# IDENTIFICATION AND STUDY OF IMPACTS OF DRYING SPRINGS IN DEVPRAYAG, UTTARAKHAND: A PERCEPTION ANALYSIS

***Major Project Thesis***

*Submitted by*

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*For the partial fulfillment of the*

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**CLIMATE SCIENCE AND POLICY**

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## DECLARATION

This is to certify that the work that forms the basis of this project IDENTIFICATION AND IMPACTS DUE TO DRYING OF SPRINGS IN DEVPRAYAG, UTTARAKHAND: A PERCEPTION ANALYSIS" is an original work carried out by me and has not been submitted anywhere else for the award of any degree.

I certify that all sources of information and data are fully acknowledged in the project thesis.

Trinayana Kaushik
TRINAYANA KAUSHIK

Date: 13 June 2017

**CERTIFICATE**

This is to certify that TRINAYANA KAUSHIK has carried out her major project in partial fulfillment of the requirement for the degree of Master of Science in CLIMATE SCIENCE AND POLICY on the topic "IDENTIFICATION AND STUDY OF IMPACTS DUE TO DRYING OF SPRINGS IN DEVPRAYAG, UTTARAKHAND: A PERCEPTION ANALYSIS" during January 2017 to May 2017. The project was carried out at the THE ENERGY AND RESOURCES INSTITUTE.

The thesis embodies the original work of the candidate to the best of our knowledge.

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# List of Abbreviations

1) GLOF: Glacial lake outburst floods
2) SANDRP: South Asia Network on Dams, Rivers and People
3) OGD: Open Government Data
4) UJS: Uttarakhand Jal Sansthan
5) GEC: Groundwater Estimation Committee
6) GoUK: Government of Uttarakhand
7) CHIRAG: Central Himalayan Rural Action Group
8) PSI: People's Science Institute
9) RWSS: Rural Water Supply and Sanitation
10) URWSSP: Uttarakhand Rural Water Supply and Sanitation Project
11) GoI: Government of India
12) UJN: Uttarakhand Peyjal Nigam
13) PMU: Project Management Unit
14) WATSAN: water-sanitation
15) RTI: Right to Information
16) UPA: United Progressive Alliance
17) NRDWP: National Rural Drinking Water Programme
18) LPCD: liters per capita per day
19) UDWDP: Uttarakhand Decentralized Watershed Development Project
20) WMD: Watershed Management Directorate
21) CGWB: Central Ground Water Board
22) ICIMOD: International Center for Integrated Mountain Development
23) Hi AWARE: Himalayan Adaptation Water and Resilience Research
24) CCM- crore cubic meters
25) CEDAR: Center for Ecology Development and Research
26) GPS- Global Positioning System
27) FGD- Focus Group Discussion
28) SHC- Stake Holder Consultation
29) TERI: The Energy and Resources Institute
30) ITSZ: Indus-Tsangpo suture zone
31) MCT: Main Central Thrust

32) MBT: Main Boundary Thrust

33) AWC: Available Water Capacity

34) BCM: billion cubic meter

35) LPS: liters per second

36) NIDM: National Institute of Disaster Management

37) LPHD: liters per household per day

38) MGNREGA: Mahatma Gandhi National Rural Employment Guarantee Act

39) LPD: liters per day

40) MW: megawatt

41) DVY: Dhara Vikas Yojana

42) RMDD: Department of Rural Management and Development

43) FSI: Forest Survey of India

44) mbgl: meters below ground level

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# 1.0 Abstract

My study is a part of ICIMOD's spring-shed research programme, which is a part of Hi-AWARE project. Rural population is most Himalayan region depends on mountain springs as their sole resource for daily water needs. But recent climate trends and various human interventions have led many of these springs to dry up. As a result many rural areas are facing acute water shortage. The chosen study area of Devprayag is one such tehsil where the people feel a severe water crunch every day. This brings me to my research question "What could be the driving forces and consequential impacts of drying springs in rural areas of Devprayag tehsil?"

The research was conducted with the help of primary data collected by CEDAR through field visit and secondary data collected from existing literature. An attempt to study the geology of the region was made to substantiate the existing scenario. Real life incidents were listed through informal interviews and various tools like FGDs and KIIs. Some critical springs of the region were also mapped so that their on-ground rejuvenation can be done by ICIMOD.

The geological study indicates, the presence of hard crystalline rocks in Tehri Garhwal making groundwater an already scarce resource. On the top of it, due to recent changes in rainfall patterns the infiltration contribution to groundwater recharge has further reduced. 45% of the chosen springs have been found to be in a critically endangered stage. Water crisis has been perpetual, in spite of numerous existing water supply schemes. Thus the study finds that, the recent changes in climate, insufficient implementation of water supply schemes coupled with low groundwater potential of the region could be reasons of the current situation of water scarcity.

*Key Words:* Geology, Spring-shed, Climate change, Groundwater, water-supply scheme

# 2.0 Introduction

2.1 Water availability and access of the Himalayan region

Himalayas are called the ‘third pole’ of the world and are experiencing climate change at an unprecedented rate. Various form of extreme events like flash floods, landslides, glacial lake outburst floods (GLOFs), are therefore frequently seen the Himalayan states of India. (SANDRP, 2013).

On one hand while most of the glaciers of South Asian Hindu Kush Himalayas are retreating, the consequences for the region’s water supply has not become very clear. In spite of having numerous perennial river systems some of the Himalayan region faces acute water shortage. Thus it was concluded that glacial retreat has no explicit impact on water availability of the region, however other factors like rainfall patterns, groundwater depletion, increasing number of urban settlements and growing water demands are the cause of the water insecure status.

One of the most visible outcomes of climate change has been changing rainfall patterns. In has been very prominent in the hill states of Indian Himalayan region. As established by SANDRP (South Asia Network on Dams, Rivers and People) there is an increase in intensity of rainfall and decrease in the frequency of rainfall. Data collected from 2000 to 2006 at AWS Gangtok also suggests a similar observation (Seetharaman 2008; Ravindranath et al. 2006). There has been shifts in location, intensity, duration and frequency in rainfall and it is highly likely to impact regional water supplies mostly in the mid hill region of Himalayas. (Prakash A., Shresth A. B., 2016)

2.2 Water availability and access of Uttarakhand

In Uttarakhand too, this trend has been increasingly felt. (SAPCC, 2014, Govt. of UK) As per data obtained from Open Government Data (OGD) Platform, India, the seasonal area weighted rainfall of Uttarakhand shows that maximum rainfall is obtained during the monsoon months of June to September while most of the other months have a huge number of ‘no rain’ days.

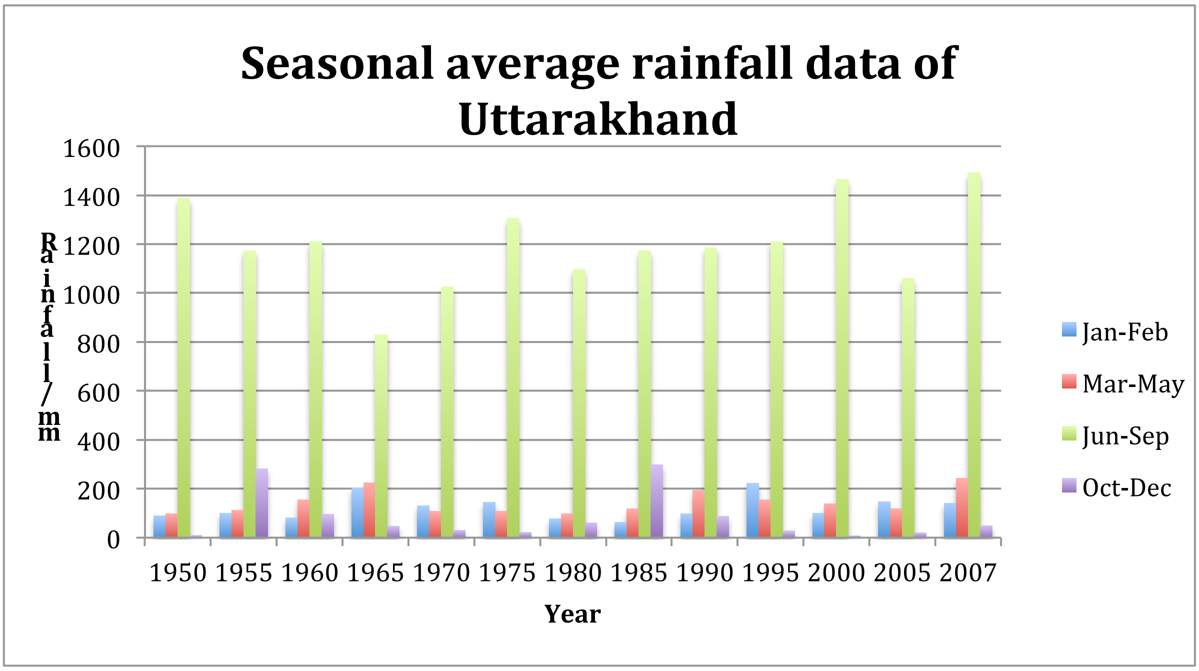



**Figure 1: Seasonal average rainfall of Uttrakhand from 1950-2007**

**Source: OGD Platform**

Uttarakhand houses many of the Himalayan rivers and they contribute to a significant percentage of the country's water resource. However, it is ironical that the rural residents of the state hardly use any river water for their daily chores. Except for minor utilities in the form of a watermill or occasional irrigation, not more than 2% of total water potential of these rivers is used. (Bhatt V., Pandey P., 2005)

It has been estimated that springs support more than one million people in the entire Himalayan region and they serve as a safe and perennial source of water. They are very common in the Himalayan region. (ICIMOD's spring's initiative, 2015)

Uttarakhand Jal Santhan (UJS) has also identified mountain springs as a major source of both drinking water and water required for domestic chores in rural Uttarakhand. Springs are ground water resource, which come out to the surface in the form of seepage when groundwater finds an opening to the surface. These have been tapped at many places, while many of these are free flowing and residents directly collect water from them. In Uttarakhand, over 90% of drinking water systems are spring based. But over the past years this vital resource has seen a declining discharge due to environmental degradation, changing land use patterns and changing climate. As groundwater quantity and quality is decreasing, springs are ought to be impacted. The state of Uttarakhand has a high average annual rainfall of 1229 mm. (NIDM). But from *Figure 1*, we can see that maximum rainfall is received only during the monsoon season while the other months receive negligible amount of rainfall. Also, according to the Groundwater Estimation Committee (GEC-97) norms, the areas having more than 20% slope are not considered suitable for ground water recharge. It is also to be mentioned that Uttarakhand has a very wide altitudinal range from the plains of Dehradun to Nanda Devi (7,817 meters), which is the second highest mountain range in India. Consequently a lion's share of the water received during the monsoon months is lost as run off. Thus groundwater recharge from rainfall is much less than existing potential. (CGWB, GoI, 2014)

Various think tanks like (Central Himalayan Rural Action Group) CHIRAG, (People's Science Institute) PSI, Himotthan Society and other NGOs have successfully implemented spring-shed protection programmes in collaboration with Government of Uttarakhand (GoUK). However, the results achieved have huge scopes of improvement. (ICIMOD's spring's initiative, 2015)

The purpose of this study is to throw light on the existing status of water availability on the rural areas of the state. Firstly, the report puts forward the details of existing water supply schemes of the rural areas in Uttarakhand. This highlights the plight of most of the people who are not covered under a scheme. The purpose is to bring out the significance of such a study. The first objective is a spring specific inventory based on local indicators of springs' criticality as decided by ICIMOD. The purpose of this objective is to identify critical springs that need rejuvenation immediately. This is part of ICIMOD's spring-shed research, which includes the following steps:

STEP 1: Comprehensive mapping of springs and spring-shed

STEP 2: Data monitoring for identification of critical springs.

STEP 3: Understanding social and governance aspects of springs

STEP 4: Hydrogeological mapping

As groundwater is substantially connected with the rocks it occurs in, a delve into the geology of the state can help us understand what could be the reasons of increasing situation of water crisis in a water abundant state. Thus a broad study of existing geology is taken up to establish the water availability scenario of the region. The last objective is to understand the impacts on people due to drying up of springs. This objective is fulfilled based on data collected from field along with existing secondary literature of a few selected villages of Devprayag.

# 3.0 Literature Review

Uttarakhand (28°43'N-31°28'N, 77°34'E-81°03'E) (Forest Survey of India, 2009) became the 27$^{th}$ state of India when it was carved out of northern Uttar Pradesh in 2000. It is mostly a hill state with a total geographical area of 53,483 square kilometers. (FSI, 2009) Uttarakhand is very rich in natural resources mainly forest and water. (Govt. of UK) Uttarakhand has numerous big and small rivers flowing all across the state, which plays a significant role in the state's economic, social, cultural and environmental well being. The state has a total forest cover of 34,651 square kilometers, which makes 64.79% of total area. (FSI, 2009) In spite of the abundance of these premium resources, the state suffers from some serious environmental concerns. One such issue is scarcity of water among the rural population of the state. 75% of the population of the state lives in the 16,623 villages spread across 39,967 habitations (Census, 2011). River water is highly under utilized among the people of these remotely located habitations. It has been already established by various organizations that a major portion of water supply to the people of Uttarakhand is supported by mountain springs. Historically, they were used in rural and urban areas, for irrigation, drinking, livestock and religious purposes. But, increasing changes in rainfall and land use have converted these perennial sources to seasonal, leaving communities struggle to meet their demands. Aggravating the problem is the water quality of the springs, which is deteriorating due to changing land use and improper sanitation.

## 3.1 Current status of water accessibility in rural Uttarakhand

Ever since the problem of water scarcity has been felt in the state, the central government has designed many state agencies in top-down manner to focus on building infrastructure for the same. Rural Water Supply and Sanitation (RWSS) project launched by Ministry of Drinking water and Sanitation, Government of India (GoI); in the 1990s was activated in the state and Uttarakhand Rural Water Supply and Sanitation Project (URWSSP) was launched in 2006. A major policy change under URWSSP was when Uttarakhand became the first Indian state to decentralize its drinking water supply to increase the role of

Panchayati Raj and local communities in procuring its own water. The sponsors of this programme were GoUK, GoI and World Bank. (World Bank, 2016) The key government agencies appointed for water supply in Uttarakhand are Uttarakhand Jal Sansthan (UJS) and Uttarakhand Peyjal Nigam(UJN). They are responsible for planning, survey, design and execution of urban as well as rural water supply and sewage schemes in the state. (UJS, GoUK, 2016).

