ICIMOD Working Paper 2019/2

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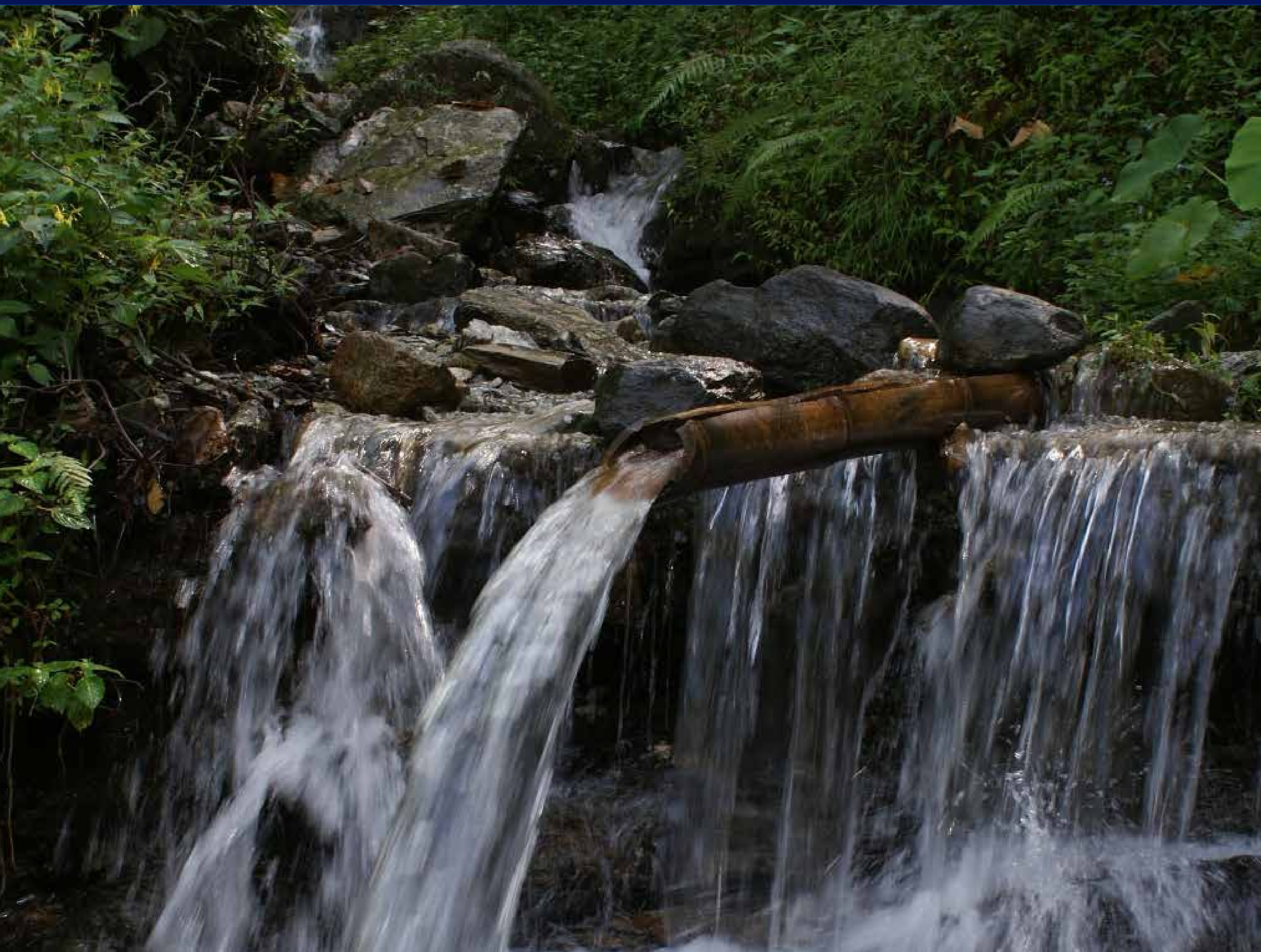
FOR MOUNTAINS AND PEOPLE

Conserving springs as climate change adaptation action

Lessons from Chibo–Pashyor Watershed, Teesta River Basin, Kalimpong, West Bengal, India



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The International Centre for Integrated Mountain Development, ICIMOD, is a regional knowledge development and learning centre serving the eight regional member countries of the Hindu Kush Himalaya—Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan—and is based in Kathmandu, Nepal. Globalization and climate change have been asserting an increasing influence on the stability of the fragile mountain ecosystems and the livelihoods of the mountain people. ICIMOD aims to assist the mountain people to understand these changes, adapt to them, and make the most of new opportunities, while also addressing upstream–downstream issues. It supports regional transboundary programmes through partnership with regional partner institutions, facilitates the exchange of experience, and serves as a regional knowledge hub. It strengthens networking among regional and global centres of excellence. Overall, ICIMOD is working to develop an economically and environmentally sound mountain ecosystem to improve the living standards of the mountain populations and to sustain the vital ecosystem services for the billions of people living downstream—now, and for the future.

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The Mountain Institute (TMI) established its branch in India in Sikkim in 1996, and was later, in 2006, registered as TMI India. TMI itself and TMI India are committed to working towards conserving the world's high-priority mountain ecosystems, improving the livelihoods of the mountain people, and increasing awareness about mountain issues through research, advocacy, education, and outreach. Currently, TMI India is involved in community-based conservation programmes in the Eastern Himalayan Region, partnering with local people to strengthen their communities and to conserve natural resources and cultural heritage. TMI India has conceived three broad programmes: Ecosystem Services; Biodiversity and Environmental Change; and Livelihoods of Mountain Communities and Their Cultures. As a mountain-based organization, TMI India, along with the local and indigenous communities, seeks to develop and provide innovative solutions, in cooperation with numerous regional, international, national, and local partners, to foster action and change in order to overcome the mountain people's economic, social and physical vulnerability.

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Conserving springs as climate change adaptation action

Lessons from Chibo–Pashyor Watershed, Teesta River Basin, Kalimpong, West Bengal, India

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Acronyms and abbreviations

ACWADAM	Advanced Centre for Water Resources Development and Management
BIS	Bureau of Indian Standards
CBOs	Community-Based Organizations
EC	Electrical conductivity
FGDs	Focus Group Discussions
GTA	Gorkhaland Territorial Administration
GSI	Geological Survey of India
ha	Hectare
HHs	Households
HKH	Hindu Kush Himalaya
HI-AWARE	Himalayan Adaptation, Water and Resilience Research on Glacier and Snowpack Dependent River Basins for Improving Livelihoods
ICIMOD	International Centre for Integrated Mountain Development
KII	Key Informant Interview
IPCC	Intergovernmental Panel on Climate Change
lpd	litres per day
lpcd	litres per capita per day
lpm	litres per minute
masl	metres above sea level
MNREGA	Mahatma Gandhi National Rural Employment Guarantee Act
NRDWP	National Rural Drinking Water Programme
NREGS	National Rural Employment Guarantee Scheme
PES	Payment for Ecosystem Services
PHED	Public Health and Engineering Department
PMGSY	Pradhan Mantri Gram Sadak Yojana
PRA	Participatory Rural Appraisal
RM&DD	Rural Management and Development Department
RWSS	Rural Water Supply Scheme
TDS	Total dissolved solids
TMI	The Mountain Institute India
VWSP	Village Water Security Plan
WHO	World Health Organization
WSS	Water Supply Scheme

Executive summary

Springs are the most important source of water for millions of people in the mid-hills of the Himalaya. Both rural and urban communities depend on springs for meeting their drinking, domestic, and agricultural water needs. There is now increasing evidence of springs drying up or their discharge reducing, as a result of which communities are facing water stress. The science of springs and hydrogeology are usually not well understood; aspects like linking recharge areas, the movement of groundwater and the difference between 'source' and 'resource' of springshed systems need to be demystified to local communities, administrators, and landowners. Springs are also part of complex social and informal governance systems, which are often inadequate both in terms of governance and management of the sources. This can also lead to disruption in the recharge areas.

To provide more insights into these issues, this Working Paper identifies and maps spring systems, water budgeting, groundwater flows, and governance issues around the pilot areas of the Chibo–Pashyor watershed of Kalimpong. A total of 55 springs were mapped in the study site and 12 critical springs were selected for monitoring and detailed study, based on vulnerability criteria developed for this research. An analysis of water access, discharge, and budgeting, based on the "National Rural Drinking Water Programme Guidelines 2013", was also conducted. Furthermore, in order to understand spring sources and resources as well as recharge areas, hydrogeological and lithological studies were conducted.

For this study, understanding groundwater flow was critical. Groundwater is stored and transmitted through aquifers. So, an aquifer is considered the basic element in any study of groundwater or watershed development. Spring water is part of the groundwater system and only becomes "surface water" after flowing into a surface waterbody such as a stream or a lake.

Based on a study of critical springs in the watershed, the paper presents a set of recommendations related to key issues of governance and management. It also explains the science behind the drying up of springs in the study area. Finally, key take-home messages for communities, practitioners, and administrators are provided to promote conservation of these springs for the future water security of the area, and to link it to climate change adaptation actions.

Key words: Climate change adaptation, hydrogeology, springshed management, reviving springs, water resources, integrated water management, Teesta basin

1. Introduction

The Intergovernmental Panel on Climate Change (IPCC) arrived at the consensus that climate change will cause increased frequency of extreme climatic events such as intense storms, heavy rainfall, and droughts (Kusangaya et al. 2014). The adverse impacts of climate change are already being felt in the Himalaya (Beniston 2003; Cruz et al. 2007) and such climatic change over the coming decades will have additional negative impacts across these mountains, including by way of natural hazards, and significant cascading effects on river flows, groundwater recharge, and biodiversity, as well as on ecosystem composition, structure, and function, not to speak of human livelihoods (Parmesan 2006; Bates et al. 2008; Ma et al. 2009; J. Xu et al. 2007). During the last few decades, the Greater Himalaya (the highest mountain range of the Himalayan range system) have experienced increasing and decreasing precipitation trends in different parts of the region (Z. Xu et al. 2007; Ma et al. 2009).

Adapting to future climate trends and impacts, especially on water availability, is becoming crucial for local adaptation plans and actions. Potential regional impacts of climate change could include increased frequency and magnitude of droughts and floods, and long-term effects on renewable water supplies through changes in precipitation, temperature, humidity, wind intensity, duration of snowpack accumulation, nature and extent of vegetation, soil moisture, and run-off. Given the levels of climatic uncertainty, there are disconnects between the rural communities and natural resource decision-making (J. Xu et al. 2009).

Water scarcity is expected to be a major challenge for most of the Himalayan region due to increased water demand and lack of proper management (IPCC 2014). The future adequacy of freshwater resources is difficult to assess, owing to the complex and rapidly changing geography of water supply and use. This is partly due to the fact that an overwhelmingly high proportion of rainfall occurs during the monsoon season, while the natural groundwater recharge is hampered by high levels of surface run-off (Tambe et al. 2012). In many parts of the Himalaya, the springs fed during the monsoon by groundwater or underground aquifers are now drying up, threatening a whole way of life of the local communities. Climate change as well as socio-economic and demographic changes have put unprecedented pressure on these water resources, leading to uncertain supplies, increased demands, and higher risks of extreme events like floods and droughts (Mukherji et al. 2015).

In a recent study and review of the present status of knowledge on springs (Tambe et al. 2009; NITI Aayog 2018), it was found that while there are a number of studies covering the Himalayan rivers and glaciers, there are not enough on springs and streams. There is abundant literature on climate change impacts on water resources in the Himalaya with focus on topics that primarily affect the lowland communities: receding glaciers; declining river flows and precipitation; glacier mass balance; water resources; water availability in the snow areas; run-off stimulation; streamflow patterns in rivers; hydro-climatological variability; geomorphology and geology; hydrological hazards; and GIS modelling and remote sensing (Hannah et al. 2004; Barnett et al. 2005; Rees et al. 2006; Akhtar et al. 2008; Immerzeel 2009; Bookhagen et al. 2010; Shrestha et al. 2012; IPCC 2014).

Tambe et al. (2009, 2012) explain that this may be due to the micro-nature of springs and the limited human dependency on them; the insufficient data may also have to do with the fact that a concerted attempt has not yet been made to understand this scattered resource. All major Himalayan rivers have been instrumented and their discharge monitored for several decades. However, the historical discharge data of springs and streams is largely unavailable despite the fact that the direct interface between local livelihoods and springs is all too evident.

Groundwater, from springs in the mid-hills of the HKH, is an important contributor to river baseflow, but the exact extent of this contribution is not known due to limited scientific studies and evidence. The role and contribution of springs to overall water budgets in the region is also poorly understood. We urgently need better scientific knowledge of groundwater in the HKH—especially because millions of mountain people depend directly on springs (Wester et al., 2019). Water governance in the HKH region is characterized by hybrid formal–informal regimes with a prevalence of informal institutions at the local level and formal state institutions at the national and regional levels. Here, the synergy and support between formal and informal water management institutions are often lacking.

Moreover, gender inequity is prevalent in both formal and informal institutions, and translates into inequity in terms of access to water (Scott et al. 2019).

Many aspects of spring hydrogeology are still poorly understood, as are the social aspects related to the use of spring and groundwater. Aquifers need to be considered as an integral part of the ecosystem as they help in the maintenance of springsheds in natural settings as well as in human-manipulated situations. A combination of advanced scientific methods and social engineering studies needs to be carried out at the micro-watershed level to establish strong linkages among groundwater flows (hydrogeology), recharge areas, and spring distribution and patterns based on rock types and geology (Pradhan 2016). Given the widespread concern about the drying up of springs and the deterioration in spring water quality, the desirable policy response is to revive the springs using both local and scientific hydrogeological knowledge. The *Protocol for Reviving Springs in the Hindu Kush Himalaya* recently published by ICIMOD (Shrestha et al. 2018), produced in consultation with a wide range of partners, including the strategic partner to this work, The Mountain Institute India, defines "spring revival" to mean any of the following, individually or in combination:

- The total discharge of the spring has increased, especially in the lean season
- Spring water is available during more months than before
- There has been an appreciable improvement in spring water quality, thereby reducing health risks
- Spring water is better managed, so there is more equitable access to water
- Recharge areas are better protected and managed

The Eastern Himalaya is abundant in water resources, yet many of its areas suffer from acute water scarcity, often intensified by climate change and its triggering factors, resulting in "too much or too little water". Indeed, water demand is changing in high, mid, and lower altitudes in these areas. It is observed that communities in the hilly areas of Sikkim and Darjeeling—the latter despite getting plentiful rains—face acute water shortage due to the drying up of springs. Even as water rights run through many of these studies as a sub-theme, little attention has been focused on how water resources feature in the region's socio-economic landscape and political context (Drew and Rai 2016).

TMI India has been working for over a decade with the Sikkim government's Rural Management and Development Department (RM&DD) on the "Dhara Vikas" initiative, part of which includes a focus on reviving drying springs in dry areas of south and west Sikkim. The entire Himalayan region has much to learn from the Dhara Vikas initiative, specifically on spring revival work. ICIMOD's HI-AWARE initiative and TMI India jointly conducted springshed research in the identified pilot areas of the Teesta basin. The aim of the collaborative research was both to take lessons and best practices from the project in Sikkim to other HI-AWARE partners in the Indus, Upper Ganga, and Gandaki basins, and to disseminate the knowledge to researchers, practitioners, and policymakers.

Building on the work carried out in the region, this paper summarizes the findings of a collaborative research in the Chibo–Pashyor watershed in the Teesta River Basin in Kalimpong district of West Bengal.

Main objectives of the study

1. Identify the recharge areas in the Chibo–Pashyor watershed of Kalimpong district, West Bengal
2. Understand the area's socio-economic dynamics through a survey
3. Understand the area's formal and informal spring governance mechanisms
4. Investigate the geo-lithology and the hydrogeology of the springs and their catchments, and further identify critical springs with high human dependency
5. Identify the potential recharge areas of the critical springs
6. Draft recommendations for springshed development

2. Study area

Kalimpong District, West Bengal

As per the official website of the District Magistrate of Kalimpong, the new district has 65 gram panchayats with 51,285 households and a total population of 251,642 people. The area covers around 1,075.92 sq. km. Located between the Teesta and the Jaldhaka rivers and stretching from the lesser Himalaya to its foothills, Kalimpong District is rich in flora and fauna, and has a temperate climate that favours agro-horticulture. More than 80% of the people in Kalimpong depend on farming for their livelihood. Major agro-products include paddy, maize, millet, pulse, oilseed, and potato; however, the district is more widely known as a hub of cash crops like broom grass, ginger, cardamom, betel nut, and oranges (Sharma and Sharma 2017).

The water supply and distribution network in Kalimpong is yet to be regulated and drinking water scarcity has been rapidly increasing every year. The water for the Kalimpong Municipality is sourced from Neora Forest, stored in a reservoir at Deolo and then supplied to the town (Figure 2). The responsibility for delivering water from the reservoir to households within the municipality's 23 wards lies with the Public Health and Engineering Department (PHED), which is administratively under the Gorkhaland Territorial Administration (GTA) at the local level, and the Neora Water Supply and Maintenance Division (NWSMD) at the state level. The PHED works with the Kalimpong Municipality in facilitating water distribution.

A household survey conducted as a part of this study revealed that 55% of the households have access to municipal water connections, while the other 45% depend on springs or water supplied by tankers. Altogether, 73% of the households are dependent on springs, with or without the municipal water supply (Sharma et al. 2019).

