JULY 1, 2016

ACWADAM's recommendations

Based on fieldwork and analysis of results:

For KSL project, in partnership with ICIMOD

SPRING HYDROGEOLOGY OF DIKTOLI-SIM, PITHORAGARH (UTTARAKHAND-INDIA)

ACWADAM

Advanced Center for Water Resources Development and Management

SPRING HYDROGEOLOGY OF DIKTOLI-SIM
PITHORAGARH (UTTARAKHAND-INDIA)

INCLUDES CONCEPTUAL MODELS AND SUGGESTIONS FOR

GROUNDWATER RECHARGE LOCATIONS

Technical Report no: ACWA/Hydro/2016/H48

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INTRODUCTION

Chandak –Aulaghat Watershed (CAW) is located 20 km North West of Pithoragarh city, Bind block, Pithoragarh district, Uttarakhand, India and covers approximately 24.19 sq.km area. It is a combination of two sub-watersheds which in its upper reaches forms the greater Gorang valley or Gorang-Desh while at lower reaches it forms the Aulaghat watershed, located further West of Gorang valley. The watershed comprises of 23 villages of which 16 viz. Bhurmuni, Chanana Pande, Chedda, Dharapani, Dharigaon, Dhungabhul, Diktoli, Godiyagaon, Halpati, Kaante, Majheda, Nakot, Naikina, Ratwali, Sinchaura and Sintholi are located in Gorang valley while the remaining 8 villages viz. Baksil, Bans-Maitoli, Jajrauli, Khati Gaon, Maanu, Pabhai, Sainkanla and Sanghar forms the Aulaghat watershed. Currently, under the KSLCDI project, study is conducted in Diktoli, Bans, Pabhai, Jajrauli and Baksal village. The present document is focused on observations made in Diktoli-Sim.

The Gorang valley is a U-shaped valley filled with unconsolidated sediments at its centre with gently sloping ridges at the periphery. It stretches from N29°36.00'- N29°37.00' latitude to E80°09.00'- E80°11.00' longitude with elevation ranging between 1600m and 2100m. Upper reaches of the valley are covered with dense forest. All the water of the valley collects through various gads to form the Gaukarneshwar stream which is the main stream flowing through the center of the valley. It finally joins the Ramganga river flowing NE-SW at the western edge of the watershed.

On the basis of vulnerability assessment survey conducted by GBPIHED for the whole Gorang valley, Diktoli was proposed as pilot site for initiating the SSM activities. Diktoli is recognized as a micro-watershed. Sim is another village located on the other side of ridge and is a part of another adjacent watershed known as Sim watershed which is positioned north of Diktoli. Owing to their geological continuity, they both form a springshed which, from this point onward, can be referred to as ‘Diktoli-Sim Springshed’.

Diktoli is situated on the escarpment slope and Sim rests on the dip slope at westward and eastward side of the ridge respectively. Being a micro watershed, Diktoli has its own drainage system with three prominent gads which combine to form a single gad before finally merging into Gaukarneshwar stream at its base on the westward side of the ridge. While five major gads draining eastward exist in the Sim watershed, ultimately joining the Ramganga River which flows in NE-SW direction at its base. The gradient of the gads is highly steep allowing increased rate of erosion during monsoon and carry boulders in the matrix of debris, often breaching its own embankments. Sim, on other hand is relatively stable with a large number of cultivation land and dense forest cover at the top of the ridge. A trellis type of drainage pattern is observed in the springshed.

Rautgara formation of Damtha group which forms the base for overlying deposits of Deoban Formation is classified under Tejam group of rocks constituting a part of Inner Lesser Himalaya. In general, the Rautgara formation is characterised by slate while limestone and dolostone represents the Deoban formation. The age of these rocks have been estimated to range from 1400-800 million years old i.e., from Mesoproterozic to Neo-Proterozoic era.

GEOLOGICAL SETUP

The dominant rock types observed in the study area are quartzite, slate and limestone. Slate is generally found interbedded with thin beds of sandstone and is metamorphosed completely into phyllite. Thick bands of chert are also observed intercalated with powdered ferruginous sandstone. The beds are generally dipping in the NE direction striking N330° with dip angles varying from 9° to 30°. The inclination of beds drops progressively towards the dip direction.

The order of superposition of beds in the region, from SW to NE direction (Fig. 1), is massive quartzite at the base which forms its sharp contact with overlying compact sandstone bed (bajni naula emanates from this contact) after which a thick layer of quartzite is found. Above it lies massive bed of highly cleaved slate which gradually grades into greenish phyllites near the contacts. Phyllite is mostly observed as thin laminae intercalated between slate, sandstone and limestone. The interbedded sequence repeats itself until a massive slate bed is encountered overlain by thick limestone. Chert rests above the limestone in association with powdered sandy layer and thick sandstone bed. These are again overlain by slate above which massive quartzite is found.

