A Report on

Hydrogeological mapping of springs in Dhankuta, Nepal

(Bojhepani and Chanchaladevi Mul Dhankuta 1,

Dhwoje and Kesharikharka of Chhathar Jorpati Rural Municipality 2)

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Executive summary

In the Hindu Kush Himalaya (HKH) region, spring sources play a vital role as potable water resources for a large population. However, these valuable springs are disappearing, leading to a crisis. To address this, the International Centre for Integrated Mountain Development (ICIMOD) is implementing action research and pilot projects focused on hydrogeology-based springshed management in Kavre and Dhankuta district, Nepal. In this endeavor, the Integrate Earth System (IES) consult offered consultancy services to ICIMOD, providing hydrogeological insights to delineate recharge areas. The study followed a protocol adapted from the six steps protocol for reviving springs, incorporating steps 1, 2, and 4. Field-based surface geological mapping and available land ownership information were used to estimate several recharge areas for intervention around the spring sources.

The study of springs was conducted in the midlands of Nepal, specifically in Municipalities of Dhankuta District. The study area are two sites (Bojhepani and Chanchaladevi spring) of Ward 1 in Dhankuta Municipality and another two (Dhwoje and Kesharikharka spring) of Ward 2 in Chhathar Jorpati Rural Municipality conducted in first quarter of the year 2024 AD. Geologically, the study area belongs to the Higher Himalayan Crystalline rocks. The area is dominant with varieties of gneiss rock throughout the area.

Several springs in the study areas, including Bojhepani, Chanchaladevi, Dhwoje, and Kesharikharka, are drying up, indicating a gradual decline in spring health. The springs downstream suffer from water contamination because of dumping community waste in the tributaries is an additional issue. This decline is likely due to disruptions caused by road construction, other human activities impacting traditional water sources and lack of impactful guidelines for the protection and conservation of springs and their surroundings.

The goal of this assessment was to enhance the ability of surface runoff to percolate and contribute to the mountain aquifers specially for four selected springs. This approach aims to sustain and protect these valuable water resources in the region.

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Chapter 1: Introduction

Background

The International Centre for Integrated Mountain Development (ICIMOD) has been conducting springshed management pilots in Dhankuta Municipality and Chhathar Jorpati Rural Municipality of Dhankuta district in Nepal in partnership with local communities and local government with the intention of scaling up the solution through local government. ICIMOD together with the local government and communities has already initiated intervention activities to conserve springs (locally *mul*) located in selected wards of Dhankuta Municipality. ICIMOD is implementing action research and pilot projects on hydrogeology-based springshed management in Kavre district and Dhankuta district, Nepal. The initiatives are co-designed with partners and communities to generate evidence on springshed management that contribute to policy formulation or implementation and capacity building strategies for scaling up springshed management across the Hindu Kush Himalaya.

Roadside Spring Protection to Improve Water Security (RoSPro) project of MetaMeta, FutureWater and ICIMOD is looking at the issue of springs of hill and mountain areas particularly along the roadsides. The triggering issue is the depletion of springs, which is the main sources of water (drinking, domestic and agriculture) for over 10 million of people living in hill and mountain region of Nepal, due to many factors such as degradation of catchments, land use changes and climate change. But barely any attention has been paid to the contribution of the rapid expansion of road networks in the mountain areas to the demise of natural springs. RoSPro is focusing on protecting and developing springs as a part of local road development practice.

During the springs protection journey of RoSPro of MetaMeta, FutureWater and ICIMOD four springs that are used by local communities for irrigation and drinking water particularly along the roadsides are selected for the conservation and management process. The springs will also be monitored, and results will be published as evidence for scaling.

Integrate Earth System (IES) Consult is a firm specializing in research and development by technical solutions and consulting. IES Consult is involved in this project to provide consultancy service to ICIMOD for the role to provide hydrogeological input to delineate the recharge area for 4 selected springs from Ward 1 of Dhankuta Municipality (DM1) and Ward 2 of Chhathar Jorpati Rural Municipality (CJRM2). During this project, IES map hydrogeological settings of the research area and prepare conceptual hydrogeological layouts of the springs area in the springshed approach. The working approach in this project is incorporating technical steps from the six-steps protocol for reviving drying springs (Shrestha et al., 2018)

Objectives

The objective of this consultancy is to map recharge areas hydrogeologically of four springs in Dhankuta, Nepal using hydrogeological techniques, employing the methodology outlines in the Protocol for reviving drying springs in the HKH especially utilizing 3D conceptual hydrogeological layout.

Study area

The study investigated four areas across Dhankuta Municipality 1 (DM1) and Chhathar Jorpati Rural Municipality 2 (CJRM2) within Dhankuta District, Koshi Province, Nepal (Figure 1). These areas include Bojhepani spring (DM1-B) and Chanchaladevi spring (DM1-C) in Dhankuta ward 1, and Dhwoje (or Dhoje) spring (CJRM2-D) and Kesharikharka area (CJRM2-K) in Chhathar Jorpati ward 1. Nibuwa and Tankhuwa are the region's major rivers, originating from springs in the hilltops of Hile and Chhathar Jorpati villages. This makes the area important for maintaining the flow of these rivers.

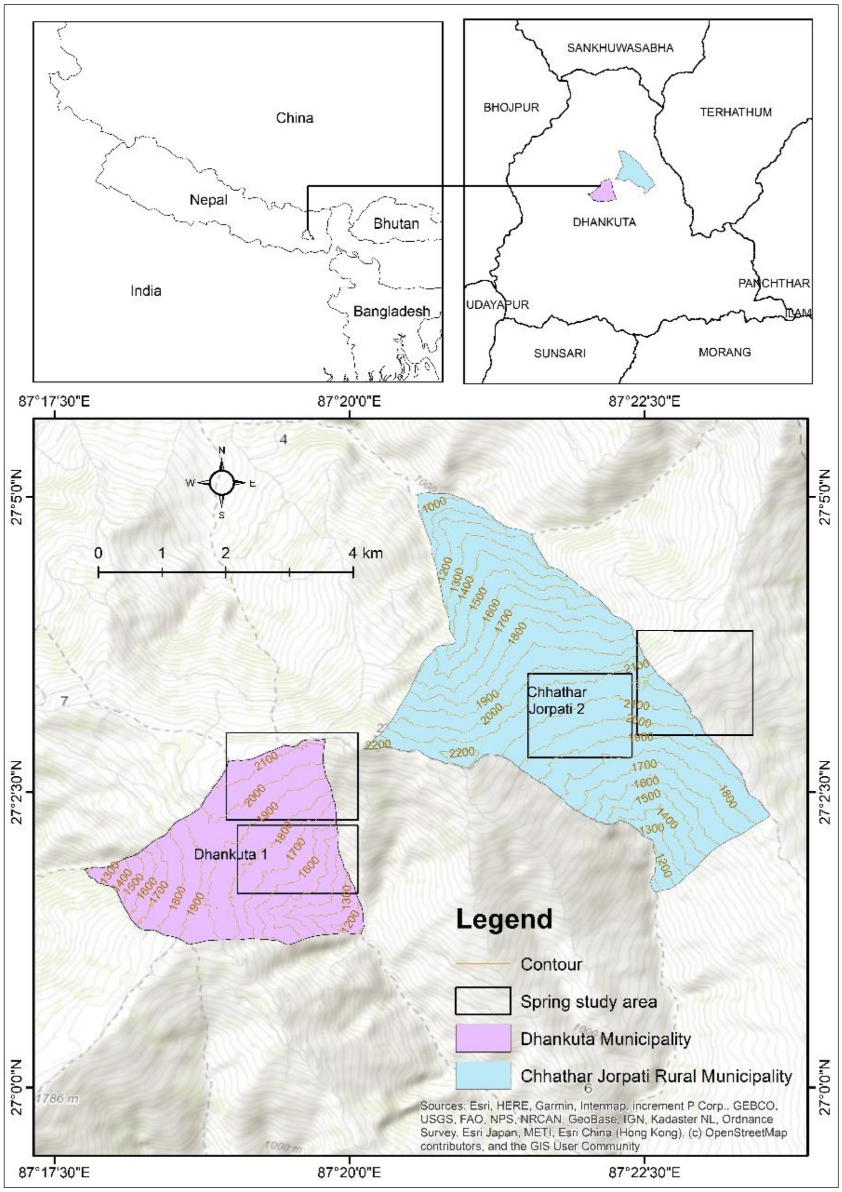

Figure 1:Location map of four study areas inside the rectangular boxes within DM1 and CJRM2.

Climate

This study examines climate patterns in a representative area of Nepal's mid-hill region. The analysis, based on data from a nearby weather station (Station No. 1307, Dhankuta) for the past few decades, reveals a significant warming trend. Both the maximum and minimum temperatures have been steadily increasing (ICIMOD, 2021). Additionally, temperature-based indices also show a rising trend. However, precipitation patterns haven't shown any significant changes. The average annual rainfall remains around 960 mm, with most of it (around 73%) concentrated during the monsoon season (June-September). Conversely, precipitation levels are very low between November and March. On average, the station experiences a high of 24°C and a low of 17.6°C throughout the year. The warmest month is

August (average high: 27°C), while January is the coldest (average low: 7°C). Similarly, the average minimum temperature is 15°C, with July being the warmest (average high: 20°C) and January the coldest (average low: 7°C).

