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# Hydrogeological assessment for planning springshed management in Bans-Pabhe, Pithoragarh, Uttarakhand

ACWADAM

Advanced Center for Water Resources Development And Management

# Hydrogeological assessment for planning springshed management in Bans-Pabhe, Pithoragarh, Uttarakhand

Based on fieldwork and analysis of results: For KSL project- Indian sites, in partnership with ICIMOD

Technical report no. ACWA/Hydro/2017/H52

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# INTRODUCTION

Chandaak-Aulaghat watershed (CAW) is located north-west of the Pithoragarh city beyond Chandaak. The study area is located N29° 05'- N29° 10' and E80° 35'- E80° 40' grid of the toposheet number 62 C/2 issued by Government of India. The Ramganga River flows to the west of the CAW approximately in north-south direction at an elevation of 600m while the highest elevation is 2100m at Pabhe village (Fig. 2). The watershed is also bounded by Kalapani gad in north and Kin gad at south direction of the watershed while the Gokarneshwar gad is the major the streamlet which flows through the watershed. All of them flow towards west to merge finally into the Ramganga River.

In CAW three springshed viz. 'Digtoli-Seem', 'Bans-Pabhe' and 'Jajrauli-Baksil' springshed have been identified for piloting the springshed management approach under the KSLCDI project being implemented by ICIMOD and partners. The 'Digtoli-Seem' springshed is the part of Gorang valley while the other two belongs to Aulaghat valley. During the spring inventory exercise 131 springs are identified altogether by various partners of whom 52 springs are in the selected springsheds. On the basis of questionnaires viz. Focal Group Discussions (FGD's), spring questionnaire and Key Informant Interview (KII) conducted jointly by ICIMOD, ACWADAM and partners, further selection of springs is done to conduct hydrogeological studies.

Geologically, the study area consists of Proterozoic rock formations of Inner Lesser Himalaya which are tectonically bounded to the south by the North Almora Thrust (NAT) and to the north by the Main Central Thrust (MCT). In accordance with field observations and reference to the Geological map of Kumaun Lesser Himalaya by Prof. K S Valdiya, the rocks observed in the study area belong to Deoban (Dolomite and Limestone) and Mandhali (Sor Slate) Formation of Tezam group and Berinag Formation (Quartzite and metavolcanics) of Jaunsar group.

Hydrogeological assessment of 'Digtoli-Seem' springshed has already been discussed in the previous report. There is no information on springs being monitored at Jajrauli and Baksil, hence, this report primarily focuses on the hydrogeological assessment of 'Bans-Pabhe' springshed while also reflecting on the hydrographs produced from currently available data from various springs under the study.

Bans village is the part of Aulaghat valley which forms the relatively lower and south-western extension of the CAW. Pabhe is situated towards south-west of Bans at the top portion of the ridge and is extended on both sides of the ridge. Together they form a 'springshed'. Unlike Gorang valley, Aulaghat is devoid of quaternary sedimentary deposits and there is more structural control on the topography. Reduction in discharge of spring-water is an acute problem especially in the upper reaches of the watershed. Currently, 'Chandaak-Aulaghat Yojna' which intends to tap water from the Ramganga is in progress to benefit the residents of Pithoragarh City and have left no meaning for the village community.