The rocks have been subjected to metamorphism owing to the tectonics involved in the Himalayan orogeny. Slate gains the phyllitic character and the thickness of beds is highly reduced. A shear zone is also observed in the springshed in the vicinity where the rocks are highly sheared and fractured. Structurally, the regional setting of the rocks is controlled by tectonic activity evident in the study area. The structural features like fractures and joints are more prominent and sparsely distributed in massive and compact quartzite and limestone while less competent slate and phyllite exhibit ‘crumbled’ appearance. Two phases of deformation can be predicted from the analysis of measurement of sets of fracture planes. Gentle folding of the beds is also observed.

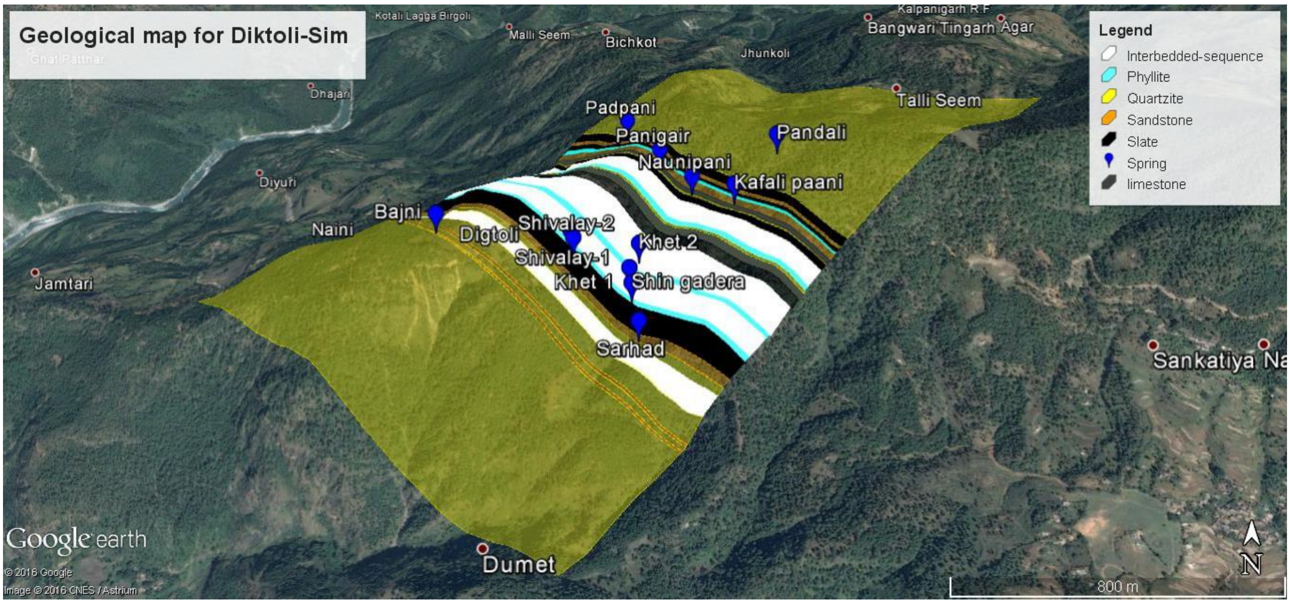


Figure1: Generalised Geological map of Diktoli-Sim Springshed showing lithological variation and location of identified springs.

HYDROGEOLOGY OF DIKTOLI-SIM SPRINGSHED

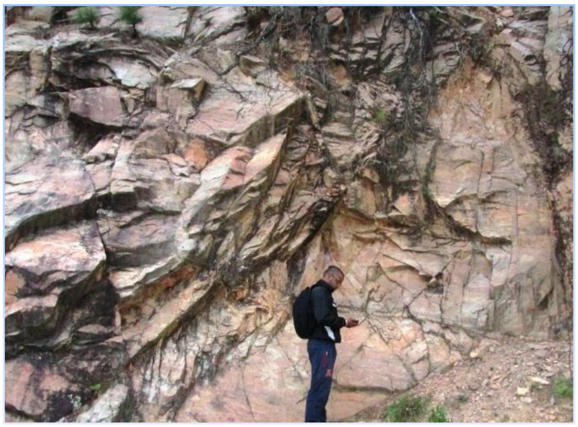
Springs emanate in the form of ‘naula’ and ‘dhara’. The inventory of 53 springs in the Gorang valley was done by GBPIHED. It can be concluded from the general observation made on the basis of plotting spring location in the study area that dhara emerge from the slopes where water table cuts the topography while naula frequently occur at lower reaches of the valley where the unconsolidated material is abundant. The analysis of the area suggests a probability of locally confined/unconfined aquifers controlled by fractures at places. They occur as springs at the intersection of aquifer with topography as depression springs.

