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EDITORIAL

It is with great pleasure that we present the 9th Bulletin of the Nepal Hydrogeological Association (NHA). This edition highlights contributions from senior hydrogeologists and professionals providing useful popular types of articles. The diverse types of articles have provided information on water resource management, sustainable development, and climate resilience and exploration techniques of groundwater.

We extend our heartfelt gratitude to all the authors who have shared their invaluable research and insights. Your dedication to excellence and commitment to the advancement of hydrogeology is commendable. We also appreciate the efforts of the reviewers, who ensured the quality of this publication.

The success of this bulletin would not have been possible without the generous support of our sponsors, well-wishers, and professionals whose unwavering commitment to our cause has been instrumental. We highly wish to acknowledge the contributions of our members of the association, partners, advertisers, and individual supporters who continue to believe in and support our vision.

We would also like to express our sincere thanks to the executive committee for providing us with the opportunity to work together for such a respected organization. The editorial team members, with their unique contributions, have played a pivotal role in bringing this bulletin to its present stage. Your hard work, dedication, and collaborative spirit are the backbone of our success.

We hope this bulletin serves as a valuable resource and history of the association for all our readers, and we look forward to continued collaboration in the future.

Warm Regards,

Thank you !!!

The Editorial Board
Nepal Hydrogeological Association (NHA)
Date: 9/6/2024

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MESSAGE FROM THE PRESIDENT OF SEVENTH EXECUTIVE COMMITTEE ON FOURTEENTH AGM

The Nepal Hydrogeological Association (NHA) represents all groundwater specialists from all disciplines working on various areas of groundwater resources and development throughout Nepal. Since its inception, it has consistently pushed for the advancement of professionals working in the groundwater sector in Nepal, with a primary focus on groundwater investigation, exploration, regulation, and management. Professional activities include the organization of various discussions, talk programs, seminars, and conferences, while academic activities include the publication of books, bulletins, journals, and so on.

The involvement of hydrogeologists in the government organization has been the matter of serious debate in the context of changed administrative arrangement. The Groundwater Resources Development Board was a key institution responsible for policy making, hydrogeological study and study data preservation for the entire country. In addition to further strengthen this organization, GWRDB has been completely disappeared from the Government framework. In view of the requirement of proper assessment, sustainable exploitation and protection of this important natural resources that has direct connection in the agriculture, industry, and domestic use, it is high time to improve the administrative framework and technical expertise in this area that ultimately lead towards groundwater availability for the coming generation.

NHA has been annually publishing Bulletin since 2016 and present Volume 9 is the reflection of its continuity. It is our pleasure to further enhance academic endeavors of the professional organization through initiating the publication of the first volume of Journal of Nepal Hydrogeological Association from this year-2024.

We are eagerly looking for collaborations with groundwater enthusiasts from all over the world for the betterment of environment and society with sustainability of the groundwater resource.

Prof. Dinesh Pathak
President
Nepal Hydrogeological Association
2081/05/25

नेपाल हाइड्रो जियोलोजिकल एशोसियसनको
१३ औं साधारण सभामा छैटौं कार्य समितिका अध्यक्ष
श्री मोती बहादुर कुँवरको मन्तव्य

१३औं साधारण सभाका प्रमुख अतिथिज्यू, विशेष अतिथिज्यू, आजको कार्यक्रममा सम्मानित हुनु भएका विशिष्ट व्यक्तित्वहरू, NHA र NGS का पूर्व अध्यक्षज्यूहरू, NGS, IAH, तथा IAEG का अध्यक्षज्यूहरू, Nepal Hydrological Association (NHA) कार्यकारी समितिका सम्पूर्ण सदस्य साथीहरू लगायत यस कार्यक्रममा उपस्थित सम्पूर्ण आजिवन सदस्यज्यूहरूलाई १३ औं साधारण सभामा हार्दिक अभिवादन गर्दछु । यहाँहरूको गरिमामय उपस्थितिले यो कार्यक्रम भव्य रूपले सम्पन्न भएकोमा हार्दिक आभार सहित धन्यवाद ज्ञापन गर्दछु ।

NHA एक विशुद्ध व्यवसायिक तथा सामाजिक संस्था हो । यस संस्थामा रहेर भूमिगत जलश्रोतको क्षेत्रमा कार्यरत सबै बैज्ञानिक तथा इन्जिनियर मित्रहरूले राष्ट्र निर्माणमा उत्कृष्ट एवं महत्वपूर्ण योगदान पुऱ्याउन सफल हुनु भएकोमा हामीले गौरवान्वीत भएको महशुस गरेका छौं ।

१२औं वर्ष पूरा गरी १३औं वर्षमा प्रवेश गरेको NHA लाई आजको अवस्थासम्म ल्याउन अथक प्रयास गर्ने हाम्रा सम्पूर्ण अग्रजहरू, पूर्ववर्ति कार्यकारी समितिका अध्यक्ष सहित सबै पदाधिकारीहरू, NHA का आजीवन सदस्यहरू एवं सल्लाहकार मित्रहरूलाई हार्दिक धन्यवाद सहित आभार व्यक्त गर्दछु ।

यस कार्य समितिले 13th Oct 2022 मा NHA-NGS-DMG को संयुक्त व्यवस्थापनमा "Substantially increase the availability of and access to multi-hazard early warning systems and disaster risk information and assessment to people by 20230." भन्ने नारालाई अगाडि सारेर IDDR-2022 Celebration जस्तो महत्वपूर्ण राष्ट्रिय महत्वको कार्य सम्पन्न गर्न सम्भव भएको छ । यस कार्यमा सहयोग गर्नु हुने गृह मन्त्रालय, उद्योग मन्त्रालय, उर्जा जलश्रोत तथा सिंचाई मन्त्रालय, नेपाली सेना, नेपाल प्रहरी, नेपाल प्रहरी सशस्त्र बल, DMG, DoED, DOWRI, GWRDB, TU, UNDP, समेत सम्बन्धित सबैलाई हार्दिक धन्यवाद सहित आभार व्यक्त गर्न चाहन्छु । IDDR आयोजक समितिका सम्पूर्ण साथीहरूलाई हार्दिक बधाई सहित धन्यवाद दिन चाहन्छु । यस कार्यक्रममा महत्वपूर्ण कार्यपत्र प्रस्तुत गर्नु हुने इन्जिनियर तथा बैज्ञानिकहरूलाई हार्दिक धन्यवाद ज्ञापन गर्दछु । साथै यस IDDR Celeberation कार्यक्रममा प्रमुख आतिथ्य ग्रहण गर्नुहुने उर्जा जलश्रोत सिंचाई मन्त्रालयका सचिव श्री सागर कुमार राईज्यूलाई हार्दिक धन्यवाद दिन चाहन्छु ।

यस कार्य समितिले NHA का सदस्यहरूको हक हित र संरक्षण तथा बृत्ति विकासको लागि सम्बन्धित निकायहरूमा आवश्यक पहलकदमी गर्ने कार्य र भूमिगत जलश्रोतसँग सम्बन्धित संस्थालाई स्थायी दिगो र भरपर्दो बनाउने तर्फ समेत नेपाल सरकारका विभिन्न निकायहरूसित आवश्यक समन्वय गर्ने कार्यको शुरूवात गरिएको छ ।

साथै भुमिगत जलश्रोतको अध्ययन, अनुसन्धान र विकासमा महत्वपूर्ण योगदान पुऱ्याएका आदरणीय अग्रजहरू, विशिष्ट व्यक्तित्वहरू र NHA का सदस्यहरूलाई उच्च मूल्यांकन गरी स-सम्मान मानार्थ सदस्य र सम्मान-पत्र प्रदान गरिएको छ । यो शुभ अवसरलाई हामीले गौरवपूर्ण क्षणको रूपमा लिएका छौं ।

यस साधारण सभामा सम्मानित हुनु हुने सबै महानुभावहरूलाई हार्दिक बधाइ सहित सुस्वास्थ्य र दिर्घायुको कामना गर्न चाहन्छु । यस महत्वपूर्ण कार्यमा समन्वय गर्नु हुने NHA का शुभेच्छुक साथीहरू सहित कार्यसमितिका सबै साथीहरूलाई हार्दिक धन्यवाद दिन चाहन्छु ।

महत्वपूर्ण लेखरचना सहित यस संस्थाको ८औं वार्षिक बुलेटीन तयार गर्न अनवरत कार्यरत सम्पादन मण्डलका संयोजक श्री एण्डी प्रकाश भट्टज्यू सहित सम्पादन मण्डलका सबै सदस्यहरू लगायत लेख रचना उपलब्ध गराउने सबै विज्ञ मित्रहरूलाई विशेष धन्यवाद दिन चाहन्छु ।

यस संस्थाको वार्षिक गतिविधि समावेश भएको महासचिव श्री अमर बहादुर चन्द ठकुरीको प्रतिवेदन तथा आर्थिक गतिविधि सहित कोषाध्यक्ष श्रीमती रसिला कोइरालाको प्रतिवेदन पारित गर्न सहयोग गर्नु भएकोमा साधारणसभाका सम्पूर्ण सदस्यज्यूहरूलाई हार्दिक धन्यवाद दिन चाहन्छु ।

NHA को कार्य संचालनमा सदैव सहयोग गर्ने भूमिगत जलश्रोत विकास समिति परिवारलाई आभार व्यक्त गर्दै विशेष धन्यवाद दिन चाहन्छु । साथै NHA को नियमित कार्यमा निरन्तर लागि रहने कार्यकारी समितिका सम्पुर्ण साथीहरू प्रति धन्यवाद सहित आभार व्यक्त गर्दछु ।

NHA लाई सदैव विज्ञापन प्रदान गरी सहयोग गर्ने सम्पूर्ण सरकारी निकाय, Drilling Company तथा Consulting Firm हरू प्रति हार्दिक आभार र धन्याद ज्ञापन गर्दछु । NHA को यस १३औं सभालाई हल प्रदान गर्नु हुने भुमिगत जलश्रोत विकास समिति परिवारलाई समेत हार्दिक धन्यवाद दिन चाहन्छु ।

NHA ले सञ्चालन गर्दै आएको महत्वपूर्ण Talk programme, workshop तथा Seminar हरूमा सकृयरूपले सहभागि हुनु हुने सम्पूर्ण बैज्ञानिक तथा इन्जिनियर मित्रहरूलाई हार्दिक धन्यवाद दिन चाहन्छु ।

अति व्यस्त कार्यक्रमका बाबजुद यस कार्यक्रमको प्रमुख आतिथ्य ग्रहण गरिदिनु हुने उर्जा, जलश्रोत तथा सिंचाई मन्त्रालयका सचिव श्रीमान दिनेश कुमार घिमिरेज्यूलाई हार्दिक आभार सहित धन्यवाद ज्ञापन गर्दछु । यस कार्यक्रममा Honrary Member बाट सम्मानीत हुनु भएका विशेष अतिथि पूर्व सचिव श्रीमान यादव लाल बैद्यज्यू र वरिष्ठ भूमिगत जलश्रोत विज्ञ श्री मोहन सिंह खड्काज्यूलाई हार्दिक बधाई दिन चाहन्छु ।

साथै यस साधारण सभाबाट सम्मानित हुनु भएका श्रद्धेय अग्रजहरू प्रातस्मरणीय डा. चन्द्रकान्त शर्माज्यू, श्री तेजमान सिंह भण्डारीज्यू, श्री गिरिजा प्रसाद चतुर्वेदीज्यू, श्रीकृष्ण श्रेष्ठज्यू, श्री प्रेम बहादुर शाहज्यू, श्री विष्णु गैरेज्यू प्रति हार्दिक श्रद्धासम्मान अर्पण गर्दछु ।

साथै अन्य आदर्णीय अग्रज व्यक्तित्वहरू श्री अरूण कुमार श्रीवास्तवज्यू, श्री जागेश्वर झा ज्यू, श्री ऋषीराम शर्माज्यू, श्री श्यामकृष्ण श्रेष्ठज्यू, श्री केशव केसीज्यू, श्री जीवनलाल श्रेष्ठज्यू, श्री प्रेम बहादुर कार्कीज्यू लाई हार्दिक बधाई ज्ञापन गर्दछु ।

त्यस्तै NHA का past president हरू, talk program speakers, member of editorial board, 13th AGM आयोजक समितिका साथीहरू, IDDR celeberation committee, author of NHA bulletin सहित अन्य व्यक्तिहरू सबैलाई हार्दिक धन्यवाद सहित बधाई दिन चाहन्छु । विभिन्न सरकारी तथा गैरसरकारी संस्था एवं अन्तर्राष्ट्रिय संस्थाहरूमा बढुवा, नयाँ नियुक्ति तथा सम्मानित हुनु भएका विद्वान मित्रहरूलाई समेत हार्दिक बधाई ज्ञापन गर्दछु ।

विशिष्ट व्यक्तित्वहरू उर्जा जलश्रोत तथा सिंचाई मन्त्रालयका सहसचिवज्यू, शिक्षा मन्त्रालयका सहसचिवज्यू, सिंचाई विभागका महानिर्देशक तथा उपमहानिर्देशकज्यू, सिंचाइ विभागका आयोजना निर्देशकज्यू, GWRDB का कार्यकारी प्रमुखज्यू, NGS का अध्यक्षज्यू, IAH का अध्यक्षज्यू, IAEG का अध्यक्षज्यू लगायत सबैलाई विशेष धन्यवाद दिन चाहन्छु ।

कार्यक्रम सञ्चालन गर्नु हुने NHA का सचिव श्री अनिल खत्रीज्यू र कोषाध्यक्ष रसिला कोइरालाज्यूलाई समेत धन्यवाद दिंदै यस साधारण सभामा उपस्थित भई सकृयरूपले सहभागी भएर आफ्नो अमूल्य सुझव प्रस्तुत गरी सफल गराउनु हुने NHA का सम्पूर्ण आजिवन सदस्यज्यूहरू प्रति मेरो र कार्यसमितिको तर्फबाट धन्यवाद सहित हार्दिक आभार व्यक्त गर्न चाहन्छु । साथै NHA का नयाँ Life Member मित्रहरूलाई हार्दिक स्वागत तथा अभिवादन गर्दै उज्ज्वल भविष्यको कामना गर्दछु ।

अन्त्यमा NHA को सातौं कार्यकारीणि समितिका नवनिर्वाचित अध्यक्ष प्रा.डा.श्री दिनेश पाठकज्यू सहित सबै पदाधिकारी मित्रहरूलाई हार्दिक बधाइ सहित सफल कार्यकालको शुभकामना व्यक्त गर्दछु ।

बिजया दशमी, दिपावली, छठ पर्व, नेपाल सम्बत आदि पर्वहरूको उपलक्ष्यमा सबैमा मंगलमय शुभकामना व्यक्त गर्दछु ।

धन्यवाद ।

एशोसिएशनको १३ औं वार्षिक साधारण सभामा महासचिव अमर बहादुर चन्द ठकुरीको प्रतिवेदन

नमस्कार,

यस नेपाल हाइड्रोजियोलजिकल एसोसिएसन (NHA) का अध्यक्ष तथा सभाका सभाध्यक्षज्यू, प्रमुख तथा बिशेष अतिथिज्यूहरू, यस एसोसियशनका पूर्व अध्यक्षज्यूहरू, एसोसियशनका पधाधिकारीज्यू तथा सम्पूर्ण सदस्यज्यूहरू । यस NHA को १३औं वार्षिक साधारण सभामा उपस्थित सम्पूर्ण आजिवन सदस्यज्यूहरू तथा अतिथिज्यूहरूलाई स्वागत गर्न चाहन्छु ।

आज मिति २०८९ भाद्र २९ गते शुक्रवार यस NHA को बाह्रौं बाषिर्क साधारण सभामा महासचिवको हैसियतले आ.ब. २०७९।८० मा यस एसोसियशनबाट भएका गतिविधिहरू प्रस्तुत गर्न पाउँदा मलाई ज्यादै खुशी लागेको छ ।

अब म यस एसोसियशनबाट भएका कार्यहरूको विवरण यहाँहरू समक्ष प्रस्तुत गर्न गईरहेको छु ।

१. विगतका बर्षहरूमा झैं यस बर्षपनि यस एसोसियशनको बार्षिक गतिविधी तथा Research Articles हरू समावेश भएको 8th Edition of Bulletin प्रकाशन गरी यहाँहरूलाई email मार्फत Digital Copy उपलब्ध गराई सकिएको छ साथै Hard Copy पनि आजै उपलब्ध भईसकेको जानकारी गराउँदछु ।

२. बिगतका बर्षमा जस्तै यस बर्ष पनि यस एसोसियशन तथा नेपाल जियोलोजिकल सोसाइटी लगाएत अरू बिभिन्न संस्थाहरूको संयुक्त आयोजनामा IDDR Day 2022 Symposium (October 13, 2022) खानी तथा भूगर्भ विभागमा सम्पन्न भएको थियो । उक्त कार्यक्रममा यस एसोसियशनका अध्यक्ष श्री मोति बहादुर कुँवर convenor. रहनु भएको थियो ।

३. गत 20th March 2023 मा CREEW, The Small Earth Nepal, KVWSMB र GWRDB संयुक्त आयोजनामा भएको 11th National Groundwater Symposium मा यस एसोसियशनका पदाधिकारीहरू क्रमश अध्यक्ष श्री मोति बहादुर कुँवर र सचिब अनिल खत्री सहभागी हुनु भएको थियो । उक्त कार्र्यक्रममा श्री मोति बहादुर कुँवर ज्यु ले Key Note Speech दिनु भएको थियो ।

४. यस वर्ष पनि एसोसियशनको तर्फबाट विगत बर्षहरूमा झैं नयाँ वर्षको शुभकामना आदान प्रदान गरी सम्पन्न गरियो ।

५. उर्जा जलस्रोत तथा सिचाइ मन्त्रालयका सचिव, भूमिगत जलश्रोत विकास समितिका कार्यकारी निर्देशक लगायत ब्यक्तित्वहरूसंग हाइड्राजियोलोजिष्ट तथा भूमिगत जलश्रोतको संस्थागत बिकास सम्बन्धि विषयमा बिभिन्न चरणमा छलफल गरियो ।

६. यस बाहेक यस संस्थाले बाषिर्क रूपमा गर्ने नियमित गतिविधिहरू जस्तै दशैं-तिहार शुभकामना आदान प्रदान, संस्थाको प्रशासनिक काम, लेखा परिक्षण, संस्था नविकरण, बैंक खाता नविकरण जस्ता महत्व पूर्ण कार्यहरू सम्पन्न भएको छ ।

नेपाल हाइड्रोजियोलजिकल एसोसिएसनको आगामी बर्षको भाबी कार्यक्रम

१. भूमिगत जलस्रोतको क्षेत्रसँग सम्बन्धित बैज्ञानिक अनुसन्धान तथा खोजमुलक विषयमा Groundwater Talk Program सम्बन्धी कार्य संचालनको लागि उच्च प्राथमिकता दिइनेछ ।

२. नेपाल भौगर्भिक समाज (NGS), विपद व्यवस्थापन प्राधिकरण समेतका अन्य सम्बन्धित निकायहरूसँग आवश्यक समन्वय गरि अन्तरराष्ट्रिय विपद जोखिम न्यूनीकरण सम्बन्धी सशक्तिकरण कार्य (IDDR–2023 Celebration) लाई सफलतापुर्बक सम्पन्न गरिनेछ ।

३. महत्वपूर्ण लेखरचना सहित यस संस्थाको वार्षिक बुलेटिन तयार गर्ने कार्यलाई आगामी वर्ष पनि निरन्तरता दिइनेछ र Scientific Journal प्रकाशन गर्ने कार्यलाई बिशेष प्राथमिकता दिइनेछ ।

४. भूमिगत जलस्रोतसँग सम्बन्धित महत्वपूर्ण खोज अनुसन्धानलाई पहिचान गरि आवश्यक समन्वय गरेर Talk Programme/Seminar तथा Workshop संचालन गर्ने कार्यलाई उच्च प्राथमिकता दिइनेछ ।

५. यस कार्य समितिले NHA का सदस्यहरूको हकहित संरक्षण र बृतिविकासको लागि सम्बन्धित निकायमा आवश्यक पहलकदमी (Advocacy) गर्ने उद्देश्य राखेको छ । साथै भूमिगत जलस्रोतसँग सम्बन्धित संस्थालाई स्थायी, दिगो र भरपर्दो बनाउने तर्फ समेत नेपाल सरकारका बिभिन्न निकायसंग आवश्यक समन्वय गरिनेछ ।

६. भूमिगत जलस्रोतको अध्ययन, अनुसन्धान र विकासमा महत्वपूर्ण योगदान पुर्याएका व्यक्तिहरूलाई उच्च मुल्यांकन गरि स-सम्मान मानार्थ सदस्य र सम्मानपत्र प्रदान गर्ने लक्ष्य राखिएको छ ।

७. आगामी बर्षमा NHA को Fund Raising कार्यलाई अझ बढी प्रभावकारी रूपले अगाडि बढाइनेछ ।

८. समयमा लेखा परिक्षण र साधारण सभाको कार्य सम्पन्न गरि NHA को संस्था नबिकरण गर्ने र खाता संचालन गर्ने कार्यलाई प्राथमिकता दिइनेछ ।

९. NHA को Website लाई आवश्यकता अनुसार update गरिनेछ र महत्वपूर्ण तथ्यांक तथा लेख रचना एबम सूचना सामग्रीलाई समयानुकुल upload गरिनेछ ।

१०. यस आ.ब देखि हाईड्रोजियोलोजिस्टहरूको क्षमता अभिवृद्धि कार्यक्रम संचालन गरिने छ ।

अमर बहादुर चन्द ठकुरी
महासचिव

भूमिगत जलस्रोतको नियमन निकायको आवश्यकता

नेपाल हाइड्रोजियोलोजिकल एसोसिएसन (NHA) भूमिगत जलको उपयोग, आवश्यकता र उपादेयतालाई ध्यानमा राखी यसको संरक्षण, उपयोग तथा व्यवस्थापन सम्बन्धमा विभिन्न गतिविधिहरु गर्दै आइरहेको भूमिगत जलस्रोतसंग सम्बन्धित विज्ञहरुको संगठन हो । यसको प्रमुख उदेश्य सरकारी, निजि निकायहरुमा भूमिगत जलस्रोतको अध्ययन अनुसन्धान, विकास तथा व्यवस्थापन सम्बन्धमा आवश्यक राय परामर्श समेत उपलब्ध गराउने, देशको आम नागरिकमा भूमिगत जलस्रोत सम्बन्धि जनचेतना मुलक कार्य गर्ने समेत रहेको छ ।