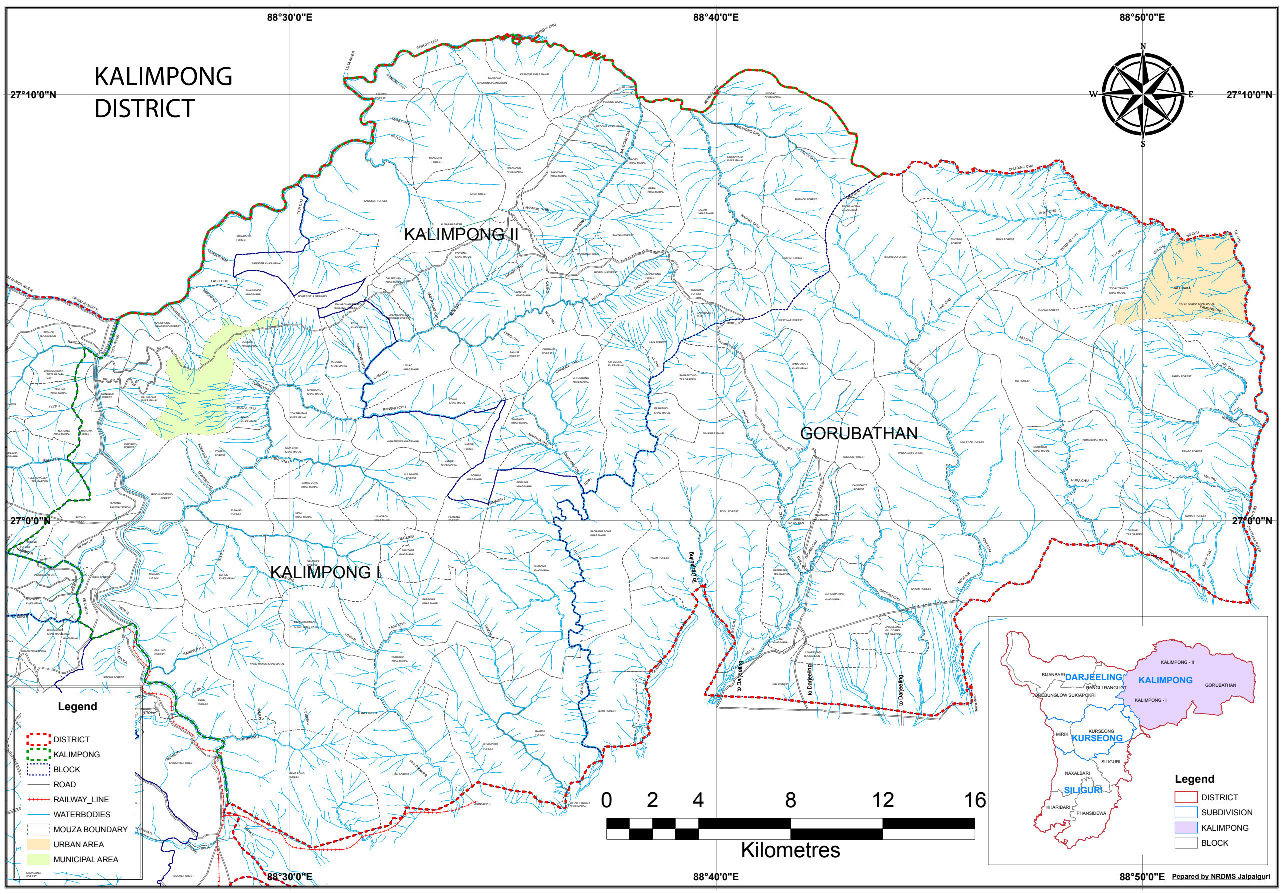


Figure 1: Kalimpong district map (Source: Natural Resouce Data Management System [NRDMS], Jalpaiguri)

Demographic profile

Kalimpong municipality is located within Kalimpong District, West Bengal. Both the district and the municipality are ethnically diverse; the three major ethnic groups are Lepcha, Bhutia, and Nepali. Administratively, it is divided into four units: Kalimpong Block I, Kalimpong Block II, Gorubathan Block, and the Kalimpong Municipality (Figure 1).

Kalimpong Municipality itself is divided into 23 wards. As per the 2011 census, it has population of 49,403 (25,100 male, 24,303 female).

The Municipality has administrative responsibility over 10,113 households and provides basic urban services like water supply, sewerage, and waste management. The GTA and the state government have authorized the Kalimpong Municipality to build roads within its boundary limits and to impose taxes on properties under its jurisdiction. The total geographical area of Kalimpong Municipality is 9 km^2 and it is the biggest city by area in the district. The population density of the city is 5,692 persons per km^2. Among the 23 wards in the city, Kalimpong Ward No.16 is the most populous with a population of 4,737 and Kalimpong Ward No.17 is the least populous ward with population of 845 (Kalimpong District Official Website of the District Magistrate, n.d.).

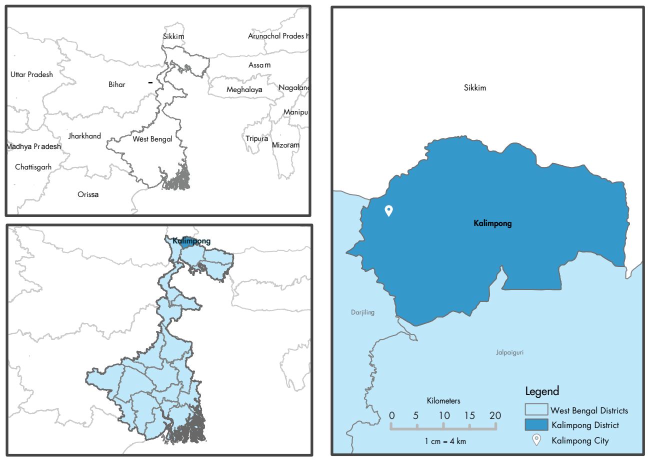
Chibo–Pashyor Watershed, which is close to Kalimpong Municipality, was chosen for the spring study. It falls in Kalimpong I Block.

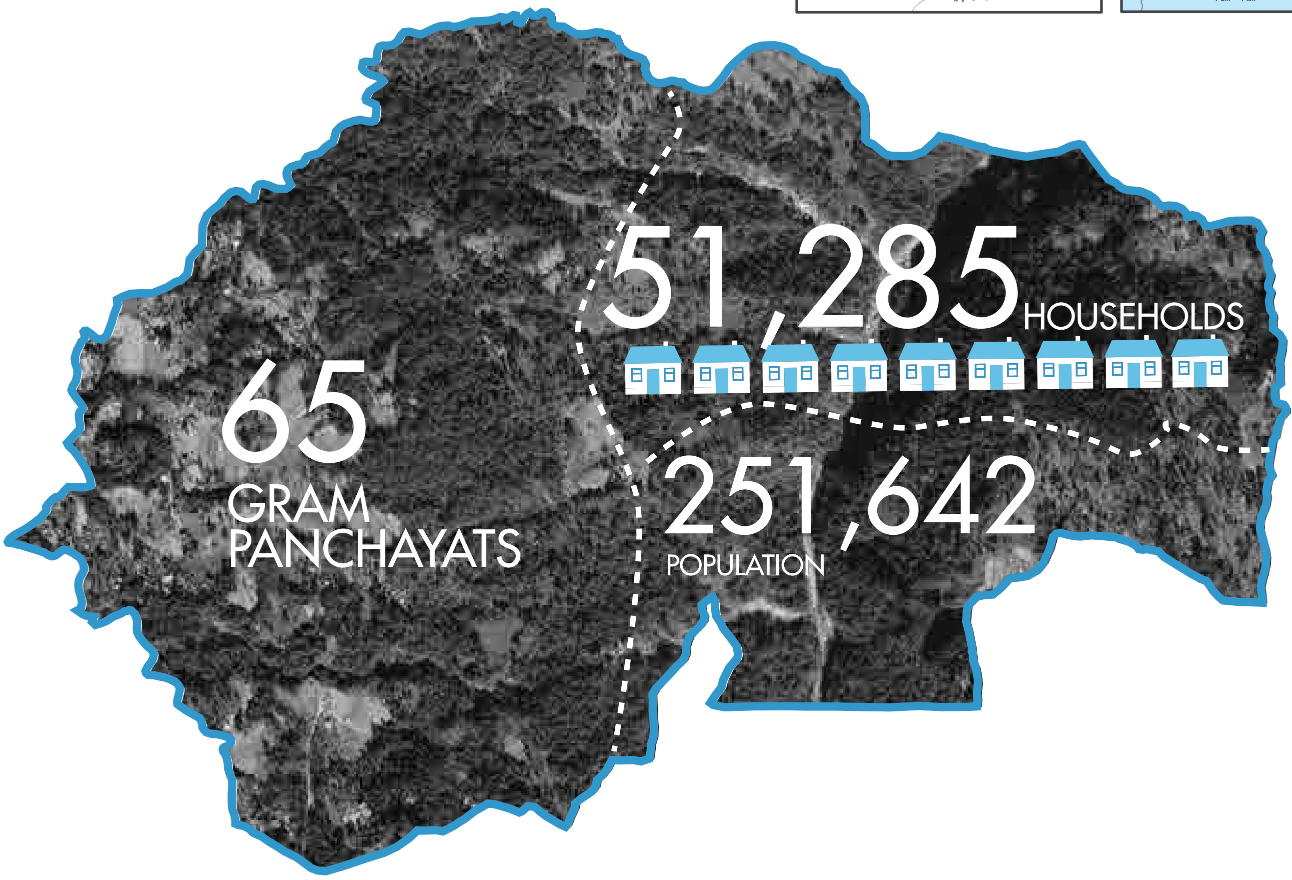
Climate

The maximum summer temperature is 27°C and the minimum 16°C. Temperatures in winter hover between a high of 17°C and a low of 3°C. The average annual rainfall is 220 cm. The Chibo–Pashyor watershed (GPS coordinates: 27° 03′ 37.12.″ N 88° 26′ 5.62″ E to 27° 02′ 18.40″ N 88° 27′ 34.06″ E) is situated between 554 and 1,405 masl and has a tropical to cool subtropical climate. However, change in climate, and weather phenomena (especially reduction in temporal cover of rainfall) over the last decade is having a marked impact on the water resources according to the local people in the watershed. This has resulted in drying of springs and streams, which are the primary sources of water for domestic use.

A typical small farm in the area

KALIMPONG DISTRICT PROFILE





Stretching from the lesser Himalaya to its foothills, Kalimpong District is rich in flora and fauna, with a temperate climate that favours agro-horticulture.

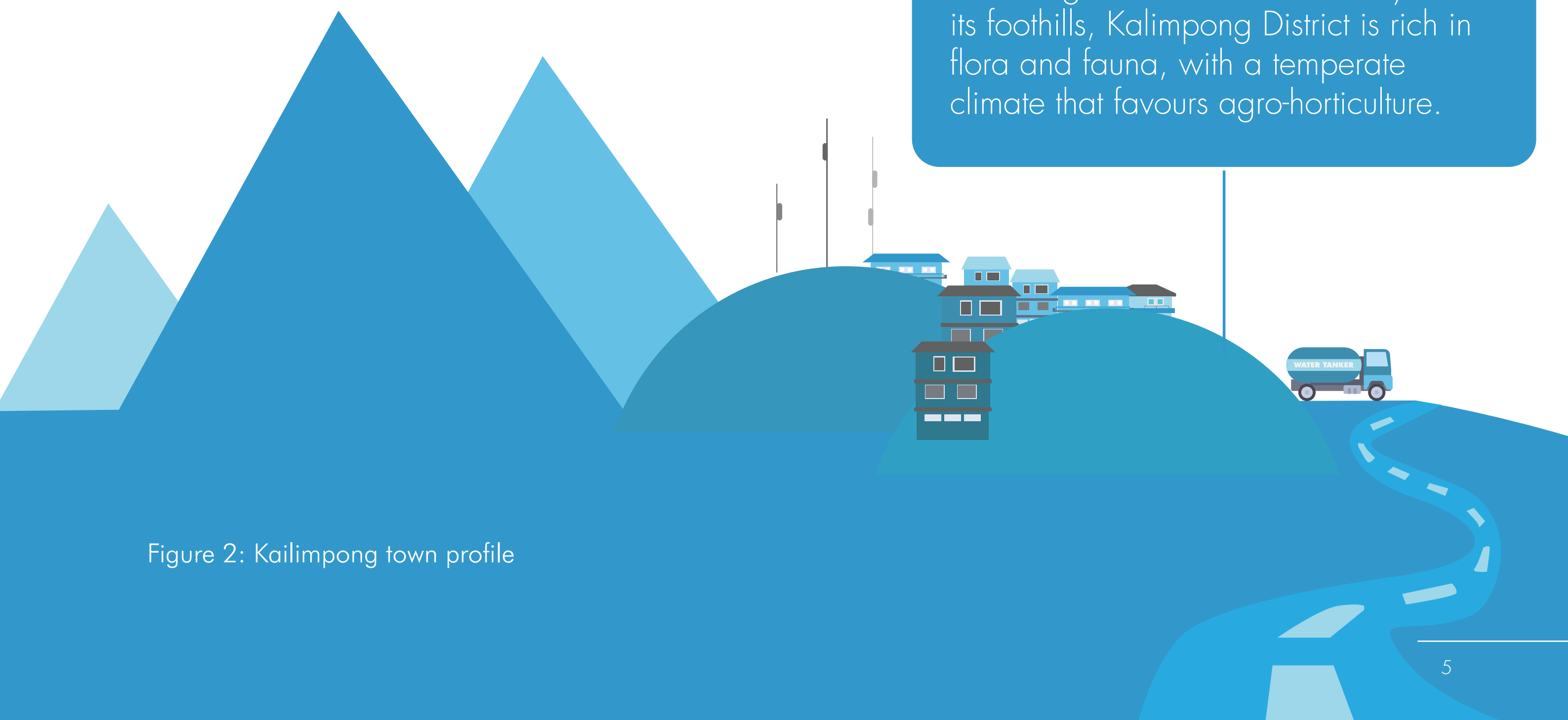


Figure 2: Kailimpong town profile

DRINKING WATER

It is a growing perception among households in the Chibo-Pashyor watershed in Kalimpong that water supply from springs and streams has reduced drastically during the winter and spring seasons in recent years.

The effects on these traditional sources of water have been largely attributed to deforestation and destruction of other ground vegetation, which in turn is leading to soil erosion, poor infiltration of rain water and recharging of groundwater (Khawas 2004). The Government of India wants to establish road connectivity to every village through the Pradhan Mantri Gram Sadak Yojana (PMGSY) but the lack of environmental impact assessment before road construction has led to either the disappearance or shift of springs leading to acute water shortages (Sharma et al 2012).

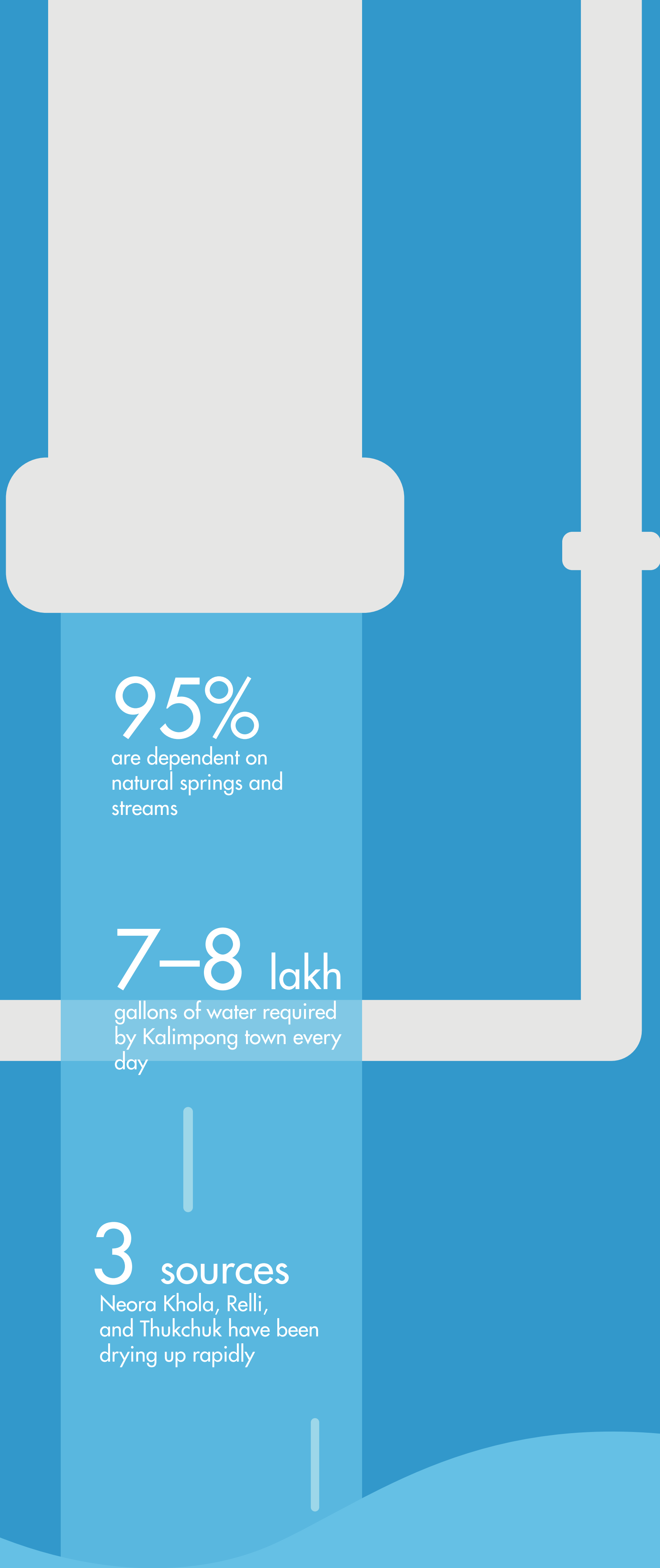


Figure 3: Situation analysis of drinking water in the Chibo–Pashyor area

2.1. Situation analysis of drinking water in Kalimpong Municipality and Chibo–Pashyor watershed

In the Kalimpong hills, more than 95% of the people are dependent on natural springs and streams for water, but the status of these springs and streams are yet to be studied and documented. There is dire scarcity of water in Kalimpong town where water is supplied from Neora Khola, Relli, and Thukchuk streams. The city requires about 700,000–800,000 gallons of water every day (Figure 3).

