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

केंद्रीय भूमि जल बोर्ड
Central Ground Water Board

NAQUIM 2.0

जल भृतप्रबंधन योजना
बालासोर सदरऔर रेमुना ब्लॉक, बालासोर जिला, ओडिशा।

Aquifer Management Plan
Balasore Sadar and Remuna Blocks, Balasore District, Odisha.

भारतसरकार

Government of India

जलशक्तिमंत्रालय

Ministry of Jal Shakti

जलसंसाधनविभाग, नदीविकासऔरगंगासंरक्षण

Department of Water Resources

River Development andGanga Rejuvenation

केंद्रीयभूमिजलबोर्ड

Central Ground Water Board

जलभृतप्रबंधनयोजना
बालासोर सदर और रेमुना ब्लॉक, बालासोर जिला, ओडिशा।

Aquifer Management Plan
Balasore Sadar and Remuna Blocks, Balasore District, Odisha.

प्राथमिकताप्रकार: तटीयअध्ययनक्षेत्र

Priority Type: Coastal Study Area

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South Eastern Region(SER)
Bhubaneswar
2024

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

भारत सरकार
जल शक्ति मंत्रालय
जल संसाधन,
नदी विकास और गंगा संरक्षण विभाग
केन्द्रीय भूमि जल बोर्ड
Government of India
Ministry of Jal Shakti
Department of Water Resources,
River Development & Ganga Rejuvention
Central Ground Water Board

Message

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

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

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

SKAmbast

(Dr. Sunil Kumar Ambast)

Chairman, CGWB

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N. Varadaraj
Member (East)

भारत सरकार
जल शक्ति मंत्रालय
जल संसाधन, नदी विकास
और गंगा संरक्षण विभाग
केंद्रीय भूजल बोर्ड
भुजल भवन, एन एच -IV, फरीदाबाद
Government of India
Ministry of Jal Shakti
Department of Water Resources, River
Development & Ganga Rejuvenation
Central Ground Water Board
Bhujal Bhawan, NH-IV,Faridabad.

FOREWORD

CGWB, SER, Bhubaneswar had completed the National Aquifer Mapping and Management (NAQUIM) study across the state of Odisha in March, 2023. Based on the broader recommendations of NAQUIM, CGWB, SER, Bhubaneswar took up a focused study in the coastal aquifers of Balasore and Remuna blocks of Balasore district. The NAQUIM 2.0 initiative aims to enhance our understanding of groundwater dynamics and quality in these priority regions, thereby supporting effective water resource management and sustainability. The study was undertaken in close collaboration with the State Water Resources Department, ensuring that the findings and recommendations are aligned with regional priorities and will effectively address local water management challenges.

It is with great pleasure that I present to you the report on NAQUIM 2.0 for the Balasore Sadar and Remuna blocks of Balasore district. This study represents a significant advancement in our ongoing efforts to understand and manage groundwater resources in coastal areas.

The findings presented in this report are the result of rigorous research and analysis conducted by the Central Ground Water Board (CGWB), South Eastern Region (SER), Bhubaneswar. They provide critical insights into the aquifer systems of Balasore Sadar and Remuna blocks, offering valuable data for planning and implementing strategies to safeguard our vital water resources.

I extend my heartfelt thanks to The Regional Director and the team involved in this comprehensive study. Their dedication and expertise have been instrumental in achieving the milestones of this assignment. I also express my gratitude to the stakeholders and local communities for their cooperation and support throughout this process.

N. Varadaraj

Date: 14.11.2024 **(N. Varadaraj)**

Dr. B K Sahoo
Head of Office

भारत सरकार
जल शक्ति मंत्रालय
जल संसाधन, नदी विकास
और गंगा संरक्षण विभाग
केंद्रीय भूजल बोर्ड
दक्षिण पूर्वी क्षेत्र, भुवनेश्वर ओडिशा
Government of India
Ministry of Jal Shakti
Department of Water Resources, River Development & Ganga Rejuvenation
Central Ground Water Board
South Eastern Region, Bhubaneswar
Odisha

PREFACE

Groundwater is a critical resource that sustains the livelihoods of people across regions. As population pressures increase, the demand for groundwater has surged to meet the requirements of agriculture, industry, and domestic use. After the successful completion of the 1st phase of the aquifer mapping under NAQUIM (National Aquifer Mapping and Management) studies by Central Ground Water Board (CGWB) for the entire state of Odisha which was carried out on regional scale, there has been a need to carry out the next phase of aquifer mapping (NAQUIM 2.0) studies in a more detailed manner with more data granularity for the identified problematic areas. The NAQUIM study, which involves the integration of multidisciplinary scientific approaches, plays a vital role in understanding the quantity, quality, and movement of groundwater within aquifers. This study is crucial for developing strategies for the optimal and sustainable management of ground water resources, particularly at the local level.

As part of the Annual Action Plan for 2023-24 under NAQUIM 2.0, an in-depth study was conducted in Balasore-Chandipur coastal area to assess and mitigate saline ingress, a critical issue impacting groundwater quality and availability in the region. The study area is situated in the northern coastal region of Odisha, India. The geology of the Balasore-Chandipur area is predominantly characterized by its coastal plain formation. The study area have experienced significant decline in ground water levels, with the piezometric surface dropping below mean sea level in some parts. With the fast agricultural development, rapid ground water decline during Rabi season has been noted in pockets of the study area. The over exploitation may lead to saline water ingress in coastal of the district. In the coastal tract within a width range of 5 to 10 kms from the coast, the saline water is occurring above the fresh ground water.

The selection of the study area was made with the approval of the Directorate of Ground Water Development, Department of Water Resources, Government of Odisha. The study involved the extensive collection, compilation, and analysis of field data, with contributions from state governmental agencies such as Agriculture, Odisha Lift Irrigation Corporation, Minor Irrigation, Rural Water Supply & Sanitation, and the Department of Economics & Statistics.

The present report is the result of the dedicated efforts of a skilled team: Sh. Prahallad Das, Scientist-D, Sh. Binay Kumar Behera, Scientist-C, Sh. Karnakar Kollipaka, Assistant Chemist and, Sh. Rajesh Babu Annavarapu, Assistant Geophysicist and under the guidance of team lead, Sh. Sambit Kumar Samantaray, Scientist-D. This report is expected to serve as a valuable resource for user agencies, planners, managers, academicians, and researchers, offering guidance and reference for groundwater management.

BKSahoo

Bhubaneswar
14.08.2024

(Dr. B K Sahoo
Head of Office

NAQUIM 2.0/2023-24/Theme: Coastal Area

Ground Water Management in
Parts of Balasore Sadar and Remuna Blocks
Balasore District, Odisha

Contributor's Page

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कार्यकारी सारांश

परिचय में NAQUIM 2.0 कार्यक्रम का संदर्भ और उद्देश्य दिया गया है, जिसका उद्देश्य पंचायत स्तर तक अधिक विस्तृत, साइट-विशिष्ट जलविज्ञान संबंधी जानकारी और प्रबंधन अनुशंसाएँ प्रदान करके पिछली NAQUIM पहल को आगे बढ़ाना है। मुख्य फोकस क्षेत्रों में जलभृत निपटान का आकलन, जलभृत मापदंडों को परिष्कृत करना, हस्तक्षेपों की पहचान करना और टिकाऊ भूजल प्रबंधन के लिए सुरक्षित जलभृतों का सीमांकन करना शामिल है।

बालासोर-चांदीपुर अध्ययन का प्राथमिक उद्देश्य खारे पानी के प्रवेश का आकलन करना और उसे कम करना है, जो इस क्षेत्र में भूजल की गुणवत्ता और उपलब्धता को प्रभावित करने वाला एक महत्वपूर्ण मुद्दा है। अध्ययन का उद्देश्य विभिन्न घटकों के माध्यम से इसे प्राप्त करना है, जैसे कि जलभृत निपटान विश्लेषण, जलभृत मापदंडों का परिशोधन, हस्तक्षेप योजना, पेयजल और सिंचाई के लिए संभावित जलभृतों की पहचान, और कृत्रिम पुनर्भरण के लिए पुनर्भरण क्षेत्रों का चित्रण।

यह अध्याय बालासोर-चांदीपुर अध्ययन क्षेत्र का अवलोकन प्रदान करता है, जिसमें इसकी भौगोलिक स्थिति, जलवायु परिस्थितियों और सामाजिक-आर्थिक विशेषताओं पर प्रकाश डाला गया है। यह क्षेत्र ओडिशा के उत्तरी तटीय क्षेत्र में स्थित है और यहाँ गर्म, आर्द्र ग्रीष्मकाल और हल्की सर्दियाँ वाली उष्णकटिबंधीय जलवायु का अनुभव होता है। अर्थव्यवस्था मुख्य रूप से मछली पकड़ने, पर्यटन और कृषि द्वारा संचालित है, जिसमें अच्छी तरह से विकसित परिवहन अवसंरचना है।

बालासोर-चांदीपुर क्षेत्र में जल निकासी पंचपारा , बुरहाबलांग नदियों और उनकी सहायक नदियों और वितरिकाओं द्वारा नियंत्रित होती है। नदियों का प्रवाह दक्षिण-पूर्व दिशा में है, और तट के पास स्थलाकृति के समतल होने के कारण, जल निकासी की भीड़ और मुख्य भूमि में ज्वार के पानी का प्रवेश आम बात है।

बालासोर-चांदीपुर क्षेत्र का भूविज्ञान मुख्य रूप से तटीय जलोढ़ द्वारा चिह्नित है, जिसमें युवा जलोढ़ (इकाई-I) और पुरानी जलोढ़ (इकाई-II) संरचनाएं प्राथमिक घटक हैं। तटीय मैदान रेत, गाद और मिट्टी जैसे असंगठित तलछटों से बना है, जो समय के साथ नदियों द्वारा जमा किए गए हैं। कटाव और जमाव सहित गतिशील तटीय प्रक्रियाओं ने भी परिदृश्य को आकार दिया है।

बालासोर-चांदीपुर क्षेत्र की भू-आकृति विज्ञान नदी-जल , अपरदन, अनाच्छादन और निक्षेपण प्रक्रियाओं से प्रभावित है। अध्ययन क्षेत्र की विशेषता विभिन्न भू-आकृति इकाइयों से है, जिसमें युवा जलोढ़ मैदान, पुराने जलोढ़ मैदान, समुद्र तट, चैनल बार, तटीय मैदान, बाढ़ के मैदान और लैटेराइट ऊपरी भूमि आदि शामिल हैं। इन विशेषताओं का भूजल व्यवस्था और इसकी विशेषताओं पर महत्वपूर्ण प्रभाव पड़ता है।

बालासोर-चांदीपुर क्षेत्र के भूमि उपयोग और भूमि आवरण विश्लेषण से पता चलता है कि अधिकांश भूमि (64%) का उपयोग कृषि योग्य उद्देश्यों के लिए किया जाता है, उसके बाद ग्रामीण बस्तियों (8%) का स्थान आता है। कुल वन भूमि भौगोलिक क्षेत्र का लगभग 1% है, जबकि जल निकाय और आर्द्रभूमि कुल क्षेत्र का लगभग 4% हिस्सा है।

बालासोर-चांदीपुर क्षेत्र की मिट्टी की संरचना में तीन मुख्य मिट्टी समूहों का प्रभुत्व है: अल्फिसोल , एरिडिसोल और एंटिसोल । अल्फिसोल सबसे अधिक प्रचलित हैं, जो भौगोलिक क्षेत्र के लगभग 59% हिस्से को कवर करते हैं, इसके बाद एरिडिसोल (36%) और एंटिसोल (5%) हैं। इन मिट्टी की विशेषताओं का भूजल पुनर्भरण, गुणवत्ता और क्षेत्र की समग्र जल विज्ञान स्थितियों पर सीधा प्रभाव पड़ता है।

बालासोर-चांदीपुर क्षेत्र का भूभाग मुख्य रूप से समतल है, जिसकी समुद्र तल से ऊँचाई 0 से 30 मीटर तक है। निचले तटीय क्षेत्रों की ऊँचाई 0-10 मीटर है, जबकि अध्ययन क्षेत्र का उत्तर-पश्चिमी भाग, जो नीलगिरि पर्वत श्रृंखला के संपर्क में है, की ऊँचाई 20-30 मीटर है।

पिछले NAQUIM अध्ययन के आधार पर, बालासोर-चांदीपुर अध्ययन क्षेत्र को भूजल गर्तों की उपस्थिति, भूजल स्तर में महत्वपूर्ण गिरावट और खारे पानी के घुसपैठ के जोखिम के कारण उच्च प्राथमिकता वाले क्षेत्र के रूप में पहचाना गया है। इस क्षेत्र को तटीय खारे पानी के प्रवेश के लिए प्रवण और फ्लोराइड और लौह संदूषण जैसे जल गुणवत्ता के मुद्दों से प्रभावित के रूप में भी वर्गीकृत किया गया है, जिसके लिए लक्षित हस्तक्षेप की आवश्यकता है।

यह अध्याय बालासोर जिले में किए गए पिछले NAQUIM अध्ययन के प्रमुख निष्कर्षों और गतिविधियों का सारांश प्रस्तुत करता है, जिसमें सभी 12 ब्लॉकों को शामिल किया गया था और जिले के लिए भूजल व्यवस्था, जलभृत विशेषताओं और प्रबंधन रणनीतियों की व्यापक समझ प्रदान की गई थी।

यह अध्याय अध्ययन क्षेत्र में खोदे गए अन्वेषण कुओं और डेटा से प्राप्त जलभृत मापदंडों का विवरण प्रस्तुत करता है। असंबद्ध/फ्रीएटिक जलभृत के बारे में जानकारी सीजीडब्ल्यूबी अन्वेषण कुओं, अवलोकन कुओं, पीजोमीटर और ओडिशा लिफ्ट सिंचाई कुओं से प्राप्त की गई है। जलभृत निपटान विश्लेषण ने युवा जलोढ़ (इकाई-I) और पुराने जलोढ़ (इकाई-II) जलभृतों की उपस्थिति का खुलासा किया है, जिसमें जलभृत मापदंडों, जैसे कि संप्रेषणीयता और भंडारण क्षमता , को परिष्कृत किया गया है।

अध्ययन क्षेत्र में भूमिगत लिथोलॉजी और जलभृत व्यवस्था को चित्रित करने के लिए वर्टिकल इलेक्ट्रिकल साउंडिंग (वीईएस) सर्वेक्षणों सहित भूभौतिकीय जांच की गई। वीईएस डेटा व्याख्या ने विभिन्न लिथोलॉजिकल परतों की प्रतिरोधकता और मोटाई में भिन्नताओं की पहचान करने में मदद की है, जिन्हें फिर संबंधित हाइड्रोजियोलॉजिकल मापदंडों में अनुवादित किया गया। अध्ययन ने क्षेत्र का एक 3डी स्ट्रेटीग्राफी मॉडल भी प्रदान किया है, जो जलभृत प्रणाली को समझने में सहायता करता है।

यह अध्याय अध्ययन क्षेत्र से मानसून-पूर्व और मानसून-पश्चात अवधि के दौरान एकत्रित भूजल स्तर के आंकड़ों का विश्लेषण प्रस्तुत करता है। मानसून -पूर्व अवधि में जल स्तर की गहराई 3.26 से 23.54 mbglऔर मानसून-पश्चात अवधि में 2.35 से 23.65 mbgl तक होती है। जल स्तर में उतार-चढ़ाव 1.00 से 10.00 मीटर तक होता है, और दीर्घकालिक जल स्तर के रुझान मानसून-पूर्व और मानसून-पश्चात अवधि दोनों में मामूली गिरावट दर्शाते हैं।

भूजल गुणवत्ता विश्लेषण में भौतिक-रासायनिक मापदंडों, प्रमुख आयन सांद्रता और हाइड्रो-भू-रासायनिक पहलुओं सहित विभिन्न पहलुओं को शामिल किया गया है। अध्ययन में पाया गया कि भूजल के नमूनों में उच्च विद्युत चालकता (1000 μS / सेमी से ऊपर के 24-26% नमूने) और उच्च फ्लोराइड सांद्रता (पीने के लिए स्वीकार्य सीमा से अधिक 10-15% नमूने) प्रदर्शित होती है। धनायन और ऋणायन अनुपातों के विश्लेषण के साथ-साथ गिब्स आरेख, भूजल प्रणाली को नियंत्रित करने वाली हाइड्रो-भू-रासायनिक प्रक्रियाओं में अंतर्दृष्टि प्रदान करते हैं।

सिंचाई उद्देश्यों के लिए भूजल की उपयुक्तता के आकलन में विभिन्न जल गुणवत्ता सूचकांकों की गणना शामिल थी, जैसे सोडियम अवशोषण अनुपात (एसएआर), सोडियम प्रतिशत (एनए%), अवशिष्ट सोडियम कार्बोनेट (आरएससी), और मैग्नीशियम खतरा (एमएच)। परिणाम बताते हैं कि भूजल नमूनों का एक महत्वपूर्ण अनुपात (40-48%) सिंचाई के लिए "संदिग्ध" या "अनुपयुक्त" के रूप में वर्गीकृत किया गया है, मुख्य रूप से उच्च लवणता और सोडियम से संबंधित चिंताओं के कारण।

पीने के प्रयोजनों के लिए भूजल की गुणवत्ता के विश्लेषण से पता चलता है कि फ्लोराइड को छोड़कर, प्रमुख आयन सांद्रता आम तौर पर भारतीय पेयजल मानक (आईएस 10500:2012) द्वारा निर्धारित अनुमेय सीमाओं के भीतर हैं। हालांकि, नमूनों का एक बड़ा हिस्सा (52-45%) जल गुणवत्ता सूचकांक (डब्ल्यूक्यूआई) गणना के आधार पर "खराब" जल गुणवत्ता के रूप में वर्गीकृत किया गया था, मुख्य रूप से उच्च फ्लोराइड स्तर और खराब भौतिक रासायनिक विशेषताओं के कारण।

अध्ययन क्षेत्र में समुद्री जल घुसपैठ के आकलन में विभिन्न संकेतकों का विश्लेषण शामिल था, जैसे कि Cl-/HCO3- अनुपात, Na/Cl अनुपात, और हाइड्रोकेमिकल फेसेस इवोल्यूशन (HFE) आरेख। परिणाम बताते हैं कि समुद्री जल घुसपैठ की सीमा अपेक्षाकृत सीमित है, जिसमें 67-68% भूजल नमूनों को Cl-/HCO3- अनुपात के आधार पर "अच्छी गुणवत्ता" वाले पानी के रूप में वर्गीकृत किया गया है। हालांकि, मध्यम से हानिकारक संदूषण के स्थानीयकृत क्षेत्रों की पहचान की गई, जो निरंतर निगरानी और प्रबंधन की आवश्यकता को दर्शाता है।

पिछले अध्याय में किए गए विश्लेषण के आधार पर, यह खंड बालासोर-चांदीपुर क्षेत्र में खारे पानी के घुसपैठ की सीमा का व्यापक मूल्यांकन प्रदान करता है। अध्ययन में भूजल प्रणाली पर समुद्री जल के प्रभाव को निर्धारित करने के लिए Cl-/HCO3- अनुपात, Na/Cl अनुपात और HFE आरेख सहित कई संकेतकों का उपयोग किया गया है। निष्कर्ष समुद्री जल घुसपैठ की अपेक्षाकृत सीमित सीमा का सुझाव देते हैं, जिसमें अधिकांश भूजल नमूने मीठे पानी की विशेषताओं को प्रदर्शित करते हैं।

समुद्री जल के प्रवेश की सीमा के विश्लेषण के आधार पर, यह अध्याय अध्ययन क्षेत्र में खारे पानी के प्रवेश को रोकने और कम करने के लिए अनुशंसित हस्तक्षेपों की रूपरेखा प्रस्तुत करता है। प्रमुख रणनीतियों में कृत्रिम भूजल पुनर्भरण तकनीकों को लागू करना, सतही जल और भूजल के संयुक्त उपयोग को बढ़ावा देना, भूजल निष्कर्षण के लिए एक मजबूत नियामक ढांचा स्थापित करना और भूजल की गुणवत्ता की निरंतर निगरानी करना शामिल है।

इस अध्याय में अध्ययन के दौरान किए गए अतिरिक्त उपायों और अवलोकनों को शामिल किया गया है, जिसमें स्थानीय क्षेत्रों में ट्रेस धातु संदूषण (जैसे, बेरियम, बोरॉन, लोहा) की पहचान, फ्रीएटिक और उथले सीमित जलभृतों में लौह संदूषण की सीमा, बढ़ते झींगा पालन उद्योग का भूजल संसाधनों पर प्रभाव, और स्थानीय किसानों से मानसून की वर्षा पर उनकी निर्भरता और सिंचाई के लिए भूजल तक सीमित पहुंच के बारे में प्राप्त फीडबैक शामिल हैं।

बालासोर-चांदीपुर क्षेत्र के लिए भूजल संसाधन का आकलन जीईसी-2022 दिशा-निर्देशों के अनुसार आबंटन विधि का उपयोग करके किया गया था। अध्ययन में कुल वार्षिक भूजल पुनर्भरण (18,055.2 हैम), प्राकृतिक निर्वहन (1,487.569 हैम) और निकाले जाने योग्य भूजल संसाधनों (16,567.63 हैम) का परिमाणन किया गया है। इस विश्लेषण के आधार पर, भूजल संसाधन उपयोग के संदर्भ में क्षेत्र को "सुरक्षित" के रूप में वर्गीकृत किया गया है।

यह अध्याय बालासोर-चांदीपुर क्षेत्र के लिए अनुशंसित भूजल गुणवत्ता प्रबंधन हस्तक्षेपों की रूपरेखा प्रस्तुत करता है, जिसमें आपूर्ति पक्ष की रणनीतियाँ (कृत्रिम भूजल पुनर्भरण, सतही जल और भूजल का संयुक्त उपयोग) और माँग पक्ष की रणनीतियाँ (भूजल निष्कर्षण प्रबंधन, भूजल गुणवत्ता निगरानी और उपचार, सामुदायिक सहभागिता, सिंचाई जल प्रबंधन, और भूजल मूल्य निर्धारण/प्रोत्साहन तंत्र) शामिल हैं। अध्याय में विभिन्न उद्देश्यों के लिए सुरक्षित जलभृतों की पहचान और सीमांकन पर भी चर्चा की गई है।

अध्ययन क्षेत्र में भूजल और वर्षा के स्थिर समस्थानिक विश्लेषण से भूजल प्रणाली को नियंत्रित करने वाले स्रोतों, पुनर्भरण तंत्रों और हाइड्रोजियोकेमिकल प्रक्रियाओं के बारे में बहुमूल्य जानकारी मिलती है। वर्षा और भूजल की समस्थानिक संरचना, साथ ही ड्यूटेरियम अधिशेष विश्लेषण, क्षेत्र में वाष्पीकरण प्रक्रियाओं के प्रभुत्व को इंगित करता है, जिसका भूजल पुनर्भरण और प्रबंधन पर प्रभाव पड़ता है।

भूजल गुणवत्ता विशेषताओं और पुनर्भरण क्षमता के आकलन के आधार पर, यह अध्याय बालासोर-चांदीपुर क्षेत्र में कृत्रिम भूजल पुनर्भरण तकनीकों को लागू करने की संभावनाओं पर चर्चा करता है। विश्लेषण से पता चलता है कि भूजल नमूनों का एक महत्वपूर्ण अनुपात अनुकूल पारगम्यता विशेषताओं को प्रदर्शित करता है, जो कृत्रिम पुनर्भरण विधियों, जैसे कि घुसपैठ तालाब, पुनर्भरण कुओं और प्रबंधित जलभृत पुनर्भरण की क्षमता को दर्शाता है।

यह अध्याय बालासोर-चांदीपुर क्षेत्र में पीने के उद्देश्यों के लिए भूजल स्रोतों की स्थिरता पर केंद्रित है। सामान्य जल गुणवत्ता, फ्लोराइड संदूषण और जल गुणवत्ता सूचकांक (WQI) के विश्लेषण से पता चलता है कि भूजल संसाधनों का एक बड़ा हिस्सा (52-45%) उचित उपचार के बिना सीधे उपभोग के लिए उपयुक्त नहीं है। अध्याय उन विशिष्ट स्थानों की पहचान करता है जो उच्च फ्लोराइड स्तरों या खराब समग्र जल गुणवत्ता के कारण पीने के लिए अनुपयुक्त हैं।

यह अध्याय बालासोर-चांदीपुर क्षेत्र में सिंचाई उद्देश्यों के लिए भूजल संसाधनों की उपयुक्तता का आकलन करता है। विभिन्न सिंचाई उपयुक्तता सूचकांकों, जैसे लवणता जोखिम, सोडियम अवशोषण अनुपात (एसएआर), सोडियम प्रतिशत (एनए%), अवशिष्ट सोडियम कार्बोनेट (आरएससी), और मैग्नीशियम जोखिम (एमएच) का मूल्यांकन, यह दर्शाता है कि भूजल नमूनों का एक महत्वपूर्ण अनुपात (40-48%) उच्च लवणता और सोडियम-संबंधी चिंताओं के कारण सिंचाई के लिए "संदिग्ध" या "अनुपयुक्त" के रूप में वर्गीकृत किया गया है।

बालासोर-चांदीपुर अध्ययन क्षेत्र में किए गए व्यापक अध्ययन से विभिन्न पहलुओं पर मूल्यवान डेटा और जानकारी प्राप्त हुई है, जिसमें जलभृत की स्थिति और विशेषताएं, भूजल स्तर की गतिशीलता, भूजल की गुणवत्ता, सिंचाई की उपयुक्तता, पीने के पानी की गुणवत्ता और समुद्री जल के घुसपैठ की सीमा शामिल है। अध्ययन से प्राप्त प्रमुख निष्कर्ष और अंतर्दृष्टि क्षेत्र के सामने आने वाली महत्वपूर्ण चुनौतियों का समाधान करने के लिए प्रभावी भूजल प्रबंधन रणनीति विकसित करने के लिए एक ठोस आधार प्रदान करते हैं।

अध्ययन के विश्लेषण और निष्कर्षों के आधार पर, अध्याय में बालासोर-चांदीपुर क्षेत्र के लिए सिफारिशों का एक सेट प्रस्तुत किया गया है, जिसमें कृत्रिम पुनर्भरण के माध्यम से भूजल संवर्धन, सतही जल और भूजल के संयुक्त उपयोग, भूजल निष्कर्षण के विनियमन, जल गुणवत्ता के मुद्दों (फ्लोराइड और लौह संदूषण) का समाधान, झींगा पालन के प्रभावों का प्रबंधन, और स्थायी भूजल प्रबंधन के लिए स्थानीय समुदायों के साथ जुड़ने पर ध्यान केंद्रित किया गया है।

Executive Summary

The introduction provides the context and objectives of the NAQUIM 2.0 program, which aims to build on the previous NAQUIM initiative by providing more detailed, site-specific hydrogeological information and management recommendations down to the panchayat level. The key focus areas include assessing aquifer disposition, refining aquifer parameters, identifying interventions, and demarcating safer aquifers for sustainable groundwater management.

The primary objective of the Balasore-Chandipur study is to assess and mitigate saline ingress, a critical issue impacting groundwater quality and availability in the region. The study aims to achieve this through various components, such as aquifer disposition analysis, refinement of aquifer parameters, intervention planning, identification of potential aquifers for drinking water and irrigation, and delineation of recharge areas for artificial recharge.

This chapter provides an overview of the Balasore-Chandipur study area, highlighting its geographical location, climatic conditions, and socio-economic characteristics. The area is situated in the northern coastal region of Odisha and experiences a tropical climate with hot, humid summers and mild winters. The economy is primarily driven by fishing, tourism, and agriculture, with well-developed transportation infrastructure.

The drainage in the Balasore-Chandipur area is controlled by the Panchpara, Burhabalang rivers, and their tributaries and distributaries. The rivers have a south-easterly flow direction, and due to the flattening of the topography near the coast, drainage congestion and tidal water ingress into the mainland are common occurrences.

The geology of the Balasore-Chandipur area is predominantly characterized by coastal alluvium, with the Younger Alluvium (Unit-I) and Older Alluvium (Unit-II) formations being the primary constituents. The coastal plain is composed of unconsolidated sediments like sand, silt, and clay, deposited by rivers over time. Dynamic coastal processes, including erosion and deposition, have also shaped the landscape.

The geomorphology of the Balasore-Chandipur area is influenced by fluviomarine, erosional, denudational, and depositional processes. The study area is characterized by various geomorphic units, including younger alluvial plains, older alluvial plains, beaches, channel bars, coastal plains, flood plains, and lateritic uplands, among others. These features have a significant impact on the groundwater regime and its characteristics.

The land use and land cover analysis of the Balasore-Chandipur area reveals that the majority of the land (64%) is used for arable purposes, followed by rural settlements (8%). The total forest land covers around 1% of the geographical area, while water bodies and wetlands account for approximately 4% of the total area.

The pedology of the Balasore-Chandipur area is dominated by three main soil groups: Alfisols, Aridisols, and Entisols. Alfisols are the most prevalent, covering approximately 59% of the geographical area, followed by Aridisols (36%) and Entisols (5%). These soil characteristics have a direct influence on the groundwater recharge, quality, and overall hydrogeological conditions of the region.

The terrain in the Balasore-Chandipur area is primarily flat, with an elevation ranging from 0 to 30 meters above mean sea level. The low-lying coastal areas have an elevation of 0-10 meters, while the northwestern part of the study area, which is in contact with the Nilgiri hill range, has an elevation of 20-30 meters.

Based on the previous NAQUIM study, the Balasore-Chandipur study area has been identified as a high-priority area due to the presence of groundwater troughs, significant decline in groundwater levels, and the risk of saline water intrusion. The area has also been categorized as prone to coastal saline ingress and affected by water quality issues, such as fluoride and iron contamination, requiring targeted interventions.

The chapter summarizes the key findings and activities of the previous NAQUIM study conducted in the Balasore district, which covered all 12 blocks and provided a comprehensive understanding of the groundwater regime, aquifer characteristics, and management strategies for the district.

This chapter presents the details of the exploratory wells drilled in the study area and the aquifer parameters derived from the data. The information on the unconfined/phreatic aquifer has been obtained from the CGWB exploratory wells, observation wells, piezometers, and Odisha Lift Irrigation wells. The aquifer disposition analysis has revealed the presence of the Younger Alluvium (Unit-I) and Older Alluvium (Unit-II) aquifers, with the aquifer parameters, such as transmissivity and storativity, being refined.

The geophysical investigations, including Vertical Electrical Sounding (VES) surveys, were carried out to delineate the subsurface lithology and aquifer disposition in the study area. The VES data interpretation has helped in identifying the variations in resistivity and thickness of the different lithological layers, which were then translated into corresponding hydrogeological parameters. The study has also provided a 3D stratigraphy model of the area, aiding in the understanding of the aquifer system.

This chapter presents the analysis of groundwater level data collected from the study area during the pre-monsoon and post-monsoon periods. The depth to water level ranges from 3.26 to 23.54 mbgl in the pre-monsoon period and 2.35 to 23.65 mbgl in the post-monsoon period. The water level fluctuations vary from 1.00 to 10.00 meters, and the long-term water level trends indicate a modest decline in both pre-and post-monsoon periods.

The groundwater quality analysis covers various aspects, including physicochemical parameters, major ion concentrations, and hydrogeochemical facies. The study found that the groundwater samples exhibit high electrical conductivity (24-26% of samples above 1000 μS/cm) and elevated fluoride concentrations (10-15% of samples exceeding the permissible limit for drinking). The analysis of cation and anion ratios, as well as Gibbs diagrams, provides insights into the hydrogeochemical processes governing the groundwater system.

The assessment of groundwater suitability for irrigation purposes involved the calculation of various water quality indices, such as Sodium Adsorption Ratio (SAR), Sodium Percentage (Na%), Residual Sodium Carbonate (RSC), and Magnesium Hazard (MH). The results indicate that a significant proportion of the groundwater samples (40-48%) are classified as "doubtful" or "unsuitable" for irrigation, primarily due to high salinity and sodium-related concerns.

The analysis of groundwater quality for drinking purposes reveals that the major ion concentrations, except for fluoride, are generally within the permissible limits set by the Indian drinking water standard (IS 10500:2012). However, a substantial portion of the samples (52-45%) were classified as having "poor" water quality based on the Water Quality Index (WQI) calculation, primarily due to high fluoride levels and poor physicochemical characteristics.

The assessment of seawater intrusion in the study area involved the analysis of various indicators, such as the Cl^-/HCO_3^- ratio, Na/Cl ratio, and Hydrochemical Facies Evolution (HFE) diagram. The results suggest that the extent of seawater intrusion is relatively limited, with 67-68% of the groundwater samples classified as having "good quality" water based on the Cl^-/HCO_3^- ratio. However, localized pockets of moderate to injurious contamination were identified, indicating the need for continued monitoring and management.

Building on the analysis in the previous chapter, this section provides a comprehensive assessment of the extent of saline intrusion in the Balasore-Chandipur area. The study utilizes multiple indicators, including Cl^-/HCO_3^- ratio, Na/Cl ratio, and HFE diagram, to determine the influence of seawater on the groundwater system. The findings suggest a relatively limited extent of seawater intrusion, with the majority of the groundwater samples exhibiting freshwater characteristics.

Based on the analysis of the extent of seawater intrusion, this chapter outlines the recommended interventions for containing and mitigating the saline ingress in the study area. The key strategies include implementing artificial groundwater recharge techniques, promoting conjunctive use of surface water and groundwater, establishing a robust regulatory framework for groundwater extraction, and continuous monitoring of groundwater quality.

This chapter covers additional measures and observations made during the study, including the identification of trace metal contamination (e.g., barium, boron, iron) in localized areas, the extent of iron contamination in the phreatic and shallow confined aquifers, the impact of the growing shrimp farming industry on groundwater resources, and the feedback received from local farmers regarding their dependence on monsoon rainfall and limited access to groundwater for irrigation.

The groundwater resource estimation for the Balasore-Chandipur area was carried out using the apportioning method, as per the GEC-2022 guidelines. The study quantifies the total annual groundwater recharge (18,055.2 Ham), natural discharges (1,487.569 Ham), and extractable groundwater resources (16,567.63 Ham). Based on this analysis, the area has been categorized as "safe" in terms of groundwater resource utilization.

This chapter outlines the recommended groundwater quality management interventions for the Balasore-Chandipur area, including supply-side strategies (artificial groundwater recharge, conjunctive use of surface water and groundwater) and demand-side strategies (groundwater abstraction management, groundwater quality monitoring and remediation, community engagement, irrigation water management, and groundwater pricing/incentive mechanisms). The chapter also discusses the identification and demarcation of safer aquifers for various purposes.

The stable isotopic analysis of groundwater and rainfall in the study area provides valuable insights into the sources, recharge mechanisms, and hydrogeochemical processes governing the groundwater system. The isotopic composition of rainfall and groundwater, as well as the deuterium excess analysis, indicate the dominance of evaporation processes in the region, which has implications for groundwater recharge and management.

Based on the assessment of groundwater quality characteristics and recharge potential, this chapter discusses the scope for implementing artificial groundwater recharge techniques in the Balasore-Chandipur area. The analysis suggests that a significant proportion of the groundwater samples exhibit favorable permeability characteristics, indicating the potential for artificial recharge methods, such as infiltration ponds, recharge wells, and managed aquifer recharge.

This chapter focuses on the sustainability of groundwater sources for drinking purposes in the Balasore-Chandipur area. The analysis of general water quality, fluoride contamination, and the Water Quality Index (WQI) reveals that a substantial portion of the groundwater resources (52-45%) are not suitable for direct consumption without appropriate treatment. The chapter identifies specific locations that are unsuitable for drinking due to high fluoride levels or poor overall water quality.

The chapter assesses the suitability of groundwater resources for irrigation purposes in the Balasore-Chandipur area. The evaluation of various irrigation suitability indices, such as salinity hazard, Sodium Adsorption Ratio (SAR), Sodium Percentage (Na%), Residual Sodium Carbonate (RSC), and Magnesium Hazard (MH), indicates that a significant proportion of the groundwater samples (40-48%) are classified as "doubtful" or "unsuitable" for irrigation due to high salinity and sodium-related concerns.

The comprehensive investigation carried out in the Balasore-Chandipur study area has generated valuable data and information on various aspects, including aquifer disposition and characteristics, groundwater level dynamics, groundwater quality, irrigation suitability, drinking water quality, and the extent of seawater intrusion. The key findings and insights from the study provide a solid foundation for developing effective groundwater management strategies to address the critical challenges faced by the region.

Based on the analysis and findings of the study, the chapter presents a set of recommendations for the Balasore-Chandipur area, focusing on groundwater augmentation through artificial recharge, conjunctive use of surface water and groundwater, regulation of groundwater extraction, addressing water quality issues (fluoride and iron contamination), managing the impacts of prawn farming, and engaging with local communities for sustainable groundwater management.

Contents

List of Figures:

List of Tables:

List of Annexures:

1. Introduction

National Aquifer Mapping & Management (NAQUIM) programme was launched by CGWB in 2012. The study was carried out on 1:50,000 Scale, NAQUIM 2.0 was carried out on small scale to address specific issues. It also aims to enhance data density, to involve state agencies and to ensure output maps and management plan are put in place with a sense of local ownership.

NAQUIM 2.0 studies will be i) providing information in higher granularity with a focus on increasingly density of dynamic data like ground water level, ground water quality etc. ii) Providing issue based scientific inputs for groundwater management in Panchayat level, iii) providing printed maps to the users and iv) putting in place a stratergy to ensure implementation of the recommended stratergies.

2. Objective of the study Area:

The primary objective of the Balasore-Chandipur study area is to assess and mitigate saline ingress, a critical issue impacting groundwater quality and availability in the region. The study, conducted during the AAP 2023-24, focuses on several key components to achieve this objective:

Aquifer Disposition Analysis: Through field data acquisition and analysis, the study aims to determine the disposition of aquifers in the area. Understanding the distribution and characteristics of aquifers is essential for assessing groundwater resources and identifying areas susceptible to saline intrusion.

Refinement of Aquifer Parameters: The study seeks to estimate and refine aquifer parameters crucial for resource assessment. By analyzing aquifer-specific groundwater levels and quality data, the refinement of parameters such as transmissivity and storativity can be better utilized for effective groundwater management.

Intervention Planning and Safer Aquifer Demarcation: Utilizing the data on groundwater levels and quality, interventions can be proposed, and safer aquifers can be demarcated. This is vital for managing saline intrusion and ensuring sustainable groundwater usage in the area.

Identification of Potential Aquifers for Drinking Water and Irrigation: The study aims to identify potential aquifers suitable for drinking water supply and irrigation purposes. This involves assessing groundwater quality and availability to prioritize aquifers for sustainable water supply and agricultural needs.

Delineation of Recharge Areas for Artificial Recharge: Mapping recharge areas and developing suitable artificial recharge plans are crucial steps in sustaining groundwater resources. By delineating recharge areas, the study facilitates informed decision-making for artificial recharge initiatives, contributing to long-term groundwater sustainability.

Overall, the Balasore-Chandipur study area aims to address the pressing issue of saline ingress by comprehensively analyzing aquifer disposition, refining/estimation of the aquifer parameters, planning interventions, identifying suitable aquifers for water supply and irrigation, delineating recharge areas and other measures. The insights gained from this study will not only inform policy-making decisions but also aid in sustainable groundwater management and resource allocation for the benefit of both the state government and stakeholders involved.

3. Study Area:

Balasore-Chandipur, situated in the northern coastal region of Odisha, India, boasts a picturesque landscape characterized by sandy beaches along the Bay of Bengal. With its coordinates approximately at 21^0 20’ 07’’- 21^0 30’ 50’’ N latitude and 87^0 54’ 37’’ -87^0 07’ 30’’E longitude, the area experiences a tropical climate, featuring hot, humid summers and mild winters, with significant monsoon rainfall from June to September. Economically, fishing thrives due to its coastal location, while tourism flourishes, particularly in Chandipur, renowned for its unique tidal phenomenon and scenic beaches. Agriculture also plays a vital role, with crops like rice and pulses cultivated in the surrounding areas. Transportation is facilitated by well-connected road networks, a major railway junction at Balasore, and proximity to Biju Patnaik International Airport in Bhubaneswar. Culturally, the region is rich in history, dotted with ancient temples and archaeological sites, and celebrates festivals like Durga Puja and Ratha Yatra with enthusiasm. Overall, Balasore-Chandipur is a vibrant blend of natural beauty, economic activity, and cultural heritage, making it a significant part of Odisha's coastal landscape.

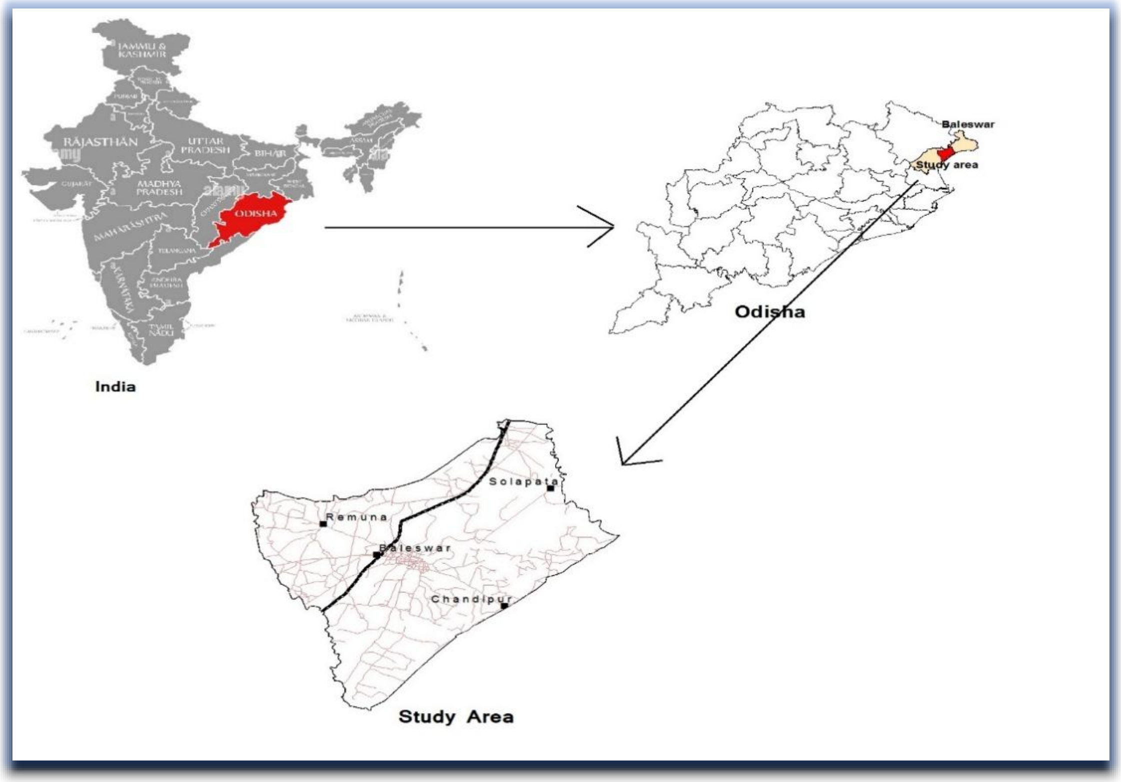


FIGURE 1: LOCATION MAP OF THE STUDY AREA.

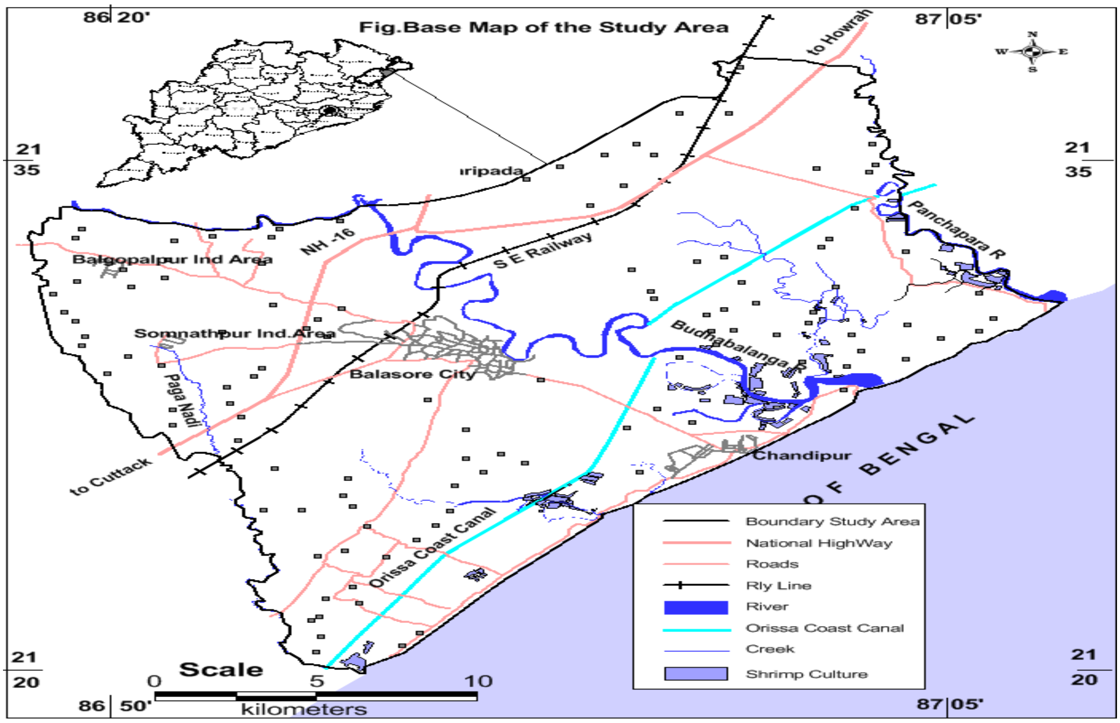


FIGURE 2: ADMINISTRATIVE MAP OF BALASORE-CHANDIPUR STUDY AREA.

Temperature: During summer months the maximum temperature rises to 45^0 C and May is the hottest month. December is the coldest month of the year when the night temperature sometimes drops down to 9^0C.

TABLE 1: MONTHLY LONG TERM AVERAGE TEMPERATURES OF BALASORE CHANDIPUR AREA.

Month	Daily Mean Temperature °C		
	Minimum	Maximum	Average
January	14.4	27.1	20.8
February	17.5	29.5	23.5
March	21.4	33.4	27.4
April	24.4	35.9	30.2
May	25.7	35.7	30.7
June	26.0	33.9	30.0
July	25.7	32.2	29.0
August	25.6	31.7	28.7
September	25.2	32.1	28.7
October	23.1	31.9	27.5
November	18.7	30.1	24.4
December	14.5	27.4	21.0
ANNUAL	**21.9**	**31.7**	**26.8**

I. **Rainfall:** Southwest monsoon is the principal source of precipitation in the study area. The normal annual rainfall of the district is 1568.4, out of which about 85% is received during monsoon season (mid June to mid October). The month of July and August gets the heaviest rainfall of the year, though rainfall is not very regular throughout the season but uniform throughout the district.

There are on the average 60 – 85 rainy days in a year. Besides, the relative humidity varies between 30 % to 86 %. The district faces occasional flash floods, which, because of the terrain, cause heavy damage to roads and crops. Drought is an almost constant feature that visits the district almost every alternate year. Year-wise monthly rainfall and long-term analysis of rainfall data has been attached in the annexure-I And annexure-II.

TABLE 2: MEAN ANNUAL PRECIPITATION EVENTS IN THE STUDY AREA.

Month	**Yearly Mean Number of days with**				
	RAIN	**HAIL**	**THUNDER**	**FOG**	**SQUALL**
January	1.0	0.0	0.3	0.7	0.0
February	2.4	0.0	1.7	0.9	0.0
March	2.6	0.1	3.3	0.5	0.0
April	4.3	0.3	4.7	0.0	0.3
May	7.3	0.1	6.3	0.0	0.5
June	11.3	0.0	5.8	0.0	0.2
July	13.6	0.0	5.5	0.0	0.0
August	15.3	0.0	5.9	0.0	0.0
September	11.5	0.0	6.6	0.0	0.0
October	5.9	0.0	3.5	0.1	0.0
November	1.7	0.0	0.2	0.0	0.0
December	0.5	0.0	0.0	0.1	0.0
Annual	**77.5**	**0.5**	**43.9**	**2.2**	**1.1**

TABLE 3: AVERAGE MONTHLY (1995-2022) RAINFALL IN THE STUDY AREA.

Month	J	F	M	A	M	J	J	A	S	O	N	D	Total
Rainfall (mm)	**12.89**	**20.7**	**26.58**	**53.70**	**148.**	**243.81**	**289.69**	**341.6**	**334.85**	**207.39**	**32.78**	**7.63**	**1658.6**

II. **Humidity:** Relative humidity is around 26 - 82% throughout the year. Humidity of the air is generally high during southwest monsoon season and decreases from the end of November due to cold wave.

TABLE 4: MONTHLY LONG TERM AVERAGE RELATIVE HUMIDITY IN THE STUDY AREA.

Month	**Daily Mean Relative Humidity (Expressed as %)**		
	Highest	**Lowest**	**Average**
January	67	64	66
February	60	55	58
March	59	60	60
April	63	64	64
May	74	74	74
June	77	76	77
July	78	77	78
August	78	79	79
September	81	89	85
October	81	83	82
November	61	69	65
December	63	65	64
ANNUAL	**70**	**71**	**71**

III. **Wind:** Wind is generally light to moderate. During summer and southwest monsoon season, wind velocity increases. In the post-monsoon months and in winter, wind is mainly from the north and east. During summer wind direction is variable and in rainy season wind from southwest direction is very common. The southern part of the district is prone to cyclonic storms.

4. Drainage:

The Balasore-Chandipur area is not particularly known for its extensive river systems, but it does have some notable rivers and canals that contribute to the local ecosystem and economy. The details are as follows:

Budhabalanga River: Another notable river in the area is the Budhabalanga River. Originating in the Similipal Hills of Odisha, it flows through Balasore district. The Budhabalanga is not as large as the Subarnarekha but still contributes to the agricultural activities and ecology of the region. It meets the Bay of Bengal at the Chandipur area.

Panchupada River: Another river in the area is Panchpada river which is in the eastern most end of the study area which is generated due to conjuction of two rivers namely Baradia river and Jalaka river of the Mayurbhanj. It also contributes to the agricultural activities and ecology of the region. It meets the Bay of Bengal at the Dublagadhi area.

Canals: In addition to rivers, there are several smaller canals and waterways in the Balasore-Chandipur area. These canals are often used for irrigation purposes, helping to distribute water from the rivers to agricultural lands. They also serve as transportation routes for local communities and facilitate the movement of goods.

Drainage: The drainage in the area is controlled by Panchpara, Burhabalang rivers and their tributaries and distributaries. All these rivers are having south easterly flow direction. Due to flattening of topography nearby the coast, drainage congestion takes place along the month of the river and during high tide often the tidal water ingress into quite a long distance into the mainland. During heavy downpour also, the runoff water inundates the low-lying areas due to very low capacity of the rivers and the streams. The rivers often meander giving rise to the occasional formation of oxbow lakes along their courses. The drainage patterns of the streams are dendritic nearby the foothills.

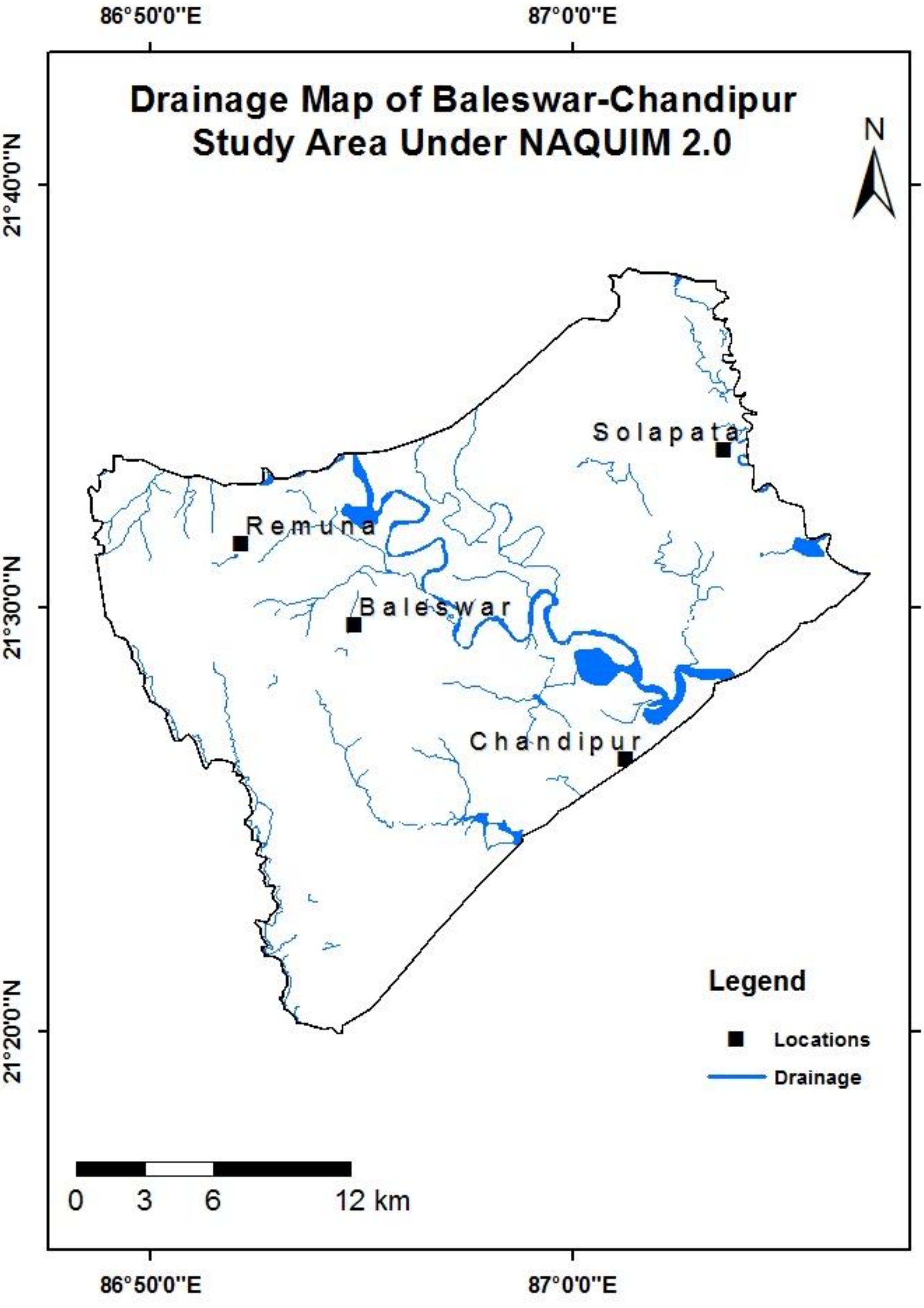


FIGURE 3: DRAINAGE MAP OF BALASORE-CHANDIPUR STUDY AREA.

5. Geology:

The geology of the Balasore-Chandipur area, is predominantly characterized by its coastal plain formation. The coastal plain is predominantly composed of Aeolian alluvium termed as the younger alluvium. This plain, extending from the coastline to inland regions, consists of unconsolidated sediments like sand, silt, and clay, primarily deposited by rivers such as the Subarnarekha and Budhabalanga over millions of years and represented as the older alluvium. These

Alluvial deposits contribute to the fertility of the soil, supporting agriculture, which is vital to the region's economy. Along the coastline, various features such as beaches, dunes, and estuaries are prominent, with Chandipur Beach showcasing unique phenomena like the receding sea during low tide. While the terrain is generally flat, localized geological structures such as minor faults or folds might be present. Dynamic coastal processes, including erosion to form the Lateritic deposits in the northern part of the study area and deposition, continually shape the coastline, leading to the formation of diverse features like spits, bars, and lagoons.

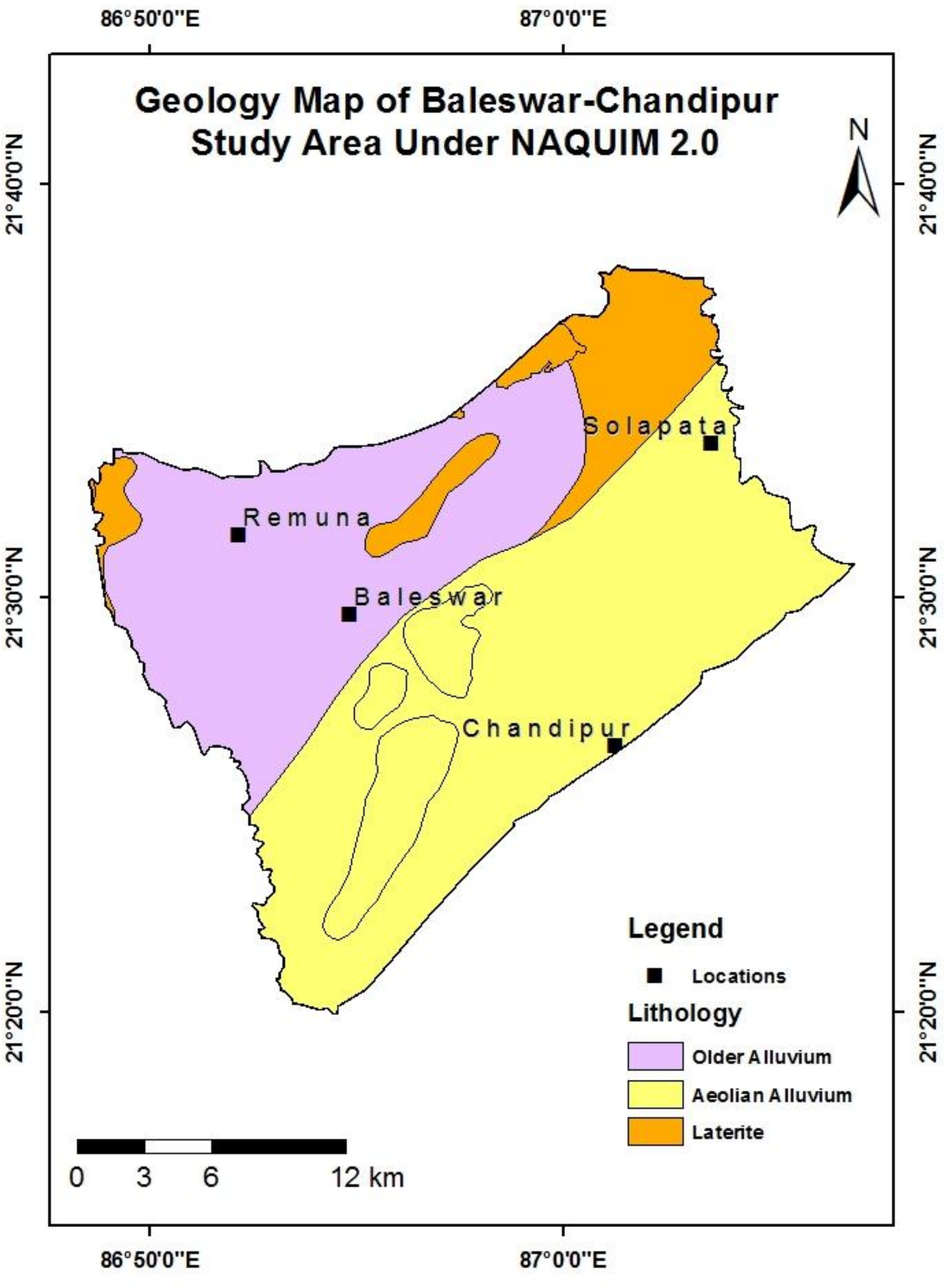


FIGURE 4: GEOLOGY MAP OF BALASORE-CHANDIPUR STUDY AREA.

