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Advanced Center for Water Resources Development And Management

GEOHYDROLOGY IN SPRINGWATER MANAGEMENT: GARHWAL HIMALAYA,UTTARAKHAND

Process Document

ACWADAM

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GEOHYDROLOGY IN SPRINGWATER MANAGEMENT: GARHWAL HIMALAYA, UTTARAKHAND

PROCESS DOCUMENT

Prepared for

Himmotthan, Dehradun, Uttarakhand.

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FIELD-BASED CAPACITY BUILDING IN GEOHYDROLOGY-BASED CATCHMENT AREA PLANNING FOR SPRING WATER MANAGEMENT UNDER THE HIMMOTTHAN INITIATIVE (WITH SPECIAL REFERENCE TO WATSAN PROJECTS)

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CONTENTS

INTRODUCTION

The Himalayan region is an irony of nature; despite being the source of many great rivers that provide water for millions of people downstream, the Himalayan dwellers face shortage of water. For nearly everyone residing in the Himalayan mountain villages or hamlets springs are the exclusive source of water for drinking, domestic needs and occasionally for irrigation. The past decades have been witnessing a decline in rainfall and consequentially diminishing discharge of springs. Several springs have become seasonal and many others have completely dried up.

Himmotthan with an aim to improve the approach towards catchment area planning and treatment for spring water management in Uttarakhand collaborated with ACWADAM. Initial objective involved the development of geohydrological understanding of the partner organisations. A training exercise was conducted in this regard in September 2008 under the Water and Sanitation Programme (WATSAN). The scope of the programme was later widened and ACWADAM undertook a complete geohydrological study of four springs. The objectives of the study include:

1. Detailed hydrogeological investigation – demarcation of the recharge area, characterizing the nature of the spring (type), collection of spring discharge and quality data.
2. Dissemination of the information obtained by investigations to *Himmotthan* and other partners.
3. Recommendations for the enhancement of spring discharge, limitations thereof; aquifer characteristics and spring water quality.
4. Recommendations for the protection of the aquifer and prevention of source water contamination.
5. Training individuals from partner organisations and the community for collection of spring discharge and water quality data.

Four springs were selected for the geohydrological study from the following locations and the observations and analysis is presented in the following pages. -

1. Dangla (Chaulana – D1), Jaunpur block, Tehri District, Uttarakhand.
2. Mundani (Bijliyana – J1), Thatyur, Jaunpur block, Tehri District, Uttarakhand.
3. Mathamali (Churinda – C1), Thatyur, Jaunpur block, Tehri District, Uttarakhand.
4. Bandawali (Bandawali – B1), Raipur block, Dehradun District, Uttarakhand.

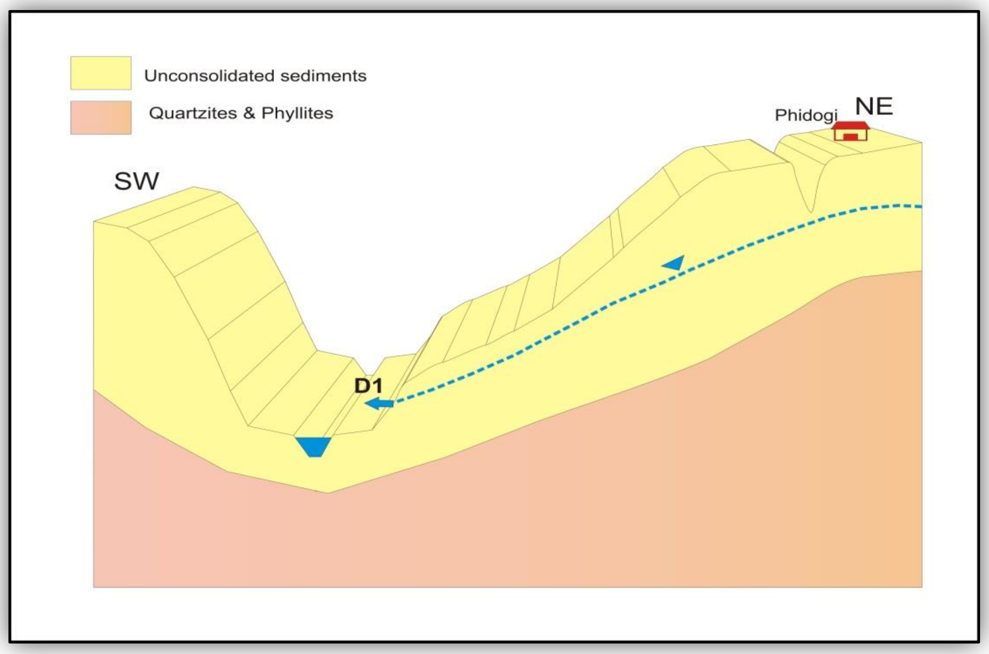
Chaulana spring (D1)

LOCATION:

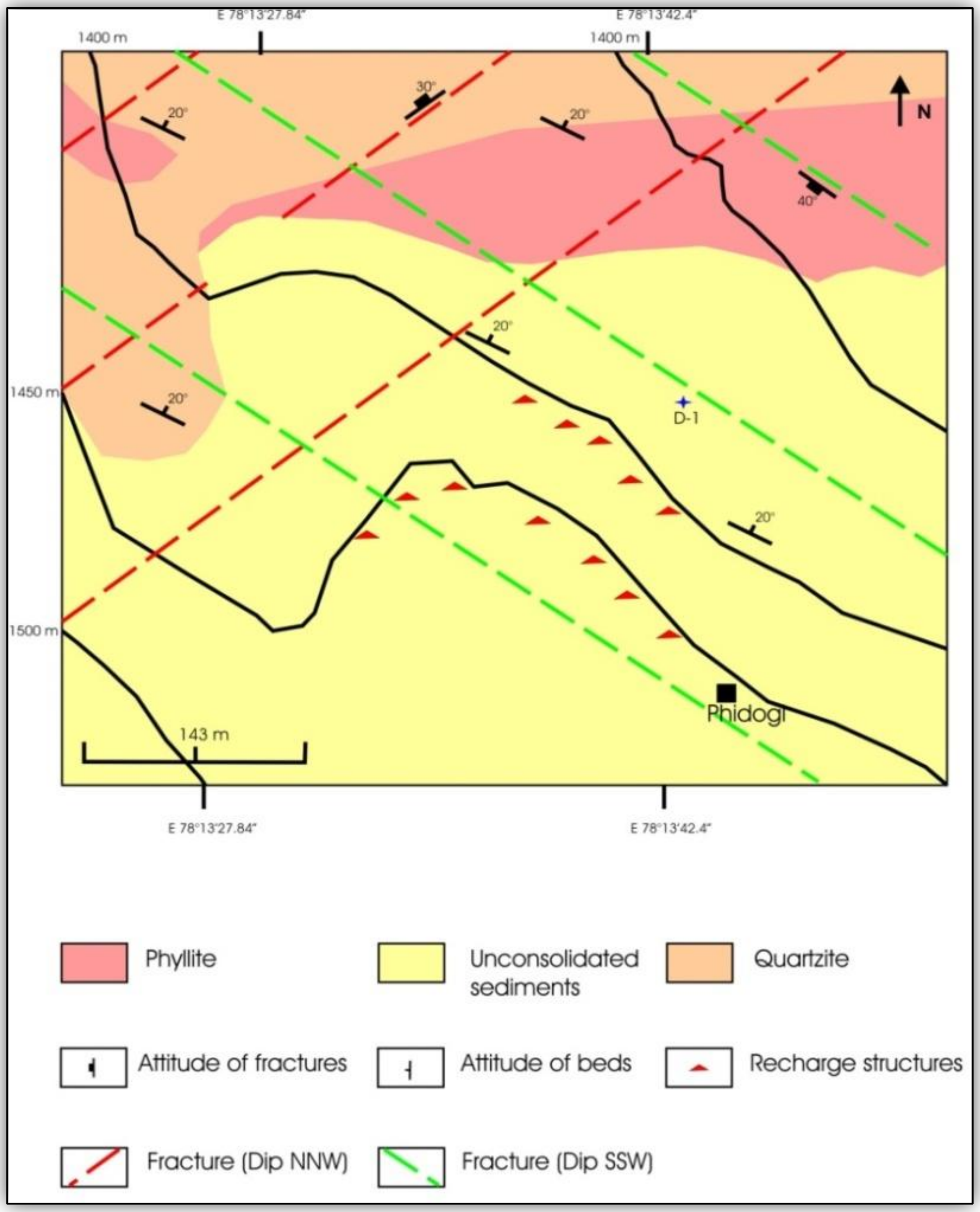
- The Chaulana spring (D1) is located in the vicinity of Dangla village (SE of the main Thatyur town).
- The spring is located at N 30°28" 7.3' 78° 13" 42.5' at an elevation of 1370 m.

GEOLOGICAL SETTING

- The lithology in the area primarily consists of metasedimentary formations – dominantly quartzite and phyllite.
- The quartzite and phyllite are overlain by a thick deposit of unconsolidated sediments of varying grain size.
- The quartzite and phyllite beds are not horizontal but dip by 20^{o}-22^{o} towards NE.
- The rock strata have been intensely fractured.
- Two prominent set of fractures are developed in the area –
  - One set of fractures dips NNW by 30^{o}- 40^{o}.
  - One set of fractures dip SSW by 40^{o}- 48^{o}.
- The spring emerges from the thick sediment deposit overlying the quartzite and phyllite.



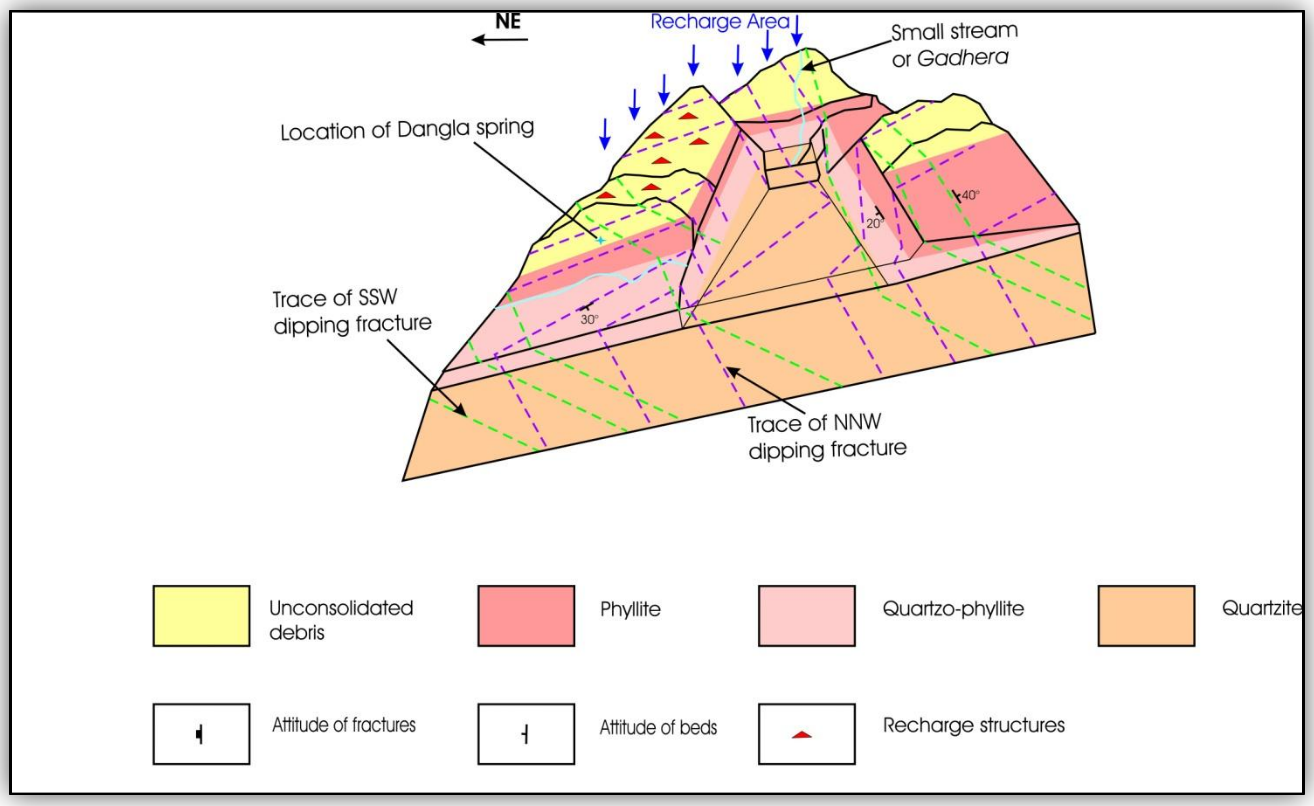
Conceptual model of Chaulana spring (D1): Diagram not scale