The three main sources of water for Kalimpong town—Neora Khola, Relli and Thukchuk—have been drying up rapidly due to the springs running out of water in the catchments which feed these streams. Earlier, the Deolo reservoir used to store 800,000 gallons of water. But due to changes in climatic conditions such as prolonged dry periods and less rainfall in the last several years, in the winter season, the storage reduces to around 350,000 gallons. Kalimpong town gets its water supply from the Deolo reservoir. During the dry season, the PHED supplies water twice or thrice a week for an hour, based on the availability, but this is not enough as it barely fills a 1,000 litre tank. So, the households depend on rainwater for domestic purposes. A survey conducted as part of this study highlights that almost every household in Kalimpong experiences water stress, apart from a handful who are situated near natural water sources.

The Chibo–Pashyor watershed in Kalimpong does not receive water supplied by the Water Works Department, and households in the area are dependent on springs and streams. There is a growing perception among households that discharge from the springs and streams have reduced drastically during the winter and spring seasons which are the dry, lean seasons. These traditional sources of water have been decreasing rapidly in the dry period from September to April, more so in the urban areas. This is largely attributed to deforestation and the destruction of other ground vegetation, which, in turn, is leading to soil erosion, poor infiltration of rainwater, and weak recharging of the groundwater (Khawas 2004). The Pradhan Mantri Gram Sadak Yojana (PMGSY) of the Government of India has a mission to establish roads in every village in Sikkim, but as the required environmental impact assessment was not carried out, the road construction has led to either disappearance or shifting of the spring water, resulting in acute water shortages in several locations (Sharma et al. 2012).

2.2. Teesta River basin

The Teesta River originates as Chhombo Chhu from a glacial lake, Khangchung Chho, in the state of Sikkim, at an elevation of 5,280 masl. The glacial lake is located at the tip of the Teesta Khangse Glacier, which descends from Pauhunri peak. The Chhombo Chhu, the headstream of the Teesta, flows eastwards, joining the Zemu Chhu to become the Lachen Chhu. At Chungthang, the Lachen Chhu is joined by the Lachung Chhu to become the Teesta.

The river traverses a length of 293 km in India, passing through Sikkim and West Bengal. It enters Bangladesh near the city of Jalpaiguri in West Bengal and after covering a distance of 121 km, meets the Brahmaputra (Jamuna) in Rangpur District (Prasai and Surie 2013). The total catchment area of the Teesta is 12,159 sq. km, out of which 10,155 sq. km lies in India (Tamang et al, 2005). A large number of tributaries join the Teesta both from the right and left banks. Although the left bank has a higher number of tributaries than the right, the latter has a higher water discharge contribution. The river is largely fed by precipitation, although glaciers and snowmelt also contribute.

2.3. Study site

For this study, the study site within the Chibo–Pashyor watershed was located in Kalimpong District. The area experiences subtropical monsoon climate, with an average annual rainfall of 2,237 mm (as per the data provided by Save the Hills, a local NGO). The total population of the spring study area (watershed) is 10,000 people (approximately). There are approximately 3,500 households in all of the recharge areas.

The villages of Chibo–Pashyor are inhabited by various caste and ethnic groups. The main occupation is farming, mostly agriculture and dairy. The main crops cultivated are paddy, maize, and vegetables. Recently, the villagers have also taken up floriculture. As for educational institutions, there is only one primary school in the village, so for higher education the students have to go to Kalimpong town, where there are a number of private and government schools. The women of Pashyor village work in the farms and most do not have other formal employment.

The primary source of water for the Chibo–Pashyor watershed are springs and streams, as well as surface and subsurface water flows originating mostly from unconfined aquifers. Springs occur where sloping ground and impenetrable rocks intersect with the groundwater table. Several forms of springs such as *dharo/pandhero* (pool/fountain), *kuwa* (shallow well) and *simsaar* (marshland) are the major sources of drinking water in the area. This area is vulnerable in terms of water availability and access, as a result of seasonal water flows, erratic rainfall patterns, anthropogenic disturbances in the catchments, and weak management.

Pocket tracer to measure water quality

3. Methodology

The three components of the study and the survey methodology are described in the sections below:

Mapping of springs in the research area: spring types, water availability, access, and budgeting

1. Socio-economic survey and study of governance and management of springs; which both included key informant interviews (KIIs), questionnaire surveys, focus group discussions (FGDs), and participatory rural appraisals (PRAs)

2. Hydrogeology and geo-lithological studies: field data observation and collection, and geological surveys

Survey methodology

The survey sites were chosen purposively. The reasons are detailed below:

1. Stratified random sampling can generally turn out to be expensive, as compared to designing a survey area purposively, provided it meets the research criteria.

2. The intention was to utilize information and resources gleaned from this research and integrate them with the social research conducted under ICIMOD's HI-AWARE Initiative, in order to develop new approaches to an inclusive socio-economic analysis of adaptation practices through scientific and stakeholder-driven monitoring. Reports and data were referred through secondary data and literature review, which were useful in identifying survey locations and villages.

3. An additional reason for choosing the Chibo–Pashyor watershed area for this spring-related study was that it aligned with a HI-AWARE climate change study which had highlighted water scarcity as one of the primary issues resulting from springs drying up and the unequal distribution of water. As the study team interacted with local community members, immediate problems became quite apparent and alarming, such as the disappearance of local water sources, and the lack of other water sources for both domestic and agricultural use.

4. The upper areas along the Kalimpong ridge get their water from the Neora forest, around 86 km away from the town, and the demand is higher than the supply. The Chibo–Pashyor watershed is not covered by the Municipality's water supply system and is completely dependent on local water sources, making it particularly vulnerable to the impacts of climate and other changes on water availability.

3.1. Spring mapping and data collection (boundary delineation)

The maps published by the Geological Survey of India (GSI) and initial consultations with HI-AWARE colleagues provided the basis for identifying the potential areas for springshed research. In addition, an initial visit to Kalimpong to assess the local geology, landuse patterns, settlements, and location of springs helped identify the springs for the study and also provided a preliminary understanding of landslide-prone areas, hydrogeology, and socio-economic issues (Figure 4; Table 1).

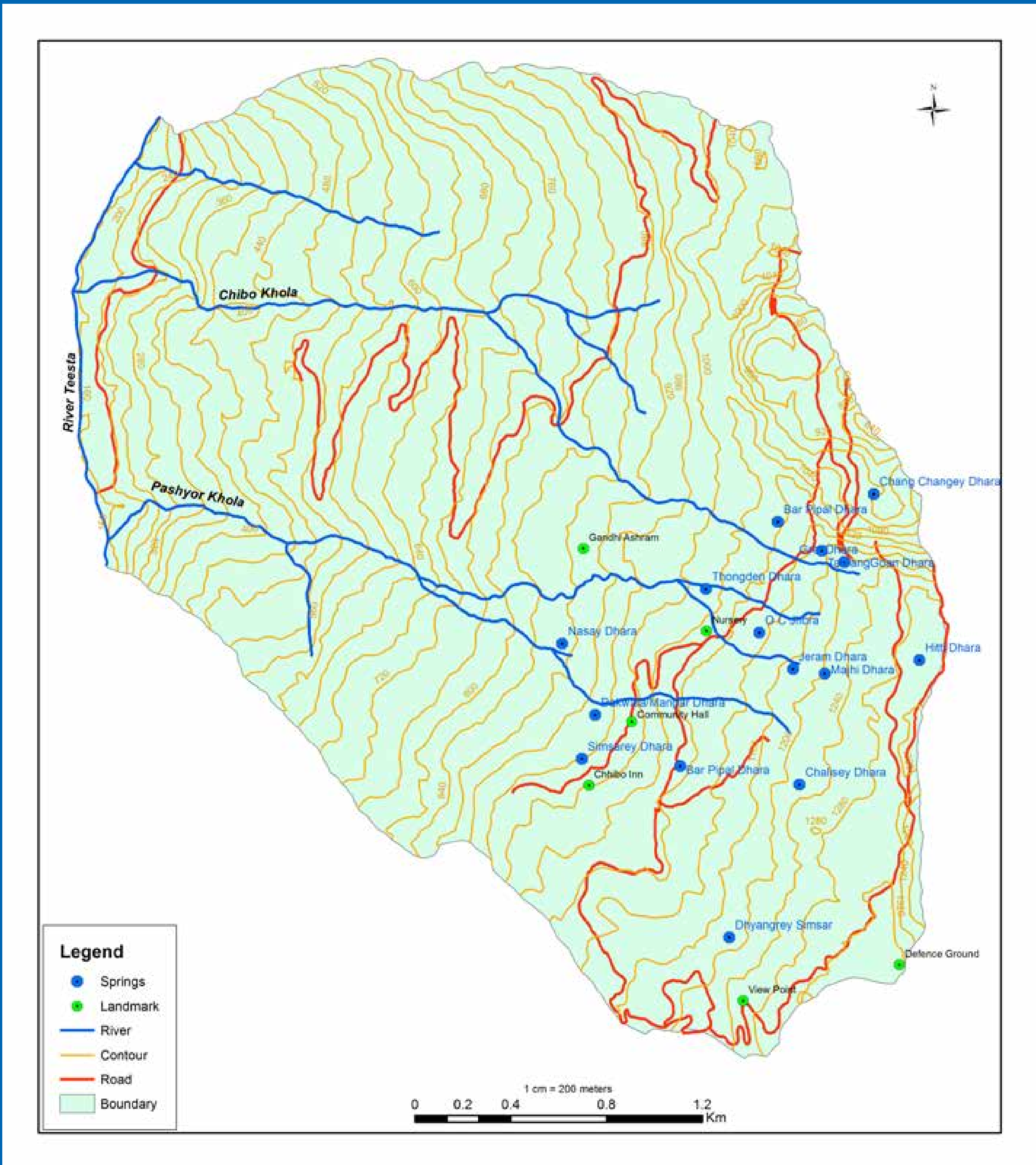


Figure 4: Base map showing critical springs in the Chibo–Pashyor area

Field data collection:

- Mapping: A total of 55 springs were mapped in the areas. Using GSI maps for reference, the seasonal and perennial springs and their springshed areas were marked using a Global Positioning System (GPS).
- Water quality and hydrogeology: An electronic tracer device was used to measure and check water quality (in terms of pH, electronic conductivity, total dissolved solids, and temperature) and groundwater system parameters.
- Water quantity and discharge: To measure the water quantity of each spring and discharge in litres per minute (lpm), a bucket and stopwatch were used to take an average of three water flow measurements.
- Water availability and access: Data was collected on the drinking water consumption pattern of the households, including on the climate change impacts on the water sources, and adaptation strategies initiated by the communities. The current water management and conservation practices in the spring recharge area were also studied. All this data was collected using PRA tools such as informant interviews and focus group discussions with the communities.
- Vulnerability assessment and ranking: This was measured by interviewing the key informants and by holding FGDs. Rank 1 as the lowest score, and 10 as the highest.

Table 1: Field equipment used for data collection

Equipment	Purpose
Brunton compass	Dip direction, dip strike, etc.
Geological hammer	Rock type
Garmin GPS	Location
Tracer pocket tester	Water quality and hydrogeology
Bucket and stopwatch	Water quantity and discharge in lpm
Fieldwork datasheet	Field data collection

3.2. Socio-economic survey (governance and management of springs)

The study team based its approach to understanding the social and governance systems related to springs on the ICIMOD *Protocol for Reviving Springs in the Hindu Kush Himalayas* (Shrestha et al. 2018), which outlines the following objectives and outputs:

Objective: A comprehensive understanding of current water-use patterns and their socio-economic implications, and of the institutions and governance systems that are in place for managing springs

Output: A report that synthesizes the findings from FGDs, KIIs, and questionnaire survey/interviews, presenting various aspects of water use, institutions, and governance

A series of socio-economic surveys was conducted in the Chibo–Pashyor watershed. The survey was designed to understand water availability and access. Information on the drinking water consumption pattern of the households was assessed. The impacts of climate change on the water sources, and the adaptation strategies initiated by the communities, were also studied. The other area that was explored was the current water management and conservation practices in the springshed.

The methodology/tools used in conducting the socio-economic surveys consisted of the following:

1. Focus group discussions and key informant interviews to understand the use of water resources, and the management of the springshed.
2. Household questionnaire survey of water users of respective springs (or taps)
3. Household survey on drinking water supply to obtain primary information on water usage pattern, water supply/distribution system, storage infrastructure, etc.

3.3. Hydrogeological study

Similar to its approach to the socio-economic and governance survey methodology, the study team based its approach to understanding the hydrogeology and geo-lithology related to springs (Figure 5) on the *Protocol for Reviving Springs in the Hindu Kush Himalayas* (Shrestha et al. 2018), which recommends a detailed study of rocks, rock structures, streams and springs; preparation of a geological map (and/or a cross-section) of the spring recharge area; and geological map to support the development of a conceptual hydrogeological layout.

The most important concept in understanding hydrogeology or groundwater systems involves the study of the behaviour of aquifers (Kulkarni, et al. 2015). Groundwater is stored in aquifers, replenished, and then, based on differing geological conditions, it surfaces due to fractures or depression in the rocks. The hydrogeological field mapping of the sites involved the study of groundwater systems and detailed geological mapping. Information was collected to understand the seasonality (perennial or seasonal) of the springs (Table 2). In the study of groundwater parameters such as pH, TDS, electrical conductivity (EC), temperature are important to understand flow and movement of groundwater. The capacity of an aquifer to store and transmit groundwater directly reflects on the nature of the spring discharge. The "dip" and "strike" of different types of rocks forms the basis of geological mapping. Outcrops are studied to gather information about the various rock types and trends of openings which may be in the form of bedding planes, foliation planes, fractures, faults, etc. Hydrogeological mapping requires the study of a base map of the area and the use of simple instruments like a geological hammer and a clinometer compass. GPS instruments are critically essential to the data gathering process (Mahamuni and Upasani 2011).

Field investigations and base maps from the GSI were consulted to get a broad sense of the rock types and structures in the area.

Data analysis

The data collected from the field and the maps generated through GIS were analysed through a simple statistical procedure (data collection, validation, coding, and processing statistical survey data). These are presented in figures, tables, infographs, and conceptual models.

All the data collected from the FGDs, KIIs, and questionnaire surveys were recorded properly. In the case of FGDs, detailed transcripts were written out and the information synthesized into a report. The KII information was stored in a database and a report prepared. A data entry format was prepared and survey data and the data entered. Some of the common analysis parameters were demographic composition, types of water use, perceptions of water availability and quality, and the presence and types of institutions and governance (Shrestha et al. 2018).

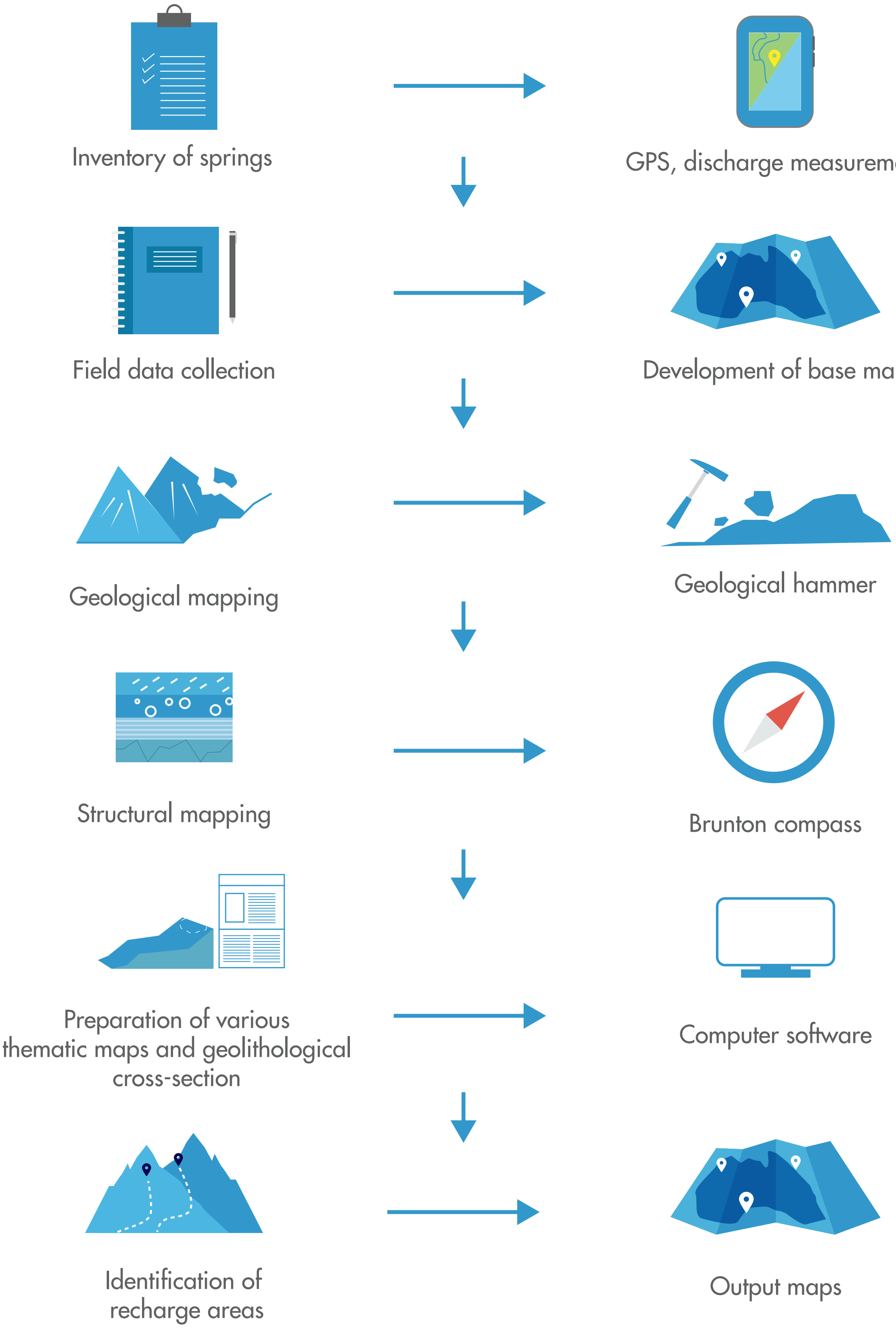


Figure 5: Flow chart of methods involved in the hydrogeological study

SPRING LOCATIONS

CRITICAL SPRING LOCATIONS (Marked in red)