The original WATSAN (water-sanitation) programme was running with a build-forget-rebuild syndrome. According to a report from the World Bank, named 'Uttarakhand - Decentralizes Rural Water Supply and Sanitation Project : innovations in development', the central government claimed that 96% of the areas have been covered with a tap or a well under various water supply schemes likes SWAJAL, NRDWP etc., within a reasonable distance from the households. However the truth is that most of them are not functional. The reasons attributed for this are negligence in maintenance of infrastructure and tapped sources, drying up of water sources itself, deterioration of water quality, and in some cases the systems have long outlived their design and use. The consumers have also treated water as a right to be provided free-of-cost by the government, rendering their water supply schemes both financially and environmentally unsustainable. (World Bank, 2013)

3.2 Some major water supply schemes by GoI and GoUK are described below:

**1) Uttarakhand Rural Water Supply and Sanitation Project (URWSSP)**
With the launch of URWSSP (2006-2015), the Project Management Unit (PMU), Swajal along with UJS and UJN undertook various community-based initiatives in all the districts of the state. The project development objective of URWSSP was to improve effectiveness of rural water supply and sanitation facilities by increased role of Panchayati Raj. (Sinha V. K., 2015)

In keeping with the $73^{rd}$ constitutional amendment, the decentralized approach became a law in both letter and spirit in Uttarakhand. Decision-making was also decentralized in all stages i.e. planning, procurement, construction and management. Communities inspected the progress of the schemes at all stages and grievances were discussed in public meetings. The funds and functions were being transferred to the Gram Panchayat and locals could choose the kind of water supply service they wanted and were willing to pay for. (Dobhal A. (n.d.) [ppt]) This was a very important step, considering the inefficiency of the prevailing WATSAN system. It was increasingly felt that pricing of water was necessary to ensure economic and financial viability and sustenance of the water supply schemes. However, in case of rural households it was more important to consider this approach in a holistic manner and keep the household's affordability and willingness to pay, to be reflected to develop a more acceptable pricing structure for all. Thus with such an implementation, the role of the government changed from a water supplier to water facilitator. UJS and UJN, which were also working with SWAJAL, decreased the burden on a single agency and provided back support during a natural calamity. (World Bank, 2013)

Maintaining sustainability of the water sources was made an integral part of the URWSSP along with building infrastructure. This was a unique and smart measure under URWSSP because real success of any project is measured by its long-term sustenance. Trees were planted in the upper catchment areas and check dams, recharge pits, and contour trenches were constructed to ensure the continued discharge of streams and springs, from which the water was tapped. Out of these tapped springs, 80-90% of the supply systems were gravity based which gave households access to water without any use of power.

GoI defines *'coverage'* as *'access to water'* defined as '*40 liters per capita per day within a distance of 1.6 kilometers from the center of the village and 100 meters height.* Through SWAJAL which ended in 2015, a total of 8,105 habitations were covered benefitting more than 7,50,000 rural residents. Decentralization to local communities eliminated all those layers of bureaucracy that usually exists in government projects and reduced the leakage of funds. The State Information Commission, Uttarakhand has twice honored the project with the RTI Award for transparency and good governance practices. (Sinha V. K., 2015)

However out a total of 39,000+ rural habitations, URWSSP could cover only 25% of it. The original target for habitation coverage for URWSSP was 17,741, which was later revised to 8,270. Out of the target of 8,270 habitations, 8,105 habitations were finally achieved at the end of the project in 2015. *Figure 2* shows the habitation coverage achievement of URWSSP (SWAJAL) by different implementing agencies.

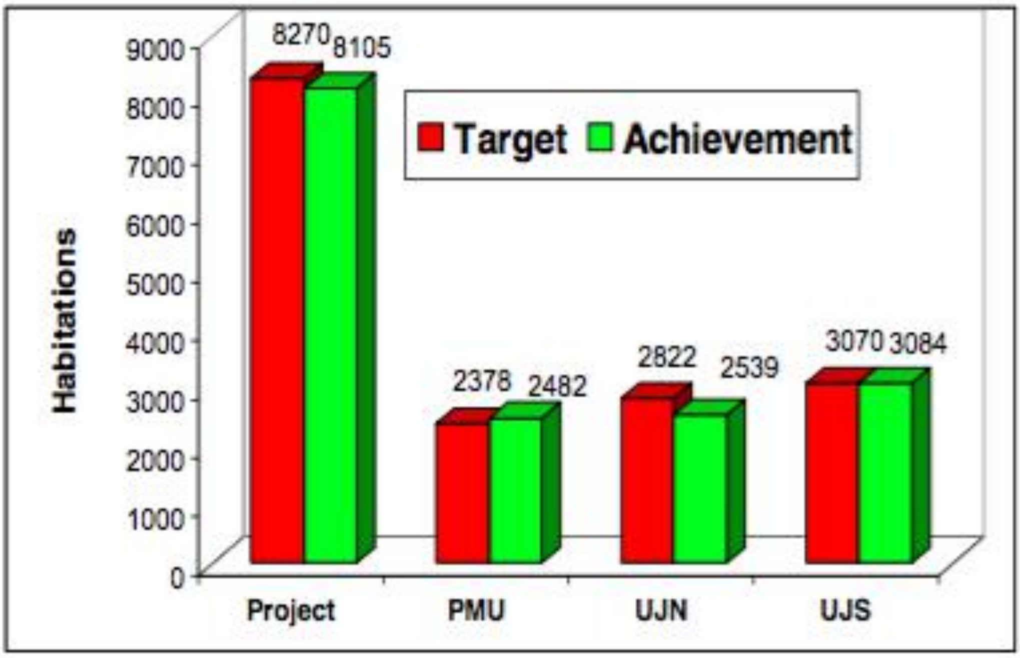



**Figure 2: Agency-wise habitation coverage of SWAJAL**

**Source: Sinha V. K., 2015**

Thus we can also say that the existing RWSS service delivery in Uttarakhand does not adequately serve the requirements of all the user communities.

SWAJAL project appraisal document suggests that there has been 30% drop out rate of habitation from project design to project implementation phase. Most habitations were dropped out due to non-availability of water source and various community disputes in the habitations. (Sinha V. K., 2015) The schemes that were implemented were also put at sites without consideration of community needs or preference, due to which many households couldn't access water source point of these schemes. Planning at various RWSS service sites took place without due attention to resource availability or quality, and the schemes were sometimes financially non-viable. (SWAJAL, GoUK)

**2) Other schemes by UJS**

Along with URWSSP, UJS and UJN has set up various water supply schemes in different parts of the district based on feasibility and funds. A programme of 221 water supply schemes by UJS has covered the districts of Dehradun, Pauri, Tehri, Rudraprayag, Chamoli, Almora, Bageshwar and Pithoragarh. However the primary loophole in implementation of all these schemes was that the coverage was not uniform all over the districts and some of the districts were not even supplied with a single water supply scheme. (GoUK)

For example, the water supply schemes of UJS and UJN in Tehri Garhwal district is all concentrated towards the north-west of the district. Devprayag tehsil which is located towards the south-east of the district is not supplied with a single scheme source under this programme. *Figure 3* shows map of supply scheme sources of UJS.

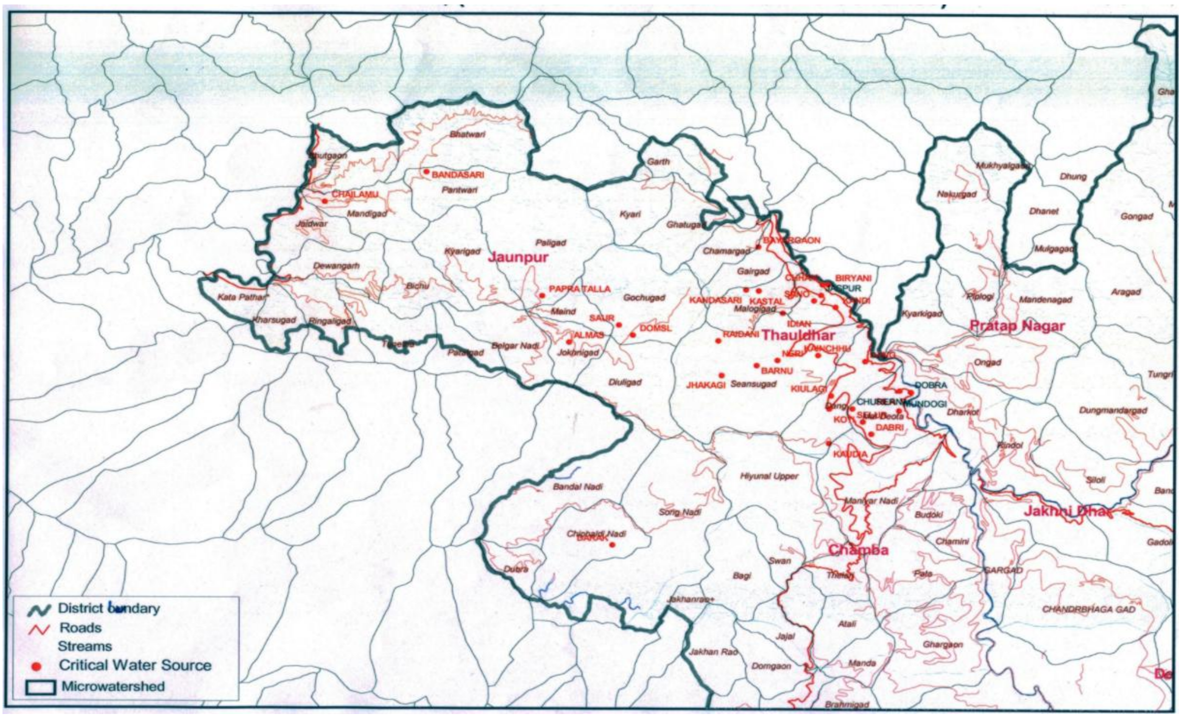



**Figure 3: Water supply schemes in Tehri Garhwal district by UJS**
**Source: UJS website**

**3) National Rural Drinking Water Programme (NRDWP)**
Another measure for drinking water supply that was taken up country-wide during the time of United Progressive Alliance (UPA) Government was National Rural Drinking Water Programme (NRDWP). The aim of NRDWP was to supply to all rural households. NRDWP schemes have coverage of 61.81% in the state of Uttarakhand.

*Table 1* gives the details of NRDWP contribution to drinking water supply in Uttarakhand as per 40 LPCD (liters per capita per day)

**Table 1: District-wise NRDWP coverage in Uttarakhand as per 40 LPCD**

| | Total Habitations | Habitations with population coverage | | | |
|---|---|---|---|---|---|
| | | 0-<25% | >25-<75% | >75-<100% | 100% |
| **Uttarakhand** | **39,209** | **1,984** | **9,668** | **6,204** | **21,345** |
| Almora | 5,151 | 91 | 1,192 | 570 | 3,298 |
| Bageshwar | 2,789 | 98 | 373 | 61 | 2,257 |
| Chamoli | 3,198 | 288 | 941 | 410 | 1,559 |
| Champawat | 2,237 | 4 | 356 | 274 | 1,603 |
| Dehradun | 2,735 | 1 | 546 | 1,082 | 1,106 |
| Pauri Garhwal | 4,734 | 827 | 1,422 | 1,078 | 1,407 |
| Hardwar | 615 | 4 | 76 | 233 | 284 |
| Nainital | 2,702 | 0 | 120 | 256 | 2,326 |
| Pithoragarh | 4,726 | 85 | 467 | 608 | 3,566 |
| Rudraprayag | 1,675 | 0 | 220 | 682 | 773 |
| Tehri Garhwal | 5,665 | 575 | 3,540 | 669 | 881 |
| Udham Singh Nagar | 1,046 | 0 | 7 | 57 | 982 |
| Uttarkashi | 1,936 | 1 | 408 | 224 | 1,303 |

**Source: NRDWP Reports**

*Table 2* gives the details of NRDWP contribution to drinking water supply in Uttarakhand as per 55 LPCD (liters per capita per day)

**Table 2: District-wise NRDWP coverage in Uttarakhand as per 55 LPCD**

| | **Total Habitations** | **Habitation with population coverage** | | | |
|---|---|---|---|---|---|
| | | **0-<25%** | **>25-<75%** | **>75-<100%** | **100%** |
| **Uttarakhand** | **39,209** | **3096** | **22,266** | **8,063** | **5,766** |
| Almora | 5,151 | 133 | 1951 | 2,845 | 222 |
| Bageshwar | 2,789 | 123 | 820 | 1,689 | 157 |
| Chamoli | 3,198 | 317 | 2,775 | 103 | 3 |
| Champawat | 2,237 | 13 | 2,094 | 122 | 8 |
| Dehradun | 2,735 | 3 | 1,873 | 324 | 535 |
| Pauri Garhwal | 4,734 | 991 | 2,945 | 627 | 171 |
| Hardwar | 615 | 14 | 329 | 218 | 36 |
| Nainital | 2,702 | 0 | 571 | 576 | 1,555 |
| Pithoragarh | 4,726 | 123 | 3,131 | 861 | 611 |
| Rudraprayag | 1,675 | 7 | 1,190 | 310 | 168 |
| Tehri Garhwal | 5,665 | 1,161 | 3,952 | 365 | 42 |
| Udham Singh Nagar | 1,046 | 0 | 0 | 14 | 968 |
| Uttarkashi | 1,936 | 211 | 426 | 9 | 1,290 |

**Source: NRDWP Reports**

From the tables above we can see that while most of the habitations are covered with NRDWP schemes, very few habitations are covered such that 100% of its population has access to water supply. For example, while all districts are covered with water supply schemes, in Tehri Garhwal, only 881 and 42 habitations out of 5,665 habitations are covered such that all its population has water access as per 40 and 55 LPCD scheme, i.e.

only 15.5% and a mere 0.74% of habitations are totally covered under each water supply scheme respectively.