Geological map of Dangla – Phidogi area: Chaulana Spring (D1)

GEOHYDROLOGY

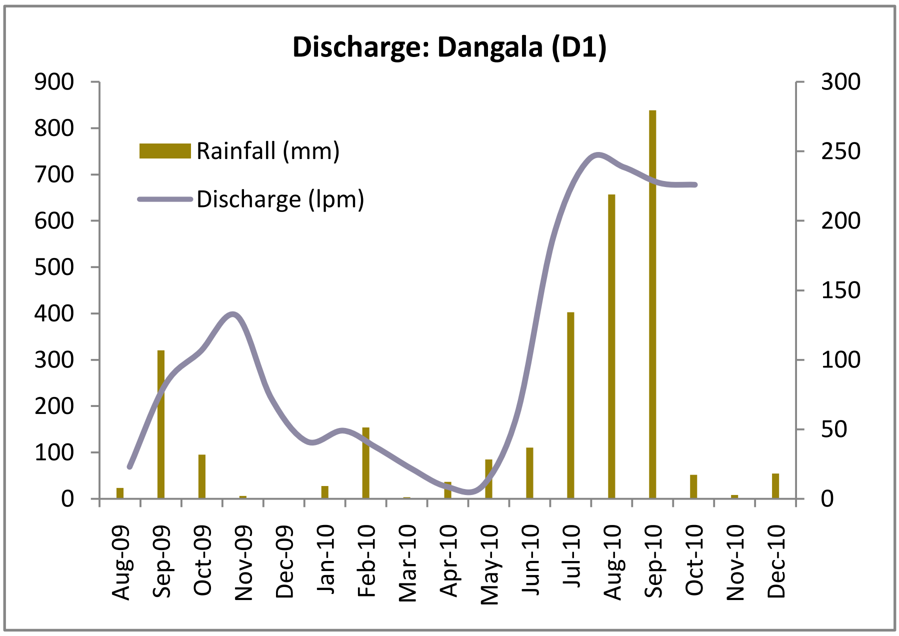
- Generally quartzite and phyllite both have very low primary *porosity* and *permeability*.
- In contrast, unconsolidated sediments have much higher *porosity* and *permeability*.
- The aquifer is composed of highly intermixed sediment layer dominantly comprising pebbles, sand and silt with some amount of clay.
- As the sediment layer predominantly consists of coarse grains the aquifer possesses high *permeability* and consequentially higher *hydraulic conductivity*.
- The *hydraulic conductivity* of the sedimentary aquifer is particularly high in comparison to its *storativity* or storage capacity.
- Spring D1 can be classified as *Depression* / *Contact* spring as it emerges from the sediment debris a few metres above the contact between phyllite and the overlying sediment deposit. The spring may also be classified as a *sedimentary spring* on account of the aquifer's geology.
- Groundwater movement is from SW to NE – controlled by the dip of the beds.

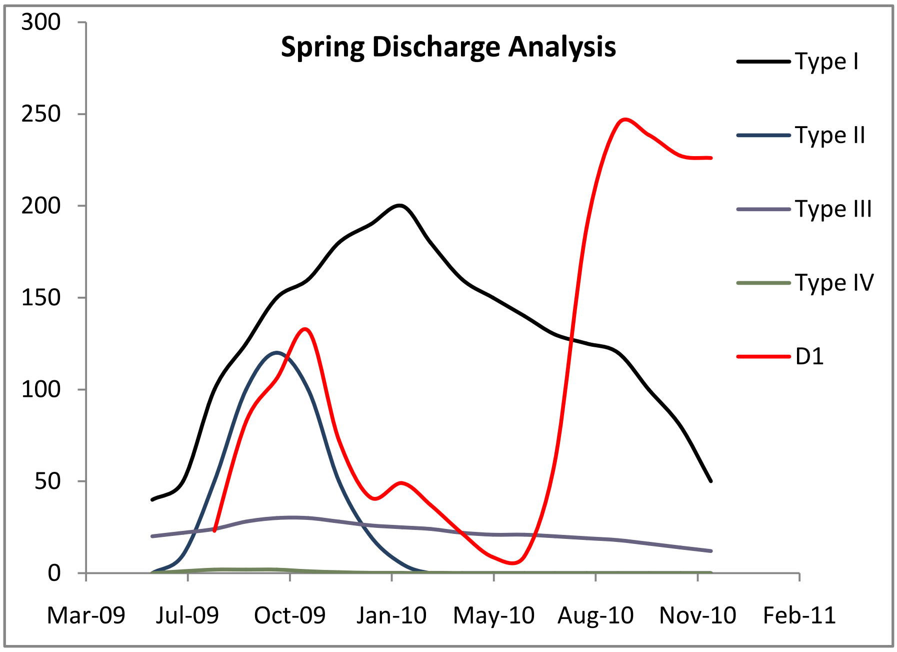


Geological cross-sections / block diagram for Dangla spring catchment area depicting the relationship of the spring to the dip of the lithological units and the fractures. Locations best suited for construction of recharge structures is also depicted.

SPRING DISCHARGE

- The rate of discharge of the spring varies enormously from 8 lpm to approximately 170 lpm.
- Due to the high hydraulic conductivity or transmissivity of sedimentary aquifer, meteoric / surface water recharging the aquifer is transmitted rapidly. Hence, there is instant increase in the discharge of the spring following rainfall.
- The average discharge (Aug 2009 – June 2010) of the spring is 52.97 lpm.





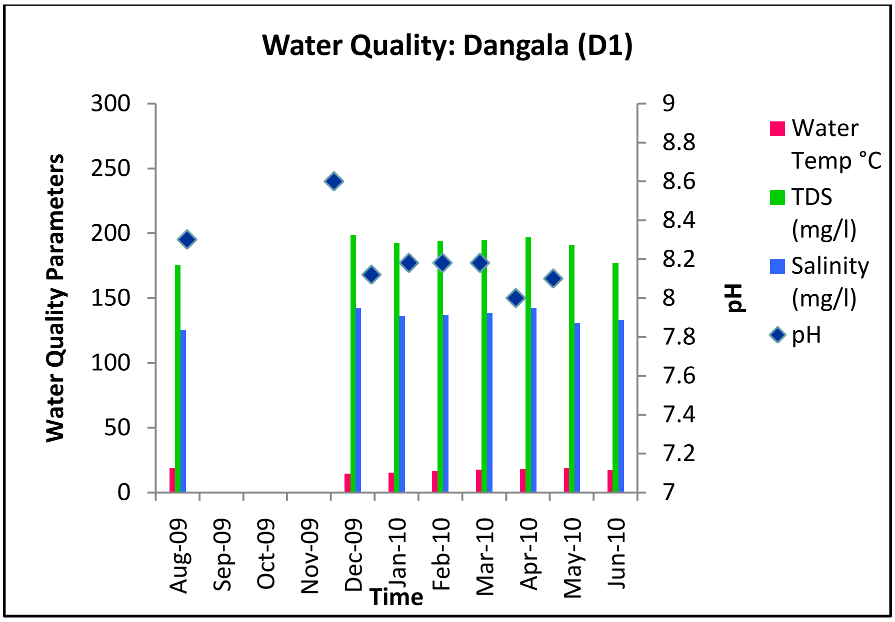
- Change in spring discharge reflects on the hydrogeological parameters of the aquifer viz. Transmissivity and Storativity.
- Based on the pattern of spring discharge one can deduce the nature of the aquifer.
- The spring discharge curves depicted in the figure "***D1 Spring Discharge Analysis"*** are model patterns with understood hydrogeological properties.

MODEL	***Aquifer Attributes***	***Transmissivity and Storativity of Aquifer***	***Nature of the Aquifer***	***Classification based on Discharge***
Type I	Large Storage, rapid flow	High T, High S	Unconfined / Confined	High perennial discharge
Type II	Low storage, quick transmission	High T, Low S	Unconfined / Confined	Widely ranging discharge
Type III	Slow flow, moderate to large storage	Low T, High S	Mostly Confined	Sustained perennial discharge
Type IV	Very Limited storage	Low T, Low s	Very local aquifer	Low discharge, highly seasonal

- The discharge pattern of the spring D1 nearly resembles the ***Type II*** in the figure.
- This implies that the aquifer has high transmissivity (T) and moderate storativity (S). The high transmissivity of the aquifer is responsible for the tremendous variation in the spring discharge.
- Such high transmissivity is characteristic of sedimentary aquifers and discharge pattern of the spring corroborates well with field observations.

<u>WATER QUALITY</u>

- The quality of water issuing from a sedimentary spring is generally good due to natural filtration of infiltrating water.
- Regular monitoring of water quality is essential to understand changes in the chemistry of spring water with the rainfall.
- As water is transmitted rapidly through the sediment layer, the time available for rock – water interaction is less and consequentially the TDS of the spring water is reasonably low.
- In the months of heavy rainfall the TDS content in the spring water is expected to decline due to influx of fresh water.