Population

DM has a total population of 35,983, with nearly equal numbers of males (47.78%) and females (52.22%). DM1 ward possesses the highest population within the municipality at 3,436 males and 3,677 females (Figure 2, left). In CJRM, the total population is 16,456 with a slightly higher percentage of females (51.71%) compared to males (48.29%). CJRM2 holds the second-highest population in this rural municipality with 1,559 males and 1,629 females (Figure 2, right).

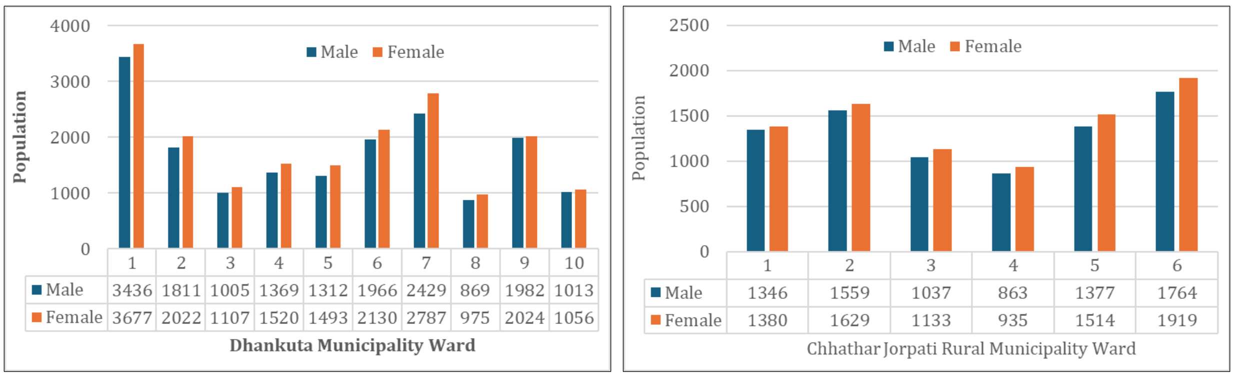

Figure 2:Ward wise population distribution of DM1 and CJRM2 (NPHC, 2021)

Chapter 2: Methodological approach

The hydrogeological mapping of springs in Dhankuta Municipality and Chhathar Jorpati Rural Municipality, Dhankuta started informing the purpose of study and collecting data by interviewing community people with the help of representatives of local government and community resource person in a defined methodological framework (Figure 3). The coordinates of springs, rock exposures and land cover were collected using GPS. In the case of some restricted/unreachable places, information was collected by interpreting the Google Earth image. The present status of springs has also been assessed. The brief socio-economic status acquired by the opinions of the local people. Different photographs of the springs were taken throughout the field survey.

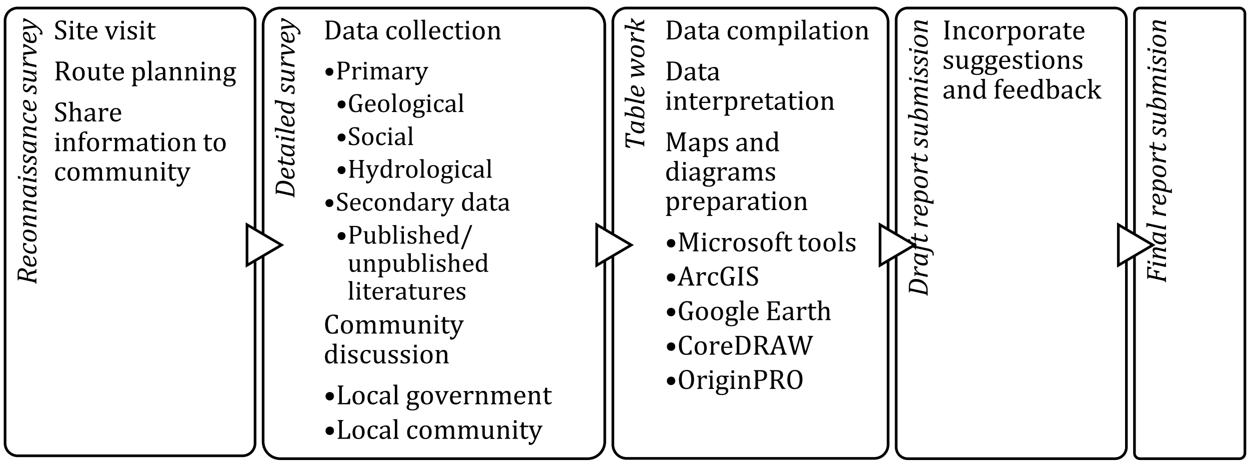

Figure 3: Flow chart of methodological approach.

Data acquisition tools

The major tools useful in hydrogeological mapping of springs are discussed briefly in the following paragraphs.

GPS Device

It is used to locate and track investigation sites with the help of coordinates. The device requires signals from satellites to provide an accurate location. The model number of the GPS device is GARMIN GPS map 62sc.

Measuring tape

It is often used during springs assessment to measure the dimensions and characteristics of the springs for the discharge measurement. It is also useful during the measurement of discontinuities present in the rock exposure.

Measuring Jug

The purpose of using measuring jug while measuring spring discharge is to estimate the availability of water for water budgeting. It helps understand how discharge varies with rainfall, different months, and seasons during monitoring of springs. It is also useful in measuring in-situ water quality by dipping handheld tracer.

Brunton compass

The Brunton compass, also known as pocket transit, may be adjusted for declination angle according to one's location on the Earth. It is used to get bearing and directional degree measurements (azimuth) through the Earth's magnetic field. It measures the orientation of discontinuities (i.e., bedding, foliation, lineation, joints, etc.) in the rocks.

Geological hammer

A geological hammer is used for splitting and breaking rocks. In field geology, they are used to obtain a fresh surface of a rock to determine its composition, nature, mineralogy, history, and field estimate of rock strength. Sometimes it is used as a scale in a photograph.

Inventory form

Inventory forms are used during hydrogeological assessment to record and document the primary data systematically. These forms provide a standard method for evaluating local hydrogeology. By collecting this data, we can develop maps and models to identify recharge area and discharge of any typical springs, monitor fluctuation of quantity and quality over time, and plan for the conservation efforts.

Camera

A camera is valuable for spring assessment, providing valid proof for researchers and decision-makers to understand and manage springs better. The photographs of study locations have been captured using digital cameras and smartphones.

Digital Elevation Model (DEM) data

They are often used during spring assessment because it provides information about the topography of an area, including the slope, aspect, and elevation which are more likely to represent runoff and direction of flow. Additionally, aspect maps created from DEM data can help identify areas that receive more sun exposure, leading to higher rates of evaporation and soil drying.

Reconnaissance survey

A reconnaissance survey conducted for the collection of preliminary data related to the physical and geological aspects of the area, such as topography, rock types, soil composition, and the presence of water bodies. The survey also includes the collection of socio-economic data related to the available water bodies around the study area.

Detailed survey

A detailed survey is led to measure available water quantity and in-situ water quality, measurement of underlying geology linked with water bodies, intense field traverse to find the possible rock outcrop and present land cover conditions. The community resource person also involved in this survey to guide the way and share knowledge based on their understanding.

To identify areas of groundwater recharge basically a three-steps approach was employed. First, created a representative cross-section depicting the rock formations and any fractures within them. This initial analysis provided a foundational understanding of potential water pathways. Secondly, a 3D conceptual model was built in software like ArcScene and CorelDRAW. This model incorporated the rock structure and the locations of existing water bodies, offering a more comprehensive view of subsurface geology. Finally, by integrating this model with Google Earth Pro, recharge zones directly delineate on a map. This visualization tool not only clarifies recharge areas but also serves as a valuable platform for planning and implementing water management strategies.

Report submission

After collection of primary and secondary data from different sources, the next step is interpretation. This involved analyzing the data, identifying patterns, and drawing meaningful conclusions. When the interpretation is complete, a draft report was prepared. The draft report serves as an initial version, capturing the key findings and insights. After incorporating necessary revisions, the final report will be ready for submission.

Chapter 3: Results and Discussion

Topography and Drainage

The Dhankuta Municipality 1 and Chhathar Jorpati Rural Municipality 2 lies in the Midlands, consisting of gradually sloping hills, wide river valleys and tectonic basins in the central part of Nepal, encompass the scenic lowlands between the Mahabharat Range to the south and the high mountains to the north (Hagen 1969) (Figure 3).