Another problem along with access is the declining discharge in available sources. In spite of this ever-increasing problem, the effort taken for sustainable maintenance in much less than what has been invested in building infrastructure in the state. The status of ground water development in the state in 66.33% however the stage of development of recharges structures is very poor. *Table 3* shows the number of recharge structures available under NRDWP in Uttarakhand.

**Table 3: Number of recharge structures under NRDWP in Uttarakhand**

| Recharge structure type | Quantity |
|---|---|
| Pits and trenches | 60 |
| Check dams | 163 |
| Percolation tanks | 45 |
| Point source recharging | 0 |
| Dug/Injection/Skimming wells | 7 |
| Village Ponds | 48 |
| Roof top | 413 |
| Recharge shaft | 0 |
| Others (Infiltration rings/Sub-surface dykes) | 53 |

**Source: NRDWP Reports**

**4) Uttarakhand Decentralized Watershed Development Project (UDWDP)**

Along with individual water supply schemes, GoUK also felt the need to take up watershed based planning. The Himalayan watersheds of Uttarakhand are under constant threat of mass wasting, hydrological imbalances and erosion due to various causes. With the support of World Bank, GoUK had launched the Uttarakhand Decentralized Watershed

Development Project (UDWDP) in 2014. Though the direct aim of the project is not water supply, the project aims on holistic improvement of people settled in a watershed. UDWDP has identified water as the most climacteric input, which is of utmost importance for maintenance of ecology, biodiversity and livelihoods in a watershed. The government has identified a total of about 8 watersheds, 116 sub-watersheds and 1110 micro-watersheds for regeneration and sustainable development work. A separate directorate-Watershed Management Directorate (WMD) was set up for coordination, monitoring and implementation of the project.

As mountain springs serve as the major source of water, keeping a check on groundwater level is of utmost importance to ensure the viability of any type of scheme established in the state. As on January 2015, a total of 207 groundwater-monitoring stations were present to monitor water level in wells and discharge in springs four times in a year. However *Figure 4* shows that these wells do not cover all the districts in the state. In fact most of the wells only cover the Outer Himalayan region where groundwater is relatively abundant and recharge is possible, compared to the Lesser and Greater Himalayan region of mid hills and high hills. (CGWB)


**Figure 4: Groundwater monitoring stations established by CGWB in Uttarakhand**

**Source: CGWB Brochure, GoUK**

In spite of continuous efforts and numerous schemes, most of rural households are still trying very hard to make both ends meet in term of water supply. The motto of most of these schemes has been ‘reaching the unreached’ which has failed tremendously due to the inhospitable terrain of the region and most importantly the dispersed rural communities.

# 4.0 Objectives

1. Inventorization of springs of Devprayag tehsil to identify the most critical springs based on local indicators as decided by ICIMOD.
2. To understand the broad geology of the region, which plays a role in availability and accessibility of the spring water in the region?
3. To understand the impacts on people due to drying up of springs based on perception analysis.

# 5.0 Methodology

## 5.1 Inventorisation of springs of Devprayag to identify the most critical springs based on local indicators as decided by ICIMOD.

### 5.1.1 Study Area: Devprayag

Devprayag (30.1459° N, 78.5993° E) is a tehsil in the Tehri Garhwal district of Uttarakhand. It comprises of about 353 villages with a population of 2,868 (Census, 2011). Devprayag falls in the region of lower-Bhagirathi basin. It is a mountainous zone depicting high ridges, valleys and slope tracts. Devprayag is the last prayag of Garhwal’s panch-prayag (heavenly confluences) and marks the confluence of Ganga’s largest tributary Bhagirathi and Alaknanda rivers to finally form the Ganges. Therefore, it is an irony that many of the villages of this tehsil face severe water crunch every day.

Both Bhagirathi and Alaknanda rivers are blessed with a bounty of water resources. Unfortunately this vast potential is not rationally exploited. Although the area in endowed with huge water potential, it witnesses worst water resources problems rendering untold sufferings to millions of rural locals everyday. Both the rivers have high annual drainage of 253.3 and 534.2 crore cubic meters (CCM) (Survey of India toposheets). But still Devprayag, which is an area of unlimited water resource availability faces water shortage of drinking and irrigation facilities due lack of accessibility. A plausible solution to this could be construction of numerous micro hydro- power projects to serve as water reservoir during the dry season. Devprayag is one of the ten tehsils of Tehri Garhwal district, which has Asia's tallest dam- the Tehri Dam, and numerous other mega dams, but the number of micro hydro projects in the district is negligible. (Sati V., P., [n.d.]). Also it is to be mentioned that the chief occupation of the people in rural Devprayag is agriculture. Water being inaccessible, most people depend on rain-fed agriculture. With increasing water scarcity, the livelihood of the people has come under threat.

This study is to identify the water availability scenario of Devprayag tehsil, mainly focusing on the springs of few chosen villages. A literature-based study of the geology in and around the place might help us to draw parallels on the groundwater status of the area. This is important because springs are groundwater resource and people's dependence on them is ever increasing as quality and accessibility of surface water is decreasing rapidly due to various human interventions and climate change.

### 5.1.2 Materials and Methodology of the study

Field visit to Devprayag and primary data collected by Centre for Development Ecology and Research (CEDAR) is used to fulfill this objective.

**5.1.2.1** A small catchment of Devprayag tehsil in Tehri Garhwal district is chosen. This step is selection of the spring-shed from which few springs are to be mapped.

**5.1.2.2** 11 springs are mapped according to STEP 1 of ICIMOD's spring shed research. A Global Positioning System (GPS) device is used to obtain the location of each spring

**5.1.2.3** The selection of the springs is done based on a systematic assessment including intensive discussions and interviews of local residents. Tools like Focus Group

Discussions (FGDs) and Stake Holder Consultations (SHCs) are used to gather information about the selected springs.

**1) FGD:** A Focus Group Discussion is a group discussion where participants are the various stakeholders of the issue in hand. While conducting a FGD it has to be made sure that the participants represent the entire population that is affected by the issue.

**2) SHC:** Stake Holder Consultation is like a two way process of dialogue between the project organizers and its stakeholders. It helps to bring out minute details and multi-dimensionality of an issue, which might be missed in a FGD.

**5.1.2.4** Simple Random Sampling technique is used. A random representative sample is selected from each village to conduct the survey-study. The selection was based upon a simple logic that, the first respondent shall be either the head (*sarpanch/ pradhan* etc.) or the eldest of the village and she/he will invite and engage more participants in the discussion; keeping in mind that most preferred were the people who are impacted by water crisis directly. Also, the people who were involved in the maintenance, collection and distribution of water in the area were invited.

**5.1.2.5** According to STEP 2, the springs are ranked in terms of their importance for users based on the responses collected from them. The terminology that forms the basis of ranking these springs - is known as the Hardship Ranking System.

**5.1.2.6** A certain percentage of the selected springs are categorized as ‘needing immediate attention’, based on results obtained from Hardship Ranking System.

## 5.2 To understand the broad geology of the region that plays a role in availability and access of the spring water in the region.

This objective is divided into following sections and is accomplished using existing secondary literature. The purpose is establishing the groundwater scenario of the region, including its access and availability, which could help us draw parallels on the current status of spring water of the region.

**5.2.1** Evolution of geology of Himalayas is described from the beginning of time.

**5.2.2** A brief description of different Himalayan regions is given, which make up different geological zones on Uttarakhand.

**5.2.3** A correlation of type of rock availability and corresponding groundwater scenario is tried and established mainly for Tehri Garhwal district. The aquifer character of the district is also studied to establish whether groundwater can be a reliable source of water for the local rural inhabitants of the area.

**5.2.4** Very brief discussion of other related concepts like tectonic activity, earthquake effects on groundwater is done

## 5.3 To understand the impacts on people due to drying up of springs based on perception analysis.

The methodology used for my third objective is mainly field data collected by CEDAR, along with information obtained from secondary literature. The data is qualitative in nature and is thus put in the report as it is.

**5.3.1** CEDAR had conducted a series of interviews with local people of a few villages in Devprayag.

Secondary literature in terms of research papers, news articles, blogs are also referred to, for obtaining information about impacts on people due to water inaccessibility in Devprayag mainly with the context of springs.

- Long-term studies of small catchments are important to identify changing situations with respect to spring discharge of the catchments. One such study conducted in the Danda watershed; locally known as Khas Patti, which is located in the Hindolakhal block of Devprayag tehsil; is referred.
- Study area**:** Danda watershed has an area of around 1.34 square kilometers and is located between latitude 30° 14' N to 30° 16' N and longitude 78° 37' E to 78° 39' E at an altitude of 780 m to 1800 m above mean sea level with average annual rainfall of around of 900 mm. The study is done by collection of data over a period of 11 years using 9 automatic rain gauges and 2-river gauging site.
- Spring flow measurements were carried out daily, and almost all springs were covered using the help of local inhabitants.
- A relationship between precipitation and spring discharge was tried and established.
- Impact on residents due to the existing situation was evaluated. (Agarwal A., Bhatnagar, N. K., Nema R. K., Agarwal N. K., 2012)

**5.3.2** A key informant contact of The Energy and Resources Institute (TERI), Mr. Amar Singh Gosain (Phone number- +919634410245 ) who is a local resident of Kim Khola village gave me some information of the real life situation of the rural people. The set of questions asked to our key informant in Devprayag is given in *Section 1 in Annexure.*

# 6.0 Results

## 6.1. Inventorisation of springs of Devprayag to identify the most critical springs based on local indicators as decided by ICIMOD.

ICIMOD under its spring-shed management programme, 2016 has designed six indicators to assess the criticality of springs based on perception on local people (primary stakeholders) that use these springs daily. These indicators are:

**i)** Dependency/ Number of user households.
**ii)** Reduction in discharge over a period of ten years.
**iii)**Quality of water (Drinkable without treatment/ Drinkable without treatment/ Not drinkable)
**iv)** Proximity of other sources.
**v)** Water availability (in terms of quantity)
**vi)** Number of months water is sufficient/ Seasonality of springs.

**6.1.1** A small catchment of Devprayag tehsil in Tehri Garhwal district is chosen. This step is selection of the spring-shed from which springs are to be mapped.


**Figure 5: Google Earth image of the selected catchment in Devprayag tehsil**

The water of the springs of this spring shed is utilized by a number of villages. Some of them are Aamni, Jagthi, Kandi, Kim Khola, Mahar, Pyunkhari. The rural settlements in these villages in and around the spring-shed are without any irrigation infrastructure and the main livelihood – agriculture, is totally dependent on rains. Climate change has a major impact in this region as water scarcity being the root of many issues has aggravated due to changes in the precipitation patterns and solstice trends. The demography of these villages is given in *Section 2* in *Annexure.*

**6.1.2** Eleven springs are mapped according to the STEP 1 of the procedure. A GPS device is used to obtain the location of each spring.

The mapped springs are then categorized according to its type and seasonality. *Table 4* gives the database of the mapped springs. The *number on the table* can be matched with *Figure 6* to identify the location of each spring in the catchment.

**Table 4: Database of mapped springs**

| Spring Code | Number on map | Village | Latitude | Longitude | Elevation (meters) | Type (dhara, kuwa) | Nature (Perennial, Seasonal) |
|---|---|---|---|---|---|---|---|
| DPYSP1 | 73 | Pyunkhari | 30°11'46.28" N | 78°36'23.97" E | 1293 | Kuwa (Well) | Perennial |
| DPYSP2 | 98 | Pyunkhari | 30°11'49.32" N | 78°36'27.52" E | 1247 | Kuwa (Well) | Perennial |
| DKKSP1 | 77 | Kim Khola | 30°11'23.78" N | 78°36'21.72" E | 1285 | Kuwa (Well) | Perennial |
| DKKSP2 | 78 | Kim Khola | 30°11'27.89" N | 78°36'30.25" E | 1227 | Dhara | Perennial |
| DKKSP3 | 79 | Kim Khola | 30°11'24.50" N | 78°36'35.83" E | 1174 | Kuwa (Well) | Perennial |
| DKKSP4 | 81 | Kim Khola | 30°11'19.99" N | 78°36'31.96" E | 1157 | Kuwa (Well) | Perennial |
| DMRSP1 | 86 | Mahar | 30°10'56.79" N | 78°36'40.19" E | 851 | Kuwa (Well) | Perennial |
| DMRSP2 | 88 | Mahar | 30°11'0.24"N | 78°36'34.57" E | 939 | Kuwa (Well) | Seasonal |
| DMRSP3 | 89 | Mahar | 30°11'18.16" N | 78°36'50.54" E | 949 | Dhara | Perennial |
| DJGSP1 | 91 | Jagthi | 30°11'18.45" N | 78°36'47.54" E | 964 | Dhara | Perennial |
| DKDSP1 | 99 | Kandi | 30°11'56.21" N | 78°36'38.23" E | 1143 | Dhara | Seasonal |


**Figure 6: Google Earth image showing the location of mapped springs**

The mapped springs are further investigated for their discharge level and perception of people, social disputes, and governance institutions associated with them. *Table 5* gives the social database of the mapped springs. The springs are sparsely located in the area and the land belongs to different *Gram Panchayats* (A *Gram Panchayat* includes a single big village or two-or-more smaller hamlets).