Quartzite and limestone do not have any primary porosity and slate possess poor primary porosity and permeability. These rocks form the major portion of the study area. Phyllite is a regional metamorphic rock with well-developed cleavage surfaces but occur as thin bands at few places. Sandstone and ferruginous sandy layer has very good porosity and permeability. They are also found interbedded with chert which has no porosity at all and hence is likely to form a confining layer. But like phyllite these rocks again have a very limited extent. Therefore, the presence of sets of joints and fractures (Fig. 2) becomes very crucial for the development of secondary porosity and permeability in these rocks.

As mentioned earlier, these structural elements have developed as a result of tectonic activity initiated during the formation of Himalayan orogeny. The joints and fractures, thus produced, act as conduits for transmission and storage of water within the rocks although their distribution varies according to the rock type. Also, limestone is generally weathered forming cavities at places while the slate dominant lithology is eroded to form gads/gullies in the escarpment slope of the springshed.

In total 60 springs are identified in the Gorang valley including 7 springs in Sim Watershed. Particularly in the Diktoli-Sim springshed a total of 20 springs are identified (Table 1). Of these 20 springs, 3 springs are recognised for the implementation of SSM activities on the basis of FGD’s conducted by ICIMOD team. These are Shivalay, Naunipani and Dhara whose details are discussed further in this section.

(a)



(b)

Figure 2: Significance of fracture and joint set in imparting hydrogeological characteristics to (a) interbedded sequence of chert, phyllite and quartzite and (b) massive compact quartzite.

Latitude	Longitude	Elevation (m)	Code	Name	Village	Occurrence	Seasonality	Spring Type	Discharge (LPM)
29.62903333	80.1548	1631	CAWDG-01	Shivalay (a)	Digtoli	Depression	Perennial	Dhara	5.3
29.62911667	80.1548	1622	CAWDG-02	Shivalay (b)	Digtoli	Depression	Perennial	Naula	6
29.62925	80.1547	1621	CAWDG-03	Shivalay (c)	Digtoli	Depression	Perennial	Naula	1
29.63081667	80.15878333	1671	CAWDG-04	Naunipani	Digtoli	Fracture	Perennial	Dhara	2.3
29.63176667	80.1577	1759	CAWDG-05	Panigair	Digtoli	Depression	Seasonal	Dhara	0.06
29.6278	80.15675	1549	CAWDG-06	Shin gadera	Digtoli	Depression	Perennial	Dhara	6
29.62638333	80.15698333	1546	CAWDG-07	Sarhad	Digtoli	Fracture	Perennial	Naula	1.07
29.63121667	80.1616	1826	CAWDG-08	Pandali	Digtoli	Fracture	Perennial	Naula	
29.63001667	80.16015	1702	CAWDG-09	Kafali paani	Digtoli	Fracture	Seasonal	Dhara	0.12
29.62833333	80.15666667	1590	CAWDG-10	Khet 1	Digtoli	Depression	Seasonal	Dhara	
29.62911667	80.15698333	1561	CAWDG-11	Khet 2	Digtoli	Depression	Perennial	Dhara	2.9
29.62933333	80.15028333	1700	CAWDG-12	Bajni	Digtoli	Contact	Seasonal	Dhara	0
29.63375	80.15655	1673	CAWDG-13	Padpani	Digtoli	Fracture	Perennial	Naula	
29.63730556	80.159	1753	CAWS-14	Cham Naula	Malli Sim	Depression	Perennial	Naula	
29.63586111	80.16122222	1710	CAWS-15	Angu Naula	Talli Sim	Depression	Seasonal	Naula	0.02
			CAWS-16	Birkhati Naula	Talli Sim		Perennial	Naula	0
29.63630556	80.16166667	1700	CAWS-17	Dhara	Talli Sim	Depression	Perennial	Dhara	3.6
29.63544444	80.15127778	1772	CAWS-18	Gogin Gad	Malli Sim	Depression/ Fracture	Perennial	Naula	
29.63494444	80.152	1791	CAWS-19	Ghati Gad ka Naula	Malli Sim	Depression/ Fracture	Perennial	Naula	
29.63427778	80.16552778	1816	CAWS-20	Jadyo Naula	Malli Sim	Depression	Seasonal	Dhara	

Table 1: Spring inventory sheet of Diktoli-Sim Springshed

Shivalay group of springs

Location	Latitude N29.62903	Longitude E80.1548	Elevation 1631 m	
Discharge	1.03 lpm			
Water Quality	pH- 7.3	EC- 520 µS	Salt- 251 ppm	TDS- 370 ppm
	Temperature- 22.2 °C			
Spring Type	Fracture-Depression			

Shivalay group of springs is situated near the base of Diktoli micro-watershed and comprises of a dhara and two naulas. Dhara is commonly used for drinking water purpose. Also a storage tank is constructed for other domestic uses in the proximity of the springs where water from dhara is collected. The springs emerge besides a gadhera through a thick pile of unconsolidated debris. A depression cone lies above the spring in NW direction (Refer to Fig. 3a and 3b). The west and NE flanks of the depression cone are marked by gentle to steeply sloping gad, forming water divide on both the sides. It is a perennial spring in which, after the onset of monsoon, the water overflows through the slate outcrop on the northern edge of unconsolidated debris.