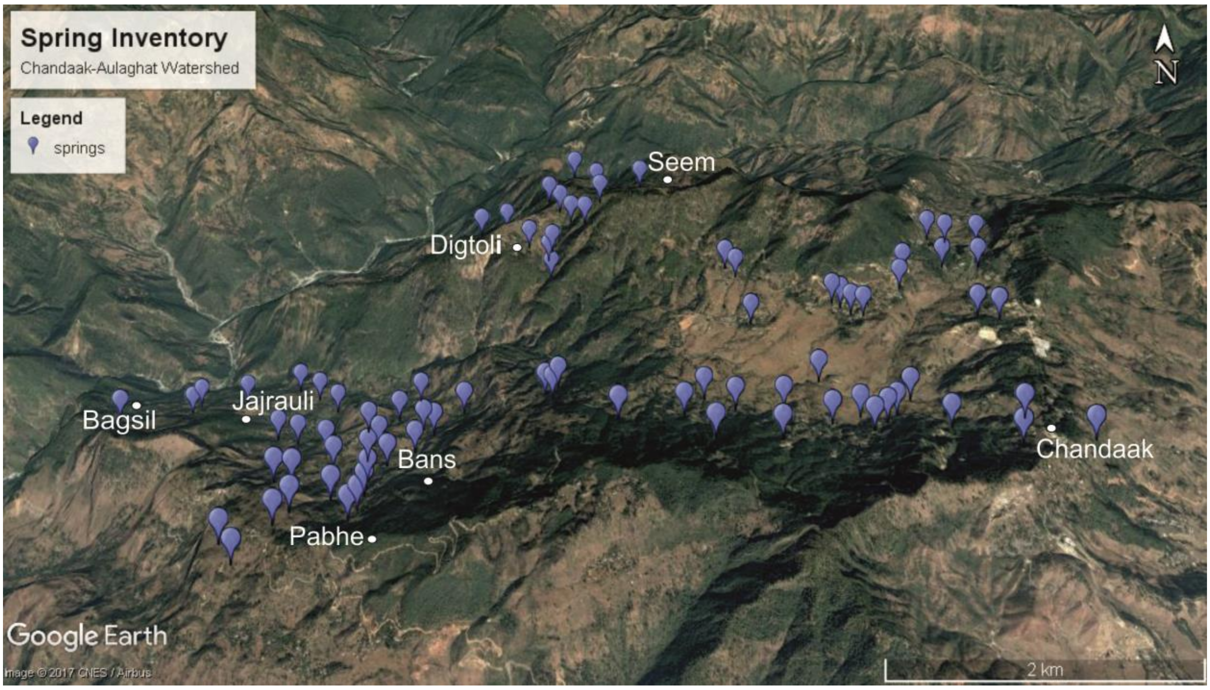



Figure 1: Spring Inventory of Chandaak-Aulaghat watershed; 131 springs inventorised and still counting within 24.56 sq.km.