**Table 5: Social database of the mapped springs**

| **Spring Code** | **Discharge (LPM)** | **Dependency (High, Medium, Low)** | **Purpose of Use** | **Water Conflicts** | **Perception on water discharge over past 10 years (Decrease/Increase/Same)** | **Informal body managing the springs** |
|---|---|---|---|---|---|---|
| **DPYSP1** | 30 | High | Drinking (Domestic) | Yes | Decrease | Gram Panchayat |
| **DPYSP2** | 10 | Low | Drinking (Domestic) | No | Decrease | Gram Panchayat |

| | | | | | | |
|---|---|---|---|---|---|---|
| **DKKSP1** | 25 | Low | Drinking (Domest ic) | No | Decrease | Gram Panchayat |
| **DKKSP2** | 4 | High | Drinking (Domest ic) | Yes | Decrease | Gram Panchayat |
| **DKKSP3** | 12 | High | Drinking (Domest ic) | Yes | Decrease | Gram Panchayat |
| **DKKSP4** | 15 | Low | Drinking (Domest ic) | No | Decrease | Gram Panchayat |
| **DMRSP1** | 9 | High | Drinking (Domest ic) | Yes | Decrease | Gram Panchayat |
| **DMRSP2** | 5 | Low | Drinking (Domest ic) | No | Decrease | Gram Panchayat |
| **DMRSP3** | 7 | High | Drinking (Domest ic) | Yes | Decrease | Gram Panchayat |
| **DJGSP1** | 25 | High | Drinking (Domest ic) | Yes | Decrease | Gram Panchayat |
| **DKDSP1** | 2 | Low | Drinking (Domest ic) | No | Decrease | Gram Panchayat |

As already mentioned in the methodology the springs are chosen based on various hydrological, environmental and social issues relevant to the population that utilize the spring water. *Tables 4* and *5*, give the details of all natural and social factors that make this choice relevant.

**6.1.3** Simple Random and Snowball Sampling technique is used for selecting the participants in the FGDs and SHCs.

*Table 6* gives the details of FGDs and SHCs performed

**Table 6: Details of village-wise FGDs and SHCs performed for the mapped springs**

| Gram Panchayat | Households | Total Population | FGDs | No. of Participants | SHCs | No. of Participants |
|---|---|---|---|---|---|---|
| 1. Aamni | 66 | 227 | 1 | 19 | 1 | 5 |
| 2. Jagthi | 43 | 161 | 1 | 15 | 1 | 2 |
| 3. Kandi | 84 | 441 | 2 | 26 | 1 | 3 |
| 4. Kim Khola | 95 | 413 | 2 | 27 | 1 | 7 |
| 5. Mahar | 182 | 740 | 2 | 24 | 1 | 3 |
| 6. Pyunkhri | 36 | 162 | 1 | 12 | 1 | 2 |
| **Total** | **506** | **2144** | **9** | **123** | **6** | **22** |

A total of 123 and 22 individuals participated in the FGDs and SHCs respectively. Individuals from different localities, gender, and occupation were incorporated to obtained a representative sample of the total population.

Pre-determined indicators were used to conduct the survey-study with the representative sample. *Table 7* gives the details of these indicators.

**Table 7: Indicators for identifying the criticality of springs.**

*(The criteria under each indicator are decided on the basis of consultations with peer groups and organizations like ACWADAM and Himmothhan Society.)*

| Indicator | Needs no attention | Needs moderate attention | Needs immediate attention |
|---|---|---|---|
| Number of user Households | Less than 5 | 5 to 10 | More than 10 |
| Discharge reduced by half in last 10 years | Less than half | Almost half | More than half |
| Quality of water – drinkable, without treating | Without treating | With treating | Not drinkable |
| Proximity of the other source (meters) | Up to 100 m | 100 to 200 m | Above 200 m |
| Water availability- liters per household per day (LPHD) | Above 40 lit | 20 to 40 lit | Up to 20 lit |
| No. of months water is sufficient | Above 6 | 4 to 6 | Less than 3 |

### **6.1.4** Hardship Ranking System

The Hardship Ranking System was used to rank the selected springs based on the responses of the participants in FGDs and SHCs. According to the pre determined indicators each of the above indicators is marked into the three given criteria (no attention, moderate attention, immediate attention) for each spring. *Table 8* gives the details of the Hardship Ranking for each spring.

**Table 8: Hardship Ranking of each mapped spring**

| Spring Code | Number of user Households | Discharge reduced by half in last 10 years | Quality of water – drinkable, without treating | Proximity of the other source (meters) | Water quantity/ availability (LPHD) | No. of months water is sufficient |
|---|---|---|---|---|---|---|
| DPYSP1 | 23 | Less than half | Without treating | 100 | 45 | 6 |
| DPYSP2 | 5 | Almost half | With treating | 200 | 15 | 4 |

| | | | | | | |
|---|---|---|---|---|---|---|
| DKKSP1 | 9 | Almost half | Without treating | 250 | 25 | 6 |
| DKKSP2 | 15 | More than half | Without treating | 100 | 15 | 3 |
| DKKSP3 | 19 | Almost half | Without treating | 100 | 40 | 6 |
| DKKSP4 | 4 | Almost half | With treating | 200 | 15 | 4 |
| DMRSP1 | 27 | Almost half | Without treating | 250 | 15 | 4 |
| DMRSP2 | 15 | More than half | Not drinkable | 100 | 15 | 3 |
| DMRSP3 | 38 | More than half | Without treating | 200 | 15 | 4 |
| DJGSP1 | 16 | Less than half | With treating | 50 | 25 | 6 |
| DKDSP1 | 6 | More than half | Not drinkable | 100 | 15 | 3 |

After the Hardship ranking, some springs are chosen as the ones that need immediate attention. These springs are chosen based on the following results for each indicator:

- Household Dependency (if >=15)
- Discharge decreased by more than half over the last decade.
- 'Not Drinkable' water quality status.
- Located in isolation without any other source nearby.
- Very low discharge (if <=15 LPHD)
- Number of months of water availability (if <=3)

**6.1.5** A certain percentage of the selected springs are termed as critical, based on results obtained from Hardship Ranking System.

Based on the above-mentioned criteria, 5 springs out of 11 are categorized as the ones 'needing immediate attention' and probable rejuvenation over the next work period. Thus

45% of the mapped springs are selected as critical springs that need immediate attention. These spring codes are:

1. **DKKSP2**
2. **DMRSP1**
3. **DMRSP2**
4. **DMRSP3**
5. **DKDSP1**

## 6.2. Understanding the broad geology of the region that plays a role in availability and access of the spring water.

**6.2.1** Evolution of the geology of Himalayas from the beginning of time.

Geology is a complicated science and its study often requires delving into history of formation. Around 50 million years ago, during the Paleozoic era, India was an island off the coast of Australia separated from Asia by the Tethys Sea. The gradual shift and sub-duction of the Indian plate followed by its collision with the Eurasian plate produced the structures and lithologies we see today in the Himalayas. Consequently, the mountains and surrounding regions are characterized by bewildering complexity, having several phases of tectonic and deformational events. The Himalayas can be divided into six primary litho-tectonic zones that occur in parallel belts. These are:-

1) Trans-Himalayas

2) Indus-Tsangpo suture zone (ITSZ)

3) Tethys Himalayas

4) Greater Himalayas

5) Lesser Himalayas

6) Outer Himalayas

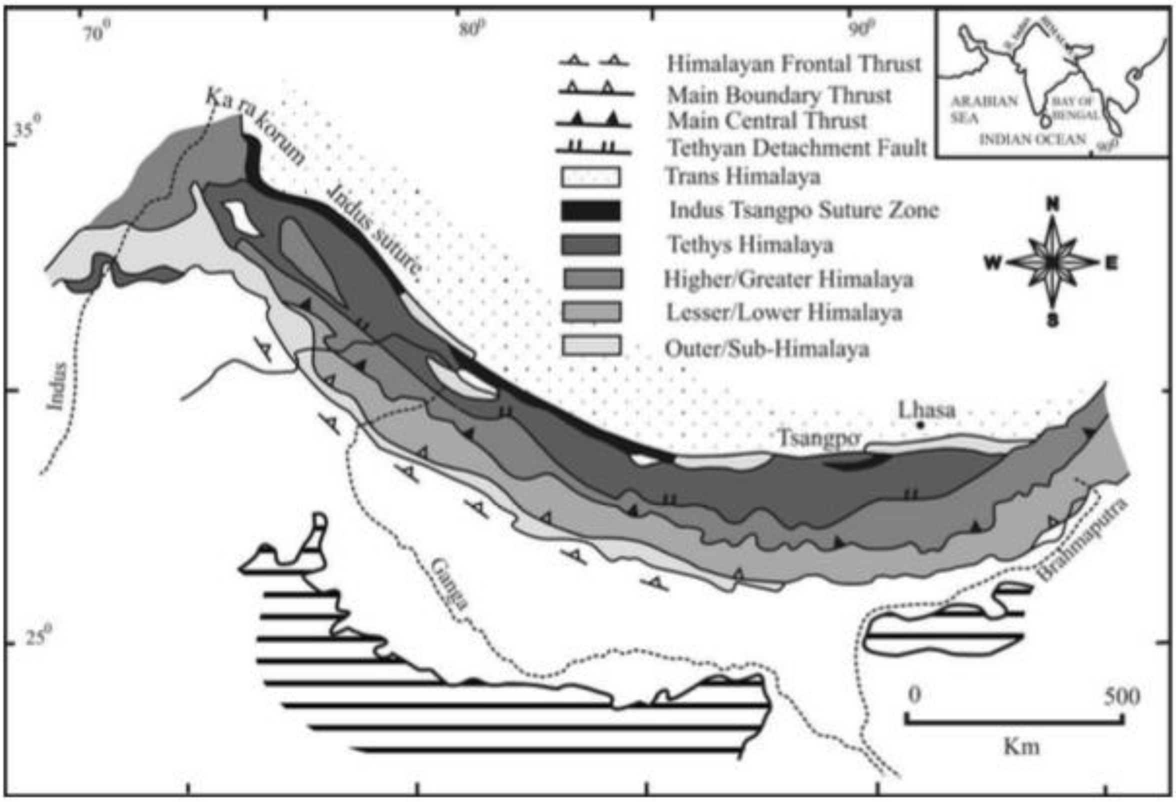



**Figure 7: Image showing various litho-tectonic zones of Himalayas**

**Source: MOEFCC**

*Figure 7* shows the parallel litho-tectonic zones of the Himalayan region. Tectonic environments within these zones also vary. Two main faults the Main Central Thrust (MCT) and the Main Boundary Thrust (MBT) separates the crystalline Greater Himalayas from the Lesser Himalayas and Lesser Himalayas from Outer Himalayas respectively. (Wilson L., Wilson B. [n.d.])

The geological formations that exist today in the Himalayas range from Proterozoic eon to Quaternary period. The varied geological set up coupled with complex structures, controls the geological framework of the Himalayan region. Along with its geology, the morphological features also play an important role on the occurrence and movement of groundwater in the area. Large part of the crystalline Himalayas has schistose, meta-sedimataries and volcanic rocks dating back to pre-Cambrian super-eon and Phanerozoic eon. These rocks hardly have any primary porosity and thus groundwater occurs only in formations where secondary porosity has developed through joints, fractures and solution cavities. Primary porosity in this region is found only towards the Outer Himalayas and sedimentary deposits. Most groundwater occurs in localized aquifers under favorable structural conditions. This is crucial for the state of Uttarakhand due to the absence of local surface water bodies unlike many other Himalayan states. The area covered by local ponds and lakes in Uttarakhand is negligible (Pangare G., Pangare V., Das B., 2006)**,** which makes water accessibility a huge concern for the local people residing away from the major rivers. Also, the rivers flow deep down the valleys, which is impossible to access without organized pumping schemes. Though the state, houses many perennial rivers, rural Uttarakhand faces the problem of water accessibility in spite of having availability. Thus there is heavy dependence on groundwater in the state.

Recharge of groundwater therefore becomes crucial. The chief source of recharge in most Himalayan region is glaciers. Only in the foothills, rainfall can contribute copious amount to ground water. In Uttarakhand, mid and high hills are comprised of Greater and Lesser Himalayas with high relief and sloppy rock surfaces, hence larger proportion of the incoming precipitation flows out as overland flow and only a meager amount infiltrates to subsurface ground water bodies. (CGWB, GoI, 2014)

The stage of groundwater development is very low in the Himalayas i.e. 28.80% with Uttarakhand at a decent stage of development at 66.33%. Natural source of groundwater is through seepages as springs under favorable conditions. The quality of groundwater in the Himalayas is good for drinking and for agricultural purposes. However inorganic constituents like iron, nitrate, fluoride, arsenic etc. are present in various concentrations in various regions. Nitrate in more than acceptable limit is observed in shallow aquifers in the valleys of Uttarakhand. Along with the geology and groundwater content, it is worthwhile to mention that the surface soil in the hilly parts of the state is categorized as low available water capacity soil (AWC) that is present along with rock outcrops. Most regions have severely or moderately eroded soil. (CGWB, GoI, 2014)

**6.2.2** A brief description of different Himalayan regions that make up different geological zones on Uttarakhand

The geology of Uttarakhand is largely influenced by the Himalayan geology. The state is broadly divided into two geomorphological units:

1) Gangetic Alluvial Plain

2) Himalayan Mountain Belt

Most of the districts fall in the Himalayan mountain belt except for Udham Singh Nagar, Haridwar and parts of Dehradun. In the plain areas, groundwater occurs is multi aquifer systems. Various numbers of perched aquifers are also present in the Bhabar zone and Doon valley. While in the hills groundwater occurs in small, localized aquifers developed through secondary porosity as already mentioned.

The Himalayan mountain belt, which covers most of Uttarakhand from central to northern regions, has an intricately designed geology. *Figure 8* shows, majority of mid and high hills are comprised of Greater and Lesser Himalayas.


**Figure 8: Himalayan zones of Uttarakhand**
**Source: MOEFCC**

Geographically Uttarakhand comprises of the following litho-tectonic zones of the Himalayan mountain belt. They are briefly described below:

**1) Trans Himalayas**

It comprises of fore-arc rocks and continental molasse sedimentary rocks, which are primarily made up of terrestrial deposits. These assemblages are due to up-liftment of magmatic rocks during tectonic collision and subsequent erosion. There is also an igneous component to these rocks. As the Thethys Sea collided with the Eurasian plate, lots of magma arising from the collision solidified deep inside the earth's crust to form plutonic igneous rocks. These are devoid of any groundwater and mostly mark extreme northern Himalayas or extreme northern most region of Uttarakhand.

