Hydrogeological assessment of Demul and Chicham village of Lahaul and Spiti district, Himachal Pradesh

Conducted by

ACWADAM

Advanced Center for Water Resources Development And Management

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Ecosphere-Spiti, Himachal Pradesh

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BACKGROUND

The Spiti valley is cold desert mountain valley that forms the part of Spiti-Lahaul district of Himachal Pradesh. Spiti, surrounded by high mountains on all sides, is located on the leeward side of the Trans-Himalayas. The average elevation of the mountain ranges is around18,000 ft. and the lowest parts of valley are considerably more than 11,000 ft. above the sea. The Spiti River flows approximately160km in a south-easterly direction up to its confluence with the Pare Chu at Sumdo (district border between Spiti and Kinnaur) and later merges into Sutlej further downstream.

Lying in the rain shadow of the mighty Himalayas, Spiti receives scanty rainfall. A cold desert at an average altitude of 4000mts, the valley experiences extremes of climate and temperature variations ranging from -25 degree to +30 degrees centigrade. Lahaul & Spiti district falls in the rain shadow area of Himalaya. The monsoon hardly penetrates and rarely reaches the valley in the form of mostly drizzle. The summer months are invariably dry. The winter snow starts evaporating once the summer sun begins to scorch the valley and that is when rivers starts flowing with high discharge.

The villages that are situated over the hilltops have the source of fresh water in the form of springs that emerge from the ground naturally. Springs are points on the Earth's surface through which groundwater emerges and flows. Most springs are fed by aquifers, a system of rocks/rock material, which stores and transmits water to such springs and to wells. Almost the entire population of the villages in the Spiti depend on these springs for their drinking, domestic and irrigation needs. In the recent times, these springs have started experiencing receding discharge due to changes in the rate and pattern of snowfall that induce recharge to them.

With this backdrop, Ecosphere a social enterprise based out of Spiti took the initiative to address the issue of drying springs with the help of ACWADAM. Ecosphere is a collaborative effort of the local community of Spiti and professionals from diverse backgrounds, with a wide spectrum of skills and experience, effectively spanning the bridge from the general to the niche. It focuses to create sustainable livelihoods that are linked to nature and culture conservation. As a social enterprise, it attempts at addressing the triple bottom-line of conservation, development and economies.

Ecosphere and ACWADAM together identified two villages viz. Demul and Chicham in which hydrogeological surveys were conducted to identify potential recharge sites for facilitating recharge to aquifers feeding the springs. The objective behind this initiative is to implement engineering structures like trenches, percolation pits etc. in the identified recharge area (*based on hydrogeological assessment*) to trap rain and snow for inducing recharge.

REGIONAL GEOLOGY

The Spiti valley forms a part of the Spiti-Zanskar basin that belongs to the geotectonic zone of the Tethyan Himalaya. The basin is bounded by the Indus-Tsangpo Suture Zone (ITSZ) in the north and metamorphic basement of the Central Crystalline in the south. It offers a remarkably thick sequence of sedimentary rocks of Permo-carboniferous age resting upon Precambrian Crystalline Basement. The sequence is thick towards the north-western and south-eastern boundaries of the basin, but remains comparatively thinner throughout the major part of Spiti. The Triassic succession is the thickest in the Spiti basin and exist in almost all parts of the basin. Later sections in the report provide more insights into the local geological setup of the study area.

SPRING INVENTORY

Springs are the lifeline for majority of the population inhabiting Spiti. Most the villages situated over the hilltops get little or no access to rivers flowing through the valley. Hence, springwater constitutes the main source of water in these cold desert areas.

Figure 1: Spring inventory map of Demul village

The effects of climate change in the form of reduced snowfall have made severe impacts on the water sources in this region. Spring discharge in particular has started showing declining trend over last couple of years affecting livelihoods of the people inhabiting this region.

