DAILEKH SPRINGS: HYDROGEOLOGY

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Based on fieldwork and synthesis of results: for WLE Project,
in partnership with ICIMOD

INCLUDES CONCEPTUAL MODELS AND SUGGESTIONS FOR GROUNDWATER RECHARGE SITES

TECHNICAL REPORT NO. ACWA/HYDRO/2017/H63

ACWADAM

ADVANCED CENTER FOR WATER RESOURCES DEVELOPMENT AND MANAGEMENT

INTRODUCTION

ACWADAM's hydrogeological investigations in Dailekh involved the study of 10 springs where detailed geological studies and spring monitoring was carried out. The following springs were studied based on spring selection criteria applied from previous reconnaissance visits and through the social mapping tool applied by Helvetas, a partner on the WLE project.

1. Bukakhali Dhara
2. Buspani spring
3. *Dharma khola / Maikarol mul (Vaikarol mul)*
4. Batokuwa mul
5. Kathnaula mul
6. Ganja Khanepani
7. Kanna mul / Dhara khola
8. Badarukha mul
9. Tallodhara mul
10. *Lekhkhet mul*

Geological and hydrogeological data was collected for mapping of the springsheds of 10 springs mentioned above. Steps 3, 4, 5 and 6 from the training manual developed under the WLE programme, were followed in developing a conceptual model for each of the springs / spring clusters that included a simplified description of the geology based on hydrogeological mapping, identifying the typology of the springs including a reference to the aquifer system(s) below and then mainly to the precise identification of the recharge zone for each of the springsheds. Similarly, a set of measures within the recharge area has been suggested in the case of each of the springs. Rock type found in the field area was Phyllitic schist with lenses of Gritty phyllite and quartz.

GEOLOGY

All the springs are located along a WNW-ESE trending ridge, northeast of Nepa. The ridge slopes westward with valleys to the north, south and west. The ridge is underlain by southwesterly dipping rocks, dominated mostly by a sequence of low-grade schists with quartz veins and fractures marking the contacts between the major lithological elements. While the dips of rocks change locally, they generally follow a north-dipping pattern. There are various fracture sets, some of which are regional, while others local. One clear set of fractures runs roughly NS and controls the course of some streams that flow along the slopes, although the regional drainage is westerly with the lower order streams and the highest order drainage (rivers) largely following the strike of the major geological formations.

A regional perspective showing the two major lithologies that influence spring systems in the project location. Green colour accounts for areas dominated by Schists.

1. All ten springs were visited but data could be collated for 8 of the above listed springs. Data was not complete for Lekhkhet mul and Dharmakhola mul in order to complete their hydrogeological conceptualisation.
2. Of the 8 springs, 4 springs are exclusively of depression type, 3 springs are fracture springs and one spring is a combination type
3. All the aquifers are phreatic aquifers, although studies with details would be required to establish if at least two of the fracture springs also receive discharge from deeper aquifers; however, the data collected during this study do not conclusively show evidence of deep transmission of groundwater for any of the springs, particularly their water quality data.

Bukhakhali Spring

Location	Latitude 81.5463º	Longitude 28.8938º		Altitude 876 m asl
Discharge	3 lpm			
Water quality	pH 7.23	TDS 348 ppm	Salts 32.7 ppm	Temp 21.9 ºC
Type	Contact Spring			

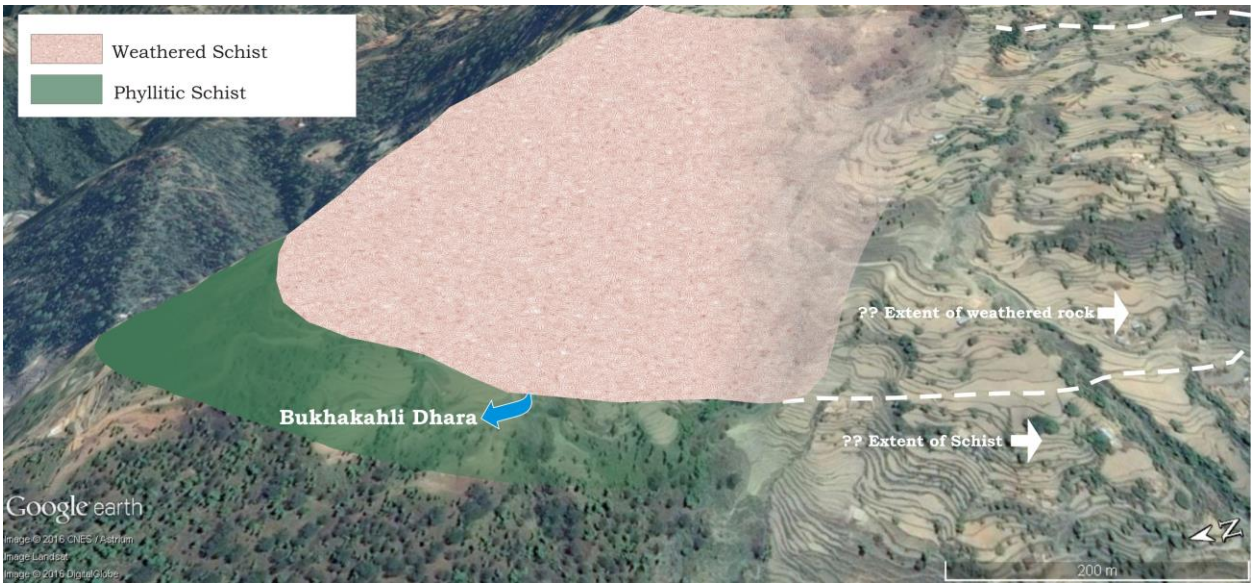
Hydrogeology and recharge zone

The springshed is constituted of NW dipping rocks, with dips in the range of 25º to 40º with average dips of 30º. The softer weathered rocks overlie the more durable and consistent schists. There are quartz veins in some locations at the contact zone between phyllite and quartzite's, especially on the south-facing escarpment ridge in the Bukhakhali springshed. The spring emerges on the NW-facing slopes below the contact between the weathered rock (upslope) and Phyllitic Schist (downslope). It emerges well and truly at the contact of weathered rock above underlained by Schist indicating shallow unconfined aquifer within the weathered rock. Hence, it is classified as a *Contact* spring.

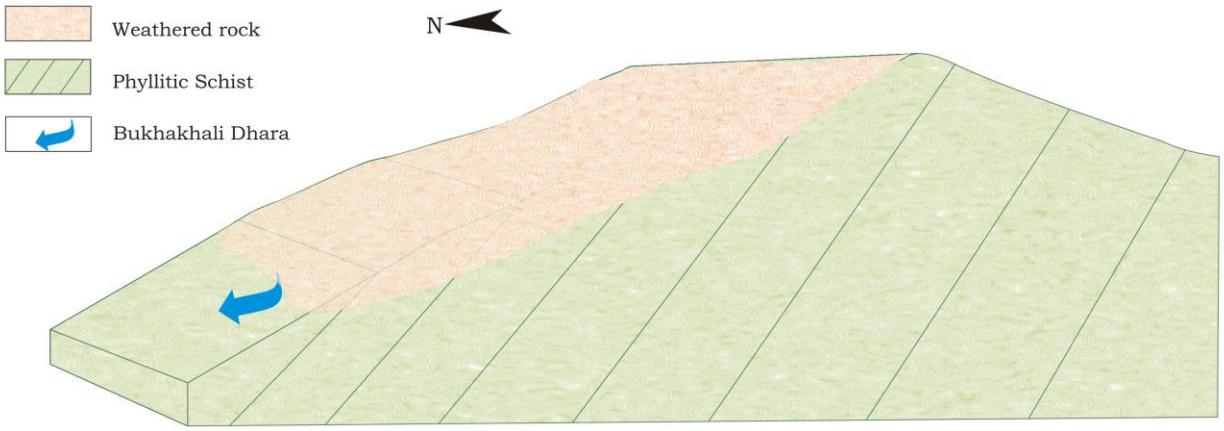
While the spring emerges in what is the discharge zone of the weathered rock aquifer, its recharge zone lies at the top further upslope. The recharge and discharge zones of the aquifer are exposed on the same slope. In other words, the recharge zone is on the same slope as that where the spring emerges.