**2) Tethys Himalayas**

This zone is towards the south of the ITSZ (refer to *Figure 7*) and has 10-17 kilometers of marine sediments on the continental shelf or the sloping portion of the Indian subcontinent. This portion is very loosely metamorphosed and is excellent for fossil preservation in their syncline layers. The large variety of size and distribution of fauna suggests that life was flourishing in this area before orogeny.

The Trans and Thethys Himlayas are not widely developed in Garhwal region and show some presence in the district of Pithoragarh. The rocks originate from Pre-Cambrian super-eon to Jurassic period. (Negi, S. S., 1995)

**3) Greater Himalayas**

Most districts in the high and mid hills of the state fall in the Greater Himalayan region. This is a 30 kilometers wide stretch and is made up of series of ductily deformed crystalline metamorphic rocks.

The primary rocks of these regions are crystalline metamorphic like mica schist, garnetiferous gneiss, black schist/gneiss, quartzite, paragneiss, migmatite, etc. This type of rocks are indicative of multi phase deformation, first being Barrovian type (normal geothermal gradient conditions) and then there was a change to Buchan type metamorphism (low pressure and high temperature conditions). (Wilson L., Wilson B. [n.d.])

The crystalline nature of these rocks indicates that, it has been formed over a long period of geological time. Barrovian type metamorphosis indicates that all these rocks marked the development of a sequence of index minerals. Some major rocks that characterize this region are described below

- **Gneiss** is a very high grade metamorphic rock formed from extremely high temperatures and pressure. Unlike soft metamorphic rocks, gneiss doesn't break easily to form cracks and fissures. It has alternate layers of different minerals that indicate Barrovian metamorphism. It is formed when sedimentary or felsic igneous rocks are subjected to great temperatures and pressure. It is the main building block of mountains.

- **Schist** is softer compared to gneiss. If it undergoes weathering it might get split into thin irregular plates, which are composed of different minerals. However it is also to be mentioned that the weathered material of schist is usually clay and hence doesn't yield much groundwater. Confined aquifers if at all formed in hard rocks are better preserved in high grade metamorphic than low grade metamorphic like schist.
- **Quartzite,** which is another component of Greater Himalayas of Uttarakhand, is also an extremely compact hard granular rock essentially consisting of quartz. Weathering of quartz material usually yields clay decomposed from feldspar, mica and unaltered residual, which are further resistant to weathering. (Chandra P. C., 2015)
- **Migmatite** on the other hand are composed of two types of rocks- typically a granitic rock with a metamorphic host rock. The granite, if is coarse-grained, provides good scope of weathering compared to thin-bedded quartzite.

**4) Lesser Himalayas**

The Lesser Himalayan zone is bounded by MCT, which separates it from Greater Himalayas in the north, and MBT in the south. Unlike the Greater Himalayas, the Lesser Himalayas have mostly undergone only greenschist facies metamorphism. It means that most of the rocks of Lesser Himalayas are formed under processes of orogenic regional metamorphism under lower temperatures and pressure. Such metamorphism is associated with rocks having high content of green minerals such as chlorite, muscovite, epidote and platy minerals. Rocks of greenschist facies include slates, phyllites and schist. There are also zones of quartzite, siltstone, shale and carbonates along with some granites and acid volcanics in the Lesser Himalayan region. (Anon 2013)

These are loosely metamorphosed sedimentary rocks or can be considered as meta-sedimentary rocks. Weathering is possible in such rocks to form fractures and joints, as they are much softer than high grade metamorphic like gneiss or migmatites. Such joints and fractures may act as groundwater repositories. However the weathered material of slate, phyllites and schist is clay and hence do not yield much ground water. Some rocks and formations that characterize this region are described below:

- **Phyllite** is a foliated metamorphic rock that can weather in form of sheets. If present without clay, they can serve as good confined aquifers.
- **Schist** in the Lesser Himalayas can undergo excessive weathering, which may lead to clay deposits. This may hinder groundwater movement that is present in the rocks. (Chandra P. C., 2015)
- **Sandstone** and **mudstone** are present as a part of Dagshai formation in this region.
- **Quartzite in association of limestone** in present in Upper Tal and Jaunsar formation.
- Multi-coloured (red, maroon, black or green) **shale or phyllites** are found in the Lower Tal formation. (Srivastava P., Patel S., Singh N., Patel R., 2013)
- The Damtha group of Outer Lesser Himalayas is another formation, which is late Paleoproterozoic and Mesoproterozoic in origin and is much similar to Jaunsar formation. (Valdiya K., S., 2015)

The Lesser Himalayas also show complex folds in its structure in form of synclines (concave fold with layers converging towards centre) and anticlines (convex fold with the oldest rock at the core). Various features like nappes (large bodies of rock that has traveled a certain distance from their original place), klippes (remnants of nappes that are formed by erosion) and tectonic windows (faulted escarpments) are found in this region.

**5) Outer Himalayas**

Also called the Shivalik, these hills range from 900-1500 meters in height. Its formation dates back to late tertiary sediments and has extremely rugged and restive topography. Landslides are most common in the Outer Himalayas because it has very steep slopes and deep valleys. These ranges are comparatively young and tectonically very active. The Shivaliks can be classified into Upper, Middle and Lower Shivaliks succession phases:

- **Upper Shivaliks** has conglomerate top with a bottom layer of sandstone, grit and clay. Below these layers lies soft grayish sandstone. The base is made up of coarse conglomerate giving evidence of quick deposition by rivers and deltas during its evolution.

- The topmost layer of **Middle Shivaliks** has brownish sandstone, gravel beds, shale, orange clay and claystone. It is the richest fossiliferous stage of the Shivaliks. Beneath this lies grey, hard, compact sandstones associated with shales. This stage of succession is poor in fossils.
- The **Lower Shivaliks** comprises of bright red sandstones intercalated with siltstones.

Most recent deposits of the Shivaliks are primarily gravel which are known as Dun Gravels and makes up most of Dehradun valley'. The sediments are coarse and poorly graded which indicates that large bodies of water and swampy basins have carried them. Groundwater availability is abundant compared to mid and high hills and is mostly found in unconfined aquifers. (Negi, S. S., 1995)

**6.2.3.** A correlation of type of rock availability and corresponding groundwater scenario is tried and established mainly for Tehri Garhwal district. The aquifer character of the district is also studied to establish whether groundwater can be a reliable source of water for the local inhabitants of the area.

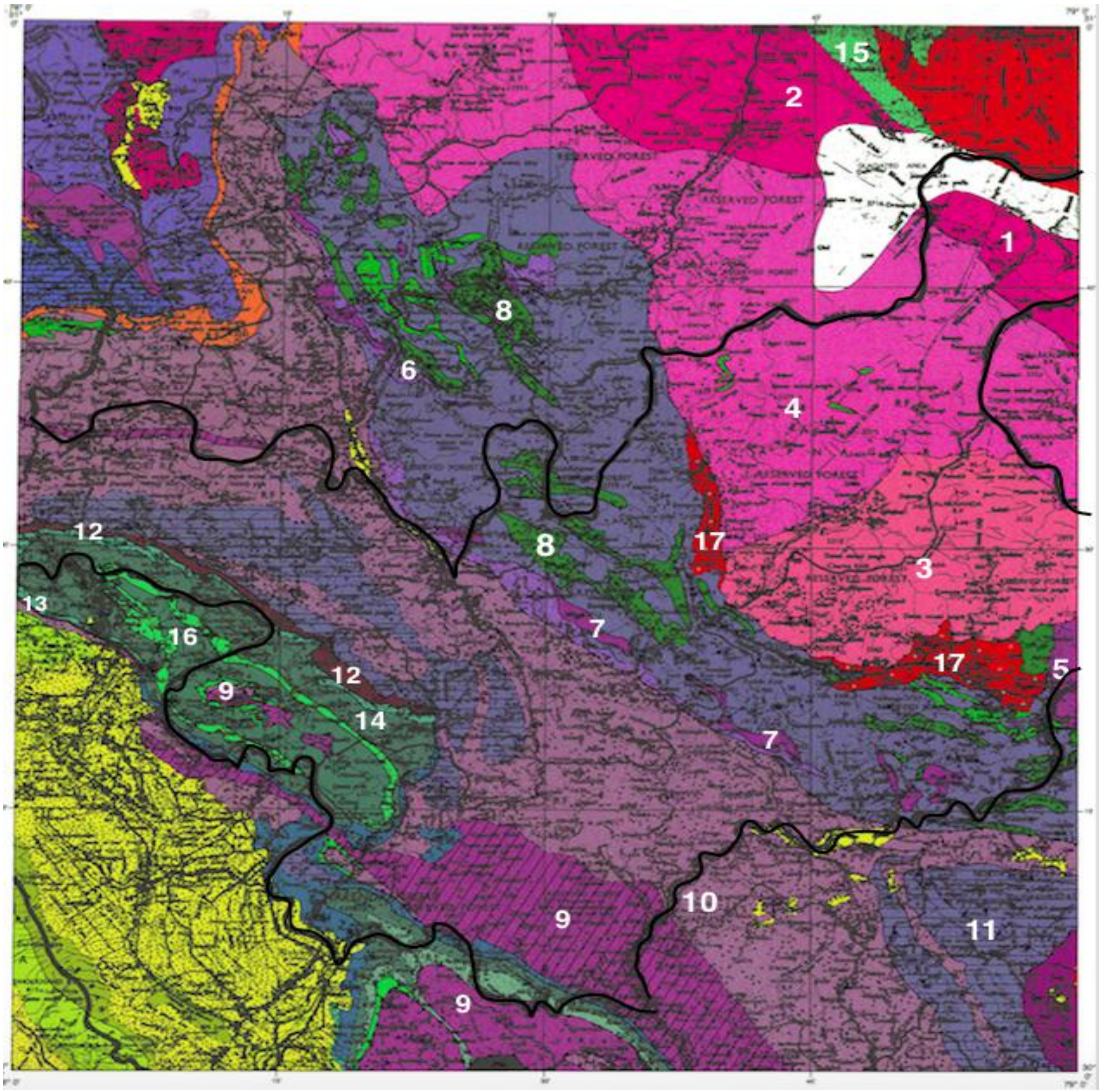



**Figure 9: Geological map of region in and around Tehri Garhwal district Source: Geological survey of India**

*Figure 9* is marked with different types of formations found in and around Tehri Garhwal district. From *Table 9* we can identify the formation along with their groundwater potential.

**Table 9: Formations of Tehri Garhwal along with their rock composition and groundwater potential.**

| Number on Map | Formation | Composition | Groundwater Potential | Extraction Measures and Depth |
|---|---|---|---|---|
| **1** | Khatling | Gneiss | Hardly any groundwater | |

| | | | | |
|---|---|---|---|---|
| | | | present | |
| 2 | Yamunotri | Gneiss, Schist, Migmatitie, Igneous intrusives | In weathered residuum | Bore well in a depth span on 10-70 mbgl |
| 3 | Bhilangana | Gneiss, Quartzite, Schist, Amphibolites | Fractures and Joints | Bore well in a depth span on 10-70 mbgl |
| 4 | Wazri | Graphite, Gneiss, Schist, Limestone, Calcareous Quartzite, Igneous intrusives | Rare possibility in secondary porosities. | Can be found upto 100 mbgl through bore wells.<br>Dug well in weathered zones.<br>Harnessing of springs is possible<br>Hand pumps fro igneous up to 15-73 mbgl |
| 5 | Agastmuni | Phyllite, Schist, Quartzite, Igneous intrusives | Varied potential for groundwater | |
| 6 | Uttarakhasi | Interbedded quartzite, multi coloured slate | Weathered residuum | |
| 7 | Lameri | Limestone, Dolomite, Phyllite, Slate | Secondary porosites | |
| 8 | Nagnithank | Quartzite, Slate and | Weathered residuum | |

| | | | | |
|---|---|---|---|---|
| | | metavoltaics | | |
| **9** | Mandhali/Bijni | Stale, sandy limestone, quartzite, shale | Groundwater occurs in unconfined to semi-confined conditions | Large diameter dug wells<br>Hand pump fitted tube wells up to 25-200 mbgl<br>Bore wells |
| **10** | Chandpur/Amri (Devprayag block) | Phyllite, Slate, Schistose Quartzite, Igneous intrusives | Possibility of dry fractures and joints for most low grade metamorphic cannot hold groundwater. | |
| **11** | Nagthat | Quartzite with Phyllite and slate | Possibility of dry fractures and joints for most low grade metamorphic cannot hold groundwater. | |
| **12** | Blaini | Shally slate and boulder bed | | |
| **13** | Infro Krol | Carboneous shale, Phyllite, Slate | Secondary porosites | Groundwater found up to 100 mbgl<br>Tubewells and Dugwells |
| **14** | Krol | Dolomite, Limestone, Calcareous shale | Secondary porosites | For limestone groundwater may be available at 60-70 mbgl |
| **15** | Martoli | Carboneous slate, Quartzite | Weathered residuum, Fractures and Joints | |
| **16** | Tal | Quartzite with limestone and | | |