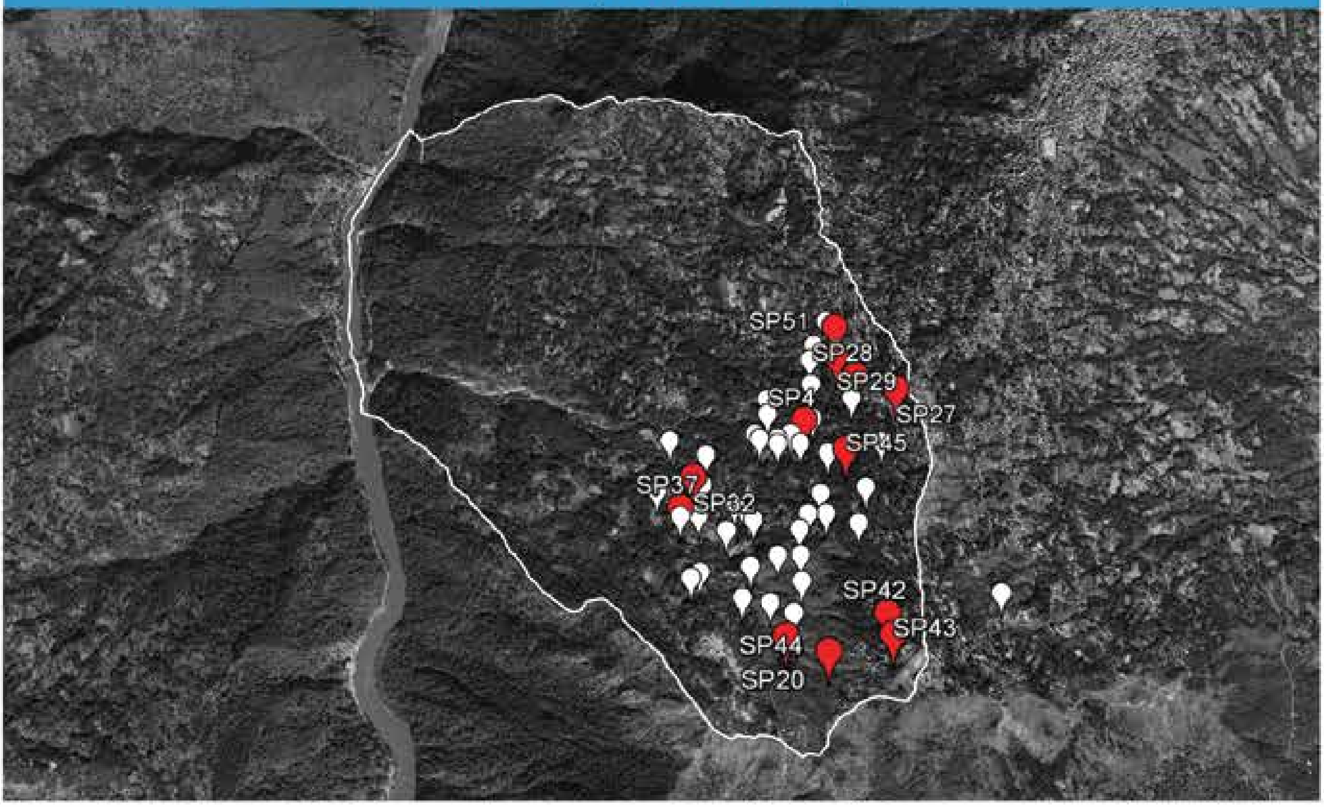


Figure 6: Atlas of 55 springs

4. Results

A total of 55 springs were identified during the initial spring reconnaissance survey, and seasonal water discharges were monitored during 2016–17.

4.1. Mapping of springs in the research area: Spring types, water availability, access, and budgeting

Spring water is a major source of water for drinking, agricultural, and industrial requirements. In the study area, as many as 107 households are directly dependent on springs, while around 80 households are indirectly or partly dependent on them. The availability of water determines the location and activities of humans in an area and our growing population is placing great demands upon natural fresh water resources. However, they are sometimes exposed to various forms of pollution such as agricultural, industrial, and residential. Therefore, we conducted a series of tests to determine the limits of pollutants in drinking water.

TDS are inorganic compounds (principally calcium, magnesium, potassium, sodium, bicarbonates, chlorides, and sulphates) that are found in water. Apart from salts and heavy metals, organic compounds too are found dissolved in spring water. While some of these compounds or substances are essential to life, they can also be harmful to humans and livestock when imbibed beyond the permissible limits. As per the Bureau of Indian Standards (BIS: 10500) guidelines, 500 mg/l is the desirable limit and 2,000 mg/l the permissible limit, which means that drinking water having TDS in excess of 2,000 mg/l must be rejected. The TDS readings in the water of the selected springs were all below 100 mg/l, and so are under permissible limits.

EC is a measurement of the dissolved material in an aqueous solution, which relates to the ability of the material to conduct electricity. The electrical conductivity of the groundwater of these areas depends on locations. In the present study, the values of EC at the sampling points ranged from 18 to 126 µS/cm. The values obtained from all the sampling sites were within the accepted standard of the BIS for drinking water quality, which is 1,000 µS/cm.

The pH value of water indicates whether it is acidic or alkaline. In our study, the water pH was found between 5.1 and 7.4, and all the water samples analysed had a concentration of TDS within the safe limit of 6.5 to 8.5—the standard set by the WHO and the BIS.


In-situ water quality assessment

In the Chibo–Pashyor area, as many as 55 springs located between 700–1,350 masl were surveyed for detailed study. These springs cater to the domestic water needs of around 721 households. They are informally and privately managed by the dependent households. Our survey revealed that the discharge of all these springs has been declining over time, particularly in the last 5–10 years.

Of the 55 springs, 39 springs had discharge of less than 10 lpm; 8 springs had 10–20 lpm discharge, 4 had 21–40 lpm discharge, 2 had 60–80 lpm discharge and 2 had around 100 lpm discharge. This data confirms that the discharge rate of springs is declining over time. According to the dependent households, the discharge status of springs in the area in the past 5–10 shows that as many as 29 springs have very low discharge rates, 13 have medium discharge rates, and around 13 have high discharge rates.

Water access, discharge, and budgeting

As per the "Goals—Strategic Plan (2011–2022)" laid down in the "Guidelines on National Rural Drinking Water Programme 2013" by the Ministry of Drinking Water and Sanitation, Government of India, for the Twelfth Five-Year Plan, a piped water supply scheme should have a design of 70 litres per capita per day (lpcd) for household a connection—within a horizontal or vertical distance of 100 m—for ensuring drinking water security.

The average discharge was found to be more than 20 to 30,000 litres per day (lpd) in four springs. Only one spring was found to have a high discharge rate of more than 70,000 lpd. Four springs had a discharge between 10,000 to 20,000 lpd, while three were found to be below 10,000 lpd (Table 2).

Table 2: Average annual discharge, per capita availability, and demand

Spring code	Name of spring	Water access type by users	Annual average discharge (lpd)	Per capita water availability* (lpcd)	Total water requirement at 70 lpcd	Water surplus/ deficit
SP43	Changchangey Dhara	Fetching	20,304	70	18,200	—
SP44	Bar-Pipal Dhara	Fetching	20,880	90	14,560	—
SP45	Manjhi Dhara	Drawing through polypipe	28,656	152	11,830	—
SP28	GREF Jhora	Fetching and drawing through polypipe	8,640	60	9,100	460
SP27	Hitti Dhara	Fetching	5,040	43	7,280	2,240
SP20	Dhyangrey Simsaar	Drawing through polypipe	14,256	164	5,460	—
SP32	Mangar Devithan Dhara	Drawing through polypipe	77,040	1,063	4,550	—
SP37	Simsarey Dhara	Drawing through polypipe	9,504	164	3,640	—
SP29	Tamanggaon Dhara	Fetching	25,488	676	2,366	—
SP51	Amrita Dhara	Fetching and drawing through polypipe	16,416	566	1,820	—
SP42	Pashupati/Mangal Dara Dhara	Drawing through polypipe	11,808	1,018	728	—
SP04	OC Jhora	Drawing through polypipe	19,152	3,302	364	—

*Per capita water availability at spring level

Most of the households in Chibo–Pashyor depend on the respective springs to fulfil their daily needs, as there is an absence of formal water supply/distribution mechanism in the watershed. The total water discharge, the per capita water availability from springs, and the total water requirement are provided in Table 2. The total water availability is greater than the required volume (on a per capita per day demand basis) in most of the springs. So, the existing water scarcity is due to the absence of water storage infrastructure (collection tanks/storage tanks/reservoirs) at the spring source and at the household level, as well as poor water management/mechanism and inequitable distribution.

The findings indicate that the management and maintenance responsibility lies with every water user. We also found that there are informal rules established among the water users, such as rules for opening and closing of taps, limiting water use during the dry season, as well as prohibiting water use for bathing, washing clothes, and cleaning vehicles during lean periods.

Table 3: Management and operational rules for spring water taps, and informal rules for collection

Spring code	**Name of spring**	**Management/ maintenance responsibility (yes; no; every user)**	**Operational rules for tap**	**Informal rules for water collection**	**Charges for maintenance and repairs**	
					Yes/ No	Amount/ year (INR)
SP43	Changchangey Dhara	Every user	Timely opening and closing of tap	First come, first served	No	NA
SP28	GREF Jhora	Every user	Limiting water use during dry season; have to buy water for construction purposes	First come, first served	No	NA
SP44	Bar-Pipal Dhara	Every user	Bathing, washing clothes, and cleaning vehicles prohibited during dry season	First come, first served	No	NA
SP45	Manjhi Dhara	Every user	No rules	No rules	No	NA
SP20	Dhyangrey Simsaar	Every user	No rules	No rules	No	NA
SP32	Mangar Devithan Dhara	Every user	Timely opening and closing of tap	No rules	No	NA
SP37	Simsarey Dhara	Every user	Timely opening and closing of tap	No rules	No	NA
SP29	Tamanggaon Dhara	Every user	Timely opening and closing of tap	First come, first served	No	NA
SP51	Amrita Dhara	Every user	Timely opening and closing of tap	No rules	No	NA
SP27	Hitti Dhara	Every user	Limiting water use during dry season	No rules	No	NA
SP42	Pashupati/ Mangal Dara Dhara	Every user	No rules	No rules	No	NA
SP04	OC Jhora	Every user	No rules	No rules	No	NA

4.2. Community perceptions

Impacts of climate change

Rainfall and temperature

As per the FGDs and surveys conducted in Chibo–Pashyor, communities have observed an increase in the intensity of hot days, and an overall increase in both day and night temperatures (Table 3). They attribute this to lower rainfall and the resultant drying up of springs and water resources like wetlands. It was learnt that about 50–60 years ago, there used to be six *jheels* (ponds) which have all gone dry over the years, especially after the earthquake of 2011.

Due to phenological changes and increase in temperature, the number of pests and pathogens has increased, impacting cash crops, especially ginger. Overall, agricultural productivity has decreased, which is partly due to decreased rainfall as well as due to an increase in the intensity of rain, and the inconsistency in monsoon and winter precipitation (Table 4). Due to low rainfall, households have slowly started to abandon paddy cultivation. High intensity rainfall during the monsoons has also led to soil erosion and landslides. The heavy rainfall and soil erosion impact local infrastructure such as water supply systems and wooden bridges.

In the upper belt (Chibo), farmers have been cultivating large cardamom for the last 10 years. Due to the failure of cash crops like ginger and oranges, and failure of rice crop due to poor rainfall, farmers have shifted to cultivation of vegetables like cabbage, beans, cauliflower, tomato, potato, cucumber, chili pepper, and peas. They have also taken up broom grass cultivation. And over the last four or five years, in a bid to boost production, the farmers have been increasingly using chemical fertilizers, pesticides, and insecticides.

Anthropogenic changes

During the dry season (December–March), water scarcity is a major issue. This means that women have to do a lot more by way of collecting water or repairing the water supply systems.

Another major issue is that the youth are getting less involved in agricultural activities. They are moving to Kalimpong city in search of employment opportunities. The advent of information technology and social media, and the quest for higher education have also triggered the outmigration of the youth.

Measuring spring discharge

Since agricultural practices are on the wane, there is a shortage of livestock. It is also becoming difficult to find bulls—and if they are used, the hiring charge is rather high—for ploughing the fields during the paddy plantation season. This has resulted in farmers keeping their fields fallow.

Due to limited government intervention in supporting farm livelihoods, there has been an increase in support from civil society and NGOs such as World Vision and the Glenn Family foundation. They help in managing water supply and improving sanitation facilities, while also being part of initiatives to preserve the local culture and motivating the youth. This has led to the formation of self-help groups, and the adoption of new strategies in poultry and dairy farming.

In the wake of trends like nature and farm holidays, ecotourism and homestays are becoming popular in the area. A significant number of households in Chibo have recently entered the tourism business by constructing well-equipped rooms in their houses.

Table 4: Occurrence of climate-induced hazards and coping mechanism in the Chibo–Pashyor area

Climatic parameter	Climatic extremes and hazards	Coping and adaptation practices	Institutional support
Pashyor, Kalimpong			
• Decrease in annual rainfall, delayed onset of rain, and shorter rainy season; heavy rainfall during monsoon, long periods of drought followed by sudden and excessive rainfall • Increase in annual temperature, long and dry summer months, prolonged dry/lean period • Frequent hailstorms, mostly during the months of March to May	• During the monsoon, due to sudden and excessive rainfall in short periods, landslides sweep away the bamboo bridge, and the fields adjacent to agricultural farms cutting off the entire village. • New crop diseases appeared in the last 5–10 years; ginger affected by chlorosis, resulting in decline in productivity • Drying up of wetlands and streams • Drying up of springs leading to scarcity of water • Complete loss of Mandarin orange trees from the entire village • Wild animals and birds from lower altitudes, especially peacock, damage agricultural produce • Frequent forest fires • Crop damage due to drought, long dry periods, and hailstorms from November through May	• Shifting from orange to ginger and vegetable cultivation • Broom grass cultivation, development of multipurpose agroforestry systems • Cultivation of fodder trees, fuelwood, and tubers • Cultivation of off-season vegetables • Water harvesting, the use of Azolla for soil-nutrient enrichment	• Extension services supported by organizations like the Glenn Family Foundation, World Vision, and Gandhi Ashram to encourage schooling and support the construction of toilets • Rainwater harvesting for water security • Dairy as well as cattle and poultry farming as a new livelihood option
Chibo area			
• Decrease in annual rainfall, sharp decrease in winter rainfall • Water scarcity • Extremely cold winter nights	• Drying up of seasonal springs, perennial springs becoming seasonal, water scarcity from the months of November to June • Winter nights getting colder due to cold wind from the lower belts • New diseases emerging because of polluted air from the hydropower dam in the Teesta River (methane emission). • Production of oranges and ginger has totally stopped over the last 5–10 years. • Decline in butterfly population • Decline in bird population (such as blue whistling thrush and red-vented bulbul)	• Increase in broom grass cultivation, some revival of large cardamom cultivation • Adoption of floriculture as an alternative livelihood option • Adoption of organic tea cultivation	• Rainwater harvesting; and the construction of jeepable roads for rural connectivity under the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) • House repair and construction for those below the poverty line

4.3. Springs profile

A total of 12 major and critical springs were identified based on dependency and discharge for long-term monitoring. These springs are mostly located in the catchments of the Chibo area and around 66% of households are dependent on them (Figure 7). Over the years, there has been rapid land-use land-cover change due to agricultural land transformation for infrastructure development, frequent landslides, road construction, and impacts of climate change in the form of a prolonged dry season.