काठमाडौं उपत्यका तथा नेपालको समग्र तराई भुभागमा पानीको मुख्य स्रोत भनेको भूमिगत पानी नै हो । स्थानअनुसारको भूमिगत जल भण्डार (Aquifer) को अवस्थिति अनुसार कुनै ठाउमा Shallow तथा Deep Aquifer बाट भूमिगत पानीको दोहन हुदैं आइरहेको छ । तराई भूभागमा बर्षैपिच्छे व्यक्तिगत, संस्थागत, सरकारी निकाय (संघ प्रदेश र स्थानियतह) हरुबाट खानेपानी , सिंचाइ, पशुपालन ,र उद्योगहरुका लागि पानीको आवस्यकता पूर्तिकालागि थुप्रै ट्युबवेलहरु निर्माण हुने गरेको भएता पनि सरकारी निकायसंग कुन ठाउमा कुन प्रकारको कति ट्युबवेलहरु निर्माण भएका छन् सोको एकिकृत अध्यावधिक तथ्यांक रहेको पाइदैन भने अत्याधिक दोहनले पार्ने असरहरुका बारेमा नेपाल सरकारका अधिकारिक निकायहरुबाट पनि पर्याप्त मात्रामा अध्ययन अनुसन्धान भएको भेटिदैन । नागरिकसंग प्रतक्ष्य सरोकार राख्ने पानीजस्तो अत्याबश्यक बस्तुमा राज्यको प्राथमिकतामा पर्न नसकेको भान हुन्छ । बढ्दो शहरीकरण, बसाई सराई, उद्योगधन्दा तथा कृषि प्रणालीहरुमा उपलब्ध भूमिगत जलस्रोतको अत्याधिक उपयोग भईरहेको अवस्था र उद्योगधन्दारुबाट जथाभावी रुपले भूमिगत जलस्रोतको दोहन तथा प्रदुषण गर्ने कार्य पनि गरिरहेको हुँदा अब यो बहुमूल्य प्राकृतिक स्रोतको उचित रेखदेख, नियमन, नियन्त्रण तथा अनुमति लिएर मात्र उपयोग गर्ने व्यवस्था गर्न नितान्त जरूरी भएको छ ।

भूमिगत जलस्रोतको अध्ययन तथा अनुसन्धान गर्ने एक मात्र सरकारी निकाय भूमिगत जलस्रोत विकास समिति आ.व.२०८०/८१ को बजेट बक्तब्यबाट खारेजीमा परेपछि भूमिगत जलस्रोतको अध्ययन तथा अनुसन्धान गर्ने आधिकारिक निकाएको अभाब खड्किएको छ । भूमिगत जलस्रोतको अत्याधिक दोहनले Thailand को Bangkok तथा चिन को Sanghai जस्ता ठूला शहरहरुमा Land subsidence को समस्या देखिएको छ भने नेपालमा पनि भूमिगत जलस्रोतको अब्यवस्थित तबरले अत्याधिक दोहन गरिदा काठमाडौँ उपत्यका तथा तराईका केहि भुभागहरुमा पानीको सतह घट्न जाँदा हातेपम्पबाट पानी तान्न नसकिने,पानी प्रदुषित हुने जस्ता समस्याहरु देखिन थालिसकेको अबस्थामा भूमिगत जलस्रोतको नियमन गर्ने आधिकारिक निकाए नहुँदा निकट भविष्यमा यो भन्दा गम्भिर समस्या नआउला भन्न सकिन्न । त्यसैले अब बन्ने उर्जा जलस्रोत तथा सिंचाई मन्त्रालय वा अन्तरगतका निकायको संगठन संरचनामा भूमिगत जलस्रोतको अध्ययन तथा अनुसन्धान र नियमन गर्न सक्ने दक्ष जनशक्ति सहितको अधिकार सम्पन्न निकायको रुपमा विकास गर्न सम्बद्ध सबैले बेलैमा विचार पुर्याउनु पर्ने देखिन्छ । उक्त कार्यमा सहभागिता तथा नेतृत्वका लागि नेपाल हाइड्रोजियोलोजिकल एसोसिएसन (NHA) सदैब तत्पर रहेको र आगामी दिन हरुमा आवश्यक गतिबिधि बढाउने प्रतिबद्धता ब्यक्त गर्दौ छौ ।

सातौ कार्यकारिणी समिति
नेपाल हाइड्रोजियोलोजिकल एसोसिएसन (NHA)

AUDITOR'S REPORT (2079/80)

Reg. No. 2780 PAN No. 500020911

M.K. Paudel & Company
Registered Auditor
Gokarneshwor-5, Kathmandu

INDEPENDENT AUDITOR'S REPORT

TO

M/s Nepal Hydro Geological Association

We have audited the accompanying Balance Sheet of M/s **Nepal Hydro Geological Association Babarmal-11,**Kathmandu,Nepal For The Year ended On Ashad 31,2080 (16,July 2023) the related Statements of Income & Expenditure Statement of Changes in Equity and Cash-Flow for the year ended and significant Accounting Policies and Notes to Accounts.
Management is the responsibility for the preparation and fair presentation of these financial statements in accordance with Nepal Accounting Standards.This responsibility includes; designing, implementing and maintaining internal control relevant to the preparation and fair presentation of financial statement that are free from material misstatement, whether due to fraud or error; selecting and applying appropriate accounting policies; and making accounting estimate that are reasonable in the circumstances.

Our responsibility is to express an opinion on these financial statements based on our audit. We conducted our audit in accordance with Nepal Standards on Auditing or relevant practices. Those Standards or relevant practices require that we plan and perform the audit to obtain reasonable assurance about whether the financial statements are free from material misstatement. An audit includes examining, on a test basis, evidence supporting the amounts and disclosures in the financial statements. An audit also includes assessing the accounting principles used and significant estimates made by management, as well as evaluating the overall presentation of the financial statements. We believe that our audit evidence we obtained is sufficient and appropriate to provide a reasonable basis for our audit opinion.

In our opinion, the accompanying financial statements give a true and fair view of in all material respects, the financial position of the organization as On Ashad 31,2080 (16,July 2023) End of the results of its operations and its Cash Flows for the year then ended in accordance with Nepal Accounting Standards or relevant practices and comply with rules and regulation of related government departments.

(For M.K.Paudel & Company)
Registered Auditor
UDIN Number : 230912RA0052244vSg

Date : 2080.05.26
Place : Kathmandu,Nepal

Tel.: 01-4435666 Email: maheshkpaudel@gmail.com

Nepal Hydrogeological Association
Kathmandu, Nepal
Balance Sheet
As on Ashad 31, 2080

Particulars	Note	As on Ashad 31 2080	As on Ashad 32 2079
A. Source of Funds:			
Reserve Funds		101,958	(32,844)
Total		**101,958**	**(32,844)**
B. Application of Funds			
Fixed Assets	1	-	-
Current Assets:			
Sundry Debtors and Advances	3	83,972	34,280
Cash and Bank Balances	4	32,987	77,876
Total Current Assests		**116,959**	**112,156**
Current Liabilities			
Sundry Creditors	5	-	-
Other payables	6	15,000	145,000
Total Current Liabilities		**15,000**	**145,000**
Net Current Assets		**101,959**	**(32,844)**
Total		**101,959**	**(32,844)**

Significant accounting policies & Notes to account — 8

As per our Report of Even Date

Treasurer

Chairperson

M. K. Paudel and Company
Gokarneshwor-5
Kathmandu
Registered Auditor

Auditor

Date:
Place: Kathmandu

Nepal Hydrogeological Association
Kathmandu, Nepal

Income Statement

For the year ended Ashad 31, 2080

Particulars	Note	Current Year	Previous Year
Income			
Membership Fee		19,000	37,200
AGM Registration Fee		30,000	30,000
General Donation		25,000	
Interest Income		3,657	3,212
Other Income		8,000	-
Donation for Bulletin		364,200	45,000
Total incomes		**449,857**	**115,412**
Expenses			
Project Expenses		-	-
Administrative Expenses	7	315,055	297,043
Depreciation		-	-
Finance Costs		-	-
Total Expenses		**315,055**	**297,043**
Surplus/(Deficit)		**134,802**	**(181,631)**

Significant accounting policies & Notes to account — 8

As per our Report of Even Date

M. K. Paudel and Company
Gokarneshwor-5
Kathmandu
Registered Auditor

Treasurer

Chairperson

Auditor

Date:
Place: Kathmandu

Nepal Hydrogeological Association
Kathmandu, Nepal
Cash Flow Statement
For the year ended Ashad 31, 2080

Particulars		Current Year	Previous Year
A.	**Operating Activities:**		
	Profit after tax	134,802	(181,631)
	Add:		
	Depreciation	-	-
	Cash Flow before change in Working Capital	**134,802**	**(181,631)**
	Decrease/(Increase) in Current Assets	(49,691)	73,211
	Increase/ (Decrease) in Current Liabilities	(130,000)	121,000
	Net Cash Flow from Operating Activities	**(44,889)**	**12,581**
B.	**Investment Activities:**		
	(Purchase of Fixed Assets)	-	-
	Decrease/(Increase) in Investments		
	Net Cash Flow from Investment Activities	-	-
C.	**Financial Activities:**		
	Increase/(Decrease) in Capital funds	-	-
	Increase in Loan and advances	-	-
	Net Cash Flow from Financial Activities	-	-
	Total Cash Flow (A+B+C)	**(44,889)**	**12,581**
	Opening Cash & Bank Balance	77,876	65,295
	Closing Cash & Bank Balance	**32,987**	**77,876**

Significant accounting policies & Notes to account 8

As per our Report of Even Date

M. K. Paudel and Company
Gokarneshwor-5 Kathmandu
Auditor
Registered Auditor

Treasurer

Chairperson

Date:
Place: Kathmandu

Nepal Hydrogeological Association
Kathmandu, Nepal
Note Forming Part of the Accounts
For the year ended Ashad 31, 2080

Note - 1

Property, Plant & Equipment

Particulars	Dep Rate	Opening Balance	Addition Upto			Disposal	Total	Depreciation Base	Depreciation	Closing Balance
			Poush	Chaitra	Asadh					
Non-Depreciable Assets										
		-	-	-	-	-	-	-	-	-
Depreciable Assets							-	-	-	
Pool 'B'	25%						-	-	-	
							-	-	-	
		-	-	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-	-
Pool 'C'	20%						-	-	-	
		-	-	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-	-
Pool 'D'	15%						-	-	-	
		-	-	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-	-
Pool 'E'							-	-	-	
		-	-	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-	-
Total		-	-	-	-	-	-	-	-	-

M. K. Paudel and Company
Gokarneshwor-5
Kathmandu
Registered Auditor

Nepal Hydrogeological Association
Kathmandu, Nepal
Notes to Financial Statements
For Fiscal Year 2079-80

Capital Fund — Note -2

Particulars	Current Year	Previous Year
Reserve Upto Previous year	(32,844)	148,787
Reserve this year	134,802	(181,631)
Total	**101,958**	**(32,844)**

Sundry Debtors and other Receivables — Note -3

Particulars	Current Year	Previous Year
Sundry Debtors	-	33,950
Advance paid for Buletin	82,223	-
TDS Receivables	1,749	330
Total	**83,972**	**34,280**

Cash & Bank Balances — Note -4

Particulars	Current Year	Previous Year
Cash and Bank Balance as certified by management		
Cash in hand	-	-
NMB Bank	32,987	77,876
Total	**32,987**	**77,876**

Sundry Creditors — Note -5

Particulars	Current Year	Previous Year
Account Payable		-
Total	-	-

Other Payables — Note -6

Particulars	Current Year	Previous Year
Audit Fee Payable	14,800	14,800
TDS on Audit Fee	200	200
Other Payables	-	130,000
Total	**15,000**	**145,000**

Administrative Expenses — Note -7

Particulars	Current Year	Previous Year
Audit Fees	15,000	15,000
Registration and renewal expenses	2,750	5,750
Traveling Expenses	-	1,000
Flex and printing expenses	45,882	8,140
AGM Expenses	215,728	96,523
Website Expenses	3,000	23,000
Cleaning Expenses	1,000	-
Courier Expenses	325	-
Office Expenses	6,500	-
Refreshment and Tea Expenses	6,660	6,264
Water Expenses	3,000	280
Mask and Paper cup Expenses	410	-
Other Expenses	-	7,518
Stationery expenses	14,800	3,068
Newspaper and Buletin publishing Expenses	-	130,000
Telephone Expenses	-	500
Total	**315,055**	**297,043**

M. K. Paudel and Company
Gokarneshwor-5
Kathmandu
Registered Auditor

NEPAL HYDROGEOLOGICAL ASSOCIATION **NOTE-8**

NOTES TO THE FINANCIAL STATEMENTS
For the year ended 31 Ashadh 2080

1. GENERAL INFORMATION

Nepal Hydrogeological Association is a NGO established in Nepal under District Administration Office, Kathmandu and at Inland Revenue Office with PAN- 304960556. The registered office of the organisation is located at Kathmandu, Nepal.

2. SIGNIFICANT ACCOUNTING POLICIES AND KEY ACCOUNTING ESTIMATES AND JUDGEMENTS

2.1 Basis of Preparation

The balance sheet, statement of Income and Expenditure, Fund flow Statement and statement of cash flows, together with the accounting policies and other explanatory notes of the Company for the year are prepared in accordance with Nepal Accounting Standards ("NAS") issued by Accounting Standards Board, Nepal ("ASB") except where stated otherwise.

The financial statements are prepared under the historical cost convention.

2.2 Use of Estimates

The preparation of the financial statements is in conformity with Nepal Accounting Standards requires management to make estimates and assumptions that affect the reported amounts of assets and liabilities at the date of Balance Sheet. Actual amount could differ from those estimates. Any differences from those estimates are recorded in the period in which they are identified.

2.3 Going Concern

The financial statements are prepared on the assumption that the Company is a going concern.

2.4 Revenue Recognition

Initial Recognition and Measurement

Revenue is recognized to the extent that it is probable that the economic benefits will flow to the company and the revenue and associated costs incurred or to be incurred can be reliably measured.

2.5 Expenses

Expenses are recognized on accrual basis.

2.6 Cash and Cash Equivalents

Cash and cash equivalents are defined as cash in hand, demand deposits and short-term highly liquid investments, readily convertible to known amounts of cash and subject to insignificant risk of changes in value. For the purpose of cash flow statements, cash and cash equivalents consist of cash in hand and deposits in banks presented in Note-4.

2.7 Investment

No investment has been made by the company during the current financial year.

2.8 Provisions and Contingent Liabilities:

There are no any contingent liabilities of the company till the date of preparation of Financial Statements.

2.9 Subsequent Event:

No event has occurred subsequent to audit period that would require adjustment or disclosure in the financial statement.

2.10 Comparative figure

Previous period figures have been regrouped or rearranged wherever necessary. Figures are presented in Nepalese Rupees and rounded off to the nearest Rupee.

M.K. Paudel and Company
Gokarneshwor-5
Kathmandu
Registered Auditor

१३ औं वार्षिक साधारण सभाका झलकहरू


NEPAL HYDROGEOLOGICAL ASSOCIATION
१२ औं बार्षिक साधारण सभा
तथा द्विवार्षिकी कार्यक्रम


NEPAL HYDROGEOLOGICAL ASSOCIATION
१३ औं बार्षिक साधारण सभा
तथा द्विवार्षिकी कार्यक्रम
13th AGM and Biennial Function


NEPAL HYDROGEOLOGICAL ASSOCIATION

CONGRATULATIONS

Promotions/Appointments/Academic Award

Nepal Hydrogeological Association extends its heartiest congratulations to the following members of the society for their achievements. Also wishes for their successful tenure.

Prof. Dr. Dinesh Pathak (LM55)
Appointed to Head of Department,
Central Department of Geology,
TU, Nepal

Date of Appointment: 2080-10-24

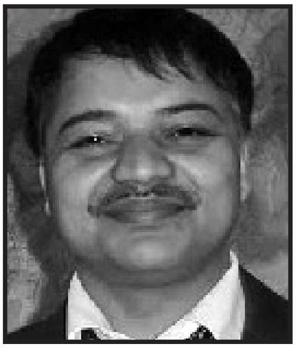
Dr. Dilli Ram Thapa (LM 97)
Appointed to Head of Department,
Department of Geology, Birendra Multiple Campus,
Chitwan, Nepal

Date of Appointment: 2081-03-01

Promotions

Ms. Monika Jha (LM 150)
Deputy Director General,
Department of Mines and Geology,
Government of Nepal

Date of Promotion: 2080-08-17



Dr. Mukunda Bhattarai (LM 153)
Senior Divisional Geologist,
Department of Mines and Geology,
Kathmandu

Date of Promotion: 2080-11-15

Mr. Bikash Thakur (LM 79)
Senior Divisional Hydrogeologist (Officer 9th level),
Groundwater Resources and Irrigation Development
Division, Sarlahi

Date of Promotion: 2080-09-04

Mr. Nayan Pokhrel (LM 70)
Senior Divisional Hydrogeologist (Officer 9th level),
Groundwater Resources and Irrigation Development Division,
Mahottari

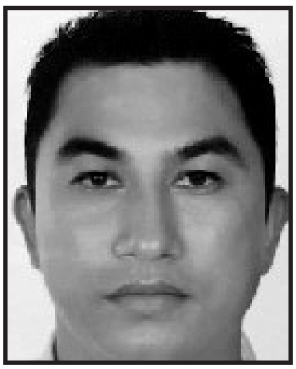
Date of Promotion: 2080-09-04

Ms. Alina Karki (LM 84)
Assistant Manger (8th level),
Geological Investigation Department,
Nepal Electricity Authority, Nepal

Date of Promotion: 2080-10-18

Mr. Keshav Jaisi (LM 159)
Senior Divisional Hydrogeologist (Officer 9th level), Groundwater Resources and Irrigation Development Division, Chitwan

Date of Promotion: 2080-12-08



Mr. Kedar Shrestha (LM 152)
Senior Divisional Hydrogeologist (Officer 9th level), Groundwater Resources and Irrigation Development Division, Kavre

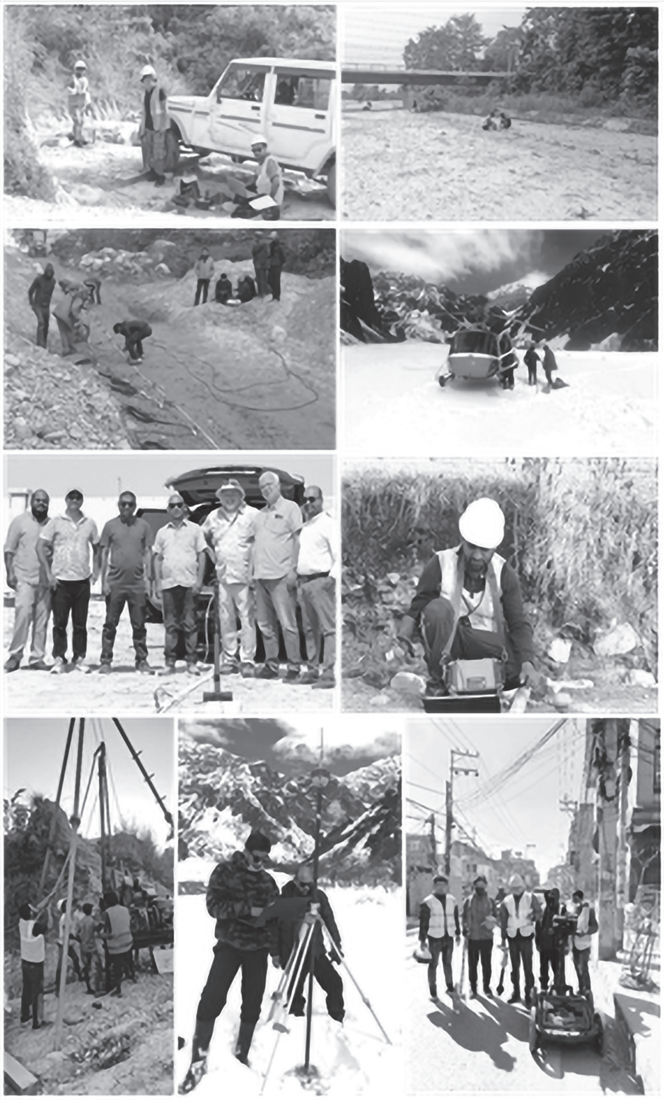
Date of Promotion: 2081-04-06

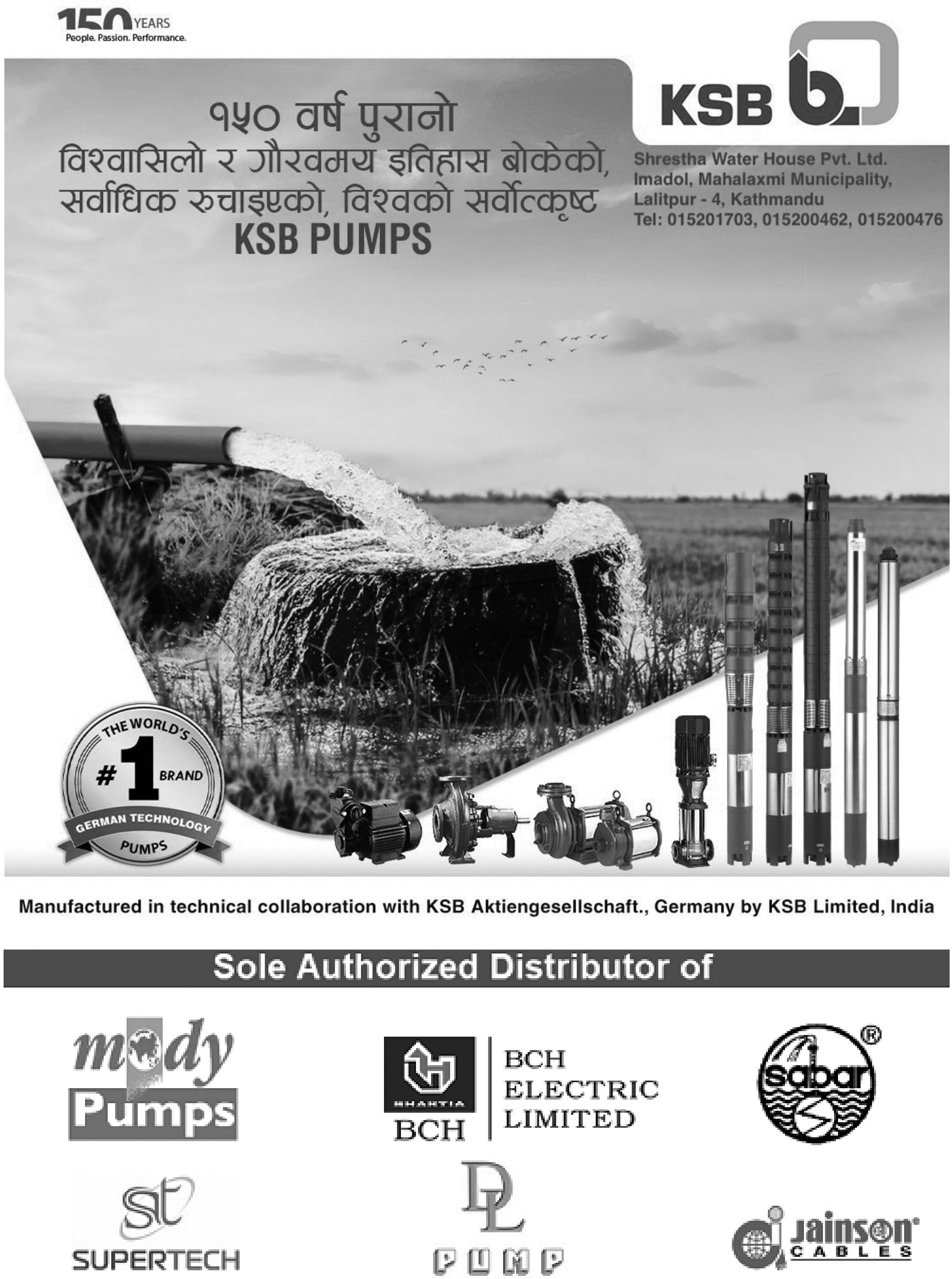
जन्म मिति :२००६/१२/१९ **स्वर्गारोहण:२०८०/०७/१७**