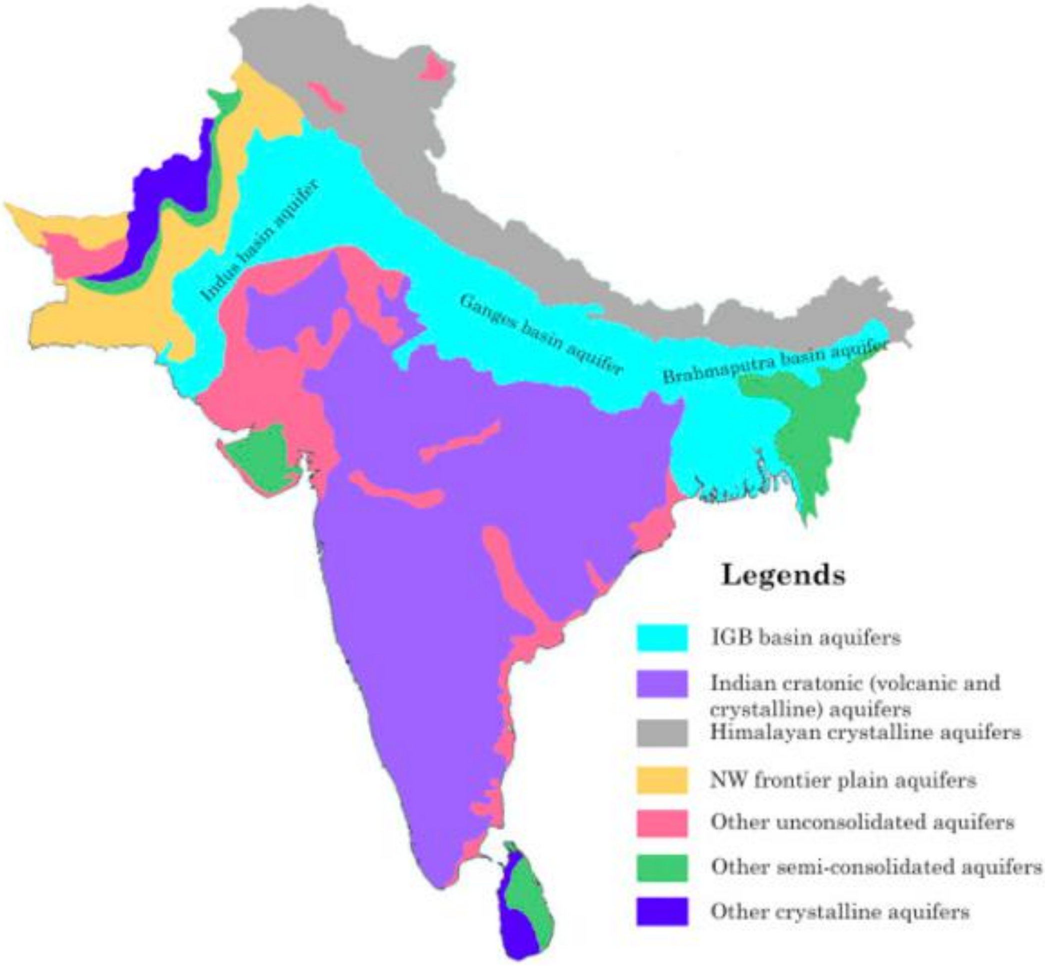
| | | | | |
|---|---|---|---|---|
| | | conglomerate | | |
| **17** | Igneous intrusives | Biotite-granite | Groundwater depends on weathering and degree of openness of the fractures. Groundwater quality may be affected by various granitic minerals like muscovite etc. | |

**Source: GSI and CGWB**

From *Table 9* we can also come to a conclusion about the limited potency of groundwater as reliable resource for rural inhabitants who are residing away from the major rivers.

**6.2.3.1** Aquifer Character of Tehri Garhwal

Along with geology, a brief discussion of aquifer character of the region is relevant in this study. Geology of a region defines the type of aquifers present, which in turn defines the quantity and quality of groundwater availability. India is known to be a country that has one of the most voluminous usages of groundwater. Annual groundwater withdrawals of Indian subcontinent are known to exceed 340 billion cubic meter (BCM). Increasing demand for food production with rising population has called for irrigated agriculture. This has put tremendous pressure mainly on the Gangetic aquifers of north India. *Figure 11* shows map illustrating major aquifer systems of Indian subcontinent. (Mukerjee A., Saha D., Harvey C., F., Taylor R., G., Ahmed K., M., Bhanja S., N., 2015)




*(The figure is not to scale and the aquifer and country boundaries are only for illustrative purpose).*

**Figure 11: Different aquifer systems of Indian subcontinent**
**Source: Mukherjee A., et. al, 2015**

From *Figure 11* we can see that entire state of Uttarakhand is covered under Himalayan crystalline aquifer system. This is in correspondence to the type of geology found in the state as mentioned in the sections above. Along with groundwater being found only in confined aquifers, exploration of groundwater is difficult in such geological terrain. It has already been mentioned that the Central Groundwater Board (CGWB) has set up Groundwater Monitoring Stations to examine working condition of wells and checking timely discharge in inventoried mountain springs, only in Shivalik and Bhabar region of the state.

Not a single exploration well has been set up for Tehri Garhwal district which comprises of crystalline and meta sedimentaries of Greater and Lesser Himalayas. Hydrogeology of district is such that groundwater occurs in disconnected localized aquifer systems formed from joints, fractures, fissures in crystalline rocks or subterranean caverns of limestone and dolomite of Lesser Himalayas. (CGWB, Tehri Garhwal) Movement of water depends on degree of interconnections of the secondary porosities. Springs often emerge when the water table intersects the ground surface. Rainfall is the principal source of groundwater replenishment. But as mentioned already, most of the rainfall is lost as run off and the amount that infiltrates is insufficient to bring about efficient recharge. Also the district is categorized as a minor groundwater basin and has very low annual recharge. (Mukerjee A., Saha D., Harvey C., F., Taylor R., G., Ahmed K., M., Bhanja S., N., 2015)

Based on the study of CGWB, the district has two types of aquifers: Local or Discontinuous Aquifers and Localized Aquifers. *Table 10* gives details of both the aquifer systems of Tehri Garhwal.

**Table 10: Details of Aquifer system of Tehri Garhwal**

| **Aquifer Character** | **Localized** | **Local/Discontinous** |
|---|---|---|
| Aquifer Type | Confined aquifers formed in secondary aquifers of medium grade metamorphic rocks like amphibolite, quartzite | • Unconfined and semi-confined aquifers in sedimentary rocks (shale, sandstone) and meta-sedimentaries (dolomite, phyllite)<br>• Calcareous limestone and dolomite hold groundwater in solution cavities formed by chemical weathering. |
| Age | Paleoproterozoic | Paleo/Neoproterozic |
| Himalayan Zone | Greater and Lesser Himalayas | Lesser Himalayas |
| Rock Composition | Gneiss, Schist, Amphibolite, Migmatite, Quartzite and | Shale, Slate, Quartzite, Phyllite, Sandstone, Limestone, Dolomite |

| | | |
|---|---|---|
| | intercalated granite | |
| Yield (liters per second/LPS) | Very Low (<1) | Low (1-5) |

**Source: CGWB, Tehri Garhwal**

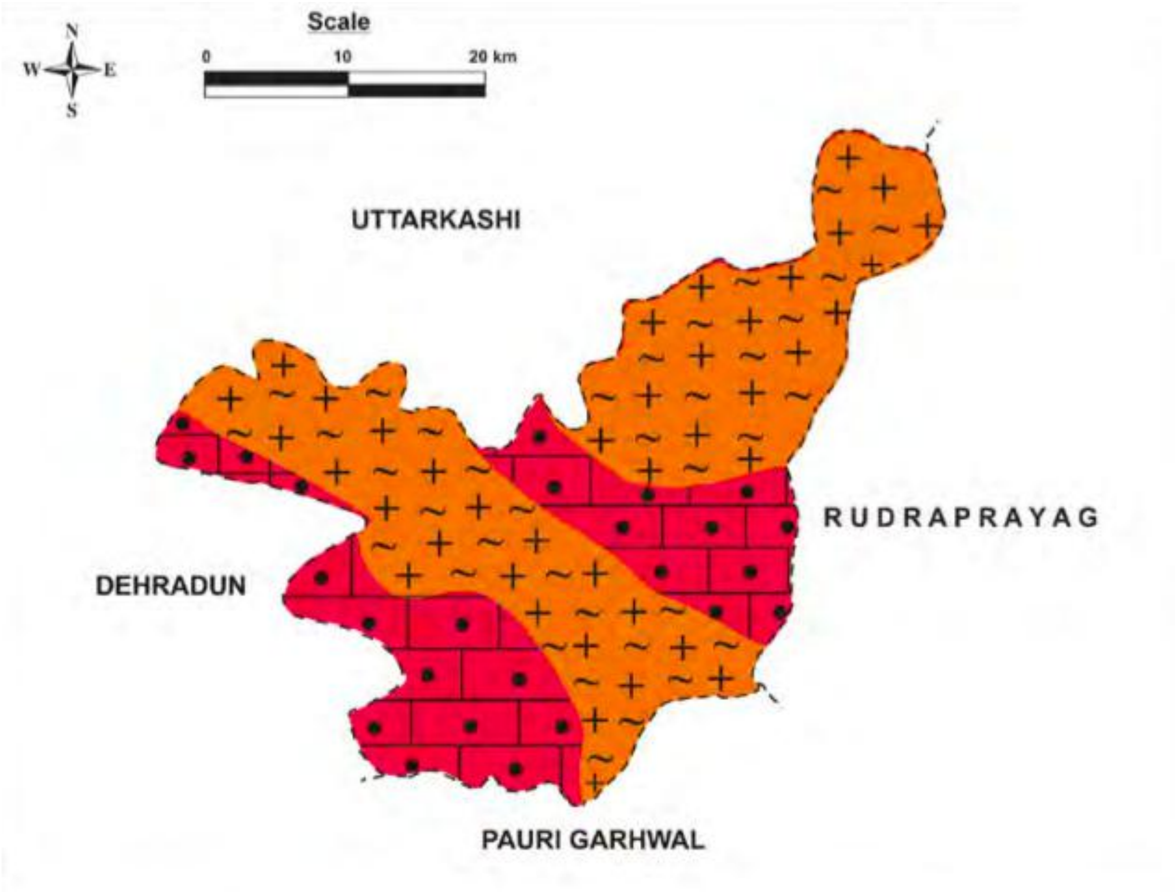



**Figure 12: Map of Tehri Garhwal showing regions of local and localized aquifers.**

**Source: CGWB, Tehri Garhwal**

*Figure 12* shows map of Tehri Garhwal depicting the two types of aquifer character. The regions can be identified using the colours given in *Table 10*. Devprayag block lies at the junction of localized and local aquifer system.

### 6.2.4 Very brief discussion of other related concepts like tectonic activity, earthquake effects on groundwater

Formation of Himalayas was by collision of Indian plate with Eurasian plate. The Indian plate is still undergoing a northerly movement varying from about 2 to 4 cm/yr. Due to such geodynamic activity, the Himalayan region is undergoing continuous deformity in its rocks in forms of folding, fracturing, shearing, metamorphism and igneous activity in regional scale. The presence of ITSZ, MCT, MBT and numerous other faults are conspicuous manifestation of this activity. (Sati, Rautela, 1998; Kumar *et al.,* 2001; Thakur, Pandey, 2004; Virdi *et al* 2006; Bali *et al.,* 2011).

The state of Uttarakhand can be roughly divided into three seismic blocks: Greater Himalayan Seismic block, Lesser Himalayan Seismic Block and Frontal Hill Seismic Block out of which, the Lesser Himalayan Seismic Block, which lies between MBT in south and MCT in north, has highest level of seismicity. Continual tectonic activity of the existing faults causes earthquakes. Occurrence and movement of fault plane largely determine distribution and magnitude of earthquakes. (MOEFCC)

According to a report published by National Institute of Disaster Management (NIDM), Uttarakhand is prone to severe earthquakes as it falls in the highest seismic zones of the country i.e. zone IV and V. *Figure 13* shows map of Uttarakhand divided into seismic zones IV and V.

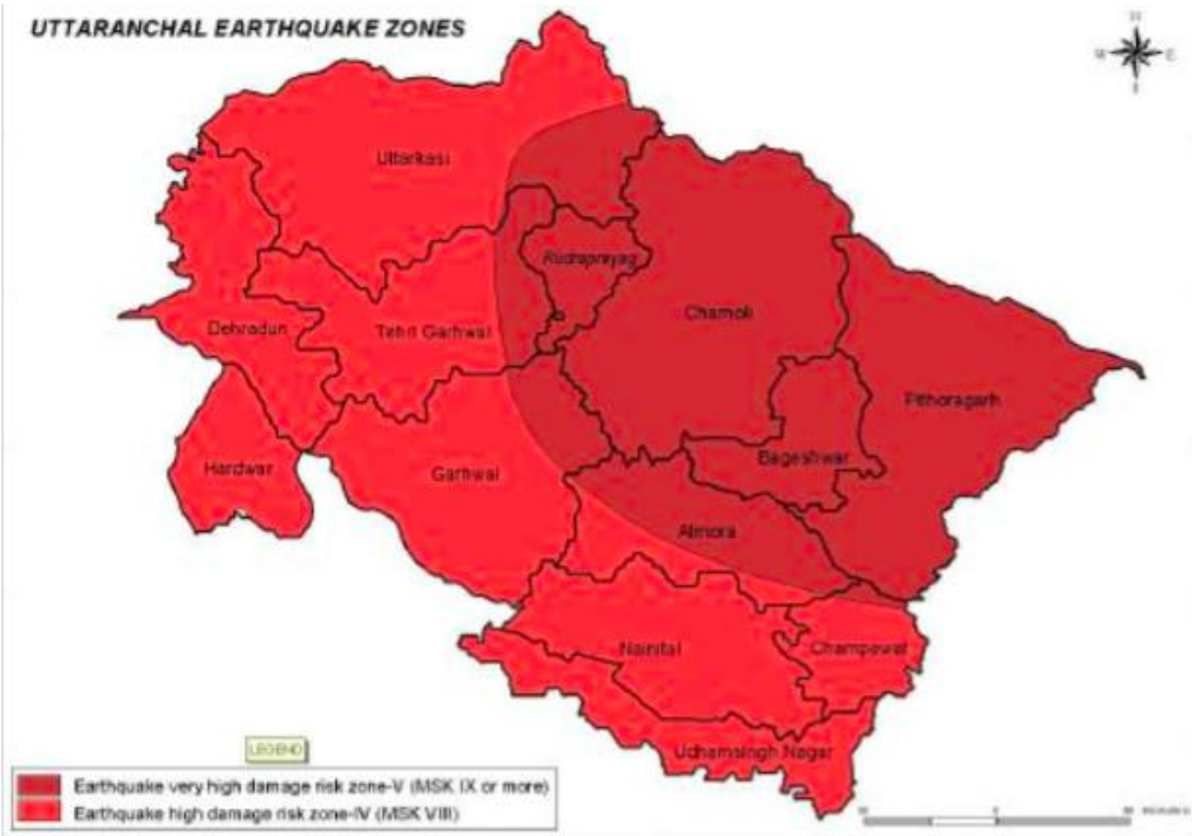



**Figure 13: Different seismic zones of Uttarakhand**

**Source: NIDM**

The state has experienced many earthquakes of small and large scale while the two major earthquakes has been in Uttarkashi in 1991 and Chamoli in 1999. Most of Tehri Garhwal lies in zone IV, however eastern most part of the district lies in seismic zone V. (NIDM)

No major earthquake has been reported in Devprayag or Tehri district so far, but highly uncertain and continuous geological activity under the ground along with unsustainable human practices on ground is ever increasing the risk of bigger disasters in future.