Recharge measures

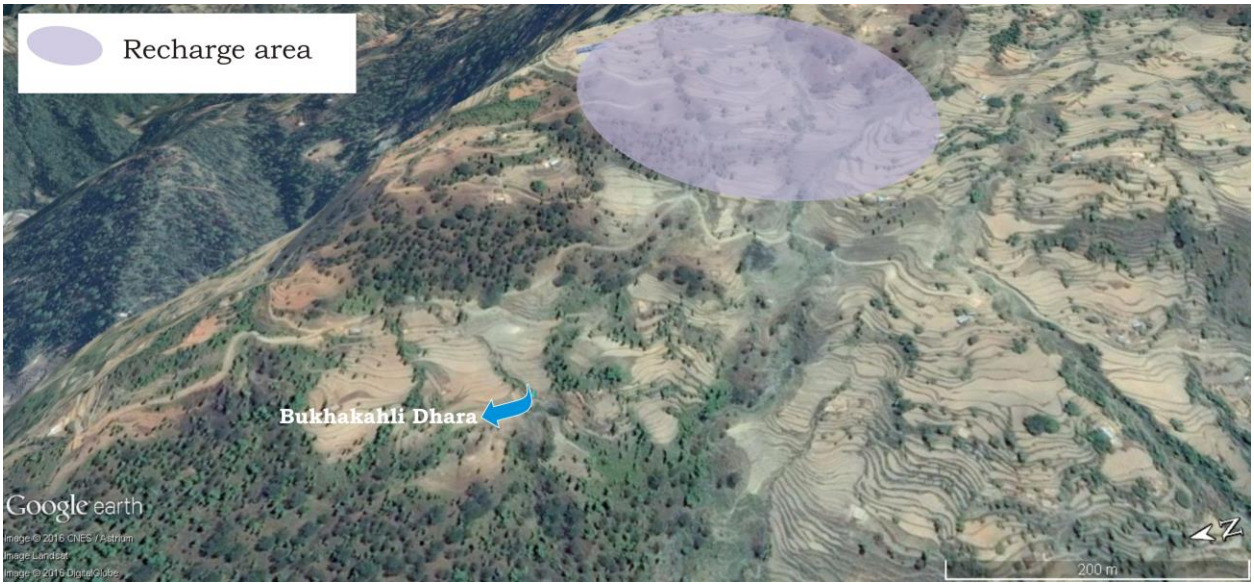
Given that the slopes are variable across the recharge zone that roughly follows the slopes in the springshed, the major set of measures will include 'staggered contour' trenches that have dimensions of 2m x 0.6 m x 0.45 m (length X width X depth). The distance between trenches along a contour should be 1.22 m while the distance between contours along which two sets of trenches are to be made should be 4.6 m. Details, including a table for reference is provided in the *Dhara Vikas Handbook (Govt. of Sikkim, India and GIZ publication).* Terrace farms, which already prevail on the slope, can facilitate recharge if terraces are made with inward facing slopes. Sinkholes (small pits) at every corner of the farm will also account for some amount of recharge.



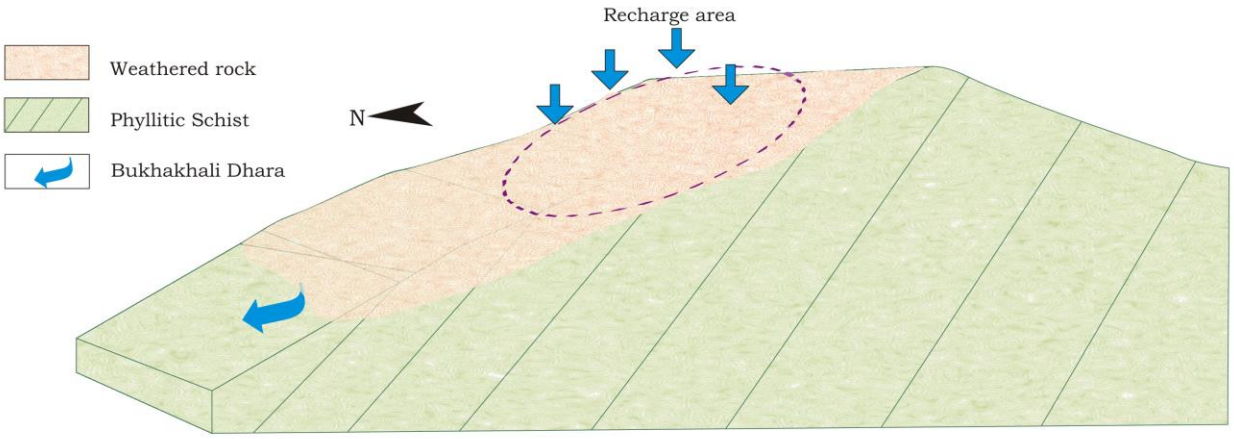
(a) Overlay of main lithological types in Bukhakhali spring on Google Image



(b) Conceptual layout of Bukhakhali springshed



(c) Overlay of recharge zone on Google Image (Bukhakhali springshed)



(d) Conceptual layout of Bukhakhali springshed including demarcated recharge zone

Ganjakhanepani Spring and Kathnaula mul

Ganjakhanepani spring

Location	Latitude 81.5683º	Longitude 28.89438º	Altitude 1031 m asl	
Discharge	3 lpm			
Water quality	pH 6.87	TDS 74.9 ppm	Salts 50.9 ppm	Temp 15.8 ºC
Type	Fracture spring			

Kathnaula mul

Location	Latitude 81.567º	Longitude 28.89203º	Altitude 1084 m asl	
Discharge	Not measured			
Water quality	pH 7.68	TDS 96.9 ppm	Salts 65.5 ppm	Temp 15.7 ºC
Type	Depression spring			

Hydrogeology and recharge zone

The springshed is constituted of northerly dipping rocks. The dip direction swings from NW to NE as one travels from north to south. The dips are steep along the northern slope - in the range of 50º to 60º with average dips of 55º. Further, south, the dips are a little gentler, in the range of 40º to 45º. The softer unconsolidated material overlies the more durable and consistent schists on the northern slope where the Kathnaula spring emerges. The spring emerges through the unconsolidated material (downslope). It emerges where the water table in the shallow unconfined aquifer cuts the topography (discharge zone). Hence, it is classified as a *depression* spring.

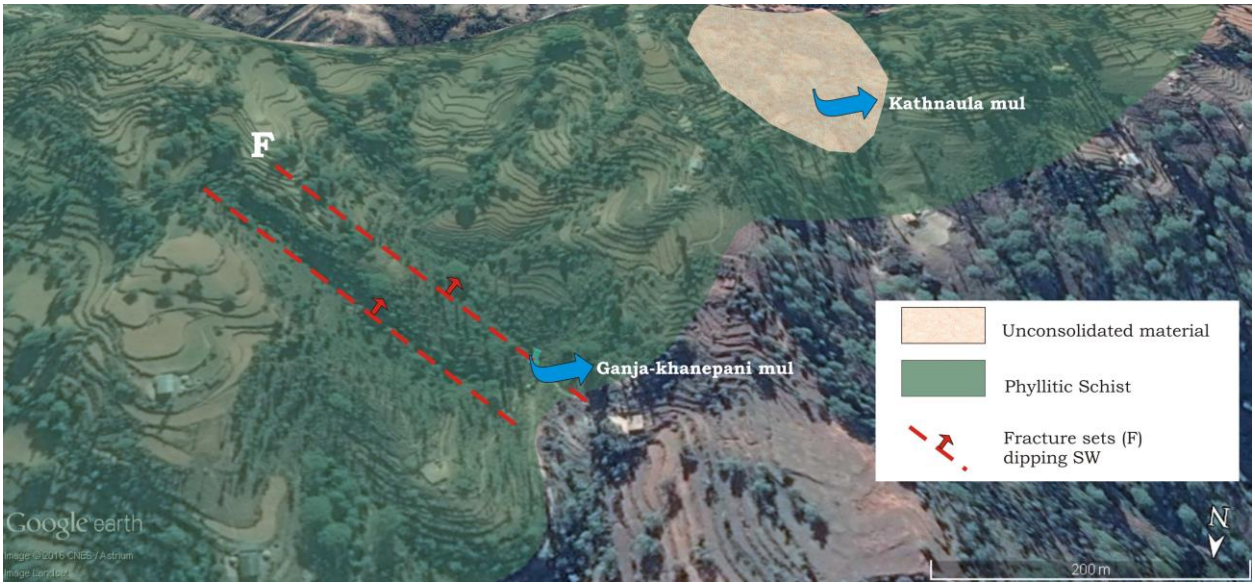
While the spring emerges in what is the discharge zone of the unconsolidated debris aquifer, its recharge zone lies at the top further upslope. The recharge and discharge zones of the aquifer are exposed on the same slope. In other words, the recharge zone is on the same slope as that where the spring emerges.

On the other hand, the Ganjakhanepani mul emerges further downslope, on the northern slope from within the relatively more compact and indurated schist. However, it is located along a fracture zone that traverses the schist. The fracture trends 110º to 290º, i.e. ESE-WNW, and controls the spring emergence very clearly. Hence, this is a fracture spring, with its transmission and storage of groundwater controlled by the fracture zone in schist. The spring is part of a highly local aquifer that may have some depth but limited extent. The recharge zone for GanjaKhanepani spring is located along the fracture trace on the northern slope. In the field, there is clear evidence of infiltration along the fracture zone through the presence of red, coarse-grained soil.