6. Geomorphology:

Geomorphology: Hydrogeomorphological features of Balasore district are mainly attributed to fluviomarine, erosional, denudational and depositional processes. The coastal plain has been developed due to fluviomarine processes. The alluvial plains owe their origin due to various fluviatile actions of major rivers. The details of the geomorphic unit as identified are as below:
Younger Alluvial Plain: This is a flat to gently undulating plain of large extent formed by river action. The area encompasses various fluvial landforms in the latter stage of deposition in the fluvial cycle. This constitutes unconsolidated materials like gravel, sand and clay of varying size and forms prolific aquifers. Ground water prospects is good to excellent.

Older Alluvial Plain: These landforms have been developed during earlier cycle of deposition in a fluviatile environment. The lithology and ground water prospect are like that of younger alluvial plain.

Beach: Beach is mainly formed by marine action. Beach ridges are very common, and these are formed due to sea waves. They are mainly consisting of sand mixed with silt etc. Ground water prospect is good within a depth of 30-40 m, where fresh ground water pockets are available. Deep tube wells in these areas may lead to sea water ingress.

Channel Bar: It is a depositional fluvial landform developed inside the channel due to the recession of the velocity of water. It is mainly consisting of alluvial deposits. Ground water prospect is good.

Coastal Plain: Coastal plain predominantly consist of sand silt and clay is developed all along the coast of Balasore district. It is developed all along the coast of Balasore district. It is gently slopping plain occurring parallel to the coast. The saline marshy tract with shrubby vegetation comes under this coastal plain. Tidal streams are very active during high tide time. Ground water prospect is good, but salinity is a major problem in this tract.

Flood Plain: This is an area adjacent to the river and mostly built up by river borne deposits during high floods. Flood plains primarily consist of unconsolidated materials like sand, gravel and silt. Groundwater prospect is good to very good.

Lateritic Upland: These are mostly formed on the highland areas and over early Pleistocene sediments. The lateritic appears to form in the surfacial decomposition zone of iron rich rocks where the seasonal rainfall regime causes considerable water table fluctuation, where the rainfall is heavy enough to cause leaching and deep weathering. Lateritic uplands are occurring in the western hilly tact in Nilgiri and northern tertiary tract bordering Mayurbhanj district. The thickness of this lateritic crust varies from 10 to 12 m. The depth to water level is deeper in these formations.

Mud flat: This is a relatively marshy area covered with fine silt and mud along the shore. Mangroves vegetation is very common. Ground water quality is mostly saline.

Paleo mud flat:

These are the ancient mud flat consisting of fine sand and mud. These are mostly converted to agricultural land in due course of time. Due to marine regression ground water quality is saline.

Meander Deposits: This is an abandoned river course mostly filled with alluvial deposits. Ground water prospects are good to excellent.

Oxbow Lake: This is a cut off meander filled with alluvial material. The shape of the landform looks like an oxbow. Ground water prospect is excellent.

Paleo Channel: This includes buried as well as abandoned channels. These are mostly comprised of fluvial deposits of varying grain size. Ground water prospect is good to excellent.

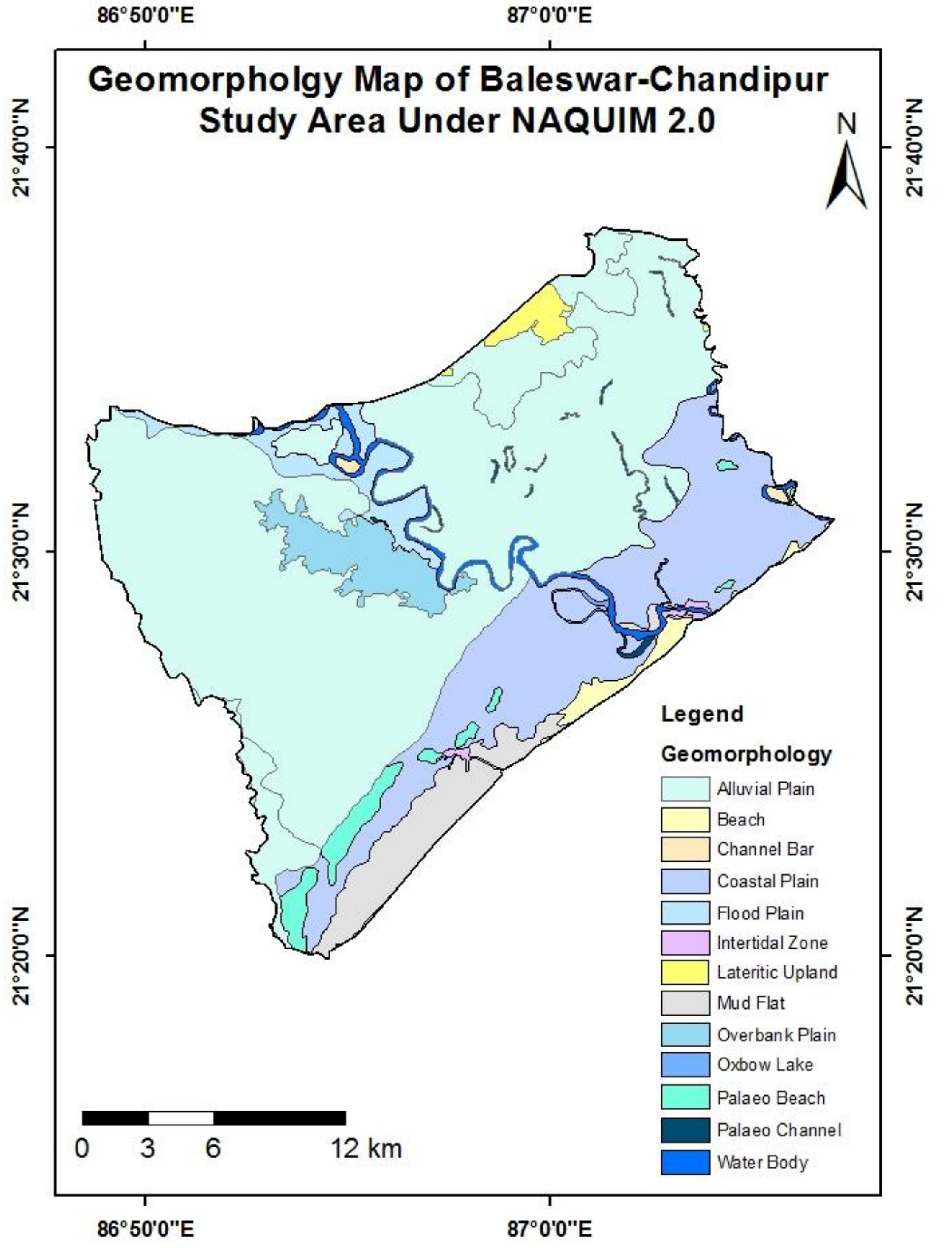


FIGURE 5: GEOMORPHOLOGY MAP OF BALASORE-CHANDIPUR STUDY AREA.

TABLE 5: GEOGRAPHICAL DISTRIBUTION OF GEOMORPHIC UNITS OF THE STUDY AREA, ODISHA

Geomorphology Unit	**In Sq. Km.**
Alluvial Plain	323.9106
Beach	20.3352
Channel Bar	2.905028
Coastal Plain	114.7486
Flood Plain	8.715084
Intertidal zone	2.905028
Lateritic Upland	2.905028
Mud Flat	13.07263
Overbank Plain	1.452514
Oxbow Lake	1.452514
Paleo Beach	8.715084
Paleo Channel	2.905028
Water Body	15.97765

7. Land Use & Land Cover:

The district being primarily agrarian can be appreciated from the fact that the major landuse in the study area is Arable land covers 64% of the geographical area. This is followed by Rural Settlements which covers around 8% of the geographical area. Total forest land grouped together covers around 1% of the geographical area. This is followed by water bodies which covers around 3% of the geographical area. Waterlogged part and wetlands cover around 1% of the total geographical area of the Balasore-Chandipur study area.

TABLE 6: LAND USE OF THE STUDY AREA.

Land Use	**In Sq.km**
Arable Land	332.4808
Fallows	110.3836
Waste Land	3.98977
Forest	3.98977
Plantation	3.98977
Settlements	42.55754
Water Body	14.62916
Waterlogged area	7.97954

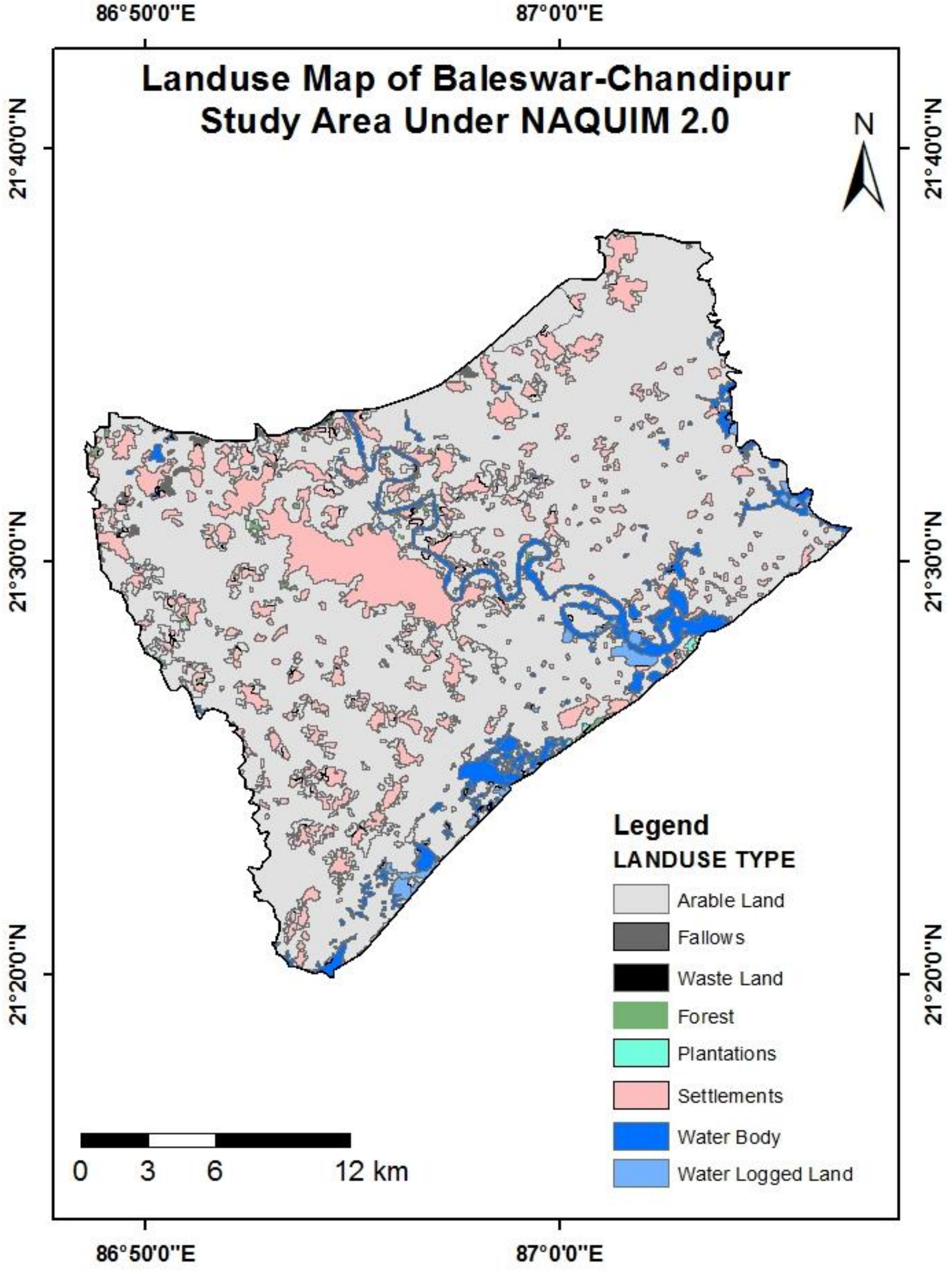


FIGURE 6: LANDUSE AND LAND COVER MAP OF THE AREA.

8. Pedology:

Pedology: Four main types of soil groups (USDA Soil Classification System) can be observed in the Balasore District. These are Alfisols, Aridisols, and Entisols. The brief description of each of these pedologic units are given below:

I. Alfisols:

Alfisols form in semiarid to humid areas, typically under a hardwood forest cover. They have a clay enriched subsoil and relatively high native fertility. "Alf" refers to aluminium (Al) and iron (Fe). Because of their productivity and abundance, the Alfisols represent one of the more important soil orders for food and fiber production. They are widely used both in agriculture and forestry and are generally easier to keep fertile than other humid climate soils. Alfisols have undergone only moderate leaching. definition, they have at least 35% base saturation, meaning calcium, magnesium, and potassium are relatively abundant. They are the most dominant soil groups in the district, occupying approximately 59% of the geographical area. They can be further sub-divided into Older Alluvial Soils, Red Gravelly Soils and Red Sandy Soils.

II. Aridisols:

Aridisols (from the Latin aridus, for “dry”, and solum) form in an arid or semi-arid climate. Aridisols dominate the deserts and xeric shrublands, Aridisols have a very low concentration of organic matter, reflecting the paucity of vegetative production on these dry soils. Water deficiency is the major defining characteristic of aridisols. Also required is sufficient age to exhibit subsoil weathering and development. Limited leaching in aridisols often results in one or more subsurface soil horizons in which suspended or dissolved minerals have been deposited: silicate clays, sodium, calcium carbonate, gypsum or soluble salts. These subsoil horizons can also be cemented by carbonates, gypsum or silica. Accumulation of salts on the surface can result in salinization. This soil group is the third most predominant pedologic unit in Balsore District covering about 36% of the geographic area. They can be further sub-divided into Saline& Saline Alkaline soils and Saline Beach Soils.

III. **Entisols:**

Entisols are defined as soils that do not show any profile development other than an A horizon. An entisol has no diagnostic horizons, and most are basically unaltered from their parent material, which can be unconsolidated sediment or rock. Entisols have been abundant in the paleopedological record ever since Silurian, though, unlike other soil orders, they do not have value as indicators of climate. This soil group is the least predominant soil group in the Balsore District occupying around 5% of the studyarea.

TABLE 7: SOIL TYPES

Soil Type	Spreading in Sq.Km.
Alfisol	307.3389356
Aridisol	189.3557423
Entisol	23.30532213

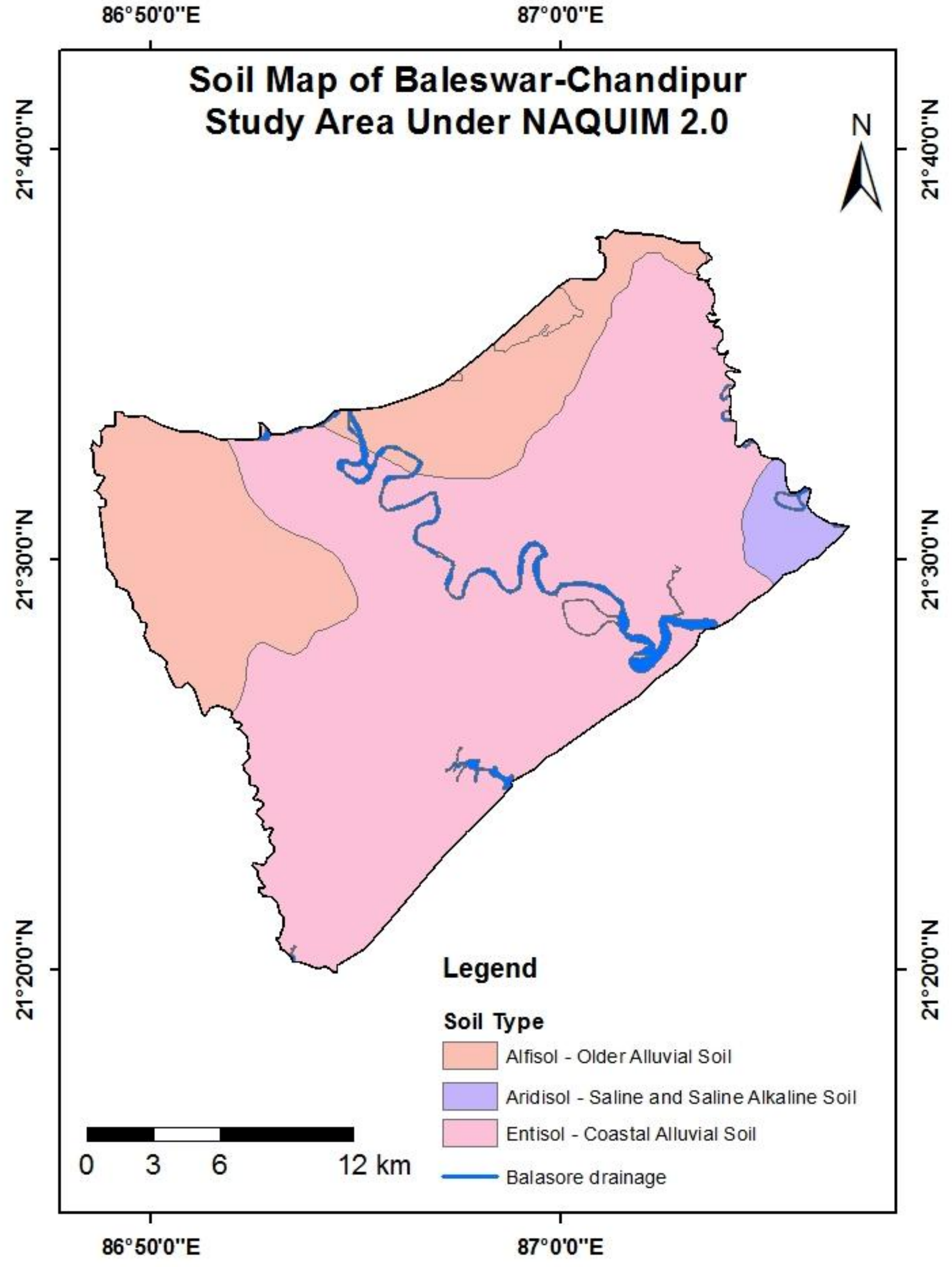


FIGURE 7: PEDOLOGY MAP OF BALASORE-CHANDIPUR AREA

9. Elevation:

The Balasore-Chandipur area is primarily influenced by the geomorphology of its river and coastal systems. Over time, sediments from the province have been deposited, starting from the tertiary period, Quaternaries and continuing with recent sequential sedimentation by rivers such as Budhabalanga, Subarnarekha, and Panchupada. As a result, the terrain near the coastline is flat with a low elevation of 0-10 meters above mean sea level. In the northwestern part of the study area, there is contact with the Nilgiri hill range, which can be identified by an elevation level of 20-30 meters above mean sea level.

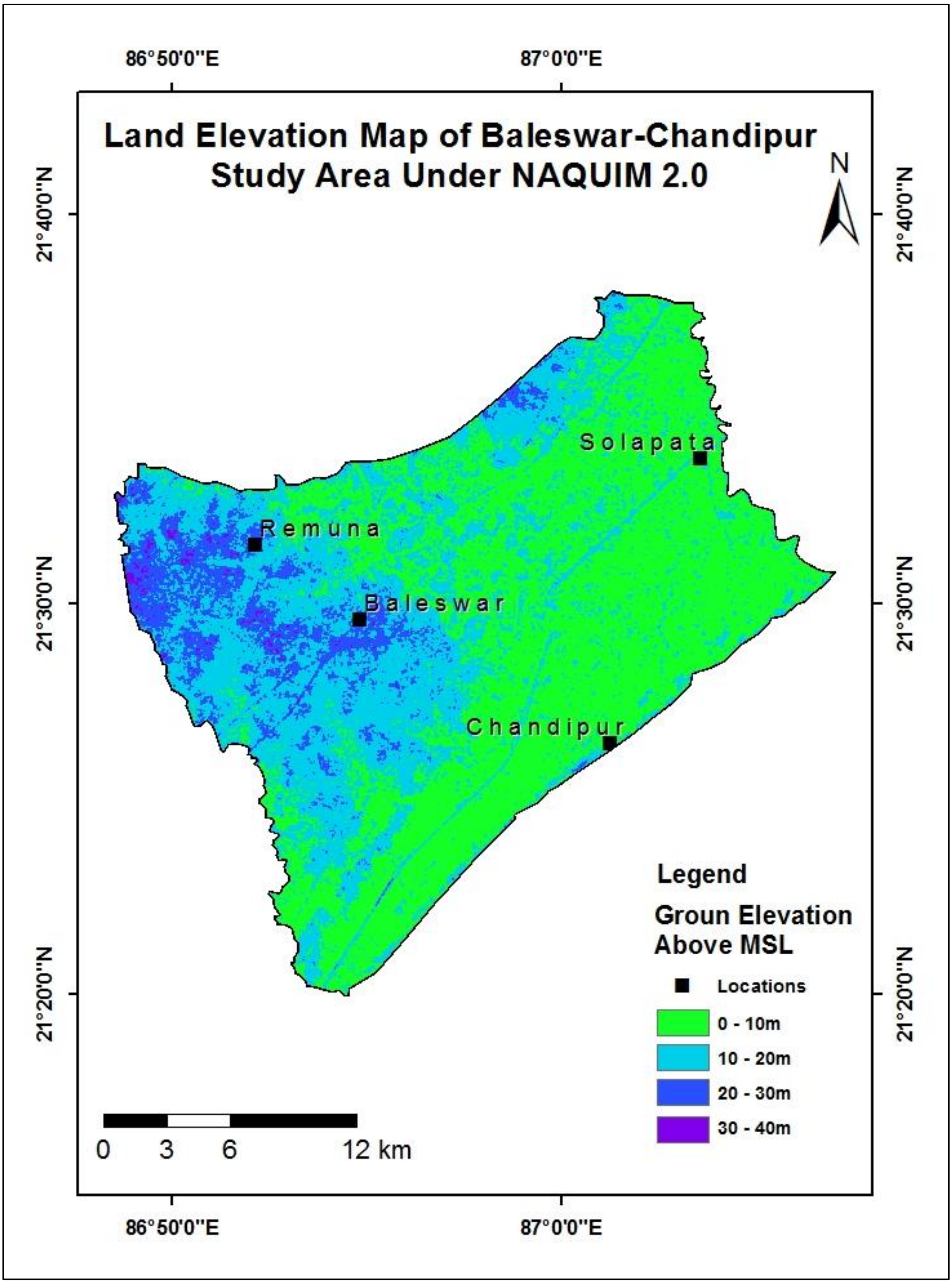


FIGURE 8: ELEVATION MAP OF THE BALASORE-CHANDIPUR STUDY AREA.

10. Priority types

- Based on the information of NAQUIM Report of the Balasore district, the Balasore-Chandipur study areas come under the Groundwater trough area. These areas have experienced significant decline in ground water levels, with the piezometric surface dropping below mean sea level in some parts. This poses a risk of saline water intrusion. These were identified as high priority areas requiring immediate interventions.
- Prone Coastal Saline Ingress Areas: as per the previous NAQUIM study in the year 2016-17.
    - Kalyani-Chandipur-Chandaneswar tract in Balasore, Baliapal and Bhograi blocks.
    - Narrow coastal strip of 4-10 km width where fresh and saline water aquifers are intermixed
- Careful management of ground water extraction is required in these coastal areas to prevent saline water intrusion.
- Water Quality Affected Areas:
    - Parts of Nilgiri, Remuna and Balasore blocks affected by fluoride contamination, mainly in the hard rock aquifers
    - Isolated pockets in alluvial areas affected by iron contamination, especially near the laterite contact zones
- These areas require specific interventions like artificial recharge, surface water utilization, and treatment systems to address the water quality issues.
- Other Areas:
    - The remaining parts of the district, where ground water development is relatively lower, were considered as medium priority areas.

11. Previous Studies

- National Aquifer Mapping and Management (NAQUIM) program was undertaken by CGWB in Balasore district during the 12th Five Year Plan period (2012-2017). The objective was to carry out detailed hydrogeological investigations and aquifer mapping.
- The study covered all 12 blocks of Balasore district, which has a total geographical area of 3,806 sq. km.
- CGWB compiled and analysed historical data from various sources like state government departments, IMD, Census, etc. along with data generated during the NAQUIM study.
- Key activities undertaken included:
  - Compilation of existing ground water data and identification of data gaps
  - Generation of additional ground water data through exploratory wells, geophysical surveys, water level and quality monitoring
  - Preparation of aquifer maps indicating aquifer geometry, characteristics and disposition of fresh/saline water zones
  - Preparation of aquifer management plans for sustainable development and management of ground water resources
- The study found that the district is underlain by consolidated Archaean-Proterozoic formations in the northwest, overlain by Tertiary and Quaternary sedimentary formations in the rest of the district.
- Ground water occurs under unconfined, semi-confined and confined conditions. Aquifer systems were delineated into Aquifer-I (shallow aquifer), Aquifer-II (deeper semi-confined) and Aquifer-III (deeper confined).
- Key ground water issues identified were - formation of ground water troughs, salinity ingress in coastal areas, and water quality issues like iron and fluoride contamination in parts of the district.
- Aquifer management strategies were proposed, including artificial recharge, shifting to surface water sources, and remedial measures for water quality problems.

In summary, the CGWB carried out a comprehensive hydrogeological assessment of Balasore district under the NAQUIM program to understand the ground water regime and develop management plans for sustainable utilization of the resource.

12. Aquifer Disposition:

I. Details of Exploratory Wells:

The information in respect of un-confined/Phreatic aquifer has been generated from CGWB Exploratory wells (EW), OW and Piezometers and Odisha Lift Irrigation wells are necessary for establishing aquifer geometry and determining aquifer parameters. Data from the existing exploratory wells drilled in the area under Ground Water Exploration programme of CGWB is presented in Figure below and the adequacy of Exploration data is given in Table below.

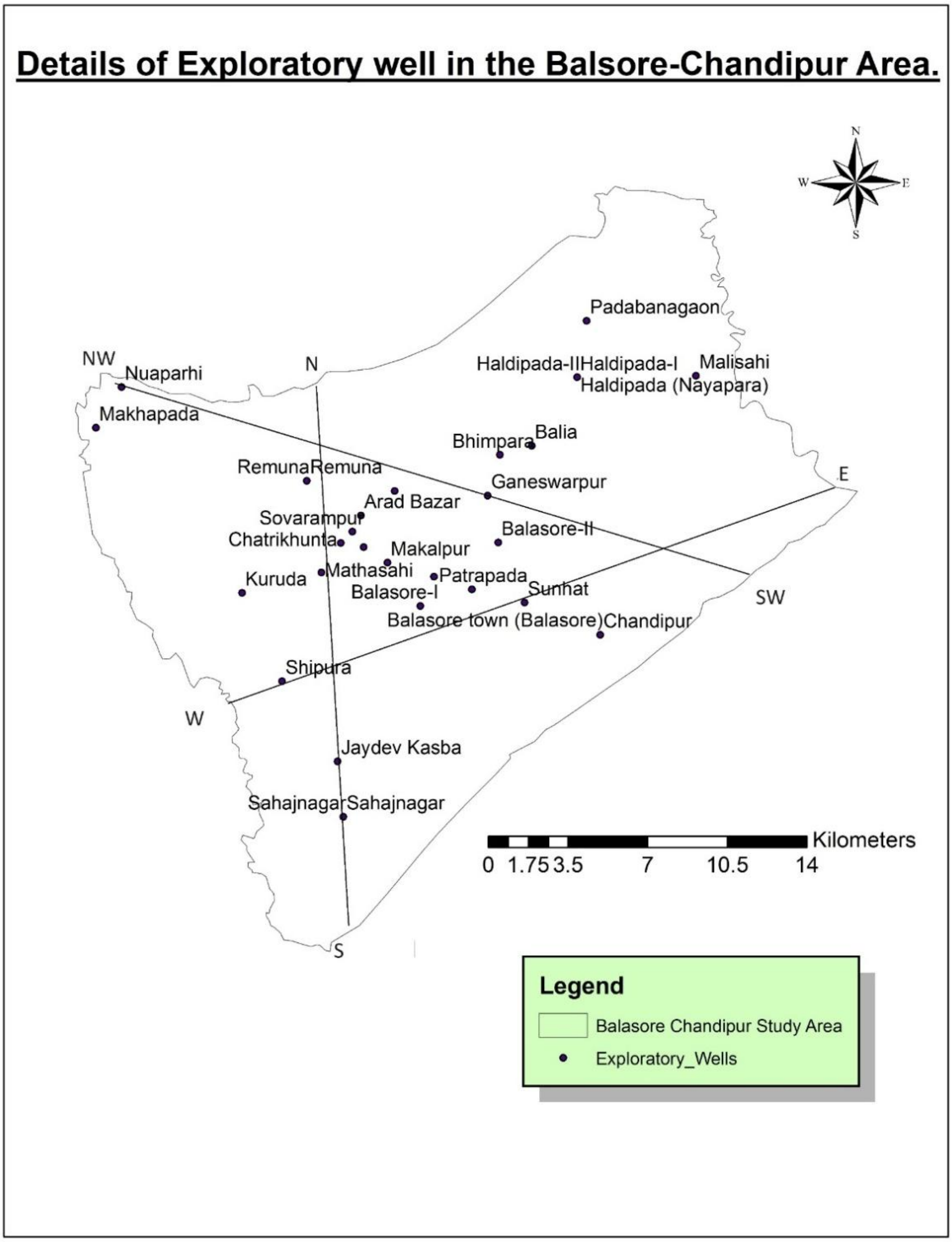


FIGURE 9: EXISTING EXPLORATORY WELLS UNDER NAQUIM STUDY OF BALASORE.

TABLE 8: DETAILS OF THE EXPLORATORY WELLS

Sl. No.	Name of Site	Depth of Drilling	Aquifers Tapped			Aquifer Parameter									Aquifer Quality			Any Other Information
			Aq-I	Aq-II	Aq-III	Aq-I			Aq-II			Aq-III			Aq-I	Aq-II	Aq-III	
						K	T	S	K	T	S	K	T	S				
1	Kuruda	77.5	41-44, 52-61, 68-71 m				490											Yield- 36 lps DD-7.95m
2	Arad Bazar	70	39-46, 52-66 m															Yield- 12.5 lps DD-8.81m
3	Balasore-I	102		90-96 m												Fresh		
4	Bhimpara	76.97	17-25, 30-50, 55-70 m				491.7								Fresh			Yield- 54 lps DD-12.2m
5	Chandipur	307	12-157, 157-244, 244-307 m				217 m² / day								12-157(S), 157-244 (F) 244-307 (S)			Yield- 4.72 lps DD-13.1m
6	Dharampur	302.63	18-25, 32-39, 44-63, 66-72, 84-90				661								Fresh			Yield- 21 lps DD- 11.31m
7	Haldipada (Nayapara)	112	38-44				873	1.3x10-3										Yield- 40 lps DD- 6.7m
8	Malisahi	222			155-185, 200-220 m								1160 m² / day				Fresh	Yield- 65.83 lps DD-10.775m
9	Padabanagaon	268.55	20-30, 34-42, 57-65, 73-86, 100-115, 160-168				261								Fresh			Yield- 49 lps DD- 13.81m
10	Rupsa	124		61-67, 87-93, 97-103, 118-121											Fresh			Yield- 30 lps DD- 3.5m
11	Matasahi	103.78	34- 38, 45-51, 57- 60 m												Fresh			Yield- 10 lps DD- 2.84 m
12	Police Line	84	47-54, 67-75.0m				202								Fresh			Yield- 26.28 lps DD- 8.59 m

13	Public High School	71.68	42-48, 51-55, 60-66 m				405								Fresh			Yield- 37.8 lps DD- 4.6 m
14	Sobharampur	74	44-56,62-65 m				411								Fresh			Yield- 36 lps DD- 17 m
15	Sunhat	309	37-40, 43-52, 55-59, 63-75, 89-92 m				217								0-214 (F) 214-304 (B)			Yield- 34.4 lps DD- 18.34 m
16	Ganeswarpur	101.2	30-33, 36.5-44, 45.5-47, 49-52, 57.5-55.5,				374.5								Fresh			Yield- 31 lps DD- 7.21 m
17	Remuna	300		**34-40, 44-50, 55-61, 84-96 m**			**1734 m² / day**								**All Fresh**			**Yield-** 50.69 **lps** **DD-** 8.77

II. Hydrogeology

The hydrogeological conditions vary from place to place depending upon the aquifer characteristics of the litho units, sources of groundwater recharge and the structural setting of the area. The hydrogeological unit of the area is mainly consisting of Unconsolidated formations.

Unconsolidated Formation:

A. Older Alluvium (Unit-II)

River carrying sediments from Tertiary Period as well as the Quaternary period by the rivers Budhabalanga, Subarnarekha and Panchupada forms the older alluvium. The Older alluvium strips constitute the most potential aquifers due to their high degree of porosity and permeability but are only limited in their occurrence. Ground water in these formations occurs under unconfined to semi-confined condition. These formations generally consist of alternating layers of sand and clay/silt, forming a multiple aquifer system. Since these are oxidized sediments, there is a higher likelihood of groundwater quality issues compared to the younger alluvium. Due to the proximity of the coast to the study area, the only potential cause of groundwater quality issues is saline intrusion from the sea or interactions between aquifers that may result in certain hydrogeochemical reactions leading to increased levels of certain parameters.

B. Younger Allvium (Unit-I)

River carrying sediments from Sub recent to recent period by the rivers Budhabalanga, Panchupada forms the younger alluvium. Mainly Laterites and alluvium of Sub-recent to Recent age constitute the younger alluvium formations. Laterites occurring as capping over older formations are highly porous in nature and form good aquifers to be tapped through dug wells. The alluvial deposits of recent origin occur as thin discontinuous patches along the prominent drainage channels. The alluvium strips constitute the most potential aquifers due to their high degree of porosity and permeability but are only limited in their occurrence. Ground water in these formations occurs under unconfined to semi-confined conditions. These mainly consist of Clay, silt, and sand which form potential shallow aquifers tapped through tubewell.

The information regarding unconfined/phreatic aquifers has been obtained from CGWB exploratory wells, observation wells, piezometers and Odisha lift irrigation wells. The map showing the distribution of aquifers has been created using the collected data and is illustrated below.

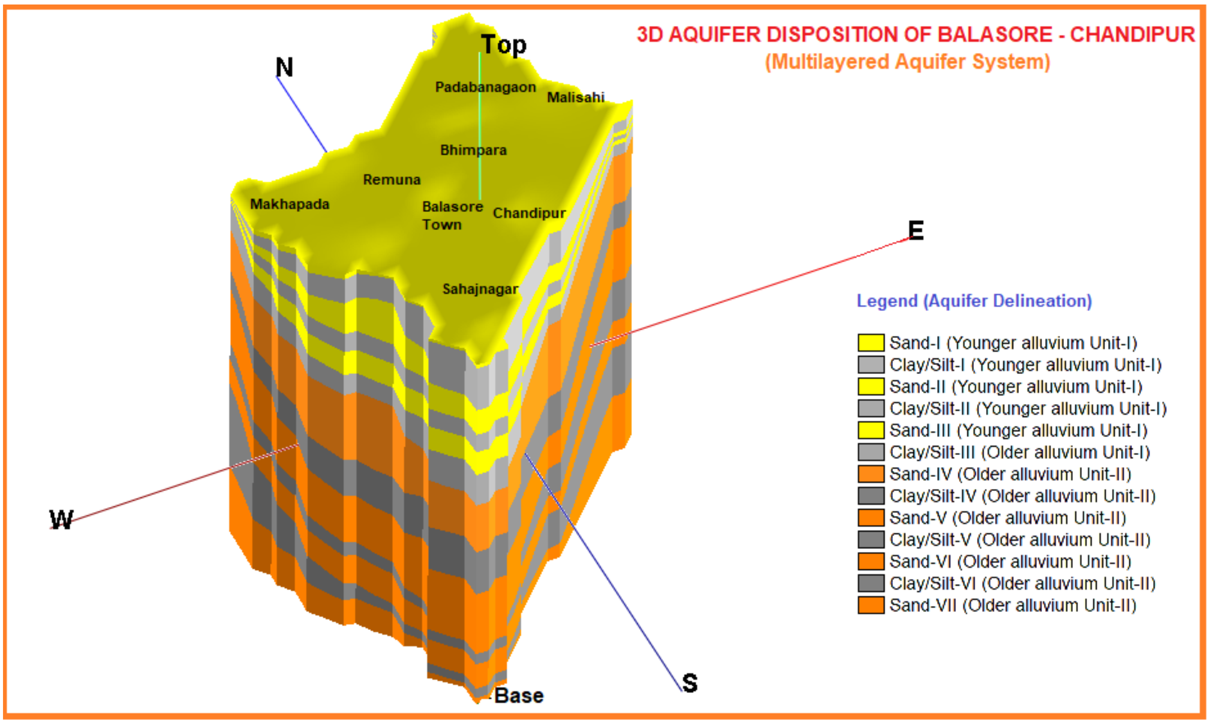


FIGURE 10: 3D- AQUIFER DISPOSITION OF BALASORE-CHANDIPUR AREA.

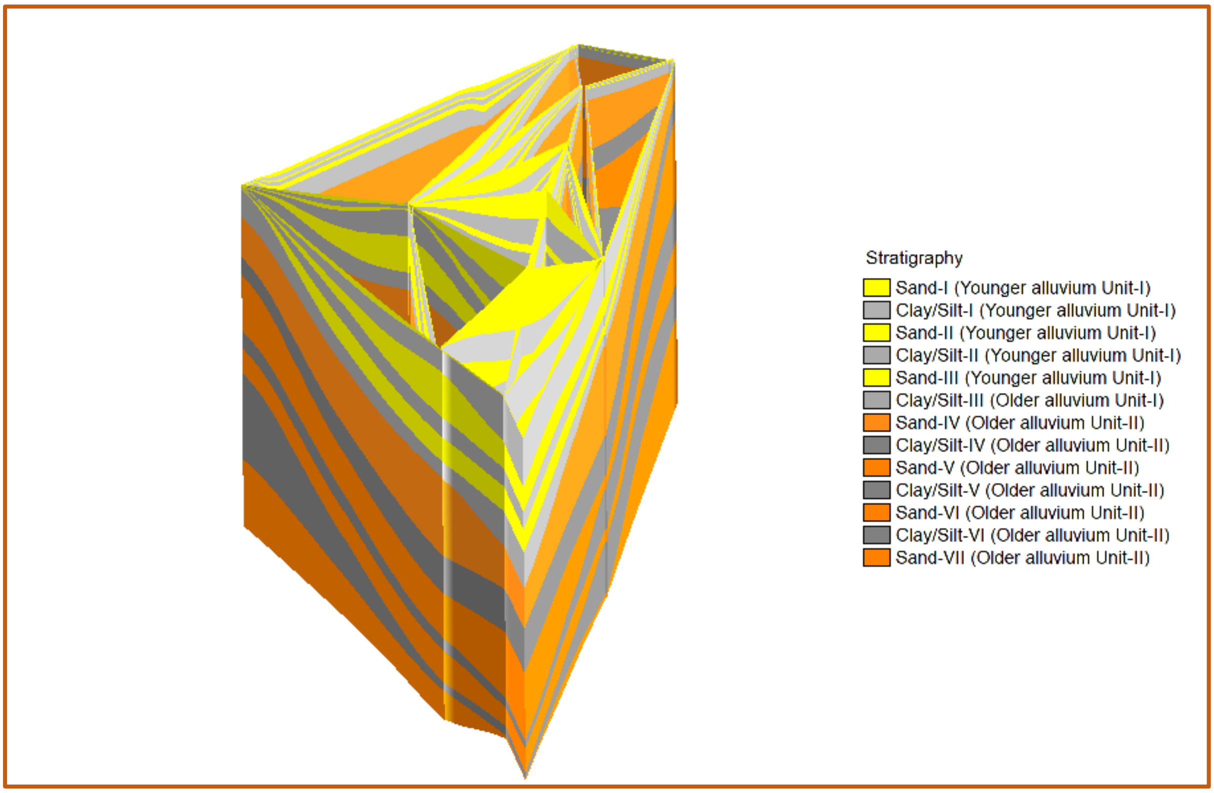


FIGURE 11: 3 D FENCE DIAGRAM OF THE AQUIFER SYSTEMS OF THE STUDY AREA.

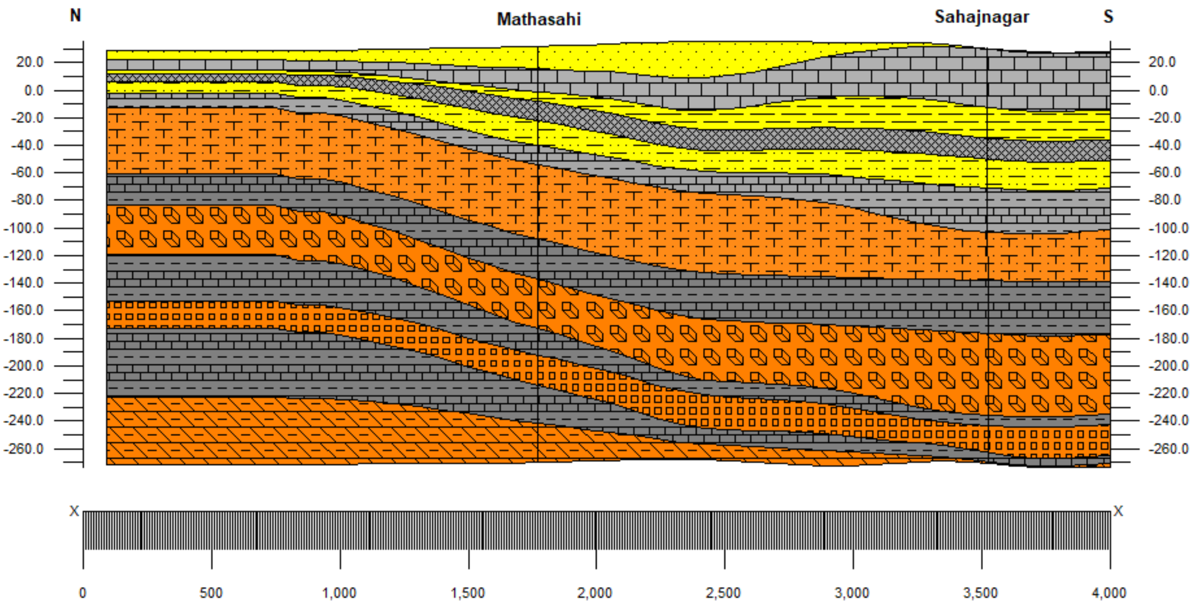


FIGURE 12: N-S CROSS-SECTION VIEW OF THE AQUIFERS OF THE AREA.

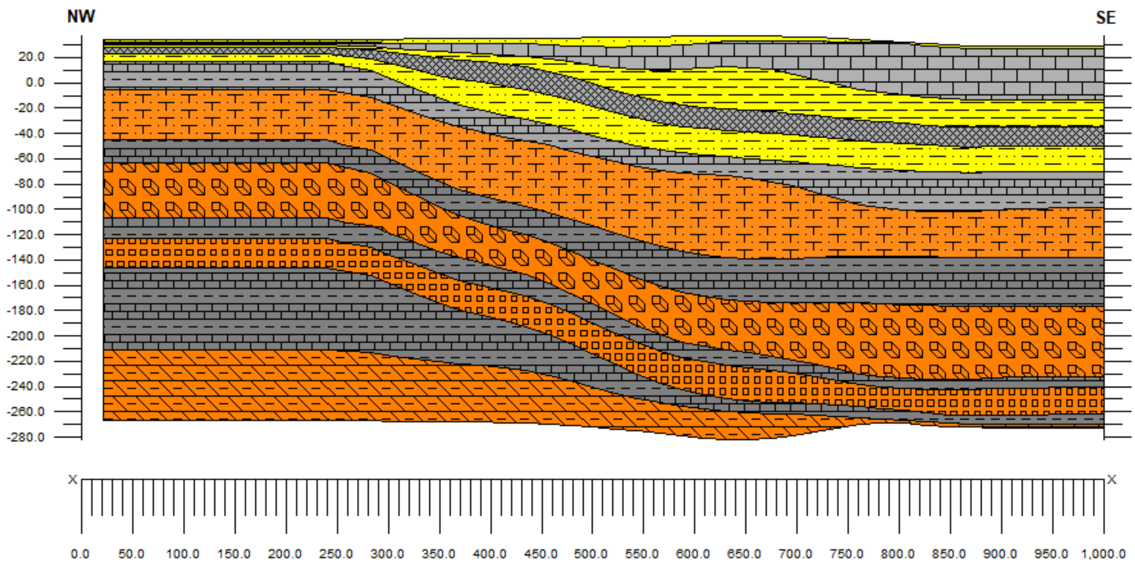


FIGURE 13:NW-SE CROSS-SECTION VIEW OF THE AQUIFERS OF THE AREA.

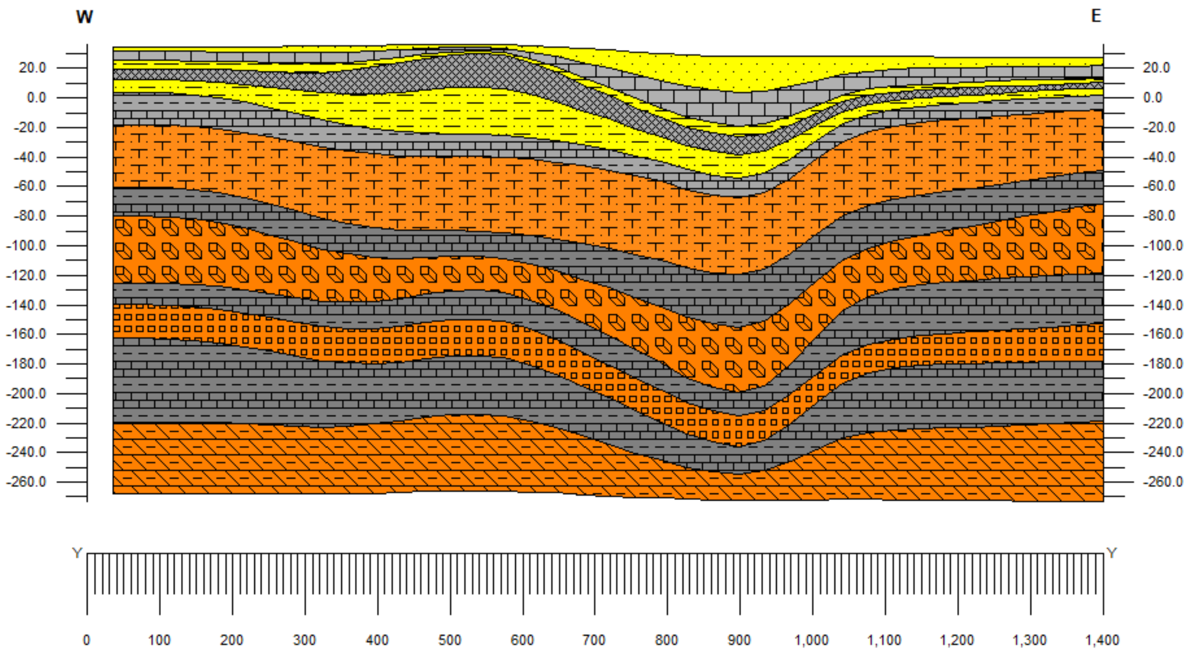


FIGURE 14:W-E CROSS-SECTION VIEW OF THE AQUIFERS OF THE BALASORE-CHANDIPUR AREA.

13. Geophysical Investigations:

3D electrical resistivity imaging to Delineation of Sub- Surface Lithology by using Geophysical Methods in Parts of Remuna& Sadar Blocks of Balasore District of Odisha

Geophysics is the application of physics to the study of the Earth. The Rocks have different types of properties. The Rocks doesn't differ only by their macroscopic or microscopic properties studied field Geologists or Petrologists. They also differ by their chemical and physical properties. Hence as the rocks differ according to their origin, structure, texture, etc. they also differ by their density, magnetisation, resistivity, etc. The Geophysical Geo-electrical method is the best method for groundwater exploration. This method is also used in environmental applications and other engineering applications.

I. Objective of the Study:

The purpose of this study is to delineate the aquifer system of the study area and to determine the extension of potential freshwater aquifer for groundwater development through geophysical electrical resistivity sounding survey. In this regard total of 46 VES were designed to be surveyed in the study area using the Schlumberger method in alluvial formation. The study also aims to delineate the aquifer group model based on the geoelectric layer parameters inputs.

II. Geophysical Materials and Methods:

The resistivity technique involves calculating the resistivity of geo-electrical subsurface materials by transmitting the direct electric current in the subsurface and recording the potential difference developed by the infused current.

The Vertical Electrical Sounding (VES) data collected by employing the Schlumberger configuration are plotted as a graph of the apparent resistivity (ρ) against the half-electrode spacing AB/2. An approximation for the depth of the interface suggested equal to (2/3) two-thirds of the spacing of the electrode at the point of inflection (Vingoe 1972). In this context, the VES survey was accomplished using the linear four-electrode Schlumberger configuration at 46 location stations have been employed to decifer the aquifer disposition, the location of VES shown on the map (Fig.15). The study aims to figure out the aquifer disposition the resistivity and thickness in terms of layer parameters are translated into corresponding hydrogeological parameters.

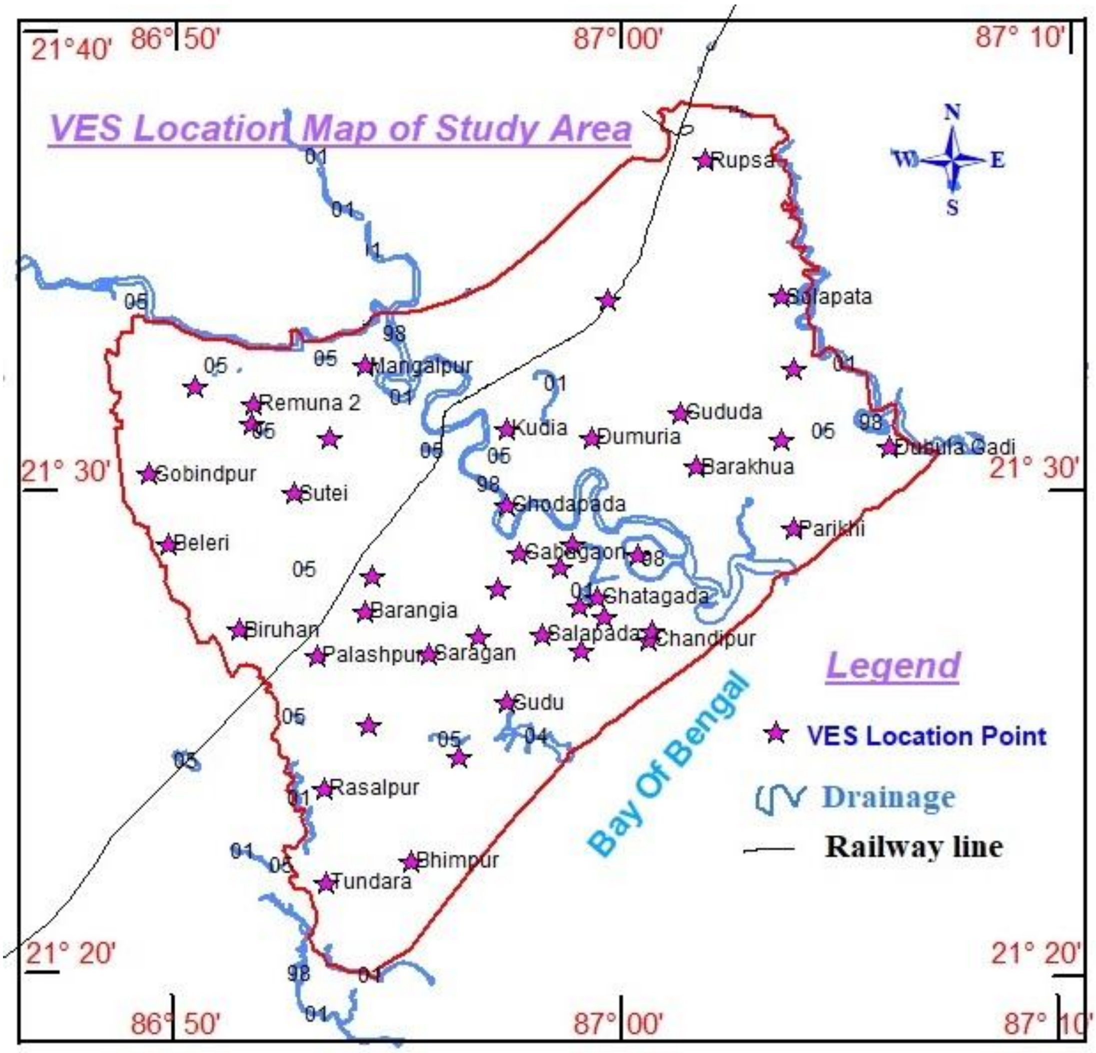


Figure 15: VES location map of the study area.

III. VES Data Interpretation

All the 46 VES were interpreted in terms of layer parameters. The field curves were obtained as H, HK, KH, KQ, HKH, QH and Q type. The long spread VES and Borehole logs spatially distributed were utilized for interpretation. VES interpretation results suggest non-uniformity in the distribution of resistivity in vertical as well as in lateral directions. From the interpretation of VES curves several geo-electric models of different thickness and resistivity are identified (**Annexure-9**).

Lithology of individual layers has been approximated from existing borehole data. Alternating sand and clay layers exist below the topsoil across the study area. The topsoil of the area is characterized by resistivity variation from 1.31-380 Ω m and the thickness varies from 0.7 m to 6.8 m. The large range of resistivity variation is related to nature and the wetness of the topsoil. Dry and hard compacted silty soil shows higher resistivity while clayey moist soil shows lower resistivity.

A continuous clay or silty clay layer, identified as aquitard, is present below the topsoil and the resistivity value ranges from 1.65 Ω m to 15 Ω m. This aquitard is underlain by a sand layer acting as shallow aquifer showing resistivity varying from 0.02 Ω m - 37.11 Ω m reflecting the pore space water as of variable quality. The depth of the shallow aquifer ranges from 6m to 24 m, but in some areas, it extends to 117m. In general, the shallow aquifer is brackish to saline except for some isolated freshwater pockets where resistivity is within 13 Ω m to 37.11 Ω m. Brackish to saline water saturated sand shows low resistivity in the range of clay and it is difficult to differentiate them without the help of borehole log or water quality data. The fresh water pockets were identified as shallow acquifertowordsbalasore from nuanal (Chandipur).

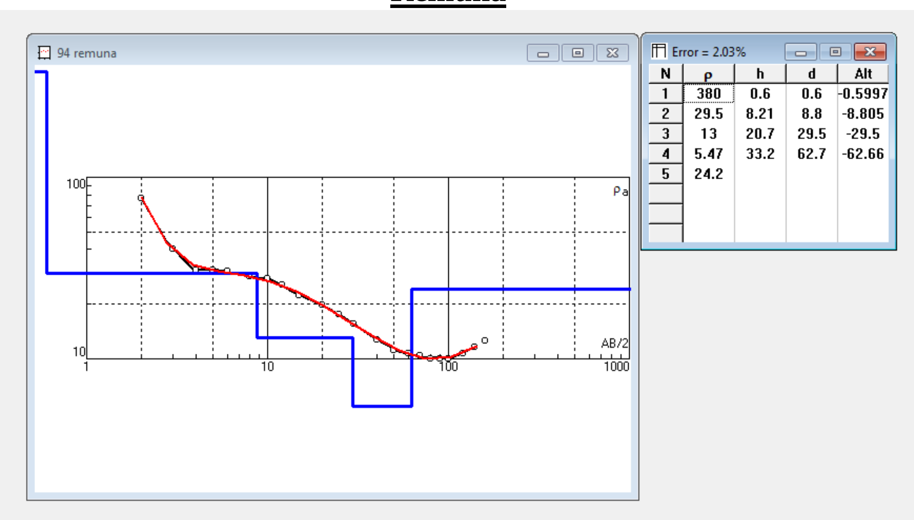
The shallow aquiferis followed by laterally extended second aquitard of variable thickness. Second aquitard of varying thickness is underlain by the second freshwater aquifer, it appears mostly weatern side of the study area. The second aquifer shows resistivity in the range of 16 Ω m to 84 Ω m, indicating the pore space water as fresh. Wide range of resistivity may be related to sand sizes, the compactness of the sand grains, degree of mineralization of pore space water, etc.

Where mostly east side of study area not get the deeper information due to the saline sands appears as first acquifer their very difficult to do the survey. Some of the representative VES curves are presented below table 9.

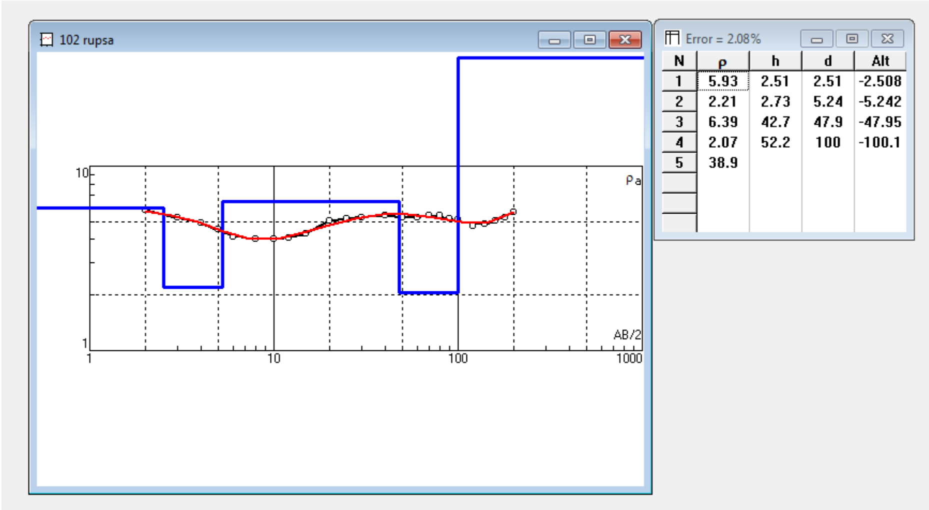
TABLE 9: DEMARCATIONS OF VARIOUS LITHOLOGIES IN THE AREA.