यस नेपाल हाइड्रोलोजिकल एसोसियसनको आजिबन सदस्य तथा संस्थापक अध्यक्ष **स्व. श्री जितेन्द्र घिमिरे**ज्यु को मिति २०८०/०७/१७ भएको असामयिक निधनले यस नेपाल हाइड्रोलोजिकल एसोसियसन मा आबद्ध सम्पूर्ण पदाधिकारी तथा सदस्यहहरुलाई अत्यन्तै मर्माहत र स्तब्ध बनाएको छ। यस दुखद घडीमा देहमुक्त आत्माको चिर-शान्ति तथा बैकुण्ठ बासको कामना गर्दै भावपूर्ण श्रदान्जलि अर्पण गर्दछौ साथै शोकाकुल परिवारजनामा धैर्यधारण गर्न सक्ने शक्ति प्राप्त होस् भन्ने कामनाका साथ हार्दिक समबेदना ब्यक्त गर्दछौ।

जन्म मिति :२००९/०१/२८ **स्वर्गारोहण:२०८०/०९/२३**

यस नेपाल हाइड्रोलोजिकल एसोसियसनको आजिबन सदस्य **स्व. नवराज श्रेष्ठ**ज्यु को मिति २०८०/०९/२३ भएको असामयिक निधनले यस नेपाल हाइड्रोलोजिकल एसोसियसन मा आबद्ध सम्पूर्ण पदाधिकारी तथा सदस्यहहरुलाई अत्यन्तै मर्माहत र स्तब्ध बनाएको छ। यस दुखद घडीमा देहमुक्त आत्माको चिर-शान्ति तथा बैकुण्ठ बासको कामना गर्दै भावपूर्ण श्रदान्जलि अर्पण गर्दछौ साथै शोकाकुल परिवार जनामा धैर्यधारण गर्न सक्ने शक्ति प्राप्त होस् भन्ने कामनाका साथ हार्दिक समबेदना ब्यक्त गर्दछौ।




150 YEARS
People. Passion. Performance.
KSB
१५० वर्ष पुरानो
विश्वासिलो र गौरवमय इतिहास बोकेको,
सर्वाधिक रुचाइएको, विश्वको सर्वोत्कृष्ट
KSB PUMPS
Shrestha Water House Pvt. Ltd.
Imadol, Mahalaxmi Municipality,
Lalitpur - 4, Kathmandu
Tel: 015201703, 015200462, 015200476
THE WORLD'S #1 BRAND
GERMAN TECHNOLOGY
PUMPS
Manufactured in technical collaboration with KSB Aktiengesellschaft., Germany by KSB Limited, India
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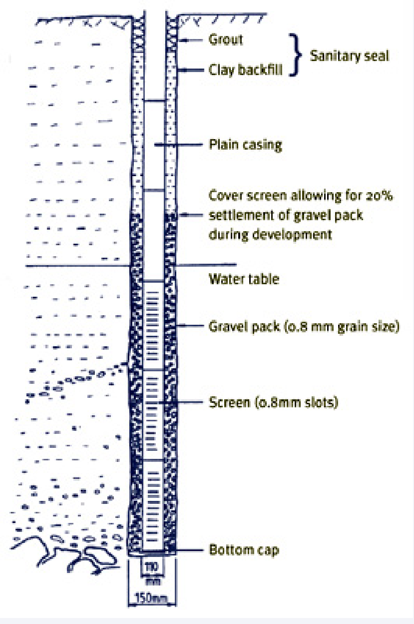
mody Pumps
BCH
BCH ELECTRIC LIMITED
sabar
SUPERTECH
DL PUMP
Jainson CABLES

- खोला, नाला, ताल, तलैया, पोखरी तथा अन्य जलस्रोतको संरक्षण गरौं।
- जलस्रोतको उचित प्रयोग र व्यवस्थापन गरौं।
- वातावरण संरक्षण गरी जलवायू परिवर्तनबाट हुने असरलाई न्यूनिकरण गरौं।
- जल-उत्पन्न विपद्बाट बचौं र बचाऔं।
- नवप्रवर्तन तथा वैज्ञानिक प्रविधिलाई प्रोत्साहन गरौं।

नेपाल सरकार
ऊर्जा, जलस्रोत तथा सिंचाइ मन्त्रालय
जलस्रोत अनुसन्धान तथा विकास केन्द्र
पुल्चोक, ललितपुर


Grout
Clay backfill
Sanitary seal
Plain casing
Cover screen allowing for 20% settlement of gravel pack during development
Water table
Gravel pack (0.8 mm grain size)
Screen (0.8mm slots)
Bottom cap
110 mm
150mm

Best Wishes and Success

To,

Nepal Hydrogeological Association (NHA)

On the occassion of it's

14th Annual General Meeting

From

Groundwater Resource and Irrigation Development Division

Jaleshwor, Mahottari

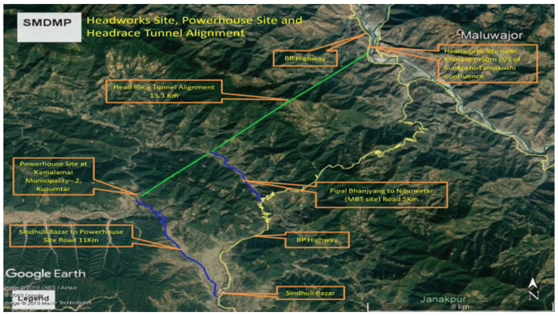
राष्ट्रिय गौरवको रुपान्तरणकारी

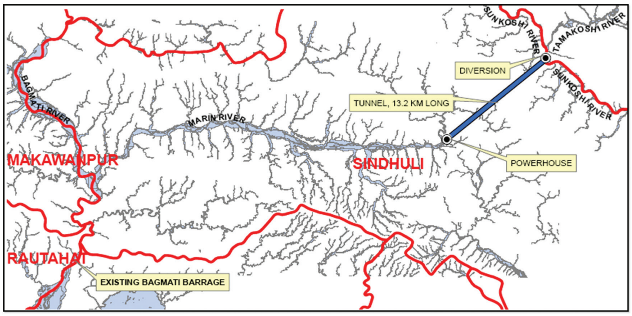
सुनकोशी मरिन डाईभर्सन बहुउद्देश्यीय आयोजना, सिन्धुली

१. आयोजनाको परिचय

सुनकोशी मरिन डाइभर्सन बहुउद्देश्यीय आयोजना सिन्धुली र रामेछाप जिल्लाको सिमानामा अवस्थित सुनकोशी नदीको पानीलाई बाँध बाँधी १३.३ कि.मी. लामो सुरुङ मार्फत मरिन नदीमा पानी पथान्तरण गरि प्राप्त हुने ६६.२९ मिटर को Gross Head को उपयोगले करिब ३१.०७ मेगावाट जलबिद्युत उत्पादन हुने बहुउद्देश्यीय आयोजना हो। विद्युत उत्पादन पश्चात निस्केको पानी मरिन नदीमा मिसाई बाग्मती नदी हुँदै बाग्मती सिंचाइ आयोजनाको पूर्वी तथा पश्चिम नहरबाट क्रमशः ७६,४०० हे. र ४५,६०० हे. गरी जम्मा १,२२,००० हे. जमिनमा वर्षै भरी सिंचाइ सुविधा पुऱ्याउने लक्ष्यका साथ राष्ट्रिय गौरव तथा रुपान्तरणकारी आयोजनाको रूपमा कार्यान्वयनको चरण मा छ।यस आयोजनाको कुल लागत अनुमान रु. ४९ अर्ब ४२ करोड ३१ लाख रहेको छ।

यस आयोजना अन्तरगत सिन्धुली जिल्लाको खुर्कोट देखि लगभग २ कि. मि. माथि (सुनकोशी र तामाकोशी को दोभान भन्दा करिब ९०० मि. तल) सुनकोशी नदीमा बाँध निर्माण हुने छ भने बिद्युत गृह, सर्जसाफ्ट, स्विचयार्ड कमलामाइ न.पा. -२ कुसुमटार सिन्धुलीमा पर्दछ।





सुनकोशी मरिन डाइभर्सन बहुउद्देश्यीय आयोजनाको हेडवर्क्स (बाँधस्थल), पावर हाउस (विद्युतगृह), हेडरेस टनेल (सुरुङ्ग), मारिन नदी र बागमती ब्यारेज को अवस्थिति

यस आयोजनाको निर्माण कार्य आ.व. २०७७/७८ मा शुरु गरी आ.व. २०८५/८६ सम्ममा सम्पन्न गर्ने लक्ष्य रहेको छ।

२. दीर्घकालीन दृष्टिकोण

२.१ आयोजनाको दूरदृष्टी

"सक्षम र सुदृढ सार्वजनिक क्षेत्रको माध्यमबाट आधुनिक प्रविधिको सफल प्रयोग मार्फत अन्तर जलाधार जल स्थानान्तरण तथा बहुउद्देश्यीय जलस्रोत आयोजनाहरुको विकास गरी जल विद्युत उत्पादनको साथै कृषि योग्य भूमिमा बाह्रै महिना सिंचाइ सुबिधा उपलब्ध गराई कृषि उत्पादन र उत्पादकत्व वृद्धि गर्दै देशको दिगो आर्थिक विकास हासिल गर्न सहयोग पुऱ्याउने मूलभूत लक्ष्य रहेको छ।"

२.२ आयोजनाको उद्देश्य

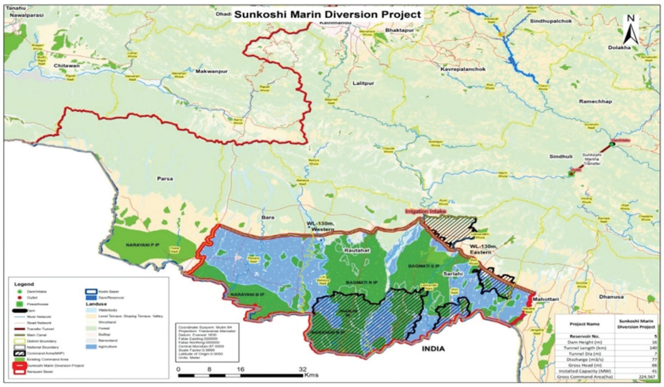
आ.व. २०८४।०८५ सम्म आयोजना सम्पन्न गरी मधेस प्रदेशको वाग्मती सिंचाइ आयोजनाबाट हाल ४५,६०० हेक्टर जमीनमा सिंचाइ सुविधा उपलब्ध भइरहेकोमा सुनकोशी मरिन डाइभर्सन बहुउद्देश्यीय आयोजनाको पावर हाउसको टेलरेसबाट निस्केको ६७,००० लिटर प्रति सेकेन्ड पानी मरिन नदीमा खसाली धनुषा, महोत्तरी, सर्लाही, रौतहट र बारा जिल्लाहरु अन्तरगतको कूल १,२२,००० हेक्टर जमीनमा वर्षैभरी सिंचाइ सुविधा पुऱ्याउने प्रमुख उद्देश्य रहेको यस आयोजनाबाट ३१.०७ मेगावाट जल विद्युत उत्पादन गरी देशको उर्जा क्षेत्रमा थप योगदान दिनेछ। यस आयोजनाका थप उद्देश्यहरू निम्नानुसार रहेका छनः-

- १३.३ किलोमिटर लामो तथा Lesser Himalaya को भौगर्भिक अवस्था को सुरूङ्ग निर्माणमा Double Shield Tunnel Boring Machine (TBM) को सफल प्रयोग गर्ने,
- जलस्रोत तथा सिंचाइ क्षेत्रमा कार्यरत क्रियाशिल प्राविधिकहरुको नयाँ प्रविधिको उपयोग गर्दै प्राविधिक दक्षता वृद्धि गर्ने,
- सुनकोशी, तामाकोशी र मरिन नदीबाट प्रभावित स्थानहरूमा वातावरणीय, सामाजिक, पूर्वाधार विकासका कार्यक्रमहरू संचालन गरी जीवनयापनलाई सहज र समृद्ध बनाउने ।

२.३ आयोजनाबाट हुने फाइदा

सुनकोशी मरिन डाइभर्सन बहुउद्देश्यीय आयोजनाको विकासबाट निम्नानुसारका उपलब्धिहरू हासिल हुनेछन् ः

- सुनकोशी मरिन डाइभर्सन बहुउद्देश्यीय आयोजनाको विकासबाट धनुषा, महोत्तरी, सर्लाही, रौतहट र बारा जिल्ला अन्तर्गतको कुल १,२२,००० हेक्टर जमीनमा वर्षैभरी सिंचाइ सुविधा पुगी कृषि एवं नगदेबालीको उत्पादन र उत्पादकत्व वृद्धि भै आत्मनिर्भर अर्थतन्त्रमा सघाउ पुग्नुका साथै ३१.०७ मेगावाट जलविद्युतको उत्पादनबाट औद्योगिक विकासमा टेवा पुग्नुका साथै अन्य आमोद-प्रमोद, पर्यटन तथा वातावरणीय उपलब्धिहरू हासिल हुनेछन् ।



आयोजनाको सिंचित क्षेत्रको नक्सा

सुनकोशी मारिन डाइभर्सन बहुउद्देश्यीय आयोजनाको विकासबाट हाल संचालनमा रहेको वाग्मती सिंचाइ आयोजनामा दिगो रूपमा सर्लाही, धनुषा, महोत्तरी, रौतहट र बारा जिल्लाका

कृषियोग्य जमिनमा बाह्रै महिना सिंचाइ सुविधा पुऱ्याउनुको साथै सतह र भूमिगत जलस्रोतको संयोजनात्मक रुपमा उपयोग गरी उर्वर भूमिबाट कृषि उत्पादन तथा उत्पादकत्व वृद्धि गरि हाल कृषिमा भएको आयातको असन्तुलन (Trade Deficit) कम गर्न मद्दत पुऱ्याउनेछ। आयोजनाको विकासबाट जलस्रोत तथा सिंचाइ विभागमा कार्यरत प्राविधिक जनशक्तिको बहुद्देश्यीय तथा अन्तर जलाधार जलस्रोत आयोजनाहरुको विकासको लागि क्षमता अभिवृद्धि हुनुको साथै यस्तै प्रकृतिका अन्य आयोजनाहरु निर्माण गर्न सहयोगी सिद्ध हुनेछ ।

- यस आयोजनाले मरिन नदी नियन्त्रण तथा मरिन नदी किनार स्थित कृषक कुलोहरुको समेत पुनःस्थापना गर्ने गरि गुरुयोजनामा समेटेको छ । आयोजनाको कार्यान्वयन संगै सो गुरुयोजनाको समेत कार्यान्वयन हुने र मरिन नदी आसपासका वासिन्दाका आर्थिक समुन्नती हुनेछ। डुबानमा पर्ने जग्गाको सुरक्षाका साथै हात्तीटार स्थित करिब २७ हेक्टर जग्गाको उकास गरी वर्षौं देखि भोगचलन गरिरहेका माझी समुदायलाई नै हस्तान्तरण गर्ने कार्यले अल्पसंख्यक तथा सिमान्तकृत समुदायको समुत्थानमा सहयोग पुग्नेछ ।
- आयोजना संचालन पश्चात सुनकोशी र तामाकोशी क्षेत्रमा बसोवास गर्ने जनसंख्याको वहुआयामिक विकास हुनेछन । सो क्षेत्रमा माछा पालनदेखि आन्तरिक तथा बाह्य पर्यटनको उल्लेख्य वृद्धी हुनुका साथै मनोरन्जन तथा ताल/जलाशयमा पर्यटन व्यवसाय समेत फस्टाउने निश्चित छ । यसले गर्दा यहाँका स्थानिय वासिन्दाको आयआर्जन वृद्धि भई जिवनस्तरमा सुधार हुनेछ ।

२.४ आयोजनाको बर्तमान अवस्था

आयोजनाको पहिलो चरणको कार्य अन्तर्गत सुरुङ्ग निर्माणको लागि निर्माण व्यबसायी M/S China Overseas Engineering Group Co. Ltd., China (COVEC) संग 19th March, 2021 मा निर्माण सम्झौता भै निर्माण कार्य तिब्र गतिमा भैरहेको छ। TBM Inlet Portal, Segment plant, Crushing plant, TBM Platform, Batching Plant, Starter Tunnel को निर्माण कार्य सम्पन्न भएको छ TBM

Re–engineering कार्य सम्पन्न भई TBM को सम्पूर्ण सामान साईटमा आइपुगेको तथा TBM Backup System को जडान कार्यसम्पन्न भई TBM Assembly at site (जडान कार्य) समेत सम्पन्न भएको छ । तथा मिति २०८१ अषाढ मसान्तसम्म सुरुङ्गको ब्रेक थ्रु भई सकेको छ। आयोजनाको दोस्रो चरणको कार्य अन्तर्गत बाँध (Barrage), Surge Shaft, बिद्युत गृह र हाइड्रो-मेकानिकल लगायतका संरचना हरुको निर्माण कार्यको साथै सिन्धुली

आयोजनाको हेडवर्क्स बाँधस्थल) को 3D चित्र

जिल्लाको खुर्कोटबाट करिब २ कि.मि.काठमाडौं तर्फ सुनकोशी नदीमा करिब ३० मि. अग्लो १५२ मि. लम्बाइको बाँध (Barrage) निर्माण हुँदा बि.पि. राजमार्गको ९६५ मि. सडकको केहि भाग डुबानमा पर्ने तथा केहि भागमा बाँध (Barrage) का संरचना (जस्तै Intake, Approach Culvert, Settling Basin, Head pond, Power Conduit) बन्ने भएकोले उक्त लम्बाईको सडक Realign गर्नु पर्ने भएको हुनाले सोको लागि Traffic Diversion गर्न २.९६ कि.मी. सडक Service road निर्माण कार्य समेत रहेको छ । Headworks Package को निर्माण कार्यको ठेक्का सम्झौता मिति २०७९/०९/१७ मा भई प्रारम्भिक तयारीका कार्यहरुका साथै Coffer dam निर्माण कष्तभ अकउ निर्माण Batching / Crusher Plant जडान कार्यहरु गरेको छ । जग्गा अधिग्रहणको सम्बन्धमा सिन्धुली जिल्ला तर्फको जग्गाको मूल्याङ्कन सम्पन्न भइ मुआब्जा बितरणको कार्य सम्पन्न भैसकेको छ भने रामेछाप जिल्ला अन्तर्गतको डुवानमा पर्ने जग्गाको मूल्याङ्कन सम्पन्न भइ मुआब्जा बितरणको कार्य भइरहेको छ ।

सुरुङ्ग निर्माणको लागि TBM मेसिन जडानको क्रममा

TBM द्वारा आयोजनाको सुरुंग ब्रेक थ्रु

Coffer dam को निर्माण कार्य हुँदै

Concreting of foundation of block in stilling basin.