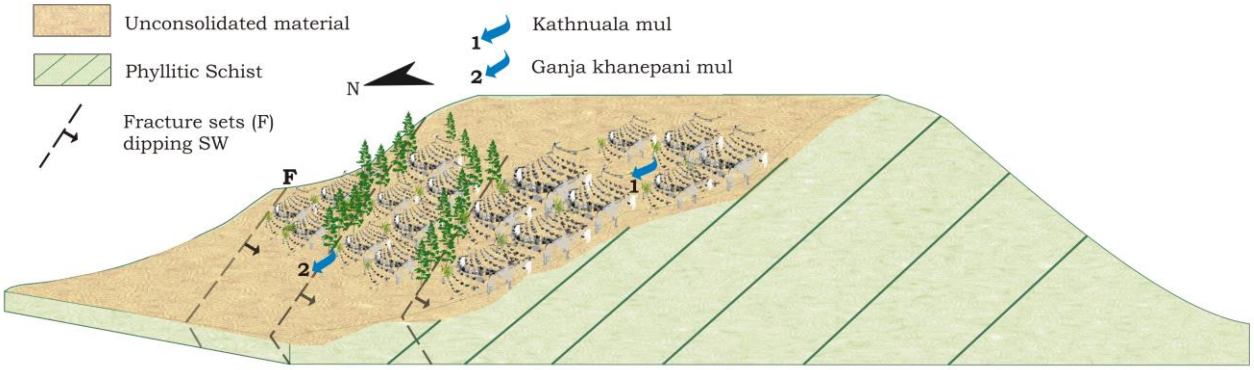
Recharge measures

Kathnaula mul: Given that the slopes are variable across the recharge zone that roughly follows the slopes in the springshed, the major set of measures will include 'staggered contour' trenches that have dimensions of 2m x 0.6 m x 0.45 m (length X width X depth). The distance between trenches along a contour should be 1.22 m while the distance between contours along which two sets of trenches are to be made should be 4.6 m. Details, including a table for reference is provided in the *Dhara Vikas Handbook (Govt. of Sikkim, India and GIZ publication)*. Tree plantation on immediate slope along the ridge will avoid soil erosion protecting aquifer feeding this spring.

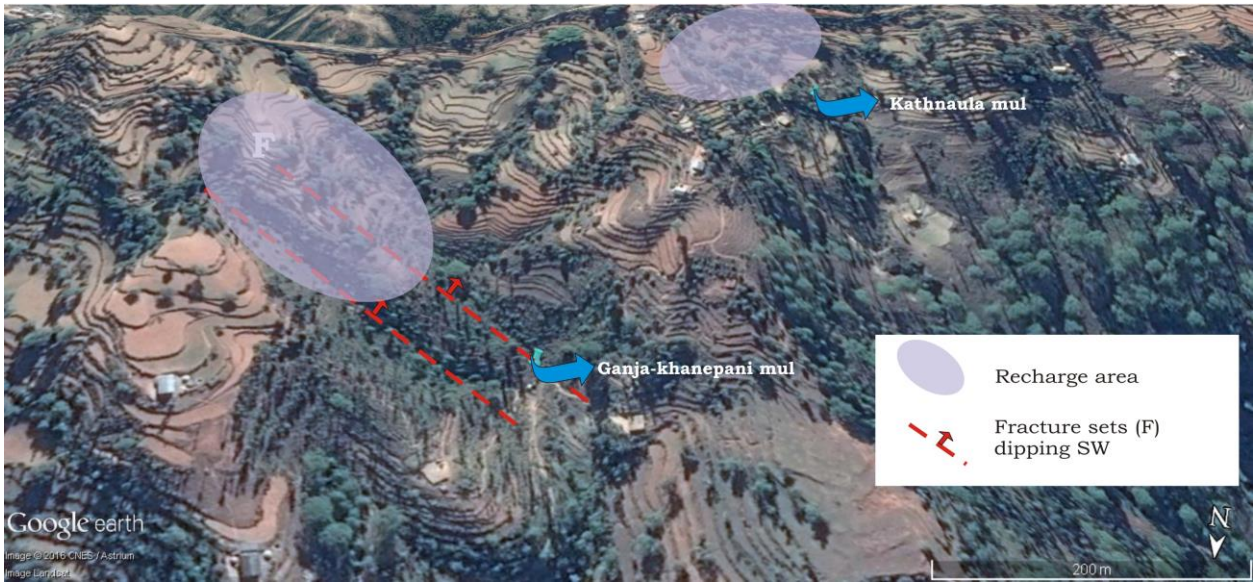
Ganjakhanepani Spring: The linear geometry of the identified fracture (recharge) zone for the spring implies a combination of trenches (as above) as well as some shallow ponds along the recharge zone, especially on the southern slopes. The ponds could have dimensions of 5 m x 3 m x 1m. Feeder channels may connect the ponds appropriately, wherever possible – *please refer to Dhara Vikas Handbook for further details.* Stream treatment measures like gully plugs, bunds can also facilitate recharge.



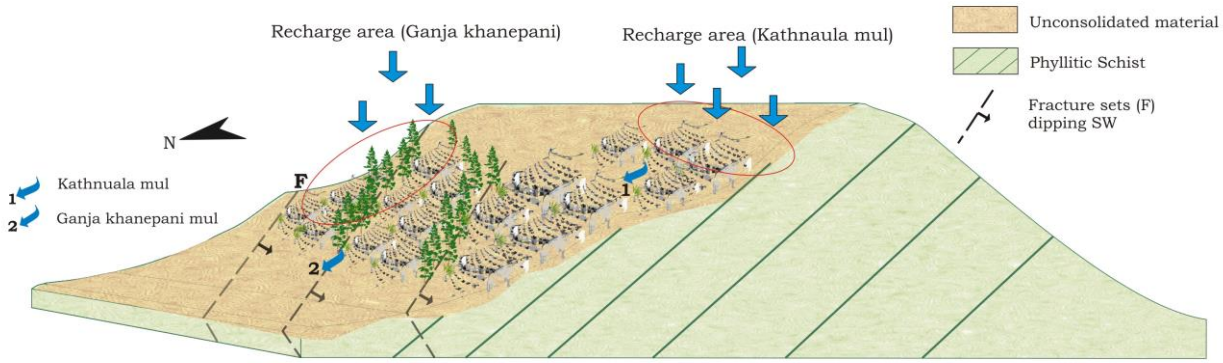
(a) Overlay of main lithological types for Kathanula mul and Ganjakhanepani spring on Google Image



(b) Conceptual layout of Kathanula mul and Ganjakhanepani spring springshed



(c) Overlay of recharge zone on Google Image (Kathanula mul and Ganjakhanepani spring)



(d) Conceptual layout of Kathanula mul and Ganjakhanepani (spring) springshed including demarcated recharge zone

Badarukha mul

Location	Latitude 28.8874º	Longitude 81.5886º	Altitude 1107 m asl	
Discharge	3 lpm			
Water quality	pH 7.25	TDS 90.1 ppm	Salts 59.7 ppm	Temp 11.9 ºC
Type	Depression spring			

Hydrogeology and recharge zone

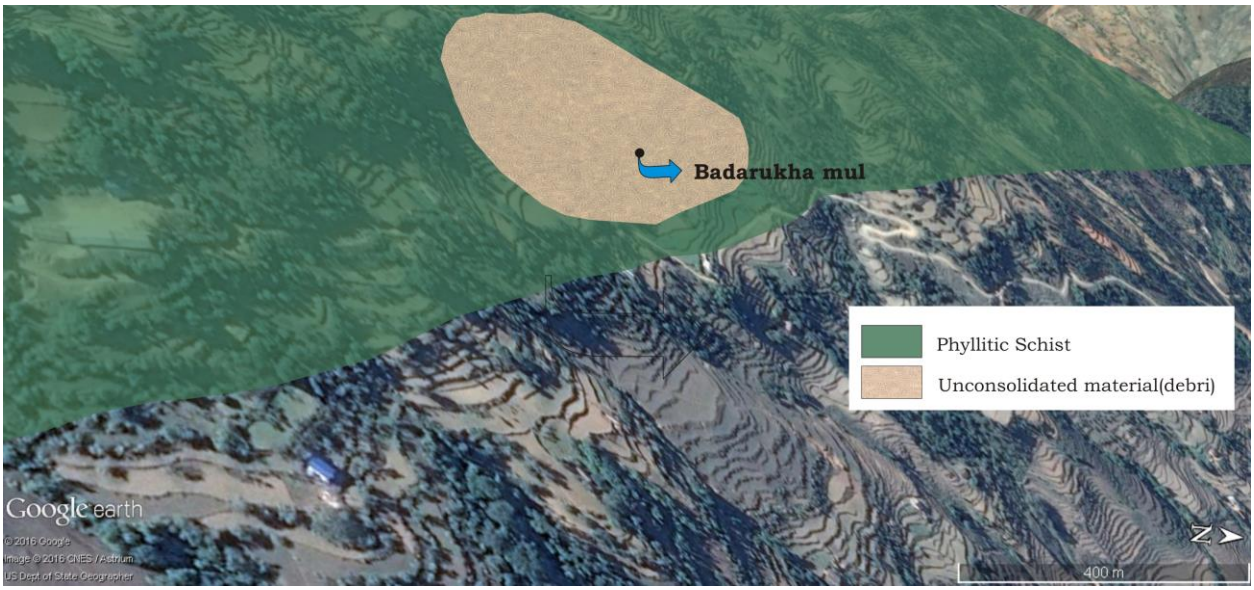
The springshed is constituted of northerly dipping rocks consistent with the regional geology of the ridge along with these springsheds under consideration are present. The dip direction swings from NW to NE as one travels from north to south, this trend being consistent with the other locations along the ridge as well. The dips are steeper along the northern slope - in the range of 30º to 40º with average dips of 35º. Further, south, the dips are a little gentler, in the range of 15º to 25º. The softer unconsolidated section overlies the more durable and consistent schists on the northern slope where the Badarukha spring emerges. It emerges where the water table in the shallow unconfined aquifer cuts the topography (discharge zone). Hence, it is classified as a *depression* spring. The interesting feature of the aquifer here is that although its overall thickness is limited, the lower part of the Phyllitic Schist is likely to hold a significant storage as compared to the above-localized aquifer.

