Water Bodies	212.4	0.5
Manmade/Eroded	1135.5	2.9
Mixed Forest/Tree/Shrubs	9802.8	25.3

#### 6.4 Soil Hydro-physical Parameters and Productivity

Topsoil plays an important role in sponging up rainfall and controlling the surface runoff by allowing it to pass through it. The rate of infiltration depends on the hydraulic conductivity of soils/rocks. Therefore, to ascertain the recharge efficiency of constructed water storage structures the hydraulic conductivity was estimated (Figs. 77 to 81, Table 4). The integrated assessment of soil hydro-physical parameters and land productivity across the project districts reveals a heterogeneous but predominantly moderate permeability system, governed by the interplay of overburden thickness, soil texture, hydraulic conductivity, and erosion intensity, which collectively control infiltration, moisture retention, and groundwater recharge potential. Analysis of the spatial maps indicates that hydraulic conductivity largely ranges between 0.1 to 0.5 m/day, with localized high-permeability pockets (0.5–1.92 m/day) aligned along drainage corridors and weathered/fractured zones, particularly in Churchu, Dadi, and parts of Jama and Palojori, while low-permeability zones (0.03–0.1 m/day) occur in compact clay-dominated terrains such as parts of Tundi and Dalbhumgarh. The field dataset further substantiates this variability, where clay and silty clay textures dominate a significant proportion of villages, exhibiting low to moderate conductivity (typically 0.05–0.30 m/day), thereby restricting vertical percolation but enhancing soil moisture retention, which supports rainfed agriculture but limits deep aquifer recharge. In contrast, sandy loam, sandy clay loam, and sand-dominated zones (e.g., Bedla, Chichikhurd, Kajri, Kanki, Mashanjour, and Rikba) demonstrate significantly higher conductivity values (0.6–1.9 m/day), indicating favorable infiltration conditions and higher recharge potential, albeit with lower water-holding capacity, necessitating careful water management for sustained productivity. The overburden thickness, ranging from <1 m to >10 m, plays a critical role in modulating infiltration and storage; shallow overburden zones ( $\leq 2$  m), widely observed in upland and plateau areas, exhibit rapid runoff and limited soil moisture retention, contributing to lower agricultural productivity and higher vulnerability to drought, whereas moderate to thick overburden zones (3–8 m), common in valley fills and gently sloping terrains, provide enhanced storage capacity and sustained soil moisture availability, supporting both rainfed and irrigated cropping systems. The soil erosion maps indicate that the majority of the project area falls under moderate erosion category, with localized severe erosion patches in parts of Churchu, Dalbhumgarh, and Jama, particularly along steeper slopes

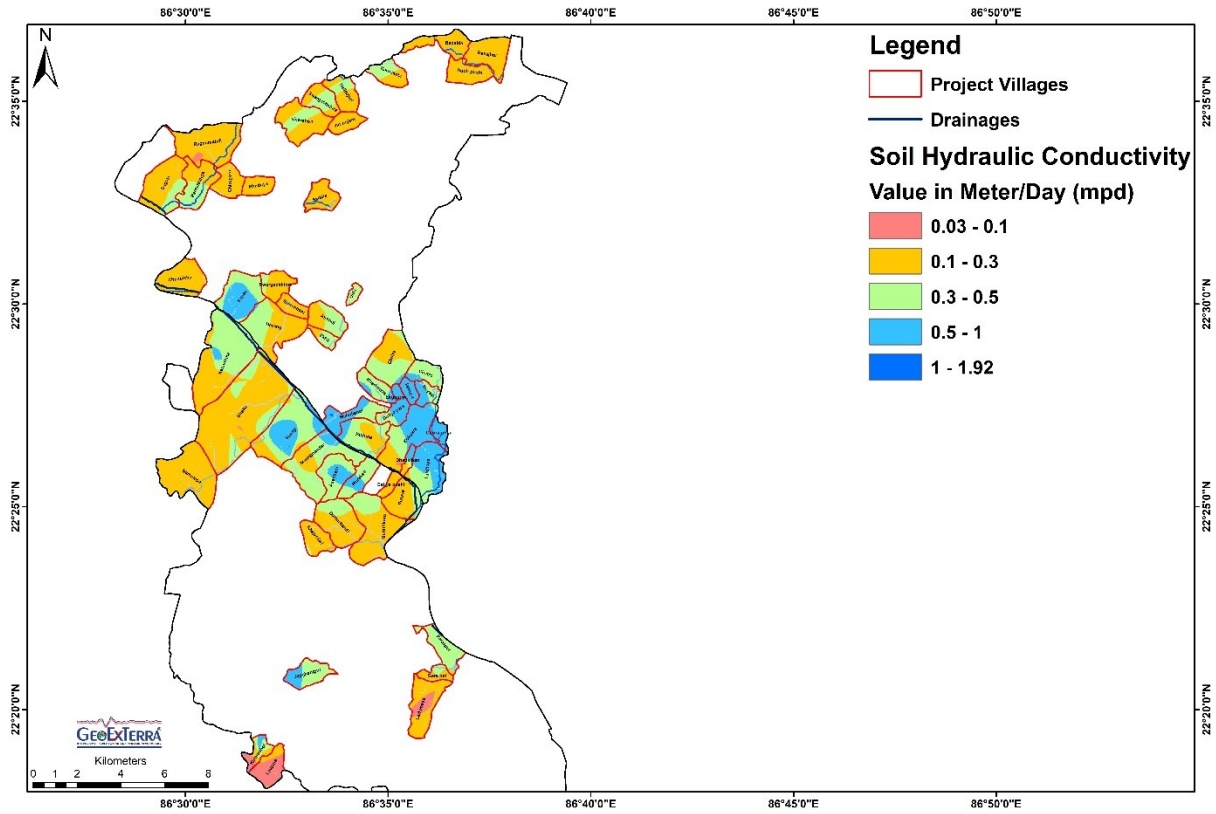


Fig. 77 Hydraulic Conductivity of Soils in the Project Villages of East Singhbhum.

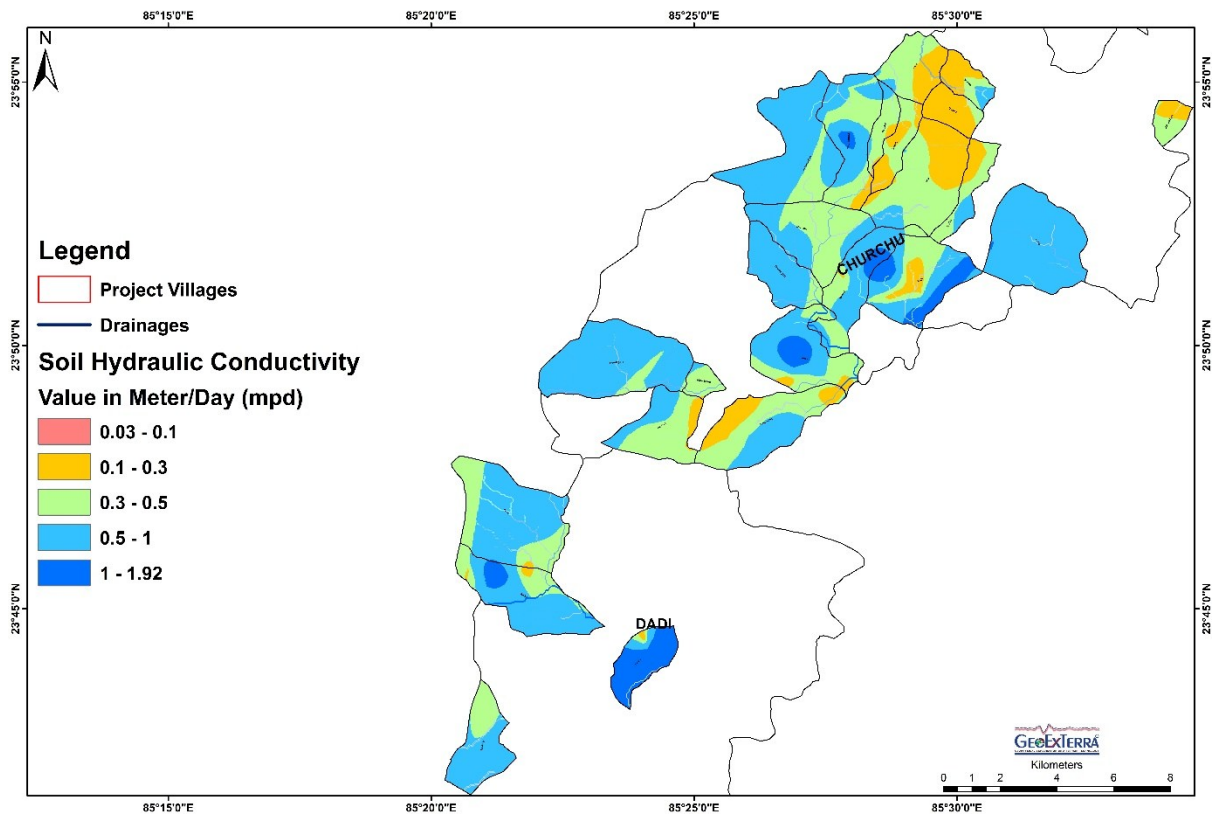


Fig. 78 Hydraulic Conductivity of Soils in the Project Villages of Hazaribagh.

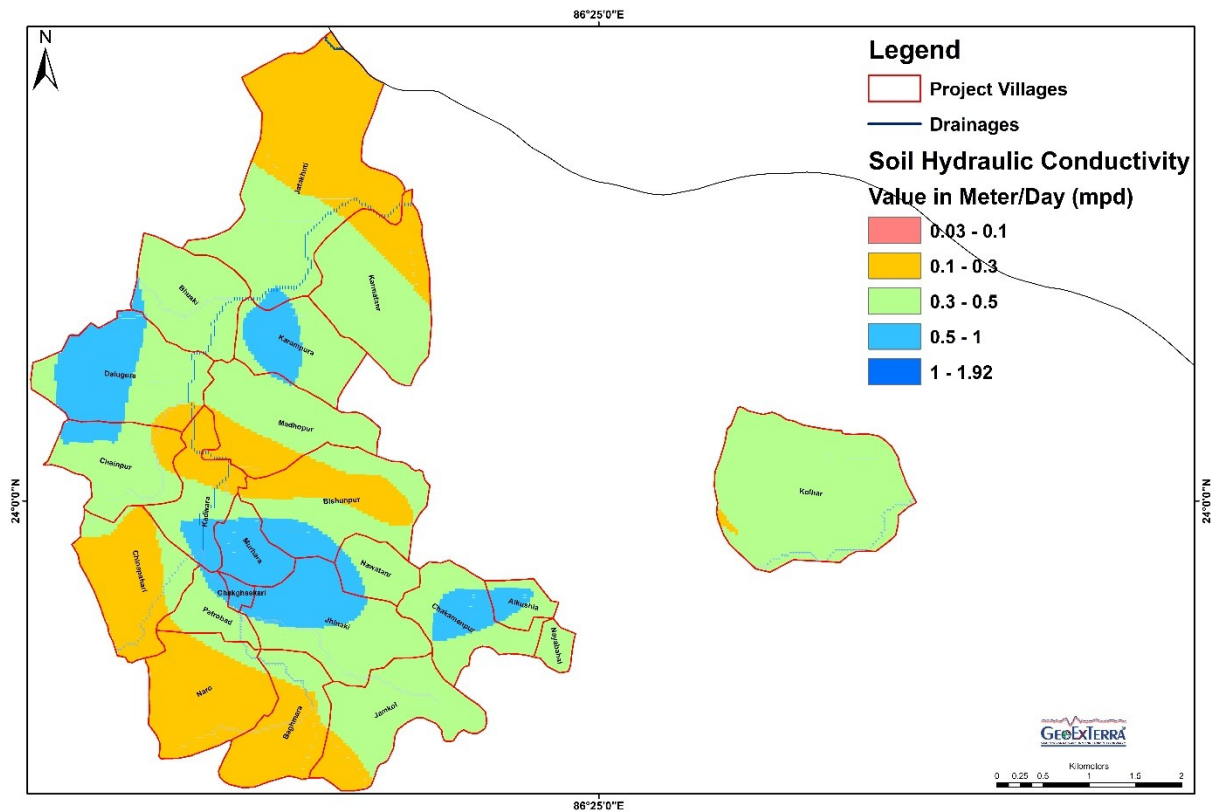


Fig. 79 Hydraulic Conductivity of Soils in the Project Villages of Dhanbad.

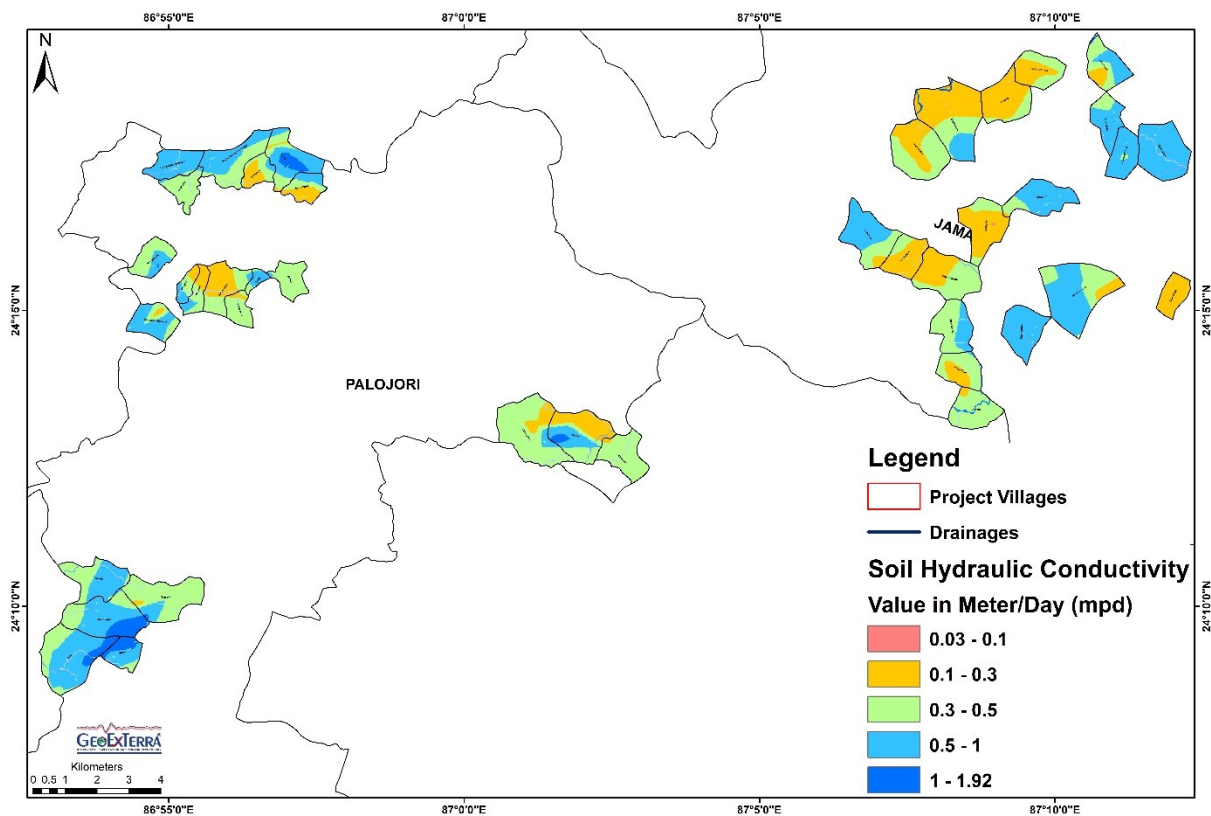
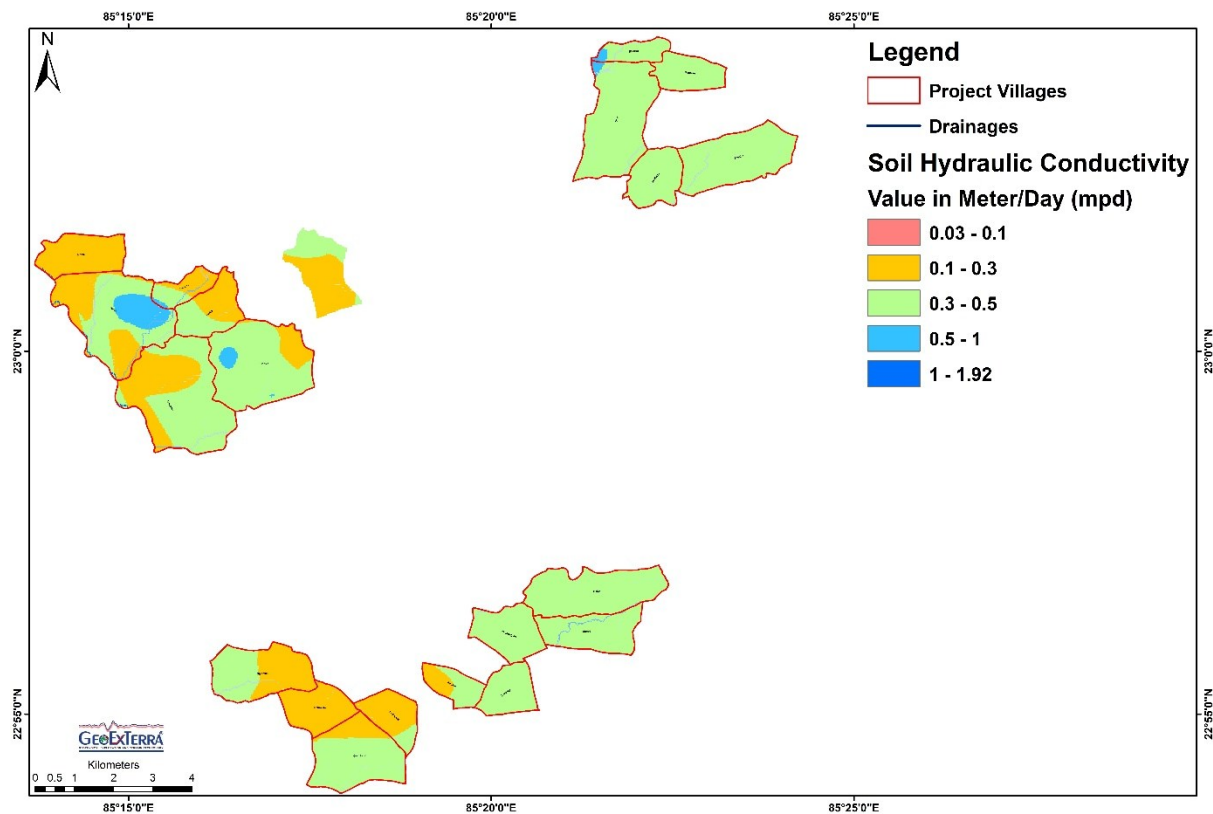


Fig. 80 Hydraulic Conductivity of Soils in the Project Villages of Deoghar and Dumka.



**Fig. 81 Hydraulic Conductivity of Soils in the Project Villages of Khunti.**

and degraded lands (Figs. 82 to 86). These erosion-prone zones correspond closely with areas of reduced vegetation cover and anthropogenic disturbance, leading to loss of topsoil, decline in soil fertility, and reduced infiltration capacity, thereby negatively impacting both groundwater recharge and agricultural productivity. Conversely, areas categorized under least erosion (though limited in extent) are typically associated with forested or well-managed agricultural lands, where soil structure is preserved, and infiltration processes remain efficient. From a productivity perspective, the interaction of these hydro-physical parameters indicates that moderately permeable soils (0.3–0.7 m/day) with loamy to sandy clay loam textures and adequate overburden thickness represent the most productive zones, as they provide an optimal balance between infiltration and moisture retention, supporting stable crop growth and groundwater recharge. In contrast, highly clayey soils, despite good moisture retention, suffer from poor permeability and drainage issues, leading to seasonal waterlogging in lowlands and reduced aeration, while highly sandy zones, although conducive for recharge, exhibit rapid moisture loss, limiting crop sustainability without supplemental irrigation. The spatial correlation between hydraulic conductivity and drainage further highlights that lineament-controlled and valley-aligned zones serve as preferential recharge pathways, which can be strategically targeted for artificial recharge interventions. Overall, the hydro-physical characterization demonstrates that the region exhibits a transitional hydrogeological regime, where productivity and groundwater sustainability are strongly influenced by micro-level variations in soil texture, depth, and erosion status. For achieving climate-resilient water security, the study emphasizes the need for site-specific land and water management strategies, including contour bunding and vegetative barriers in erosion-prone zones, recharge structures in high-permeability areas, and soil moisture conservation practices in clay-dominated terrains. Such

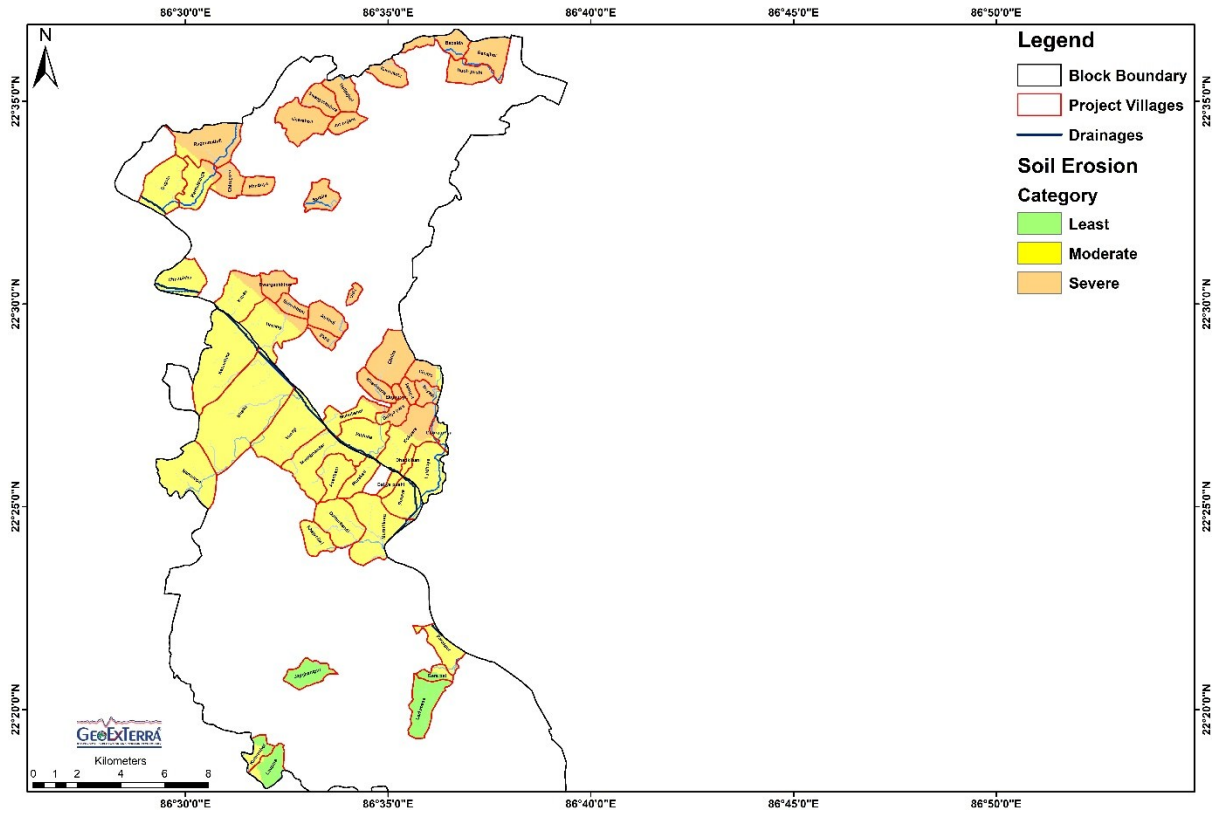


Fig. 82 Soils Erosion in the Project Villages of East Singhbhum.

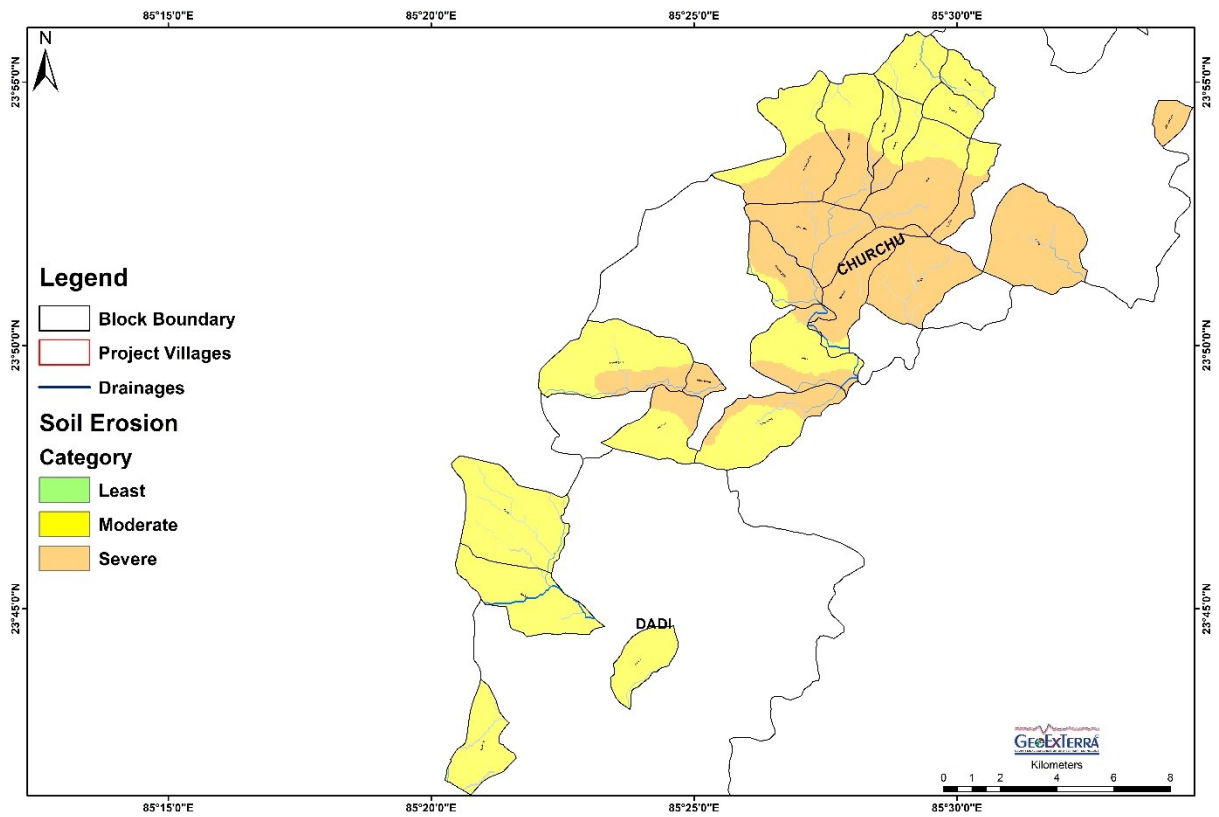


Fig. 83 Soils Erosion in the Project Villages of Hazaribagh.

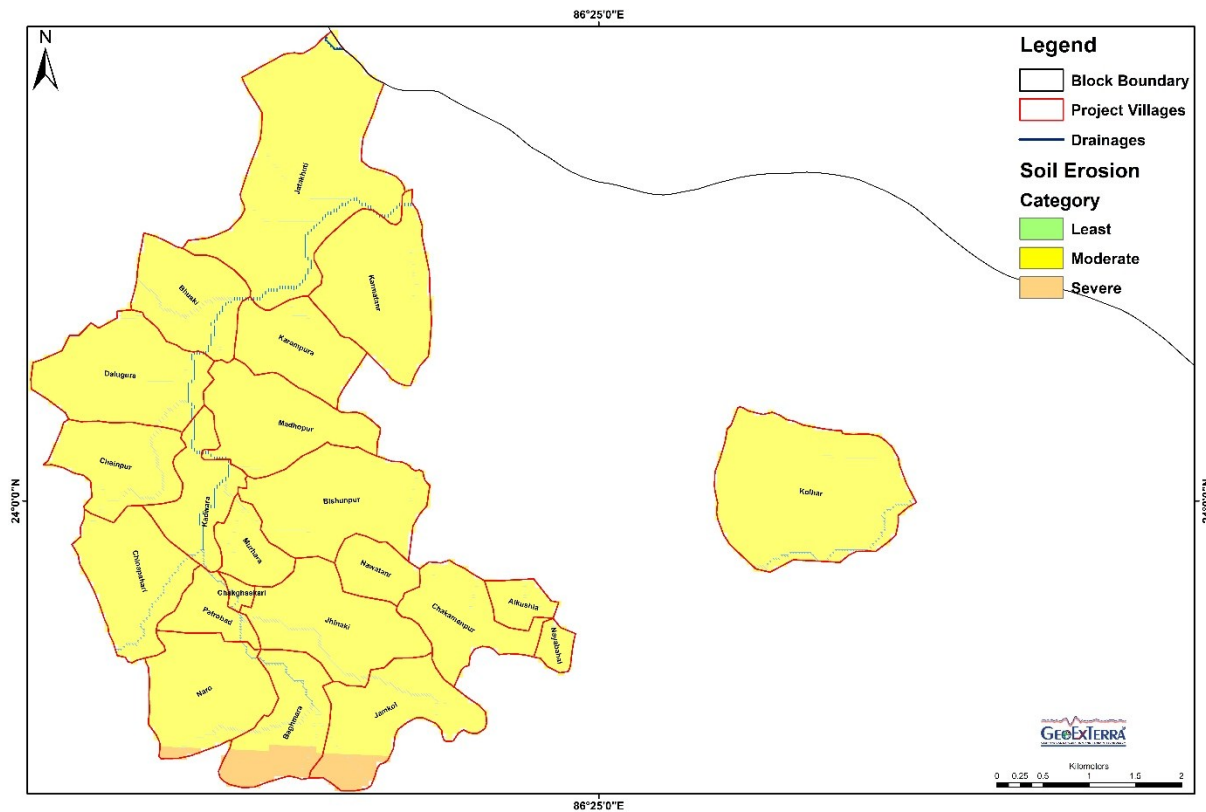


Fig. 84 Soils Erosion in the Project Villages of Dhanbad.

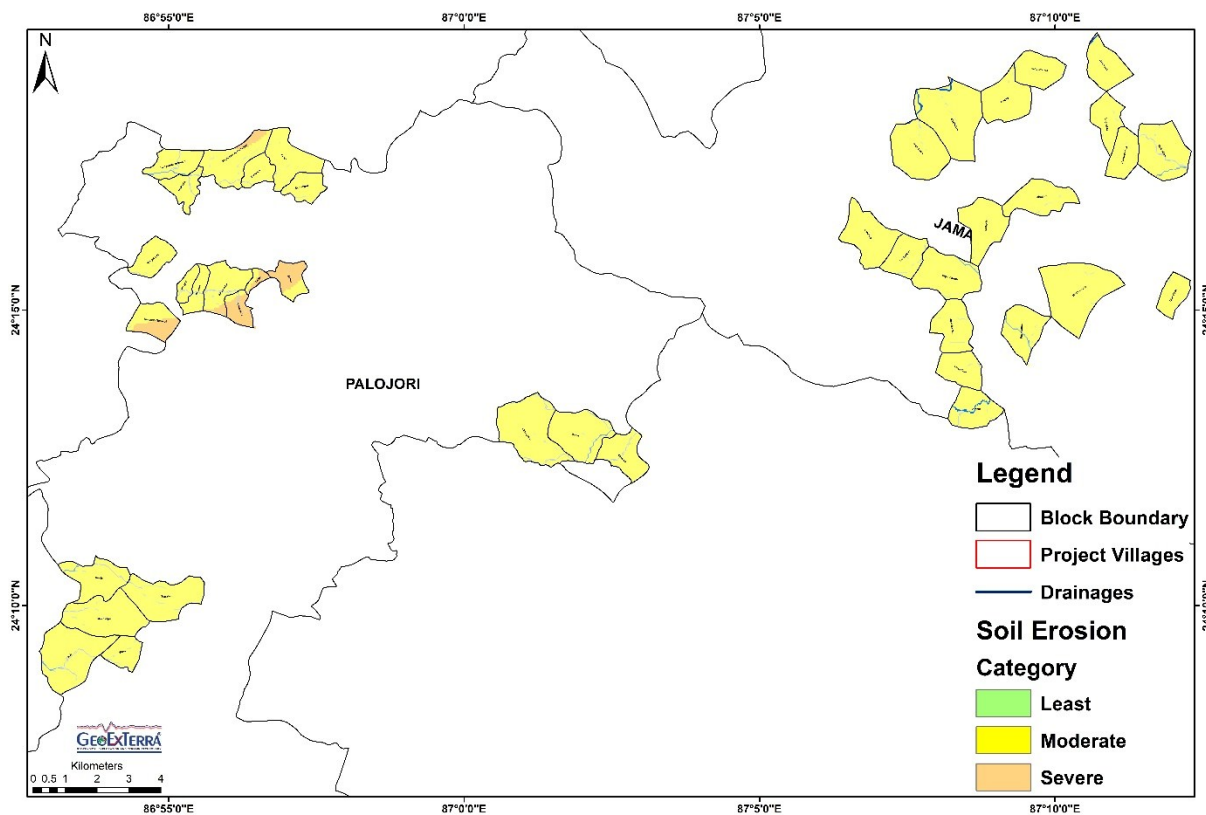
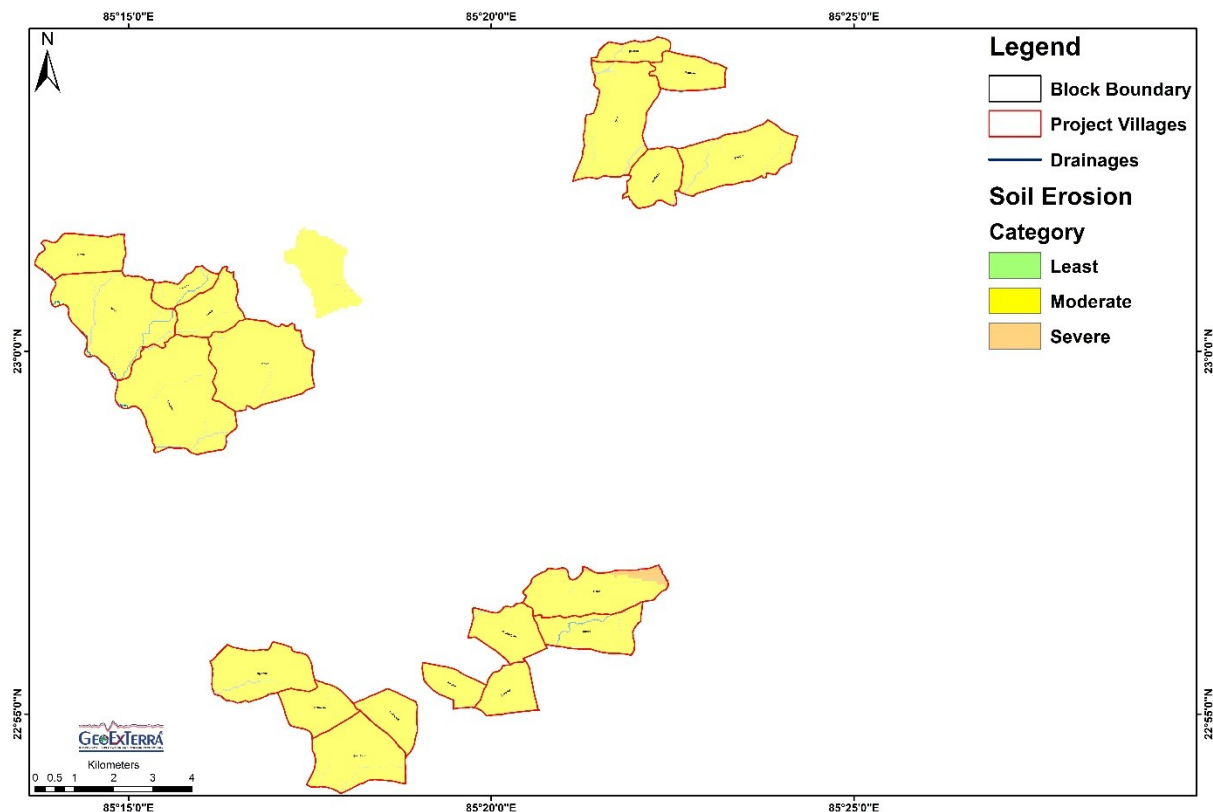


Fig. 85 Soils Erosion in the Project Villages of Deoghar and Dumka.



**Fig. 86 Soils Erosion in the Project Villages of Khunti.**

integrated interventions will enhance infiltration, reduce soil degradation, and optimize agricultural productivity while ensuring long-term aquifer sustainability across the diverse physiographic and hydrogeological settings of the project area.

**Table 4. Soil Hydro-physical Parameters.**

ID	Village	Latitude°	Longitude°	Overburden Depth (m)	Hydraulic Conductivity (mpd)	Texture
W16	Outer	22.60995	86.61692	3	0.187	clay
W40		22.48772	86.50881	4.6	0.133	silty clay
W186		23.81424	85.46071	2.8	0.255	clay
W97		23.02803	85.29137	3.1	0.394	clay loam
W341	Amgachhi	24.30375	87.17853	2.6	0.594	sandy clay loam
W29	Asanbani	22.43082	86.55939	1.2	0.557	sandy clay
W342		24.31726	87.18072	6.6	0.166	clay loam
W333		24.32085	87.18249	4.5	0.610	sandy clay loam
W17	Babaida	22.60884	86.61082	3.6	0.280	clay
W316	Baghmara harladangal	24.28843	86.93305	5.5	0.501	sandy loam
W335		24.29320	86.93116	4.6	0.713	sandy clay
W18	Bagula	22.54638	86.49830	5.1	0.402	clay
W204	Bahera	23.85175	85.46511	4.5	0.476	sandy clay loam
W208		23.85547	85.46394	3.9	0.245	clay loam
W202		23.84451	85.46733	7.8	0.716	sandy loam
W201		23.83735	85.46147	3.1	0.397	clay
W238	Bali	23.89519	85.48344	4.3	0.530	sandy loam
W239		23.89433	85.49853	4.5	0.121	clay loam
W234		23.88521	85.50017	6.25	0.208	clay loam
W227		23.87876	85.49285	3.55	0.415	sandy clay
W226	Baramasia	23.87489	85.47809	3.1	0.594	sandy clay loam
W232		23.88461	85.48303	3.45	0.324	sandy clay
W323		24.29188	87.12951	6.3	0.261	clay
W324		24.29761	87.12072	8.65	0.317	sandy clay

W310	Barudih	24.25347	87.18109	6	0.117	clay loam	
W334	Basmata	24.28124	86.92193	5.15	0.344	sandy clay	
W315		24.28688	86.92118	5.4	0.362	sandy clay loam	
W287	Bedia	24.21362	87.02656	7.4	1.391	sand	
W291		24.21879	87.03068	4.65	0.208	clay loam	
W292		24.21446	87.03675	1.25	0.186	clay	
W248	Belgara	23.91553	85.47758	3.1	0.619	sandy loam	
W302	Belmi	24.25997	86.94840	6.15	0.338	sandy clay loam	
W48	Bera pal	22.35068	86.60480	3.6	0.416	silt	
W21	Bhaduya	22.55162	86.52774	6.4	0.241	sandy clay	
W9	Bhalki	22.46176	86.54043	1.4	0.247	clay	
W30		22.44965	86.52120	4	0.051	silty clay	
W32		22.44970	86.52114	4.4	0.261	silty clay	
W33		22.46347	86.53141	3.9	0.155	silty clay	
W34		22.46469	86.53761	2.9	0.227	silty clay	
W35		22.46486	86.52036	2.7	0.336	silt	
W39		22.46921	86.52737	8.6	0.301	sandy clay	
W308		Bhotokauria	24.26007	87.16462	5.9	0.412	sandy clay
W309			24.25815	87.17195	4.1	0.612	loamy sand
W303			24.24695	87.17285	4.65	0.863	sandy loam
W70	Bhursa	23.06723	85.35674	1.2	0.644	sandy clay	
W71		23.06893	85.36261	0.8	0.382	sandy loam	
W347	Bhuski	24.02551	86.37263	3.7	0.427	clay loam	
W269		24.01913	86.37676	3.4	0.304	clay	
W306	Bigai bandh	24.25995	87.13297	2.55	0.182	clay	
W307		24.25959	87.13984	5.9	0.427	sandy clay	
W31		22.44811	86.57837	2.5	0.325	silty clay	
W53	Bihinda	22.45114	86.57077	8	0.338	sandy clay	
W54		22.44915	86.57535	5.9	0.145	silty clay	
W78	Binda	22.91287	85.28943	2.7	0.273	clay loam	
W321	Birajpur	24.28413	87.16227	7.1	0.688	sandy clay	
W263	Bishunpur	23.99938	86.39511	2.8	0.239	clay	
W262		24.00176	86.38486	1.15	0.108	clay	
W240	Bodra	23.89436	85.50933	5.1	0.294	sandy clay	
W235		23.88733	85.50509	5.4	0.264	clay loam	
W265	Chainpur	24.00632	86.37467	1.55	0.182	clay loam	
W260	Chakamanpur	23.98900	86.40409	1.1	0.585	clay	
W215	Chanaro	23.86889	85.44712	4.1	0.820	sandy loam	
W223		23.87376	85.44714	3.9	0.386	sandy loam	
W216		23.86785	85.45560	2.4	0.353	clay	
W207		23.86072	85.45835	3.5	0.358	sandy clay	
W330	Chatra	24.30538	87.15260	4.2	0.259	clay loam	
W329		24.30561	87.14760	4.5	0.233	silty clay	
W56	Chatro	22.47400	86.59909	3	0.334	silty clay	
W74	Chendagutu	22.93399	85.33954	2.3	0.427	sandy clay loam	
W289	Chhaglajor	24.22001	87.01152	7.65	0.448	clay loam	
W290		24.21786	87.02007	4.8	0.197	sandy clay	
W286		24.21098	87.02106	5	0.331	sandy clay	
W241	Chichikhurd	23.90434	85.45854	3.4	0.328	clay	
W246		23.91395	85.45971	4.4	0.874	sandy loam	
W242		23.90438	85.46915	3.5	0.385	sandy loam	
W236		23.89933	85.46524	2.5	1.369	sand	
W225		23.87972	85.47094	9.5	0.204	clay	
W247		23.91490	85.46548	4.3	0.486	sandy clay	
W349		Chinapahari	23.99585	86.37199	7.45	0.170	clay loam
W350	23.98927		86.36879	1.2	0.142	clay	
W57	Choiria	22.47907	86.58688	2.7	0.247	silty clay	
W58		22.48028	86.58255	3.9	0.159	silty clay	
W311	Chundoba	24.25864	87.20319	1.95	0.211	clay loam	
W348	Dalugura	24.01517	86.36864	7.25	0.698	sandy clay loam	
W264		24.00786	86.36945	2.5	0.558	clay	
W317	Damadih	24.28911	86.94054	4.3	0.181	clay loam	
W72	Damriay	22.92114	85.33817	0.2	0.412	silty clay	
W326	Dandodumria	24.29341	87.18694	5.15	0.485	sandy loam	
W192	Daso khap	23.81933	85.46006	4.65	0.257	clay loam	
W180		23.80568	85.43902	3.65	0.618	sandy loam	
W181		23.80451	85.44288	6.2	0.807	sandy clay	
W184		23.81192	85.43107	1.9	0.181	clay loam	
W179		23.80552	85.42515	4.7	0.208	clay loam	

W75	Dekla	22.94086	85.34970	2.1	0.375	sandy clay loam
W43	Derang	22.49704	86.53497	3	0.316	silty clay
W44		22.49072	86.54235	4	0.179	silty clay
W45		22.49712	86.53568	3.1	0.468	silty clay
W46		22.49664	86.53729	3.1	0.202	sandy clay
W244	Dumar	23.90590	85.50211	4.2	0.109	sandy clay
W25	Dumurbandi	22.40087	86.56565	2.5	0.177	clay
W327	Gaibathan	24.29506	87.19410	5.05	0.772	sandy loam
W69	Gajgaon	22.99083	85.24890	1.9	0.258	sandy clay
W85		22.99585	85.26418	3	0.208	clay loam
W86		22.98428	85.26353	4	0.435	sandy clay loam
W87		22.97714	85.26929	0.4	0.306	sandy loam
W300	Ghorparha	24.26119	86.93258	6.1	0.182	clay
W296		24.25451	86.92942	4.6	0.217	sandy clay
W77	Gumpuru	22.90528	85.30840	0.3	0.389	clay
W65	Haildajuri	22.58732	86.56157	3.7	0.519	sandy clay
W66		22.58668	86.56495	5.8	0.126	clay
W79		22.98971	85.28321	2	0.505	sandy loam
W80	Hansa	22.99253	85.28801	3.1	0.462	sandy clay
W81		22.99859	85.28885	4.2	0.182	clay loam
W82		23.00151	85.28116	5.8	0.387	sandy clay
W83		22.99929	85.27216	3	0.573	sandy clay
W84		22.99231	85.27286	4.3	0.460	sandy clay
W178	Harhad	23.80880	85.41532	1.65	0.278	clay loam
W183		23.81523	85.41694	2.4	0.257	clay loam
W182		23.81407	85.40619	3.5	0.666	sandy clay
W190	Hendegara	23.82407	85.40628	6.15	0.900	sandy loam
W189		23.82183	85.39902	6.85	0.383	sandy clay loam
W196		23.83016	85.40856	1.2	0.619	sandy loam
W88	Hesel	23.02303	85.23395	2	0.212	clay loam
W89		23.02056	85.24139	1.9	0.220	silt
W200	Indra	23.84076	85.44755	3.1	0.521	sandy clay
W193		23.81998	85.46550	7.25	0.211	clay loam
W199		23.82704	85.45383	2.2	0.773	sandy clay
W191		23.82298	85.44631	4.3	0.244	clay loam
W197		23.83419	85.43517	3.85	0.563	sandy clay
W198		23.82997	85.44922	4.6	1.885	sand
W257	Jamkol	23.98058	86.39431	8.85	0.356	clay loam
W55	Jamuya	22.46481	86.59286	3.8	0.773	sandy clay
W67	Jar pojara	22.57639	86.56605	6.2	0.300	sandy clay
W312	Jarjokha	24.27507	87.11284	4.85	0.894	sandy loam
W340		24.26450	87.11607	1.3	0.261	clay loam
W275	Jatakhati	24.03615	86.38767	6.1	0.244	sandy clay
W273		24.02836	86.38661	0.65	0.319	clay
W231	Jordag	23.89021	85.47413	1.3	0.182	clay loam
W243		23.90684	85.48582	6.1	0.325	sandy clay
W237		23.89897	85.48161	3.4	0.205	clay
W59	Jorshol	22.49471	86.55167	5.7	0.087	sandy clay
W60		22.49531	86.56140	6.2	0.422	clay
W261	Kadwara	23.99759	86.37607	7.8	0.530	clay loam
W205	Kajri	23.84877	85.47909	3.5	0.172	sandy clay
W209		23.85726	85.47734	3.4	1.779	sand
W210		23.85724	85.48449	4	0.181	clay loam
W206		23.85009	85.48860	9.2	0.280	sandy loam
W203	Kalipurranga	23.84372	85.48885	6	1.292	sand
W331		24.31692	87.15637	3.4	0.275	silty clay
W332		24.31838	87.16356	4.6	0.280	sandy loam
W36	Kananluka	22.47103	86.51576	1.1	0.236	clay
W37		22.47194	86.51246	0.5	0.228	clay
W38		22.47988	86.51150	1.4	0.640	sandy clay
W41	Kanas	22.50825	86.52617	2.3	0.342	clay loam
W42		22.50280	86.52292	1.55	0.886	sandy clay
W276	Kanki	24.14203	86.88655	3.1	0.445	clay loam
W345		24.15125	86.89516	4.6	1.171	sandy loam
W277		24.15057	86.88493	5.4	0.658	sandy clay loam
W279		24.15874	86.88544	5.1	0.338	sandy loam
W150		23.72140	85.39250	3.2	1.110	sand
W152		23.73343	85.40255	3.1	1.931	sand
W151		23.73279	85.39191	4.7	1.801	sand

W156		23.74023	85.40111		6.1	0.254	silt
W270	Karampura	24.01628	86.38524		5.6	0.641	loam
W229	Kargi	23.87850	85.51630		4.3	0.850	sandy loam
W76	Katingkel	22.91880	85.31478		1.7	0.182	clay loam
W288		24.21090	87.04096		5.9	0.485	clay loam
W346	Khairwa	24.21057	87.04735		4.8	0.366	clay loam
W294	Khapchua	24.22886	87.14084		6	0.138	clay loam
W26	Khejurdari	22.40316	86.55747		4	0.247	clay
W14		22.43629	86.58827		1.6	0.247	clay
W15		22.43912	86.58563		10.6	0.228694	clay loam
W50	Kokpara	22.43746	86.58537		1.7	0.16201	silt
W52		22.43531	86.58832		4.7	0.033771	silty clay
W322		24.29653	86.94591		0.95	0.255217	clay
W336	Kolgi	24.29267	86.95101		4.8	1.59676	sand
W352		23.99648	86.43066		5.3	0.298452	clay loam
W353	Kolhar	23.99521	86.43177		4.75	0.449368	sandy clay
W319		24.2779	87.14421		6.3	0.30664	clay loam
W320	Kulhoria	24.27442	87.14947		6	0.088597	clay loam
W2		22.32058	86.5307		2.45	0.960867	sandy loam
W3	Kumrashol	22.3208	86.53168		2.7	0.495342	sandy loam
W96	Kundibartoli	23.01802	85.29428		2.7	0.250083	sandy clay
W168		23.78071	85.35508		3.85	0.624036	sandy clay
W169		23.779	85.36163		2.9	0.941284	sandy clay
W166	Kura	23.77029	85.37478		2.2	0.339769	clay
W165		23.77011	85.36435		4.6	0.481662	clay
W164		23.77045	85.35352		5.1	0.652615	clay
W149		23.71533	85.35057		3.1	0.418625	silt
W146	Kurkuta	23.69888	85.34053		1	0.628907	sandy clay loam
W147		23.69693	85.35108		2.5	0.688084	sandy clay
W305		24.26361	87.12201		3.5	0.295796	sandy clay
W313	Lakhanpur	24.26744	87.12576		2.9	0.257059	sandy clay
W10		22.42564	86.59799		1.1	0.394037	clay loam
W11		22.43677	86.59445		7.25	0.812221	sandy loam
W12	Laldhuya	22.43677	86.602		5.8	0.581659	clay loam
W13		22.44165	86.60422		5.3	0.632277	clay
W253		23.92199	85.48423		4.2	0.319619	sandy clay
W249	Lara	23.91191	85.48943		2.5	0.181184	clay loam
W254		23.92353	85.49183		4.5	0.280191	sandy loam
W47	Larkabasa	22.34049	86.60211		2.3	0.091984	clay loam
W1	Laupara	22.30914	86.52998		1	0.028808	sandy clay loam
W314	Lodhna	24.27097	87.14135		5.5	0.150058	sandy clay
W301	Lusio	24.25911	86.94286		6.3	0.760171	sandy loam
W6	Madhbhandar	22.43472	86.55034		0.65	0.088735	clay
W266	Madhopur	24.00548	86.38672		2	0.319065	clay
W325		24.29689	87.14004		4.3	0.635501	sandy clay
W328	Madhuban	24.30742	87.13454		4.6	0.177203	clay loam
W90		23.00472	85.24111		2.7	0.421084	clay
W91		23.00944	85.23912		2.6	0.179607	clay loam
W92	Mahil	23.00417	85.24917		2.3	0.189714	silty clay
W93		23.00833	85.25222		3.3	0.802283	sandy clay
W51	Maholishol	22.45428	86.56016		5.7	1.056107	sand
W280		24.16302	86.89597		5.7	0.59724	sandy clay
W281	Mashanjor	24.1599	86.90749		3.4	1.779313	sand
W154	Misrain morha	23.74167	85.37129		0.1	0.693185	sandy clay
W318	Mohanpur	24.2841	86.95737		3.9	0.182247	clay
W28	Murakati	22.42512	86.57188		1.9	0.567075	silty clay
W23		22.41381	86.58428		6.2	0.122	sandy clay
W24	Murathkura	22.41572	86.57576		2.5	0.470606	sandy clay
W27		22.4136	86.57038		3.3	0.242318	silty clay
W351	Murhara	23.99515	86.38391		3.6	0.884108	clay
W337	Nand kura	24.25352	86.93811		5.35	0.290322	silty clay
W256	Naro	23.98315	86.37356		1.9	0.134066	clay
W338		24.24922	86.91392		1.4	0.148709	clay loam
W339	Nawadih nunurai	24.24536	86.9089		4.75	0.552177	sandy clay
W245	Oreya	23.90812	85.56215		4.2	0.520989	sandy clay
W344	Pachkathia	24.2411	87.15494		5.45	0.910834	sandy loam
W49	Paraspur	22.35705	86.60654		7.9	0.381255	silt
W259	Patrobad	23.99072	86.37805		6.5	0.442295	clay loam
W95	Perka	23.00972	85.27194		0.8	0.215701	sandy clay

W299	Phuljori	24.26	86.9227	6.05	0.259978	clay loam
W295		24.25133	86.92049	3.2	0.639945	sandy clay
W19	Raghunathdi	22.55919	86.50369	0.7	0.081453	clay loam
W20		22.55643	86.5054	5.6	0.13943	clay
W22	Reruya	22.4215	86.58367	3.7	0.186128	sandy clay
W162	Rikba	23.76203	85.36251	2.7	0.206604	silt
W161		23.76044	85.35401	1.6	1.609249	sand
W163		23.76671	85.3461	1.1	0.688631	sandy clay
W160		23.76251	85.34489	4.8	0.274784	silt
W157		23.75593	85.35034	4.7	0.842168	clay
W158		23.75119	85.36422	1.7	0.561952	silty clay
W153		23.74522	85.3618	2.6	0.532437	clay
W159		23.7512	85.37251	4.6	0.592664	sandy clay
W155		23.74965	85.37997	4.1	0.504501	clay
W293		Sampur	24.22301	87.14282	5.35	0.450451
W252	Sanri	23.9115	85.56699	0.8	0.182247	clay
W61	Sarbila	22.54967	86.55243	1.6	0.279068	sandy clay
W94	Sardula	23.0155	85.26743	2.3	0.121543	silty clay
W73	Simbua	22.92161	85.32908	3.7	0.368852	sandy clay
W278	Simla	24.15113	86.90672	5.45	0.503067	sandy clay loam
W282	Sirsia	24.17044	86.89741	6.8	0.590532	sandy clay loam
W98	Siyankel	22.92365	85.2838	4	0.203184	clay loam
W99		22.92027	85.27773	3.1	0.302667	clay loam
W100		22.92482	85.27672	0.8	0.396865	sandy clay
W101		22.92317	85.27323	2	0.342418	sandy clay
W284	Sonatanr	24.16977	86.91777	5.4	0.358165	sandy clay
W283		24.16723	86.90767	4.65	0.208101	clay loam
W4	Sunrgi	22.44146	86.54278	1.1	1.044241	sand
W5		22.43662	86.54265	4.1	0.42608	clay
W7		22.44101	86.54575	1.25	0.121135	clay loam
W8		22.45463	86.55024	1.1	0.332408	sandy loam
W64	Swargachhinra	22.58688	86.5591	4.7	0.328298	clay
W255	Tasnalo	23.92014	85.49997	7	0.169779	clay loam
W251		23.912	85.51032	3.7	0.75734	sandy loam
W250		23.91296	85.50004	3.8	0.17241	sandy clay
W304	Tengdhoya	24.26734	86.91242	6.1	0.46534	sandy loam
W298		24.26282	86.91353	3.5	1.052279	sand
W343	Upar balram	24.25232	87.14061	5.55	0.521466	sandy clay
W297		24.24014	87.13897	0.95	0.51244	sandy clay loam
W62	Uparsholl	22.57107	86.5479	4.6	0.182247	clay
W63		22.57471	86.54515	0.9	0.364264	sandy clay

## 6.5 Land Degradation

The comprehensive assessment of land degradation reveals a multi-dimensional degradation regime dominated by water-induced erosion processes, supplemented by localized anthropogenic disturbances and geomorphic constraints, as interpreted from the thematic maps. The spatial distribution clearly indicates that water erosion in the form of sheet erosion (slight to severe) constitutes the most extensive degradation process, particularly evident across Churchu, Dadi, Tundi, and parts of Jama and Palojori, where moderate and severe sheet erosion zones are widely developed along agricultural slopes and drainage corridors (Figs. 87 to 91). These areas correspond to undulating plateau topography with shallow to moderate overburden and predominantly loamy to clayey soils, where intense monsoonal rainfall generates high surface runoff, leading to progressive removal of fertile topsoil. The occurrence of gully erosion, although spatially limited, is significant in dissected terrains and along ephemeral drainage lines, indicating advanced stages of land degradation where concentrated flow has incised channels, further accelerating sediment transport and reducing land usability. In addition to natural erosion processes, anthropogenic degradation features—such as brick kilns and mining/dump areas—are observed in localized clusters, especially within parts of Churchu and adjoining mineralized belts, reflecting human-induced land

transformation and soil structure disruption, which not only degrade surface conditions but also alter infiltration characteristics and groundwater recharge dynamics. The presence of barren rocky and stony waste lands in patches across the study area signifies zones of either severe soil loss or inherently shallow lithic soils, typically associated with hill slopes and exposed bedrock conditions, where agricultural productivity is inherently low and restoration potential is limited without significant intervention. Minor occurrences of riverine sand deposition and related geomorphic features along drainage channels further indicate sediment redistribution processes, especially in downstream reaches, which can both degrade upstream soils and create unstable depositional environments downstream. From a hydrogeological perspective, the dominance of sheet erosion—particularly moderate to severe categories—has critical implications for groundwater recharge and aquifer sustainability, as it reduces infiltration capacity by stripping fine soil fractions and organic matter, leading to increased runoff coefficients and reduced soil moisture retention. This is corroborated by the spatial association of degraded zones with areas of low to moderate hydraulic conductivity and thin overburden, where infiltration is already constrained. Conversely, areas exhibiting slight erosion or relatively stable surfaces indicate better vegetation cover and soil structure, supporting improved infiltration and recharge conditions. The degradation patterns also show strong alignment with drainage networks, emphasizing the role of surface hydrology in controlling erosion intensity, with higher degradation observed along first- and second-order streams where flow concentration is maximum. Overall, the land degradation scenario across the project area reflects a cumulative impact of geomorphology, soil characteristics, rainfall intensity, land use practices, and anthropogenic pressures, resulting in a landscape where productive capacity is unevenly distributed and increasingly vulnerable to climatic variability. For achieving climate-

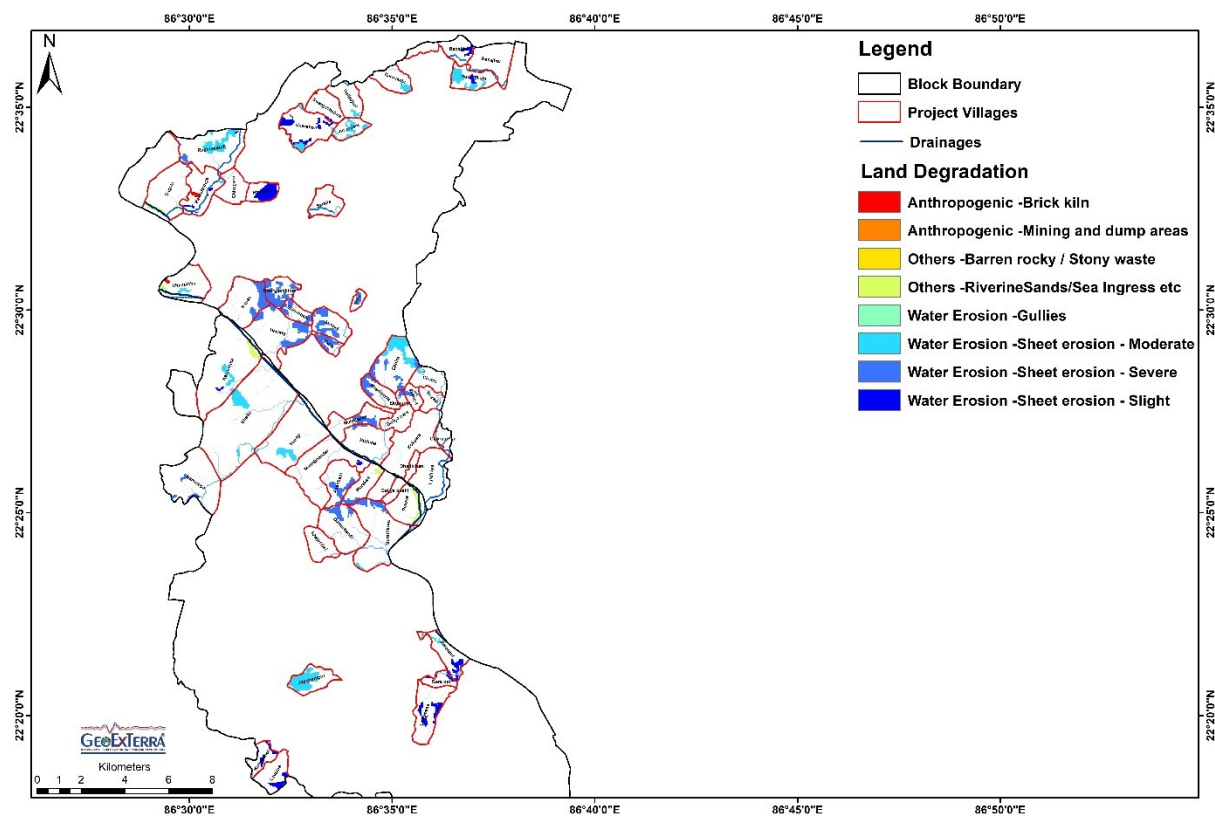


Fig. 87 Land Degradation in the Project Villages of East Singhbhum.