हाल सम्म आयोजनाको कुल लक्ष्य/प्रगति

- भौतिक लक्ष्यः ३४.४०% (२०८१ अषाढ मसान्त सम्म) * हासिल प्रगतिः ३४.४०%
- वित्तीय लक्ष्यः ३४.४०% (२०८१ अषाढ मसान्त सम्म) * हासिल प्रगतिः ३०.९६%

वार्षिकको तुलनामा आयोजनाको कुल हाल सम्मको लक्ष्य/प्रगति

- भौतिक लक्ष्यः १००% (२०८१ अषाढ मसान्त सम्म) * हासिल प्रगतिः ११८.११%
- वित्तीय लक्ष्यः १००% (२०८१ अषाढ मसान्त सम्म) * हासिल प्रगतिः ९८.०९%

२.५ सामाजिक विकास कार्यक्रमहरु

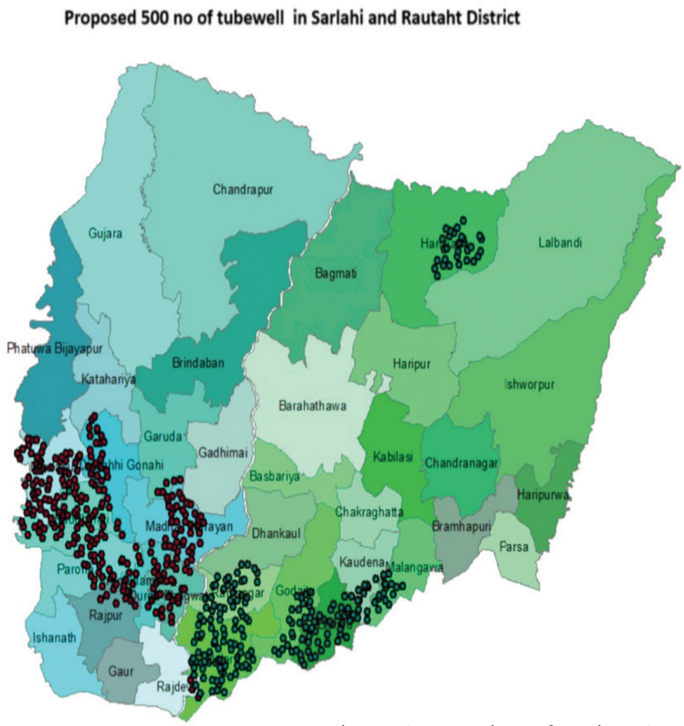
सुनकोशी मरिन बहुउद्देश्यीय आयोजनाले सामाजिक दायित्व तथा वातावरणीय सुधारका कार्यक्रम अन्तर्गत विभिन्न कार्यक्रमहरु संचालन गर्ने छ। यस अन्तर्गत Headworks को डुबान क्षेत्र र मरिन नदीमा निर्माण हुने पावरहाउस क्षेत्रमा नदी नियन्त्रण, सडक, सिंचाइ कुलो, लिफ्ट सिंचाइ, खानेपानी लगायतका कार्यक्रमहरु आवश्यकता अनुरुप संचालन हुनेछन्। यस बाहेक आयोजनाबाट प्रत्यक्ष वा अप्रत्यक्ष रुपमा प्रभावित समुदायमा विभिन्न सीप विकास तथा क्षमता अभिवृद्धिका विभिन्न कार्यक्रमहरु समेत संचालन भैरहेका छन्।

आयोजना परिचय

नविनतम यान्त्रिक सिंचाइ आयोजना

नविनतम यन्त्रिक सिंचाइ आयोजना मधेश प्रदेशको सर्लाही तथा रौतहट जिल्लामा भूमिगत जलको प्रयोग बाट करिव ४०,०००.०० हे. जमिनमा १००० वटा डिप ट्यूववेल सिंचाई प्रणाली मार्फत बर्षभरी भरपर्दो सिंचाइ सुविधा पुर्याउने गरी अध्ययन गरिएकोमा हाललाई ५०० वटा डिप ट्यूबवेल सिंचाई प्रणाली मार्फत २२४०० हे. जमिनमा वर्षेभरी भरपर्दो सिंचाइ सुबिधा पुर्र्याउने लक्ष्यका साथ अगाडी वढाइएको आयोजना हो। आ.व. २०७८-७९ बाट बजेट लाइन प्राप्त भै आयोजनाको कार्यालय स्थापना भएको यस आयोजनाले ५०० वट डिप ट्यूबबेल सिंचाई प्रणाली ४ बर्ष मा निर्माण सम्पन्न गरी जलश्रोत तथा सिंचाई विभागको इतिहासमै पहिलो पटक Design, Built and Operation (DBO) ठेक्का पद्दति बाट १० बर्ष पानी संचालन तथा मर्मत संभार गर्न ठेक्का व्यवस्थापन (जम्मा १४ बर्ष) गर्ने तथा तत्पश्चात आयोजनाको व्यवस्थापन, संचालन मरम्मत तथा सम्भार नेपाल सरकारकै ५१% शेयर हुने सिंचाइ व्यवस्थापन कम्पन्नी लिमिटेडले गर्ने लक्ष्य राखिएको छ। एशियाली बिकास बैंकको Consultation Mission अनुशार आयोजना लागत १६० मिलियन अमेरिकन डलर रहेकोमा १२५ मिलियन अमेरिकन डलर एशियाली बिकाश बैंकको ऋण तथा अनुदान सहयोग तथा बाँकी ३५ मिलियन नेपाल सरकार ले व्यहोर्ने उल्लेख भएको यस आयोजनाको ऋण सम्झौता सन् २०२४ सेप्टेम्बरमा हुने तय गरिएको छ। त्यस्तै निर्माणकर्ता कम्पनीले गरेको डिजाइनको स्वीकृति, उसले गरेको कामको सुपरिबेक्षण, करार ब्यबस्थापन र यस्तै प्रकृतिको नयाँ आयोजनाको तयारि गर्न Project Management, Design and Supervision Consultant लाई ६ बर्षको लागी नियुक्ति गरिने छ। आयोजनाको दिगोपनाको आधारनै किसानको निर्वाहमुखी कृषि बाट ब्यबसायिक कृषिमा हुने रुपान्तरण भएकोले त्यस क्षेत्रमा हुन सक्ने कृषिको नयाँ प्रजातीको बिउ, बिजनको अनुसन्धान र विकास, कृषकलाइ जीविकोपार्जनको लागि गरिने कृषिबाट ब्यबसायिक कृषिमा रुपान्तरण गर्न तालिम, सहकारी मार्फत कृषि आधुनिकीकरणका मेशिन, उपकरण प्रदान गर्नुको साथै ऋयमि क्तयचबनभ निर्माण सहितको कार्य गर्न कृषक सहयोगी कार्यक्रम लागु गर्ने एउटा बिदेशी बिज्ञ सहितको बिदेशी र स्वदेशी परामर्शदाताले आयोजनाको निर्माण कार्य संगै कृषि विकासको कार्य गर्ने छन्।

तसर्थ आयोजना डिजाइनको क्रममा Hydrogeological Modelling मार्फत ट्यूबवेलको संख्या र अवस्थिति यकीन गरिएको, सिंचाई संरचना निर्माणमा आधुनिक प्रविधि प्रयोग गरी आयोजनाको निर्माण, प्रस्तावित सिंचित क्षेत्रमा कृषिका नया प्रजाती अनुसन्धान र बिकाश, कृषकलाई कृषि बिकास सम्बन्धी आवश्यक तालिम र सहयोग उपलब्ध गराउन स्वदेशी तथा बिदेशी परामर्शदाता नियुक्तिका साथै सिंचाई शुल्क र त्यसको ब्यबस्थापन गर्न सिंचाई ब्यबस्थापन कम्पनी हुने भएकोले आयोजनाको दिगो ब्यबस्थापन सुनिस्चित भई त्यस क्षेत्रको कृषि उत्पादनमा उल्लेख्य वृद्धि हुने देखिन्छ। यस आयोजनाको सफल कार्यान्वयन पश्चात भूमिगत जलको सम्भाव्यता भएको तराइको चितवन, रुपन्देही, कपिलवस्तु, झापा, धनुषा आदि जिल्लामा यस्ता प्रकृतिको आयोजनाको बिस्तार गरी सम्पूर्ण रास्ट्रको कृषि उत्पादनमा सारभूतरुपमा वृद्धि हुने अपेक्षा गरिएको छ।



District	Local level/ Ward no:	1	2	3	4	5	6	7	8	9	10	11	12	Total
Rautahat	Baudhimai	8	7	6	6	5	11	4	3	4				54
	Paroha	2	3	10	7		6							28
	Durgabhagwati	5	5	6	8	2								26
	Maulapur			10	4	6	9	10	9	8				56
	Rajpur		9	5										14
	Devahi Gonahi		1	2	6	12	8							29
	Garuda	4												4
	Madhav Narayan				12	6	10	8	4					40
	Yemunamai	8	1	4	6									19
	Sub-total Rautahat													**270**
Sarlahi	Balara	9	5	6	6	8	4	0	4	11	6	9		68
	Bishnu	5	6	3	7	4	15							40
	Godaita	4	9	9									1	23
	Hariwan	10	2	9	9									30
	Kaudena							12						12
	Malangwa	1				5	19							25
	Ramnagar	10	5	2	10			5						32
	Sub-Total Sarlahi													**230**
	Total													**500**

Figure 1: Location of Project Area

New Life Members of Nepal Hydrogeological Association

S.N.	Name	M. No.	Office/Designation	Contact No
1	Mr. Prakash Rawat	LM 166	Freelancer Geologist	9869482046
2	Dr. Ramita Bajracharya	LM 167	Central Department of Geology, TU	9841843309
3	Mr. Bikash Rana Bhat	LM 168	Aquifer Geo and Engineering Consultancy P Ltd.	4314097
4	Ms. Yojana Neupane	LM 169	Department of Water Resources and Irrigation	9841762920
5	Mr. Dhurba Raj Thapa Chhetri	LM170	Former Senior Divisional Hydrogeologist, DoW-RI	
6	MS. Sunita Magar	LM171	Researcher, NDRI Maan Bhawan	9841171949
7	Mr. Dhirendra Prasad Pandey	LM172	Freelancer Geologist	984-9896289
8	Mr. Hari Khanal	LM173	Engineering Geologist, Megha Dang Irrigation Project	9849050501
9	Dr. Ashok Sigdel	LM174	Trichandra Multiple Campus	9843643061

Past NHA Executive Committees

Sixth Executive Committee of Nepal Hydrogeological Association

S.N	Position	Name	Membership No
1	President	Mr. Moti Bahadur Kuwar	LM 15
2	Vice Precident	Mr. Shanmukesh Chandra Amatya	LM 12
3	General Secretary	Mr. Amar Bdr. Chand Thakuri	LM 26
4	Secretary	Mr. Anil Khatri	LM 37
5	Treasurer	Ms. Rasila Koirala	LM 93
6	Immediate Past President	Mr. Narendra Khatri	LM 20
7	Executive Member	Mr. Mahesh Pokhrel	LM 5
8	Executive Member	Ms. Goma Khadka	LM 120
9	Executive Member	Mr. Chhabilal Pokhrel	LM 125
10	Executive Member	Mr. Shrawan Shakya	LM 86
11	Executive Member	Mr. Prabin Chandra K.C	LM 74
12	Executive Member	Ms. Alina Karki	LM 84
13	Executive Member	Mr. Chhabilal Pokhrel	LM 125

Fifth Executive Committee of Nepal Hydrogeological Association (2019-2021)

SN	Position	Name	Membership No.
1	President	Mr. Narendra Khattri	LM 20
2	Vice President	Mr. Nir Shakya	LM 3
3	Gen Secretary	Mr. Anoj Khanal	LM 67
4	Treasurer	Mr. Manoj Khatiwada	LM 96
5	Secretary	Mr. Arpan Parajuli	LM 92
6	Immediate Past President	Mr. Andy Prakash Bhatta	LM 56
7	Executive Member	Mr. Shahid Muslim	LM 100
8	Executive Member	Mr. Jinita Shakya	LM 94
9	Executive Member	Mr. Lelin Raj Dhungel	LM 60
10	Executive Member	Ms. Rasila Koirala	LM 93
11	Executive Member	Mr. Bhaskar Khatiwada	LM 66
12	Executive Member	Mr. Shrawan Shakya	LM 86

Fourth Executive Committee of Nepal Hydrogeological Association

SN	Position	Name	Membership No.
1	President	Mr. Andy Prakash Bhatta	LM 56
2	Vice President	Mr. Surendra Raj Shrestha	LM 36
3	Gen Secretary	Mr. Ajay Raj Adhikari	LM 52
4	Treasurer	Ms. Anupama Dhakal	LM 67
5	Secretary	Mr. Umesh Chandra Bhusal	LM 59
6	Immediate Past President	Mr. Suresh Raj Uprety	LM 42
7	Executive Member	Mr. Bhaskar Khatiwada	LM 66
8	Executive Member	Mr. Saroj Niraula	LM 73
9	Executive Member	Mr. Nir Shakya	LM 3
10	Executive Member	Mr. Anoj Khanal	LM 67
11	Executive Member	Ms. Sabina Khattri	LM 83

Third Executive Committee of Nepal Hydrogeological Association

SN	Position	Name	Membership No.
1	President	Mr. Suresh Raj Uprety	LM 42
2	Vice President	Mr. Andy Prakash Bhatta	LM 56
3	Gen Secretary	Mr. Shanmukesh Chandra Amatya	LM 12
4	Treasurer	Mrs. Pramila Shrestha	LM 9
5	Secretary	Mr. Umesh Chandra Bhusal	LM 59
6	Immediate Past President	Mr. Pratap Singh Tater	LM 4
7	Executive Member	Dr. Khet Raj Dahal	LM 62
8	Executive Member	Mr. Narayan Krishna Ganesh	LM 50
9	Executive Member	Mr. Arvinda Kumar Misra	LM 19
10	Executive Member	Mr. Nir Shakya	LM 3
11	Executive Member	Mr. Surendra Raj Shrestha	LM 36

Second Executive Committee of Nepal Hydrogeological Association

SN	Position	Name	Membership No.
1	President	Mr. Pratap Singh Tater	LM 4
2	Vice President	Mr. Narendra Khatri	LM 20
3	Gen Secretary	Mr. Andy Prakash Bhatta	LM 56
4	Treasurer	Mrs. Pramila Shrestha	LM 9
5	Secretary	Mrs. Pramoda Pradhan	LM 49
6	Executive Member	Mr. Umesh Chandra Bhusal	LM 59
7	Executive Member	Mr. Anil Khatri	LM 37
8	Executive Member	Mr. Rajendra Neupane	LM 1
9	Executive Member	Mr. Hari Ghimire	LM 58
10	Executive Member	Mr. Surendra Shah	LM 34
11	Executive Member	Mr. Shanmukesh Chandra Amatya	LM 12
12	Executive Member	Mr. Churna Bahadur Wali	LM 51
13	Executive Member	Mrs. Jamuna Bana Shrestha	LM 57

First Executive Committee of Nepal Hydrogeological Association

SN	Position	Name	Membership No.
1	President	Mr. Jitendra Ghimire	LM 8
2	Vice President	Mr. Sagar Kumar Rai	LM 16
3	Gen Secretary	Mr. Narendra Khatri	LM 20
4	Secretary	Mr. Shyam Krishna Shrestha	LM 46
5	Treasurer	Mrs. Pramoda Pradhan	LM 49
6	Executive Member	Dr. Dinesh Pathak	LM 55
7	Executive Member	Mr. Icchya Kumar Shrestha	LM 24
8	Executive Member	Mr. Churna Bahadur Wali	LM 51
9	Executive Member	Mrs. Pramila Shrestha	LM 9
10	Executive Member	Mr. Keshab K.C	LM 14
11	Executive Member	Mr. Ajya Raj Adhikari	LM 52

AD HOC Committee of Nepal Hydrogeological Association

SN	Position	Name	Membership No.
1	President	Mr. Jitendra Ghimire	LM 8
2	Vice-President	Dr. Suresh Das Shrestha	LM 11
3	General Secretary	Mr. Pratap Singh Tater	LM 4
4	Secretary	Mr. Nir Shakya	LM 3
5	Treasurer	Mrs. Pramila Shrestha	LM 9
6	Member	Mr. Puskar Nath Ghimire	LM 22
7	Member	Mr. Khila Nath Dahal	LM 21
8	Member	Mr. Jageshor Jha	LM 6
9	Member	Mr. Mahesh Pokhrel	LM 5

ARTICLE SECTION

ESTIMATING ANNUALLY RECHARGEABLE GROUNDWATER POTENTIAL OF NEPAL

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ABSTRACT

Groundwater is one of the most important natural resources of Nepal. The information published by the Government of Nepal indicates that Nepal is rich in water resources but Nepalese hills and mountains are not rich in groundwater. However, the case is just the reverse: Nepal has no water resources but a very high amount of groundwater in the hills and the mountains as well as in the Tarai of Nepal. Nepal cannot rely on the floods occurring in the monsoon season; similarly, it cannot actually rely on the river flows that are concentrated in the deep river valleys. But groundwater, located much nearer to the ground surface compared to the river water can play an important role in Nepal's economic development if explored and developed properly.

Keywords: ***groundwater, water resources, river water, annual recharge, Nepal Himalaya***

INTRODUCTION

Nepal is a water-stressed country with the stress of too much water in the monsoon four months followed by lean season drought until the next monsoon. However, Nepal is rich in terms of its annually replenishable groundwater. However, the actual volume of groundwater in Nepal is debated mainly due to inaccurate input data that includes inaccuracies in watershed as well as spring-shed areas, sparse network for data acquisition, data acquisition system mostly with untrained operators, etc.

The white paper published by the Ministry of Water Resources and Irrigation of Nepal has concluded that the groundwater potential of the hills and mountains of Nepal is 1.5 billion cubic meters (BCM) and the same for Nepal Tarai is 8.86 BCM (Pun, 2072). The two numbers together show that the total annually replenishable ground water potential of Nepal is 10.36 BCM. This is about 950 liters of ground water per capita per day for whole of Nepal. However, I have serious doubts regarding the value of the whole of the hills and mountains of Nepal which is a meager volume that cannot sustain either the first-order rivers or the other lower-order spring-fed rivers. Therefore, the objective of this work is to discuss about the annual gap of ground water volume and to conclude the logical volume of annually rechargeable groundwater.

GEOGRAPHY OF NEPAL

Nepal located in the south-central lap of the great Himalayas is characterized by great differences in land elevations that range between about 65 m amsl at the eastern Tarai and 8848.86 amsl at the top of Mt. Everest; this has resulted in eleven different ecological zones with specific flora, fauna and incomparable biodiversity. The great Himalayas located at the northern margin of Nepal help the rains to precipitate mainly in the monsoon that lasts for about 4 months between mid-June and early October. The total area of Nepal is 147,480 square kilometers (sq.km.) including an area of about 21,100 sq. km. of relatively flat land called "Tarai or Tarai" and the rest of 126,380 sq. km. in the hills, mountains, and river valleys. I have derived using various sources of rainfall data available in the public domain and concluded that the mean annual precipitation of the Tarai is 1,899.60 mm whereas the mean annual precipitation of the rest of Nepal is 1,946.51 mm (Pokharel, 2024). These values of mean annual precipitation are totally different from the ones published by the Government of Nepal. The hydrological data published by the Government of Nepal show that about 73.5 percent of the total volume of water flows to India (as measured by the gauging stations located near the foot-hills) in the monsoon with the rest of about 26.5 percent flowing in the rest of the 8 months of the year (Mool et. al, 2001 and Pokharel G. S., 2019). Similarly, the data published by the Government show that the monsoon precipitation amounts to 81.2% of the total mean annual precipitation of Nepal. The water balance of Nepal prepared with the involvement of the author shows that the total volume of annually replenishable groundwater in Nepal's hills and mountains of Nepal amounts to 27.66 BCM including water loss of 2.51 BCM in the process of charging and discharging groundwater (Pokharel G. S., and Gyawali D., 2019).

Defining Ground Water

The groundwater should be defined properly so as to avoid obtaining different numbers for the same thing as mentioned hereinabove. Under normal circumstances, replenishable groundwater can be defined as water that comes out to the ground surface or is extracted from the ground irrespective of the length of its stay under the ground within a period of time generally taken as one year. This means, water falling on the ground as rain may come out to the ground surface immediately after entering into the ground for brief seconds should also be considered as groundwater. However, the quantity of such water will be difficult to measure, calculate, or estimate and therefore, should be avoided. Therefore, it is proposed that the quantity of water coming out through water springs, water that sustains the rivers when other sources of water seem absent or water that is extracted from the ground without affecting the groundwater table be only included in the category of groundwater which may be divided into replenishable or non-replenishable or annually replenishable if it is replenished on an annual basis. The sources of water for groundwater replenishment may be monsoon rain, other rain, snow-melt, or ablation whatever the case may be. But, for Nepal, as most of the replenishment of all sources of water is occurs during annual precipitation in the monsoon, other sources of groundwater replenishment may be ignored under normal circumstances. Therefore, water replenished by the monsoon rain that emerges on the ground surface or extracted from the ground without permanently damaging the groundwater table or is spent on sustaining rivers as well as other water bodies between the consecutive monsoon seasons shall be the definition of replenishable ground water.

METHODOLOGY OF ESTIMATION

A large number of models, techniques, and complex mathematical relationships have been developed and are in use for determining the volume of annually replenishable ground water but the accuracy of the result depends on the accuracy of the input data. For Nepal, the biggest problems are the quantity as well as the quality of the data. Therefore, simple logic based on the principle of mass balance is applied herein to obtain the volume of annually replenishable groundwater in Nepal. However, the limitations imposed by the quality of input data have affected the quality of the output in its totality. Apart from the input data, the following assumptions set the limitation of the calculations.

1. It is assumed that the mean monthly flow for the month of November for the first order rivers contains 90% of the water from the groundwater with the remaining 10% from various other sources.
2. The mean value of the mean monthly flow for the month of October is assumed as 20% higher than the values for November.
3. The mean monthly flows for the months of December, January, February and March for the first-order rivers are assumed to be completely fed by ground water (apart from the flow from China and the water from ablation).
4. For the month of April, the mean monthly flow is assumed as 80% of the total mean monthly flow for the first order rivers and for the month of May, it is 50% of the mean monthly flow of April.
5. The GW contribution of the second order rivers is considered as 90% of the total flows for the months between October and May.
6. An allowance of 15% to the total flow of the second-order rivers has been made to account for the flow of other smaller lower-order rivers.
7. Groundwater recharge in cubic meters per square kilometer for Mahakali River has been assumed as a mean between the first and second-order rivers.
8. The total volume of groundwater for the hills of Nepal as per the white paper has been added to the value as annually consumed groundwater for the hills of Nepal.

9. The rainwater contribution of the groundwater is assumed equal to water loss in the process of storage of groundwater and its discharge until the measurement sites.
10. The dry season contribution of the flow from China and flow from ablation totaling 26.5% of the total annual contribution from China and ablation has been deducted from the total value of flows for the first-order rivers.
11. The computation of the replenishable mean annual groundwater is presented herein in Table 1.

Table 1: Computation of mean annual groundwater potential of hills of Nepal, MCM.

S. No.	Description of the recharge period	Quantity
1	Recharge for November at 90% of the flow of November) for the 1st order rivers	5,182.7
2	Recharge for October at 20% higher than the same for the month of November	6,219.2
3	Recharge for the months of December, January, February and March as measured at the gauging stations	12,122.4
4	Recharge for the month of April at 80% of the measured value for April at the gauging station	2,637.7
5	Recharge of May at 50% of flow of April	1,648.6
	Sub-Total of annual recharge for first order rivers	27,810.6
6	Groundwater recharge for second-order rivers at 90% of the total lean season flow	2,613.5
7	Ground Water recharge of Mahakali River	506.25
8	Groundwater recharge of lower order rivers at 15% of second-order rivers	391.96
9	Groundwater recharge of Nepal hills as water consumption in the hills (Ref. White Paper)	1,500.0
6	Flow from China including ablation at 26.5% of total flow (7.49+2.12BCM)	2,546.7
	Mean Annual Ground Water Recharge of Hills and Mountains of Nepal	30,275.6

Hence, the mean annual replenishable groundwater reserve of Nepal hills is 30,275.60 million cubic meters (MCM).The volume of annually replenishable groundwater of Tarai as per the white paper is added to the value of the annually replenishable groundwater volume of the hills and the mountains of Nepal which together amount to 39.13 billion cubic meters, BCM.

RESULTS AND CONCLUSIONS

Given the limitation of the paper, the total annual replenishable groundwater resource of Nepal's hills and mountains has been estimated as 30,275.6 million cubic meters and the total annually replenishable groundwater potential of Nepal is calculated as 39.13 BCM. It is my second effort to quantify the volume of annually replenishable ground water, especially for the hills and mountains as the value published in the white paper of the Government seems to be unacceptably preliminary. However, the value of annually replenishable groundwater of Tarai region is not debatable. The estimated value of mean annually replenishable groundwater is not accurate because of the limitations set by the assumptions but I am confident that this number is much closer to numbers published by the government. Because of the data published in the white paper I felt the urge to estimate it on my own to provide a better value for the annually rechargeable groundwater reserve of Nepal.