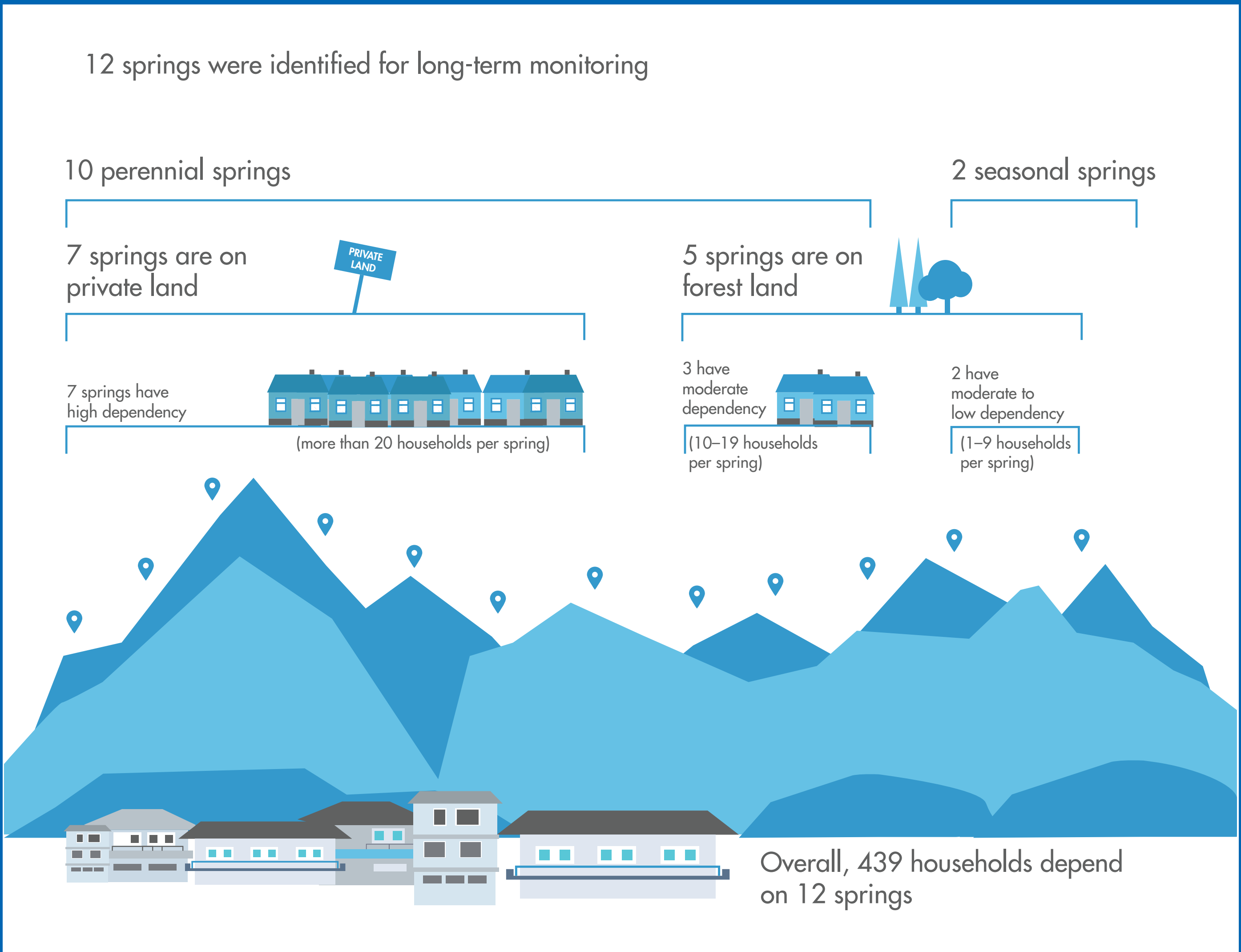


Figure 7: Springs profile of study area

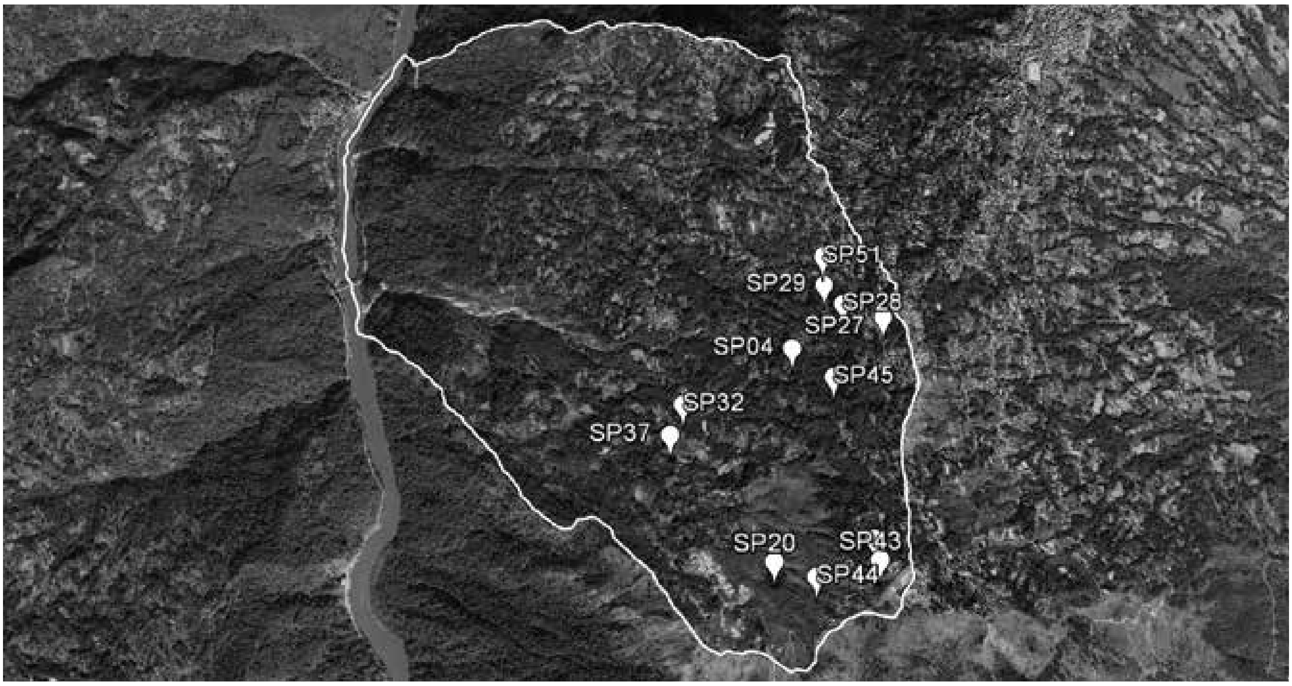


Figure 8: Location of springs in study area

SP43 – Changchangey Dhara (Latitude: 27°03′18″ N; Longitude: 88°27′32″ E; Elevation: 1,292 masl)		
100 households	Good discharge during monsoon	2,000 ltr capacity water storage
SP44 – Bar-Pipal Dhara (Latitude: 27°03′15″ N; Longitude: 88°27′18″ E; Elevation:1,241 masl)		
80 households	Good discharge during monsoon	Spring considered sacred due the location of a pipal (*Ficus religiosa*) tree in its vicinity
SP45 – Manjhi Dhara (Latitude: 27°02′54″ N; Longitude: 88°27′24″ E; Elevation: 1,225 masl)		
65 marginal community households	No water management system	During lean periods, bathing, washing of cars is discouraged
SP28 – GREF Jhora (Latitude: 27°03′09″ N; Longitude: 88°27′27″ E; Elevation:1,246 masl)		
100 households	Unstable landslide prone terrain – as a result, water discharge varies in different seasons	
SP27 – Hitti Dhara (Latitude: 27°03′06″ N; Longitude: 88°27′36″ E; Elevation:1,325 masl)		
40 households	Absence of water collection/storage tank worsens the situation	
SP20 – Dhyangrey Simsaar (Latitude: 27°02′18″ N; Longitude; 88°27′09″ E; Elevation: 1,219 masl)		
30 households	Water is collected through pipes	

SP32 – Mangar Devithan Dhara (Latitude: 27°02′49″ N; Longitude: 88°26′50″ E; Elevation: 950 masl)		
25 households	Highest discharge among all springs and high discharge throughout the year	
SP37 – Simsarey Dhara (Latitude: 27°02′43″ N; Longitude: 88°26′47″ E; Elevation: 1,004 masl)		
20 households	Major source of water for lower Chibo and Possyor villages	Located in a private holding in lower Chibo village
SP51 – Amrita Dhara (Latitude: 27°03′19″ N; Longitude: 88°27′23″ E; Elevation: 1,161 masl)		
10 households	Water users carry out repair and maintenance of the pipelines on their own	
SP37 – Pashupati Dhara (Latitude: 27°03′22″ N; Longitude: 88°27′31″ E; Elevation: 1,266 masl)		
4 households	Little or no discharge during the months of February through May	Mainaining household hygiene is difficult for households during the lean period
SP04 – OC Jhora (Latitude: 27°02′60″ N; Longitude: 88°27′15″ E; Elevation: 1,150 masl)		
2 households	Perception of decline in spring discharge following September 2011 earthquake	
SP29 – Tamang Gaon Dhara (Latitude: 27°03′13″ N; Longitude: 88°27′23″ E; Elevation: 1,173 masl)		
13 households	Tap and collection tank located near the spring	

4.4. Water governance and management

Water governance usually refers to a political, social, economic, and administrative system that influences water use and management. The study findings show that while Kalimpong has a functional water supply system built during the colonial period, the majority of communities in the Chibo–Pashyor area are left out of this distribution system. There are no formal water governance institutions or water-user groups in place. This is partly due to the current political situation in the Darjeeling hill region, which has undermined local governance structures, thus impacting the management and distribution of water resources[2].

As for the gender equations at work here, women have to carry out the laborious task of collecting water, while the men are engaged in the conservation and management of spring sources. Some households have to spend a lot of time fetching water from the sources in vessels.

[2] The rural local bodies under the Darjeeling Gorkha Hill Council (DGHC) Act were dissolved in 1988; they were outside the purview of the Panchayat Act and Municipal laws under Article 243. As per the agreement signed between West Bengal state and Gorkha Janmukti Morcha in 2011, DGHC was repealed and a new body, the Gorkhaland Territorial Administration (GTA), was formed. There is still no clarity about local governance under the new agreement and thus this vacuum in terms of local self-governance.

Due to the lack of local planning institutions or relevant government bodies, there appears to be inequity and inefficiency in the allocation and distribution of water. There is mismanagement of distribution systems and of the supply of the spring water through taps. For example, around the Mangal Dara area, the water supply through pipes is rather haphazard. Construction of water storage tanks could be one of the possible options for water harvesting and distribution (Table 5).

The surveys reflect the following:

- Lack of relevant government institutions and active local bodies with roles and responsibilities in governing water
- Lack of water supply schemes and programmes such as the Rural Water Supply Scheme (RWSS) and the National Rural Drinking Water Programme (NRDWP)
- Lack of stakeholder awareness about drinking water schemes and absence of infrastructure planning

Table 5: Water distribution, land use, and infrastructure in the Chibo–Pashyor watershed

Spring code	Name of spring	Type of spring	Land-use type	Collection tank (yes / no)	Tank capacity (litres)	Financial support by	Water supply pipeline to all HHs (yes/no)
SP43	Changchangey Dhara	Dhara	Settlements, road	Yes	2,000	Kalimpong Municipality	No
SP44	Bar-Pipal Dhara	Dhara	Settlements, road	Yes	1,500	Samaj Sewa Samiti	No
SP45	Manjhi Dhara	Jhora	Vegetation	Yes	2,000	Chandramani Kharka	No
SP28	GREF Jhora	Jhora	Settlements, prone to landslide	No	NA	NA	No
SP27	Hitti Dhara	Dhara	Settlements, road	No	NA	NA	No
SP20	Dhyangrey Simsaar	Dhara	Vegetation/ forest cover	No	NA	NA	Yes
SP32	Mangar Devithan Dhara	Dhara	Settlements	Yes	3,000	Gram Panchayat	Yes
SP37	Simsarey Dhara	Dhara	Agricultural field	No	NA	NA	Yes
SP29	Tamanggaon Dhara	Dhara	Settlements	Yes	8,000	Kalimpong Municipality	No
SP51	Amrita Dhara	Dhara	Settlements, road	Yes	2,000	NA	Yes
SP42	Pashupati/Mangal Dara Dhara	Dhara	Settlements, road	No	NA	NA	No
SP04	OC Jhora	Jhora	Settlements	Yes	1,500	NA	Yes

Findings:

- Due to the lack of storage tanks in 42% of the springs, the night-time flow is not collected (resulting in large run-off).
- There is no proper water distribution system in 58% of the springs.

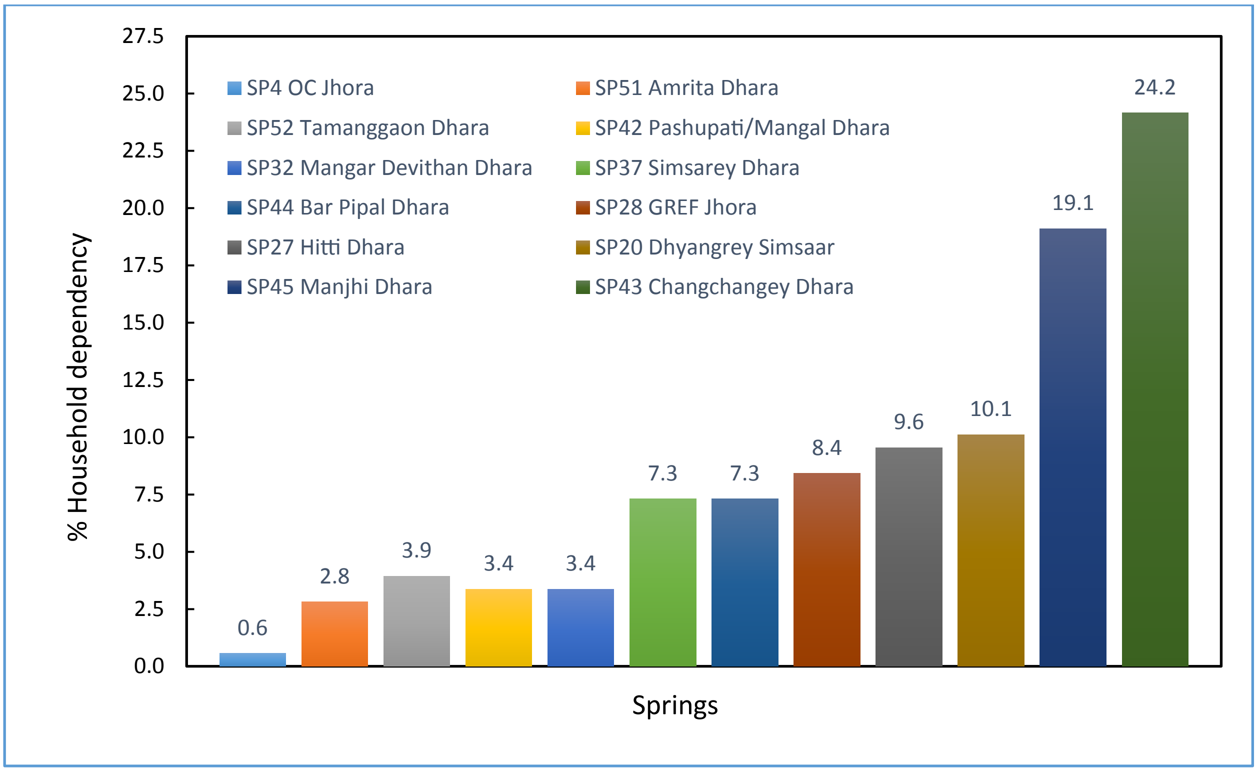


Figure 9: Dependency on critical springs in the Chibo–Pashyor area

Spring discharge is categorized based on the volume of the flow and discharge during the lean season. The volume of the water discharge is calculated in litres per minute (Figures 9 and 10). The discharge is classified into five types. Table 6 shows the percentage of spring discharge in the study area.

Most of the springs have low discharge rates (54%) during the lean season (February–May) owing to low rainfall which retards the recharge of the underground aquifers. Only 4% of water sources/springs have sufficient discharge throughout the year. There are very few sources with constant water flow throughout the year (Table 6).

Table 6: Discharge category and percentage of spring discharge

Litres per minute (lpm)	Discharge category	% of spring discharge
0–5 lpm	Very low	54%
6–10 lpm	Low	16%
11–20 lpm	Medium	18%
21–50 lpm	High	8%
51+ lpm	Very high	4%

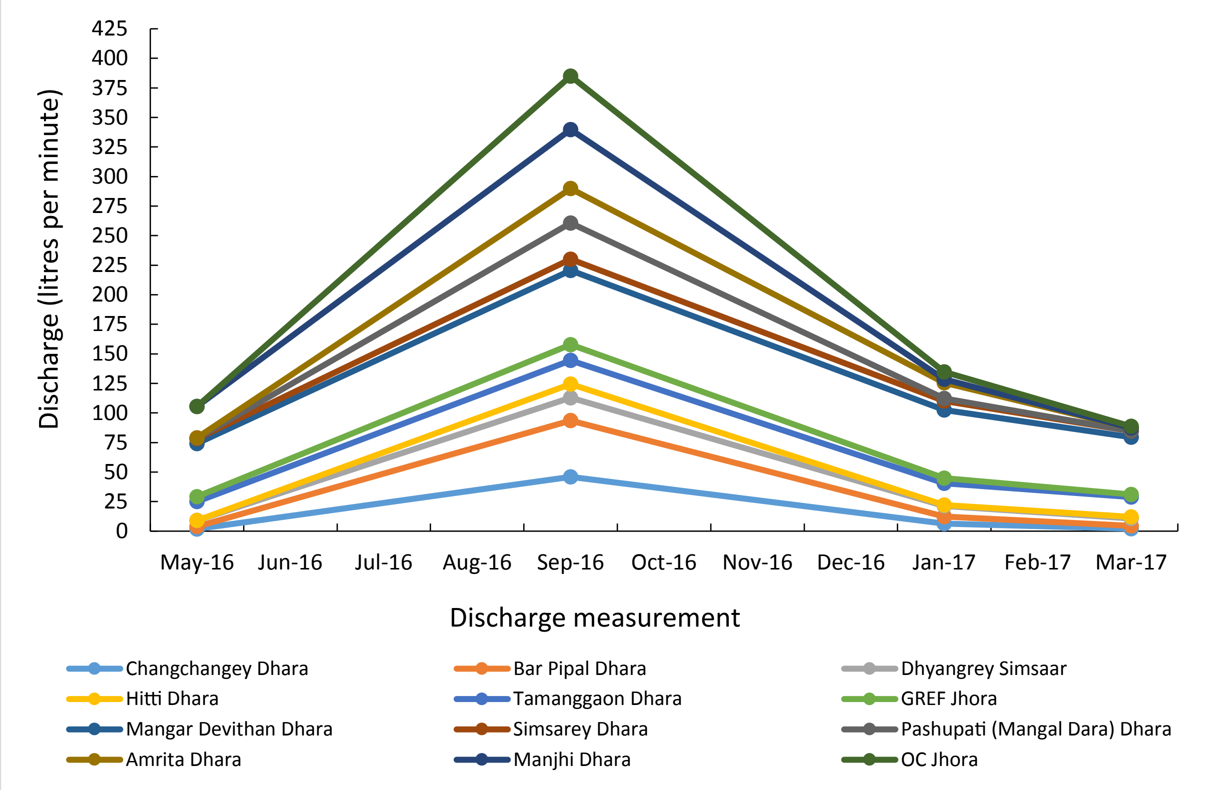


Figure 10: Seasonal discharge trend of springs

Other observations

Change in discharge

The seasonal discharge levels of the identified springs indicate that most of them high discharge rates during the post-monsoon period (September–October) and low discharge rates during the lean period (December–May) (Figures 9 and 10). Of the 12 springs, Mangar Devithan Dhara and Tamanggaon Dhara, have relatively constant discharge throughout the year; but the discharge levels of both these springs are different — Mangar Devithan Dhara has an average discharge of 53.5 lpm, while Tamanggaon Dhara has an average discharge of 18 lpm.