Massive and fractured slate is the dominant rock type. The slate outcrop is observed above and below the springs. Slate is found dipping in the NE direction with two major fracture set, one set dipping SE while another set dipping NW with joint plane along the bedding. These fractures in slate also account for water storage and transmission wherein they too feed the unconsolidated debri cover overlying it. The water is collected in the depression cone formed by unconsolidated debris and emerges out at the point where the topographical depression is met. Hence it is classified as both fracture and depression spring. The perennial nature with sustained discharge, even during the lean summer season, suggests that aquifer system for Shivalay has good storage.

Recharge measures

Considering the geomorphology of the area, the natural depression above the springs can be the potential recharge area for implementing SSM activities (Refer to Fig 3c and 3d). The orientation of fracture sets would be important with regards to transmission and thus fracture trends should be taken into account while implementing recharge structures (Refer to Fig. 3b). Staggered contour trenches can be implemented as per details included in *Dhara Vikas Handbook (Govt. of Sikkim, GIZ publication).* Since recharge area encompasses cultivation land as well, certain structures like recharge pits can be implemented. Also inward sloping (in the dip direction) of agricultural fields will help in additional recharge to the aquifer.

Taking into consideration good forest cover on the escarpment slope, it can be demarcated as protection zone to preserve natural conditions (Refer to Fig. 3d).

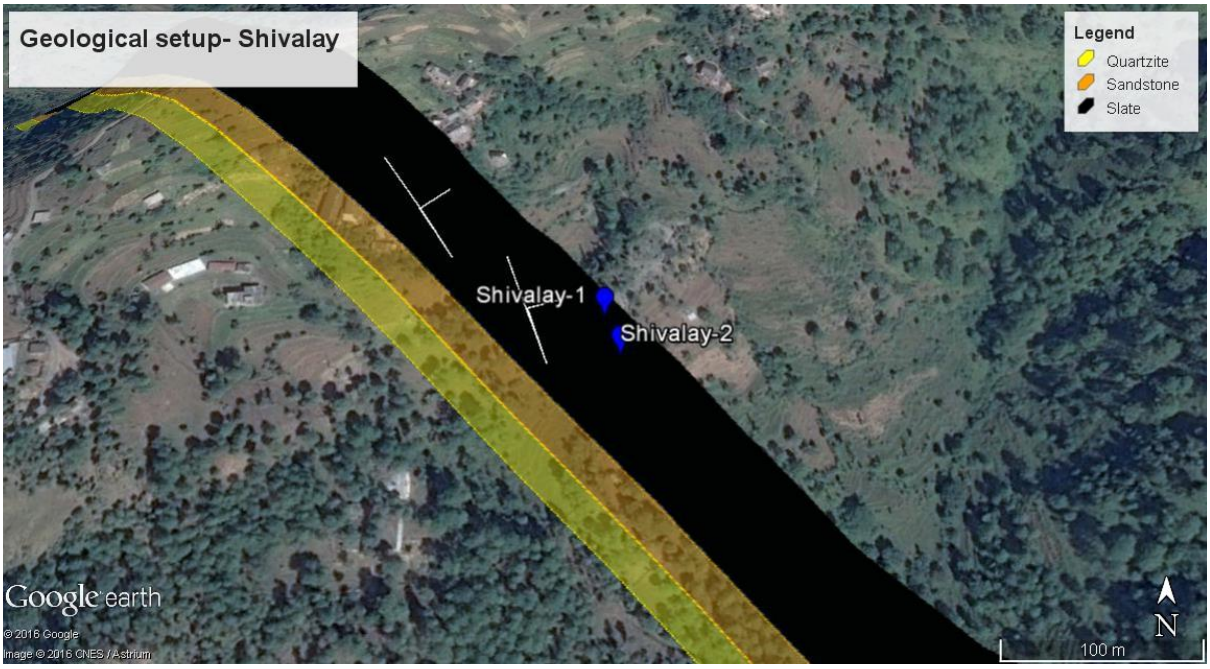


Figure 3a: Geological layout of Shivalay group of springs on Google image.