S.No	**Lithology**	**Resistivity Range**
1.	Top Soil/Dry Soil	1.31 to 380 Ω.m.
2	Clay/Silty Clay	1.65 to 15 Ω.m
3	Fine Sand (Saline)	Less than 5 Ω.m
4	Fine Sand (Fresh)	13 to 30 Ω.m
5	Medium Sand (Fresh)	30 to 84 Ω.m

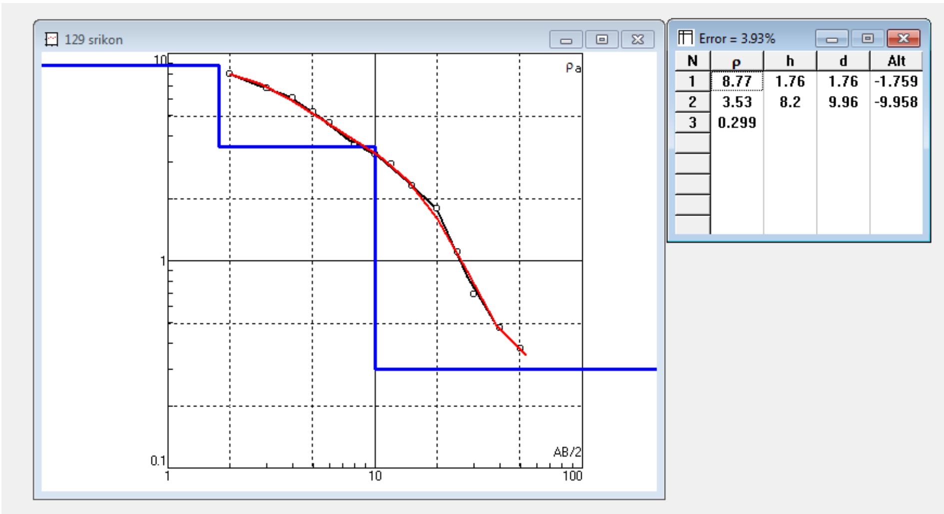
Remuna



Rupsa



Srikona



IV. Conclusion

In this study, resistivity VES data coupled with Litho Log data have been employed for the aquifer disposition/Sub surface lithology in the study area. The data was incorporated into the vertical lithological distribution to demarcate the Fresh & Saline sands, governing the aquifer geometry.

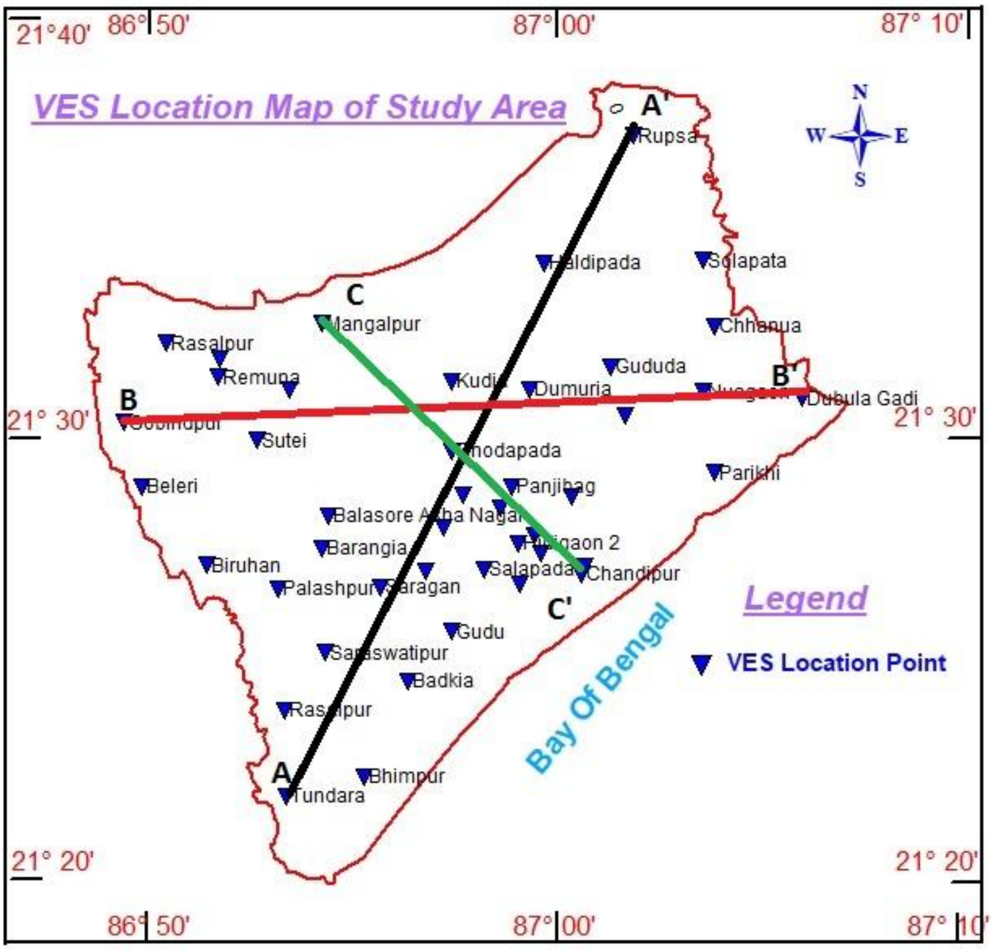


Figure 16: VES Locations and the Cross-Section.

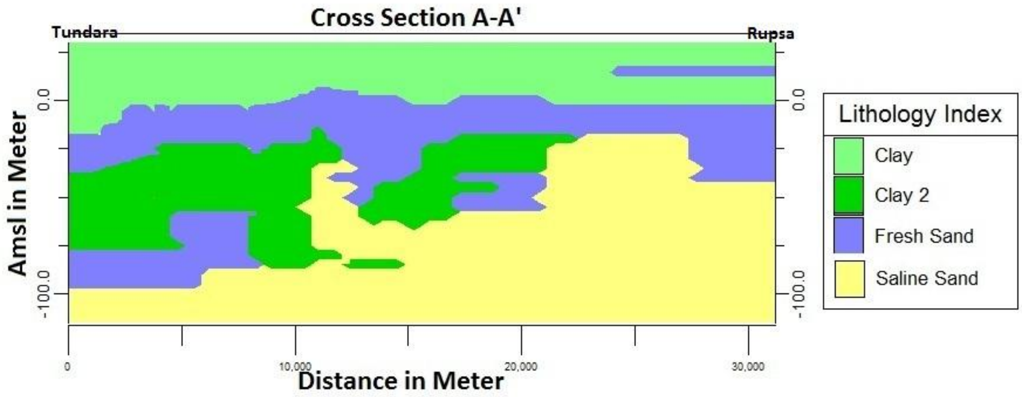


FIGURE 17: 2D CROSS SECTION A-A'

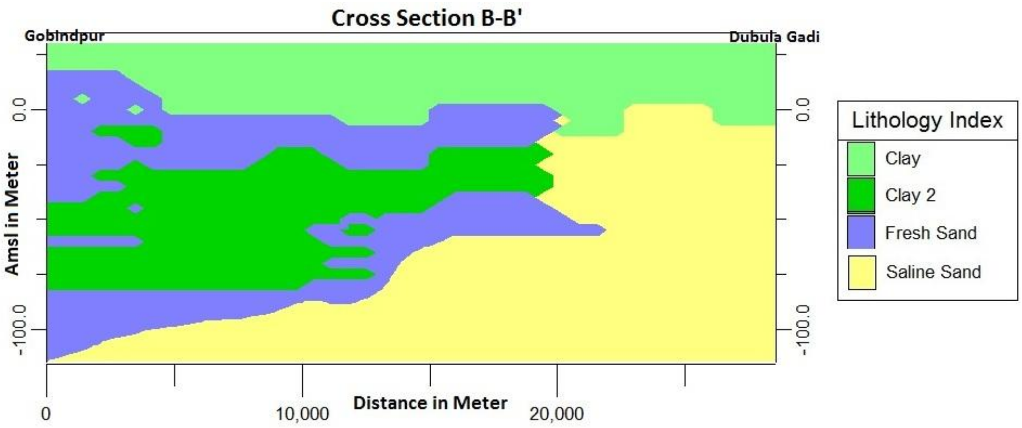


FIGURE 18: 2D CROSS SECTION B-B'.

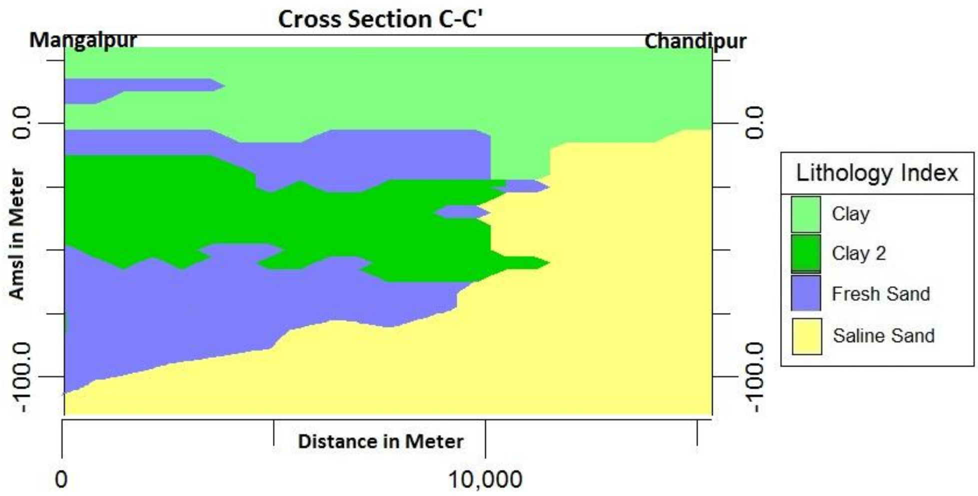


FIGURE 19: 2D CROSS SECTION C-C'

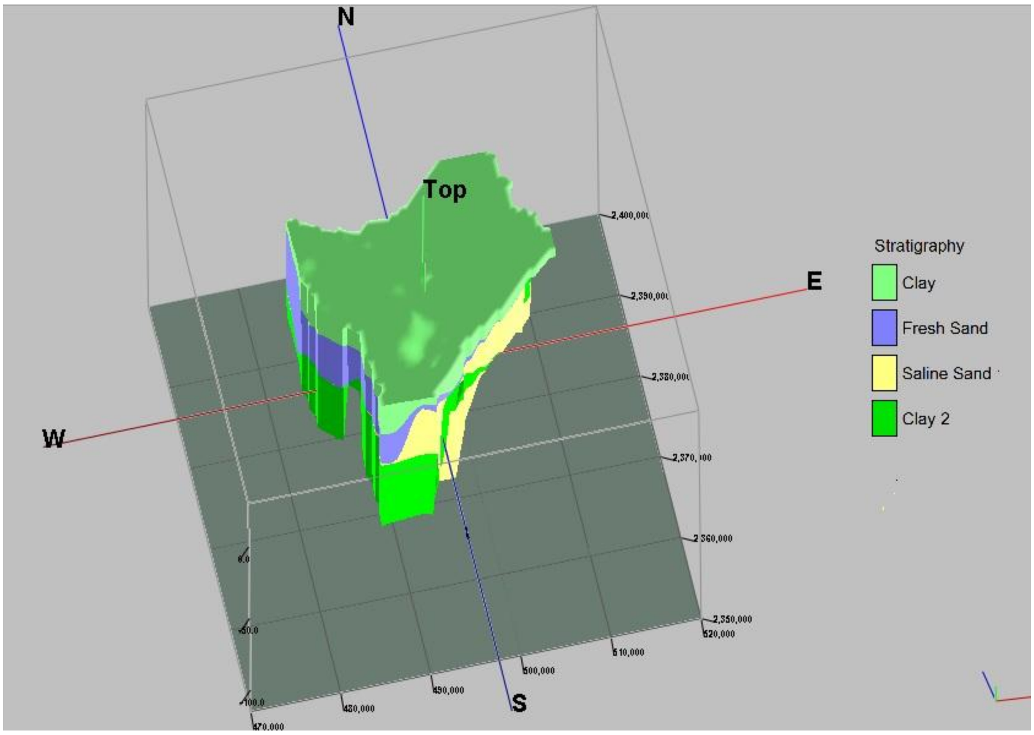


FIGURE 20: 3D STRATIGRAPHY MODEL OF THE STUDY AREA.

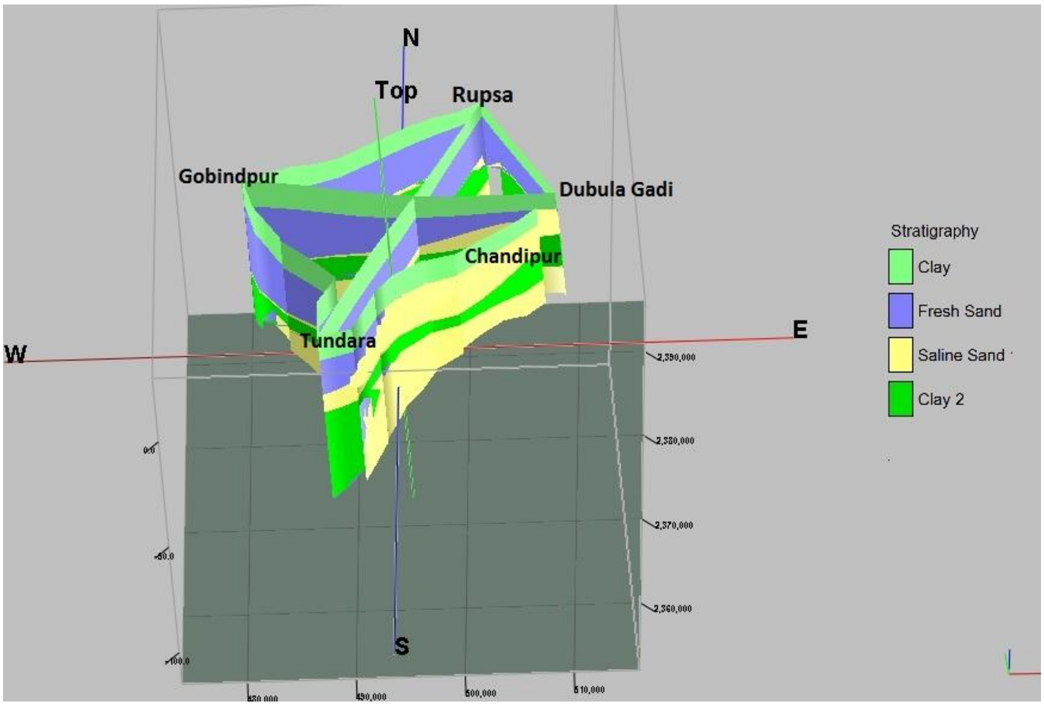


FIGURE 21: 3D STRATIGRAPHY FENCE DIAGRAM OF THE STUDY AREA.

14. Aquifer-wise ground water levels:

I. Depth to Water Level of the area.

Pre-monsoon and post-monsoon water level data were collected from the key wells and piezometers in the district for 2023. Depth to water level maps prepared for the pre-monsoon and post-monsoon periods have been below, as shown in Figures 22 and 23. The water level data collected from the wells indicate a cumulative depth of aquifer 1 and aquifer 2, with the depth varying from 50-80 mbgl.

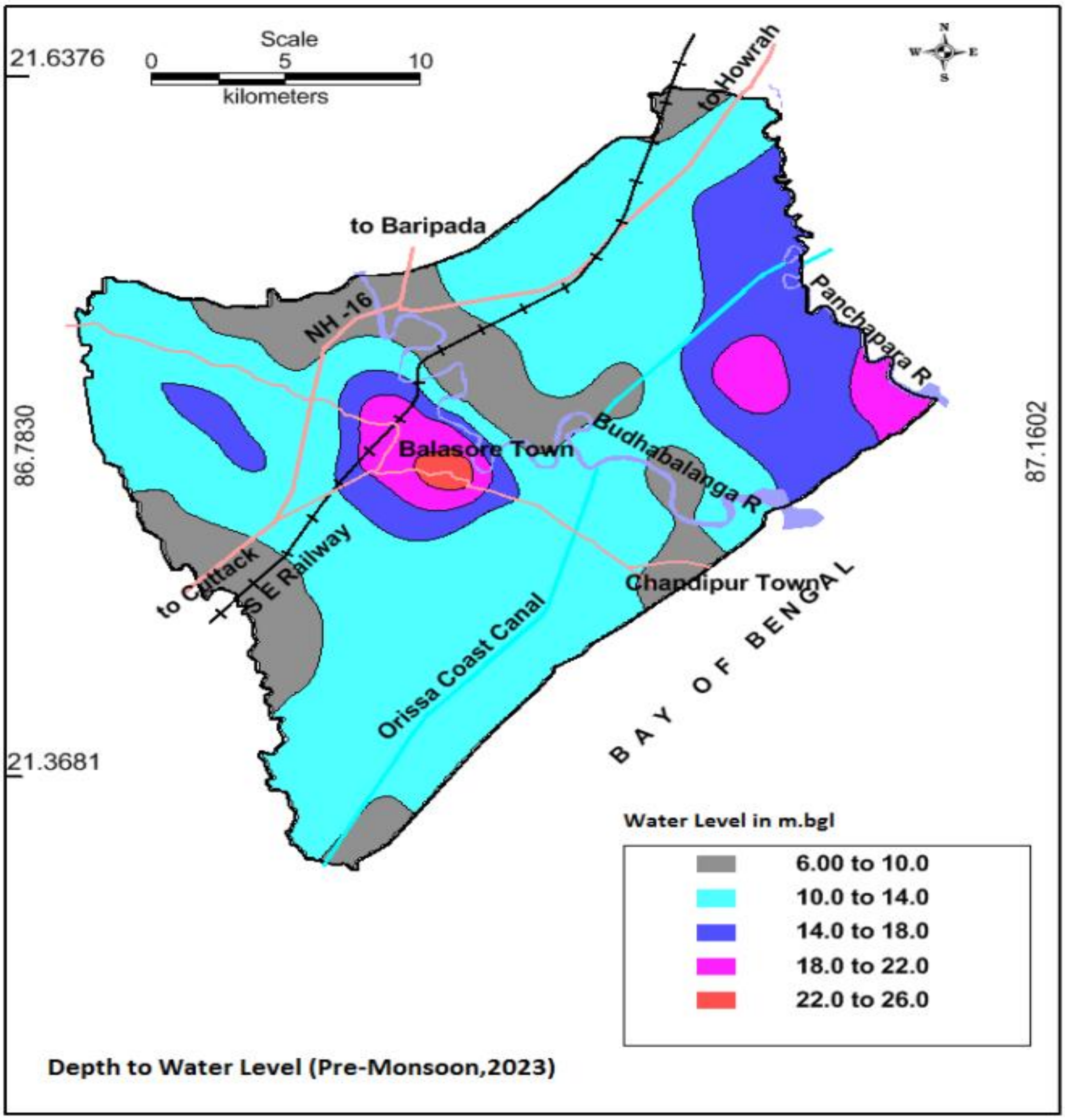


FIGURE 22: PRE-MONSOON DEPTH TO WATER LEVEL MAP OF THE STUDY AREA.

The groundwater level data was collected in pre-monsoon and post-monsoon across the region, revealing significant variations. Pre-monsoon depths to water levels ranged from 3.26 meters below ground level (mbgl) to 23.54 mbgl. In contrast, post-monsoon depths varied slightly more, between 2.35 mbgl and 23.65 mbgl.

Most of the study area experienced water levels commonly found within a narrower range of 10 to 14 mbgl. Notably, deeper water levels were observed in specific regions, notably in the central part of the study area, Balasore Urban, and the northeastern regions, where the depths ranged from 14 to 26 mbgl.

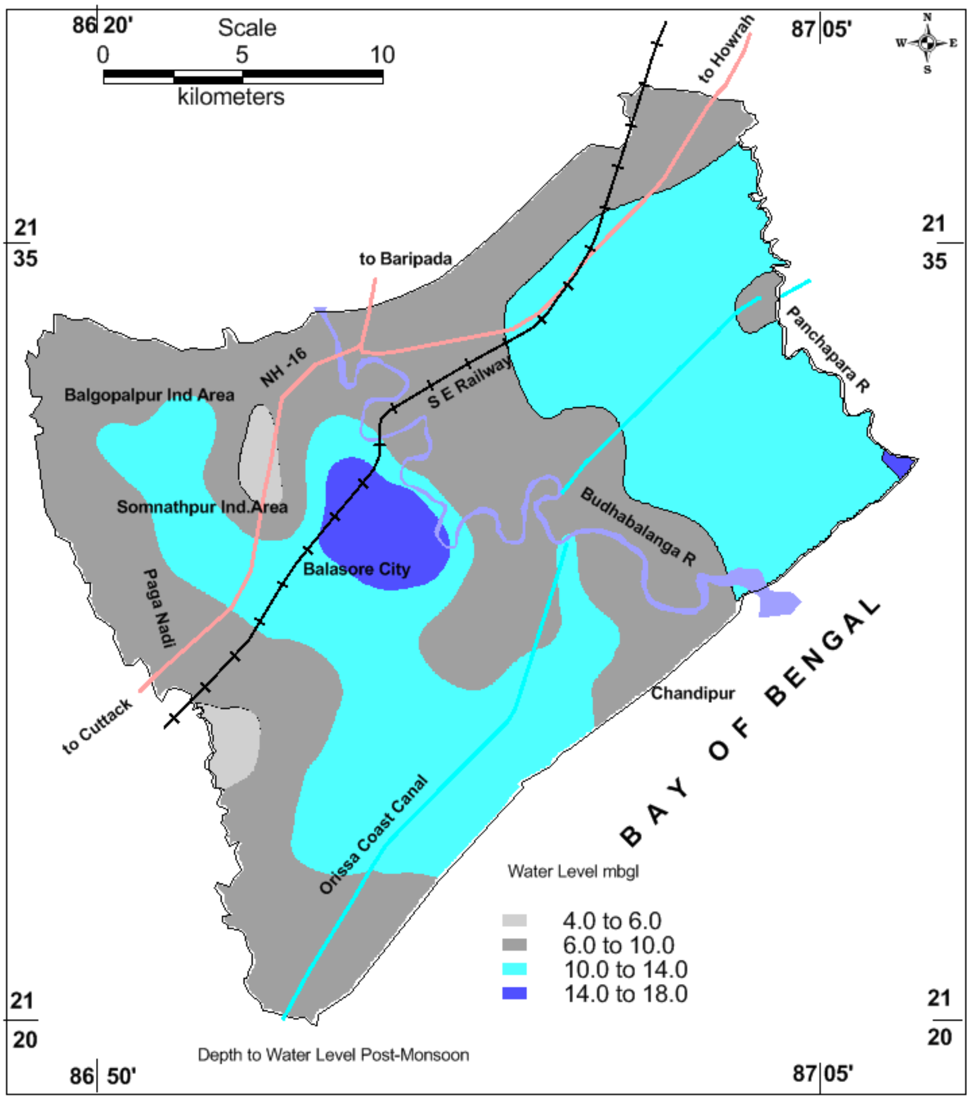


FIGURE 23: POST-MONSOON DEPTH TO WATER LEVEL MAP OF THE STUDY AREA.

The investigation reveals that the Post-monsoon Period, depth to the water level in the study area varies significantly, ranging from 4 to 18 meters below ground level (mbgl). In most parts of the study area, the water level is found to lie between 6 to 14 mbgl. This range indicates a relatively moderate depth, suggesting that groundwater is accessible but not particularly close to the surface.

However, in the central part of the study area, specifically in the Balasore urban region, the water level is notably deeper, exceeding 14 mbgl. This deeper water table could be attributed to various factors, such as urbanization, over-extraction, and geological characteristics that impact groundwater replenishment.

II. Water Level Fluctuation of Deeper Aquifer:

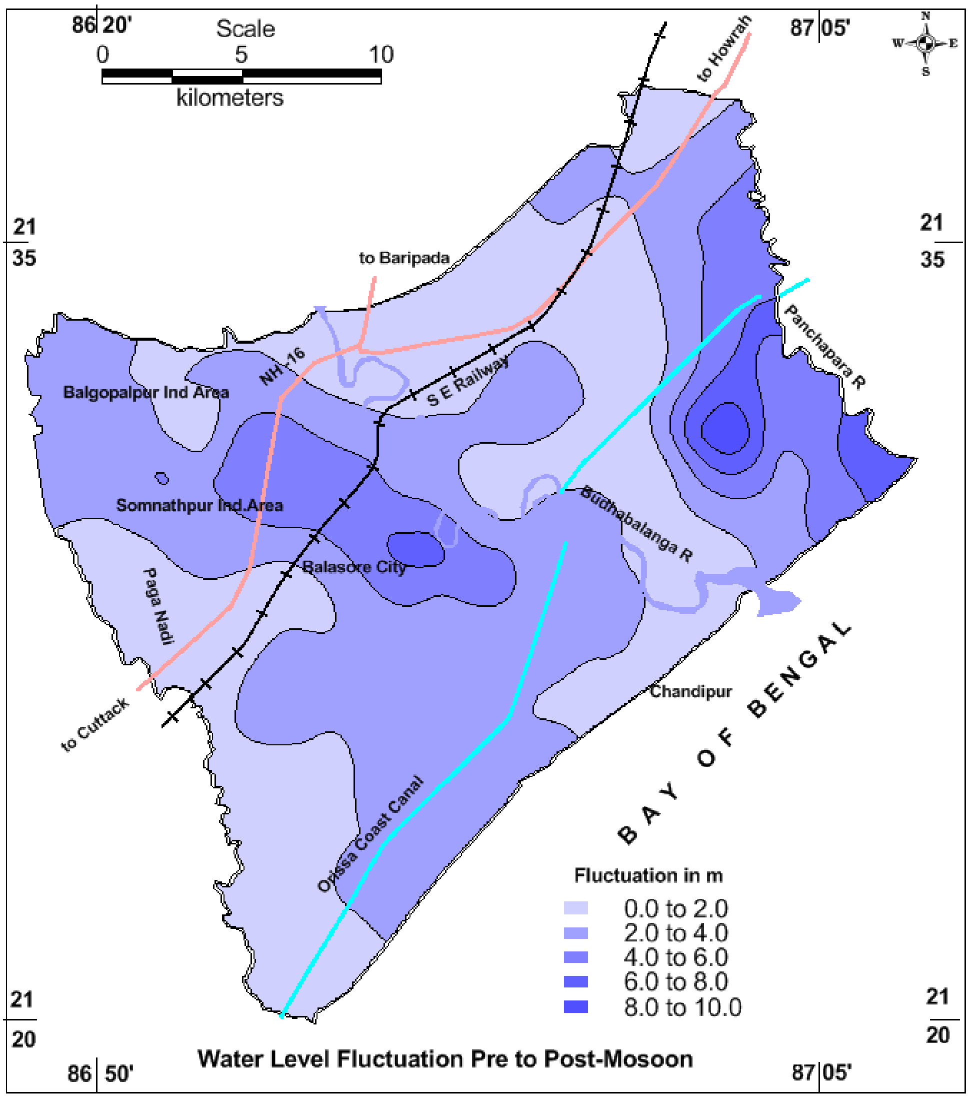


FIGURE 24: WATER LEVEL FLUCTUATION PRE TO POST MONSOON PERIOD.

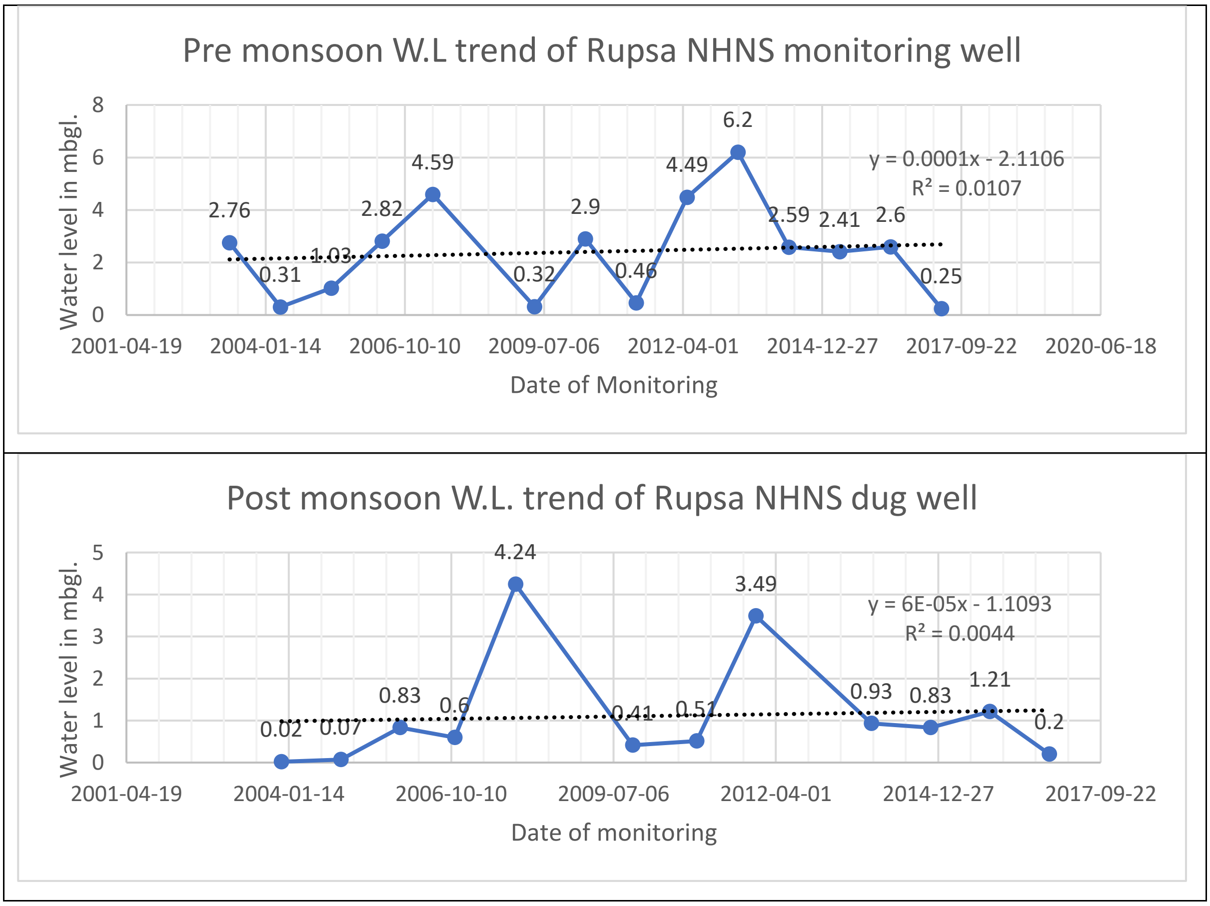
In our study region, the seasonal water level fluctuation ranges significantly from as low as 1.00 meter to as high as 10.00 meters. These variations are most prominently observed in zones exhibiting deeper water levels during the pre-monsoon period.

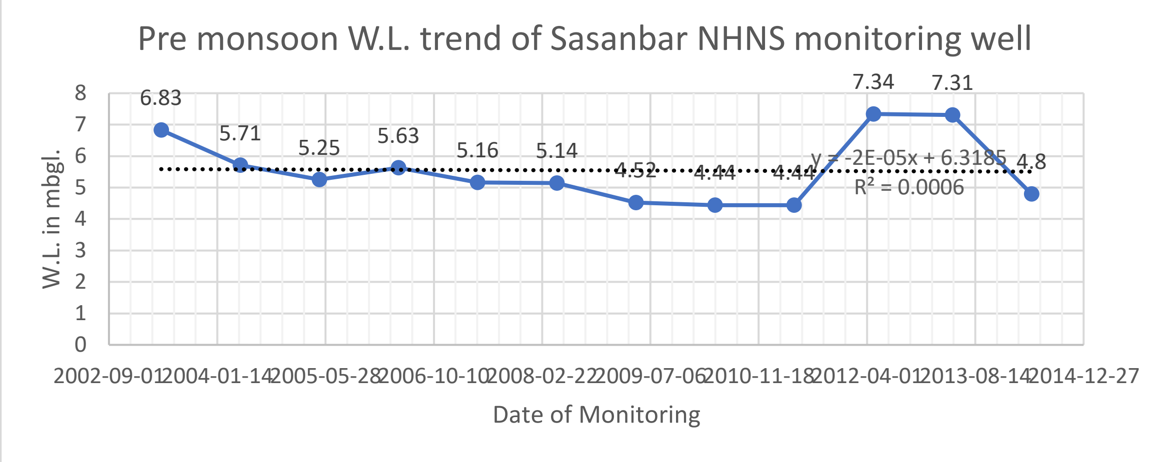
Remarkably, the maximum fluctuations are noted in specific urban and northeastern parts of the study area, particularly in Balasore Urban. This trend suggests that areas with initially lower water levels before the monsoon experience the most substantial changes as the season progresses.

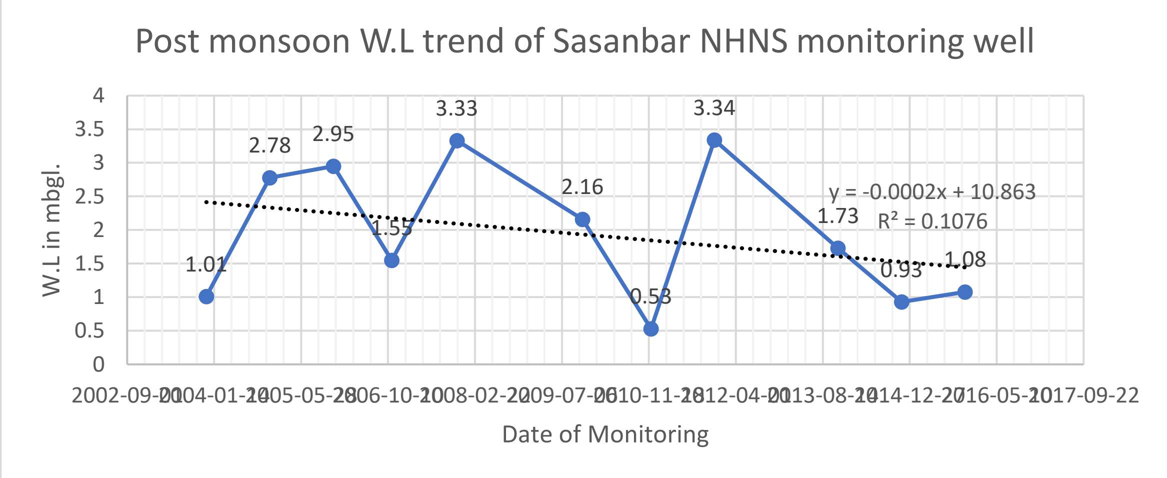
III. Water Level Trend of tubewells:

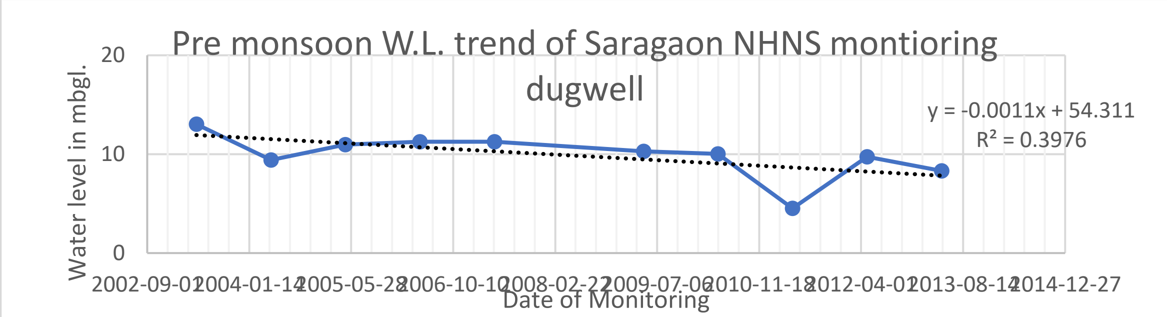
Long-term water level trends are depicted in water level hydrographs, which show how groundwater storage in the phreatic zone has changed over time. Variations in storage are caused by variations in atmospheric pressure, as well as variances in refill and outflow rates throughout time. A long-term waterlevel trend for the pre-and post-monsoon phase has been calculated and reported using long term water level data of the NHNS monitoring wells of the CGWB (Figure 25):

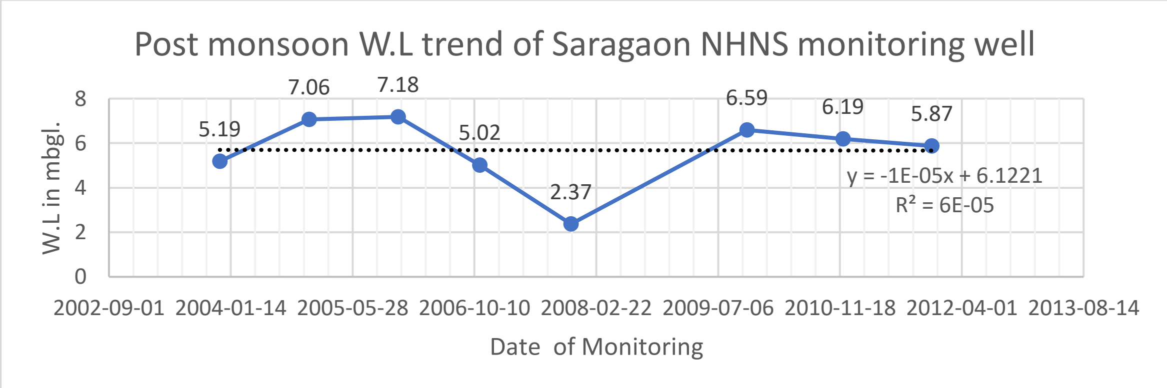
FIGURE 25: WATER LEVEL TREND OF THE NHNS MONITORING WELLS

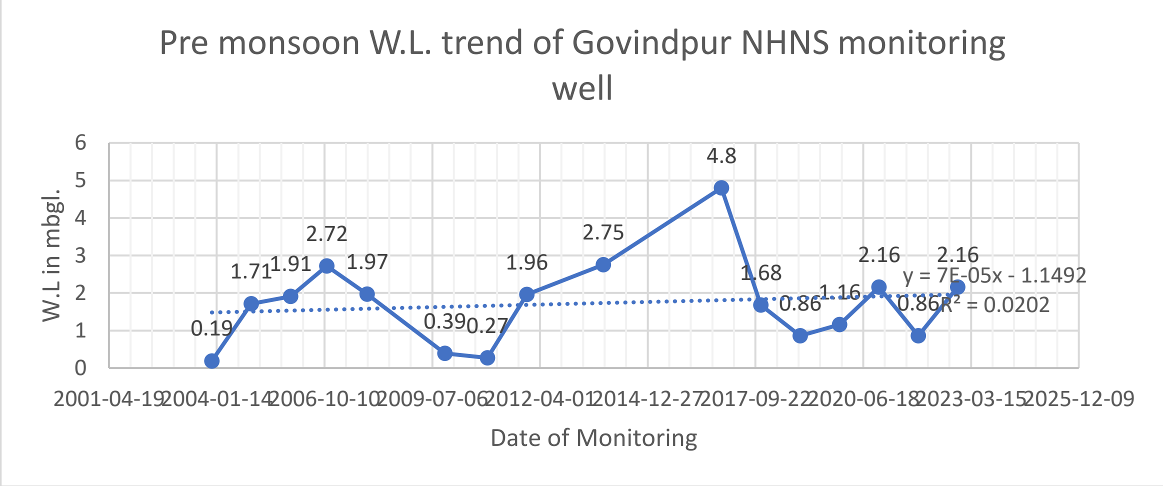


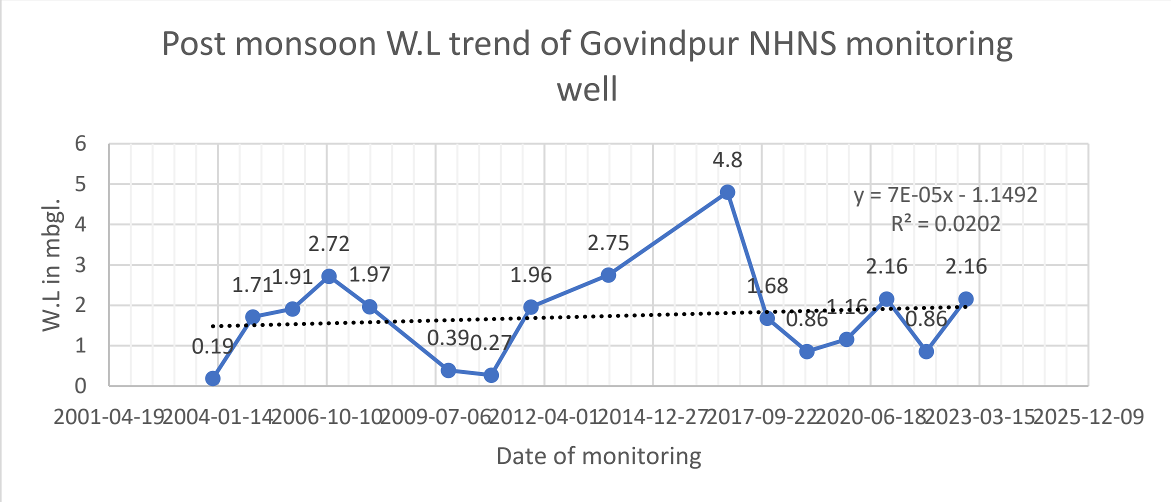

Pre monsoon W.L. trend of Sasanbar NHNS monitoring well
W.L. in mbgl.
Date of Monitoring
6.83
5.71
5.25
5.63
5.16
5.14
4.52
4.44
4.44
7.34
7.31
4.8
y = -2E-05x + 6.3185
R² = 0.0006
2002-09-01 2004-01-14 2005-05-28 2006-10-10 2008-02-22 2009-07-06 2010-11-18 2012-04-01 2013-08-14 2014-12-27

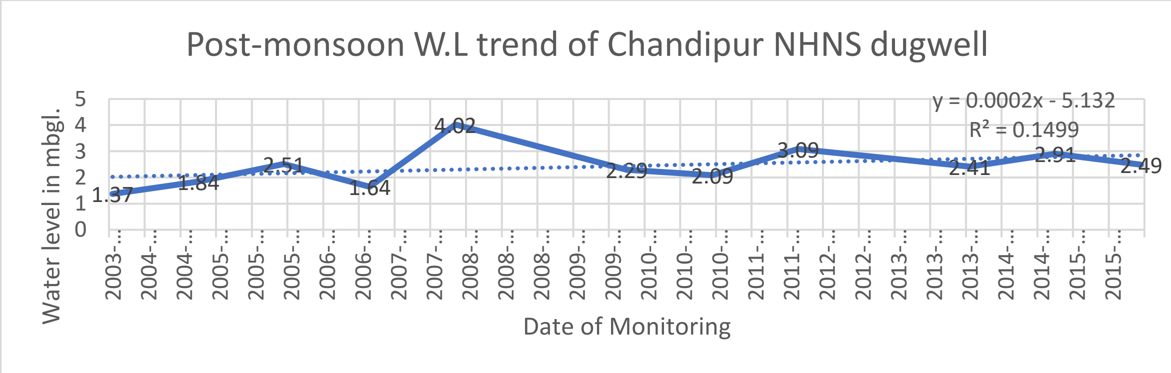

Post monsoon W.L trend of Sasanbar NHNS monitoring well
W.L in mbgl.
Date of Monitoring
1.01
2.78
2.95
1.55
3.33
2.16
0.53
3.34
1.73
0.93
1.08
y = -0.0002x + 10.863
R² = 0.1076
2017-09-22

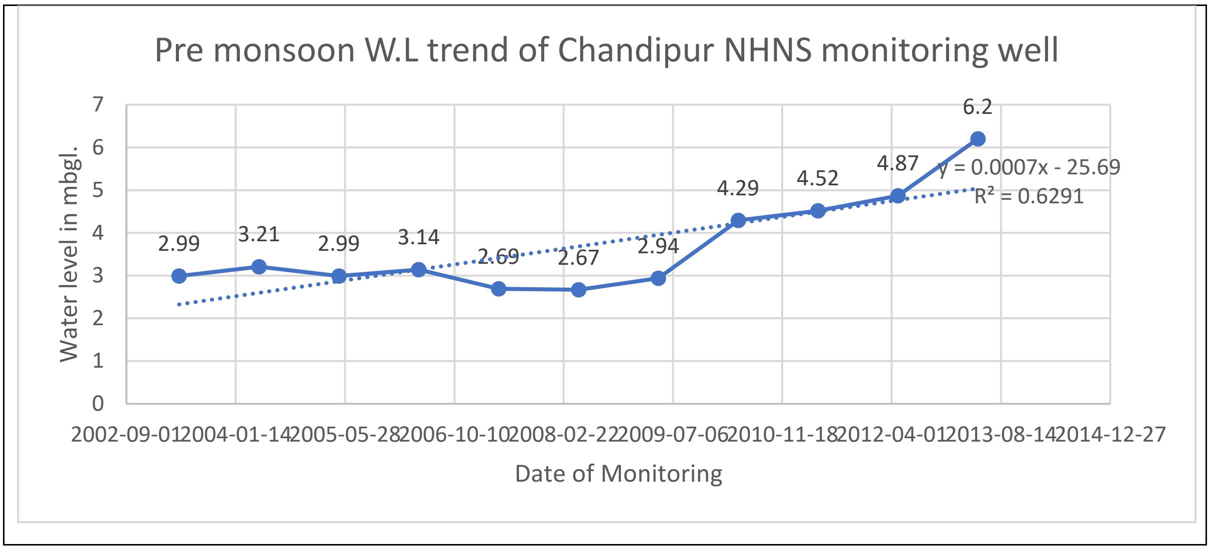

Pre monsoon W.L. trend of Saragaon NHNS montioring dugwell
Water level in mbgl.
Date of Monitoring
y = -0.0011x + 54.311
R² = 0.3976
2002-09-01 2004-01-14 2005-05-28 2006-10-10 2008-02-22 2009-07-06 2010-11-18 2012-04-01 2013-08-14 2014-12-27


Post monsoon W.L trend of Saragaon NHNS monitoring well
W.L in mbgl.
Date of Monitoring
5.19
7.06
7.18
5.02
2.37
6.59
6.19
5.87
y = -1E-05x + 6.1221
R² = 6E-05
2002-09-01 2004-01-14 2005-05-28 2006-10-10 2008-02-22 2009-07-06 2010-11-18 2012-04-01 2013-08-14


Pre monsoon W.L. trend of Govindpur NHNS monitoring well
W.L in mbgl.
Date of Monitoring
y = 7E-05x - 1.1492
R² = 0.0202
0.19
1.71
1.91
2.72
1.97
0.39
0.27
1.96
2.75
4.8
1.68
0.86
1.16
2.16
0.86
2.16
2001-04-19
2004-01-14
2006-10-10
2009-07-06
2012-04-01
2014-12-27
2017-09-22
2020-06-18
2023-03-15
2025-12-09


Post monsoon W.L trend of Govindpur NHNS monitoring well
W.L in mbgl.
Date of monitoring
y = 7E-05x - 1.1492
R² = 0.0202
0.19
1.71
1.91
2.72
1.97
0.39
0.27
1.96
2.75
4.8
1.68
0.86
1.16
2.16
0.86
2.16
2001-04-19
2004-01-14
2006-10-10
2009-07-06
2012-04-01
2014-12-27
2017-09-22
2020-06-18
2023-03-15
2025-12-09


Post-monsoon W.L trend of Chandipur NHNS dugwell
Water level in mbgl.
Date of Monitoring
y = 0.0002x - 5.132
R² = 0.1499
1.37
1.84
2.51
1.64
4.02
2.29
2.09
3.09
2.41
2.91
2.49



According to the hydrograph trend, there has been a modest drop in water level in the majority of the district both in the "pre-monsoon and post-monsoon periods," which might be attributed to over-exploitation of groundwater and reduced recharge. Throughout the "pre-monsoon season" as well as "post-monsoon period,".

TABLE 10: LONG TERM WATER LEVEL FLUCTUTIONS OF THE NHNS MONITORING WELLS OF THE STUDY AREA.

S. No.	Location	Pre-Monsoon			Post-Monsoon		
		Data Points	Rise (m/year)	Fall (m/year)	Data Points	Rise (m/year)	Fall (m/year)
1	Chandipur DW	11		0.26857	11		0.04083
2	Govindpur DW	16		0.0236	16		0.03473
3	Saragaon DW	10	0.1183		10	0.085	
4	Sasanbar DW	11	0.1416		11	0.203	
5	Rupsa DW	12	0.021		12	0.0461	

15. Groundwater Quality:

I. Physicochemical Parameters:

The statistical analysis results for physicochemical parameters of groundwater, both pre-monsoon and post-monsoon are summarized in Table 11. The pH values for groundwater samples during pre-monsoon vary between 6.37 to 8.28 with mean pH of 7.77. For post-monsoon, it ranges from 5.67 to 8.28 with a mean pH of 7.54. Most of the ground water samples pH values within the permissible limit expect one sample being acidic during both seasons. Electrical conductivity values range from 122-2615µs/cm with mean value of 815µs/cm and 115-2513µs/cm with mean value of 822 µs/cm during pre-monsoon and postmonsson respectively. Approximately 24 % & 26 % of all samples EC values above 1000µs/cm during pre and post monsoon respectively. Total Dissolved solids (TDS) range from 71-1472mg/l during the premonsoon period and 93-1443 mg/l during the post monsoon period. TDS mean values of both seasons nearly 460 mg/L, indicates TDS of the ground water samples of this study area within the permissible limit. The concentration of fluoride varies from 0.06-4.34 mg/L and 0.09-4.81 mg/L during the period of premonsoon and post monsoon respectively, nearly about 10 % of all samples (6 samples) and 14.5% of all samples (10 samples) of ground water samples above the permissible limit (1.5 mg/L) during the period of premonsoon and post monsoon respectively. Due to the high fluoride values, these groundwater samples are not suitable for drinking purposes. The maximum values of other physicochemical parameters within the permissible limit. In this study, thecation chemistry ruled by sodium ion and followed by calcium and magnesium. Cations abundance sequence was observed as Na>Ca> Mg > K in the ground water samples and anion abundance sequence was observed as HCO_3>Cl> SO_4> NO_3> F based on mean values of parameters in the both seasons.

TABLE 11. DESCRIPTIVE STATISTICS OF THE MEASURED PHYSICOCHEMICAL PARAMETERS DURING PRE MONSOON AND POST MONSOON

Parameter	Unit	Pre-Monsoon				Post-Monsoon			
		Min	**Max**	**Mean**	**SD**	**Min**	**Max**	**Mean**	**SD**
pH		6.37	8.28	7.77	0.33	5.67	8.28	7.54	0.50
EC	µs/cm	122.00	2615.00	815.60	500.55	115.00	2513.00	822.20	505.86
TDS	mg/l	71.00	1472.00	457.05	284.67	93.00	1443.00	459.83	279.03
Total Hardness	as $CaCO_3$ mg/l	49.00	530.00	262.97	101.93	49.00	556.00	194.20	96.35
Total Alkalinity	as $CaCO_3$ mg/l	39.60	470.25	246.38	97.45	32.09	497.35	259.75	103.16
Ca^{+2}	mg/l	11.90	112.20	63.51	24.14	6.40	151.40	43.76	25.44
Mg^{+2}	mg/l	5.00	61.00	25.44	10.99	4.00	43.00	20.65	9.42
Na^{+1}	mg/l	8.60	423.25	75.81	86.54	5.65	426.62	106.55	103.81
K^{+1}	mg/l	0.56	9.28	2.59	1.89	0.59	41.60	3.76	5.32
HCO_3^{-1}	mg/l	48.31	573.71	300.58	118.89	39.15	606.77	316.89	125.86
Cl^{-1}	mg/l	13.09	652.36	106.79	115.45	9.37	548.73	101.09	107.98
SO_4^{-2}	mg/l	3.04	227.82	32.72	30.40	2.27	139.10	24.13	27.99
NO_3^{-1}	mg/l	0.00	8.30	1.50	2.22	0.00	36.34	3.27	5.06
F^{-1}	mg/l	0.06	4.34	0.72	0.77	0.09	4.81	0.83	0.90

TABLE 12: CORRELATION COEFFICIENT MATRIX OF WATER QUALITY PARAMETERS DURING PREMONSOON

	pH	*EC µS/cm*	*TDS*	*Hardness*	*Alkalinity*	*Ca++*	*Mg++*	*Na+*	*K+*	*HCO3-*	*Cl-*	*SO4=*	*NO3-*	*F -*
pH	1.00													
EC µS/cm	0.48	1.00												
TDS	0.47	1.00	1.00											
Hardness	0.69	0.73	0.73	1.00										
Alkalinity	0.72	0.77	0.76	0.93	1.00									
Ca++	0.69	0.71	0.70	0.98	0.91	1.00								
Mg++	0.63	0.71	0.71	0.95	0.87	0.87	1.00							
Na+	0.28	0.95	0.95	0.48	0.55	0.46	0.48	1.00						
K+	0.25	0.39	0.40	0.28	0.38	0.30	0.23	0.39	1.00					
HCO3-	0.72	0.77	0.76	0.93	1.00	0.91	0.87	0.55	0.38	1.00				
Cl-	0.31	0.95	0.95	0.52	0.55	0.49	0.52	0.98	0.34	0.55	1.00			
SO4=	0.19	0.72	0.74	0.50	0.43	0.46	0.52	0.70	0.23	0.43	0.66	1.00		
NO3-	0.18	0.08	0.08	-0.04	-0.01	-0.04	-0.03	0.10	- 0.06	-0.01	0.10	0.02	1.00	
F -	0.36	0.33	0.31	0.51	0.51	0.47	0.51	0.18	- 0.09	0.51	0.16	0.18	0.15	1.00

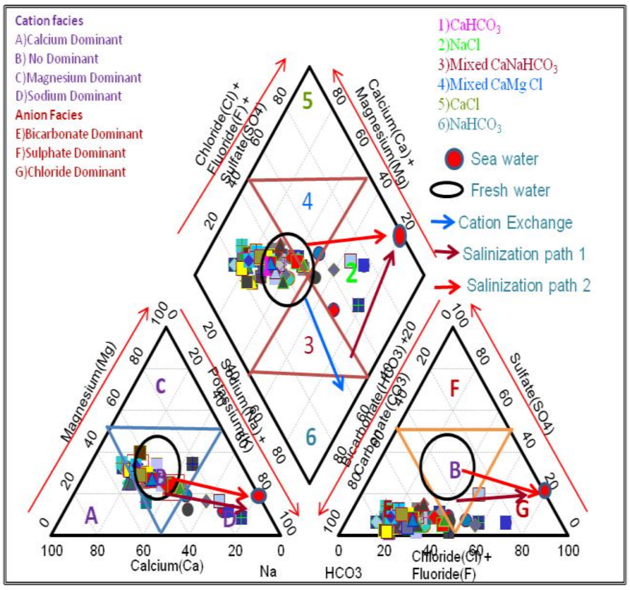
TABLE 13 :CORRELATION COEFFICIENT MATRIX OF WATER QUALITY PARAMETERS DURING PREMONSOON

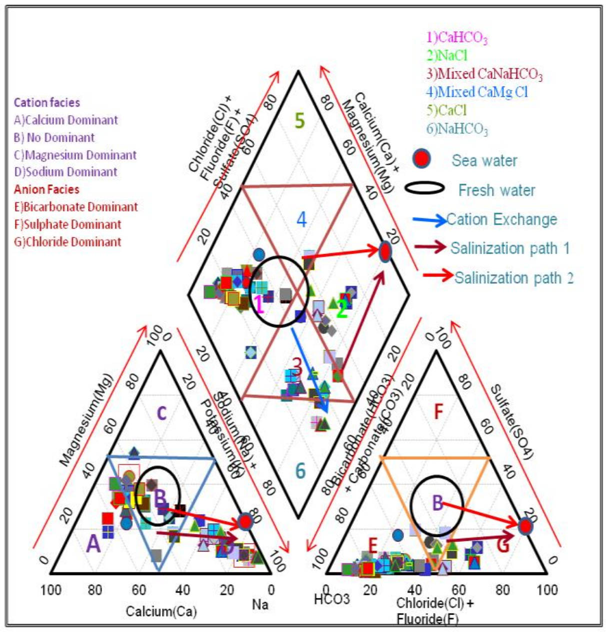
	pH	*EC µS/cm*	*TDS*	*Hardness*	*Alkalinity*	*Ca++*	*Mg++*	*Na+*	*K+*	*HCO3-*	*Cl-*	*SO4*	*NO3*	*F -*
pH	1.00													
EC µS/cm	0.53	1.00												
TDS	0.49	0.97	1.00											
Hardness	-0.20	0.26	0.29	1.00										
Alkalinity	0.60	0.70	0.74	0.30	1.00									
Ca++	-0.25	0.19	0.23	0.97	0.22	1.00								
Mg++	-0.07	0.35	0.35	0.90	0.39	0.76	1.00							
Na+	0.60	0.91	0.93	-0.08	0.68	-0.13	0.03	1.00						
K+	0.22	0.54	0.60	0.43	0.39	0.43	0.35	0.43	1.00					
HCO3-	0.60	0.70	0.74	0.30	1.00	0.22	0.39	0.68	0.39	1.00				
Cl-	0.31	0.92	0.94	0.29	0.49	0.25	0.32	0.85	0.59	0.49	1.00			
SO4	0.34	0.71	0.75	0.15	0.32	0.13	0.17	0.70	0.54	0.32	0.73	1.00		
NO3	0.18	0.36	0.37	-0.01	0.18	0.02	-0.04	0.38	0.15	0.18	0.35	0.34	1.00	
F -	0.42	0.37	0.32	-0.11	0.33	-0.13	-0.07	0.38	0.02	0.33	0.20	0.37	0.08	1.00

The correlation matrix was used to determine the level of connection between several physicochemical parameters. A strong correlation between the parameters is shown by values of + 1 (positive correlation) or -1 (negative correlation), whereas a value of zero denotes no link. A correlation coefficient of 0.5 to 0.7 indicates variables that are moderately correlated, and between 0.7 and 0.9 are highly correlated, whereas those with values of 0.9 or higher are very highly correlated. These three categories of correlation coefficients were bolded in the correlation matrix table12. Table 13 shows that the results of correlation analysis of major ions during premonsoon season. The correlation shows that EC and TDS have correlation with Na^{+}, Cl^{-} (high correlation), HCO_3^{-}, SO_4^{-2} , Ca^{+2} , Mg^{+2}(moderate correlation) indicates that these ions are derived from same source. The very high correlation between Na^{+} and Cl^{-} (r = 0.98) emphasizes the effects of chemical weathering, secondary salt leaching, and SWI(Abu-alnaeem et al., 2019; Prasanna et al., 2010; Srinivasamoorthy et al., 2011). HCO_3^{-} shows strong correlation with Ca+2 and Mg+2 suggest the carbonate dissolution. The weak correlation between $Ca+^{2}$ and SO_4^{-2} indicate that gypsum is not the source of $Ca+^{2}$. However, in the post monsoon season, the correlation shows that EC and TDS with Na^{+}, Cl^{-} (high correlation) and HCO_3^{-}, SO_4^{-2}, K^{+}(moderate correlation) indicates that these ions are derived from same source. The correlation between Na^{+} and Cl^{-} (r = 0.85) decrease while compare with premonsoon whereas correlation between Na^{+} and $HCO3^{-}$slightly increased in post monsoon. it is evident that the weak correlation between HCO3, Ca and Mg Ion exchange process involve in the ground water.