All Nepalese water professionals, both surface and ground water need to understand the importance of ground water and value-added water which belongs of our children and grandchildren. The narrative that

Nepal is rich in water is wrong as it is used to justify giving away not only naturally flowing water but also regulated water as something of no value to Nepal. Dismal use of groundwater in Nepal Tarai resulting in over 70% of the total annually replenishable groundwater extraction across the border (Nepal S. et.al, 2019) with the government of Nepal ignoring it indicates our government's willingness to give it away against the national interest.

The groundwater in the hills and the mountains is not as uniform as in Nepal Tarai but is widely spread over the whole area. Availability of large volume of ground water in the hills can open up venues for better economic opportunities including use of ground water for irrigation in the hills.

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THE ENIGMA OF WATER SPRINGS: NATURE'S HIDDEN RIDDLES

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ABSTRACT

Water springs are natural phenomena that present a variety of intriguing mysteries, from their formation and source to their temperature, quality, and flow rates. These features not only contribute to the springs' ecological and cultural significance but also pose complex scientific questions. The article explores how springs are formed, the challenges in tracing their water sources, and the implications of these findings. It delves into the temperature variations of springs, influenced by geothermal and tectonic activity, and the factors affecting their flow rate. The springs' natural beauty and their ecological and cultural importance are highlighted, emphasizing the need for conservation in the face of human impacts. This exploration underscores the vital role of springs in both natural systems and human society, advocating for their protection and sustainable management.

Keywords: ***springs, water sources, geothermal activity, tectonic activity, sustainable management***

INTRODUCTION

Ever marveled at water gushing out from the ground in the heart of a mountain, forming cascading streams? These wonders, known as water springs, 'धारा' or 'मूल' in Nepali, have intrigued people and enthusiasts for centuries. These natural water outlets have been treasured for their beauty, purity, and the vital role they play in the ecosystem. Beneath their tranquil appearance lies a world of complex processes and sometimes unanswered questions that captivate scientists, explorers, and enthusiasts alike.

Water springs have captivated human imagination and reverence throughout history. They are not only essential sources of fresh water but also hold cultural and spiritual significance across various societies. From ancient civilizations to modern times, springs have been regarded as symbols of life, renewal, and purity. They have been central to rituals, myths, and legends, embodying the profound connection between nature and human culture.

In the scientific realm, water springs pose fascinating questions that challenge our understanding of geology, hydrology, and environmental science. The processes that lead to their formation, the origins of their water, the variations in their temperatures, and their ecological roles are subjects of ongoing research and curiosity. Each spring, with its unique characteristics, offers insights into the natural world's complexities and the delicate balance of Earth's systems.

A Spring in Nepal Himalaya (Photo: Ayush Manandhar), Retrieved from: gripp.iwmi.org.

This article aims to uncover the enigmas of water springs, shedding light on the natural phenomena that make them both beautiful and mysterious. By exploring the formation, sources, temperatures, water quality, flow rates, natural beauty, ecological impact, and cultural significance of springs, we may hope to enhance our appreciation and understanding of these remarkable features of our planet and underscore the importance of preserving them for future generations. To carry out the studies related to the present work, several references were studied and analyzed (Boulton, and Hancock, 2006; Fetter, 2001; Kresic, 2010; Meinzer, 1923; Rai, Bhattarai, and Khatiwada, 2020; Springer, and Stevens 2009).

A Spring in Nepal Himalaya (Photo: Ayush Manandhar), Retrieved from: gripp.iwmi.org

FORMATION PUZZLE

The first riddle surrounding water springs is their formation. How does water find its way from underground aquifers to the earth's surface? The process involves a delicate balance of geology and hydrology. Springs form when water pressure in an aquifer causes the water to flow out of the ground through a point of weakness or a natural opening. The precise locations and conditions that lead to the emergence of a spring can be unpredictable, making each spring unique. Key factors in the formation of springs include:

Permeable Rock Layers: The permeable rock layer, also known as the aquifer, has interconnected pores and spaces, allowing water to move freely through them. Examples include sandstone and limestone. Aquifers act as conduits for groundwater flow, facilitating the movement of water from deeper underground to the surface.

Impermeable Barriers: The presence of impermeable rocks or layers, such as clay or shale, that do not allow water to pass through. These barriers trap water, increasing pressure within the aquifer until it finds an outlet.

Topography: The landscape's shape, which can direct the flow of groundwater to the surface. Sloping terrains, valleys, and other geological formations can influence where springs emerge.

SOURCE OF WATER

Another intriguing riddle is identifying the source of water that feeds a spring. While it may seem straightforward that springs are fed by rainfall or snowmelt, tracing the exact origin of the water can be complex. Isotope analysis and tracing techniques are used to determine the age and origin of spring water. These methods reveal whether the water is from recent precipitation or ancient aquifers, sometimes dating back thousands of years. The information on the source of spring water may have the following implications:

Age of Water: The age of water in springs can vary significantly. In some cases, the water may have percolated through the ground recently, while in others, it may come from ancient aquifers that have stored water for thousands of years. Determining the age of the water helps in understanding the dynamics of groundwater flow and the timescales over which aquifers recharge.

Geological History: The study of spring water sources also provides valuable information about the geological history of a region. The presence of certain isotopes or minerals in the water can indicate past climatic conditions, volcanic activity, or tectonic movements. This historical perspective is essential for understanding how current geological processes may impact future water availability.

Water Resource Management: Understanding the source and age of spring water has significant implications for water resource management. It helps scientists and policymakers ensure the sustainability of water supplies by providing insights into recharge rates and potential vulnerabilities. For instance, if a spring is primarily fed by ancient water, it may be more susceptible to depletion if not managed properly.

By using isotope analysis and tracing techniques, scientists can unravel the complex journey of water from its origins to the springs, offering a deeper understanding of the hydrological cycle, groundwater flow, and the sustainability of water resources.

TEMPERATURE RIDDLES

The temperature of spring water is a fascinating riddle that varies widely among springs. While some springs produce cold water, with temperatures lower than the ambient surroundings, others are warm, ranging from slightly above the average ambient temperature of the region to around human body temperature (approximately 37°C). A select few springs are hot enough to be classified as hot springs or thermal springs, typically ranging from human body temperature to well over the boiling point of water (100°C). Several factors influence the temperature of spring water:

Geothermal Gradient: This refers to the rate at which temperature increases with depth beneath the Earth's surface. Regions with higher geothermal gradients tend to have hotter spring water.

Magmatic Activity: In volcanic regions, water is heated by magma before emerging at the surface. Many hot springs are associated with magmatic activity.

Tectonic Activity: Movements of the Earth's crust can create fractures and faults that allow deeper, hotter water to reach the surface. In Nepal, hot springs are mainly found near tectonic structures such as thrust faults, which are major geological fissures and cracks that dissect the crust to significant depths.

Radioactive Disintegration: The decay of radioactive elements within the Earth's crust generates heat, contributing to higher temperatures in some springs.

Chemical Changes: Exothermic chemical reactions within the Earth's crust can also heat groundwater, resulting in warmer springs.

WATER QUALITY RIDDLES

The quality of water emerging from springs can be a perplexing enigma. While springs are often associated with pure, crystal-clear water of exceptional quality, various factors can influence water quality. Contaminants from agricultural runoff, industrial activities, and urban development may infiltrate groundwater sources feeding the springs, impacting their quality. Additionally, natural processes such as mineral leaching and bacterial growth within aquifers can affect the composition and safety of spring water.
Understanding the complex interplay of factors influencing water quality in springs is essential for ensuring their suitability for drinking, recreation, and ecological support. Deciphering the mysteries of water quality in springs requires comprehensive monitoring, analysis, and management strategies to safeguard these vital natural resources.

FLOW RATE RIDDLES

The flow rate of springs presents another set of riddles. Some springs gush with powerful flows, while others trickle. Flow may vary from seepage to well over 13,000 liters per second. Factors influencing flow rate include:

Aquifer Size: Larger aquifers with higher recharge rates can sustain greater flows. Recharge typically comes from precipitation or snowmelt that infiltrates the ground. The capacity of the aquifer to store and transmit water directly affects the spring's flow rate.

Permeability of Rocks: The permeability of the rocks or the aquifer plays a crucial role in determining the flow rate of springs. Highly permeable rocks, such as sandstone and limestone, allow water to flow more freely, resulting in higher flow rates. In contrast, less permeable rocks restrict the flow of water, leading to lower flow rates.

Climatic Conditions: Seasonal variations in precipitation and temperature can affect the amount of water available for discharge. During wet seasons or periods of heavy rainfall, springs may have higher flow rates, while dry periods can reduce the flow.

Human Activity: Human activities such as pumping of groundwater and land development can significantly alter the natural flow rates of springs. Excessive groundwater extraction can deplete aquifers, reducing the flow of springs. Similarly, land development can alter surface runoff patterns, affecting the recharge of aquifers and consequently the flow rates of springs.

Tectonic Activity: Movements of the Earth's crust can create fractures and faults that enhance water flow from deeper sources. These geological features can act as conduits, allowing water to travel more freely and increasing the flow rate of springs.

These factors combine in complex ways to produce the varied flow rates observed in springs around the world, from gentle seeps to powerful gushers. Understanding these factors is crucial for managing water resources and predicting the behavior of springs, especially in areas dependent on spring water for drinking and agriculture.

NATURAL BEAUTY

The captivating beauty of springs presents another intriguing riddle. Springs are not only sources of water but also oases of natural splendor, often nestled in serene landscapes and adorned with lush vegetation. Their crystal-clear waters shimmer in the sunlight, reflecting the surrounding scenery like a mirror. The gentle babbling of water and the vibrant colors of aquatic plants create a mesmerizing ambiance that enchants visitors.

Examples of such beautiful springs in Nepal include the stunning Tatopani Springs in Myagdi and Sindhupalchok, known for their soothing hot waters and picturesque settings. Gosainkunda in Nuwakot, with its high-altitude lake fed by springs, offers breathtaking views, especially when the spring waters reflect the surrounding peaks. Ridi in Palpa and Muktinath in Mustang also exemplify this natural beauty, with their serene environments and vibrant local flora.

However, unraveling the mystery of what makes each spring uniquely beautiful is a challenge. The geological formations, surrounding flora and fauna, and even the cultural significance attributed to these natural wonders contribute to their aesthetic appeal. Understanding the intricate interplay of these factors adds to the enigma of springs, inviting exploration and appreciation of their natural beauty.

As visitors marvel at the scenic vistas and tranquil atmospheres of springs, they are drawn into the mysteries of their allure, inspiring reverence for the wonders of the natural world.

ECOLOGICAL SIGNIFICANCE

Springs, with their constant flow of fresh water, foster unique ecosystems that harbor a rich diversity of flora and fauna. Ecological riddles include understanding how these isolated environments sustain such biodiversity. Factors contributing to the ecological richness of springs are:

Stable Water Conditions: One of the key mysteries surrounding spring habitats is how they maintain stable water conditions, providing a reliable environment for diverse organisms to thrive. The steady flow of water, often at a constant temperature, creates a microclimate conducive to life. This stability offers refuge to species adapted to specific ecological niches, ensuring their survival even in harsh environmental conditions.

Nutrient Availability: Springs not only supply water but also bring forth essential minerals and nutrients from deep underground. These nutrients enrich the surrounding soil and water, providing vital sustenance for a myriad of organisms. From microscopic algae to aquatic plants and invertebrates, the availability of nutrients fuels the productivity of spring ecosystems, supporting complex food webs and biodiversity.

Isolation: Geographic isolation is a defining feature of spring habitats, often nestled in remote and pristine landscapes. This isolation fosters the evolution of unique species adapted to the specific conditions of each spring. Over time, isolation leads to genetic divergence and the emergence of endemic species found nowhere else on Earth. The ecological mysteries of spring isolation unveil the remarkable adaptive strategies employed by organisms to thrive in their secluded environments.

As we unravel these ecological mysteries, we gain a deeper appreciation for the intricate interplay of factors that shape the biodiversity and resilience of spring ecosystems. Each discovery brings us closer to understanding and conserving these invaluable natural treasures for future generations.

CULTURAL MYSTERIES

Throughout history, springs have held an enduring cultural and spiritual significance for diverse societies around the world. These natural wonders have been revered as sources of healing, purification, and renewal, embodying mysteries that transcend mere physical attributes. Across cultures, springs have often been focal points of rituals and ceremonies, their waters believed to possess sacred qualities that connect humanity to the divine. The intricate tapestry of beliefs and practices surrounding springs reveals a profound cultural enigma, where the tangible and intangible intertwine to shape the collective consciousness of communities. From ancient traditions to modern interpretations, the cultural riddles of springs continue to intrigue and inspire, inviting us to delve deeper into the rich tapestry of human experience.

In Hindu traditions, springs are frequently decorated with pieces of colorful cloth as part of local customs and religious practices. This act serves as both an offering and a way to seek blessings and protection. Examples of springs of cultural significance in Nepal include Tatopani in Myagdi, Gosainkunda in Nuwakot, Ridi in Palpa, Muktinath in Mustang, and Tatopani in Sindhupalchok.

HUMAN IMPACT

Humans have long been fascinated by springs, using them for drinking water, recreation, and spiritual practices. However, the impact of human activity on springs poses modern riddles. Over-extraction, pollution, and climate change threaten the delicate balance of these natural resources. Efforts to protect and preserve springs require a deep understanding of their mysteries and the implementation of sustainable practices.

As we continue to unravel the mysteries of springs, we gain a deeper appreciation for the intricate interplay between geological, hydrological, ecological, and cultural factors. Each discovery brings us closer to understanding and conserving these invaluable natural treasures for future generations.

CONCLUSIONS

Water springs are not merely natural phenomena; they are intricate systems that challenge our understanding of the world around us. From their enigmatic formation to their ecological significance and cultural importance, springs embody a tapestry of mysteries waiting to be unraveled.

As we delve deeper into the secrets of springs, we gain invaluable insights into the delicate balance of nature and the interconnectedness of geological, hydrological, ecological, and cultural systems. Each discovery serves as a reminder of the importance of safeguarding these natural wonders for future generations.

By studying and preserving water springs, we not only protect vital water resources but also honor the rich tapestry of human heritage and biodiversity they support. Let us continue to explore, appreciate, and conserve these remarkable features of our planet, ensuring that their mysteries endure for generations to come.

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MODERN TECHNIQUES AND METHODS FOR HYDROGEOLOGICAL INVESTIGATION AND RESEARCH IN THE RECENT WORLD

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ABSTRACT

This article explores modern techniques and methods revolutionizing hydrogeological investigations and research in the contemporary world. With growing concerns about water scarcity, pollution, and climate change, advanced technologies such as remote sensing, geophysical methods, drilling, and borehole logging have become essential for studying groundwater systems. Groundwater modelling, environmental isotope analysis, and AI-driven predictive tools further enhance our understanding of aquifer dynamics, water quality, and contaminant transport. By integrating these innovative approaches, hydrogeologists can make more informed decisions, ensuring sustainable management and protection of groundwater resources in an increasingly complex environmental landscape.

Keywords: ***hydrogeology, climate change, isotope analysis, groundwater modelling, AI-driven tools***

INTRODUCTION

Hydrogeological investigation plays a crucial role in understanding groundwater resources, which are vital for drinking water, agriculture, industry, and ecosystem sustainability. With growing concerns about climate change, pollution, and water scarcity, modern techniques have revolutionized the way hydrogeologists study groundwater systems. This article explores the latest methods and technologies that have transformed hydrogeological research, making investigations more accurate, efficient, and insightful.

1. Remote Sensing and Geographic Information Systems (GIS)

Remote sensing and GIS have become indispensable tools in hydrogeology. They provide valuable spatial data that can be used to analyze groundwater potential, aquifer characteristics, and land-use impacts on groundwater resources. The remote sensing and GIS approach serves as an effective preliminary method for assessing groundwater potential and identifying suitable zones for further investigations. The RS-GIS methodology narrows down target areas for further hydrogeophysical exploration, suggesting the use of specific ground geophysical methods for site characterization.

Remote Sensing Applications: Remote sensing (RS) technology is highlighted for its efficiency and precision in analyzing satellite or aerial photographs for hydrogeological assessments. Satellite imagery and aerial photography help in identifying surface water features, vegetation cover, and geological formations that indicate the presence of groundwater. Techniques such as Synthetic Aperture Radar (SAR) and Light Detection and Ranging (LiDAR) are particularly useful in mapping terrain and detecting subsurface structures. GeoFrame is utilized to interpret RS images, capitalizing on the distinct spectral characteristics of water bodies for effective analysis. However, the selection of appropriate synthetic bands is crucial for optimizing the interpretation of RS data, with specific bands yielding better results for different ground objects. Effective human-computer interaction is crucial for achieving high-quality interpretations of RS data. Commonly, A mathematical model for detecting groundwater resources through RS images can be developed, demonstrating its feasibility and effectiveness (Wang, 2023).

GIS Integration: GIS software enables the integration and analysis of various datasets, including topography, hydrology, geology, and land use. This spatial analysis helps in creating groundwater potential maps, modelling aquifer recharge zones, and identifying areas vulnerable to contamination. Recently, in the Ratu Khola section of Nepal Himalaya, research successfully identified suitable areas for artificial recharge using GIS and AHP methods, categorizing them into five suitability classes (Aryal et al, 2023).

2. Geophysical Methods

Geophysical techniques have significantly improved the ability to investigate subsurface conditions without extensive drilling. These non-invasive methods provide insights into aquifer properties, groundwater quality, and subsurface structures. Airborne electromagnetic surveys are particularly effective for mapping aquifers on a regional scale. The conductivity of groundwater in many areas, which ranges from 20 to 120 mS/m, makes these surveys a valuable tool for identifying potential groundwater zones (Bhattacharya, 2019). Water harvesting from the riverbeds of shallow aquifers based on simple pitting or any useful geological technique is one of the very simple but useful techniques for the small communities where the water demand is realized. Such type of study was carried out in the Hariwan municipality of the southern part of Nepal (Paudyal, et al, 2023).

Electrical Resistivity Tomography (ERT): ERT measures the subsurface electrical resistivity, helping identify aquifers, clay layers, and contaminants. It is widely used in groundwater exploration, monitoring contamination plumes, and mapping fracture zones.

Magnetotelluric (MT) Method: MT measures the Earth's natural electromagnetic fields to explore deeper subsurface structures. It is highly effective for identifying deep aquifers and understanding geological formations in tectonically complex areas.

Seismic Refraction and Reflection: These techniques use seismic waves to map subsurface layers. Seismic refraction helps in identifying shallow aquifers, while seismic reflection is used for deeper explorations.

3. Drilling Techniques and Borehole Logging

Drilling remains a primary method for direct investigation of subsurface conditions. Modern drilling technologies and borehole logging tools provide detailed information about aquifers.

Rotary Drilling: This technique allows drilling to significant depths and is commonly used in hydrogeological studies to extract core samples and install monitoring wells.

Borehole Geophysical Logging: Tools such as gamma-ray, neutron, and resistivity logs measure the physical and chemical properties of subsurface formations. These logs help determine lithology, porosity, and water quality.

Packers and Pumping Tests: Packers are used to isolate sections of boreholes during hydraulic testing, which measures aquifer properties such as transmissivity and storability.

4. Groundwater Modeling and Simulation

Groundwater models are essential tools for understanding and predicting the behaviour of aquifer systems. They integrate data from various sources to simulate groundwater flow, solute transport, and the impacts of different management scenarios.

Numerical Modeling: Models like MODFLOW and FEFLOW are widely used for simulating groundwater flow and contaminant transport. These models help assess the sustainability of groundwater extraction, predict the movement of contaminants, and design effective remediation strategies.

Coupled Surface-Subsurface Models: These models integrate surface water and groundwater interactions, providing a holistic view of the hydrological cycle. They are particularly useful for studying the impacts of land-use changes and climate variability on water resources.

5. Environmental Isotope Techniques

Environmental isotopes are powerful tracers in hydrogeological research. They provide insights into groundwater age, recharge rates, and the sources of water and contaminants. The most used environmental isotopes in hydrology include stable isotopes of hydrogen (2H, 3H) and oxygen (18O), as well as carbon isotopes (13C, 14C), which are integral to understanding water composition. Stable isotopes are measured using isotope ratio mass spectrometry, while radioactive isotopes are quantified through decay counting or accelerator mass spectrometry, allowing for precise analysis of groundwater samples.

Stable Isotopes (δ18O, δ2H): These isotopes help identify the origin and movement of groundwater, recharge zones, and mixing processes between different water bodies. Variations in stable isotope ratios are influenced by chemical reactions and phase changes, with lighter isotopes showing greater variability due to their mass differences. The isotopic composition of groundwater is linked to precipitation patterns, which are affected by temperature, evaporation, and condensation processes, providing insights into past and present climatic conditions.

Radioactive Isotopes (14C, 3H): These isotopes are used to date groundwater, which is crucial for understanding recharge rates and the sustainability of aquifers. Radioactive isotopes, such as tritium and carbon-14, are used to trace groundwater movement and age, with tritium being particularly useful for identifying recent recharge events due to its transient behavior following atmospheric nuclear tests. The measurement of radioactive isotopes often requires advanced techniques like accelerator mass spectrometry, which allows for the analysis of very small sample sizes, enhancing the study of groundwater systems.

Tritium, with a half-life of 12.43 years, serves as a key indicator of recent groundwater recharge, especially in semi-arid regions where groundwater is a critical resource. The combination of tritium and its decay product, helium 3, provides a powerful method for estimating groundwater residence times and recharge rates, although challenges arise as natural tritium levels return to baseline post-nuclear testing (Aggarwal et al., 197; Aggarwal and Dillon, 1998).

6. Advanced Chemical Analysis, Contaminant Transport Studies, and Hydrometric Methods

Understanding groundwater quality is essential for managing water resources. Modern analytical techniques and contaminant transport models help assess and mitigate the impacts of pollution. Influences of climate change can be assessed in terms of the water chemistry. Such type of study was carried out recently from the Mustang, a remote region of the Nepal Himalaya (Ghezzi et al, 2017). There are complex interactions between surface runoff, groundwater flow, and water chemistry, which are influenced by geological and environmental factors, including mineral weathering processes that affect nutrient and toxic element release. Analytical techniques in general include ion chromatography and ICP-MS for major ions and trace elements in several interpretations. In one study of Nepal Himalaya (Marshyangdi River system), the presence of potentially toxic elements like thallium and arsenic in some hot springs raises concerns for local health and environmental safety, while cold springs generally showed acceptable water quality. The findings indicate that water chemistry in the Marsyangdi basin is influenced by carbonate and silicate weathering processes, with distinct hydrofacies observed in THS and GHS waters. The study suggests that changes in water chemistry may be linked to geological processes, including pyrite weathering and the effects of the 2015 Gorkha earthquake on CO2 outgassing and thermal water characteristics. It emphasizes the need for monitoring potentially hazardous elements in thermal waters using modern techniques like ion chromatography and ICP-MS as described above (Lisa et al, 2019).