Earthquakes are not known to have profound effects on groundwater. Minor changes in terms of quality of water, depth of water table, aquifer pressure etc. can occur. (Martin K., 2015) Sometimes that can cause change in the type of groundwater motion into a turbulent stream. This can happen if the water is present too close to the epicenter. However a causal link of any changes in groundwater cannot be firmly established with an earthquake. Many studies (Sarkar, I., Chander, R., 2002) although claim that certain changes in groundwater chemistry was seen in the region after Chamoli earthquake of 1999.

## 6.3 To understand the impacts on people due to drying up of springs based on perception analysis.

### 6.3.1 Results obtained from series of informal interviews conducted by CEDAR with local people of villages in Devprayag. *(See Section 3 in Annexure for transcript of interviews)*

Following results were obtained from the field:

i. UJS has provided each village with at least one pump/tap, which operates once in three days. The flow of water is adequate in some villages while insufficient in others. The villagers report that sometimes due to low discharge, filling of their water pots can take the entire day, as they need to wait in long queues. Some of them thus settle for collection of water from nearby springs. However, they complained that water quality of the spring have deteriorated over the years and is only used for other household chores like cleaning or for livestock.

ii. The villagers said that the average requirement of water for a house with livestock is 100 LPHD. Usually it is the children and women folk who have to walk a distance of at least 2-4 kilometers to reach the Jal Sansthan pump/tap or a spring.

They usually have to make numerous trips to the source points because most households have water pots of 20 liters capacity.

iii. The chief occupation of the rural people is agriculture. The area being without any irrigation infrastructure the rural people solely depend on rainfall for their crops. With changing trends of rainfall and increasing number of no rainfall days, men folk often have to migrate to urban areas seasonally.

iv. Under the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA), a community initiative came in 1984. A percolation pit called 'chahal' was constructed which provides water to villages of Kim Khola, Pyunkhari, Kandi, Jali, Koti, Mahar. Chahal is located at the top of the watershed and is providing water to these villages till date.

v. It was also observed that the local people possessed basic understanding of spring terminology and displayed interests in issues regarding springs. They understood the importance of the matter in hand and the urgent need to address issues of water crunch. They set forth attentiveness to recharge zones and channelization of spring for increasing water accessibility.

vi. Female drudgery was rampant. Women folk of the households have to walk at least 10 kilometers each day to collect water for daily chores. Among the children, it is the girls who are seen accompanying their mothers on these trips. As migration is increasing among the men folk, the responsibility of looking after the fields has also come upon the women along with fulfilling daily household chores. (CEDAR, 2016)

**6.3.2** Results obtained from Key Informant Interview

Amar Singh Gosain (Contact no.+919634410245) who is a local resident of Kim Khola district has been working closely with ICIMOD in its spring-shed initiative and is also a local contact of TERI in Devprayag. He gave us hands on information on the situation of rural people in Devprayag due to decreasing water availability. The results obtained from KII with Amar Singh Gosain are:

i. Our key informant mentioned that UJN has tapped the springs in and around the area for making water accessible to local people living in the mountain pockets. The taps set up by UJN delivers water once in every 2-3 days. However he also added that the taps are functional only during the months of rain and during the winter months the taps work once in 15 days or sometimes never at all.

ii. Mostly women and sometimes children go to fetch water from these taps, which are located at of 100-500 meters from almost each household. So for the days water is not supplied, the villagers live, based on the amount of water they can stock from the previous day. During days of severe scarcity, villagers walk to rivers or local ponds to collect water.

iii. Regarding governance of the existing water supply system, he said there is no spring operational and management institution established to take care of the quality, quantity and maintenance of infrastructure, in the villages of Devprayag. However, each household is charged a sum of Rs. 20 per month for accessing tap water in Kim Khola.

iv. Water scarcity has emerged the biggest concern among the villagers of Devprayag and they have to face the impetus of it every day. Yet no local initiative has been taken from the community's side to solve the problem. On the contrary, various inter-community disputes have taken place in the past few years, which has often prevented people from coming together to find a logical solution to this problem.

v. Our key informant also validated that even in Kim Khola, male members of a few families have migrated to states like Punjab and Haryana because agriculture in these villages has become highly unsustainable during the winter. Agriculture has become a gritty occupation in the region even during summers, with increasing temperatures and minimal water left for irrigation after being used for household chores. Rainfall dependence is making the livelihoods of the people highly uncertain.

vi. Another issue that came to light was the quality of available water. During monsoons, though the quantity increases but the quality of water sometimes degrades if flooding takes place in the spring source point. However, not much impact on health has been reported so far but there lies great risk if the quality degrades further. Ad hoc and unauthorized settlements are making the sanitary conditions worse.

vii. There is growing awareness and knowledge about spring hydrogeology, as displayed by some individuals during the field surveys; yet the locals have not figured out a way to find a way out of their perpetual water-deficient situation. According to the locals the vegetation cover in the district has reduced in the past few years; however there is still a lot of greenery around.

**6.3.3.** Results obtained from secondary literature

Secondary literature is highly limited for information on springs of Devprayag.

As mentioned in the methodology, the Danda watershed receives ample amount of rainfall, yet the local residents face water shortages mostly during the winter and pre-monsoon season. There are many gravitational fracture springs in the region, which are mostly seasonal in nature. This is because of the soil's degrading water retaining capacity due to deforestation, thinning of forest cover and erratic trend of recent rainfall. *Figure 14* shows the location of the mapped springs in the spring-shed.

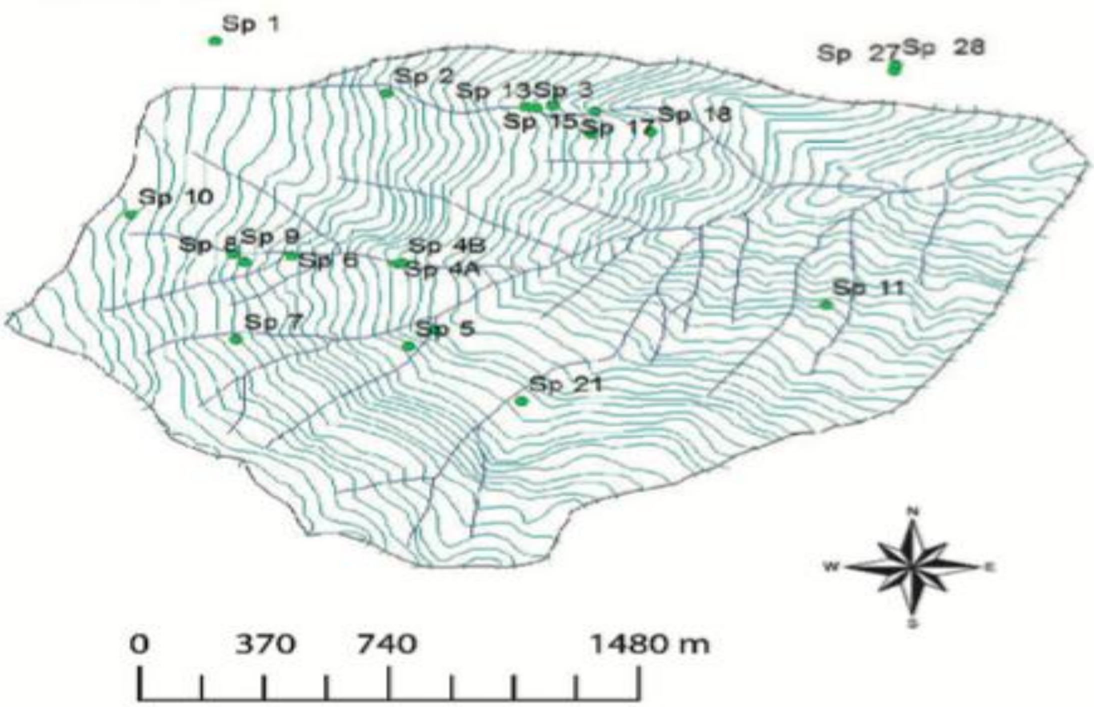



**Figure 14: Mapped springs of Danda watershed in Hindolakhal, Devprayag**
**Source: Agarwal A., Bhatnaga, N. K., Nema R. K., Agarwal N. K., 2012**

Established rainfall-spring discharge relationship for a few springs in the region shows high correlation. *Figure 15* shows spring flow-rainfall dependence of high yielding springs of the watershed. It can be understood that the springs are fast responding in nature. As the cumulative rainfall increased, the cumulative spring discharge had correspondingly increased. This is indicative of the recharge area being close to the source point of these high yielding springs. Thus, artificial recharge practices for such springs are a feasible option if locals are trained for such an activity.

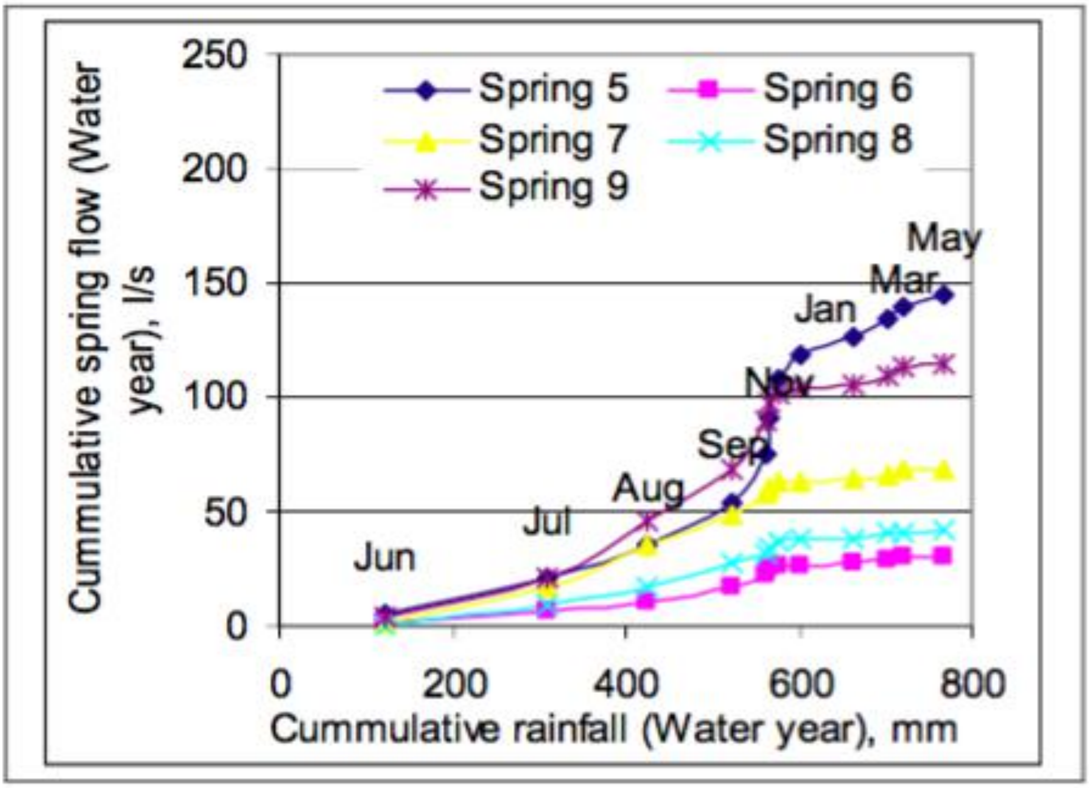



**Figure 15: Change in spring's discharge with precipitation**
**Source: Agarwal A., et. al 2015**

**6.3.3.1** Impacts on residents in terms of demand and usage of spring water

Danda watershed has a population of 427 men, 377 women, 472 children and 367 animals. The total domestic demand for water is 40,570 liters per day (LPD), while usage is only 12,670 LPD. Thus demand is three times more than actual requirement of water for domestic chores. This is reflective of the population's living conditions and difficulty in acquiring water. The minimum monthly flow calculated for all springs in the watershed is 38,364 LPD, which is twice the domestic water usage but is less than the water demand. Thus we understand that the water usage requirements of the population can be met even during the lean season while water demand of the population can't be met. This is again reflective of self-restrictive water consumption practices of the residents. (Agarwal A., et. al 2015)

The residents of Kirtinagar town in Devprayag said that Uttarakhand minister of water resources has claimed to lay down pipelines to increase water accessibility of the people of the area, but there is hardly anything done in reality. Kirtinagar, which lies on the bank of Alaknanda river, has smooth water supply only in few pockets of the region.

Another village called Chaurash, which lies on the bank of Alaknanda complains about decreasing quality and quantity of water in the river because of the 330 MW Srinagar Hydro power project nearby. A resident of the village claims that, dirty water is supplied to their homes and many residents are facing the brunt of water-borne diseases. (Sharma S., 2017)

# 7.0 Discussions and Conclusion

There is no doubt that the issue of water insecurity is highly pervasive in rural areas of Uttarakhand. Through our entire study we have tried to explore almost all relevant aspects of the issue. The research question of the study aims to find the probable factors and consequential impacts of drying springs in Devprayag, Uttarakhand.