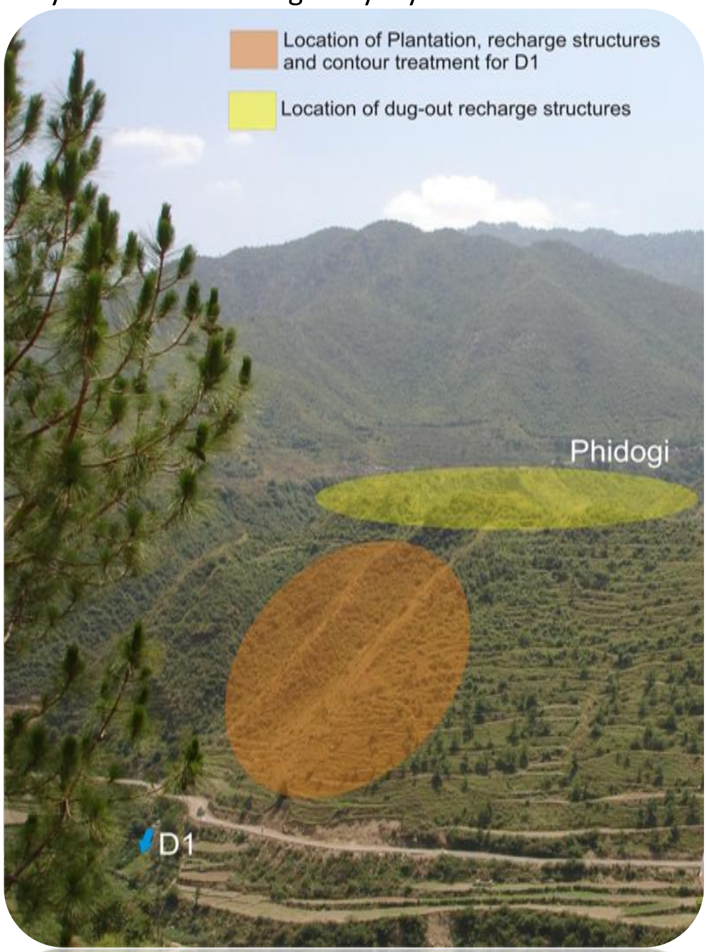


MONITORING THE SPRING

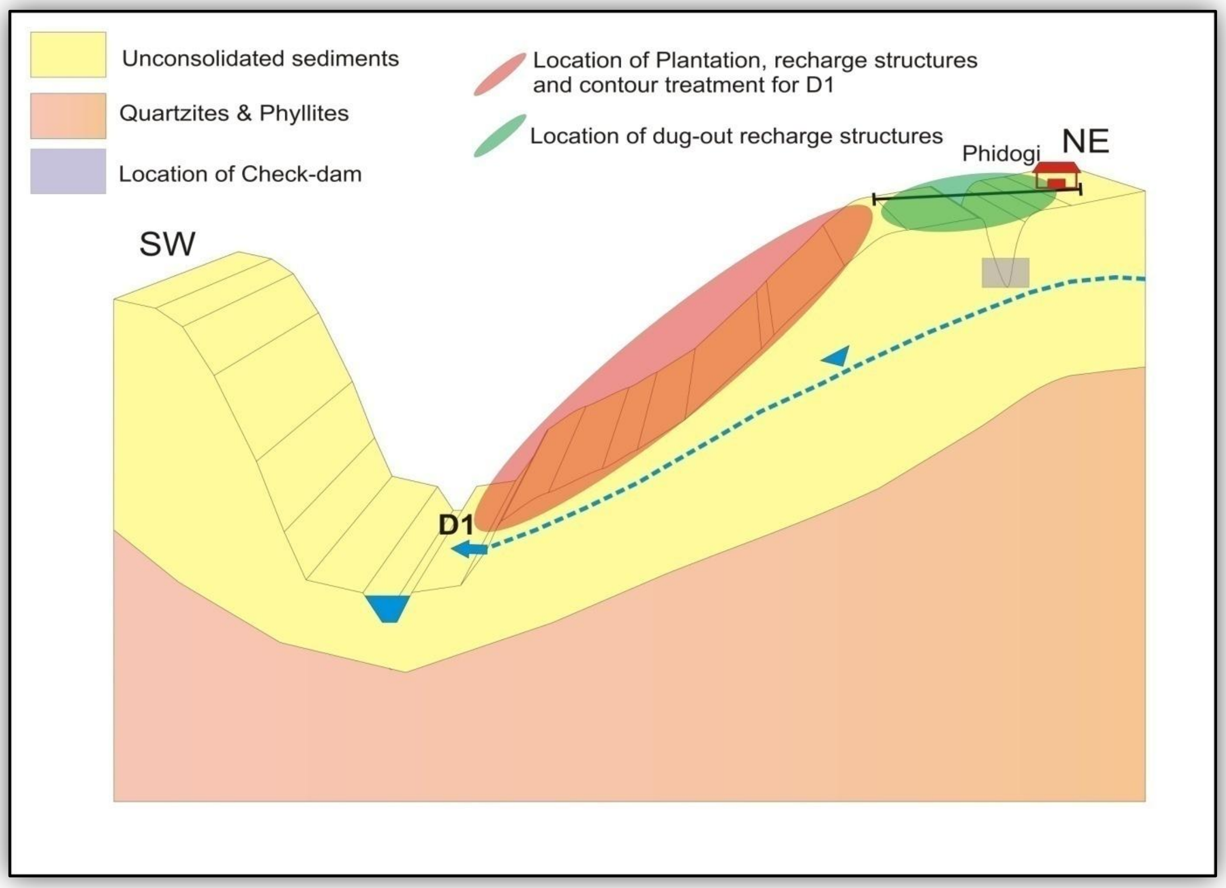
- The spring discharge as well as water quality is monitored regularly by the staff members of HERDS.
- Discharge and Quality data is collected every month.

RECHARGE MEASURES

- Trenches and infiltration pits - constructed on the higher reaches of the mountain slopes along the *dip slope*.
- Sloping of the farms to check runoff and facilitate infiltration.
- Plantation of Napier grass, local grasses and other trees to stabilize recharge structures and retain moisture in the soil.



Treatment Plan for Dangla Spring (D1)



Treatment Plan for Dangla Spring (D1): (Diagram not to scale)

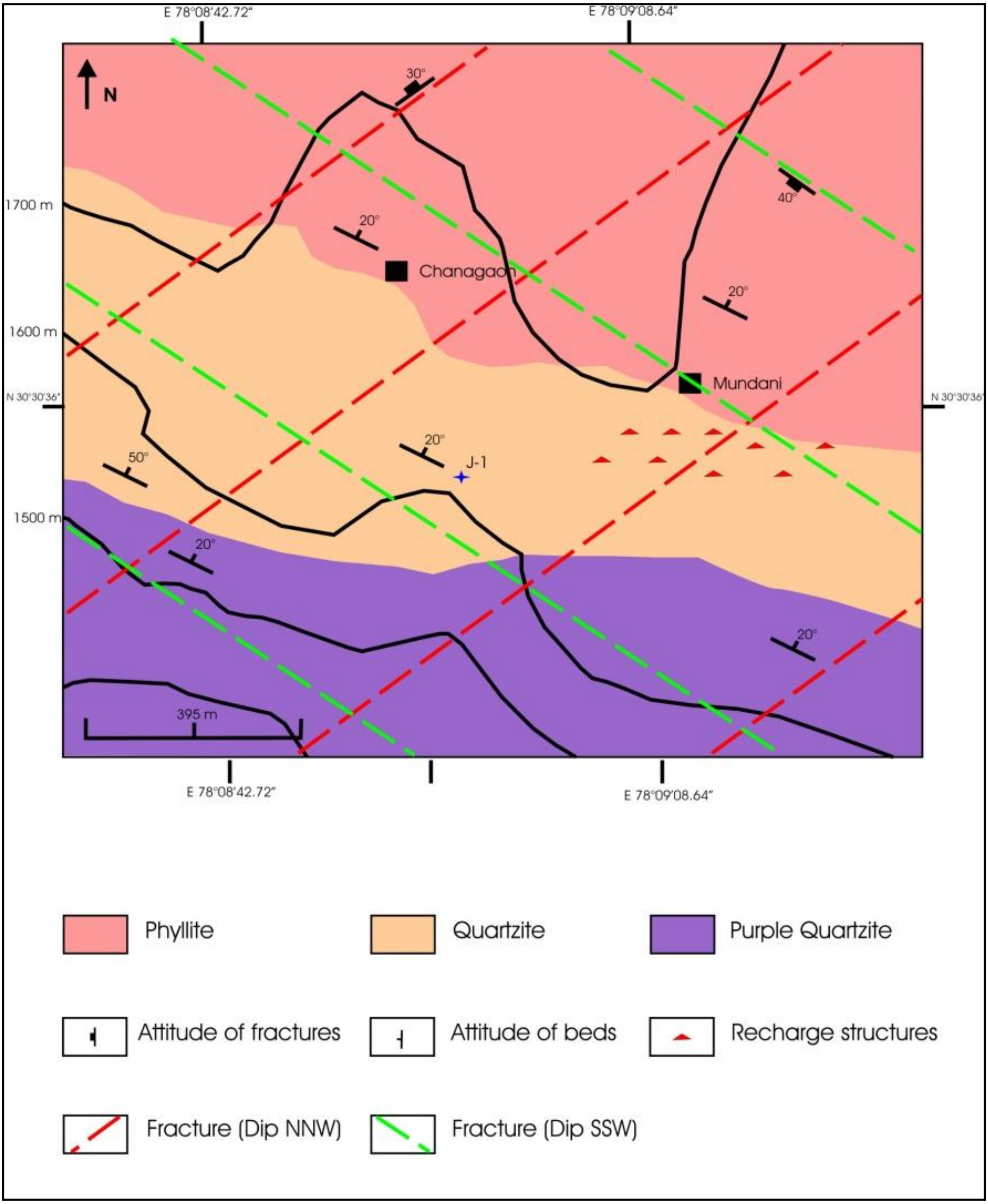
Bijliyana spring (J1)

LOCATION:

- The Bijliyana spring (J1) is located in Mundani village (NE of the Thatyur town).
- The spring is located at N 30° 30' 33.7''E 78° 08' 54.8" at an elevation of 1610 m.

GEOLOGICAL SETTING

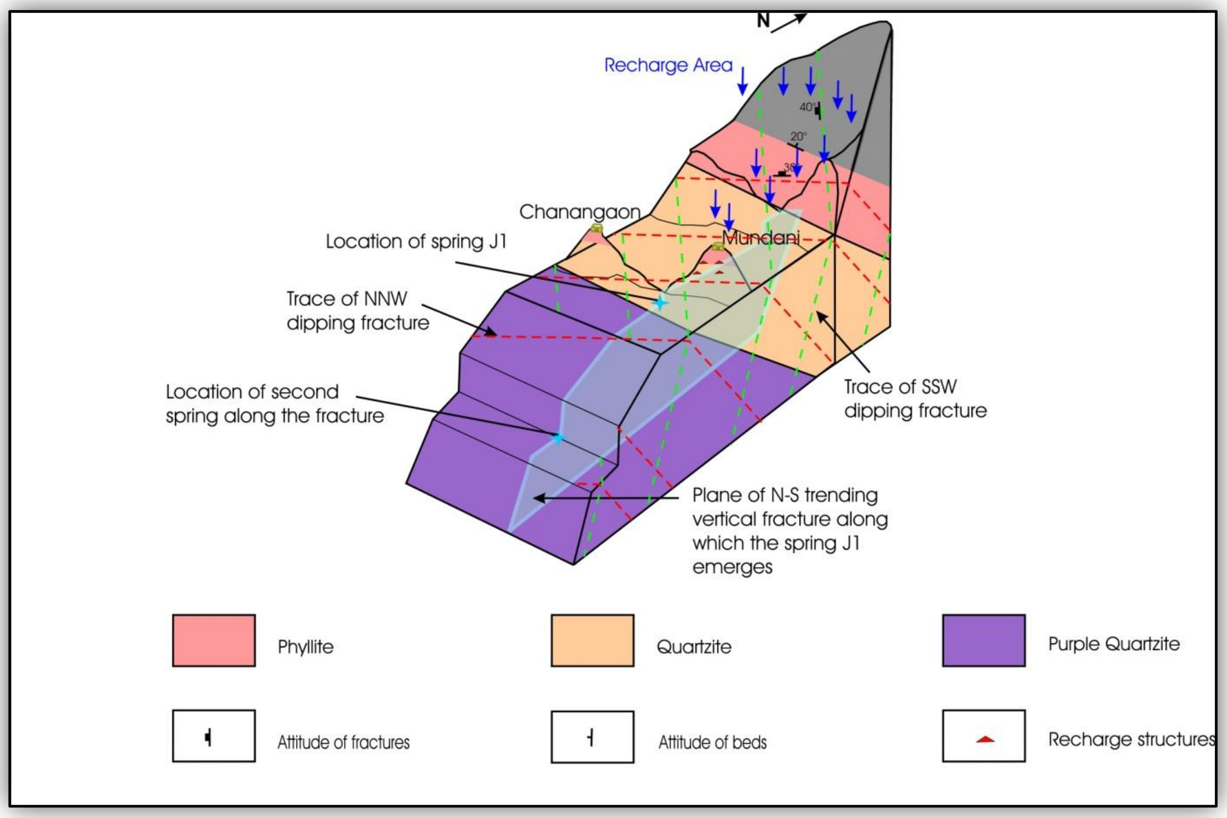
- The lithology in the area primarily consists of metasedimentary formations – purple quartzite, buff coloured quartzite and phyllite.
- The purple quartzite is at the base overlain by buff coloured quartzite and phyllite.
- The quartzite and phyllite beds dip towards NE by 30^{o} and strike by 120^{o}-300^{o} and are overlain by highly intermixed unconsolidated debris.
- Two prominent set of fractures are developed in the area –
  - One set of fractures dips NNW by 30^{o}-40^{o}.
  - One set of fractures dip SSW by 40^{o}- 48^{o}.
- A major N-S trending vertical fracture is the dominant control in the development of the spring.
- The spring issues from the buff coloured quartzite along the scarp slope of the ridge from the N-S trending fracture.