High-Resolution Mass Spectrometry (HRMS): HRMS allows for the detection of trace contaminants, such as pharmaceuticals and pesticides, which are otherwise difficult to identify.

Reactive Transport Modeling: These models simulate the chemical reactions that occur as groundwater moves through different geologic media. They are used to predict the spread of contaminants and design effective remediation measures.

DNA-Based Tracers: These techniques are innovative tools used in hydrogeological investigations to track water movement, identify sources of contamination, and study groundwater-surface water interactions with high specificity. These tracers involve synthetic or naturally occurring DNA molecules that are introduced into the water system and later detected using advanced molecular techniques like quantitative PCR (qPCR). DNA-based tracers are highly sensitive, environmentally safe, and customizable, allowing for simultaneous tracing of multiple pathways due to their unique genetic codes. This technology provides precise, reliable data on subsurface flow dynamics, making it a valuable method for groundwater research and water resource management (Zhang and Huang 2022).

Modern Hydrometric Methods: Hydrogeological investigations involve advanced techniques for measuring and analyzing water flow, levels, and related hydrological parameters to better understand groundwater and surface water systems. Sonars are recognized as the most accurate and straightforward devices for measuring water depths, with significant advancements made possible by digital technologies in recent years. They are utilized across various sectors, including navigation, hydrography, oceanography, and fishing, facilitating the creation of detailed underwater maps. Modern signal processing algorithms enhance sonar sensitivity and minimize noise interference, allowing for the visualization of complex seabed structures. Adaptive acoustic location methods enable effective depth determination in challenging conditions, such as noise interference or variable geometries. The integration of sonars with technologies like GIS, laser systems, and multisensory systems has improved data accuracy and expanded their application in fields like geology and hydrology. Stationary sonars from brands like Lowrance and Garmin are increasingly used in academic settings for small water bodies due to their ease of installation and high accuracy. The choice of floating devices, such as inflatable boats, is crucial for effective sonar operation, with specific installation guidelines to minimize interference from motor propellers. Accurate data collection requires careful consideration of water levels, which can fluctuate significantly, necessitating the use of water level recorders. The integration of continuous recording and water level adjustments enhances the reliability of sonar measurements across various conditions (Fatkhi et al, 2022). Some of the key methods include:

Acoustic Doppler Devices: These instruments use sound waves to measure water velocity and discharge in rivers, streams, and groundwater outflows with high accuracy.

Laser Scanning and LiDAR: Used to create high-resolution topographic maps, these tools help assess surface water flow patterns, catchment areas, and water pathways in complex terrains.

Pressure Transducers and Data Loggers: These devices continuously record water levels, temperature, and pressure in wells and surface waters, providing real-time data on aquifer responses and recharge rates.

Hydraulic Conductivity Testing: Methods like slug tests and pumping tests are used to measure the permeability of aquifers, which is crucial for understanding groundwater flow dynamics.

7. Artificial Intelligence (AI) and Machine Learning (ML)

Artificial Intelligence (AI) and Machine Learning (ML) are revolutionizing hydrogeological research by providing powerful tools for data analysis, prediction, and decision-making. These modern methodologies are transforming traditional approaches, enabling more accurate modelling and analysis of hydrological parameters. ML techniques are revolutionizing hydrological predictions by utilizing extensive datasets like CAMELS and GRACE, improving accuracy in modelling streamflow and groundwater levels (Hasan et al, 2024). A Self-adaptive Extreme Learning Machine (SAELM) can be very useful in estimating hydrogeological parameters, especially in wetland analysis with results compared against other models like LSSVM, MLR, and ANFIS (Poursaeid et al., 2022). The Adaptive Neuro-Fuzzy Inference System and Genetic Programming are the recently proposed analytical techniques as hybrid models that can improve prediction robustness in groundwater analysis. Hybrid models have demonstrated significant promise in managing groundwater quality and quantity, outperforming traditional models in accuracy and efficiency. Ethical and social implications of hybrid

AI models are crucial considerations, necessitating research into their impact on privacy, fairness, and accountability (Zaresefat and Derakhshani, 2023). Other applications in hydrogeology include:

Data Analysis and Pattern Recognition: AI and ML algorithms can process vast amounts of complex hydrogeological data, such as groundwater levels, water quality parameters, and geological features, to identify patterns, trends, and anomalies that are often not apparent through traditional methods.

Predictive Modeling: ML models are employed to predict groundwater levels, contamination risks, recharge rates, and aquifer behavior under different scenarios, including climate change impacts. These predictive capabilities enable proactive water resource management and risk mitigation.

Optimization of Water Resources Management: AI helps optimize the management of groundwater extraction, artificial recharge, and water distribution by analyzing real-time data and suggesting efficient strategies to minimize environmental impacts.

Remote Sensing and Image Analysis: AI techniques, such as deep learning, are used to analyze satellite images, aerial photographs, and geophysical data, enhancing the mapping of aquifers, detection of water bodies, and monitoring of land-use changes affecting groundwater.

Anomaly Detection: AI-driven models can detect unusual patterns in hydrological data that may indicate contamination events, illegal extractions, or changes in aquifer recharge dynamics, enabling timely interventions.

Integration with IoT Sensors: AI systems can process real-time data from IoT-enabled hydrometric sensors, automating the monitoring of groundwater conditions, and providing actionable view for water management.

Conclusions

The rapid advancement of technology has significantly enhanced hydrogeological investigations, making them more accurate, efficient, and comprehensive. Modern techniques such as remote sensing, geophysics, isotope analysis, and AI-driven models are now integral to the study of groundwater systems. As these technologies continue to evolve, they will provide even greater insights into the challenges of managing groundwater resources in a changing world.

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FREQUENT EARTHQUAKES IN NEPAL: CAUSES, PREPAREDNESS, AND MITIGATION MEASURES

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ABSTRACT

Nepal's geographical location and tectonic setting make it highly susceptible to earthquakes, posing significant risks to life and property. Although earthquakes cannot be prevented, their impacts can be mitigated through structural improvements, public education, and disaster preparedness. A recent study suggests additional structural and non-structural mitigation strategies that could be implemented beyond current practices in Nepal. By learning from past events and investing in these measures, the country can reduce the human and economic toll of future earthquakes. Furthermore, planned urbanization is crucial for minimizing the loss of life and property, underscoring the need for a proactive approach to earthquake risk management.

Keywords: ***earthquake, structural mitigation, non-structural mitigation, retrofitting***

INTRODUCTION

Earthquakes are unpredictable disaster events that occur globally, and Nepal is particularly vulnerable due to its location above the converging Indian and Eurasian tectonic plates, where the Indian Plate is sub-ducting beneath the Eurasian Plate (USGS, 2024). The most recent significant seismic events include the Gorkha Earthquake of 2015, which had a magnitude greater than 7 and severely affected the central part of Nepal, and the Jajarkot Earthquake of 2023, which caused widespread damage to people and infrastructure. These earthquakes destroyed numerous homes and public infrastructure, injuries, displacement, and significant impacts on livelihoods. Nepal ranks 11th globally in terms of earthquake risk and impact (Maplecroft, 2011; MoPE, 2016) and is among the top 20 countries facing multiple hazards worldwide (UNDRR, 2019). The country is situated in a high seismic hazard zone, with over 80% of its population exposed to the risk of natural disasters, including earthquakes, droughts, floods, landslides, extreme temperatures, and glacier lake outburst floods (MoHA, 2015). The vulnerability is especially concerning in densely populated areas such as the Kathmandu Valley, which has experienced major earthquakes approximately every 75 years.

In Historical records, Nepal has a long history of destructive earthquakes, with the earliest recorded event dating back to June 7, 1255, during the reign of King Abhaya Malla. The recent well-studied last major earthquake was the 1934 Bihar-Nepal earthquake, with a magnitude of 8.4 on the Richter scale, which devastated the Kathmandu Valley, causing extensive loss of life and property. More recent earthquakes include the 1980 Bajhang earthquake (magnitude 6.5), which resulted in 178 deaths and damage to around 40,000 houses, and the 1988 earthquake in eastern Nepal (magnitude 6.6), which claimed 721 lives and damaged approximately 60,000 houses and other infrastructure. On September 18, 2011, a magnitude 6.9 earthquake struck the far-eastern part of Nepal, near the border with Sikkim, India (USGS/EHP, 2011a). The following day, Kantipur Television reported that eight people had died, 150 were injured, and many traditional homes were damaged. Earthquake-induced landslides further exacerbated the damage to homes and roads. The tremors were felt as far as the Kathmandu Valley, where additional damage occurred. The earthquake of August 30, 2013, with a magnitude of 6.0 and an epicentre approximately 330 km north of Kathmandu, followed by a 5.0 magnitude aftershock.

Though the tremors were felt across the Kathmandu Valley and other parts of Nepal, no significant damage was reported (eKantipur Online, 2013b, c). Another notable event was the Gorkha earthquake in 2015 caused a casualty of about 9000 people.

In recent years, Nepal has continued to experience significant seismic activity. The earthquake of 3 November 2023, with a magnitude of 5.7 struck at the Jajarkot district epicenter has caused a casualty of about 157 people.

CAUSES OF EARTHQUAKES IN NEPAL

The primary cause of earthquakes in Nepal is its location along the convergent boundary between the Indian Plate and the Eurasian Plate. The Indian Plate is continuously moving northward at a rate of approximately 5 centimetres per year, colliding with the Eurasian Plate, which creates significant tectonic stress (USGS, 2024). This process, known as subduction, involves the Indian Plate being forced beneath the Eurasian Plate, leading to the buildup of immense pressure within the Earth's crust. When this pressure is eventually released, it results in seismic activity, causing earthquakes. Nepal's position along this highly active tectonic boundary makes it one of the most earthquake-prone regions in the world, with the Main Himalayan Thrust fault playing a critical role in the occurrence of these events (MoPE, 2016). The uplift of the Himalayan Mountain range, driven by this ongoing tectonic collision, further contributes to the region's seismic activity.

Tectonic Plate Movements

Tectonic plate movements in Nepal are primarily driven by the collision between the Indian Plate and the Eurasian Plate. The Indian Plate is moving northward at a rate of about 5 centimetres per year and is being forced beneath the Eurasian Plate, a process known as subduction (USGS, 2024). This tectonic interaction is responsible for the uplift of the Himalayas, including Mount Everest, as the Earth's crust is compressed and thickened. The immense pressure and strain that build up along the convergent boundary are eventually released as seismic energy, leading to frequent and sometimes devastating earthquakes in Nepal. The Main Himalayan Thrust (MHT) is the primary fault line in this region, where the accumulated stress due to the ongoing plate movements results in significant seismic activity (MoPE, 2016).

The 2015 Gorkha Earthquake, with a magnitude of 7.8, is one of the most notable examples of the impact of these tectonic movements. It was caused by a sudden release of stress along the MHT, highlighting the ongoing and dynamic nature of tectonic processes in the region. Nepal's location on this active tectonic boundary makes it one of the most earthquake-prone areas in the world, with significant implications for both its natural environment and human settlements (UNDRR, 2019).

SEISMIC CLUSTERS

Seismic clusters in Nepal, such as the notable mid-crustal seismic clusters, are significant in understanding the region's tectonic activity. One of the most studied seismic clusters occurred during the 2021 Lamjung earthquake sequence. This cluster involved a series of 129 seismic events within 14 days, closely clustered around the mainshock's rupture zone, indicating intense aftershock activity. These events were primarily located at depths between 14 to 25 km showing a strong correlation with the tectonic features of the region, such as steeply dipping thrust faults. Nepal's seismicity is primarily driven by the interaction between the Indian and Tibetan tectonic plates, making it one of the most seismically active regions in the world. Historical records indicate that Nepal has experienced several devastating earthquakes due to this tectonic activity. Seismic clusters in Nepal are often analyzed using various seismological techniques to understand the mechanics of earthquakes and to assess seismic hazards in the region. (National Earthquake Monitoring and Research Center (NEMRC) of Nepal)

PREPAREDNESS AND MITIGATION PRACTICE IN NEPAL

Nepal's history of earthquakes has led to the development of several preparedness and mitigation measures aimed at reducing the impact of these natural disasters. These measures are divided into structural and non-structural approaches, seismic retrofitting, and both pre-and post-disaster preventive strategies.

STRUCTURAL MITIGATIONS

Building Codes

Implementing and enforcing building codes that require structures to withstand seismic forces is critical in reducing the damage caused by earthquakes. These codes should be regularly updated based on the latest seismic research.

Seismic Retrofitting

Retrofitting older buildings to make them more resistant to earthquakes can significantly reduce the risk of collapse during a seismic event. This involves strengthening the structural elements of buildings to improve their resilience.

NON-STRUCTURAL MITIGATIONS

Public Awareness

Educating the public about earthquake preparedness, such as how to secure heavy furniture, store emergency supplies, and create family emergency plans, is essential in reducing injuries and fatalities.

Early Warning Systems

Developing and implementing early warning systems can provide valuable time for people to take protective actions before the shaking starts.

PRE-DISASTER PREVENTIVE MEASURES

Hazard Mapping

Identifying and mapping high-risk areas helps in planning land use and guiding construction practices. This information is vital for disaster management planning and emergency response.

Community Preparedness Programs

Programs that train communities in earthquake response, including first aid and search and rescue operations, can save lives immediately after an earthquake.

POST-DISASTER MEASURES

Immediate Rescue and Relief

The first 72 hours after an earthquake are critical for saving lives. Rapid deployment of search and rescue teams, medical assistance, and the provision of temporary shelters are essential in this phase.

Reconstruction and Rehabilitation

Long-term recovery involves rebuilding homes, infrastructure, and services in a way that reduces future risks. This phase can last from six months to three years, depending on the scale of the disaster.

International Support and Technological Advances

International organizations have played a significant role in enhancing earthquake preparedness in Nepal. The development of technology to track people during disasters has revolutionized how first responders operate. Programs like the Kathmandu Valley Earthquake Risk Management Project (KVERMP), initiated in 1997, have been instrumental in preparing for seismic events. This project, among others, has helped simulate earthquake scenarios, assign roles to various agencies, and ensure coordinated response efforts.

DISCUSSION AND CONCLUSION

As earthquakes are a natural process, they can't be blocked but from the proper mitigation measures and preparedness minimization of the loss of life and property can be made. Beyond the practice of the Nepal structural mitigation measures such as base isolation, damping systems, foundation reinforcement, flexible utility connections, structural redundancy, the use of lighter building materials, shear walls and cross bracing, soil improvement techniques, earthquake-resistant infrastructure, and seismic zoning and land use planning can be implemented.

Non-structural mitigation beyond the practice of Nepal such as securing furniture and equipment to prevent toppling, installing safety latches on cabinets and drawers, using flexible connections for gas lines and electrical conduits, and securing hanging objects like light fixtures and suspended ceilings, safe storage of hazardous materials, bracing mechanical systems can also be implemented by improving it from the policy level.

In conclusion, Nepal's rapid urban growth, particularly in the Kathmandu Valley, necessitates comprehensive and well-coordinated infrastructure development to ensure balanced growth and harmony in its cities. The current National Building Code of Nepal is inadequate for addressing the demands of modern infrastructure, including high-rise constructions. Therefore, it is essential to develop a family of codes and standards, including the immediate upgrade of the current building code, planning and zoning codes, and the implementation of a new seismic-retrofitting code. These measures are critical to strengthening existing structures, especially in the Kathmandu Valley, to minimize damage from future earthquakes. Additionally, building codes must be tailored to the diverse climate, geological, and geographical conditions of Nepal, from its cold mountainous regions to the hot and humid plains of the Terai. Addressing these challenges is a high priority for all stakeholders involved in earthquake preparedness.

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ARTESIAN FLOWING TUBEWELLS IN EASTERN TERAI NEPAL

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ABSTRACT

Groundwater use research conducted indicates the increasing pressure on this valuable resource. This phenomenon persists all over the globe. The pressure is created due to the ever-increasing extraction driven by population growth and rising demand. Groundwater levels in Kathmandu Valley are declining which is proven by many reports. The cause of this may be over-extraction. The Terai and Inner Terai regions may face similar issues in the future. The aquifers in some areas of the Terai region are confined, causing some tubewells to flow as artesian wells. Flowing wells discharge water without the need for pumps due to pressure. The unregulated free flow if allowed to be continued, may cause depletion of groundwater, although they may be serving as a source of water for various uses.

The research paper explores the geographical distribution of flowing artesian wells in the Sunsari, Morang, and Jhapa districts giving specific details about their locations, free flow discharge, and the hydrological conditions of the areas. The study identifies 164 deep tubewells, with 24 currently in a flowing state, classified based on their discharge rates. Recommendations encompass the restoration of non-flowing wells, upkeep of moderately flowing wells, and regulation of highly flowing wells to curtail waste and enhance efficiency. Up-to-date maps and data provide crucial insights for improved groundwater management in this part of Terai region.

Keywords: ***artesian wells, deep tubewells, groundwater depletion, groundwater management, eastern Terai***.

INTRODUCTION

A recent global study on groundwater usage has revealed that this vital resource is facing considerable strain due to excessive extraction driven by population growth and increasing demand. In Nepal's Kathmandu Valley, the groundwater level is decreasing, indicating that more water is being drawn out than replenished. This is mainly due to the high population density and inadequate recharge. Although this issue has not been observed in the Terai and Inner Terai regions yet, it may emerge in the future if the overuse of groundwater for agricultural and domestic purposes persists.

In the Terai region, many aquifers are confined (artesian), meaning they are enclosed between layers of impermeable clay. When tubewells are drilled in these confined aquifers, the pressure within them causes groundwater to rise in the well. In some areas, this drilling may lead to the formation of flowing artesian wells. An artesian well is one in which groundwater naturally rises to a level above the top of the aquifer due to pressure inside the confined aquifer. If the pressure is high enough to raise the water level in the well above the ground surface, the outcome is a flowing artesian well, in which water flows freely out of the well without the need for pumps. Uncontrolled flowing wells can lead to wastage of water and potentially deplete the aquifer. However, these flowing artesian wells can provide a reliable source of water for the community.

Numerous flowing deep tubewells have been reported in the regions of Sunsari, Morang, and Jhapa. This report includes details about the specific locations and numbers of these flowing wells in these districts, along with maps that demonstrate the areas where the water is flowing. The report aims to review existing databases to identify potential flowing artesian wells in these three districts.

The spatial distribution and specific details of the wells in the study districts are the main focus of this work. A brief description of the groundwater hydrology, aquifer parameters, and tubewell information are provided for the study districts.

STUDY AREA

The study area includes the three districts belonging to the Koshi province. Jhapa, Morang and Sunsari, are the districts chosen for the study and carried out the location of the flowing artesian wells (see fig 1).

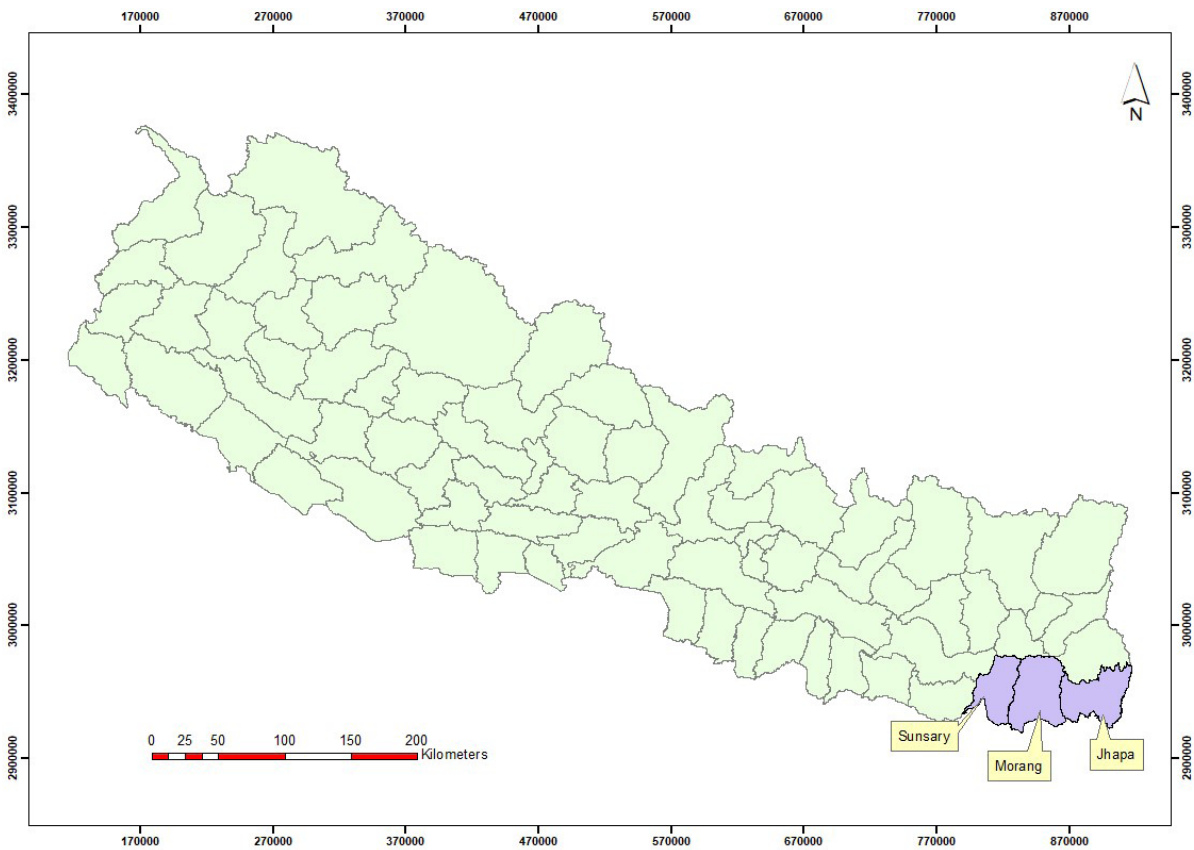

Figure 1: The study districts of Terai of Nepal.