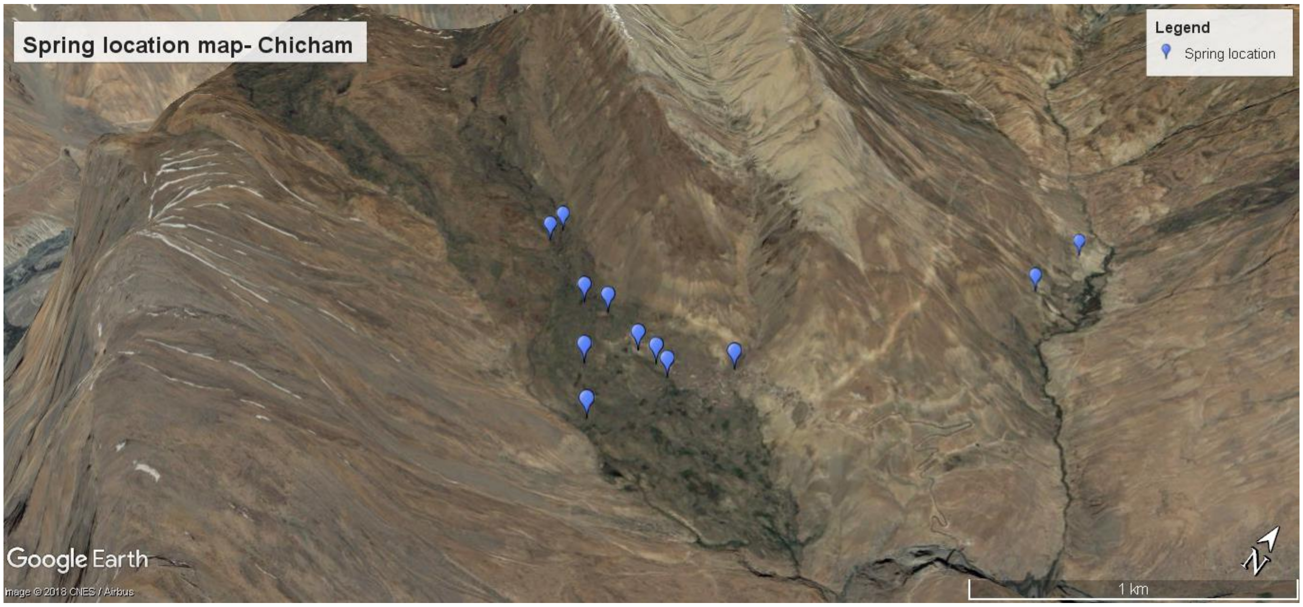

Figure 2: Spring inventory map of Chicham and Dumla village

To understand the current situation, a detailed spring inventory was carried out to identify the density and status of springs in the identified villages. It was observed that both the villages have more than 10 springs (Table 1&2) and the entire population of the village depend on these sources.

S. No.	Latitude	Longitude	Elevation	Village	Code	Spring Name	Seasonality	Spring type
1	32.3449	77.9806	4155	Chicham	CL-1	Chara	Perennial	Depression
2	32.3448	77.98235	4142	Chicham	CL-2	Konchokse	Perennial	Depression
3	32.34081	77.98143	4145	Chicham	CL-3	Lungyet	Perennial	Depression
4	32.34278	77.97943	4196	Chicham	CL-11	-	Perennial	Depression
5	32.3468	77.98449	4137	Chicham	CL-13	-	Perennial	Depression
6	32.36605	77.99325	4139	Dumla	CL-14	Shingok	Perennial	Depression
7	32.39497	77.99324	4122	Dumla	CL-15	Shingok-2	Perennial	Depression
8	32.34567	77.97813	4246	Dumla	CL-23	Tizing	Perennial	Depression
9	32.3606	77.99293	4149	Dumla	CL-19	Chumua	Perennial	Depression
10	32.34725	77.97298	4353	Chicham	CL-25	Wkhang	Perennial	Depression
11	32.345	77.98155	4181	Chicham	CL-30	Kaunchow Che	Perennial	Depression

Table 1: Spring inventory data sheet of Chicham and Dumla village

S. No.	Latitude	Longitude	Elevation	Village	Code	Spring Name	Seasonality	Spring type
1	32.169	78.177	4365	Demul	DL-1	Thong Che 1	Perennial	Depression
2	32.169	78.177	4354	Demul	DL-2	Thong Che 2	Perennial	Depression
3	32.171	78.177	4354	Demul	DL-3	Girimute	Perennial	Fracture
4	32.17	78.18	4330	Demul	DL-5	Siri Che	-	Depression
5	32.17	78.182	4304	Demul	DL-6	Lugum Spring	-	Depression
6	32.174	78.173	4433	Demul	DL-10	Storage tank	-	
7	32.177	78.171	4488	Demul	DL-11	Wetland	-	Depression
8	32.176	78.17	4503	Demul	DL-12	Kapchaphima	-	Depression
9	32.169	78.181	4281	Demul	DL-13	Takche	-	
10	32.169	78.181	4281	Demul	DL-14	Nugum	-	Depression
11	32.176	78.172	4465	Demul	DL-15	Wetland	Seasonal	Depression
12	32.174	78.168	4511	Demul	DL-16	KhapsaChurma	-	Depression
13	32.173	78.169	4509	Demul	DL-17		Seasonal	
14	32.14	78.767	4595	Demul	DL-18	Chakosa Neima	Seasonal	Depression
15	32.165	78.171	4488	Demul	DL-19	Thaknak	Perennial	Depression
16	32.168	78.174	4413	Demul	DL-20	Rititi	-	

Table 2: Spring inventory data sheet of Demul village

CHICHAM VILLAGE

GEOLOGY

The geology of Chicham village comprises dominantly of Quartzites, Shales and Limestones (Fig.3). Quartzites are fractured while the shales are highly weathered. Limestones are found only in the ridge areas. The mapping data indicates a synclinal fold with a fault running along the axis of it. The village sits on the top of thick loose colluvial deposit which overlies the quartzites and shales.