Land-use change

Over the years, springs have been drying up in the area owing to several anthropogenic factors such as change in land-use patterns (deforestation, road-building, construction, and formation of settlements, all leading to catchment degradation) and the impacts of climate change (low or unpredictable precipitation). All these factors have retarded the recharge of the underground water-bearing aquifers which feed the springs. Consequently, there is a shortage of drinking water in the villages in the springshed. The locals have noted that there has been a decline in water volume in all the springs.

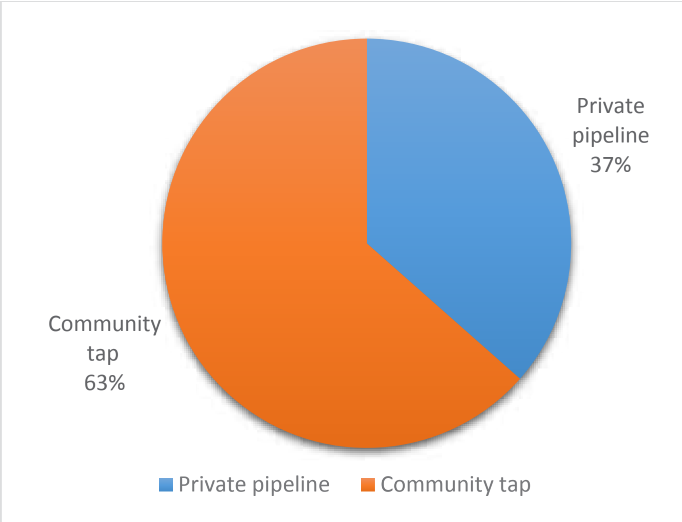


Figure 11: Water access in the Chibo–Pashyor area

Out of the surveyed households that depend on springs, and which we considered for long-term monitoring in the Chibo–Pashyor watershed, 63% of them fetch water from the community taps, whereas 37% have invested in their own supply systems (Figure 11). Most of the respondents were of the opinion that the water quality was good. Local perceptions about rainfall and temperature trends were also recorded during the PRA consultation.

Table 7: Rainfall and temperature (over the last 5 years) based on farmers' perceptions

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall	*	*	*	*	*	**	***	***	***	**	**	**
Temperature	*	**	**	**	***	***	***	***	**	**	*	*

(Rainfall intensity: *** – Good; ** – Drizzle; * – No rainfall) (Temperature: *** – Hot; ** – Cool; * – Cold)

The climatic/environmental conditions in Chibo–Pashyor have been changing over the years. In terms of weather, the months of January through May are the driest, which largely affects water availability in the streams and springs, while May–August are the hottest months. Extreme dryness during the lean season results in the springs running out of water or a decline in volume, which, in turn, affects cultivation (Table 7).

Table 8: Vulnerability assessment and ranking (Points – 1 [low], 10 [high])

Village	Parameters					Total Points	Vulnerability Rank
	Water source availability (0–10)	Water access/ supply (0–10)	Water storage infrastructure (0–10)	Equitable water supply (0–10)	Proper water management (0–10)		
Chibo	7	3	3	2	1	16	II
Pashyor	1	3	2	3	1	10	I

The vulnerability assessment showed that Pashyor is the more vulnerable village (Tables 7 and 8). Almost all the water resources are located in Chibo, and the households in Pashyor draw water from the sources located in Chibo. Poor water management, inadequate water storage infrastructure, lack of water supply projects, and absence of water-governing institutions/bodies are the prime factors at play in water-related vulnerability/insecurity in Chibo–Pashyor.

Gender dimension of water governance

Gender roles and responsibilities are different in Chibo–Pashyor as far as spring management and collection of water are concerned. Time is a significant factor that reflects the gender disparity in these villages in terms of water supply, agriculture, and overall livelihood. The gender division of labour means that women often work across domestic and non-domestic, as well as on-farm and off-farm spheres, leaving them "time poor". In terms of the amount of time and labour, women bear the brunt, particularly during periods of water stress. As they spend more time in water provisioning, they often have no time left for agricultural or other productive activities.

Several questions were posed purposefully—in both group discussions and individual interviews—regarding the role and influence of women and men in the decision-making processes related to water (Parker et al. 2016). It was found that both men and women work together in all spheres of domestic activities and are also partners in decision-making. However, other than the usual activities, the women are expected to spare time for domestic chores, child care, and income generation (growing vegetables, for example). And, with the decreasing availability of water near their locality and the drying up of springs, women have to spend more time fetching water from distant sources, thereby leaving them with very little time to contribute to farm-related activities or to off-farm income-generating work.

A woman carrying drinking water from a nearby spring

4.5. Geology

The study site falls within the inner and axial belts of the Darjeeling Himalaya, and has a medium-grade metamorphic rock sequence, which is represented by chlorite–sericite–phyllite and their variants, as well as by banded gneiss, with an occasional band of mica schist with or without quartz veins. These rocks belong to the Daling Group, or the Gorubathan Formation, of the Proterozoic age.

The study area near Chibo village is largely a part of the Teesta basin, locally drained by the Pyrani, OC, and Raja jhoras. OC jhora and Raja jhora merge together to form Pashyor khola in the Pashyor watershed on the eastern flank of the ridge. Raja jhora and Dhobi jhora are perennial while others are seasonal. The drainage density (Figure 12) of the study area is high, and it is interesting to note that the drainage pattern is sub-parallel to parallel i.e., streams meet roughly at a ninety-degree angle suggesting a strong structural control on the basin.

Geologically, the study area is located in the Lingtse formation of the Lesser Himalayan Zone, comprising mainly of gneiss with schist interbeds. Tectonically, it is

Measuring rock dip and strike direction using a clinometer surrounded by Main Boundary Thrust (MBT) to its south and Main Central Thrust (MCT) to its north. Gneisses are highly sheared at places and weathered to schist.

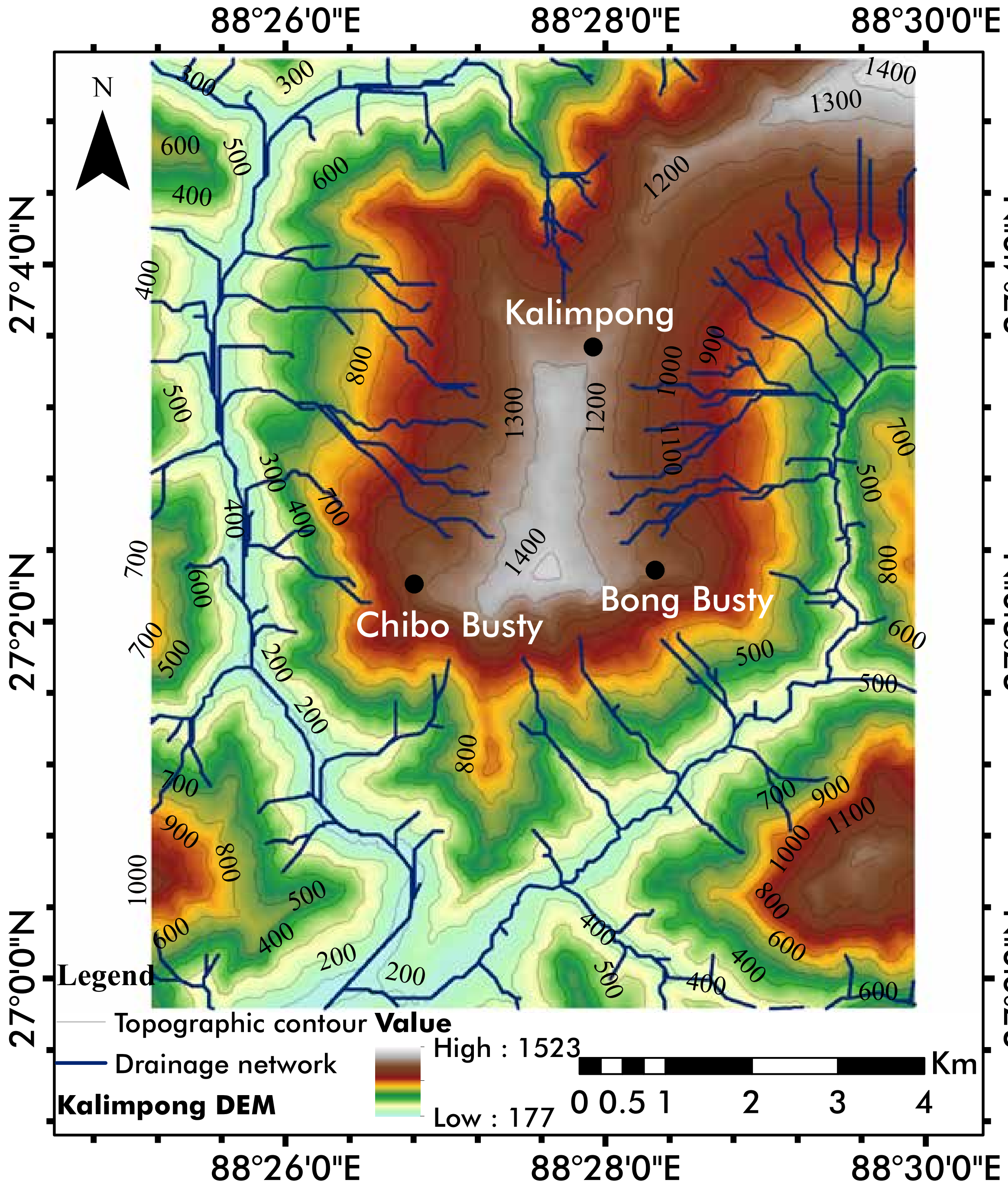


Figure 12: Topographic relief with drainage network in the 'Chibo–Bong Busty Springshed'

Owing to the highly fragile nature of the study area, detailed mapping was done at 1:20,000 scale. Exposures in an area of 6.25 sq km between Chibo Busty, Bong Busty, and Kalimpong square along roadcut sections and streamlets have been mapped extensively. The inclination of trees along the direction of tilt and sliding zones served as bioindicators to identify the sliding direction of rock layers.

Although rock beds are highly deformed and variously oriented between NW and E, the general trend of the bedding planes is NW–SE, dipping gently towards NE by 30 to 50 degrees to almost horizontal at places. Gneiss beds are relatively more compact at the base while they are fragile and weathered on the top. During mapping, gneiss, fragile in nature, and the relatively soft schist, when found to be compact, were classified into soft and hard rock categories, respectively. Presently, hydrogeological boundaries are drawn on the basis of the hydrogeological character or water bearing ability (relatively soft and compact beds) of the rock rather than lithological contacts.

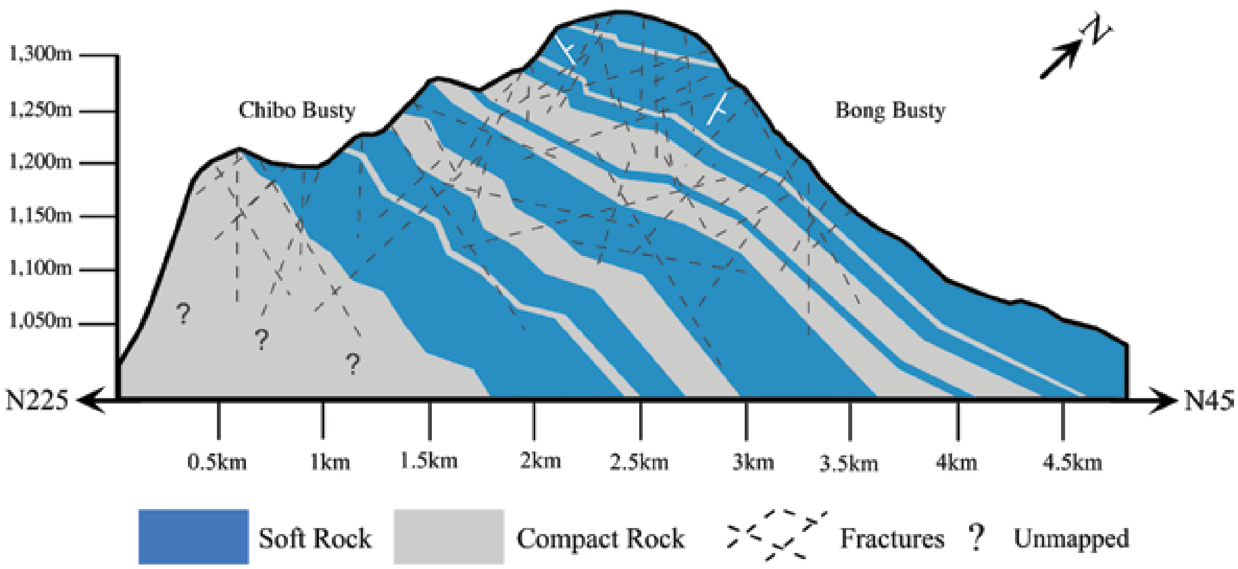


Figure 13: Hydrogeological cross-section of the study area demarcated on the basis of aquifer geometry of the rock strata

Altogether, a hydrogeological cross section demarcating the interbedded zones of compact and soft rocks was prepared along the NE–SW section (Figure 13). Apparent dips have been calculated and plotted for better understanding along the section. The cross-section is also in alignment with the location of the springs visited during the fieldwork.

The undulation of the beds, trellis drainage pattern, land subsidence, and recurring earthquakes all point towards the role of tectonics in shaping the regional structural setting of the study area. The major fractures trend in NE–SW and NW–SE towards NW and SW by 40–75 degrees respectively. Vertical fractures are N–S and E–W are also present. Shear zones are parallel to bedding planes and extend about 10–50 metres in thickness. The compact beds, either gneiss or schist, are found to have widely spaced (5–8m) fractures while soft beds and shear zones, and possess multiple closely spaced (1–10cm) fracture sets. The opening in fractures ranges from a few cm at places.

Hydrogeological status

Seven springs viz. Changchangey, Bar-Pipal, GREF, OC/Manjhi, Happy Villa, Dhyangrey Simsaar and Simsarey (Figure 14) were previously identified for the study. These springs occur on the eastern slope. Adhering to the orientation of beds, both eastern and western slopes are in oblique relation with the underlying geology. Therefore, there is more likelihood of the same aquifer systems being exposed on both sides. This suggests that Chibo and Bong Busty form a springshed, which from here onwards will be referred to as 'Chibo–Bong Busty Springshed'.

Interestingly, the distribution of springs in the Chibo watershed is throughout from the base to the top, in contrast to the Bong Busty watershed where springs mostly occur below 1,000 masl, except towards the north. A total of 40 springs in an elevation range of 1,000–1,340 masl were mapped in the Chibo–Bong Busty springshed during fieldwork. Most springs located on the ridge are perennial in nature and occur either as depression or fracture type springs.

Figure 14: Spring inventory in the 'Chibo–Pashyor and Bong Busty' springshed; 1–Changchangey; 2–Bar-Pipal; 3–GREF; 4–Happy Villa; 5–Manjhi; 6–Dhyangrey Simsaar; 7–Simsaar springs

Gneiss is a compact rock formed by metamorphism of schist. From a hydrogeological perspective, both gneisses and schists, being hard and compact, usually lack primary permeability. Thus, the role of openings developed along joints, fractures, and shear zones in the form of secondary porosity and permeability is important in the movement and accumulation of groundwater. Therefore, fracture spacing and their openings, along with their orientation, were measured to understand groundwater movement in the study area. Weathering is highly pronounced in this region and plays a significant role in groundwater storage.

Based on field data analysis, seven zones were identified (Figure 15) based on the hydrological characteristics of the litho units present in the study area. These zones were mapped from top to bottom and the details are provided in the section below.

Zone 1: This zone of soft rock support Warley (1,340 masl) and Shakti spring (1,274 masl) on the eastern dip slope; and, Changchangey (1,295 masl) and Raniban (1,264 masl) springs on the western slope. A 94m deep borewell (1,331 masl) at Albela School struck groundwater at 45.72m below ground level (10m above Shakti spring) which probably taps into this zone, and consumes around 2,000 litres per day. The total discharge from springs in the aquifer is 6.48 lpm.

Zone 2: This zone hosts the Bar-Pipal Dhara (1,266 masl) on the western slope; Tsering (1,156 masl), SK (1,197 masl), Dhobikua (1,164 masl), and Gurung Dhara (1,184 masl) springs on the eastern slope; and Peepal (1,157 masl), Eight and Half Mile (1,169 masl), Barsana (1,226 masl), Dhobighat (1,203 masl), Tapoban (1,217 masl), and SAS (1,201 masl) springs on the northern slope.

Zone 3: According to available data, this layer supports GREF (1,246masl) and Happy Villa (1,256 masl) springs on the western slope, and Reiyukai (1,126 masl) spring on the eastern slope. The quantity of water is reported to have increased in the Reiyukai spring after the 2015 earthquake according to locals.