The Jhapa district is situated in the Mechi Zone of the Eastern Development Region of Nepal. It is bordered by Morang to the west, Ilam to the north, and India to the east and south. The district comprises two distinct topographical regions: the Churia hills in the north and the Terai plain in the south. Moving on to the Morang district, which is part of the Koshi Zone, it also includes the Churia Hills in the north and the Terai Plain in the south, and is bordered by Sunsari to the west, Ilam, Panchthar, and Dhankuta to the north, Jhapa to the east, and

India to the south. Sunsari district, also in the Koshi Zone, is elongated north-south and includes both plains and hills. The district is crossed by the East-West Highway, with major market areas like Inaruwa and Itahari along the highway. The Koshi River forms the western border, with several other rivers also flowing north-south. The northernmost part of the district falls within the Siwalik range and falls climatically between the Tropical and Sub-tropical zones.

GEOLOGY AND HYDROGEOLOGY

The geology of Jhapa district can be broadly categorized into alluvium, terrace deposits, and the Churia group. The alluvium in the Bhabhar zone, consisting of over 20 meters of sand and gravel, is located in the northern part of the district, formed by rivers from the Lesser Himalaya and Churia Hills. The Bhabhar and non-Bhabhar zones cover approximately 1000 km² and 586 km², with annual rainfall recharge calculated at 60 MCM for Bhabhar and 211 MCM for non-Bhabhar, totaling 271 MCM per year. The northern alluvium extends southwards from the East-West highway to the forested terraces south of Bhadrapur, with sediments of alternating sand, gravel, clay, and silt layers about 15 meters thick, dating to the Holocene epoch. Terrace deposits, primarily clay, silt, and coarse sand, extend southward to the Gangetic Alluvium Formation, with a thickness of about 10 meters, dating to the Pleistocene epoch.

In Morang district, Siwalik rocks dominate the north, with Quaternary deposits in the south, featuring alternating layers of sand, gravel, and clay, with finer sediments southward. Morang's Bhabhar and non-Bhabhar zones span 2000 km² and 520 km² respectively, with a total recharge of 320 MCM per year.

Sunsari district's Siwalik region is bordered by Terai alluvium to the south and the Main Boundary Fault to the north, featuring varied sediment layers from Neogene to recent times. The Terai plain, part of the Indo-Gangetic Plain, is covered by Pleistocene-Recent alluvium averaging 1500 meters thick, with sediments deposited over older geological formations. Sunsari's northern zone is highly permeable, comprising outwash, boulders, cobbles, gravels, and sand, with an annual recharge potential of about 200 MCM.

GROUNDWATER HYDROLOGY

The landscape of Jhapa district is heavily shaped by rivers like Mechi, Hadiya, Phulbas, Devnia, Aduwa, Ghagara, Biring, and Kankai. These rivers have created a wide plain with many small stream channels, allowing water to move from riverbeds to underground aquifers. This transformation has resulted in a flat alluvial plain stretching from the East-West highway to the Indian border. The average groundwater level in the shallow aquifer is between 1m and 2.6m below ground level, and water levels generally remain shallow before the monsoon, not exceeding 5m, except in the far north Bhabhar zone. The annual water level fluctuations are less than 3m.

In Morang district, the average groundwater level in the shallow aquifer is 3.5m below ground level, and the water levels fluctuate between 1.6m and 9m from September to May, showing variations of more than 7m. Around 55% of the aquifer is within 40m below ground level.

In Sunsari district, the Koshi River and smaller tributaries from the Siwaliks form a drainage network that impacts the shallow aquifer system. The average groundwater level is 5m below ground level, with fluctuations between 2m and 7m from September to May. Similarly, 55% of the aquifer is within 40m below ground level.

EXISTING TUBE WELL INFORMATION

The information regarding the existing tubewsell is based on secondary sources. The inventory work includes the collection of data of the spatially distributed wells in the study districts. The complete secondary information about the wells drilled in the study area was very rare to find. Even in the agencies involved in the development of groundwater, the consultant could not get comprehensive information regarding technical details of the wells. Altogether, information on 164 deep tubewells was collected from the three districts. Among which, 49 belongs to Sunsari district, 37 from Morang district and rest 80 is from Jhapa district. The location of the these deep tubewells is shown in figure number 2.

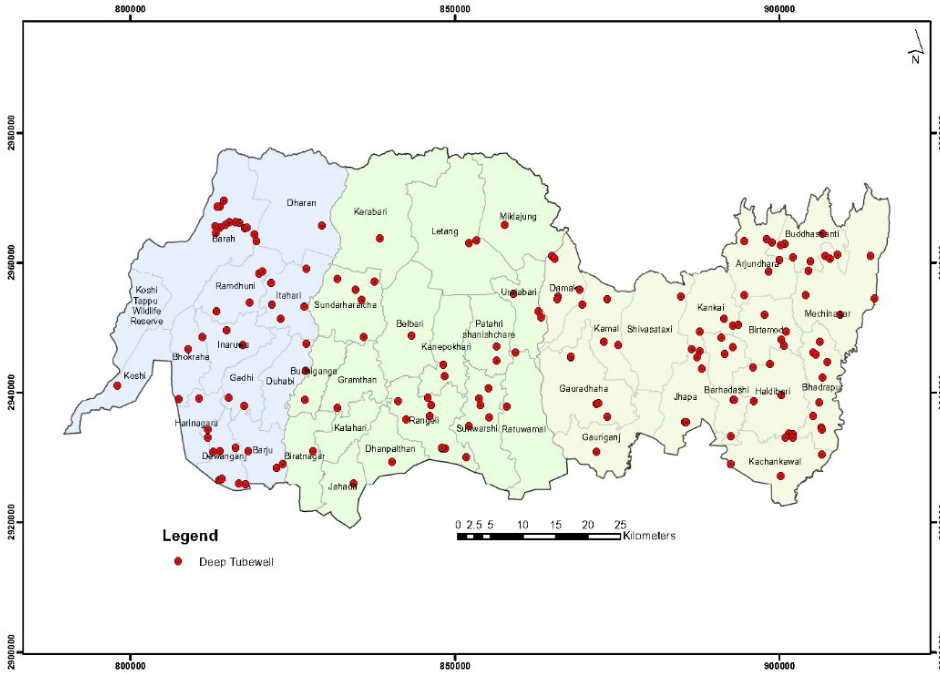

Figure 2: Location of deep tubewells.

Among these 164 deep tubewells 24 tubewells are flowing. In Sunsari district, 6 deep tubewells are flowing. Similarly in Morang and Jhapa district 12 and 6 respectively are flowing. The flowing tubewells are shown in figure number 3.

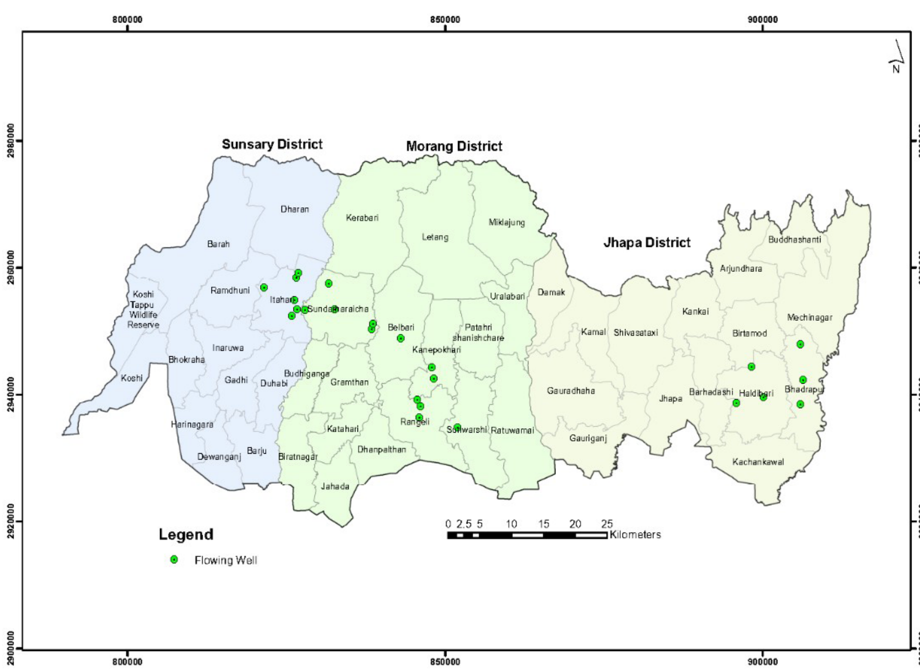

Figure 3: Location of flowing tubewells.

The technical details of these wells are presented in Table 1.

Table 1: Summary of technical details of flowing deep tubewell.

S. No	District	Location	Coordinate		Drilled Depth (m)	Total Lowering (m)	Size of the well (mm/mm)	Screen Length (m)	Screen Materials	SWL (mbgl)	PWL (mbgl)	Free flow (lps)	Yield (lps)	Transmissivity m^2/day
			Latitude	Longitude										
1		Haldibari-8	87.9958	26.5588	200	200	250/150	21	M. S.	+1.22	29.23	1	40	390
2		Jalthal	88.0129	26.5152	150	150	250/150	15	M. S.	+3.5	30.84	1	20	1130
3	Jhapa	Mahespur	88.0764	26.5373	146.3		250/150	24.4	M. S.	+0.3	16.76	1.95	32	660
4		Prithivinagar	88.0706	26.5028	200	200	250/150	21	M. S.	+8.55	24.1	10	50	650
5		Prakashpur	88.0741	26.5874	148.4	*N A*	150	18.3	M. S.	+1		0.3	5.3	100
6		Haldibari-5, Jalthal	87.9701	26.5076	*N A*	100.0	250/150	18.00	M. S.	*Flowing*	25	*3*	*N A*	*N A*
7		Daangihat-7	87.4440	26.6129	128.3	112.77	250/150	33.8	M.S.	*Flowing*	*NA*	4	*NA*	*NA*
8		Daleli, Nahar Tole, Kerum - 4	87.4919	26.5709	125.6	125.57	250/150	30.66	M.S.	*Flowing*	13.56	5	1.5	13.6
9		Thadiya Sunder, Dulari-4	87.3403	26.6569	75	64	150		M.S.	*Flowing*	2.43	*3.5*	*NA*	*NA*
10		Thadiya Sunder, Dulari-11	87.2939	26.6570	*N A*	*N A*	*N A*	*N A*	*N A*	*Flowing*	*NA*	10	*NA*	*NA*
11		Sundarpur-4,kalibudi	87.3319	26.6937	*N A*	*N A*	*N A*	*N A*	*N A*	*Flowing*	40	*NA*	*NA*	*NA*
12	Morang	TakuwaTadiya	87.5293	26.4847	*N A*	76.0	150	*N A*	*N A*	*Flowing*	3	*NA*	*NA*	*NA*
13		Keroun Daleli	87.4938	26.5545	*N A*	105.0	250/150	*N A*	*N A*	*Flowing*	20	*NA*	*NA*	*NA*
14		Sundarharaicha-1, KumarGaun, Morang	87.3978	26.6272	*125*	125.0	250/150	*15*	*SS*	*Flowing*	32	*4*		
15		Sundarhariancha 1, Khoriyatol, Morang	87.4007	26.6346	*115*	115.0	250/150	*18*	*SS*	*Flowing*	-	*5*		
16		Rangeli-3, Nishanthan, Morang	87.4719	26.5157	*N A*	103.0	250/150	18.00	*N A*	*Flowing*	30	*3*	*NA*	*NA*
17		Rangeli-3, Chainpuretol, Morang	87.4667	26.5255	*N A*	103.0	250/150	15.00	*N A*	*Flowing*	25	*0.5*	*NA*	*NA*
18		Rangeli-3 Babusahevtol Morang	87.4691	26.4998	*N A*	106.0	250/150	21.00	*N A*	*Flowing*	30	*1*	*NA*	*NA*
19		Jute Reserch Centre, Itahari	87.2805	26.6583	96	80.77	150	13.71	M.S.	*Flowing*	7.65	*NA*	5.54	1757
20		NARC Tarahara-9	87.2811	26.7032	31.4	30.78	250/150	7.62	M.S.	*Flowing*	5.56	0.5	23.4	4400
21	Sunsari	Pakali, Badhawa-2	87.2299	26.6909	91.4	74.37	150	7.84	M.S.	*Flowing*	*N A*	*N A*	*N A*	*N A*
22		Army Camp, Itahari	87.2778	26.6713	*N A*	*N A*	*N A*	*N A*	*N A*	*Flowing*	*N A*	*N A*	*N A*	*N A*
23		Gaishar, Itahari -7	87.2720	26.6487	*N A*	*N A*	*N A*	*N A*	*N A*	*Flowing*	*N A*	*N A*	*N A*	*N A*
24		Hasposa,Tarahara Agriculture Research	87.2842	26.7092	*N A*	*N A*	*N A*	*N A*	*N A*	*Flowing*	*N A*	*N A*	*N A*	*N A*

On the basis of discharge of these flowing tubewells, they are classified into three groups namely

- Category I: Initial flowing but not at present.
- Category II: Tube well with the flowing discharge of in-between 0.5 to < 5lps
- Category III: Tubewell having flowing discharge> 5lps

Category I tubewells, which initially had flowing water but at present they are no more flowing. It suggests that these wells may have potential to become operational again with some maintenance or upgrades, thus restoring their usefulness for water supply. In this regard they are recommended for rehabilitation and development, provided they are not damaged.

Category II tubewells, with a flowing discharge of 0.5 to 5 liters per second, should be left as is. Local communities currently use these wells for drinking water and residential reasons. Any alterations or interventions may disrupt their current utility, therefore maintaining their current status guarantees that the local population continues to have access to critical water resources.

Category III consists of tubewell having a flowing discharge of more than 5 liters per second. Most of them do not have any mechanism to regulate free flow. In this context, they require the establishment of a regulating mechanism to manage the free flow of water. In addition, the free-flowing water from these wells is not being properly utilized which is creating in some places water logging. By implementing a regulating mechanism, the flow of water can be controlled to prevent wastage and ensure that this valuable resource is used more efficiently and effectively by the community.

FLOWING AREA

In 1994 Groundwater Development Consultant carried the groundwater studies as a part of a reappraisal of groundwater development for irrigation in the Terai. The study includes a review of aquifer systems, aquifer development potential, the methods currently being used to exploit these aquifers for tubewell irrigation and the possibility that tubewells may be better designed and constructed at sizes and cost appropriate to the Terai Irrigation.

For the development of tube well irrigation in the Terai districts of Nepal, the Groundwater Development Committee (GDC) prepared a comprehensive groundwater development strategy. As part of this strategy, the GDC developed hydrogeological maps, with updated versions completed in 1994. These maps illustrate the groundwater potential across the entire Terai region and include detailed groundwater potential. It also shows flowing areas. Figure 4 presents the hydrogeological map of the Jhapa, Morang, and Sunsari districts, which was prepared by the GDC. At the time these maps were created, the availability of deep tubewell data was limited. Despite this, the maps were valuable for representing the groundwater potential and providing essential insights into the region's groundwater resources.

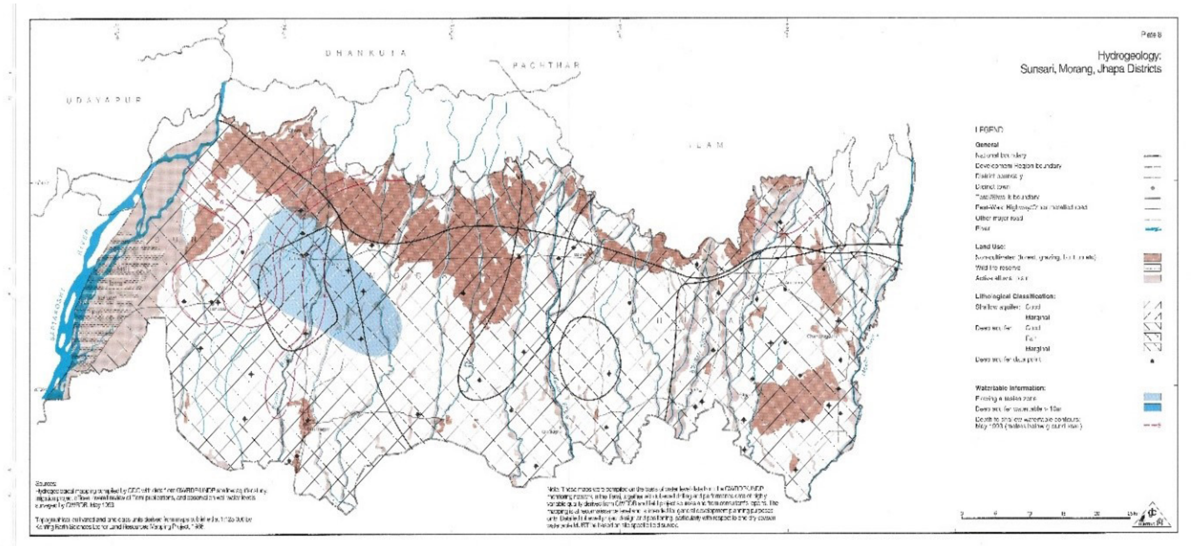

Figure 4: Hydrogeological map of Jhapa, Morang and Sunsari prepared by GDC.

The number of tubewells developed in the Terai areas has increased significantly since the maps were created. The data from these new tubewells paint a more thorough and complete picture of groundwater conditions. Figure 5 displays the updated "flowing areas" in the Jhapa, Morang, and Sunsari districts, which reflect the improved data provided by the newly installed tubewells. The revised data can be used to augment and improve the original GDC maps, providing more precise and thorough information on groundwater resources. This updated mapping can aid in the better management and utilization of groundwater for irrigation and other uses in the Terai region.

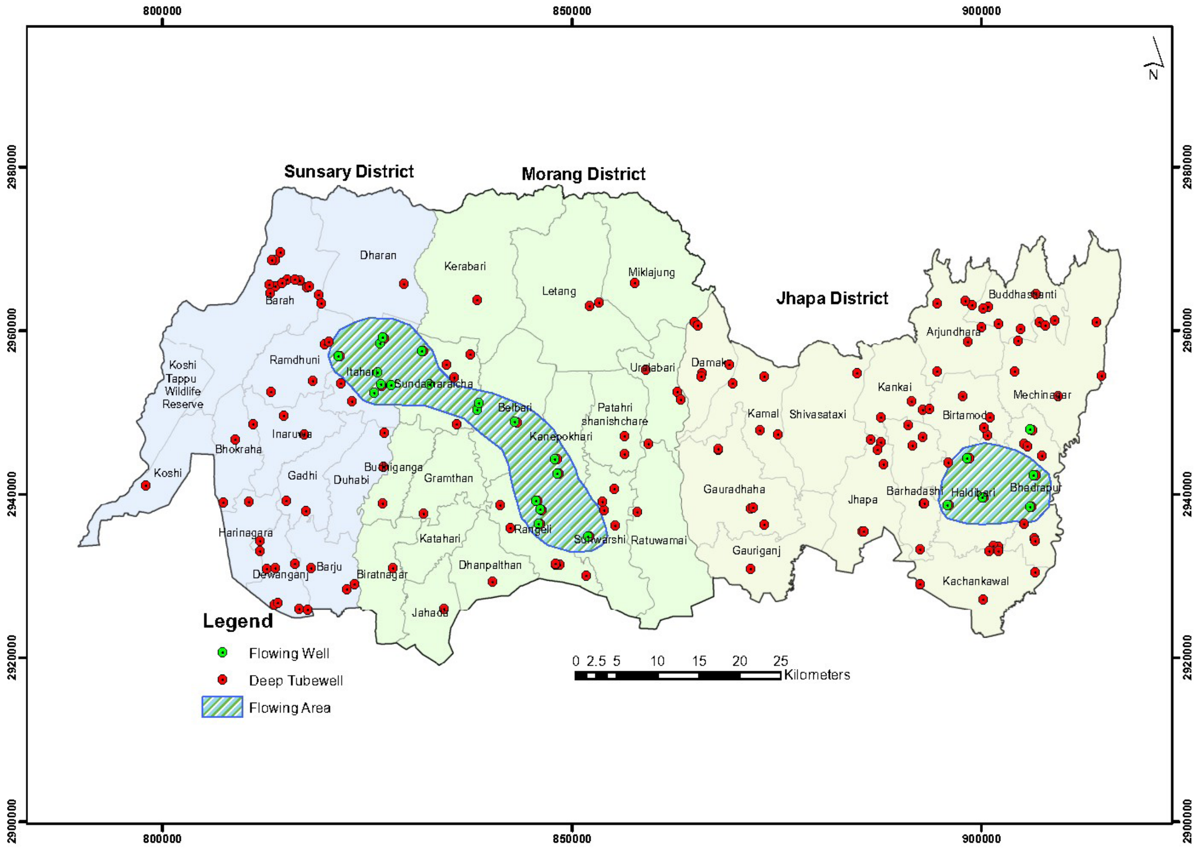

Figure 5: Updated after GDC Flowing area in Jhapa, Morang and Sunsari.

CONCLUSIONS

The presence of flowing artesian wells in these areas brings both opportunities and challenges. While these wells serve as an important water source for local communities, the lack of regulation has led to water wastage and the potential depletion of aquifers. Categorizing the wells based on their discharge rates emphasizes the need for different management approaches, including rehabilitating inactive wells, maintaining moderately flowing wells, and installing regulatory mechanisms for those with high discharge rates.

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GROUNDWATER EXPLORATION BY MAGNETOTELLURIC METHOD IN MID-WESTERN NEPAL

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ABSTRACT

The Magnetotelluric (MT) geophysical method has been effectively utilized for groundwater exploration in the Terai and Dun Valley regions of Mid-western Nepal. This study aims to evaluate the application of MT in mapping subsurface resistivity structures and delineating aquifer systems up to a depth of 500 meters, providing crucial insights into hydrogeological conditions. The MT method measures naturally occurring electromagnetic fields to determine the resistivity of subsurface materials, enabling the identification of aquiferous zones and the general depth of burial of sediments. Results from the study indicate that the resistivity of subsurface materials in the area ranges from 0.1 Ωm to 4.0 Ωm, highlighting significant variations that correlate with different geological formations. The groundwater occurrence in the region is predominantly controlled by unconfined and confined aquifers, which are critical for water supply in the Midwestern region. The MT survey's ability to distinguish these aquifer types has proven essential for determining suitable locations for tubewell installation and optimizing drilling depths, thereby enhancing the accuracy of groundwater exploration efforts. The effectiveness of the MT method in both sedimentary environments and fractured rock settings makes it a valuable tool for groundwater exploration in complex geological terrains. Its non-invasive nature and ability to provide high-resolution resistivity data make it particularly advantageous in areas where traditional exploration methods may be limited or challenging. This study demonstrates the potential of the MT method as an integral part of groundwater exploration strategies in Nepal, contributing to more informed decision-making in water resource management. Overall, the findings underscore the importance of advanced geophysical techniques like MT in enhancing the understanding of subsurface hydrogeological frameworks, especially in regions with diverse geological settings. The MT method not only offers a detailed assessment of aquifer distribution but also supports sustainable groundwater management practices in areas with critical water needs.