Geological map of Mundani – Chanangaon section: Bijliyana spring (J1)

__GEOHYDROLOGY__

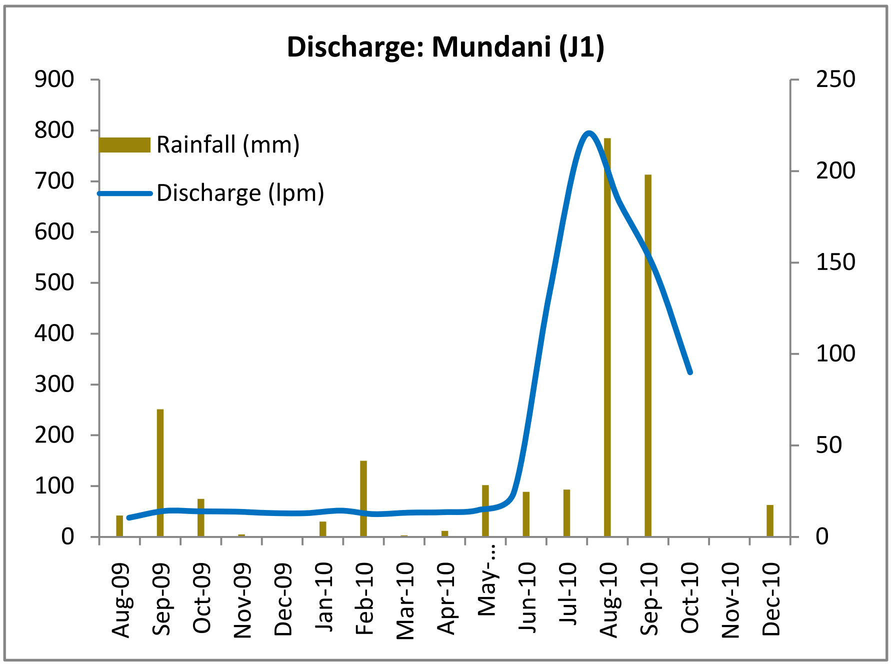
- Generally quartzite and phyllite both have very low primary *porosity* and *permeability*.
- Fractures in the quartzite may increase its *hydraulic conductivity* and it may form an *aquifer*, the overlying phyllite acting as the semi-confining strata.
- The recharge to spring is by means of the fractures. The major N-S trending fracture is likely to be the dominant control.
- The *hydraulic conductivity* of fracture is relatively lower and a dependent on their width.
- Spring J1 is a *Fracture* spring that emerges from the N-S trending fracture from the quartzite bed.
- Groundwater movement is from east to west – controlled by NNW and SSW dipping fractures.
- Groundwater movement is complicated by the dip of the beds and the N-S trending fracture.

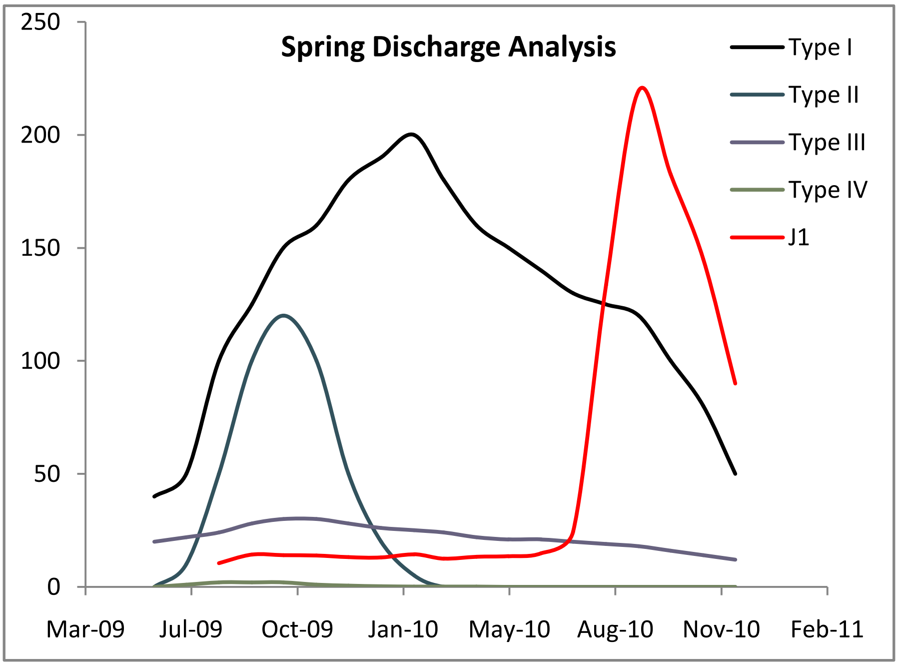


Geological cross-sections / block diagram for Mundani spring showing the different lithological units and fracture pattern, depicting the relationship of the spring to the dip of the lithological units and the fractures. Locations best suited for construction of recharge structures is also depicted.

SPRING DISCHARGE

- The rate of discharge of the spring varies enormously from 10.5 lpm to approximately 14.85 lpm.
- The average discharge (Aug 2009 – June 2010) of the spring is 13.4 lpm.





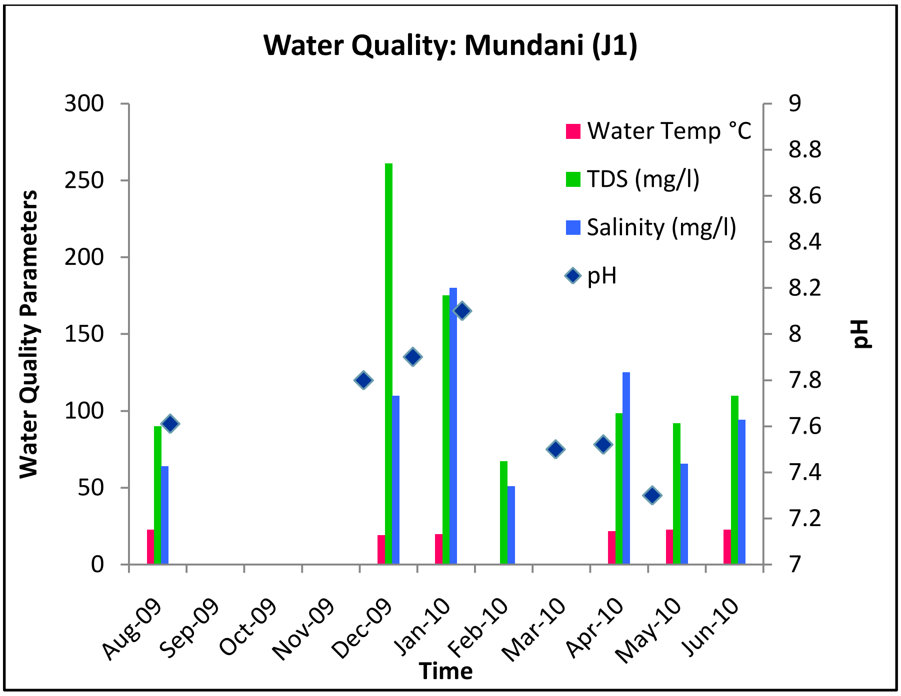
- Change in spring discharge reflects on the hydrogeological parameters of the aquifer viz. Transmissivity and Storativity.
- Based on the pattern of spring discharge one can deduce the nature of the aquifer.
- The spring discharge curves depicted in the figure "***J1 Spring Discharge Analysis"*** are model patterns with understood hydrogeological properties.

MODEL	***Aquifer Attributes***	***Transmissivity and Storativity of Aquifer***	***Nature of the Aquifer***	***Classification based on Discharge***
Type I	Large Storage, rapid flow	High T, High S	Unconfined / Confined	High perennial discharge
Type II	Low storage, quick transmission	High T, Low S	Unconfined / Confined	Widely ranging discharge
Type III	Slow flow, moderate to large storage	Low T, High S	Mostly Confined	Sustained perennial discharge
Type IV	Very Limited storage	Low T, Low s	Very local aquifer	Low discharge, highly seasonal

- The discharge pattern of the spring J1 nearly resembles the ***Type III*** in the figure.
- This implies that the aquifer has low transmissivity (T) and high storativity (S). Although the spring has low discharge it is sustained year long due the high storativity or large storage of the aquifer.
- As the spring is dominantly controlled by fractures, the transmissivity and therefore spring discharge is expected to remain fairly constant through the year. This assumption is also supported by the discharge pattern of the spring.
- It is important to note the sudden rise in discharge in September 2010 due to heavy rains. The sudden rise is attributed to the second hydrogeological system that operates – which is the major N-S trending fracture traversing the valley. This transmits rain water almost immediately to the spring.

WATER QUALITY

- The quality of water issuing from a fracture spring is depends on the lithology of the aquifer.
- The rock water interaction in quartzite is expected to be limited due to the stability of its primary mineral constituent Quartz.
- Overlying phyllite and unconsolidated deposit contain minerals that can easily dissolve many of their constituents.
- In the months of low rainfall the TDS content in the spring water is observed to increase suddenly.