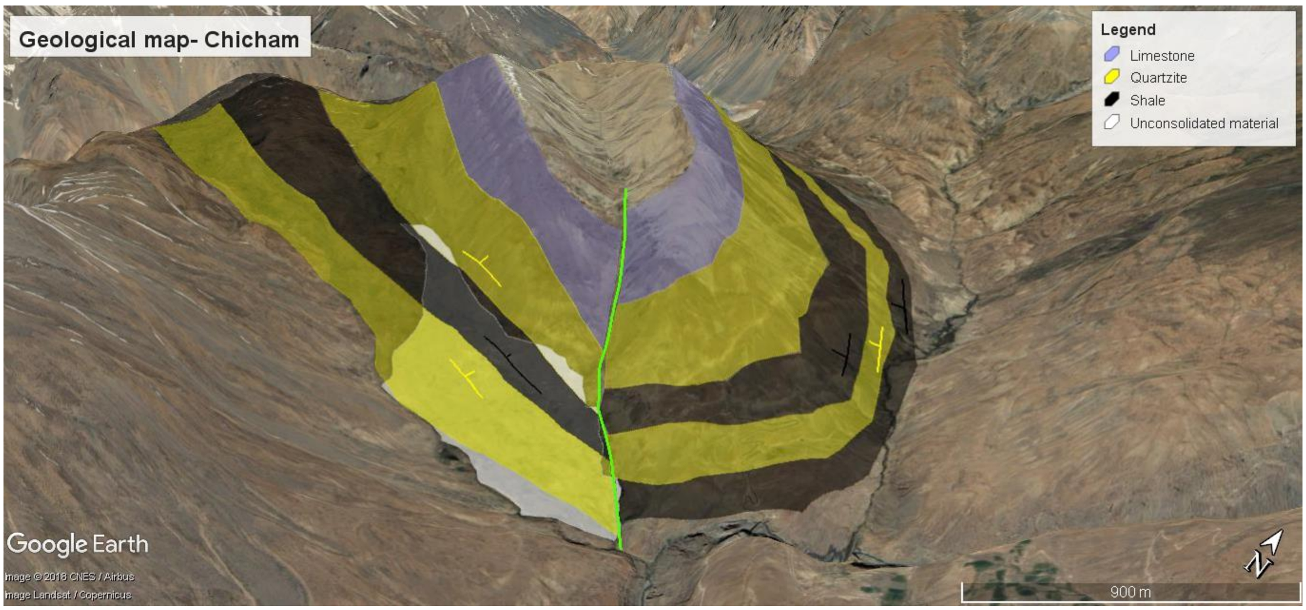

Figure 3: Geological map of Chicham

The rocks on the left of the fault striking WNW- ESE have dips towards NE while the rocks on the right striking NNW-SSE have dips towards SW. The limestones present on the top forms the core of the syncline. The village lies on the left side of the fault. While mapping it was observed that quartzites exposures were prominent while the shales being fissile were highly weathered with weak traces of fractures.

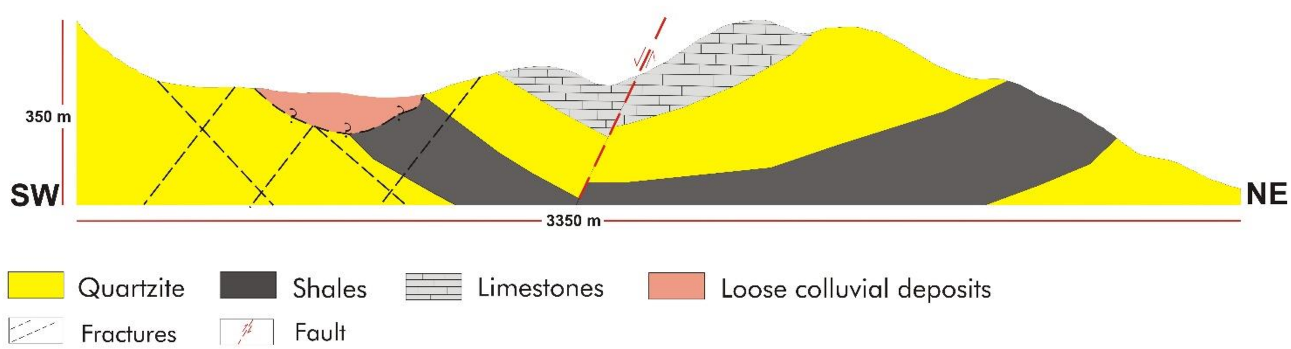

Figure 4: Geological cross-section of Chicham

The fractures traversing the region have varying orientations. The prominent amongst all are the two sets striking NNE-SSW and WNW-ESE with dips in the NW and SSW respectively. However the major portion of the valley is covered with loose unconsolidated material with varying thickness. Much of the area is covered by thick deposits and almost all the springs are found emerging out from them (Fig.4).