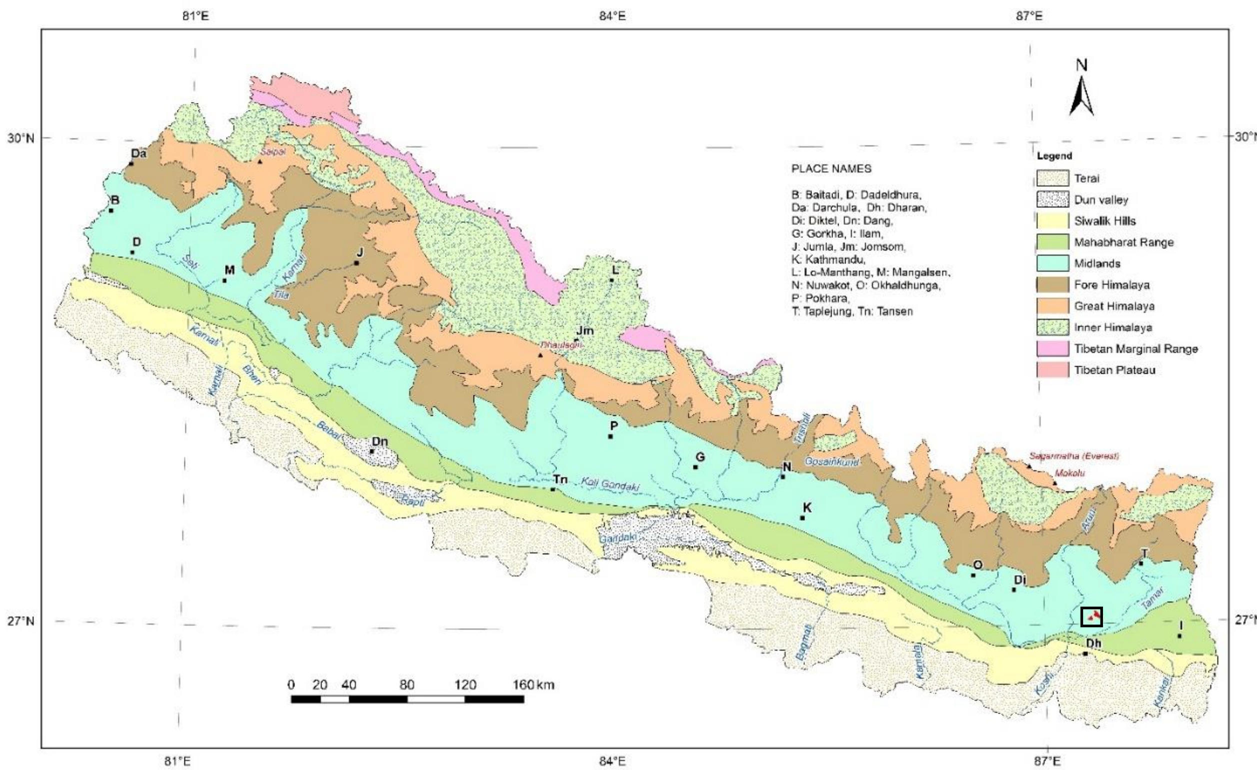

Figure 4: Physiography of Nepal (Hagen, 1969) highlighting the study area in Dhankuta Municipality 1 and Chhathar Jorpati Rural Municipality 2, Dhankuta under red patch inside rectangle.

Geology and Hydrogeology

The regional geology of the study area is solely lies on Higher Himalayan Crystallines (Figure 5) which consists of dark gray, blue-gray, and greenish gray kyanite schists, garnetiferous schists, actinolite schists, and quartzites, with banded and augen gneisses. The age of these group is Proterozoic (Dhital, 2015).

The region has abundant groundwater resources that emerge as natural springs and seepages. These act like nature's water fountains, continuously replenishing the adjacent Nibuwa-Tankhuwa watershed. This watershed, in turn, plays a vital role by feeding the much larger Tamor River downstream. The importance of these groundwater sources cannot be overstated. They act as a recharge for streams ensuring a steady flow of water in the Nibuwa and Tankhuwa rivers, even during dry seasons. This consistent flow is crucial for the health of the ecosystem downstream.

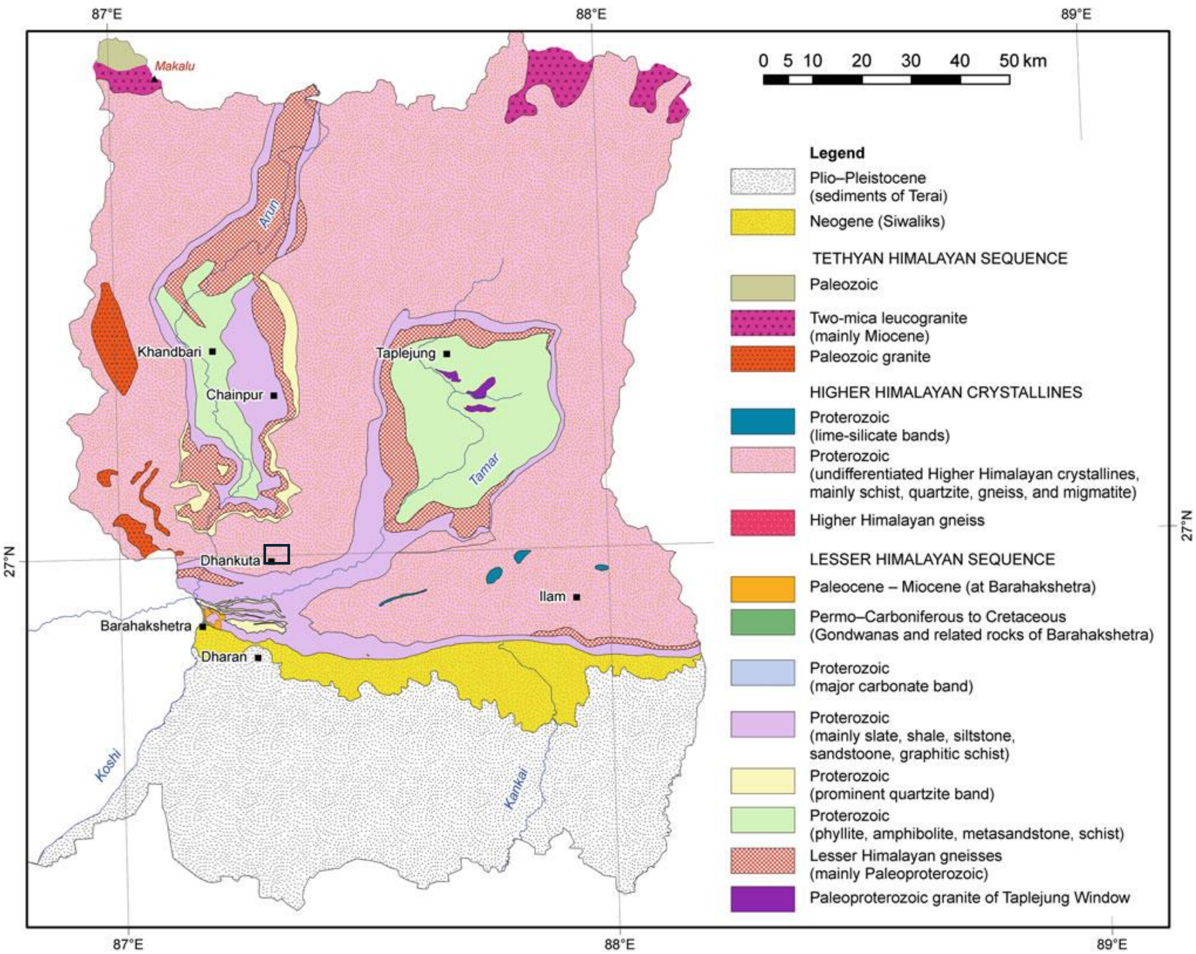

Figure 5: Study area marked with a small black rectangular box in simplified geological map of the Arun–Tamar region (Dhital, 2015).

In the following sections, hydrogeology of the four specific sites within this region will be discussed. Detailed descriptions and schematics will be provided to illustrate the unique characteristics of each groundwater system and hence identify the groundwater recharge.

Bojhepani spring, Dhankuta Ward 1 (DM1-B)

The range of slope is gentle (0˚) to steep slope (71.93˚), steep slope is dominant in northwest and southeast remaining regions have moderate to gentle slope. The maximum elevation in the area is 2222 m in the northwest and minimum is 1586 m in southwest. Hillshade is a visual representation of a shaded relief, and the values are not dependent on the elevation itself but of the aspect and angle illumination. In hillshade map, a value of 0 represents areas completely in shadow (no light). Values ranging from 1 to 255 indicate increasing levels of illumination, with higher values corresponding to brighter, well-lit areas and lower values indicating darker shadows. The dominant slope-aspect of the region is south and southeast whereas less portion has northern aspect (Figure 6).

The area is covered by loose materials like soil and vegetation, making it difficult to find rock formations during the survey. The spring is likely originated from these loose sediments. However, analyzing water flow data suggests that the perennial springs throughout the region are ultimately fed by deep fractures of underlying gneiss rock. Spring discharge is 1.71 lpm and in-situ water quality parameters of DM1-B are within the Nepal Drinking Water Quality Standards (NDWQS) (see Annex 1). Also, it is observed that DM1-B faces water stress due to 14 households relying on it.