II. Hydrogeochemical Facies

The Piper trilinear plot illustrates the variations in the concentration of cations and anions in the water samples from the study area during both the pre-monsoon and the post-monsoon seasons. In the pre-monsoon season, the majority of the samples, as depicted in the figure, fall within Zone B (No Dominant) and Zone D (Sodium Dominant) concerning cations, with a few exceptions found in Zone A (Calcium Dominant). On the other hand, for anions, most samples are situated in Zone E (Bicarbonate Dominant), while only a few are in Zone G (Chloride and Fluoride Dominant). Additionally, a significant portion of the samples fall within the zone of Mixed CaMgHCO3 water type, with a minority appearing in the Mixed NaCl water type. This observation highlights the dominance of Na+ and Ca+ among cations, and HCO3- and Cl- among anions. Similarly, during the post-monsoon season, there is a shift in the distribution of groundwater samples, in case of Cation, samples move from Zone B (No Dominant) to Zone D (Sodium Dominant) with some still remaining in Zone A (Calcium Dominant). Anion distribution remains consistent with the pre-monsoon season, with the majority in Zone E (Bicarbonate Dominant) and only a few in Zone G (Chloride Dominant). Notably, there is a transition observed from Mixed CaMgHCO3 water type to CaNaHCO3 water type. The prevalence of sodium dominance over other cations suggests the ion exchange activities due to rock weathering, while bicarbonate dominance indicates silica weathering. It is also evident that based on Ca/Mg ration, if ratio is value of 0.6 and above, dissolution of dolomite and silicate rock minerals in ground water. Approximately 100% and 96% of the groundwater samples during the pre-monsoon and the post-monsoon period, the Ca/Mg ratio falling within the ranges of 0.62-3.12 and 0.30-5.76 respectively, indicates that the groundwater samples exhibit evidence of the dissolution of dolomite and silicate rock minerals within the groundwater.


Cation facies
A)Calcium Dominant
B) No Dominant
C)Magnesium Dominant
D)Sodium Dominant
Anion Facies
E)Bicarbonate Dominant
F)Sulphate Dominant
G)Chloride Dominant
1)CaHCO3
2)NaCl
3)Mixed CaNaHCO3
4)Mixed CaMg Cl
5)CaCl
6)NaHCO3
Sea water
Fresh water
Cation Exchange
Salinization path 1
Salinization path 2
Magnesium(Mg)
Calcium(Ca)
Na
HCO3
Sulfate(SO4)
Chloride(Cl) + Fluoride(F)


Cation facies
A)Calcium Dominant
B) No Dominant
C)Magnesium Dominant
D)Sodium Dominant
Anion Facies
E)Bicarbonate Dominant
F)Sulphate Dominant
G)Chloride Dominant
1)CaHCO3
2)NaCl
3)Mixed CaNaHCO3
4)Mixed CaMg Cl
5)CaCl
6)NaHCO3
Sea water
Fresh water
Cation Exchange
Salinization path 1
Salinization path 2
Magnesium(Mg)
Calcium(Ca)
Na
HCO3
Sulfate(SO4)
Chloride(Cl) + Fluoride(F)

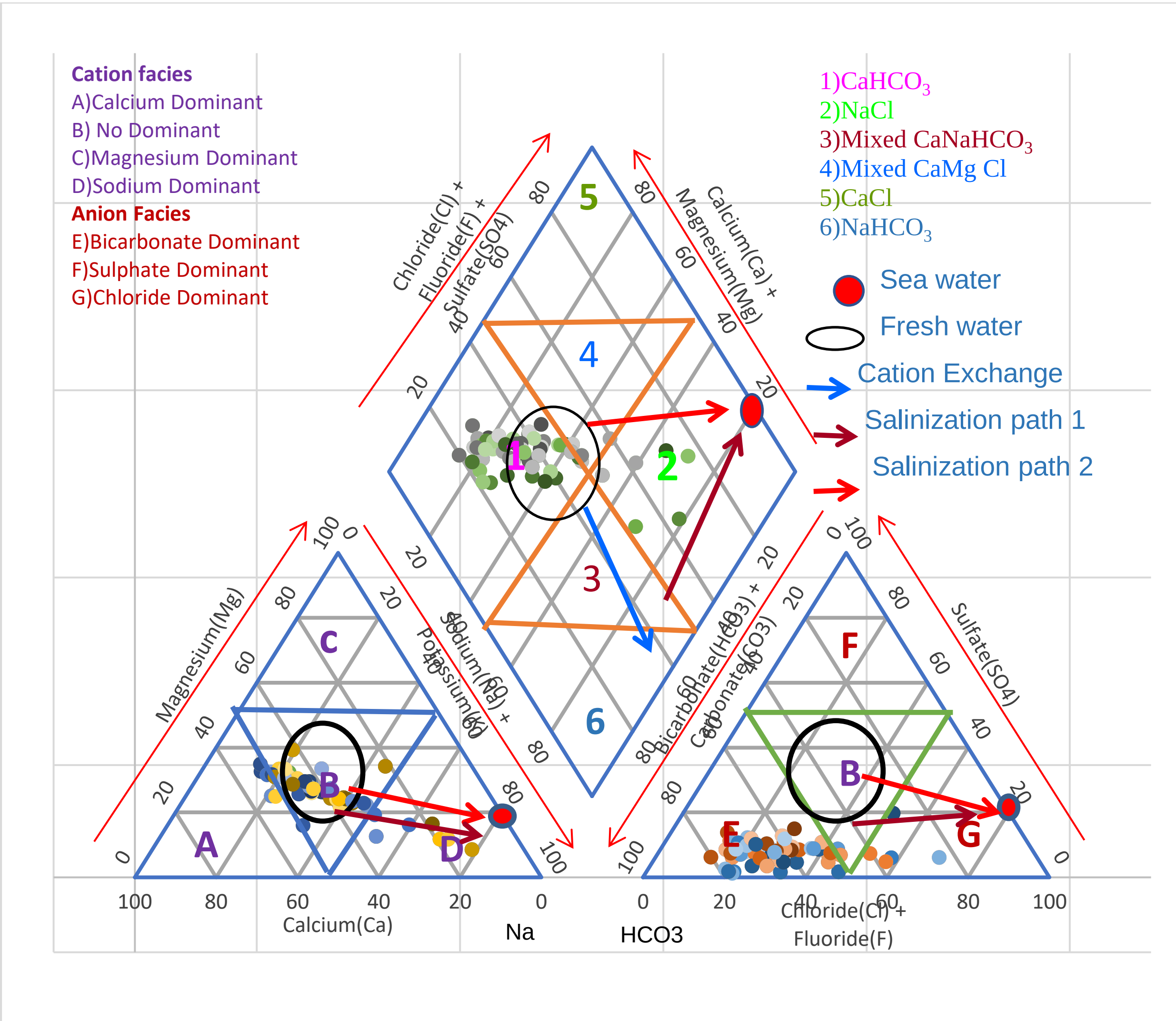


FIGURE 26 :PIPER DIAGRAM DURING PRE-MONSOON PERIOD

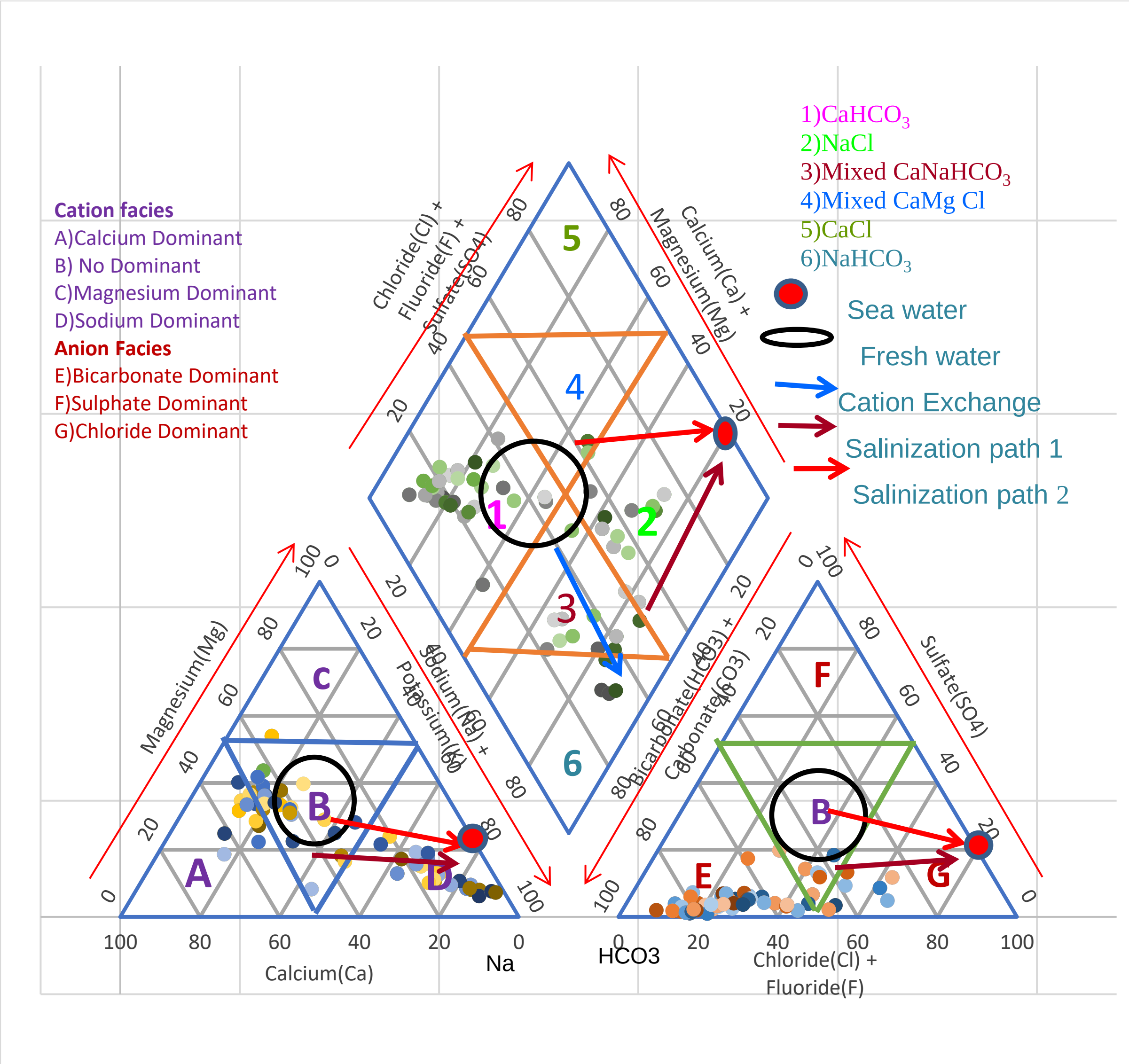


FIGURE 27: PIPER DIAGRAM DURING POST-MONSOON PERIOD

III. Groundwater natural mechanisms

Gibbs diagrams are essential tools used to analyze key natural processes within groundwater systems. Gibbs diagrams help to understand the relationship between the concentration of ions in groundwater and various aquifer characteristics like the chemical composition of the rocks, types of rocks present, geochemical reactions occurring, the rate of evaporation, the chemistry of precipitated water, and the solubility of rock formations. Gibbs diagrams primarily focus on three main natural mechanisms: rock dominance, evaporation dominance, and precipitation dominance. These mechanisms are determined through a scatter plot representation of Total Dissolved Solids (TDS) against the ratios of sodium to the sum of sodium and calcium (Na/(Na+Ca) and chloride to the sum of chloride and bicarbonate (Cl/(Cl+HCO3). As shown in the figure:31 (A) & (B) that water-rock/sediment interactions are the primary factors influencing groundwater composition in both seasons of the study area.

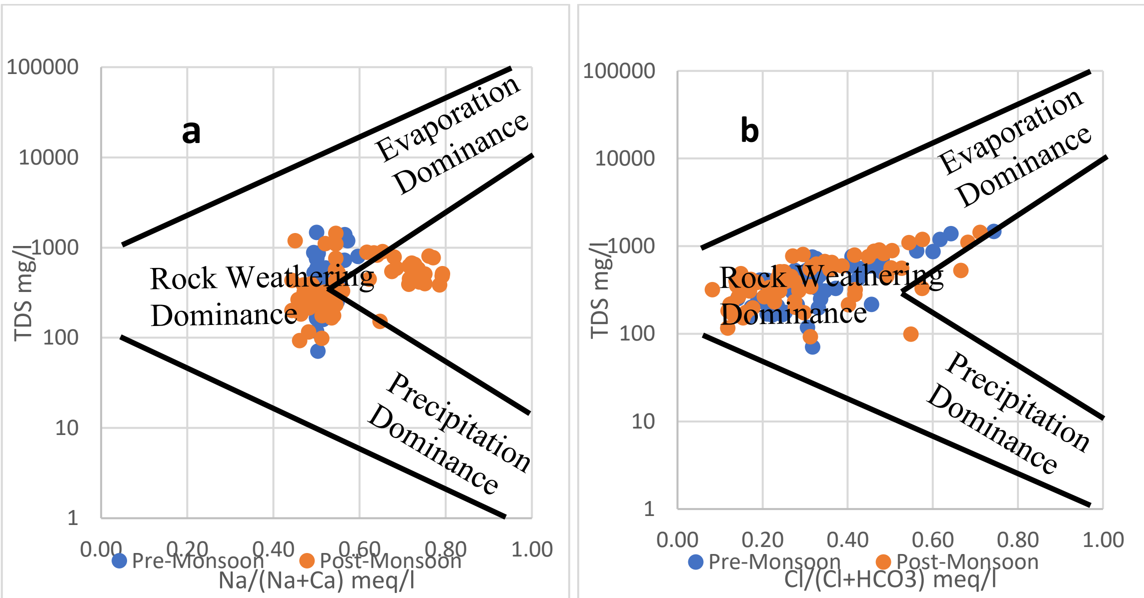
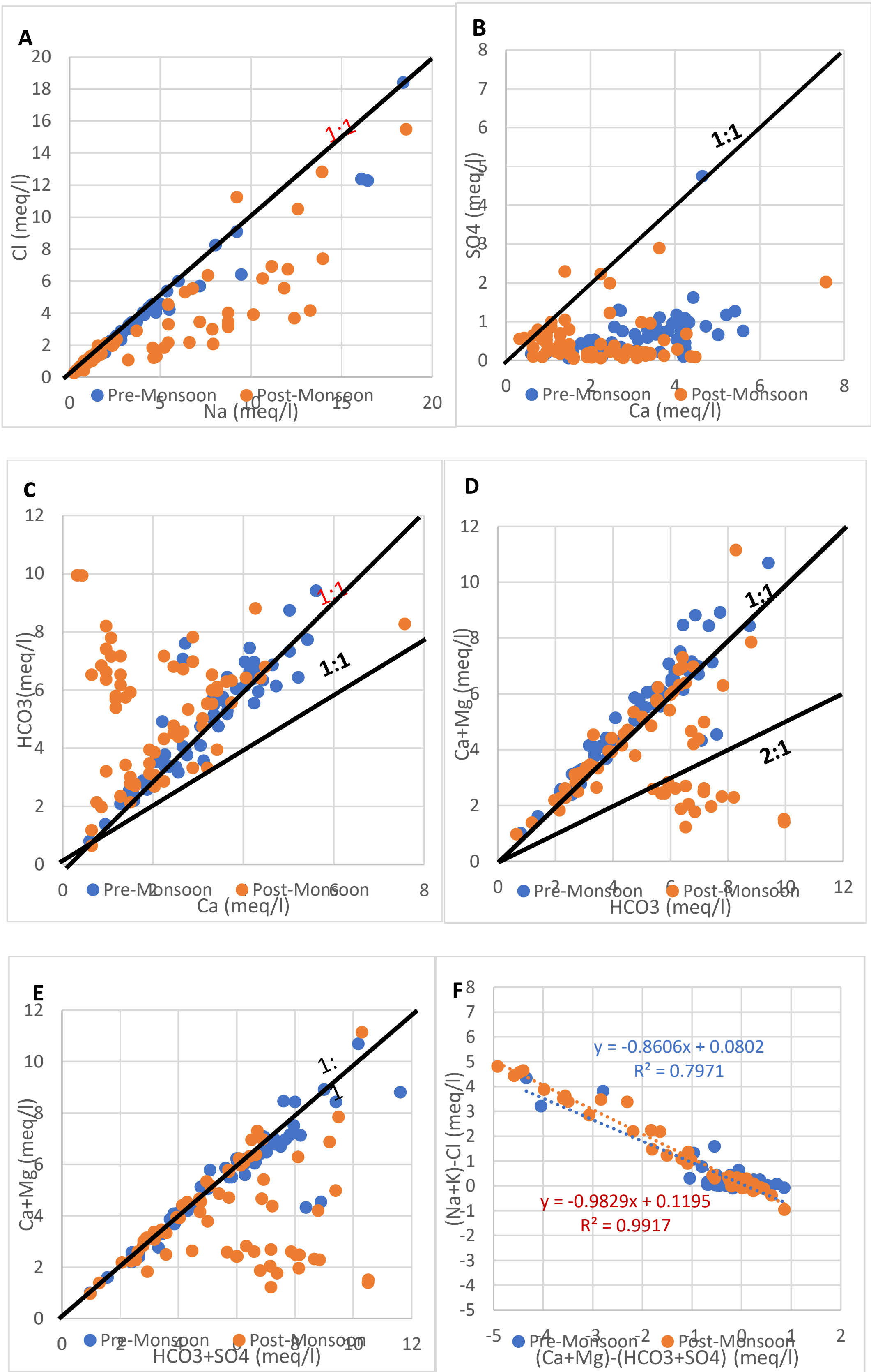


FIGURE 28 (A) GIBBS DIAGARM FOR CATIONS, (B) GIBBS DIAGRAM FOR ANIONS.

IV. Sources of Major Ions

Bivariate diagrams of ions serve as effective tools for illustrating the sources of major ions and their source and the mechanism that changed the composition of water. The relationship between sodium and chloride ions reveals that mechanism of acquiring salinity, Fig 32 (A). the Shows that in premonsoon season, sodium and chloride ions of the groundwater samples lies on 1:1 ration lone. which suggests that the mechanism of Halite Dissolution, whereas During post monsoon season the abundance of Sodium ion greater than chloride ion, indicates that increased sodium ion in the samples could be due to base ion exchange and weathering of silicates. Fig B. illustrates that almost all samples fall below the 1:1 line during both seasons, indicates that the dissolution of carbonates, such as calcite and dolomite, may be responsible for the calcium excess. Fig C. The groundwater samples during premonsoon season near to 1:1 line, indicate calcite dissolution is primary mechanism, where as in post monsoon season groundwater samples below the 2:1 ration, which suggest that excess of bicarbonate over calcium reflects that dominance of bicarbonate Fig D. The most of the groundwater samples of both seasons concentrated in the area of $HCO3^-$ against Ca^++ Mg^+ equaling from 1:1 to 2:1, indicating that dolomite dissolution is the primary source of Ca^+& $Mg^{+,}$ whereas 23 % of all samples (16 samples) fell below the 2:1 line indicate that effect of dolomite dissolution second reflects that dominance of bicarbonate over Ca^++ $Mg^{+.}$ It is associated with excess of sodium ions. The ratio of $HCO3^-$ +$SO4^{2-}$ against Ca^++ Mg^+ is close to 1, indicates that dominate reaction in the groundwater system would be dissolution of carbonate minerals and gypsum minerals. Fig E shows that in the post monsoon season, $HCO3^-$ +$SO4^{2-}$ dominants over Ca^++ Mg^+ may be due to silicate weathering and cation exchange. Similarly, the linear correlation between (Na+K)-Cl and (Ca+Mg) -(HCO3+SO4) demonstrates a slope close to -1, when cation exchange dominates within the groundwater system. Figure F illustrates that during the post-monsoon season, the slope of the linear fitting line is approximately -0.9829, indicating significant cation exchange occurring within the groundwater system.

Figure 29: Bivariant diagrams of major ionic concentration in ground water samples (A): Cl vs Na, (B) SO4 Vs Ca,(C): HCO3 vs Ca,(D):HCO3 + Ca+Mg: (E): HCO3+SO4 vs Ca+Mg: (F): Na+K-Cl vs (Ca+Mg)-(HCO3+SO4)



16. Water Quality for Irrigation Purpose

TABLE 14: SUMMARY OF WATER QUALITY INDICES FOR IRRIGATION

Indices	Formula
Sodium adsorption ratio (SAR)	$SAR = \frac{Na^{+}}{\sqrt{Ca^{+2} + Mg^{+2}}/2}$
Sodium Percentage (Na %)	$Na\ \% = \frac{(Na^{+} + K^{+}) \times 100}{(Ca^{+2} + Mg^{+2} + Na^{+} + K^{+})}$
Kelly's ratio	$KR = \frac{Na^{+}}{(Ca^{+2} + Mg^{+2})}$
Permeability Index (PI %)	$PI = \frac{(Na^{+} + \sqrt{HCO3}) \times 100}{(Ca^{+2} + Mg^{+2} + Na^{+} + K^{+})}$
Residual Sodium carbonate(RSC)	$RSC = (HCO3^{-} + CO3^{2-}) - (Ca^{+2} + Mg^{+2})$
Magnesium Hazard (MH %)	$MH = \frac{Mg^{+2}}{(Ca^{+2} + Mg^{+2})} \times 100$

TABLE 15: DESCRIPTIVE STATISTICS OF THE MEASURED IRRIGATION WATER QUALITY INDICES DURING PRE MONSOON AND POST MONSOON

	Pre-Monsoon				Post Monsoon			
	Min	Max	Mean	SD	Min	Max	Mean	SD
EC µs/cm	122	2615	816	501	115	2513	822	505
Na%	13.39	78.54	32.29	14.16	9.48	90.48	44.99	27.07
SAR	0.16	3.86	0.68	0.73	0.08	5.60	1.34	1.41
RSC	-2.03	3.06	-0.37	0.77	-2.89	8.54	1.29	2.37
MH	24.27	61.91	39.77	4.62	14.79	77.20	45.86	10.31
PI	99.40	1849.93	360.28	368.22	32.14	1864.60	492.27	444.31
KR	0.15	3.62	0.58	0.59	0.10	9.45	1.66	2.07
PS	0.45	19.21	3.35	3.47	0.31	16.93	3.10	3.27
KR	1.07	21.61	6.34	4.19	1.35	21.43	7.04	4.61

TABLE 16: STATISTICS OF THE MEASURED IRRIGATION WATER QUALITY INDICES DURING PRE MONSOON AND POST MONSOON

			Pre Monsoon		Post Monsoon	
Parameter	Range	Water Class	(N=62)	(%)	(N=69)	(%)
EC	<250	Excellent	2	3	3	4
	250–750	Good	33	53	32	46
	750–2250	Permissible	25	40	33	48
	> 2250	Doubtful	2	3	1	1
SAR	<10	Excellent	59	95	54	78
	10–18	Good	3	5	12	17
	18–26	Doubtful	NIL	NIL	3	4
	>26	Unsuitable	NIL	NIL	NIL	NIL
Na%	< 20	Excellent	11	18	20	29
	20–40	Good	38	61	14	20
	40–60	Permissible	9	15	8	12
	60–80	Doubtful	4	6	18	26
	> 80	Unsuitable	NIL	NIL	9	13
RSC	<1.25	Good	60	97	46	67
	1.25–2.5	Doubtful	NIL	NIL	3	4
	>2.5	Unsuitable	2	3	20	29
KR	<1	Suitable	56	90	39	57
	> 1	Unsuitable	6	10	30	43
PI	<80	Good	57	92	40	58
	80-100	Moderate	5	8	19	28
	100-120	Poor	NIL	NIL	10	14
MH	<50	Suitable	61	98	46	67
	>50	Harmful and Unsuitable	1	2	23	33
PS	<3.0	Excellent to good	37	60	45	65
	3.0-5.0	Good to injurious	16	26	11	16
	>5.0	Injurious to unsatisfactory	9	15	13	19

I. Salinity Hazard (SH)

Salinity hazard in groundwater for irrigation occurs when the concentration of salts in the groundwater is too high for healthy plant growth. This hazard is typically assessed through electrical conductivity values. High salinity poses a significant threat to soil health, it reveals in several detrimental ways, including reduced water availability, toxicity, soil structure degradation, nutrient imbalance, and decreased crop yield. In the present study, the electrical conductivity values ranged from 122 to 2615 µs/cm with a mean value of 816 µs/cm during the pre-monsoon period, and from 115 to 2513 µs/cm with a mean value of 822 µs/cm during the post-monsoon period. Groundwater classifications based on the salinity hazard are provided in the table. During the pre-monsoon period, the majority of the samples (35 samples) accounting for 56% of all samples) fell within the C1 (low) and C2 (medium) salinity hazard classes, indicating suitability for irrigation. Similarly, during the post-monsoon period, 35 samples (50% of all samples) were classified under these categories. However, samples falling under the high salinity hazard class (C3) are considered doubtful for irrigation water quality. In this class, 25 samples (40% of all samples) were observed during the pre-monsoon period, and 33 samples (48% of all samples) during the post-monsoon period. Furthermore, samples categorized as very high salinity hazard class (C4) were deemed unsuitable for irrigation. Two samples (Haldipada and Jhinkaria) were identified during the pre-monsoon period, and one sample (Jhinkaria) during the post-monsoon period.

TABLE 17: SALINITY HAZARD CLASS IN THE STUDY AREA.

			Pre-Monsoon		Post-Monsoon	
Salinity Hazard Class	EC (µs/cm)	Water Quality	(N=62)	(%)	(N=69)	(%)
Low C1	<250	Excellent	2	3	3	4
Medium C2	250–750	Good	33	53	32	46
High C3	750–2250	Doubtful	25	40	33	48
Very High C4	> 2250	Unsuitable	2	3	1	1

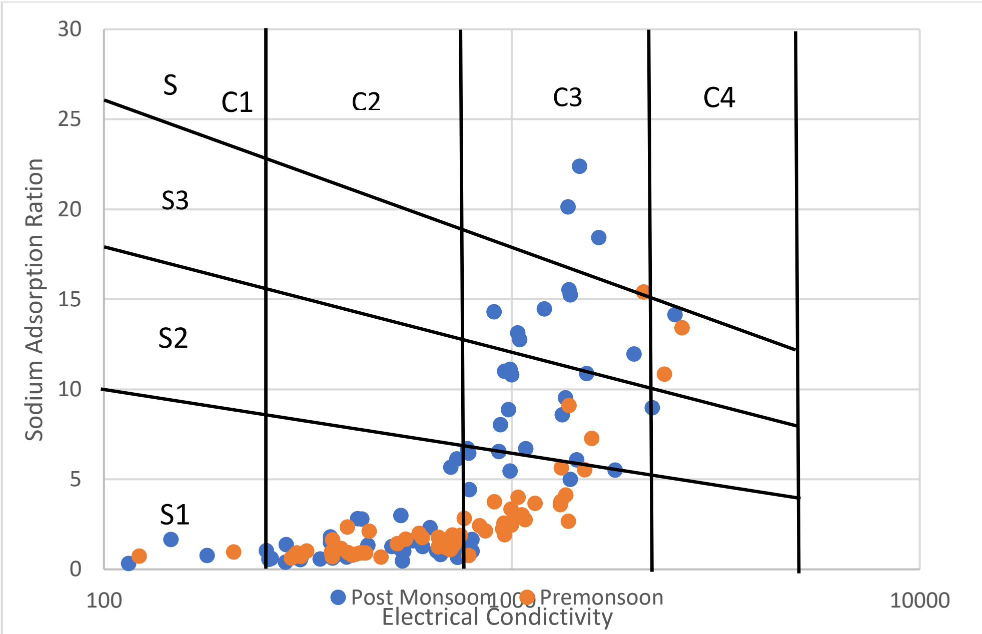


FIGURE 30. THE USSL DIAGRAM FOR CLASSIFICATION OF IRRIGATION WATER.

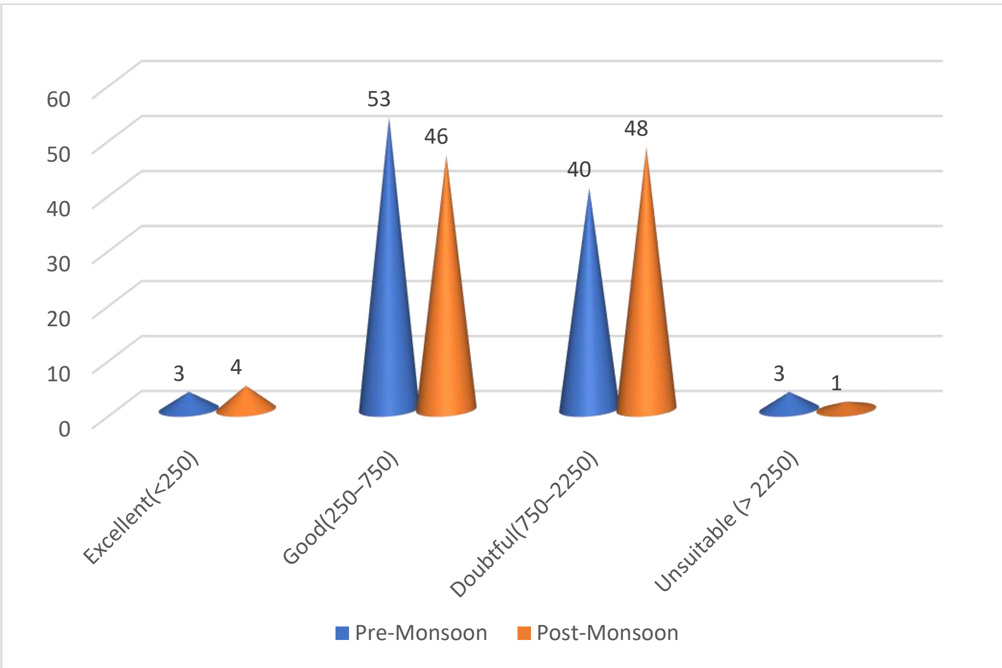


FIGURE 31: NUMBERS OF SAMPLE LOCATIONS UNSUITABLE FOR IRRIGATION WITH RESPECT TO EC.

II. SAR

The SAR serves as an indicator of sodium hazards, signifying the potential risk of reducing soil permeability leads to limiting the water absorption by crops. Groundwater classifications for irrigation based on SAR are presented in the table. SAR values of groundwater samples during the pre-monsoon period ranges from 0.6 to 15.4, with a mean of 2.9, while post-monsoon groundwater samples ranges from 0.3 to 22.4, with a mean of 5.7. For better understanding of water suitability for irrigation can be achieved by the plotting SAR against electrical conductivity (EC) values using a USSL diagram. In the figure, approximately 3% of all samples (2 samples) during the pre-monsoon period and 4% of all samples (3 samples) during the post-monsoon period were classified as C1S1, indicating low salinity and low sodium levels. Moreover, about 53% of all samples (33 samples) during the pre-monsoon period and 46% of all samples (32 samples) during the post-monsoon period fell into the category of C2S1, suggesting medium salinity and low sodium levels. Consequently, these findings imply suitability for irrigation. About 4% of samples (3 samples) fell within the C doubtful range (18-26) during the post-monsoon period, indicating that these groundwater samples are unsuitable for irrigation.

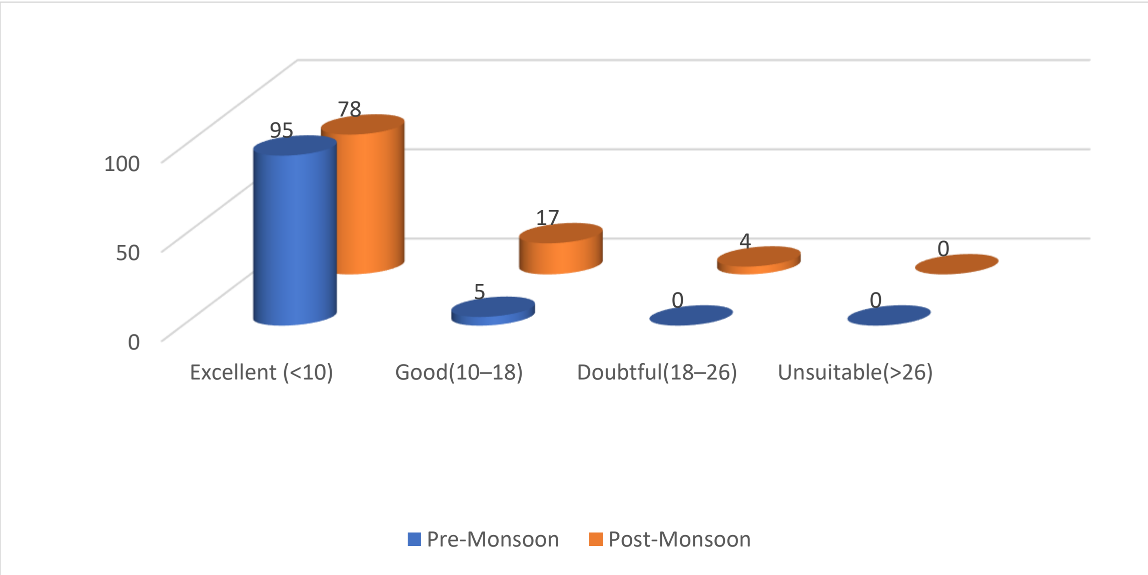


FIGURE 32: COMPARISON OF SAR DURING PRE- & POST-MONSOON PERIOD.

III. Sodium Percentage

The Sodium Percentage indicates the sodium hazard present in soil. When water contains an excess of sodium ions, it displaces calcium and magnesium ions from soil particles. This process results in soil degradation, leading to deterioration of soil structure, reduced water infiltration, increased soil compaction, and decreased nutrient levels. The table shows that the Na% (sodium percentage) of both pre- and post-monsoon groundwater samples ranges from 13.4% to 78.5% and from 9.5% to 90.5%, with mean values of 32.3% and 45.0% respectively. During the pre-monsoon period, approximately 96% of samples were within permissible limit for irrigation, while 6% of samples were categorized as doubtful for irrigation purposes. Similarly, about 61% of samples met the permissible limits for irrigation during the post-monsoon period, where as 26% of the ground water samples falling under the doubtful category. However, approximately 13% of samples exhibited a high sodium percentage, indicating that these groundwater samples are not suitable for irrigation due to the high sodium content.

A Wilcox diagram was utilized to evaluate the suitability of groundwater for irrigation. In the figure, the majority of samples from the pre-monsoon period were categorized as excellent to good and good to permissible, indicating that these groundwater samples are suitable for irrigation. However, approximately 8% of all samples (5 samples) were classified as permissible to doubtful and doubtful to unsuitable, suggesting that these samples are not suitable for irrigation. Similarly, for post-monsoon groundwater samples, approximately 57% of all samples were rated as excellent to good and good to permissible, indicating suitability for irrigation. However, 43% of all samples were distributed between permissible to doubtful and doubtful to unsuitable categories, indicating that they are not suitable for irrigation due to high sodium percentages. This suggests that during the post-monsoon season, groundwater experiences a strong interaction with rocks, leading to cation exchange, particularly with increased sodium percentages.

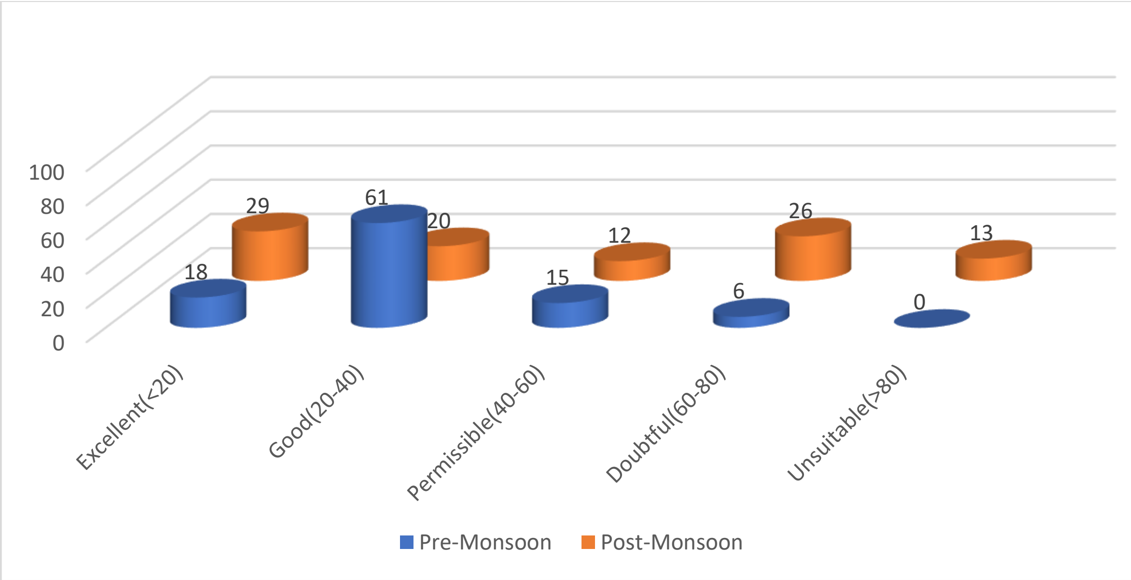


FIGURE 33: COMPARISION OF SODIUM PERCENTAGE DURING PRE MONSOON AND POST MONSOON PERIOD.

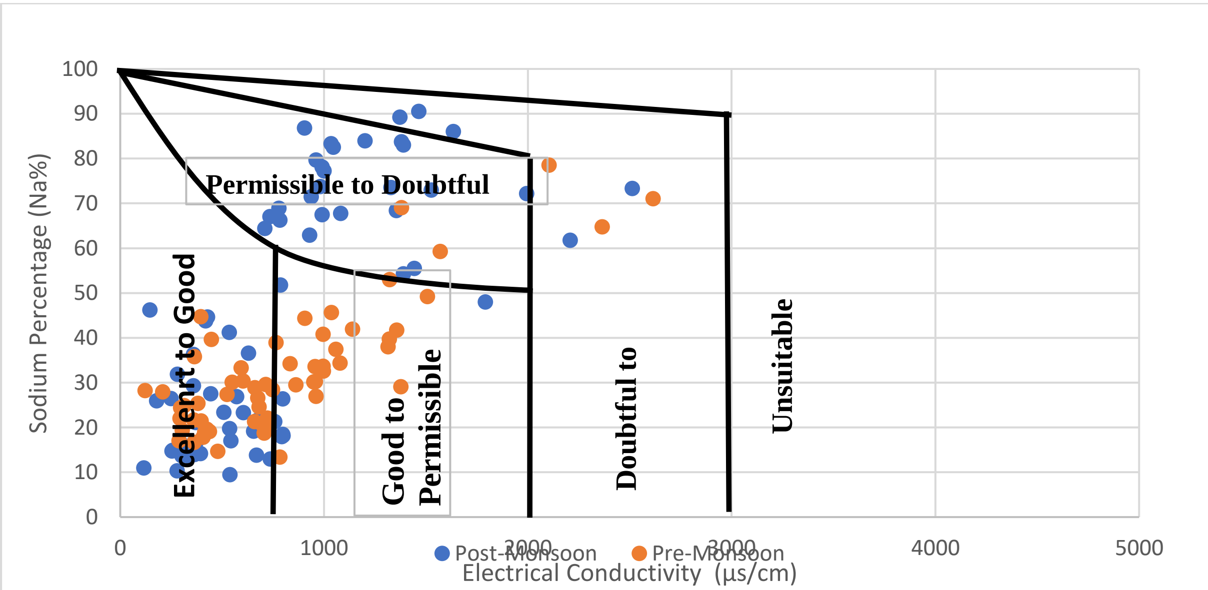


FIGURE 34: WILCOX PLOT .

IV. Residual Sodium Carbonate (RSC)

Bicarbonate is a major indicator for evaluating the carbonate hazard of irrigation water. The Residual Sodium Carbonate (RSC) index serves as a valuable tool in assessing the carbonate hazard of soil. It quantifies the relationship between the combined concentrations of carbonate and bicarbonate ions and those of calcium and magnesium ions. Elevated RSC values in irrigation water can lead to soil infertility due to the accumulation of sodium carbonate. In this study, the RSC of pre-monsoon groundwater samples ranges from -2.03 to 3.06 meq/L, with a mean value of -0.34 meq/L. Similarly, the RSC of post-monsoon groundwater samples varied from -2.89 to 8.54 meq/L, averaging at 1.33 meq/L (Table). The table provides the groundwater classifications based on RSC in the study area. During the pre-monsoon period, approximately 97% of all samples were classified as having good water quality, with only 3% falling under doubtful irrigation quality. However, during the post-monsoon season, 67% of samples were categorized as good, while 4% fell under doubtful quality, and 29% of all samples (20 samples) were deemed unsuitable for irrigation. A comparison between both seasons reveals that groundwater samples with high RSC values during the post-monsoon season indicate the silicate weathering.

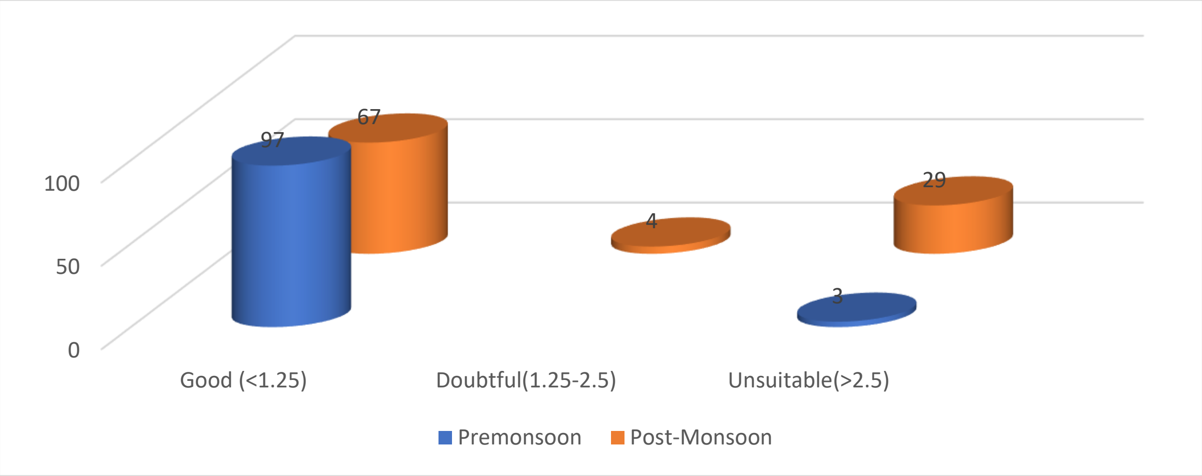


FIGURE 35: NUMBER OF SAMPLE LOCATIONS UNSUITABLE FOR IRRIGATION WITH RESPECT TO RSC.

V. Magnesium Hazard (MH)

The Magnesium hazard is a crucial irrigation index used to evaluate soil health for irrigation purposes. Elevated levels of magnesium in irrigation water can result in soil alkalinity and a reduction in soil infiltration capacity, ultimately leading to decrease the crop yields. The classification of irrigation water quality concerning Magnesium hazard is outlined in the table. The Magnesium Hazard ranged from 24.6% to 64.2% (with a mean value of) during the pre-monsoon period and from 14.8% to 72.4% (with a mean value of) during the post-monsoon period, as indicated in the table. Furthermore, during the pre-monsoon period, approximately 98.4% of all samples (61 samples) fell below the 50% threshold, indicating suitability for irrigation. Similarly, during the post-monsoon period, around 66.7% of all samples (46 samples) were below 50%, suggesting suitability for irrigation. However, during the pre-monsoon period, only one sample exceeded the 50% threshold for Magnesium Hazard. Conversely, during the post-monsoon period, approximately 33.3% of all samples (23 samples) exceeded the 50% threshold, indicating that during this season, some samples may not be suitable for irrigation purposes.

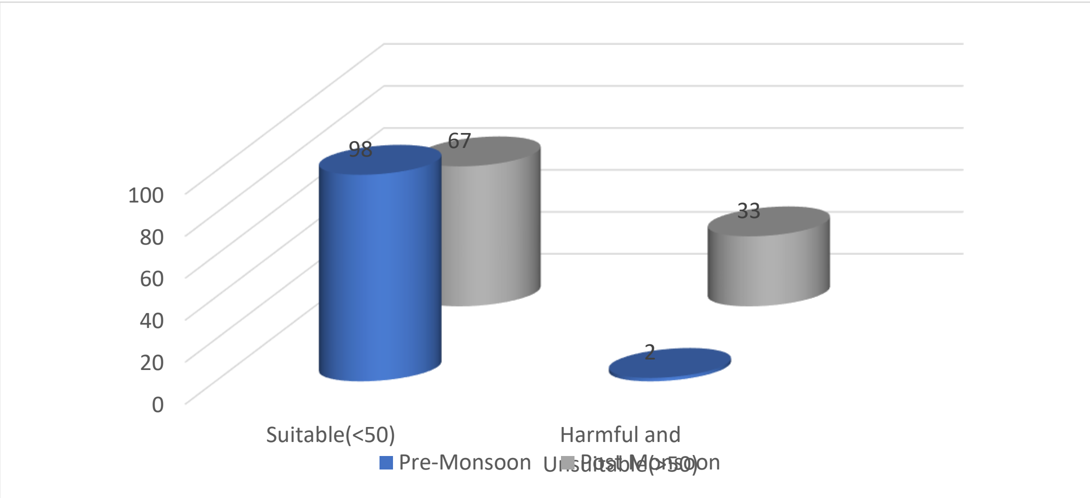


FIGURE 36: NUMBER OF SAMPLE LOCATIONS UNSUITABLE FOR IRRIGATION WITH RESPECT TO MH.

VI. Permeability Index (PI)

The Permeability Index (PI) act as a key indicator for assessing the suitability of water for irrigation purposes. It evaluates the soil permeability, which is significantly influenced by the long-term utilization of irrigation water containing ions (Na^+, $Ca2^+$, $Mg2^+$, and $HCO3^-$) with high concentrations. PI formula has been developed by Doneen (1964), to assess water movement capability in the soil as the suitability of any kind of source of water for irrigation. The Donnen diagram developed using the total concentration of salts and the PI. The Permeability Index (PI) of pre-monsoon groundwater samples ranged from 45% to 91% (with a mean value of 62%), while post-monsoon groundwater samples varied from 45% to 113% (with a mean value of 75%). As illustrated in the Figure, approximately 92% and 8% of all samples during pre-monsoon, and 58% and 28% of all samples during post-monsoon, were classified as class I (75% maximum permeability) and class II (25% maximum permeability), respectively. This suggests that the groundwater samples are suitable for irrigation. However, about 14% of all samples (10 samples) during the post-monsoon period fell under class III (below 25% maximum permeability), indicating unsuitability for irrigation. High PI values are associated with Na+ and HCO3− ions, possibly due to ion exchange and carbonate dissolution processes.

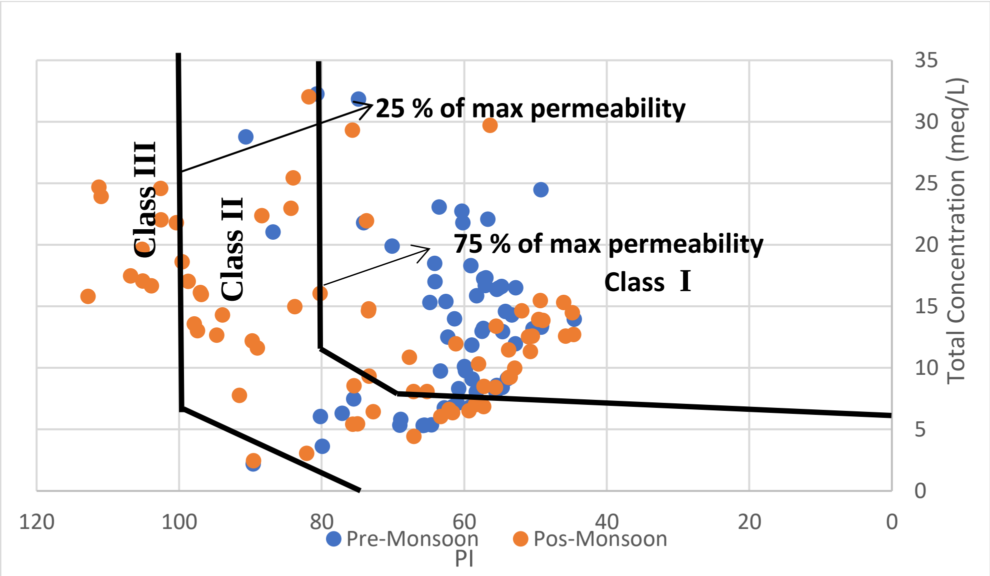


FIGURE 37: PERMEABILITY DATA PLOT OF THE WATER SAMPLES.

VII. Kelley's Ratio

The suitability of irrigation water can also be assessed using Kelley's ratio. A Kelley's ratio value less than 1 indicates suitability for irrigation, while a value greater than 1 reflects unsuitability. As shown in the table, Kelley's ratios ranged from 0.15 to 3.62 (with a mean value of 0.58) during the pre-monsoon period and from 0.10 to 9.45 (with a mean value of 1.66) during the post-monsoon period. According to Kelley's ratio classification, approximately 90% of all samples (56 samples) and 57% of all samples (39 samples) had a KR value less than 1 during the pre-monsoon and post-monsoon periods, respectively. However, about 10% of all samples (6 samples) and 43% of all samples (30 samples) had a KR value greater than 1, indicating unsuitability for irrigation. Comparing pre-monsoon and post-monsoon samples, a higher percentage of samples during the post-monsoon period were unsuitable for irrigation, possibly due to intensified cation exchange, leading to an excess of Na^+ ions.

VIII. Potential Salinity (PS)

Potential Salinity is calculated as the sum of the chloride (Cl^-) concentration and half of the sulfate ($SO4^{2-)}$ concentration, serving as an indicator of groundwater suitability for irrigation. Groundwater is categorized based on PS, as tabulated in Table... PS values range from 0.45 to 19.20, with a mean value of 3.35 during the pre-monsoon period, and from 0.31 to 16.93, with a mean value of 3.10 during the post-monsoon period. During the pre-monsoon period, 60% of all samples were classified as excellent to good, while 26% and 15% were categorized as good to injurious and injurious to unsatisfactory, respectively. For post-monsoon groundwater samples, approximately 65% were classified as excellent to good, with 16% and 19% falling into the good to injurious and injurious to unsatisfactory classes, respectively.

Parameter	Pre Monsoon	Post Monsoon
EC	Sadar, Remuna	Jhinkaria
SAR	NIL	NIL
Na%	NIL	Balramgadi-Mirzapur,BadagobraTW,Angula ,Tentulimundi,RaghunathpurTubewell,RaghunathpurHP,NilidaTubeWell,Kayakada,Gudupahi
RSC	Kantarada,Hidigaon,	Tundara/Kungarpur,Balramgadi-Mirzapur,Srikona II T.W,Pinchabania, Kharji, Salpata/Sunipat, Badagobra T.W.,PutadiaTW,Angula ,Tentulimundi,RaghunathpurTube well, Raghunathpur, NilidaTubeWell,Nilada ,Bahabalpur,Bahabalpur,Dublagudi ,Parkhi,Kayakada,Gudupahi
KR	Kantarada,Khandahara, Haldipada, Jhampara,Srikona,Hidigaon,Jhinkaria,	Tundara/Kungarpur,Bardhanpur,BK chowk,Gopalgaon,Hidigaon,Jhampara,Srikona,Balramgadi-Mirzapur,Srikona,Srikona II T.W,SrikonaHp-II,Kasimpur , Dahapada G.P.,Odangi,Khandahara, Haldipada,Pinchabania,Pinchabania,Rupsa,Kharji,Salpata/Sunipat,Bada gobra T.W.,Jhinkaria,PutadiaTW,Angula ,Tentulimundi,Tentulimundi,Raghunathpur Tube well,Raghunathpur,Sindiya,Nilida Tube Well,Nilada ,Bahabalpur,Bahabalpur,Hidinga,Dublagudi ,Parkhi,Kayakada,Gudupahi
PI	NIL	Balramgadi-Mirzapur,BadagobraT.W.,Angula ,Tentulimundi,Raghunathpur Tube well,Raghunathpur,Nilida Tube Well,Nilada ,Kayakada,Gudupahi ,
MH	Gopalgaon	Udambar,UdambarTubewell (210ft.),Januganj,Naraharipur,Meghadamburu Tube Well (210ft.),Aladia,Hidigaon,Balramgadi-Mirzapur,Srikona,Srikona II T.W,Salpata/Sunipat,Angula ,Tentulimundi,Raghunathpur Tube well,Raghunathpur,Nilida Tube Well,Nilada ,Bahabalpur,Bahabalpur,Hidinga,Dublagudi ,Parkhi,Gudupahi
PS	Kantarada,Khandahara, Haldipada,Jhampara,Srikona,Hidigaon,Gudupahi ,Srikona HP, Jhinkaria,Tentulimundi	Rasalpur Tube Well (250 ft.),Hidigaon,Jhampara,Srikona,Balramgadi-Mirzapur,SrikonaHp-II,Odangi,Khandahara, Haldipada,Jhinkaria,PutadiaTW,Tentulimundi,Hidinga,Gudupahi

17. Water Quality for Drinking Purpose

The hydro chemical analysis of groundwater samples from both seasons was compared with IS 10500:2012 drinking water specifications. The major ions, except fluoride, in the groundwater samples were found to be within permissible limits, indicating suitability for drinking purposes if there are no alternative water sources. However, the low pH values indicate the acidic nature of the groundwater. Only a few samples exhibited low pH values in both seasons. The electrical conductivity (EC) of the groundwater samples showed that approximately 24% and 26% of all samples had EC values above 1000µs/cm during the pre- and post-monsoon periods, respectively. This suggests that the groundwater samples are of poor quality based on EC values. One of the primary concerns for drinking water quality is fluoride concentration. The effects of fluoride on human health vary based on its concentration in groundwater, as shown in the table. Approximately 10% (6 samples) and 15% (10 samples) of all samples during pre-monsoon and post-monsoon periods, respectively, fell within the range of low to high risk due to high fluoride concentration. The table illustrates that the listed sample locations are not suitable for drinking purposes due to fluoride contamination.

TABLE 18: FLUORIDE CONTAMINATION COMPARISON IN PRE-MONSOON AND POST-MONSOON PERIOD.

			Pre-Monsoon		Post-Monsoon	
Range of Fluoride in mg/L	Classification	Associated Risk	N=62	%	N=69	%
0-1.5	Safe	within permissible limit	56	90	59	86
1.5-3.0	Low risk	Dental Fluorosis	3	5	6	9
3.0-5.0	High risk	Dental and mild skeleton Fluorosis	3	5	4	6
>5.0	Very High risk	Severe Skeleton Fluorosis	0	0	0	0

TABLE 19: LOCATIONS OF FLUORIDE CONTAMINATION.

S.No	Block	Location	Source	Depth of Well	Fluoride mg/L
Pre-Monsoon					
1	Sadar	Rupsa	HP	45	4.34
2	Sadar	Angula	HP	45	1.51
3	Sadar	Jhampara	HP	45	1.56
4	Sadar	Kurunia	HP	45	3.01
5	Remuna	Tentulimundi	HP	45	1.58
6	Remuna	Raghunathpur	HP	45	3.66
Post-Monsoon					
1	Remuna	Kurunia	HP	45	3.26
2	Sadar	Jhampara	HP	45	2.16
3	Sadar	Srikona	HP	45	2.26
4	Sadar	Kasimpur ,Dahapada G.P.	HP	45	1.81
S.No	**Block**	**Location**	**Source**	**Depth of Well**	**Fluoride mg/L**
5	Sadar	Khandahara, Haldipada	HP	45	1.89
6	Sadar	Pinchabania	Tube Well	45	4.81
7	Sadar	Angula	HP	45	1.68
8	Sadar	Tentulimundi	HP	45	1.72
9	Sadar	Raghunathpur	Tube well	45	3.53
10	Sadar	Raghunathpur	HP	45	3.92

I. Water Quality index calculation for drinking purpose:

Table 20: Assign and relative WQI computation with IS10500:2012 Drinking water standards

S.No	Parameters	Unit	IS 10500:2012 Acceptable limit	Assigned Weight (Wi)	Relative Weight (RWi)
1	pH		6.5-8.5	4	0.11
2	TDS	mg/l	500	4	0.11
3	Total Hardness	as CaCO3 mg/l	300	3	0.08
4	Total Alkalinity	as CaCO3 mg/l	200	3	0.08
5	Calcium	mg/l	75	3	0.08
6	Magnesium	mg/l	30	3	0.08
7	Chloride	mg/l	250	4	0.11
8	Sulphate	mg/l	200	4	0.11
9	Nitrate	mg/l	45	4	0.11
10	Fluoride	mg/l	1	5	0.14
			Total	37	1.00

Water Quality Index (WQI) WQI is a single score derived by considering different important parameters of water quality. It is an integration of the individual effect of all the parameters in right proportion in deciding the quality of water WQI is generally computed in three steps by several researchers (Water programme, 2007, Ramkrishnaiah et al 2009). Here a different approach of assigning weightage was considered to identify and highlight the location specific reasons for contamination of water. At first each parameter was assigned a weight (Wi) according to its relative importance in the overall quality of water for drinking purposes based on per cent of samples within the permissible limit as per the standards. Weights of 5, 4, 3, 2, 1 are assigned to the quality parameters when 0-20, 21-40, 41-60, 61-80 and 81-100 % of samples are within the permissible limit respectively (Raychaudhuri et al 2011).

1. The relative weights (RWi) are calculated as per the formula

$$RWi = \frac{Wi}{\sum_i^n Wi} \qquad (1)$$

Where n is the number of parameters being assessed by WQI

2. Each parameter is assigned a quality rating scale (qi) as per formula

$$qi = \frac{ei - vi}{bi - vi} \times 100 \qquad (2)$$

Where e_i is the value of each parameter observed experimentally, $v_i$is the base value for each parameter (0 for all parameters except p H(7).b_i is the standard value as recommended by IS 10500:2012

3. The sub index (S.I.i) each parameter for a place is thus calculated as

$$S.I.i = qi \times RWi \qquad (3)$$

4. WQI of each station is calculate as

$$WQI = \sum_1^n S.I.i \qquad (4)$$

The computed WQI values are then categorized into five classes, “excellent” “good”, “poor”, “very poor” and “unsuitable” for drinking purpose. The WQI identifies the causative element or group of parameters responsible for the deteriorated quality so that appropriate measures can be implemented for its restoration.