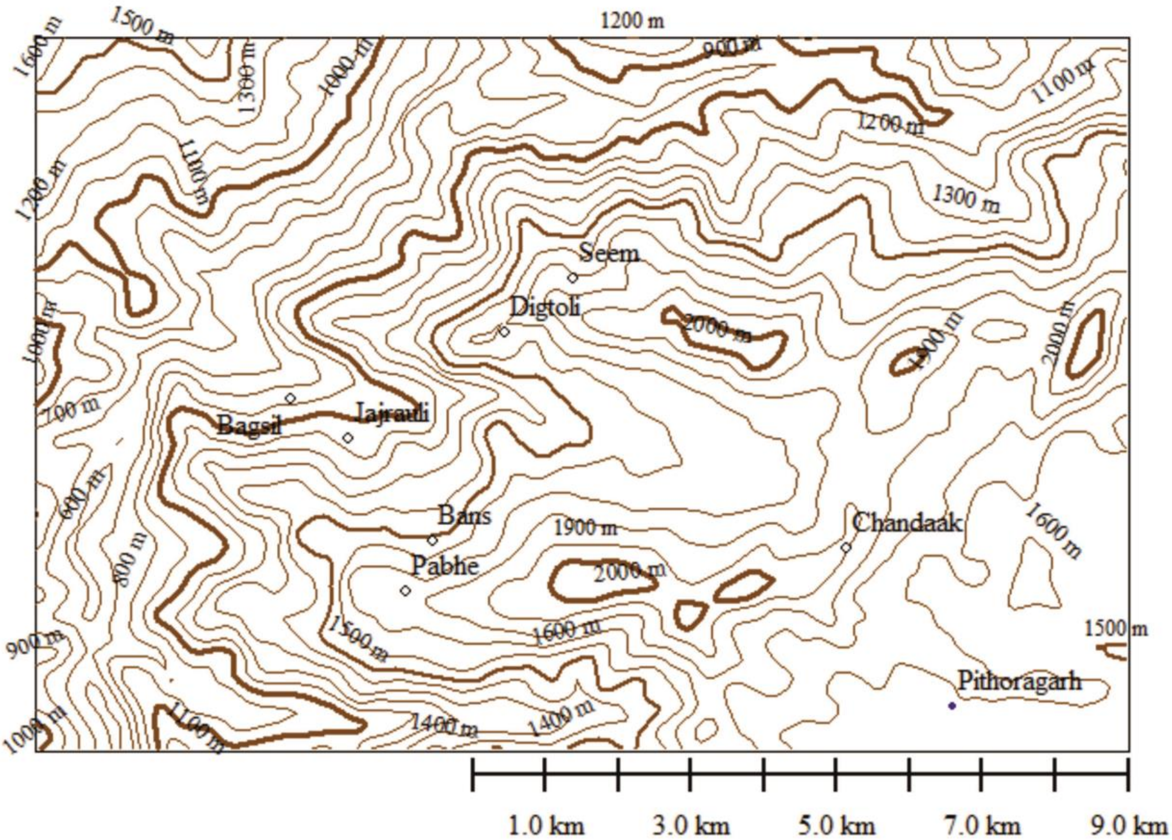



Figure 2: Contour map of Chandaak-Aulaghat watershed

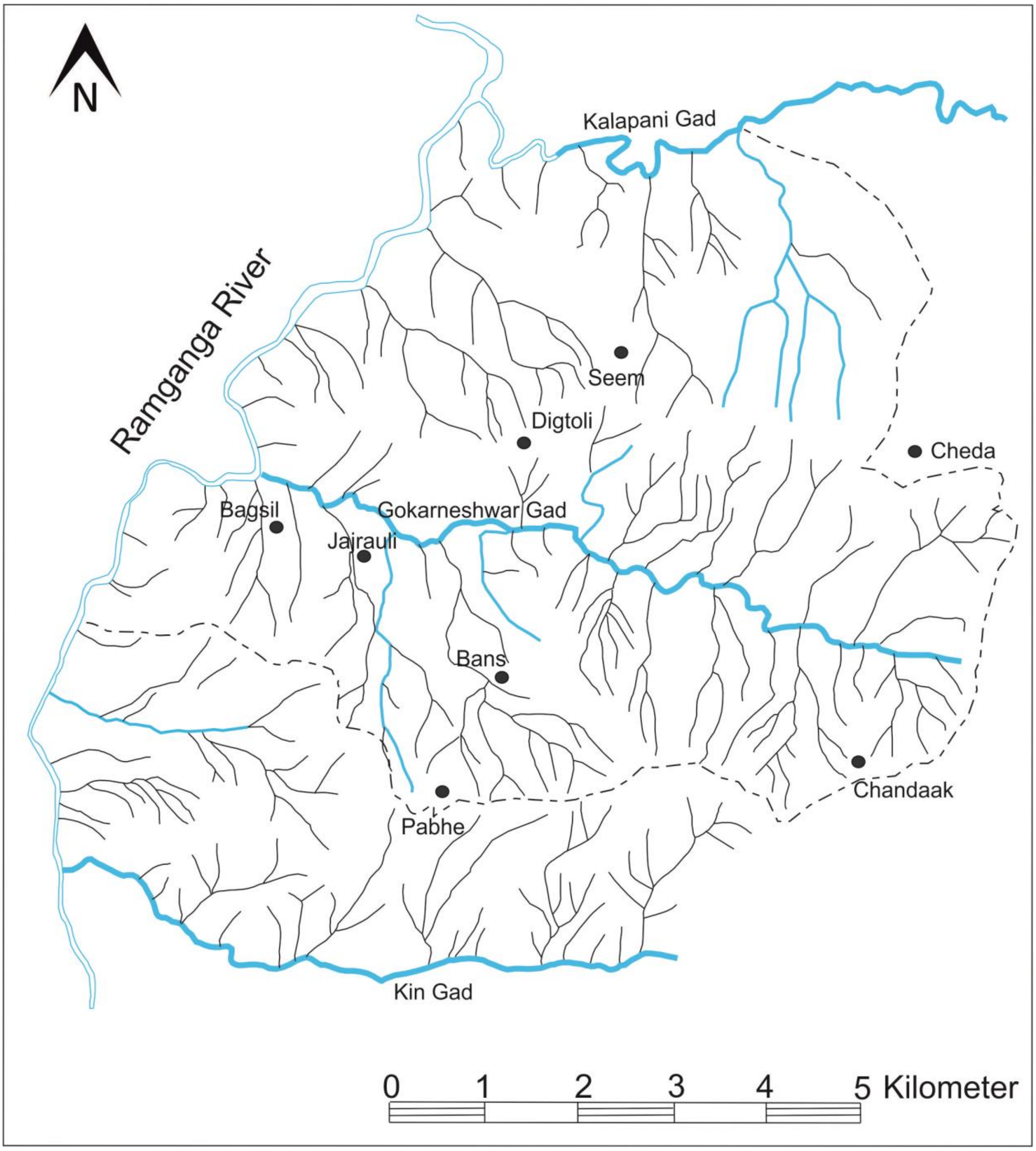



Figure 3. Drainage network of Chandaak-Aulaghat watershed with its springshed(s) as represented by dotted lines and major streams, which drain into Ramganga River. Blue colour refers to the perennial flow while the black colour marks the seasonal Gad(s). The Drainage pattern observed is sub-dendritic to Trellis

## GEOLOGICAL SETUP

The dominating rock types in the study area are slate, bedded limestone and magnesite with occurrence of laminated chert, quartzite and talc beds intercalated at some places (Figure 4). The slate is commonly observed along the roadside and is massive near Kafaldhungri. It is mostly phyllitic in character and at places has been completely metamorphosed to phyllite. Two types of limestone are observed during the fieldwork. Grey limestone, which is thickly bedded, and possess cavities of various scales. The pink limestone, on the other hand, is also massive, exposed in the lower reaches of the watershed but possesses no cavities and is relatively more compact. Quartzite, chert, sandstone and phyllite occur as interbedded sequence. Phyllite, talc and magnesite repeat itself in the lowermost section of the valley. Quartzite is white in colour and coarse-grained in nature. The rock beds are generally dipping towards northeast direction and the dip amount varies between 15° to 55°. Since the direction of slope in Kafaldhungri coincides with the dip direction of the rock beds it is said to be located on a dip slope while the Pabhe village rests on the top and extends its borders towards dip slope as well as escarpment slope. Magnesite is the dominant lithology in Pabhe at uppermost part of the ridge where nicely developed crystals of magnesite mineral can be seen.