A representative cross-sectional view of rock exposure observed near No.1 camp gate was taken for the visualization of real field conditions (Photo 1). Then a 3D conceptual model with rock discontinuities (color lines) and spring (blue arrow) in Bojhepani area created with the help of attitude data extracted from the available rock exposures in the area (Figure 7). Later, the data again plotted in the Google Earth which shows rock discontinuities in the Bojhepani area (Figure 8). Lastly, the recharge area delineated will be utilized for conservation activities (Figure 9).

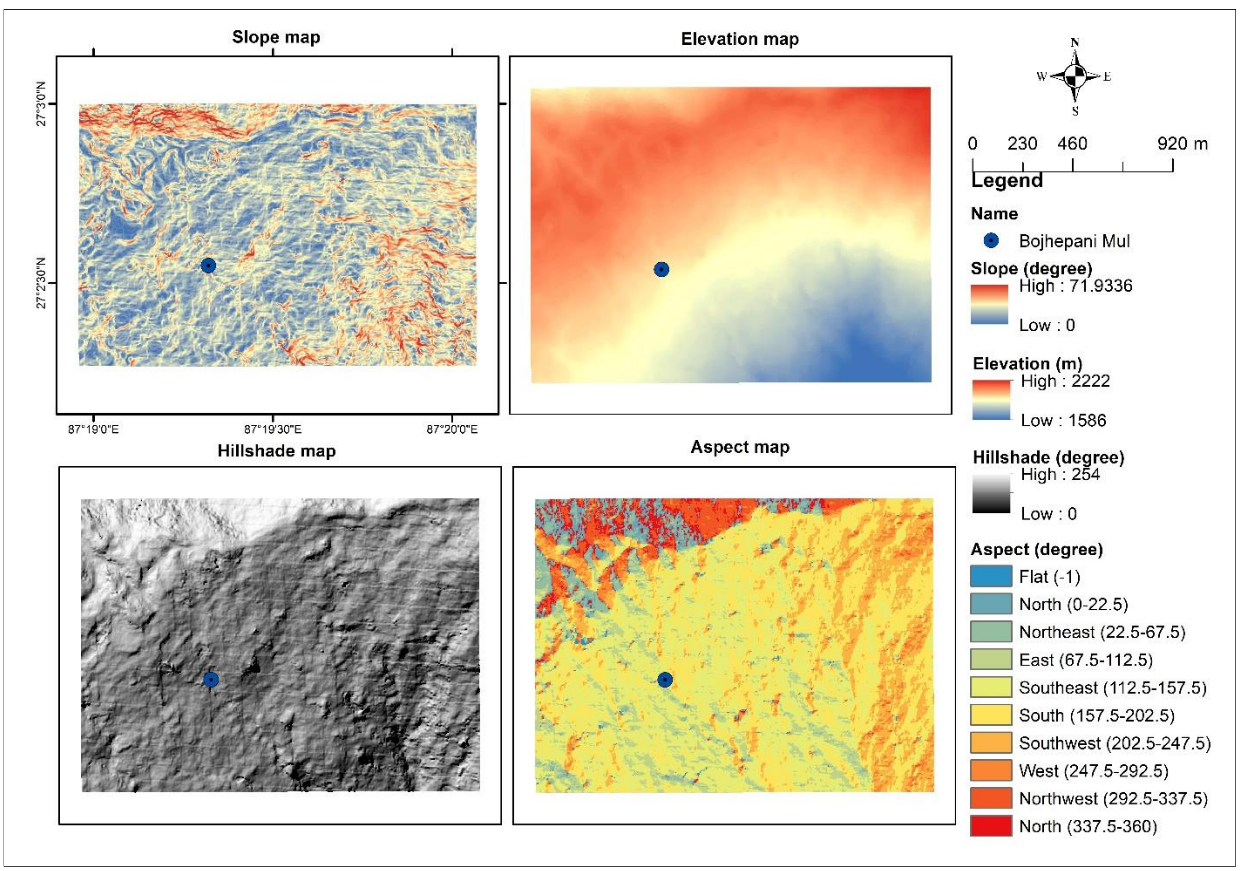

Figure 6: Bojhepani spring overlying in Slope, Elevation, Hillshade and Aspect maps.

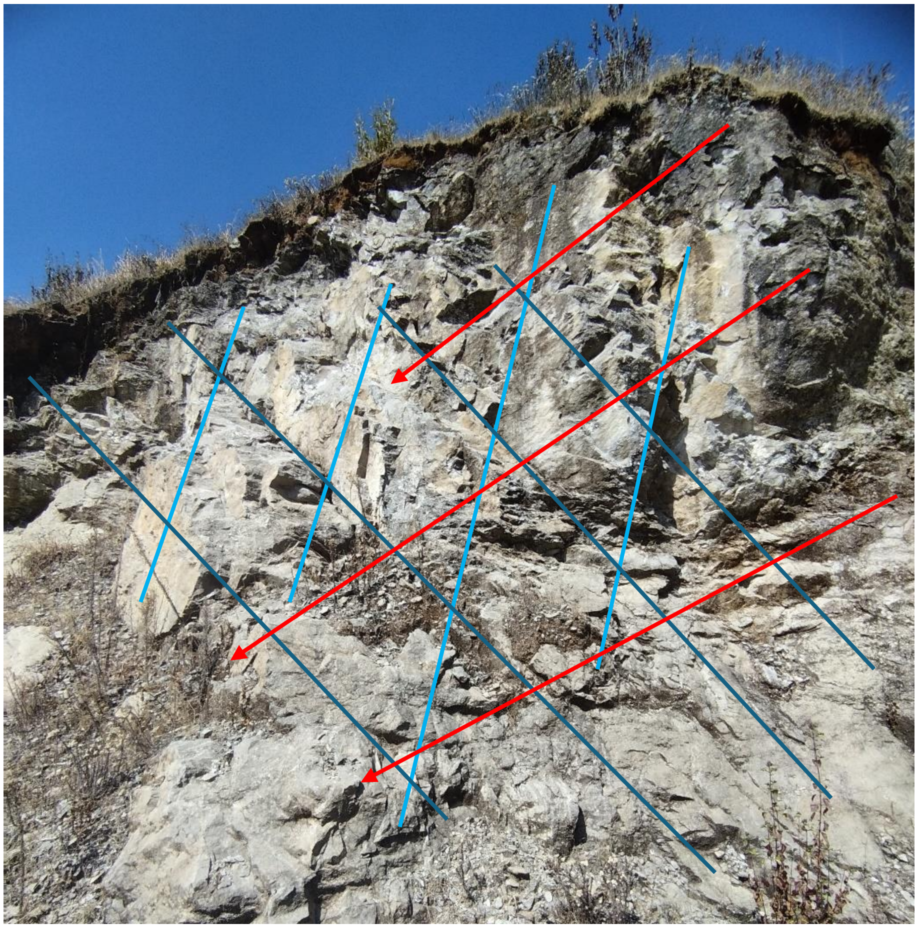

Photo 1: A representative cross-sectional view of rock exposure observed near No.1 camp gate.

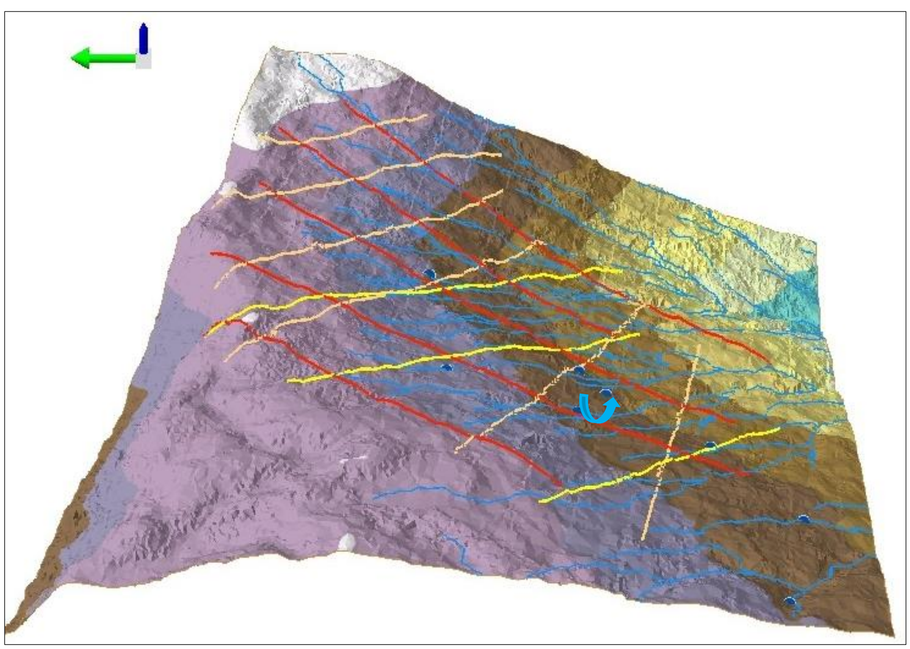

Figure 7: 3D conceptual model with rock discontinuities (color lines) near Bojhepani spring (blue arrow).