Keywords: ***magnetotelluric, groundwater exploration, subsurface resistivity, aquifer systems, geophysical method***

INTRODUCTION

Groundwater is a vital resource that supports domestic, agricultural, and industrial needs, particularly in regions with limited surface water availability. In Nepal, groundwater plays a crucial role in the livelihoods of millions, especially in the mid-western region, where surface water resources are often scarce, seasonal, or difficult to access. However, despite its importance, systematic exploration and management of groundwater resources remain limited. The growing demand for water due to increasing population, urbanization, and agricultural expansion has intensified the need for efficient groundwater exploration and sustainable management practices.

Traditional methods of groundwater exploration, such as drilling and surface geophysical surveys, often face challenges in the complex geological settings of mountainous regions like Nepal. These methods may provide limited resolution of subsurface features, making it difficult to identify and delineate aquifers accurately. In this context, the Magnetotelluric (MT) method has emerged as a powerful tool for groundwater exploration.

In this geophysical survey, we used the Magnetotellurics (MT) method, an electrical geophysical exploration technique that utilizes naturally occurring electromagnetic energy propagating into the earth to determine the electrical resistivity of the subsurface. The low-frequency electromagnetic field is measured, and the wave impedance is calculated and expressed in terms of the resistivity of the subsurface. The depth of investigation depends on the frequency of the electromagnetic wave, leveraging the principle that lower frequencies penetrate deeper into the Earth's crust. MT surveys typically explore depths ranging from a few hundred meters to over 10 km. The resistivity versus depth cross-section developed from MT data can be interpreted in terms of rock type, and spatial variations in the resistivity-depth relationship at closely spaced surface locations can reveal subsurface geological structures.

Mid-Western Nepal, characterized by a diverse geological setting with complex tectonic features, presents unique challenges and opportunities for groundwater exploration. The region encompasses a range of geological units, including sedimentary, metamorphic, and igneous rocks, often disrupted by faulting, and folding due to active tectonic processes. These geological complexities significantly influence the distribution and movement of groundwater. Therefore, advanced geophysical methods like MT are essential for accurately mapping aquifer systems and assessing groundwater potential in such challenging terrains.

This study aims to explore the effectiveness of the Magnetotelluric method in identifying and characterizing groundwater resources in Mid-Western Nepal. By integrating MT data with geological and hydrological information, we aim to provide a comprehensive understanding of the subsurface aquifer systems and contribute to the sustainable management of groundwater resources in the region. This research will not only enhance the knowledge of groundwater distribution but also guide future exploration and management strategies in similar geologically complex regions of Nepal.

STUDY AREA AND SURFACE GEOLOGY

The Magnetotelluric (MT) method was utilized for groundwater exploration at 46 locations across the Banke, Bardiya, and Surkhet districts in mid-western Nepal. Banke and Bardiya, located in the Terai region of the Nepal Himalaya, are characterized by extensive alluvial deposits mainly composed of sand, silt, clay, and gravel. These sediments create an ideal setting for unconfined and confined aquifers, which are essential for the region's water supply. In contrast, Surkhet is situated within the Dun Valley, a geologically complex area with a mixture of alluvial deposits. The Surkhet valley features a combination of sand, silt, clay, gravel, and rock deposits, reflecting a dynamic depositional environment shaped by active tectonic processes.

METHODOLOGY

This method measures natural variations in the Earth’s electromagnetic field to determine subsurface resistivity, which correlates with geological formations and water-bearing zones. Data acquisition involved deploying MT sensors at each site, capturing signals over a range of frequencies to probe different depths. The resistivity profiles were analyzed to identify potential aquifer zones, delineate their extent, and assess their quality. The useful reference for this study is shortly described below:

Cagniard, L. (1953). The basic theory of the magnetotelluric method of geophysical prospecting from *Geophysics, 18*, 605–635 is very useful for the present work. This seminal work outlines the foundational theory behind the Magnetotelluric (MT) method, providing insights into the principles that guide geophysical prospecting using electromagnetic fields.

Essam Aboud. Water exploration using magnetotelluric and gravity data analysis; authored by Wadi Nisah, Riyadh, Saudi Arabia is very useful reference for the present study. This study highlights the application of MT and gravity data analysis in water exploration, demonstrating the effectiveness of these methods in identifying aquifer systems in complex geological settings.

Spitz, S. (1985). This paper discusses the properties of the MT impedance tensor, focusing on the impact of rotational transformations on data interpretation and providing critical insights for accurate subsurface mapping. In the present work the conceptual framework was derived from this reference.

Zhdanov, M. S. (2009). This comprehensive book covers advanced theories and methods in geophysical electromagnetics, offering a detailed exploration of electromagnetic techniques, including the MT method, for subsurface investigations.

PQWTS-S500 Manual and Catalogue
The manual provides operational guidelines, technical specifications, and detailed instructions for using the PQWTS-S500 system in groundwater exploration. It includes calibration procedures, data interpretation, and maintenance tips to optimize the use of this geophysical tool.

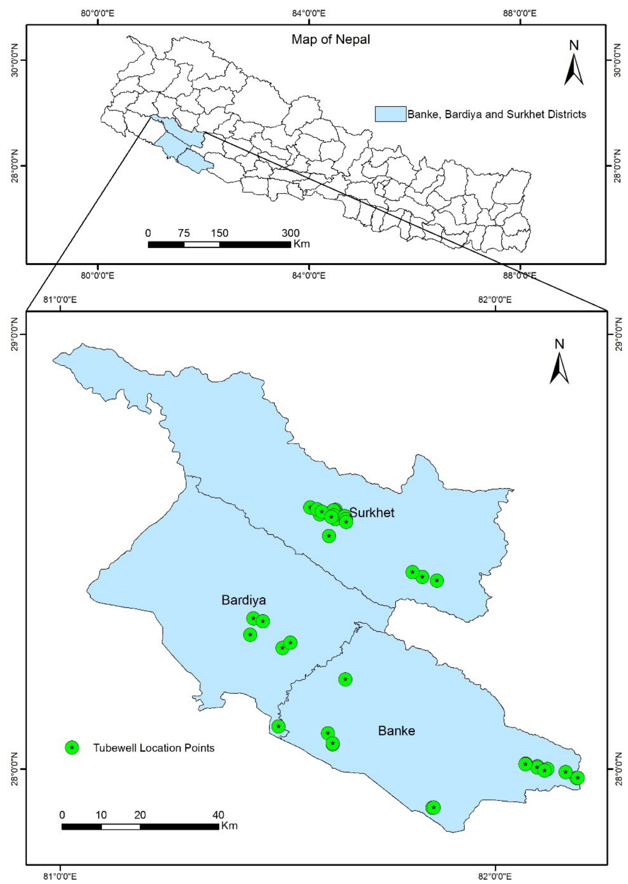


Figure 1: Tubewell study location map.

RESULTS AND DISCUSSIONS

2D image and interpretation

To identify water-bearing aquifers in the study area, a resistivity survey was conducted at 46 different locations. In the survey results, the dark blue color indicates clay or low-permeable materials, while light blue signifies water-bearing formations with high resistivity. Yellow and red colors represent rock and hard formations with very low resistivity, as shown in Figure 2. A frequency value below 200 megahertz indicates a low-permeable formation, whereas a value above 200 megahertz suggests high-permeable materials with a high likelihood of containing water-bearing aquifers.

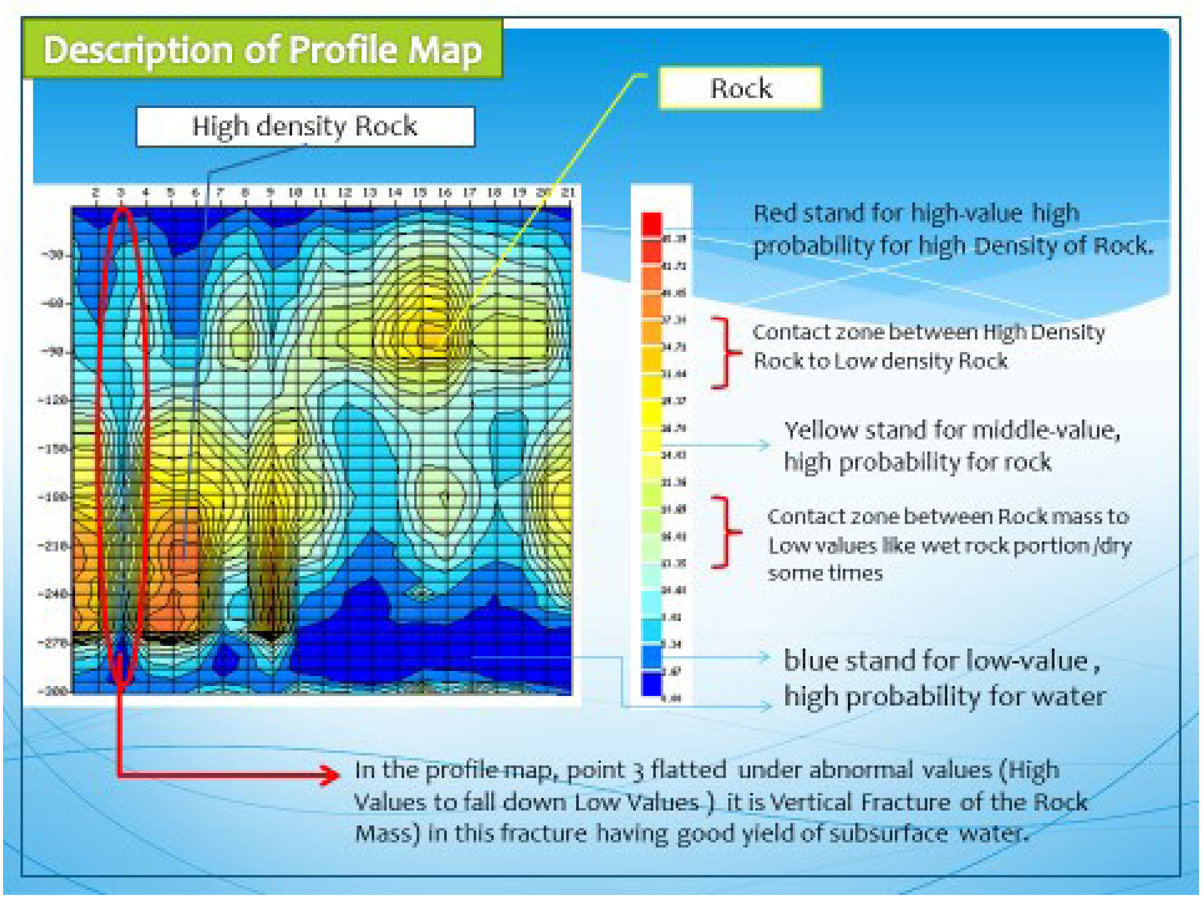
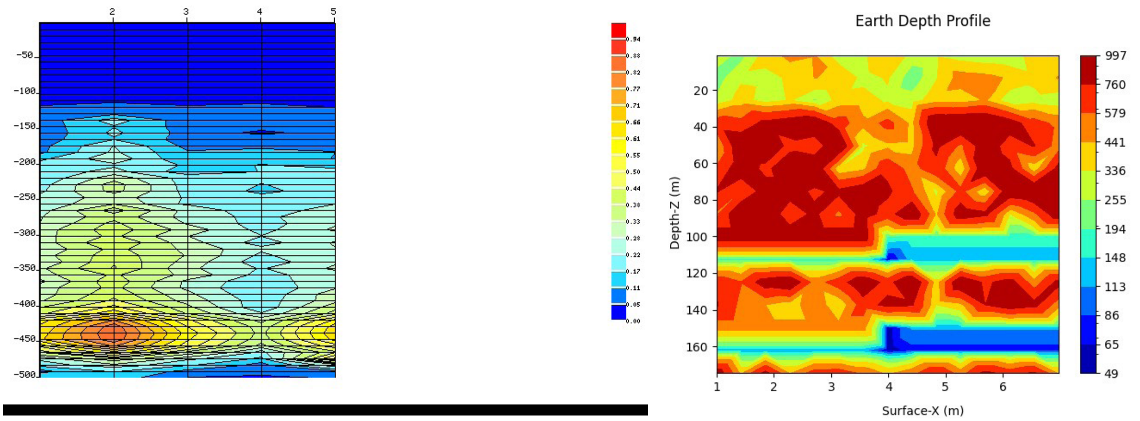


Figure 2: Description and analysis of profile map.

Dhakaila deep tubewell Bardiya

A well drilled at Point 2 encountered a water-bearing aquifer at a depth of 141 meters, yielding a water flow rate of 24 liters per second (Fig. 3).



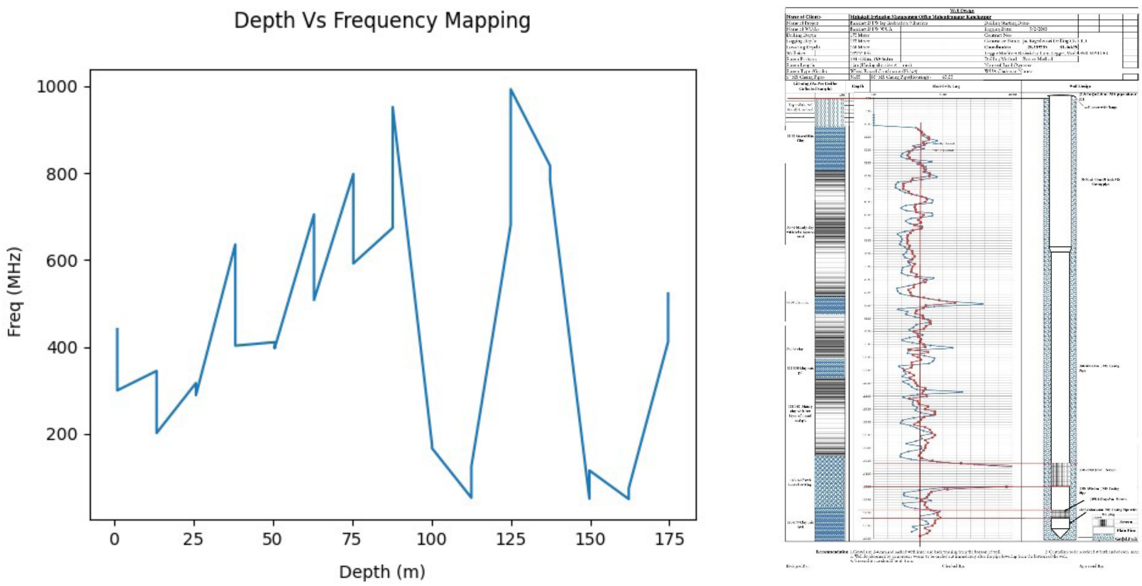
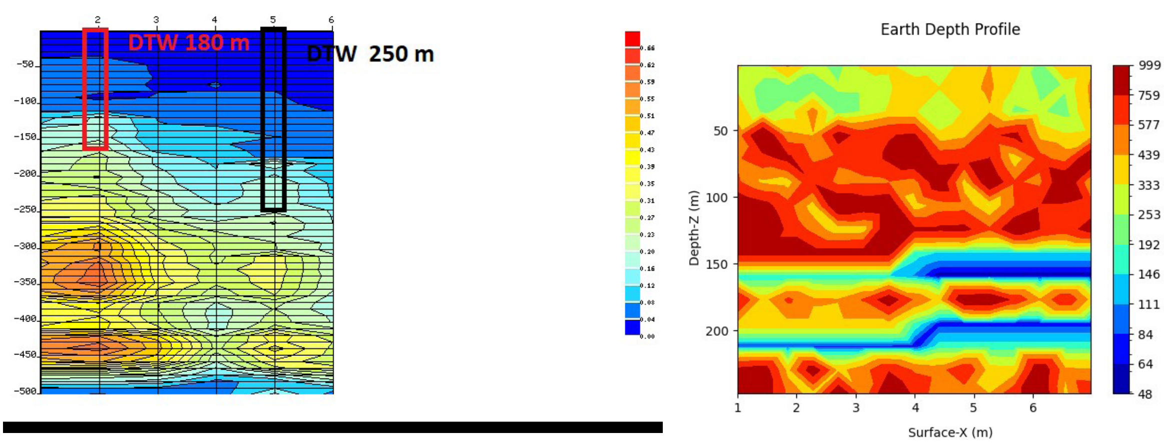


Figure 3: 2D profile map and well logging report of Dhakaila deep tubewell.

Rajena deep tubewell Banke

A well drilled at Point 5 revealed a sequence of subsurface layers: the first layer, a mix of gravel, was found at a depth of 45-50 meters. Below this, a clay layer was encountered between 50-75 meters. The second aquifer layer was identified at 78-81 meters, followed by the third layer at 187-190 meters, and the fourth layer at 230-233 meters (Fig. 3). The well yielded a water quantity of 15 liters per second from these aquifer layers.



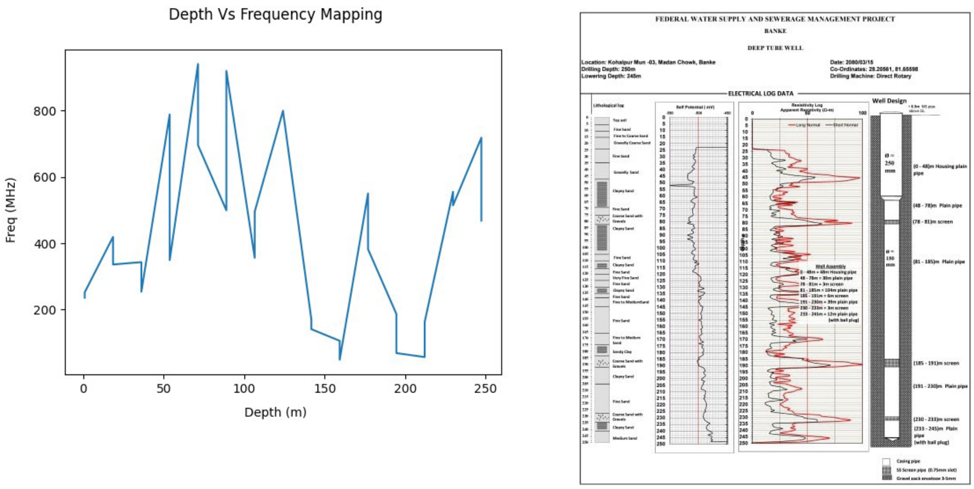


Figure 4: 2D profile map and well logging illustration of Rajena deep tubewell.

Katarniya Deeptubewell Bardiya

A well drilled at Point 14 encountered a water-bearing aquifer at a depth of 135 meters, yielding a water quantity of 18 liters per second.

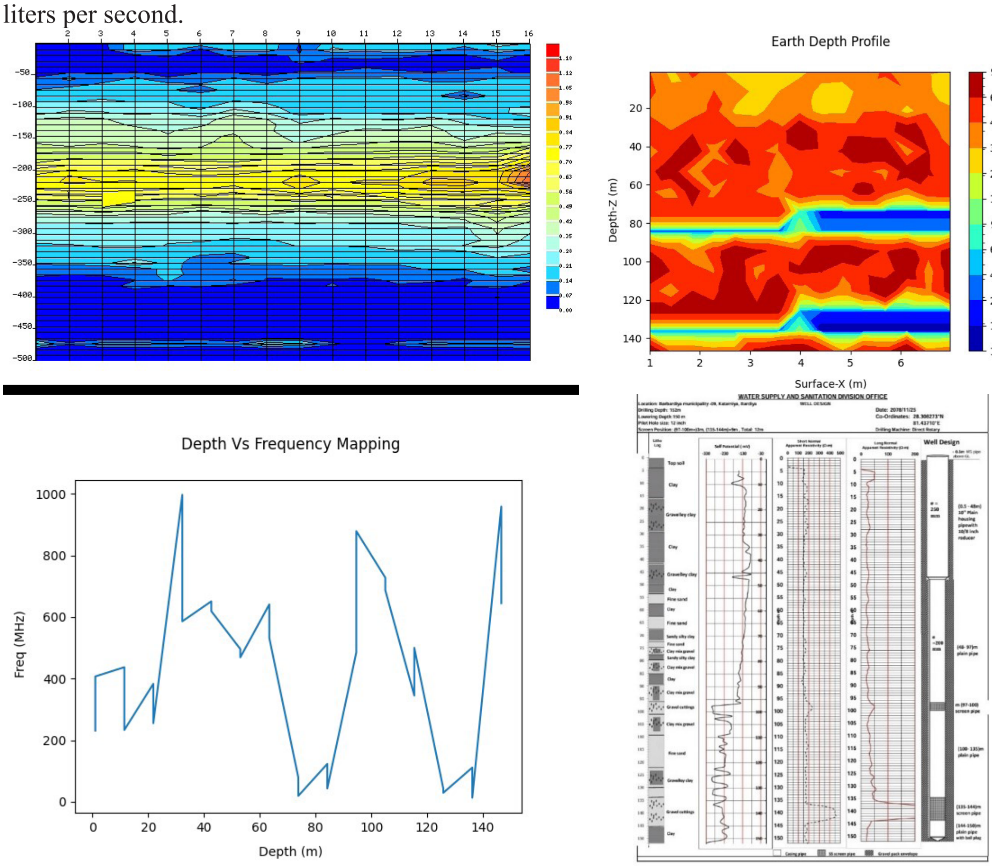


Figure 5: 2D profile map and well logging report of Katarniya deep tubewell.

CONCLUSIONS

The Magnetotelluric (MT) geophysical method has been successfully applied for groundwater exploration in the Terai and Dun Valley regions of the Nepal Himalaya. This technique has provided valuable insights into aquifer and sediment relationships within an investigative depth of up to 500 meters, making it highly suitable for hydrogeological studies. The MT method effectively identifies aquiferous zones and determines the general depth of tube wells. The study revealed that the resistivity of subsurface materials within the area ranges from 0.1 Ωm to 4.0 Ωm. Groundwater occurrence in the study area is primarily controlled by fractured and weathered zones in rocky formations, while in the Terai region, it is mainly influenced by sediment types and formation permeability. There is a high probability of encountering groundwater in rocky and silty zones. The MT method proves to be effective and relatively cost-efficient for investigating great depths compared to deep electrical sounding, although it is sensitive to surface and urban noise due to the urbanization level in the study area.

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