While the spring emerges in what is the discharge zone of the local unconsolidated material section acting as an aquifer, its recharge zone lies at the top of this section further upslope. The recharge and discharge zones of the aquifer are exposed on the same slope, although the recharge area in the case of Badarukha spring is closer to the ridge top.

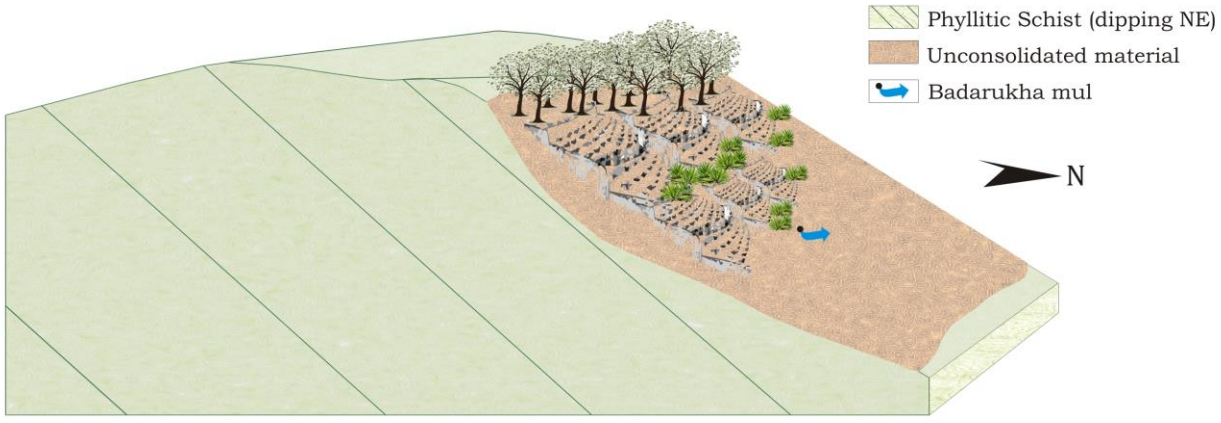
Recharge measures

The advantage of dividing the recharge zone into two different classes of slopes – a gentler portion near the ridge top and a steeper portion further downslope toward north – implies that a combination of measures can be adopted. Firstly, ‘staggered contour’ trenches with dimensions of 2 m x 0.6 m x 0.6 m (length X width X depth) can be constructed in the upper slightly gentler slope closer to the ridge-top; the distance between adjacent trenches along a contour should be 1.83 m while the distance between the contours along which these trenches are made should be kept at 6 m. On the steeper slightly downslope portions of the recharge zone, ‘straggered contour trenches’ with dimensions 2m x 0.6 m x 0.45 m (length X width X depth) can be taken in the areas indicated on the google map while the distance between trenches along a contour should be 1.22 m while the distance between contours along which two sets of trenches are to be made should be 4.6 m. Details, including a table for reference is provided in the *Dhara Vikas Handbook (Govt. of Sikkim, India and GIZ publication).*

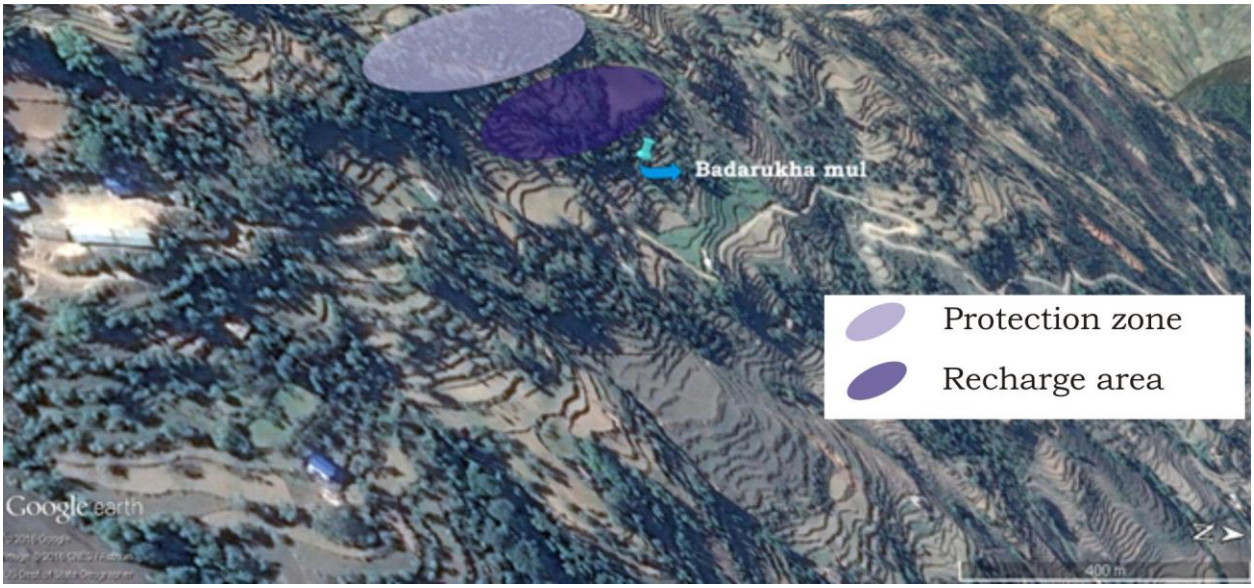
Although shallow ponds are not strongly recommended along the recharge zone, a couple of them may be constructed just south of the spring at the crest of the ridge, seeking an appropriately flat portion. These ponds could have dimensions of about 5 m x 3 m x 1.5 m – *please refer to Dhara Vikas Handbook for further details.* Forest cover over the immediate slopes along the ridge can be demarcated as Protection zone to prevent soil erosion protecting the aquifer feeding the spring. Also inward sloping terraces will facilitate additional recharge.



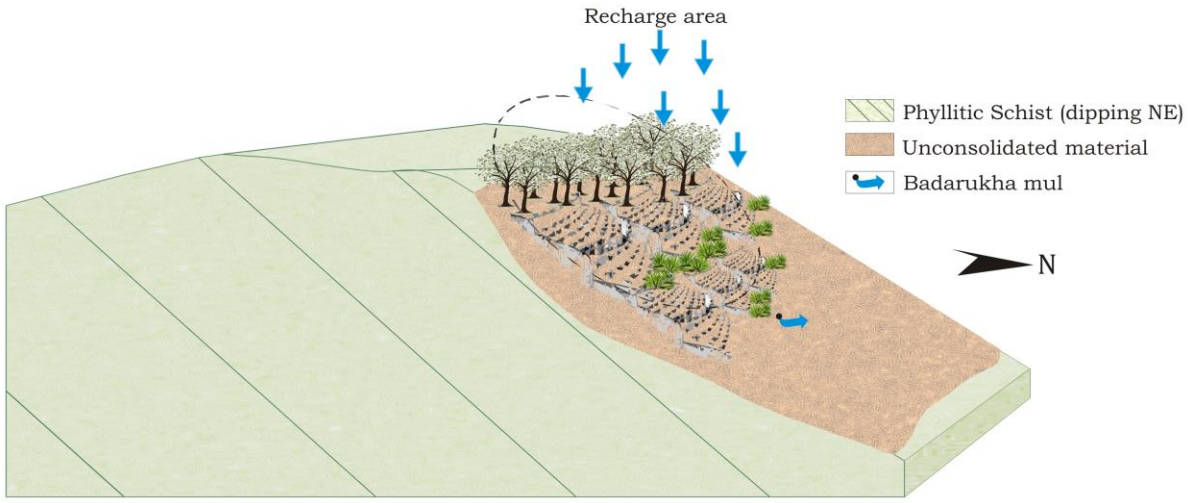
(a) Overlay of main lithological types for Badarukha mul (spring) on Google Image



(b) Conceptual layout of Badarukha mul (spring) springshed



(c) Overlay of recharge zone on Google Image (Badarukha mul (spring))



(d) Conceptual layout of Badarukha mul (spring) springshed including demarcated recharge zone

Batokuwa Mul

Location	Latitude 28.89371º	Longitude 81.5722º	Altitude m asl	
Discharge	3 lpm			
Water quality	pH 6.79	TDS 123 ppm	Salts 81.4 ppm	Temp 17.3 ºC
Type	Depression spring			