Figure 8: Google Earth image showing rock discontinuities (colorful lines) near Bojhepani spring.

Figure 9: Estimated recharge zones for Bojhepani spring.

Chanchaladevi spring, Dhankuta Ward 1 (DM1-C)

The region exhibits a diverse topography, ranging from gentle slopes (0˚) to steep slopes reaching 74.38˚. Steeper slopes dominate the northwest-southeast trend, while the remaining regions have a mix of moderate and gentle slopes. The elevation also varies significantly, with the highest point reaching 1951 meters in the northwest and the lowest point at 1224 meters in the southwest. In terms of slope aspect, southeast to southwestern aspects are most prevalent across the region, with a minor portion facing north. This aspect distribution can influence factors like sun exposure and precipitation patterns (Figure 10).

The underlying geological features are weathered and fractured gneiss beds, facilitating groundwater flow. Interestingly, springs originate from deep fractured rock interfaces, while surficial flow from residual and colluvial deposits. However, overburden materials cover the springs during the monsoon season. The discharge of spring DM1-C is 2.2 lpm and in-situ water quality parameters are within the Nepal Drinking Water Quality Standards (NDWQS) (see Annex 1).

A representative cross-sectional view of rock exposure observed near Chanchaladevi temple was taken for the visualization of real field conditions (Photo 2). Then a 3D conceptual model with rock discontinuities (color lines) and spring (blue arrow) in Chanchaladevi area created with the help of attitude data extracted from the available rock exposures in the area (Figure 11). Later, the data again plotted in the Google Earth which shows rock discontinuities and Chanchaladevi spring (Figure 12). Lastly, the recharge area delineated will be utilized for conservation activities (Figure 13).

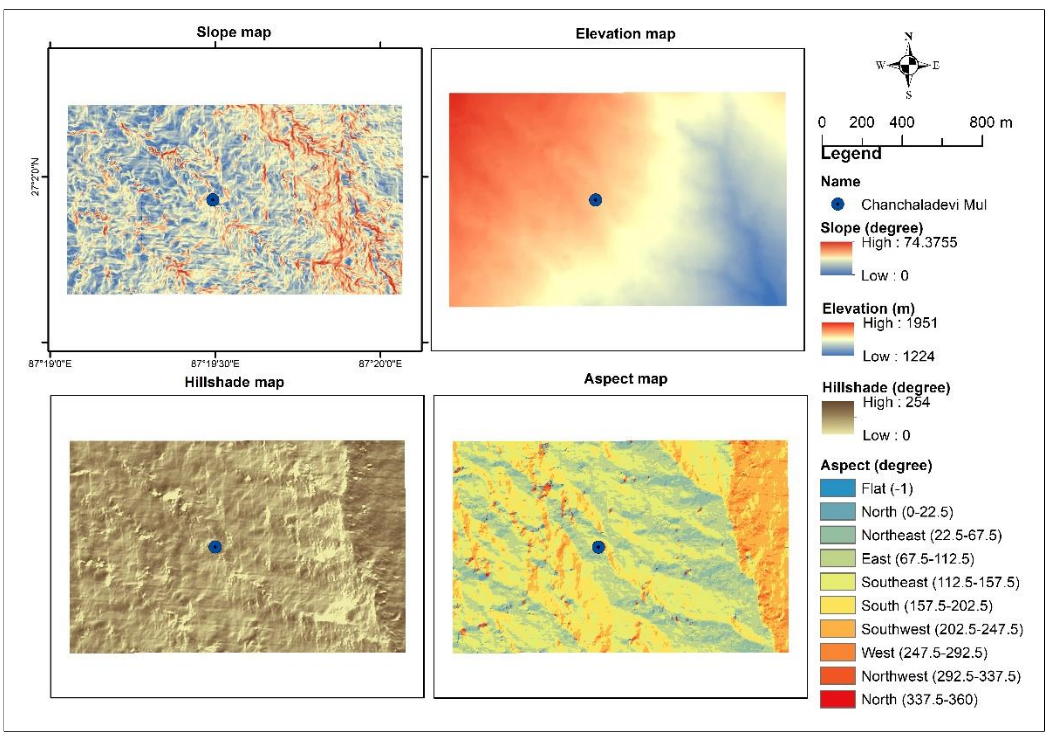

Figure 10: Chanchaladevi spring overlying in Slope, Elevation, Hillshade and Aspect maps.

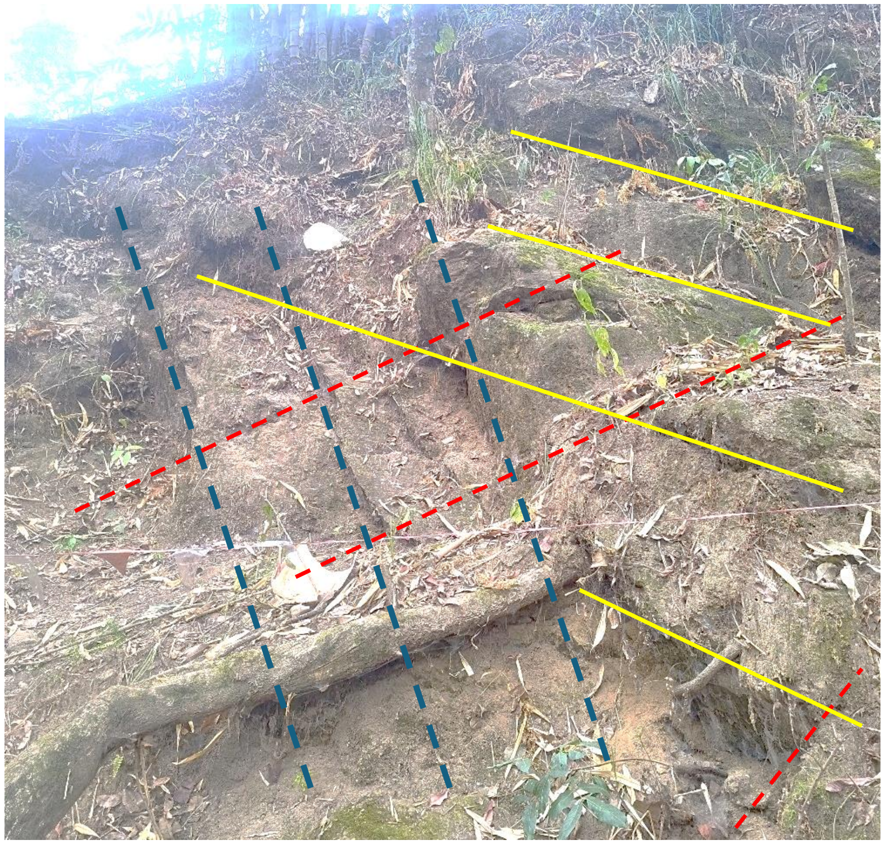

Photo 2: A representative cross-sectional view of rock exposure observed near Chanchaladevi temple.

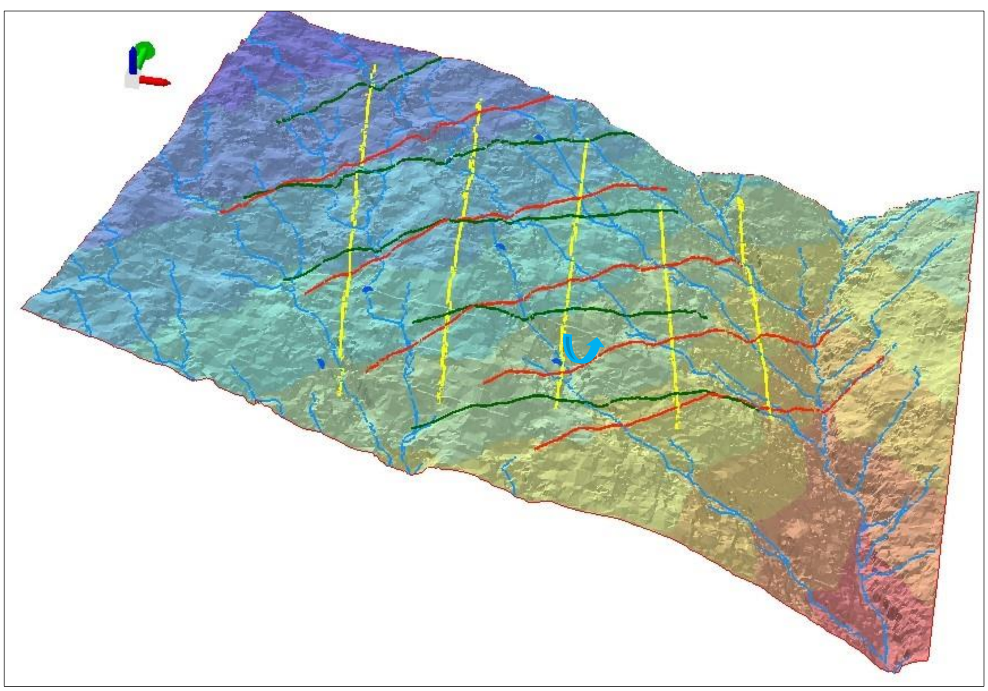

Figure 11: 3D conceptual model with rock discontinuities (colorful lines) near Chanchaladevi spring (blue arrow).