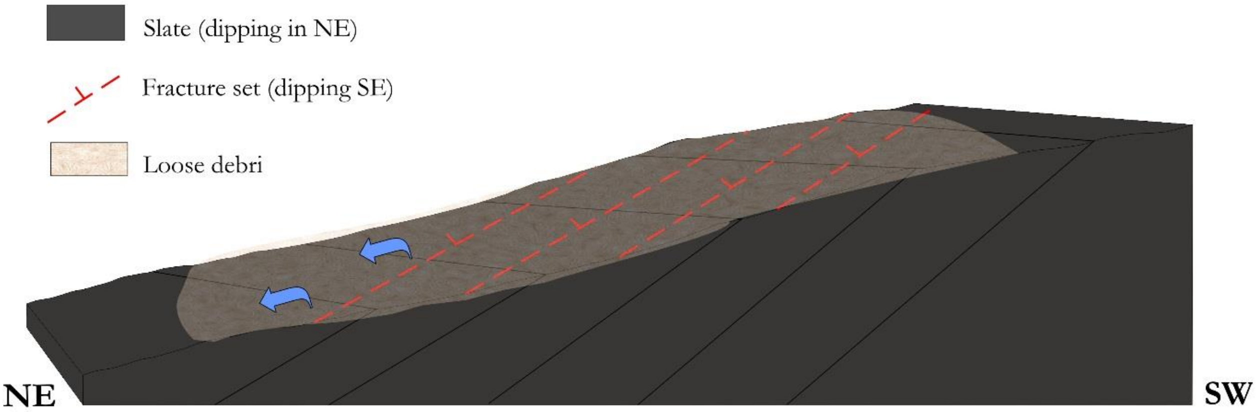


Figure 3b: Conceptual layout of Shivalay group of springs exhibiting geological setup

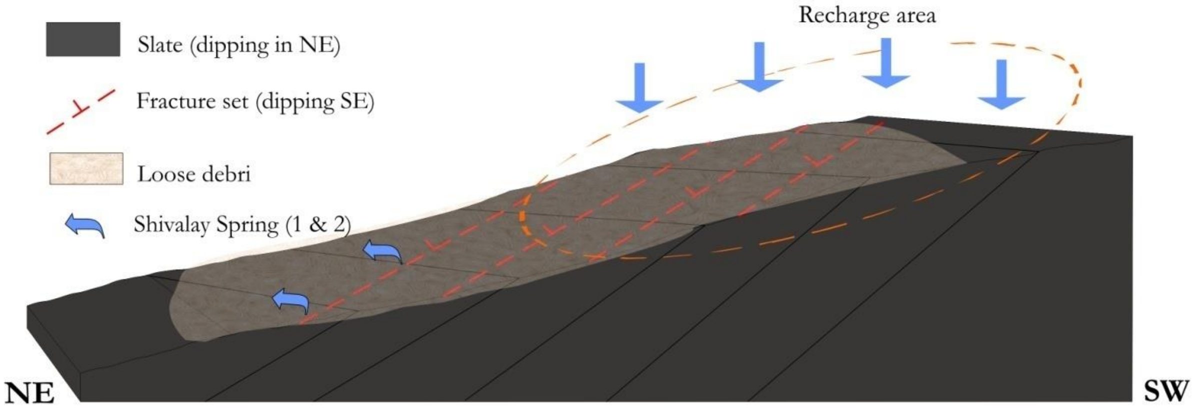


Figure 3c: Conceptual layout of Shivalay group of springs demarcating the recharge zone and dominant fracture set to be considered before implementing recharge measures.