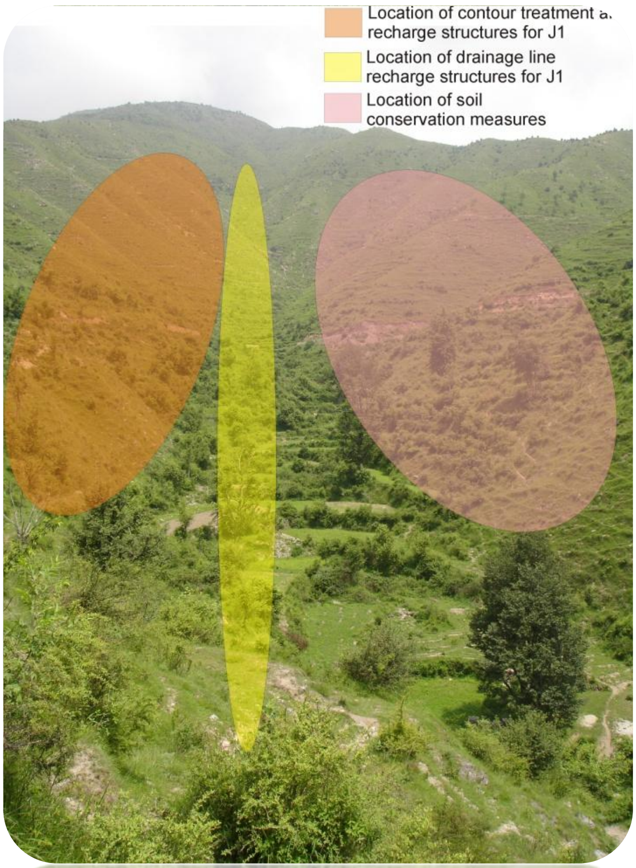


MONITORING THE SPRING

- The spring discharge as well as water quality is monitored regularly by the staff members of GVK.
- Discharge and Quality data is collected every month.

RECHARGE MEASURES

- Trenches and infiltration pits - constructed on both eastern and western flanks of the ridge along the *scarp slope*.
- Plantation of Napier grass, local grasses and other trees to stabilize recharge structures and retain moisture in the soil.
- Recharge measures on both eastern and western slopes of the ridge, concentrated along the NNW and SSW dipping fractures.



Treatment Plan for Mundani (J1) Spring

Churinda spring (C1)

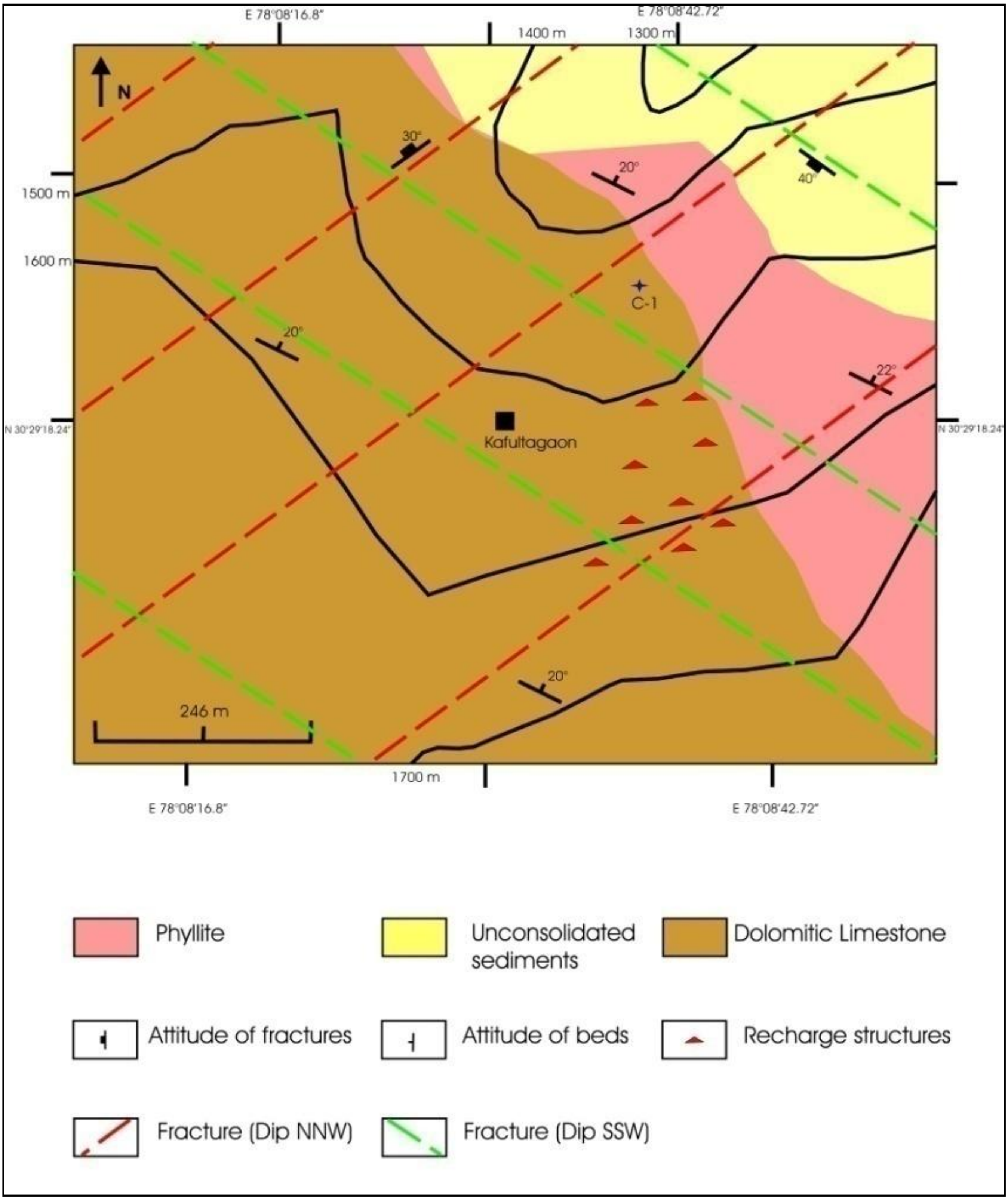
LOCATION

- The Churinda spring (C1) is located near the village of Mathamali (SE of the main Thatyur town).
- The spring is located at N 30° 29' 42.4" E 78° 08'44.9" at an elevation of 1235 m.

GEOLOGICAL SETTING

Karstic Limestone

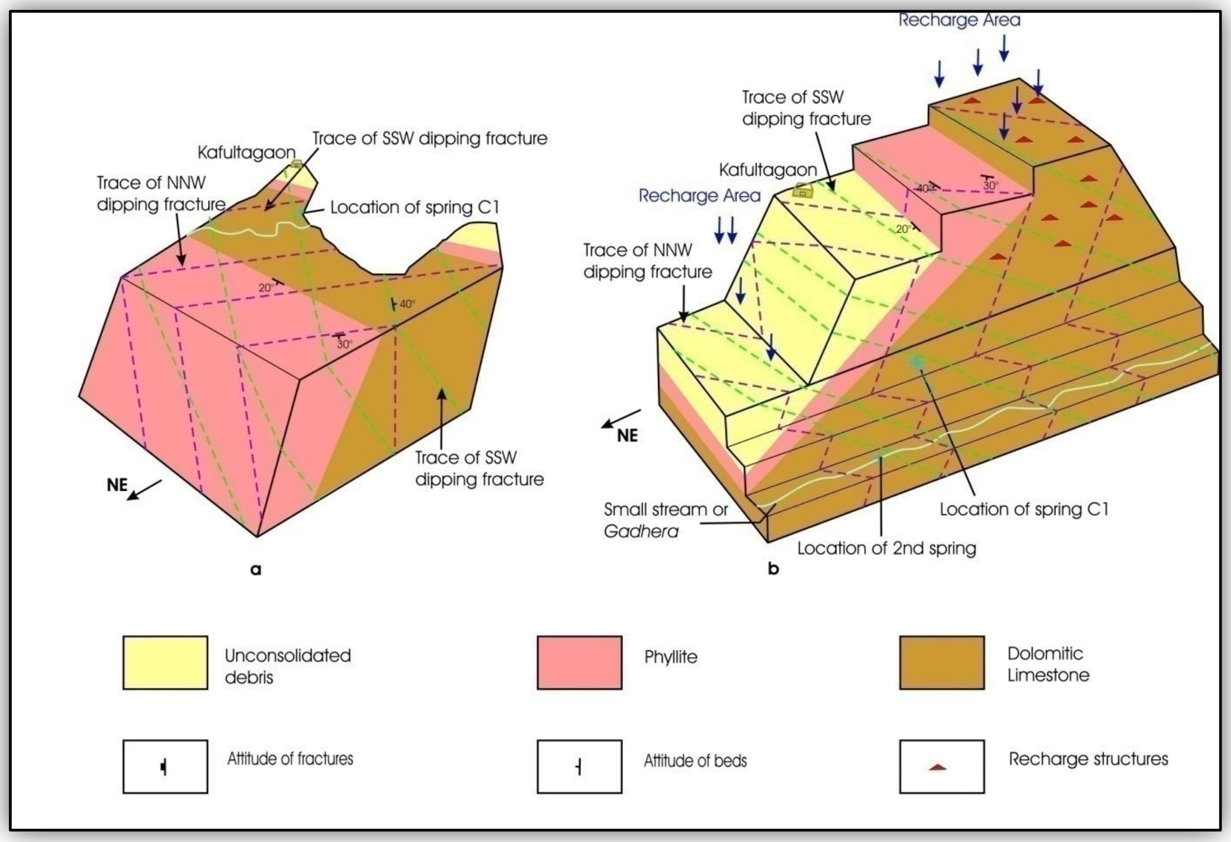
- The lithology in the area primarily consists of cherty dolomitic limestone and phyllite.
- The limestone and phyllite are overlain by unconsolidated sediments of variable grain size.
- The limestone and phyllite beds dip towards NE by 10^{o}-20^{o}.
- Two prominent set of fractures are developed in the area –
  - One set of fractures dips NNW by 30^{o}- 40^{o}.
  - One set of fractures dip SSW by 40^{o}-48^{o}.
- The spring issues from the limestone bed near the phyllite – limestone contact on along the dip slope of the ridge.



Geological map of Mathamali – Kafultagaon area: Churinda spring (C1).

GEOHYDROLOGY

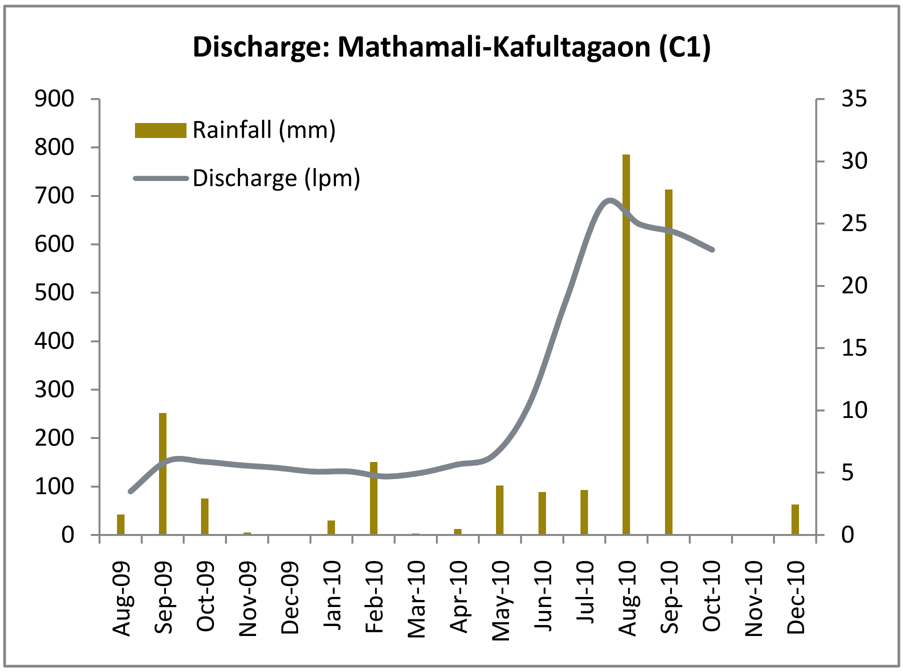
- Primary *porosity* and *permeability* of limestone is nearly negligible.
- *Secondary porosity* and *permeability* in limestone is generally developed by fractures, faults and cavities produced by dissolution of rock.
- The NNW dipping fractures in the limestone bed control the recharge to the spring C1.
- Spring C1 can be referred to as a *fracture or tubular spring* issuing through fractures from the limestone bed.
- Recharge area of the catchment is to the south of the spring along the dip slope of the ridge.
- Groundwater movement is from the SW to the NW – controlled by the NNW dipping fracture and the dip of the beds.