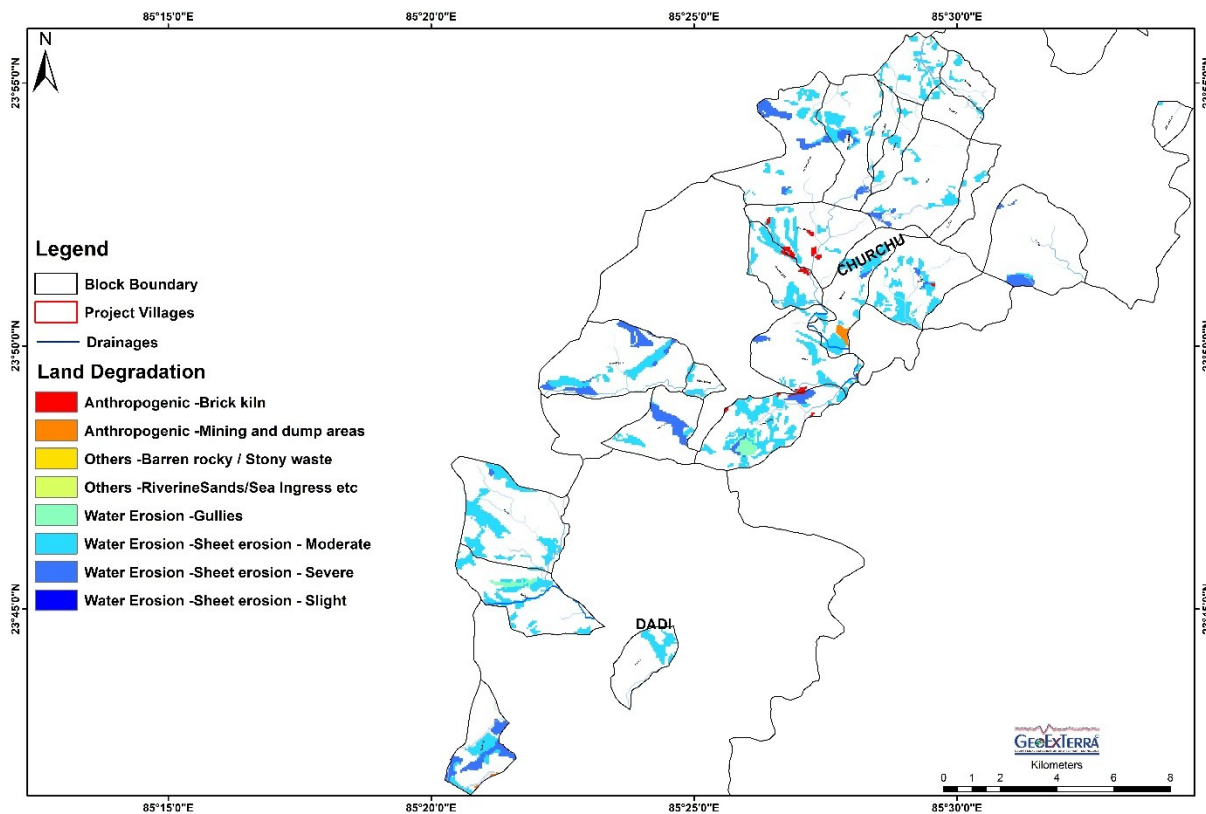


Fig. 88 Land Degradation in the Project Villages of Hazaribagh.

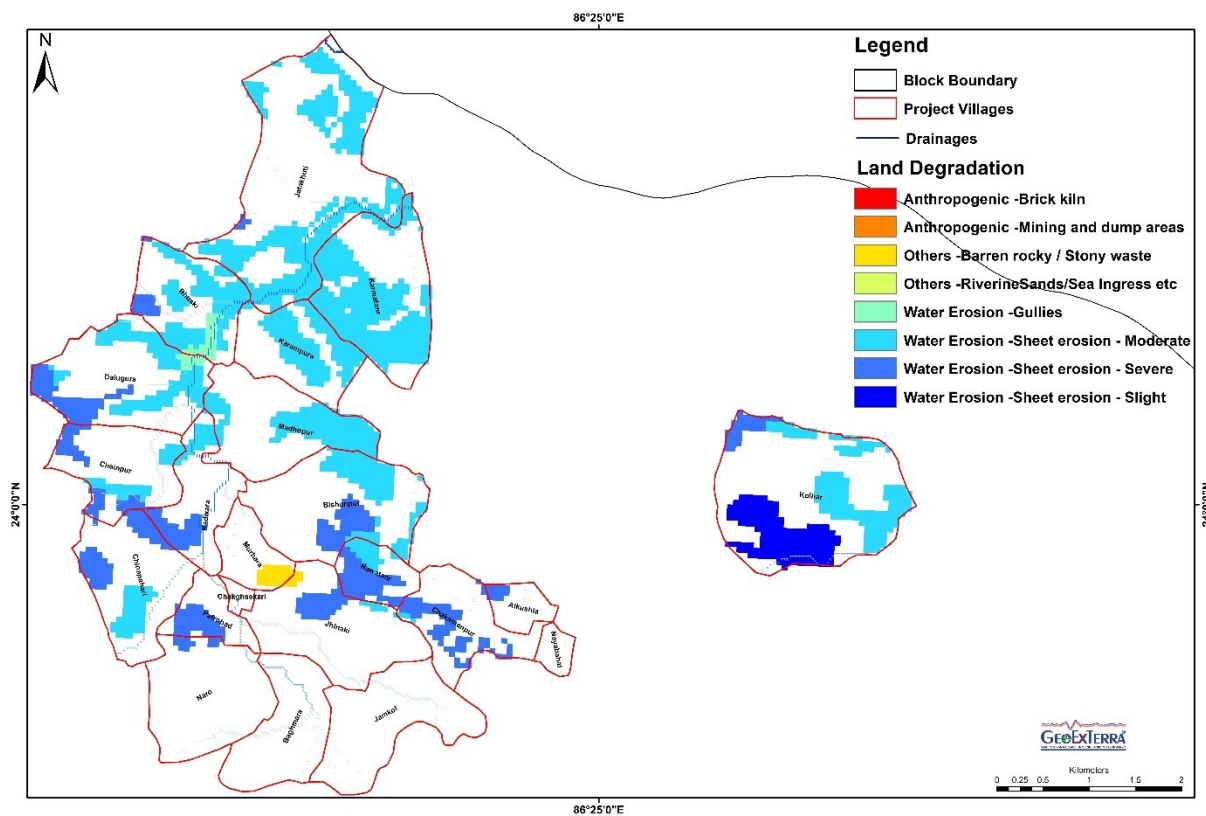


Fig. 89 Land Degradation in the Project Villages of Dhanbad.

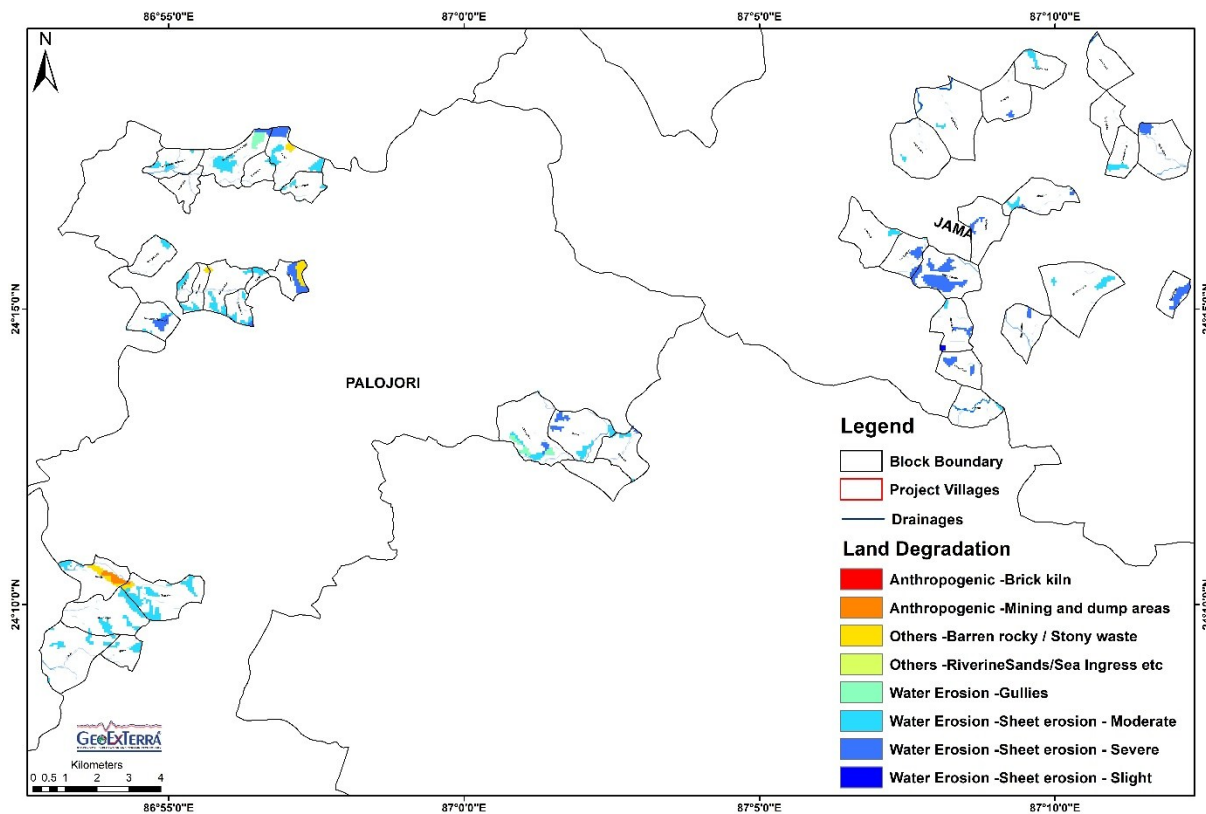


Fig. 90 Land Degradation in the Project Villages of Deoghar and Dumka.

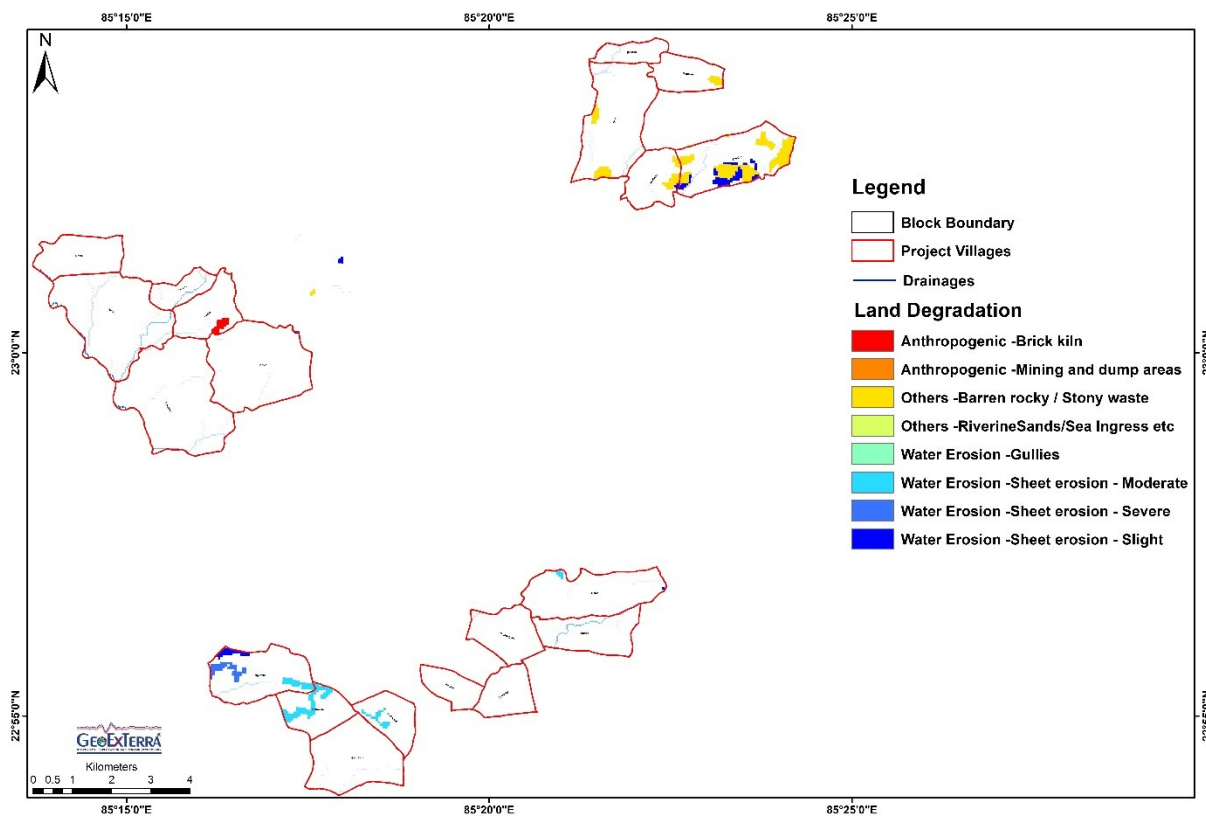


Fig. 91 Land Degradation in the Project Villages of Khunti.

resilient water security, the analysis underscores the need for targeted watershed management interventions, including gully plugging and check dams in incised channels, contour trenching and vegetative barriers in sheet erosion zones, reclamation of mining-affected lands, and regulation of brick kiln activities. Such integrated measures will not only reduce ongoing land degradation but also enhance soil health, improve infiltration, and strengthen groundwater recharge, thereby contributing to sustainable agricultural productivity and long-term hydrogeological stability across the region.

### 6.6 Hydrological Modelling

Precipitation and conserving surplus runoff are useful resources for water harvesting, baseflow management, and groundwater recharge of an area. To assess the water availability, it is essential to understand the rainfall and runoff phenomenon and rate of evapotranspiration. Rainfall and runoff are significant constituents and sources of water for recharging groundwater. Rainfall is a major primary source of recharge into the groundwater. Other, substantial sources of recharge include seepage from tanks, canals, streams, and functional irrigation. Understanding rainfall and runoff is essential for the evaluation of the water availability of an area. Hydro-meteorological and hydrological data have an important role in the assessment, planning, and designing of artificial recharge structures, controlling baseflow, reservoir, and soil erosion control measures. The occurrence and quantity of runoff are dependent on the characteristics of rainfall events like intensity, duration, and areal distribution, affected by geomorphological factors, particularly, the land cover change affects the runoff volume

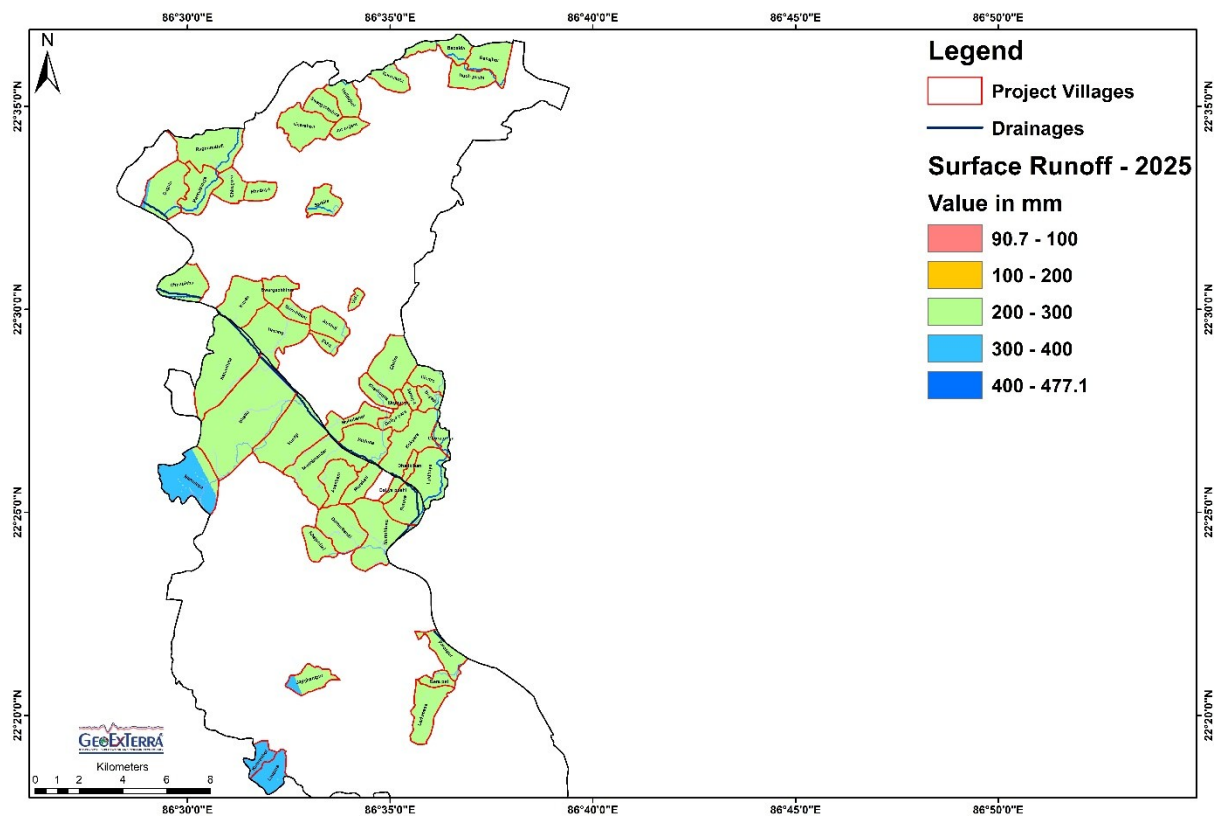


Fig. 92 Annual Surface Runoff Distribution During 2025 in the Project Villages of East Singhbhum.

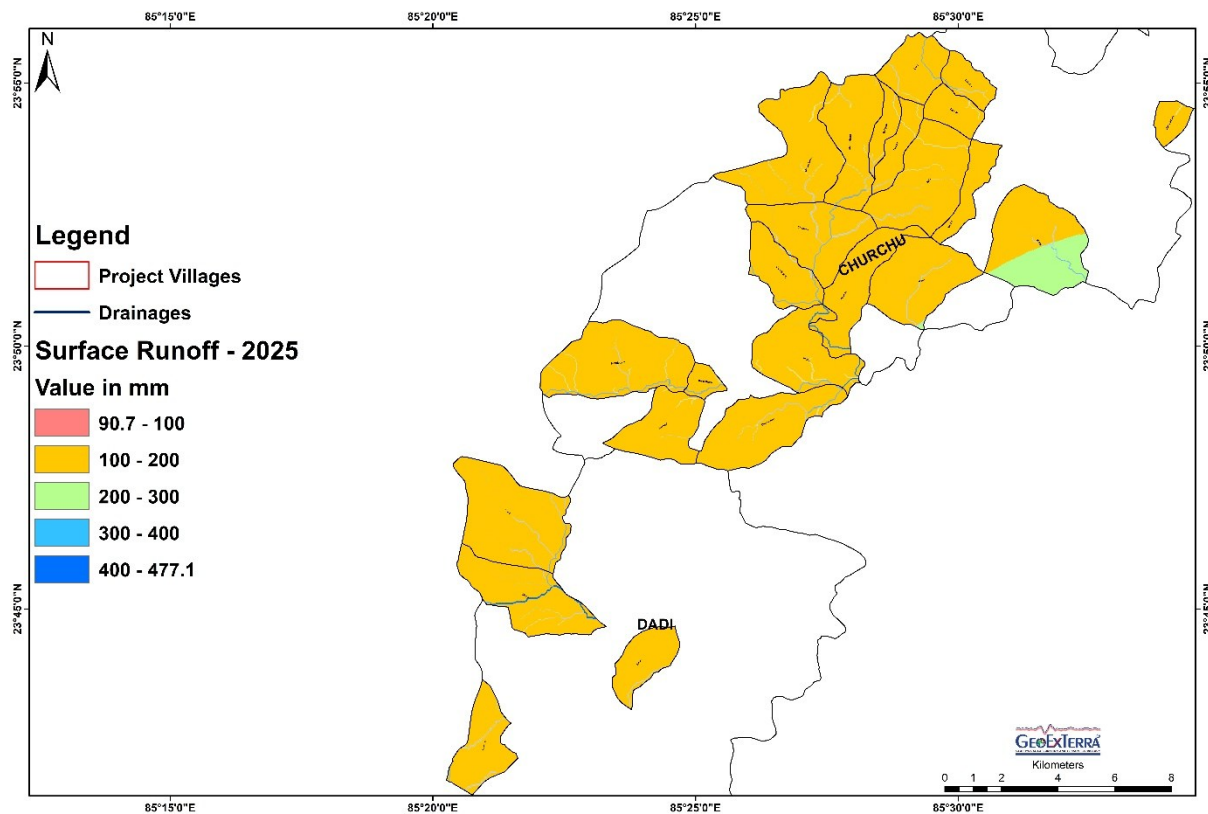


Fig. 93 Annual Surface Runoff Distribution During 2025 in the Project Villages of Hazaribagh.

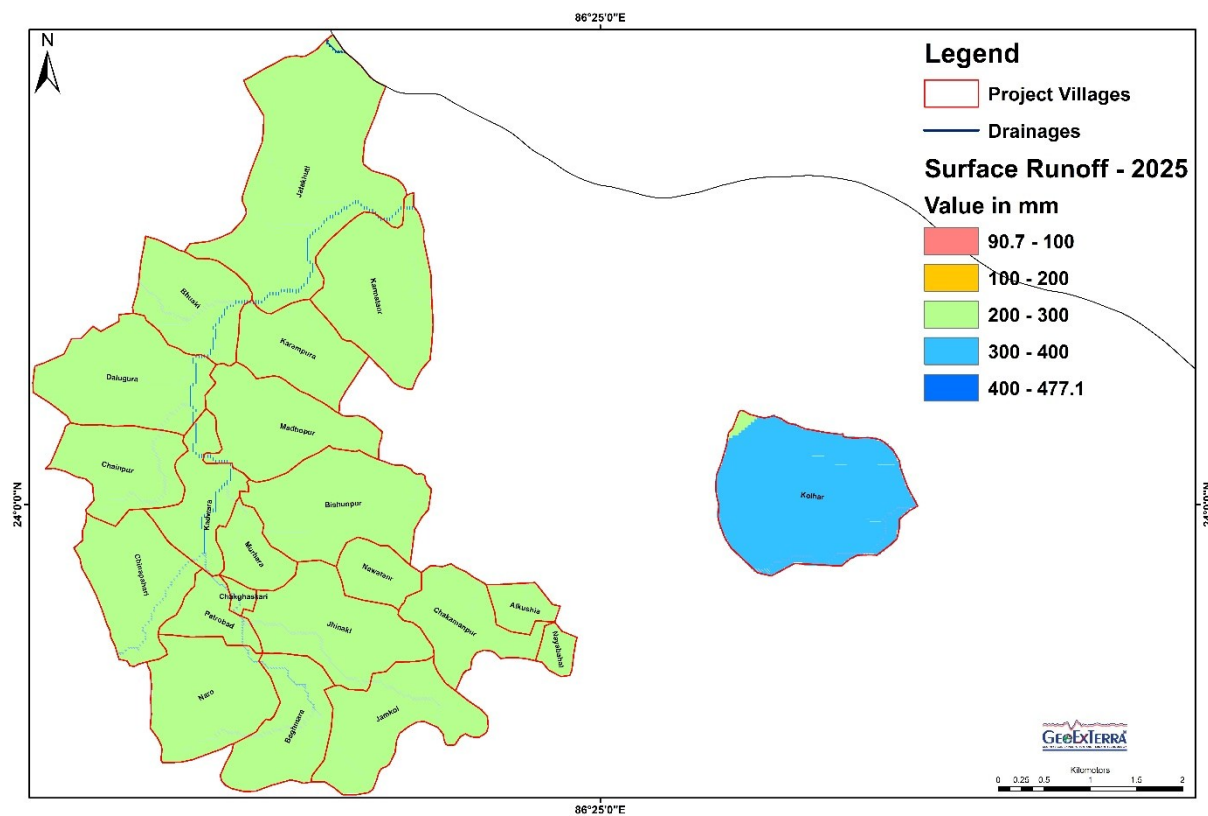


Fig. 94 Annual Surface Runoff Distribution During 2025 in the Project Villages of Dhanbad.

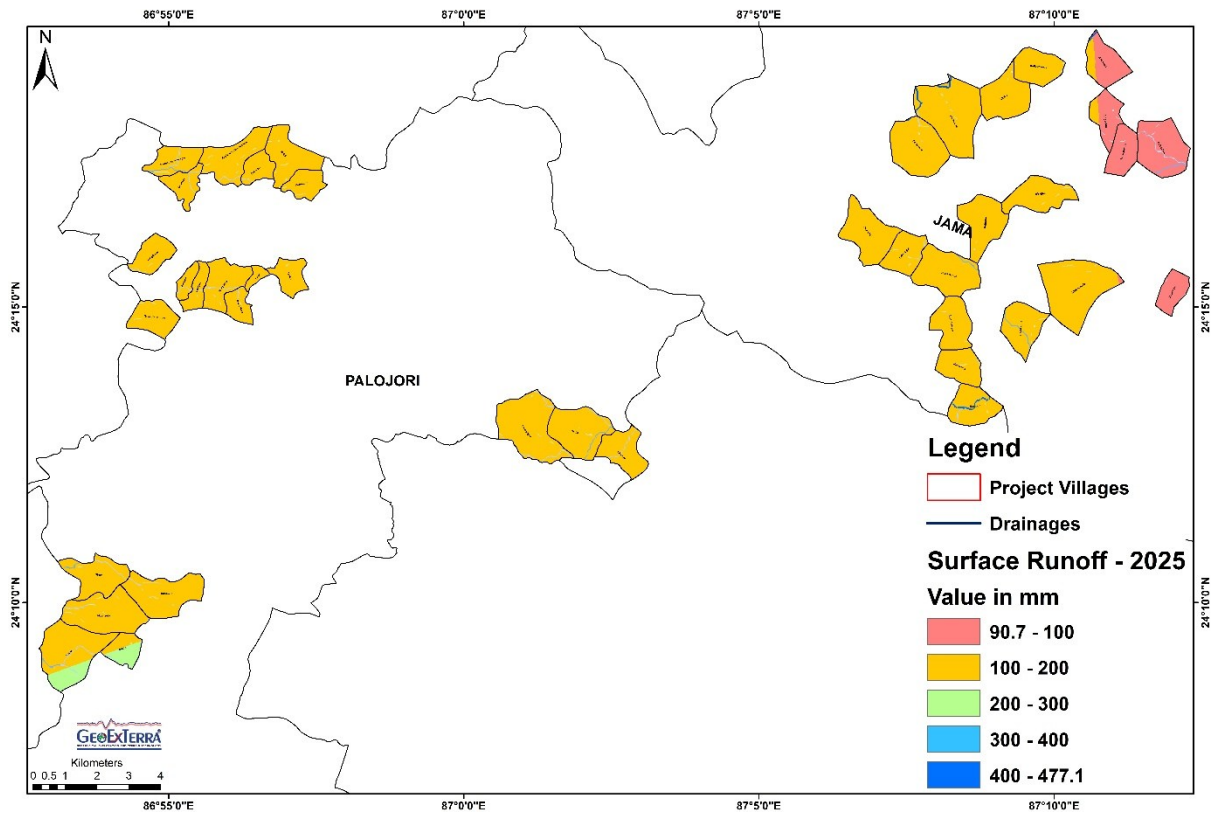


Fig. 95 Annual Surface Runoff Distribution During 2025 in the Project Villages of Deoghar and Dumka.

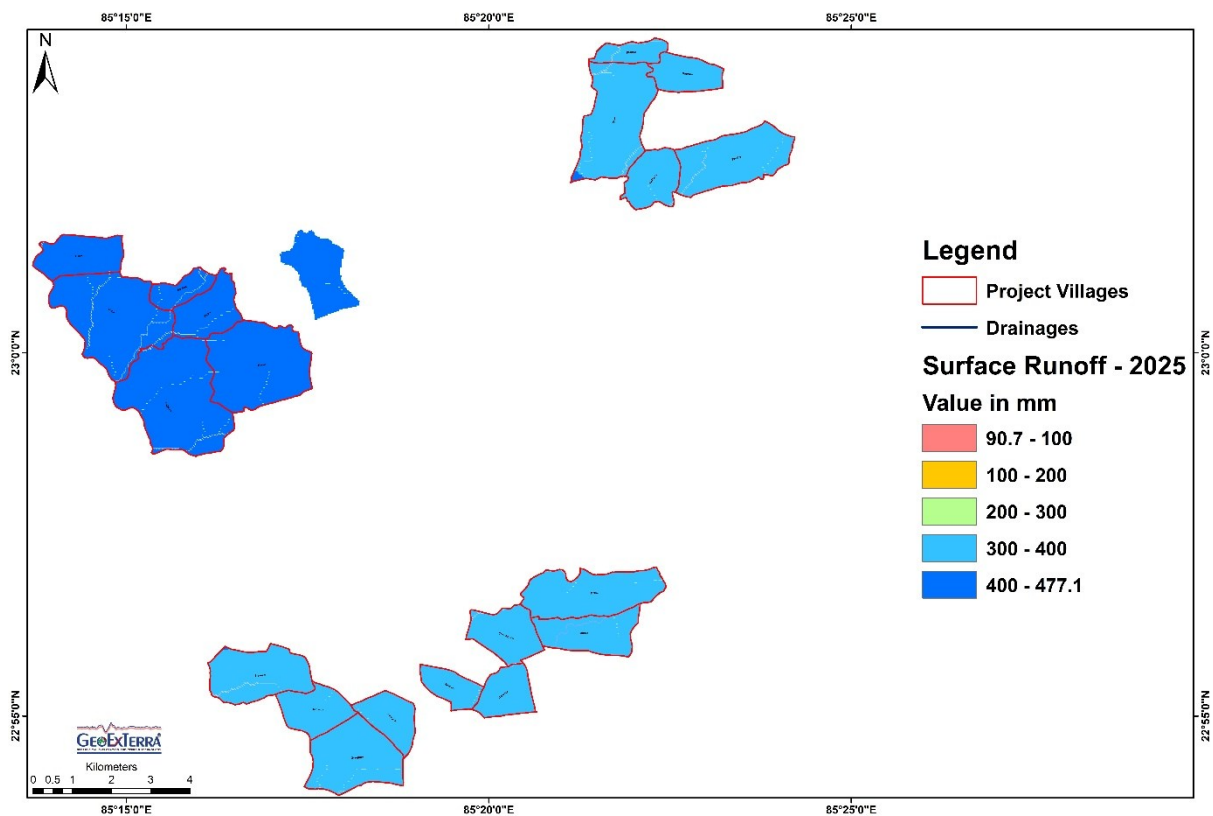


Fig. 96 Annual Surface Runoff Distribution During 2025 in the Project Villages of Khunti.

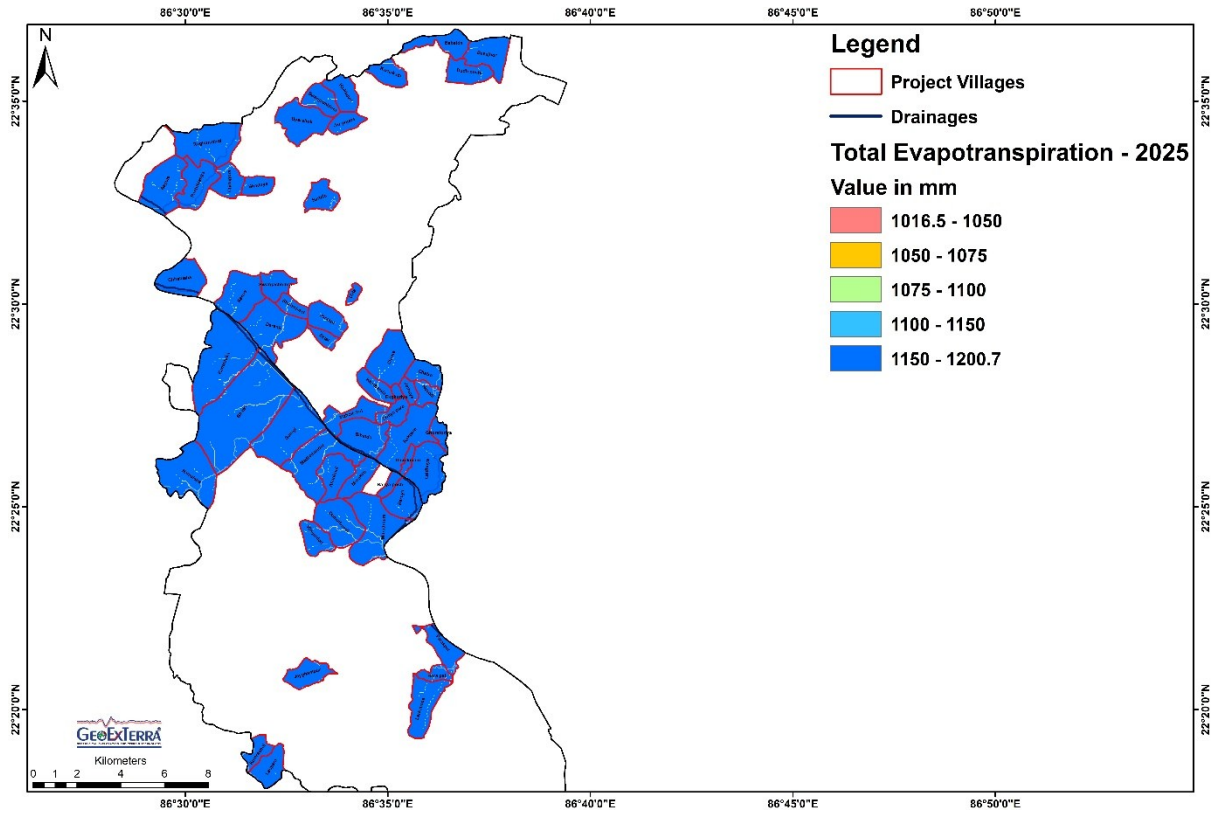


Fig. 97 Annual Evapotranspiration During 2025 in the Project Villages of East Singhbhum.

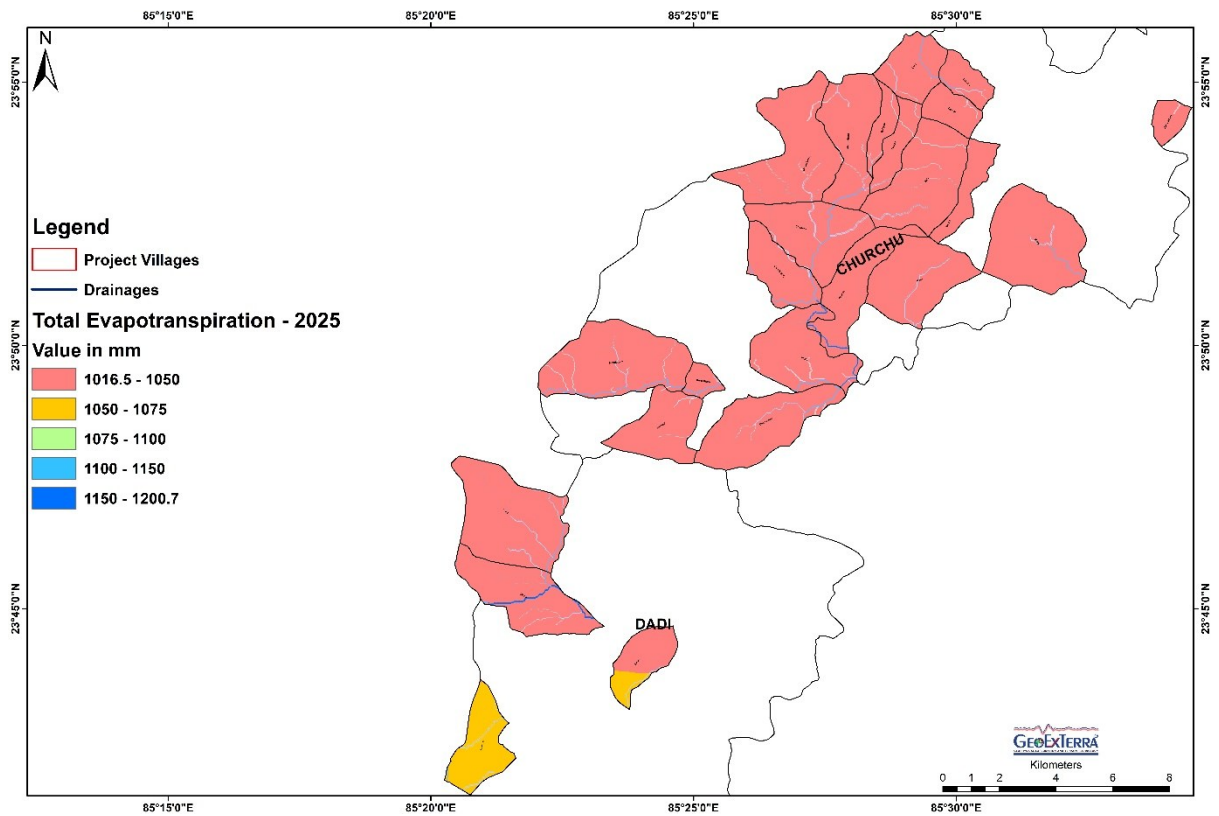


Fig. 98 Annual Evapotranspiration During 2025 in the Project Villages of Hazaribagh.

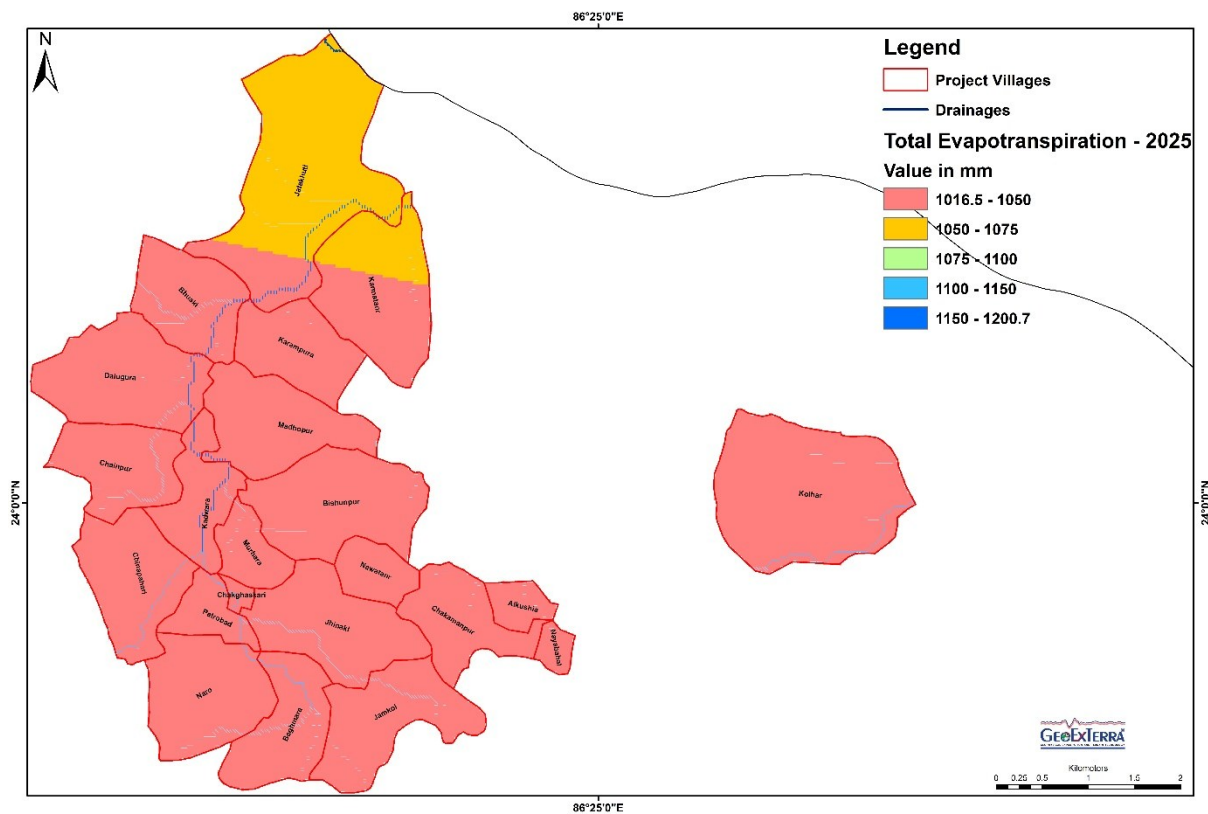


Fig. 99 Annual Evapotranspiration During 2025 in the Project Villages of Dhanbad.

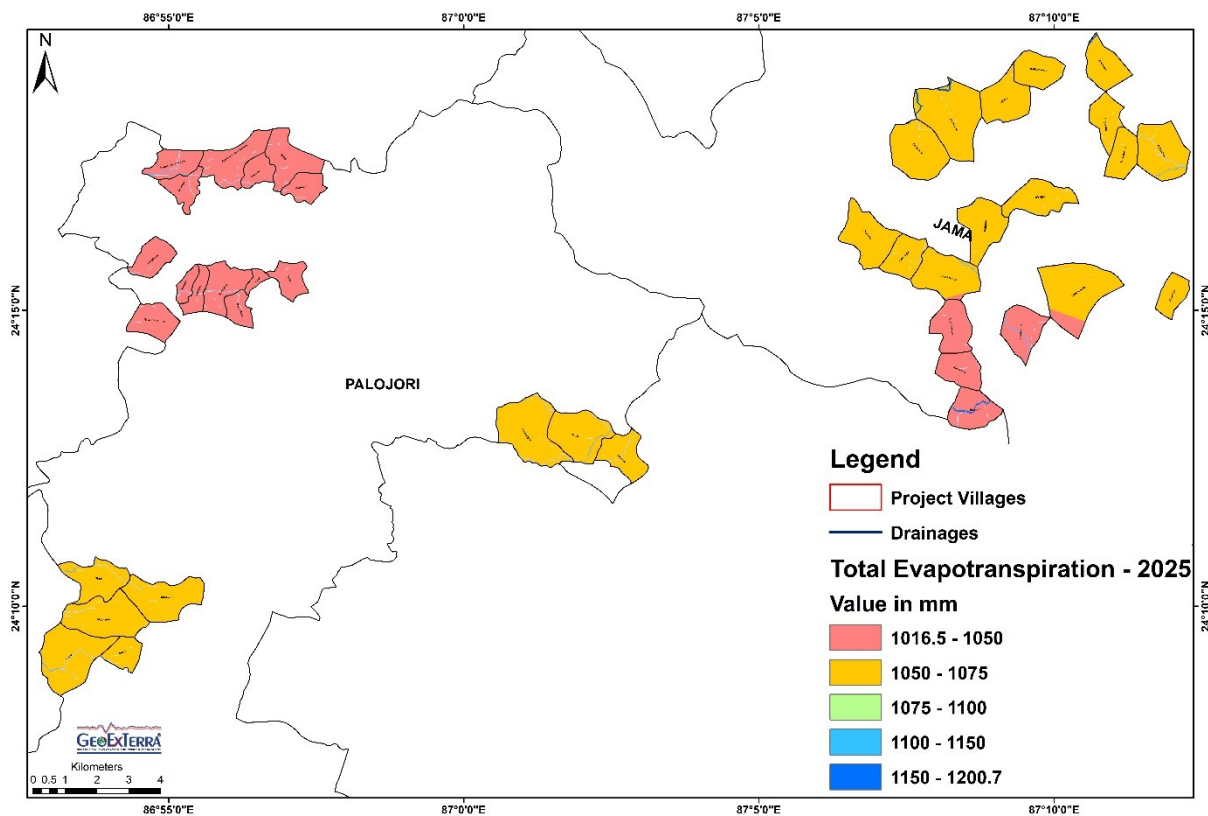


Fig. 100 Annual Evapotranspiration During 2025 in the Project Villages of Deoghar and Dumka.

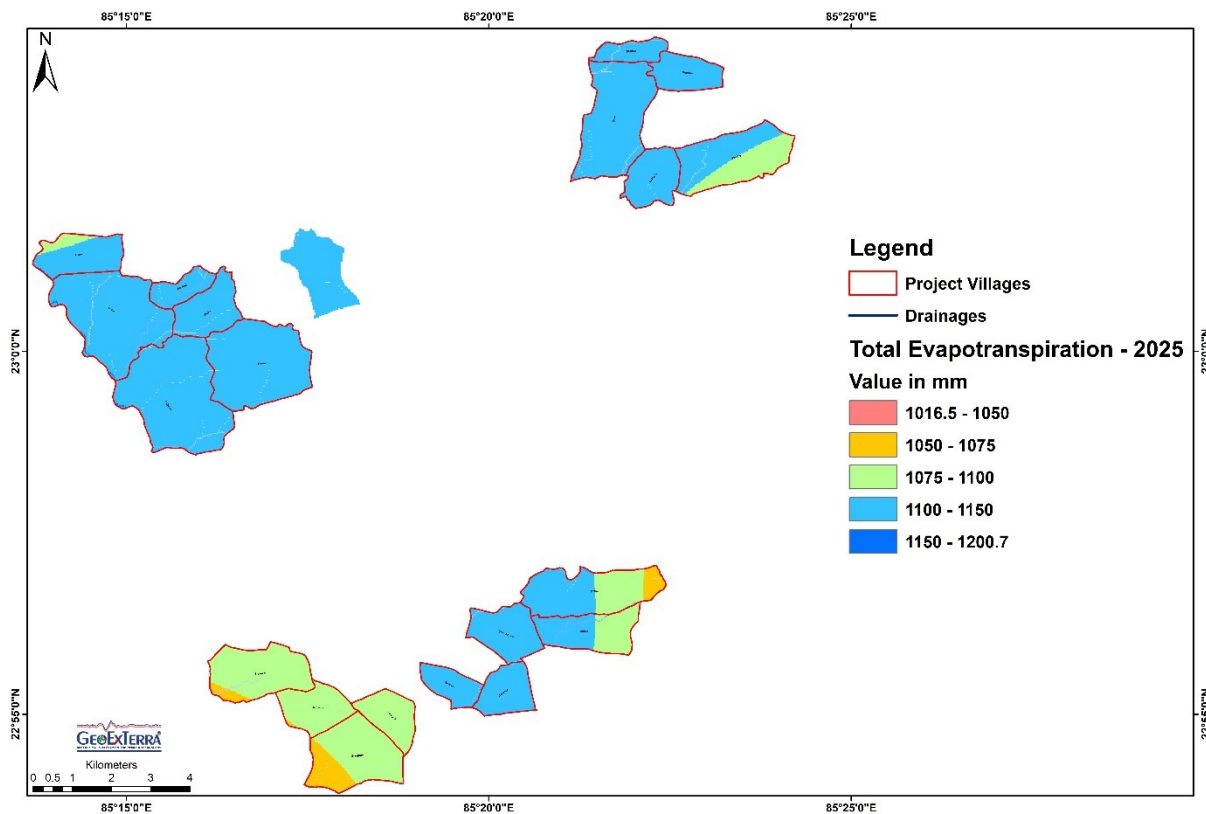


Fig. 101 Annual Evapotranspiration During 2025 in the Project Villages of Khunti.

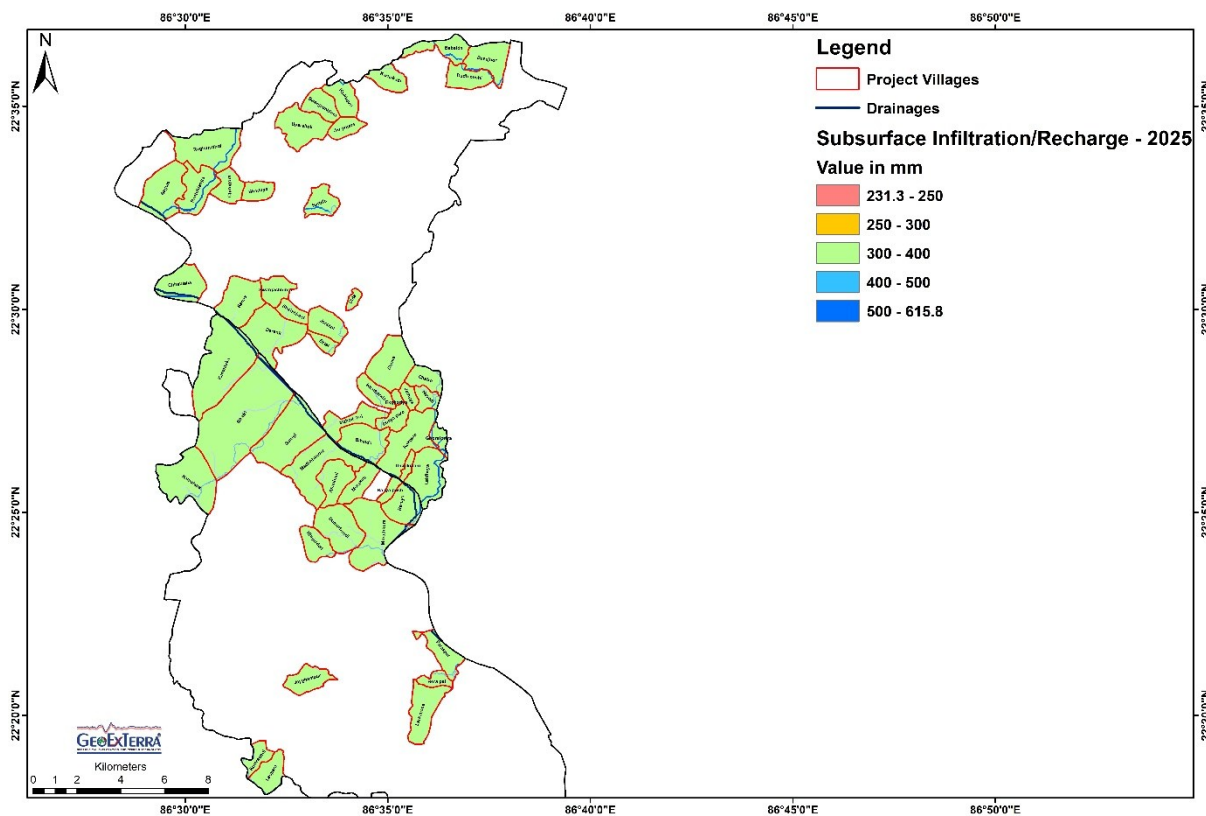


Fig. 102 Subsurface Infiltration/Natural Recharge/Annual Water Balance for the Year 2025 - East Singhbhum.