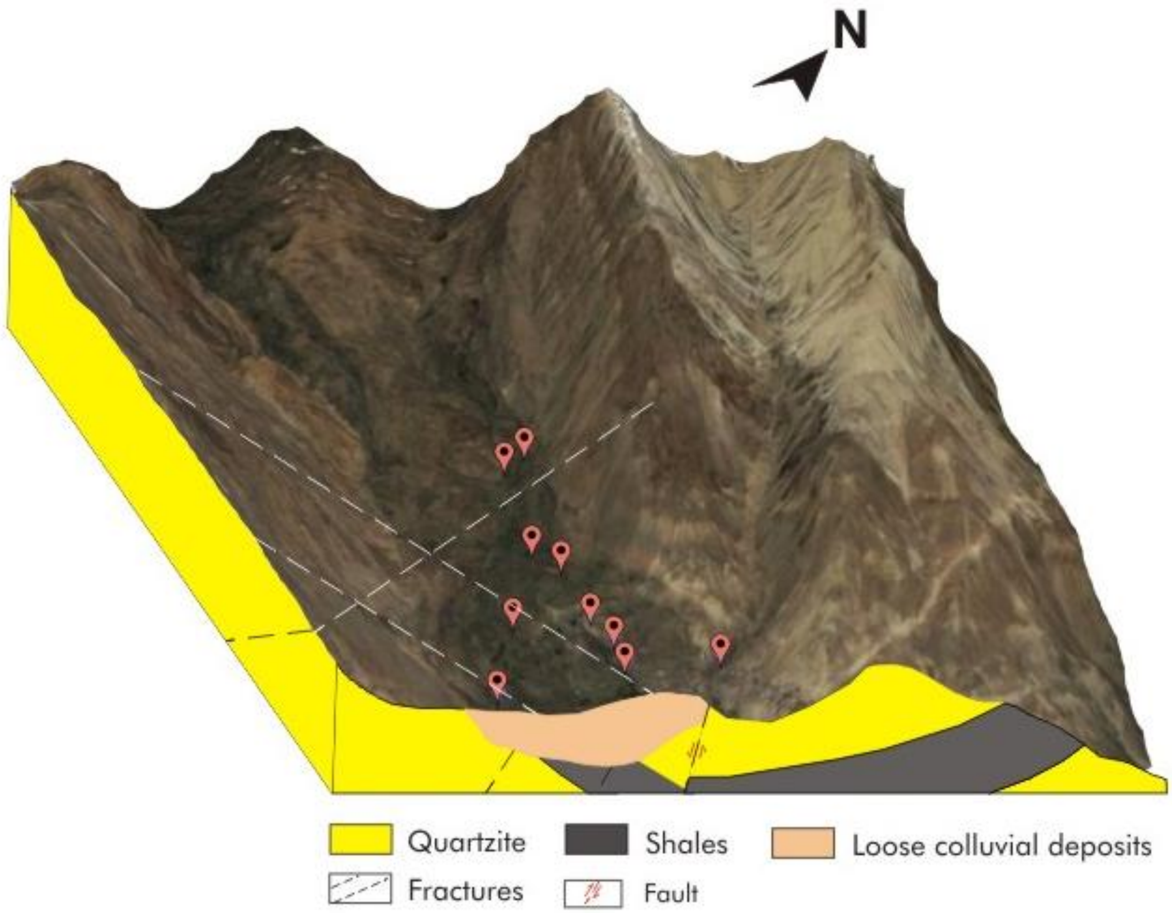

Figure 5: Conceptual layout of the springshed in Chicham

HYDROGEOLOGY

Based on the location of the springs and surrounding geological setting, almost all the springs are classified as depression type (Fig. 5) which are fed by groundwater residing in the loose, unconsolidated colluvial deposits formed due to in situ weathering, transport and deposition of weathered material forming the principal aquifer. There could be case of a combination types as well but no such strong evidence was found in the field. But taking into account the underlying geological setting, the fractured quartzites and weathered shales could also be feeding into the colluvial deposits saturating it. Therefore, to understand the hydraulic continuity across multiple litho-units, studying their orientations and properties was crucial for identifying the recharge areas.

Figure 6: A spring emerging out through the thick pile of loose colluvial deposit

Figure 7: A high altitude spring that forms main source of the village

Sr. No.	Spring Name	Spring Code	Spring Type	Discharge (lpm)	pH	EC (µS)	TDS (ppm)	Salt (ppm)	Temperature (°C)
1	Chara	CL-1	Depression	8.4	8.4	539	383	259	17.9
2	Konchokse	CL-2	Depression	21.7	8.3	554	393	261	12.1
3	Lungyet	CL-3	Depression	-	8.4	456	323	210	8.6
4		CL-13	Depression	7.7	8.2	620	442	294	11.6
5	Shingok	CL-14	Depression	-	8.2	540	386	252	9.2
6	Shingok-2	CL-15	Depression	4.5	8.1	648	461	301	8.5
7	Tizing	CL-23	Depression	-	8.1	555	395	257	9.4
8	Chumua	CL-19	Depression	-	8	710	507	326	5.7
9	Wkhang	CL-25	Depression	-	8.6	426	303	196	8.6
10	Saicha	CL-35	-	-	8.2	605	430	291	-
11	Chucha	CL-36	-	-	8.1	953	678	466	-

In-situ water quality testing of the springs in Chicham indicate water with TDS and Salinity ranges within the permissible limits. Majority of the spring being depression types are fed by the aquifer which is getting recharge on an annual basis maintaining lower concentrations of TDS and Salinity. However pH is a bit on the higher side ranging between 8-8.5. As per the drinking water standard *(IS 10500: 2012),* the water with the current pH range is fit for consumption. The presence of carbonaceous shales could be the reason for slightly higher pH. The discharge measurement was carried out in certain springs only. CL-2 showed high discharge (21.7 lpm) while others had discharges below 10 lpm.