Figure 4: Lithological map of the 'Bans-Pabhe springshed'

It is evident from the rock type (phyllite, quartzite and talc) that the region is affected by dynamic metamorphism. This is owing to compressional tectonics during Himalayan orogeny and has resulted in shearing of beds as well as their brittle deformation expressed in the form of fracture sets. Commonly two types of fracture sets have been observed. One trending NNE-SSW and dipping towards ESE by 45° while the other set runs ESE-WNW and dips at an angle of 80°. Magnesite, quartzite and limestone being resistant rock have fairly less density of fractures giving them a massive and blocky appearance while slate, phyllite and talc being soft are subjected to more deformation and are highly cleaved. Two gadheras parallel to NNE-SSW trend are also observed in the study area. Shear Zones are visible but bear less significance in relation to spring characteristics.

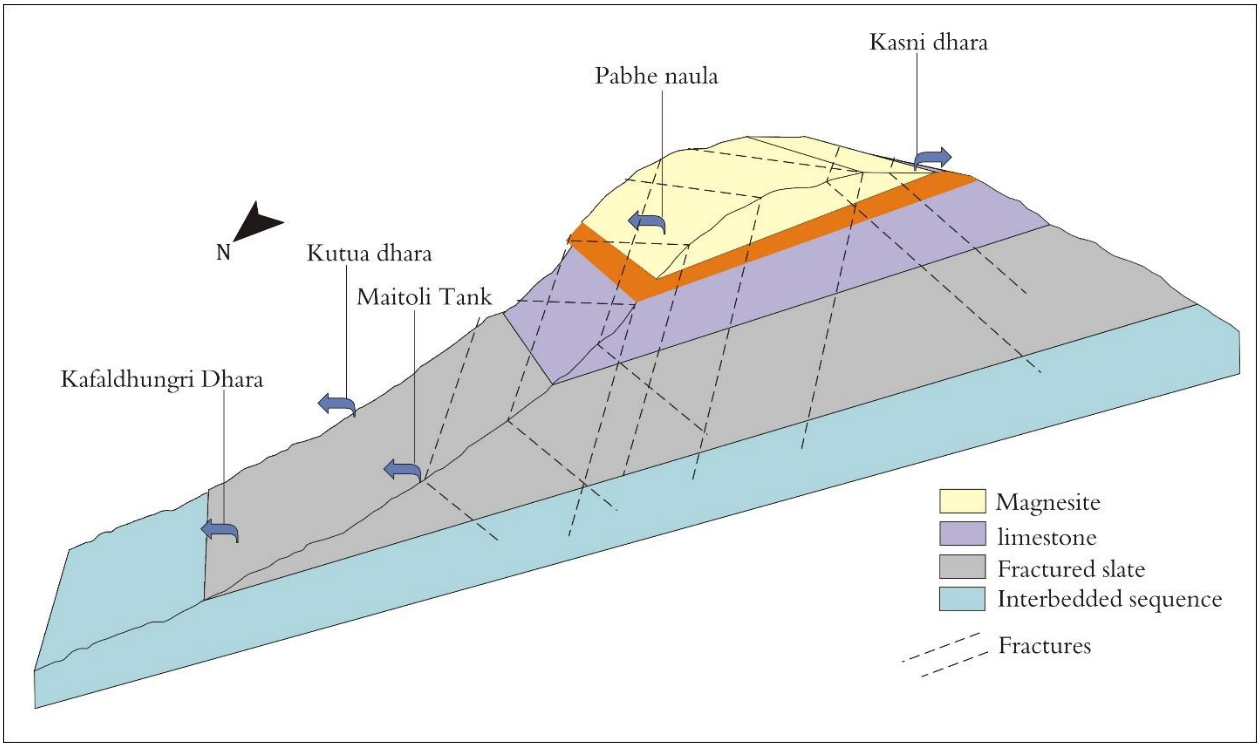



Figure 5: Hydrogeological conceptual layout of the 'Bans-Pabhe springshed'

## HYDROGEOLOGY

In quartzite and sandstone, the primary porosity is governed by its coarse-grained nature but their extent in the study area is limited. The limestone has no primary porosity. Based on geological mapping and structural analysis it is envisaged that the secondary porosity exceed the primary porosity. Though magnesite does not possess any primary porosity and has poor permeability but the presence of two fracture-set provide the secondary porosity and permeability. The slate shows three set of fractures and are highly cleaved. So is the case with phyllite. Therefore, they have good secondary porosity and permeability. Presence of a sinkhole near the boundary of Kafaldhungri and Pabhe and a huge cavity discernible on the way to Bastey village bear testimony to the presence of karst topography produced by differential weathering and erosion of limestone and magnesite. All the secondary porosity thus developed is the major contributing factor for the storage and transmission of water in the study area.