TABLE 21. RANGE AND CLASSIFICATION OF WQI FOR DRINKING PURPOSE

S.No	WQI Value	Water Quality	Pre-Monsoon		Post Monsoon	
			N=62	%	N=69	%
1	<50	Excellent water	7	11	6	9
2	50-100	Good water	18	29	28	41
3	100-200	Poor water	32	52	31	45
4	200-300	Very poor water	3	5	3	4
5	>300	Unsuitable for drinking	2	3	1	1

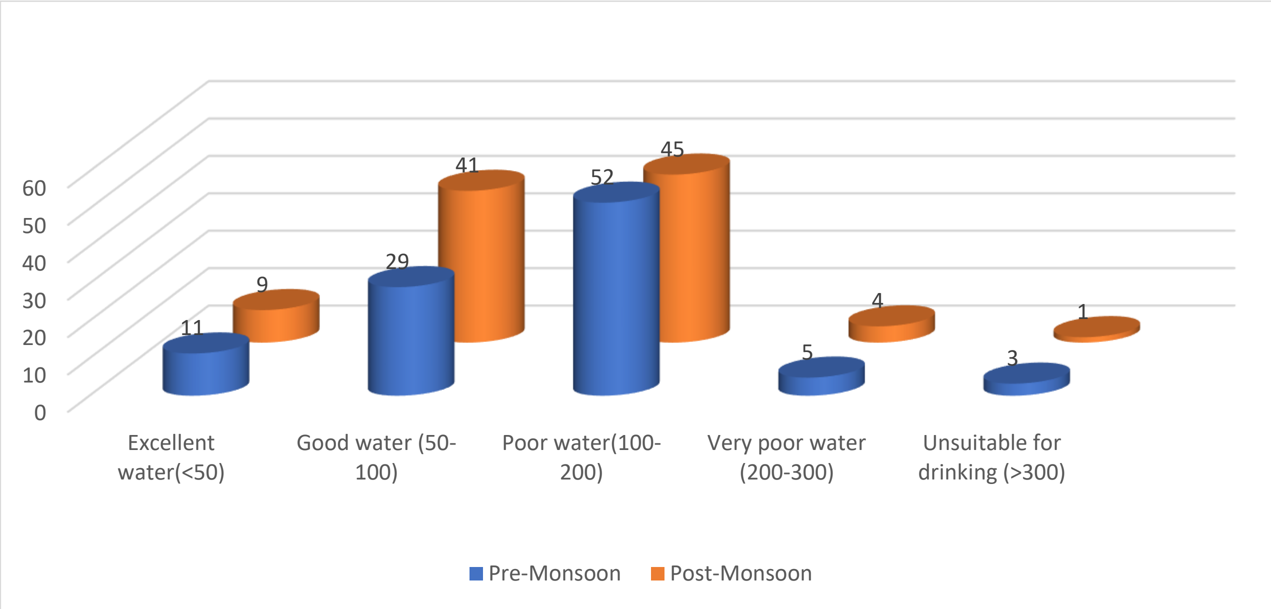


FIGURE 38: NUMBER OF SAMPLE LOCATIONS UNSUITABLE FOR IRRIGATIONWITH RESPECT TO WQI.

Table 22: Unsuitable for Drinking as per Water Quality Index.

S.No	Block	Location	Source	Depth of Well	WQI
Pre Monsoon					
1	Sadar	Khandahara, Haldipada	HP	45	303
2	Remuna	Jhinkaria	HP	45	312
Post Monsoon					
1	Remuna	Jhinkaria	HP	45	300

18. Sea water ingress

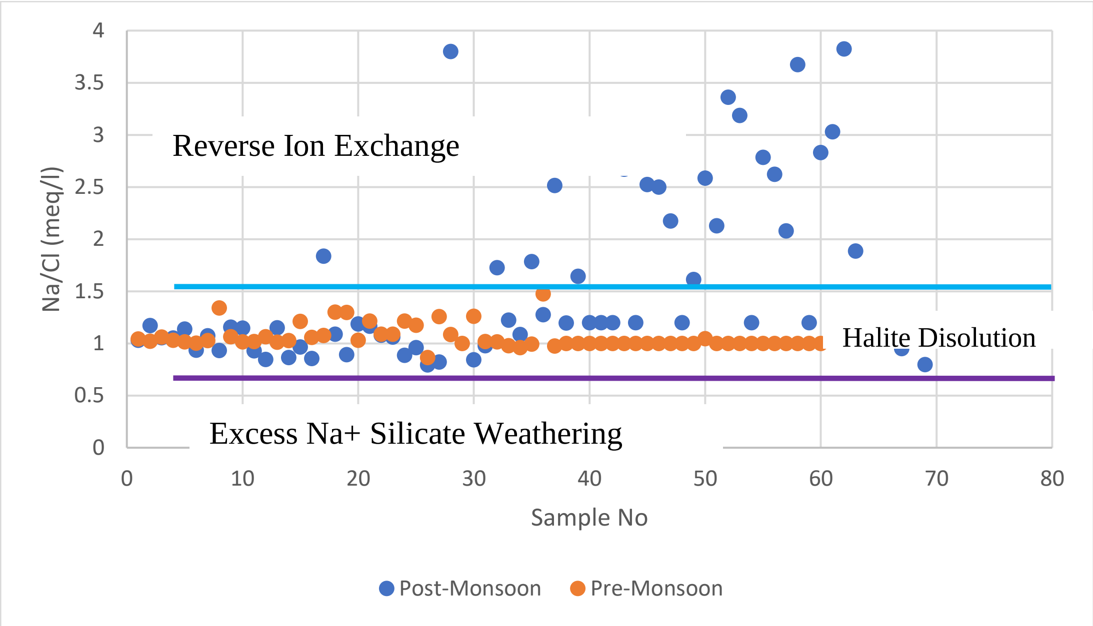


FIGURE 39: SAMPLE VS SODIUM/CHLORINE PLOT

I. Sea water Instrusion indices

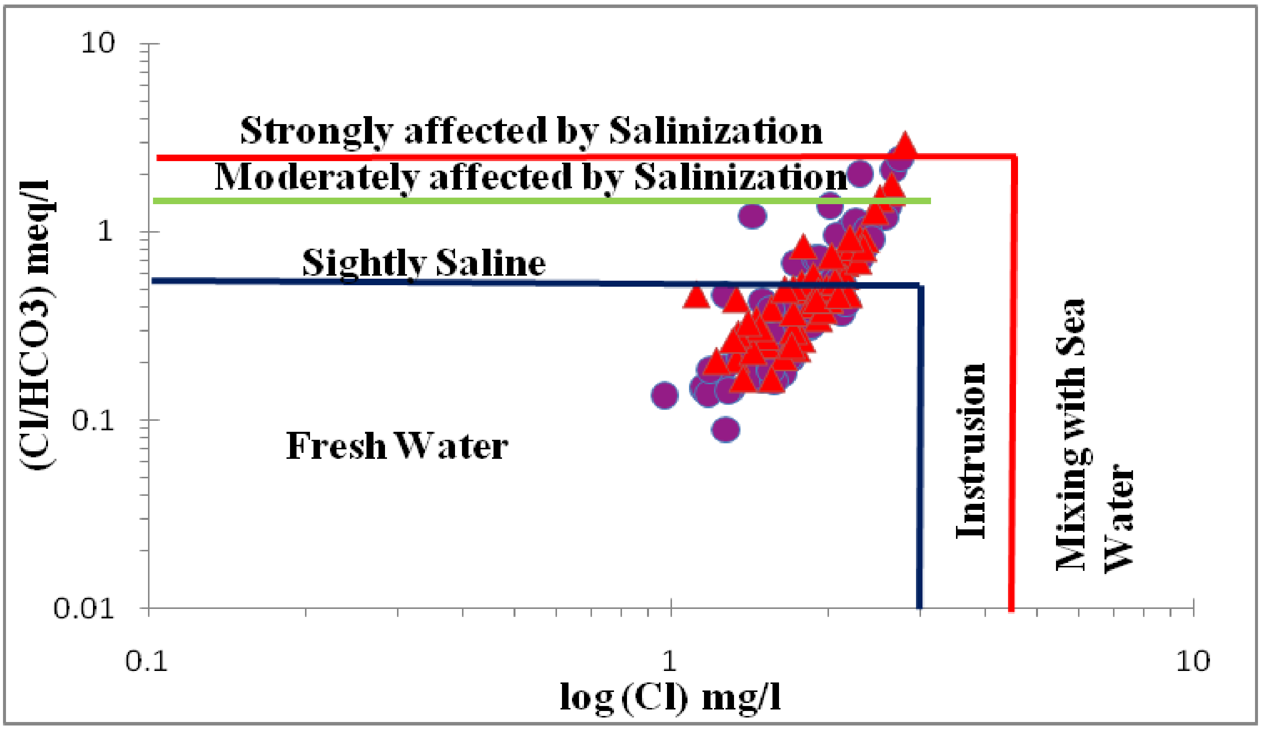
There are many indicators to identify seawater intrusion from other sources of salinity, like an elevated chloride concentration, Na/Cl ratio, Simpson ratio, Base Exchange indices, etc. From the results of chemical analysis, seawater intrusion is identified through qualitative approaches (Bear 1999).

The Cl-/HCO3- ratio is one indicator of seawater intrusion. In freshwater, the chloride to bicarbonate ratio (Cl-/HCO3-) tends to be relatively low compared to seawater. Monitoring changes in this ratio can help detect the presence of seawater in groundwater.. Bicarbonate (HCO3-) is a common ion found in freshwater sources, often originating from the weathering of rocks and minerals. Chloride (Cl-) concentrations in freshwater are generally lower compared to seawater due to limited exposure to marine sources. The Cl-/HCO3- ratio in freshwater can vary depending on factors such as geological characteristics, land use, and anthropogenic influences. The Simpson ratio (Todd 1959) is described as the ratio of Cl/(HCO3 + CO3). There are five classes to identify the level of groundwater contamination: a ratio of 0.5 indicates good quality water, a ratio of 0.5–1.3 indicates slightly contaminated water, a ratio of 1.3–2.8 indicates moderately contaminated water, a ratio of 2.8–6.6 indicates injuriously contaminated, and a ratio of 6.6–15.5 indicates highly contaminated water.

However, this ratio can vary based on regional geology and hydrology. Monitoring the Cl-/HCO3- ratio in freshwater is important for understanding water chemistry and identifying potential sources of contamination or changes in water quality. High Cl-/HCO3- ratios in freshwater may indicate influences from saline sources, such as seawater intrusion or anthropogenic contamination.

TABLE 23: (CL/(HCO3-)) VS THE CORRESPONDING LEVELS OF GROUNDWATER CONTAMINATION DURING PRE MONSOON AND POST MONSOON PERIOD.

Range of Cl/(HCO^-_3)	Level of Ground water Contamination	Pre-Monsoon		Post –Monsoon	
		N=62	%	N=69	%
< 0.5	Good Quality	42	68	46	67
0.5-1.3	Slightly contaminated groundwater	16	26	18	26
1.30-2.80	Moderately contaminated groundwater	3	5	5	7
2.80-6.60	Injuriously contaminated groundwater	1	2	0	0
6.60-15.50	Highly Contaminated groundwater	-			
>200.00	Sea water	-			



The table illustrates the chloride to bicarbonate ratio (Cl/(HCO3-)) ranges and the corresponding levels of groundwater contamination before and after the monsoon season. For groundwater categorized as Good Quality (Cl/(HCO3-) < 0.5), 68% of samples were classified as such before the monsoon season. This percentage slightly increased to 67% after the monsoon. Around 26% of samples were marginally contaminated both before and after the monsoon. Moderately Contaminated Groundwater (with a ratio between 1.30 and 2.80) comprised only a small percentage (5-7%) of samples, indicating moderate contamination. Injuriously Contaminated Groundwater (with a ratio between 2.80 and 6.60) was observed in a very small percentage of samples (2% before the monsoon and 0% after). No samples were classified as Highly contaminated Groundwater (>200.00) or as Seawater (>200.00), suggesting no significant intrusion of seawater into the groundwater sources either before or after the monsoon season.

II. Na/Cl Ratio:

Sea water intrusion can be detected and analysed using various indicators, and one such indicator is the sodium to chloride (Na/Cl) ratio. The Na/Cl ratio serves as a valuable indicator for detecting and quantifying seawater intrusion into freshwater aquifers. It helps in understanding the extent of contamination and enables effective management of groundwater resources to safeguard against the adverse effects of seawater intrusion. In freshwater sources unaffected by seawater intrusion, the Na/Cl ratio tends to be low (<0.86). This is because in natural freshwater, sodium concentrations are usually lower compared to chloride concentrations. When seawater infiltrates into freshwater aquifers, it introduces higher concentrations of sodium and chloride ions. As a result, the Na/Cl ratio in the affected groundwater increases significantly. By measuring the Na/Cl ratio in groundwater samples; one can identify deviations from the natural ratio. A higher-than-usual Na/Cl ratio indicates the influence of seawater intrusion. The degree of seawater intrusion can also be estimated based on the magnitude of the increase in the Na/Cl ratio. A more substantial increase suggests a higher level of seawater contamination in the freshwater aquifer. Furthermore, the observed relationship between sodium and chloride (with respective coefficients of determination, r2, of 0.93 and 0.85 during pre-monsoon and post-monsoon periods) underscores the significance of ion exchange processes, particularly during post-monsoon periods.

This correlation further supports the inference of seawater intrusion, as deviations from expected ratios can be attributed to the intrusion phenomenon.

III. Hydro chemical Facies Evolution diagram

The Hydrochemical Facies Evolution diagrams (HFE-D), developed by Gimenez-Fprcada and Sanchez San Roman (2015), is a tool used to identify groundwater samples within intrusion and mixing zones. This diagram consists of four hyperopic facies: Na-Cl, Ca-HCO3, Ca-Cl2, and Na-HCO3. The Na-Cl facies is characteristic of seawater, while the Ca-HCO3 facies represents freshwater. When seawater intrudes, the exchange of Na+ for Ca+ results in the transition from Na-Cl water to $Ca\text{-}Cl_2$ water facies. Conversely, during the freshening phase, the exchange of Ca for Na leads to the formation of Na-HCO3 water. In the diagram, the line separating the two distinct phases (known as the conservative mixing line) represents the mixing zone of freshwater and seawater. Facies located below and to the right of this line indicate seawater intrusion and include intrusion sub-stages such as i_1, i_2, i_3, i_4, and SW (seawater). On the other hand, facies located above and to the left of the line indicate the freshening phase and include freshening sub-stages such as f_1, f_2, f_3, f_4, and FW (freshwater). These sub-stages help in determining the salinization processes of groundwater samples.

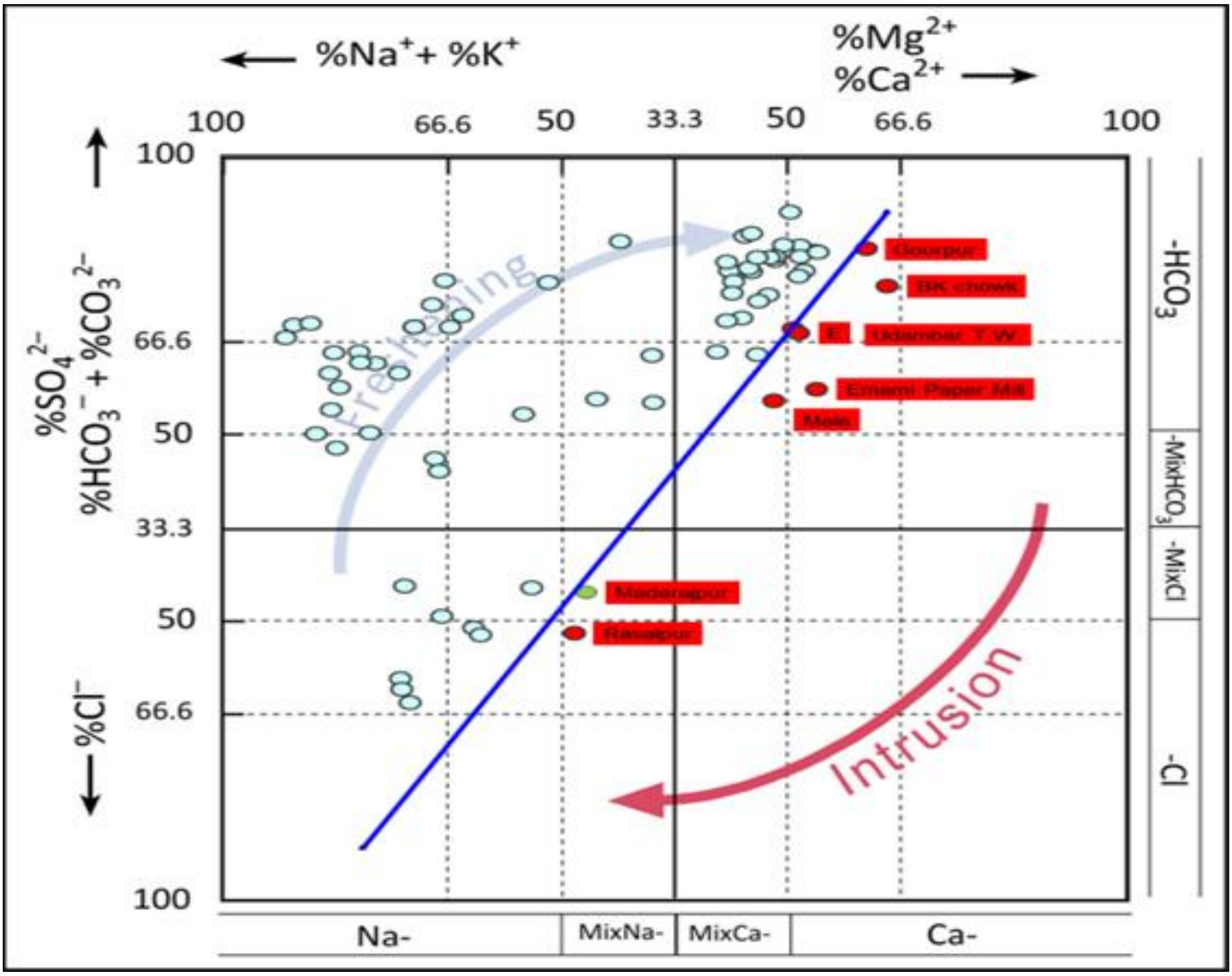


FIGURE 40: HFE-DIAGRAM DURING POST MONSOON.

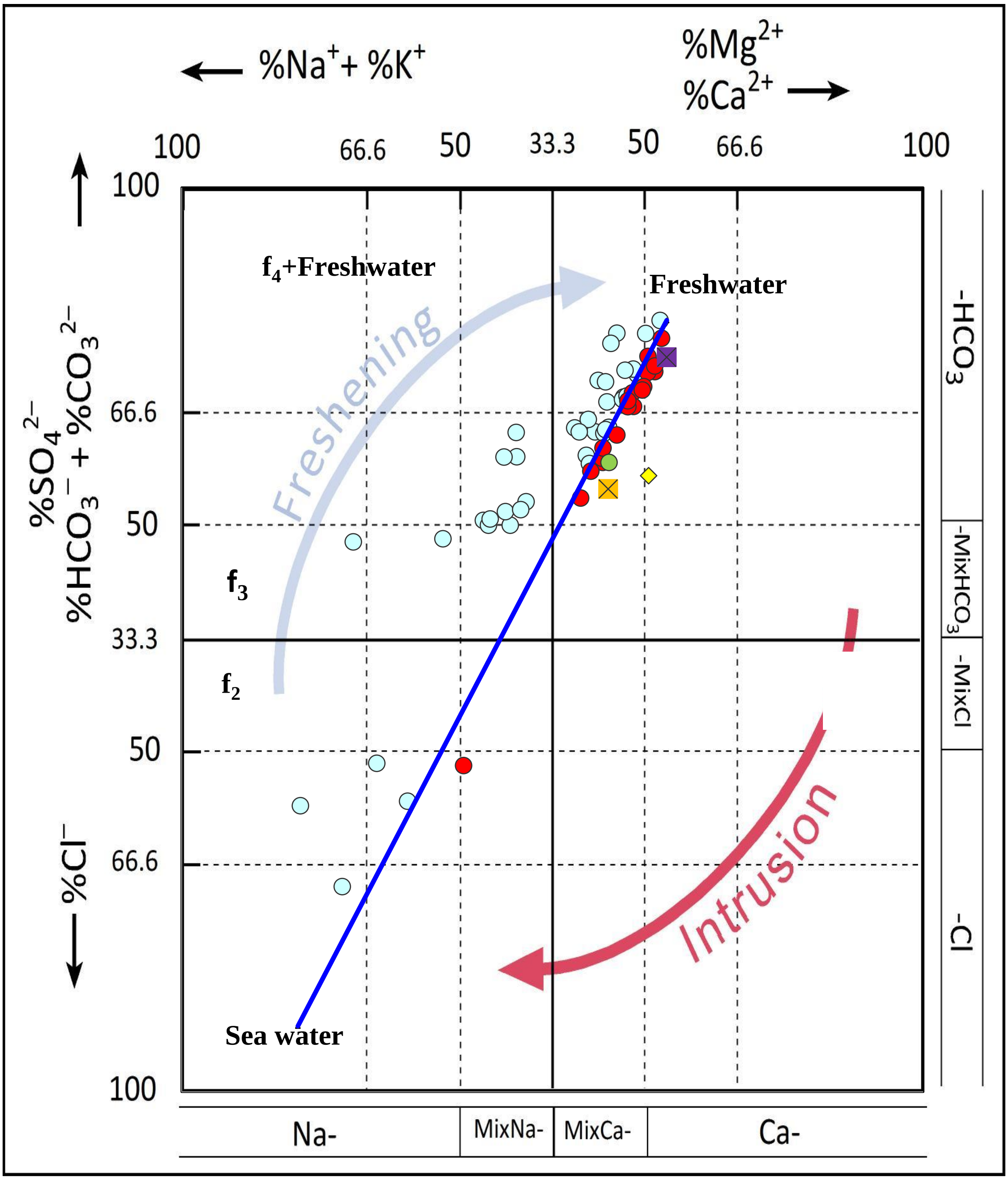


FIGURE 41: HFE-DIAGRAM AND THEIR RELATED HEATCAPS OF HYDROCHEMICAL FACIES SUB-STAGESS DURING PREMONSOON.

TABLE 24: GROUND WATER SAMPLE LOCATIONS COMPARISION WITH HFE-D AND SALINISATION PROCESS

S.No	Block	Location	Source	Depth of Well	HFE-D Facies		salinization processes
Pre Monsoon							
1	Remuna	Meghadamburu	TW	80	Ca	HCO3	Freshwater
2	Sadar	Mala	HP	45	MixCa	HCO3	Freshwater
3	Sadar	Rasalpur	HP	45	MixCa	HCO3	Freshwater
4	Sadar	Rasalpur	TW	80	MixCa	HCO3	Freshwater
5	Sadar	Bartana	HP	45	Ca	HCO3	Freshwater
6	Sadar	Bartana TW	TW	80	MixCa	HCO3	Freshwater
7	Remuna	Remuna	HP	45	MixCa	HCO3	Freshwater
8	Remuna	Emami Paper Mill	TW	80	MixCa	HCO3	Freshwater
9	Remuna	Madarajpur	HP	45	MixCa	HCO3	Freshwater
10	Remuna	Babanpur	HP	45	Ca	HCO3	Freshwater
11	Remuna	Patrapada	HP	45	Ca	HCO3	Freshwater
12	Balasore Municipality	BalsoreBustand	HP	45	Ca	HCO3	Freshwater
13	Balasore Municipality	BK chowk	HP	45	MixCa	HCO3	Freshwater
14	Balasore Municipality	JK chowk	HP	45	MixCa	HCO3	Freshwater
15	Sadar	Sarswatipur	HP	45	MixCa	HCO3	Freshwater
16	Sadar	SanSaun	HP	45	Ca	HCO3	Freshwater
17	Remuna	Naraharipur	HP	45	MixCa	HCO3	Freshwater
18	Sadar	SuteiBadagaon	HP	45	MixCa	HCO3	Freshwater
19	Sadar	Kurunia	HP	45	Ca	HCO3	Freshwater
20	Sadar	Mukhura	HP	45	MixCa	HCO3	Freshwater
21	Sadar	Pinchabania	HP	45	MixCa	HCO3	Freshwater
22	Remuna	Gopinathpur	HP	45	MixCa	HCO3	Freshwater

23	Remuna	Gudupahi	HP	45	MixNa	Cl	Saline
Post Monsoon							
1	Remuna	Emami Paper Mill	Tube well (150ft.)	45	Ca	HCO3	Freshwater
2	Remuna	Gourpur	HP	45	Ca	HCO3	Freshwater
3	Remuna	Udambar T.W.	Tube well (210ft.)	70	Mg	HCO3	Freshwater
4	Sadar	Mala	HP	45	MixCa	HCO3	Freshwater
5	Sadar	Rasalpur	Tube Well (250ft.)	80	MixNa	Cl	Saline
6	Balasore Muncipality	BK chowk	HP	45	Ca	HCO3	Freshwater
7	Remuna	Madarajpur	HP	45	MixNa	Mix Cl	saline
8	Balasore Muncipality	E			Ca	HCO3	Freshwater

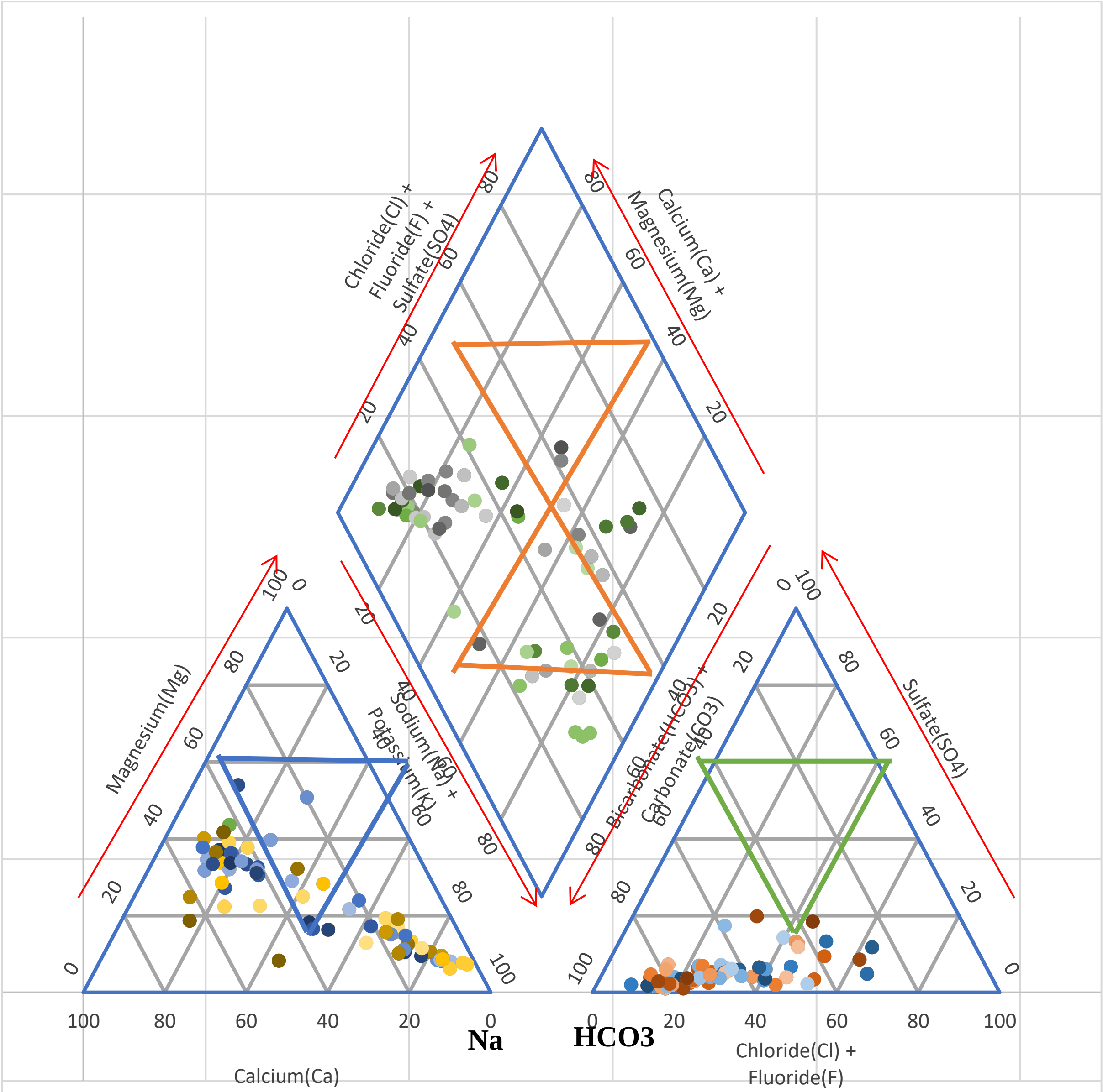


FIGURE 42: LOCATIONS PLOTS IN TRILINEAR PLOT FOR DEMARCATION OF HYDROGEOCHEMICAL FACIES TO KNOW SALINISATION PROCESS DURING PRE-MONSOON PERIOD.

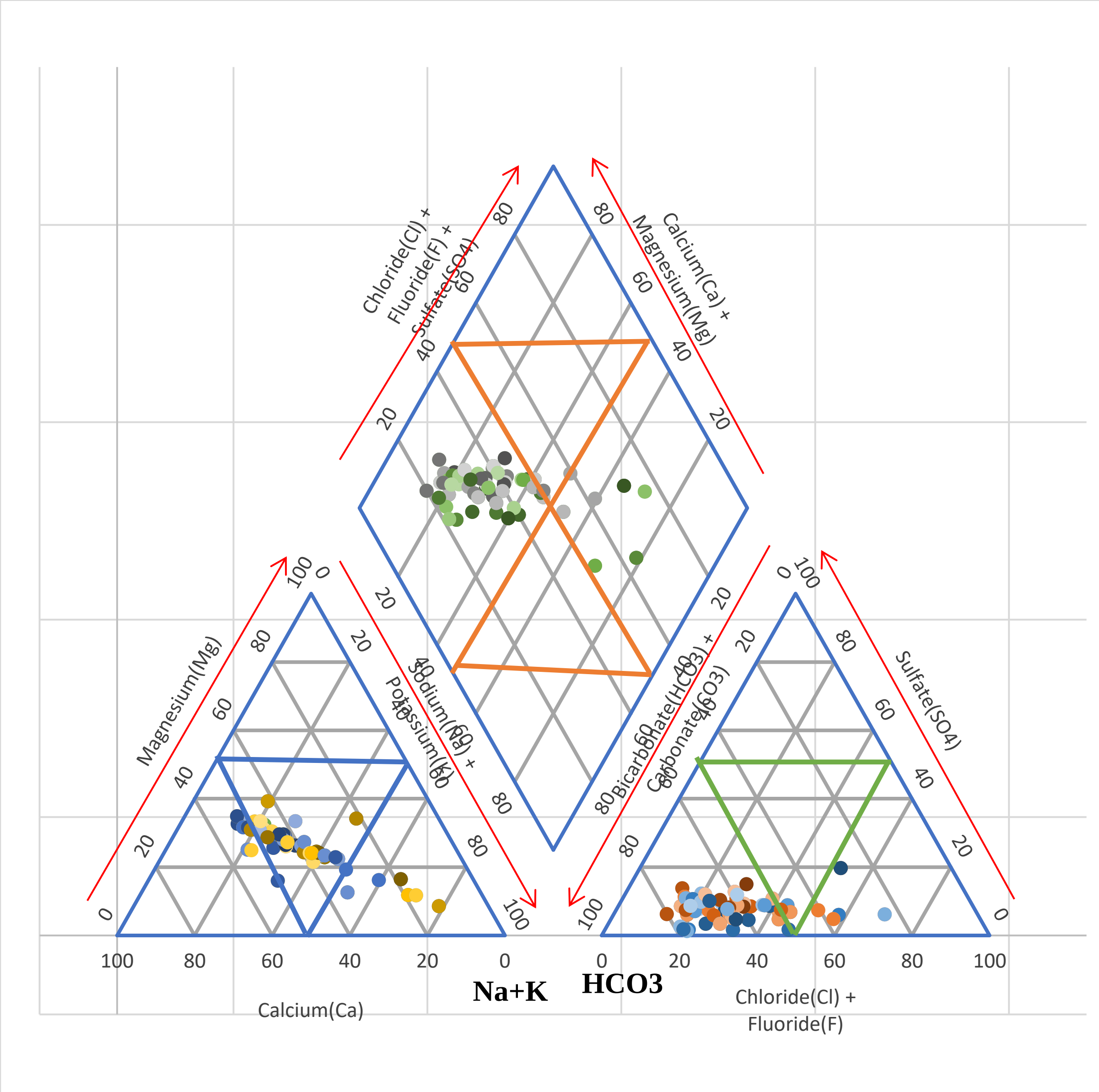


FIGURE 43: : LOCATIONS PLOTS IN TRILINEAR PLOT FOR DEMARCATION OF HYDROGEOCHEMICAL FACIES TO KNOW SALINISATION PROCESS DURING POST-MONSOON PERIOD.

19. Extent of Saline Ingress:

Based on the hydrogeochemical parameters analysis of Groundwater sample collected from the wells upto the depth of 80 mbgl., the following insights can be provided regarding the extent of saline ingress or seawater intrusion in the study area:

I. Indicators of Seawater Intrusion:

A. Chloride to Bicarbonate Ratio (Cl-/HCO3-):

- This ratio is a useful indicator of seawater intrusion, as seawater typically has a higher Cl- concentration compared to HCO3-.
- During the pre-monsoon period, 68% of the samples were classified as having "good quality" water, with a Cl-/HCO3- ratio less than 0.5.
- During the post-monsoon period, this percentage slightly increased to 67%, indicating a relatively stable situation regarding seawater intrusion.
- However, a small percentage of samples (5-7%) were classified as moderately to injuriously contaminated, with Cl-/HCO3- ratios between 1.3 and 6.6.

B. Sodium to Chloride Ratio (Na/Cl):

- The Na/Cl ratio is another indicator of seawater intrusion, as seawater typically has a higher Na/Cl ratio compared to freshwater.
- The document observed a strong correlation between sodium and chloride concentrations, with coefficients of determination (r2) of 0.93 and 0.85 during the pre-monsoon and post-monsoon periods, respectively.
- This correlation suggests the influence of ion exchange processes, particularly during the post-monsoon season, which can be indicative of seawater intrusion.

C. Hydrochemical Facies Evolution (HFE) Diagram:

- The HFE diagram is a tool used to identify groundwater samples within intrusion and mixing zones.
- The document provided HFE diagrams for both pre-monsoon and post-monsoon periods, which showed the distribution of groundwater samples among different facies.
- During the post-monsoon period, some samples were located in the intrusion sub-stages (i1, i2, i3, i4), indicating the influence of seawater intrusion.
- However, the majority of the samples were positioned in the freshwater and freshening facies, suggesting a limited extent of seawater intrusion.

D. Extent of Seawater Intrusion:

- Based on the hydrochemical indicators, the document suggests that the extent of seawater intrusion in the study area is relatively limited.
- The majority of the groundwater samples (67-68%) were classified as having "good quality" water, with Cl-/HCO3- ratios less than 0.5, indicating minimal seawater influence.
- Only a small percentage of samples (5-7%) showed moderate to injurious levels of contamination based on the Cl-/HCO3- ratio, suggesting a localized presence of seawater intrusion.
- The HFE diagram analysis further supports the limited extent of seawater intrusion, with most samples falling within the freshwater and freshening facies.

E. Temporal Variations:

- The hydrochemical indicators showed relatively stable conditions regarding seawater intrusion between the pre-monsoon and post-monsoon periods.
- The percentages of samples classified as "good quality" water based on the Cl-/HCO3- ratio remained similar during both seasons, indicating that seasonal variations did not significantly impact the extent of seawater intrusion.

20. Recommended interventions for containing saline ingress.

In conclusion, the analysis of water samples indicated that the extent of seawater intrusion in the study area is relatively limited, with most of the groundwater samples exhibiting characteristics of freshwater. However, localized pockets of moderate to injurious contamination were identified, indicating the need for continued monitoring and management of groundwater resources to mitigate the potential impacts of seawater intrusion.

21. Other Measures:

I. Trace Metal Contamination in the study area:

TABLE 25: ACCEPTABLE AND PERMISSIBLE LIMIT AS PER BIS-10500:2012 DRINKING WATER STANDARDS

Trace Metals	BIS 10500:2012 Acceptable Limit	BIS 10500:2012 Permissible Limit	Maximum Reported the area.
Barium (as Ba), mg/l	0.7	No Relaxation	0.086
Boron (as B), mg/l	0.5	1.0	4.012
Aluminium (as Al), mg/l	0.03	0.2	0.087
Arsenic (as As), mg/l	0.01	0.05	0.001
Cadmium (as Cd), mg/l	0.003	No Relaxation	0.001
Chromium (Cr), mg/l	0.05	No Relaxation	0.013
Copper (as Cu), mg/l	0.05	1.5	0.167
Iron (as Fe), mg/l	0.3	No Relaxation	10.352
Manganese (as Mn), mg/l	0.1	0.3	1.549
Molybdenum (as Mo), mg/	0.07	No Relaxation	0.007
Nickel (as Ni), mg/l	0.02	No Relaxation	0.093
Selenium (as Se), mg/l	0.01	No Relaxation	0.001
Silver (as Ag), mg/l	0.1	No Relaxation	0.000009
Strontium (as Sr), mg/l *(EI	4.0	No Relaxation	1.272
Lead (as pb), mg/l	0.01	No Relaxation	0.146
Uranium (as U), mg/l	0.03	No Relaxation	0.006
Zinc (as Zn), mg/l	5	15	6.226

Table 26: List of the Locations above permissible limit

S.No	Trace Metal	Block	Village	Source	mg/l
1	Barium (as Ba), mg/l	-	-	-	-
2	Boron (as B), mg/l	Sadar	Srikona Hp-II	HP	2.10
		Sadar	Pinchabania	HP	1.23
		Sadar	Putadia TW	Tube Well	1.17
		Sadar	Angula	HP	1.29
		Sadar	Tentulimundi	HP	3.16
		Sadar	Raghunathpur	Tube well	4.01
		Sadar	Gudupahi	HP	1.38
3	Aluminium (as Al), mg/l	-	-	-	-
4	Arsenic (as As), mg/l	-	-	-	-
5	Cadmium (as Cd), mg/l	-	-	-	-
6	Chromium (Cr), mg/l	-	-	-	-
7	Copper (as Cu), mg/l	-	-	-	-
8	Iron (as Fe), mg/l	Remuna	Madarajpur	HP	10.35
		Remuna	Naraharipur	HP	2.56
9	Manganese (as Mn), mg/l	-	-	-	-
10	Molybdenum (as Mo), mg/l	-	-	-	-
11	Nickel (as Ni), mg/l	Remuna	Madarajpur	HP	0.09
12	Selenium (as Se), mg/l	-	-	-	-
13	Silver (as Ag), mg/l	-	-	-	-
14	Strontium (as Sr), mg/l *(EPA	-	-	-	-
15	Lead (as pb), mg/l	Remuna	Madarajpur	HP	0.15
		Remuna	Naraharipur	HP	0.03
16	Uranium (as U), mg/l	-	-	-	-
17	Zinc (as Zn), mg/l	-	-	-	-

Anthropogenic pollutant like Lead, Nickel can be identified near the Madrajpur and Naraharipur village of the study area. Whereas Boron effected area may be due to the natural sources such as weathering of rocks and soils and sea water spray, as well as fossil fuel combustion and Industrial and municipal and industrial waste water discharge. High boron in the groundwater may cause poor crop quality in these areas.

II. Iron Contamination in the area:

- During the pre-monsoon period, iron-contaminated spot were reported in the phreatic aquifers of the study area. However, the deeper aquifer is not affected by iron contamination.
- The concentration of Iron ranges from 1.082 to 13.52 mg/l.
- 60.60% of the total groundwater samples collected were reported to be iron contaminated.

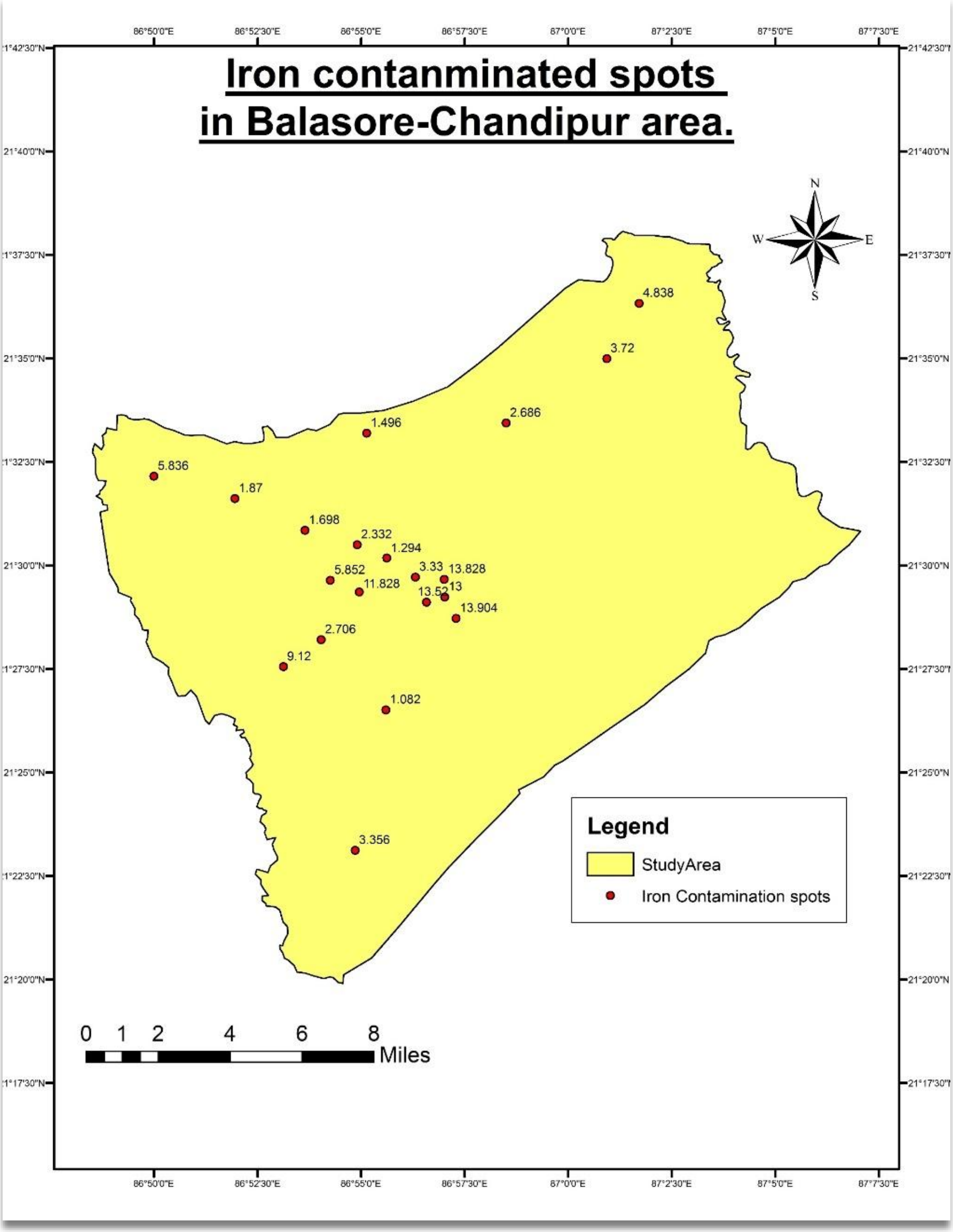


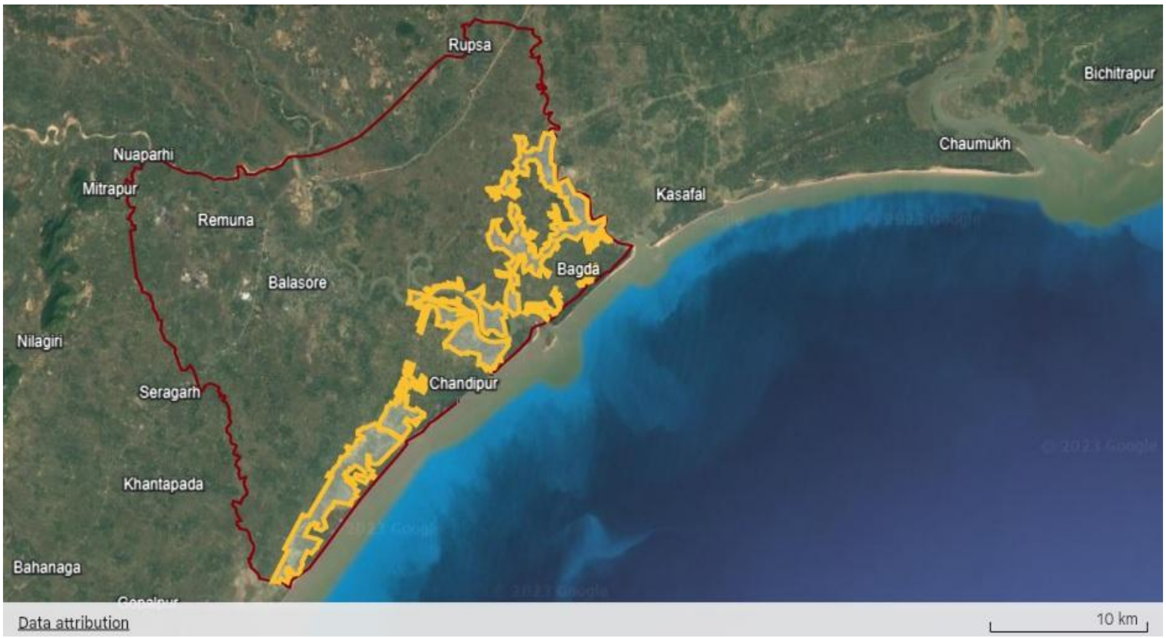
FIGURE 44: SPORADIC DISTRIBUTION OF IRON CONTAMINATION IN THE STUDY AREA.

III. Farmers Feedback:

Out of 47 no.s of farmer Feedback collected from farmers revealed that their cultivation is solely dependent on the monsoon. Due to their backwardness and financial instability, they are unable to afford the construction of a tubewell for cultivation during non-monsoon periods.

IV. Abrupt growth of Shrimp Farming enhancing the EC of the shallow aquifers in last decade:

- In 2012, shrimp farming occupied 22.09 square km. of land in the study area, accounting for 4.24% of the total area.
- During those days, the production of shrimp farming yielded significant profits for farmers. The growth of shrimp was favourable due to the natural habitat, climate and quality of the water of the tidal river, as per the Farmers Feedback received.



- In 2023, shrimp farming occupied 52.09 square km. of land in the study area, accounting for 10.09% of the total area.
- In the current situation, farmers have experienced significant losses due to the slow growth in shrimp production. They attempt to maintain a suitable environment for shrimp by monitoring and adjusting the EC, pH, and dissolved oxygen levels through the use of salt and medicines which may affect the shallow aquifers.
- Most farmers tap into two aquifers, one from a fresh aquifer and the other from a saline aquifer, in order to maintain the appropriate EC for shrimp farming.
- Impacts of Prawn Farming on Groundwater Resources: the study area is located near the coast, the practice of prawn farming through the excavation of ponds and the mixing of saline water with freshwater can have significant impacts on the groundwater resources. Here's a note on the potential impacts and suitable remedial measures:

- Saline Water Intrusion:
  - The mixing of saline water from the ponds with the freshwater aquifers can lead to the intrusion of saline water into the groundwater system.
  - This can result in an increase in the salinity of the groundwater, rendering it unsuitable for domestic, agricultural, and industrial uses.
  - The saline water intrusion can also impact the soil quality, leading to soil salinization and reduced agricultural productivity.
- Depletion of Groundwater Levels:
  - The excavation of ponds and the extraction of freshwater for mixing with saline water can contribute to the depletion of groundwater levels.
  - Excessive groundwater extraction for prawn farming can lower the water table, making it more difficult and costly to access groundwater for other purposes.
- Groundwater Contamination:
  - The use of chemicals, pharmaceuticals, and other inputs in prawn farming can potentially leach into the groundwater, leading to contamination.
  - This can impact the quality of the groundwater, making it unsuitable for various uses and posing risks to human health and the environment.
- Disruption of Aquifer Recharge:
  - The excavation of ponds and the modification of the land surface can alter the natural groundwater recharge processes.
  - This can reduce the replenishment of the aquifers, leading to a long-term decline in groundwater availability.

22. Groundwater resource estimation of the study area:

TABLE 27: GROUNDWATER RESOURCE CALCULATED DATA USING THE APPORTIONING METHOD.

Annual Extractable Ground Water Resource(Ham)	16567.63
Ground Water Extraction for Irrigation Use(Ham)	8132.872
Ground Water Extraction for Industrial Use(Ham)	487.0208
Ground Water Extraction for Domestic Use(Ham)	1273.295
Total Extraction(Ham)	9893.181
Annual GW Allocation for Domestic Use as on 2025 (Ham)	1330.207
Net Ground Water Availability for future use(Ham)	6617.537
Stage of Ground WaterExtraction(%)	59.71392
Categorization (Over-Exploited/Critical/Semi-Critical/Safe/Saline)	Safe

Based on the apportioning Method of Groundwater resource data of the Balasore and Remuna block data of GEC-2022, the groundwater resource of the area is calculated, According to this method, the Balasore-Chandipur area falls under the safe groundwater categorization, having a 59.7% stage of GW extraction.

The Graphical Representation of the data is presented below:

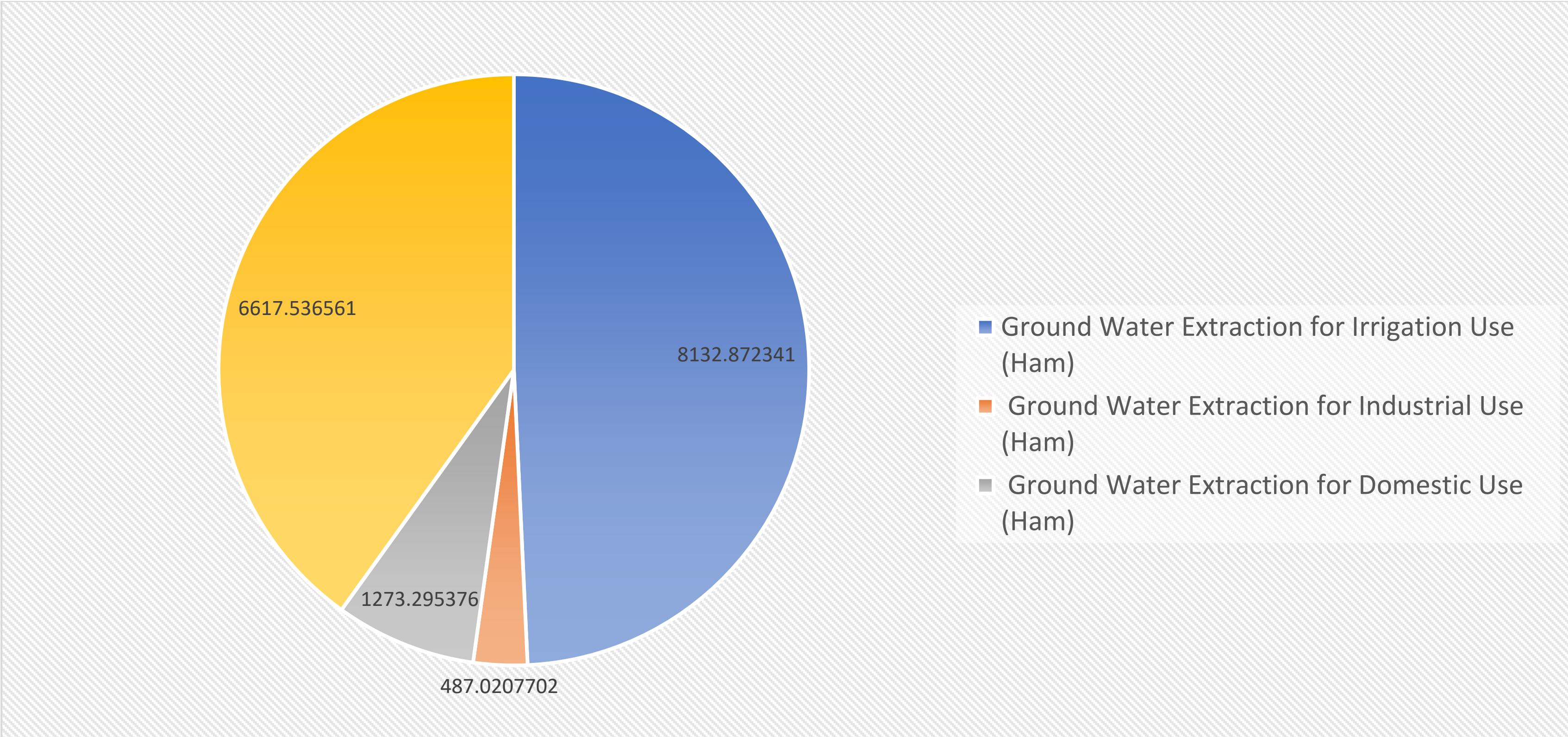


FIGURE 45: PIE CHART OF THE GROUNDWATER RESOURCES UTILISED FOR VARIOUS USES AND FUTURE AVAILABILITY.

23. Ground Water Quality Management Interventions including demarcation of safer aquifers

I. Supply Side Management Strategies:

A. Artificial Groundwater Recharge:

- As discussed earlier, the groundwater quality analysis reveals significant salinity issues, with a substantial portion of the samples falling under the "doubtful" or "unsuitable" categories for irrigation.
- The evaluation of the Permeability Index (PI) indicates that most of the groundwater samples during the pre-monsoon period have favorable recharge characteristics, with around 92% classified as having a "maximum permeability" of 75%.
- Therefore, implementing artificial groundwater recharge techniques could be a suitable strategy to improve the overall groundwater quality and replenish the aquifer system.
- Potential artificial recharge methods to be explored include:
    i. Infiltration ponds or basins
    ii. Recharge wells or shafts
    iii. Managed Aquifer Recharge (MAR) systems
    iv. Rainwater harvesting and groundwater recharge

B. Conjunctive Use of Surface Water and Groundwater:

- The study area likely experiences seasonal variations in water availability, with the post-monsoon period potentially exhibiting lower groundwater recharge and higher salinity levels.
- Integrating the use of surface water resources (e.g., rivers, lakes, or reservoirs) with groundwater can help to optimize water supply and address the temporal variability in water availability.

- Conjunctive use strategies can involve:
    i. Utilizing surface water during the wet season and groundwater during the dry season.
    ii. Artificial recharge of groundwater using surface water sources during the monsoon.
    iii. Managed aquifer recharge to store surface water in the subsurface for later use.

II. Demand Side Management Strategies:

A. Groundwater Abstraction Management:

As a general strategy, sustainable groundwater abstraction management should be implemented to prevent further deterioration of groundwater quality and quantity. This can include measures such as:

i. Regulating groundwater extraction through the establishment of well permits or licenses.
ii. Implementing volumetric-based groundwater pricing to incentivize water conservation.
iii. Promoting the use of water-efficient irrigation technologies and practices.
iv. Encouraging the adoption of crop varieties and farming practices that are less water intensive.

B. Groundwater Quality Monitoring and Remediation:

- The detailed groundwater quality analysis presented in annexure-2 to 6 can serve as a baseline for ongoing monitoring and assessment of water quality trends.
- Establishing a comprehensive groundwater quality monitoring network, with regular sampling and analysis, can help track changes over time and identify any emerging issues.

- In areas where groundwater quality is found to be severely degraded, targeted remediation measures may be necessary, such as:
    i. Groundwater treatment (desalination, ion exchange, or other appropriate technologies)
    ii. Blending of high-quality surface water with saline groundwater
    iii. Restricting the use of groundwater for specific purposes (e.g., drinking water vs. irrigation)

C. Community Engagement and Capacity Building:

- Effective groundwater management requires the active involvement and participation of local communities and stakeholders.
- Initiatives to raise awareness, promote water conservation practices, and build the capacity of farmers and water users can contribute to the sustainable use of groundwater resources.
- This can include:
    i. Educational campaigns on the importance of groundwater conservation and management
    ii. Training programs on water-efficient irrigation techniques and crop selection
    iii. Establishing community-based groundwater user associations or committees to manage and monitor local groundwater resources

D. Irrigation Water Management:

- The analysis of water quality indices, such as Sodium Adsorption Ratio (SAR), Sodium Percentage (Na%), and Permeability Index (PI), indicates that a significant portion of the groundwater samples are not suitable for irrigation, particularly during the post-monsoon season.
- Implementing efficient irrigation water management practices can help reduce the demand for groundwater and minimize the impact on soil and crop health. Strategies may include:
    i. Promoting the adoption of water-efficient irrigation technologies (e.g., drip irrigation, sprinklers)
    ii. Educating farmers on irrigation scheduling and water-saving techniques.

iii. Encouraging the use of conjunctive surface water and groundwater for irrigation.
iv. Introducing crop diversification and the cultivation of less water-intensive crops.

E. Groundwater Pricing and Incentive Mechanisms:

- Implementing appropriate groundwater pricing policies can help manage the demand for groundwater and encourage water conservation.
- Strategies may include:
  i. Volumetric-based groundwater pricing, where users pay for the actual amount of groundwater extracted.
  ii. Tiered pricing structures, with higher rates for excessive or wasteful groundwater use.
  iii. Incentives or subsidies for the adoption of water-efficient technologies and practices.
  iv. Penalty or fee structures for groundwater over-extraction or unsustainable use.

F. Groundwater Extraction Regulations and Monitoring:

- Establishing a robust regulatory framework and monitoring mechanisms can help manage and control the demand for groundwater. This may include:
  i. Groundwater extraction permits or licenses, with strict enforcement and penalties for non-compliance
  ii. Metering of groundwater extraction points to monitor and regulate usage
  iii. Groundwater abstraction limits or quotas based on the sustainable yield of the aquifer
  iv. Coordinated monitoring of groundwater levels and quality to inform decision-making.

G. Crop and Irrigation Advisory Services:

- Providing farmers with tailored crop and irrigation advisory services can help optimize groundwater use and improve agricultural productivity.

- This can involve:
    i. Developing and disseminating information on crop water requirements, irrigation scheduling, and water-saving techniques.
    ii. Establishing farmer field schools or demonstration plots to showcase best practices.
    iii. Leveraging digital technologies (e.g., mobile apps, remote sensing) to provide real-time guidance on irrigation management.
    iv. Collaborating with agricultural extension services to reach and support farmers.

H. Demand-Side Awareness and Capacity Building:

- Engaging and educating the local community, particularly farmers and water users, is crucial for effective demand-side management of groundwater.
- Initiatives may include:
    i. Raising awareness of the importance of groundwater conservation and sustainable use
    ii. Providing training and capacity-building programs on water-efficient irrigation, crop selection, and soil management
    iii. Establishing community-based water user associations or committees to foster collective responsibility and decision-making
    iv. Promoting water-saving behaviors and best management practices through targeted communication campaigns

I. Integrated Water Demand Management:

- The groundwater demand-side management strategies should be part of a broader Integrated Water Demand Management (IWDM) approach.
- IWDM considers the various water uses (e.g., domestic, agricultural, industrial) and their interconnections, aiming to optimize water security.
- Measures should be taken to modify creeks and decrease their adverse impact on the groundwater system.

Miscellaneous Management Plan:

Suitable Remedial Measures in Connection to Prawn Farming in the area:

A. Regulated Groundwater Extraction:

- Implement strict regulations and monitoring systems for groundwater extraction, especially for prawn farming activities.
- Establish groundwater abstraction limits and licensing requirements to control the overall groundwater use in the area.