RECHARGE RECOMMENDATIONS

Considering the local hydrogeological setting, interventions have to be carried out based on watershed approach. The spread of the loose colluvial deposit which forms the principal aquifer system feeding almost all the spring needs to be targeted for recharge interventions.

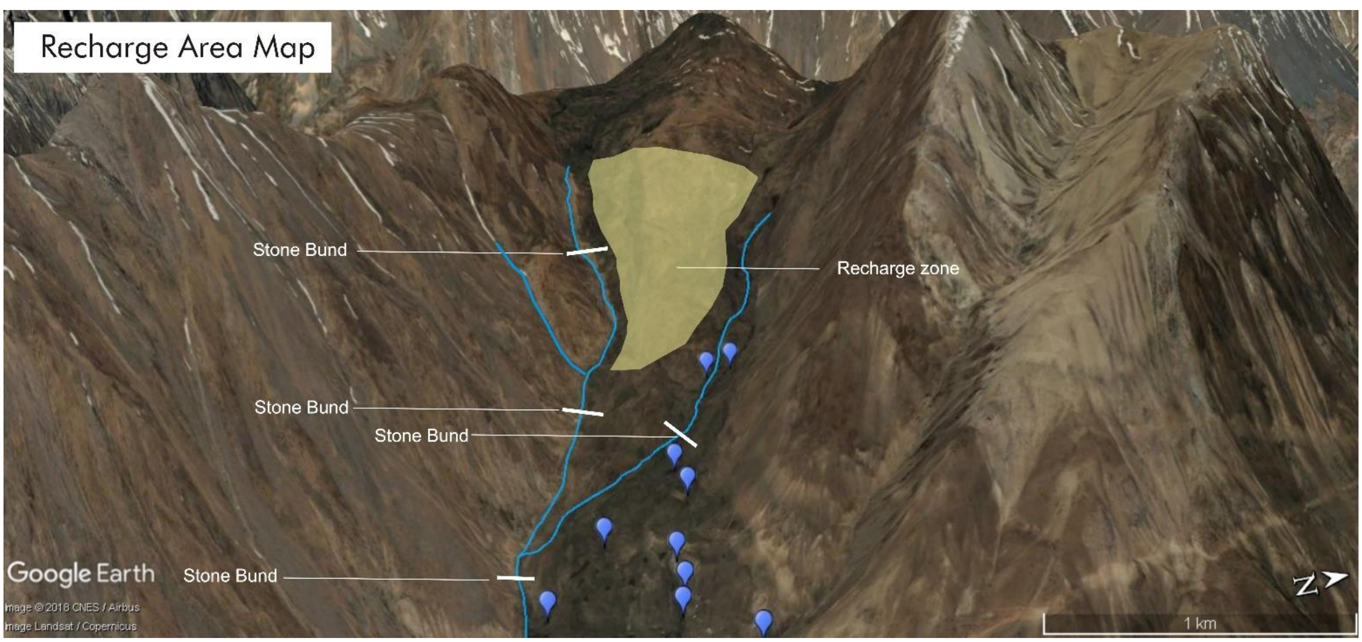

Figure 8: Google image showing recharge areas

The slope facing the NE direction is the ideal site for carrying out recharge interventions. However, the slope being steep will make it difficult to undertake any physical treatment measure like trenching, percolation pit etc. Therefore the other potential site for recharge is through the drainage network where some of the drainage line treatment measures can be planned. Stone bunds or loose boulder check dam construction across the stream channel will allow snow/rainwater to get accumulated facilitating recharge (Fig. 9).

Figure 9: Stone bund structure constructed in a stream channel (Source: Velu GP, Maharashtra)

The higher reaches of the watershed have natural depressions which will anyway trap snow/rain. However some physical recharge structures can be planned in the proposed recharge zone. Some primary recharge structures like staggered trenches (Fig.10), small percolation pit can be created to trap rainwater/ snow, which will facilitate recharge to the aquifer system feeding springs.

Figure 10: Staggered trenching on the slopes (Source: PSI, Dehradoon)

DEMUL VILLAGE

GEOLOGY

The geology of Demul village comprises dominantly of Quartzites with thin interbedded sandstone, Shales and Limestones (Fig.11). The village is situated in the lower reaches of the watershed. The geology of Demul is very much similar to that of Chicham. Based on geological observations and measurements, it is inferred that the watershed forms a part of synclinal fold.