Hydrogeology and recharge zone

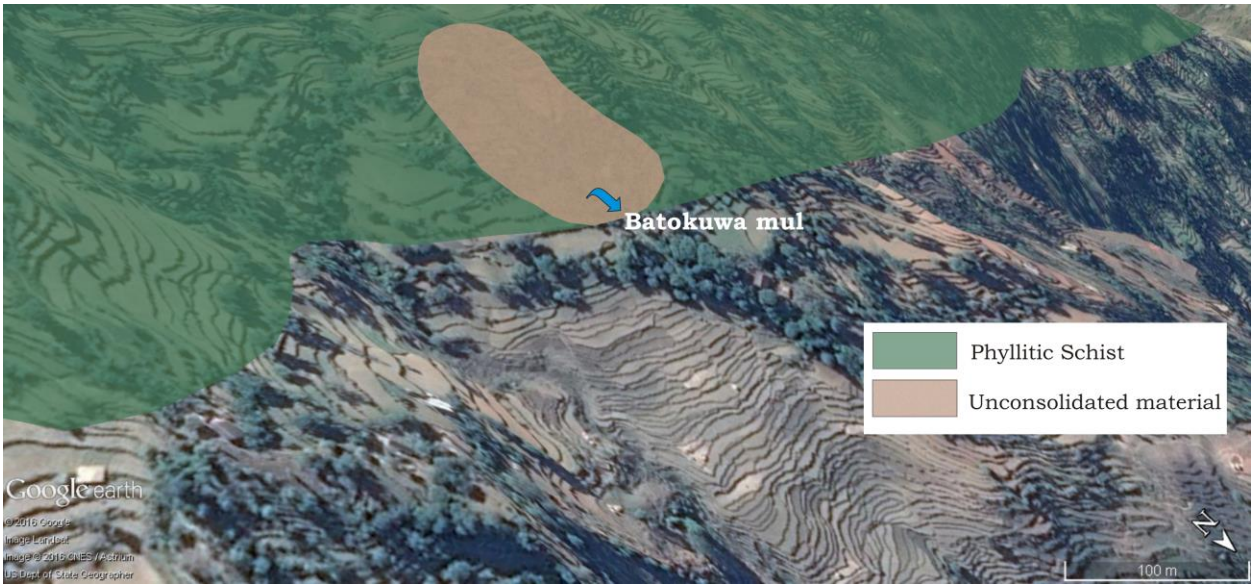
The springshed is constituted of northerly dipping rocks, with dips in the range of 18º to 30º with average dips of about 23º. The spring emerges on the north-facing slopes from a thick overburden of unconsolidated material (downslope). The thick unconsolidated section indicates that the aquifer is quite thick and the spring marked by the water table defining the upper limit of the aquifer. Hence, it is classified as a *depression* spring.

While the spring emerges in what is the discharge zone of the weathered Phyllitic schist aquifer, its recharge zone lies upslope within the top weathered layer on the northern slope. The recharge and discharge zones of the aquifer are exposed on the same slope. In other words the recharge zone is on the same slope as that where the spring emerges.

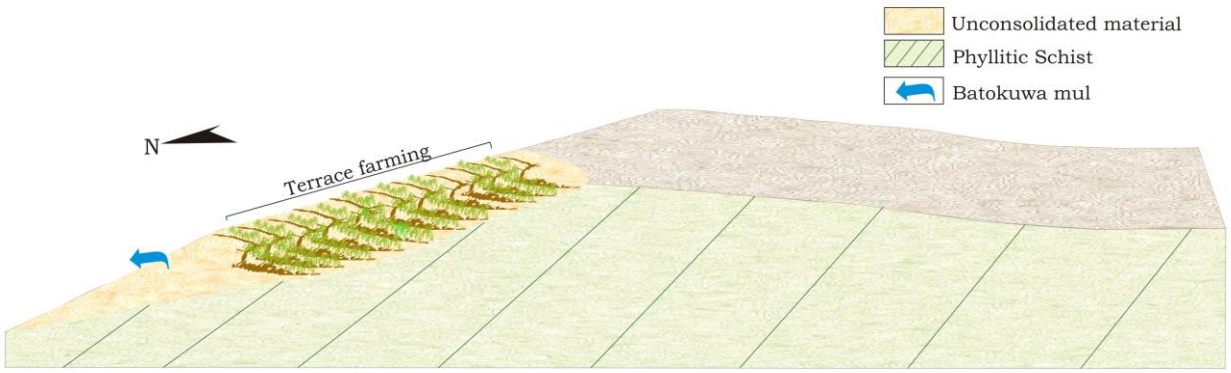
Recharge measures

Given that the slopes are variable across the recharge zone that roughly follows the slopes in the springshed, the major set of measures will include 'staggered contour' trenches that have dimensions of 2m x 0.6 m x 0.45 m (length X width X depth). The distance between trenches along a contour should be 1.22 m while the distance between contours along which two sets of trenches are to be made should be 4.6 m. Details, including a table for reference is provided in the *Dhara Vikas Handbook (Govt. of Sikkim, India and GIZ publication).*

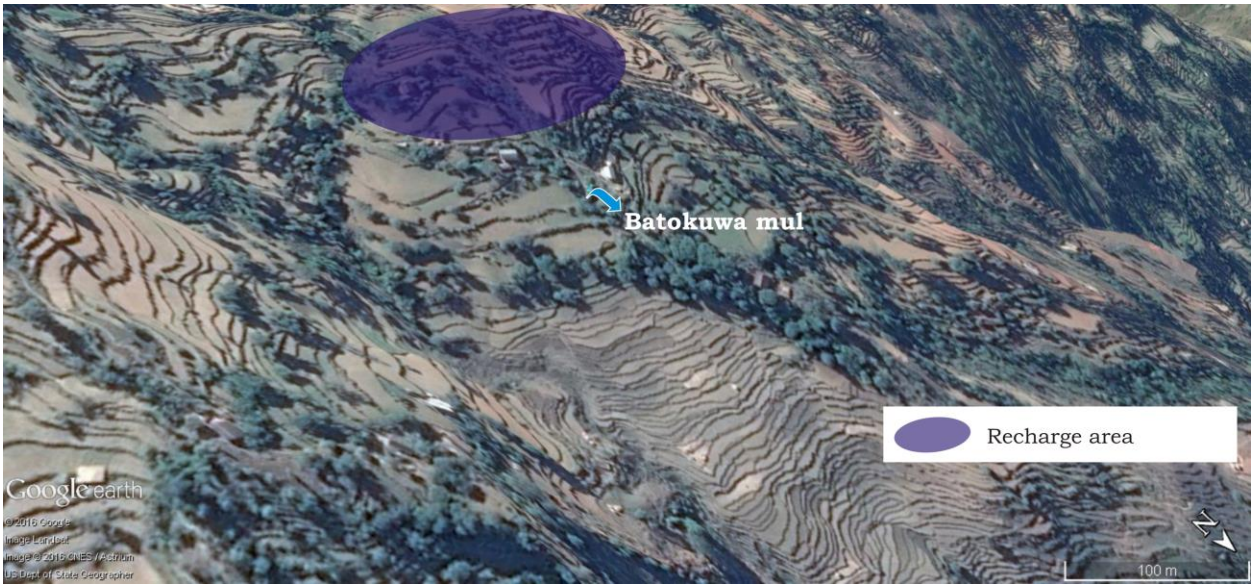
Although slopes show terraced farming, shallow ponds are not strongly recommended along the recharge zone, a couple may be constructed just south of the spring at the crest of the ridge, seeking an appropriately flat portion. These ponds could have dimensions of about 5 m x 3 m x 1.5 m – *please refer to Dhara Vikas Handbook for further details.* Having Inward facing slopes of the terraces can account for additional recharge.



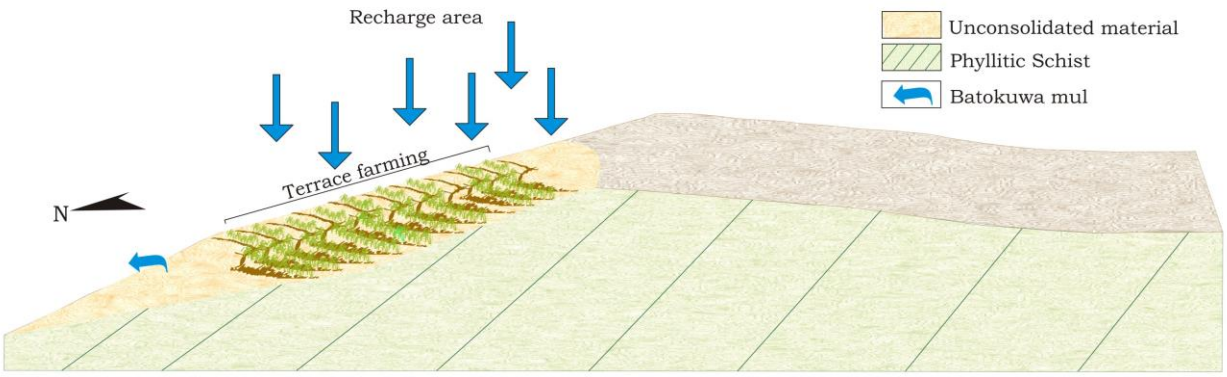
(a) Overlay of main lithological types for Batokuwa mul (spring) on Google Image



(b) Conceptual layout of Batokuwa mul (spring) springshed



(c) Overlay of recharge zone on Google Image (Batokuwa mul (spring))



(d) Conceptual layout of Batokuwa mul (spring) springshed including demarcated recharge zone