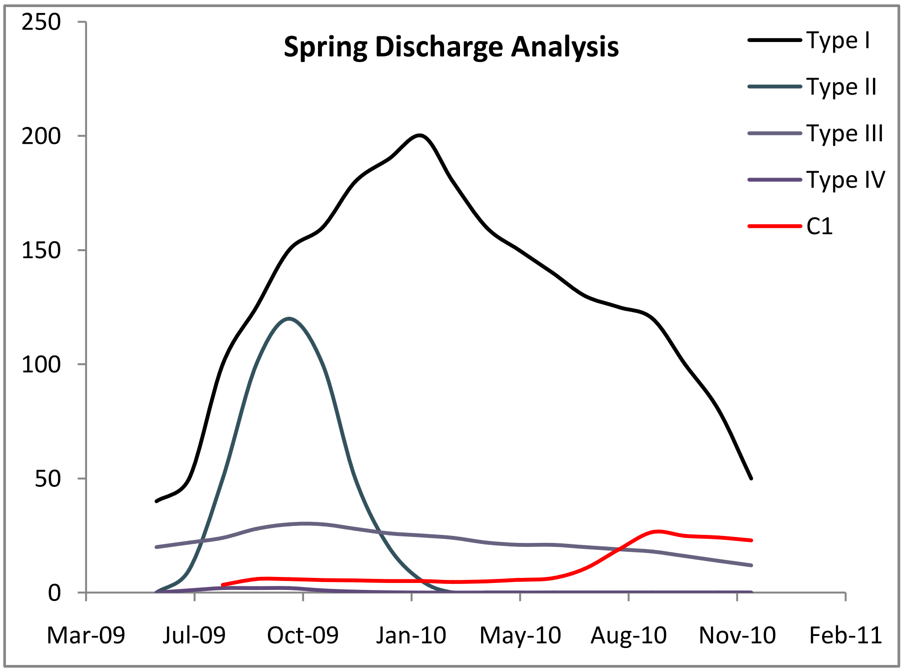


Geological cross-sections / block diagram for Kafultagaon/ Mathamali spring. a) Relationship between the two major set of conjugate fractures. b) Block diagram of the catchment area depicting the relationship of the spring to the dip of the lithological units and the fractures. Location best suited for construction of recharge structures is also depicted.

SPRING DISCHARGE

- The rate of discharge of the spring varies enormously from 3.5 lpm to approximately 6.4 lpm.
- The average discharge (Aug 2009 – June 2010) of the spring is 5.3 lpm.





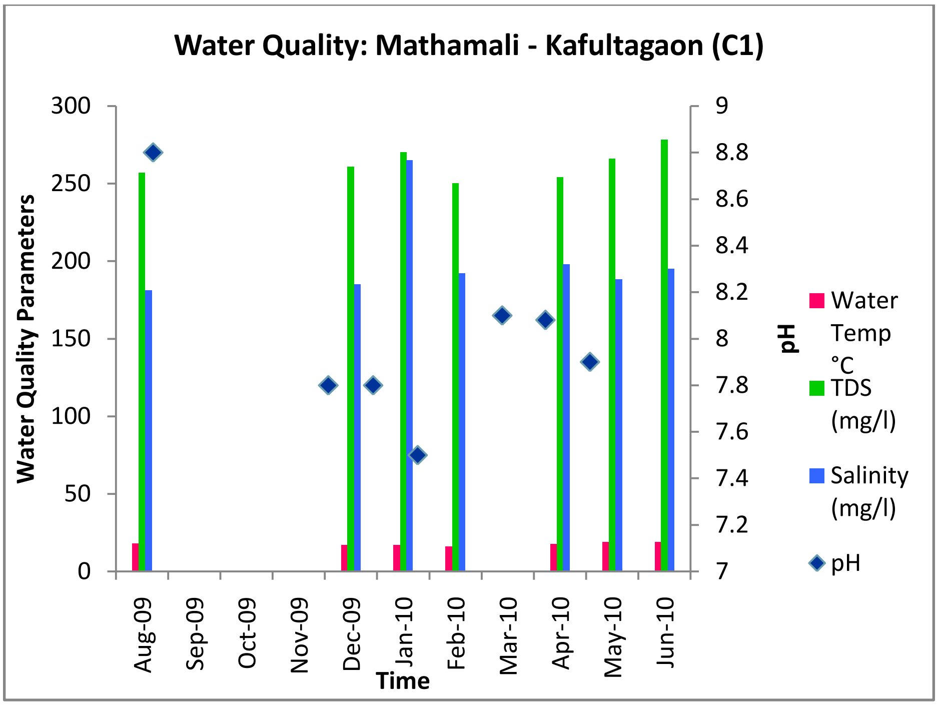
- Change in spring discharge reflects on the hydrogeological parameters of the aquifer viz. Transmissivity and Storativity.
- Based on the pattern of spring discharge one can deduce the nature of the aquifer.
- The spring discharge curves depicted in the figure "***C1 Spring Discharge Analysis"*** are model patterns with understood hydrogeological properties.

MODEL	***Aquifer Attributes***	***Transmissivity and Storativity of Aquifer***	***Nature of the Aquifer***	***Classification based on Discharge***
Type I	Large Storage, rapid flow	High T, High S	Unconfined / Confined	High perennial discharge
Type II	Low storage, quick transmission	High T, Low S	Unconfined / Confined	Widely ranging discharge
Type III	Slow flow, moderate to large storage	Low T, High S	Mostly Confined	Sustained perennial discharge
Type IV	Very Limited storage	Low T, Low s	Very local aquifer	Low discharge, highly seasonal

- The discharge pattern of the spring C1 nearly resembles the ***Type III*** in the figure.
- As in the case of J1 the aquifer of spring C1 also has low transmissivity and possibly high storativity.
- The spring C1 yields sustained perennial discharge of low magnitude.
- The aquifer is expected to be unconfined in nature with moderate to large storage.
- The field observations are confirmed by the discharge analysis – the aquifer for spring C1 is fractured limestone confined by an overlying phyllite bed.

WATER QUALITY

- As dolomitic limestone is composed of minerals which are calcium - magnesium carbonates, they are readily soluble in water.
- The spring water is expected to have a moderately high TDS content and it is observed that the C1 has a much higher TDS and salinity in comparison to J1 and D1.
- TDS content in the spring water is observed to decline by influx of fresh water during rainfall.



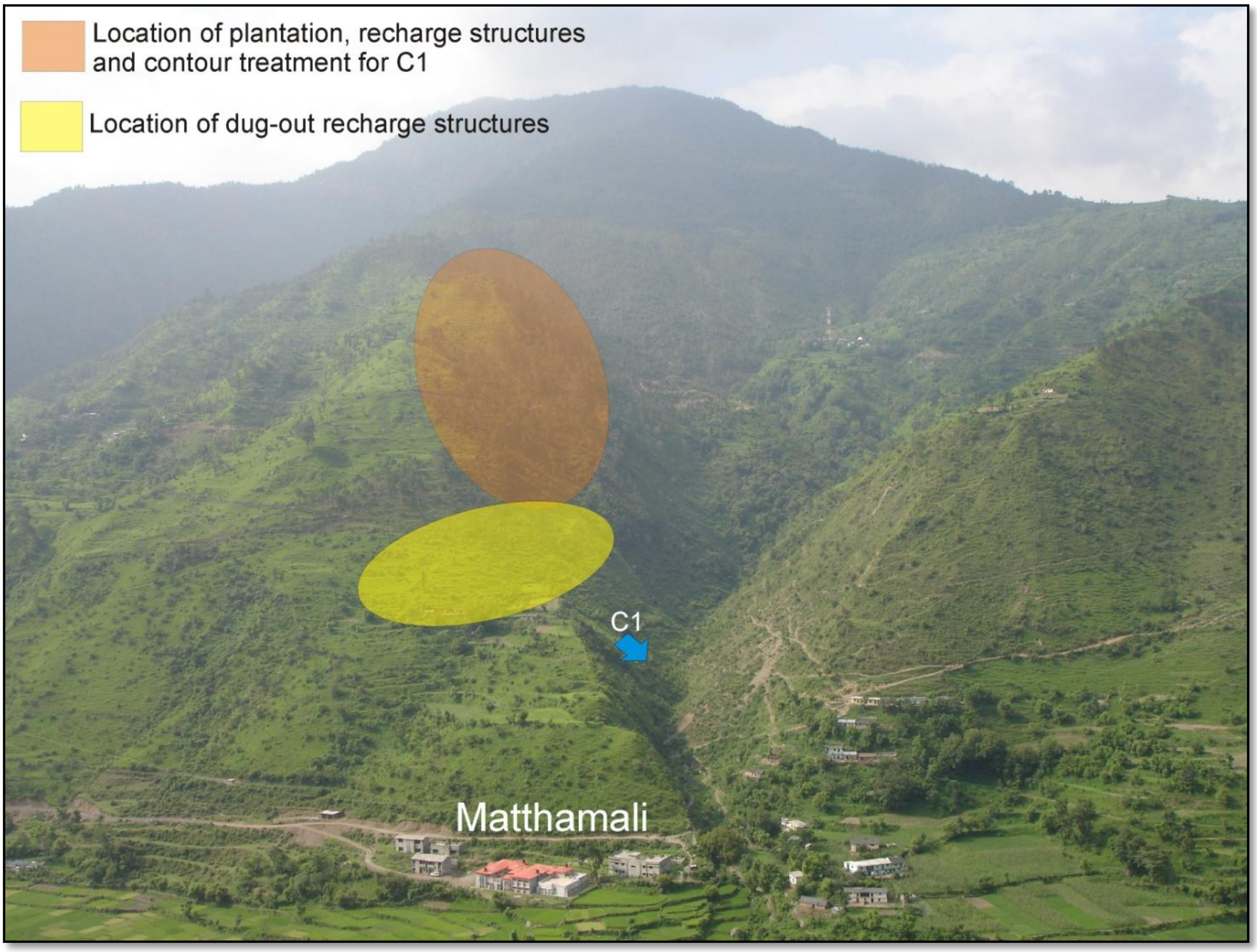
MONITORING THE SPRING

- The spring discharge as well as water quality is monitored regularly by the staff members of GVK.
- Discharge and Quality data is collected every month.

RECHARGE MEASURES

- Trenches and infiltration pits - constructed along the *dip slope*.
- Plantation of Napier grass, local grasses and other trees to stabilize recharge structures and retain moisture in the soil.
- Construction of check dams along *Gadheras*.
- Recharge measures concentrated on the limestone bed below the contact between limestone and phyllite, as phyllite acts as semi-confining layers.

Recharge Structure: Contour Trench with slope adjustment of farm.



Treatment Plan for Mathamali (C1) Spring.