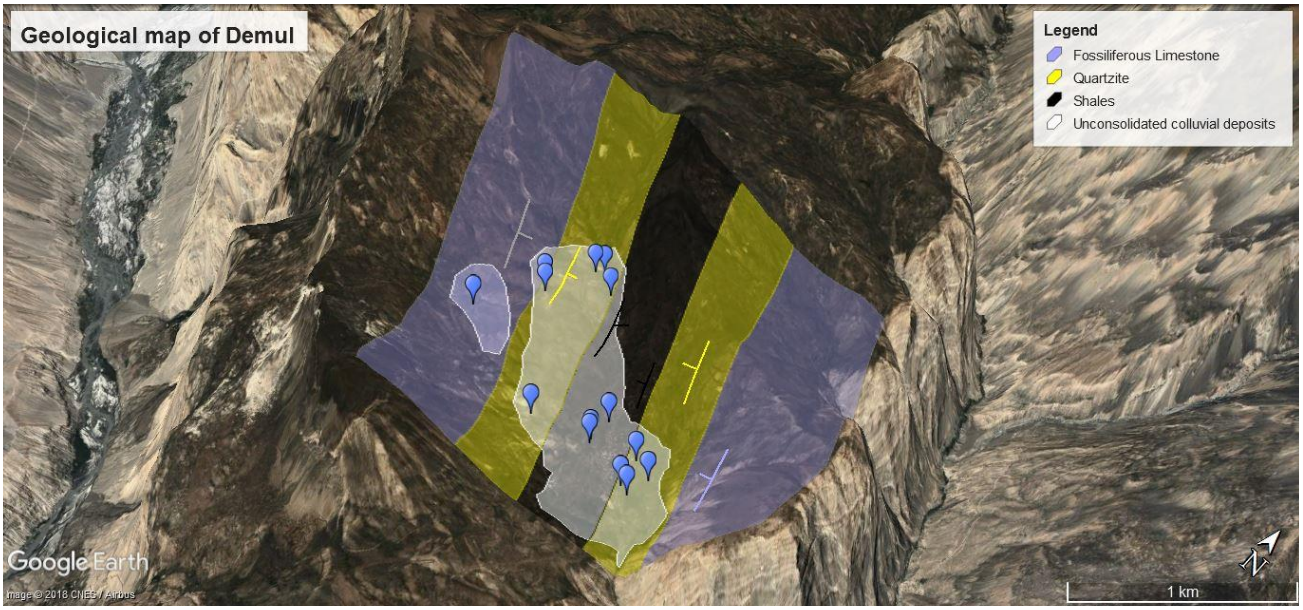

Figure 11: Geological map of Demul

The village here also sits on the top of loose colluvial deposits that is derived from the weathering and erosion of the existing rocks in the area. However unlike Chicham, Demul had much better rock exposures to bring about a better geological correlation. The shales are highly weathered as it forms a part of shear zone that traverses through the watershed (Fig. 12).

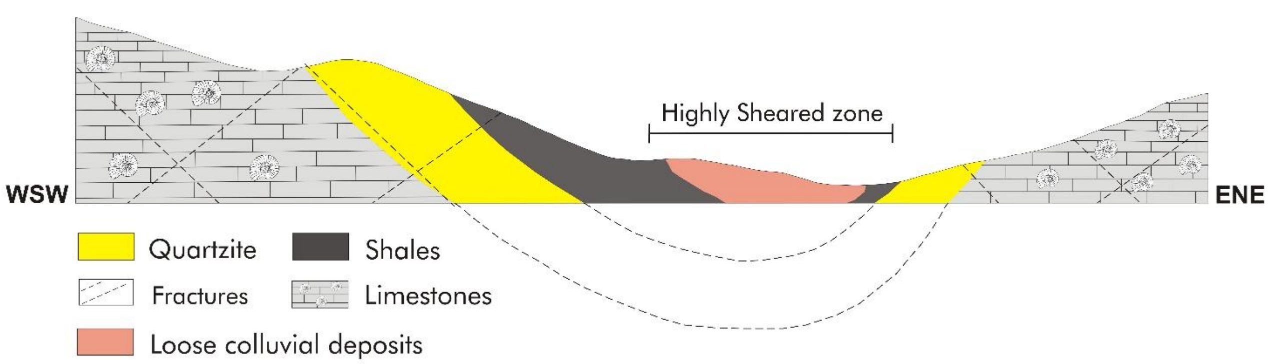

Figure 12: Geological cross section of Demul

The limestones and quartzite's are compact and fractured. The rocks on one side of the watershed have dips in the ENE while the rocks on the other side have dips in the WNW forming a syncline. The fractures have varied orientations. The most prominent ones traverse NW-SE dipping SW and NW-SE dipping NE. The degree of opening in these fracture sets vary across multiple exposures. The majority of the springs occur through the loose colluvial deposit forming depression types along with one fracture spring.