B. Saltwater Intrusion Monitoring and Mitigation:

- Regularly monitor the groundwater quality, particularly the salinity levels, to detect and address any signs of saline water intrusion.
- Implement groundwater management strategies, such as the installation of physical barriers or the creation of freshwater recharge zones, to prevent the further intrusion of saline water.

C. Sustainable Prawn Farming Practices:

Encourage the adoption of more sustainable prawn farming techniques that minimize the reliance on freshwater extraction and saline water mixing.

Promote the use of recirculating aquaculture systems (RAS) or the integration of prawn farming with other agricultural activities to reduce the overall water demand.

D. Wastewater Treatment and Recycling:

Implement effective wastewater treatment systems to remove contaminants and enable the recycling of water within the prawn farming operations. Encourage the reuse of treated wastewater for purposes other than direct prawn farming, such as irrigation or industrial applications.

24. Stable Isotopic Studies in the Study area

I. Isotopic Composition of Rainfall:

Rainfall is the main source of water in the hydrologic cycle and its isotopic composition is determined mainly by two processes.

i. Ratio of water vapour that has condensed into liquid state to the initial amount of water vapor in clouds.

ii. Temperature at which condensation has occurred before precipitation.

Other processes that play a vital role include latitude, temperature, humidity, source of water vapor, and close distance from the seashore.

At regional scales, the isotopic composition is defined by surface water bodies and compared to the Global Meteoric Water Line (GWML), which is defined by multiple stations recording the variation in isotopic composition globally. The isotopic composition of rainfall follows a cyclic evolution with enrichment in summer flowed by depletion in winter, due to variations in the temperature of atmosphere. Analysis of $\delta\,^{18}O$ and $\delta\,^{2}H$ values of groundwater and rainfall for a specific location can reveal the efficiency of water transfers from one source to another.

The isotopic composition of precipitation of the study area ranges from –3.67 $_{0/00}$ to -3.52 $_{0/00}$ for $\delta^{18}O$ and -23.53 $_{0/00}$ to -20.91 $_{0/00}$ for $\delta^{2}H$. The isotopic composition of River water ranges from -0.14 $_{0/00}$ to 6.01 $_{0/00}$ for $\delta^{18}O$ and –6.19 $_{0/00}$ to -20.91 $_{0/00}$ for $\delta^{2}H$. The isotopic composition of Groundwater ranges from -3.67 $_{0/00}$ to -3.52 $_{0/00}$ for $\delta^{18}O$ and –23.53 $_{0/00}$ to -20.91 $_{0/00}$ for $\delta^{2}H$. In the data is observed that groundwater isotopic signature much resembles with the precipitation data, Groundwater is generally meteoric water. The δ^{18} -$\delta^{2}H$ binary precipitation plot of the study area resembles GMWL. The intercept can be interpreted as evaporation affecting the precipitation at the source. The isotopic composition of Ocean water ranges from -0.09 $_{0/00}$ to 0.61 $_{0/00}$ for $\delta^{18}O$ and –0.09 $_{0/00}$ to 4.51 $_{0/00}$ for $\delta^{2}H$. The isotopic values of all the water samples are attached in the annexure-8.

The equations for various meteoric water lines have been given below –

GMWL: $\delta^{2}H = 8.17^{*}\ \delta^{18}O + 11.27$

Binary graph of δ^{18} (‰)vs δ^{2} (‰) of precipitation of the study area has been attached below as

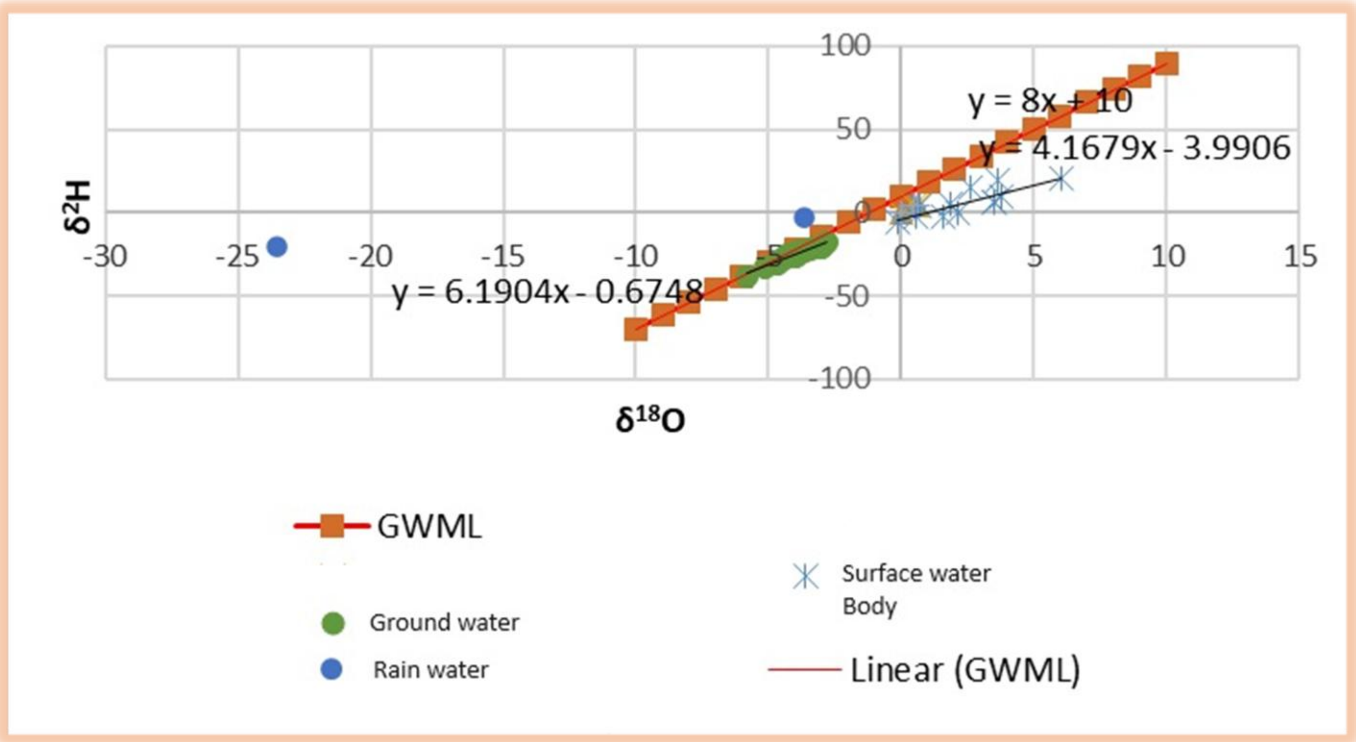


FIGURE 46: BINARY GRAPH OF Δ^{18} (‰)VS Δ^{2} (‰) OF PRECIPITATION OF THE STUDY AREA.

II. Isotopic Composition of Groundwater.

Groundwater recharge via unsaturated zone depends on climatic conditions and an average of 5% to 25 % of annual precipitation and thought to recharge unconfined aquifers. Groundwater recharge depends on soil moisture conditions and seasonal precipitation inputs and higher recharge during the monsoon. Isotopic values found to resemble weighted annual precipitation values as attenuation of seasonally varied precipitation values and mixing of different precipitation sources is seen during the passage of water through unsaturated zone.

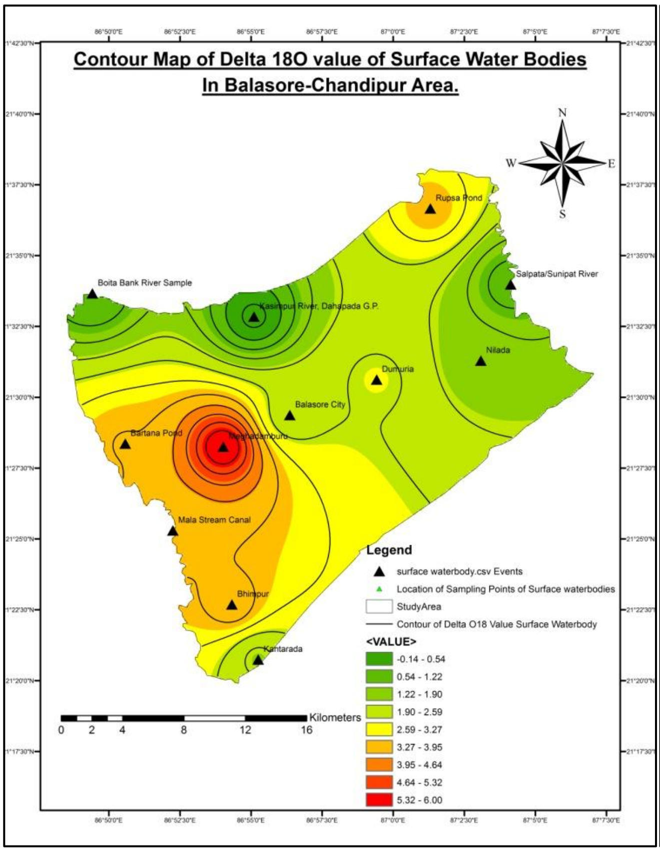
The climatic condition of the study area is sub-tropical and is reflected in the isotopic composition of the groundwater. The dD of groundwater ranged between --38.3788 $_{0/00}$ to -18.08$_{0/00}$, with mean -24.9643 $_{0/00}$. The dO18 ranged between -2.81155 $_{0/00}$ to -5.80349 $_{0/00}$,

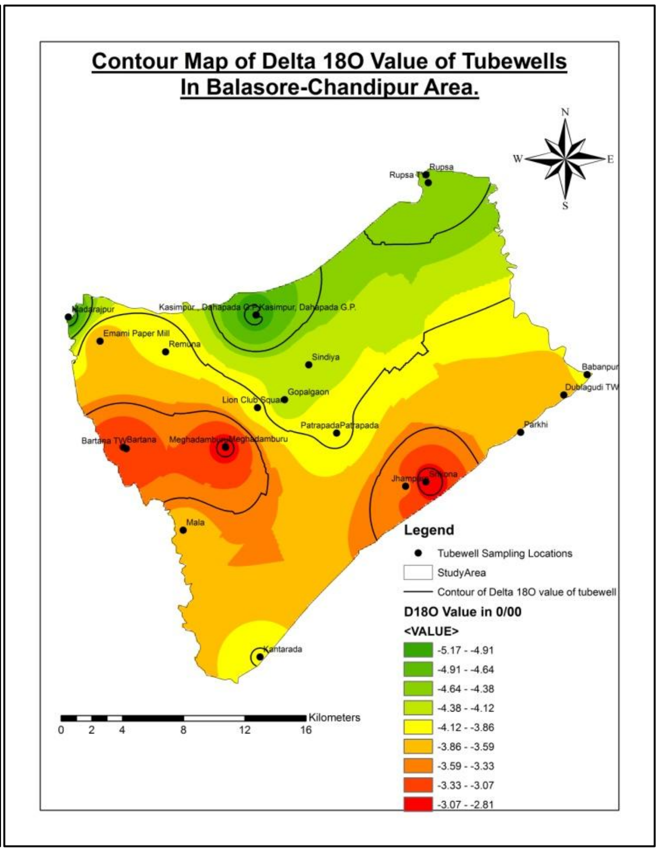
Plotting values of δ^2H against δ^{18}O obtained from shallow groundwater in Figure shows significant amount of evaporation since the fractionation is to the right of the Global Meteoric Water Line. This phenomenon is a result of recharge from enriched sources such as rivers, ponds etc. or the evaporation of meteoric water prior to groundwater recharge due the high temperature and humidity in the coastal area of Balasore-Chandipur area.

The stable isotopic composition of the groundwater indicates that the rainfall seeps through soil to reach the aquifer. Significant amount of the precipitation reaches to the aquifer, since the process is isotopically fractionating.

III. Spatial Distribution Maps

Inverse Distance Weighted Technique of GIS has proved to be an important tool for evaluation and analysis of spatial information in hydrological sciences. Generation of spatial distribution maps based on various themes reveal trends and other necessary information regarding the study area. Spatial distribution maps of δ^2H and δ^{18}O of the study area were prepared and have been attached as Figs and respectively.



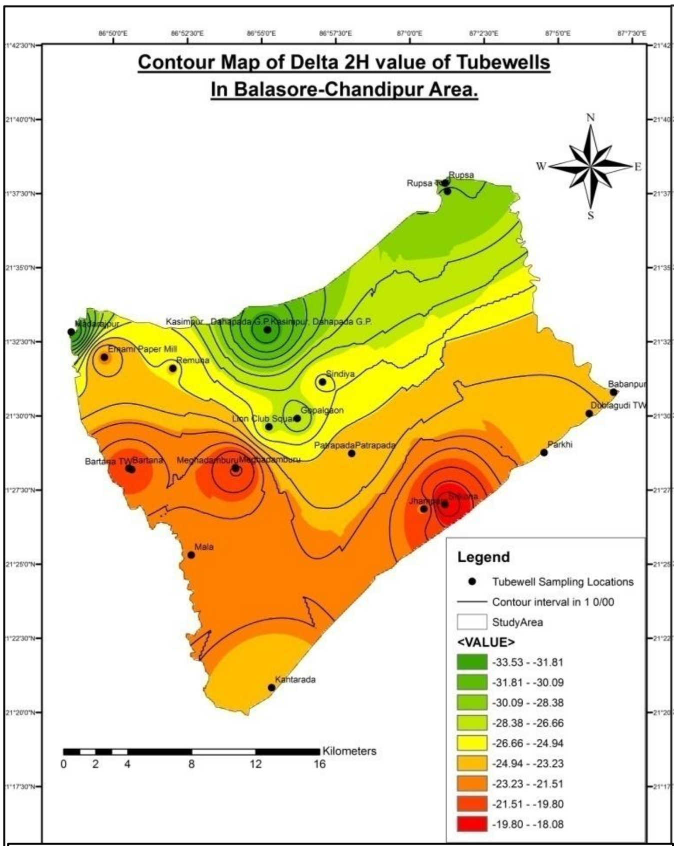
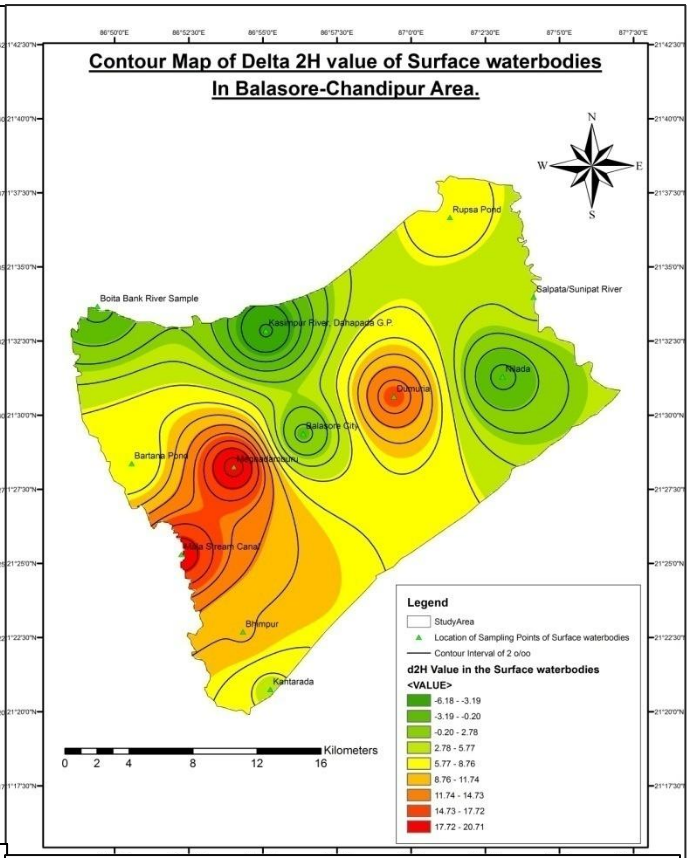
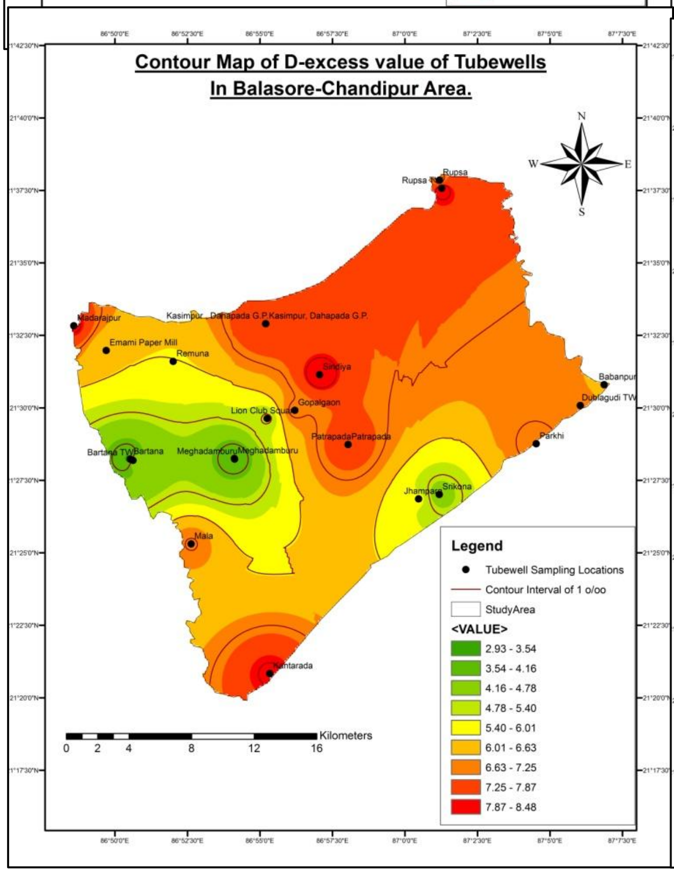
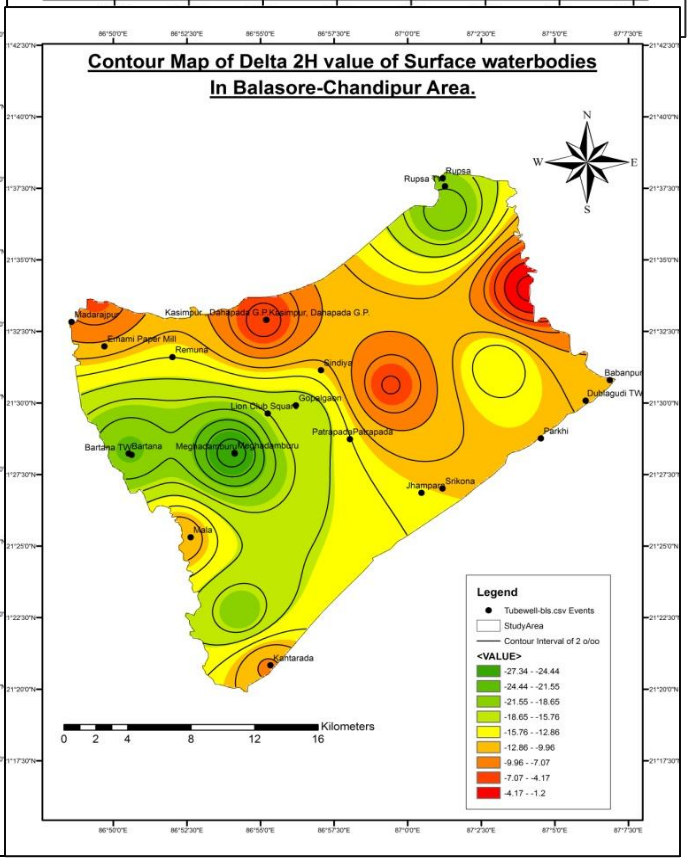


Perusal of the map reveals depletion of $\delta^{18}O$ values of groundwater in the Northern fringe of the study area i.e., opposite side of the Coast line and Northern part of the study area Patches of enrichment observed, northern portion are suspected to be unconfined aquifer being in direct contact with surface water bodies like rivers and ponds as well as direct recharge from the rain water.

The pattern only reaffirms that the flow direction of groundwater is southwards.

Low slopes of evaporation lines (Linear -Series 6 Mentioned in the figure) of these groundwater samples are often linked to diffusive evaporation

from soil water and fractionation already before the percolation takes place.


Contour Map of Delta 2H value of Tubewells
In Balasore-Chandipur Area.
Legend
Tubewell Sampling Locations
Contour interval in 1 0/00
StudyArea
<VALUE>
-33.53 - -31.81
-31.81 - -30.09
-30.09 - -28.38
-28.38 - -26.66
-26.66 - -24.94
-24.94 - -23.23
-23.23 - -21.51
-21.51 - -19.80
-19.80 - -18.08
Kilometers
0 2 4 8 12 16
Rupsa
Kasimpur
Dahapada G.P.
Emami Paper Mill
Remuna
Sindiya
Gopalgaon
Lion Club Squar
Patrapada
Babanpur
Dublagudi TW
Parkhi
Bartana TW
Bartana
Meghadamburu
Jhampai
Srikona
Mala
Kantarada

Contour Map of Delta 2H value of Surface waterbodies
In Balasore-Chandipur Area.
Legend
StudyArea
Location of Sampling Points of Surface waterbodies
Contour Interval of 2 o/oo
d2H Value in the Surface waterbodies
<VALUE>
-6.18 - -3.19
-3.19 - -0.20
-0.20 - 2.78
2.78 - 5.77
5.77 - 8.76
8.76 - 11.74
11.74 - 14.73
14.73 - 17.72
17.72 - 20.71
Kilometers
0 2 4 8 12 16
Rupsa Pond
Salpata/Sunipat River
Boita Bank River Sample
Kasimpur River, Dahapada G.P.
Nijada
Dumuria
Balasore City
Bartana Pond
Meghadamburu
Bhimpur
Kantarada

Contour Map of D-excess value of Tubewells
In Balasore-Chandipur Area.
Legend
Tubewell Sampling Locations
Contour Interval of 1 o/oo
StudyArea
<VALUE>
2.93 - 3.54
3.54 - 4.16
4.16 - 4.78
4.78 - 5.40
5.40 - 6.01
6.01 - 6.63
6.63 - 7.25
7.25 - 7.87
7.87 - 8.48
Kilometers
0 2 4 8 12 16
Rupsa
Madarajpur
Kasimpur
Dahapada G.P.
Emami Paper Mill
Remuna
Sindiya
Gopalgaon
Lion Club Squar
Patrapada
Babanpur
Dublagudi TW
Parkhi
Bartana TW
Bartana
Meghadamburu
Jhampai
Srikona
Mala
Kantarada

Contour Map of Delta 2H value of Surface waterbodies
In Balasore-Chandipur Area.
Legend
Tubewell-bls.csv Events
StudyArea
Contour Interval of 2 o/oo
<VALUE>
-27.34 - -24.44
-24.44 - -21.55
-21.55 - -18.65
-18.65 - -15.76
-15.76 - -12.86
-12.86 - -9.96
-9.96 - -7.07
-7.07 - -4.17
-4.17 - -1.2
Kilometers
0 2 4 8 12 16
Rupsa
Madarajpur
Kasimpur
Dahapada G.P.
Emami Paper Mill
Remuna
Sindiya
Gopalgaon
Lion Club Squar
Patrapada
Babanpur
Dublagudi TW
Parkhi
Bartana TW
Bartana
Meghadamburu
Jhampai
Srikona
Mala
Kantarada

IV. DEUTERIUM EXCESS

Majority of the rainfall all over the world follows the equation defined by GWML. However, some areas with different environment, varied condensation and evaporation conditions, have a unique slope and intercept for their Local meteoric water line.

Increased evaporation: Warmer temperatures cause water to evaporate more quickly, leading to higher concentrations of salt in remaining water bodies. In coastal regions, this increased evaporation can exacerbate the salinity problem.

The slope represents temperature ratio relation between δ^2H and $\delta^{18}O$ during condensation and intercept represents conditions controlling evaporation in source area(s). The intercept is also known as Deuterium excess or d-excess and is calculated by the formula defined by Dansgaard:

d-excess = $\delta^2H - 8 * \delta^{18}O$

The Deuterium excess, also represented as d-excess is often utilized to identify vapour source of precipitation and identifying air masses from which precipitation has originated.

The intercepts in most locations worldwide is about 10‰. Lower d-excess values (<10‰) imply some portion of rainfall has evaporated before reaching water table whereas higher d-excess values (>10‰) implies evaporation of precipitation under less humid climate or an imprint of recycled moisture. Values of d-excess between 8‰ to 10‰ represent primary precipitation has recharged groundwater.

The d-excess values were computed using the formula given by Daansgard and were found to range between -2.90‰ to 8.49‰ with an average value of 6.425‰ and All of the area having an evaporation dominance effect Warmer temperatures cause water to evaporate more quickly and create humidity in the area, leading to higher concentrations of salt in remaining water bodies and implies evaporation of precipitation under less humid climate or an imprint of recycled moisture. In coastal regions, this increased evaporation can exacerbate the salinity problem.

A spatial distribution map of the study area showing variation in d-excess values has been attached.

25.Artificial Recharge Plan:

Based on the observation made in the study area, the following insights can be given regarding the scope for artificial groundwater recharge in the study area:

i. Groundwater Quality Characteristics:

- The detailed analysis of the groundwater quality in the study area, covering various parameters such as major ions, salinity, and irrigation suitability.
- The results show that a significant portion of the groundwater samples (40-48%) during both pre-monsoon and post-monsoon periods fall within the "doubtful" or "unsuitable" categories for irrigation based on electrical conductivity (EC) values.
- Elevated EC values can indicate high salinity levels, which can reduce the availability of water for plant growth and adversely affect soil health.
- Additionally, the analysis of parameters like Sodium Adsorption Ratio (SAR), Sodium Percentage (Na%), Residual Sodium Carbonate (RSC), and Magnesium Hazard (MH) further highlights the potential suitability concerns for irrigation use.

ii. Groundwater Recharge Potential:

- On the basis of Permeability Index (PI) of the groundwater samples in the study area, which is an indicator of soil permeability and the suitability of water for irrigation reveals that During the pre-monsoon period, the majority of the samples (92%) were classified as having a "maximum permeability" of 75%, indicating good suitability for groundwater recharge.
- However, during the post-monsoon period, a notable percentage of samples (14%) were classified as having a "maximum permeability" below 25%, suggesting limited suitability for groundwater recharge.

III. Scope for Artificial Groundwater Recharge:

- The presence of a significant proportion of groundwater samples with high salinity levels and suitability concerns for irrigation suggests a need for artificial groundwater recharge initiatives.
- The majority of the groundwater samples during the pre-monsoon period exhibit good permeability characteristics, indicating favourable conditions for artificial recharge techniques.
- However, the lower permeability observed in some samples during the post-monsoon period highlights the need for a more detailed assessment of site-specific soil and hydrogeological conditions to identify the most suitable artificial recharge methods.
- Potential artificial recharge techniques that could be explored include:
- Infiltration ponds or basins
- Recharge wells or shafts
- Managed aquifer recharge (MAR) systems.

IV. Rainwater harvesting and groundwater recharge.

- Rainfall data analysis of past 27 years from 1995 to 2022 indicates that the quantum of rainfall is declining over time due to climate change and will have a cascading effect on replenishing surface and groundwater resources. Since climatic phenomenon is purely natural and there is no established technique to enhance the quantum of rainfall over a specific area, the only way to enhance recharge of groundwater is via construction of suitable Aquifer Recharge structures in the entire study area Except few regions where Gopinathpur area and the west Central part of the study area.

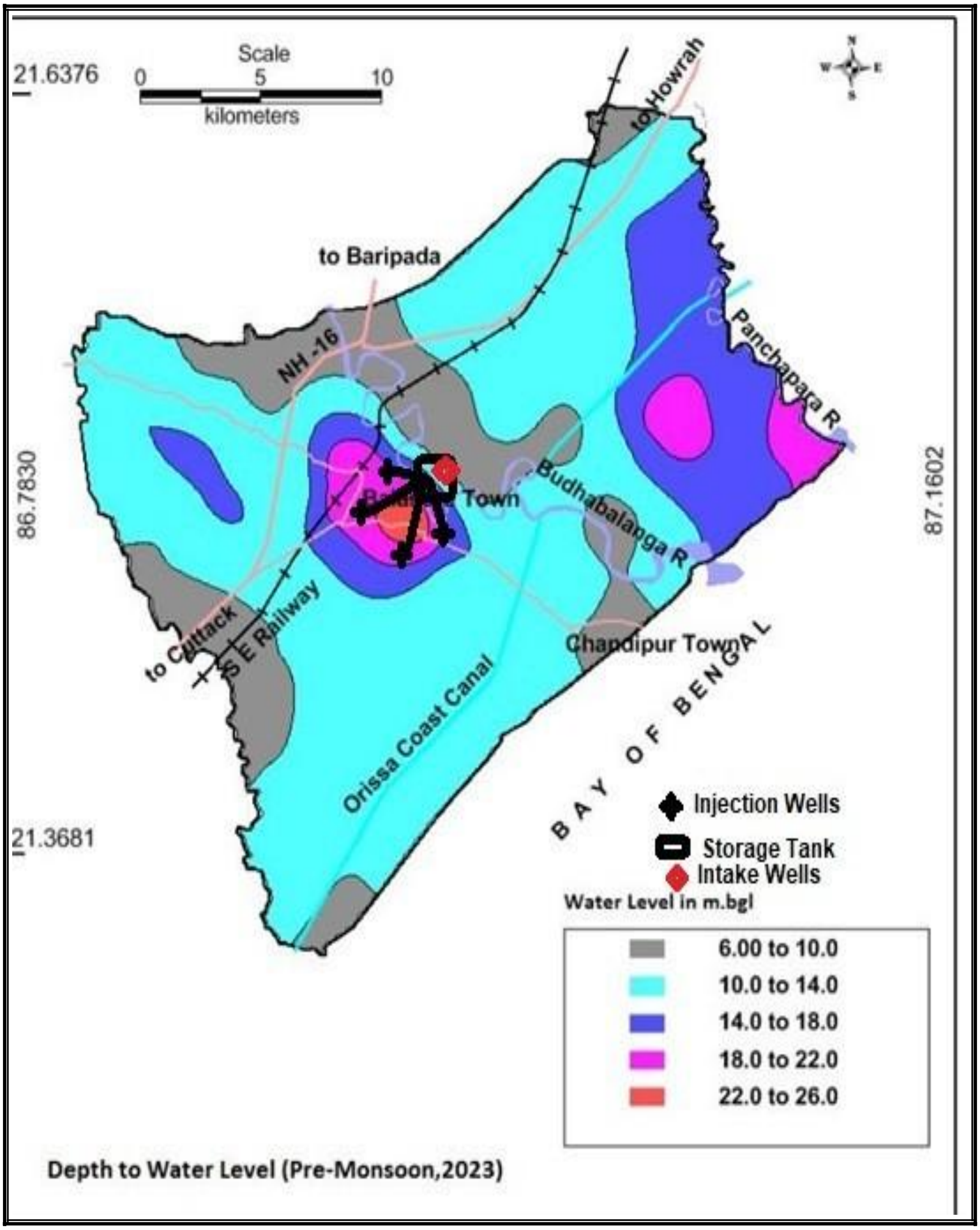
- Isotopic composition of rainfall reveals some portion of rainfall has undergone evaporation prior to recharging groundwater due to humid climate of the area and isotopic composition of unconfined aquifer reveals the rainfall has undergone some degree of fractionation when passing through unsaturated zone in addition to some enrichment by surface water bodies. Spatial distribution map of $\delta^{18}O$ reveals that the major recharge area is located in the southern portion of the study area and groundwater flow follows the topographic gradient that lies northwards.

V. Groundwater Recharge Techniques:

- the information provided on groundwater quality and recharge potential can inform the selection and design of appropriate artificial recharge methods.

VI. Arresting the deeper Water level in the Balasore urban area.

In the Balasore Municipality surrounding area the water level ranges from 14.00 to 22.00 mbgl. in the pre-monsoon period. However, the Ground water level ranges from the 10.00 to 18.00 mbgl. which is the maximum deep water relative to the Balasore coastal study area. As the Balasore city is near to the coast it is prone to the saline water intrusion. To mitigate the problem with considering the increasing demand over groundwater resource of the Balasore municipality area. It is proposed to construction of 4 no.s of Injecion wells and 2 numbers of Intake wells and 1 storage tank on experimental basis.



Schematic Diagram Location for the Injection Wells, Intake wells and Storage tank.

TABLE 28: TENTATIVE LOCATIONS OF THE STRUCTURES.

Type of Structure	Latitude	Longitude
Injection Well-I	21^{0}29’43’’	86^{0}55’48’’
Injection Well-II	21^{0}29’25’’	86^{0}56’45’’
Injection Well-III	21^{0}28’34’’	86^{0}56’03’’
Injection Well-IV	21^{0}29’50’’	86^{0}54’30’’
Storage Tank	21^{0}30’08’’	86^{0}56’32’’
Intake Well	21^{0}30’17’’	86^{0}56’37’’

Intake Wells:

It is proposed to construct two intake wells at the designated locations, each with a depth of approximately 7 to 8 meters below ground level (mbgl). Each well will be fitted with two submersible pumps of 5 HP capacities, running for 8 hours each in a day.

Storage Tank:

It is proposed to construct one storage tank with a minimum capacity of 2.5 lakh liters, linked to the pipe connection supplying the intake wells. This will be located at the provided site or a nearby location where the setup for the injection well can be carried out effectively.

Injection Wells:

It is proposed to construct four injection wells at the designated locations or nearby areas, depending on land availability. Each well will have a depth ranging from 50 to 70 mbgl and will be connected to the storage tank using pipe connections.

The calculation of the recharge through the injection wells is mentioned below:

- The least recharge rate through one injection well in alluvial terrain is 4 liters per second (lps).
- Groundwater recharge through one injection well in one day = 4 lps × 3600 seconds × 24 hours = 345,600 liters.
- Groundwater recharge through four injection wells in one day = 345,600 liters × 4 = 1,382,400 liters per day (lpd).

The population of the Balasore Municipality notified area is 144,373.

The domestic consumption for the Balasore Municipality notified area is calculated as follows: 144,373 × 150 = 21,655,950 lpd.

The efficiency of the four injection wells in mitigating domestic consumption in the Balasore Municipality notified area is 6.38%.

With just four injection wells, the groundwater requirement for domestic use can be reduced by up to 6.38% on the groundwater resources. After successfully implementing this injection well concept, it can be applied to other areas following a post-assessment of the study area.

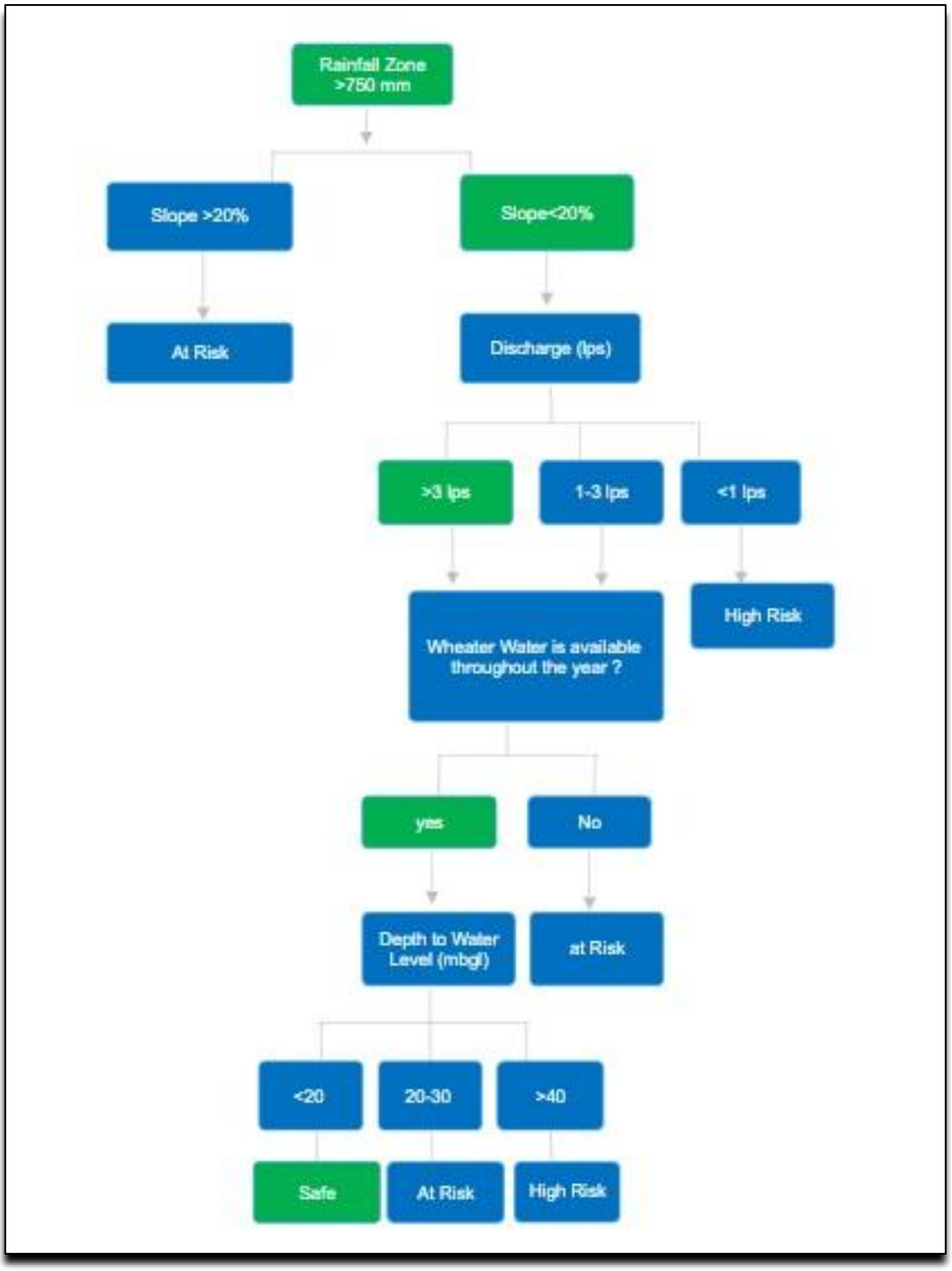


FIGURE 47: THE FLOW DIAGRAM FOR RISK ASSESSMENT OF THE GROUNDWATER RESOURCE IN THE STUDY AREA.

- The Groundwater resource of the phreatic aquifer and deep aquifers shows a safer side on the risk assessment, as per the SoP of Sustainability of Groundwater sources.

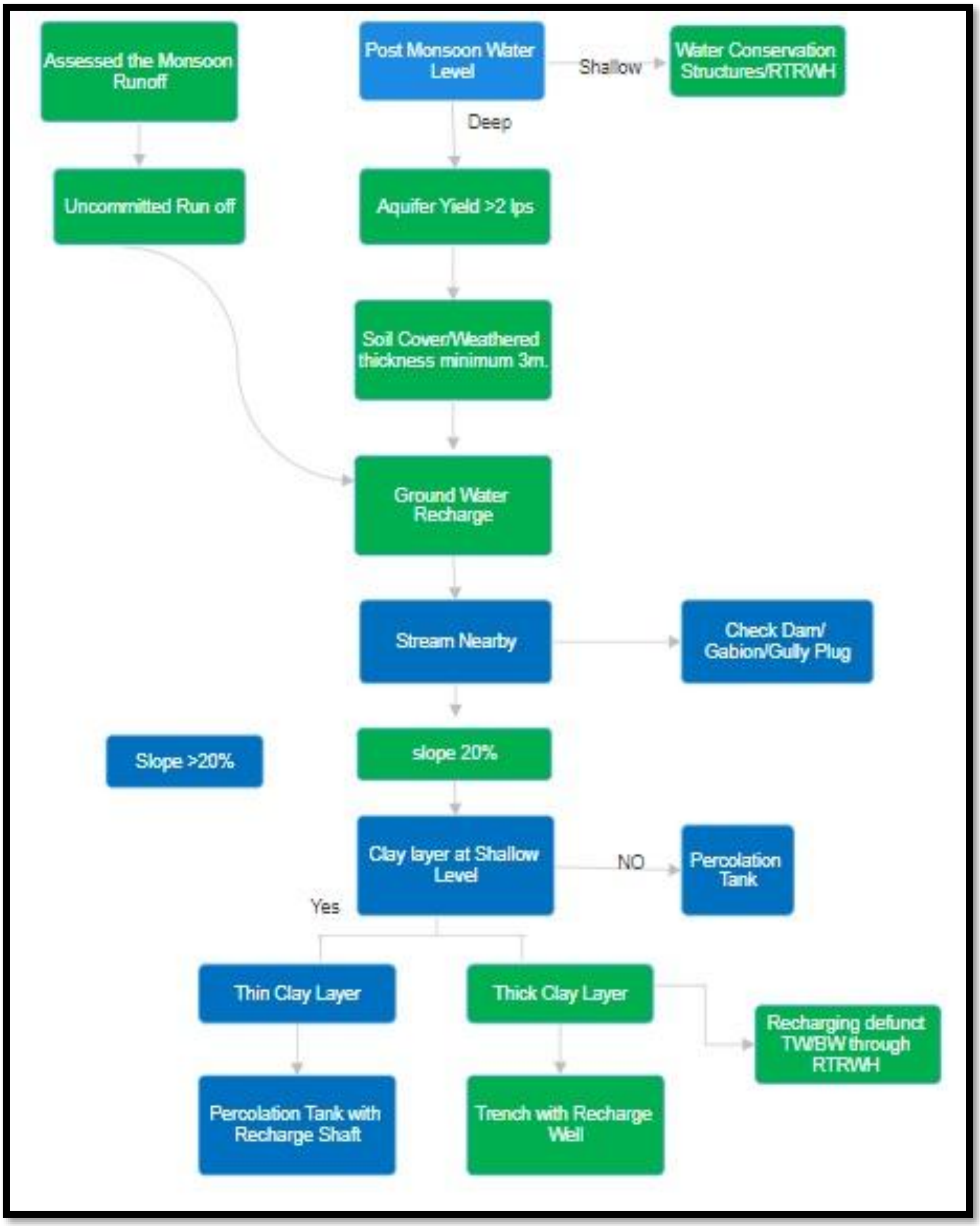


FIGURE 48: SUITABLE SOURCE FINDING FOR SUSTAINABILITY OF GW RESOURCES IN THE STUDY AREA.

Water Conservation Structures/ RTRWS, Trench with Recharge well, Recharging defunct TW/BW through RTRWH are recommended in the study area for sustaining the Groundwater resource.

26. A plan for drinking water source Sustainability:

Based on the detailed water quality analysis of the water samples collected from the wells up to depth of 80 mbgl., the following insights can be provided regarding the sustainability of the groundwater sources for drinking purposes:

i. General Water Quality:

- The major ion concentrations, except for fluoride, in the groundwater samples were found to be within the permissible limits set by the Indian drinking water standard (IS 10500:2012), indicating the general suitability of the groundwater for drinking purposes.

- However, the groundwater exhibited low pH values in a few samples, indicating an acidic nature that may require treatment before consumption.

- Approximately 24% and 26% of the samples had electrical conductivity (EC) values above 1000 μS/cm during the pre- and post-monsoon periods, respectively, suggesting poor water quality based on EC.

ii. Fluoride Contamination:

- Fluoride concentration is a major concern for drinking water quality in the study area.

- During the pre-monsoon period, 10% of the samples (6 samples) and during the post-monsoon period, 15% of the samples (10 samples) had fluoride levels within the range of low to high risk for dental and skeletal fluorosis.

- The table in the document lists the specific sample locations that are not suitable for drinking due to high fluoride concentrations.

Water Quality Index (WQI) for Drinking:

- The Water Quality Index (WQI) was calculated to provide a comprehensive assessment of the groundwater quality for drinking purposes.

- During the pre-monsoon period:

  - 11% of the samples were classified as having "excellent" water quality.

  - 29% were classified as having "good" water quality.

  - 52% were classified as having "poor" water quality.

  - 5% were classified as having "very poor" water quality.

  - 3% were classified as "unsuitable" for drinking.

- During the post-monsoon period:

  - 9% of the samples were classified as having "excellent" water quality.

  - 41% were classified as having "good" water quality.

  - 45% were classified as having "poor" water quality.

  - 4% were classified as having "very poor" water quality.

  - 1% was classified as "unsuitable" for drinking.

The WQI results indicate that a significant portion of the groundwater resources in the study area (52-45% during the pre- and post-monsoon periods, respectively) are not suitable for direct drinking purposes without appropriate treatment. The high fluoride concentrations and poor physicochemical parameters in some samples are the primary factors contributing to the unsuitability of the groundwater for direct consumption.

iii. Unsuitable Locations for Drinking:

- The document identifies specific sample locations that are unsuitable for drinking purposes due to high fluoride concentrations or poor overall water quality based on the WQI.

- These include Khandahara, Haldipada, and Jhinkaria, which had fluoride levels exceeding the permissible limit and were classified as having "unsuitable" water quality for drinking.

In summary, the groundwater in the study area exhibits variable quality for drinking purposes. While a significant portion of the samples meet the drinking water standards, a considerable number of samples are not suitable for direct consumption due to high fluoride levels and poor physicochemical characteristics. Appropriate treatment and management strategies would be necessary to ensure the sustainability of the groundwater resources for drinking purposes in the region.

27. Identification of potential aquifers for Irrigation:

Based on the detailed hydrochemical analysis and water quality assessment of shallow as well as deep wells upto 80 mbgl. presented in the study area, the following insights can be provided regarding the groundwater source sustainability for agricultural purposes:

i. Salinity Hazard:

- The electrical conductivity (EC) values of the groundwater samples ranged from 122 to 2615 µS/cm during the pre-monsoon period and 115 to 2513 µS/cm during the post-monsoon period, with mean values of 816 µS/cm and 822 µS/cm respectively.

- Approximately 56% of the samples during the pre-monsoon and 50% during the post-monsoon periods were classified under the low (C1) to medium (C2) salinity hazard classes, indicating suitability for irrigation.

- However, 40% of the samples during the pre-monsoon and 48% during the post-monsoon periods were classified under the high salinity hazard class (C3), which is considered doubtful for irrigation.

- Additionally, 3% of the samples during the pre-monsoon and 1% during the post-monsoon periods were categorized as having very high salinity hazard (C4), which is unsuitable for irrigation.

ii. Sodium Adsorption Ratio (SAR):

- The SAR values ranged from 0.6 to 15.4 (mean of 2.9) during the pre-monsoon and 0.3 to 22.4 (mean of 5.7) during the post-monsoon periods.

- About 53% of the samples during the pre-monsoon and 46% during the post-monsoon periods were classified as C2S1, indicating medium salinity and low sodium levels, which is suitable for irrigation.

- However, 4% of the samples during the post-monsoon period were categorized as C3S2, suggesting they are unsuitable for irrigation due to high salinity and sodium levels.

iii. Sodium Percentage (Na%):

- The Na% ranged from 13.4% to 78.5% (mean of 32.3%) during the pre-monsoon and 9.5% to 90.5% (mean of 45.0%) during the post-monsoon periods.

- During the pre-monsoon, about 96% of the samples were within the permissible limits for irrigation, while 6% were categorized as doubtful.

- In the post-monsoon period, 61% of the samples met the permissible limits, 26% were categorized as doubtful, and 13% were unsuitable due to high sodium content.

iv. Residual Sodium Carbonate (RSC):

- The RSC values ranged from -2.03 to 3.06 meq/L (mean of -0.34 meq/L) during the pre-monsoon and -2.89 to 8.54 meq/L (mean of 1.33 meq/L) during the post-monsoon periods.

- During the pre-monsoon, 97% of the samples were classified as having good water quality for irrigation, while 3% were doubtful.

- In the post-monsoon, 67% were good, 4% were doubtful, and 29% were unsuitable for irrigation due to high RSC values.

Magnesium Hazard (MH):

- The MH ranged from 24.6% to 64.2% (mean of 39.8%) during the pre-monsoon and 14.8% to 72.4% (mean of 45.9%) during the post-monsoon periods.

- During the pre-monsoon, 98.4% of the samples were below the 50% threshold, indicating suitability for irrigation, while only 1 sample exceeded the limit.

- In the post-monsoon, 66.7% of the samples were below 50%, and 33.3% exceeded the threshold, suggesting some samples may not be suitable for irrigation.

Permeability Index (PI):

- The PI ranged from 45% to 91% (mean of 62%) during the pre-monsoon and 45% to 113% (mean of 75%) during the post-monsoon periods.

- Approximately 92% and 8% of the samples during the pre-monsoon, and 58% and 28% during the post-monsoon, were classified as class I (75% maximum permeability) and class II (25% maximum permeability) respectively, indicating suitability for irrigation.

- However, 14% of the samples during the post-monsoon period fell under class III (below 25% maximum permeability), suggesting unsuitability for irrigation.

Kelley's Ratio (KR):

- The KR ranged from 0.15 to 3.62 (mean of 0.58) during the pre-monsoon and 0.10 to 9.45 (mean of 1.66) during the post-monsoon periods.

- Approximately 90% of the samples during the pre-monsoon and 57% during the post-monsoon had a KR value less than 1, indicating suitability for irrigation.

- However, 10% of the samples during the pre-monsoon and 43% during the post-monsoon had a KR value greater than 1, suggesting unsuitability for irrigation.

28.Conclusion

The comprehensive investigation carried out in the Balasore-Chandipur study area has generated valuable data and information through various field investigations and data analysis techniques. The key outputs and their significance are as follows:

1. Aquifer Disposition and Characterization:

The detailed field data acquisition and analysis have resulted in a detailed understanding of the aquifer disposition and characteristics in the study area. This includes the depth ranges, thicknesses, and lateral extents of the Younger Alluvium (Unit-I) and Older Alluvium (Unit-II) aquifers, as well as the refinement of critical aquifer parameters such as transmissivity (217 to 1,734 m^2/day) and storativity (1.3 x 10^{-3} to 1.3 x 10^{-6}).

2. Groundwater Level Dynamics:

The study has generated comprehensive groundwater level data, including pre-monsoon (3.26 to 23.54 mbgl) and post-monsoon (2.35 to 23.65 mbgl) water levels, water level fluctuations (1.00 to 10.00 meters), and long-term water level trends (modest decline in both pre- and post-monsoon periods). This information provides insights into the seasonal and temporal variations in groundwater storage.

3. Groundwater Quality Characteristics:

The groundwater quality analysis has yielded a wealth of data, including physicochemical parameters, major ion concentrations, and various water quality indices. For instance, the electrical conductivity (EC) values ranged from 122 to 2,615 µS/cm, with 40-48% of the samples falling under the "doubtful" or "unsuitable" categories for irrigation. The fluoride concentrations ranged from 0.06 to 4.81 mg/L, with 10-15% of the samples exceeding the permissible limit for drinking water.

4. Irrigation Suitability Indices:

The study has calculated numerous irrigation suitability indices, such as Sodium Adsorption Ratio (SAR), Sodium Percentage (Na%), Residual Sodium Carbonate (RSC), and Magnesium Hazard (MH), to assess the suitability of groundwater for agricultural purposes. The numerical values of these indices have been used to categorize the groundwater samples and identify areas with potential constraints for irrigation.

5. Drinking Water Quality Index (WQI):

The Water Quality Index (WQI) has been calculated to provide a comprehensive assessment of the groundwater's suitability for drinking purposes. The numerical WQI values ranged from "excellent" to "unsuitable," with 52-45% of the samples classified as "poor" water quality, highlighting the need for targeted interventions.

6. Iron Contamination:

The study has identified iron-contaminated spots in the phreatic aquifers, with concentrations ranging from 1.082 to 13.52 mg/L, and 60.60% of the samples being iron-contaminated.

7. Prawn Farming Impacts:

The study has documented the significant increase in prawn farming area from 22.09 km^2 (4.24%) in 2012 to 52.09 km^2 (10.09%) in 2023, highlighting the potential impacts on groundwater quality and availability due to saline water intrusion and excessive extraction.

8. Stable Isotopic Studies:

The stable isotopic analysis of groundwater and rainfall has provided valuable insights into the sources, recharge mechanisms, and hydrogeochemical processes governing the groundwater system. The isotopic composition of rainfall ($\delta^{18}O$: -38.38 to -18.76‰, δ^2H: -38.38 to -18.76‰) and groundwater ($\delta^{18}O$: -5.80 to -2.81‰, δ^2H: -38.38 to -18.76‰), as well as the deuterium excess analysis (6.425‰ average), indicate the dominance of evaporation processes.

9. Groundwater Resource Estimation:

The study has conducted a detailed groundwater resource estimation for the Balasore-Chandipur area, quantifying the total annual groundwater recharge (18,055.2 Ham), natural discharges (1,487.569 Ham), and extractable groundwater resources (16,567.63 Ham). The area has been categorized as "safe" based on the apportioning method.

29.Recommendations:

In conclusion, the analysis of water samples indicates that the extent of seawater intrusion in the study area is relatively limited, with the majority of the groundwater samples exhibiting characteristics of freshwater. However, localized pockets of moderate to injurious contamination were identified, indicating the need for continued monitoring and management of groundwater resources to mitigate the potential impacts of seawater intrusion. However, to address this declining water level trend, the following measures are recommended:

1. Groundwater augmentation is necessary. It will be achieved through extensive rooftop rainwater harvesting and trench with recharge well in the Balasore Urban and North Eastern part of the study area.
2. Supplement the use of surface water for drinking and domestic purposes in urban areas.
3. Regulation of groundwater withdrawal by industries in the surrounding urban area and aquaculture farming in the coastal tract.
4. There are instances of higher concentrations of iron and fluoride in localized areas in shallow aquifers in the study area. These aquifers should be search for alternate source.
5. The prawn farming area is continuously increasing. Prawn farming is shifting from coastal areas to inland areas. Prawn farming involves storing saline water in ponds. This cause increase the salinity in the shallow aquifer affecting the increase in soil Stalinization process and seepage of saline water to fresh aquifers. Regulation of prawn farming is necessary.
6. Measures should be taken to modify creeks and decrease their adverse impact on the groundwater system.

ANNEXURE- 1: LONG-TERM RAINFALL DATA OF STUDY AREA.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Year	**(Rainfall in mm)**												
1995	12	50	39	15	423	193	228	426	306	265	213	0	**2170**
1996	13	12	0	21	51	215	346	534	77	141	4	0	**1414**
1997	18	25	108	182	95	330	346	584	362	61	36	54	**2201**
1998	29	31	95	113	101	170	199	156	458	182	72	0	**1606**
1999	0	0	0	9	224	300	240	352	445	530	110	0	**2210**
2000	8	87	0	72	166	291	246	220	332	53	2	0	**1477**
2001	0	10	68	49	167	366	397	385	152	211	33	0	**1838**
2002	28	0	46	80	57	232	121	272	373	52	60	0	**1321**
2003	0	12	50	26	76	287	340	213	184	538	34	16	**1776**
2004	0	0	4	37	78	260	326	388	231	266	0	0	**1590**
2005	16	0	63	71	88	227	403	222	549	432	0	0	**2071**
2006	0	0	25	27	112	240	370	524	429	25	22	0	**1774**
2007	3	93	0	19	97	296	452	544	603	44	35	0	**2186**
2008	67	18	4	23	98	633	263	287	304	10	35	0	**1742**
2009	0	0	9	0	171	90	430	303	336	199	42	0	**1580**
2010	0	0	2	2	201	93	254	177	306	199	6	27	**1267**
2011	0	16	3	33	109	348	112	374	472	20	0	0	**1487**
2012	71	0	0	80	30	97	147	291	233	28	33	18	**1028**
2013	1	2	5	50	192	241	252	0	346	697	0	0	**1786**
2014	0	42	44	24	225	177	479	490	316	134	0	0	**1931**
2018	0	0.4	5.9	164.9	154.7	287.6	330.4	323.8	338.5	259.7	0	8	**1873.9**
2019	0	58.3	29.1	74.9	158.2	130.1	195.4	316.6	363.9	232.8	77.5	2.4	**1639.2**
2020	41	21.9	64	124.8	257.6	213.8	135.8	446.7	147.4	191.8	3.1	0	**1647.9**
2021	0	0	0.4	36.3	312.6	221	258.1	246.5	502.7	204.2	2	65.4	**1849.2**
2022	15.4	39.9	0.3	8.8	78.4	156.8	371.7	465.9	204.8	209.4	0	0	**1551.4**
Average	**12.896**	**20.74**	**26.588**	**53.708**	**148.9**	**243.812**	**289.696**	**341.66**	**334.852**	**207.396**	**32.784**	**7.632**	**1658.608**

ANNEXURE- 2: : LONG-TERM RAINFALL ANALYSIS OF STUDY AREA.

Year	Normal Rainfall (mm)	Actual Rainfall (mm)	Departure From Normal (mm)	Departure From Normal (%)	Remarks
1995	1658.608	2170	511.392	30.8326018	Excess
1996	1658.608	1414	-244.61	-14.7477885	Deficit - Normal
1997	1658.608	2201	542.392	32.701639	Excess
1998	1658.608	1606	-52.608	-3.17181637	Normal
1999	1658.608	2210	551.392	33.2442627	Excess
2000	1658.608	1477	-181.61	-10.9494226	Deficit - Normal
2001	1658.608	1838	179.392	10.8158166	Normal
2002	1658.608	1321	-337.61	-20.3549	Deficit - Normal
2003	1658.608	1776	117.392	7.0777423	Normal
2004	1658.608	1590	-68.608	-4.13648071	Deficit - Normal
2005	1658.608	2071	412.392	24.8637412	Excess
2006	1658.608	1774	115.392	6.95715926	Normal
2007	1658.608	2186	527.392	31.7972661	Excess
2008	1658.608	1742	83.392	5.02783057	Normal
2009	1658.608	1580	-78.608	-4.73939593	Deficit - Normal
2010	1658.608	1267	-391.61	-23.6106422	Deficit - Mild Drought
2011	1658.608	1487	-171.61	-10.3465074	Deficit - Normal
2012	1658.608	1028	-630.61	-38.0203158	Deficit - Severe Drought
2013	1658.608	1786	127.392	7.68065752	Normal
2014	1658.608	1931	272.392	16.4229281	Excess
2018	1658.608	1873.9	215.292	12.9802823	Excess
2019	1658.608	1639.2	-19.408	-1.17013785	Deficit - Normal
2020	1658.608	1647.9	-10.708	-0.64560161	Deficit - Normal
2021	1658.608	1849.2	190.592	11.4910817	Excess
2022	1658.608	1551.4	-107.21	-6.46373344	Deficit - Normal

ANNEXURE- 3: WATER LEVEL DATA OF THE PRE-MONSOON AND POST-MONSOON PERIOD OF THE STUDY AREA.