(5a) (5b)


(5c) (5d)

Figure 5(a): Natural pond(s) formed at the top portion of the springshed where magnesite is the dominant rock type. These are formed during monsoons. 5(b): Scope of Primary porosity in magnesite; fully grown magnesite crystals 5(c): Secondary porosity (cavities) in magnesite (5d): massive slate bed saturated with water and allowing its percolation through bedding plane (indicated by growth of algae along BP)

| **Spring Name** | **Latitude** | **Longitude** | **Elevation** | **Village** | **Occurrence** | **Seasonality** | **Spring type** |
|---|---|---|---|---|---|---|---|
| Kafaldhungri Dhara | 29.60291667 | 80.14388889 | 1550 | Bans | Depression | Perennial | Dhara |
| Kutuadhara | 29.60108333 | 80.14388889 | 1603 | Bans | Depression | Perennial | Dhara |
| Maitoli Tank | 29.60197222 | 80.14158333 | 1632 | Bans | Fracture | Perennial | Dhara |
| Kasni dhara | 29.59580556 | 80.13661111 | 1706 | Pabhe | Fracture | Seasonal | Dhara |
| Pabhe Naula | 29.59811111 | 80.13916667 | 1721 | Pabhe | Depression | Seasonal | Naula |

Table1. Details of springs identified for detailed hydrogeological studies from Bans-Pabhe Springshed

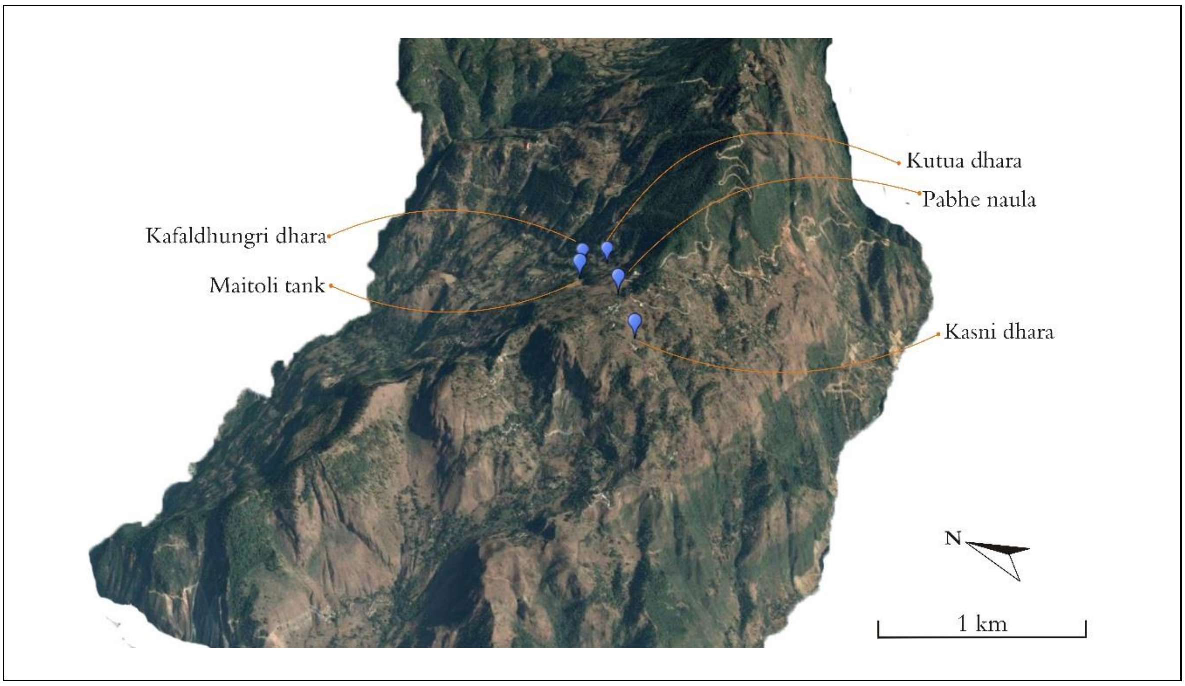


Figure 6: Springs identified for detailed hydrogeological studies from Bans-Pabhe Springshed

Keeping in view the above mentioned points and integrating them with field observations, it is envisaged that in Kafaldhungri, springs are generally found to emerge from slate which forms the aquifer system to feed its springs while at Pabhe the spring are the integral part of karst topography and may also feed other springs in the downstream. The details of hydrogeological behaviour have been discussed in the following section.