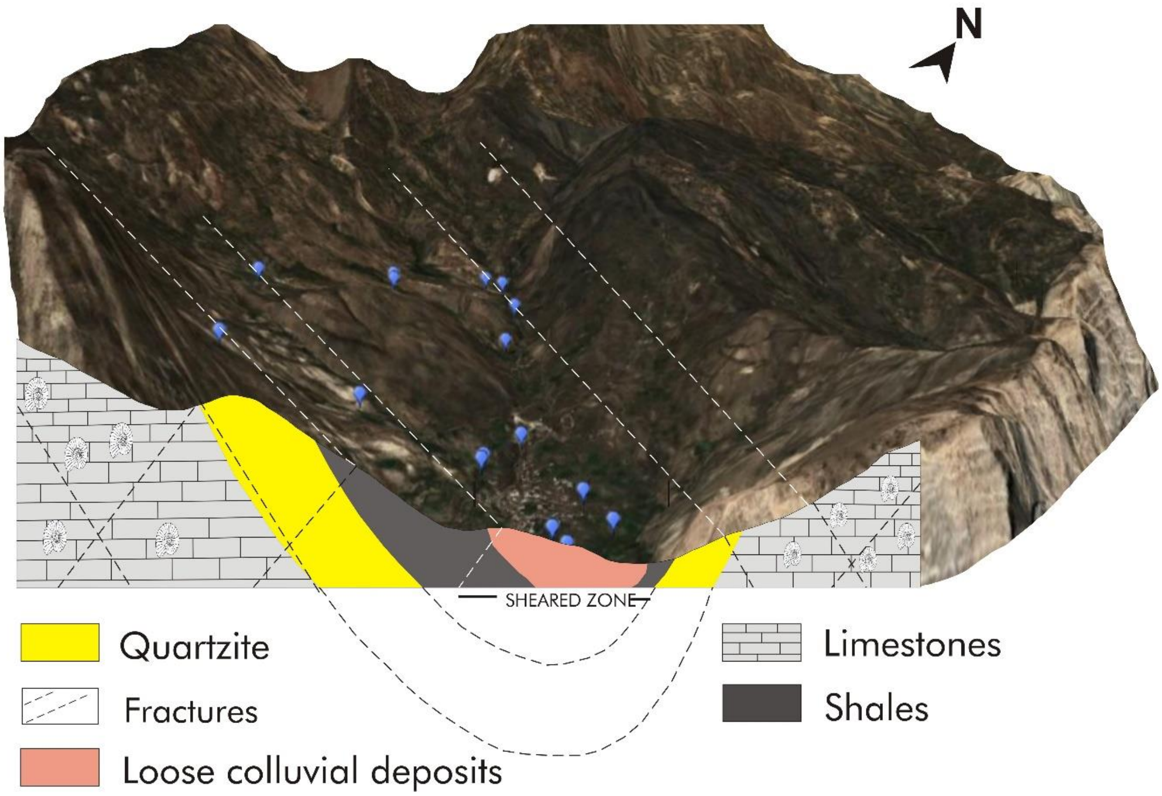

Figure 13: Geological map of Demul

HYDROGEOLOGY

Based on primary geological observations and spring locations, groundwater feeding the majority of the springs occur in the weathered shales (Fig.14) and loose colluvial deposit forming the main aquifer system. The synclinal structure facilitates groundwater to move towards the midst of watershed leading to the saturation in sheared-weathered shales and loose colluvial deposit. Some amount of groundwater also occurs in fractured limestones and quartzites. However, the groundwater in these fractures ultimately contribute to the main aquifer system owing to the structure present in the area (Fig.13).

Figure 14: A section showing fractured quartzite overlying weathered shales

Figure 15: A classical depression spring emerging out through loose colluvial deposits

Sr no.	Spring Name	Spring Code	Spring Type	Discharge (lpm)	pH	EC (µS)	TDS (ppm)	Salt (ppm)	Temperature (°C)
1	Thong Che	DL-1	Depression	-	8.7	730	520	347	11.5
2	Girimute	DL-3	Fracture	20	8.8	954	685	443	7.1
3	SiriChe	DL-5	Depression	5.8	7.8	1196	850	574	10.1
4	Lugum Spring	DL-6	Depression	15.8	7.8	1078	768	510	7.7
5	Kapchaphima	DL-12	Depression	-	7.8	452	323	206	7.7
6	Nugum	DL-14	Depression	8.7	7.8	1486	1050	710	7.36
7	KhapsaChurma	DL-16	Depression	-	8.6	434	307	208	21.1
8	Thaknak	DL-19	Depression	-	8.1	680	483	313	6.3

In-situ water quality testing of the springs (Table no.) in Demul indicate water having TDS and Salinity with higher range. Interestingly the springs that lie below the village which show higher values of TDS and Salinity. As per the drinking water standard *(IS 10500: 2012)*, some springs like DL-12, 16 and 19 have values within desirable limits while the rest are within permissible limits. However pH values of some springs are slightly outside permissible limits (more than 8.5) which could be due to the presence of limestones. Some more investigation is required to understand the relation between the water quality and geology in Demul.

Besides this it is crucial to carry out fecal coliform test on springs that lie below the village as the habitat sits on top of the aquifer which might be getting contaminated by human activities. A quick social survey will indicate fecal contamination if people are facing some regular gastric problems on consumption of water from these springs.

Depending on the feasibility, discharge of some springs was measured. DL-3 which is a fracture spring shows a reasonably high discharge and is used for drinking purpose by many. The high discharge indicates this spring to be of combination types but there was no such clear evidence. The other springs, which are of depression types, show fair discharge.