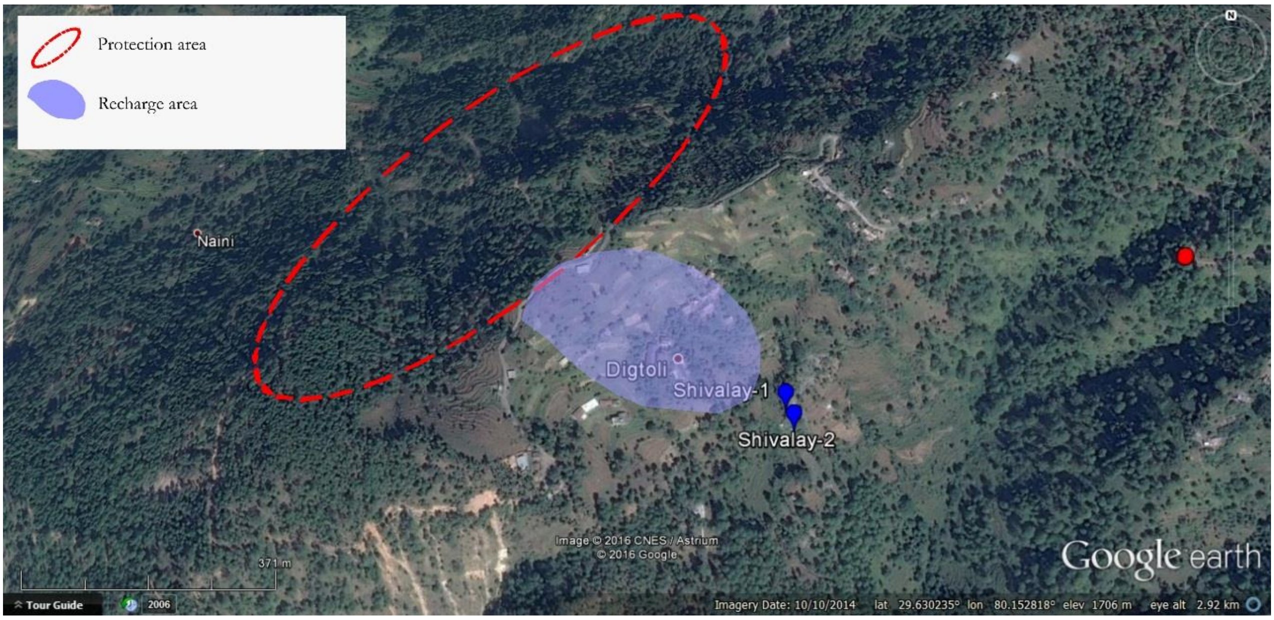


Figure 3d: Recharge zone demarcation on Google Image

Naunipani

Location	Latitude 29.63081667		Longitude 80.15878333	Elevation 1671 m
Discharge	1.25 lpm			
Water Quality	pH- 7.66	EC- 545µS	Salt- 269 ppm	TDS- 395 ppm
	Temperature- 20 °C			
Spring Type	Fracture			

Naunipani spring is a dhara, situated on steeply sloping Nauni-gad which is located in the upper-middle reaches of the Diktoli micro-watershed. It is a perennial spring whose discharge reduces during the lean summer season. After Shivalay, the dependency of people is highest on this spring, especially the lower caste people residing in the Dadipata region. It is a series of springs initiating from Pandali naula at the top of the ridge and goes beyond Shin gadhera at its base.

It is located on the escarpment slope where outcrop is revealed along the strike of the beds thereby exposing various rock types encountered along the highly eroded Nauni-gad section (Refer Fig. 4a). The dominant rock types observed along the Nauni-gad are interbedded sequence consisting of phyllite, slate, quartzite, sandstone and chert. The beds are gently dipping towards the NE direction with dip amount varying from 15° to 35°. A massive limestone bed with cavities is present in the NNW direction from the spring. The interbedded sequence is traversed by two set of fractures, one dipping in the SE while another one dipping in the NW, playing a major role in accumulation and movement of groundwater. Emergence of spring is through these fracture sets. Recharge area for the Naunipani lies close to it in the upper reaches of the slope.

Recharge measures

Recharge area demarcation becomes crucial while taking into account the varied conditions present in the springshed. Recharge measures should be taken considering the dip direction of the rocks in association with the orientation of fractures. Adhering to this fact, the recharge area is found to be situated towards the NW direction of the spring location where the rocks above Naunipani cuts the surface (Refer Fig. 4b and 4c). Staggered contour trenches can be implemented as per details included in *Dhara Vikas Handbook (Govt. of Sikkim, GIZ publication).*

Stream adjacent to the spring can be treated with gully plugs to check erosion and facilitate additional recharge into fractured aquifer feeding the spring.

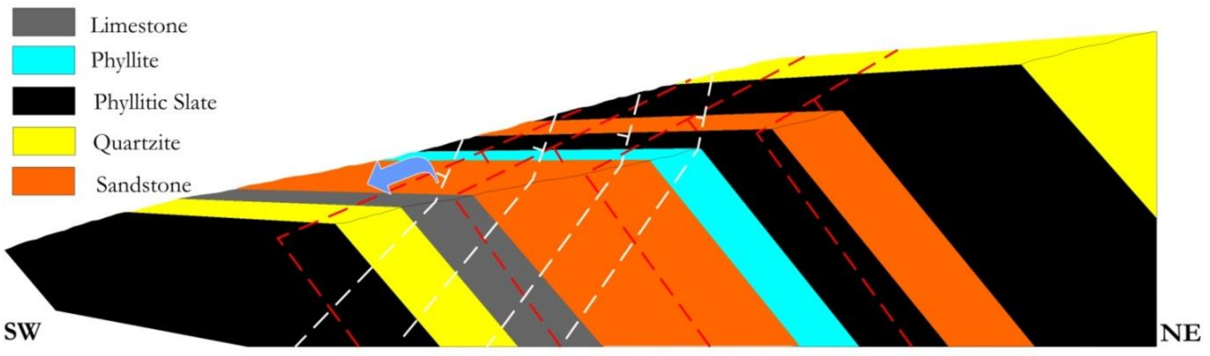


Figure 4a: Conceptual layout for geological setup of Naunipani spring.