## BANS (KAFALDHUNGRI) VILLAGE

### KAFALDHUNGRI DHARA AND KUTUA DHARA

Both Kafaldhungri Dhara and Kutuadhara are depression spring emerging amidst cultivation land from the dip slope. They are perennial springs but their discharge reduces greatly during the lean period especially the Kafaldhungri Dhara. Based on geological data, it is inferred that both the springs are supported by aquifer system in the slate. The precipitation is taken up by secondary openings in magnesite from where it travels as groundwater into the deeper layers through fractures in the limestone and sandstone. Sandstone is absent near the vicinity of kafaldhungri Dhara. Sandstone has good primary porosity and permeability, thus it stores and transmits a good amount of water but due to presence of fractures, the water trickles down to slates prevailing under the cultivation land. The pink limestone underlying the slate is highly compact, possesses very less secondary porosity, and is interbedded sequence of chert, phyllite and quartzite. The presence of sandstone bed above Kutuadhara accounts for its higher discharge rate of Kutuadhara (4lpm) as compared with Kafaldhungri Dhara (1 lpm) during the lean period.

## RECHARGE MEASURES

The area above both the springs is cultivation land, which can be treated for inward sloping to recharge the fractured aquifer system. Potential recharge area demarcated can be treated with staggered contour trenching depending on slope feasibility. The highly dense mix forest over the ridge area and especially in the south-west direction should be preserved taking into the consideration the dip of the fracture sets trending NNE-SSW and ESE-WNW. Small dimension deep recharge pits can be structured in this area limiting no. of pits. Nala's can be treated with drainage line water conservation structures to facilitate additional recharge to the system (Fig.7).

## MAITOLI TANK

Maitoli tank is constructed on a Gad trending in NNE-SSW direction. The gad is perennial in nature and its source is through a fracture connected to a sinkhole in the upper reaches of the valley. It takes groundwater from all the overlying litho-units. The tank is piped and supplies water to both Maitoli and Kafaldhungri village. In the recent past there have been conflicts about the distribution system. Since the tank is closed, no discharge measurements could be made.

## RECHARGE MEASURES

The overlying karst topography is natural recharge to the Gad feeding the Maitoli Tank. Though recharge structures can be constructed here as the soil in the recharge zone is thick, it is important to note here that the recharge zone falls in the boundary of Pabhe, which prohibits the inhabitants of bans to carry out any activity in the region (Fig.7).