In the background section, it has been pointed out that both state and central government has inventoried numerous fund and labour intensive schemes to aid the population but clearly that has not been enough. Uttarakhand is blessed to be free from severe contaminations of groundwater unlike many other regions of India. (Mukerjee A., et. al, 2015) Minor mineral contaminant arising due to geological origin of groundwater is harmless. But it is distressing to realize that such a pristine resource is poorly utilized and now is also reducing.

The first objective is the first step towards working on ICIMOD's spring initiative, which is a part of Hi-AWARE project. From the results obtained it can be concluded that almost 50% of the mapped springs were categorized as 'needing immediate attention' according to ICIMOD's indicators of spring criticality. This is a matter of concern because the local people solely depend on spring water for all their water needs. It is already mentioned that river water is highly underutilized in these habitations situated in remote pockets of Devprayag tehsil. The challenges faced in such a study are immense because it is a highly time consuming, field-intensive and labour-intensive work. The project is still on going and tools are already being developed to carry out the STEP 3 *of ICIMOD'S* spring initiative as mentioned in the introduction. Understanding the social and governance aspects is crucial to solve all sorts of anthropogenic issues related to the springs before diving into tackling the natural causes of spring endangerment. Then comes STEP 4 - the hydrogeological mapping of the critical springs, which is the work of a geologist on source site of the critical springs. Once completed, ICIMOD can further venture into the real task of reviving the springs on ground. From an individual perspective, the project gave me immense knowledge on rural livelihoods and issues. If the work is further carried on, I will have an opportunity to make a difference to the lives of people who depend on these springs.

The second objective of geological study of the region was a humble attempt into broad establishment of the type of rocks that are present in the area. Since most of Tehri Garhwal is made of crystalline and meta-sedimentary rocks, groundwater in this region is ought to be rarefied if not sparse. Owing to its location in the Himalayas, the hydrogeological scenario of the region is highly complex. This coupled with lack of detailed geological mapping and studies creates serious dearth of hydrogeological data. Under such circumstance, study of springs, which is a groundwater resource, remains highly incomplete. The stage of groundwater development in Uttarakhand is 66.33% which is a much improved situation compared to the overall stage of groundwater development in the Himalayan region, which is 28.80% (CGWB) Various NGOs and non-profit organization like PSI, CHIRAG, CEDAR etc. have come up with countless probes in this regard and has endeavored to map, assess and also ameliorate the condition of decreasing spring discharge for many localities all over the state. (ICIMOD's spring initiative). The CGWB has inventoried many springs in different parts of the state, (CGWB) but it has to be mentioned that a staggering number of 12,000 natural springs in Uttarakhand are speculated to completely parched. (Sharma S., 2016) Thus it is time, to extend our work beyond paperwork research in Uttarakhand to real applications of spring rejuvenation on ground.

One of the most inspiring examples comes from Sikkim, which is another Himalayan state. Dhara Vikas Yojna (DVY) by the Department of Rural Management and Development (RMDD), Sikkim was implemented under centrally sponsored MGNREGA. DVY's innovative approach served multiple purposes of employment generation, awareness generation and establishing water security by breaking the chain of abundance and scarcity of water. (Kaushik T., 2016) Trenches and percolation pits were dug after recharge zones were identified. DVY had never required a review or grievances redressal mechanisms as maximum involvement in the operation and implementation has come from the primary stakeholders i.e. the villagers. The villagers thus maintained a sense of ownership throughout, which increased the efficiency of the project. (RMDD, Sikkim)

The third objective is a perception-based study of impacts due to drying springs of Devprayag tehsil by mainly focusing on few villages, which were surveyed for the first objective. No pre-formed research procedure or technical tools were utilized in accomplishing this objective. The generalized viewpoint of the people is put forward through various informal interviews that were carried out with CEDAR. It is interesting to note that all the interviews yielded similar opinions. This gives substance to our concern and makes this study highly significant. In fact from secondary literature it has been found that various other tehsils of Tehri Garhwal faces a similar problem.

One of the most noteworthy discoveries in the entire survey is the prevalence of gendered vulnerability due to water insecurity. 72% of the total women folk and 14% children bear the responsibility of carrying portable water for daily requirements. An average of 60% women walk half a kilometer daily while 10% of them walk up to four kilometers to fetch water for their families. In various other regions of Tehri, women mentioned about their helpless situation where they have to climb 1.5 kilometers uphill carrying 40 liters of water daily. The situation has hit rock bottom in the village of Kandakholi in Tehri, which is located at an altitude of 1800 meters, where family members have to take bath one by one and only once in a week. Many villagers have decreased the number of livestock they had due to the same reason. As male members have migrated, it has come upon the women to take care of the field along with the houses. (Bhatt V., Pandey P., 2005)

All these findings have brought out the deplorable conditions rural people have been living in, in certain areas of rural Uttarakhand. The change has taken place gradually and over a long period of time and its reasons can't be ascertained accurately. Climate change, which is exceptionally felt especially in the Himalayas, has to play a role in this change. More than glacier melt; decrease in rainfall frequency has raised disquiet among scientists and researchers. (IANS, 2016)

Along with this, other contributing anthropogenic factors like increasing urban settlements, dynamiting of hills for various types of construction, building of mega dams etc. are exacerbating the situation multiple folds. Existing human interventions are insufficient to address the issue. For example SWAJAL, though highly efficient has coverage of only 20.67% all over the state. Similarly, other schemes like NRDWP has coverage of only 15% and 0.2% for 40 LPCD and 55 LPCD respectively, such that 100% of population in a habitation is covered. Also it is worthwhile to mention that most of the efforts by different agencies have been to supply water through water supply schemes rather than addressing the root causes of the issue. Lack of funds, knowledge, infrastructure and expertise is another hindrance in the way of a sustainable long-term solution.

A plausible solution can come only when all stakeholders come together and take the issue as a common challenge. More initiatives like the 'chahal' should be encouraged among villagers. However before more such initiatives, hydrogeological training needs to be imparted. Another step, would be detailed hydrogeological mapping of the villages, which will help to identify recharge area of critical water sources so that spring rejuvenation can be practiced on ground.

In conclusion, I would like to briefly point out the probable factors that make water accessibility difficult in rural Uttarakhand:

i. Insufficient coverage of various government schemes in making water accessible to rural people. River water should be made a source of various water supply schemes instead of springs. Also more focus on infrastructure building is given rather than finding long-term solution to decreasing decline.
ii. Rural people solely depend of spring water, as rivers are located far away from their habitations. *Tables 9 and 10* indicate the potency of groundwater as a reliable resource for Tehri Garhwal is not very high..
iii. Lack of community based initiatives, unlike in states like Sikkim where local people have themselves found solution to their water insecure status.
iv. Dearth of data and lack of understanding of geology for identifying recharge zones for individual springs.
v. Human activities and religious tourism is increasing the water demand in and around the area.

Coming to impacts of drying springs following are to be mentioned:

i. Gendered vulnerability.
ii. Close association of water scarcity and out migration.
iii. Changing rainfall patterns could probably affect livelihoods of the people.
iv. Basic human entitlements like bathing, cleaning are breached.

# 8.0 Limitations

As already mentioned, study of any natural resource is a time-consuming job. This report entails study of springs, which is a groundwater resource. Following were the limitations of the study

i. The study required collection of various types of data like socio-economic, governance, climatic, hydrological and geological for the period of our interest, which wasn't easy to obtain. A major challenge was inadequacy of geological data especially of the Himalayan states in India. Under such conditions finding relevant information from secondary literature to aid the research was difficult. Information on geology of the area around the critical springs or even Devprayag tehsil was not available due to which, a larger area had to be selected and a broad review had to be given.
ii. Data was highly qualitative in nature and was subject to people's perception. Thus this form of data can't be considered factual in nature and hence not highly reliable.
iii. The last and most important limitation was lack of time. The STEP 3 of ICIMOD's spring initiatives couldn't be completed. Understanding all socio-economic and governance ingredients of all five critical springs would have required a very long field work which couldn't be accommodated in these four and a half months' time. However tools are developed for the same, and as a part of Hi-AWARE project it will be completed within this year. Also due to lack of time, efforts couldn't be undertaken to study the water quality of the springs. This is important because such a study could bring out possibility of cases of water availability but with poor quality. The interventions required to tackle with such scenarios are likely to be different.

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# Annexure

1. Set of questions asked during KII

Q1: From where do you get your daily water and who collects it?

Q2: Who collects water from the springs?

Q3: For what purposes is water used?

Q4: Has the flow changed over time? (increased, decreased, is same)

Q5: Are there any existing spring management institutions present?

Q6: Is there any government or local initiative taken to protect the springs?

Q7: Are there any dispute or conflict regarding distribution of spring water?

Q8: What are the other sources they are accessing due to unavailability of spring water? (river water, pond water, hand pumps, bore-wells etc. and their locations and timings)

Q9: How is the water quality?

Q10: Does the water quality change with seasons (poor quality due to flooding during monsoons)

Q11: How has the forest cover in the neighboring area changed over time?

Q12: Do you know anything about groundwater recharge and is there any practice done for GWR?

Q13: Have people migrated to other areas due to lack of water?

Q14: Has there been a mass occupational shift due to water scarcity?

Q15: Do you pay any money for maintenance of the tapped springs?

Q16: What are you sanitation practices when water is unavailable?

Q17: Are there any operational rules with respect to the tapped springs?

2. Demography of villages

| Gram Panchayat | Households | Total Population | Male Population | Female Population | Child (0-6) Population | Literacy (%) | Workers Population |
|---|---|---|---|---|---|---|---|
| 1. Aamni | 66 | 227 | 108 | 119 | 33 | 77.32 | 131 |
| 2. Jagthi | 43 | 161 | 77 | 84 | 24 | 62.04 | 72 |
| 3. Kandi | 84 | 441 | 219 | 222 | 56 | 76.36 | 250 |
| 4. Kim Khola | 95 | 413 | 170 | 243 | 61 | 65.91 | 180 |
| 5. Mahar | 182 | 740 | 329 | 411 | 102 | 60.97 | 361 |
| 6. Pyunkhri | 36 | 162 | 69 | 93 | 24 | 64.49 | 65 |
| **Total** | **506** | **2144** | | | | | |

3. Transcript of interviews

| Village | Details |
|---|---|
| Mehar | a. Name: Smt. Lakshmi Devi<br>b. Occupation: Basic Health Worker<br>c. Summary of Ocuupation: Works in 7 Gram Sabhas; Kandi, Mehar, Kimkhola, KotiGosayin, Gosayin, GosayinGaon, Gadakot, Amni. Heavy rainfall causes flooding and destruction in 2010. Helicopters were brought in for aid. Cases of viral fever are widely reported during monsoons, as well as typhoid and increase of uric acid. Also many cases of Chikanguniya were reported in 2010.<br>d. Water: Hand pump was constructed in June, 2000 and tapping by Jal Sansthan has existed since 90s. The flow of water has relatively increased since last year as compared to before. It has become even better since a month, i.e. it now comes twice a day. Number of hand pumps available is 1, which previously delivered water once in three days. It used to be the main source. It has an 11th-12th century temple, built around the |

| | |
|---|---|
| | same time the village was setup. Mostly children carry water from hand pumps. One child carries around 5 liter/canister/trip. Few people have private connections from the tank. Tank capacity is 10Kl which delivers water every day at 3 p.m.. 1 can of water = 20 liters. Private connection provides an average of 100 liters per day<br>e. Crop: Sesame (Black) |
| Amni | a. Name: Harish Chandra<br>b. Occupation: Ex-army, currently working as farmer & daily shop owner<br>c. Status of water: Amni has 4 springs. Piped water is supplied from Bhagwan village (80 kilometers away) by Jal Sansthan since 1985 due to growing shortage of water in springs.<br>d. Common crops grown are daal, mandwa, jhangora (Sawank), gehat, chaulayi and soya bean. But he hasn"t grown anything since two years due to lack of adequate rainfall.<br>e. Water scenario: The Jal Sansthan tap, which is about 1-2 kilometers away from home provides water every third day. He believes that the hand pumps are drawing all the water of springs leading to dry springs. He talks about a chahal, a percolation pit constructed with funding from Forest Department in 1984 to provide water to villages, Kimkhola, Pyunkhari, Kandi, Jali, Koti&Mehar. |
| Pyunkahri | a. Location: Topmost part of the hill, near the Chahal<br>b. Population: 200-250 voters<br>c. Crops on rotational basis; Sawank-Gehun, Mandwa-Dhan<br>d. Landholding: Average – 50 nali |
| Jali | a. Water Scenario: They have a water guarding system where people of the village periodically guard the water source and everyone ration their use of water in times of shortage. |
| Baidgath | a. Households: 18 |

| | |
|---|---|
| | b. Crops: Jhangora (Sawank), gehat, daal, dhaan<br>c. Water scenario: A structure for collection of water for irrigation was made 7-8 years ago. Check dams were built by villagers with the help from the Forest Department. They believe the water in the spring decreased after the road was built. Now the villagers depend largely on Jal Sansthan's tap. The spring swells during rains. |
| Kandi | a. Interview: Female resident<br>b. Water scenario: There are two hand pumps close to the village; one is preferred more than the other because of the quality of water. However, it is subject to frequent malfunctions. There was also a well, which dried up 7-8 years ago but has water in the first two months of rainfall each year. In case if both hand pumps break down the women have to walk to the hand pump in Amni. The Jal Sansthan tap also provides water every alternate day, but the discharge is very low. It takes almost a day to fill cans. They have a mutual agreement regarding tap water and each household is allowed to draw only 2 pots of water from it. They do not have concrete tanks for storage and carry out rain water harvesting on a very small scale using the plastic drums. This water although covers a very small portion of the demand but is quite helpful and can potentially is a relief mechanism for at least 2-3 months.<br>c. Agriculture: Crops - soya bean, dal, dhan; they were provided guava seeds by the Pradhan but the trees did not survive due to lack of water.<br>d. Cash crops: toor dal, soyabeans, marsu, udad dal, chaulayi, mandwa<br>e. Output: 1 sack = 50 kg; 561 landholding produces minimum 2 sacks of crop. The output is sold to the artiya who visits them frequently at their village to collect the crop.<br>f. Human Wildlife Conflict: Wild Boar |