Sr. NO.	Location	Latitude	Longitude	Location Detail	Source of Data	Date	Pre Monsoon W.L (mbmp)	M.P (mbgl)	W.L (mbgl)	Post Monsoon W.L.(mbmp)	W,L.(mbgl)	Seasonal Fluctuation (mt.)
1	Meghadamburu	21.47092	86.90199	Sample collected from the Meghadamburu Village Chowk.	Govt. Mark II H.P. (150 ft.)	24.12.2023	13.91	0.35	13.56	12.34	11.99	1.57
2	Purusottampur/ Khannagar G.P.	21.44365	86.87512	Sample collected from the Maa Tarini Temple after Crossing the Train level Crossing.	Govt. Mark II H.P. (150 ft.)	24.12.2023	9.59	0.6	8.99	8.04	7.44	1.55
3	Mala	21.42176	86.87714	Sample collected from the Trijunction of Mala Chowk, Satsang G.P.	Govt. Mark II H.P. (150 ft.)	24.12.2023	7.01	0.45	6.56	5.1	4.65	1.91
4	Rasalpur	21.39018	86.89448	Sample collected from the residence of Lakhsman Nayak's Residence, Ghantisahi, Rasalpur.	Govt. Mark II H.P. (150 ft.)	25.12.2023	11.69	0.5	11.19	10.37	9.87	1.32
5	Tundara/Kungarpur	21.36495	86.89816	Sample collected in the premises of Hemalata Nodal Higher Primary School.	Govt. Mark II H.P. (150 ft.)	25.12.2023	11.5	0.5	11	9.76	9.26	1.74
6	Kantarada	21.34719	86.92232	Sample collected near the Cyclone rescue Center.	Govt. Mark II H.P. (150 ft.)	29.12.2023	10.05	0.75	9.3	8.75	8	1.3
7	Bartana	21.47052	86.84208	Sample collected Near the Bartana village Chowk.	Govt. Mark II H.P. (150 ft.)	24.12.2023	10.25	0.37	9.88	9.02	8.65	1.23
8	Remuna	21.52667	86.86683	Sample collected Near the Basanti Market ,Remuna Chowk.	Govt. Mark II H.P. (150 ft.)	24.12.2023	13.25	0.45	12.8	12.32	11.87	0.93
9	Madarajpur	21.54716	86.80972	Sample collected in front of the Christian Cremation Ground.	Govt. Mark II H.P. (150 ft.)	23.12.2023	12.65	0.45	12.2	8.97	8.52	3.68
10	Khirachora Temple	21.54193	86.88001	Sample collected 200mt north side of Khirachora Gopi nath temple.	Govt. Mark II H.P. (150 ft.)	24.12.2023	9.23	0.5	8.73	6.78	6.28	2.45
11	Kasimpur ,Dahapada G.P.	21.54838	86.92004	Sample collected Near the Kasimpur Water Head Tank.	Govt. Mark II H.P. (150 ft.)	28.12.2023	9.48	0.45	9.03	8.15	7.7	1.33
12	FMU old Campus	21.50674	86.89029	Sample collected near the Guest House of Old FMU campus.	Govt. Mark II H.P. (150 ft.)	25.12.2023	11.22	0.5	10.72	5.44	4.94	5.78
13	Odangi	21.56196	86.97211	Sample collected end of the Village.	Govt. Mark II H.P. (150 ft.)	28.12.2023	12.37	0.5	11.87	10.47	9.97	1.9
14	Khandahara, Haldipada	21.58387	87.00963	Sample collected from the Tarini Temple, Khandahar, Haldipada.	Govt. Mark II H.P. (150 ft.)	28.12.2023	13.28	0.65	12.63	11.98	11.33	1.3
15	Rupsa	21.6308	87.01982	Sample collected from the Rupsa Railway level Crossing.	Govt. Mark II H.P. (150 ft.)	28.12.2023	9.55	0.45	9.1	8.78	8.33	0.77

16	Salpata/Sunipat	21.565	87.0608	Sample collected near weekly vegetable Market, Sunipat.	Govt. Mark II H.P. (150 ft.)	28.12. 2023	16.21	0.5	15.71	10.32	9.82	5.89
17	Babanpur	21.5133	87.11446	Sample Collected Near the fish market of the Babanpur Village.	Govt. Mark II H.P. (150 ft.)	28.12. 2023	22.37	0.55	21.82	14.8	14.25	7.57
18	Nilada	21.52161	87.05141	Sample collected from the pond in front of the Nilada Primary School.	Govt. Mark II H.P. (150 ft.)	28.12. 2023	21.67	0.5	21.17	12.56	12.06	9.11
19	Angula	21.52005	87.00241	Sample collected from the Angula Hanuman Temple.	Govt. Mark II H.P. (150 ft.)	28.12. 2023	8.85	0.45	8.4	7.68	7.23	1.17
20	Saragaon	21.43955	86.92908	Sample Collected from the south of the village about 300mtr. From the main Road.	Govt. Mark II H.P. (150 ft.)	25.12. 2023	13.61	0.4	13.21	11.2	10.8	2.41
21	Bardhanpur	21.39519	86.92066	Sample Collected In front of the Maninageswar Temple, Bardhanpur.	Govt. Mark II H.P. (150 ft.)	25.12. 2023	13.15	0.72	12.43	11.45	10.73	1.7
22	Patrapada	21.47889	86.96728	Sample Collected Near the Overhead water Tank.	Govt. Mark II H.P. (150 ft.)	25.12. 2023	14.47	0.45	14.02	9.6	9.15	4.87
23	Jhampara	21.44764	87.0078	Sample Near the Garage at the Chowk.	Govt. Mark II H.P. (150 ft.)	30.12. 2023	13.23	0.45	12.78	11.39	10.94	1.84
24	Hidinga	21.4342	86.9882	Sample collected at the Trijunction near the bridge.	Govt. Mark II H.P. (150 ft.)	27.12. 2023	13.31	0.45	12.86	11.46	11.01	1.85
25	Balramgadi-Mirzapur	21.4711	87.0517	Sample collected at the Trijunction near the trijunction near the temple.	Govt. Mark II H.P. (150 ft.)	27.12. 2023	13.55	0.45	13.1	10.38	9.93	3.17
26	BalsoreBustand	21.50291	86.91948	Beside the Balasore Bus stand, Near the Garage.	Govt. Mark II H.P. (150 ft.)	30.12. 2023	21.37	0.48	20.89	16.45	15.97	4.92
27	BK chowk	21.48513	86.94328	In the Trijunction of Auto Rickshaw Stand.	Govt. Mark II H.P. (150 ft.)	26.12. 2023	24.15	0.45	23.7	17.67	17.22	6.48
28	Hidigaon	21.45685	86.9855	In the Trijunction of Hidigaon Village.	Govt. Mark II H.P. (150 ft.)	27.12. 2023	13.89	0.7	13.19	10.62	9.92	3.27
29	Gudupahi	21.42423	86.96984	On the Canal Road.	Govt. Mark II H.P. (150 ft.)	29.12. 2023	13.94	0.5	13.44	10.79	10.29	3.15
30	JK chowk	21.38971	86.93389	Right side of the J.K Chowk, near the J.K. High School.	Govt. Mark II H.P. (150 ft.)	29.12. 2023	13.78	0.45	13.33	10.69	10.24	3.09
31	Sarswatipur	21.4116	86.90801	In side the Devi temple Satsang Centre.	Govt. Mark II H.P. (150 ft.)	31.12. 2023	12.12	0.45	11.67	10.54	10.09	1.58
32	SanSaun	21.44184	86.90138	Inside the Village, in the Biswal Street.	Govt. Mark II H.P. (150 ft.)	24.12. 2023	11.35	0.65	10.7	8.09	7.44	3.26
33	Aladia	21.46062	86.95128	In the Aladia Chowk, In front of Devi Temple.	Govt. Mark II H.P. (150 ft.)	25.12. 2023	13.38	0.45	12.93	10.21	9.76	3.17
34	Srikona Hp	21.48746	86.99668	Near the Bank of oxbow of Budhabalanga River.	Govt. Mark II H.P. (150 ft.)	26.12. 2023	13.74	0.45	13.29	10.51	10.06	3.23

35	Srikona Hp-II	21.45525	87.01338	In the Center of the Village, In the Grassland.	Govt. Mark II H.P. (150 ft.)	30.12. 2023	13.94	0.5	13.44	10.69	10.19	3.25
36	Gourpur	21.51852	86.8408	In the Chowk of Gourpur Village.	Govt. Mark II H.P. (150 ft.)	23.12. 2023	14.59	0.55	14.04	10.88	10.33	3.71
37	Naraharipur	21.50731	86.85688	Near the IOCL plant.	Govt. Mark II H.P. (150 ft.)	24.12. 2023	14.77	0.45	14.32	10.74	10.29	4.03
38	SuteiBadagaon	21.49619	86.86737	In the Trijunction near the Temple.	Govt. Mark II H.P. (150 ft.)	24.12. 2023	15.01	0.65	14.36	12.1	11.45	2.91
39	Kurunia	21.54031	86.85115	In front of Kurunia High School.	Govt. Mark II H.P. (150 ft.)	23.12. 2023	10.54	0.45	10.09	8.65	8.2	1.89
40	Mukhura	21.51153	86.81542	In the trijunction of village beside the Kirana Shop.	Govt. Mark II H.P. (150 ft.)	23.12. 2023	11.45	0.55	10.9	8.9	8.35	2.55
41	Pinchabania	21.60781	87.00318	In side the Village Main Road.	Govt. Mark II H.P. (150 ft.)	28.12. 2023	10.79	0.45	10.34	8.34	7.89	2.45
42	Kharji	21.5834	87.05164	Near the Prawn Farm.	Govt. Mark II H.P. (150 ft.)	28.12. 2023	15.78	0.55	15.23	11.39	10.84	4.39
43	Chanuan	21.53584	87.06964	Near the Hath Chowk.	Govt. Mark II H.P. (150 ft.)	29.12. 2023	16.57	0.6	15.97	11.64	11.04	4.93
44	Kayakada	21.48738	87.02304	In the Main Road, neighboring the Himat Meity's Kirana shop.	Govt. Mark II H.P. (150 ft.)	29.12. 2023	8.67	0.55	8.12	7.04	6.49	1.63
45	Bagda	21.4985	87.08546	Near the Temple.	Govt. Mark II H.P. (150 ft.)	29.12. 2023	17.07	0.65	16.42	12.34	11.69	4.73
46	Bahabalpur	21.50588	87.07288	Near the Bahabalpur Shiv temple.	Govt. Mark II H.P. (150 ft.)	29.12. 2023	16.79	0.65	16.14	13.35	12.7	3.44
47	Parkhi	21.4793	87.0753	Near the Prarkhi Sea Beach.	Govt. Mark II H.P. (150 ft.)	29.12. 2023	16.67	0.6	16.07	13.24	12.64	3.43
48	Gopinathpur	21.50736	87.02756	In the Southern end of Village.	Govt. Mark II H.P. (150 ft.)	30.12. 2023	13.87	0.65	13.22	12.54	11.89	1.33
49	Jhinkaria	21.53924	87.01784	Near the Hanuman statue of the Village.	Govt. Mark II H.P. (150 ft.)	28.12. 2023	13.69	0.6	13.09	12.55	11.95	1.14
50	Tentulimundi	21.532	86.99209	In the Main Chowk of the Village.	Govt. Mark II H.P. (150 ft.)	28.12. 2023	13.45	0.55	12.9	10.92	10.37	2.53
51	Raghunathpur	21.49743	86.97401	Beside the Overhead Tank.	Govt. Mark II H.P. (150 ft.)	28.12. 2023	9.77	0.55	9.22	8.02	7.47	1.75
52	Udambar	21.55435	86.8979	Near the Overhead Tank and In front of Primary school.	Govt. Mark II H.P. (150 ft.)	24.12. 2023	9.64	0.45	9.19	7.99	7.54	1.65
53	Sindiya	21.51903	86.95092	In the Main Chowk of the Village.	Govt. Mark II H.P. (150 ft.)	28.12. 2023	8.64	0.45	8.19	6.54	6.09	2.1

54	Lion Club Square	21.49386	86.92076	Right side of the Lions Club Square, Balasore.	Govt. Mark II H.P. (150 ft.)	31.03. 2023	21.45	0.5	20.95	16.54	16.04	4.91
55	Gopalgaon	21.49859	86.93672	In the Main Market of the Gopalgaon Square.	Govt. Mark II H.P. (150 ft.)	30.12. 2023	21.63	0.55	21.08	17.34	16.79	4.29
56	Srikona Basudha TW	21.45018	87.01975	W.L taken from the Overhead water Tank Tubewell (Direct),Srikona.	Deep TW of 80mbgl.	30.12. 2023	7.2	0.4	6.8	6.41	6.01	0.79

ANNEXURE- 4: GROUNDWATER QUALITY DATA OF THE WATER SAMPLE COLLECTED IN THE STUDY AREA DURING PRE-MONSOON PERIOD.

Sl No	Type of Sample	Date of Sampling	Dist.	Block	Village	Source	Lat Decimal	Long Decimal	Depth mbgl	Aquifer	pH	EC µS/cm	TDS	Hardness	Alkalinity	Ca++	Mg++	Na+	K+	CO3=	HCO3-	Cl-	SO4	NO3	F -	U
											at 25 °C	at 25°C	mg/L	as CaCO3 mg/L		mg/L										
1	NAQUIM	09.06.2023	BALASORE	Remuna	Meghadamburu	TW	21.47049	86.90211	80	Alluvium	7.58	363	201	163	144	40	15	15	1	0	175	21	21	1	0.24	BDL
2	NAQUIM	09.06.2023	BALASORE	Remuna	Meghadamburu	HP	21.47092	86.90199	45	Alluvium	7.72	314	176	128	119	32	12	19	1	0	145	29	12	0	0.30	BDL
3	NAQUIM	09.06.2023	BALASORE	Remuna	Purusottampur/ Khannagar G.P.	HP	21.44365	86.87512	45	Alluvium	7.81	432	251	204	176	42	24	21	2	0	215	31	25	0	0.45	0.001
4	NAQUIM	09.06.2023	BALASORE	Sadar	Mala	HP	21.42176	86.87714	45	Alluvium	7.86	603	335	221	188	55	20	43	2	0	229	64	36	0	0.49	0.001
5	NAQUIM	10.06.2023	BALASORE	Sadar	Rasalpur	HP	21.39018	86.89448	45	Alluvium	7.5	693	389	300	264	73	29	36	2	0	322	55	36	0	0.51	0.001
6	NAQUIM	10.06.2023	BALASORE	Sadar	Rasalpur	TW	21.39011	86.89507	80	Alluvium	7.75	1059	590	353	297	87	33	93	7	0	362	143	47	0	0.51	0.002
7	NAQUIM	10.06.2023	BALASORE	Sadar	Tundara/Kungarpur	HP	21.36495	86.89816	45	Alluvium	7.71	950	523	346	325	85	33	68	2	0	397	102	38	0	0.44	0.001
8	NAQUIM	10.06.2023	BALASORE	Sadar	Kantarada	HP	21.34719	86.92232	45	Alluvium	8.11	2104	1191	224	380	54	22	378	7	0	464	435	62	5	0.79	0.005
9	NAQUIM	11.06.2023	BALASORE	Sadar	Bartana	HP	21.47052	86.84208	45	Alluvium	7.52	288	160	125	114	31	12	12	1	0	139	17	12	8	0.30	BDL
10	NAQUIM	11.06.2023	BALASORE	Sadar	Bartana TW	TW	21.46979	86.84373	80	Alluvium	7.64	381	214	154	129	37	15	24	1	0	157	36	19	5	0.49	BDL
11	NAQUIM	11.06.2023	BALASORE	Remuna	Remuna	HP	21.52667	86.86683	45	Alluvium	7.61	549	309	206	158	51	19	39	3	0	193	60	41	0	0.57	0.001
12	NAQUIM	11.06.2023	BALASORE	Remuna	Emami Paper Mill	TW	21.53297	86.82831	80	Alluvium	7.59	397	221	164	146	39	16	20	2	0	178	29	25	3	0.61	BDL
13	NAQUIM	11.06.2023	BALASORE	Remuna	Madarajpur	HP	21.54716	86.80972	45	Alluvium	6.37	122	71	49	40	12	5	9	1	0	48	13	8	0	0.06	BDL
14	NAQUIM	12.06.2023	BALASORE	Remuna	Khirachora Temple	HP	21.54193	86.88001	45	Alluvium	7.68	425	236	187	168	45	18	21	1	0	205	31	20	0	0.27	0.001
15	NAQUIM	12.06.2023	BALASORE	Remuna	Kasimpur, Dahapada G.P.	TW	21.54832	86.9199	80	Alluvium	7.67	447	250	139	144	36	12	41	2	0	176	52	21	0	0.20	0.001
16	NAQUIM	12.06.2023	BALASORE	Remuna	Kasimpur ,Dahapada G.P.	HP	21.54838	86.92004	45	Alluvium	7.91	996	554	301	259	73	29	95	2	0	316	138	53	8	1.14	0.001
17	NAQUIM	12.06.2023	BALASORE	Remuna	FMU old Campus	HP	21.50674	86.89029	45	Alluvium	7.91	478	252	216	203	53	20	17	1	0	248	24	15	0	0.31	0.001

18	NAQUIM	12.06.2023	BALASORE	Sadar	Odangi	HP	21.56196	86.97211	45	Alluvium																
19	NAQUIM	13.06.2023	BALASORE	Sadar	Khandahara, Haldipada	HP	21.58387	87.00963	45	Alluvium	7.45	2365	1390	436	343	93	50	370	4	0	419	438	228	0	1.07	0.008
20	NAQUIM	13.06.2023	BALASORE	Sadar	Rupsa	HP	21.6308	87.01982	45	Alluvium	8.16	1320	723	417	437	100	41	126	3	0	533	150	32	4	4.34	0.001
21	NAQUIM	13.06.2023	BALASORE	Sadar	Rupsa TW	TW	21.62622	87.02113	80	Alluvium	7.57	661	358	250	238	61	24	46	2	0	290	69	12	0	1.32	0.001
22	NAQUIM	13.06.2023	BALASORE	Remuna	Salpata/Sunipat	HP	21.565	87.0608	45	Alluvium	7.91	681	409	304	322	73	30	43	5	0	393	55	10	0	0.10	0.001
23	NAQUIM	13.06.2023	BALASORE	Remuna	Babanpur	HP	21.5133	87.11446	45	Alluvium	7.88	690	386	309	277	85	24	35	5	0	338	50	22	0	0.10	0.001
24	NAQUIM	13.06.2023	BALASORE	Remuna	Dublagudi TW	TW	21.50135	87.10077	80	Alluvium	7.93	1036	594	309	277	73	31	115	9	0	338	163	36	1	0.06	0.001
25	NAQUIM	14.06.2023	BALASORE	Remuna	Nilada	HP	21.52161	87.05141	45	Alluvium	7.99	862	489	349	336	85	33	65	3	0	409	83	16	2	0.34	0.001
26	NAQUIM	14.06.2023	BALASORE	Sadar	Angula	HP	21.52005	87.00241	45	Alluvium	7.98	1140	606	334	348	81	32	110	3	0	425	144	26	1	1.51	0.001
27	NAQUIM	14.06.2023	BALASORE	Remuna	Saragaon	HP	21.43955	86.92908	45	Alluvium	7.68	414	234	181	189	45	17	19	2	0	230	34	4	0	0.52	0.001
28	NAQUIM	14.06.2023	BALASORE	Remuna	Bardhanpur	HP	21.39519	86.92066	45	Alluvium	7.69	675	371	274	282	66	27	45	2	0	344	55	6	0	0.57	0.001
29	NAQUIM	15.06.2023	BALASORE	Remuna	Patrapada	TW	21.4789	86.96728	80	Alluvium	7.67	706	392	299	288	71	30	31	2	0	351	44	41	0	0.66	0.001
30	NAQUIM	15.06.2023	BALASORE	Remuna	Patrapada	HP	21.47889	86.96728	45	Alluvium	7.76	722	406	307	318	84	24	40	1	0	388	61	5	0	0.62	0.001
31	NAQUIM	15.06.2023	BALASORE	Sadar	Jhampara	HP	21.44764	87.0078	45	Alluvium	7.96	1322	716	324	307	95	21	165	4	0	374	202	42	1	1.56	0.006
32	NAQUIM	15.06.2023	BALASORE	Remuna	Hidinga	HP	21.4342	86.9882	45	Alluvium	8.07	997	555	349	348	85	33	75	4	0	425	114	34	0	0.51	0.001
33	NAQUIM	15.06.2023	BALASORE	Remuna	Srikona	TW	21.45018	87.01975	80	Alluvium	7.87	1571	866	319	302	77	31	212	4	0	368	322	37	1	1.22	0.001
34	NAQUIM	15.06.2023	BALASORE	Remuna	Balramgadi-Mirzapur	HP	21.4711	87.0517	45	Alluvium	8.05	957	529	339	332	83	32	65	4	0	405	102	41	2	0.37	0.001
35	NAQUIM	19.07.2023	BALASORE	Balasore Municipality	BalsoreBustand	HP	21.50291	86.91948	45	Alluvium	7.08	593	330	206	178	62	12	47	1	0	217	75	25	0	0.37	0.001
36	NAQUIM	19.07.2024	BALASORE	Balasore Municipality	BK chowk	HP	21.48513	86.94328	45	Alluvium	7.32	438	249	204	168	50	19	21	1	0	205	33	22	0	0.48	0.001
37	NAQUIM	19.07.2026	BALASORE	Remuna	Hidigaon	HP	21.45685	86.9855	45	Alluvium	7.74	1381	802	216	353	53	20	218	7	0	431	228	63	1	0.40	0.004
38	NAQUIM	19.07.2027	BALASORE	Remuna	Gudupahi	HP	21.42423	86.96984	45	Alluvium	8.13	1508	880	422	322	104	39	185	6	0	393	293	56	3	0.53	0.003
39	NAQUIM	20.07.2027	BALASORE	Balasore Municipality	JK chowk	HP	21.38971	86.93389	45	Alluvium	7.85	748	417	290	238	69	29	53	1	0	290	81	41	0	0.63	0.001
40	NAQUIM	20.07.2028	BALASORE	Sadar	Sarswatipur	HP	21.4116	86.90801	45	Alluvium	7.83	660	372	275	248	67	26	34	1	0	302	52	42	0	0.71	0.001
41	NAQUIM	20.07.2029	BALASORE	Sadar	SanSaun	HP	21.44184	86.90138	45	Alluvium	7.73	406	231	191	168	47	18	18	2	0	205	28	16	0	0.51	BDL
42	NAQUIM	20.07.2030	BALASORE	Remuna	Aladia	HP	21.46062	86.95128	45	Alluvium	7.74	361	207	157	139	37	16	20	1	0	169	30	20	0	0.51	0.001
43	NAQUIM	20.07.2031	BALASORE	Remuna	Srikona Hp	HP	21.48746	86.99668	45	Alluvium	8.02	1315	762	442	386	108	42	124	3	0	471	190	61	1	0.65	0.001

44	NAQUIM	20.07.2032	BALASORE	Remuna	Srikona Hp-II	HP	21.45525	87.01338	45	Alluvium	8.23	961	529	353	337	85	35	59	2	0	411	91	52	2	1.36	0.001
45	NAQUIM	21.07.2023	BALASORE	Remuna	Gourpur	HP	21.51852	86.8408	45	Alluvium	7.52	294	164	123	108	30	12	14	3	0	132	22	11	6	0.56	BDL
46	NAQUIM	21.07.2024	BALASORE	Remuna	Naraharipur	HP	21.50731	86.85688	45	Alluvium	7.35	208	118	79	69	19	8	14	1	0	85	22	9	5	0.40	BDL
47	NAQUIM	21.07.2025	BALASORE	Sadar	SuteiBadagaon	HP	21.49619	86.86737	45	Alluvium	7.63	297	166	120	109	30	11	16	2	0	133	25	16	0	0.47	BDL
48	NAQUIM	21.07.2026	BALASORE	Sadar	Kurunia	HP	21.54031	86.85115	45	Alluvium	7.95	784	418	339	307	81	33	23	1	0	374	36	56	0	3.01	0.001
49	NAQUIM	21.07.2027	BALASORE	Sadar	Mukhura	HP	21.51153	86.81542	45	Alluvium	7.49	304	169	128	109	32	12	13	1	0	133	21	10	8	6.28	BDL
50	NAQUIM	22.07.2023	BALASORE	Sadar	Pinchabania	HP	21.60781	87.00318	45	Alluvium	7.46	524	299	211	199	54	18	34	4	0	242	52	17	0	0.50	0.001
51	NAQUIM	22.07.2024	BALASORE	Sadar	Kharji	HP	21.5834	87.05164	45	Alluvium	8.14	834	464	279	274	67	27	66	1	0	335	98	38	2	0.23	0.001
52	NAQUIM	22.07.2025	BALASORE	Remuna	Chanuan	HP	21.53584	87.06964	45	Alluvium	8.12	715	412	275	257	67	26	51	3	0	314	79	28	2	0.15	0.001
53	NAQUIM	22.07.2027	BALASORE	Remuna	Kayakada	HP	21.48738	87.02304	45	Alluvium	8.2	995	555	344	317	83	33	78	3	0	387	121	43	3	0.91	0.001
54	NAQUIM	23.07.2023	BALASORE	Remuna	Gopinathpur	HP	21.50736	87.02756	45	Alluvium	8.22	956	537	324	302	79	31	75	1	0	368	116	46	7	0.61	0.001
55	NAQUIM	23.07.2028	BALASORE	Remuna	Jhinkaria	HP	21.53924	87.01784	45	Alluvium	7.9	2615	1472	373	317	89	37	423	1	0	387	652	78	2	0.37	0.008
56	NAQUIM	24.07.2023	BALASORE	Remuna	Tentulimundi	HP	21.532	86.99209	45	Alluvium	8.14	1356	749	417	366	100	41	138	1	0	447	213	32	3	1.58	0.003
57	NAQUIM	24.07.2024	BALASORE	Remuna	Raghunathpur	HP	21.49743	86.97401	45	Alluvium	8.28	1377	754	530	470	112	61	100	1	0	574	155	37	3	3.66	0.001
58	NAQUIM	24.07.2025	BALASORE	Remuna	Udambar	HP	21.55435	86.8979	45	Alluvium	7.1	395	217	108	104	26	11	40	1	0	127	62	15	0	0.32	BDL
59	NAQUIM	25.07.2023	BALASORE	Remuna	Sindiya	HP	21.51903	86.95092	45	Alluvium	7.81	709	392	304	282	71	31	32	6	0	344	50	32	0	0.64	0.001
60	NAQUIM	25.07.2024	BALASORE	Balasore Municipality	Lion Club Square	HP	21.49386	86.92076	45	Alluvium	7.39	364	198	118	129	30	11	29	2	0	157	45	3	0	0.42	BDL
61	NAQUIM	25.07.2025	BALASORE	Balasore Municipality	Gopalgaon	HP	21.49859	86.93672	45	Alluvium	7.52	906	511	288	246	44	43	104	3	0	300	160	8	0	0.48	0.001
62	NAQUIM	25.07.2023	BALASORE	Balasore Municipality	Januganj	HP	21.51497	86.8924	45	Alluvium	7.96	765	425	255	204.44	61	25	74	2	0	249	107	32	0	0.23	0.002
63	NAQUIM	19.07.2023	BALASORE	Remuna	Parkhi	HP	21.48715	87.05964	45	Alluvium	8.12	1078	591	353	372.24	83	36	85	2	0	454	121	35	2	0.56	0.004

ANNEXURE- 5: GROUNDWATER QUALITY DATA OF THE WATER SAMPLE COLLECTED IN THE STUDY AREA DURING POST-MONSOON PERIOD.

										pH	EC µS/cm	TDS	Hardness	Alkalinity	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	$CO_3^{=}$	HCO_3^{-}	Cl^{-}	SO4	NO3	F^{-}	U
Sl No	Dist.	Block	Village	Source	Lat Decimal	Long Decimal	Depth mbgl	Aquifer	Date of Sampling	at °C	at 25°C	mg/L	as $CaCO_3$ mg/L		mg/L										
1	BALASORE	Remuna	Emami Paper Mill	**Tubewell (150ft.)**	21.533	86.8283	45	Alluvium	23.12.2023	6.95	508	310	227	165.79	64	16	31.34	0.83	0	202.26	46.86	47.06	4.29	0.33	0.001
2	BALASORE	Remuna	Gourpur	HP	21.5185	86.8408	45	Alluvium	23.12.2023	7.21	303	177	157	142.79	44.8	11	11.05	0.79	0	174.21	14.53	2.78	6.46	0.5	BDL
3	BALASORE	Remuna	Mukhura	HP	21.5115	86.8154	45	Alluvium	23.12.2023	7.23	304	176	151	137.98	32	17	12.81	0.922	0	168.33	18.74	2.27	9.06	0.45	BDL
4	BALASORE	Remuna	Madarajpur	HP	21.5472	86.8097	45	Alluvium	23.12.2023	5.67	146	99	49	32.09	12.8	4	18.84	0.628	0	39.15	27.65	15.5	0	0.09	BDL
5	Balasore	Remuna	Kuruniapatna	**Tubewell (200ft.)**	21.5326	86.8498	65	Alluvium	23.12.2023	6.94	280	174	113	106.96	29.9	9	23.7	0.784	0	130.49	32.1	11.3	2.19	0.32	BDL
6	BALASORE	Remuna	Kurunia	HP	21.5403	86.8511	45	Alluvium	23.12.2023	7.86	736	355	308	278.1	74.7	30	19.31	3.4	0	339.28	31.86	24.99	1.01	3.26	0.002
7	BALASORE	Remuna	Remuna	HP	21.5267	86.8668	45	Alluvium	24.12.2023	7.52	539	319	297	299.49	66.1	32	13.2	2.01	0	365.38	18.98	6.46	0	0.63	
9	BALASORE	Remuna	Udambar	HP	21.5544	86.8979	45	Alluvium	24.12.2023	6.8	359	215	130	116.59	25.6	16	33.57	1.15	0	142.24	55.53	13.09	0	0.212	BDL
10	BALASORE	Remuna	Udambar T.W.	**Tubewell (210ft.)**	21.5544	86.8979	70	Alluvium	24.12.2023	7.05	359	233	173	159.91	19.2	30	32.3	1.16	0	195.08	43.11	10.28	0.27	0.361	BDL

11	BALASORE	Balasore Muncipality	Januganj	HP	21.515	86.8924	45	Alluvium	24.13.2023	6.93	429	281	151	150.28	29.9	19	56.61	0.65	0	183.34	76.15	8.184	0	0.324	BDL
12	BALASORE	Remuna	Naraharipur	HP	21.5073	86.8569	45	Alluvium	25.12.2023	6.92	115	116	108	98.4	17.1	16	5.65	0.91	0	120.05	9.37	4.44	2.95	0.418	BDL
13	BALASORE	Remuna	SomanathpurT.W	**Tubewell (300ft.)**	21.4842	86.8475	100	Alluvium	25.12.2023	7.09	257	197	167	153.49	40.6	16	12.86	1.16	0	187.25	23.43	4.18	6	0.378	BDL
14	BALASORE	Remuna	Bartana	HP	21.4705	86.8421	45	Alluvium	25.12.2023	7.14	254	166	140	135.3	32	15	10.84	0.82	0	165.07	14.53	3.98	7.9	0.4	BDL
15	BALASORE	Sadar	SuteiBadagaon T.W.	**Tube Well (225ft.)**	21.4962	86.8674	70	Alluvium	25.12.2023	7.27	279	183	167	156.16	38.4	17	8.41	0.74	0	190.52	15	8.45	0	0.493	BDL
16	BALASORE	Sadar	Purusottampur/ Khannagar G.P.	HP	21.4436	86.8751	45	Alluvium	25.12.2023	7.37	394	268	232	227.82	53.3	24	17.05	1.09	0	277.95	27.18	7.8	0	0.527	BDL
17	BALASORE	Sadar	Meghadamburu	**Tube Well (210ft.)**	21.4709	86.902	70	Alluvium	25.12.2023	7.42	179	93	70	58.83	12.8	9	10.52	1.17	0	71.77	18.98	4.83	0	0.406	BDL
18	BALASORE	Sadar	Meghadamburu	HP	21.4709	86.902	45	Alluvium	25.12.2023	7.16	250	152	113	117.66	25.6	12	18.15	1.13	0	143.54	15.23	8.56	0	0.383	BDL
19	BALASORE	Sadar	Mala	HP	21.4218	86.8771	45	Alluvium	25.12.2023	7.46	419	319	167	165.79	57.6	6	59.54	1.6	0	202.26	84.35	10.34	0	0.544	BDL
20	BALASORE	Sadar	SanSaun	HP	21.4418	86.9014	45	Alluvium	25.12.2023	7.33	655	320	265	236.38	61.9	27	27.13	3.31	0	288.39	46.86	11.23	0.517	0.491	BDL
21	BALASORE	Sadar	Patrapada	HP	21.4789	86.9673	45	Alluvium	26.12.2023	7.36	726	417	346	339.6	89.6	30	38.6	0.92	0	414.31	50.14	4.27	0	0.596	BDL
22	BALASORE	Sadar	Patrapada	TW	21.4789	86.9673	80	Alluvium	26.12.2023	7.62	543	370	313	315.53	74.7	31	29.07	1.32	0	384.95	38.43	5.91	0	0.559	BDL
23	BALASORE	Sadar	Aladia	HP	21.4606	86.9513	45	Alluvium	26.12.2023	7.43	364	221	194	197.34	38.4	24	14.28	0.59	0	240.76	20.38	4.25	0.11	0.512	BDL

24	BALASORE	Sadar	Saragaon	HP	21.4395	86.9291	45	Alluvium	26.12.2023	7.46	339	217	194	192.53	40.6	23	13.23	1.55	0	234.88	19.21	3.87	0.17	0.52	BDL
25	BALASORE	Sadar	Sarswatipur	HP	21.4116	86.908	45	Alluvium	26.12.2023	7.57	669	386	346	320.35	87.5	31	25.05	1.03	0	390.82	43.58	4.85	0.21	0.664	BDL
26	BALASORE	Sadar	Sarswatipur	**Tube Well (210ft.)**	21.4066	86.9109	70	Alluvium	26.12.2023	7.71	673	385	302	304.84	68.3	32	30.62	13.4	0	371.9	49.2	7.23	0.27	0.695	BDL
27	BALASORE	Sadar	Rasalpur	HP	21.3902	86.8945	45	Alluvium	26.12.2023	7.45	792	434	362	320.88	81.1	39	36.1	1.16	0	391.47	70.06	13.6	0.247	0.624	BDL
28	BALASORE	Sadar	Rasalpur	**Tube Well (250 ft.)**	21.3901	86.8951	80	Alluvium	26.12.2023	7.19	1792	1196	556	413.4	151.4	43	212	41.6	0	504.35	398.31	97.16	4.208	0.512	0.002
29	BALASORE	Sadar	Tundara/Kungarpur	HP	21.3654	86.8957	45	Alluvium	26.12.2023	7.55	787	485	216	348.69	57.6	18	106.83	2.1	0	425.4	43.35	11.66	36.34	0.484	0.001
30	BALASORE	Sadar	Bardhanpur	HP	21.3952	86.9207	45	Alluvium	26.12.2023	7.42	535	400	232	335.85	53.3	24	74.45	1.26	0	409.74	37.96	6.72	0.59	0.485	BDL
31	BALASORE	Balasore Muncipality	BK chowk	HP	21.4851	86.9433	45	Alluvium	26.12.2023	7.37	372	265	221	197.34	68.3	12	19.6	1.21	0	240.76	35.85	8.81	0.36	0.44	BDL
32	BALASORE	Balasore Muncipality	Gopalgaon	**Tube Well (200 ft)**	21.4986	86.9367	65	Alluvium	26.12.2023	7.78	605	308	227	219.27	51.2	24	31.17	1.17	0	267.51	49.2	18.29	1.21	0.375	BDL
33	BALASORE	Sadar	Hidigaon	HP	21.4569	86.9855	45	Alluvium	27.12.2023	7.74	1355	874	248	358.32	44.8	33	244.7	6.38	0	437.15	218.37	106.95	3.78	0.665	0.002
34	BALASORE	Sadar	Jhampara	HP	21.4476	87.0078	45	Alluvium	27.12.2023	8.02	1329	529	124	139.05	29.9	12	156	5.4	0	169.64	196.58	38.08	5.8	2.16	0.002
35	BALASORE	Sadar	Srikona	TW	21.4502	87.0197	80	Alluvium	27.12.2023	7.6	1995	1107	270	298.42	68.3	24	320	5.61	0	364.07	454.54	45.8	8.72	1.23	0.004

36	BALASORE	Sadar	Balramgadi-Mirzapur	HP	21.4711	87.0517	45	Alluvium	27.12.2023	8.12	1390	828	124	357.78	21.4	17	276.71	4.89	0	436.49	238.99	47.58	6.3	0.63	0.002
38	BALASORE	Sadar	Srikona	HP	21.4875	86.9967	45	Alluvium	27.12.2023	8.19	991	330	92	106.96	15	13	85	4.12	0	130.49	102.62	37.84	5.3	2.257	0.001
39	BALASORE	Sadar	Srikona II T.W	**Tubewell**	21.4677	86.9896	250	Alluvium	27.12.2023	7.96	1000	624	130	358.32	25.6	16	201	4.3	0	437.15	123.24	33.54	3.67	1.35	0.002
40	BALASORE	Sadar	Srikona Hp-II	HP	21.4552	87.0134	45	Alluvium	28.12.2023	7.84	1390	567	232	225.15	49.1	27	125	5.99	0	274.68	161.2	58.7	4.47	1.16	0.001
41	BALASORE	Sadar	Kasimpur ,Dahapada G.P.	HP	21.5484	86.92	45	Alluvium	28.12.2023	7.84	1082	449	130	171.14	27.8	15	125.25	4.18	0	208.79	117.38	50.04	4.87	1.81	0.002
42	BALASORE	Sadar	Odangi	HP	21.562	86.9721	45	Alluvium	28.12.2023	6.93	929	562	189	238.52	49.1	16	146.457	1.86	0	291	188.38	10.8	6.07	0.611	0.001
43	BALASORE	Sadar	Khandahara, Haldipada	HP	21.5839	87.0096	45	Alluvium	28.12.2023	7.53	2208	1097	389	440.14	85.3	43	289.27	3.98	0	536.97	372.07	33	4.61	1.89	0.003
44	BALASORE	Sadar	Pinchabania	HP	21.6078	87.0032	45	Alluvium	28.12.2023	6.98	572	339	243	266.31	55.5	25	40.4395	0.982	0	324.9	52.01	3.42	0.79	0.66	BDL
45	BALASORE	Sadar	Pinchabania	**Tube Well**	21.6078	87.0032	45	Alluvium	28.12.2023	8.28	990	653	124	287.36	27.8	13	201	2.61	0	350.58	115.98	110	4.89	4.81	0.001
46	BALASORE	Sadar	Rupsa	HP	21.6308	87.0198	45	Alluvium	28.12.2023	7.21	536	309	259	251.05	61.9	25	28.2348	1.67	0	306.28	36.32	3.27	0.94	0.81	BDL
47	BALASORE	Sadar	Kharji	HP	21.5834	87.0516	45	Alluvium	28.12.2023	8.01	784	452	140	295.78	29.9	16	125	4.39	0	360.85	76.38	19.81	3.33	0.16	BDL
48	BALASORE	Sadar	Salpata/Sunipat	HP	21.565	87.0608	45	Alluvium	28.12.2023	8.06	709	393	130	269.47	23.5	17	105.2	4.31	0	328.75	64.9	13.46	2.84	0.153	BDL

49	BALASORE	Sadar	Bada gobra T.W.	**Tube Well**	21.5411	87.0366	45	Alluvium	28.12.2023	8.18	1045	592	92	317.89	19.2	11	201	3.78	0	387.82	142.45	21.21	2.35	0.35	0.001
50	BALASORE	Remuna	Jhinkaria	HP	21.5392	87.0178	45	Alluvium	28.12.2023	7.68	2513	1443	340	314.2	72.5	39	426.619	12.3	0	383.33	548.73	139.1	16.44	0.54	0.004
51	BALASORE	Sadar	Putadia TW	**Tube Well**	21.5328	87.0164	45	Alluvium	28.12.2023	7.87	1526	890	211	339.99	49.1	21	256.5	8.11	0	414.79	245.08	95.53	9.74	0.91	0.003
52	BALASORE	Sadar	Angula	HP	21.52	87.0024	45	Alluvium	28.12.2023	8.14	1201	671	97	370.52	19.2	12	233	4.959	0	452.03	138.94	34.5	4	1.68	0.003
53	BALASORE	Sadar	Tentulimundi	HP	21.532	86.9921	45	Alluvium	29.12.2023	8.06	1381	789	113	389.46	21.4	15	272	4.04	0	475.14	197.05	41.7	2.63	1.72	0.002
54	BALASORE	Sadar	Raghunathpur	**Tube well**	21.4974	86.9741	45	Alluvium	29.12.2023	8.21	1373	774	76	496.83	8.6	13	285	3.93	0	606.13	130.74	27.67	3.23	3.53	0.005
55	BALASORE	Sadar	Raghunathpur	HP	21.4974	86.974	45	Alluvium	29.12.2023	8.15	1465	808	70	497.35	6.4	13	305	3.28	0	606.77	147.61	26.64	3.9	3.92	0.003
56	BALASORE	Sadar	Sindiya	HP	21.519	86.9509	45	Alluvium	29.12.2023	7.42	759	397	319	326.31	66.1	37	38.2536	2.56	0	398.09	49.2	6.34	0.76	0.685	0.002
57	BALASORE	Sadar	Nilida	**Tube Well**	21.5168	87.048	60	Alluvium	29.12.2023	8.16	1034	580	86	342.1	17.1	11	201	4.64	0	417.36	111.29	25.97	3.17	0.56	0.001
58	BALASORE	Sadar	Nilada	HP	21.5216	87.0514	45	Alluvium	29.12.2023	8.24	961	553	103	331.04	19.2	13	181	5.41	0	403.87	106.37	25.26	3.08	0.29	BDL
59	BALASORE	Sadar	Bahabalpur	H.P	21.5059	87.0729	45	Alluvium	29.12.2023	8.02	982	544	130	308.41	25.6	16	165	6.35	0	376.26	122.3	20.47	2.88	0.218	BDL
60	BALASORE	Sadar	Bahabalpur	H.P	21.5059	87.0729	45	Alluvium	29.12.2023	8.11	734	387	119	284.2	23.5	15	110	5.7	0	346.73	46.16	14.29	1.89	0.153	BDL
61	BALASORE	Sadar	Hidinga	H.P	21.4342	86.9882	45	Alluvium	29.12.2023	8.1	1443	761	313	391.04	57.6	41	175.42	8.3	0	477.07	225.63	13.37	4.53	0.2	0.001

62	BALASORE	Sadar	Dublagudi	H.P	21.5013	87.1008	80	Alluvium	30.12.2023	8.07	778	416	119	289.47	23.5	15	120	5.7	0	353.15	65.37	11.07	1.76	0.109	BDL
63	BALASORE	Sadar	Parkhi	HP	21.4872	87.0596	45	Alluvium	30.12.2023	7.05	799	337	286	275.78	64	31	28.0526	2.53	0	336.45	36.08	9.534	0.469	0.61	BDL
64	BALASORE	Sadar	Kayakada	HP	21.4874	87.023	45	Alluvium	30.12.2023	8.12	904	513	59	326.31	12.8	7	182	5.6	0	398.09	73.34	30.92	5.5	0.72	BDL
65	BALASORE	Sadar	Gudupahi	HP	21.4242	86.9698	45	Alluvium	30.12.2023	7.99	1634	904	113	409.99	19.2	16	321	5.53	0	500.18	262.42	30.67	3.04	0.47	0.001
66	BALASORE	Sadar	JK chowk	HP	21.3897	86.9339	45	Alluvium	30.12.2023	7.05	798	339	286	276.31	66.1	29	28.2348	2.49	0	337.1	36.32	9.756	0.459	0.61	BDL
67	BALASORE	Sadar	Kantarada	H.P	21.3472	86.9223	45	Alluvium	30.12.2023	7.02	444	232	167	173.68	38.4	17	28.2348	1.55	0	211.89	36.32	5.26	0.01	0.44	BDL
68	BALASORE	Balasore Muncipality	Police Line	**Tube Well**	21.4926	86.9222	60	Alluvium	31.12.2023	7.05	798	395	286	276.83	64	31	46.2	2.48	0	337.74	74.98	9.451	0.534	0.61	BDL
69	BALASORE	Balasore Muncipality	BalsoreBustand	HP	21.5029	86.9195	45	Alluvium	31.12.2023	7.05	630	343	205	215.78	44.8	23	54.2837	1.4	0	263.26	69.82	20.34	0.02	0.442	BDL
70	BALASORE	Balasore Muncipality	Gopalgaon	HP	21.4986	86.9367	45	Alluvium	31.12.2023	7.07	370	201	157	133.7	40.6	13	18.76	0.6	0	163.11	36.32	9.981	0.51	0.39	BDL

ANNEXURE- 6: PRE-MONSOON WATER SAMPLE RESULT SHOWING IRON CONTAMINATION IN THE STUDY AREA.

Sl.no	Sample No	Sample Location	District	Longitude	Latitude	Type of Well	Date of collection	Fe in mg/l
1	1	Sahajanagar	Balasore	86.9143	21.3853	HP	27-09-2023	3.356
2	2	Saragaon	Balasore	86.9266	21.4418	HP	27-09-2023	1.082
3	3	Bankakhejuri	Balasore	86.943	21.48516	HP	27-09-2023	13.52
4	4	ITR,Chandipur	Balasore	86.91866	21.47866	TW	27-09-2023	0.188
5	5	Meghadamburu	Balasore	86.9006	21.47006	HP	28-09-2023	2.706
6	6	Harida	Balasore	86.8854	21.4592	HP	28-09-2023	9.12
7	7	Balia	Balasore	86.9043	21.494	HP	28-09-2023	5.852
8	8	Collectorate,Balasore	Balasore	86.927	21.503	TW	28-09-2023	1.294
9	9	Townhall,Balasore	Balasore	86.9385	21.4953	HP	28-09-2023	3.33
10	10	Balighat	Balasore	86.9501	21.4944	HP	28-09-2023	13.828
11	11	Phulbazar	Balasore	86.9503	21.4873	HP	28-09-2023	13
12	12	Patrapada	Balasore	86.9549	21.4787	HP	28-09-2023	13.904
13	13	Srikona	Balasore	86.9884	21.4619	HP	28-09-2023	0.266
14	14	Balramgadi	Balasore	87.052	21.4712	HP	28-09-2023	0.246
15	15	Chandipur	Balasore	87.0227	21.4435	TW	28-09-2023	0.112
16	16	Chandipur-II	Balasore	87.0125	21.4444	TW	28-09-2023	0.074
17	17	FMCollege	Balasore	86.9333	21.4907	TW	28-09-2023	0.084
18	18	Police line,Balasore	Balasore	86.921	21.4922	TW	29-09-2023	0.746
19	19	Shyamkhunta	Balasore	86.9151	21.5083	HP	29-09-2023	2.332
20	20	Remuna on NH	Balasore	86.8941	21.5141	HP	29-09-2023	1.698

21	21	Remuna	Balasore	86.8659	21.5269	HP	29-09-2023	1.87
22	22	Balgopalpur	Balasore	86.8333	21.5359	HP	29-09-2023	5.836
23	23	Govindpur	Balasore	86.9189	21.5532	HP	29-09-2023	1.496
24	24	Odangi	Balasore	86.975	21.5573	HP	29-09-2023	2.686
25	25	Tentulimundi	Balasore	86.992	21.5322	HP	29-09-2023	0.17
26	26	Belda	Balasore	86.9974	21.5109	HP	29-09-2023	0.228
27	27	Haldipada	Balasore	87.0155	21.5832	HP	29-09-2023	3.72
28	28	Salpata	Balasore	87.0611	21.5652	HP	29-09-2023	0.122
29	29	Chanua	Balasore	87.067	21.5359	HP	29-09-2023	0.198
30	30	Rupsa	Balasore	87.0285	21.6055	HP	29-09-2023	4.838
31	31	Somnathpur	Balasore	86.8474	21.4884	HP	29-09-2023	0.352
32	32	MES,Balasore	Balasore	86.9211	21.4956	TW	30-09-2023	0.382
33	33	Angargadia	Balasore	86.9159	21.4893	HP	30-09-2023	11.828

ANNEXURE- 7: LIST OF WATER SAMPLE RESULTS SHOWING THE HEAVY METAL VALUES IN THE STUDY AREA.

Sl No	Sample Code	Type of Sample	Type of Analysis	Date of Sampling	Dist.	Village	Source	Lat Decimal	Long Decimal	Aquifer	Lab Sample ID	B	Al	Cr	Mn	Fe	Ni	Cu	Zn	As	Se	Sr	Mo	Ag	Cd	Ba	Hg	206 [Pb] [He]	207 [Pb] [He]	208 Pb [He]	238 U [He]
												ppb																			
1	1H	NAQUIM	HM & Fe	27-09-2023	Balasore	Sahajanagar	HP	21.3853	86.9143	Alluvium	2023-24/4015	68.06	24.72	4.70	104.48	3275.10	1.21	3.43	1170.30	0.47	0.036	558.47	0.40	0.34	0.24	37.54	BDL	51.03	56.28	53.39	0.31
2	2H	NAQUIM	HM & Fe	27-09-2023	Balasore	Saragaon	HP	21.4418	86.9266	Alluvium	2023-24/4016	2.19	8.51	0.29	205.66	1154.95	0.30	0.38	56.16	0.46	BDL	299.59	0.22	0.01	0.02	8.24	BDL	1.42	1.55	1.50	0.02
3	3H	NAQUIM	HM & Fe	27-09-2023	Balasore	Bankakhejuri	HP	21.48516	86.943	Alluvium	2023-24/4017	19.09	9.79	1.38	181.69	14633.13	1.05	31.41	266.71	0.24	0.021	331.85	0.12	0.06	0.01	31.81	BDL	10.00	10.70	10.41	0.04
4	4H	NAQUIM	HM & Fe	27-09-2023	Balasore	ITR	TW	21.47866	86.91866	Alluvium	2023-24/4018	3.77	5.16	0.13	35.34	138.92	0.20	0.09	1.08	0.13	0.411	219.18	0.08	0.01	0.00	7.63	BDL	BDL	BDL	BDL	0.07
5	4N	NAQUIM	HM & Fe	28-09-2023	Balasore	ITR	TW	21.47866	86.91866	Alluvium	2023-24/4019	3.66	4.16	0.14	32.94	98.54	0.18	0.29	2.06	0.12	0.368	211.99	0.09	BDL	0.00	6.91	BDL	BDL	BDL	BDL	0.07
6	5H	NAQUIM	HM & Fe	28-09-2023	Balasore	Meghadamburu	HP	21.47006	86.9006	Alluvium	2023-24/4020	BDL	6.81	0.73	237.69	3660.64	2.68	18.59	832.78	0.60	BDL	516.09	0.08	0.97	0.02	74.26	BDL	12.19	12.93	12.61	15.10
7	6H	NAQUIM	HM & Fe	28-09-2023	Balasore	Harida	HP	21.4592	86.8854	Alluvium	2023-24/4021	15.50	10.51	0.57	365.52	13502.66	0.30	1.42	189.60	0.88	BDL	423.96	0.36	0.03	0.01	13.81	BDL	4.22	4.46	4.37	0.49
8	6N	NAQUIM	HM & Fe	29-09-2023	Balasore	Harida	HP	21.4592	86.8854	Alluvium	2023-24/4022	17.79	2.28	0.72	346.94	9767.82	0.44	1.69	141.57	0.86	BDL	424.42	0.43	BDL	0.00	11.70	BDL	4.00	4.23	4.14	0.35
9	7H	NAQUIM	HM & Fe	28-09-2023	Balasore	Balia	HP	21.494	86.9043	Alluvium	2023-24/4023	BDL	4.00	2.44	182.83	6019.47	1.20	7.47	108.34	0.44	BDL	213.10	0.49	BDL	0.00	10.66	0.17	5.65	5.95	5.82	0.01
10	7N	NAQUIM	HM & Fe	29-09-2023	Balasore	Balia	HP	21.494	86.9043	Alluvium	2023-24/4024	BDL	6.74	2.63	172.87	5027.29	0.97	5.76	165.60	0.42	BDL	209.49	0.54	BDL	BDL	9.99	0.18	5.47	5.77	5.65	BDL
11	8H	NAQUIM	HM & Fe	28-09-2023	Balasore	Collectorate	TW	21.503	86.927	Alluvium	2023-	BDL	1068.84	0.53	653.12	1254.03	1.73	3.89	34.29	0.41	BDL	506.83	0.10	BDL	0.07	65.05	0.10	1.35	1.45	1.41	0.10

											24/4025																				
12	8N	NAQUIM	HM & Fe	29-09-2023	Balasore	Collectorate	TW	21.503	86.927	Alluvium	2023-24/4026	BDL	939.93	0.97	662.97	1119.35	1.82	4.67	40.15	0.45	0.011	509.45	0.11	BDL	0.09	66.47	0.07	0.88	0.94	0.92	0.09
13	9H	NAQUIM	HM & Fe	28-09-2023	Balasore	Townhall	HP	21.4953	86.9385	Alluvium	2023-24/4027	BDL	43.69	0.02	218.48	2842.47	0.24	0.70	10.14	0.54	BDL	431.75	0.20	BDL	BDL	28.66	BDL	0.66	0.70	0.68	0.00
14	9N	NAQUIM	HM & Fe	29-09-2023	Balasore	Townhall	HP	21.4953	86.9385	Alluvium	2023-24/4028	BDL	2.21	BDL	207.34	2910.69	0.17	0.51	13.26	0.54	BDL	430.73	0.21	BDL	BDL	26.85	BDL	0.66	0.70	0.69	BDL
15	10H	NAQUIM	HM & Fe	28-09-2023	Balasore	Balighat	HP	21.4944	86.9501	Alluvium	2023-24/4029	13.15	49.39	0.32	1725.11	18002.52	0.34	6.87	296.43	0.95	BDL	1133.63	0.30	BDL	0.02	365.06	BDL	0.65	0.70	0.68	0.08
16	10 N	NAQUIM	HM & Fe	29-09-2023	Balasore	Balighat	HP	21.4944	86.9501	Alluvium	2023-24/4030	13.96	57.30	0.48	1832.79	19269.61	0.36	5.82	350.30	0.97	BDL	1176.34	0.31	BDL	0.03	380.21	BDL	0.70	0.75	0.73	0.08
17	11H	NAQUIM	HM & Fe	28-09-2023	Balasore	Phulbazar	HP	21.4873	86.9503	Alluvium	2023-24/4031	BDL	5.84	0.71	597.07	14362.87	0.74	10.80	215.41	0.63	BDL	487.32	0.43	BDL	0.00	30.36	BDL	6.30	6.73	6.55	0.00
18	11 N	NAQUIM	HM & Fe	29-09-2023	Balasore	Phulbazar	HP	21.4873	86.9503	Alluvium	2023-24/4032	BDL	2.13	1.14	504.53	12922.14	0.80	10.54	221.41	0.46	BDL	462.76	0.50	BDL	0.00	14.24	0.00	11.86	12.72	12.35	BDL
19	12H	NAQUIM	HM & Fe	28-09-2023	Balasore	Patrapada	HP	21.4787	86.9549	Alluvium	2023-24/4033	BDL	2.23	0.15	285.05	19135.87	0.19	6.52	105.31	0.06	BDL	341.75	0.30	BDL	BDL	39.99	BDL	1.27	1.36	1.32	BDL
20	12 N	NAQUIM	HM & Fe	29-09-2023	Balasore	Patrapada	HP	21.4787	86.9549	Alluvium	2023-24/4034	BDL	2.09	0.69	269.27	18286.03	0.52	7.45	60.42	0.05	BDL	342.25	0.26	BDL	BDL	44.39	BDL	1.03	1.11	1.07	BDL
21	13H	NAQUIM	HM & Fe	28-09-2023	Balasore	Srikona	HP	21.4619	86.9884	Alluvium	2023-24/4035	921.23	4.41	0.55	41.79	826.06	0.21	0.52	9.01	0.05	BDL	305.82	2.53	BDL	0.01	12.65	BDL	0.25	0.27	0.27	0.00
22	13 N	NAQUIM	HM & Fe	29-09-2023	Balasore	Srikona	HP	21.4619	86.9884	Alluvium	2023-24/4036	976.79	1.86	BDL	34.73	163.29	BDL	BDL	6.70	0.03	BDL	310.74	2.64	BDL	0.01	9.36	BDL	0.08	0.09	0.08	BDL
23	14H	NAQUIM	HM & Fe	28-09-2023	Balasore	Balramgadi	HP	21.4712	87.052	Alluvium	2023-24/4037	255.99	11.48	0.53	35.49	66.12	0.26	0.88	16.08	0.06	0.04	216.22	1.45	BDL	0.01	7.98	BDL	0.19	0.21	0.20	0.08
24	14N	NAQUIM	HM & Fe	29-09-2023	Balasore	Balramgadi	HP	21.4712	87.052	Alluvium	2023-	249.62	10.81	0.16	36.17	222.59	0.11	0.56	21.08	0.05	0.007	211.54	1.23	BDL	0.01	6.08	BDL	0.11	0.12	0.11	0.01

											24/4038																				
25	15H	NAQUIM	HM & Fe	28-09-2023	Balasore	Chandipur	TW	21.4435	87.0227	Alluvium	2023-24/4039	732.46	4.25	BDL	17.66	74.75	BDL	0.34	2.01	0.27	BDL	150.02	2.17	BDL	0.01	3.97	BDL	BDL	BDL	BDL	0.02
26	16H	NAQUIM	HM & Fe	28-09-2023	Balasore	Chandipur-II	TW	21.4444	87.0125	Alluvium	2023-24/4040	929.68	3.02	BDL	18.88	36.60	BDL	0.24	102.42	0.17	BDL	207.19	2.67	BDL	0.01	4.58	BDL	0.08	0.10	0.09	0.01
27	17H	NAQUIM	HM & Fe	28-09-2023	Balasore	FMCollege	TW	21.4907	86.9333	Alluvium	2023-24/4041	306.40	BDL	0.03	91.21	7.12	0.12	0.03	12.19	0.30	0.008	302.50	0.67	BDL	BDL	15.56	BDL	BDL	BDL	BDL	0.11
28	17N	NAQUIM	HM & Fe	29-09-2023	Balasore	FMCollege	TW	21.4907	86.9333	Alluvium	2023-24/4042	32.49	2.14	BDL	231.49	135.19	0.21	1.96	27.82	0.47	0.029	305.41	0.20	BDL	0.00	18.58	0.03	0.40	0.43	0.42	0.13
29	18N	NAQUIM	HM & Fe	29-09-2023	Balasore	Police line	TW	21.4922	86.921	Alluvium	2023-24/4043	BDL	25.75	BDL	383.41	767.61	0.19	0.06	44.01	0.24	BDL	273.48	0.15	BDL	0.01	11.28	0.03	0.03	0.04	0.03	0.01
30	19N	NAQUIM	HM & Fe	29-09-2023	Balasore	Shyamkhunta	HP	21.5083	86.9151	Alluvium	2023-24/4044	715.98	29.16	0.40	169.39	2037.59	0.34	1.12	12.92	0.36	BDL	346.47	0.40	BDL	0.00	35.82	BDL	1.52	1.60	1.57	BDL
31	20N	NAQUIM	HM & Fe	29-09-2023	Balasore	Remuna on NH	HP	21.5141	86.8941	Alluvium	2023-24/4045	10.98	0.48	0.23	271.98	1496.16	0.01	0.62	3.41	0.36	BDL	257.90	0.20	BDL	BDL	8.70	BDL	0.16	0.19	0.18	0.00
32	21N	NAQUIM	HM & Fe	29-09-2023	Balasore	Remuna	HP	21.5269	86.8659	Alluvium	2023-24/4046	BDL	37.61	0.33	257.14	1541.20	0.16	0.28	547.58	0.65	BDL	270.43	0.22	BDL	0.01	29.29	BDL	1.01	1.08	1.06	BDL
33	22N	NAQUIM	HM & Fe	29-09-2023	Balasore	Balgopalpur	HP	21.5359	86.8333	Alluvium	2023-24/4047	BDL	14.76	0.63	187.96	5683.28	1.07	4.79	93.65	0.04	BDL	197.39	0.11	BDL	0.17	22.57	BDL	5.64	5.98	5.84	0.03
34	23N	NAQUIM	HM & Fe	29-09-2023	Balasore	Govindpur	HP	21.5532	86.9189	Alluvium	2023-24/4048	1132.58	8.91	0.37	75.11	1443.49	0.38	2.43	5.56	0.50	0.027	198.86	1.98	BDL	0.01	18.36	BDL	0.63	0.66	0.64	0.07
35	24N	NAQUIM	HM & Fe	29-09-2023	Balasore	Odangi	HP	21.5573	86.975	Alluvium	2023-24/4049	1279.15	9.81	0.23	41.37	2556.59	0.23	1.59	5.35	0.59	BDL	213.52	2.79	BDL	0.02	7.15	BDL	0.77	0.82	0.80	0.07
36	25N	NAQUIM	HM & Fe	29-09-2023	Balasore	Tentulimundi	HP	21.5322	86.992	Alluvium	2023-24/4050	1223.45	1.30	0.72	47.98	173.18	0.04	0.08	35.90	0.02	BDL	253.24	2.66	BDL	0.01	13.70	BDL	0.02	0.03	0.03	0.04
37	26N	NAQUIM	HM & Fe	29-09-2023	Balasore	Belda	HP	21.5109	86.9974	Alluvium	2023-	3183.97	4.01	BDL	3.75	127.20	BDL	BDL	10.99	0.07	BDL	179.44	5.88	BDL	0.03	2.05	BDL	0.08	0.08	0.08	0.12

											24/4051																				
38	27N	NAQUIM	HM & Fe	29-09-2023	Balasore	Haldipada	HP	21.5832	87.0155	Alluvium	2023-24/4052	760.58	15.43	0.33	253.70	3492.26	0.42	0.87	23.78	0.71	BDL	673.65	1.13	BDL	0.01	26.55	BDL	0.16	0.18	0.17	2.16
39	28N	NAQUIM	HM & Fe	29-09-2023	Balasore	Salpata	HP	21.5652	87.0611	Alluvium	2023-24/4053	132.93	3.23	BDL	36.26	183.47	0.12	0.04	27.55	0.04	BDL	361.35	0.47	BDL	BDL	6.68	BDL	0.11	0.12	0.12	0.07
40	29N	NAQUIM	HM & Fe	29-09-2023	Balasore	Chanua	HP	21.5359	87.067	Alluvium	2023-24/4054	170.76	8.32	0.14	31.10	158.24	0.19	0.75	45.82	0.04	BDL	325.92	0.43	BDL	0.01	5.56	BDL	0.38	0.42	0.40	0.00
41	30N	NAQUIM	HM & Fe	29-09-2023	Balasore	Rupsa	HP	21.6055	87.0285	Alluvium	2023-24/4055	491.33	18.26	1.51	249.28	4580.41	0.93	4.40	201.80	4.04	BDL	446.70	1.59	BDL	0.01	60.46	BDL	1.97	2.17	2.09	1.46
42	31N	NAQUIM	HM & Fe	29-09-2023	Balasore	Somnathpur	HP	21.4884	86.8474	Alluvium	2023-24/4056	0.04	82.35	0.88	14.59	490.13	1.35	7.73	9034.46	0.15	0.383	209.09	0.08	BDL	0.39	6.52	BDL	32.25	36.42	35.53	0.05
43	32N	NAQUIM	HM & Fe	30-09-2023	Balasore	MES,Balasore	TW	21.4956	86.9211	Alluvium	2023-24/4057	16.09	2.91	BDL	534.33	355.30	0.01	BDL	203.19	0.18	0.013	286.43	0.17	BDL	0.01	10.45	BDL	0.70	0.79	0.74	0.04
44	33N	NAQUIM	HM & Fe	30-09-2023	Balasore	Angargadia	HP	21.4893	86.9159	Alluvium	2023-24/4058	BDL	3.26	5.06	1744.92	32670.36	10.68	582.31	251.43	0.03	BDL	329.26	0.05	BDL	0.04	7.95	BDL	77.59	81.37	78.54	0.00

Concentraion in ppb

ANNEXURE- 8: STABLE ISOTOPE RESULT OF THE WATER SAMPLE COLLECTED IN THE STUDY AREA.