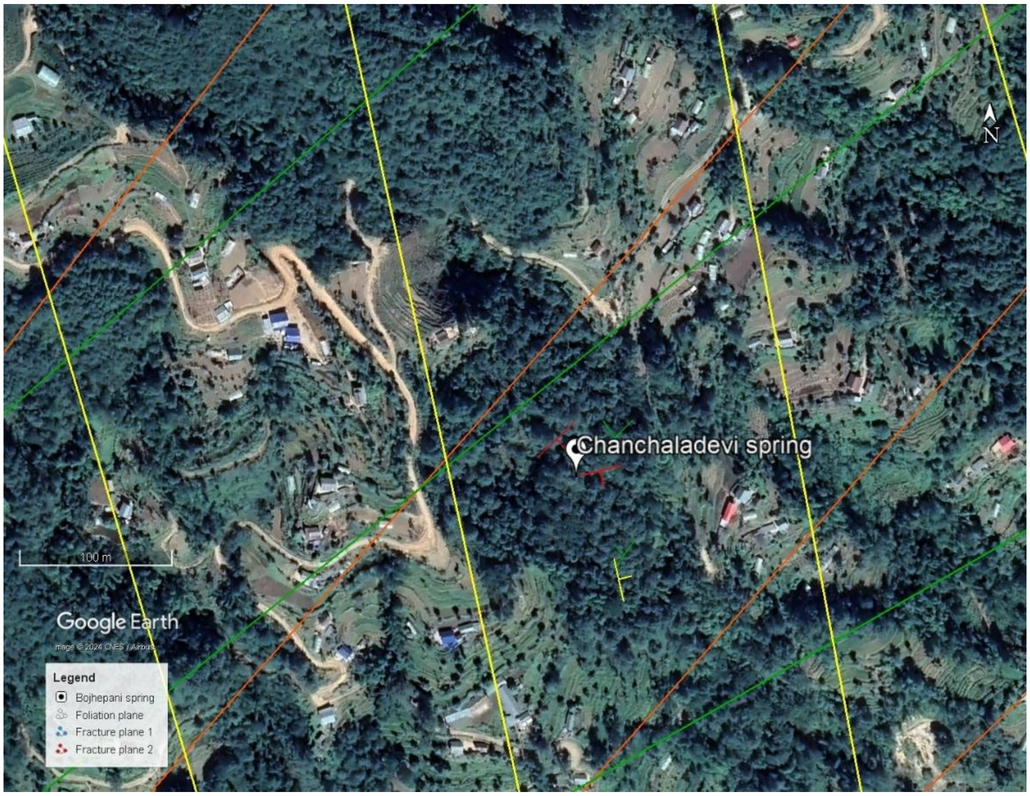

Figure 12: Google Earth image showing rock discontinuities (colorful lines) near Chanchaladevi spring.

Figure 13: Estimated recharge zones for Chanchaladevi spring.

Dhwoje spring, Chhathar Jorpati Ward 2 (CJRM2-D)

The region showcases diverse topography, with slopes varying from gentle (0˚) to steep (reaching 75.1˚). Steeper slopes dominate in a northwest-southwest direction and some in southeast, while the remaining areas feature a mix of moderate and gentle slopes. Elevation also varies significantly, with the highest point reaching 2301 meters in the central part and the lowest point at 1812 meters in the downstream periphery of Dhwoje hill. In terms of slope aspect, eastern to southeaster aspects are most prevalent across the region, with a lesser portion facing northwest. This aspect distribution can influence factors like sun exposure and precipitation patterns (Figure 14).

The exposed rock formations in spring CJRM2-D suggest it is a fractured spring originating from moderately weathered gneiss. The springs seem to emerge from the interface between loose sediments and underlying rock downhill. The spring discharge is 7.5 lpm and in-situ water quality parameters are within the Nepal Drinking Water Quality Standards (NDWQS) (see Annex 1).

A representative cross-sectional view of rock exposure observed near Dhwoje Gumba was taken for the visualization of real field conditions (Photo 3). Then a 3D conceptual model with rock discontinuities (color lines) and Dhwoje spring (blue arrow) created with the help of attitude data extracted from the available rock exposures in the area (Figure 15). Later, the data again plotted in the Google Earth which shows rock discontinuities and Dhwoje spring (Figure 16). Lastly, the recharge area delineated will be utilized for conservation activities (Figure 17).

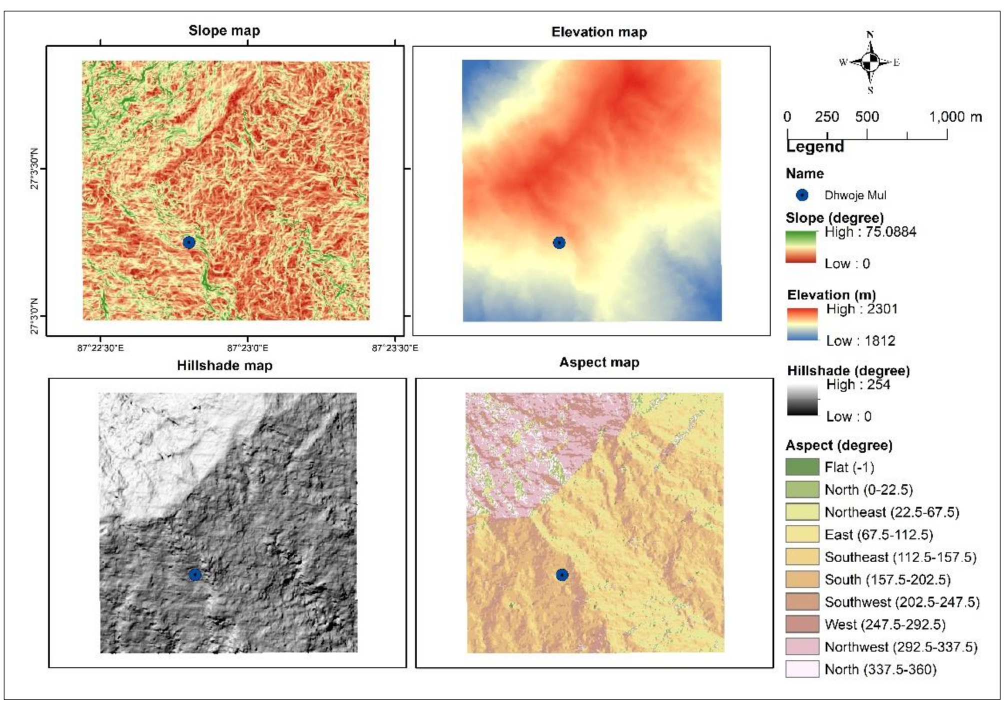

Figure 14: Dhwoje spring overlying in Slope, Elevation, Hillshade and Aspect maps.

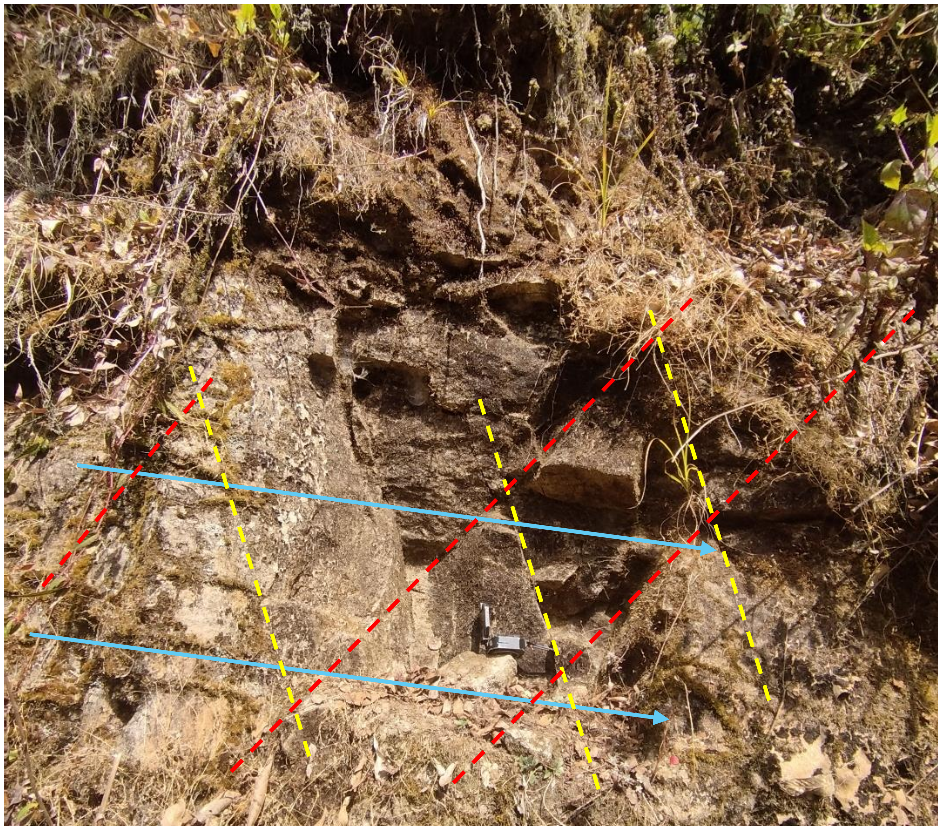

Photo 3: A representative cross-sectional view of rock exposure observed near Dhwoje Gumba.