Bandawali spring (B1)

LOCATION:

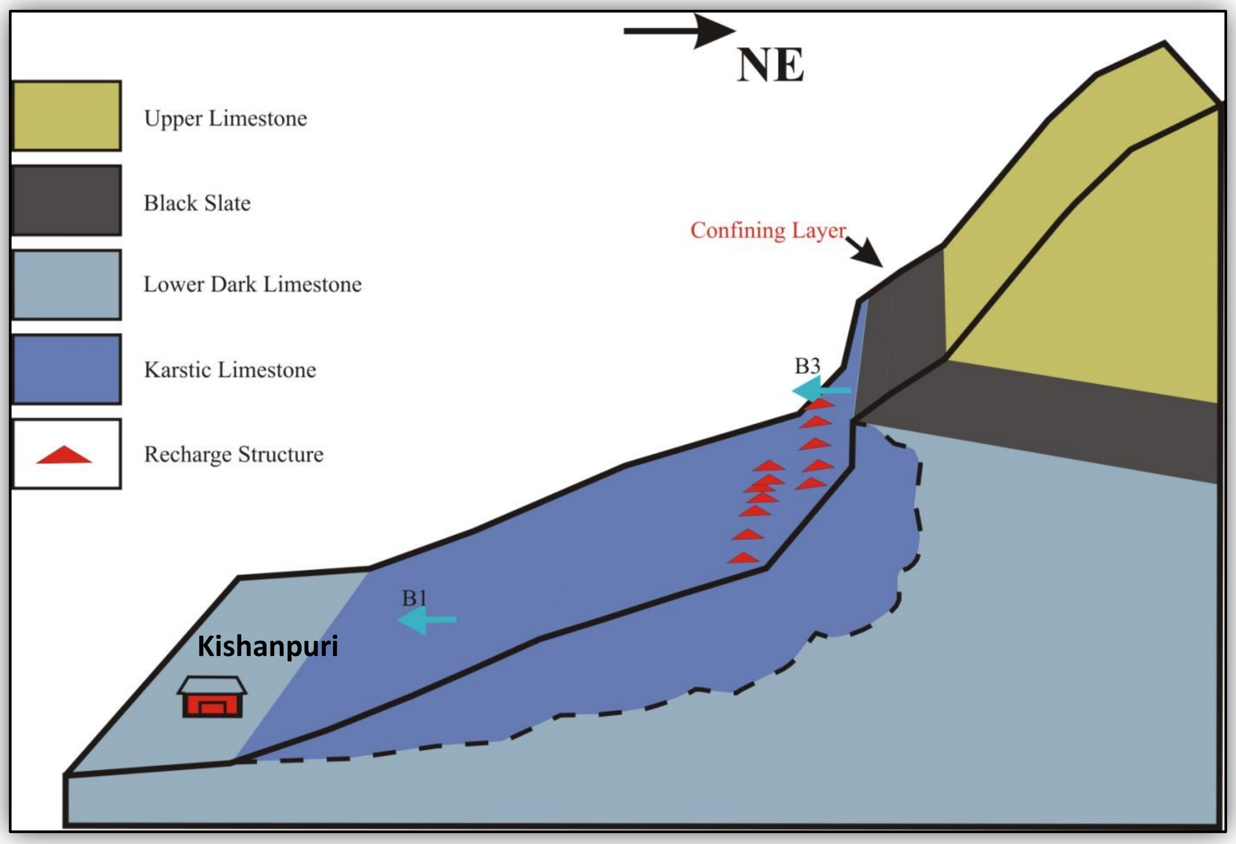
- The spring (B1) is located in the village of Bandawali (NE of the main Dehradun town).
- The spring is located at N 30° 22' 17.7" E 78°6' 56.4".

GEOLOGICAL SETTING

- The dominant lithology in the area is limestone.
- The lower reaches of the ridge are dominated by dark coloured limestone
- The limestone is overlain by a bed of dark black slate.
- Another bed of limestone is present above the slate on the upper reaches of the ridge.
- The lower dark limestone has undergone considerable amount chemical weathering to produce *Karstic* features on the surface along the scarp slope.
- The spring issues from *Karstic* horizon of the dark limestone bed underlying the slate bed.

GEOHYDROLOGY

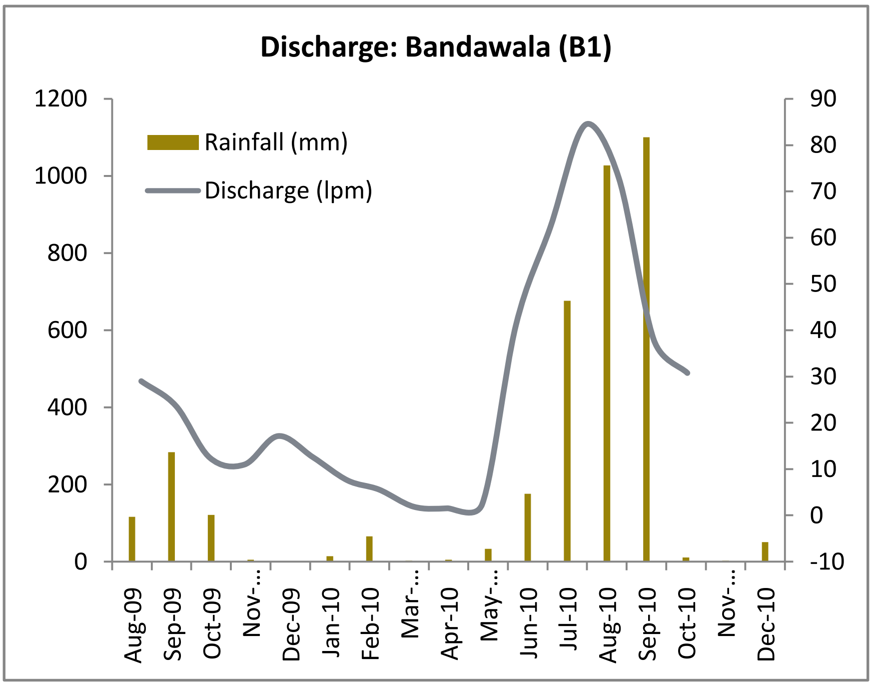
- As the dominant rock type in the area is limestone it forms the chief aquifer, the hydraulic conductivity of the limestone aquifer in the area is controlled by the development of solution channels and to some extent by the fractures.
- The recharge area of the aquifer lies to the N of the spring below the contact between limestone and phyllite.
- The spring may be classified as a *Karstic spring*.

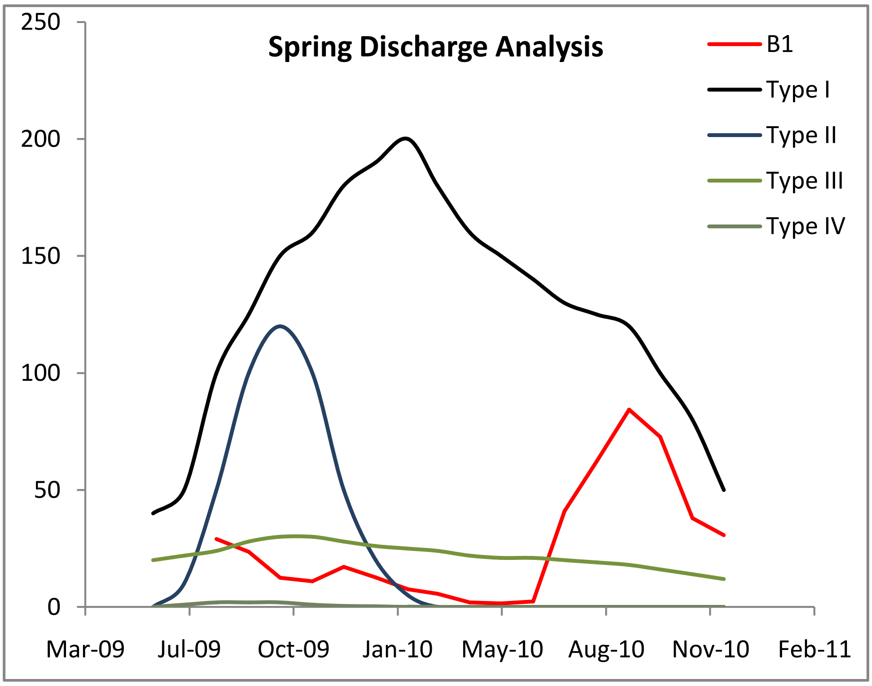


Geological cross-section / block diagram for Bandawali spring: Block diagram of the catchment area depicting the relationship of the spring to the dip of the lithological units. Location best suited for construction of recharge structures is also depicted.

SPRING DISCHARGE

- The rate of discharge of the spring varies enormously from 2.4 lpm to approximately 24 lpm.
- As the hydraulic conductivity or Transmissivity of limestone aquifer is controlled by the solution cavities and fissures, there is a sharp rise in the discharge following rainfall.
- Similarly, the discharge of the spring drops instantly after the cessation of rain.
- The average discharge (Aug 2009 – June 2010) of the spring is 11.36 lpm.





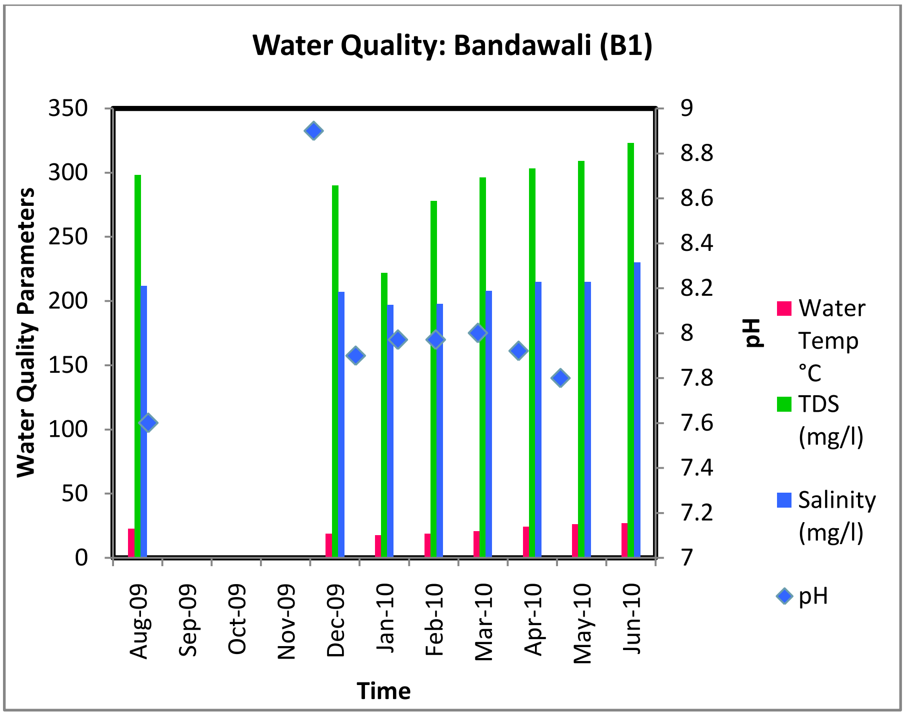
- Change in spring discharge reflects on the hydrogeological parameters of the aquifer viz. Transmissivity and Storativity.
- Based on the pattern of spring discharge one can deduce the nature of the aquifer.
- The spring discharge curves depicted in the figure "***B1 Spring Discharge Analysis"*** are model patterns with understood hydrogeological properties.