Village	Source	Lat Decimal	Long Decimal	S.No.	Sample ID	δO18	δD	LAB ID O	LAB ID H	D-excess value
Meghadamburu	Pond	21.470933	86.900349	1	CGWB BHUBANESHWAR SI-01	6.01	20.73	CF 75375	97248	-27.35
Meghadamburu	Deep TW (80mt.)	21.470493	86.902111	2	CGWB BHUBANESHWAR SI-02	-2.89	-18.76	CF 75376	97249	4.39
Meghadamburu	Govt. Mark II H.P. (150 ft.)	21.470915	86.901987	3	CGWB BHUBANESHWAR SI-03	-3.02	-21.10	CF 75377	97250	3.05
Mala	Govt. Mark II H.P. (150 ft.)	21.421758	86.877142	4	CGWB BHUBANESHWAR SI-04	-3.73	-22.79	CF 75378	97251	7.05
Mala Stream Canal	Stream Canal -01	21.421723	86.870868	5	CGWB BHUBANESHWAR SI-05	3.66	19.07	CF 75379	97252	-10.21
Bhimpur	Pond	21.378207	86.905473	6	CGWB BHUBANESHWAR SI-07	3.76	10.10	CF 75380	97253	-19.95
Kantarada	Pond	21.345819	86.920897	7	CGWB BHUBANESHWAR SI-08	1.88	5.37	CF 75381	97254	-9.66
Kantarada	Govt. Mark II H.P. (150 ft.)	21.34719	86.922315	8	CGWB BHUBANESHWAR SI-09	-4.01	-24.00	CF 75382	97255	8.07
Bartana	Govt. Mark II H.P. (150 ft.)	21.470518	86.842079	9	CGWB BHUBANESHWAR SI-10	-2.99	-21.01	CF 75383	97256	2.90
Bartana Pond	Pond	21.472745	86.84293	12	CGWB BHUBANESHWAR SI-13	3.52	6.15	CF 75386	97259	-21.98
Bartana TW	Deep TW (80mt.)	21.469793	86.84373	13	CGWB BHUBANESHWAR TW-14	-3.26	-21.09	CF 75387	97260	5.02
Remuna	Govt. Mark II H.P. (150 ft.)	21.526671	86.866828	15	CGWB BHUBANESHWAR SI-15	-3.87	-24.93	CF 75389	97262	6.00
Emami Paper Mill	Tubewell (150ft.)	21.532965	86.828313	16	CGWB BHUBANESHWAR SI-16	-3.62	-22.94	CF 75390	97263	6.04
Madarajpur	Govt. Mark II H.P. (150 ft.)	21.547161	86.80972	17	CGWB BHUBANESHWAR SI-17	-5.14	-32.99	CF 75391	97264	8.12
Boita Bank River Sample	River Sample	21.561148	86.823705	18	CGWB BHUBANESHWAR SI-18	0.54	-2.41	CF 75392	97265	-6.72
Kasimpur, Dahapada G.P.	Deep Tubewell (80mt.)	21.548324	86.9199	19	CGWB BHUBANESHWAR SI-19	-5.80	-38.38	CF 75393	97266	8.05
Kasimpur River, Dahapada G.P.	River Sample	21.547476	86.918409	20	CGWB BHUBANESHWAR SI-20	-0.14	-6.19	CF 75394	97267	-5.05
Kasimpur ,Dahapada G.P.	Govt. Mark II H.P. (150 ft.)	21.548376	86.920036	21	CGWB BHUBANESHWAR SI-21	-4.28	-26.61	CF 75395	97268	7.62
Rupsa	Govt. Mark II H.P. (150 ft.)	21.630804	87.019815	39	CGWB BHUBANESHWAR HP-08 SI-22	-4.64	-30.48	CF 75413	97286	6.61

Rupsa Pond	Pond	21.611051	87.021801	23	CGWB BHUBANESHWAR SI-23	3.48	6.73	**CF 75397**	**97270**	-21.12
Rupsa TW	Deep Tubewell (80mt.)	21.626215	87.021134	24	CGWB BHUBANESHWAR SI-24	-4.59	-28.20	**CF 75398**	**97271**	8.49
Salpata/Sunipat River	River Sample	21.566377	87.068914	25	CGWB BHUBANESHWAR SI-25	0.72	4.51	**CF 75399**	**97272**	-1.27
Babanpur	Govt. Mark II H.P. (150 ft.)	21.513297	87.11446	26	CGWB BHUBANESHWAR SI-26	-3.89	-24.67	**CF 75400**	**97273**	6.46
Dublagudi TW	Deep Tubewell (80mt.)	21.501347	87.100773	27	CGWB BHUBANESHWAR SI-27	-3.81	-23.57	**CF 75401**	**97274**	6.89
Dublagudi Sea sample	Ocean Sample	21.495159	87.101767	28	CGWB BHUBANESHWAR SI-28	0.61	4.50	**CF 75402**	**97275**	-0.41
Nilada	Pond	21.521609	87.051407	29	CGWB BHUBANESHWAR SI-29	1.61	-2.50	**CF 75403**	**97276**	-15.42
Parkhi Sea Beach	Ocean Sample	21.476639	87.078727	30	CGWB BHUBANESHWAR SI-30	0.52	4.57	**CF 75404**	**97277**	0.45
Parkhi	Govt. Mark II H.P. (150 ft.)	21.479339	87.075401	31	CGWB BHUBANESHWAR SI-31	-3.82	-23.36	**CF 75405**	**97278**	7.17
Dumuria	River Sample	21.510443	86.990303	32	CGWB BHUBANESHWAR SI-32	2.62	15.25	**CF 75406**	**97279**	-5.71
Muhana- DRDO-OP-6000	Ocean sample	21.409513	86.979307	33	CGWB BHUBANESHWAR SI-33	-0.01	-0.09	**CF 75407**	**97280**	0.00
Balasore City	Pond	21.489608	86.9394	34	CGWB BHUBANESHWAR SI-34	2.15	-0.46	**CF 75408**	**97281**	-17.68
Patrapada	Deep Tubewell (80mt.)	21.478898	86.967278	35	CGWB BHUBANESHWAR SI-35	-4.06	-24.25	**CF 75409**	**97282**	8.23
Patrapada	Govt. Mark II H.P. (150 ft.)	21.478893	86.967275	36	CGWB BHUBANESHWAR SI-36	-3.99	-24.76	**CF 75410**	**97283**	7.14
Jhampara	Govt. Mark II H.P. (150 ft.)	21.447642	87.007798	37	CGWB BHUBANESHWAR SI-37	-3.39	-21.64	**CF 75411**	**97284**	5.49
Srikona	Deep Tubewell (80mt.)	21.450178	87.019749	38	CGWB BHUBANESHWAR SI-38	-2.81	-18.08	**CF 75412**	**97285**	4.41
Minor Irriagation Dept., Balasore	Rain Water	21.503609	87.924993	10	CGWB BHUBANESHWAR SI-11	-3.67	-23.53	**CF 75384**	**97257**	5.83
Minor Irriagation Dept., Balasore	Rain Water	21.503609	87.924993	40	CGWB BHUBANESHWAR SI-06	-3.52	-20.91	**CF 75414**	**97287**	7.21
Sindiya	Govt. Mark II H.P. (150 ft.)	21.519031	86.950917	11	CGWB BHUBANESHWAR SI-12	-4.30	-25.89	**CF 75385**	**97258**	8.49
Lion Club Square	Govt. Mark II H.P. (150 ft.)	21.493858	86.92076	22	CGWB BHUBANESHWAR SI-22	-3.98	-26.91	**CF 75396**	**97269**	4.91
Gopalgaon	Govt. Mark II H.P. (150 ft.)	21.49859	86.936719	14	CGWB BHUBANESHWAR HP-15 SI-14	-4.36	-27.74	**CF 75388**	**97261**	7.16

ANNEXURE- 9: LAYER PARAMETERS OF VES OF STUDY AREA.

SL NO.	LOCATION	Latitude	Longitude	Direct interpretation of VES layer parameters by software				Inferred lithology	Aquifer Charectristics		
				Layer	Resistivity (ohm. m)	Thickness(m)	Depth(m)		Aquifer	Depth Range(m)	Inferred aquifer water quality
1	Chandipur	21.4491	87.00976	1	12.8	1.62	1.62	Top Soil			
				2	6.76	0.36	1.90	Clay			
				3	0.133	Undefined		Very Fine sand (Saline)			
2	Chandipur 2	21.4491	87.00976	1	1.31	1.9	1.9	Top Soil			
				2	0.111	21	22.9	Very Fine sand (Saline)			
				3	0.27	Undefined					
3	Balasore Asha Nagar	21.471	86.90756	1	49.2	1.2	1.2	Top Soil			
				2	6.26	1.26	2.46	Clay			
				3	15.1	7.93	10.4	Fined Sand (Fresh)			
				4	7.51	10.9	21.3	Clay			
				5	32.1	22.5	43.8	Medium Sand (Fresh)	Aquifer	22-43	Potable
				6	2.48	Undefined		Clay			
4	Kaindhari	21.46662	86.95386	1	35.1	1.2	1.2	Top Soil			
				2	15	1.4	2.6	Clay			

				3	33.8	55.7	58.3	Medium Sand (Fresh)	Aquifer	3-58	Potable
				4	6.17	Undefined		Clay			
5	Panjibag	21.48216	86.98162	1	47.4	1.42	1.42	Top Soil			
				2	6.51	2.92	4.34	Top Soil			
				3	2	26	30.3	Clay			
				4	0.25	86.5	117	Very Fine sand (Saline)			
				5	0.0624	Undefined					
6	Hindigaon	21.4451	86.98464	1	11	1.68	1.68	Top Soil			
				2	1.75	5.59	7.26	Clay			
				3	0.0805	20.4	27.6	Very Fine sand (Saline)			
				4	0.0122	53.9	81.5				
				5	0.0011	Undefined					
7	Gobindpur	21.50625	86.82414	1	56.6	0.579	0.579	Top Soil			
				2	12.5	7.11	7.69	Clay			
				3	33	56.9	65.6	Medium Sand (Fresh)	Aquifer	8-65	Potable
				4	4.97	Undefined		Clay			
8	Remuna	21.52328	86.86257	1	380	0.6	0.6	Top Soil			
				2	29.5	8.21	8.8	Medium Sand (Fresh)			
				3	13	20.7	29.5	Fined Sand (Fresh)	Aquifer	9-29	Potable
				4	5.47	33.2	62.7	Clay			
				5	24.2	Undefined		Medium Sand (Fresh)	Aquifer		Potable

9	Remuna 2	21.5304	86.86321	1	22.31	1.2	1.2	Top Soil			
				2	8.5	1.9	3.065	Clay			
				3	18.2	16.98	20.04	Fined Sand (Fresh)	Aquifer	4-20	Potable
				4	42.3	Undefined		Medium Sand (Fresh)	Aquifer		Potable
10	Rasalpur	21.53631	86.84148	1	95.84	0.9	0.9	Top Soil			
				2	23.87	1.132	2.044	Top Soil			
				3	8.94	54.86	56.89	Clay			
				4	37.11	Undefined		Medium Sand (Fresh)	Aquifer		Potable
11	Januganj	21.51876	86.89162	1	80.6	0.86	0.86	Top Soil			
				2	4.49	0.904	1.76	Clay			
				3	36.7	2.78	4.55	Medium Sand (Fresh)			
				4	4.8	4.08	8.62	Clay			
				5	17	Undefined		Fined Sand (Fresh)	Aquifer		Potable
12	Mangalpur	21.54367	86.90475	1	17.6	0.875	.875	Top Soil			
				2	6.76	3.68	4.56	Clay			
				3	1.89	4.5	9.06	SiltyClay			
				4	30.5	10.1	19.1	Medium Sand (Fresh)	Aquifer	10-19	Potable
				5	2.951	22.4	41.5	Clay			
				6	80	Undefined					
13	Haldipada	21.56638	86.9945	1	4.73	1.2	1.2	Top Soil			
				2	3.48	4.1	5.3	Clay			
				3	12.59	17.7	23	Fine Sand (Fresh)			

				4	3.99	77.1	100	Fine sand (Saline)			
				5	7.2	Undefined		Clay			
14	Haldipad 2	21.56638	86.9945	1	4.45	2.02	2.02	Top Soil			
				2	3.04	7.92	9.95	Clay			
				3	0.948	7.89	17.8	Very Fine sand (Saline)			
				4	4.15	Undefined		Clay			
15	Solapata	21.56726	87.05928	1	3.22	2.05	2.05	Top Soil			
				2	2.13	26	28.8	Very Fine sand (Saline)			
				3	0.552	Undefined					
16	Rupsa	21.61462	87.03060	1	5.93	2.51	2.51	Top Soil			
				2	2.21	2.73	5.24	Clay			
				3	16.39	42.7	47.9	Fine sand (Fresh)			
				4	2.07	52.2	100	Fine sand (Saline)			
				5	38.9	Undefined		Medium Sand (Fresh)	Aquifer		Potable
17	Gududa	21.52737	87.02146	1	8.9	1.2	1.2	Top Soil			
				2	3.58	5.73	6.93	Clay			
				3	1.63	9.72	16.7	Fine sand (Saline)			
				4	4.17	20.2	36.8	Clay			
				5	0.565	Undefined		Very Fine sand (Saline))			
18	Kudia	21.52187	86.95707	1	14.3	0.838	0.838	Top Soil			
				2	6.08	10.6	11.4	Clay			

				3	34.1	21.4	32.9	Medium Sand (Fresh)	Aquifer	12-32	Potable
				4	5.51	Undefined		Clay			
19	Chhanua	21.54273	87.06368	1	3.24	3.54	3.54	Top Soil			
				2	0.395	1.99	5.53	Very Fine sand (Saline)			
				3	8.55	6.83	12.4	Clay			
				4	0.0242	Undefined		Very Fine sand (Saline)			
20	Dubula Gadi	21.51525	87.09944	1	3.966	1.76	1.76	Top Soil			
				2	0.97	6.673	8.433	Very Fine sand (Saline)			
				3	.222	Undefined					
21	Parikhi	21.48709	87.06355	1	3.54	1.2	1.2	Top Soil			
				2	1.84	1.87	3.07	Clay			
				3	0.582	17	20.1	Very Fine sand (Saline)			
				4	2.95	Undefined					
22	Nuagaon	21.51769	87.05898	1	3.959	1.107	1.107	Top Soil			
				2	1.967	1.993	3.099	Clay			
				3	0.844	9.717	12.82	Very fine sand (saline)			
				4	0.0022	Undefined					
23	Barakhua	21.50868	87.02792	1	4.93	1.6	1.6	Top Soil			
				2	1.63	5.19	6.79	Fine sand (saline)			
				3	2.43	10	16.8	Clay			
				4	0.279	Undefined		Very fine sand (saline)			

24	Dumuria	21.51861	86.98903	1	10.23	1.897	1.897	Top Soil			
				2	23	19.18	21.06	Medium Sand (Fresh)	Aquifer	2-21	Potable
				3	4.213	22	43.06	Clay			
				4	22.25	Undefined		Medium Sand (Fresh)	Aquifer		Potable
25	Ghodapada	21.49549	86.95702	1	14.7	0.96	0.96	Top Soil			
				2	6.51	4.88	5.04	Clay			
				3	26.2	23.7	29.6	Medium Sand (Fresh)	Aquifer	6-29	Potable
				4	2.75	31.9	61.4	Clay			
				5	302	Undefined					
26	Sutei	21.49934	86.87859	1	13	1.2	1.2	Top Soil			
				2	9.36	22.1	23.3	Clay			
				3	27.7	25	48.2	Medium Sand (Fresh)	Aquifer	24-48	Potable
				4	4.81	52.2	100	Clay			
				5	87.3	Undefined		Sand (Fresh)	Aquifer		Potable
27	Beleri	21.48198	86.83175	1	26.9	0.87	0.87	Top Soil			
				2	9.1	23.76	24.63	Clay			
				3	33.2	21.71	46.35	Medium Sand (Fresh)	Aquifer	25-46	Potable
				4	11.8	Undefined		Clay			
28	Biruhan	21.45221	86.85779	1	8.9	6.8	6.8	Top Soil			
				2	5.6	5.4	12.24	Clay			
				3	12.4	30.3	45.54	Fine Sand (Fresh)	Aquifer	13-45	Potable

				4	2.28	37.11	79.65	Clay			
				5	25.2	Undefined		Medium Sand (Fresh)	Aquifer		Potable
29	Palashpur	21.44349	86.88671	1	21.5	1.05	1.05	Top Soil			
				2	8.1	1.26	2.31	Clay			
				3	25.6	2.55	4.85	Medium Sand (Fresh)			
				4	7.43	5.94	10.8	Clay			
				5	48.6	9.65	20.4	Medium Sand (Fresh)	Aquifer	11-20	Potable
				6	9.62	Undefined		Clay			
30	Saraswatipur	21.4192	86.9058	1	9.24	8.42	8.42	Top Soil			
				2	3.27	10.7	19.1	Clay			
				3	22	18.9	38.1	Medium Sand (Fresh)	Aquifer	20-38	Potable
				4	1.9	33.5	71.6	Clay			
				5	33.4	Undefined		Medium Sand (Fresh)	Aquifer		Potable
31	Saragan	21.44404	86.9286	1	19.6	1.12	1.12	Top Soil			
				2	8.48	19.2	20.3	Clay			
				3	29.6	18.3	38.6	Medium Sand (Fresh)	Aquifer	21-38	Potable
				4	4.37	70.1	109	Clay			
				5	50.5	Undefined		Sand (Fresh)	Aquifer		Potable
32	Barangia	21.45881	86.9047	1	14.5	1.32	1.32	Top Soil			
				2	6.04	1.47	2.78	Top Soil			
				3	13.2	17.8	20.5	Clay			
				4	45	20.1	40.7	Sand (Fresh)	Aquifer	21-40	Potable

				5	4.79	32.8	73.5	Clay			
				6	36.2	Undefined		Sand (Fresh)	Aquifer		Potable
33	Rasalpur	21.39769	86.88939	1	6.37	5.78	5.78	Top Soil			
				2	12.6	27.6	33.4	Fine Sand (fresh)	Aquifer	6-33	Potable
				3	1.95	50.7	84	Clay			
				4	23.9	Undefined		Medium Sand (Fresh)	Aquifer		Potable
34	Tundara	21.36521	86.89007	1	4.737	3.742	3.742	Top Soil			
				2	7.3	17.83	21.58	Clay			
				3	25.8	21.37	42.94	Medium Sand (Fresh)	Aquifer	22-42	Potable
				4	9.9	Undefined		Clay			
35	Bhimpur	21.37231	86.92186	1	5.38	0.768	0.768	Top Soil			
				2	1.63	1.83	2.6	Clay			
				3	0.636	2.74	5.34	Very Fine sand(saline)			
				4	4.97	56	61.4				
				5	9.67	Undefined		Clay			
36	Ranasahi	21.45033	86.94665	1	9.9	1.3	1.3	Top Soil			
				2	5.3	7.7	9	Clay			
				3	2.2	11	20.04	Fine sand (saline)			
				4	8.5	22.4	42.4	Clay			
				5	1.7	47	89.4	Fine sand(saline)			
				6	15.7	Undefined		Clay			

37	Badkia	21.40842	86.93976	1	8.62	2.522	2.522	Top Soil			
				2	5.7	12.68	15.2	Clay			
				3	12.12	Undefined		Fine sand (saline)			
38	Gudu	21.42734	86.9572	1	10.1	3.57	3.57	Top Soil			
				2	5.29	21.5	25.1	Clay			
				3	2.43	87	112	Fine sand (saline)			
				4	0.02	Undefined					
39	Salapada	21.45065	86.97054	1	5.614	1.2	1.2	Top Soil			
				2	6.9	4.043	5.243				
				3	3.3	5.713	10.96	Clay/Silty Clay			
				4	28	11.94	22.9	Medium Sand(Fresh)	Aquifer	11-22	Potable
				5	3.45	Undefined		Clay			
40	Gabagaon	21.47893	86.96158	1	5.405	1.2	1.2	Top Soil			
				2	6.342	4.061	5.261	Top Soil			
				3	1.647	5.713	10.97	Clay/ Silty Clay			
				4	20.4	37.1	48.05	Medium Sand(Fresh)	Aquifer	11-48	Potable
				5	4.22	Undefined		Clay			
41	Tigiria	21.4737	86.97667	1	13.44	1.373	1.373	Top Soil			
				2	7.5	18.87	20.25	Clay			
				3	31.2	18.83	39.07	Medium Sand(Fresh)	Aquifer	21-39	Potable
				4	4.3	Undefined		Clay			

42	Hidigaon 2	21.46048	86.98404	1	16.6	1.2	1.2	Top Soil			
				2	5.53	5.24	6.44	Clay			
				3	20.2	8.47	14.9	Medium Sand(Fresh)	Aquifer	7-14	Potable
				4	2.94	68.9	83.8	Clay			
				5	0.8	Undefined		Very fine sand (Saline)			
43	Srikona	21.47815	87.00574	1	8.77	1.76	1.76	Top Soil			
				2	3.53	8.2	9.96	Clay			
				3	0.3	Undefined		Very fined sand (Saline)			
44	Jhampura	21.45213	87.011	1	30.5	1.5	1.5	Top Soil			
				2	4.99	3.9	5.4	Clay			
				3	1.98	8.45	13.8	Very fined sand (Saline)			
				4	0.5	Undefined					
45	Ghatagada	21.46368	86.99095	1	18.4	2.41	2.41	Top Soil			
				2	3.66	5.9	8.32	Clay			
				3	1.26	16.3	24.6	Very fined sand (Saline)			
				4	0.009	Undefined					
46	Gudu Road	21.45654	86.99331	1	24.1	1.34	1.34	Top Soil			
				2	3.804	8.91	10.25	Clay			
				3	0.69	23.36	33.61	Very fined sand (Saline)			
				4	0.0012	Undefined					

ANNEXURE- 10: FARMERS FEEDBACK

Form-1

Name	Sanjay Kumar Giri
Village	Mirigimundi
Block	Sadar
District	Balasore
Address	Mirigimundi Chowk, Mirigimundi.
Mobile Number (optional)	814407590
Type and number of structures	

Type	Tube well	
Number	01	
(coordinates of the structures are to be obtained by the field officer)	Latitude: 21.447797 Longitude: 86.981926	
Drill time discharge (lps)	17 lps.	
Depth of installation of pump	300 ft	
Casing depth (Bore wells) HR	-	
Fracture encountered depth-HR	-	
Slotted pipe depths (TW) SR	150 ft. above	
Average water levels – pre-monsoon	12.36 mbgl	
Average water levels – post-monsoon	10.65 mbgl	
The well is used for	Prawn Farming. Agricultural use.	
Is water available throughout the year	Yes	
If not for how many months water is available	-	

Pumping Duration			
	Number of days pump is operated (days) of each well	What is the average pumping duration (in hours) of each well	Instantaneous Discharge Measurement (to be carried out by the field officer) in lps
Rabi (no of months to be specified)	-	-	-
Kharif (no of months to be specified)	5 months	2 hours	17 lps
Others (no of months to be specified)	-	-	-

Area Irrigated			
	Area Irrigated	Type of crop taken	Remarks
Rabi (no of months to be specified)	-	-	-

Khariff (no of months to be specified)	2 acre 55 decibel	Prawan Farming in the area of 1 Acre, and Rice cultivation.	-
Others (no of months to be specified)	-	-	-
Cropping patterns (past and present) in the village			
Traditional Cropping pattern in the village	**Kharif**	**Rabi**	**Other**
Type of Crop	Rice Cultivation	-	-
Area under crop	Farm Land		-
Prevailing Cropping pattern in the village	**Kharif**	**Rabi**	**Other**
Type of Crop	Prawn Fariming, Rice Cultivation	-	-
Area under crop	Farm Land	-	-
Reasons for change in cropping pattern in last 20 years.	Due to the profitability in the prawn farming.	-	-
If the cropping pattern is to be changed, which are the suitable crops that can be grown	Salt tolerant crops, Quinoa, Barley, sorghum. Vegetables, Citrus Fruits, Pineapples, coconuts, Legumes, Millets, Clover and Vetch is recommended.		
Available Market for the crop	Local whole sale markets, Cooperative Societies, Online Platforms and processing units.		
Average unit cost of production	3100 /- Per Quintal.		
Average unit cost of selling	-		
Existing MSP and other related information	-		
Other subsidies, facilities, restrictions.	No benefits from the Government provided to Farmers.		
Source of Energy			

Solar	NIL
Electric	Free Electricity
Diesel	NIL
Water Market*	Facilities provided by the Jal Panchayat of the Village.
Other issues/Remarks	NIL

Form-2

Name	Bhaskar Barik.	
Village	Karji	
Block	Sadar	
District	Balasore.	
Address	In the main Road of the karji	
Mobile Number (optional)	-	
Type and number of structures		
Type	Tube well	
Number	01	
(coordinates of the structures are to be obtained by the field officer)	Lat: 21.433593 Long: 86.976839	

Drill time discharge (lps)	25 lps.		
Depth of installation of pump	250 ft		
Casing depth (Bore wells) HR	30 ft		
Fracture encountered depth-HR	-		
Slotted pipe depths (TW) SR	Above 90 ft .		
Average water levels – pre-monsoon	12.20 mbgl.		
Average water levels – post-monsoon	20.00 mbgl		
The well is used for	Prawn Farming		
Is water available throughout the year	Yes		
If not for how many months water is available	4		
Pumping Duration			
	Number of days pump is operated (days) of each well	What is the average pumping duration (in hours) of each well	Instantaneous Discharge Measurement (to be carried out by the field officer) in lps
Rabi (no of months to be specified)	60	6	20 lps
Kharif (no of months to be specified)	60	6	0
Others (no of months to be specified)	0	0	0
Area Irrigated			
	Area Irrigated	Type of crop taken	Remarks
Rabi (no of months to be specified)	2 acre	Prawn farming	
Khariff (no of months to be specified)	2 acre	Prawn Farming	
Others (no of months to be specified)			
Cropping patterns (past and present) in the village			
Traditional Cropping pattern in the village	Kharif	Rabi	Other
Type of Crop	Vegetables	Rice	

Area under crop	Farm land	Farm land	
Prevailing Cropping pattern in the village	Kharif	Rabi	Other
Type of Crop	Prawn Farming.		
Area under crop	Farm Land.		
Reasons for change in cropping pattern in last 20 years.	Profitability in Prawn farming.		
If the cropping pattern is to be changed, which are the suitable crops that can be grown	Salt tolerant crops, Quinoa, Barley, sorghum. Vegetables, Citrus Fruits, Pineapples, coconuts, Legumes, Millets, Clover and Vetch is recommended.	Salt tolerant crops, Quinoa, Barley, sorghum. Vegetables, Citrus Fruits, Pineapples, coconuts, Legumes, Millets, Clover and Vetch is recommended.	
Available Market for the crop	Local whole sale markets, Cooperative Societies, Online Platforms and processing units.	Local whole sale markets, Cooperative Societies, Online Platforms and processing units.	
Average unit cost of production	May need to be contact near Krishi Vigyan Kendra for details.	May need to be contact near Krishi Vigyan Kendra for details.	
Average unit cost of selling	3100 /- Per Quintal.	3100 /- Per Quintal.	
Existing MSP and other related information	-		
Other subsidies, facilities, restrictions.	No benefits from the Government provided to Farmers.		
Solar	**Source of Energy**		
Electric	NIL		

Diesel	Free Electricity
Water Market*	NIL
	Facilities provided by the Jal Panchayat of the Village.
Other issues/Remarks	NiL

Form-3

Name	Gopinath Jena , Makarnand Pradhan, Prabhakar Jena (Sarpanch: Ranjita Sethi)	
Village	Jhinkaria	
Block	Sadar	
District	Balasore	
Address	Near the Hanuman statue.	
Mobile Number (optional)	7780421823	
Type and number of structures		
Type	No structures.	
Number	00	
(coordinates of the structures are to be obtained by the field officer)	Lat: 21.539161 Long: 87.017856	
Drill time discharge (lps)	0	
Depth of installation of pump	0	
Casing depth (Bore wells) HR	0	
Fracture encountered depth-HR	0	
Slotted pipe depths (TW) SR	0	
Average water levels – pre-monsoon	NIL	
Average water levels – post-monsoon	14.08 mbgl.	
The well is used for	11.12 mbgl.	
Is water available throughout the year	-	
If not for how many months water is available	-	

Pumping Duration			
	Number of days pump is operated (days) of each well	What is the average pumping duration (in hours) of each well	Instantaneous Discharge Measurement (to be carried out by the field officer) in lps
Rabi (no of months to be specified)	0	0	0
Kharif (no of months to be specified)	0	0	0

Others (no of months to be specified)	0	0	0
Area Irrigated			
	Area Irrigated	Type of crop taken	Remarks
Rabi (no of months to be specified)	700 acres of the village.	No Farming.	Farmers only depended upon the Rainwater.
Khariff (no of months to be specified)	700 acres of the Village.	No Farming.	Farmers only depeneded upon the Rainwater. Data unavailable.
Others (no of months to be specified)	-	-	-
Cropping patterns (past and present) in the village			
Traditional Cropping pattern in the village	Kharif	Rabi	Other
Type of Crop	Rice	Rice	
Area under crop	Farm Land.	Farm Land.	
Prevailing Cropping pattern in the village	Kharif	Rabi	Other
Type of Crop	Rice	Rice	
Area under crop	Farm Land.	Farm Land.	
Reasons for change in cropping pattern in last 20 years.	No Change.		
If the cropping pattern is to be changed, which are the suitable crops that can be grown	Salt tolerant crops, Quinoa, Barley, sorghum. Vegetables, Citrus Fruits, Pineapples, coconuts, Legumes, Millets, Clover and Vetch is recommended.	Salt tolerant crops, Quinoa, Barley, sorghum. Vegetables, Citrus Fruits, Pineapples, coconuts, Legumes, Millets, Clover and Vetch is recommended.	
Available Market for the crop	Local whole sale markets, Cooperative Societies, Online Platforms and processing units.	Local whole sale markets, Cooperative Societies, Online Platforms and processing units.	
Average unit cost of production	May need to be contact near Krishi	May need to be contact near Krishi	

	Vigyan Kendra for details.	Vigyan Kendra for details.	
Average unit cost of selling	3100 /- Per Quintal.	3100 /- Per Quintal.	
Existing MSP and other related information	-		
Other subsidies, facilities, restrictions.	No benefits from the Government provided to Farmers.		
Solar	**NIL**		
Electric	NIL		
Diesel	Free Electricity		
Water Market*	NIL		
Other issues/Remarks	This whole area is devoid of cultivation due to the Saline water in the wells as well as due to the poor facilities from the state governments related to the surface water management.		

Form-4

Name	Bhabani Shankar Nayak, Shankar Saran Rout, Ragumath Das, Pratap Ch. Nayak, Gurupada Nayak, Pradeeep Ch. Nayak.	
Village	Palasia	
Block	Sadar	
District	Balasore.	
Address	In the chowk.	
Mobile Number (optional)	7873770295	
Type and number of structures		
Type	No Structures.	
Number	00	
(coordinates of the structures are to be obtained by the field	Lat: 21.529572 Long: 87.014567	

officer)			
Drill time discharge (lps)	0		
Depth of installation of pump	0		
Casing depth (Bore wells) HR	0		
Fracture encountered depth-HR	-		
Slotted pipe depths (TW) SR	-		
Average water levels – pre-monsoon	14.57 mbgl.		
Average water levels – post-monsoon	12.37 mbgl.		
The well is used for	-		
Is water available throughout the year	-		
If not for how many months water is available	-		
Pumping Duration			
	Number of days pump is operated (days) of each well	What is the average pumping duration (in hours) of each well	Instantaneous Discharge Measurement (to be carried out by the field officer) in lps
Rabi (no of months to be specified)	-	-	-
Kharif (no of months to be specified)	-	-	-
Others (no of months to be specified)	-	-	-
Area Irrigated			
	Area Irrigated	Type of crop taken	Remarks
Rabi (no of months to be specified)	3 acre.	Rice	
Khariff (no of months to be specified)	3 acre.	No crop.	
Others (no of months to be specified)	-	-	-
Cropping patterns (past and present) in the village			

Traditional Cropping pattern in the village	Kharif	Rabi	Other
Type of Crop	-	Rice	
Area under crop	Farm Land	Farm Land.	
Prevailing Cropping pattern in the village	Kharif	Rabi	Other
Type of Crop	-	Rice	
Area under crop	Farm Land	Farm Land	
Reasons for change in cropping pattern in last 20 years.	No change.		
If the cropping pattern is to be changed, which are the suitable crops that can be grown	Salt tolerant crops, Quinoa, Barley, sorghum. Vegetables, Citrus Fruits, Pineapples, coconuts, Legumes, Millets, Clover and Vetch is recommended.	Salt tolerant crops, Quinoa, Barley, sorghum. Vegetables, Citrus Fruits, Pineapples, coconuts, Legumes, Millets, Clover and Vetch is recommended.	
Available Market for the crop	Local whole sale markets, Cooperative Societies, Online Platforms and processing units.	Local whole sale markets, Cooperative Societies, Online Platforms and processing units.	
Average unit cost of production	May need to be contact near Krishi Vigyan Kendra for details.	May need to be contact near Krishi Vigyan Kendra for details.	
Average unit cost of selling	3100 /- Per Quintal.	3100 /- Per Quintal.	
Existing MSP and other related information	-		
Other subsidies, facilities, restrictions.	No benefits from the Government provided to Farmers.		
Source of Energy			
Solar	**NIL**		

Electric	NIL
Diesel	Free Electricity
Water Market*	NIL
Other issues/Remarks	This whole area’s cultivation got affected due to the Saline water in the wells as well as due to the poor facilities from the state governments related to the surface water management.

Form-5

Name	Sushanta Kumar Giri	
Village	Mirigimundi	
Block	Sadar	
District	Balasore	
Address	In the Northern End of the village.	
Mobile Number (optional)	8917673217	
Type and number of structures		
Type	No structures.	
Number	00	
(coordinates of the structures are to be obtained by the field	Lat: 21.539161 Long: 87.017856	

officer)		
Drill time discharge (lps)	0	
Depth of installation of pump	0	
Casing depth (Bore wells) HR	0	
Fracture encountered depth-HR	0	
Slotted pipe depths (TW) SR	0	
Average water levels – pre-monsoon	NIL	
Average water levels – post-monsoon	14.08 mbgl.	
The well is used for	11.12 mbgl.	
Is water available throughout the year	-	
If not for how many months water is available	-	

Pumping Duration			
	Number of days pump is operated (days) of each well	What is the average pumping duration (in hours) of each well	Instantaneous Discharge Measurement (to be carried out by the field officer) in lps
Rabi (no of months to be specified)	0	0	0
Kharif (no of months to be specified)	150	0	0
Others (no of months to be specified)	0	0	0
Area Irrigated			
	Area Irrigated	Type of crop taken	Remarks
Rabi (no of months to be specified)	2 acre	Rice	Farmers only depended upon the Rainwater and OLIC tubewell points
Khariff (no of months to be specified)	2 acre	Vegetables	Farmers only depeneded upon the Rainwater. Data unavailable.
Others (no of months to be specified)	-	-	-

Cropping patterns (past and present) in the village			
Traditional Cropping pattern in the village	Kharif	Rabi	Other
Type of Crop	Rice	Vegetable	
Area under crop	Farm Land.	Farm Land.	
Prevailing Cropping pattern in the village	Kharif	Rabi	Other
Type of Crop	Rice	Vegeta	
Area under crop	Farm Land.	Farm Land.	
Reasons for change in cropping pattern in last 20 years.	No Change.		
If the cropping pattern is to be changed, which are the suitable crops that can be grown	Salt tolerant crops, Quinoa, Barley, sorghum. Vegetables, Citrus Fruits, Pineapples, coconuts, Legumes, Millets, Clover and Vetch is recommended.	Salt tolerant crops, Quinoa, Barley, sorghum. Vegetables, Citrus Fruits, Pineapples, coconuts, Legumes, Millets, Clover and Vetch is recommended.	
Available Market for the crop	Local whole sale markets, Cooperative Societies, Online Platforms and processing units.	Local whole sale markets, Cooperative Societies, Online Platforms and processing units.	
Average unit cost of production	May need to be contact near Krishi Vigyan Kendra for details.	May need to be contact near Krishi Vigyan Kendra for details.	
Average unit cost of selling	3100 /- Per Quintal.	3100 /- Per Quintal.	
Existing MSP and other related information	-		
Other subsidies, facilities, restrictions.	No benefits from the Government provided to Farmers.		
Solar	**NIL**		

Electric	NIL
Diesel	Free Electricity
Water Market*	NIL

Form-6

Name	Parmananda Das.	
Village	Udambar	
Block	Remuna	
District	Balasore	
Address	In the Northern End of the village.	
Mobile Number (optional)	8093494828	
Type and number of structures		
Type	Tube well	
Number	01	
(coordinates of the structures are to be obtained by the field officer)	Lat: 21.540146 Long: 86.893634	

Drill time discharge (lps)	20		
Depth of installation of pump	150 ft		
Casing depth (Bore wells) HR	-		
Fracture encountered depth-HR	0		
Slotted pipe depths (TW) SR	0		
Average water levels – pre-monsoon	NIL		
Average water levels – post-monsoon	14.08 mbgl.		
The well is used for	11.12 mbgl.		
Is water available throughout the year	-		
If not for how many months water is available	-		
Pumping Duration			
	Number of days pump is operated (days) of each well	What is the average pumping duration (in hours) of each well	Instantaneous Discharge Measurement (to be carried out by the field officer) in lps
Rabi (no of months to be specified)	0	0	0
Kharif (no of months to be specified)	150	0	0
Others (no of months to be specified)	0	0	0
Area Irrigated			
	Area Irrigated	Type of crop taken	Remarks
Rabi (no of months to be specified)	2 acre	Rice	Farmers only depended upon the Rainwater and OLIC tubewell points
Khariff (no of months to be specified)	2 acre	Vegetables	Farmers only depeneded upon the Rainwater. Data unavailable.
Others (no of months to be specified)	-	-	-
Cropping patterns (past and present) in the village			

Traditional Cropping pattern in the village	Kharif	Rabi	Other
Type of Crop	Rice	Vegetable	
Area under crop	Farm Land.	Farm Land.	
Prevailing Cropping pattern in the village	Kharif	Rabi	Other
Type of Crop	Rice	Vegeta	
Area under crop	Farm Land.	Farm Land.	
Reasons for change in cropping pattern in last 20 years.	No Change.		
If the cropping pattern is to be changed, which are the suitable crops that can be grown	Salt tolerant crops, Quinoa, Barley, sorghum. Vegetables, Citrus Fruits, Pineapples, coconuts, Legumes, Millets, Clover and Vetch is recommended.	Salt tolerant crops, Quinoa, Barley, sorghum. Vegetables, Citrus Fruits, Pineapples, coconuts, Legumes, Millets, Clover and Vetch is recommended.	
Available Market for the crop	Local whole sale markets, Cooperative Societies, Online Platforms and processing units.	Local whole sale markets, Cooperative Societies, Online Platforms and processing units.	
Average unit cost of production	May need to be contact near Krishi Vigyan Kendra for details.	May need to be contact near Krishi Vigyan Kendra for details.	
Average unit cost of selling	3100 /- Per Quintal.	3100 /- Per Quintal.	
Existing MSP and other related information	-		
Other subsidies, facilities, restrictions.	No benefits from the Government provided to Farmers.		
Solar	**NIL**		

Electric	Free electricity
Diesel	NIL
Water Market*	NIL

Form-7

Name	Tapan Kumar Panda	
Village	Chaka Padadiha.	
Block	Sadar	
District	Balasore	
Address	Rupsa Road.	
Mobile Number (optional)	9778866142	
Type and number of structures		
Type	Tube well	
Number	00	
(coordinates of the structures are to be obtained by the field officer)	Lat: 21.583046 Long: 87.0077805	

Drill time discharge (lps)	-		
Depth of installation of pump	-		
Casing depth (Bore wells) HR	-		
Fracture encountered depth-HR	-		
Slotted pipe depths (TW) SR	-		
Average water levels – pre-monsoon	-		
Average water levels – post-monsoon	-		
The well is used for	-		
Is water available throughout the year	-		
If not for how many months water is available	-		
Pumping Duration			
	Number of days pump is operated (days) of each well	What is the average pumping duration (in hours) of each well	Instantaneous Discharge Measurement (to be carried out by the field officer) in lps
Rabi (no of months to be specified)	-	-	-

Kharif (no of months to be specified)	5 months	-	-
Others (no of months to be specified)	-	-	-
Area Irrigated			
	Area Irrigated	Type of crop taken	Remarks
Rabi (no of months to be specified)	3 acre	Rice	
Khariff (no of months to be specified)	-	-	-
Others (no of months to be specified)	-	-	-
Cropping patterns (past and present) in the village			
Traditional Cropping pattern in the village	Kharif	Rabi	Other
Type of Crop	-	Rice	-

Area under crop	-	Farm Land	-
Prevailing Cropping pattern in the village	Kharif	Rabi	Other
Type of Crop	-	Rice	-
Area under crop	-	Farm Land.	-
Reasons for change in cropping pattern in last 20 years.	No Change.	No Change.	
If the cropping pattern is to be changed, which are the suitable crops that can be grown	Salt tolerant crops, Quinoa, Barley, sorghum. Vegetables, Citrus Fruits, Pineapples, coconuts, Legumes, Millets, Clover and Vetch is recommended.	Salt tolerant crops, Quinoa, Barley, sorghum. Vegetables, Citrus Fruits, Pineapples, coconuts, Legumes, Millets, Clover and Vetch is recommended.	
Available Market for the crop	Local whole sale markets, Cooperative Societies, Online Platforms and processing units.	Local whole sale markets, Cooperative Societies, Online Platforms and processing units.	
Average unit cost of production	May need to be contact near Krishi Vigyan Kendra for details.	May need to be contact near Krishi Vigyan Kendra for details.	
Average unit cost of selling	3100 /- Per Quintal.	3100 /- Per Quintal.	
Existing MSP and other related information	Crop wise details are to be collected		
Other subsidies, facilities, restrictions.	Shallow Tubewell should be subsidized.		
Source of Energy			
Solar	-		

Electric	-
Diesel	NIL
Water Market*	Pani Panchayat
Other issues/Remarks	NIL

Form-8

Name	Rajendra Sahu	
Village	Haldipada, Rupsa	
Block	Remuna	
District	Balasore	
Address	Haldipada.	
Mobile Number (optional)	7873127327	
Type and number of structures		
Type	Tubewell	
Number	00	
(coordinates of the structures are to be obtained by the field officer)	-	

Drill time discharge (lps)	-	
Depth of installation of pump	-	
Casing depth (Bore wells) HR	-	
-Fracture encountered depth-HR	-	
Slotted pipe depths (TW) SR	-	
Average water levels – pre-monsoon	8.00 mbgl	
Average water levels – post-monsoon	6.00 mbgl	
The well is used for	-	
Is water available throughout the year	-	
If not for how many months water is available	-	

Pumping Duration			
	Number of days pump is operated (days) of each well	What is the average pumping duration (in hours) of each well	Instantaneous Discharge Measurement (to be carried out by the field officer) in lps
Rabi (no of months to be specified)	1 acre 20 db	Vegetable	-
Kharif (no of months to be specified)	1 acre 20 db	Rice	
Others (no of months to be specified)	-	-	
Area Irrigated			
	Area Irrigated	Type of crop taken	Remarks
Rabi (no of months to be specified)	3	Vegetable	
Khariff (no of months to be specified)	3	Rice	
Others (no of months to be specified)	-	-	-
Cropping patterns (past and present) in the village			
Traditional Cropping pattern in the village	Kharif	Rabi	Other
Type of Crop	Vegetable	Rice	

Area under crop	Farm Land	Farm Land.	
Prevailing Cropping pattern in the village	Kharif	Rabi	Other
Type of Crop	Vegetable	Rice	
Area under crop	Farm Land	Farm land.	
Reasons for change in cropping pattern in last 20 years.	No change.	No change.	
If the cropping pattern is to be changed, which are the suitable crops that can be grown	Salt tolerant crops, Quinoa, Barley, sorghum. Vegetables, Citrus Fruits, Pineapples, coconuts, Legumes, Millets, Clover and Vetch is recommended.	Salt tolerant crops, Quinoa, Barley, sorghum. Vegetables, Citrus Fruits, Pineapples, coconuts, Legumes, Millets, Clover and Vetch is recommended.	
Available Market for the crop	Local whole sale markets, Cooperative Societies, Online Platforms and processing units.	Local whole sale markets, Cooperative Societies, Online Platforms and processing units.	
Average unit cost of production	May need to be contact near Krishi Vigyan Kendra for details.	May need to be contact near Krishi Vigyan Kendra for details.	
Average unit cost of selling	3100 /- Per Quintal.	3100 /- Per Quintal.	
Existing MSP and other related information	NIL		
Other subsidies, facilities, restrictions.	Shallow Tubewell should be subsidized.		
Source of Energy			
Solar	• NIL		

Electric	• NIL
Diesel	• NIL
Water Market*	• Pani Panchayat.
	•
Other issues/Remarks	NIL

Form-9

Name	Purna Chandra Pradhan.	
Village	Khandahar	
Block	Remuna	
District	Balasore	
Address	Agricultural center.	
Mobile Number (optional)	7978596100	
Type and number of structures		
Type	Tube well	
Number	00	
(coordinates of the structures are to be obtained by the field officer)	-	

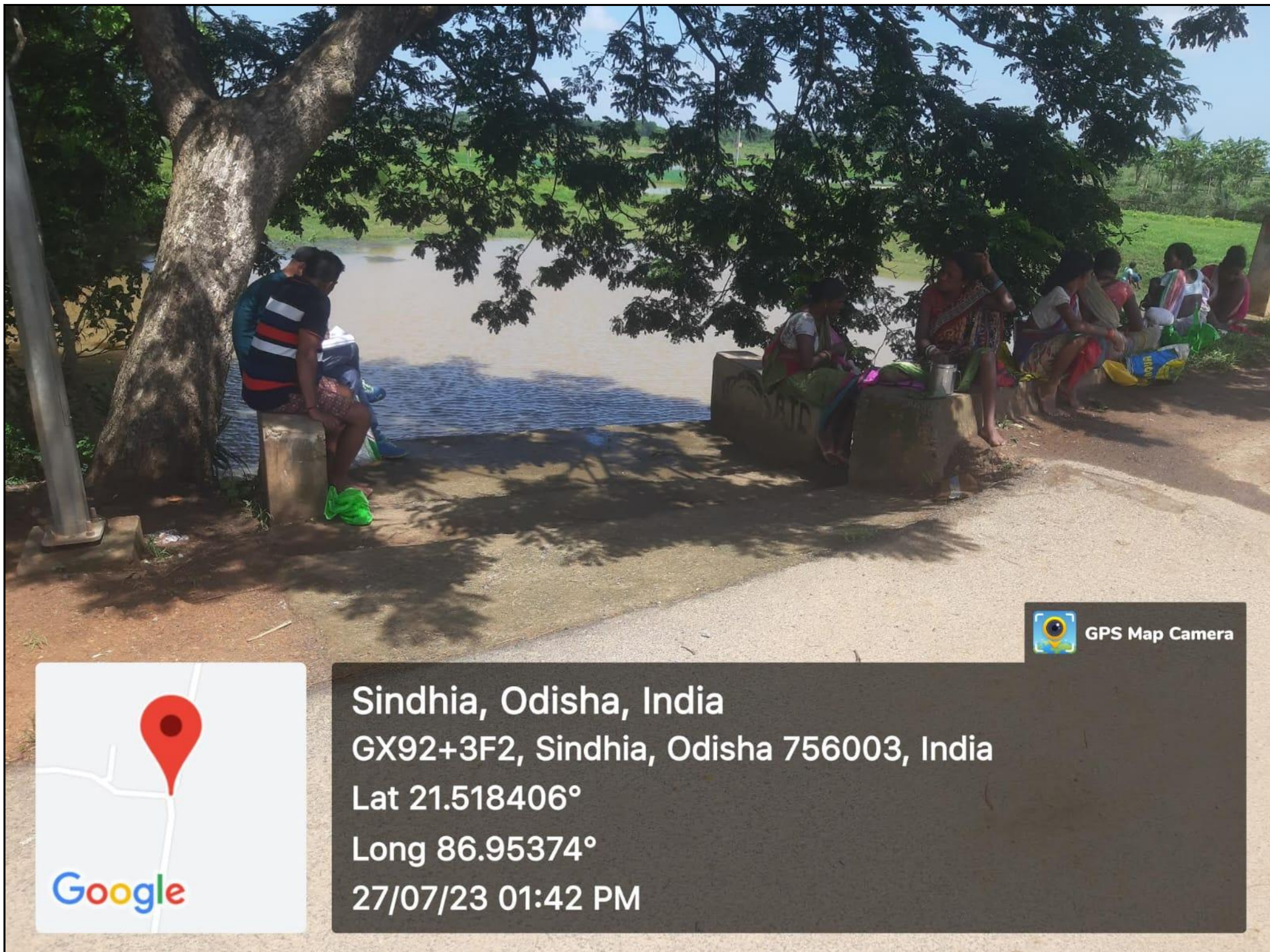
Drill time discharge (lps)	-	
Depth of installation of pump	-	
Casing depth (Bore wells) HR	-	
Fracture encountered depth-HR	-	
Slotted pipe depths (TW) SR	-	
Average water levels – pre-monsoon	10.20 mbgl.	
Average water levels – post-monsoon	8.86 mgbl.	
The well is used for	-	
Is water available throughout the year	-	
If not for how many months water is available	-	

Pumping Duration			
	Number of days pump is operated (days) of each well	What is the average pumping duration (in hours) of each well	Instantaneous Discharge Measurement (to be carried out by the field officer) in lps
Rabi (no of months to be specified)	-	-	-
Kharif (no of months to be specified)	3 months	Rice Cultivation	
Others (no of months to be specified)	-	-	-
Area Irrigated			
	Area Irrigated	Type of crop taken	Remarks
Rabi (no of months to be specified)	-	-	
Khariff (no of months to be specified)	6 acre 50 db	Rice Cultivation	
Others (no of months to be specified)	-	-	
Cropping patterns (past and present) in the village			
Traditional Cropping pattern in the village	Kharif	Rabi	Other
Type of Crop	-	Rice	-

Area under crop	-	Farm Land.	
Prevailing Cropping pattern in the village	Kharif	Rabi	Other
Type of Crop	-	Rice	-
Area under crop			
Reasons for change in cropping pattern in last 20 years.	No Change	No Change.	
If the cropping pattern is to be changed, which are the suitable crops that can be grown	Salt tolerant crops, Quinoa, Barley, sorghum. Vegetables, Citrus Fruits, Pineapples, coconuts, Legumes, Millets, Clover and Vetch is recommended.	Salt tolerant crops, Quinoa, Barley, sorghum. Vegetables, Citrus Fruits, Pineapples, coconuts, Legumes, Millets, Clover and Vetch is recommended.	
Available Market for the crop	Local whole sale markets, Cooperative Societies, Online Platforms and processing units.	Local whole sale markets, Cooperative Societies, Online Platforms and processing units.	
Average unit cost of production	May need to be contact near Krishi Vigyan Kendra for details.	May need to be contact near Krishi Vigyan Kendra for details.	
Average unit cost of selling	3100 /- Per Quintal.	3100 /- Per Quintal.	
Existing MSP and other related information	Crop wise details are to be collected		
Other subsidies, facilities, restrictions.	3100 /- Per Quintal.		
shallow Tubewell should be subsidized.			
Solar	NiL		

Electric	**NIL**
Diesel	• NIL
Water Market*	• NIL
	• NIL
Other issues/Remarks	• Pani Panchayat.

Form-10



Name	Shyam Shundar Nayak,	
Village	Silda.	
Block	Sadar	
District	Balasore	
Address	Jhinkaria	
Mobile Number (optional)	96681088722	
Type and number of structures		
Type	Tubewell	
Number	00	
(coordinates of the structures are to be obtained by the field officer)	-	

Drill time discharge (lps)	-	
Depth of installation of pump	-	
Casing depth (Bore wells) HR	-	
Fracture encountered depth-HR	-	
Slotted pipe depths (TW) SR	-	
Average water levels – pre-monsoon	12.00 mbgl	
Average water levels – post-monsoon	10.20 mbgl.	
The well is used for	Irrigation	
Is water available throughout the year	Yes	
If not for how many months water is available	-	

Pumping Duration			
	Number of days pump is operated (days) of each well	What is the average pumping duration (in hours) of each well	Instantaneous Discharge Measurement (to be carried out by the field officer) in lps
Rabi (no of months to be specified)	Vegetable	-	-
Kharif (no of months to be specified)	Rice	-	-
Others (no of months to be specified)	-	-	-
Area Irrigated			
	Area Irrigated	Type of crop taken	Remarks
Rabi (no of months to be specified)	7 acre	Vegetables	-
Khariff (no of months to be specified)	7 acre	Rice	-
Others (no of months to be specified)	-	-	-
Cropping patterns (past and present) in the village			
Traditional Cropping pattern in the village	Kharif	Rabi	Other
Type of Crop	vegetables	Rice.	

Area under crop	Farm land	Farm Land.	
Prevailing Cropping pattern in the village	Kharif	Rabi	Other
Type of Crop	Vegetable	Rice	
Area under crop	Farm Land	Farm Land	
Reasons for change in cropping pattern in last 20 years.	No change.		
If the cropping pattern is to be changed, which are the suitable crops that can be grown	Salt tolerant crops, Quinoa, Barley, sorghum. Vegetables, Citrus Fruits, Pineapples, coconuts, Legumes, Millets, Clover and Vetch is recommended.	Salt tolerant crops, Quinoa, Barley, sorghum. Vegetables, Citrus Fruits, Pineapples, coconuts, Legumes, Millets, Clover and Vetch is recommended.	
Available Market for the crop	Local whole sale markets, Cooperative Societies, Online Platforms and processing units.	Local whole sale markets, Cooperative Societies, Online Platforms and processing units.	
Average unit cost of production	May need to be contact near Krishi Vigyan Kendra for details.	May need to be contact near Krishi Vigyan Kendra for details.	
Average unit cost of selling	3100 /- Per Quintal.	3100 /- Per Quintal.	
Existing MSP and other related information	Crop wise details are to be collected		
Other subsidies, facilities, restrictions.	3100 /- Per Quintal.		
Source of Energy			
Solar	• NIL		

Electric	• NIL
Diesel	• NIL
Water Market*	Pani Panchayat.
	•
Other issues/Remarks	NIL

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