Dharakhola Mul

Location	Latitude 28.882233º	Longitude 81.59161º	Altitude 1107 m asl	
Discharge				
Water quality	pH 7.87	TDS 66.8 ppm	Salts 56.5 ppm	Temp 20.4 ºC
Type	Fracture spring			

Hydrogeology and recharge zone

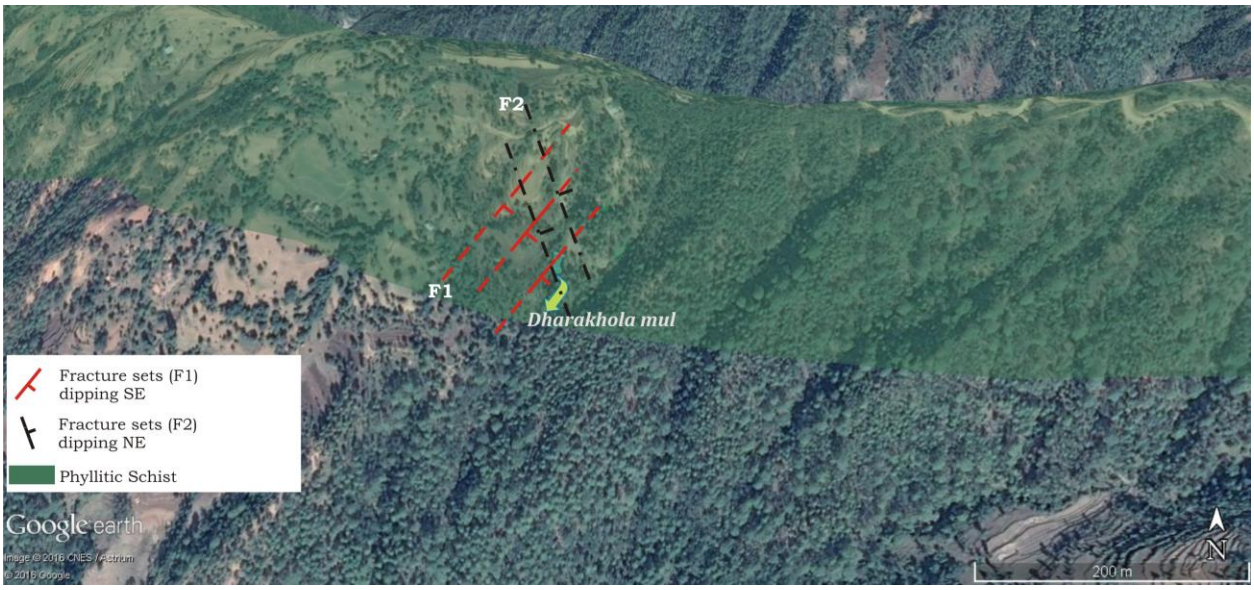
The spring is located on the escarpment slope bearing a similar geology to many of the springs described earlier. The springshed is constituted of SW dipping rocks, with dips in the range of 20º to 35º with a few sporadic locations showing local steepening of dips of the order of 60º. The main fracture zone along which the spring emerges, trends NE-SW dipping SE along with another set trending NW-SE dipping NE. The fracture-opening as the surface are quite open and it is obvious that the movement of groundwater stored in the Schist aquifer has a preferential direction in concurrence with the trend of this fracture zone. The spring emerges on the south-facing slopes. The thick weathered Phyllitic Schist shows inward dips from the slope with clear foliation-related openings indicating this aspect. However, despite the structure of the Schist, the spring emerges on the southern slope, clearly controlled by the fracture zone. Hence, it is classified as a *fracture* spring.

While the spring emerges in what is the discharge zone of the Phyllitic Schist aquifer, its recharge zone lies upslope, along the fracture, including large portions where it traverses the schistose rock. The recharge and discharge zones of the aquifer are exposed on the same, southern, slope. In other words the recharge zone is on the same slope as that where the spring emerges, also extending along the slope left up to the ridge top.

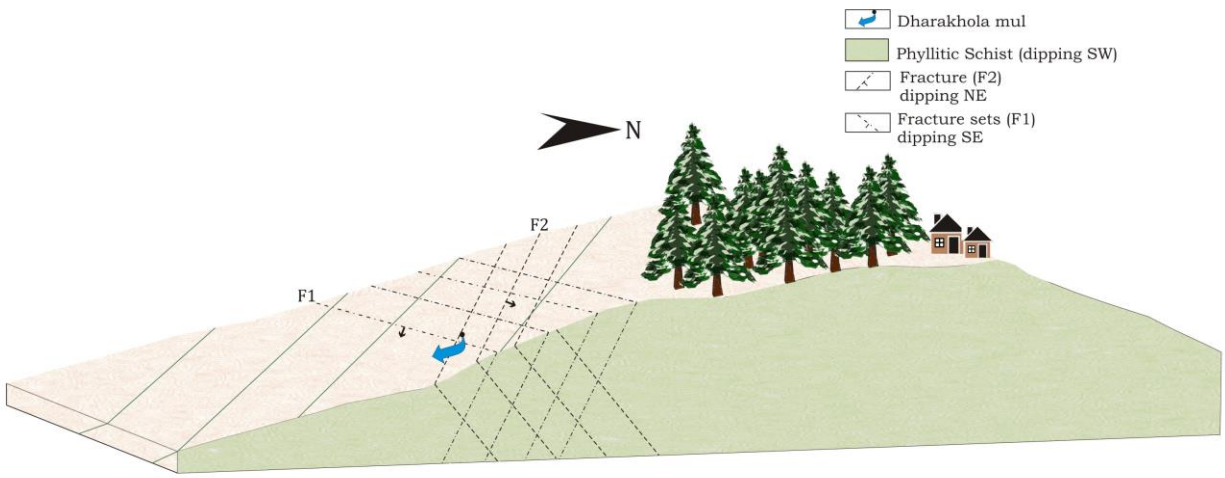
Recharge measures

Given that the slopes are variable along the recharge zone corresponding to the fracture zone, a major set of measures will include ‘staggered contour’ trenches that have dimensions of 2m x 0.6 m x 0.45 m (length X width X depth). The distance between trenches along a contour should be 1.22 m while the distance between contours along which two sets of trenches are to be made should be 4.6 m. Such trenches can also extend a little beyond the zone of the fracture exposure and the spread could be extended to encompass larger areas right of the ridge top. Details including a table for reference are provided in the *Dhara Vikas Handbook (Govt. of Sikkim, India and GIZ publication).*

Although shallow ponds are not strongly recommended along the recharge zone, a few may be constructed northwest of the spring at the contact with the schist-exposed upslope, seeking an appropriately flat portion. These ponds could have dimensions of about 5 m x 3 m x 1.5 m – *please refer to Dhara Vikas Handbook for further details.* In addition, top area on the right flank of the slope has fair amount of forest cover, which can be treated as protection zone.

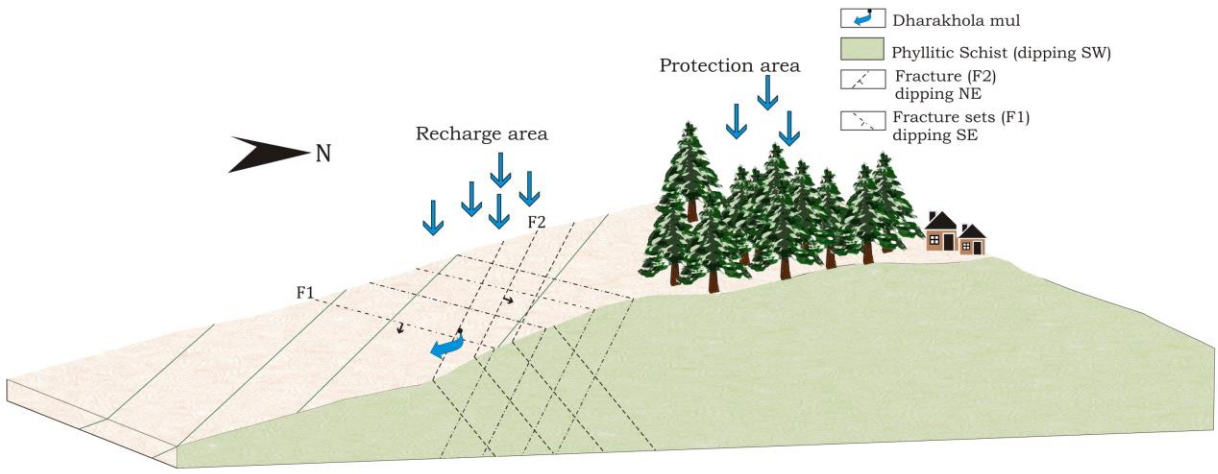


(a) Overlay of main lithological types for Dharakhola spring on Google Image



(b) Conceptual layout of Dharakhola spring

(c) Overlay of recharge zone on Google Image (Dharakhola spring)



(d) Conceptual layout of Dharakhola springshed including demarcated recharge zone

Tallodhara Mul

Location	Latitude 28.8777º	Longitude 81.616067º	Altitude 1166 m asl	
Discharge				
Water quality	pH 7.29	TDS 54.7 ppm	Salts 39.5 ppm	Temp 18.3 ºC
Type	Combination of fracture and depression types			

Hydrogeology and recharge zone

The spring is located on an East-facing escarpment slope and is located within the schist at the contact of a weathered portion of the schist and a more compact, dense, relatively un-jointed portion. However, the spring is largely controlled by the flow of groundwater through the two sets of fractures that trends NNE-SSW dipping E and NE-SW dipping NW which largely traverses the schist.