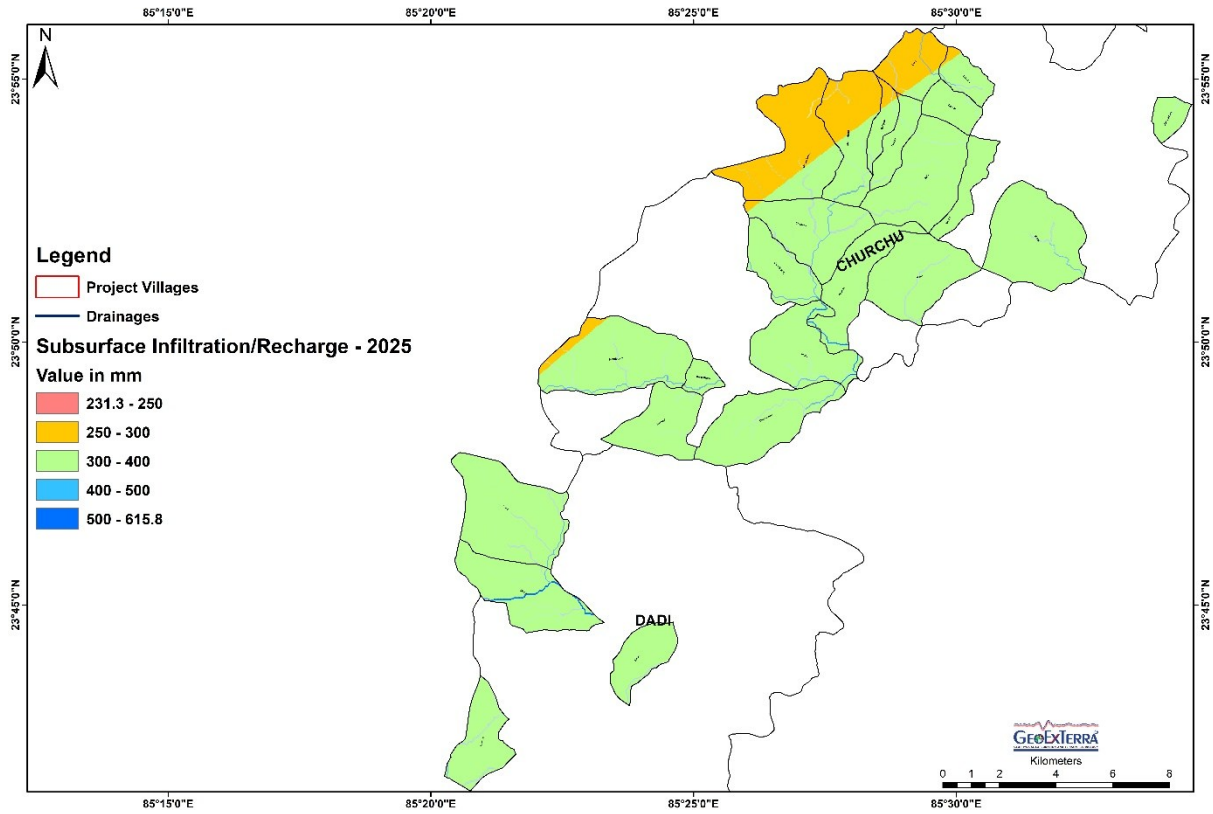


Fig. 103 Subsurface Infiltration/Natural Recharge/Annual Water Balance for the Year 2025 - Hazaribagh.

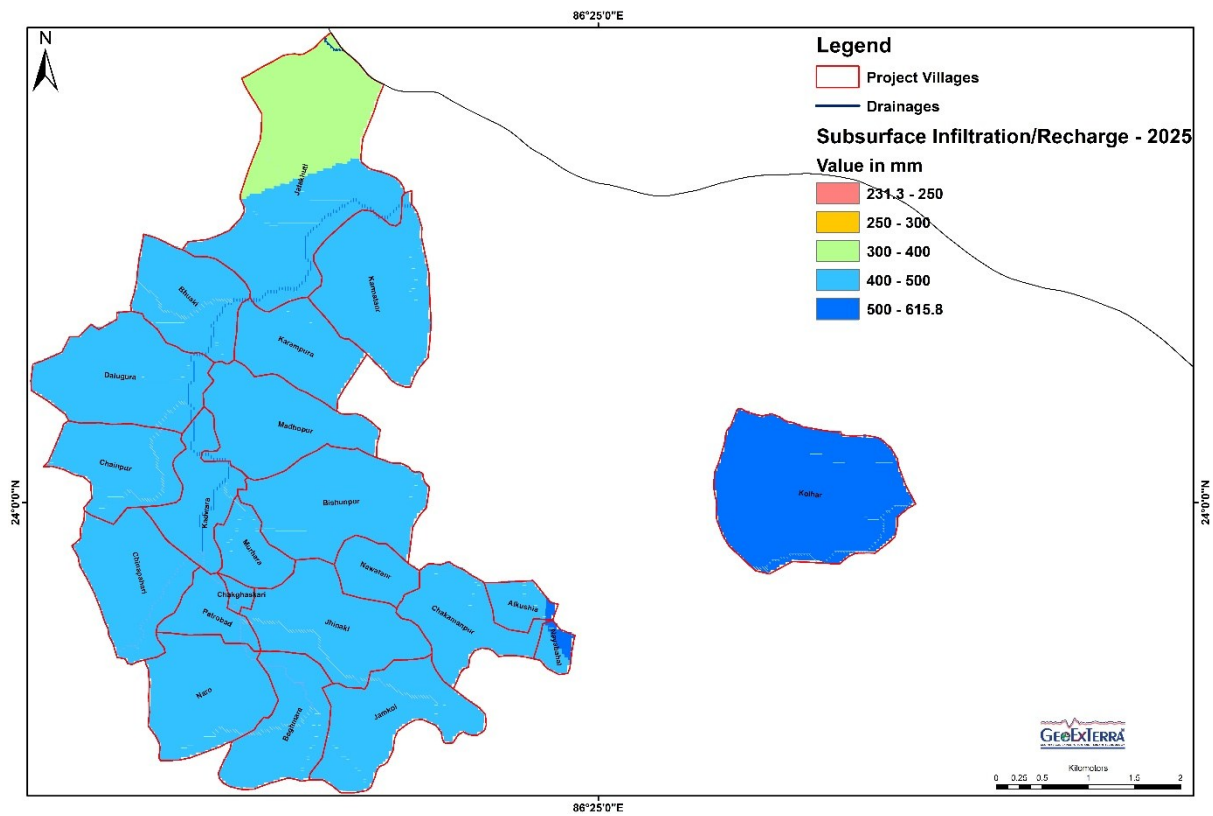


Fig. 104 Subsurface Infiltration/Natural Recharge/Annual Water Balance for the Year 2025 - Dhanbad.

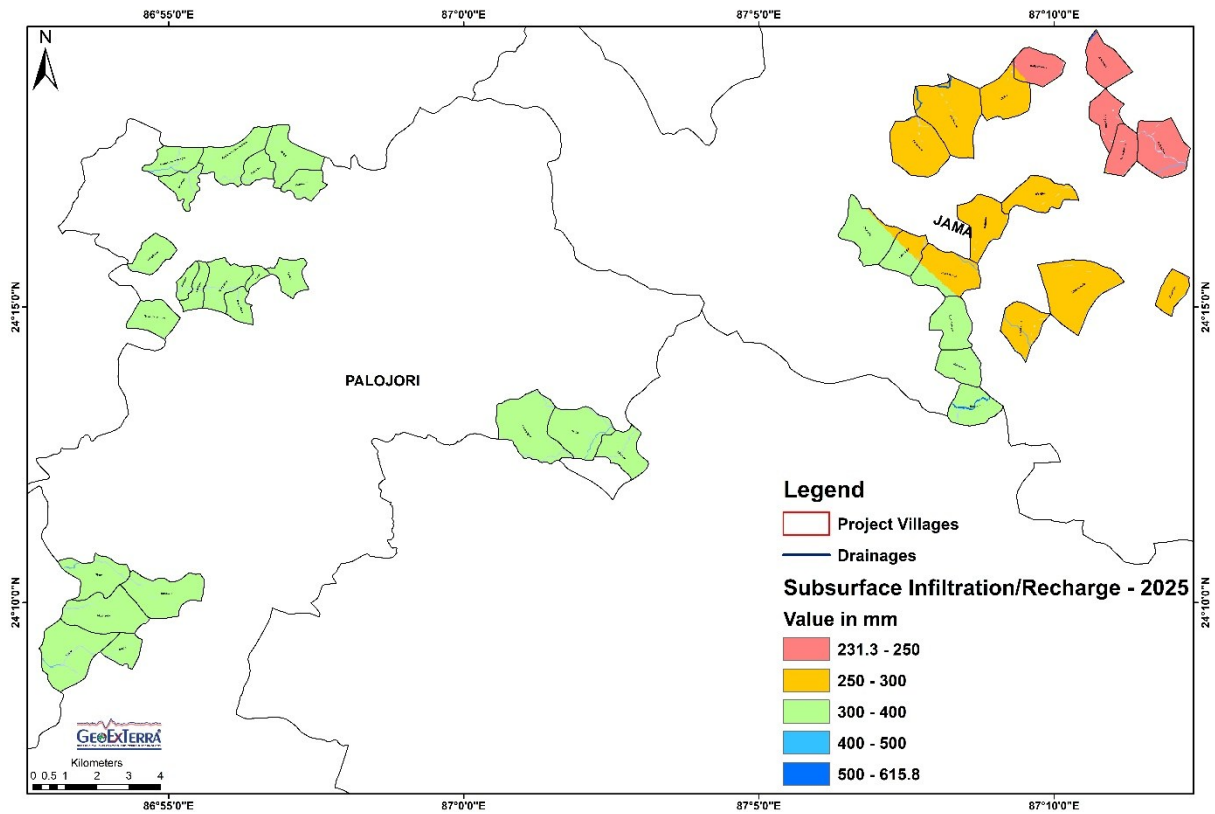


Fig. 105 Subsurface Infiltration/Natural Recharge/Annual Water Balance for the Year 2025 - Dumka.

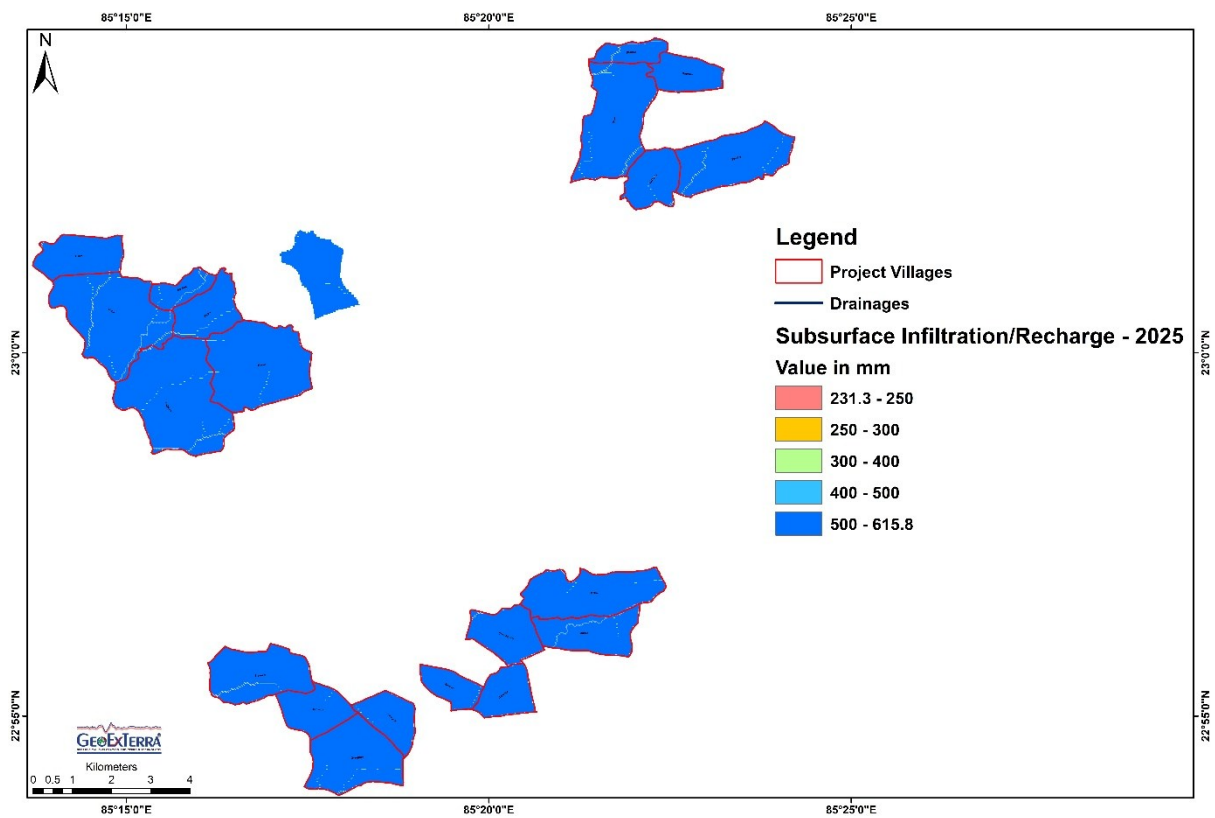


Fig. 106 Subsurface Infiltration/Natural Recharge/Annual Water Balance for the Year 2025 - Khunti.

and runoff rate significantly.

The SCS Runoff Curve Number Method is used for the calculation of the runoff from the land surface that meets in the river or streams. The evapotranspiration is used for the estimation of natural recharge/infiltration. The developed rainfall-runoff models have been used to understand the hydrological characteristics of the area and its runoff. In the project area during 2025, the surface runoff varies from 90.7 mm to 477.1 mm having a mean value of 231.5 mm (Figs. 92 to 96). The evapotranspiration varies from 1016.5 mm to 1200.7 mm having a mean of 1098.8 mm (Figs. 97 to 101) and recharge/infiltration varies from 231.3 mm to 615.8 mm having a mean value of 368.1 mm (Figs. 102 to 106). Water recharge/infiltration is a natural phenomenon as rainfall occurs. The annual water balance assessment for the project area (2025) provides a quantitative understanding of hydrological partitioning and its implications for groundwater sustainability and climate-resilient water management across the districts of Deoghar (Palojori), Dhanbad (Tundi), Dumka (Jama), East Singhbhum (Gurabanda and Dalbhumgarh), Hazaribagh (Churchu and Dadi), and Khunti (Murhu). The analysis indicates that the area receives an average annual rainfall of 1698.5 mm, corresponding to a substantial volumetric input of approximately 637.56 million cubic meters (637,561 TCM), reflecting the strong monsoonal influence typical of the eastern Indian plateau (Table 5). However, a dominant proportion of this precipitation—about 64.7% (1098.8 mm; 412,464.8 TCM)—is lost through evapotranspiration (ET), driven by high temperatures, vegetative transpiration, and extended dry periods, thereby significantly reducing the effective water availability for recharge and storage. The surface runoff component accounts for 13.6% of rainfall (231.5 mm; 86,900.3 TCM), indicating moderate runoff generation consistent with the region's undulating terrain, variable soil permeability, and seasonal rainfall intensity; this runoff is primarily conveyed through the dendritic drainage networks observed in the mapped areas, often resulting in rapid discharge from uplands and, can be conserved in the form of surface water bodies or can be infiltrated to recharge aquifers to raise the water level and water availability in the project area. Crucially, the remaining 21.7% of rainfall (368.1 mm; 138,173.6 TCM) contributes to infiltration and surface storage, which represents the effective component available for groundwater recharge, soil moisture retention, and baseflow sustenance. This proportion, while moderate, reflects the combined influence of soil hydro-physical characteristics (predominantly clay to sandy loam textures), overburden thickness variability, land cover conditions, and land degradation status, as previously analyzed. Areas with higher infiltration correspond to zones of moderate to high hydraulic conductivity and vegetative cover, whereas reduced infiltration is associated with clayey soils, degraded lands, and erosion-prone zones, where surface sealing and compaction limit percolation. The balance between runoff and infiltration highlights that although a significant fraction of rainfall is lost as ET, the system still retains a notable recharge potential, which can be strategically enhanced through watershed interventions.

From a hydrogeological perspective, the water balance clearly demonstrates that the groundwater regime is recharge-limited rather than rainfall-limited, meaning that improving infiltration efficiency and reducing non-productive losses is key to sustainable water resource development. The relatively high evapotranspiration losses underscore the importance of soil moisture conservation, afforestation, and cropping pattern optimization, while the runoff component presents an opportunity for harvesting through check dams, percolation tanks, and drainage desiltation structures, especially in medium to high runoff zones identified in Churchu, Tundi, and Jama. The

infiltration component (138 MCM annually), if effectively conserved and augmented, is sufficient to support decentralized groundwater-based irrigation and drinking water systems, provided that abstraction is regulated within recharge limits. Overall, the annual water balance reflects a hydrologically dynamic but moderately stressed system, where climatic inputs are adequate but losses through evapotranspiration and runoff constrain effective water availability. The findings emphasize that integrated watershed management, artificial recharge augmentation, and land use optimization are essential to convert the existing hydrological potential into sustainable groundwater resources. By enhancing the infiltration fraction and reducing runoff losses, the project area can significantly improve aquifer replenishment, baseflow continuity, and agricultural resilience, thereby aligning with the overarching objective of climate-resilient water security in the region.

**Table 5. Annual Water Balance of the Project Area for 2025.**

Parameters	Area Avg. Depth in mm	% of Rainfall	Volume (m3)	Volume (TCM)
Area Avg. Annual Rainfall	1698.5	100.0	637561321.5	637561.3
Area Avg. Annual Evapotranspiration	1098.8	64.7	412464835.0	412464.8
Area Avg. Annual Runoff	231.5	13.6	86900272.0	86900.3
Area Avg. Annual Infiltration & Surface Storage (available or baseflow)	368.1	21.7	138173629.8	138173.6

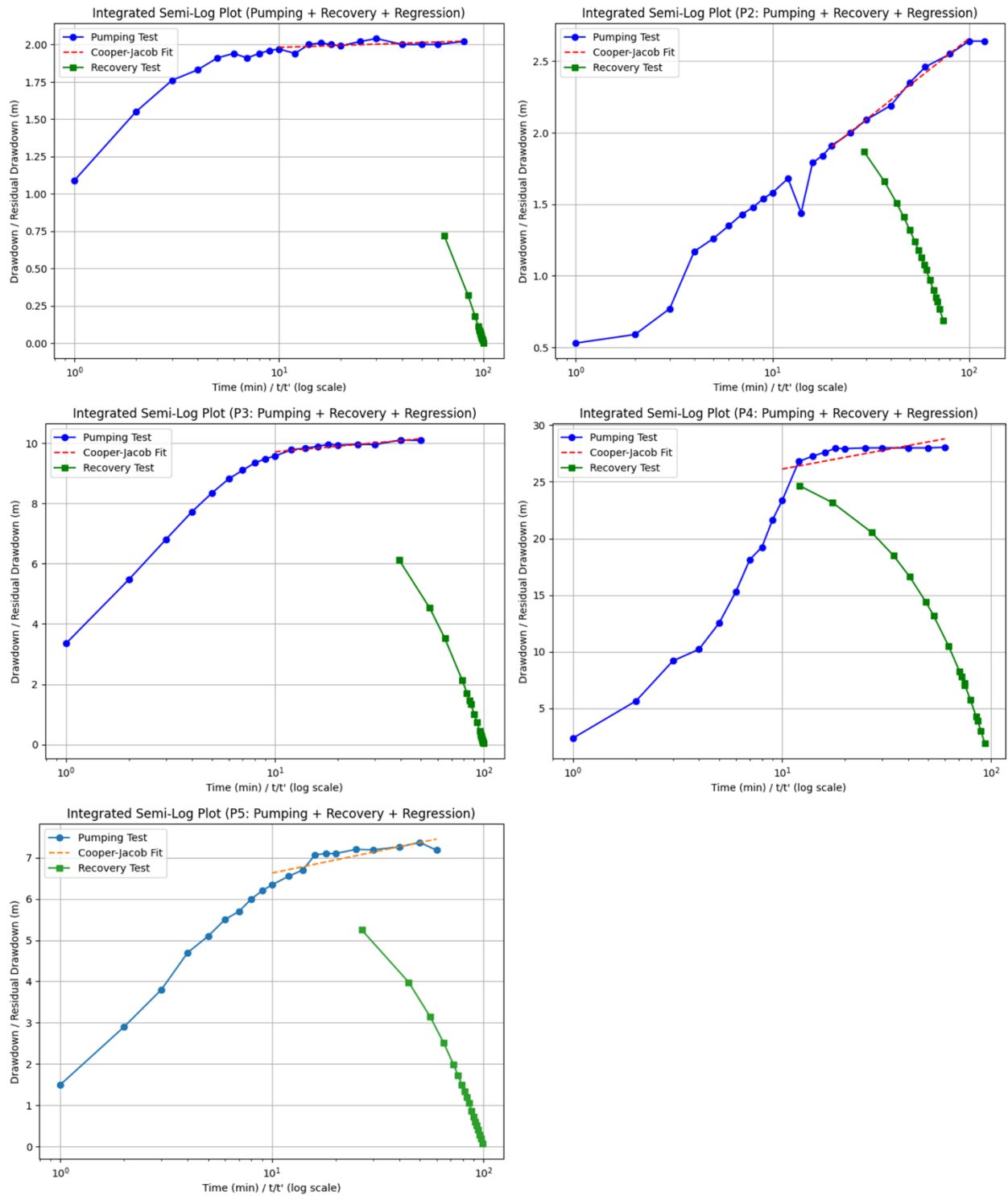
## 6.7 Pumping Test

A pumping test is the best available method to evaluate aquifer hydrogeological parameters. Among the main techniques are; analytical/conventional methods and numerical methods. Analytical/conventional methods involve one of the following: (1) curve matching, (2) finding inflection points, or for special cases, (3) fitting straight lines to the pumping test data. In curve-matching techniques and fields, results are generally plotted and matched against the results of analytical solutions. Five pumping tests were conducted in the project area (Fig. 107, Table 6). Analysis and interpretation of the pumping data were done using the Cooper Jacob Method Straight Line Method. Static water levels range from 4.91 m to 7.80 m below ground level, while discharge varies widely from 0.3587 lps (P1) to 23.08 lps (P4), indicating heterogeneity in fracture permeability and well efficiency. The transmissivity values exhibit a broad spectrum, with higher values observed at P1 (~113 m<sup>2</sup>/day) and P4 (~106.4 m<sup>2</sup>/day), suggesting well-developed fracture systems with good permeability, whereas lower transmissivity at P2 (~11.3 m<sup>2</sup>/day) and P5 (~10.4 m<sup>2</sup>/day) reflects poor fracture connectivity and restricted groundwater movement; P3 (~21.1 m<sup>2</sup>/day) represents an intermediate condition. Storativity values ranging from 0.0003 to 0.0025 confirm that the aquifers are predominantly semi-confined to confined in nature, governed by secondary porosity within weathered and fractured zones. The drawdown behavior further highlights aquifer conditions, with minimal drawdown at P1 (2.02 m) indicating stable aquifer response, moderate drawdown at P2 (2.64 m) and P5 (7.15 m) reflecting limited storage, and significantly high drawdown at P3 (10.09 m) and especially P4 (28.05 m), indicating aquifer stress, limited saturated thickness, and possible boundary-controlled flow conditions. Specific capacity values corroborate these findings, with relatively higher performance at P4 (0.823 lps/m) due to high discharge but constrained by low storage, while lower values at P3 (0.081 lps/m) and P5 (0.097 lps/m) indicate poor well productivity. Recovery test analysis shows that wells with higher transmissivity (P1 and P4) exhibit faster recovery trends, whereas P2 and P5 demonstrate slower recovery, confirming weak hydraulic connectivity. Overall, the hydrogeological regime of the project area is characterized by fractured crystalline aquifers with low storativity and

highly variable transmissivity, where groundwater occurrence and movement are controlled by the distribution, orientation, and connectivity of fractures. From a groundwater development perspective, P1 and P4 fall under moderate potential zones but require controlled abstraction due to storage limitations, P3 represents a low to moderate potential zone with stressed aquifer conditions, and P2 and P5 are classified as low potential zones suitable only for limited domestic use. The integrated analysis emphasizes that sustainable groundwater development in the region must adopt a site-specific approach combining hydrogeophysical targeting of fracture zones, regulation of pumping rates, and implementation of artificial recharge structures such as check dams, percolation tanks, and recharge shafts to enhance aquifer replenishment and ensure long-term climate-resilient water security.

**Table 6. Details and Specification of Pumping Test.**

Parameter	Value				
	P1	P2	P3	P4	P5
<b>ID</b>	P1	P2	P3	P4	P5
<b>Villages</b>	Tengdhoya, Palojori Block, Deoghar District	Chakamanpur, Tundi Block, Dhanbad District	Gaibathan, Jama Block, Dumka District	Kokpara, Dalbhumgarh Block, East Singhbhum District	Lara, Churchu Block, Hazaribagh District
<b>Well Type</b>	Dug Well	Dug Well	Dug Well	Dug Well	Dug Well
<b>Location – Latitude (°)</b>	24.26802	23.98901	24.29289	22.43452	23.91838
<b>Location – Longitude (°)</b>	86.91283	86.40153	87.19242	86.58819	85.4903
<b>Static Water Level (m bgl)</b>	6.35	4.91	5.27	7.8	6
<b>Average Discharge Rate (Ips)</b>	0.3587	0.4999	0.8206	23.08	0.695
<b>Duration of Pumping (min)</b>	80	100	50	60	60
<b>Maximum Drawdown (m)</b>	2.02	2.64	10.09	28.05	7.15
<b>Aquifer Type</b>	Basement Gneissic Complex (Fractured Rock Aquifer)	Basement Gneissic Complex (Fractured Rock Aquifer)	Basement Gneissic Complex (Fractured Rock Aquifer)	Phyllite (Fractured Rock Aquifer)	Basement Gneissic Complex (Fractured Rock Aquifer)
<b>Specific Capacity (Ips/m)</b>	0.177	0.189	0.081	0.823	0.097
<b>Specific Yield (%)</b>	2.5	0.5	1.0	0.3	0.5
<b>Transmissivity (m<sup>2</sup>/day)</b>	113	11.3	21.1	106.4	10.4
<b>Storativity (Derived Under Formation)</b>	0.0025	0.0005	0.001	0.0003	0.0005
<b>Aquifer Behaviour</b>	Semi-Confined	Semi-Confined	Semi-Confined	Confined/Boundary	Semi-Confined
<b>Potentiality Description</b>	Moderate groundwater potential; fracture-controlled aquifer with limited storage but good local transmissivity. Suitable for small-scale water supply and decentralized groundwater development; requires recharge augmentation for sustainability.	Low groundwater potential; aquifer is fracture-controlled with poor connectivity and limited storage. Suitable only for low-yield domestic use. Groundwater development should rely on targeted fracture zone identification and artificial recharge interventions for sustainability.	Low to moderate groundwater potential; aquifer exhibits moderate transmissivity but very high drawdown indicating limited saturated thickness and stressed conditions. Groundwater occurrence is fracture-controlled, and sustainable development requires regulated abstraction along with recharge augmentation measures.	Moderate groundwater potential under controlled abstraction; aquifer exhibits high transmissivity but extremely high drawdown indicating very low storage and boundary-controlled behavior. Suitable for moderate discharge wells with regulated pumping and mandatory recharge augmentation to ensure sustainability.	Low groundwater potential; aquifer exhibits low transmissivity and moderate drawdown, indicating limited permeability and restricted fracture connectivity. Suitable for small-scale domestic use, with groundwater development dependent on fracture zone targeting and recharge augmentation for sustainability.



**Fig. 107 Integrated Semi-Log Plot Showing Pumping Test, Recovery Test, and Cooper–Jacob Straight-Line Analysis for Well P1 to P5.**

## 6.8 Geophysical Data Analysis

One most useful practical application of apparent resistivity measurement is finding out the possible anomalies of the subsurface due to the presence of litho-geological (formations and their properties) and structural contrast

i.e., structural deformations caused by faults and fractures, geological contrast, and intrusive bodies. Geophysical resistivity survey brought various information related to hydrogeological properties of the subsurface i.e., the thickness of rock overburden, weathered and fractured aquifers, and their hydrological properties have been recognized and analyzed to understand the condition of groundwater, seawater intrusion in the coastal aquifer system of the project area are detailed hereunder (Annexure 1).

### 6.8.1 Geophysical Mapping of Rock Overburden Thickness

The geophysical mapping of rock overburden thickness across the project villages, provides critical insight into the subsurface conditions that control groundwater recharge, storage, and movement within the hydrogeological system. The overburden in the study area comprises soil cover, weathered rock, and semi-weathered material lying above the fractured or consolidated parent rock, which collectively form the unsaturated and partially saturated zone above the deeper aquifer system. This layer exhibits a distinct electrical resistivity contrast with the underlying bedrock, allowing its thickness and spatial distribution to be delineated effectively through geophysical investigation and mapping. Interpretation of the rock overburden thickness map (Figs. 108 to 112) indicates that the thickness of this layer across the project area varies from about 0.5 m to 8.8 m, with an average thickness of approximately 3.1 m, demonstrating significant spatial heterogeneity related to local geomorphology, drainage development, weathering intensity, and lithological variations. Areas with thin overburden (0.5–1 m) represent zones where the bedrock occurs close to the surface, typically associated with upland ridges or gently elevated

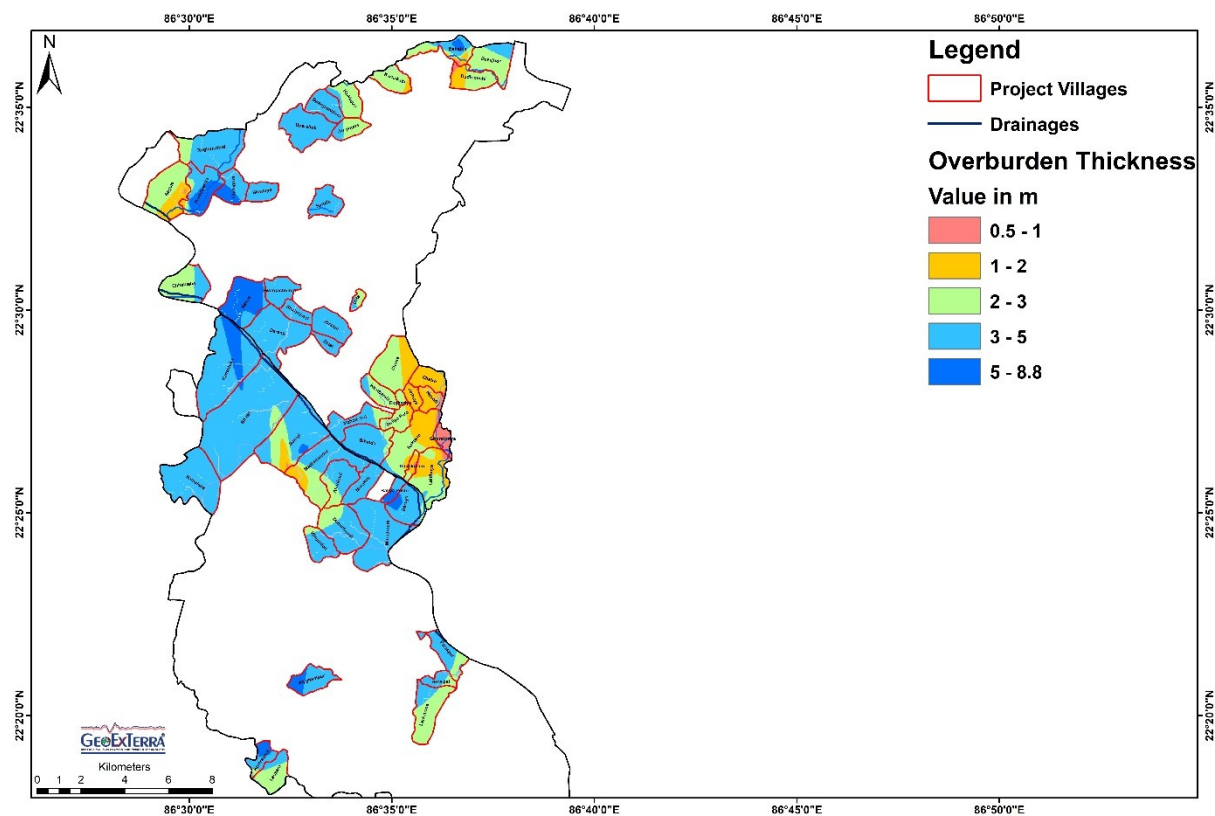


Fig. 108 Overburden Thickness Map of the Project Villages of East Singhbhum.

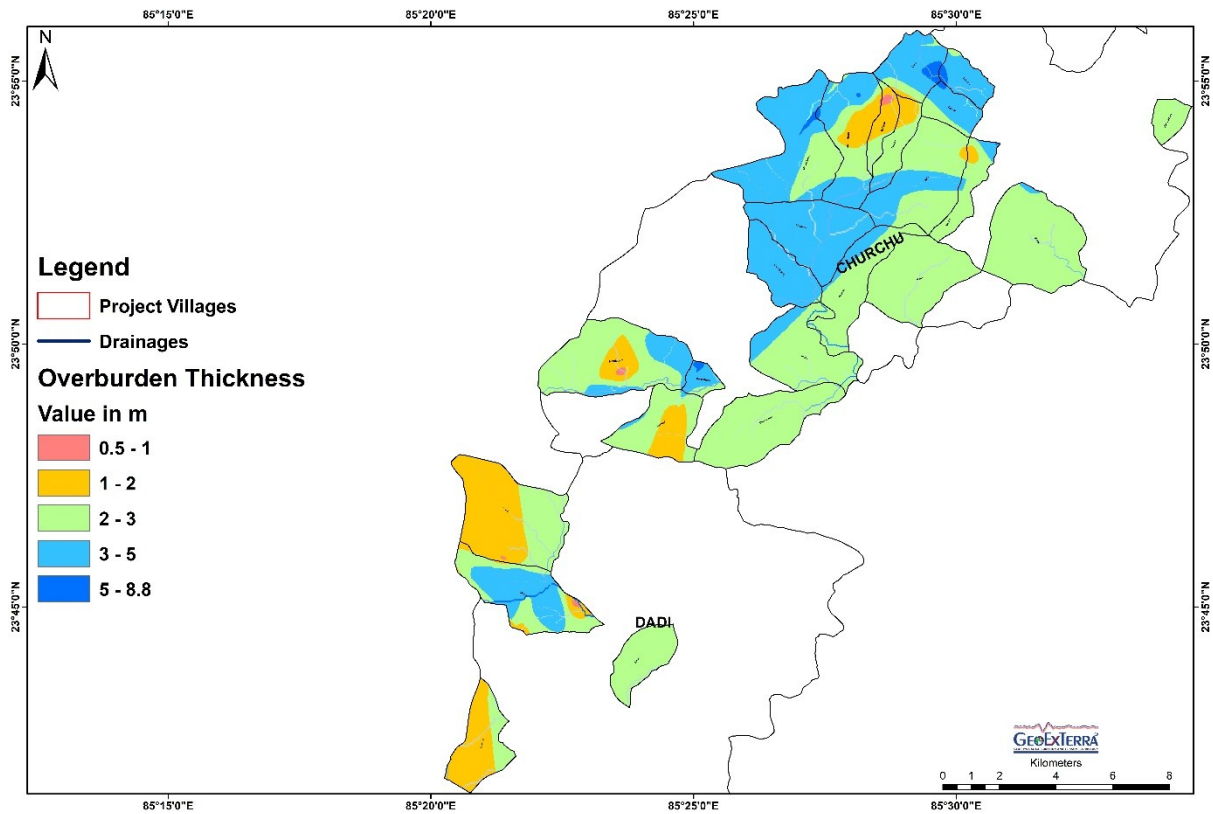


Fig. 109 Overburden Thickness Map of the Project Villages of Hazaribagh.

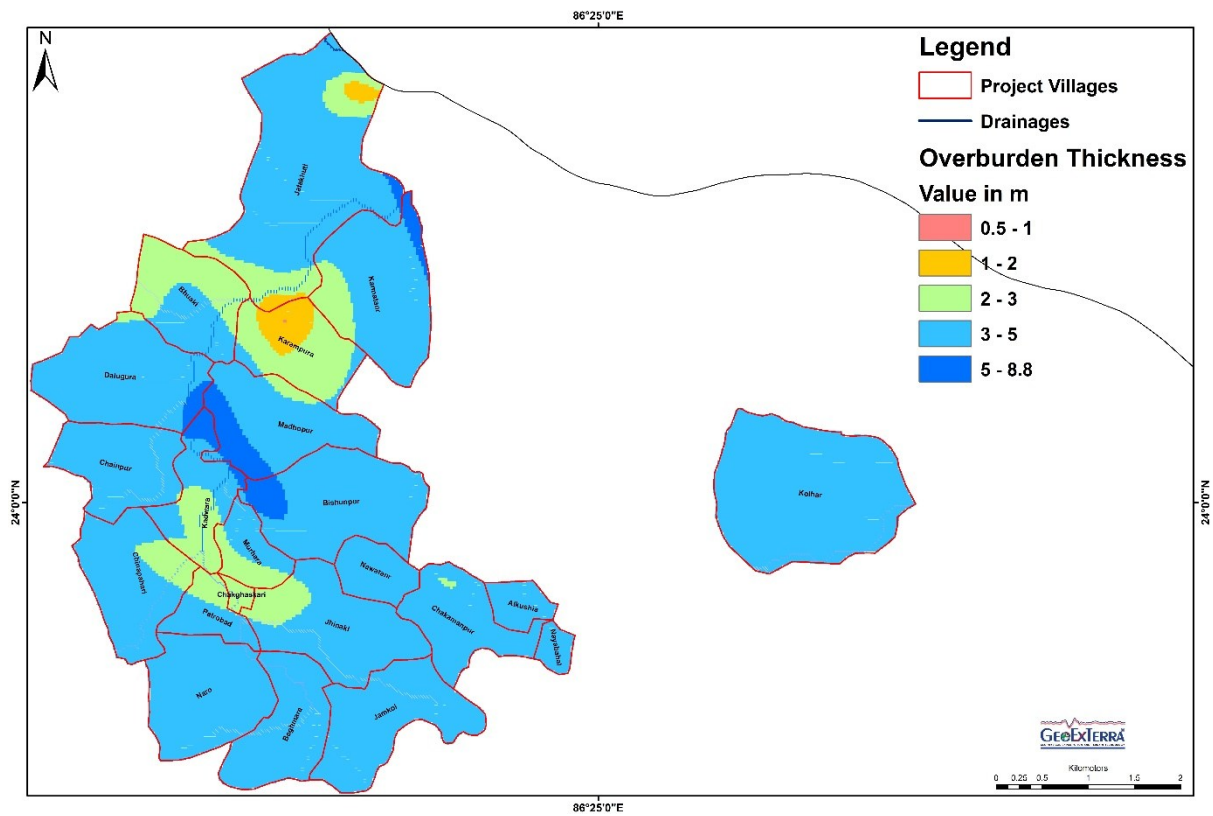


Fig. 110 Overburden Thickness Map of the Project Villages of Dhanbad.

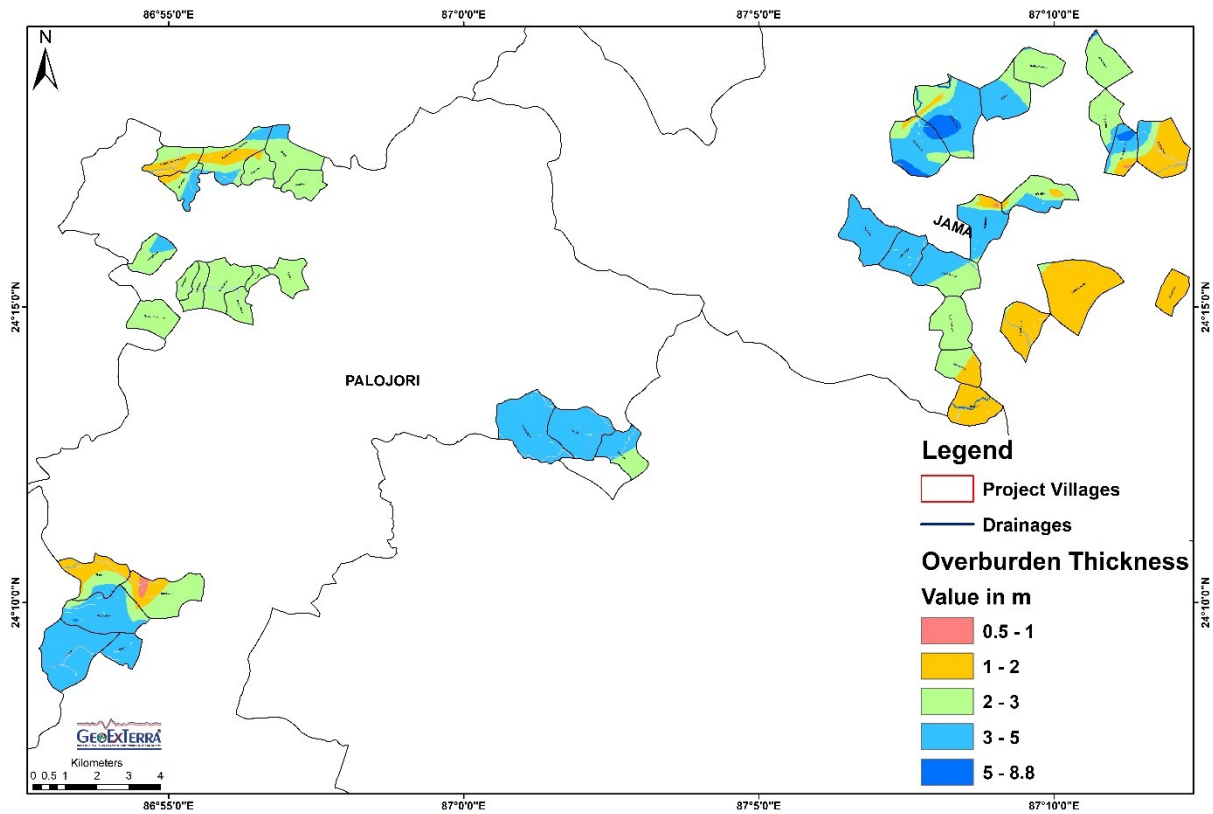


Fig. 111 Overburden Thickness Map of the Project Villages of Deoghar and Dumka.

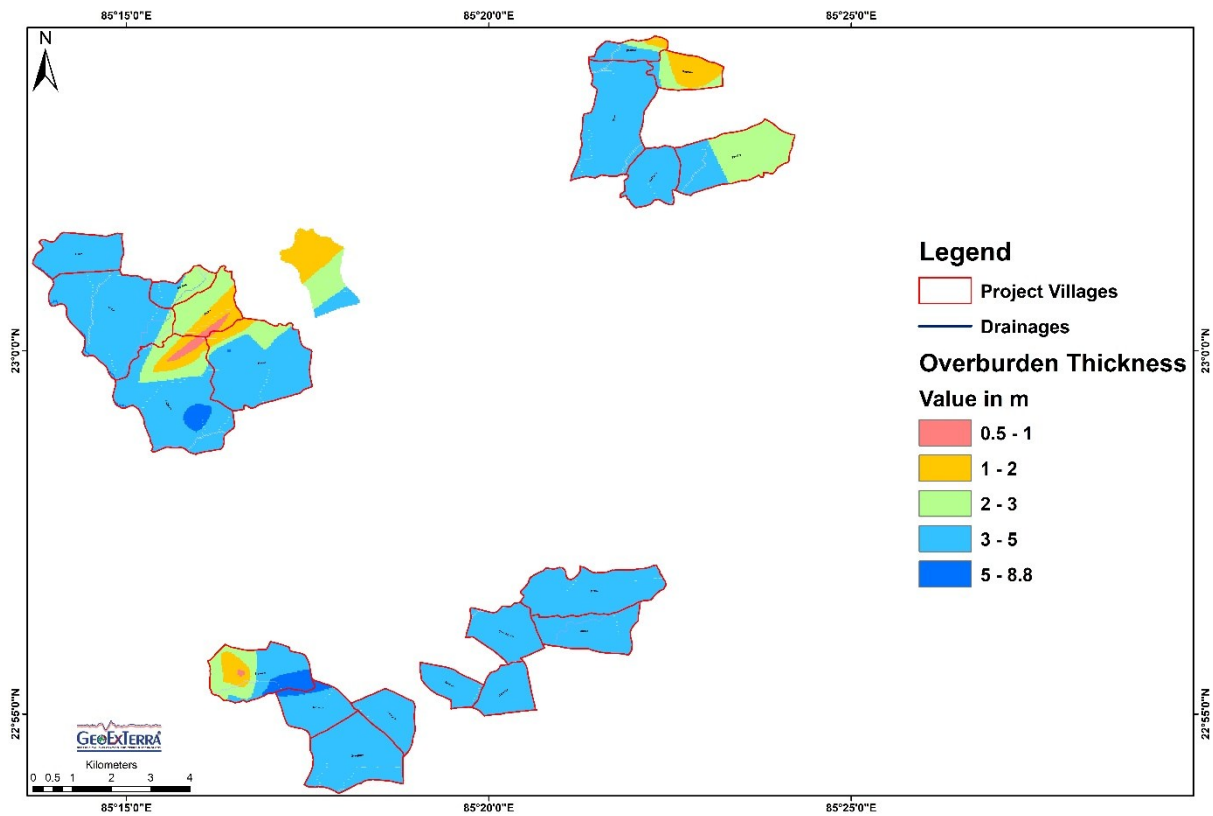


Fig. 112 Overburden Thickness Map of the Project Villages of Khunti.

terrains where weathering and soil development are relatively limited. Such zones generally exhibit lower water storage capacity and limited infiltration potential, as rainfall runoff rapidly moves over the surface or directly enters shallow fractures without significant soil storage. Moderately thick overburden zones ranging from 1–3 m and 2–3 m are widely distributed across several project villages and represent typical pediplain and gently undulating landscapes where moderate weathering has produced a reasonable thickness of soil and weathered rock capable of retaining moisture and facilitating infiltration. These areas are particularly important for natural groundwater recharge, as the moderately thick overburden acts as a permeable medium through which rainfall can percolate gradually toward the fractured bedrock aquifer system. The thicker overburden zones ranging from 3–5 m and up to 5–8.8 m occur in localized depressions, valley fills, and drainage-aligned zones where prolonged weathering and sediment accumulation have resulted in deeper regolith development. These thicker overburden sections play a crucial hydrogeological role as natural storage reservoirs, effectively acting as a “sponge layer” that absorbs rainfall runoff, stores moisture within the vadose zone, and slowly transmits water downward to deeper aquifers through percolation and fracture networks. The presence of such zones is particularly favorable for groundwater recharge enhancement and sustainable aquifer replenishment, as they provide greater infiltration capacity and delay the movement of water, thereby reducing immediate runoff losses. Additionally, the characteristics of the overburden influence not only recharge processes but also the dynamics of groundwater levels, subsurface flow regimes, and the physicochemical evolution of groundwater, as water percolating through the soil and weathered layers undergoes filtration, mineral interaction, and geochemical transformation before reaching the aquifer. Areas with thicker overburden typically exhibit greater buffering capacity for groundwater quality, whereas thinner zones may show more direct interaction between surface conditions and groundwater chemistry. Overall, the mapped distribution of rock overburden thickness across the project villages highlights a hydrogeologically favorable environment where moderate to thick overburden zones dominate many parts of the landscape, supporting effective rainfall infiltration and groundwater recharge.

### **6.8.2 Geophysical Mapping of Weathered Aquifers**

The geophysical mapping of weathered aquifers across the project villages, provides critical insight into the subsurface hydrogeological framework governing groundwater occurrence, storage, and movement within the region. The hydrogeological system of the project area is characterized by two principal aquifer types, weathered aquifers and fractured aquifers, both developed within the consolidated geological formations underlying the terrain. Geological formations capable of storing and transmitting significant quantities of groundwater are defined as aquifers, and in hard rock terrains such as the present study area, groundwater occurs primarily within secondary porosity zones created through weathering and fracturing processes. The geophysical investigations carried out across the project villages reveal that weathered rock formations typically exhibit electrical resistivity values ranging between approximately 15  $\Omega\cdot\text{m}$  and 250  $\Omega\cdot\text{m}$ , which correspond to zones where the original parent rock has undergone extensive physical disintegration and chemical alteration due to prolonged weathering processes. These weathered formations commonly occur in two forms: firstly as highly disintegrated weathering mantles consisting of fragmented rock particles, clay, and soil-filled interspaces, and secondly as partially intact weathered rock layers containing residual fragments of the parent rock embedded within a matrix of altered

material. Both forms are hydrogeologically significant because they develop enhanced porosity and permeability compared to unweathered bedrock, thereby creating favorable conditions for groundwater storage and percolation. Interpretation of the weathered aquifer thickness map (Figs. 113 to 117) indicates that the thickness of the weathered zone within the project area varies widely from about 1 m to as much as 59.9 m, although the average thickness across the villages is approximately 9.4 m, suggesting that the majority of the terrain contains a moderately developed weathered mantle capable of supporting shallow groundwater storage. Areas with thin weathered aquifer thickness (1–10 m) are commonly associated with elevated or rocky terrain where erosion has removed much of the weathered material, resulting in limited groundwater storage capacity and relatively shallow aquifer development. In contrast, moderate weathered aquifer thickness zones ranging from about 10–20 m and 20–30 m occur in several localized pockets across the project area, particularly within gently undulating pediplain regions and drainage-aligned zones where weathering processes have been more intense and prolonged. These zones represent favorable groundwater storage domains, as the thicker weathered mantle can retain greater volumes of infiltrated rainfall and gradually release water into deeper fractured rock aquifers. The thicker weathered aquifer zones exceeding 30 m and reaching up to about 59.3 m, though limited in spatial distribution, are of particular hydrogeological significance as they represent deep weathering profiles or structurally controlled zones where weathering has penetrated deeper along fracture networks and structural discontinuities. Such zones often occur in association with lineaments, drainage valleys, and structurally deformed rock masses, where long-term weathering and fracture enlargement have created enhanced permeability pathways that facilitate groundwater

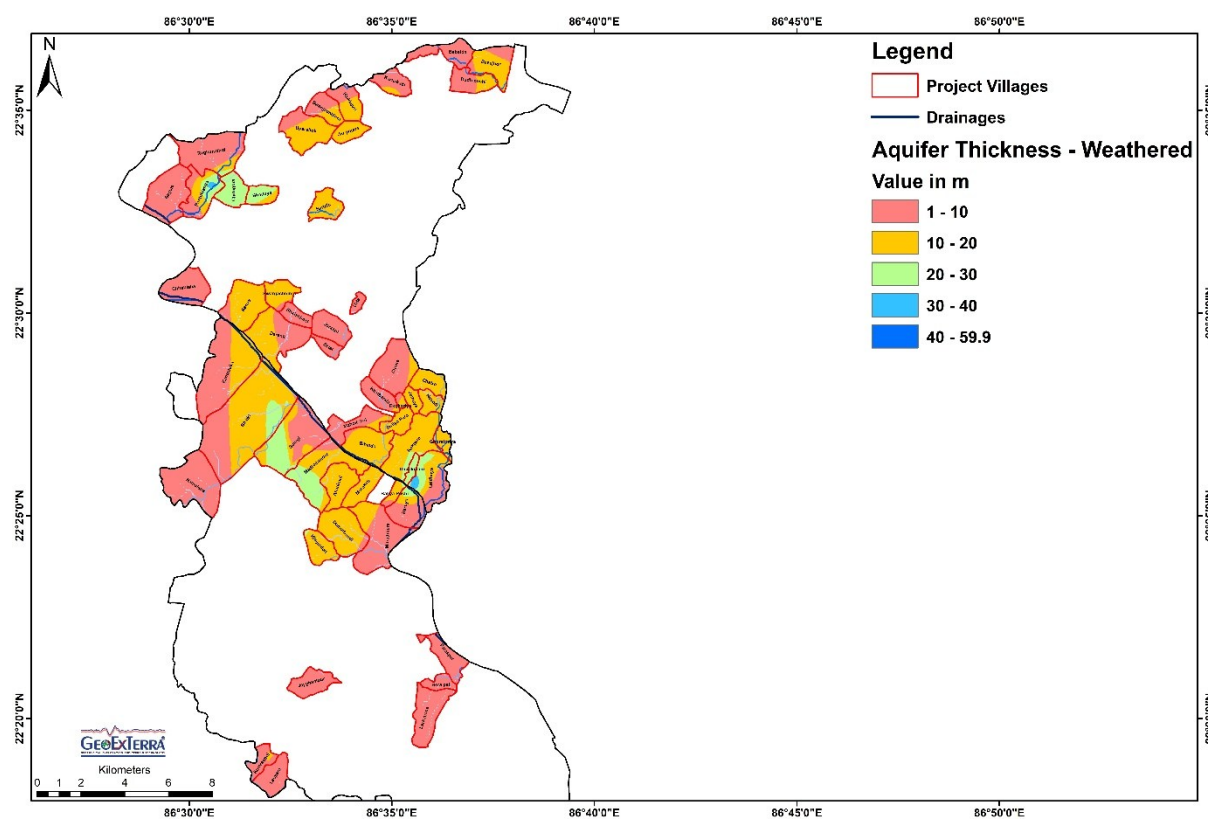


Fig. 113 Thickness of Weathered Aquifers of the Project Villages of East Singhbhum.

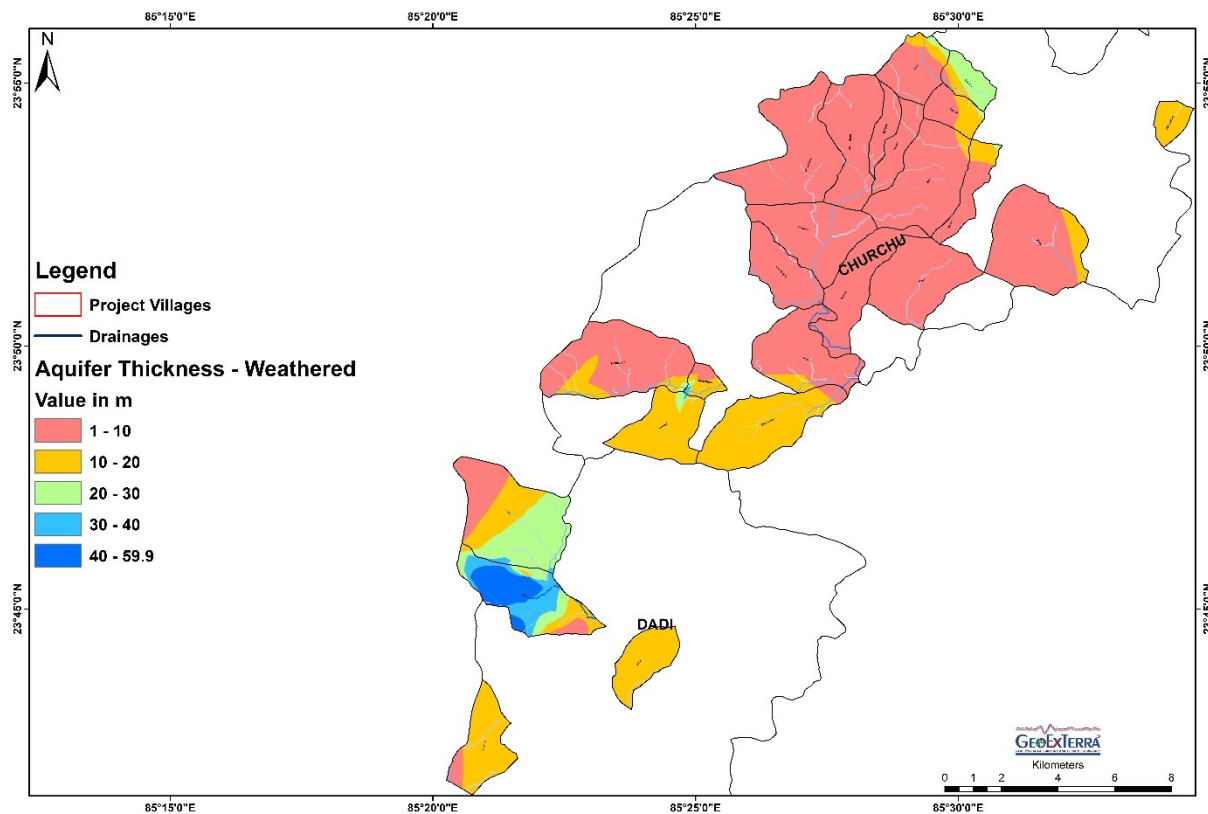


Fig. 114 Thickness of Weathered Aquifers of the Project Villages of Hazaribagh.