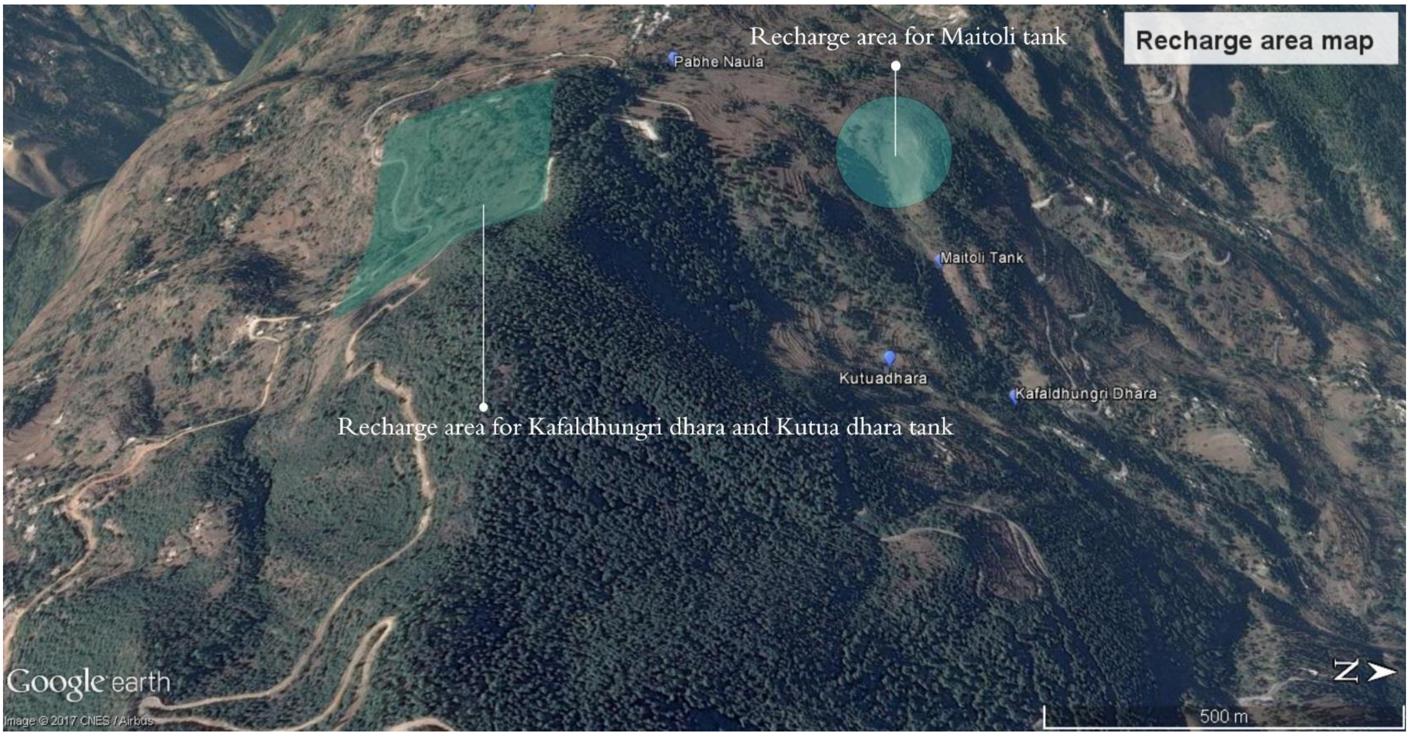



Figure 7: Google image depicting potential recharge area demarcation

## PABHE VILLAGE

### PABHE NAULA AND KASNI DHARA

Pabhe is located at the top of the ridge above Bans. A natural perennial lake has been reported here prior to road construction, which eventually got dried up after the excavation. The village is mainly built upon magnesite and limestone litho units. The magnesite outcrops are scattered but oriented with large fracture and exhibits karst topography. The openings are filled with soil. Thus, the Kasni dhara, which is on the escarpment slope, derives it water through fractures and is identified as fracture spring. The secondary opening in magnesite forms a shallow aquifer, which drains its water eventually to the underlying rock formations. It is the case with Pabhe Naula. Thus, both the springs are seasonal in nature.

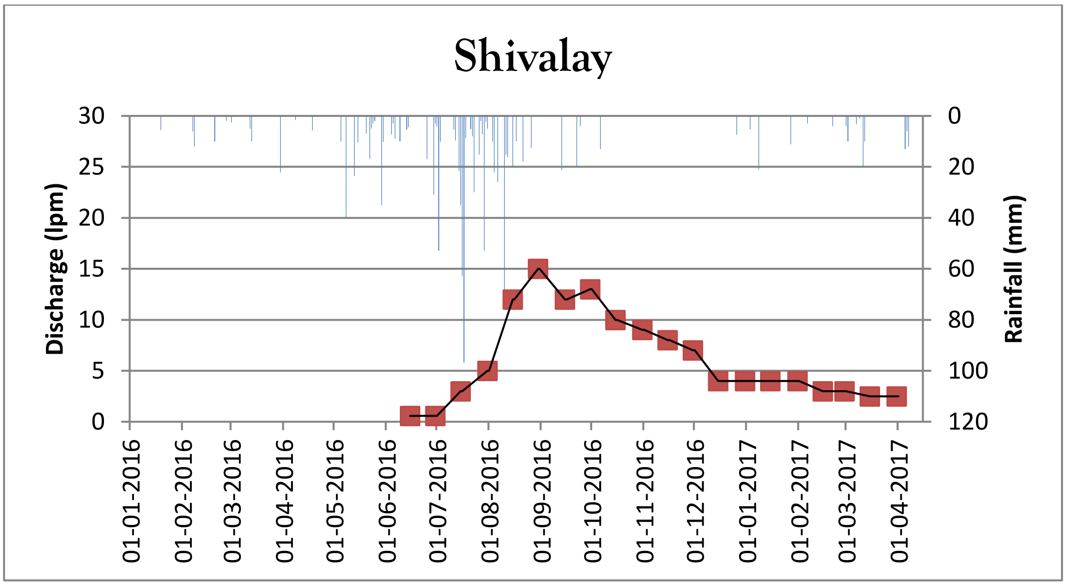
### RECHARGE MEASURES

Afforestation would be the best practice to revive the springs but since the land has been transformed for agriculture this does look as a possibility. All the land above the spring is private land. Trenches can be dug out with the support of the community. In the given scenario, rainwater harvesting would be the best practice to follow, as the community is dependant totally on rainwater the break in the hydraulic connectivity of rocks during road construction has reduced the scope of recharge in the adjoining hill.