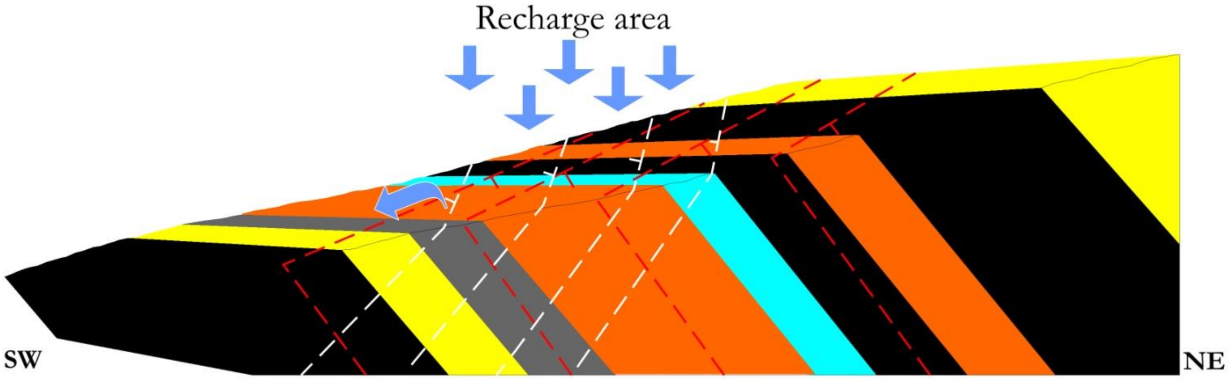


Figure 4b: Conceptual layout of Naunipani spring demarcating the recharge zone and dominant fracture set to be considered before implementing the recharge measures.

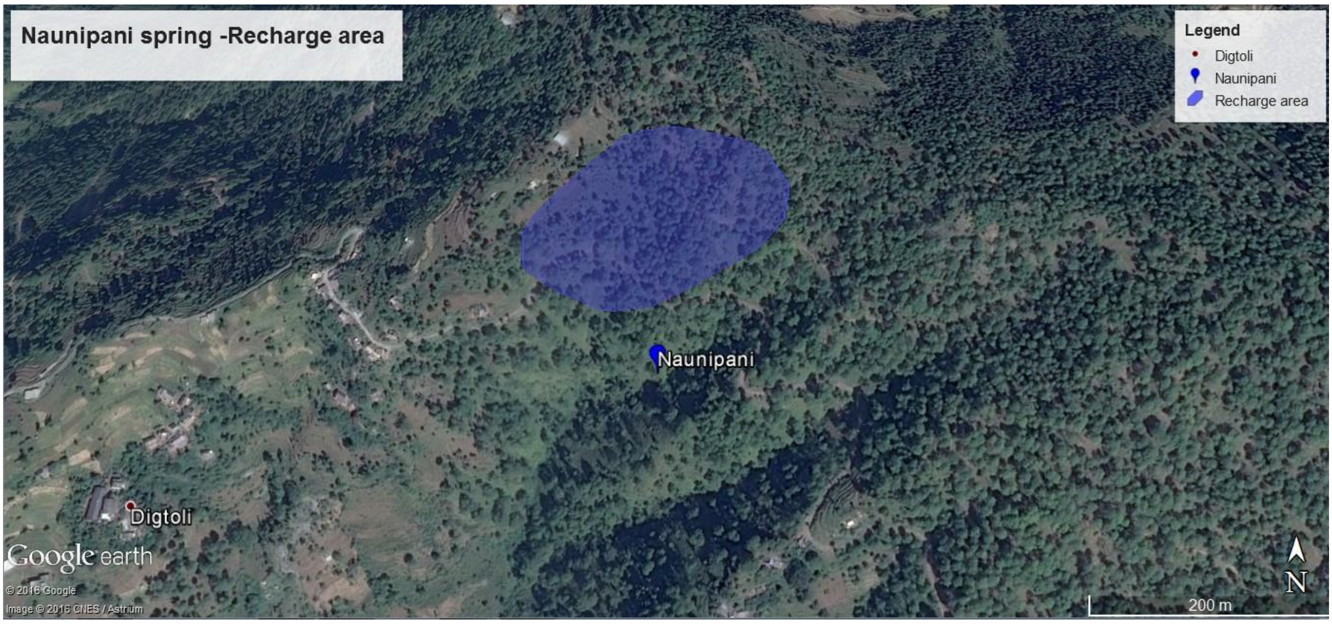


Figure 4c: Demarcation of recharge area for the Naunipani spring

Dhara

Location	Latitude 29.63630556	Longitude 80.16166667	Elevation 1700 m	
Discharge	5.3 lpm			
Water Quality	pH- 7.7	EC- 69.6 µS	Salt- 36.8 ppm	TDS- 49.4 ppm
	Temperature- 19.9°C			
Spring Type	Depression			

Dhara forms a typical depression spring emerging amidst fields on the dip slope in Talli Sim village. A very thick loose sediment cover on the slope forms a major aquifer feeding this spring. It is a perennial spring with discharge (mentioned above) enough to supply water even during lean summer period to the inhabitants of both Malli and Talli Sim which also indicates that the dependency on this spring is fairly high. Slope bears a very dense and pristine forest cover right till the top of the ridge (Refer to Fig. 5a and 5b).

The loose sediment cover on the slopes which has stabilised over many years, bears very high storage capacity. As the emergence of spring is on the dip slope, recharge area lies on the same slope.