RECHARGE RECOMMENDATIONS

The slopes facing SW direction and E direction based on hydrogeological setting form the ideal site for undertaking recharge activities. The slope stability has to be accounted before undertaking any recharge intervention. Based on slope conditions, recharge structure like contour trenching (Fig.10) can be undertaken in the identified recharge zones (Fig. 16).

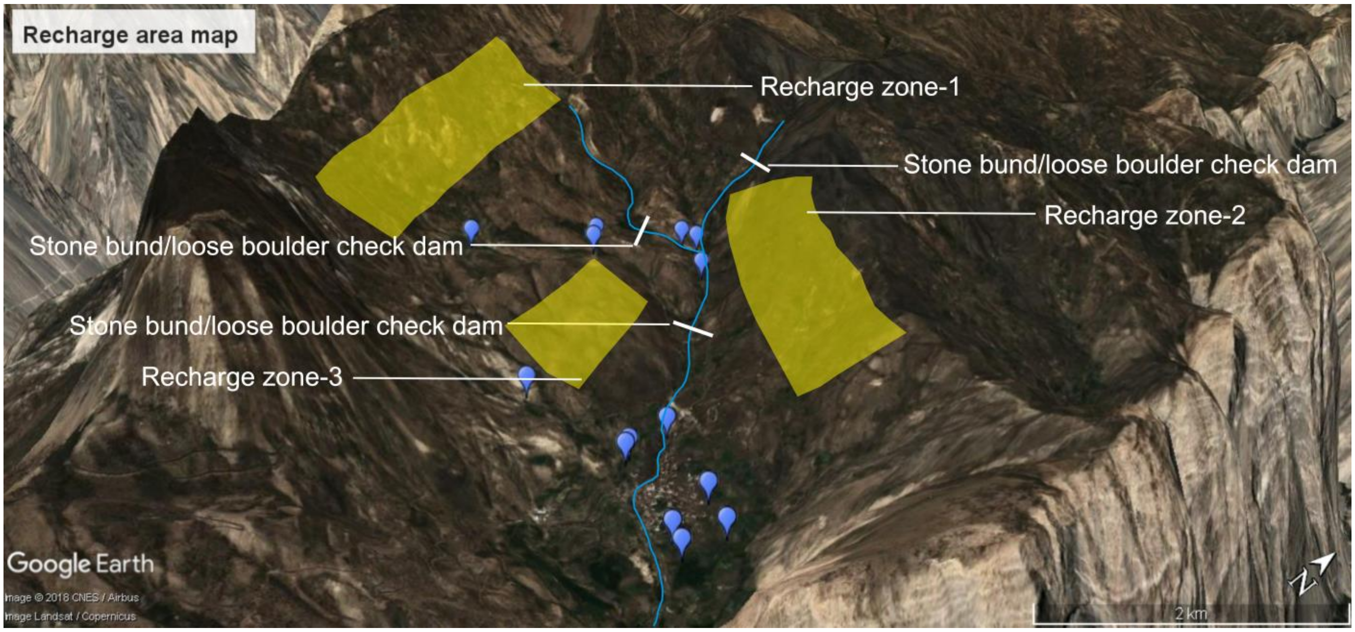

Figure 16: Google image showing recharge areas

The other potential sites for recharge is through natural drainage system, where Ecosphere has some intervention. Stone bunds or loose boulder check dam construction across the stream will allow snow/rainwater to get accumulated facilitating recharge. The above activities are planned with the intention to increase saturation levels in the aquifer to offer sustained discharge in the springs.

SUMMARY

Springs being the vital source of water in the mountains did not receive due attention in the past leading to an ever-widening gap in the understanding of the factors leading to their declining discharge. The Himalayan ecosystem is quite fragile and susceptible to several changes caused due to both natural dynamism and anthropogenic interventions. They are one of the world's most sensitive hotspots to climate change. Melting glaciers, erratic rainfall, less snow and rising temperatures are severely affecting the water sources.

Spiti has started witnessing the above effects leading to severe water crisis in the region. Much of snowfall in Spiti now takes place not in the peak winter, but during the second half of February and March. This snow is high in water content. Therefore, it does not stay at the source for long and, instead, simply flows down the valley, causing soil erosion. Irregular snowfall has made things worse. 2015-16 was an especially bad year for Spiti's farmers, with the valley receiving just around 2.5 feet of snowfall. 2016-17 was relatively better at almost 4 feet, but well below the average annual snowfall of about 7 feet for the region.

Some villages experimented with artificial glaciers to tackle the water crisis. However, it has turned out to be only a limited success. Ecosphere and ACWADAM based on the science of hydrogeology plans to develop snow-harvesting structures like the ones created in watershed programmes for harvesting water. The idea behind this approach is to artificially recharge aquifers by arresting snow and snowmelt and allowing it to infiltrate sub-surface instead of having a surface run-off.

The recommendations for recharge interventions proposed in this report are purely based on short-term hydrogeological assessment. It is important to monitor spring discharge regularly (*once a month*) to comment on any impact post intervention.

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