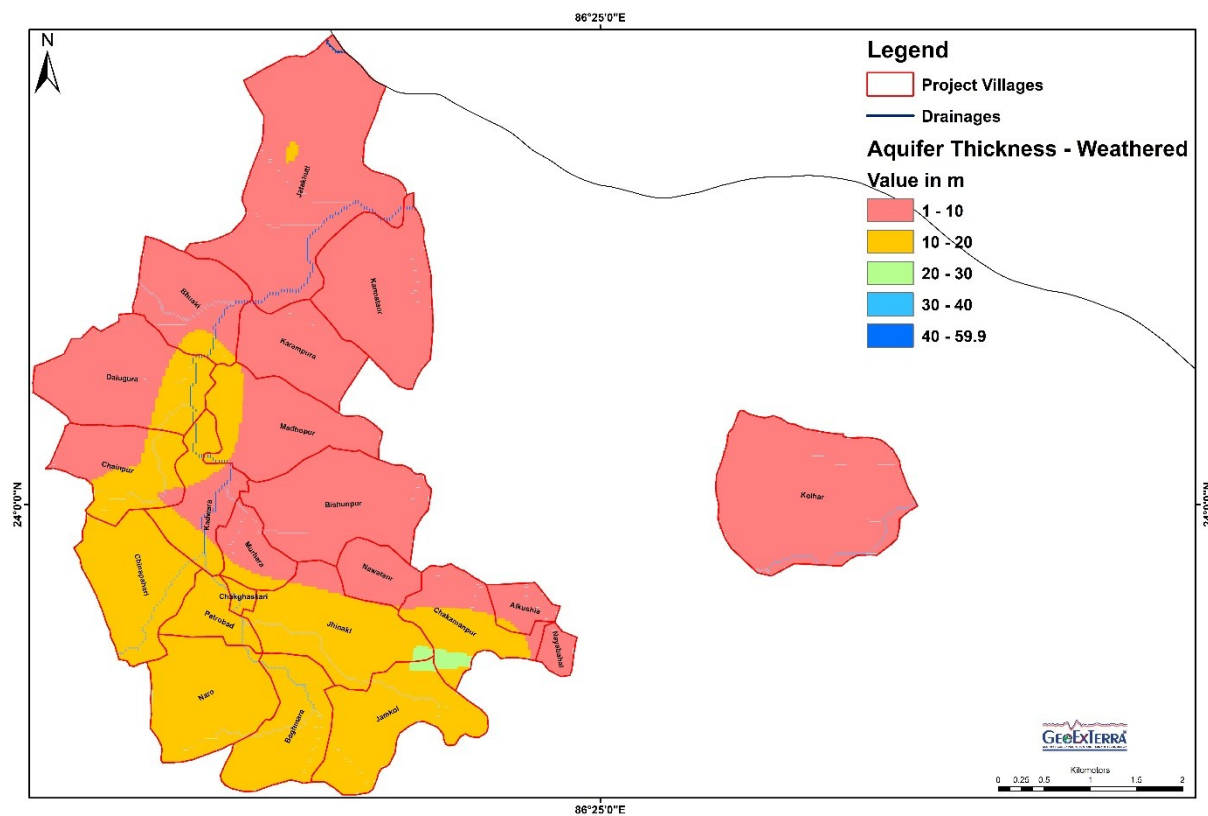


Fig. 115 Thickness of Weathered Aquifers of the Project Villages of Dhanbad.

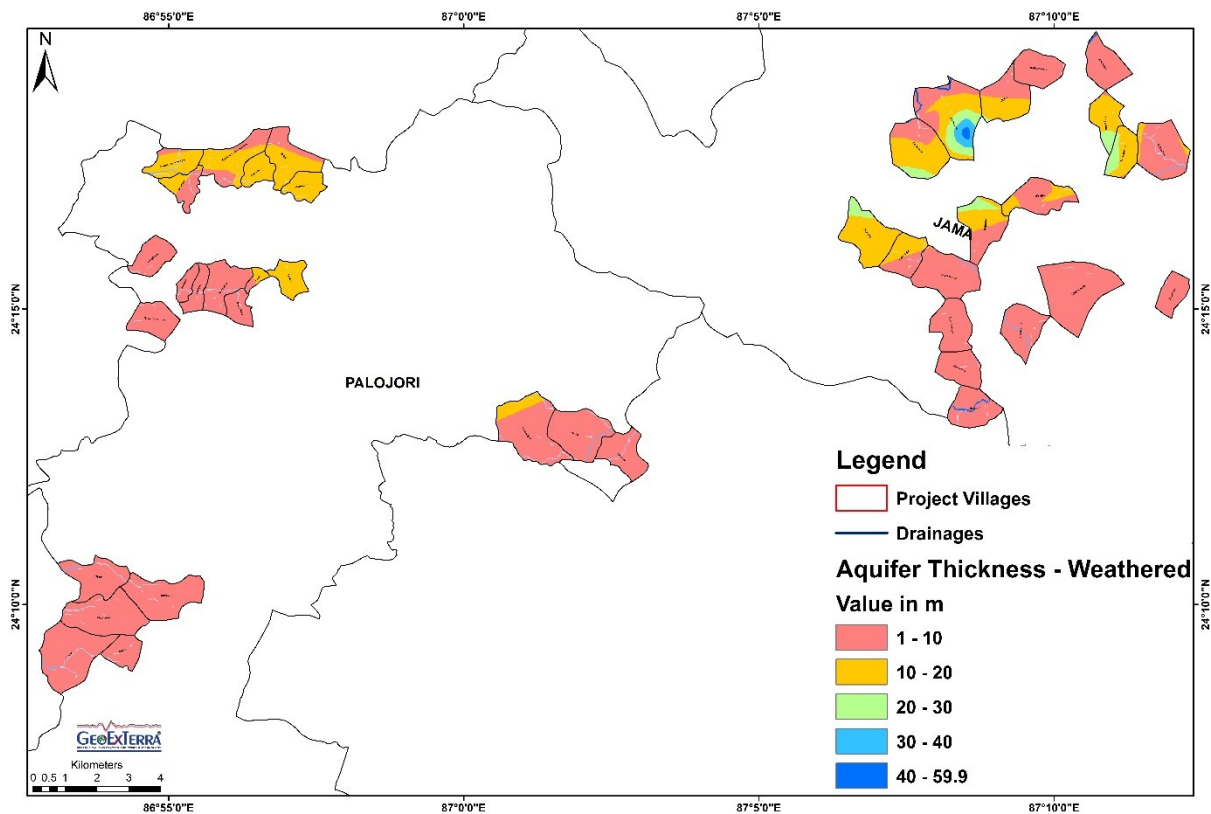


Fig. 116 Thickness of Weathered Aquifers of the Project Villages of Deoghar and Dumka.

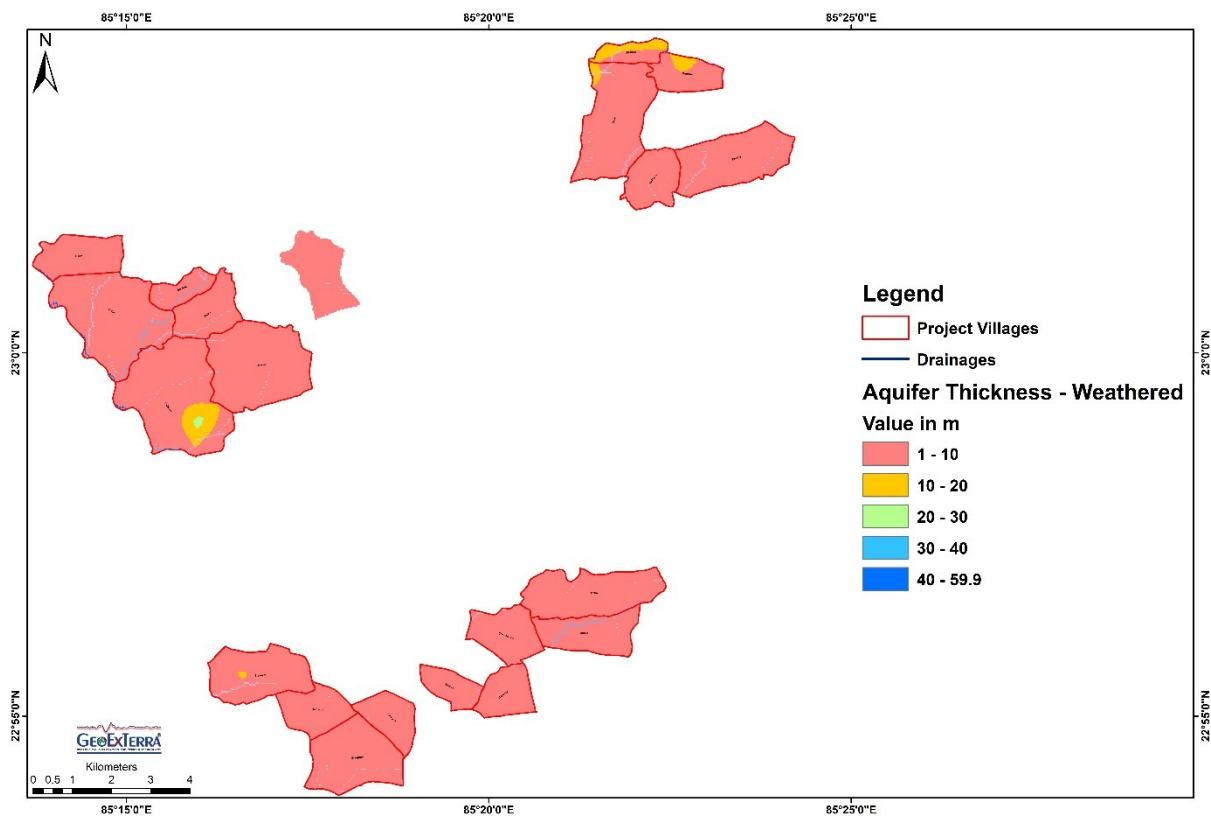


Fig. 117 Thickness of Weathered Aquifers of the Project Villages of Khunti.

movement and storage. The spatial distribution of these weathered aquifers therefore reflects the combined influence of geological structure, lithology, drainage development, and geomorphic evolution, which collectively control the depth and intensity of weathering within the region. From a groundwater resource perspective, the weathered aquifer forms an important shallow groundwater reservoir that acts as the primary recharge and storage zone, receiving infiltrated rainfall through soil and overburden layers before transmitting water downward into deeper fractured bedrock aquifers. Consequently, areas exhibiting moderate to thick weathered aquifer zones represent the most promising locations for groundwater development through dug wells and shallow bore wells, while zones with thinner weathered profiles may require deeper drilling to intercept productive fractured aquifers.

### **6.8.3 Geophysical Mapping of Fractured Aquifers**

The geophysical mapping of fractured aquifers within the project villages, provides critical insight into the deeper groundwater-bearing zones that control groundwater availability in the hard rock hydrogeological environment of the region. In crystalline and consolidated geological terrains such as those occurring in the project area, primary porosity is typically negligible; therefore, groundwater occurrence largely depends on secondary porosity and permeability created by structural discontinuities such as fractures, joints, cracks, and faults within the bedrock. These structurally controlled openings provide pathways for groundwater storage and movement and thus form the principal fractured aquifer systems underlying the weathered mantle. The geophysical investigation conducted across the project villages has enabled the delineation of fractured aquifer zones and their spatial thickness distribution, as represented in the fractured aquifer thickness map (Figs. 118-122). The interpretation of this map indicates that the thickness of fractured aquifers across the project area varies from approximately 1 m to 67.5 m, with an average thickness of about 14.2 m, suggesting a heterogeneous distribution of fracture development within the bedrock formations. Areas characterized by thin fractured zones (1–5 m) generally represent regions where bedrock fracturing is limited or poorly developed, resulting in relatively low groundwater storage capacity and limited transmissivity. Such zones are commonly associated with structurally stable bedrock areas where groundwater occurrence may be restricted to narrow fractures or isolated joints. In contrast, moderately developed fractured aquifers ranging between 5–10 m and 10–20 m thickness occur across several villages, indicating zones where the bedrock has undergone moderate tectonic deformation or prolonged weathering along structural weaknesses, thereby enhancing fracture density and hydraulic connectivity. These moderate fracture zones often provide reliable groundwater yields, particularly when intersected by bore wells that penetrate multiple interconnected fractures. The map further reveals thicker fractured aquifer zones ranging from about 20–30 m and extending locally up to 30–67.5 m, which represent highly favorable hydrogeological conditions where extensive fracturing and structural deformation have created deep interconnected fracture networks capable of storing and transmitting significant volumes of groundwater. These thicker fractured zones are typically observed in areas aligned with major drainage channels, structural lineaments, and valley zones, where tectonic stresses and erosional processes have promoted fracture development and enlargement over geological time. Spatially, the distribution pattern suggests that some of the more productive fractured aquifer zones occur in the north of Gurabanda, north and east of Dalbhumgarh, north Tundi, and Jama blocks, where localized patches exhibit greater fracture thickness and enhanced groundwater potential. The presence of these fracture-controlled aquifers is of

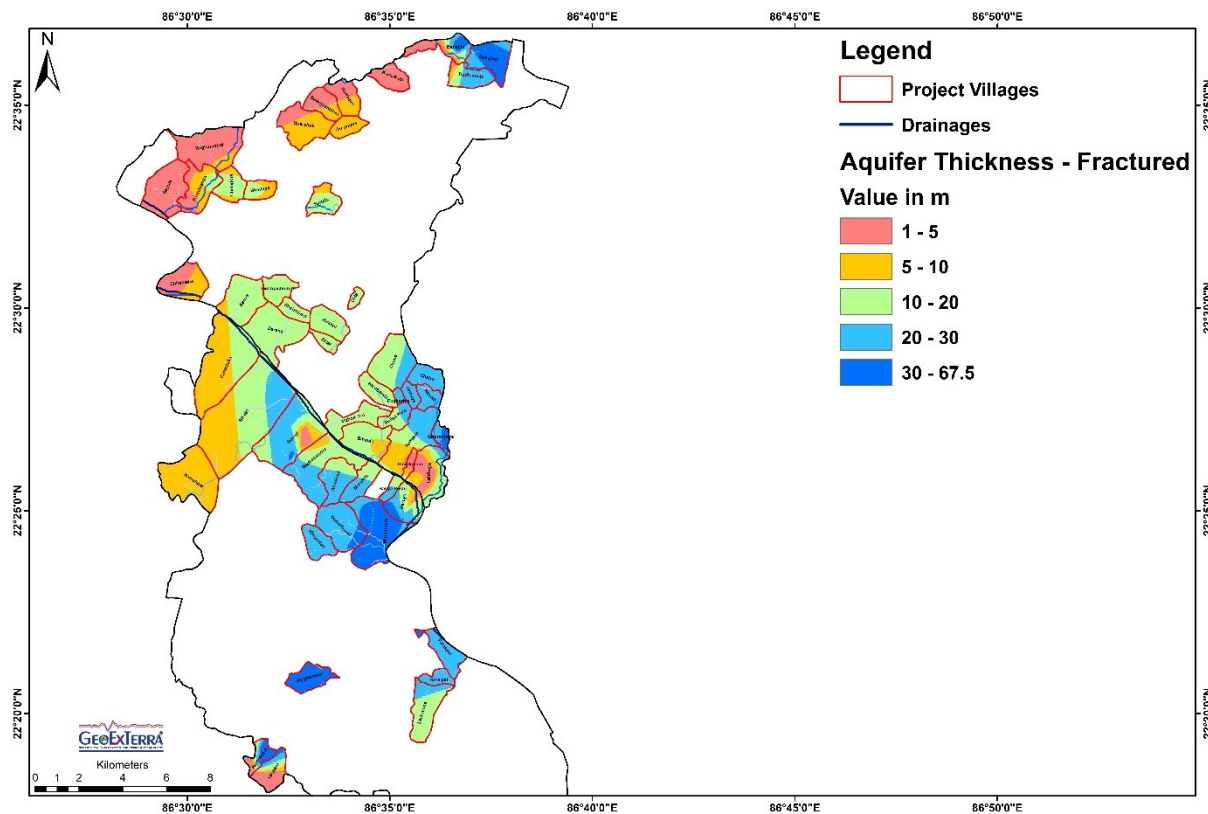


Fig. 118 Thickness of Fractured Aquifers of the Project Villages of East Singhbhum.

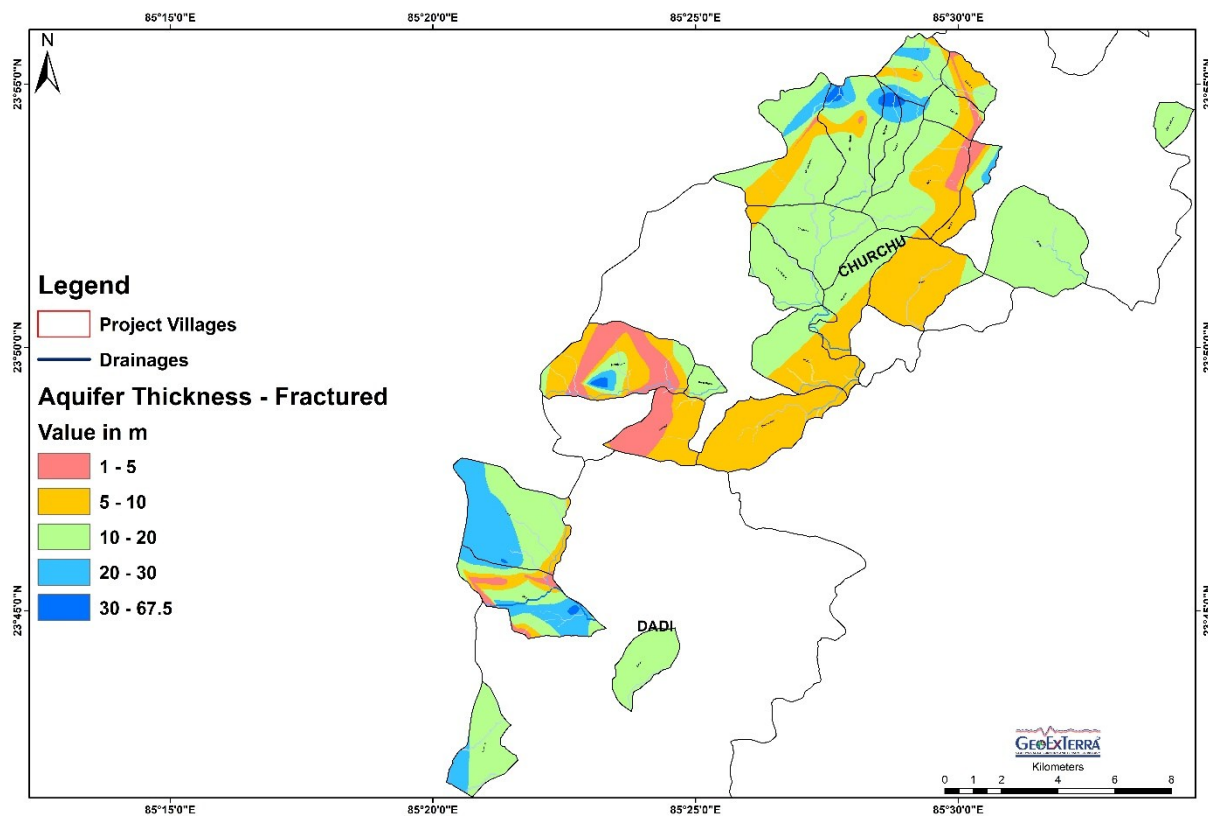


Fig. 119 Thickness of Fractured Aquifers of the Project Villages of Hazaribagh.

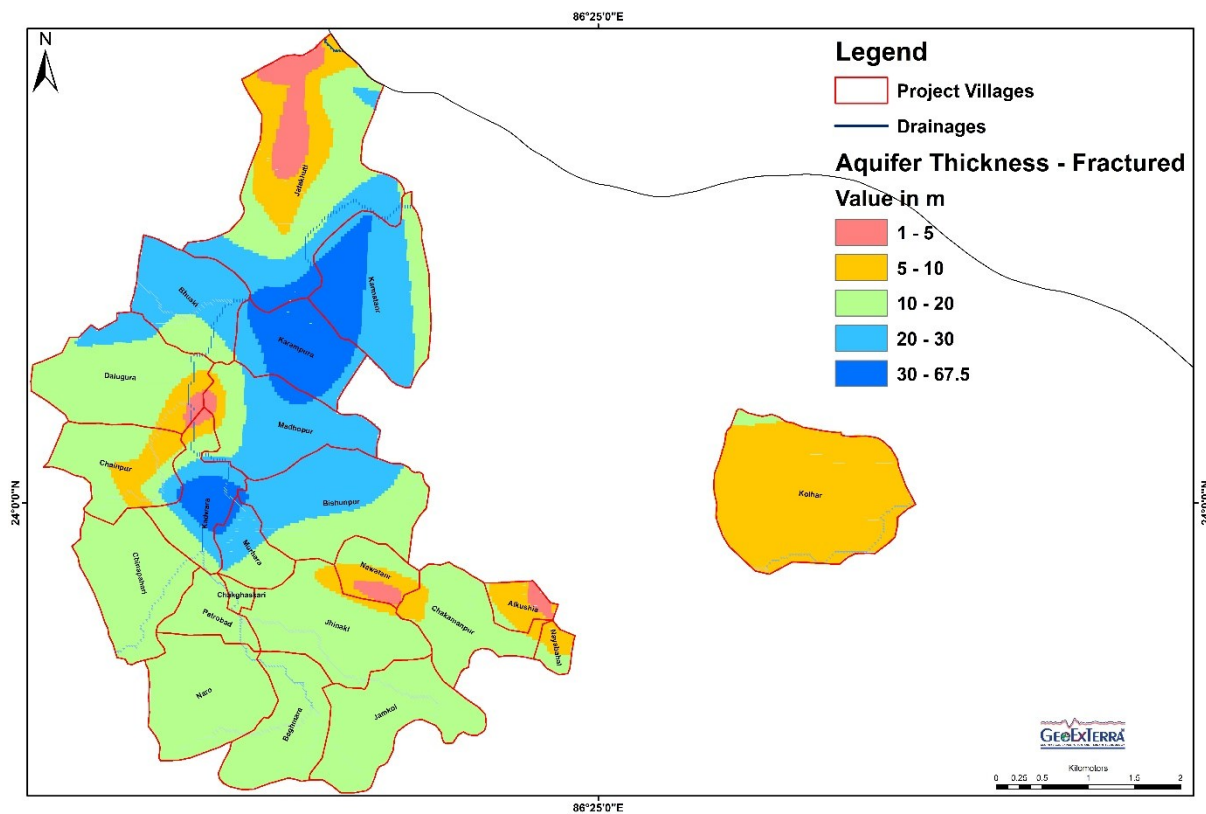


Fig. 120 Thickness of Fractured Aquifers of the Project Villages of Dhanbad.

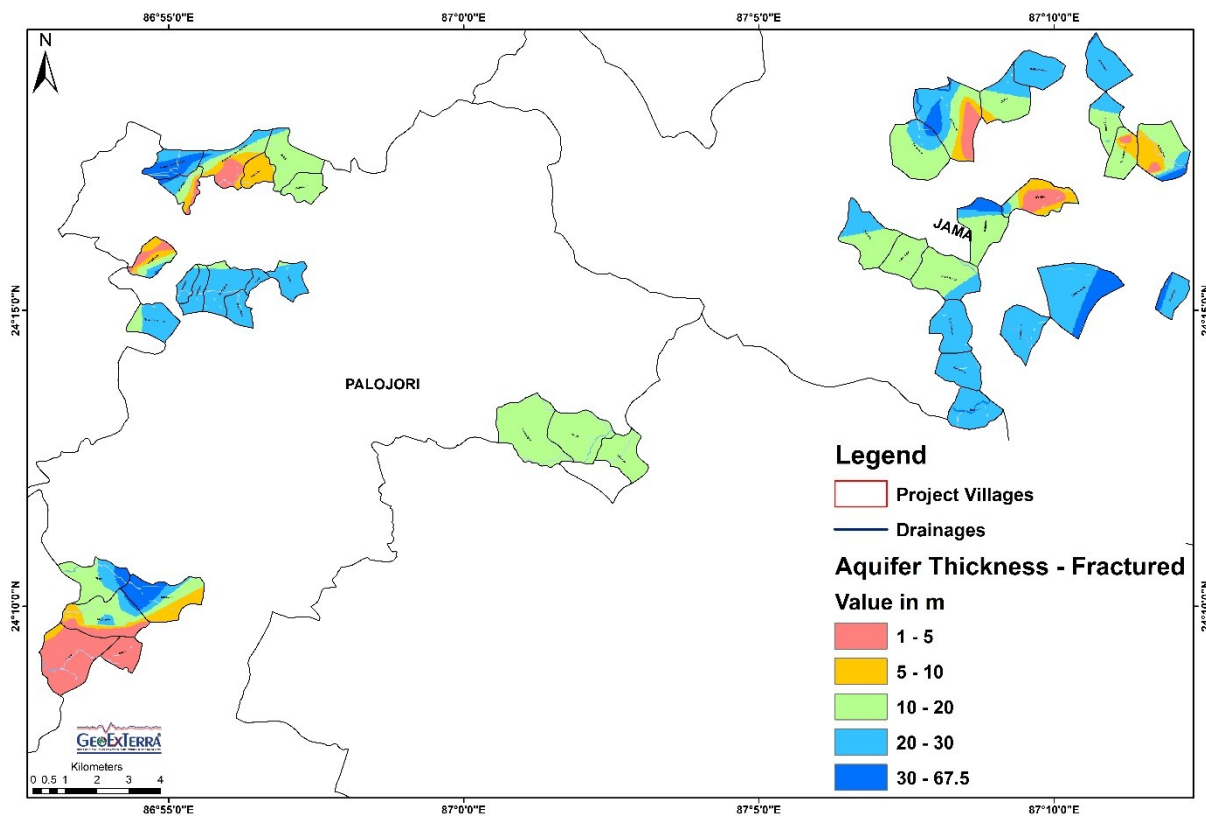
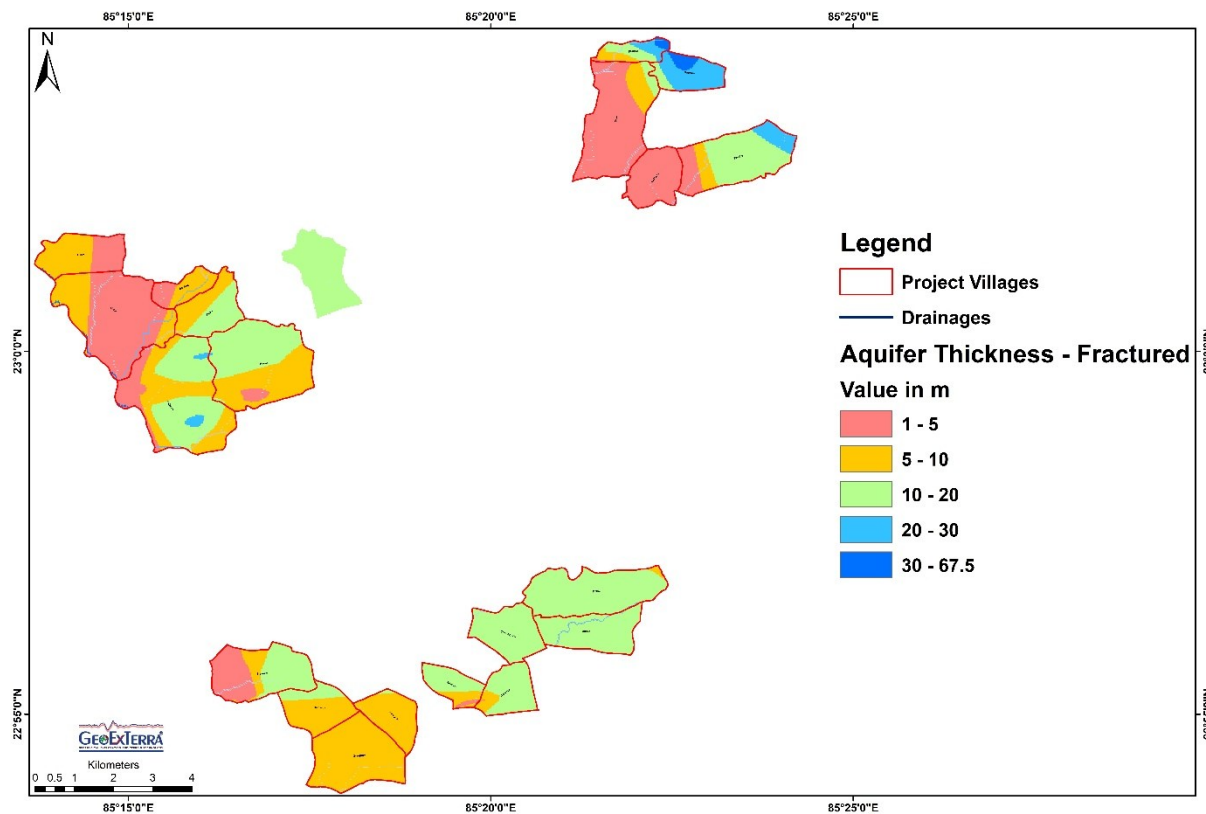


Fig. 121 Thickness of Fractured Aquifers of the Project Villages of Deoghar and Dumka.



**Fig. 122 Thickness of Fractured Aquifers of the Project Villages of Khunti.**

significant hydrogeological importance because they act as deeper groundwater reservoirs receiving recharge from the overlying weathered zone and transmitting groundwater laterally through interconnected fracture systems. The hydraulic performance of these aquifers depends not only on fracture thickness but also on fracture connectivity, orientation, aperture, and the presence of secondary mineral fillings.

#### **6.8.4 Geophysical Mapping of Aquifer Thickness**

The geophysical mapping of total aquifer thickness within the project villages, provides a comprehensive understanding of the combined groundwater storage potential of both the weathered and fractured aquifer systems that constitute the principal groundwater-bearing formations in the hard rock hydrogeological environment of the region. In such consolidated terrains, groundwater occurs primarily within secondary porosity zones created by weathering and structural fracturing, where the weathered mantle forms the shallow aquifer while the underlying fractured bedrock forms the deeper aquifer system. Fractured aquifers consist of rocks possessing secondary permeability due to structural discontinuities such as joints, cracks, and fractures, which are critical pathways for groundwater storage and movement. The geophysical resistivity investigations carried out across the project villages enabled the delineation of the total aquifer thickness representing the cumulative thickness of weathered and fractured groundwater-bearing zones, and the results reveal considerable spatial variability in aquifer development across the study area. Interpretation of the aquifer thickness map (Figs. 123 to 127) indicates that

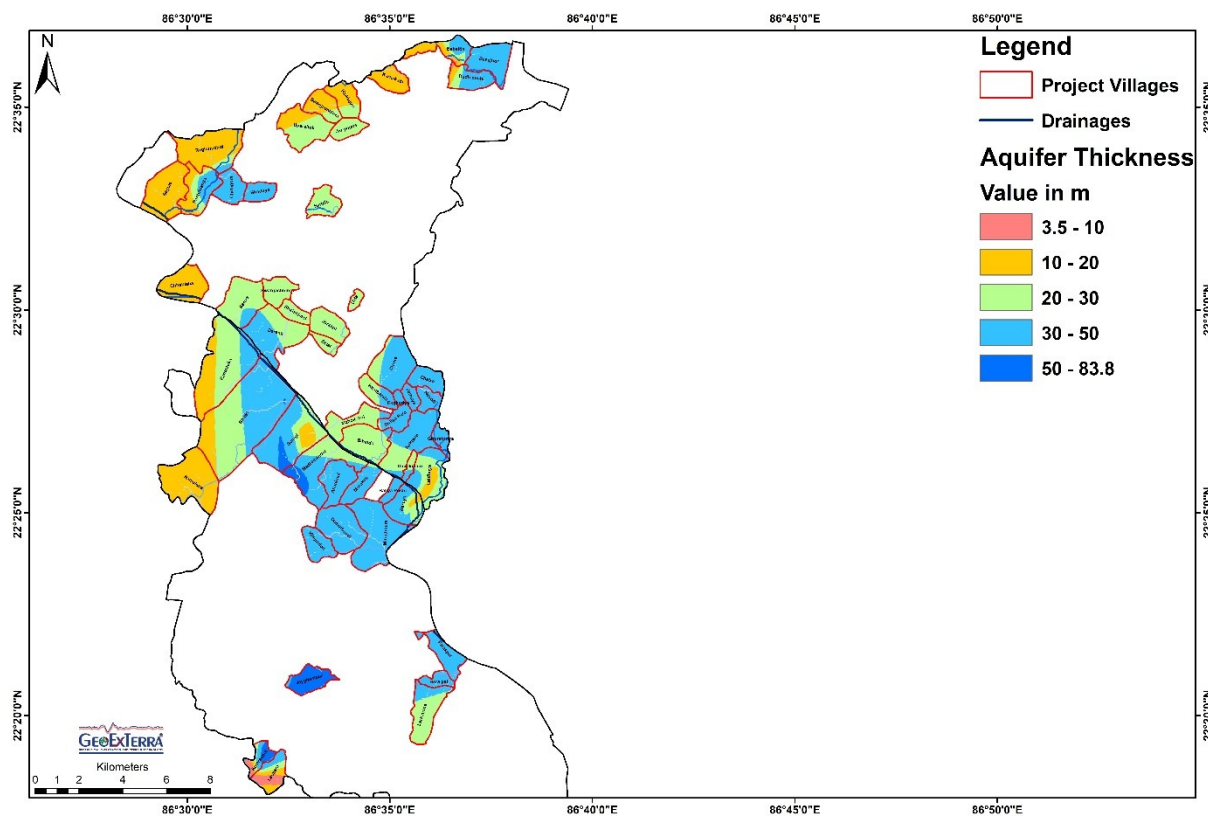


Fig. 123 Aquifer Thickness Map (Freshwater) of the Project Villages of East Singhbhum.

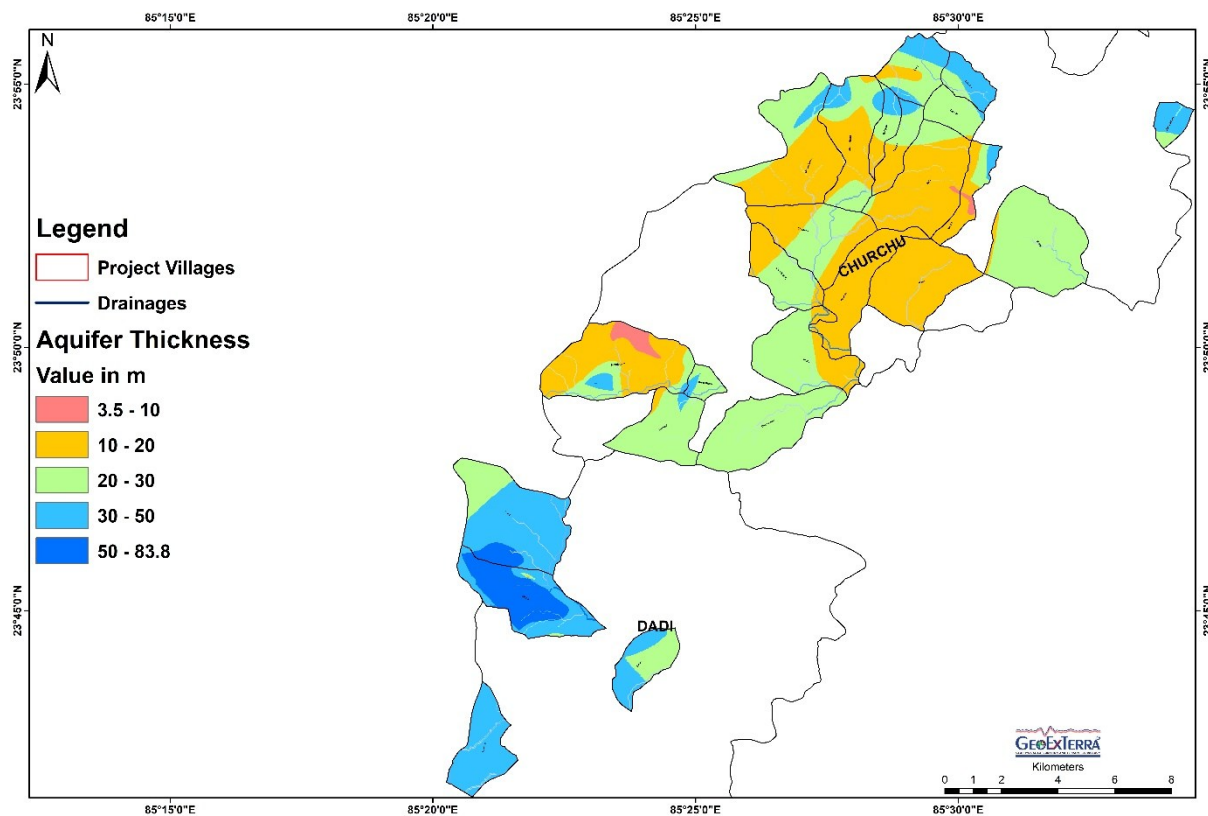


Fig. 124 Aquifer Thickness Map (Freshwater) of the Project Villages of Hazaribagh.

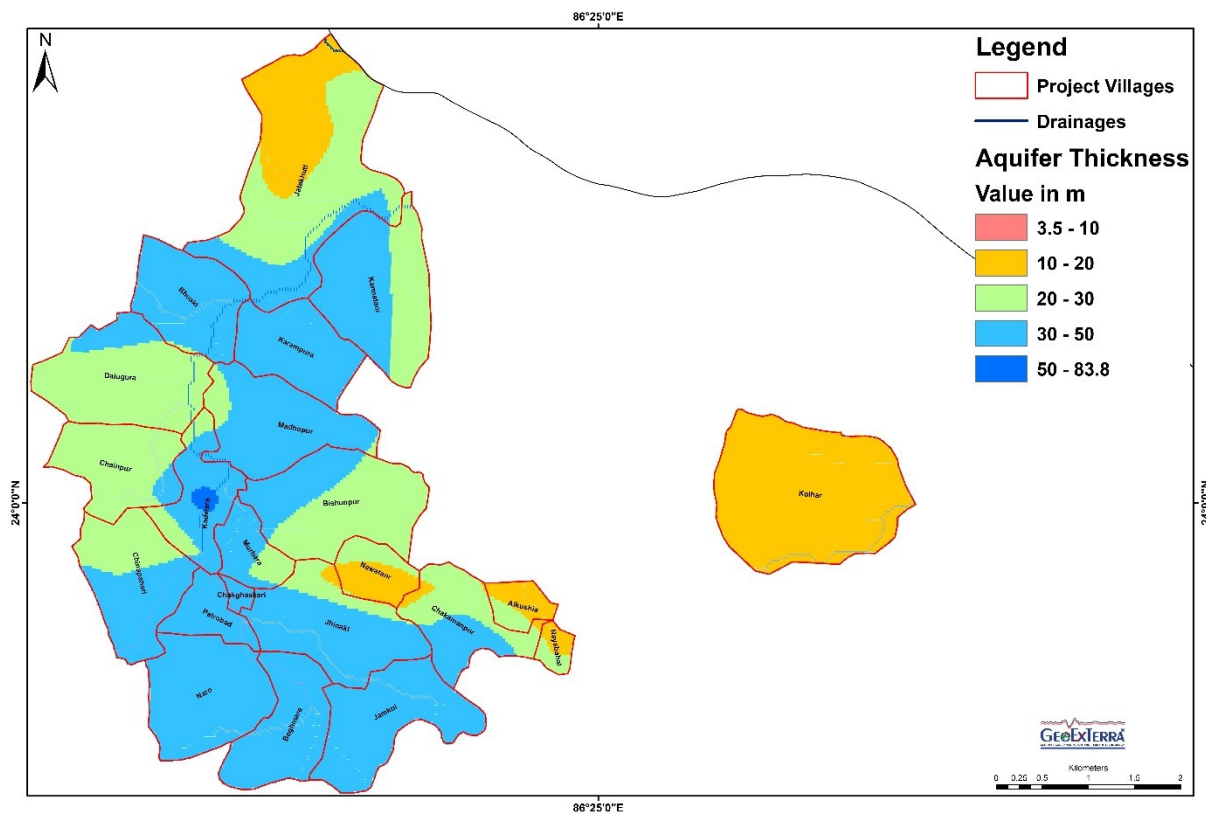


Fig. 125 Aquifer Thickness Map (Freshwater) of the Project Villages of Dhanbad.

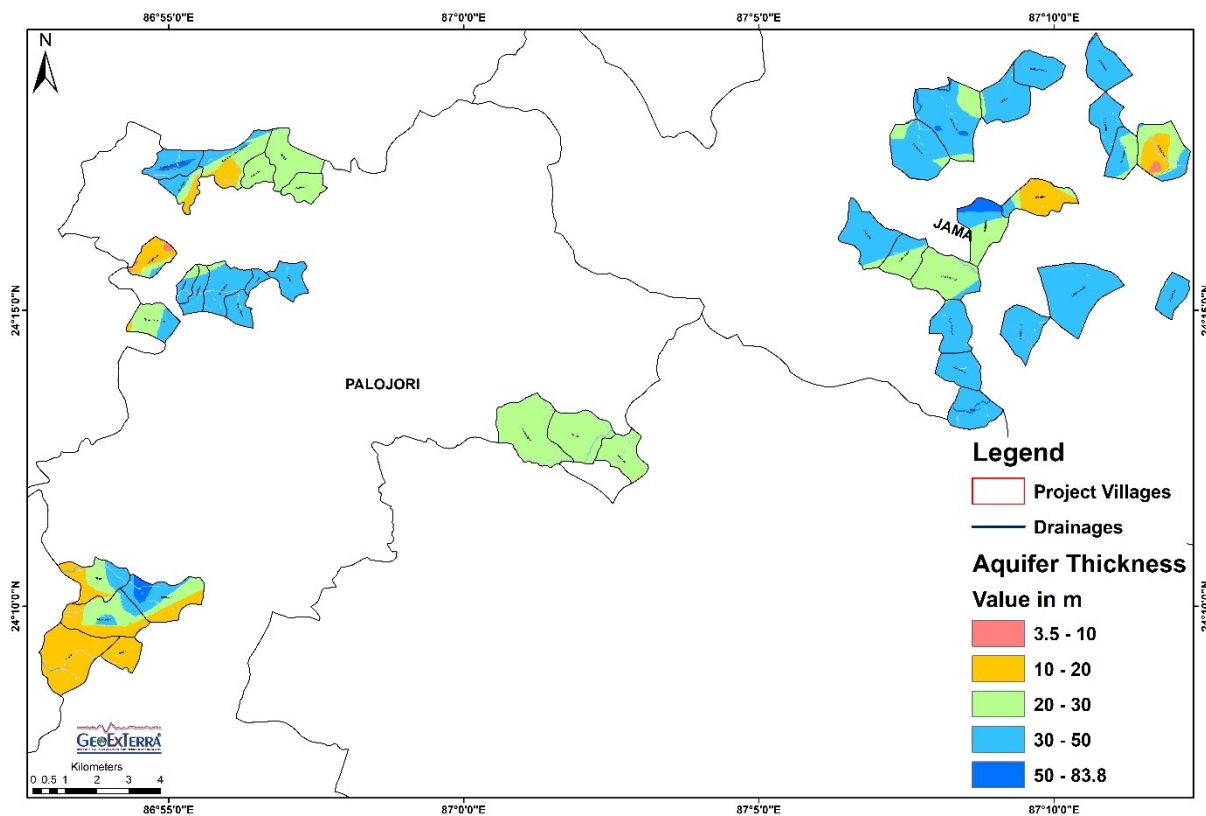
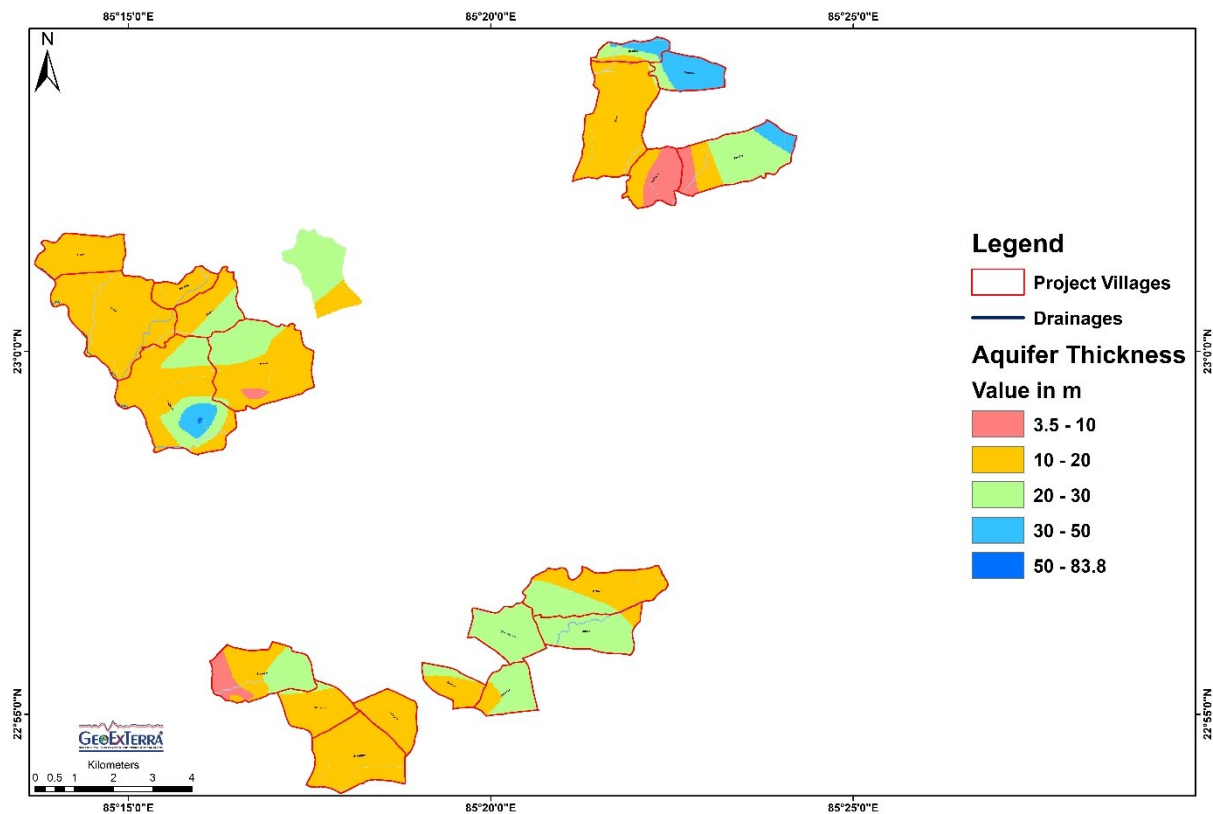


Fig. 126 Aquifer Thickness Map (Freshwater) of the Project Villages of Deoghar and Dumka.



**Fig. 127 Aquifer Thickness Map (Freshwater) of the Project Villages of Khunti.**

the total freshwater aquifer thickness varies from approximately 3.5 m to about 83.8 m, with an average thickness of around 26.7 m, demonstrating that the groundwater system in the region ranges from relatively thin aquifer sections in some areas to significantly thicker groundwater-bearing zones in structurally favorable locations. Zones exhibiting lower aquifer thickness (approximately 3.5–10 m) are generally associated with upland or structurally stable bedrock regions where both weathering and fracturing are relatively limited, resulting in reduced groundwater storage potential and comparatively lower transmissivity. These thinner aquifer sections typically occur in localized pockets across several project villages where the bedrock lies close to the surface and groundwater occurrence is restricted to narrow weathered layers or limited fracture networks. In contrast, moderate aquifer thickness zones ranging between about 10–30 m are widely distributed across many parts of the project area, representing locations where moderate weathering combined with interconnected fracture systems provides improved groundwater storage capacity and relatively better recharge conditions. Such zones form the most common aquifer environments in the Murhu, Churchu and Palojori blocks, where rainfall infiltration through the soil and overburden layers feeds the weathered aquifer, which in turn transmits groundwater downward into the fractured bedrock system. The thicker aquifer zones exceeding about 30 m and extending up to nearly 83.8 m occur in more localized areas where geological structures such as lineaments, fracture intersections, and drainage-controlled weathering zones have enhanced the depth of weathering and fracture development. These structurally controlled zones are hydrogeologically significant because they represent highly favorable groundwater reservoirs capable of storing larger volumes of groundwater and sustaining higher well yields, particularly when intersected by bore wells penetrating both weathered and fractured zones. Spatial analysis of the aquifer thickness distribution

suggests that such thicker aquifer zones tend to occur along drainage valleys, structurally weakened rock masses, and areas influenced by tectonic deformation, where long-term weathering and fracture enlargement have created deeper groundwater storage domains. Conversely, regions away from structural controls tend to exhibit thinner aquifer development due to limited weathering and fracture intensity. The mapped aquifer thickness therefore reflects the integrated influence of lithology, structural geology, geomorphology, and weathering processes, all of which govern groundwater occurrence in the hard rock terrain. From a groundwater resource perspective, the presence of moderate to thick aquifer zones across several villages indicates favorable conditions for sustainable groundwater development, particularly where thicker weathered layers coincide with well-developed fracture networks. These zones are expected to exhibit improved groundwater storage capacity, higher transmissivity, and better recharge potential compared to areas with thin aquifers. Overall, the geophysical delineation of total aquifer thickness provides an essential framework for identifying promising groundwater development zones, optimizing bore well locations, and designing groundwater recharge interventions, thereby supporting the sustainable management and development of groundwater resources in the project area.

#### **6.8.5 Geophysical Mapping of Groundwater Availability**

The geophysical mapping of fresh groundwater availability provides a quantitative assessment of groundwater storage within the weathered and fractured aquifer systems of the project area. The estimation was derived through an integrated evaluation of aquifer parameters including transmissivity, discharge, specific yield, porosity, and geological formation characteristics, jointly interpreted with geophysical resistivity data. During the estimation process, aquifer zones that were completely contaminated by seawater beyond the salinity interface were excluded to ensure that only fresh groundwater resources were considered. The analysis indicates that fresh groundwater availability during January 2026 ranges from 0 m to 6.5 m, with an average availability of approximately 0.76 m, representing the effective saturated thickness of freshwater within the aquifer system (Figs. 128 to 132). Based on this estimation, the total volume of available groundwater within the project area is approximately 283981.1 TCM, demonstrating the presence of moderate groundwater storage but with highly uneven spatial distribution across the area. The spatial pattern of groundwater availability reveals distinct high and low freshwater availability clusters. Large parts of the project villages of Churchu, Tundi and Murhu blocks fall within the very low groundwater availability category (0–0.5 m), indicating that only a thin layer of saturated freshwater exists within the aquifer at the time of observation. These zones are widely distributed across several villages and are typically associated with areas where aquifer thickness is limited, fracture connectivity is poor, or groundwater extraction exceeds natural recharge during the dry season. Moderate groundwater availability zones ranging from 0.5–1 m and 1–2 m occur in several localized patches within the study area, representing areas where moderate recharge and aquifer storage conditions allow the accumulation of relatively greater freshwater thickness. These zones are generally associated with pediplain surfaces, weathered rock zones, and areas where soil infiltration and overburden thickness promote groundwater recharge. Further localized zones of higher groundwater availability between 2–3 m and extending up to about 3–6.5 m are observed in a few structurally favorable locations, particularly where fractured aquifers coincide with thicker weathered zones, drainage alignments, and structural lineaments. These high groundwater availability zones are hydrogeologically significant because they represent the

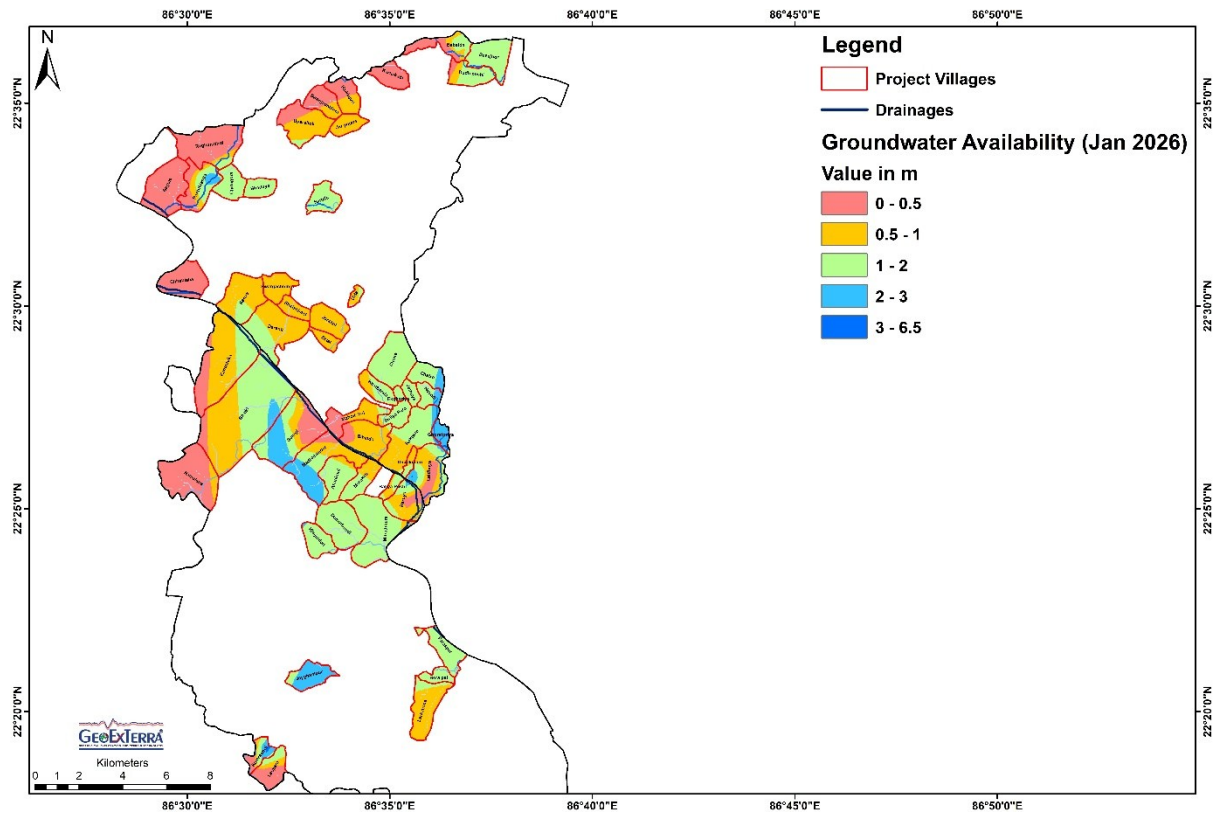


Fig. 128 Fresh Groundwater Availability in the Project Villages of East Singhbhum.