Recharge measures

As mentioned above, the existing forest cover should be kept virgin and demarcated as protection zone (Fig. 5c and 5d). Deforestation, waste disposal and open defecation should be strictly prevented in this zone to preserve natural system and ensure good quality water. Forest cover also encompasses agricultural farm lands in patches in the upper and middle reaches of the slope (Fig. 5b). These farms can be treated with deep recharge pits along with inward slope facing to facilitate additional recharge to the aquifer system.

Figure 5a: Dhara spring in Talli Seem

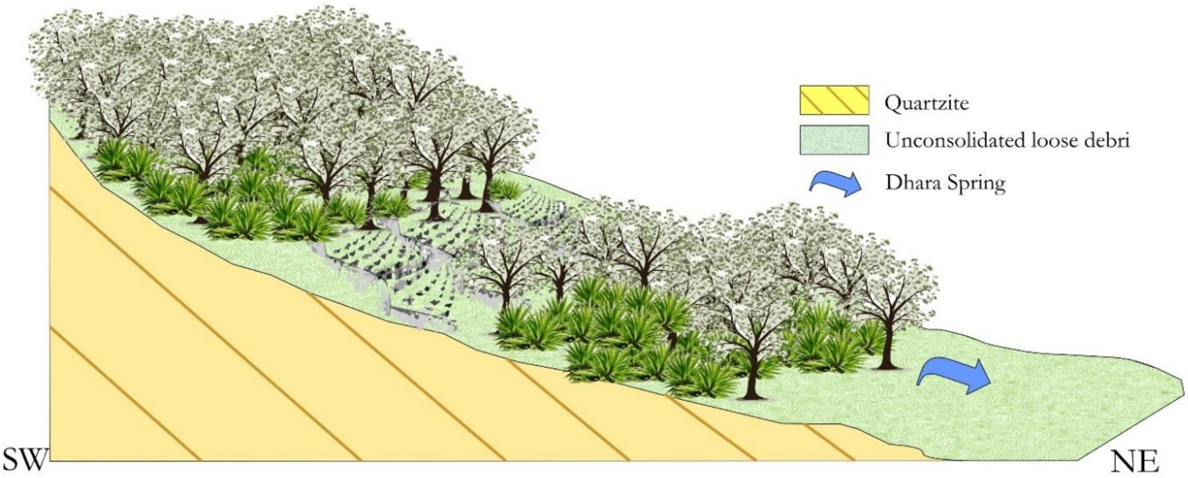


Figure 5b: Conceptual layout revealing geological setup of Dhara spring.

Figure 5c: Google earth imagery exhibiting the demarcation of protection zone for Dhara spring.

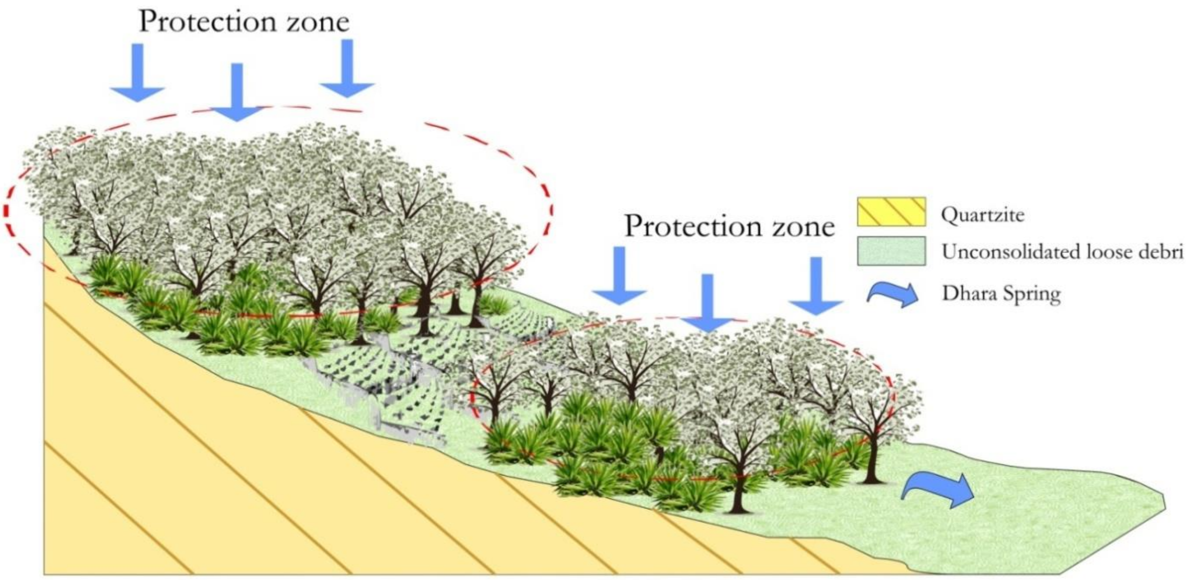


Figure 5c: Conceptual layout of Dhara spring demarcating protection zone