Zone 4: In this zone, springs are almost evenly distributed throughout the layer. Manjhi (1,237 masl) occurs at the highest elevation, along with GREF 2 (1,193 masl) and Chibo Busty (1,182 masl) springs on the western slope. While, Rajen (1,169 masl), House (1,135 masl) and SJSRY (1,077m) occur on the eastern slope.

Zone 5: Nursery (1,101 masl) and Animal Shelter (1,092 masl) springs emerge from this zone both on the western and eastern slopes respectively.

Zone 6: This layer is mostly eroded along the western slope where Dhyangrey Simsaar (1,230 masl) and Thokar (1,113 masl) springs occur. The eastern slope probably does not host any springs along this zone.

Zone 7: Simsarey (1,010masl), Deopal (1,107masl) and Nursery 2 (1,129masl) springs occur on the western slope based on available data.

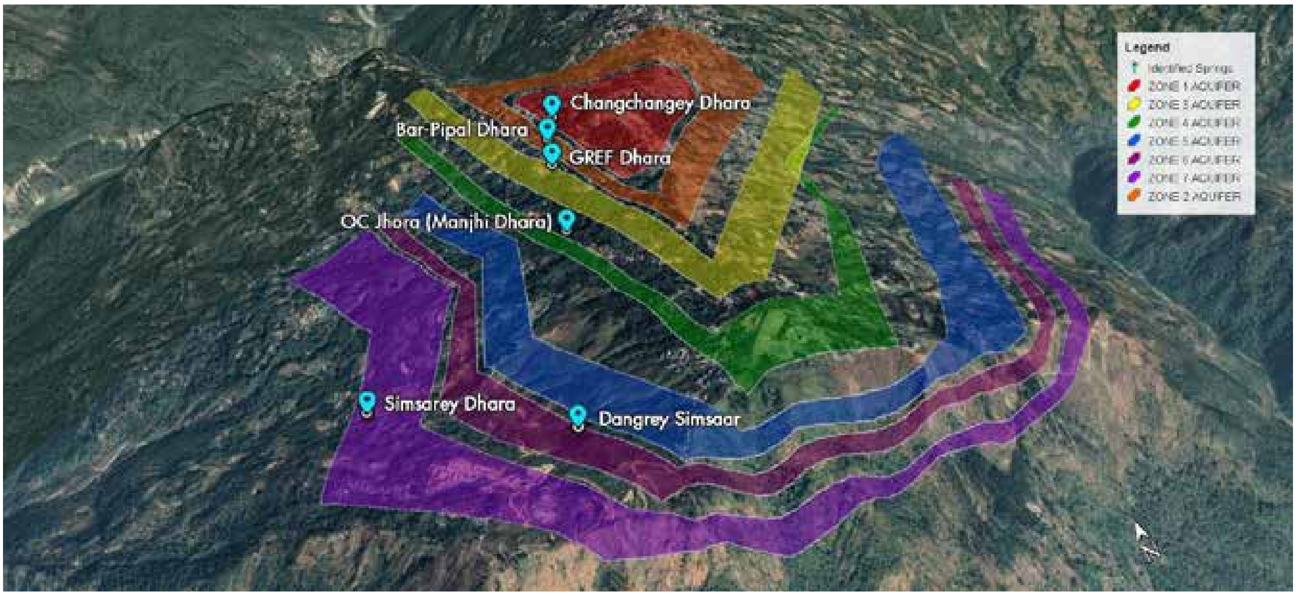


Figure 15: Zone-wise distribution of aquifers in the study area

The zonal classification of aquifers is made on the basis of their properties in terms of groundwater storage. These zones are separated from each other by a compact and fractured gneissic unit. The top two zones viz. Zone 1 and Zone 2 are highly sheared and fractured, while the rest are moderately sheared. However, due to extreme fragility caused due to the shearing and fracturing, there is a possibility of aquifer continuity across all seven zones. However, the continuity of aquifers across multiple zones can be determined by observing impact on the discharge of the below cited springs (Table 9) post implementation of recharge interventions.

Table 9: List of springs selected for detailed hydrogeological assessment

Latitude (N)	Longitude (E)	Elevation (masl)	Spot No.	Name	Village	Seasonality	Occurrence	Type
27.05427	88.45839	1,266	YB02	Bar-Pipal	Mangal Dara	Perennial	Depression	Dhara
27.05520	88.45907	1,295	SP43	Changchangey	Happy Villa	Perennial	Depression	Dhara
27.038692	88.452564	1,230	SP20	Dhyangrey Simsaar	Upper Chibo	Perennial	Depression	Dhara
27.04528	88.44639	1,010	SP37	Simsarey	Lower Chibo	Perennial	Depression	Dhara
27.04855	88.45667	1,237	SP45	Manjhi	Chalisey	Perennial	Fracture	Dhara
27.05268	88.45789	1,246	SP28	GREF Dhara	Chibo	Perennial	Depression	Dhara
27.05019	88.457746	1,256	YB05	Happy Villa	Mangal Dara	Perennial	Fracture	Dhara

4.6. Delineation of the recharge area

Identification and delineation of the recharge area(s) is the most important step in springshed management. It is crucial both for augmenting and restoring spring discharge and water quality. It can help in increasing the recharge of the aquifers feeding the spring, and in managing the aquifers and springs by protecting the recharge area. The recharge area is identified from the hydrogeological layout and then located on the map and Google Earth image (Shrestha et al. 2018).

Changchangey Dhara

The spring emerges on the escarpment slope at 1,295 masl from easterly dipping beds through a sheared zone (a highly fragile zone) in the form of a depression spring and is overlaid by a sequence of soft rocks, flaky to highly weathered in appearance. Multiple sets of fractures with 0.1m density were also mapped in that sequence, having openings ranging between 0.001 and 0.01m. The major fracture sets were found dipping in the NW and SW. Vertical fractures trending N220, N140, N290 were seen in the near vicinity of the spring towards its south. The underlying compact gneiss can be traced towards south and west, and is sparsely fractured (0.8–2m). The occurrence of the spring on the western (escarpment) slope thus points towards the fact that the spring is also supported by the fractured system along with the sheared zone, making it a combination (depression and fracture) spring (Figures 16 and 17).

The recharge area to Changchangey Dhara is thus defined by the extent of the shear zone and fracture set dipping gently towards NW and vertical fractures trending NS. The drainage located next to the spring towards south is formed on a fracture dipping steeply towards N and meets the shear zone. Vertical fractures extending along the shear zone in the N form a favourable zone for recharge to the aquifer supporting the spring. SW dipping fractures define boundary in the northern slope near an active landslide zone 150m north of the spring.

Recharge measures

Small recharge ponds can be dug towards the south of the spring at intersection points of fractures, away from kholas, on weathered and loose material towards the top. Physical recharge interventions along kholas may induce further landslides and should be avoided. The landslide zone along SW dipping fractures situated 150m north of the spring should be avoided for any physical intervention as it may further induce landslides. However, vegetative measures can be considered to bind the soil and the area should be designated a protection zone for natural recharge.

Figure 16: Recharge zone overlay on Google Earth for Changchangey Dhara.

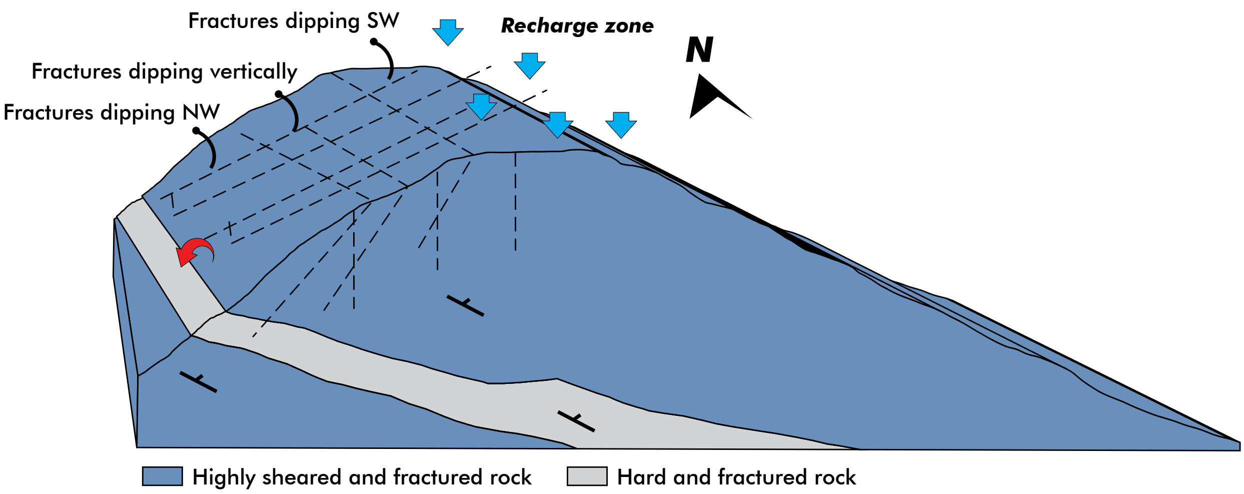


Figure 17: Hydrogeological conceptual layout and recharge zone overlay on Google Earth for Changchangey Dhara.

Bar-Pipal Dhara

Compact gneiss underlying the Changchangey dhara forms the top layer above Bar-Pipal dhara. Gneisses being compact possess poor permeability in general making groundwater recharge difficult in a few places, especially near escarpment slopes on top of the ridge towards the south. This is underlain by soft and fractured rock zone approximately 50m in thickness through which the spring occurs. This zone exhibits an interbedded sequence of gneiss and schist, mostly fragile in nature (Figures 18 and 19).

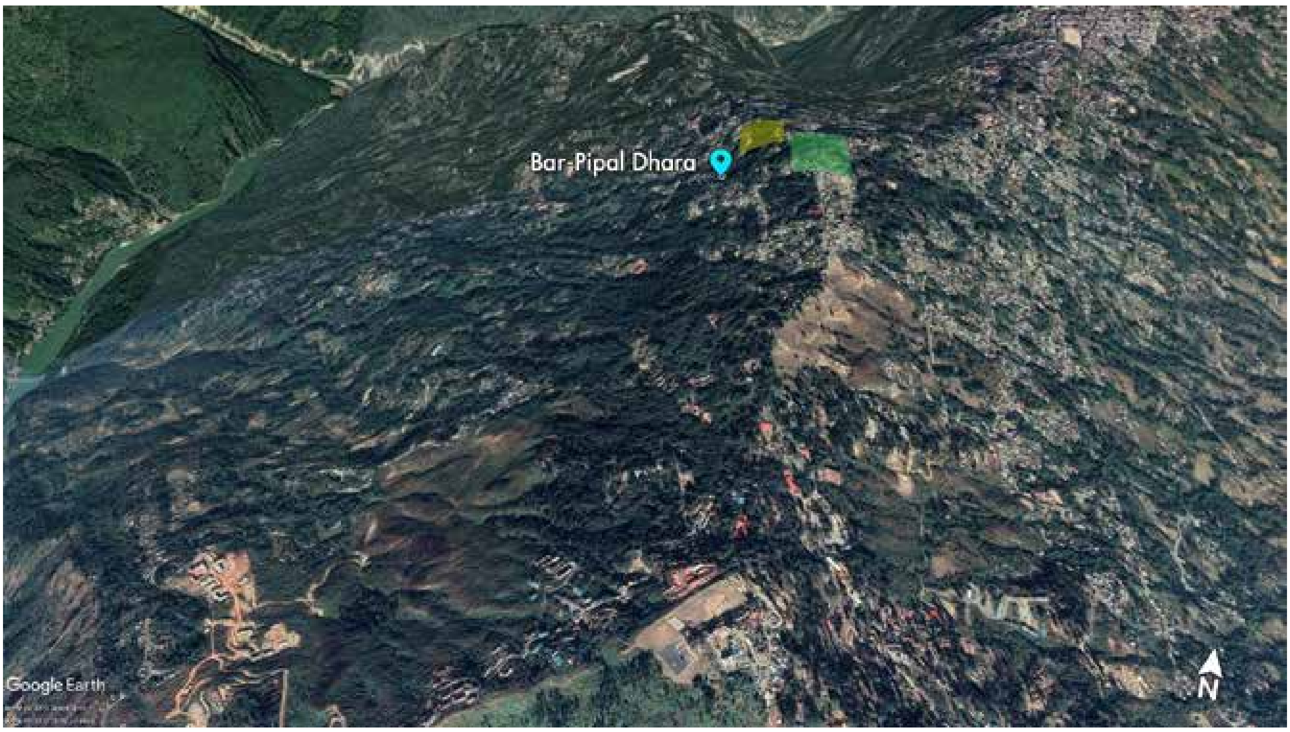


Figure 18: Recharge zone overlay on Google Earth for Bar-Pipal Dhara.

The highly permeable unit is exposed on the top towards the south on both sides of the ridge along the bedding plane orientation. The aquifer supporting Bar-Pipal Dhara is also probably hydraulically connected to the aquifer that supports Changchagney Dhara through vertical fractures and fractures dipping NW and SW. This spring also forms a classic example of combination spring, wherein the spring emerges through sheared material in the form of a depression spring but is also supported through a fracture system present in the unit through which it occurs.

The area along the bedding planes on the south western slope marks the recharge zone for this spring. Taking into account the hydraulic connectivity between the aquifers supporting Changchangey Dhara and Bar-Pipal Dhara through vertical fractures, the recharge zone extends on the top part of the ridge above the spring, extending towards the south. The fracture set, dipping gently towards the NW, defines the south-eastern recharge boundary, and can be traced back on the eastern slope. SW dipping fractures define the boundary at the northern slope near an active landslide zone 150m north of the spring.

Recharge measures

Small recharge ponds can be dug towards the south of the spring at intersection points of vertical and NW dipping fractures, away from kholas, on weathered and loose material. The kholas shouldn't be subjected to any kind of physical recharge measures as these might induce landslides like in the case of Changchangey Dhara.

Since the eastern slope is densely populated, physical measures like trenching and ponds might not be feasible. In this case, rooftop rainwater harvesting can be a useful way of supporting recharge of the spring.

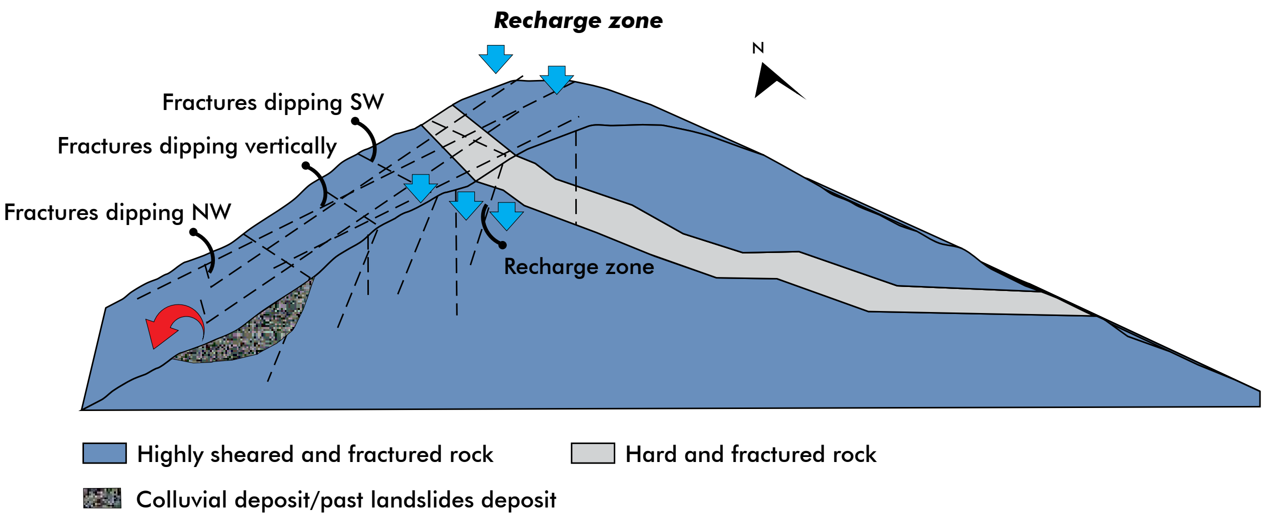


Figure 19: Hydrogeological conceptual layout and recharge zone demarcation for Bar-Pipal dhara using conceptual layout.

GREF Dhara and Happy Villa Dhara

GREF Dhara and Happy Villa Dhara occur as a depression spring at the base of Zone 3, which is underlain and overlaid by compact and fractured gneisses. The soft rock zone exhibits an interbedded sequence of gneiss and schist, mostly fragile in nature due to shearing and fracturing, and is exposed more towards the south along both the western and eastern slopes. Like in the case of Changchaney and Bar-Pipal dharas, there is possibly of a hydraulic continuity from the above zones to Zone 3, which supports both GREF Dhara and Happy Villa Dahra (Figures 20 and 21).

Figure 20: Recharge zone overlay on Google Earth for GREF Dhara and Happy Villa Dhara.

Since there is a hydraulic continuity due to vertical fractures across all three zones, the recharge zone extends on the top part of the ridge above the spring extending towards the south. The fracture set dipping gently towards N310 defines the south-eastern recharge boundary, and can be traced back on the eastern slope. Vertical fractures and fractures dipping NW thus form the pathways for recharge to the aquifer (Zone 3).

Recharge measures

On the east facing slope, a major portion of the recharge area falls on a military golf ground, which can be strategically used to implement recharge interventions. Small-dimension pits in feasible locations could help facilitate recharge. Additionally, a lot of vegetative measures can help induce natural recharge. The south-western slope, which seems to be already vegetated, should be protected from any further deterioration. Although, based on soil stability, some minor physical interventions can be carried out in that part of the recharge zone.