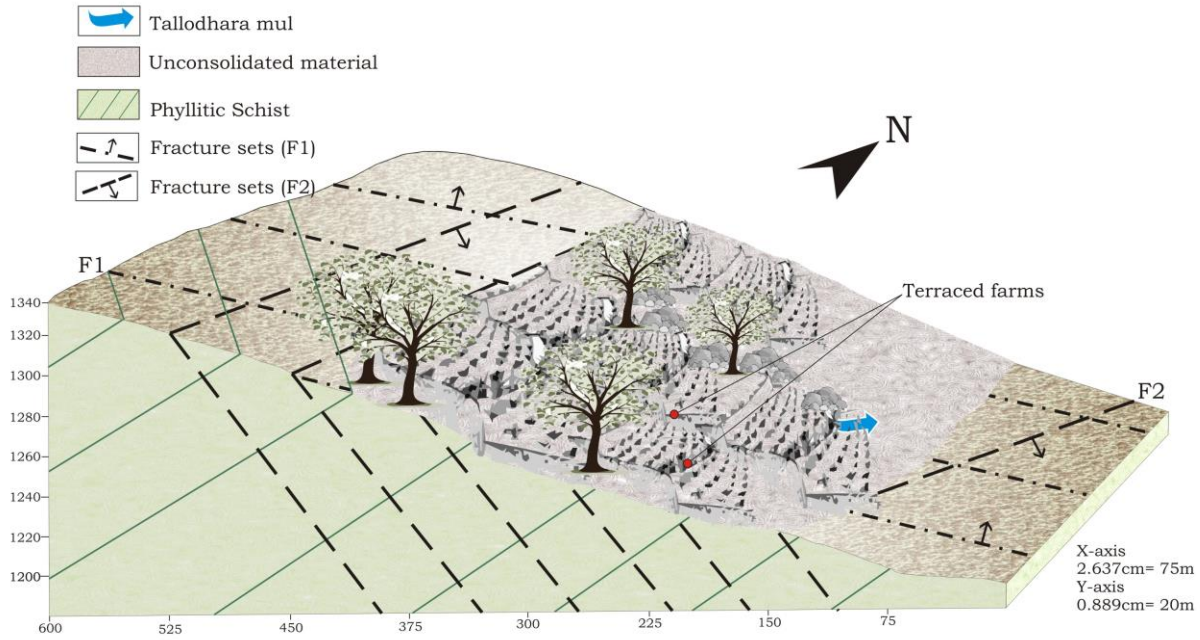
The recharge zone of the spring is defined by the upper portions of the weathered schist, particularly along the extension of the fracture zone into this weathered portion.

Recharge measures

Given that the slopes are variable along the recharge zone corresponding to the weathered schist in conjunction with the fracture zone, a major set of measures will include 'staggered contour' trenches that have dimensions of 2m x 0.6 m x 0.45 m (length X width X depth). The distance between trenches along a contour should be 1.22 m while the distance between contours along which two sets of trenches are to be made should be 4.6 m. Details, including a table for reference are provided in the *Dhara Vikas Handbook (Govt. of Sikkim, India and GIZ publication).*

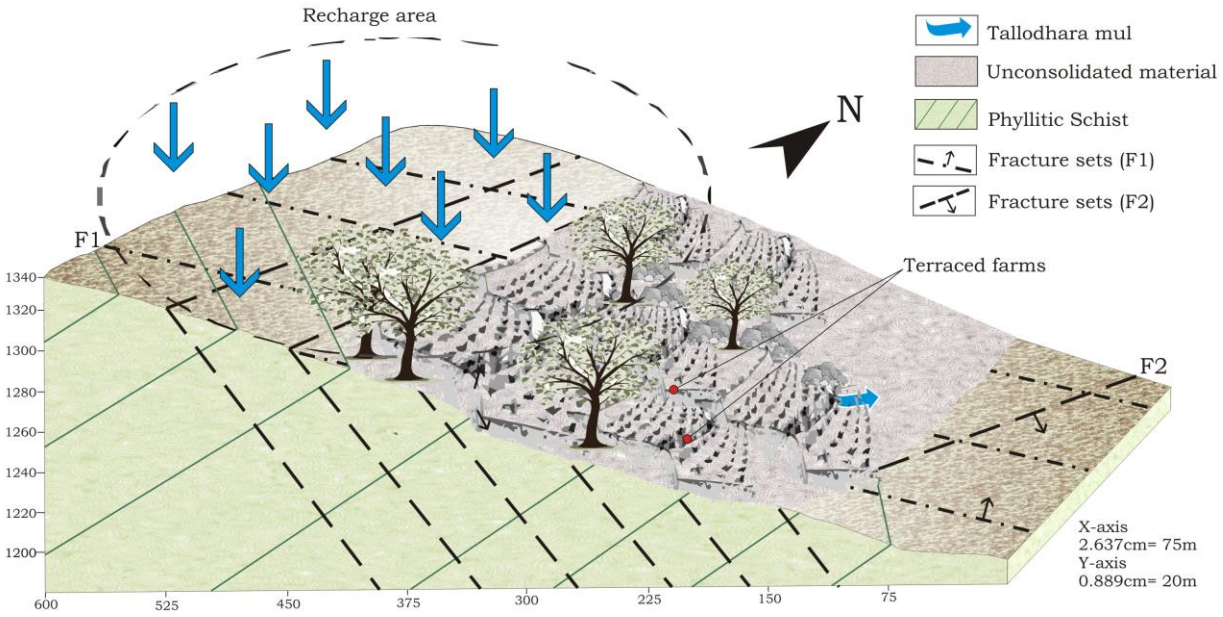
Although shallow ponds are not strongly recommended along the recharge zone, a few may be constructed northwest of the spring at the contact with the schist exposed upslope, seeking an appropriately flat portion. These ponds could have dimensions of about 5 m x 3 m x 1.5 m – *please refer to Dhara Vikas Handbook for further details.* Recharge structures like gully plugs, bandhara etc. can be implemented in the stream adjacent to the spring along with inward sloping of terraces to facilitate additional recharge.

(a) Overlay of main lithological types for Tallodhara spring on Google Image



(b) Conceptual layout of Tallodhara spring

(c) Overlay of recharge zone on Google Image (Tallodhara spring)



(d) Conceptual layout of Tallodhara springshed including demarcated recharge zone

Buspani Spring

Location	Latitude 28.87712º	Longitude 81.61245º	Altitude 1313 m asl	
Discharge	2 lpm			
Water quality	pH	TDS ppm	Salts ppm	Temp ºC
Type	Fracture spring			

Hydrogeology and recharge zone

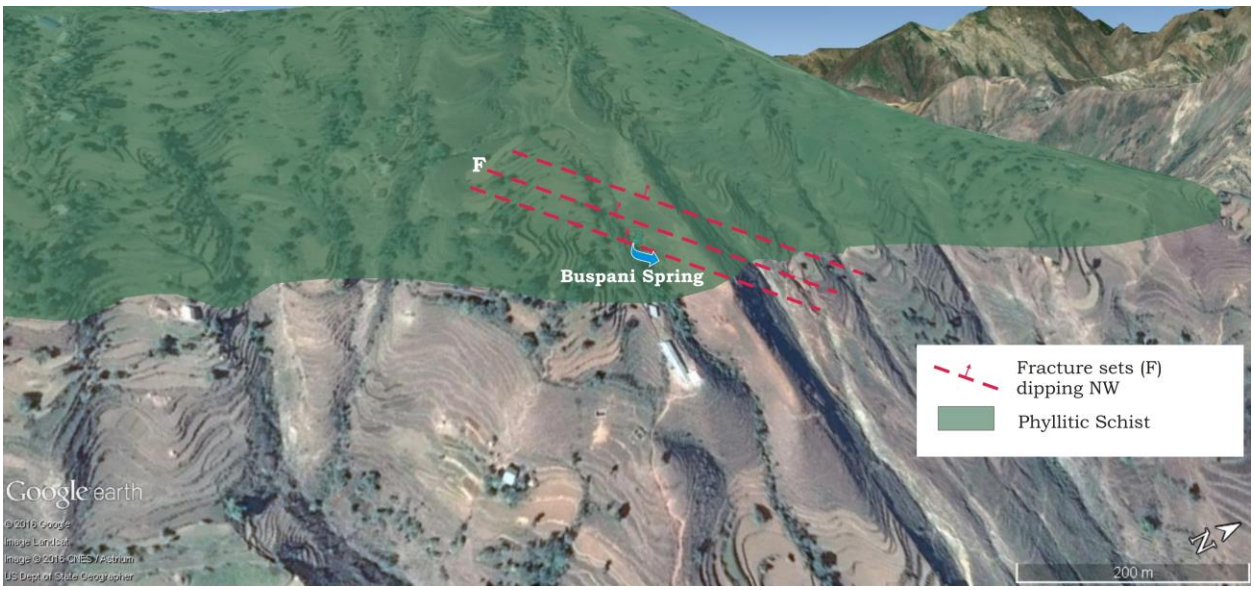
Buspani spring is located within a springshed that includes Phyllitic Schist rocks that extend further west into a folded structure. The Buspani spring lies on the escarpment slope emerging through Schists along fracture. However, the larger influence on the spring is through a set fractures (dipping toward the NNW direction) in the form of a fracture zone. The fracture zone trends WSW-ENE.