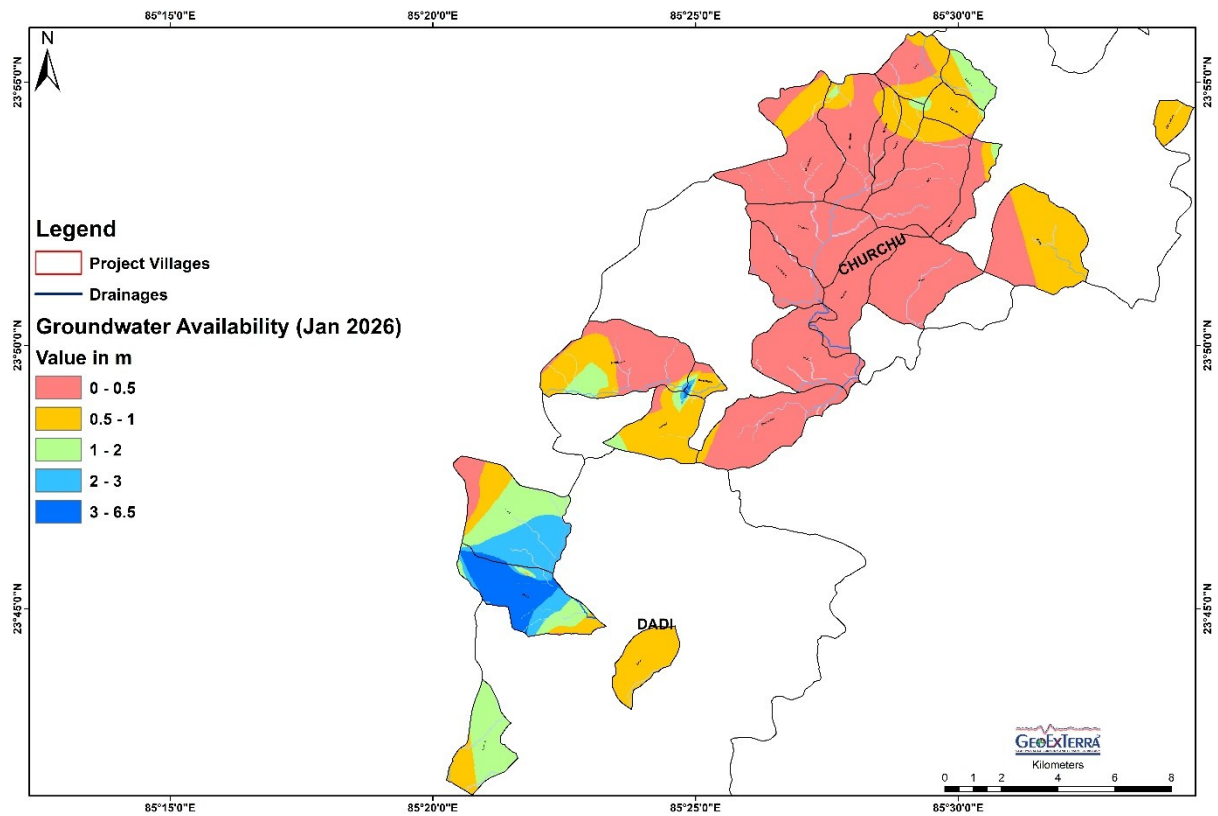
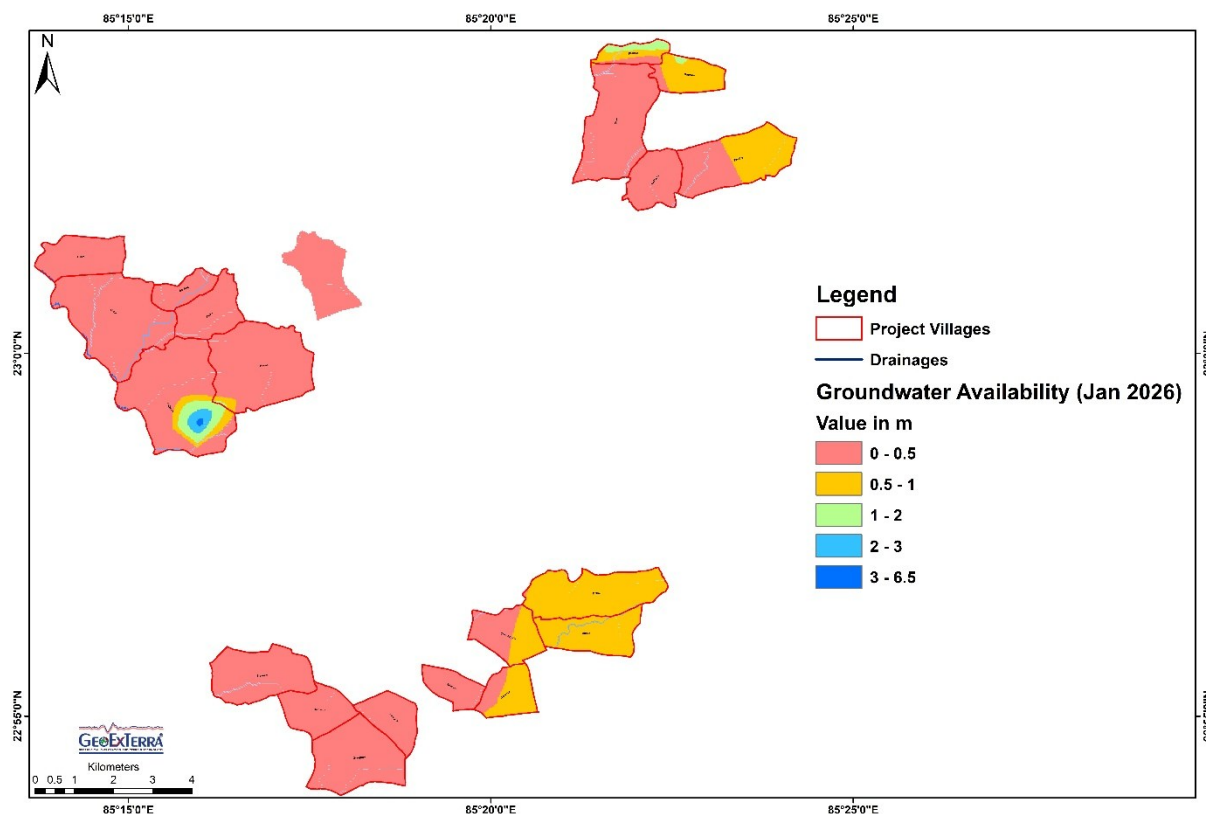


Fig. 129 Fresh Groundwater Availability in the Project Villages of Hazaribagh.





**Fig. 132 Fresh Groundwater Availability in the Project Villages of Khunti.**

most productive groundwater storage domains within the project area, where interconnected fracture systems provide enhanced storage capacity and groundwater transmissivity. Spatially, such favorable zones tend to occur in scattered pockets in a few villages of Dadi, Gurabanda and Dalbhumgarh blocks, often aligned with local drainage networks or structural weaknesses within the bedrock. Conversely, areas exhibiting minimal freshwater availability reflect conditions where aquifer recharge is limited or where groundwater storage is restricted due to shallow weathering depth, poor fracture development, or intensive groundwater abstraction. The overall distribution pattern indicates that although fresh groundwater occurs throughout the study area, its effective saturated thickness is generally limited during the post-monsoon recession period represented by January observations, emphasizing the importance of recharge-dependent groundwater systems in the region.

### 6.8.6 Geophysical Mapping and Quantification of Groundwater Recharge

The geophysical mapping and quantification of groundwater recharge across the project villages, provides an integrated evaluation of subsurface infiltration processes and the capacity of the aquifer system to receive and store recharge derived primarily from seasonal rainfall. Groundwater recharge estimation for the study area was developed through a comprehensive interpretation of geophysical resistivity investigations combined with aquifer thickness distribution, geological formations, drainage characteristics, and hydrogeological parameters such as transmissivity, porosity, and specific yield, thereby enabling a spatially distributed recharge model for the region. In the hard rock hydrogeological environment of the study area, recharge processes are strongly controlled by the

weathered and fractured aquifer systems, where infiltration through soil and overburden layers enters the weathered mantle and subsequently percolates downward into structurally controlled fracture networks that store and transmit groundwater. The resulting groundwater recharge availability map (Figs. 133 to 137) reveals considerable spatial variability across the project villages, reflecting the influence of terrain morphology, soil permeability, structural geology, and drainage alignment on recharge processes. The analysis indicates that groundwater recharge across the study area varies from approximately 0 to about 1.85 m, with an average recharge potential of around 0.58 m, demonstrating that while large portions of the project area experience relatively limited recharge thickness during the observed period, several localized zones exhibit moderate to relatively high recharge potential. Most of villages of Dalbhumgarh, and Churchu blocks falls within the very low recharge category (0–0.5 m), indicating areas where infiltration capacity is limited due to relatively thin weathered zones, compact soils, shallow bedrock, or higher runoff conditions. These zones are widely distributed across several project villages and generally correspond to areas with limited aquifer thickness or poor fracture connectivity. In contrast, moderate recharge zones ranging from about 0.5–1 m occur in several localized pockets where moderately permeable soils, thicker overburden, and improved infiltration conditions allow greater downward movement of rainfall water into the aquifer system. These areas are often associated with pediplain surfaces, gently sloping agricultural lands, and structurally weakened rock zones, where both surface infiltration and subsurface storage conditions are more favorable. The highest recharge zones ranging from approximately 1–1.85 m and locally reaching up to about 1.85 m are relatively limited but highly significant hydrogeologically, as they represent structurally favorable locations where fractured aquifers coincide with thicker weathered zones and drainage-

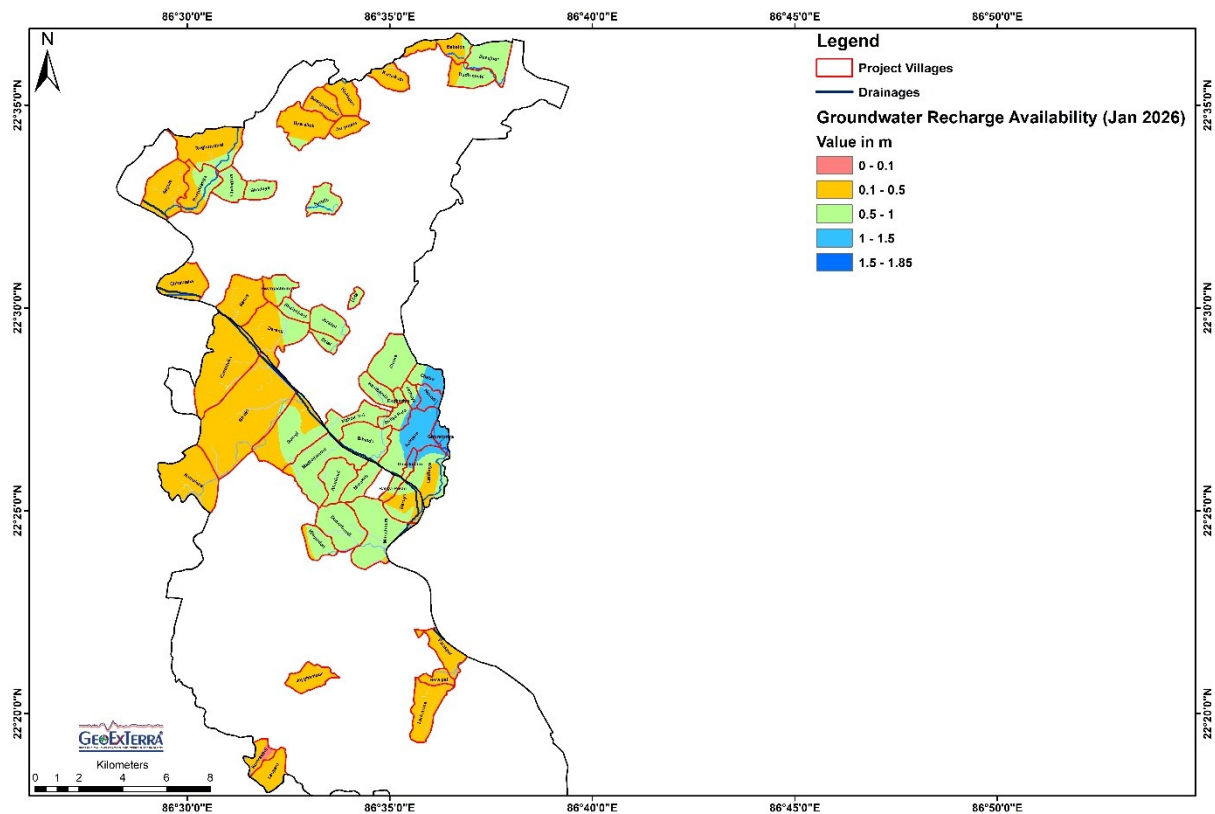


Fig. 133 Groundwater Recharge Availability in the Project Villages of East Singhbhum.

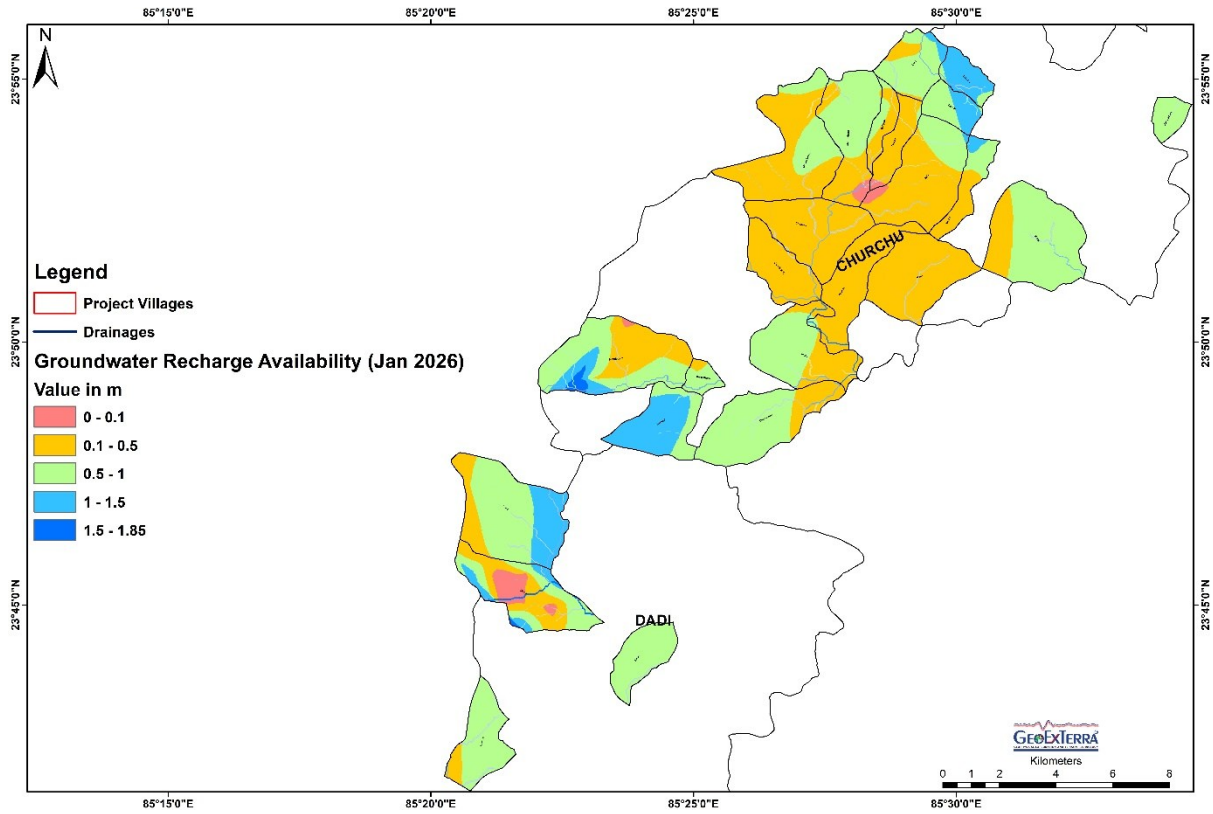


Fig. 134 Groundwater Recharge Availability in the Project Villages of Hazaribagh.

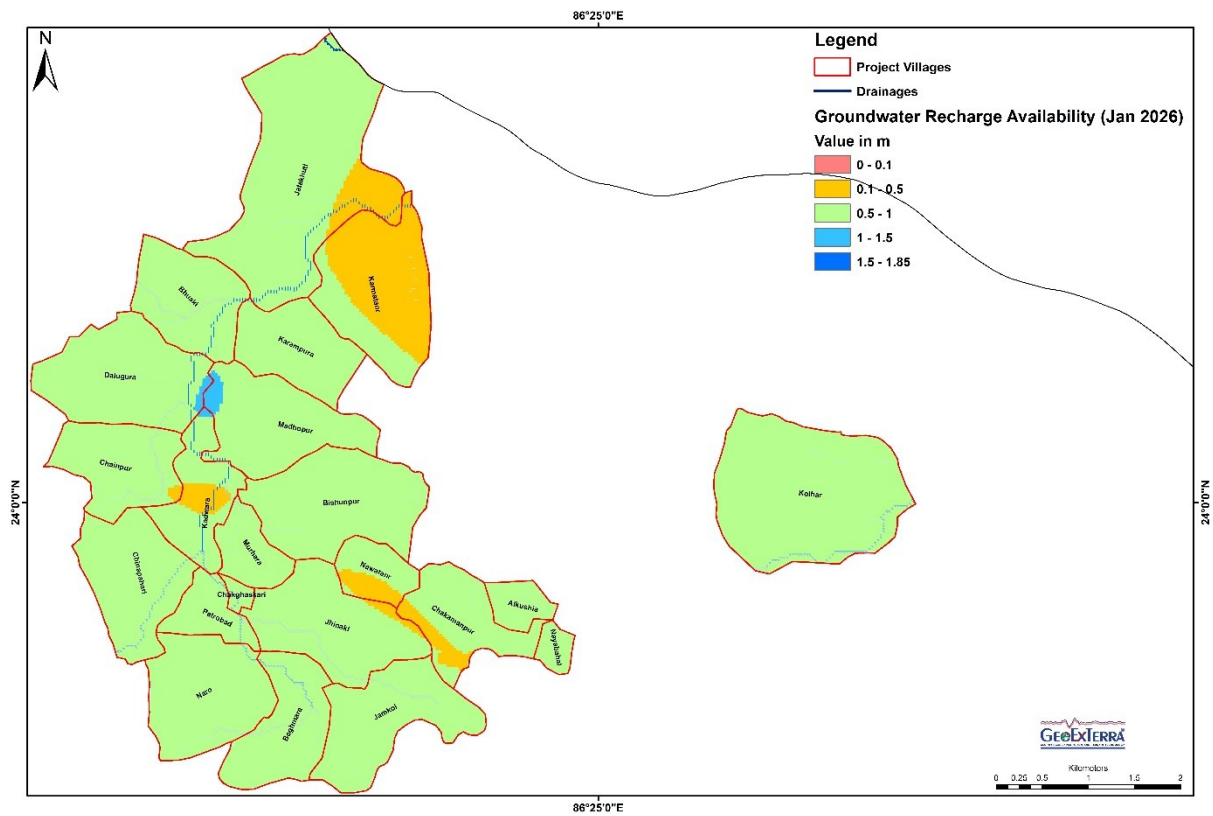


Fig. 135 Groundwater Recharge Availability in the Project Villages of Dhanbad.

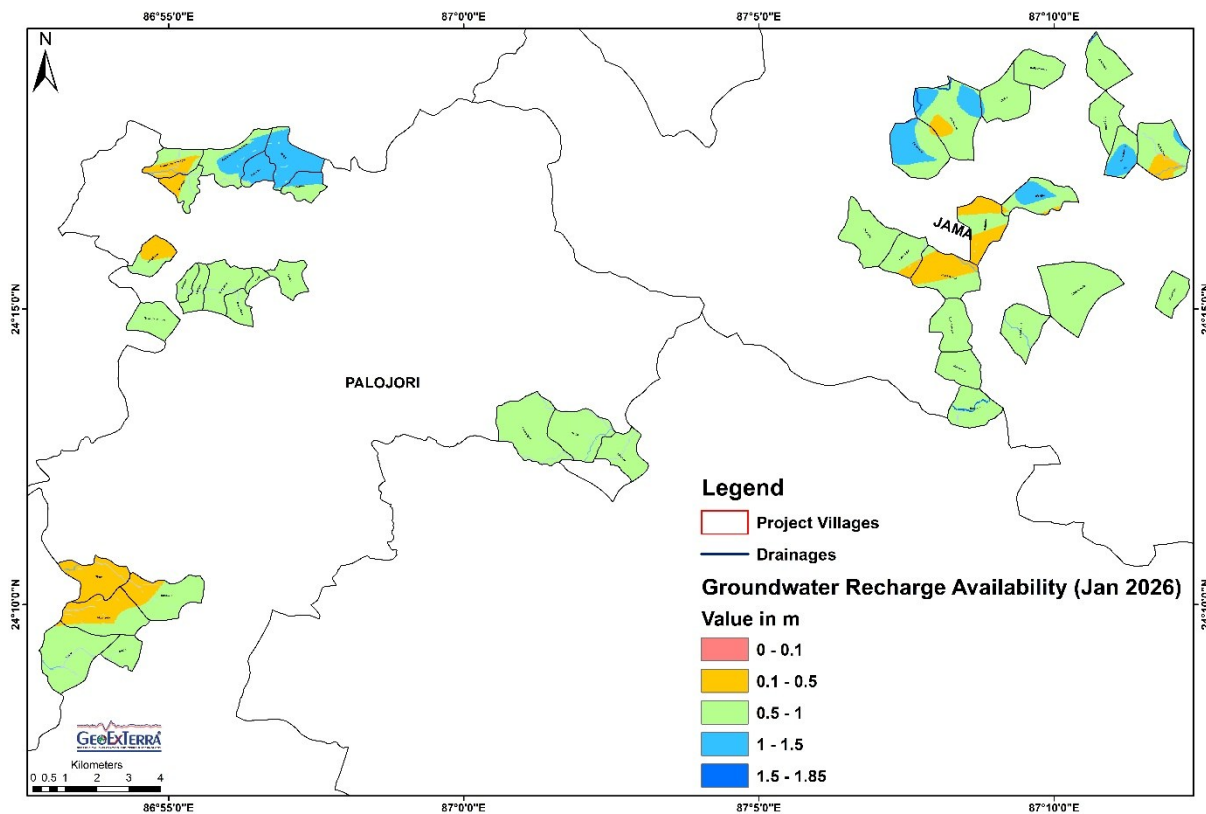


Fig. 136 Groundwater Recharge Availability in the Project Villages of Deoghar and Dumka.

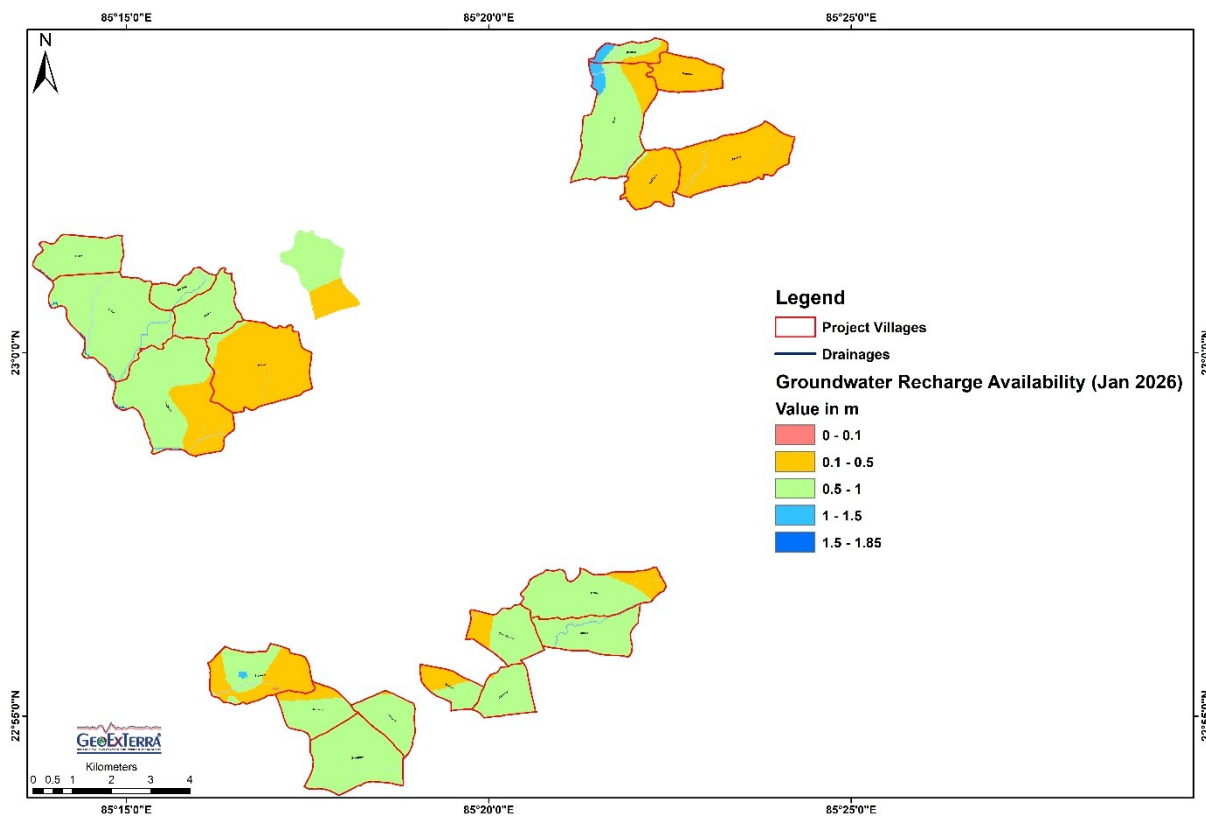


Fig. 137 Groundwater Recharge Availability in the Project Villages of Khunti.

controlled infiltration corridors. These areas tend to occur near drainage alignments, structural lineaments, and valley-fill zones where prolonged weathering and structural deformation have enhanced subsurface permeability and groundwater storage capacity. Spatially, some of these favorable recharge zones are observed in a few villages of Dalbhumgarh, Churchu, Dadi, Palojori and Jama blocks, where geological structure and surface hydrology combine to enhance infiltration potential. Based on the integrated recharge estimation, the total volume of available groundwater recharge within the project area is approximately 216947.8 thousand cubic meters (TCM), representing the estimated annual replenishable groundwater resource available for sustainable utilization. The distribution of recharge potential clearly indicates that groundwater replenishment is highly heterogeneous and structurally controlled, with the most effective recharge occurring in zones where permeable soils, thicker overburden layers, well-developed weathered aquifers, and fracture-controlled bedrock systems occur together. From a groundwater management perspective, the recharge mapping highlights priority zones where artificial recharge interventions such as check dams, percolation tanks, recharge shafts, and contour bunding can significantly enhance groundwater replenishment, particularly in areas where natural recharge is currently limited. Overall, the geophysical mapping and quantification of groundwater recharge provide an essential scientific basis for aquifer management, groundwater development planning, and watershed-based recharge enhancement strategies, thereby supporting sustainable groundwater resource development across the project area.

#### **6.8.7 Groundwater Recharge Prospecting and Water Conservation Priority Analysis**

The groundwater recharge prospecting analysis carried out for the project titled Integrated Hydrogeophysical Aquifer Mapping and Groundwater Resource Feasibility Assessment for Climate-Resilient Water Security across Deoghar (Palojori), Dhanbad (Tundi), Dumka (Jama), East Singhbhum (Gurabanda and Dalbhumgarh), Hazaribagh (Churchu and Dadi), and Khunti (Murhu) reveals a spatially heterogeneous recharge potential governed by the integrated influence of hydrogeomorphology, soil hydro-physical properties, land degradation status, slope, drainage density, and subsurface characteristics (Figs. 138 to 142). The water conservation priority maps (classified into High, Moderate, Low, and Least categories) indicate that moderate priority zones dominate the region, reflecting a balanced combination of moderate infiltration capacity and partial runoff losses, while high priority zones are discretely distributed, primarily associated with areas exhibiting low natural recharge efficiency due to clayey soils, high erosion intensity, shallow soil depth, and anthropogenic disturbances such as mining and brick kiln activities. These high-priority zones, prominently observed in parts of Churchu, Jama, and sections of Tundi and Murhu, correspond to regions where runoff generation is relatively high but infiltration is constrained, thereby necessitating artificial recharge interventions such as check dams, recharge shafts, contour bunding, and percolation tanks to enhance aquifer replenishment. Conversely, low to least priority zones are predominantly aligned along drainage corridors, valley fills, and areas with sandy loam to loamy sand textures, where hydraulic conductivity is relatively higher (often  $>0.5$  mpd) and natural recharge processes are already effective; these zones, observed in patches of Dalbhumgarh, Gurabanda, and parts of Palojori, exhibit favorable infiltration conditions supported by thicker overburden and permeable subsurface strata, thereby requiring minimal structural intervention but emphasizing protection and conservation of existing recharge regimes. The spatial distribution further highlights that structural lineaments and drainage convergence zones act as preferential recharge

pathways, particularly in hard rock terrains where secondary porosity (fractures and weathered zones) controls groundwater occurrence. In contrast, upland and plateau regions with thin overburden and compacted soils show limited recharge, aligning with their classification under higher priority for intervention. The interplay between soil texture and hydraulic conductivity plays a decisive role in recharge prospecting; areas dominated by clay and silty clay exhibit reduced permeability and higher surface runoff, whereas sandy loam and sand-dominated zones demonstrate enhanced infiltration and storage potential, directly influencing the prioritization scheme. Additionally, land degradation factors such as sheet erosion, gullies, and barren rocky exposures significantly reduce infiltration efficiency, converting potential recharge zones into runoff-dominated systems, thereby elevating their priority for soil and water conservation measures. The maps also reveal that moderate priority zones serve as transitional areas, where targeted interventions can substantially improve recharge efficiency, making them critical for watershed-scale planning. From a hydrogeological standpoint, the recharge prospecting analysis indicates that although the region receives substantial monsoonal rainfall, effective groundwater recharge is spatially constrained by surface and subsurface conditions rather than rainfall availability, reinforcing the need for site-specific, scientifically designed recharge structures. The integration of thematic layers clearly demonstrates that optimal recharge zones coincide with moderate slopes, permeable soils, low erosion intensity, and proximity to drainage lines, whereas unfavorable zones are characterized by steep slopes, degraded land, and low permeability soils. Overall, the groundwater recharge priority mapping provides a robust decision-support framework for implementing climate-resilient water management strategies, wherein high-priority zones demand immediate intervention, moderate zones require augmentation and optimization, and low-priority zones necessitate protection

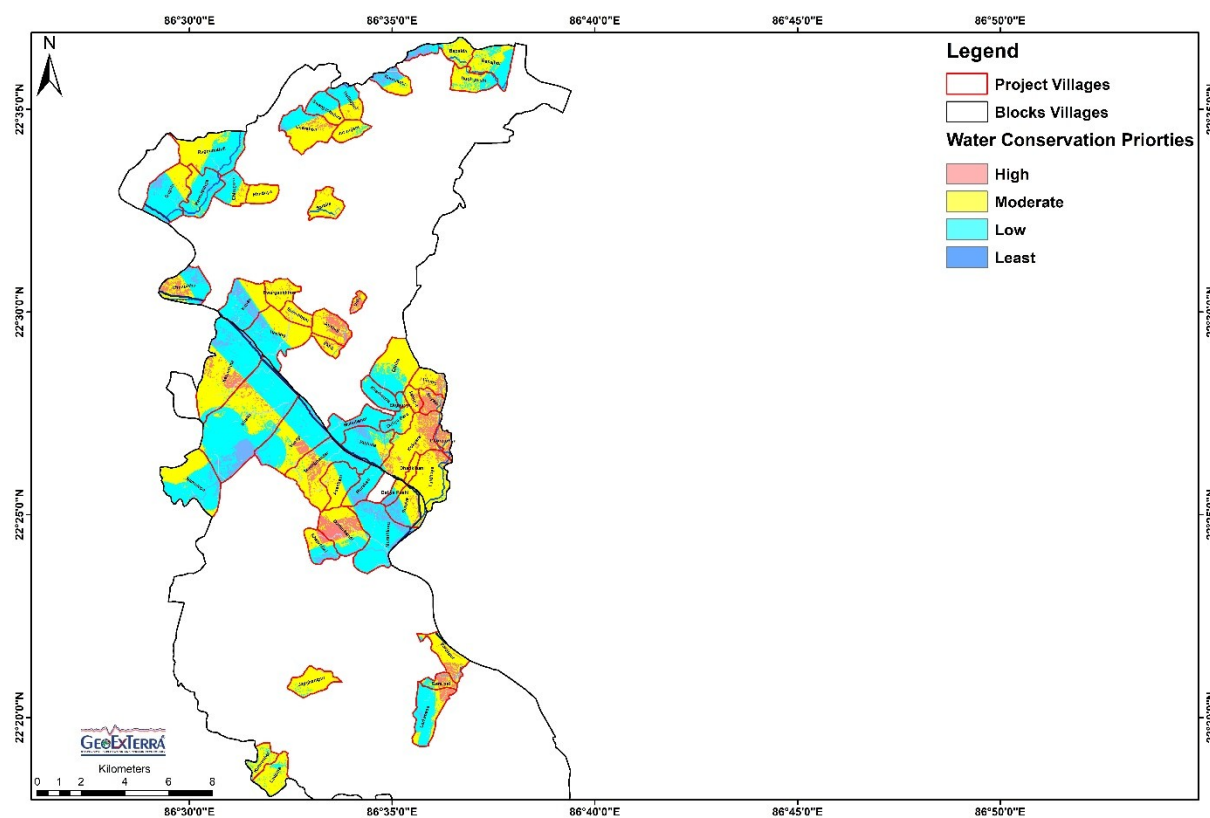


Fig. 138 Water Conservation Priorities Map in the Project Villages of East Singhbhum.

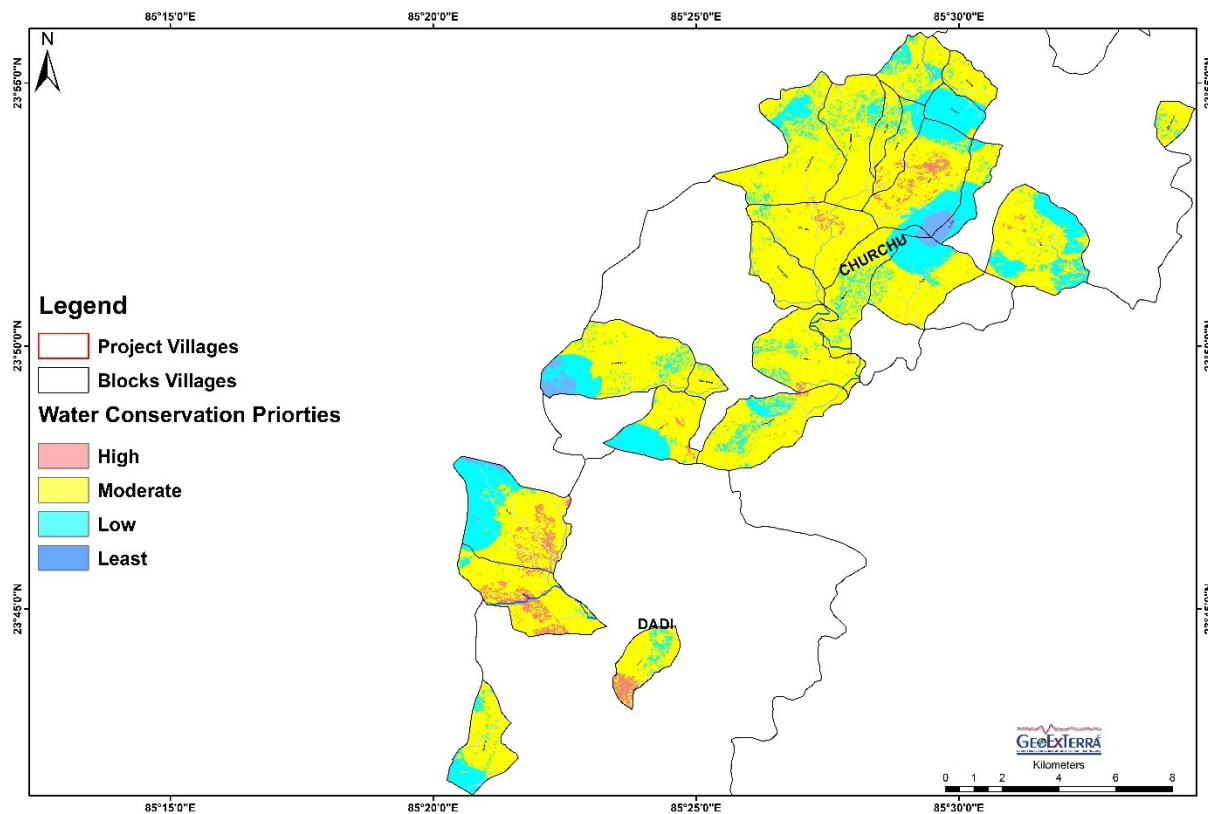


Fig. 139 Groundwater Recharge Availability in the Project Villages of Hazaribagh.

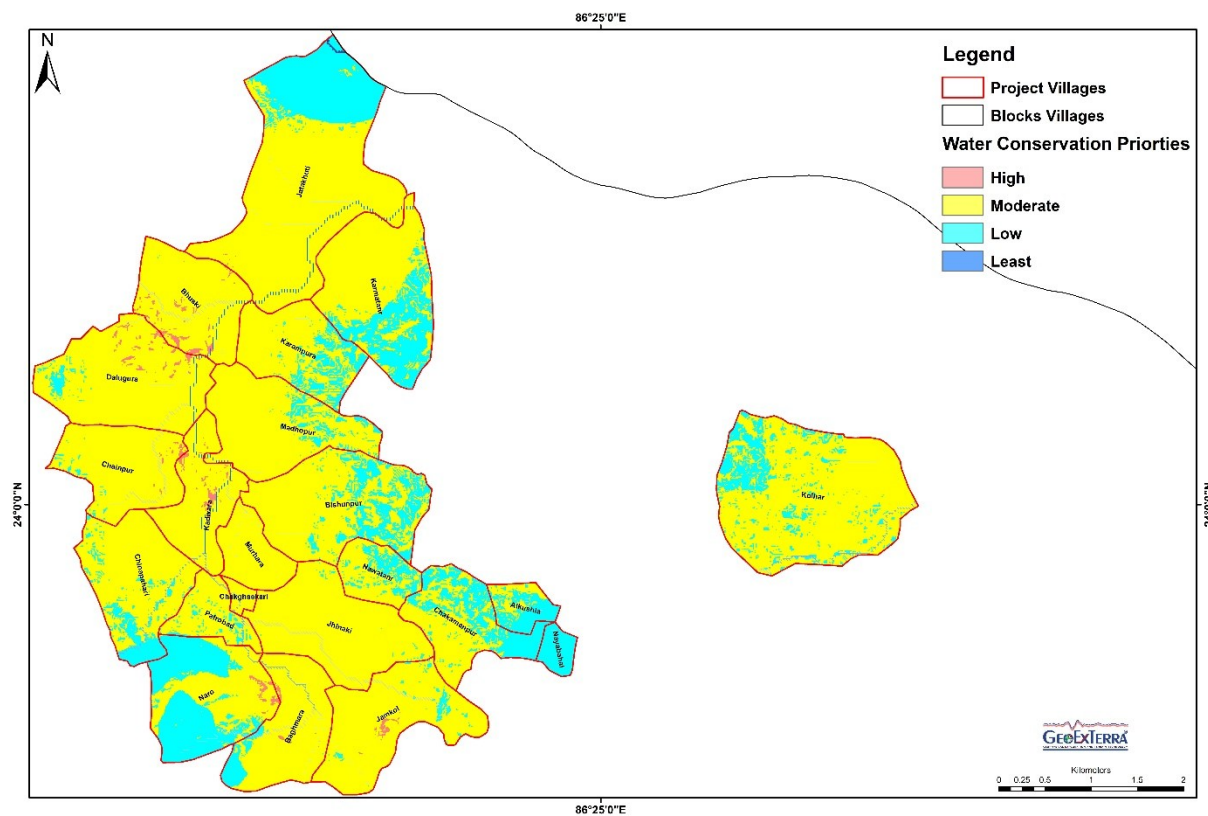


Fig. 140 Groundwater Recharge Availability in the Project Villages of Dhanbad.

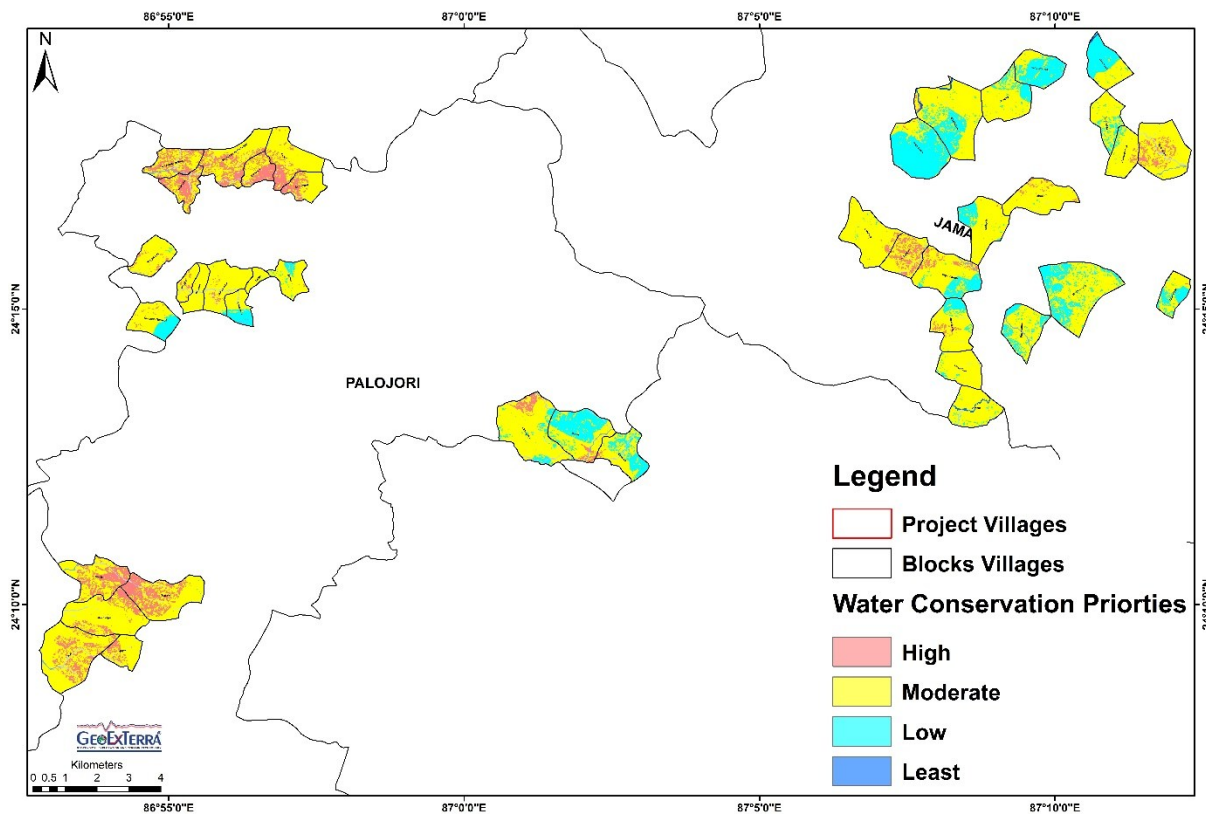


Fig. 141 Groundwater Recharge Availability in the Project Villages of Deoghar and Dumka.

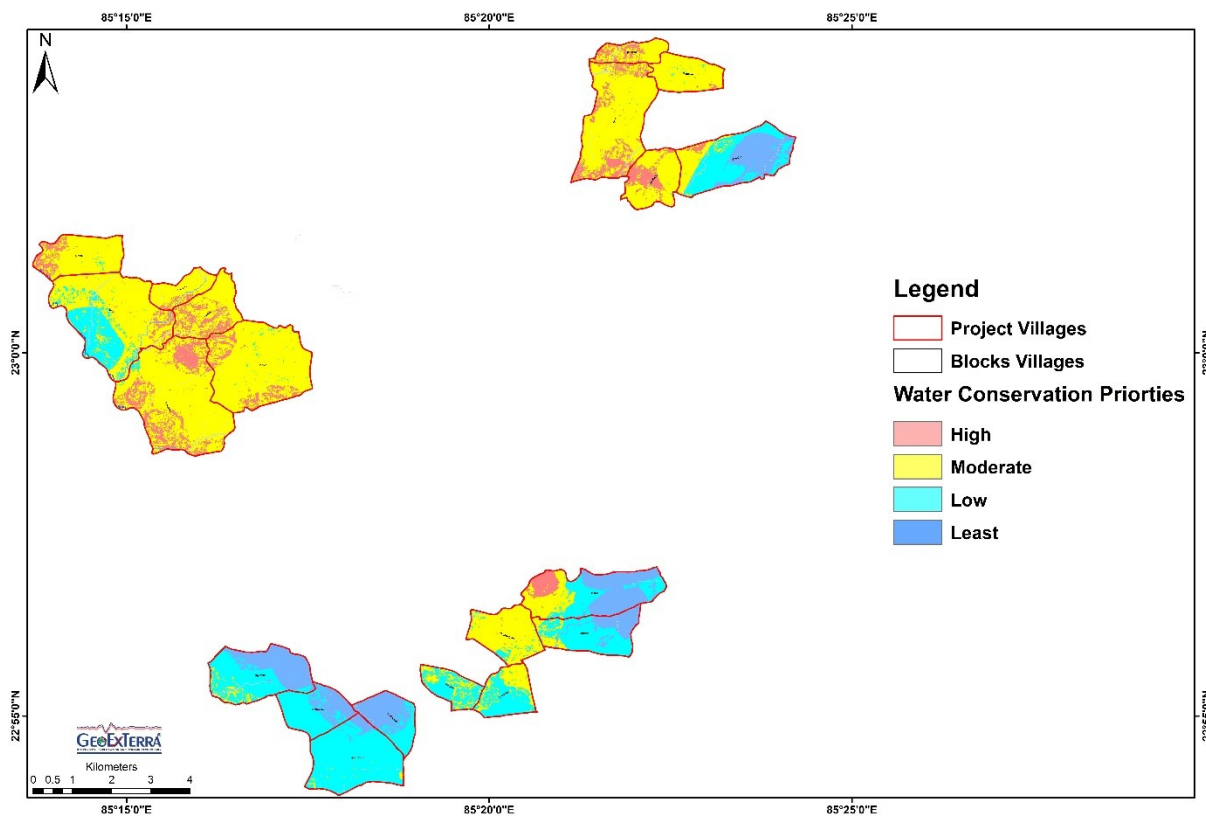


Fig. 142 Groundwater Recharge Availability in the Project Villages of Khunti.

and sustainable utilization. By aligning recharge enhancement measures with the identified priority zones, the project area can significantly improve aquifer storage, groundwater availability, and long-term water security, thereby supporting sustainable agriculture, drinking water supply, and ecological balance across the diverse hydrogeological settings of Jharkhand.

## 7. PROPOSED GROUNDWATER MANAGEMENT INTERVENTIONS – RUNOFF MANAGEMENT

Recharge is a functional relationship between the annual average rainfall and its infiltration into the subsurface. Recharge is affected by the prevailing hydrological conditions, physiographic conditions of terrain, and hydrogeological properties of the subsurface. Therefore, rainwater budgets and aquifer recharge relations highly vary for different geo-climatic regions and responses in the upholding of the annual streamflow. This relationship is critically balanced in crystalline/hard rock aquifers and gets exacerbated in areas having low annual rainfall. For the sustainable development of natural resources; terrain physical conditions, hydrological properties of the surface, hydroclimatic variations, soil hydrological characteristics, and subsurface hydrogeological conditions of the project area were accurately articulated. This reduces the uncertainty and leads to ‘safer’ decisions for effectively and efficiently developing and managing the runoff, baseflow, and groundwater recharge. All plausible and site-specific development plans oriented to local environmental issues should be taken as a precaution due to the sensitivity of the groundwater resources, particularly in coastal villages. In this regard, the proposed interventions are listed below and all feasible soil and water conservation structures have been specified and detailed below.

### 7.1. Recharge Shaft

Recharge shafts are the most efficient and cost-effective structures to recharge the aquifer directly. This technique is widely used in the areas where aquifers are overlain by poorly permeable strata and a source of water is available either for some time or perennially e.g., baseflow, springs, etc. In the project area, 148 recharge shafts have been proposed near water bodies, targeting a maximum 64 m depth (Figs. 143 to 147, and Table 7). Recharge shafts aim to puncture impermeable strata and recharge underlying aquifers. In the project area, underlying aquifers that have impermeable strata between 5 to 15 m depth and do not yield significantly due to a slower recharge rate were selected to recharge deeper aquifers using a recharge shaft. In the project, in most places the unconfined aquifers have shallow water level conditions having seasonal water level fluctuation varying from 3 to 8 mbgl, and the depth of weathering profile reaches hardly beyond 15 mbgl hence ruling out the construction of recharge shafts. The diameter of the recharge shaft must be between 1.5 to 2.5 m is to be decided locally based on space availability and the upper top head must be sealed properly by high-grade filter media to avoid eddies and direct entry of water-suspended silt load in the well. The injection pipe should be lowered below the water level to avoid air bubbles. In the areas where source water has silt, the shaft should be filled with pebbles and sand from the bottom to have an inverted filler. The uppermost sandy layer has to be removed and cleaned periodically. A filter has to be provided before the source water enters the recharge shaft.