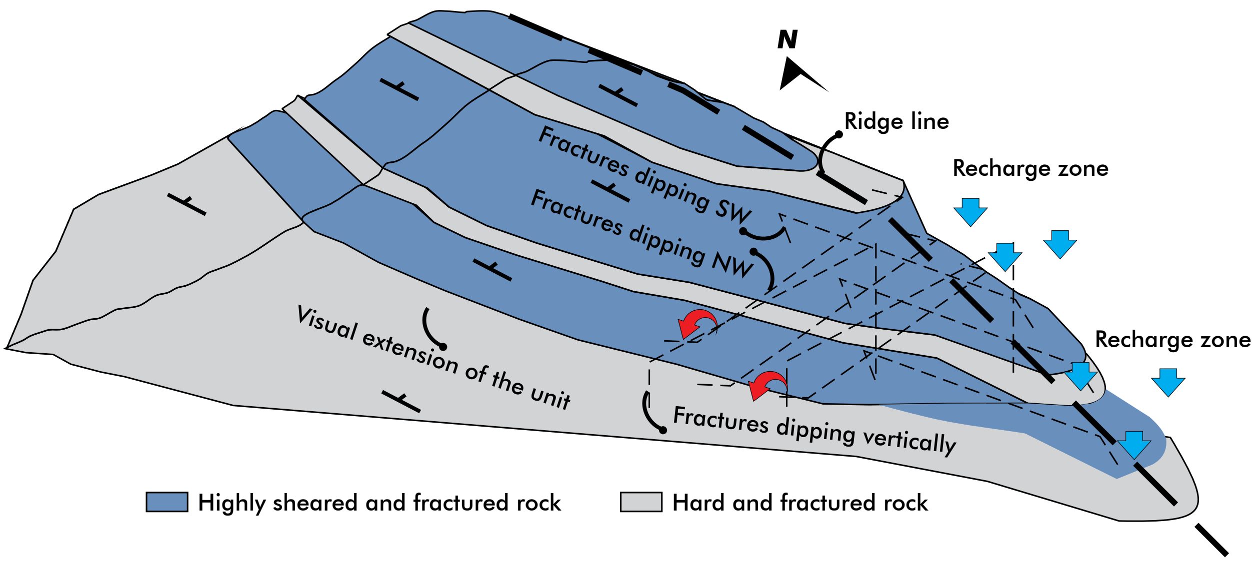


Figure 21: Hydrogeological conceptual layout and recharge zone demarcation for GREF Dhara and Happy Villa Dhara using conceptual layout.

O.C. Jhora (Manjhi Dhara)

Manjhi Dhara occurs at the base of Zone 4 and clearly emerges as a fracture spring. Zone 4 is again an interbedded sequence of weathered schists and gneisses with multiple fractures and is exposed on the top further south and on both sides of the ridge along the trend of the bedding plane. The hydraulic continuity for this zone with the zones above seems to be less as the zone extends further south. However, the fractures form the primary elements for recharge to this zone.

Zone 4 occurs as a very thin unit overlaid and underlain by compact and fractured gneisses. However, the recharge area to this spring is marked by the fractures dipping NW and SW along with N–S trending vertical fractures. The recharge zone for this spring extends more south where the ridge ends. Due to the gentle dips of the litho units Zone 4, the recharge area falls on both sides of the ridge. The fractures dipping NW and SW both tend to provide recharge to the spring and thus are taken into account while identifying and delineating the recharge area (Figures 22 and 23).

Recharge measures

The recharge area to OC Jhora slightly overlaps with the recharge area of the GREF and Happy Villa dharas. Thus, the activities that will be implemented for GREF and Happy Villa will also benefit OC Jhora to some extent. Additionally, some more physical interventions can be carried out on the eastern slopes based on land availability.

Figure 22: Recharge zone overlaid on Google Earth for OC Jhora/Manjhi Dhara

The zone identified to the north of the spring is marked as a protection zone as this part of the slope is more prone to landslides. Plantation activities should be undertaken to stabilise this part of the slope to avoid any landslide and also facilitate recharge. However, if there is better stability in this zone, some minor physical recharge interventions can be planned to facilitate additional recharge.

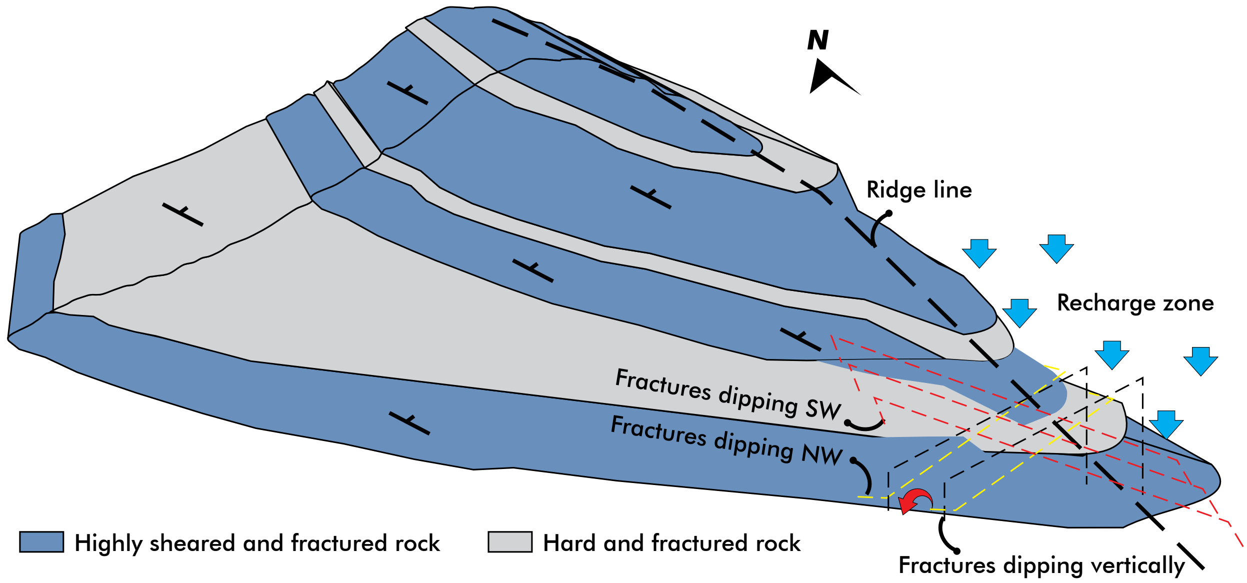


Figure 23: Hydrogeological conceptual layout and recharge zone demarcation for OC Jhora/Manjhi Dhara using conceptual layout.

Dhyangrey Simsaar Dhara

Dhyangrey Simsaar Dhara occurs in Zone 6 and clearly emerges as a depression spring. Zone 6 is an interbedded sequence of weathered schists and gneisses with multiple fractures and is exposed on the top further south and on both sides of the ridge along the trend of the bedding plane. The hydraulic continuity of this zone with the zones above is majorly through the fractures, which form the primary elements for recharge to this zone.

Zone 6 occurs as a very thin unit overlaid and underlain by compact and fractured gneisses. However, the recharge area of this spring is marked by fractures dipping NW along with E–W trending vertical fractures. The recharge zone for this spring extends further south where the ridge ends on the top. Due to the gentle dips of the litho units (Zone 7), the recharge area falls on both sides of the ridge. The fractures dipping NW and SW both tend to provide recharge to the spring and thus are taken into account while identifying and delineating the recharge area (Figures 24 and 25).

Recharge measures

The recharge area to Dhyangrey Simsaar overlaps with the recharge area of OC Jhora. Thus, the activities that will be implemented for OC Jhora will also benefit the spring to some extent. Additionally, some more physical interventions can be carried out on the eastern slopes based on land availability. Simsarey Dhara, which lies at a lower elevation, has shown decline in discharge as a late response to the 2015 earthquake. As the south-western slope is fragile, spring recharge measures must be limited to the vegetative. However, in case of better stability on the south-western slope, some minor physical recharge interventions can be planned to facilitate additional recharge.

Figure 24: Recharge zone overlaid on Google Earth for Dhyangrey Simsaar.

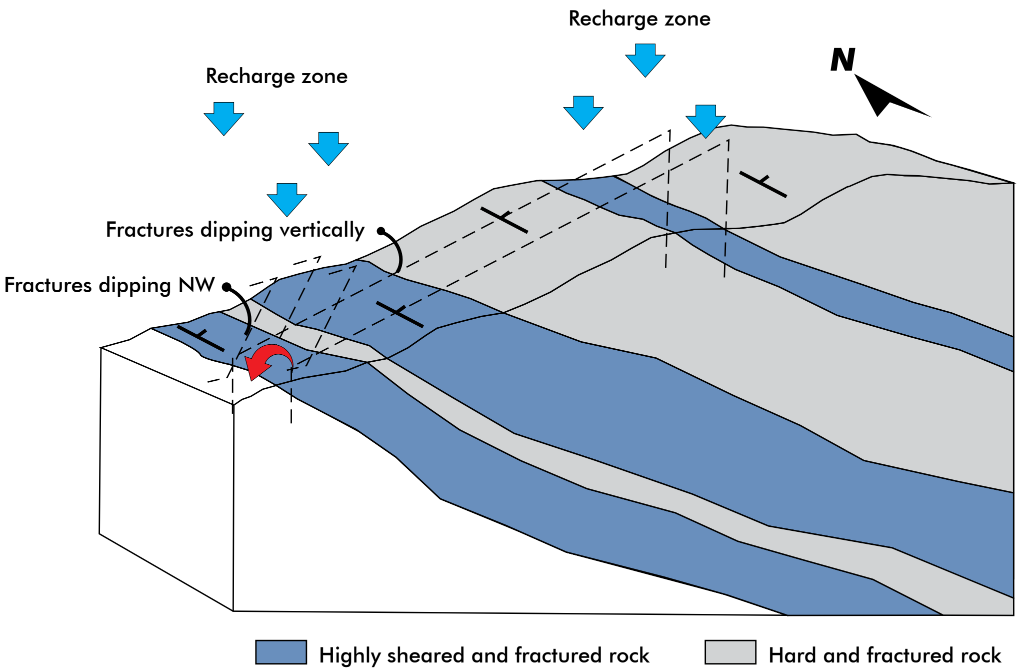


Figure 25: Hydrogeological conceptual layout and recharge zone demarcation for Dhyangrey Simsaar Dhara using conceptual layout.

Simsarey Dhara

Simsarey Dhara occurs in Zone 7 as a depression spring. Zone 7 is an interbedded sequence of weathered schists and gneisses with multiple fractures and is exposed on the top further south and on both sides of the ridge along the trend of the bedding plane. The hydraulic continuity for this zone with the zones above is majorly through the fractures, which form the primary elements for recharge to this zone. The discharge of the spring is reported to have declined due to construction activity above it, but the decline may have also resulted from a delayed response to the last earthquake.

Zone 7 occurs as a very thin unit overlaid and underlain by compact and fractured gneisses. However, the recharge area of this spring is marked by the fractures dipping NW along with E–W trending vertical fractures. The recharge zone for this spring extends further south where the ridge ends on the top. Due to the gentle dips of the litho units (Zone 7), the recharge area falls on both sides of the ridge. The fractures dipping NW and SW both tend to provide recharge to the spring and thus are taken into account while identifying and delineating the recharge area (Figures 26).

Recharge measures

The recharge area of Simsarey overlaps with the recharge area of Dhyangrey Simsaar, especially on the top. Thus, the activities that will be implemented for Dhyangrey Simsaar will also benefit the Simsarey Dhara to some extent. Additionally, some more physical interventions can be carried out on the eastern slopes based on land availability. The geomorphology, which features a huge weathered zone that forms a depression, supports recharge through the SW dipping fractures. Owing to the fragile nature of the slope, vegetative measures are recommended and the recharge areas should be marked as protected zones.

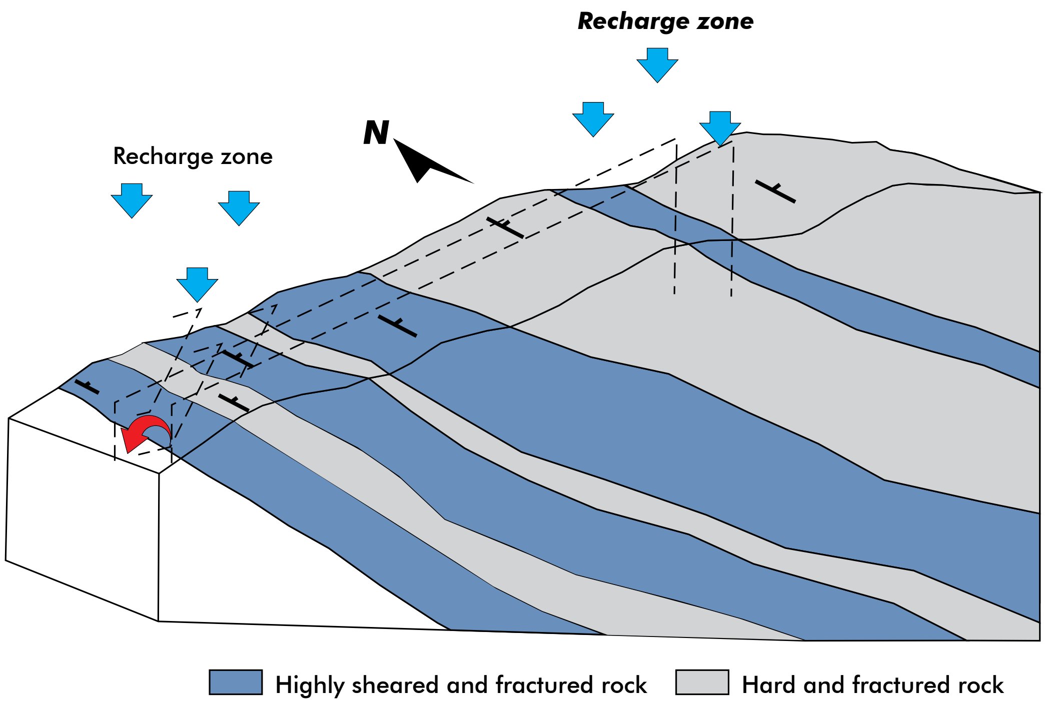


Figure 26: Hydrogeological conceptual layout and recharge zone demarcation for Simsarey Dhara using conceptual layout.

5. Conclusions and recommendations

Scientists argue that climate change has a profound impact on water resources and the management thereof, hence it is necessary to include climate change assessment and adaptation strategies for future water security (Meissner 2017). Problems of water governance have often been neglected by governments, the public, donors, and development agencies as being too intractable to deal with. In any country, however, a range of technical solutions for water problems could work if governance arrangements are good and could fail if they are poor (Bucknall 2006). Therefore, an ideal combination is a model that combines the strength of government-led models in terms of scalability and of NGO-led models in terms of monitoring and evaluating the impacts (Shrestha et al. 2018).

The above statements are also true of the study area, and it is evident that water availability and access are major issues in Kalimpong. This study also found that some critical springs are dying, so actions to recharge and conserve these springs are critical. But the most important issue here is related to the governance and management of water resources. The following are the key reasons for lack of water resource governance and management in the Chibo–Pashyor area.

- Lack of engagement of local administration (PHED and the municipality) in the construction, distribution, management, and monitoring of water resources
- Poor local-level awareness about various government schemes and programmes related to water supply and systems
- Outdated and defunct infrastructure for overall distribution and capturing of excess run-off
- Lack of properly designed schemes and projects involving community participation

The Kalimpong ridge is constituted of an interbedded sequence of gneiss and schist layers dipping between N and E. The eastern and western slopes are more or less oblique in nature, and therefore, along the soft beds, recharge extends on both sides of the ridge along with fractures traversing across the entire study area. The terrain is highly fragile, so placement of heavy recharge structures is not recommended. Soil binding vegetative measures are suggested to reduce the risk of landslides in the future.

The recharge zones of a few springs were found to be overlapping because of the interconnectivity of fractures. Recharge trenching is not recommended on the western slope due to its fragile nature, especially towards the northern part, which has been most affected by landslides.

The current fieldwork is limited to the hydrogeological assessment of the above discussed springs only. During the field studies, a borewell tapping into a shallow aquifer system was mapped, which people probably consider the right solution to fight the water crisis in the region. However, this practice is a matter of concern as such drilling practices in a fragile system like the Himalaya will lead to severe problems in the future. This paper recommends the rejuvenation of springs and does not support boring into deeper layers for resolving water-related issues as a solution in the Himalaya.

It should be noted that an analysis of data on the overall issue of climate change through downscaled climate models and long-term trends in precipitation, which are crucial for any springshed research, is lacking in this study. Due to resource constraints, the study narrowed its scope and focused only on the specific variables in order to interpret climate change and precipitation. Moreover, due to these constraints, another important parameter—the aspect of water quality and cross-contamination from the run-off—was not examined in the springshed.

The results of this study to conserve springs as a climate change adaptation action show that through a multi-stakeholder and integrated approach, communities, practitioners, researchers, and administrators can address the issue of sustainable use of water. The adaptation measures that are highly recommended include: the artificial recharge of critical springs; setting up of incentive-based mechanisms to ensure win-win situations; the conservation of catchments; changing agricultural practices to the cultivation of less water-demanding crop varieties; and water harvesting at community and household levels.

In the absence of groundwater rejuvenation/revival measures in the Chibo–Pashyor Watershed, the local springs could witness a sharp decline in discharge in the coming years, resulting in acute drinking water shortage and increased incidences of water-related conflicts in the villages. The biggest challenge for this area is that there are no potential water sources which can be tapped to augment water supply. The Kalimpong Municipality is supplied with water from the Neora forest area, which is 86 km away from the city, and this supply is insufficient to meet the current demand of 230,000 gallons per day. Hence, the issue of scarcity of water cannot be solved by tapping into any other resource in and around the Kalimpong region. Given this situation, the available 52 springs are the only sources of water for the communities living in the area. Therefore, careful and targeted conservation and climate change adaptation measures are critical for future water security.

Questionnaire survey being conducted in Chibo

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