The spring is largely controlled by the fracture zone, especially given the fact that the dips of the foliation openings in the rocks are toward the SSW. The fracture zone extends WSW wards, with the recharge zone located at the top of the ridgeline on the left flank of the spring, where the schistose rocks begin to fold (their strike becomes NW-SE). The fold axes (not well-exposed) and the extension of the fracture zone are coincident in the potential area of recharge, largely at the top-portion of the ridge-line.

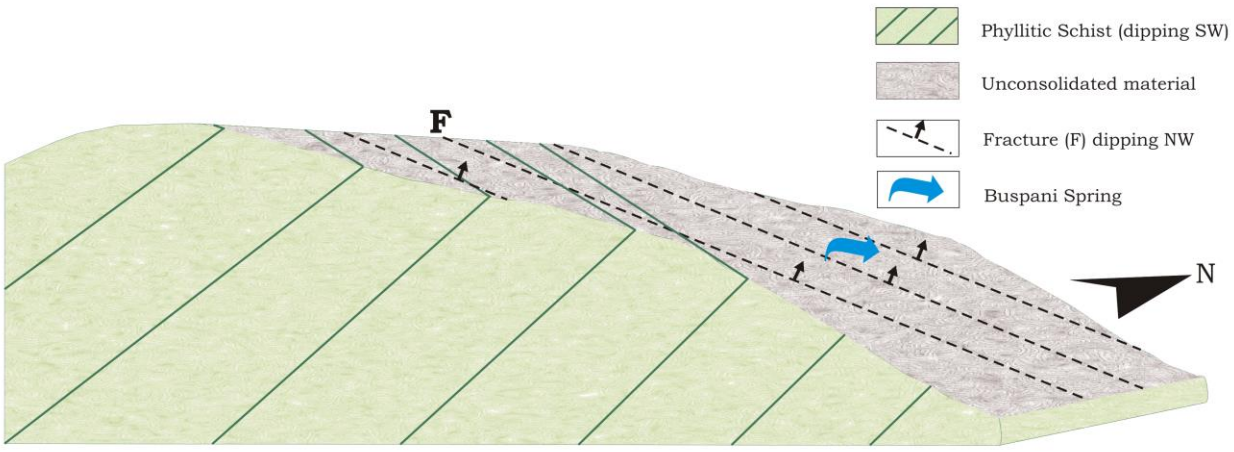
Recharge measures

The recharge zone has two major slope categories: steeper slopes closer to the spring in the demarcated recharge zone and gentler slopes at the crest and a little beyond. Firstly, 'staggered contour' trenches with dimensions of 2 m x 0.6 m x 0.6 m (length X width X depth) can be constructed in the upper slightly gentler slope closer to the ridge-top; the distance between adjacent trenches along a contour should be 1.83 m while the distance between the contours along which these trenches are made should be kept at 6 m. On the steeper slightly downslope portions of the recharge zone, 'straggered contour trenches' with dimensions 2m x 0.6 m x 0.45 m (length X width X depth) can be taken in the areas indicated on the google map while the the distance between trenches along a contour should be 1.22 m while the distance between contours along which two sets of trenches are to be made should be 4.6 m. Details, including a table for reference is provided in the *Dhara Vikas Handbook (Govt. of Sikkim, India and GIZ publication).*

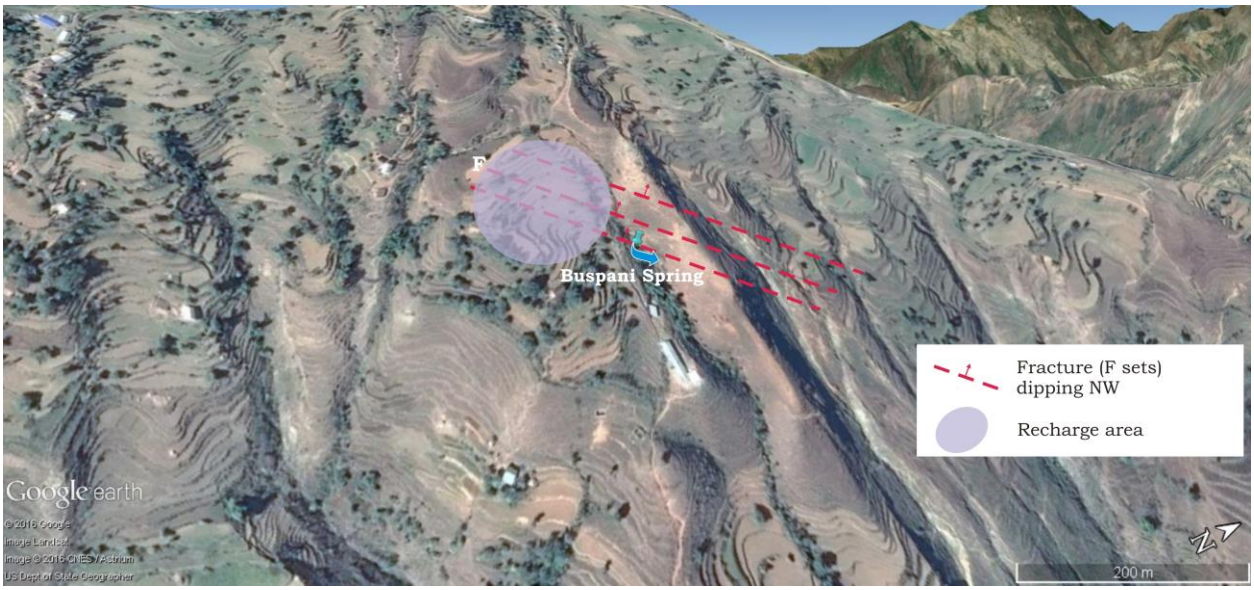
Moreover, shallow ponds constructed along the crest of the ridge and in the gentler slopes within the demarcated recharge zones, are suggested. The number of ponds could be decided on the space available and each could have dimensions of about 5 m x 3 m x 1.5 m – *please refer to Dhara Vikas Handbook for further details.*



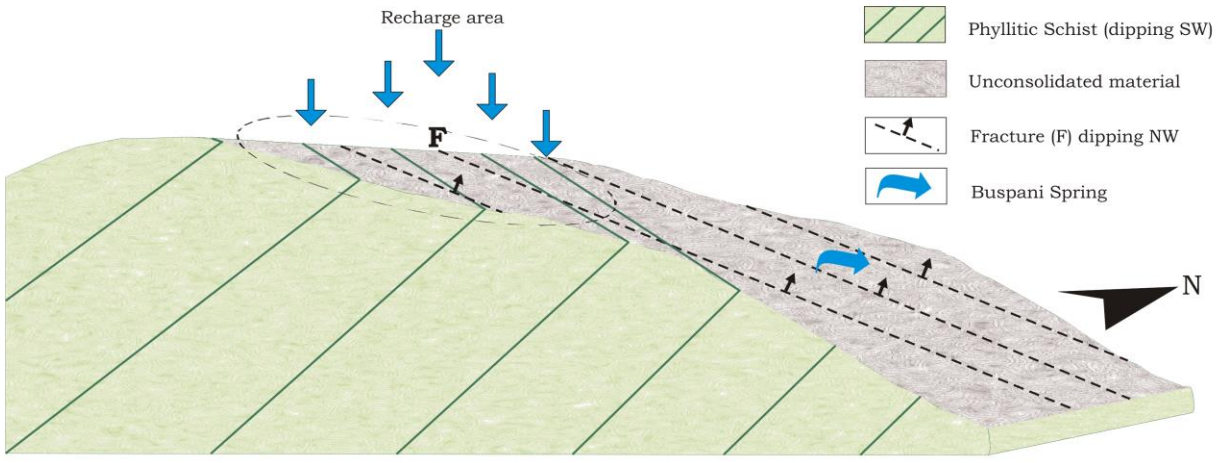
(a) Overlay of main lithological types for Buspani spring on Google Image



(b) Conceptual layout of Buspani spring



(c) Overlay of recharge zone on Google Image Buspani spring



(d) Conceptual layout of Buspani springshed including demarcated recharge zone

Summary

Spring name	Type	Recharge measures suggested	Potential area demarcated for recharge measures in hectare
Bukhakhali	Contact spring	Contour trenches	3.88
Ganjakhanepani	Fracture spring	Contour trenches	4.29
Kathnaula	Depression spring	Contour trenches + ponds	6.74
Badarukha	Depression spring	Contour trenches + ponds	3.47
Batokuwa	Depression spring	Contour trenches + ponds	About 1 ha
Dharakhola	Fracture spring	Contour trenches + ponds	7.84
Tallodhara	Combination type (Fracture and Depression)	Contour trenches + ponds	2.1
Buspani	Fracture spring	Contour trenches + ponds	1.44