**Table 7. Details and Specification of Recharge Shafts.**

Sl. No.	ID	Village	Latitude°	Longitude°	Recharge Shaft Depth (m)	Groundwater Recharge (tcm)
1	RS1	BORDER	23.75954	85.34226	29	1.36
2	RS2	BORDER	24.20833	87.01499	19	1.48
3	RS3	BORDER	22.45258	86.60736	58	1.69
4	RS4	BABAIDA	22.60460	86.61373	26	1.24
5	RS5	BAGHMARA	23.97925	86.38806	32	1.06
6	RS6	BAGHMARA	23.98379	86.38591	31	1.04
7	RS7	BAGHMARA HARLADANGAL	24.29566	86.94014	28	1.37
8	RS8	BAGHMARA HARLADANGAL	24.29482	86.94116	28	1.41
9	RS9	BAGHMARA HARLADANGAL	24.28904	86.92629	22	1.38
10	RS10	BALI	23.88867	85.49655	15	1.05
11	RS11	BANSADIH	23.82016	85.42703	23	1.34
12	RS12	BASAJHOR	22.60121	86.61458	32	1.33
13	RS13	BASAJHOR	22.59849	86.61543	35	1.38
14	RS14	BASAJHOR	22.59867	86.62309	42	1.48
15	RS15	BASMATA	24.28511	86.92260	21	1.44
16	RS16	BEDIA	24.20689	87.03464	20	1.45
17	RS17	BEDIA	24.21247	87.03696	20	1.44
18	RS18	BEDIA	24.21611	87.04100	20	1.43
19	RS19	BEDIA	24.21476	87.03909	20	1.43
20	RS20	BEDIA	24.22145	87.03506	20	1.43
21	RS21	BERA PAL	22.35088	86.60636	35	1.33
22	RS22	BERA PAL	22.34766	86.60793	34	1.32
23	RS23	BHURSA	23.06874	85.36254	23	1.59
24	RS24	BHURSA	23.07188	85.37245	27	1.70
25	RS25	BICHNA	23.02541	85.23007	18	1.92
26	RS26	BIHINDA	22.44550	86.57304	31	1.25
27	RS27	BIHINDA	22.44626	86.56968	30	1.24
28	RS28	BIRAJPUR	24.28296	87.16920	20	1.06
29	RS29	CHATRO	22.47270	86.60363	52	1.58
30	RS30	CHHAGLAJOR	24.20812	87.02979	19	1.46
31	RS31	CHHAGLAJOR	24.20670	87.02380	19	1.47
32	RS32	CHICHIKHURD	23.89707	85.47042	18	1.46
33	RS33	CHICHIKHURD	23.90719	85.47000	16	1.46
34	RS34	CHICHIKHURD	23.90115	85.47116	17	1.47
35	RS35	CHINAPAHARI	23.98549	86.37000	25	1.07
36	RS36	CHINAPAHARI	23.98713	86.37286	24	1.07
37	RS37	CHOIRA	22.47722	86.58587	39	1.26
38	RS38	DALUGURA	24.00813	86.37485	23	1.10
39	RS39	DALUGURA	24.01039	86.37669	25	1.03
40	RS40	DARI (CT)	23.71787	85.39586	33	1.34
41	RS41	DASO KHAP	23.80784	85.43702	22	1.29
42	RS42	DASO KHAP	23.81251	85.45215	19	1.34
43	RS43	DASO KHAP	23.81273	85.44386	20	1.32
44	RS44	DASO KHAP	23.81511	85.45714	18	1.36
45	RS45	DASO KHAP	23.81005	85.43763	22	1.30
46	RS46	DASO KHAP	23.80196	85.42737	24	1.27
47	RS47	DASO KHAP	23.80641	85.43387	23	1.28
48	RS48	DASO KHAP	23.81316	85.45353	19	1.34
49	RS49	DASO KHAP	23.81403	85.45062	19	1.34
50	RS50	DUDH PUSHI	22.59704	86.62507	42	1.48
51	RS51	DUDH PUSHI	22.59600	86.62610	42	1.49
52	RS52	GAIBATHAN	24.29766	87.19432	19	1.17
53	RS53	GAIBATHAN	24.29976	87.19029	24	1.09
54	RS54	GAJGAON	22.97727	85.26393	18	2.25
55	RS55	GAJGAON	22.97839	85.26491	16	2.23
56	RS56	GHORATORIYA	22.44424	86.60504	59	1.71
57	RS57	GHORATORIYA	22.45276	86.60236	55	1.63
58	RS58	GHORATORIYA	22.44716	86.60618	59	1.70
59	RS59	GURHAMI	22.97747	85.26221	18	2.21
60	RS60	GURHAMI	22.97774	85.25956	15	2.11
61	RS61	HAILDAJURI	22.58089	86.56527	23	0.99
62	RS62	HAILDAJURI	22.58605	86.56874	20	1.00
63	RS63	INDRA	23.82605	85.45222	18	1.35
64	RS64	INDRA	23.83195	85.43926	19	1.38
65	RS65	INDRA	23.82143	85.45127	18	1.34

66	RS66		23.82270	85.45650	17	1.36
67	RS67	JAMKOL	23.97436	86.39332	29	1.10
68	RS68		23.97515	86.39194	30	1.09
69	RS69	JARWA	23.81988	85.44633	19	1.33
70	RS70	JHINAKI	23.99085	86.38630	22	1.07
71	RS71	KADWARA	23.99772	86.37704	22	1.23
72	RS72	KANANLUKA	22.45901	86.50829	18	1.32
73	RS73		22.47166	86.51597	23	1.30
74	RS74		22.47798	86.51430	21	1.29
75	RS75	KANAS	22.49811	86.51917	29	1.23
76	RS76		22.51255	86.51893	29	1.18
77	RS77	KANKI	23.71988	85.39586	33	1.34
78	RS78		23.72533	85.39714	31	1.35
79	RS79		23.72697	85.39952	30	1.36
80	RS80		23.72890	85.40157	29	1.37
81	RS81		23.73018	85.40393	28	1.38
82	RS82		23.72344	85.39609	32	1.34
83	RS83		23.74153	85.40244	29	1.35
84	RS84	KARGI	23.85772	85.53612	26	1.35
85	RS85	KARU KHAP	23.81812	85.42021	26	1.34
86	RS86	KARUAKATA	22.59543	86.57848	16	1.01
87	RS87	KHAIRWA	24.20853	87.04374	22	1.43
88	RS88		24.21513	87.04872	21	1.42
89	RS89	KHARBANDA	22.46784	86.57589	35	1.13
90	RS90	KOKPARA	22.45519	86.60163	53	1.61
91	RS91		22.45824	86.60273	54	1.62
92	RS92		22.45520	86.59277	45	1.44
93	RS93	KOLGI	24.28946	86.94962	28	1.49
94	RS94	KOLHAR	23.99471	86.43453	18	1.40
95	RS95		23.99776	86.43117	18	1.40
96	RS96		23.99601	86.43197	18	1.40
97	RS97	KULHORIA	24.27232	87.14556	25	1.00
98	RS98	KUMRASHOL	22.31496	86.52817	21	1.58
99	RS99	KUNDIBARTOLI	23.02344	85.28853	22	1.96
100	RS100	KURA	23.76807	85.37343	40	1.07
101	RS101		23.77085	85.37427	39	1.08
102	RS102		23.76342	85.36861	42	1.07
103	RS103		23.77499	85.37613	37	1.08
104	RS104		23.77701	85.37518	36	1.09
105	RS105		23.76909	85.35885	38	1.13
106	RS106		23.78416	85.37076	32	1.11
107	RS107		23.78251	85.36429	30	1.14
108	RS108		23.76683	85.36461	41	1.08
109	RS109		23.76343	85.37025	43	1.07
110	RS110		23.77080	85.36858	39	1.08
111	RS111	KURKUTA	23.72027	85.35077	32	1.38
112	RS112	LAKHANPUR	24.26681	87.12614	28	1.09
113	RS113	LARA	23.92924	85.48892	29	1.11
114	RS114	LARKABASA	22.34345	86.59406	33	1.29
115	RS115		22.33282	86.59856	27	1.26
116	RS116		22.33896	86.60288	30	1.28
117	RS117	LODHNA	24.26470	87.13972	22	1.14
118	RS118	MAHISADHARA	22.59207	86.62751	42	1.49
119	RS119	NAMULEPA	22.42288	86.49940	15	1.36
120	RS120		22.42814	86.49735	15	1.35
121	RS121		22.42796	86.50632	17	1.38
122	RS122	NARO	23.97830	86.38323	31	1.05
123	RS123		23.98423	86.38299	30	1.05
124	RS124		23.98311	86.37430	28	1.06
125	RS125	NOYADI	22.46207	86.60250	53	1.60
126	RS126		22.46267	86.59850	49	1.52
127	RS127		22.46542	86.60192	52	1.58
128	RS128		22.46545	86.60385	53	1.61
129	RS129	PARASPUR	22.34902	86.61036	34	1.32
130	RS130	PENTULDANGA	22.54423	86.50577	31	1.10
131	RS131	PINDNA	24.22534	87.02227	25	1.44
132	RS132	RAHAMDAGA	23.90601	85.56926	30	1.22
133	RS133	RELIGARA ALIAS PACHHIARI (CT)	23.71305	85.35816	37	1.35
134	RS134	RIKBA	23.75650	85.35993	64	1.10

135	RS135		23.76022	85.37051	44	1.06
136	RS136		23.74668	85.38511	35	1.28
137	RS137		23.75403	85.36731	58	1.19
138	RS138	SAPRUM	23.06351	85.37945	20	1.63
139	RS139	SARBILA	22.53961	86.56075	32	0.97
140	RS140		22.54367	86.56092	32	0.97
141	RS141		22.54199	86.55988	32	0.97
142	RS142		22.54121	86.55800	33	0.96
143	RS143	SONATANR	24.16610	86.91287	23	1.47
144	RS144	TASNALO	23.91490	85.50087	30	1.13
145	RS145		23.92331	85.50040	37	0.96
146	RS146	TENGHOWA	24.28367	87.17207	24	1.09
147	RS147	ULDA	22.50130	86.56679	33	1.01
148	RS148		22.50172	86.56862	33	1.02
<b>Total Volume (tcm)</b>						<b>195.8</b>

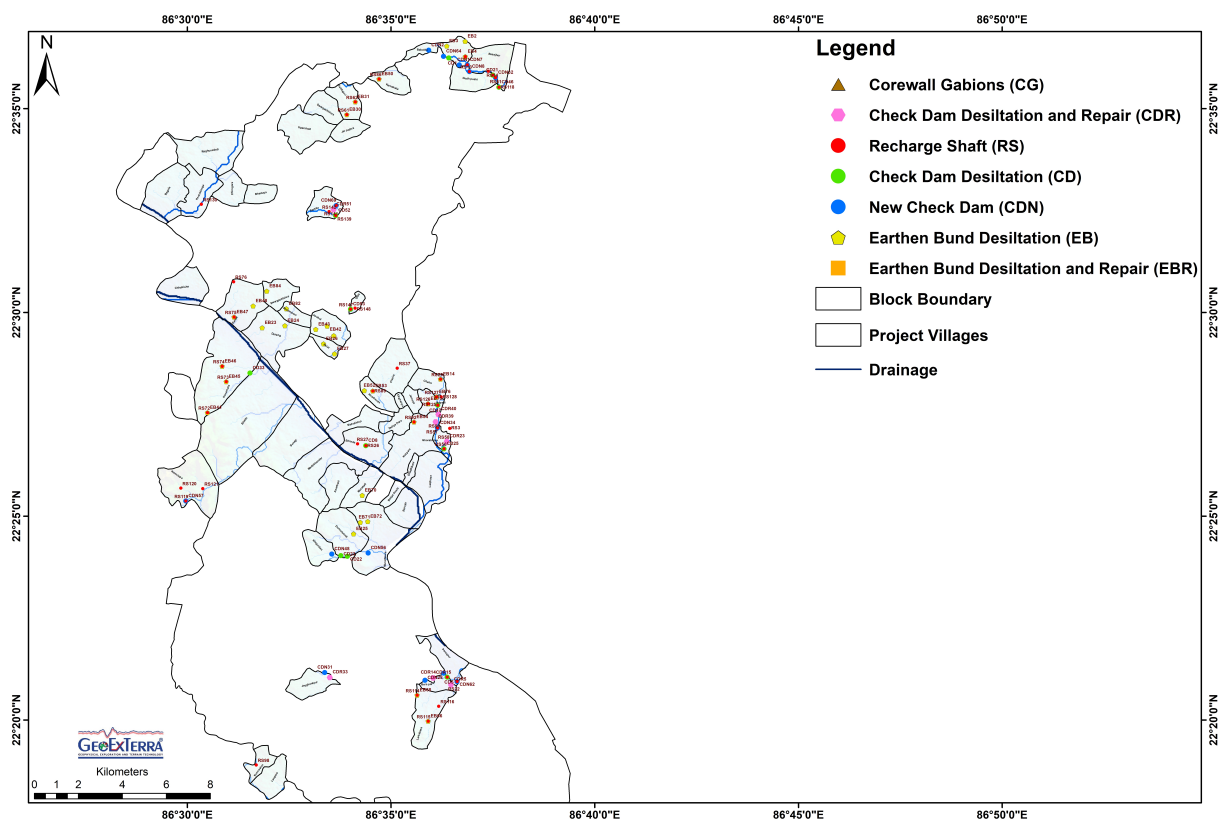


Fig. 143 Proposed Water Conservation Interventions in the Project Villages of East Singhbhum.

## 7.2. Cement Nala Bund

Cement nālā bunds are the permanent water harvesting structures created to raise the water level in the stream course to provide protective irrigation to the surrounding fields. The purpose of these structures is to provide storage of surface runoff during the runoff availability period for subsequent irrigation. Also, provides adequate infiltration opportunities to the rainwater for raising the groundwater table. Seventy three new reinforced cement concrete (RCC) cement nālā bunds have been proposed (Figs. 143 to 147, and Table 8).

Table 8. Details and Specification of Proposed New Cement Nala Bund (CNB).

Sl. No.	ID	Village	Latitude°	Longitude°	Avg. Impounding Height (m)	Width (m)	Submergence (m)	Groundwater Recharge (tcm)
1	CDN1	Babaida	22.60124	86.61130	0.5	17	180	10.5
2	CDN2		22.60725	86.59879	0.9	23	170	31.5
3	CDN3	Baghmara Harladangal	24.28598	86.93169	0.6	24	190	38.4
4	CDN4	BAHERA	23.85032	85.46953	0.8	17	100	27.6
5	CDN5		23.83262	85.46386	0.8	50	160	94.4
6	CDN6		23.85673	85.46910	0.5	13	110	20.8
7	CDN7	Basajhor	22.60121	86.61458	0.6	19	200	14.7
8	CDN8		22.59849	86.61543	0.6	16	150	9.3
9	CDN9	BASMATA	24.28511	86.92260	0.5	9.1	120	6.7
10	CDN10	Bedganwa Nawadh	24.28818	86.92061	0.5	10.7	120	10.4
11	CDN11	Bedla	24.20689	87.03464	0.8	19.9	120	27.5
12	CDN12		24.21247	87.03696	0.7	17.1	300	70.2
13	CDN13		24.21611	87.04100	0.6	11.2	300	21.6
14	CDN14		24.21476	87.03909	0.7	23.1	250	40.8
15	CDN15	BELGARA	23.90819	85.48019	0.5	14	130	11.8
16	CDN16	Bhuskl	24.01464	86.37750	0.9	13	400	59.3
17	CDN17		24.01749	86.37934	1	14	180	33.0
18	CDN18		24.01966	86.37894	0.6	9	150	9.8
19	CDN19		24.02034	86.38045	1.1	10	120	17.2
20	CDN20	CHANARO	23.86549	85.45737	0.6	13	80	7.4
21	CDN21		23.86932	85.44107	0.5	12	80	8.2
22	CDN22	CHICHIKHURD	23.89707	85.47042	0.5	20	100	22.9
23	CDN23		23.88307	85.47252	0.9	15	110	11.1
24	CDN24		23.88259	85.47054	1	13	120	14.2
25	CDN25		23.88115	85.46852	1	18	160	28.7
26	CDN26	Chlnapahari	23.98549	86.37000	0.5	25	100	5.6
27	CDN27	Chokshol	22.35247	86.60487	0.9	15	100	19.0
28	CDN28		22.34959	86.59725	1	22	180	36.8
29	CDN29	Dalugura	24.01039	86.37669	0.8	13	300	33.0
30	CDN30	DASO KHAP	23.81273	85.44386	1	12	90	17.2
31	CDN31	Dongadah	22.35274	86.55624	0.9	22	150	40.4
32	CDN32	Dudh pushi	22.59600	86.62610	0.7	15	180	12.4
33	CDN33	GAIBATHAN	24.29766	87.19432	0.9	17.9	200	64.7
34	CDN34	Ghoratoriya	22.45276	86.60236	0.9	17	150	42.8
35	CDN35	GUTIGARHA	22.95012	85.35404	1	17	200	51.9
36	CDN36	HENDEGARA	23.82009	85.39492	1.1	14	190	44.2
37	CDN37	INDRA	23.82307	85.46612	0.9	38	300	105.2
38	CDN38		23.82587	85.46716	0.9	40	300	140.8
39	CDN39	Kadwara	24.00716	86.37726	0.7	13	110	7.6
40	CDN40	KAJRI	23.85308	85.48760	0.9	14.5	90	10.1
41	CDN41		23.85763	85.49139	0.7	15	110	15.0
42	CDN42		23.84532	85.48347	0.8	26	120	70.9
43	CDN43		23.84115	85.48522	0.8	25	180	137.9
44	CDN44	Kankl	24.15333	86.89467	0.6	8	160	29.7
45	CDN45		24.14701	86.89167	0.7	9.1	80	14.4
46	CDN46		23.72344	85.39609	0.8	10.5	110	45.1
47	CDN47	Khalrwa	24.20853	87.04374	0.9	9.8	140	17.5
48	CDN48	Khejurdari	22.40119	86.55913	0.9	12	140	12.0
49	CDN49	KURA	23.76342	85.36861	0.6	15	110	11.5
50	CDN50		23.77499	85.37613	0.5	17	180	22.7
51	CDN51		23.77701	85.37518	0.5	10	100	8.4
52	CDN52	LARA	23.92489	85.48872	0.4	13	100	5.1
53	CDN53	MAHIL	23.00857	85.26027	0.8	14	150	39.8
54	CDN54	MASHANJOR	24.16473	86.88916	0.5	13.2	180	17.6
55	CDN55		24.16563	86.89369	0.4	6.8	110	5.7
56	CDN56	Murathkura	22.40165	86.57403	0.7	16	180	12.4
57	CDN57	Namulepa	22.42288	86.49940	0.9	20	80	11.2
58	CDN58	NARO	23.97830	86.38323	0.5	9	180	6.2
59	CDN59	Nawadh	24.24923	86.91370	0.9	7.2	120	5.2
60	CDN60	Nunurai	24.25138	86.91098	1	7.1	150	21.2
61	CDN61		24.24605	86.90814	1	7.1	80	10.6
62	CDN62	Paraspor	22.34902	86.61036	1	20	80	16.3
63	CDN63	Patrobad	23.99226	86.37931	0.4	12	130	11.3
64	CDN64	Rautara	22.60471	86.60484	0.6	16	200	16.1
65	CDN65	RIKBA	23.76022	85.37051	0.8	13	200	27.8

66	CDN66		23.74668	85.38511	1.3	18.5	200	90.0
67	CDN67		23.74937	85.38155	1	19.5	160	52.7
68	CDN68		23.75261	85.37773	0.7	12	180	25.8
69	CDN69	Sarbila	22.54367	86.56092	0.6	15	100	8.7
70	CDN70	SARDULA	23.01204	85.26266	0.9	12	100	19.1
71	CDN71	Slmla	24.15159	86.89924	0.6	7.9	150	25.1
72	CDN72		24.15321	86.90187	0.5	5.9	100	10.4
73	CDN73	Sonatanr	24.17136	86.90874	0.6	6.3	120	7.3
<b>Total Volume (tcm)</b>								<b>2110.3</b>

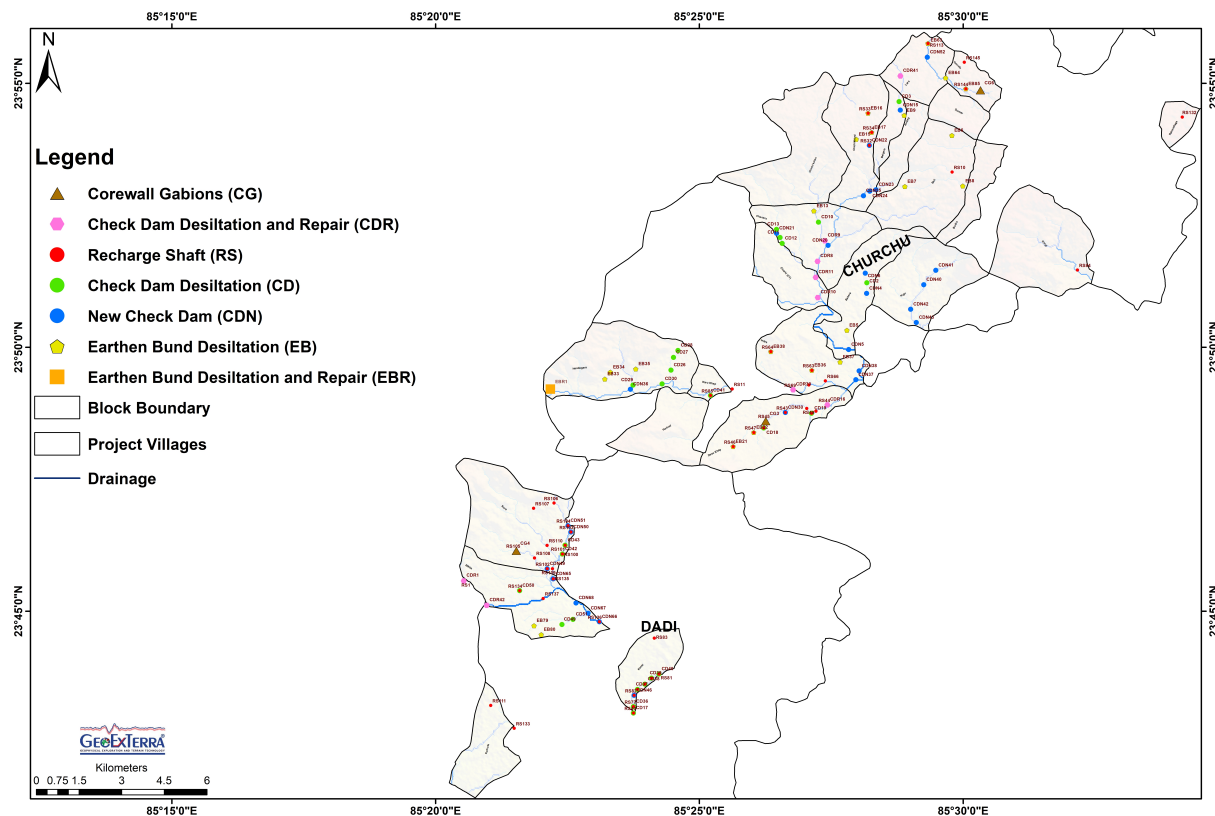


Fig. 144 Proposed Water Conservation Interventions in the Project Villages of Hazaribagh.

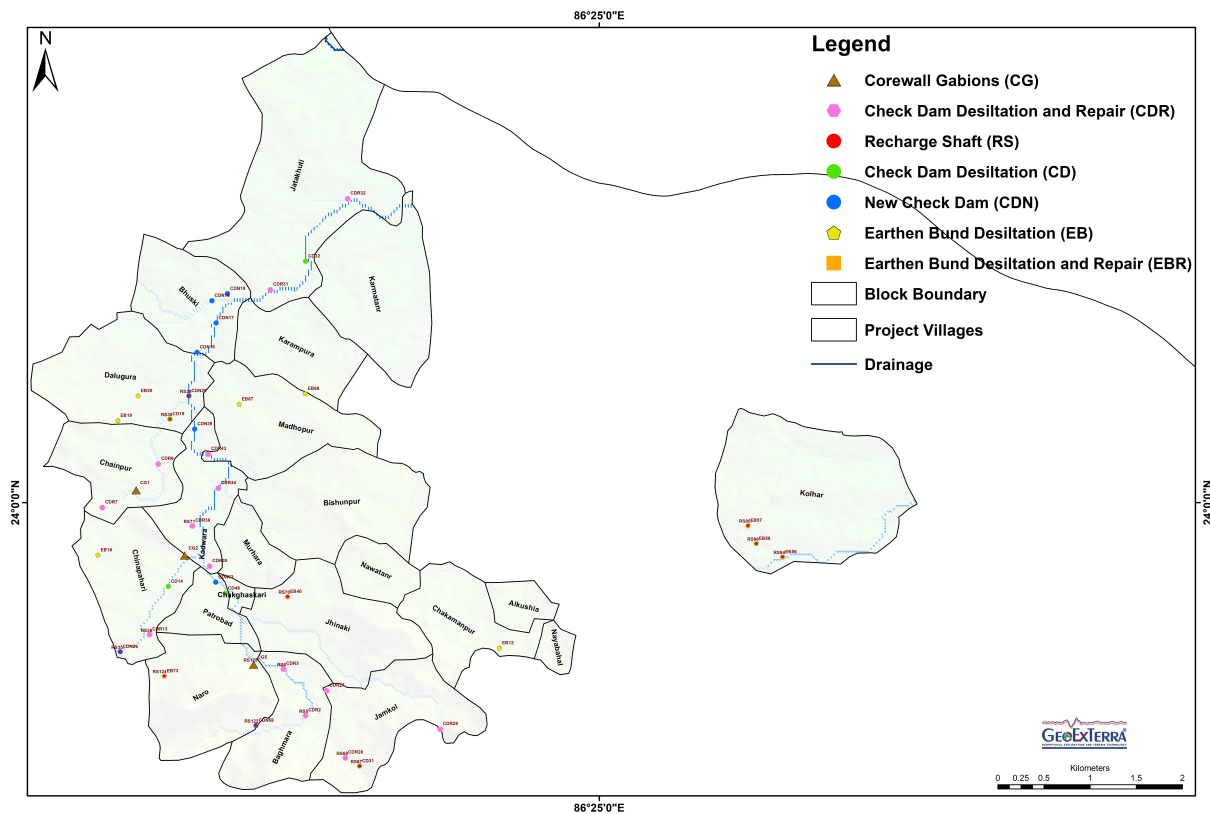
### 7.3. Corewall Gabion

Corewall gabions are gabion but have an RCC core wall in the central part, which enables them to store the runoff in the drainage/stream in a very cost-effective way. In the project area, drainages have less catchment area, and found at second and third-order streams were found suitable for corewall gabions. In the project area, six corewall gabions were proposed (Figs. 143 to 147, and Table 9).

Table 9. Details and Specification of Corewall Gabions.

Sl. No.	ID	Village	Latitude°	Longitude°	Silt Depth (m)	Avg. Impounding Height (m)	Width (m)	Submergence (m)	Groundwater Recharge (tcm)
1	CG1	Chalnpur	24.00122	86.37155	0.3	0.4	10	60	2.69
2	CG2	ChInapahari	23.99486	86.37627	0.5	0.8	15	90	15.86
3	CG3	DASO KHAP	23.81005	85.43763	0.5	0.8	10	70	8.15
4	CG4	KURA	23.76909	85.35885	0.4	0.5	9	90	7.66
5	CG5	NARO	23.98423	86.38299	0.3	0.4	8	100	3.35

6	CG6	TASNALO	23.91447	85.50548	0.3	0.8	9	50	5.70
<b>Total Volume (tcm)</b>									<b>43.41</b>



**Fig. 145 Proposed Water Conservation Interventions in the Project Villages of Dhanbad.**

#### 7.4. Desiltation of Water Harvesting Structures

Desiltation of water conservation structures not only removes the silted layer that impairs the rate of infiltration, but also increases the rainwater storing capacity of structures, reduces the celerity of rainwater in channels, and allows aquifer recharge at a faster rate. Hence enhanced groundwater recharge increases groundwater availability and level, which means the availability of groundwater for intensive agriculture irrigation practices, better moisture regimes, and water supply. In the project area, there are 53 existing check dams, and 86 existing earthen bunds/dams having approximately 0.3 to 1.3 m thick average silt/sand deposition that needs an immediate desiltation as specified in Figs. 143 to 147 and Tables 10 and 11 to harvest ~ 3818.5 TCM of runoff.

**Table 10. Details of Desiltation of Check Dams.**

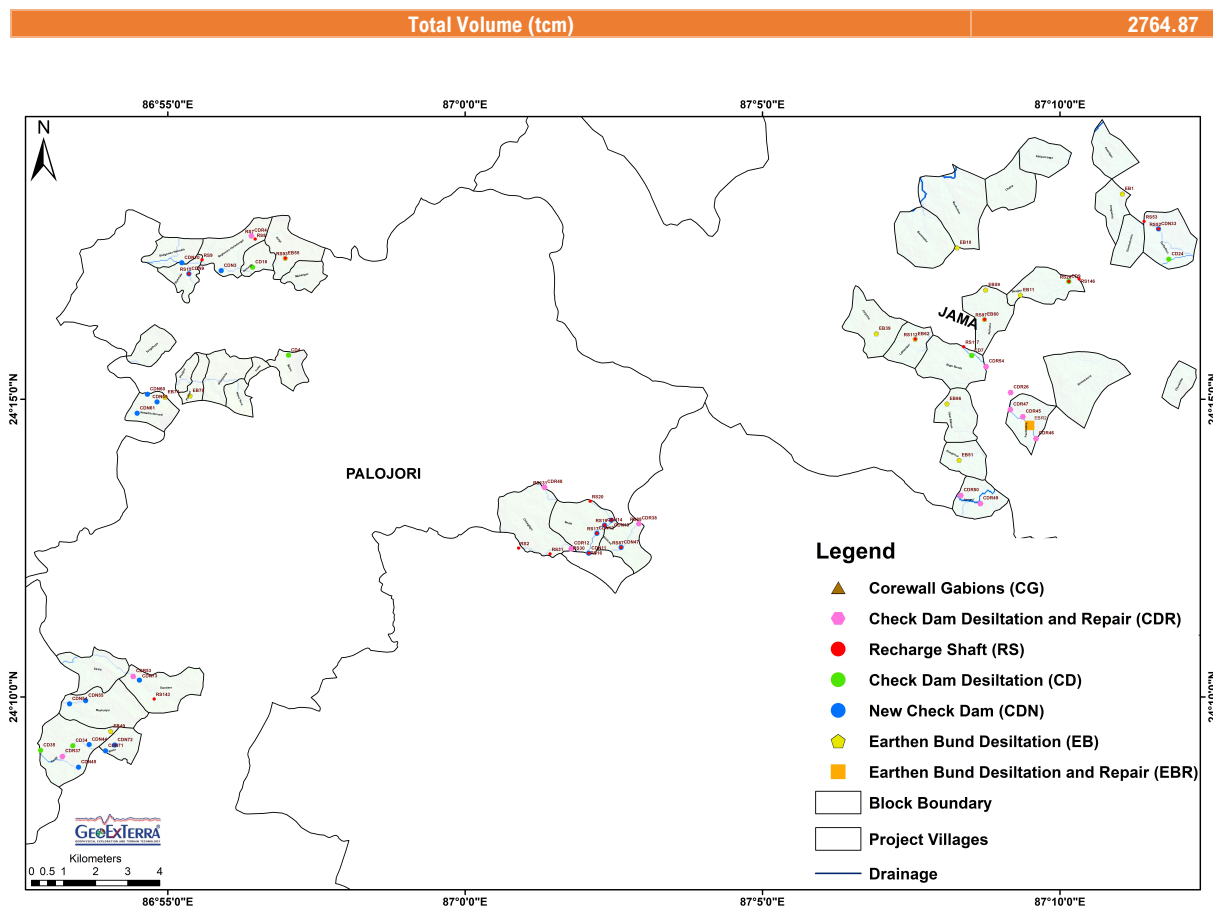
Sl. No.	ID	Village	Latitude°	Longitude°	Silt Depth (m)	Area (m <sup>2</sup> )	Additional Groundwater Potential Created (tcm)
1	CD1	Babaida	22.60407	86.60698	0.8	3040.0	18.63
2	CD2	BAHERA	23.85371	85.46961	0.4	1600.0	16.47
3	CD3	BELGARA	23.91088	85.47982	0.5	1800.0	13.47
4	CD4	Belml	24.26231	86.95054	0.3	900.0	3.21
5	CD5	Bera pal	22.35088	86.60636	0.5	2850.0	15.93
6	CD6	BHURSA	23.06874	85.36254	0.4	2000.0	12.41
7	CD7	BIGAI BANDH	24.26220	87.14199	0.5	2800.0	15.34
8	CD8	Bihinda	22.44550	86.57304	0.4	1500.0	6.27

9	CD9	BIRAJPUR	24.28296	87.16920	0.4	2000.0	14.13
10	CD10	CHANARO	23.87281	85.45434	0.4	1800.0	8.33
11	CD11		23.86800	85.44219	0.6	1200.0	11.91
12	CD12		23.86612	85.44288	0.5	1900.0	16.80
13	CD13		23.87055	85.44108	0.9	2000.0	31.42
14	CD14	Chlnapahari	23.99183	86.37470	0.4	2800.0	11.64
15	CD15	Dalugura	24.00813	86.37485	0.6	2500.0	13.38
16	CD16	Damadlh	24.28696	86.94049	0.4	600.0	2.07
17	CD17	DARI (CT)	23.71787	85.39586	0.4	1260.0	24.44
18	CD18	DASO KHAP	23.80784	85.43702	0.5	1500.0	12.44
19	CD19		23.81251	85.45215	0.6	750.0	6.77
20	CD20	DIGRI	23.06462	85.35936	0.5	1080.0	10.30
21	CD21	Dudh pushi	22.59704	86.62507	0.4	2250.0	5.84
22	CD22	Dumurbandi	22.40028	86.56554	0.5	2171.0	6.88
23	CD23		22.40054	86.56285	0.4	1800.0	5.00
24	CD24	GAIBATHAN	24.28920	87.19723	0.4	400.0	2.75
25	CD25	Ghoratoriya	22.44424	86.60504	0.4	9450.0	78.49
26	CD26	HENDEGARA	23.82614	85.40775	0.7	1400.0	23.73
27	CD27		23.83015	85.40852	0.4	900.0	7.17
28	CD28		23.83234	85.40995	0.5	1400.0	13.28
29	CD29		23.82140	85.39572	0.6	1600.0	15.02
30	CD30		23.82176	85.40495	0.5	2800.0	34.58
31	CD31	Jamkol	23.97436	86.39332	1.3	500.0	6.22
32	CD32	Jatakhutl	24.02350	86.38805	0.5	2000.0	12.97
33	CD33	Kananluka	22.47520	86.52565	0.6	1260.0	8.70
34	CD34	Kankl	24.15301	86.89009	0.4	3000.0	36.13
35	CD35		24.15174	86.88109	0.5	4000.0	32.88
36	CD36		23.71988	85.39586	0.6	1320.0	38.99
37	CD37		23.72533	85.39714	0.4	1400.0	28.84
38	CD38		23.72697	85.39952	0.9	1200.0	59.93
39	CD39		23.72890	85.40157	0.9	1320.0	66.31
40	CD40		23.73018	85.40393	0.7	1400.0	53.11
41	CD41	KARU KHAP	23.81812	85.42021	0.4	2800.0	11.75
42	CD42	KURA	23.76807	85.37343	0.9	1650.0	17.65
43	CD43		23.77085	85.37427	0.6	1500.0	11.07
44	CD44	MAHIL	23.00686	85.25592	0.7	3000.0	59.77
45	CD45		23.00642	85.25872	0.5	2100.0	25.65
46	CD46	Mahisadhara	22.59207	86.62751	0.8	5500.0	29.48
47	CD47	Noyadi	22.46207	86.60250	0.5	1760.0	13.60
48	CD48	Patrobad	23.99117	86.38025	1.0	900.0	16.15
49	CD49	RIKBA	23.74581	85.37328	0.9	1750.0	33.41
50	CD50		23.75650	85.35993	0.4	600.0	5.78
51	CD51		23.74743	85.37678	0.4	900.0	7.13
52	CD52	Sarbila	22.53961	86.56075	0.6	2000.0	11.78
53	CD53	Ulda	22.50130	86.56679	0.5	1440.0	8.22
<b>Total Volume (tcm)</b>							<b>1053.60</b>

**Table 11. Details of Desiltation of Earthen Bunds/Dams.**

Sl. No.	ID	Village	Latitude°	Longitude°	Silt Depth (m)	Area (m2)	Additional Groundwater Potential Created (tcm)
1	EB1	AMGACHHI	24.30748	87.18422	0.4	2500.0	14.52
2	EB2	Babaida	22.61083	86.61373	0.4	2100.0	5.90
3	EB3		22.60890	86.60619	0.6	1300.0	6.54
4	EB4		22.60460	86.61373	0.6	5500.0	21.61
5	EB5	BAHERA	23.83865	85.46331	0.5	16000.0	127.39
6	EB6	BALI	23.90017	85.49647	0.7	3300.0	13.41
7	EB7		23.88405	85.48164	0.4	3700.0	15.96
8	EB8		23.88420	85.49994	0.4	2500.0	8.67
9	EB9	BELGARA	23.90648	85.48140	0.6	2700.0	18.70
10	EB10	BHAIROPUR	24.29239	87.13790	0.4	4000.0	22.81
11	EB11	BIRAJPUR	24.27912	87.15562	0.4	10000.0	48.88
12	EB12	CHAKAMANPUR	23.98585	86.40695	0.7	1500.0	13.94
13	EB13	CHANARO	23.87634	85.45289	0.5	4500.0	29.77
14	EB14	Chatro	22.47270	86.60363	0.4	3300.0	17.95
15	EB15	CHICHIKHURD	23.89896	85.46625	0.5	1500.0	29.27
16	EB16		23.90719	85.47000	0.4	4000.0	21.74
17	EB17		23.90115	85.47116	0.4	1600.0	11.06

18	EB18	Chlnapahari	23.99489	86.36784	0.4	5800.0	20.23
19	EB19	Dalugura	24.00799	86.36978	0.4	2000.0	14.20
20	EB20		24.01039	86.37176	0.3	4500.0	19.38
21	EB21	DASO KHAP	23.80196	85.42737	0.4	1100.0	5.32
22	EB22		23.80641	85.43387	0.4	2200.0	13.11
23	EB23	Derang	22.49369	86.53065	0.4	2500.0	13.12
24	EB24		22.49456	86.53995	0.4	1900.0	4.87
25	EB25	Dumurbandi	22.40943	86.56806	0.4	850.0	2.66
26	EB26	Ektal	22.48711	86.55577	0.4	4700.0	19.44
27	EB27		22.48307	86.56027	0.4	3900.0	19.00
28	EB28	GAJGAON	22.99415	85.26634	0.7	28000.0	288.84
29	EB29		22.98236	85.25599	0.5	1670.0	11.82
30	EB30	Haildajuri	22.58089	86.56527	0.4	8652.0	25.86
31	EB31		22.58605	86.56874	0.4	3350.0	7.56
32	EB32	HANSA	22.99712	85.27772	0.4	7500.0	66.97
33	EB33	HENDEGARA	23.82328	85.38683	0.5	2600.0	24.55
34	EB34		23.82544	85.38859	0.6	1300.0	14.78
35	EB35		23.82645	85.39662	0.5	2500.0	21.99
36	EB36	INDRA	23.82605	85.45222	0.6	5500.0	81.40
37	EB37		23.82866	85.46117	0.4	3800.0	21.45
38	EB38		23.83195	85.43926	0.5	11000.0	125.55
39	EB39	JARJOKHA	24.26831	87.11527	0.4	3500.0	21.73
40	EB40	Jhlnaki	23.99085	86.38630	0.6	4000.0	47.83
41	EB41	Jorshol	22.49049	86.55995	0.5	1800.0	10.03
42	EB42		22.49441	86.55728	0.4	3100.0	12.01
43	EB43		22.49307	86.55260	0.4	14400.0	38.50
44	EB44	Kananluka	22.45901	86.50829	0.4	800.0	2.45
45	EB45		22.47166	86.51597	0.6	1000.0	5.35
46	EB46		22.47798	86.51430	1.0	4400.0	76.70
47	EB47	Kanas	22.49811	86.51917	0.4	5100.0	43.44
48	EB48		22.50262	86.52697	0.4	4200.0	33.39
49	EB49	Kankl	24.15704	86.90073	0.6	1500.0	36.27
50	EB50	Karuakata	22.59543	86.57848	0.4	6500.0	25.34
51	EB51	KHAPCHUA	24.23293	87.13845	0.5	1200.0	4.74
52	EB52	Kharbanda	22.46799	86.57247	0.4	5100.0	34.72
53	EB53		22.46784	86.57589	0.4	5700.0	37.05
54	EB54	Kokpara	22.45520	86.59277	0.9	8500.0	169.74
55	EB55	Kolgl	24.28946	86.94962	0.4	2000.0	23.34
56	EB56	Kolhar	23.99471	86.43453	0.7	5200.0	55.07
57	EB57		23.99776	86.43117	0.6	7000.0	53.74
58	EB58		23.99601	86.43197	0.6	900.0	7.48
59	EB59	KULHORIA	24.28055	87.14591	0.4	7500.0	32.92
60	EB60		24.27232	87.14556	0.4	1200.0	2.04
61	EB61	KUNDIRBARTOLI	23.02344	85.28853	0.6	1200.0	10.93
62	EB62	LAKHANPUR	24.26681	87.12614	0.4	2500.0	7.90
63	EB63	LARA	23.92924	85.48892	0.6	15000.0	102.26
64	EB64		23.91834	85.49452	0.4	5500.0	15.00
65	EB65	Larkabasa	22.34345	86.59406	0.4	1060.0	3.05
66	EB66		22.33282	86.59856	0.6	1400.0	2.88
67	EB67	Madhopur	24.00957	86.38159	0.4	1700.0	8.04
68	EB68		24.01061	86.38802	0.4	2100.0	12.90
69	EB69	MERAL	23.02036	85.26665	0.5	42000.0	228.50
70	EB70	Murakati	22.42517	86.57158	0.4	745.0	5.74
71	EB71	Murathkura	22.41412	86.57082	0.6	870.0	4.82
72	EB72		22.41449	86.57383	0.5	2400.0	14.42
73	EB73	NARO	23.98311	86.37430	0.4	1500.0	2.80
74	EB74	Nawadh Nunurai	24.25057	86.91593	0.5	2100.0	13.07
75	EB75	Noyadi	22.46267	86.59850	0.5	3600.0	34.08
76	EB76		22.46542	86.60192	0.5	12900.0	93.94
77	EB77	PERKA	23.00336	85.26701	0.4	1500.0	10.82
78	EB78	Phuljorl	24.25094	86.92292	0.3	2000.0	11.09
79	EB79	RIKBA	23.74541	85.36445	0.4	1700.0	13.17
80	EB80		23.74261	85.36674	0.4	3000.0	25.11
81	EB81	SAPRUM	23.06351	85.37945	0.5	3300.0	25.48
82	EB82	Shirishbani	22.50147	86.54057	0.6	4900.0	23.69
83	EB83	SIYANKEL	22.92149	85.27130	0.5	1200.0	8.65
84	EB84	Swargachhinra	22.50868	86.53252	0.4	6300.0	25.40
85	EB85	TASNALO	23.91490	85.50087	0.6	7200.0	30.66
86	EB86	UPAR BALRAM	24.24868	87.13507	0.4	1200.0	6.40



**Fig. 146 Proposed Water Conservation Interventions in the Project Villages of Deoghar and Dumka.**

### 7.5 Repair and Desiltation of Water Harvesting Structures

Over time some of the permanent RCCs check dam structures and earthen nala bunds loses their efficiency and storage retention due to leakages in the dam walls, and carvings due to erosion. To maintain the storage and functionality of these structures are required to be repaired against damages. In the project area, a total of 54 existing check dams and two earthen lala bunds were identified to be repaired and desilted to harvest 1947.9 TCM runoff (Figs. 143 to 147, Tables 12 and 13).

**Table 12. Details of Repairing and Desiltation of Check Dams.**

Sl. No.	ID	Village	Latitude°	Longitude°	Silt Depth (m)	% Loss Due to Damage	Additional Groundwater Potential Created (tcm)	Remark
1	CDR1	Border	23.75954	85.34226	0.5	40	21.31	Broken
2	CDR2	BAGHMARA	23.97925	86.38806	0.4	80	12.20	stream diverted and water bypass to check dam due to soil erosion
3	CDR3		23.98379	86.38591	0.8	75	13.07	Structure intact;Gates missing/not provided,structure partially functional
4	CDR4	Baghmara Harladangal	24.29566	86.94014	0.4	30	26.11	Base broken and side wall eroded
5	CDR5	Bera pal	22.34766	86.60793	0.3	40	13.88	Apron is broken

6	CDR6	ChalInpur	24.00374	86.37371	0.2	60	735.77	Structure intact;Gates missing/hot provided,structure partially functional
7	CDR7		23.99950	86.36826	0.4	50	23.62	Structure intact;Gates missing/hot provided,structure partially functional
8	CDR8	CHANARO	23.86042	85.45405	0.4	90	101.20	Stream diverted and structure partially broken
9	CDR9		23.86693	85.45636	0.3	70	11.59	Structure intact but gates missing
10	CDR10	CHARHI (CT)	23.84900	85.45414	0.6	80	68.95	Stream diverted and structure partially broken
11	CDR11		23.85535	85.45347	0.4	70	44.16	Stream diverted and structure partially broken
12	CDR12	Chhaglajor	24.20812	87.02979	0.4	70	18.89	side wall eroded and Water flow bypass
13	CDR13	Chlnapahari	23.98713	86.37286	0.3	40	9.73	Structure intact;Gates missing/hot provided,structure partially functional
14	CDR14	Chokshol	22.35051	86.60060	0.4	40	14.77	Broken from side
15	CDR15		22.35047	86.60062	0.4	90	41.83	Side wall eroded
16	CDR16	DASO KHAP	23.81511	85.45714	0.4	40	64.88	Side wall eroded;water bypassing structure
17	CDR17	DEKLA	22.94839	85.35062	0.5	90	52.60	Sidewall eroded
18	CDR18	DIGRI	23.06645	85.36084	0.5	80	36.32	Broken
19	CDR19	GAJGAON	22.97694	85.25618	0.4	90	43.01	Broken
20	CDR20		22.97727	85.26393	0.4	60	6.71	Broken
21	CDR21		22.99181	85.25774	0.5	20	14.37	Leaked , Vegetation and Bushes Desilation recommended
22	CDR22		22.97839	85.26491	0.6	80	23.62	Water Escaping due to no gate, Desiltation recommended for water storage.
23	CDR23	Ghoratoriya	22.44716	86.60618	0.3	40	62.86	Broken
24	CDR24	GURHAMI	22.97747	85.26221	0.4	70	23.34	Broken
25	CDR25		22.97774	85.25956	0.4	75	62.06	Side erosion caused by water bypass
26	CDR26	HATHBALRAM	24.25182	87.15290	0.3	40	23.55	CD is broken an water bypass
27	CDR27	Jamkol	23.98167	86.39012	0.3	55	11.94	Broken damaged
28	CDR28		23.97515	86.39194	0.4	50	5.66	Structure intact;Gates missing/hot provided,structure partially functional
29	CDR29		23.97793	86.40117	0.5	70	7.40	Structure intact;Gates missing/hot provided,structure partially functional
30	CDR30	JARWA	23.81988	85.44633	0.4	40	23.96	Side wall damaged;vegetation present upstream
31	CDR31	Jatakhtul	24.02071	86.38463	0.4	75	42.08	BROKEN
32	CDR32		24.02957	86.39217	0.4	50	22.42	Structure intact;Gates missing/hot provided,structure partially functional
33	CDR33	Jayghantpur	22.35064	86.55834	0.0	30	9.29	Broken
34	CDR34	Kadwara	24.00139	86.37956	0.5	90	41.42	Broken
35	CDR35		23.99379	86.37872	0.6	40	37.56	Leaked vegetation in submergence area
36	CDR36		23.99772	86.37704	0.3	60	31.35	Structure intact;Gates missing/hot provided,structure partially functional
37	CDR37	Kankl	24.14996	86.88719	0.3	30	43.17	Side wall eroded and trees are present at upstream side
38	CDR38	Khalrwa	24.21513	87.04872	0.3	90	5.92	CD is broken

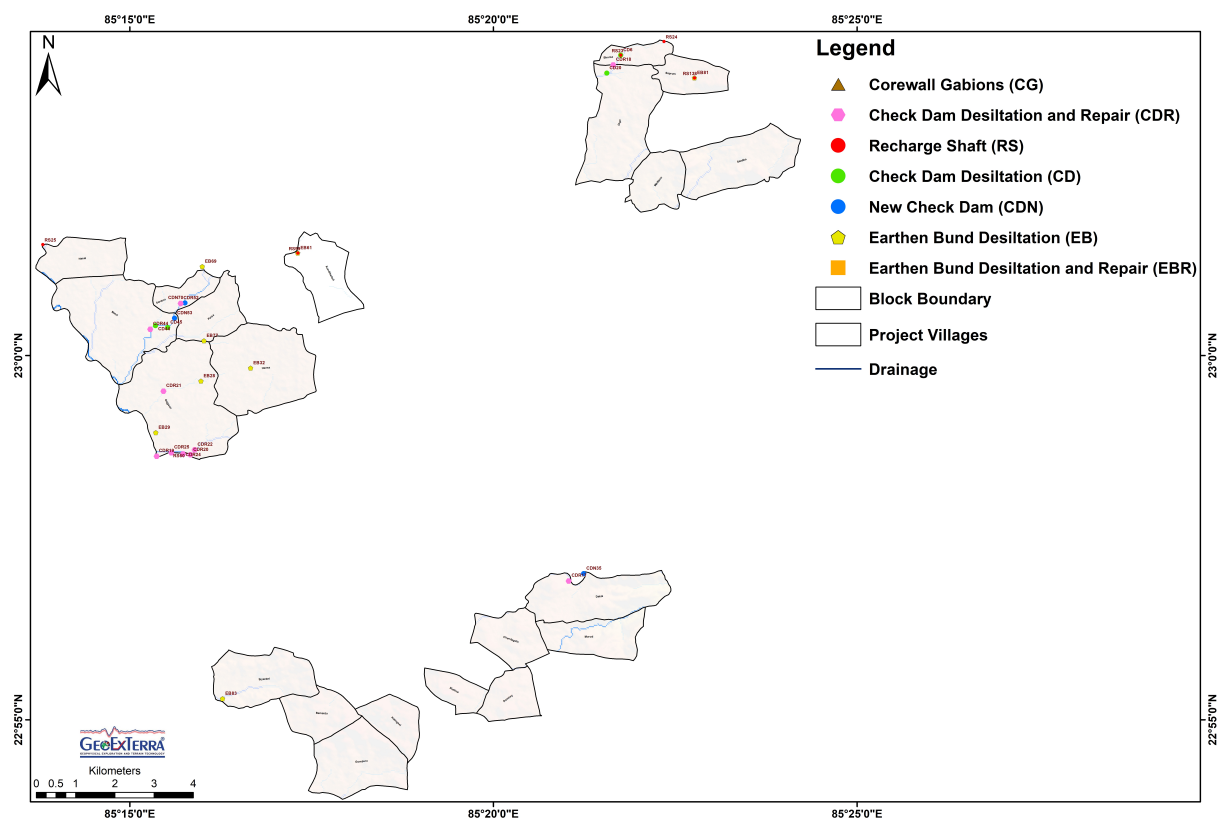
39	CDR39	Kokpara	22.45519	86.60163	0.5	25	77.68	Leaked
40	CDR40		22.45824	86.60273	0.5	25	56.51	Leaked
41	CDR41	LARA	23.91891	85.48020	0.5	85	41.86	Stream diverted and structure partially broken
42	CDR42	LUKUIYA	23.75182	85.34953	0.6	45	44.17	Broken
43	CDR43	Madhopur	24.00470	86.37859	0.5	60	39.00	Gate absent; check dam damaged
44	CDR44	MAHIL	23.00599	85.25472	0.4	80	42.35	Gates are not present
45	CDR45	PACHKATHIA	24.24504	87.15635	0.4	50	68.10	CD is broken
46	CDR46		24.23892	87.16000	0.4	90	234.07	CD is fully damage
47	CDR47		24.24702	87.15284	0.5	90	121.98	Wall eroded and water bypass, vegetation in upstream side
48	CDR48	Plndna	24.22534	87.02227	0.3	20	15.58	water flow bypass of cd due to soil erosion
49	CDR49	SAMPUR	24.22075	87.14442	0.4	90	108.24	Water bypass due to soil erosion
50	CDR50		24.22301	87.13895	0.4	80	118.29	Water bypass due to soil erosion
51	CDR51	Sarbila	22.54199	86.55988	0.4	40	12.06	Water goes from side des required
52	CDR52	SARDULA	23.01190	85.26168	0.4	80	60.18	Broken from side
53	CDR53	Sonatanr	24.17237	86.90703	0.3	80	15.41	water flow bypass of cd due to soil erosion
54	CDR54	SUKHBARIA URF MURGABANI	24.25905	87.14601	0.5	40	32.40	Side wall eroded and water bypass due to soil erosion
<b>Total Volume (tcm)</b>							<b>1734.59</b>	

**Table 13. Details of Repairing and Desiltation of Earthen Bunds.**

Sl. No.	ID	Village	Latitude°	Longitude°	Silt Depth (m)	% Loss Due to Damage	Additional Groundwater Potential Created (tcm)
1	EBR1	HENDEGARA	23.82011	85.36962	0.7	10.0	110.32
2	EBR2	PACHKATHIA	24.24263	87.15820	0.3	75.0	102.99
<b>Total Volume (tcm)</b>							<b>213.31</b>

## 8. PROJECTED SURFACE RUNOFF CONSERVATION

The Projected Surface Runoff Conservation assessment for the integrated hydrogeophysical investigation covering Deoghar (Palojori), Dhanbad (Tundi), Dumka (Jama), East Singhbhum (Gurabanda and Dalbhumgarh), Hazaribagh (Churchu and Dadi), and Khunti (Murhu) clearly demonstrates a substantial opportunity to enhance groundwater resources through scientifically designed and spatially targeted water harvesting interventions. Based on the compiled dataset, a total of 422 water augmentation structures have been proposed, collectively capable of conserving approximately 9321.7 TCM of monsoonal runoff, with an estimated capital investment of ₹1750.42 million, thereby indicating a technically robust and economically justified framework for strengthening long-term water security in the region (Table 14). A detailed evaluation of structure-wise performance highlights that repair and desiltation of check dams (54 units) contribute the highest runoff conservation potential of 2940.5 TCM, followed by desiltation of earthen bunds (86 units) with 2764.9 TCM, and new check dams (73 units) contributing 2110.3 TCM, which collectively underscores that rehabilitation and performance optimization of existing structures yield significantly higher volumetric benefits compared to new construction alone. Additionally, recharge shafts (148 units), although contributing a relatively smaller volume (195.8 TCM), play a critical role in enhancing vertical percolation and deep aquifer recharge, particularly within hard rock terrains where groundwater occurrence is governed by secondary porosity and fracture systems. Minor yet strategically important contributions are made by corewall gabions (6 units) and repair/desiltation of earthen bunds (2 units), which aid in channel stabilization,



**Fig. 147 Proposed Water Conservation Interventions in the Project Villages of Khunti.**

sediment control, and localized infiltration enhancement. The effectiveness and spatial suitability of these interventions are intrinsically governed by terrain morphology, soil hydro-physical properties, drainage density, structural lineaments, and land degradation characteristics. Regions such as Churchu, Jama, and parts of Tundi, characterized by moderate to high runoff generation and relatively low hydraulic conductivity soils (clayey to silty clay;  $K < 0.3$  m/day), exhibit high suitability for check dams, bunding, and desiltation measures, as these interventions effectively intercept rapid overland flow and convert it into surface storage and recharge. In contrast, relatively permeable zones in Dalbhumgarh, Gurabanda, and Palojori (sandy loam to sand;  $K > 0.5$  m/day) are more conducive for recharge shafts and subsurface recharge systems, facilitating rapid infiltration into deeper aquifer horizons. Furthermore, drainage convergence zones and structurally controlled valleys significantly enhance the efficiency of check dams and gabions by concentrating runoff and promoting focused recharge. The analysis also reveals that sedimentation has critically reduced the efficiency of existing water harvesting structures, as evidenced by the high contribution of desiltation interventions, indicating that immediate restoration can yield rapid and high returns in storage capacity, particularly in erosion-prone areas affected by sheet and gully erosion.

From a regional hydrological perspective, the annual water balance indicates that out of 637561.3 TCM of rainfall (2025), only 21.7% (138173.6 TCM) contributes to natural infiltration, while 64.7% (412464.8 TCM) is lost to evapotranspiration and 13.6% (86900.3 TCM) is lost as surface runoff. The proposed interventions aim to harness approximately 9321.7 TCM of this runoff, which represents about 10.7% of the total recharge potential, thereby significantly improving groundwater replenishment. Hydrogeophysical investigations further indicate groundwater

availability up to depths of ~83.6 m, with an estimated 283981.1 TCM of fresh groundwater reserves, suggesting strong aquifer potential for augmented recharge. The integration of subsurface interventions such as recharge shafts and proposed subsurface dykes is particularly important, as these structures reduce evapotranspiration losses, improve subsurface storage, enhance baseflow retention, and enable more uniform spatial distribution of water, even in areas lacking surface storage bodies. In terms of hydrological impact, the conserved runoff of ~9321.8 TCM is expected to significantly improve groundwater and soil moisture regimes across the project area. The interventions are projected to raise groundwater levels by approximately 1 to 2.7 meters, enhance soil moisture content to about 40–45% volumetric water content, and extend soil moisture availability for up to ~56 additional days, thereby improving crop resilience during dry spells. Moreover, the groundwater retention period is expected to increase by approximately 8–9 days, contributing to sustained baseflow and improved water availability during lean periods. From an agricultural standpoint, this additional water availability can potentially bring ~1864.4 hectares of land under second cropping, assuming an average irrigation requirement of 5000 m<sup>3</sup>/ha for mixed cropping systems including rice, millets, maize, oilseeds, ragi, gram, and potato. Overall, the projected runoff conservation strategy represents a comprehensive watershed-scale intervention framework, integrating surface storage, subsurface recharge, and channel stabilization measures to optimize the regional hydrological cycle. The approach not only reduces runoff losses and enhances groundwater recharge but also mitigates land degradation, improves soil moisture dynamics, supports increased cropping intensity, and strengthens climate resilience. The findings conclusively demonstrate that systematic implementation of the proposed interventions will enable the project area to transition towards a sustainable, efficient, and climate-adaptive water resource management system, fully aligned with the objectives of integrated aquifer mapping and long-term water security planning.