MODEL	***Aquifer Attributes***	***Transmissivity and Storativity of Aquifer***	***Nature of the Aquifer***	***Classification based on Discharge***
Type I	Large Storage, rapid flow	High T, High S	Unconfined / Confined	High perennial discharge
Type II	Low storage, quick transmission	High T, Low S	Unconfined / Confined	Widely ranging discharge
Type III	Slow flow, moderate to large storage	Low T, High S	Mostly Confined	Sustained perennial discharge
Type IV	Very Limited storage	Low T, Low s	Very local aquifer	Low discharge, highly seasonal

- The discharge pattern of the spring B1 nearly resembles the ***Type II*** in the figure.
- The aquifer for the spring B1 is the *Karstic* limestone bed overlain by a confining layer *dark black slate*.
- As depicted in the block diagram of the Bandawali area the limestone bed has a shallow chemically weathered zone which forms the *Karstic* aquifer for the spring.
- The *Karstic* aquifer is of very local extent developed only on the SW slope of the ridge.
- The deductions made from discharge curve analysis corroborate with field observations.

WATER QUALITY

- Typical of a karstic aquifer, water has the highest TDS content of all the four springs included in the study.
- The quality of the water varies with rainfall.
- Predictably, highest TDS is recorded in the months of least rainfall. In the months of heavy rainfall the TDS content in the spring water declines due to influx of fresh water.



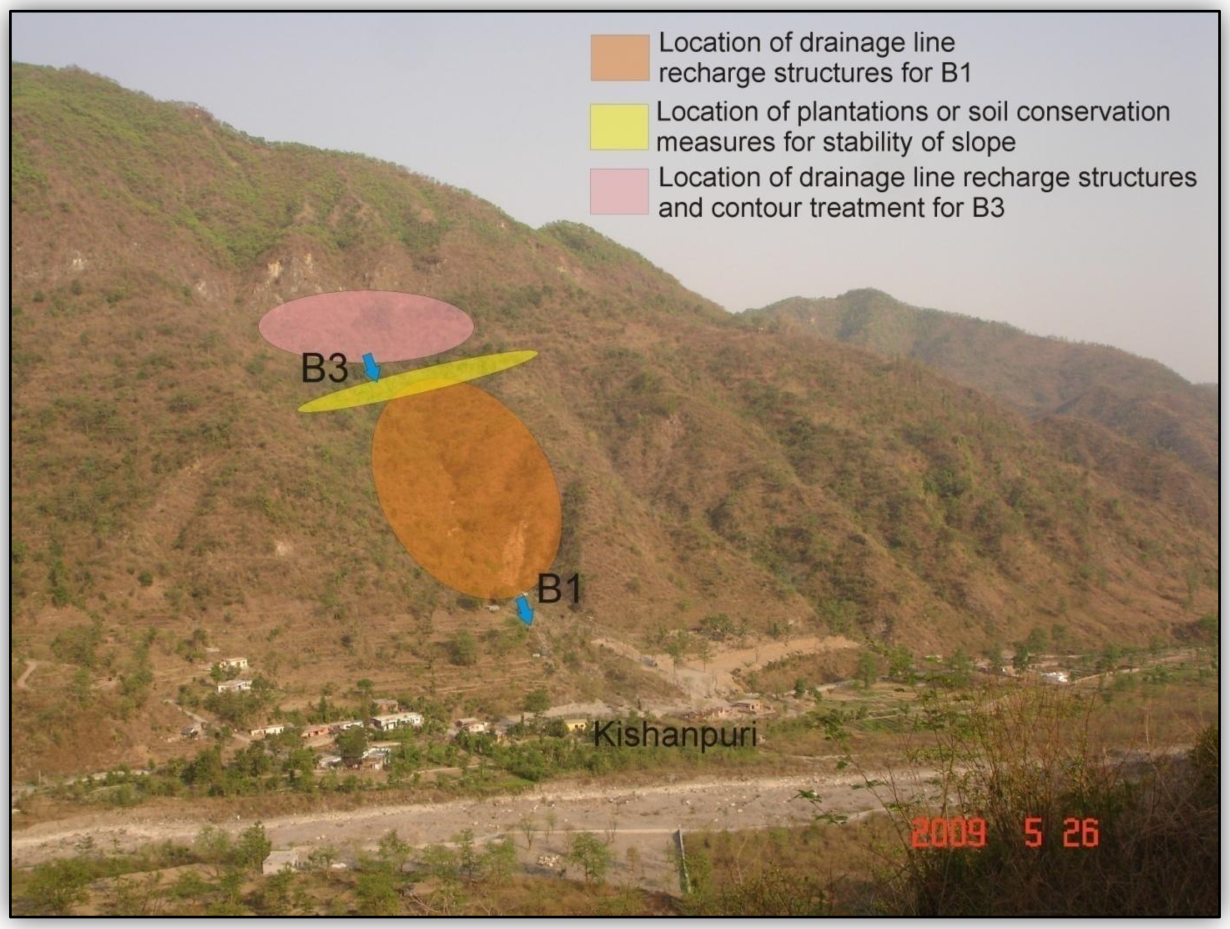
MONITORING THE SPRING

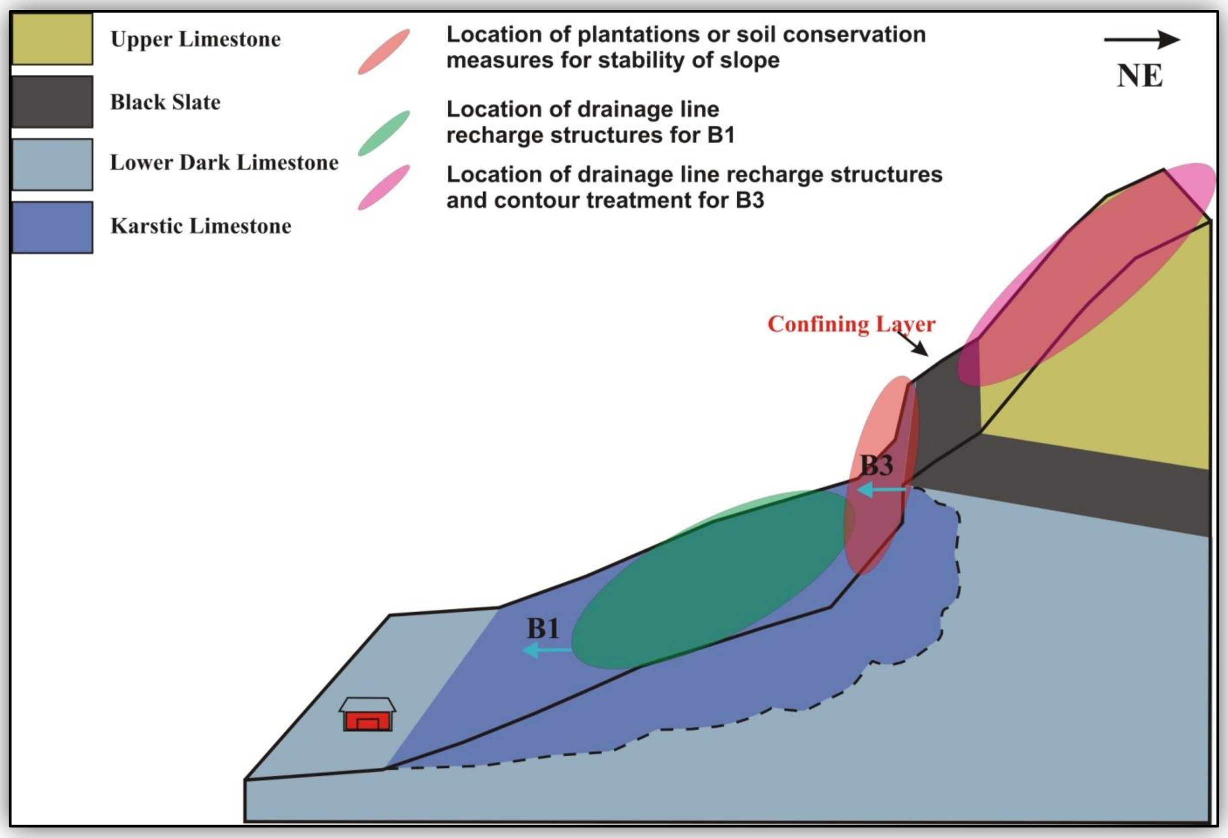
- The spring discharge as well as water quality is monitored regularly by the staff members of HERDS.
- Discharge and Quality data is collected every month.

RECHARGE MEASURES

- Trenches and infiltration pits - constructed along the *scarp slope*.
- Plantation of Napier grass, local grasses and other trees to stabilize recharge structures and retain moisture in the soil.
- Check dam construction along the numerous *Gadheras*.

Recharge Structure: Percolation pit or *Khal*





Treatment plan for Bandawali springs.

TRAINING AND SOCIAL ASPECTS

TRAINING EXPERIENCE

Feb 2010 Interactive training workshop at Dehradun

An initiation workshop conducted in September 2008 highlighted the importance of sound geological understanding in planning and management of water sources. The workshop conducted in May 2009 was concentrated on teaching the concepts of hydrogeology and its relevance in the spring development programmes. Components of the training programme included hydrogeological mapping, spring discharge measurement and identification of type of springs. In February 2010 a final interactive training workshop was conducted. Partner organizations presented their experience in the field. Evaluation of the pilot project and work by other partners following the training revealed many positive facts. Organizations have been able to successfully able to identify types of springs and incorporate the science of hydrogeology in the planning of recharge programmes.

SOCIAL CHALLENGES

Building community awareness and social mobilization are the primary challenges in spring development initiatives. Different challenges were encountered in the four villages or spring sites. Village level committees have played a significant role in the implementation of recharge measures and managing the drinking water supply scheme. However, conflicts within villages such as Mundani and Chanangaon have not been resolved. Problem at Bandawali is that the land surrounding the spring has been bought by a private construction company. Village committee has resolved the issue effectively by discussing the matter with the company, which has subsequently promised to not disturb the tank and give the villagers free access to the tank. The fencing of the spring recharge zone in Mathamali has created small divide within the village community. Few families residing near the spring site are now unable to access the protected zone for fodder and fire wood. Village level committees and partner organisations must strive to work towards resolving these issues through local administration. Partner organisations must now focus on spring management issues through capacity building of village level committees.

CONCLUSIONS AND OUTCOMES

The pilot studies highlighted the importance of hydrogeology in the development and management of mountain springs. Treatment measures planned after hydrogeological assessment of the spring-shed have proved to be more effective in recharging the springs. Under the WATSAN phase two, capacity building of partner organizations was undertaken. These capacity building interventions have empowered the partners to measure discharge parameters and therefore continuously monitor the spring discharge.

The specific technical output of the pilot studies was the generation of model spring hydrographs. These hydrographs were used to understand the properties of the aquifer. Model hydrographs, as well as water quality data, were also used to corroborate field observations and spring types. Water quality monitoring has also been part of the study. No specific contamination has been observed. However, detailed water quality analysis needs to be undertaken to reach concrete conclusions. Hydrogeological investigations also resulted in the generation of complete three dimensional understanding of the spring-shed area.

Social and administrative difficulties have been recognized which hinder the implementation of treatment measures. It has been observed that the recharge area of springs vary depending on the hydrogeological setting and may not necessarily conform to administrative boundaries. Through capacity building initiatives a change in the recharge models have been brought about. Existing models considered only 10 Ha of area above the springs, however, training and field facilitation have enabled identification of recharge area and therefore propagate the development of spring specific catchment area treatment.

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