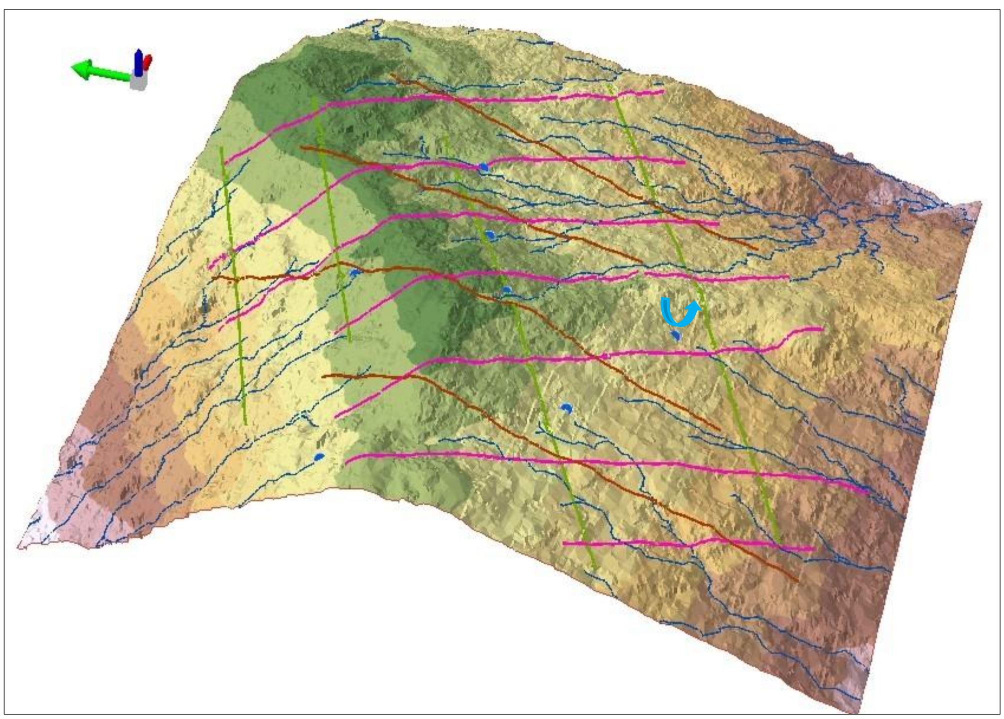

Figure 15: 3D conceptual model with rock discontinuities (colorful lines) near Dhwoje spring (blue arrow).

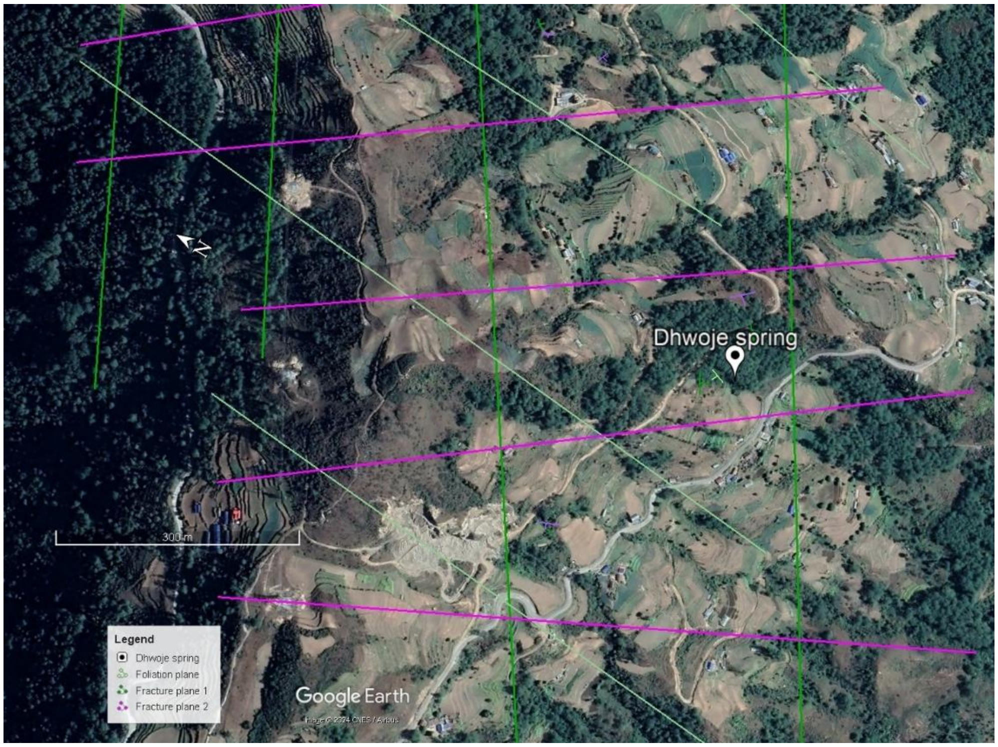

Figure 16: Google Earth image showing rock discontinuities (colorful lines) near Dhwoje spring.

Figure 17: Estimated recharge zones for Dhwoje spring.

Kesharikharka spring, Chhathar Jorpati Ward 2 (CJRM2-K)

The landscape showcases a remarkable range in elevation and slope angles. Slopes vary dramatically, from completely flat (0˚) to a challenging 73.72˚. Steeper slopes are particularly dominant in a northwest-southeast direction, while the rest of the region features a mix of moderate and gentle slopes. This diversity extends to elevation as well, with a significant difference between the highest point in the northwest (2202 meters) and the lowest point in the southwest (1767 meters). Additionally, the dominant slope aspect falls between southeast and southwest, with a limited area facing north (Figure 18).

A study of Kesharikharka spring identified it is sediment interface spring provide water year-round. The exposed rocks near the springs are heavily weathered, with faint signs of fractures. This suggests these are depression springs, a common feature in gneiss terrain and control the groundwater movement by deep-rooted fractures. The spring discharge is 3.5 lpm and in-situ water quality parameters are within the Nepal Drinking Water Quality Standards (NDWQS) (see Annex 1).

A representative cross-sectional view of rock exposure observed near Gurase ridgeline was taken for the visualization of real field conditions (Photo 4). Then a 3D conceptual model with rock discontinuities (color lines) and Kesharikharka spring (blue arrow) with the help of attitude data extracted from the available rock exposures in the area (Figure 19). Later, the data again plotted in Google Earth which shows rock discontinuities and spring in the Kesharikharka area (Figure 20). Lastly, the recharge area delineated will be utilized for conservation activities (Figure 21).

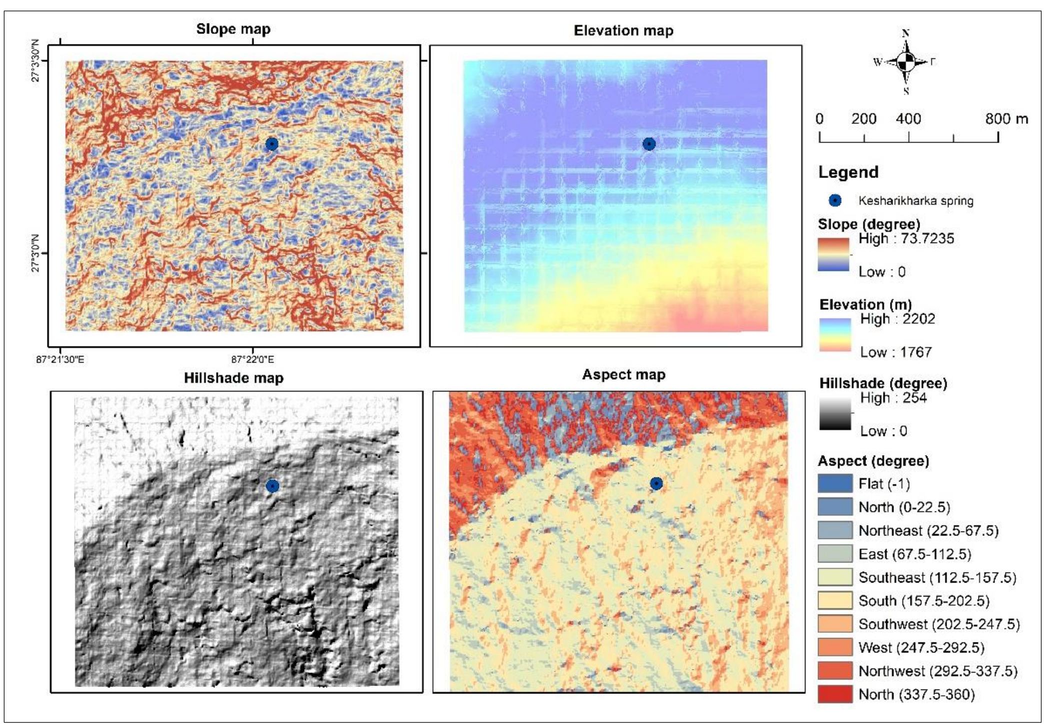

Figure 18: Kesharikharka spring overlying in Slope, Elevation, Hillshade and Aspect maps.