**Table 14. Projected Surface Runoff Conservation Through Proposed Interventions.**

Water Augmentation Structures	Structures Nos	Structure Wise Total Harvested Water Volume (TCM)	Structure Wise Total Cost (INR)
Recharge Shaft	148.0	195.8	14311539.0
New Check Dams	73.0	2110.3	97359000.0
Corewall Gabions	6.0	43.4	1501675.0
Desiltation of Check Dams	53.0	1053.6	5106825.0
Desiltation of Earthen Bunds	86.0	2764.9	18039582.0
Repair and Desiltation of Check Dams	54.0	2940.5	38237880.0
Repair and Desiltation of Earthen Bunds	2.0	213.3	485100.0
<b>Total</b>	<b>422.0</b>	<b>9321.7</b>	<b>175041601.0</b>

## 9. CONCLUSION

The present study, provides a comprehensive evaluation of the hydrogeological conditions, groundwater availability, recharge potential, and water resource management opportunities within the project area through the integration of remote sensing, geophysical investigations, hydrogeological analysis, soil studies, water quality assessment, and groundwater recharge modeling. The investigation reveals that the hydrogeological framework of the region is primarily controlled by weathered and fractured hard rock aquifers, where groundwater occurs

within the weathered mantle and deeper fracture networks that provide secondary porosity and permeability for groundwater storage and movement. Geophysical mapping indicates that the rock overburden thickness varies between about 0.5 m and 8.8 m with an average of approximately 3.1 m, while the weathered aquifer thickness ranges from about 1 m to 59.9 m (average ~9.4 m) and the fractured aquifer thickness varies from about 1 m to 67.5 m (average ~14.2 m), collectively forming an aquifer system with a total freshwater aquifer thickness ranging from approximately 8.5 m to 82.8 m with an average thickness of about 26.7 m. Groundwater level observations indicate generally shallow water table conditions in many villages, reflecting moderate recharge potential from rainfall and surface infiltration processes. Pumping tests analyzed using the Cooper–Jacob method across five wells indicate highly heterogeneous, fracture-controlled aquifers with SWL of 4.91–7.80 m bgl and discharge of 0.36–23.08 lps. Transmissivity varies significantly from low (P2, P5 ~10–11 m<sup>2</sup>/day) to high (P1, P4 ~106–113 m<sup>2</sup>/day), with storativity (0.0003–0.0025) confirming semi-confined to confined conditions. High drawdown at P3 and P4 reflects aquifer stress and limited storage, while P1 shows stable response. Overall, groundwater occurrence is fracture-governed, requiring controlled abstraction and recharge interventions for sustainability. Hydrochemical analysis of groundwater samples shows that most parameters remain within Bureau of Indian Standards (BIS) limits for drinking water, although localized occurrences of elevated TDS, require monitoring and management to ensure long-term water quality sustainability. Land cover analysis reveals that the project area is predominantly rainfed agricultural land (about 71.2%), with additional coverage of irrigated fields, forest patches, barren land, and water bodies, indicating strong dependence of agriculture on seasonal rainfall. Soil hydro-physical analysis indicates moderate permeability and variable productivity, while erosion and land degradation studies highlight that most areas experience moderate soil erosion, emphasizing the need for soil and water conservation measures to maintain land productivity and recharge potential. Hydrological water balance modeling indicates that during 2025 approximately 637561.3 TCM of rainfall occurred, of which 21.7 % (138173.6 TCM) contributed to natural groundwater recharge, 64.7 % (412464.8 TCM) was lost through evapotranspiration, and 13.6% (86900.3 TCM) was lost as surface runoff, demonstrating significant opportunities for runoff harvesting. Through integrated hydrological and geophysical analysis it was determined that approximately 9321.8 TCM of surface runoff can be conserved through the implementation of 422 water augmentation structures, including recharge shafts, check dams, gabion structures, nala desiltation works, and bund rehabilitation, at an estimated total investment of ₹1750.42 million, which could substantially enhance groundwater recharge and improve water availability for agricultural and domestic purposes. The groundwater recharge estimation indicates that fresh groundwater availability within the project area during January 2026 is approximately 283981.1 TCM, while the average groundwater recharge thickness ranges up to 1.85 m with an average of about 0.56 m, demonstrating the capacity of the aquifer system to sustain additional recharge if runoff is effectively conserved. Agricultural water demand analysis suggests that the seasonal irrigation requirement for the major mixed crops (rice, millets, maize, oilseeds, ragi, gram, and potato) ranges approximately between 2,500–4,500 m<sup>3</sup>/ha (Rabi), 4,000–6,000 m<sup>3</sup>/ha (Summer). Overall, the annual irrigation requirement ranges from 3,000–6,000 m<sup>3</sup>/ha (net) and 4,500–8,000 m<sup>3</sup>/ha (gross), with lower demand in valley alluvial zones and higher demand in upland lateritic areas, with each irrigation cycle sustaining soil moisture for about 12–18 days under prevailing climatic conditions, emphasizing the importance of improved water management for agricultural productivity. Overall, the integrated hydrogeological and geophysical assessment confirms that the Mul and Pombhurna blocks possess moderate to favorable groundwater

development potential, provided that groundwater abstraction is balanced with recharge enhancement through watershed-based water conservation measures. The implementation of the proposed surface runoff harvesting structures, recharge interventions, and sustainable irrigation practices will significantly improve groundwater storage, stabilize groundwater levels, reduce vulnerability to seasonal water scarcity, and strengthen long-term water security for rural communities in the project villages. Therefore, the study provides a scientifically robust framework for sustainable groundwater resource development, aquifer management, and integrated watershed planning aimed at supporting agricultural livelihoods, drinking water supply, and climate-resilient water resource management in the project area.

## 10. LIMITATIONS

This study involves multiple aspects dealing with geology, hydrogeology, hydrology, terrain physiography, and geophysical investigation. The parameters like generated runoff and evapotranspiration were estimated based on secondary data available from the Indian Meteorological Department (IMD) and NASA Earth Observatory. We expect good accuracy, though their field validation is required through annual monitoring river/drainage hydrograph, and also important to understand baseflow. Further, the details of the dimensions of a few proposed water conservation structures (only drainage lines) may have very little chance (say 3 to 5 %) to deviate due to practical reasons such as the measurement performed in inundated/flowing drainages/channels.

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### Annexure 1 Goelectrical Parameters Interpreted from Resistivity Sounding Data (Schlumberger) – Jharkhand.

ID	Latitude	Longitude	Curve	Layer	RMS	True Resistivity (Qm)									Thickness (m)									Depth (m)	
						$\rho_1$	$\rho_2$	$\rho_3$	$\rho_4$	$\rho_5$	$\rho_6$	$\rho_7$	$\rho_8$	$\rho_9$	$h_1$	$h_2$	$h_3$	$h_4$	$h_5$	$h_6$	$h_7$	$h_8$	$h_9$		
G1	22.43605	86.54046	H	9	2.3	281.00	14.70	619.00	52.00	992.00	88.40	21.50	58.40	228.00	0.5	0.1	0.2	9.4	5.4	0.5	17.3	3.3	24.6	61.3	
G10	22.43698	86.59326	H	8	1.8	18.37	7.30	15.35	4.41	38.52	13.99	80.51	573.20	0.00	0.6	3.1	2.3	3.4	3.9	9.3	6.6	18.4	0.0	47.6	
G100	22.54332	86.50051	HA	8	4.7	9.27	9.37	3.11	42.20	4.90	20.90	207.00	14763.00	0.00	0.5	0.2	0.7	0.8	2.5	0.8	1.7	50.6	0.0	57.8	
G101	22.55578	86.50221	HA	8	3.1	19.40	1.97	26.90	3.95	72.90	22.70	311.00	5022.00	0.00	0.5	0.1	0.2	1.4	1.7	4.2	3.8	49.2	0.0	61.2	
G102	22.54852	86.49835	HA	6	2.3	13.50	6.36	16.50	276.00	1393.00	4212.00	0.00	0.00	0.00	0.5	2.8	6.1	3.8	7.1	41.0	0.0	0.0	0.0	61.2	
G103	22.55295	86.50857	HA	8	1.0	51.81	15.96	36.82	285.90	35.33	3009.00	267.60	82.34	0.00	0.7	1.0	2.0	1.3	5.2	14.2	10.9	25.9	0.0	61.2	
G104	23.07079	85.36236	H	9	1.0	212.10	25.70	207.10	36.94	133.00	75.35	137.70	879.80	5480.00	0.5	0.2	0.5	2.1	3.0	13.2	12.1	6.0	20.8	58.3	
G105	22.46555	86.54708	A	9	1.7	169.60	1333.00	113.00	1286.00	161.40	2350.00	176.70	1148.00	4239.00	0.5	0.2	0.7	0.9	2.4	4.5	12.5	3.0	34.4	59.2	
G106	22.92388	85.27194	H	9	3.2	218.00	375.00	28.40	84.40	173.00	17.60	99.80	1663.00	16001.00	0.5	0.2	0.4	0.2	0.8	2.5	1.0	2.6	52.9	61.2	
G107	22.44144	86.60547	HA	8	2.0	9.13	5.58	25.60	43.90	178.00	1241.00	456.00	103.00	0.00	0.5	3.3	6.4	7.0	1.3	18.7	1.7	22.4	0.0	61.2	
G108	22.44144	86.60547	HA	7	2.2	9.15	5.57	12.10	30.30	8484.00	1122.00	106.00	0.00	0.00	0.5	2.9	1.5	11.1	1.3	12.1	31.8	0.0	0.0	61.1	
G109	22.42011	86.59253	H	9	3.1	150.00	31.00	442.00	8.33	80.80	8.53	38.50	331.00	12672.00	0.5	0.1	0.4	0.8	1.5	4.0	1.2	3.1	49.7	61.2	
G11	22.46240	86.54023	H	9	4.2	1623.00	136.00	1233.00	39.70	147.00	5590.00	407.00	106.00	17.00	1.9	0.9	0.9	3.3	1.1	8.5	10.4	15.4	18.9	61.2	
G110	22.42157	86.58419	H	9	0.8	260.00	35.18	165.20	60.23	298.90	52.33	202.30	2080.00	212.40	0.5	0.4	1.0	2.1	2.4	6.2	0.8	22.9	24.9	61.2	
G111	22.44165	86.59882	H	9	3.3	259.00	66.40	4.23	25.90	7.91	48.10	15.10	119.00	693.00	1.3	1.6	2.6	2.0	4.6	5.3	11.6	8.0	24.3	61.2	
G119	22.91990	85.33162	H	9	3.2	711.00	11.60	267.00	23.60	120.00	22.10	262.00	1741.00	6035.00	0.5	0.1	0.3	1.0	1.7	4.4	2.5	5.2	28.5	44.2	
G12	22.45648	86.55036	KHA	9	1.7	72.06	876.90	17.60	66.06	1451.00	144.10	582.80	211.40	3949.00	0.5	0.2	0.9	0.3	2.2	5.8	7.4	14.1	34.7	66.0	
G120	22.92562	85.33403	A	8	1.3	176.20	807.10	115.10	412.50	1871.00	185.00	631.30	10823.00	0.00	1.1	0.4	1.8	4.6	5.8	12.8	1.3	36.6	0.0	64.3	
G121	22.97756	85.26576	H	9	1.8	126.40	12.13	134.60	7.86	170.40	19.25	361.50	1735.00	9119.00	0.9	0.6	0.1	1.8	2.8	6.9	4.1	9.7	34.3	61.2	
G123	22.99868	85.26677	H	8	1.8	185.40	523.80	187.50	402.10	126.60	180.60	4693.00	19336.00	0.00	0.6	0.1	0.8	0.6	7.9	12.0	7.1	32.3	0.0	61.2	
G127	23.04583	85.37863	HA	6	1.9	195.10	604.10	98.02	310.40	51.75	86730.00	0.00	0.00	0.00	0.5	0.2	0.4	0.9	2.1	47.0	0.0	0.0	0.0	51.0	
G128	23.06608	85.36559	H	9	1.3	484.80	128.70	702.50	59.21	3593.00	154.70	444.60	2460.00	13675.00	0.6	0.3	0.7	1.5	2.8	2.3	2.3	51.0	4.4	66.0	
G129	23.06672	85.35677	AA	9	1.6	55.86	23.65	116.60	38.02	117.40	46.06	764.50	1331.00	58864.00	0.8	0.8	1.7	2.6	2.0	9.2	3.0	3.9	37.3	61.2	
G13	22.98998	85.27836	HA	8	1.46	456.80	62.95	543.70	65.10	1133.00	248.20	1656.00	79451.00	0.00	0.5	0.1	0.3	1.2	1.2	3.1	18.3	36.6	0.0	61.2	
G130	23.07017	85.37567	H	9	1.79	333.90	14.14	284.80	27.24	234.50	15.52	107.40	1166.00	474.60	0.5	0.1	0.2	6.5	7.6	5.6	4.9	14.9	25.1	65.4	
G131	23.74098	85.37227	HA	7	0.49	790.30	280.90	2003.00	290.50	1569.00	203.10	2625.00	0.00	0.00	0.5	1.8	0.4	3.2	5.5	13.1	36.8	0.0	0.0	61.2	
G132	23.74156	85.37868	H	8	1.24	174.50	93.55	573.60	102.40	409.90	27.26	109.10	3491.00	0.00	1.4	0.5	0.9	8.8	7.7	1.1	10.3	26.7	0.0	57.4	
G133	23.74859	85.38898	HA	9	1.42	16.78	7.20	50.49	6.93	82.26	5.71	19.91	275.90	3175.00	0.7	0.9	0.6	3.0	7.3	8.3	4.5	8.6	27.3	61.2	
G134	23.75021	85.35561	H	9	0.76	64.26	91.17	20.63	107.20	16.55	71.36	25.06	232.50	24.66	1.5	0.5	1.0	2.1	4.7	6.7	10.3	27.6	16.1	70.5	
G135	23.76515	85.35677	H	8	2.23	159.00	60.70	11.70	814.00	46.30	633.00	29.10	472.00	0.00	0.8	2.8	1.6	0.3	7.7	9.2	22.2	31.0	0.0	75.6	
G136	23.77117	85.33744	AA	8	1.23	167.10	793.60	185.20	3630.00	1197.00	375.80	400.80	1873.00	0.00	1.1	0.2	3.1	7.4	3.7	18.1	8.0	6.9	0.0	48.4	
G137	23.81858	85.41426	H	9	2.5	82.70	31.90	24.20	49.50	22.50	175.00	3883.00	371.00	35.50	0.5	1.2	1.2	1.7	1.4	3.4	0.9	10.2	7.5	34.9	61.2
G139	23.88809	85.51158	HA	9	2.16	215.00	14.60	62.60	535.00	86.00	20410.00	139.00	327.00	998.00	0.5	0.1	1.6	0.2	3.4	6.6	15.8	14.3	18.9	61.2	
G14	22.61030	86.59459	HA	9	3.23	64.10	2.89	22.50	7.78	18.10	6.77	57.10	271.00	3016.00	0.5	0.2	0.3	0.8	0.7	2.7	1.4	3.2	51.6	61.2	
G140	23.89634	85.51304	H	9	1.39	729.80	59.24	295.80	65.09	1618.00	194.40	3354.00	328.50	80.77	0.5	0.4	0.6	2.3	1.3	5.6	16.4	14.0	20.2	61.2	
G142	23.89909	85.45469	HA	8	2.22	121.00	28.60	116.00	27.40	469.00	148.00	5212.00	24089.00	0.00	0.5	1.2	0.9	2.5	1.9	8.4	13.8	32.0	0.0	61.2	
G143	23.91147	85.47791	H	7	1.36	177.70	89.49	31.26	147.50	26.23	2945.00	492.40	0.00	0.00	0.5	3.3	3.1	10.9	1.4	16.0	30.9	0.0	0.0	66.0	
G143	23.90106	85.50973	H	8	1.29	234.60	17.39	96.83	22.07	680.00	39.35	718.70	3522.00	0.00	0.9	0.6	0.9	2.5	7.4	12.6	9.4	26.9	0.0	61.2	
G144	23.91980	85.49414	H	9	0.82	269.10	117.30	324.80	42.72	353.10	101.80	7606.00	132.00	1458.00	0.9	1.6	0.5	1.8	1.6	6.7	9.3	11.4	29.0	62.8	
G145	23.92272	85.46916	HA	9	2.11	252.00	6.91	286.00	16.00	105.00	1581.00	37.20	158.00	1354.00	0.5	0.2	0.2	1.5	0.4	4.3	4.4	5.6	37.6	54.8	
G146	23.92710	85.47862	KH	7	1.12	169.80	1190.00	105.30	2017.00	182.80	391.60	1111.00	0.00	0.00	0.5	0.6	1.7	2.5	5.9	14.8	38.6	0.0	0.0	64.6	
G148	23.92853	85.49655	H	9	0.39	364.70	55.99	281.40	58.10	288.00	44.37	88.80	40.50	1335.00	0.5	0.2	0.8	1.2	2.7	0.4	20.8	6.4	38.7	71.7	
G149	23.96628	86.41283	HA	9	1.82	107.40	20.64	64.60	23.70	111.80	48.11	637.50	207.40	54740.00	0.5	0.2	0.3	1.2	1.6	2.7	4.5	7.2	43.0	61.2	
G15	22.60688	86.61176	H	9	1.1	759.40	16.84	114.90	19.58	196.40	1550.00	171.80	1637.00	190.40	0.5	0.0	1.7	2.5	1.2	2.9	10.2	10.6	31.6	61.2	
G150	23.99026	86.41158	HA	9	1.62	214.50	24.13	507.30	100.80	26.26	326.00	52.85	712.80	22051.00	0.5	0.2	0.3	0.2	1.2	2.3	5.2	16.2	35.2	61.2	
G151	23.99133	86.39536	H	8	2.18	257.00	97.50	23.10	113.00	12.70	64.90	1376.00	5733.00	0.00	0.5	1.2	1.2	0.6	3.8	1.7	5.0	47.3	0.0	61.2	
G152	23.99289	86.38032	H	7	2.06	69.50	19.30	28.90	81.30	3203.00	610.00	312.00	0.00	0.00	0.5	1.6	11.1	0.4	26.0	2.6	18.9	0.0	0.0	61.1	
G153	24.00100	86.38355	HA	9	1.57	130.80	22.92	100.20	34.70	84.23	11478.00	149.80	214.40	791.80	0.5	1.4	1.8	1.6	0.5	11.1	12.2	13.1	18.9	61.2	
G154	24.00039	86.37797	H	8	2.61	575.00	4.33	299.00	20.20	87.50	5141.00	130.00	446.00	0.00	0.5	0.1	0.2	1.4	6.6	5.8	27.7	18.9	0.0	61.1	
G155	24.00149	86.37139	HA	9	2.72	138.00	2.51	183.00	11.20	74.															

Integrated Hydrogeophysical Aquifer Mapping and Groundwater Resource Feasibility Assessment for Climate-Resilient Water Security in Deoghar (Palojori), Dhanbad (Tundi), Dumka (Jama), East Singhbhum (Gurabanda, Dalbhumgarh), Hazaribagh (Churchu, Dadi), and Khunti (Murhu) Districts of Jharkhand, India

G16	23.00018	85.27356	HA	9	3.11	281.00	77.60	145.00	21.50	76.90	177.00	5640.00	279.00	3734.00	0.5	0.8	0.9	2.2	0.2	0.6	5.7	17.0	33.4	61.2
G160	24.03449	86.39780	HA	9	0.91	162.50	50.94	499.90	52.89	150.30	1744.00	251.00	861.30	462.40	1.3	1.4	0.4	1.7	1.1	6.5	8.1	26.3	5.9	52.5
G161	24.04023	86.39349	H	8	2.34	1067.00	21.40	289.00	17.60	297.00	24501.00	175.00	553.00	0.00	0.5	0.1	0.5	3.1	1.5	3.3	20.3	32.0	0.0	61.2
G162	24.16946	86.88962	HA	9	1.18	129.70	12.11	78.46	20.66	261.80	1434.00	379.60	1200.00	7050.00	0.5	0.2	0.3	3.9	1.0	3.6	11.6	8.1	32.1	61.2
G163	24.16983	86.90076	HA	9	2.23	87.50	11.50	233.00	17.40	142.00	14384.00	1411.00	294.00	3192.00	0.6	0.4	0.9	2.4	0.8	5.5	8.6	10.0	32.0	61.2
G164	24.16944	86.90903	HA	8	3.07	147.00	4.58	48.30	463.00	993.00	356.00	169.00	429.00	0.00	0.5	0.0	4.1	6.4	0.6	19.4	19.1	11.1	0.0	61.2
G165	24.26223	86.90566	HA	9	5.36	95.10	46.70	17.20	49.00	186.00	48.20	1407.00	7523.00	129710.00	0.5	0.9	0.3	0.3	0.9	3.3	2.1	5.5	47.3	61.2
G166	24.26777	86.91961	AA	9	2.28	160.00	71.80	71.20	941.00	119.00	604.00	2233.00	55426.00	1237.00	1.5	0.5	0.3	0.9	3.1	0.3	1.1	12.0	41.4	61.2
G167	24.28658	86.92450	HA	9	5.07	128.00	15.40	98.80	15.90	115.00	27.50	184.00	591.00	7823.00	0.5	0.2	0.4	1.3	1.6	4.0	1.3	2.4	49.5	61.2
G168	24.29340	86.94246	KH	9	2.04	102.00	1210.00	13.20	131.00	39.40	117.00	90.40	730.00	4167.00	0.5	0.3	1.0	2.9	4.8	4.5	14.1	10.5	22.6	61.1
G169	24.29220	86.92289	K	7	0.23	69.73	542.30	49.52	1431.00	16.74	169.80	117.60	0.00	0.00	0.6	0.2	1.0	4.1	14.1	16.1	18.9	0.0	0.0	54.9
G17	22.92159	85.33800	H	9	0.74	114.50	66.05	14.11	91.15	14.57	200.50	106.70	750.20	2630.00	0.5	0.6	1.0	1.4	3.7	4.0	9.7	6.4	13.5	40.8
G170	24.29792	86.94275	HK	9	2.26	123.00	318.00	29.00	334.00	37.80	208.00	4661.00	105.00	1028.00	0.9	0.3	0.9	1.1	3.6	0.9	8.0	17.5	24.4	57.6
G171	24.28536	87.12861	HA	9	2.13	44.80	7.80	58.20	12.90	296.00	107.00	4130.00	372.00	81.60	0.8	0.8	1.1	1.9	1.9	7.9	10.1	12.0	24.9	61.3
G172	24.29045	87.14190	HA	7	3.47	36.00	5.53	2954.00	52.60	183.00	636.00	2395.00	0.00	0.00	0.5	1.5	4.2	7.0	6.2	9.8	32.0	0.0	0.0	61.2
G173	24.31595	87.13964	H	7	0.59	479.60	40.47	332.60	83.41	136.80	362.50	889.00	0.00	0.00	0.5	0.2	0.3	1.9	24.0	2.0	41.1	0.0	0.0	69.9
G175	24.27815	87.15062	H	6	0.59	281.60	48.72	93.66	59.73	222.20	162.00	0.00	0.00	0.00	0.5	0.2	9.6	11.4	21.0	18.6	0.0	0.0	0.0	61.2
G176	24.27710	87.15764	HA	9	1.84	220.10	40.93	88.67	28.64	97.40	436.80	89.56	626.40	38059.00	0.5	2.1	1.5	1.0	0.2	2.9	7.3	3.1	42.5	61.2
G176	24.29220	86.93333	H	8	4.24	396.00	43.50	277.00	32.80	62.40	24.80	440.00	10796.00	0.00	0.5	0.1	0.3	2.8	4.1	4.7	3.4	43.3	0.0	61.2
G177	24.27995	87.17550	HA	8	1.49	123.80	59.51	3629.00	240.30	189.60	325.20	15409.00	5140.00	0.00	0.6	2.4	0.1	6.4	6.8	2.2	18.9	28.5	0.0	66.0
G178	24.28974	87.17888	H	8	2.17	387.00	69.30	14.50	358.00	17.80	171.00	97.90	1299.00	0.00	0.5	1.5	1.0	2.0	3.9	11.0	29.2	16.4	0.0	65.5
G179	24.29035	87.20496	HA	9	1.85	103.20	2.75	85.61	19.02	312.60	98.92	1246.00	387.90	128.60	0.5	0.2	0.2	3.2	3.8	5.3	14.9	14.2	18.9	61.2
G18	22.98272	85.25977	H	8	0.82	417.70	181.50	112.40	272.80	105.50	730.90	165.30	3096.00	0.00	0.5	0.9	0.9	1.4	3.7	5.4	13.7	32.5	0.0	59.1
G180	24.29891	87.20537	HK	9	0.54	734.30	25.77	365.80	98.40	38.71	1079.00	373.00	33.76	2.50	0.5	0.1	0.3	0.5	3.0	8.0	4.9	11.9	32.0	61.2
G181	24.30468	87.19750	H	8	1.43	738.30	7.24	283.80	46.92	157.20	307.00	39.49	528.80	0.00	0.5	0.0	0.4	307.8	7.1	14.9	3.1	39.2	0.0	66.0
G182	24.29784	87.18223	HA	9	1.39	122.30	7.57	87.23	15.00	135.10	39.92	2716.00	440.60	92.11	0.5	0.2	0.3	1.4	5.8	3.0	13.4	14.7	21.8	61.2
G183	24.28756	87.16272	H	9	0.94	297.40	49.33	217.30	31.87	184.20	55.03	526.10	115.30	8408.00	0.5	0.2	0.4	1.3	0.4	4.1	2.3	10.2	64.4	83.6
G19	22.98407	85.26654	H	9	0.66	473.90	202.80	84.25	22.73	97.56	22.88	955.30	56.27	177.80	0.5	0.7	1.4	1.9	1.8	6.8	8.7	12.5	23.4	57.7
G2	22.42491	86.59767	HA	9	1.96	21.62	46.15	16.47	59.00	41.44	5.46	140.50	784.20	4139.00	0.7	0.3	0.7	0.9	0.4	3.6	2.5	4.8	47.3	61.2
G20	22.99124	85.25107	H	8	1.28	244.00	61.07	346.40	55.54	187.10	45.57	704.00	58124.00	0.00	0.5	0.1	0.6	0.7	1.6	6.0	1.8	49.8	0.0	61.2
G21	22.99112	85.26108	HA	9	1.68	548.80	13.41	360.70	47.98	1310.00	156.30	714.10	2165.00	19274.00	0.5	0.1	0.2	1.4	1.9	6.7	2.5	6.2	41.7	61.2
G22	22.99118	85.26966	HA	8	2.35	61.00	94.90	16.30	104.00	1273.00	148.00	2087.00	49174.00	0.00	0.5	0.2	0.8	0.2	1.8	5.9	4.1	47.7	0.0	61.2
G23	22.99872	85.26109	H	9	1.43	163.20	119.10	41.13	365.30	30.66	1025.00	173.40	445.00	7631.00	0.5	3.2	0.5	0.8	4.7	5.5	12.0	5.6	33.3	66.0
G24	23.00549	85.27930	HA	8	1.01	151.80	49.48	237.70	97.88	179.00	1799.00	466.70	10362.00	0.00	0.5	1.7	2.9	3.0	0.4	4.8	15.4	32.5	0.0	61.2
G25	23.04540	85.37001	HA	9	1.86	358.60	63.37	367.90	94.53	459.70	46.25	242.10	2484.00	96401.00	0.5	0.2	0.4	0.9	1.2	3.9	1.3	3.7	49.3	61.2
G26	22.91807	85.27516	H	7	1.32	589.00	88.07	355.70	48.14	517.80	140.00	4506.00	0.00	0.00	0.7	0.3	0.9	2.1	2.6	6.3	24.7	0.0	0.0	37.6
G27	23.06750	85.37041	H	9	1.35	696.80	15.44	583.60	53.77	359.00	141.00	427.10	659.40	25299.00	0.5	0.2	0.3	2.2	1.2	5.5	10.8	5.3	35.3	61.2
G28	23.74319	85.36113	H	9	0.84	56.70	94.28	39.64	25.00	286.20	20.08	73.84	892.20	39.00	1.1	0.6	3.3	2.1	0.3	8.5	1.7	17.7	30.6	66.0
G29	23.75002	85.36324	H	8	0.96	23.18	9.43	26.47	49.30	13.86	50.21	292.10	44.23	0.00	1.2	1.1	5.5	4.9	12.3	1.2	22.0	9.6	0.0	58.0
G3	22.41112	86.58704	HA	8	2.34	11.90	5.02	95.30	15.00	392.00	4063.00	755.00	175.00	0.00	0.8	1.0	1.2	3.1	2.0	11.3	7.7	33.9	0.0	61.1
G30	23.74950	85.37233	H	9	1.16	65.23	161.10	58.51	32.78	119.40	15.36	308.20	11.05	103.50	0.5	0.3	0.9	1.3	2.0	4.8	10.1	24.0	15.7	59.5
G31	23.75123	85.37895	HA	8	1.12	28.53	10.97	68.72	15.75	239.80	1160.00	404.90	149.10	0.00	0.5	2.9	4.5	6.4	2.1	14.2	7.7	23.0	0.0	61.2
G32	23.75980	85.34545	HKH	8	1.43	43.72	7.41	281.60	10.25	151.00	840.60	90.72	41.04	0.00	0.7	0.5	1.6	4.1	0.5	17.0	11.2	25.6	0.0	61.2
G33	23.75936	85.35482	H	9	0.67	27.34	48.75	8.99	41.58	7.90	18.18	5.18	62.17	42.04	0.6	0.2	0.8	1.4	2.0	12.9	0.6	8.3	34.3	61.1
G34	23.75977	85.36336	H	9	0.58	76.34	56.81	20.30	10.44	89.07	11.39	496.20	99.07	36.74	0.5	0.4	1.5	1.2	3.8	7.6	10.5	5.0	37.0	67.5
G35	23.75872	85.37290	H	9	1.03	82.33	24.83	16.17	48.88	4.85	48.06	22.96	734.60	50.99	0.5	0.6	0.7	1.2	3.0	3.1	8.9	10.7	19.8	48.6
G36	23.76633	85.34556	H	8	2.07	992.00	1383.00	63.10	310.00	34.00	89.80	30.20	117.00	0.00	1.8	0.1	1.0	3.5	3.0	8.2	23.0	22.4	0.0	63.0
G37	22.99914	85.28217	HA	9	1.61	220.60	52.68	489.60	47.40	418.20	89.69	8392.00	254.60	5599.00	0.5	0.2	0.3	1.1	1.1	3.0	9.5	10.9	34.6	61.2
G38	23.82188	85.38499	HA	9	2.12	50.10	1.24	66.30	16.00	120.00	4887.00	338.00	189.00	105.00	1.4	0.0	0.9	2.6	0.9	10.1	13.3	13.1	18.9	61.2
G39	23.82408	85.39377	H	7	0.87	320.90	45.18	122.80	10.33	73.73	247.60	6919.00	0.00	0.00	0.5	0.1	2.9	3.9	0.8	8.1	44.9	0.0	0.0	61.2
G4	22.43950	86.54338	HA	9	1.02	101.90	17.13	158.50	20.52	368.40	105.90	900.50	163.90	1193.00	0.7	0.5	1.1	2.2	2.6	10.3	4.6	23.6	14.6	60.2
G41	23.82256	85.41102	KH	8	1.01																			

G50	22.99077	85.28902	H	9	1.94	724.30	19.31	460.00	45.62	467.10	125.60	944.80	17456.00	1933.00	0.5	0.2	0.3	1.5	2.0	4.8	2.7	15.3	34.0	61.2	
G51	23.88185	85.47070	HA	8	1.55	938.70	71.25	219.20	858.00	347.50	723.20	444.00	4268.00	0.00	0.5	0.2	2.3	0.2	2.6	1.5	13.4	41.1	0.0	61.8	
G52	23.87919	85.50695	KH	8	0.42	230.20	1637.00	179.80	592.40	118.30	451.90	760.50	2496.00	0.00	0.5	0.2	0.5	0.8	3.1	3.5	4.1	22.2	0.0	34.9	
G53	23.88876	85.47399	H	8	1.2	1087.00	173.50	1841.00	180.60	2242.00	268.00	1484.00	51806.00	0.00	0.9	1.0	1.0	2.9	5.4	9.1	3.6	42.1	0.0	66.0	
G54	23.88613	85.50421	H	8	1.57	395.10	91.83	603.20	84.98	949.30	9453.00	224.00	769.20	0.00	1.1	0.8	1.0	3.0	0.6	6.9	14.9	17.3	0.0	45.6	
G55	23.89855	85.46551	H	8	0.7	816.20	71.76	443.90	33.13	124.20	39.30	1044.00	27558.00	0.00	0.5	0.1	0.6	0.4	13.6	3.2	5.2	37.7	0.0	61.2	
G56	23.89410	85.50496	HA	9	1.81	211.70	9.01	69.56	30.93	685.30	89.42	514.20	4645.00	10253.00	0.5	0.1	0.7	2.9	2.4	9.0	4.2	22.4	18.9	61.2	
G57	23.90631	85.45504	H	9	2.4	1160.00	293.00	116.00	432.00	99.70	552.00	96.90	215.00	83608.00	0.5	0.5	0.3	0.9	1.6	2.2	5.1	1.8	59.0	72.0	
G58	23.90571	85.46947	H	6	3.8	172.00	347.00	91.30	20.70	126.00	44880.00	0.00	0.00	0.00	0.5	0.6	5.0	4.0	2.7	48.4	0.0	0.0	61.2		
G59	23.91296	85.45952	H	9	1.68	346.30	40.96	397.10	38.97	230.90	35.68	6663.00	425.00	182.60	0.5	0.2	0.2	1.1	0.9	4.2	13.4	21.8	18.9	61.2	
G6	22.42981	86.59244	H	9	2.95	44.90	8.02	181.00	9.06	136.00	2583.00	173.00	4.08	16.20	1.1	0.6	0.8	2.9	1.3	8.7	10.7	16.1	18.9	61.1	
G6	22.42981	86.59244	H	9	1.8	38.06	154.60	8.60	143.50	11.51	1684.00	279.80	68.16	23.46	0.5	0.2	0.7	0.9	3.7	12.1	6.8	17.4	18.9	61.2	
G60	23.91203	85.46916	HA	8	1.09	291.00	58.93	187.00	1115.00	169.20	7046.00	181.20	1151.00	0.00	0.6	0.1	2.4	2.2	4.0	10.2	10.2	27.1	0.0	56.8	
G61	23.91016	85.48848	KH	6	1.19	179.30	403.70	52.77	129.60	4837.00	257.00	0.00	0.00	0.00	0.5	1.6	5.8	2.7	7.4	19.4	0.0	0.0	0.0	37.4	
G62	23.92014	85.47786	HA	9	1.99	214.90	46.31	170.90	27.28	406.30	87.93	128.80	1938.00	39866.00	0.6	0.4	0.7	2.1	3.0	3.1	2.5	4.4	49.3	66.0	
G63	23.91947	85.48655	KH	8	2.33	37.90	1183.00	37.10	498.00	229.00	37.00	183.00	7182.00	0.00	0.5	0.4	1.5	1.9	18.3	5.7	1.7	54.1	0.0	66.0	
G64	23.92775	85.48723	HA	8	1.04	207.70	141.10	2454.00	56.06	760.90	1796.00	263.90	574.80	0.00	0.5	2.5	0.1	3.2	6.2	14.0	30.7	2.7	0.0	59.9	
G65	23.98475	86.40330	H	9	0.87	616.30	25.57	346.40	31.47	234.50	2703.00	256.20	83.63	279.70	0.5	0.2	0.8	2.4	0.6	5.7	4.8	19.6	13.0	47.6	
G66	23.99198	86.40252	HA	9	1.94	181.00	14.01	298.40	15.35	1019.00	72.14	1260.00	109.30	1372.00	0.5	0.1	0.3	7.2	1.2	0.9	4.1	9.9	13.9	29.3	60.1
G67	24.02634	86.38615	H	9	1.37	145.90	49.36	146.80	65.24	288.70	55.27	156.10	2090.00	51051.00	0.7	0.8	1.4	2.0	4.6	5.6	3.1	4.1	38.8	61.2	
G68	22.92300	85.28432	A	9	3.2	134.00	203.00	106.00	3278.00	460.00	294.00	3956.00	394.00	24794.00	0.8	0.4	0.9	1.1	0.4	2.5	6.2	14.5	34.4	61.3	
G69	24.04192	86.38745	HA	8	0.12	157.00	733.60	3565.00	320.20	28.09	91.17	318.00	14459.00	0.00	0.5	0.2	1.5	0.6	1.9	4.6	2.6	49.3	0.0	61.2	
G7	22.45238	86.54089	H	9	2.08	407.00	769.00	54.00	381.00	95.70	136.00	908.00	138.00	4667.00	0.9	0.3	1.1	1.6	4.8	4.7	7.9	20.2	24.5	66.0	
G70	24.16167	86.89034	HA	9	2.87	230.00	13.70	220.00	21.10	153.00	1019.00	78.50	186.00	4369.00	0.5	0.2	0.3	1.5	0.3	2.4	4.8	2.2	64.2	76.4	
G71	24.16133	86.89939	HA	9	2.06	181.00	42.60	147.00	22.80	104.00	571.00	90.00	4200.00	318.00	0.6	0.6	0.8	1.5	0.4	3.0	6.4	21.3	26.7	61.2	
G72	24.16105	86.90661	HA	8	4.54	93.20	28.00	148.00	39.10	225.00	34.60	46.70	45241.00	0.00	0.6	0.2	0.8	1.5	2.8	0.3	6.8	48.3	0.0	61.2	
G73	24.26081	86.91429	HA	9	2.24	148.00	32.60	126.00	1102.00	72.20	688.00	14010.00	1289.00	153.00	0.6	0.6	0.1	0.7	2.7	0.6	12.1	8.7	35.0	61.2	
G74	23.76074	85.36336	H	7	1.14	110.10	27.30	99.18	25.32	50.64	633.80	37529.00	0.00	0.00	1.2	1.2	1.9	3.5	1.6	2.4	49.5	0.0	0.0	61.2	
G75	24.28526	86.93322	AA	7	3.32	24.00	10.00	29.50	179.00	30.40	641.00	29268.00	0.00	0.00	0.5	1.1	0.4	2.2	5.3	3.3	48.4	0.0	0.0	61.2	
G76	24.03455	86.38660	HA	9	0.86	39.50	3.23	48.93	7.65	92.59	599.00	60.03	525.40	1846.00	0.5	0.2	0.3	1.3	0.5	1.2	8.6	6.2	42.5	61.2	
G77	24.28188	87.15886	HA	9	2.45	87.00	10.00	132.00	16.10	91.50	20.20	135.00	1278.00	41113.00	0.5	0.2	0.3	1.2	0.9	3.7	1.5	5.2	8.4	21.8	
G78	24.28163	87.16765	AA	9	1.86	29.56	170.00	29.15	193.90	37.69	829.80	99.42	769.80	20629.00	0.5	0.3	0.2	0.5	2.9	2.5	8.7	2.3	43.2	61.2	
G79	24.29288	87.12346	HA	9	1.35	162.10	8.65	125.10	11.04	203.40	165.70	63.88	167.90	1750.00	0.5	0.1	0.3	1.3	2.5	6.7	13.9	4.1	31.8	61.2	
G8	22.44986	86.54833	H	9	4.88	382.00	2.16	67.20	5.80	25.10	14.40	94.30	707.00	2883.00	0.5	0.1	0.3	1.5	0.7	3.7	2.1	5.1	47.3	61.3	
G80	24.29224	87.13233	H	8	1.56	171.40	32.05	140.80	42.54	9.74	66.59	1753.00	272.90	0.00	0.5	0.3	0.1	1.3	0.1	12.0	16.0	13.9	0.0	44.2	
G81	24.28975	87.18696	H	9	0.96	382.80	29.34	376.70	32.60	19.21	57.10	143.30	11540.00	794.90	0.5	0.1	0.2	7.8	2.2	5.8	17.1	3.1	29.2	66.0	
G82	24.28945	87.19561	AA	7	1.65	59.40	52.30	67.70	679.40	65.04	2042.00	37654.00	0.00	0.00	1.6	9.1	0.3	15.3	1.4	11.2	22.4	0.0	0.0	61.2	
G83	24.30086	87.12447	H	9	1.07	373.90	22.83	155.00	55.74	70.13	1697.00	132.40	504.50	1523.00	0.5	0.1	1.1	3.2	4.5	3.8	17.8	7.8	22.4	61.2	
G84	24.30114	87.13315	H	9	1.59	280.90	279.50	81.51	214.90	89.80	307.40	184.40	283.20	9698.00	0.7	0.3	2.4	2.4	2.0	4.4	3.9	28.2	21.8	66.0	
G85	24.29973	87.14188	HA	9	0.52	43.05	14.05	45.56	13.47	16.31	74.35	1172.00	49.15	8.44	0.6	0.4	1.3	1.9	0.2	8.1	12.0	10.3	26.3	61.2	
G86	24.29851	87.18568	HA	9	1.24	64.51	24.77	55.04	13.59	36.58	176.00	500.20	75.96	4162.00	0.6	1.8	1.5	2.3	0.3	0.7	4.6	13.9	35.6	61.2	
G87	24.29789	87.19643	KHA	9	2.87	39.90	143.00	21.40	156.00	482.00	139.00	835.00	4786.00	16929.00	0.7	0.8	2.9	0.7	3.2	7.7	4.2	9.0	32.0	61.2	
G88	24.30828	87.13359	AA	9	1.22	32.51	277.60	14.07	92.11	24.70	57.60	2333.00	487.20	195.70	0.5	0.2	0.8	2.9	5.7	2.7	16.2	13.3	18.9	61.2	
G89	24.30794	87.14231	AA	8	1.04	79.79	35.99	56.24	32.68	323.20	51.92	1264.00	18317.00	0.00	0.5	0.2	2.4	1.4	2.5	10.7	5.1	38.4	0.0	61.2	
G9	22.43390	86.60267	H	7	2.49	31.30	3.36	12.30	5.30	260.00	883.00	1710.00	0.00	0.00	0.5	0.2	1.1	7.0	5.2	6.2	41.0	0.0	0.0	61.2	
G90	22.30857	86.52713	HA	7	2.45	104.00	25.60	72.70	13.30	29.20	702.00	33006.00	0.00	0.00	0.8	0.4	1.1	2.7	1.3	2.7	52.3	0.0	0.0	61.3	
G91	22.31316	86.52688	H	7	4.34	179.00	37.80	118.00	10.50	49.70	322.00	13157.00	0.00	0.00	0.7	1.3	1.3	3.2	0.3	1.8	52.6	0.0	0.0	61.2	
G92	22.31771	86.53310	H	7	0.73	1993.00	301.40	79.35	231.60	30.06	475.60	113.90	0.00	0.00	1.0	2.1	2.1	3.4	9.2	18.4	46.2	0.0	0.0	82.3	
G93	22.32169	86.52798	AA	9	1.29	29.66	13.91	31.08	118.50	13.28	38.04	265.90	2117.00	45725.00	0.5	0.3	1.1	0.6	2.5	1.9	2.0	5.1	47.3	61.2	
G94	22.92047	85.27834	HA	8	3.56	108.00	36.20	20.20	55.30	14.90	202.00	1133.00	24100.00	0.00	0.5	0.5	0.7	1.0	2.5	1.4	3.0	51.6	0.0	61.2	
G95	22.61322	86.61161	H	8	1.1	450.50	233.00	172.10	486.50	61.22	5846.00	744.30	243.50	0.00	0.5	1.6	1.8	1.0	6.1	15.0	12.0	23.2	0.0	61.2	
G96	22.92614	85.27675	HA	8	1.89	76.6																			

### Annexure 2 Inferred Litho-geoelectric and Hydrogeological Parameters - Jharkhand.

ID	Latitude	Longitude	Top Soil (m)	Overburden (m)	Weathered (m)	Fractured (m)	Massive (m)	Aquifer Thickness (m)	Groundwater (m)	Recharge (m)
G1	22.436047	86.540455	0.8	0.8	30.5	24.6	5.5	55.9	2904	0.480
G10	22.436983	86.593257	0.6	0.6	22.0	0.0	18.4	22.7	0.579	1.115
G100	22.543316	86.500509	0.7	7.2	1.6	1.7	50.6	10.4	0.037	0.186
G101	22.555781	86.502206	0.9	4.0	6.2	3.8	49.2	14.0	0.143	0.513
G102	22.548515	86.498349	0.5	0.5	6.1	3.8	48.1	10.3	0.054	0.283
G103	22.552949	86.508567	0.7	5.0	33.1	12.2	14.2	50.4	2.401	0.763
G104	23.07079	85.362357	0.7	3.2	15.3	15.6	26.8	34.0	1.411	1.049
G105	22.46555	86.547083	0.7	4.7	0.0	15.6	42.8	20.4	0.242	0.568
G106	22.923884	85.271942	0.7	2.1	4.1	0.8	55.5	7.1	0.029	0.299
G107	22.441436	86.60547	0.5	0.5	13.4	25.4	18.7	39.3	1.926	1.462
G108	22.441436	86.60547	0.5	0.5	12.6	31.8	13.4	44.9	2.474	1.269
G109	22.420113	86.592529	0.6	3.3	7.5	3.5	49.7	14.2	0.067	0.292
G11	22.462397	86.540226	1.9	3.6	22.2	26.9	9.4	52.7	2.037	0.403
G110	22.421565	86.584189	0.5	6.4	8.3	29.1	22.9	43.8	0.825	0.406
G111	22.441648	86.598816	1.3	2.8	23.5	8.0	24.3	34.3	1.028	1.140
G119	22.919903	85.331615	0.6	3.6	5.3	4.5	33.7	13.4	0.245	0.676
G12	22.456476	86.550362	0.7	4.1	1.2	19.8	44.3	25.1	0.189	0.345
G120	22.925624	85.334031	1.1	3.3	0.0	19.2	43.6	22.5	0.221	0.492
G121	22.977558	85.265755	0.9	3.4	8.7	7.0	44.0	19.1	0.153	0.367
G123	22.998678	85.266769	0.6	2.0	0.0	21.2	39.4	23.2	0.385	0.762
G127	23.045829	85.378633	0.7	4.0	2.4	0.9	47.0	7.3	0.042	0.284
G128	23.066075	85.365589	0.6	3.1	1.5	4.7	58.9	9.2	0.036	0.235
G129	23.066721	85.356769	0.8	3.2	11.8	3.7	44.2	18.7	0.513	1.277
G13	22.98998	85.278363	0.6	3.3	1.2	3.1	56.3	7.5	0.014	0.151
G130	23.070173	85.37567	0.8	0.8	12.0	37.9	14.9	50.7	1.157	0.354
G131	23.74098	85.372273	0.5	2.7	0.0	16.2	42.7	18.9	0.041	0.098
G132	23.741563	85.378678	1.4	2.8	1.1	26.8	27.6	30.7	0.745	0.768
G133	23.748592	85.388978	0.7	2.2	23.7	8.6	27.3	34.5	0.565	0.582
G134	23.750208	85.355607	1.5	5.1	38.8	29.7	0.0	73.6	3.951	0.006
G135	23.765154	85.356765	0.8	0.8	31.5	31.0	9.5	63.4	2.785	0.703
G136	23.771173	85.337442	1.3	1.3	0.0	29.1	18.0	30.4	0.113	0.087
G137	23.818576	85.414259	0.5	4.2	40.8	8.4	10.2	53.5	4.366	0.868
G139	23.888094	85.511584	0.6	2.3	4.9	30.1	25.6	37.3	0.779	0.713
G14	22.610296	86.594589	0.7	2.4	5.8	3.2	51.6	11.4	0.042	0.267

G140	23.896337	85.513038	0.5	5.1	22.4	20.2	17.7	47.7	1.520	0.671
G142	23.899086	85.454688	0.5	2.6	2.5	11.2	45.8	16.3	0.212	0.781
G143	23.911472	85.477911	0.5	0.5	4.5	41.8	16.0	46.8	0.833	0.442
G143	23.90106	85.509725	0.9	4.9	15.9	0.0	43.8	20.8	0.509	1.457
G144	23.919798	85.494137	0.9	6.3	1.8	20.2	38.3	28.3	0.531	0.864
G145	23.922715	85.469157	0.9	2.8	5.9	6.3	41.9	15.0	0.218	0.858
G146	23.927095	85.478622	0.5	5.3	0.0	22.4	41.0	27.7	0.143	0.246
G148	23.928527	85.496547	0.7	2.7	28.8	3.5	38.7	34.9	1.022	1.329
G149	23.986279	86.412832	0.7	3.9	4.3	8.8	47.5	16.9	0.120	0.566
G15	22.606881	86.611758	0.5	5.9	2.5	44.7	13.5	53.1	1.925	0.416
G150	23.990256	86.411575	0.7	4.7	6.3	2.5	51.7	13.6	0.134	0.649
G151	23.991334	86.395358	0.5	3.4	6.7	0.6	52.3	10.7	0.051	0.370
G152	23.992891	86.380319	0.5	2.1	11.5	18.9	28.6	32.6	0.756	0.921
G153	24.000997	86.38355	0.5	5.9	2.1	27.1	30.0	35.1	0.720	0.589
G154	24.000389	86.377971	0.8	2.2	8.0	46.8	5.8	57.0	2.144	0.347
G155	24.001493	86.371387	0.8	4.1	10.5	7.7	42.4	22.3	0.238	0.569
G156	24.009436	86.378521	0.7	5.9	19.4	0.0	41.1	25.3	0.657	1.083
G157	24.017531	86.386002	0.7	0.9	0.0	40.8	19.6	41.8	1.240	0.776
G158	24.025262	86.374338	0.5	2.5	4.7	28.0	28.0	35.2	0.922	0.841
G159	24.027339	86.393927	0.5	4.0	0.1	32.1	34.0	36.3	0.216	0.249
G16	23.000183	85.273556	0.5	5.2	2.4	18.5	39.1	26.0	0.174	0.288
G160	24.034489	86.397802	1.3	5.8	1.7	15.4	32.7	22.9	0.124	0.250
G161	24.040229	86.393494	0.6	1.1	3.1	22.2	35.3	26.4	0.398	0.770
G162	24.169462	86.889623	0.7	1.0	4.2	12.6	43.7	17.8	0.090	0.336
G163	24.169833	86.900763	0.6	5.1	2.4	11.7	46.1	19.2	0.054	0.211
G164	24.169444	86.909032	0.5	0.5	4.1	56.0	0.6	60.6	1.336	0.146
G165	24.262233	86.905655	0.5	3.0	4.0	0.9	54.9	7.9	0.026	0.522
G166	24.26777	86.919614	1.5	3.2	0.3	3.1	55.7	6.7	0.006	0.247
G167	24.28658	86.924498	0.7	4.0	5.7	3.0	51.9	12.6	0.112	0.749
G168	24.293403	86.942455	0.5	1.7	19.9	7.4	33.1	29.0	1.008	1.282
G169	24.292198	86.922892	0.8	1.7	15.0	35.0	4.1	51.7	2.768	0.399
G17	22.921586	85.338004	0.5	3.5	6.1	13.7	19.9	23.3	0.719	0.576
G170	24.297915	86.942749	0.9	3.3	4.4	19.6	32.4	27.2	0.795	1.061
G171	24.285357	87.128612	0.8	6.4	27.9	21.7	10.1	56.0	2.245	0.477
G172	24.290448	87.141902	0.5	2.1	7.0	6.2	46.0	15.2	0.193	0.916
G173	24.315946	87.139637	0.7	2.9	1.9	26.3	41.1	31.1	0.602	0.911
G175	24.278151	87.150624	0.8	0.8	20.9	39.5	0.0	61.2	2.868	0.293
G176	24.277097	87.157639	0.5	5.4	10.0	2.9	45.6	18.3	0.181	0.712

G76	24.292203	86.933326	0.6	0.9	13.6	3.7	43.3	18.2	0.380	1.260
G77	24.279949	87.1755	0.6	3.2	0.0	15.4	47.6	18.6	0.077	0.289
G78	24.289741	87.178876	0.5	5.0	34.1	13.0	16.4	52.1	2.125	0.804
G79	24.290348	87.204956	0.9	0.9	8.7	36.9	14.9	46.5	1.310	0.539
G8	22.982721	85.259769	0.5	3.8	0.0	19.7	37.9	23.5	0.378	0.648
G80	24.298908	87.205374	0.6	1.4	15.4	5.2	8.0	22.0	0.679	1.555
G81	24.304679	87.197499	0.5	1.7	3.9	22.4	39.2	28.0	0.291	0.512
G82	24.297841	87.182232	0.7	2.4	26.6	20.5	13.4	49.5	1.966	0.644
G83	24.287559	87.16272	0.7	2.7	5.3	11.0	66.7	19.0	0.155	0.832
G9	22.984065	85.266543	0.5	6.4	24.4	23.4	8.7	54.2	3.480	0.435
G2	22.424911	86.597667	0.7	3.1	5.6	2.5	52.1	11.2	0.068	0.353
G20	22.991241	85.251066	0.7	3.6	6.7	2.2	51.6	12.5	0.163	0.793
G21	22.991119	85.261077	0.8	4.1	1.4	6.8	52.3	12.3	0.080	0.439
G22	22.991181	85.269664	0.7	3.6	0.8	6.1	53.6	10.5	0.050	0.398
G23	22.998718	85.261094	0.5	0.5	5.3	18.3	38.8	24.1	0.409	0.854
G24	23.005494	85.279299	0.5	2.2	3.0	18.7	37.3	23.9	0.098	0.198
G25	23.045402	85.370008	0.7	3.1	4.7	2.9	52.9	10.7	0.097	0.499
G26	22.918074	85.275164	0.7	4.0	2.1	7.2	27.3	13.3	0.333	0.782
G27	23.067495	85.370412	0.7	4.4	2.2	17.4	40.9	24.0	0.235	0.381
G28	23.743194	85.361129	1.1	1.7	46.3	0.3	17.7	48.3	3.667	1.602
G29	23.750017	85.36324	1.2	2.4	33.6	22.0	0.0	58.0	3.297	0.109
G3	22.411116	86.58704	0.8	3.0	4.3	35.9	19.0	43.3	1.148	0.670
G30	23.749496	85.372328	0.5	5.0	31.0	27.7	0.0	63.7	2.157	-0.023
G31	23.751233	85.378951	0.5	0.5	10.9	32.7	14.2	44.1	1.538	0.808
G32	23.7598	85.345453	0.7	2.9	40.8	2.1	17.0	45.8	2.966	1.395
G33	23.759364	85.354821	0.8	4.9	60.3	0.0	0.0	65.3	6.569	-0.253
G34	23.759773	85.363362	0.5	3.6	56.1	10.5	0.0	70.1	5.335	-0.030
G35	23.758718	85.372903	0.5	3.1	33.8	0.0	10.7	36.8	3.300	1.423
G36	23.766325	85.345561	1.9	2.9	35.2	25.9	0.0	64.0	5.729	0.171
G37	22.999142	85.282167	0.7	3.1	4.1	12.3	44.2	19.4	0.118	0.368
G38	23.821876	85.384986	1.5	2.3	3.5	46.2	10.1	52.0	1.690	0.476
G39	23.824084	85.393773	0.6	0.6	4.7	11.0	44.9	16.3	0.080	0.339
G4	22.439496	86.543378	0.7	4.4	2.2	37.6	19.3	44.2	1.511	0.624
G41	23.822556	85.411019	0.6	2.0	11.4	4.2	44.8	17.5	0.253	0.810
G42	23.82598	85.418796	0.6	5.3	2.9	19.6	36.9	27.8	0.275	0.375
G43	23.821753	85.379697	0.8	2.6	17.2	1.0	19.3	20.7	1.414	1.866
G44	22.997835	85.290065	0.9	4.1	1.4	7.1	52.0	12.7	0.089	0.493
G45	23.830295	85.405418	0.7	3.7	4.4	1.4	54.6	9.5	0.039	0.437

G46	23.811288	85.411221	1.2	1.2	17.4	5.3	42.0	24.0	0.628	1.256
G47	23.816485	85.394779	0.9	4.7	8.0	2.0	50.3	14.7	0.153	0.916
G48	23.840872	85.394723	0.5	21	0.0	3.2	57.1	5.3	0.000	0.019
G49	23.883502	85.498711	0.5	3.6	1.9	3.8	37.6	9.3	0.025	0.245
G5	22.442892	86.547001	0.7	5.7	11.4	3.1	39.1	20.1	0.519	0.940
G50	22.990768	85.289018	0.7	4.4	1.5	7.1	52.0	12.9	0.087	0.425
G51	23.881851	85.470699	0.8	3.2	0.0	18.2	42.8	21.5	0.006	0.021
G52	23.879192	85.506953	0.7	2.0	0.0	7.1	27.1	9.2	0.056	0.351
G53	23.88876	85.473993	0.9	2.9	0.0	12.0	52.1	14.9	0.040	0.170
G54	23.886129	85.504213	1.1	2.9	3.0	14.9	25.8	20.7	0.169	0.326
G55	23.898552	85.465505	0.6	1.5	3.6	14.2	42.9	19.3	0.390	0.982
G56	23.894096	85.504963	0.6	1.3	12.6	0.0	48.0	13.9	0.176	1.073
G57	23.906306	85.455044	0.5	6.0	6.7	3.0	61.2	15.7	0.083	0.418
G58	23.905706	85.469472	0.5	1.1	9.0	2.7	48.4	12.8	0.156	0.826
G59	23.912963	85.459523	0.9	2.9	5.3	41.8	13.4	50.0	1.232	0.400
G6	22.429812	86.592439	1.1	2.5	21.8	12.8	8.7	37.1	0.924	0.730
G6	22.429812	86.592439	0.7	2.3	40.7	7.7	121	50.7	3.146	0.890
G60	23.912025	85.469161	0.7	5.3	0.0	16.5	39.5	21.9	0.289	0.591
G61	23.910157	85.488475	0.5	2.1	5.8	22.1	7.4	30.0	1.173	0.467
G62	23.920137	85.477861	0.6	3.7	5.2	6.2	53.6	15.1	0.122	0.590
G63	23.919471	85.486553	0.5	4.6	7.2	3.8	54.1	15.6	0.178	0.784
G64	23.927753	85.487232	0.5	3.1	3.2	30.7	23.0	37.0	0.352	0.286
G65	23.984749	86.403297	0.7	4.6	22.0	19.2	5.7	45.8	2.251	0.461
G66	23.991975	86.402524	0.6	2.9	5.3	14.2	40.1	22.4	0.519	0.954
G67	24.026341	86.386148	0.7	4.9	7.6	9.2	42.9	21.7	0.386	0.774
G68	22.923004	85.284323	0.8	6.2	0.0	18.3	41.7	24.5	0.031	0.060
G69	24.041916	86.387452	0.7	4.7	6.5	3.2	50.8	14.4	0.099	0.562
G7	22.45238	86.540894	0.9	4.0	5.9	26.5	32.4	36.3	1.057	0.933
G70	24.161669	86.890344	0.7	5.2	6.3	2.8	66.6	14.3	0.064	0.478
G71	24.161328	86.899386	0.6	3.9	7.9	27.8	24.3	39.6	0.431	0.322
G72	24.16105	86.906611	0.7	3.0	8.6	3.6	48.3	15.3	0.238	0.978
G73	24.260808	86.914292	0.6	2.0	2.7	35.1	22.1	39.8	1.236	0.806
G74	23.760737	85.363362	1.2	4.3	6.9	0.0	51.8	11.2	0.124	0.731
G75	24.285264	86.933221	0.5	4.2	5.7	2.2	51.7	12.0	0.117	0.837
G76	24.03455	86.3866	0.7	4.0	10.6	0.0	49.9	14.6	0.174	0.911
G77	24.281884	87.158861	0.7	3.0	5.8	1.8	13.6	10.6	0.344	1.371
G78	24.281634	87.167653	0.5	1.5	11.8	0.5	48.1	13.9	0.156	1.000
G79	24.292882	87.123457	0.6	4.7	15.2	13.6	31.8	33.5	0.953	1.228

G8	22.449855	86.548331	0.6	31	82	0.0	52.4	11.3	0.068	0.331
G80	24.292236	87.132328	0.5	2.3	13.5	14.0	16.0	29.8	1.274	1.042
G81	24.28975	87.186963	0.8	0.8	15.7	17.3	32.3	33.9	1.268	1.548
G82	24.289452	87.195613	1.6	1.6	1.6	0.0	48.9	3.2	0.010	0.184
G83	24.300859	87.12447	0.6	1.8	7.6	18.9	34.0	28.4	0.750	1.349
G84	24.301143	87.133154	0.7	7.8	4.4	38.8	21.8	51.0	0.523	0.223
G85	24.299726	87.141882	0.6	4.5	48.2	0.0	12.0	52.6	2.342	0.582
G86	24.298505	87.185676	0.6	7.1	17.9	0.7	40.2	25.7	0.515	0.906
G87	24.297892	87.196431	0.7	1.5	2.9	11.5	45.2	16.0	0.161	0.667
G88	24.308275	87.133592	0.7	1.5	12.1	32.2	16.2	45.7	1.398	0.652
G89	24.307938	87.142307	0.7	4.5	14.5	2.5	43.5	21.5	0.495	1.216
G9	22.433896	86.602671	0.7	1.8	8.1	5.2	47.2	15.1	0.034	0.148
G90	22.308568	86.527129	0.8	2.2	5.1	0.0	55.0	7.3	0.039	0.321
G91	22.31316	86.526877	0.7	3.3	3.5	3.1	52.6	9.9	0.027	0.154
G92	22.317706	86.533096	1.0	5.2	11.2	68.0	0.0	84.4	3.419	-0.026
G93	22.321691	86.527976	0.5	8.9	5.4	2.6	52.3	16.9	0.134	0.377
G94	22.92047	85.27834	0.5	2.7	4.2	1.4	54.6	8.3	0.021	0.219
G95	22.613217	86.611609	0.5	4.8	6.1	26.0	27.1	36.8	0.546	0.430
G96	22.926138	85.276745	0.6	0.6	11.4	1.9	47.3	13.9	0.301	1.165
G97	22.601837	86.610646	0.7	0.7	6.1	1.7	52.8	8.5	0.017	0.169
G98	22.609533	86.617229	0.8	2.8	10.6	32.1	17.5	45.5	1.810	0.749
G99	22.609574	86.60317	0.8	4.6	7.8	0.0	52.7	12.4	0.084	0.463





Day136	13.7	29.1	25.5	21.7	27.1	11.8	4.9	0.2	5.5	0.0	2.5	0.8	16.5	14.1	17.7	2.8	7.0	15.1	23.2	25.1	11.6	12.5	19.4	33.4	24.8	14.3				
Day137	0.2	0.3	0.0	1.9	0.2	0.0	26.5	26.1	39.2	49.2	16.7	28.0	8.0	11.0	11.8	2.7	5.8	6.5	1.5	1.5	0.1	1.5	0.2	0.0	4.6	3.4				
Day138	0.0	0.0	0.0	0.2	0.0	0.0	2.8	0.4	1.2	0.0	0.7	0.1	1.7	5.8	5.7	0.0	0.0	0.0	0.0	14.2	37.1	27.5	23.8	4.3	5.4	2.7				
Day139	17.6	18.1	3.9	7.3	12.8	11.6	0.8	3.2	1.6	0.0	13.7	3.2	14.7	7.3	3.3	1.7	27.2	23.8	0.0	7.4	3.8	0.5	0.0	0.0	0.0	1.0				
Day140	25.9	34.0	28.4	23.3	32.9	29.2	33.7	7.3	19.0	0.0	0.2	0.0	0.7	7.1	7.3	5.3	0.8	1.3	21.7	4.0	8.9	38.1	37.2	41.9	23.1	33.5	28.5	14.8	17.1	
Day141	0.6	1.0	7.9	4.7	3.5	3.4	3.8	6.4	16.1	10.0	3.7	8.8	0.4	10.0	2.4	4.8	0.5	2.6	0.1	0.0	3.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Day142	8.0	1.1	0.1	0.1	0.0	0.4	0.1	0.0	0.0	0.0	0.1	0.0	1.5	1.5	0.5	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.4	17.7	13.2	10.5	19.6	25.2	13.4	1.8
Day143	0.2	6.7	1.7	2.2	5.2	4.3	6.2	0.5	2.1	0.0	3.6	1.0	3.6	2.4	1.1	1.7	1.8	3.6	13.6	7.6	12.5	5.5	0.7	0.1	0.0	0.0	0.0	10.5	0.1	
Day144	8.8	10.7	0.6	0.4	6.7	3.6	6.7	7.5	46.4	0.0	1.0	3.2	2.0	0.1	0.7	4.6	2.6	2.2	25.4	4.3	5.1	2.4	0.2	0.0	2.1	0.0	0.0	8.0	0.0	
Day145	1.9	2.4	43.3	24.6	16.1	1.7	0.3	0.3	0.0	0.0	6.4	0.5	52.3	7.3	0.1	0.0	9.5	8.8	1.6	2.3	0.5	1.7	0.0	0.2	11.2	1.7	0.0	15.8	22.0	
Day146	1.7	3.4	5.3	8.6	4.1	2.0	42.6	5.9	4.5	0.0	4.2	0.4	27.5	2.1	0.2	1.8	9.3	8.1	0.0	11.7	6.9	6.7	1.9	3.2	0.0	0.5	1.0	4.9	0.0	
Day147	4.3	2.8	6.7	6.4	4.3	6.1	29.1	0.9	8.0	0.0	0.7	0.1	2.4	0.3	0.0	1.0	1.4	1.1	10.6	0.4	1.7	3.8	7.4	2.6	0.6	6.9	10.5	0.8	0.6	
Day148	6.9	2.9	3.8	2.8	2.9	2.4	1.7	16.9	0.8	0.0	0.0	0.0	7.7	0.5	0.3	5.9	8.6	7.2	2.7	0.9	4.2	14.3	10.1	9.1	17.2	10.3	11.9	16.2	15.2	
Day149	0.5	2.0	30.9	19.2	11.9	1.7	24.4	54.9	34.7	99.0	51.3	35.1	18.6	7.5	11.7	8.7	12.3	8.4	0.4	0.1	0.8	0.5	0.1	0.0	0.0	0.0	0.0	0.0	0.0	
Day150	5.0	1.1	1.4	0.8	0.6	0.6	0.1	1.9	3.9	0.0	0.0	0.0	0.0	0.0	0.0	2.4	11.2	8.5	0.3	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	
Day151	0.8	0.0	0.0	0.0	0.0	0.0	0.0	8.5	1.5	9.8	3.4	2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	7.1	11.0	5.7	8.3	0.8	19.1	11.2	
Day152	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.1	0.0	0.0	0.3	0.2	0.0	0.0	2.2	2.8	2.0	8.4	3.8	6.4	7.2	14.0	
Day153	1.7	0.5	3.2	1.7	1.3	0.0	0.0	0.0	0.0	0.0	5.0	1.5	3.1	5.3	4.9	0.1	6.5	7.3	2.1	0.6	0.0	5.3	16.6	1.2	7.7	16.4	42.7	8.4	18.7	
Day154	0.1	10.0	17.4	19.5	12.4	0.0	1.6	6.1	5.7	9.6	9.3	9.9	19.7	1.5	1.6	25.1	11.0	7.7	0.7	9.5	13.5	37.7	31.9	44.2	51.1	36.2	21.9	33.8	56.9	
Day155	0.0	0.0	1.7	1.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Day156	10.2	7.3	25.5	20.0	12.7	2.3	0.2	1.2	1.9	0.0	0.0	0.0	5.3	2.0	0.1	0.0	3.0	3.1	0.1	2.3	1.9	2.5	0.9	0.0	0.0	0.0	0.0	0.5	0.1	
Day157	1.7	2.3	0.1	0.0	1.5	1.1	0.1	1.6	0.6	3.4	1.4	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Day158	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Day159	2.0	0.0	0.2	0.0	0.0	1.4	0.4	0.0	0.0	0.0	3.3	1.2	0.0	0.9	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Day160	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0
Day161	1.7	1.7	0.7	0.3	1.3	1.4	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Day162	0.0	0.0	0.0	0.0	0.6	3.9	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5	0.0
Day163	0.2	0.2	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Day164	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Day165	0.2	0.0	0.0	0.2	0.0	0.0	2.3	0.3	1.5	0.0	0.0	0.0	0.0	0.0	0.0	1.0	2.4	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Day166	9.2	26.4	16.1	18.7	22.6	8.2	3.3	34.0	12.6	49.0	21.9	16.5	7.8	6.0	0.9	2.2	9.3	9.4	0.4	4.7	8.0	5.2	2.5	0.8	12.0	3.2	7.8	14.1	23.9	
Day167	20.4	22.9	52.5	37.0	33.2	20.3	39.1	111.3	81.4	155.8	99.5	129.9	44.2	32.1	35.2	37.3	69.3	64.4	33.6	19.3	60.4	73.8	56.1	36.7	28.3	45.1	62.3	23.2	21.1	
Day168	76.4	123.2	175.6	176.7	144.5	118.7	184.9	127.6	108.4	194	119.7	108.1	106.3	87.6	94.2	69.8	77.0	64.7	40.0	26.3	37.8	62.0	40.7	29.7	41.5	28.7	15.5	32.5	51.3	
Day169	24.0	14.4	29.8	20.2	21.4	33.2	36.6	36.5	36.6	34.6	70.4	43.7	61.7	69.4	73.1	25.7	47.3	43.3	10.9	36.2	12.2	5.8	8.5	5.1	6.9	10.8	13.4	6.5	8.2	
Day170	0.2	0.2	0.0	0.1	0.1	0.0	1.4	0.4	0.6	0.0	14.0	4.2	19.4	20.3	9.6	3.0	10.6	11.8	3.9	4.0	0.9	0.3	0.0	0.0	5.5	0.0	0.0	0.5	1.0	
Day171	0.5	0.0	0.1	0.0	0.7	5.2	0.5	0.0	0.0	0.0	2.0	1.0	0.8	2.1	0.5	5.1	2.2	2.4	13.5	1.9	0.0	0.0	0.4	1.0	0.3	0.5	0.0	0.1	0.0	
Day172	11.3	10.2	3.0	1.6	7.4	26.6	9.7	10.5	13.8	21.0	39.8	15.8	3.2	8.2	4.8	20.5	5.4	3.3	43.9	5.9	25.9	3.4	18.4	30.7	19.1	29.9	26.2	43.9	24.5	
Day173	2.6	2.3	0.8	0.4	1.5	0.3	0.0	21.7	5.4	24.8	22.7	12.3	4.9	1.1	4.8	0.6	7.5	7.0	8.0	3.6	31.9	19.1	8.8	2.5	0.4	4.1	2.2	0.3	0.0	
Day174	10.4	2.6	42.9	28.1	18.5	21.1	8.6	8.4	17.4	11.4	21.7	31.3	8.6	9.8	9.5	1.1	7.3	6.9	15.8	2.9	9.2	51.5	37.2	34.7	17.4	26.2	15.6	8.6	12.5	
Day175	16.4	16.5	12.7	13.6	14.4	13.7	24.2	37.8	25.3	59.6	37.3	24.0	23.2	35.6	17.4	10.8	27.2	24.6	18.4	3.4	12.3	2.2	6.6	8.5	10.4	10.8	6.5	7.4	10.0	
Day176	20.9	14.0	4.9	8.2	11.9	21.7	27.8	14.7	4.1	19.0	17.2	31.6	19.1	14.4	7.0	17.0	19.7	16.1	3.1	9.2	23.6	16.9	13.1	9.0	8.9	12.9	6.2	14.2	11.0	
Day177	2.5	4.4	4.3	3.9	9.3	44.1	9.3	0.0	0.0	0.0	14.0	1.6	29.8	7.3	7.6	2.5	39.8	36.9	15.8	3.1	11.1	10.9	4.2	0.3	5.0	0.7	3.2	3.5	10.7	
Day178	41.0	25.0	52.8	52.2	60.1	250.5	290.9	41.0	33.0	26.2	13.4	26.4	7.0	13.2	24.8	10.9	41.2	36.8	7.1	7.2	2.3	0.5	3.8	0.3	0.7	0.9	8.2	8.5	2.0	
Day179	14.2	22.0	31.7	26.9	24.3	6.9	30.5	17.0	8.1	21.3	33.9	31.8	23.9	27.9	24.7	11.3	38.6	36.6	6.8	5.3	22.0	21.9	8.8	1.3	0.0	8.3	12.4	0.2	0.0	
Day180	19.6	26.3	17.6	15.8	21.2	2.6	41.3	27.7	5.5	26.0	30.2	27.7	39.4	28.2	18.7	24.1	29.8	27.2	39.7	15.3	13.0	28.9	32.0	25.6	13.1	28.4	17.9	10.1	6.7	
Day181	2.5	3.0	2.7	3.9	2.8	0.4	12.2	4.9	13.1	5.6	6.5	10.0	6.8	3.7	17.3	9.1	25.7	21.9	10.9	6.6	0.5	4.2	5.2	4.5	14.3	6.1	16.3	12.7	18.2	
Day182	3.7	6.0	7.3	8.4	10.5	33.7	22.6	17.5	17.7	24.6	7.9	20.6	3.6	0.2	3.0	0.8	0.5	0.5	2.7	2.6	11.1	3.2	17.5	19.3	7.7	21.8	45.9	9.6	3.1	
Day183	14.7	4.3	13.9	8.6	6.2	3.6	5.2	6.3	5.2	6.2	1.9	2.1	0.3	2.6	4.3	9.9	8.3	8.0	26.0	19.3	9.9	2.								

Day208	15.6	10.1	5.1	8.4	7.2	1.4	40.0	32.3	6.9	32.7	17.6	18.7	6.8	5.5	5.0	29.2	14.5	9.5	27.8	20.3	127.3	63.9	49.9	20.6	22.1	35.8	59.0	44.2	32.3	
Day209	0.6	0.0	0.0	0.5	0.0	8.6	3.6	0.1	0.5	0.0	2.1	2.0	6.7	2.6	0.2	4.0	3.3	3.5	1.4	0.0	2.9	0.4	4.4	6.6	9.8	6.2	3.9	14.2	17.7	
Day210	7.4	3.6	17.3	11.7	8.0	2.3	22.6	3.7	0.6	0.0	5.3	1.0	5.4	10.6	2.9	13.6	10.8	10.8	45.1	12.3	27.0	6.9	3.2	2.2	22.4	6.3	5.9	35.8	50.7	
Day211	6.6	8.6	6.0	9.9	7.0	0.5	1.6	5.5	2.4	6.0	8.1	4.3	2.2	16.6	4.2	5.7	16.2	20.1	5.3	11.1	34.6	31.4	19.3	26.4	17.9	21.4	19.9	7.9	8.2	
Day212	17.9	21.0	2.7	3.5	13.6	6.2	24.3	0.0	0.0	0.0	0.0	0.0	0.0	10.0	4.1	12.9	18.6	15.1	10.7	0.6	4.3	6.7	24.9	25.3	33.6	33.7	49.6	16.3	11.0	
Day213	3.6	0.7	2.3	1.3	1.1	8.5	2.3	0.0	0.0	0.0	4.9	0.4	34.9	20.5	18.1	13.5	1.4	3.0	4.1	1.7	6.0	3.0	4.8	13.9	20.3	12.1	13.4	20.9	5.1	
Day214	15.7	35.6	10.7	12.6	25.2	3.5	1.3	4.8	1.0	4.0	5.6	12.2	10.3	12.7	13.0	9.3	4.4	7.6	4.1	15.8	26.4	32.3	20.2	10.0	9.6	14.7	24.0	8.7	2.1	
Day215	0.3	0.2	5.5	3.1	4.5	18.8	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.3	10.3	0.6	0.5	27.0	0.2	0.7	3.8	10.3	12.7	15.7	13.4	3.7	8.7	9.2	
Day216	22.6	21.6	37.0	30.1	24.8	2.3	6.2	19.4	17.0	0.0	4.7	1.7	4.1	1.0	0.0	3.9	10.3	6.9	8.7	11.3	8.4	19.0	16.9	2.9	4.9	17.0	38.8	4.5	3.0	
Day217	1.1	1.9	5.4	7.5	4.3	10.4	31.5	17.2	18.5	30.2	12.7	28.6	2.3	10.5	8.5	26.8	11.0	9.7	27.2	8.7	14.8	26.5	14.5	6.8	4.5	7.8	7.6	19.3	2.1	
Day218	34.5	36.6	8.3	18.5	25.0	11.6	86.4	14.4	17.5	24.8	11.8	22.5	9.7	19.3	19.0	52.2	4.7	8.6	1.3	1.2	0.0	1.2	10.3	5.2	11.2	12.0	18.0	5.3	17.0	
Day219	2.2	6.6	10.0	8.5	7.4	0.5	2.5	0.2	0.3	8.4	12.3	9.4	19.0	5.8	6.7	9.3	6.5	6.3	12.8	1.1	7.3	18.0	25.4	7.0	7.3	24.3	25.9	2.1	2.0	
Day220	4.6	0.2	0.4	0.0	0.8	5.4	0.4	5.2	2.6	11.6	5.0	26.9	2.7	3.5	0.8	0.8	3.1	3.3	5.9	0.0	0.0	1.8	2.8	4.0	4.0	3.3	1.1	2.5	0.0	
Day221	8.0	8.0	0.7	5.7	6.6	13.2	0.8	8.6	3.4	19.2	10.0	22.4	0.9	0.1	2.4	22.0	3.2	2.6	1.3	1.7	6.3	81.5	44.7	29.5	34.0	24.3	4.7	40.8	47.2	
Day222	0.0	0.1	3.8	2.0	1.3	0.0	0.0	0.0	0.0	0.0	11.6	4.1	3.0	0.5	0.0	0.0	4.1	6.2	0.3	6.2	30.1	7.0	2.6	0.3	4.1	0.0	0.3	2.9	9.9	
Day223	18.4	1.7	0.1	0.8	0.2	0.0	0.0	2.5	0.0	0.0	0.0	0.0	0.7	1.2	1.8	0.8	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.6	0.0	0.0	0.0	0.0	
Day224	4.8	6.6	22.7	13.8	13.6	15.4	12.2	6.3	1.5	0.0	3.1	0.3	18.0	2.8	0.3	1.2	7.7	9.6	17.5	3.3	9.7	20.7	6.9	1.7	2.9	0.3	0.0	0.0	3.3	5.0
Day225	14.5	7.3	2.9	3.1	5.5	16.5	18.8	10.4	7.2	15.0	8.7	5.2	0.2	2.0	2.1	4.9	7.1	5.0	2.3	0.8	1.7	1.3	5.1	5.0	10.9	6.2	5.7	14.9	19.2	
Day226	17.0	7.3	1.3	3.2	5.8	19.0	10.0	2.7	3.7	3.7	4.0	1.2	1.5	0.1	0.0	2.9	7.2	4.3	0.0	0.1	0.4	2.7	1.0	0.2	0.7	0.6	0.5	9.7	5.2	
Day227	1.0	1.2	0.1	0.0	0.9	2.7	0.7	4.9	2.0	8.6	3.1	4.6	0.0	0.0	0.0	0.0	1.1	1.2	0.7	0.0	0.0	2.5	0.0	0.0	0.0	0.0	0.0	1.1	1.5	
Day228	8.6	11.2	1.5	2.4	7.8	10.7	12.6	5.3	1.9	7.2	6.0	6.5	10.9	13.3	4.6	6.8	3.1	7.3	4.4	1.6	8.4	2.5	1.8	0.1	9.5	3.4	11.5	0.3	0.0	
Day229	3.2	3.8	32.1	18.8	14.6	11.6	8.5	9.3	3.1	11.0	11.4	4.9	8.7	3.2	0.8	1.6	9.0	8.3	12.7	6.3	4.9	1.1	1.2	0.4	1.6	2.2	5.7	4.9	3.0	
Day230	9.5	9.3	12.6	11.0	12.0	19.5	11.0	7.2	5.8	9.8	7.9	6.2	5.1	8.2	6.0	37.1	8.9	9.4	10.4	6.8	7.5	4.5	6.4	5.5	4.8	7.8	10.8	10.8	8.0	
Day231	0.0	0.1	5.4	3.4	2.0	1.3	4.1	28.1	23.8	48.8	12.3	14.2	7.1	0.9	2.5	6.7	14.6	1.1	14.5	1.9	4.4	4.0	6.0	2.7	0.4	6.1	7.6	0.6	0.0	
Day232	25.1	23.7	12.8	16.0	19.4	17.9	8.7	25.4	5.7	16.6	26.6	23.2	29.9	10.6	14.3	49.5	19.5	19.6	8.4	9.4	26.6	25.0	33.0	27.6	19.2	35.8	34.7	43.7	27.2	
Day233	27.4	39.3	70.7	63.9	51.3	37.9	178.2	83.2	56.6	80.8	69.6	68.2	18.7	25.9	73.7	45.4	29.7	15.9	28.0	13.8	25.3	44.6	20.4	8.2	3.9	8.2	9.3	12.4	2.7	
Day234	15.0	10.1	17.8	12.8	11.9	6.4	37.1	14.2	20.3	21.8	39.8	35.4	52.3	39.6	15.2	9.8	37.9	36.4	15.8	10.4	12.7	5.4	10.1	14.4	14.8	11.7	15.3	16.2	23.9	
Day235	5.6	4.7	8.5	5.5	5.5	3.5	3.9	12.1	6.2	15.4	10.0	9.8	14.7	7.6	3.5	6.6	11.2	9.6	2.5	2.8	8.2	4.0	1.1	0.0	1.7	0.4	0.2	1.2	2.0	
Day236	0.0	0.0	0.0	0.2	0.0	0.1	3.5	2.6	4.4	5.0	17.3	8.9	31.2	4.3	0.5	0.0	0.9	1.4	0.0	0.0	0.0	0.0	0.0	0.0	4.1	0.5	0.0	4.7	9.0	
Day237	3.4	2.5	0.1	0.5	1.5	1.8	7.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.9	1.3	1.2	6.5	12.2	2.1	0.3	
Day238	1.0	0.6	2.4	2.3	2.9	15.8	4.6	9.9	5.1	12.2	15.7	14.5	0.7	1.2	0.4	0.0	1.4	1.3	0.1	0.9	1.0	0.0	5.4	2.6	2.6	6.7	3.7	1.5	5.1	
Day239	3.5	0.2	3.0	3.0	1.0	0.9	9.6	4.9	0.0	0.0	2.0	0.7	6.8	0.5	0.0	1.1	8.2	7.4	4.1	1.9	1.6	5.8	6.3	2.2	1.7	4.9	2.4	0.3	1.0	
Day240	0.6	0.1	0.0	0.0	0.2	0.6	0.0	10.3	9.8	21.0	7.3	5.7	0.0	0.0	0.0	0.9	3.8	3.5	0.0	1.3	0.0	1.3	1.5	0.0	0.8	0.9	5.4	1.1	2.0	
Day241	0.8	1.2	4.4	2.4	2.2	0.4	0.1	0.0	0.0	0.0	1.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	
Day242	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.7	1.2	8.4	1.0	2.3	0.0	0.0	2.5	0.0	0.0	0.0	0.0	0.0	2.0	1.8	1.1	0.0	0.0	0.0	0.8	7.1	0.0	0.0
Day243	27.7	27.9	25.8	21.6	27.5	35.8	20.3	26.6	7.4	26.8	5.1	14.5	1.7	1.6	0.4	1.8	8.8	5.8	16.6	12.4	16.2	8.3	8.8	2.5	1.5	7.8	10.5	18.1	25.1	
Day244	5.5	2.6	7.0	3.9	4.4	11.7	18.3	10.1	11.7	8.0	5.3	13.3	3.5	4.7	5.0	1.7	4.7	3.5	3.1	2.7	11.3	33.2	28.0	12.7	5.9	19.5	17.3	2.7	0.4	
Day245	27.2	24.3	10.4	13.6	19.3	27.7	27.9	10.9	12.5	14.2	16.4	18.0	0.6	0.6	1.2	5.1	3.9	2.9	4.2	0.9	6.8	13.8	8.7	1.0	0.6	5.9	18.2	2.7	0.9	
Day246	2.8	3.5	22.8	13.6	10.6	6.7	0.6	0.4	0.2	0.0	1.7	5.1	5.8	3.4	1.3	0.4	4.1	4.7	0.1	5.3	1.2	1.1	2.0	2.3	1.0	2.2	0.7	1.1	2.2	
Day247	15.7	21.4	2.1	4.8	15.5	17.6	1.1	0.0	0.5	0.0	0.0	14.0	0.0	0.0	0.0	0.0	0.1	0.3	0.0	0.7	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Day248	1.5	0.7	0.0	0.0	1.0	4.8	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Day249	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Day250	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Day251	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.8	0.6	2.9	6.1	3.3	0.5	25.8	28.9	0.0	5.6	4.5	69.5	25.4	1.5	0.0	0.0	0.0	0.0	0.0	
Day252	7.0	18.5	3.0	12.2	13.1	14.3	4.1	17.3	11.1	37.0	38.9	19.4	6.9	3.8	4.6	1.5	8.7	8.3	1.2	5.9	4.8	5.7	4.8	19.8	12.7	13.7	0.1	0.3	1.0	
Day253	15.3	9.6	7.6	4.0	10.7	27.5	3.8	18.7	23.0	3.0	17.7	7.8	37.5	39.1	17.5	7.5	6.7	18.9	6.1	21.9	25.3	67.4	28.1	12.2	22.5	5.2	0.2	0.1	0.0	
Day254	8.6	13.8	8.6	8.9	12.5	20.0	3.5	4.2	1.4	9.4	7.2	3.7	0.0	30.1	8.1	0.9	0.0	14.5	0.3	0.3	0.0	0.0	9.5	31.5	18.0	21.7	0.4	1.6	6.0	
Day255	19.1	23.0	1.6	7.4	16.2	19.3	1.4	0.0	0.0	0.0	0.0	0.0	0.0	3.3	2.8	0.6	11.5	11.7	0.4	2.5	1.3	0.0								

Day280	0.0	1.6	8.3	5.3	3.8	0.0	0.0	0.0	0.0	0.3	0.0	0.0	9.4	0.0	0.1	0.0	0.0	0.0	0.0	0.6	0.0	0.4	0.8	0.1	0.0	0.9	0.6	0.0	0.0
Day281	7.6	1.4	0.0	0.0	0.1	0.0	0.0	4.7	1.6	10.6	1.2	2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Day282	7.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Day283	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Day284	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Day285	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Day286	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Day287	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Day288	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Day289	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Day290	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Day291	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Day292	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Day293	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Day294	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Day295	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Day296	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Day297	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Day298	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Day299	0.0	0.0	0.0	0.0	2.3	22.9	3.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Day300	18.2	16.0	29.8	24.5	22.0	26.4	27.6	20.3	7.7	25.0	15.6	21.6	12.1	9.4	7.4	3.9	11.2	9.4	3.2	4.1	3.6	1.9	1.0	0.1	0.0	0.6	0.5	8.5	0.0
Day301	13.4	11.9	18.3	17.6	16.8	41.8	34.4	7.9	20.7	5.0	8.2	11.1	21.1	14.3	10.6	12.5	18.8	19.8	15.0	5.8	16.9	27.4	20.5	30.1	35.1	23.8	15.9	30.7	48.4
Day302	5.3	0.9	0.1	2.0	0.5	1.1	2.1	5.8	0.6	2.2	10.9	2.6	20.5	11.2	49.8	26.9	11.3	11.0	32.2	14.6	19.2	12.9	4.4	1.6	2.2	1.5	2.2	3.6	3.7
Day303	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.0	5.0	1.2	4.4	10.9	10.4	8.6	3.2	4.3	6.8	0.0	0.2	1.1	11.2	3.5	25.1	12.5	19.3	21.2	28.5
Day304	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.2	0.1	1.6	1.0	0.0	0.0	1.0	0.0	0.3	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0
Day305	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Day306	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Day307	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Day308	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Day309	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Day310	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Day311	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Day312	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Day313	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Day314	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Day315	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Day316	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Day317	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Day318	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Day319	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Day320	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Day321	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Day322	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Day323	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Day324	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Day325	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Day326	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Day327	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Day328	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Day329	0.0	0.0	0.0	0.0	0.0																								



### Annexure 4 Village Wise Budget Under Different Water Augmentation Structures Through Artificial Recharge/Rain Water Harvesting – Jharkhand.

Water Augmentation Structures	Village	Nos of Sites	Site Wise Volume (TCM)	Site Wise Cost (INR)	Per Village Volume (TCM)	Per Village Cost (INR)
Desiltation of Earthen Bunds	AMGACHHI	1	14.52	90000.00	14.52	90000.00
Recharge Shaft	Babaida	1	1.24	95431.92	95.85	4157111.92
New Check Dams		1	10.46	1445000.00		
		1	31.46	1955000.00		
Desiltation of Check Dams		1	18.63	218880.00		
Desiltation of Earthen Bunds		1	5.90	75600.00		
		1	6.54	70200.00		
		1	21.61	297000.00		
Recharge Shaft	BAGHMARA	1	1.06	97670.24	27.37	1855230.44
		1	1.04	97400.20		
Repair and Desiltation of Check Dams		1	12.20	845360.00		
		1	13.07	814800.00		
Recharge Shaft	Baghmara Harladangal	1	1.37	96048.48	68.66	2715982.80
		1	1.41	96119.40		
		1	1.38	93814.92		
New Check Dams		1	38.40	2040000.00		
Repair and Desiltation of Check Dams		1	26.11	390000.00		
New Check Dams	BAHERA	1	27.63	1445000.00	286.66	7577600.00
		1	94.38	4250000.00		
		1	20.80	1105000.00		
Desiltation of Check Dams		1	16.47	57600.00		
Desiltation of Earthen Bunds		1	127.39	720000.00		
Recharge Shaft	BALI	1	1.05	91119.08	39.09	522219.08
Desiltation of Earthen Bunds		1	13.41	207900.00		
		1	15.96	133200.00		
		1	8.67	90000.00		
Recharge Shaft	BANSADIH	1	1.34	94344.32	1.34	94344.32
Recharge Shaft	Basajhor	1	1.33	97815.44	28.20	3273689.52
		1	1.38	99099.08		
		1	1.48	101775.00		
New Check Dams		1	14.68	1615000.00		
		1	9.33	1360000.00		
Recharge Shaft	BASMATA	1	1.44	93379.56	8.18	866879.56
New Check Dams		1	6.74	773500.00		
New Check Dams	Bedganwa Nawadlh	1	10.44	909500.00	10.44	909500.00
Recharge Shaft	Bedla	1	1.45	93194.00	167.35	6525185.92
		1	1.44	92859.40		
		1	1.43	92813.40		
		1	1.43	92804.68		
		1	1.43	93014.44		
		1	27.52	1691500.00		
New Check Dams		1	70.20	1453500.00		

		1	21.62	952000.00		
		1	40.83	1963500.00		
<b>New Check Dams</b>	BELGARA	1	11.82	1190000.00	43.99	1416800.00
<b>Desiltation of Check Dams</b>		1	13.47	81000.00		
<b>Desiltation of Earthen Bunds</b>		1	18.70	145800.00		
<b>Desiltation of Check Dams</b>	Belml	1	3.21	24300.00	3.21	24300.00
<b>Recharge Shaft</b>	Bera pal	1	1.33	99146.28	32.46	796100.44
		1	1.32	98504.16		
<b>Desiltation of Check Dams</b>		1	15.93	128250.00		
<b>Repair and Desiltation of Check Dams</b>		1	13.88	470200.00		
<b>Desiltation of Earthen Bunds</b>	BHAIROPUR	1	22.81	144000.00	22.81	144000.00
<b>Recharge Shaft</b>	BHURSA	1	1.59	94051.48	15.69	261817.16
		1	1.70	95765.68		
<b>Desiltation of Check Dams</b>		1	12.41	72000.00		
<b>New Check Dams</b>	Bhuskl	1	59.34	1105000.00	119.35	3910000.00
		1	33.02	1190000.00		
		1	9.79	765000.00		
		1	17.20	850000.00		
<b>Recharge Shaft</b>	BICHNA	1	1.92	92017.48	1.92	92017.48
<b>Desiltation of Check Dams</b>	BIGAI BANDH	1	15.34	126000.00	15.34	126000.00
<b>Recharge Shaft</b>	Bihinda	1	1.25	97310.20	8.76	248202.76
		1	1.24	96892.56		
<b>Desiltation of Check Dams</b>		1	6.27	54000.00		
<b>Recharge Shaft</b>	BIRAJPUR	1	1.06	92886.60	64.07	524886.60
<b>Desiltation of Check Dams</b>		1	14.13	72000.00		
<b>Desiltation of Earthen Bunds</b>		1	48.88	360000.00		
<b>Recharge Shaft</b>	Border	1	1.36	96782.04	25.84	791870.72
		1	1.48	92424.12		
		1	1.69	108164.56		
<b>Repair and Desiltation of Check Dams</b>		1	21.31	494500.00		
<b>Corewall Gabions</b>	Chalnpur	1	2.69	222800.00	762.08	1451680.00
<b>Repair and Desiltation of Check Dams</b>		1	735.77	654000.00		
		1	23.62	574880.00		
<b>Desiltation of Earthen Bunds</b>	CHAKAMANPUR	1	13.94	94500.00	13.94	94500.00
<b>New Check Dams</b>	CHANARO	1	7.36	1105000.00	226.61	4547600.00
		1	8.24	1020000.00		
<b>Desiltation of Check Dams</b>		1	8.33	64800.00		
		1	11.91	64800.00		
		1	16.80	85500.00		
		1	31.42	162000.00		
<b>Desiltation of Earthen Bunds</b>		1	29.77	202500.00		
<b>Repair and Desiltation of Check Dams</b>		1	101.20	1116000.00		
		1	11.59	727000.00		
<b>Repair and Desiltation of Check Dams</b>	CHARHI (CT)	1	68.95	989000.00	113.11	1797000.00
		1	44.16	808000.00		
<b>Recharge Shaft</b>	Chatro	1	1.58	105724.68	19.53	224524.68
<b>Desiltation of Earthen Bunds</b>		1	17.95	118800.00		

<b>Recharge Shaft</b>	Chhaglajor	1	1.46	92744.68	21.82	930271.40
		1	1.47	92526.72		
<b>Repair and Desiltation of Check Dams</b>		1	18.89	745000.00		
<b>Recharge Shaft</b>	CHICHIKHURD	1	1.46	92301.92	143.26	6154632.44
		1	1.46	91351.32		
		1	1.47	91879.20		
<b>New Check Dams</b>		1	22.86	1700000.00		
		1	11.07	1275000.00		
		1	14.20	1105000.00		
		1	28.67	1530000.00		
<b>Desiltation of Earthen Bunds</b>		1	29.27	67500.00		
		1	21.74	144000.00		
		1	11.06	57600.00		
<b>Recharge Shaft</b>	ChInapahari	1	1.07	94971.40	65.19	3480903.20
		1	1.07	94731.80		
<b>New Check Dams</b>		1	5.57	2125000.00		
<b>Corewall Gabions</b>		1	15.86	402600.00		
<b>Desiltation of Check Dams</b>		1	11.64	100800.00		
<b>Desiltation of Earthen Bunds</b>		1	20.23	208800.00		
<b>Repair and Desiltation of Check Dams</b>		1	9.73	454000.00		
<b>Recharge Shaft</b>	Choirā	1	1.26	100769.92	1.26	100769.92
<b>New Check Dams</b>	Chokshol	1	18.97	1275000.00	112.34	4632200.00
		1	36.78	1870000.00		
<b>Repair and Desiltation of Check Dams</b>		1	14.77	464800.00		
		1	41.83	1022400.00		
<b>Recharge Shaft</b>	Dalugura	1	1.10	94111.36	82.11	1622740.16
		1	1.03	95128.80		
<b>New Check Dams</b>		1	33.01	1105000.00		
<b>Desiltation of Check Dams</b>		1	13.38	135000.00		
<b>Desiltation of Earthen Bunds</b>		1	14.20	72000.00		
		1	19.38	121500.00		
<b>Desiltation of Check Dams</b>	Damadlh	1	2.07	21600.00		
<b>Recharge Shaft</b>	DARI (CT)	1	1.34	98209.80	25.78	143569.80
<b>Desiltation of Check Dams</b>		1	24.44	45360.00		
<b>Recharge Shaft</b>	DASO KHAP	1	1.29	93794.12	139.71	2991313.48
		1	1.34	92569.28		
		1	1.32	93096.68		
		1	1.36	92225.72		
		1	1.30	93705.56		
		1	1.27	94779.64		
		1	1.28	94091.08		
		1	1.34	92464.76		
		1	1.34	92586.64		
<b>New Check Dams</b>		1	17.20	1020000.00		
<b>Corewall Gabions</b>		1	8.15	253200.00		
<b>Desiltation of Check Dams</b>		1	12.44	67500.00		
		1	6.77	40500.00		

Desiltation of Earthen Bunds		1	5.32	39600.00		
		1	13.11	79200.00		
Repair and Desiltation of Check Dams		1	64.88	652000.00		
Repair and Desiltation of Check Dams	DEKLA	1	52.60	1048500.00	52.60	1048500.00
Desiltation of Earthen Bunds	Derang	1	13.12	90000.00	17.99	158400.00
		1	4.87	68400.00		
Desiltation of Check Dams	DIGRI	1	10.30	48600.00	46.61	913400.00
Repair and Desiltation of Check Dams		1	36.32	864800.00		
New Check Dams	Dongadah	1	40.36	1870000.00	40.36	1870000.00
Recharge Shaft	Dudh pushi	1	1.48	101864.44	21.18	1559744.84
		1	1.49	101880.40		
New Check Dams		1	12.37	1275000.00		
Desiltation of Check Dams		1	5.84	81000.00		
Desiltation of Check Dams	Dumurbandi	1	6.88	97695.00	14.54	193095.00
		1	5.00	64800.00		
Desiltation of Earthen Bunds		1	2.66	30600.00		
Desiltation of Earthen Bunds	Ektal	1	19.44	169200.00	38.44	309600.00
		1	19.00	140400.00		
Recharge Shaft	GAIBATHAN	1	1.17	92668.40	69.73	1723265.28
		1	1.09	94696.88		
New Check Dams		1	64.71	1521500.00		
Desiltation of Check Dams		1	2.75	14400.00		
Recharge Shaft	GAJGAON	1	2.25	92050.20	392.85	4771756.36
		1	2.23	91346.16		
Desiltation of Earthen Bunds		1	288.84	1764000.00		
		1	11.82	75150.00		
Repair and Desiltation of Check Dams		1	43.01	981000.00		
		1	6.71	616200.00		
		1	14.37	274250.00		
		1	23.62	877760.00		
Recharge Shaft	Ghoratoriya	1	1.71	108759.40	189.17	2627498.56
		1	1.63	106874.92		
		1	1.70	108674.24		
New Check Dams		1	42.76	1445000.00		
Desiltation of Check Dams		1	78.49	340200.00		
Repair and Desiltation of Check Dams		1	62.86	517990.00		
Recharge Shaft	GURHAMI	1	2.21	92136.28	89.72	1820022.56
		1	2.11	91046.28		
Repair and Desiltation of Check Dams		1	23.34	751840.00		
		1	62.06	885000.00		
New Check Dams	GUTIGARHA	1	51.92	1445000.00	51.92	1445000.00
Recharge Shaft	Haldajuri	1	0.99	94205.68	35.41	619323.80
		1	1.00	93046.12		
Desiltation of Earthen Bunds		1	25.86	311472.00		
		1	7.56	120600.00		
Desiltation of Earthen Bunds	HANSA	1	66.97	270000.00	66.97	270000.00
Repair and Desiltation of Check Dams	HATHBALRAM	1	23.55	447520.00	23.55	447520.00

<b>New Check Dams</b>	HENDEGARA	1	44.19	1190000.00	309.61	2276300.00
<b>Desiltation of Check Dams</b>		1	23.73	88200.00		
		1	7.17	32400.00		
		1	13.28	63000.00		
		1	15.02	86400.00		
		1	34.58	126000.00		
<b>Desiltation of Earthen Bunds</b>		1	24.55	117000.00		
		1	14.78	70200.00		
		1	21.99	112500.00		
<b>Repair and Desiltation of Earthen Bunds</b>		1	110.32	390600.00		
<b>Recharge Shaft</b>	INDRA	1	1.35	92153.72	479.78	7927788.56
		1	1.38	92556.16		
		1	1.34	92331.60		
		1	1.36	91947.08		
<b>New Check Dams</b>		1	105.15	3230000.00		
		1	140.79	3400000.00		
<b>Desiltation of Earthen Bunds</b>		1	81.40	297000.00		
		1	21.45	136800.00		
		1	125.55	495000.00		
<b>Recharge Shaft</b>	Jamkol	1	1.10	96670.32	33.40	2090184.80
		1	1.09	96814.48		
<b>Desiltation of Check Dams</b>		1	6.22	58500.00		
<b>Repair and Desiltation of Check Dams</b>		1	11.94	582400.00		
		1	5.66	528800.00		
		1	7.40	727000.00		
<b>Desiltation of Earthen Bunds</b>	JARJOKHA	1	21.73	126000.00	21.73	126000.00
<b>Recharge Shaft</b>	JARWA	1	1.33	92783.20	25.29	604383.20
<b>Repair and Desiltation of Check Dams</b>		1	23.96	511600.00		
<b>Desiltation of Check Dams</b>	Jatakhuti	1	12.97	90000.00	77.47	1502000.00
		1	42.08	822000.00		
		1	22.42	590000.00		
<b>Repair and Desiltation of Check Dams</b>	Jayghantpur	1	9.29	300000.00	9.29	300000.00
<b>Recharge Shaft</b>	Jhlnaki	1	1.07	93708.16	48.90	309708.16
<b>Desiltation of Earthen Bunds</b>		1	47.83	216000.00		
<b>Desiltation of Earthen Bunds</b>	Jorshol	1	10.03	81000.00	60.53	711000.00
		1	12.01	111600.00		
		1	38.50	518400.00		
<b>Recharge Shaft</b>	Kadwara	1	1.23	93865.84	119.18	3431865.84
<b>New Check Dams</b>		1	7.62	1105000.00		
<b>Repair and Desiltation of Check Dams</b>		1	41.42	1057500.00		
		1	37.56	508000.00		
		1	31.35	667500.00		
<b>New Check Dams</b>	KAJRI	1	10.11	1232500.00	233.87	6842500.00
		1	14.99	1275000.00		
		1	70.89	2210000.00		
		1	137.88	2125000.00		
<b>Recharge Shaft</b>	Kananluka	1	1.32	92396.72	97.10	826840.76

		1	1.30	94068.24		
		1	1.29	93535.80		
<b>Desiltation of Check Dams</b>		1	8.70	68040.00		
<b>Desiltation of Earthen Bunds</b>		1	2.45	28800.00		
		1	5.35	54000.00		
		1	76.70	396000.00		
<b>Recharge Shaft</b>	Kanas	1	1.23	96443.48	79.25	527666.28
		1	1.18	96422.80		
<b>Desiltation of Earthen Bunds</b>		1	43.44	183600.00		
		1	33.39	151200.00		
<b>Recharge Shaft</b>	KANKI	1	1.34	98024.20	494.28	4167590.00
		1	1.35	97364.16		
		1	1.36	96924.12		
		1	1.37	96499.72		
		1	1.38	96164.40		
		1	1.34	97661.88		
		1	1.35	96551.52		
<b>New Check Dams</b>		1	29.66	680000.00		
		1	14.39	773500.00		
		1	45.11	892500.00		
<b>Desiltation of Check Dams</b>		1	36.13	108000.00		
		1	32.88	180000.00		
		1	38.99	71280.00		
		1	28.84	50400.00		
		1	59.93	97200.00		
		1	66.31	106920.00		
		1	53.11	88200.00		
<b>Desiltation of Earthen Bunds</b>		1	36.27	81000.00		
<b>Repair and Desiltation of Check Dams</b>		1	43.17	359400.00		
<b>Recharge Shaft</b>	KARGI	1	1.35	95252.28	1.35	95252.28
<b>Recharge Shaft</b>	KARU KHAP	1	1.34	95291.48	13.08	196091.48
<b>Desiltation of Check Dams</b>		1	11.75	100800.00		
<b>Recharge Shaft</b>	Karuakata	1	1.01	91230.52	26.35	325230.52
<b>Desiltation of Earthen Bunds</b>		1	25.34	234000.00		
<b>Recharge Shaft</b>	Khalrwa	1	1.43	93763.84	26.31	1963457.84
		1	1.42	93494.00		
<b>New Check Dams</b>		1	17.54	833000.00		
<b>Repair and Desiltation of Check Dams</b>		1	5.92	943200.00		
<b>Desiltation of Earthen Bunds</b>	KHAPCHUA	1	4.74	54000.00	4.74	54000.00
<b>Recharge Shaft</b>	Kharbanda	1	1.13	99100.92	72.90	487900.92
<b>Desiltation of Earthen Bunds</b>		1	34.72	183600.00		
		1	37.05	205200.00		
<b>New Check Dams</b>	Khejurdari	1	12.04	1020000.00	12.04	1020000.00
<b>Recharge Shaft</b>	Kokpara	1	1.61	106385.24	308.60	2017736.80
		1	1.62	106662.12		
		1	1.44	103189.44		
<b>Desiltation of Earthen Bunds</b>		1	169.74	688500.00		

<b>Repair and Desiltation of Check Dams</b>		1	77.68	506500.00		
		1	56.51	506500.00		
<b>Recharge Shaft</b>	Kolgl	1	1.49	96084.36	24.82	168084.36
<b>Desiltation of Earthen Bunds</b>		1	23.34	72000.00		
<b>Recharge Shaft</b>	Kolhar	1	1.40	92174.16	120.48	1030654.32
		1	1.40	92129.80		
		1	1.40	92150.36		
<b>Desiltation of Earthen Bunds</b>		1	55.07	327600.00		
		1	53.74	378000.00		
		1	7.48	48600.00		
<b>Recharge Shaft</b>	KULHORIA	1	1.00	95166.16	35.96	408366.16
<b>Desiltation of Earthen Bunds</b>		1	32.92	270000.00		
		1	2.04	43200.00		
<b>Recharge Shaft</b>	Kumrashol	1	1.58	93232.52	1.58	93232.52
<b>Recharge Shaft</b>	KUNDIBARTOLI	1	1.96	93651.00	12.89	158451.00
<b>Desiltation of Earthen Bunds</b>		1	10.93	64800.00		
<b>Recharge Shaft</b>	KURA	1	1.07	101197.12	90.97	5105265.72
		1	1.08	100722.92		
		1	1.07	101728.20		
		1	1.08	99948.04		
		1	1.09	99533.88		
		1	1.13	100359.48		
		1	1.11	97681.08		
		1	1.14	96898.68		
		1	1.08	101263.44		
		1	1.07	102057.44		
		1	1.08	100750.44		
<b>New Check Dams</b>		1	11.51	1275000.00		
		1	22.71	1445000.00		
		1	8.37	850000.00		
<b>Corewall Gabions</b>		1	7.66	218475.00		
<b>Desiltation of Check Dams</b>		1	17.65	133650.00		
		1	11.07	81000.00		
<b>Recharge Shaft</b>	KURKUTA	1	1.38	97707.56	1.38	97707.56
<b>Recharge Shaft</b>	LAKHANPUR	1	1.09	96334.92	8.99	186334.92
<b>Desiltation of Earthen Bunds</b>		1	7.90	90000.00		
<b>Recharge Shaft</b>	LARA	1	1.11	96783.80	165.34	3158783.80
<b>New Check Dams</b>		1	5.12	1105000.00		
<b>Desiltation of Earthen Bunds</b>		1	102.26	810000.00		
		1	15.00	198000.00		
<b>Repair and Desiltation of Check Dams</b>		1	41.86	949000.00		
<b>Recharge Shaft</b>	Larkabasa	1	1.29	98383.40	9.77	404735.80
		1	1.26	95696.84		
		1	1.28	96895.56		
<b>Desiltation of Earthen Bunds</b>		1	3.05	38160.00		
		1	2.88	75600.00		
<b>Recharge Shaft</b>	LODHNA	1	1.14	93837.16	1.14	93837.16

Repair and Desiltation of Check Dams	LUKUIYA	1	44.17	579600.00	44.17	579600.00
Desiltation of Earthen Bunds	Madhopur	1	8.04	61200.00	59.94	939300.00
		1	12.90	75600.00		
Repair and Desiltation of Check Dams		1	39.00	802500.00		
New Check Dams	MAHIL	1	39.76	1190000.00	167.53	2322460.00
Desiltation of Check Dams		1	59.77	189000.00		
		1	25.65	94500.00		
Repair and Desiltation of Check Dams		1	42.35	848960.00		
Recharge Shaft	Mahisadhara	1	1.49	101878.60	30.97	497878.60
Desiltation of Check Dams		1	29.48	396000.00		
New Check Dams	MASHANJOR	1	17.57	1122000.00	23.31	1700000.00
		1	5.75	578000.00		
Desiltation of Earthen Bunds	MERAL	1	228.50	1890000.00	228.50	1890000.00
Desiltation of Earthen Bunds	Murakati	1	5.74	26820.00	5.74	26820.00
New Check Dams	Murathkura	1	12.41	1360000.00	31.64	1514980.00
Desiltation of Earthen Bunds		1	4.82	46980.00		
		1	14.42	108000.00		
Recharge Shaft	Namulepa	1	1.36	91140.20	15.31	1974040.00
		1	1.35	91131.24		
		1	1.38	91768.56		
		1	11.21	1700000.00		
Recharge Shaft	NARO	1	1.05	97325.52	15.55	1299589.32
		1	1.05	96828.76		
		1	1.06	96035.04		
New Check Dams		1	6.25	765000.00		
Corewall Gabions		1	3.35	190400.00		
Desiltation of Earthen Bunds		1	2.80	54000.00		
New Check Dams	Nawadh Nunurai	1	5.19	612000.00	50.05	1913500.00
		1	21.20	603500.00		
		1	10.59	603500.00		
Desiltation of Earthen Bunds		1	13.07	94500.00		
Recharge Shaft	Noyadi	1	1.60	106313.60	147.93	1244868.32
		1	1.52	104653.24		
		1	1.58	105804.64		
		1	1.61	106396.84		
Desiltation of Check Dams		1	13.60	79200.00		
Desiltation of Earthen Bunds		1	34.08	162000.00		
		1	93.94	580500.00		
Repair and Desiltation of Check Dams	PACHKATHIA	1	68.10	608000.00	527.14	2952500.00
		1	234.07	1170000.00		
		1	121.98	1080000.00		
Repair and Desiltation of Earthen Bunds		1	102.99	94500.00		
Recharge Shaft	Paraspur	1	1.32	98649.48	17.58	1798649.48
New Check Dams		1	16.26	1700000.00		
New Check Dams	Patrobad	1	11.34	1020000.00	27.49	1101000.00
Desiltation of Check Dams		1	16.15	81000.00		
Recharge Shaft	Pentuldanga	1	1.10	97251.40	1.10	97251.40

Desiltation of Earthen Bunds	PERKA	1	10.82	54000.00	10.82	54000.00
Desiltation of Earthen Bunds	Phuljori	1	11.09	54000.00	11.09	54000.00
Recharge Shaft	Plndna	1	1.44	95175.84	17.02	362675.84
Repair and Desiltation of Check Dams		1	15.58	267500.00		
Recharge Shaft	RAHAMDAGA	1	1.22	96950.16	1.22	96950.16
New Check Dams	Rautara	1	16.12	1360000.00	16.12	1360000.00
Recharge Shaft	RELIGARA ALIAS PACHHIARI (CT)	1	1.35	99815.88	1.35	99815.88
Recharge Shaft	RIKBA	1	1.10	110777.00	285.47	6140548.96
		1	1.06	102416.72		
		1	1.28	99022.32		
		1	1.19	108382.92		
New Check Dams		1	27.76	1105000.00		
		1	90.03	1572500.00		
		1	52.67	1657500.00		
		1	25.80	1020000.00		
Desiltation of Check Dams		1	33.41	141750.00		
		1	5.78	21600.00		
		1	7.13	32400.00		
Desiltation of Earthen Bunds		1	13.17	61200.00		
		1	25.11	108000.00		
Repair and Desiltation of Check Dams	SAMPUR	1	108.24	1080000.00	226.54	2114000.00
		1	118.29	1034000.00		
Recharge Shaft	SAPRUM	1	1.63	92964.28	27.11	241464.28
Desiltation of Earthen Bunds		1	25.48	148500.00		
Recharge Shaft	Sarbila	1	0.97	97848.72	36.42	2249173.20
		1	0.97	97853.44		
		1	0.97	97923.04		
		1	0.96	98028.00		
New Check Dams		1	8.70	1275000.00		
Desiltation of Check Dams		1	11.78	108000.00		
Repair and Desiltation of Check Dams		1	12.06	474520.00		
New Check Dams	SARDULA	1	19.06	1020000.00	79.25	1923680.00
Repair and Desiltation of Check Dams		1	60.18	903680.00		
Desiltation of Earthen Bunds	Shirishbani	1	23.69	264600.00	23.69	264600.00
New Check Dams	Slmla	1	25.14	671500.00	35.57	1173000.00
		1	10.43	501500.00		
Desiltation of Earthen Bunds	SIYANKEL	1	8.65	54000.00	8.65	54000.00
Recharge Shaft	Sonatanr	1	1.47	94126.28	24.14	1455546.28
New Check Dams		1	7.27	535500.00		
Repair and Desiltation of Check Dams		1	15.41	825920.00		
Repair and Desiltation of Check Dams	SUKHBARIA URF MURGABANI	1	32.40	517000.00	32.40	517000.00
Desiltation of Earthen Bunds	Swargachhinra	1	25.40	226800.00	25.40	226800.00
Recharge Shaft	TASNALO	1	1.13	97049.92	38.44	799896.44
		1	0.96	99846.52		
Corewall Gabions		1	5.70	214200.00		
Desiltation of Earthen Bunds		1	30.66	388800.00		
Recharge Shaft	TENGHOWA	1	1.09	94782.64	1.09	94782.64

<b>Recharge Shaft</b>	Uda	1	1.01	98000.48	10.25	260909.20
		1	1.02	98108.72		
<b>Desiltation of Check Dams</b>		1	8.22	64800.00		
<b>Desiltation of Earthen Bunds</b>	UPAR BALRAM	1	6.40	43200.00	6.40	43200.00
<b>Total</b>		422	9321.72	175041600.96	9321.72	175041600.96

**Annexure 5 Field Photographs Showing Various Data Collection/Testing and Measurement Procedures – Jharkhand.**