Photo 4: A representative cross-sectional view of rock exposure observed near Gurase ridgeline.

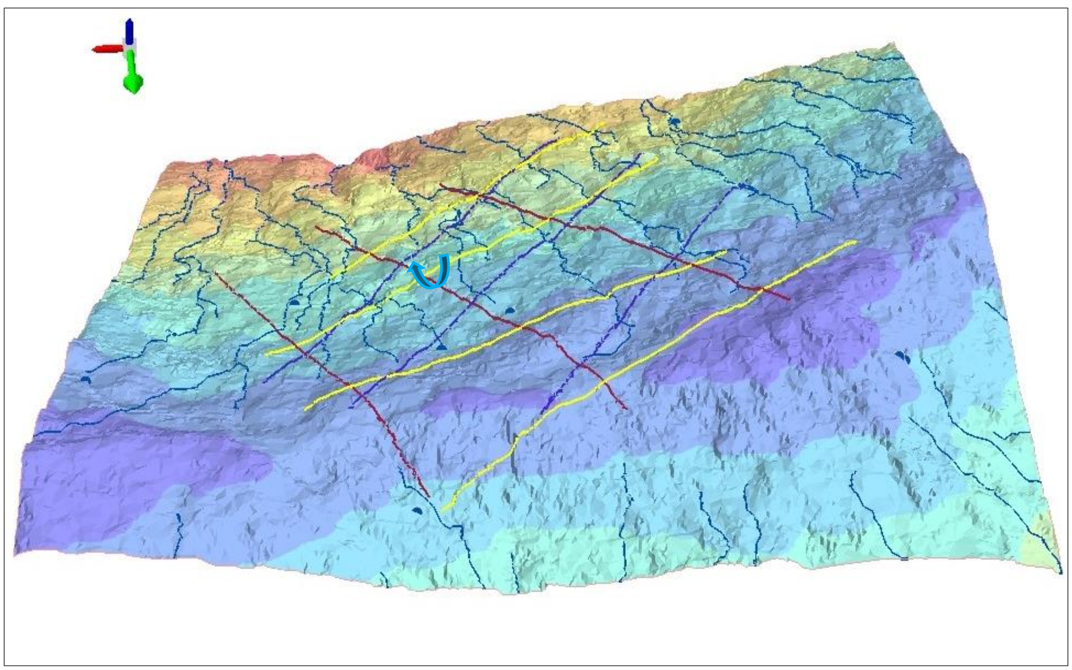

Figure 19: 3D conceptual model with rock discontinuities (colorful lines) near Kesharikharka spring (blue arrow).

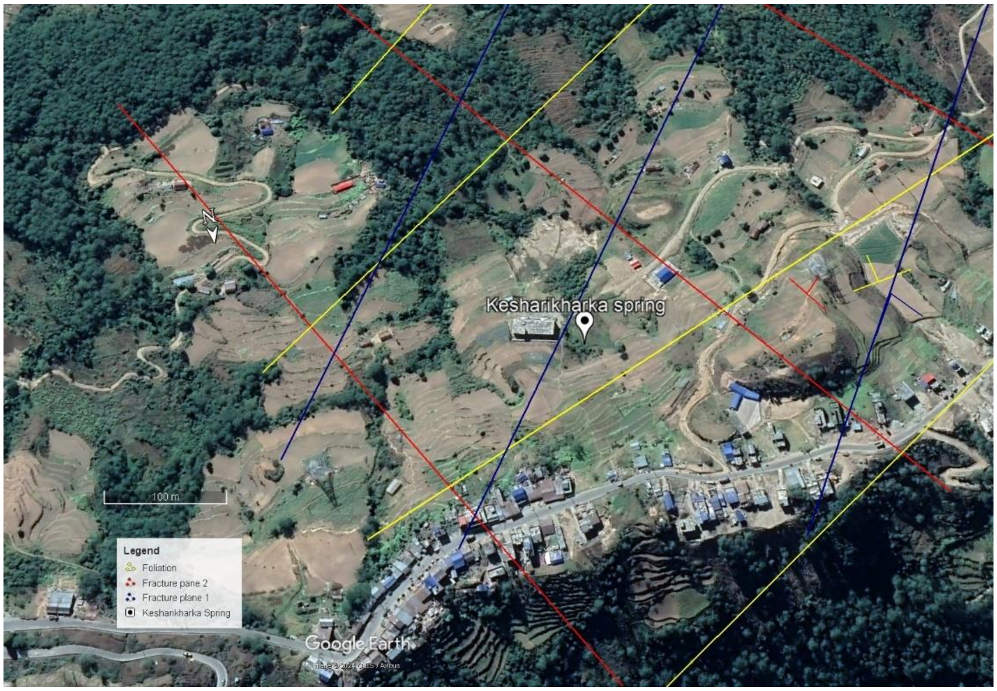

Figure 20: Google Earth image showing rock discontinuities (colorful lines) near Kesharikharka spring.

Figure 21: Estimated recharge zone for Kesharikharka spring.

Chapter 4: Conclusion

This study employed hydrogeological mapping to delineate recharge zones for four selected springs rejuvenation efforts in the Dhankuta District of Nepal. The investigation, conducted in Dhankuta Municipality Ward 1 (Bojhepani and Chanchaladevi area) and Chhathar Jorpati Rural Municipality Ward 2 (Dhwoje and Kesharikharka area), focused on areas experiencing water scarcity and relevant issues specially by roadside springs.

Key Findings:

- Spring sources in Bojhepani, Chanchaladevi, Dhwoje, and Kesharikharka show signs of decline.
- Road construction and human intervention have disrupted traditional water sources in studied areas.
- Geological formation Gneiss of Higher Himalayan Crystallines influence the presence and behavior of springs due to its weathering and erosion along with discontinuities present in the rocks.
- Spring discharge varied across the study areas as in DM1-B 1.71 lpm, DM1-C 2.2, CJRM2-D 7.5 lpm, and CJRM2-K 3.5 lpm for from one-time discharge measurement.
- In situ water quality parameters of all springs are within the range of NDWQS.

Outcomes:

- The study identified potential recharge zones (RA-B, R-C, RA-D, and RA-K) for intervention with respect to four selected springs, aiming to enhance rainwater infiltration and enhance springs discharge.
- This initiative aligns with ICIMOD and RoSPro's action research focused on hydrogeology-based springshed management in Nepal.

Future Directions:

- Implementing recharge zone interventions based on the delineated areas.
- Monitoring spring discharge to assess the effectiveness of these interventions.
- Employing the findings to inform broader springshed management strategies in the HKH region.

By implementing the delineated recharge zones and fostering collaboration, this study paves the way for sustainable spring management and improved water security of roadside springs in Dhankuta district.

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Annex

Annex 1: Springs information of Bojhepani area, Dhankuta 1

S. No.	Spring name	Code	Longitude	Latitude	Elevtion (m)	Q(lpm)	EC	TDS	Temp	HH Dependancy	Seasonality
1	Bojhepanipani Mul	DM1-B	87.322	27.042	1940	1.71	46.5	33.2	11	14 (direct)	Perennial
2	Chanchala Devi Mul	DM1-C	87.325	27.032	1618	2.2	75.9	54	15.4	15	Perennal
3	Dhwoje Mul	CJRM2-D	87.380	27.054	2075	7.5	77	56.5	13.8	13	Perennial
4	Kesharikharka Mul	CJRM2-K	87.368	27.055	2063	3.5	103.3	73.5	12.2	Office/Canteen	Perennal

Glimpses of field visit

Photo I: Community level field-based discussion for spring protection in Bojhepani area.

Photo II: Community resource person secures a pipe leak with rubber after flow measurement in Bojhepani.

Photo III: Discussion with community people about spring status in Chanchaladevi area.

Photo IV: Measuring in-situ water quality parameters with the help of handheld PCSTestr.

Photo V: Measuring the orientation of rock discontinuities in Dhwoje area with the help of Brunton compass.

Photo VI: Struggling to measure seepage discharge near Kesharikharka.