# HYDROGRAPH

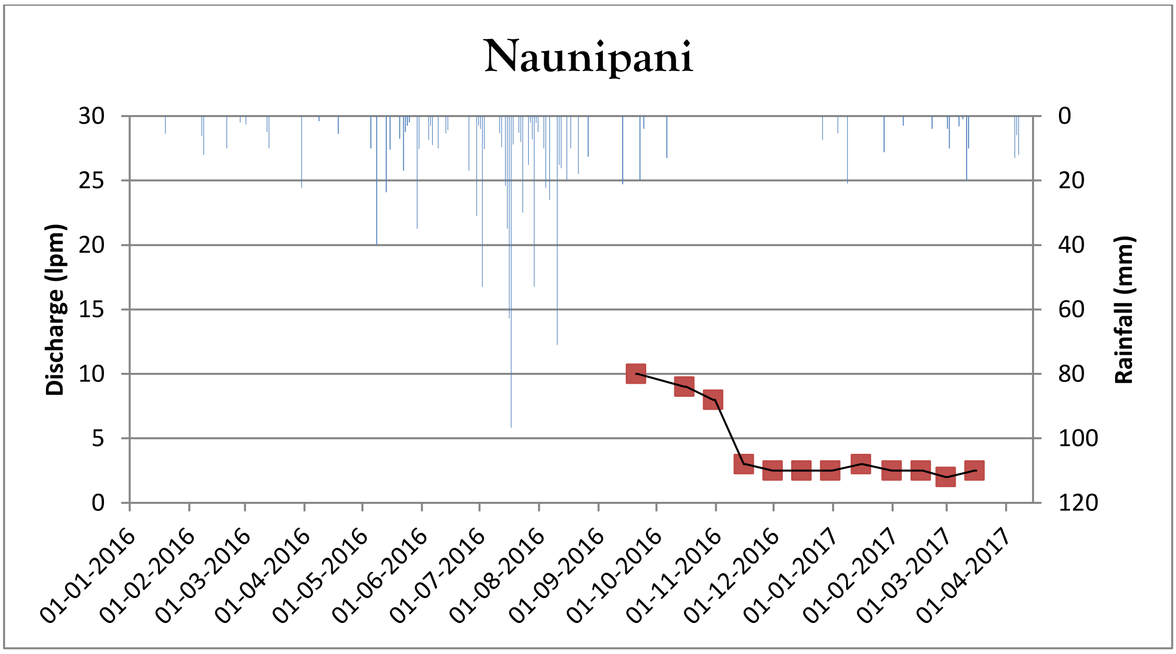
As discussed in the previous report, Shivalay, Naunipani and Dhara (Seem) springs were identified in 'Digtoli-Seem Springshed' and their discharge rate and the precipitation received in the region have also been monitored and so is the case with springs taken up in the present report. Note that rainfall data to describe all the spring is derived from rain gauge installed in Digtoli due to its high range of data availability.

## SHIVALAY



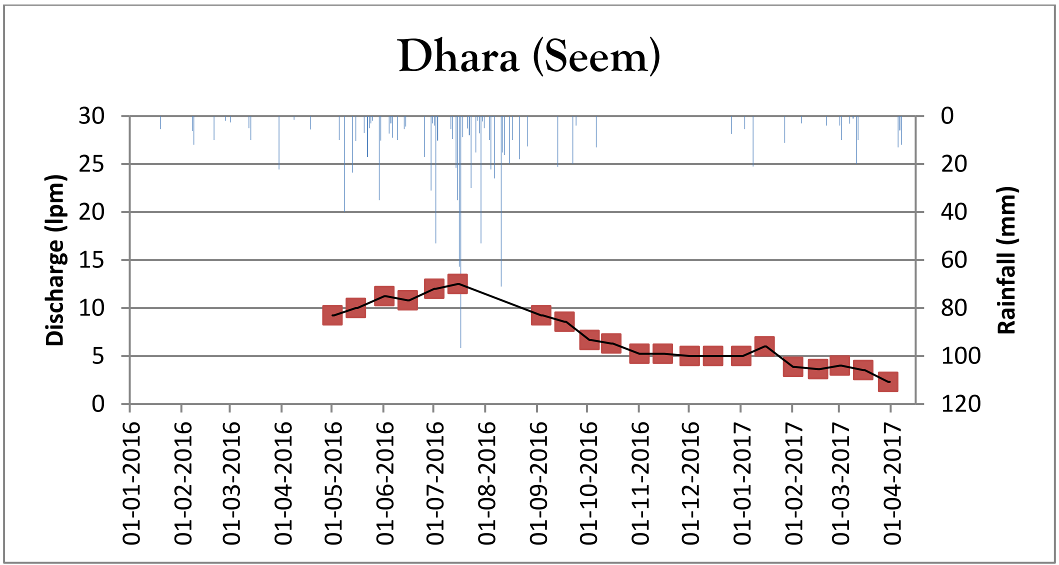
The monitoring of Shivalay spring commenced since June 2016 when its discharge was 0.59 lpm and the rainfall recorded in the same month is 90.1 mm. Before then, the region received precipitation of 245.9mm since January 2016. The discharge increased by 4 lpm in July and the recorded rainfall is 434.9 mm. In the month of August, a marked increment in discharge value is noticed i.e., by 7 lpm and the rainfall recorded is about 221.4 mm. In September, change in spring behaviour is observed. Initially, discharge value increased by 3 lpm whereas at the end of the month it decreased by the same amount and then again increased by 1 lpm. The recorded rainfall is 45.2 mm. Even in October, the discharge value further decreased by 3 lpm and the rainfall recorded is 13 mm, after that, only decline in discharge value is observed. No rainfall is observed in the month of November. In December the discharge value again decreased by 3 lpm to reach a value of 4 lpm, which remains almost constant until March, though the recorded rainfall is much since then. Thus, the Shivalay yields a maximum discharge of 15 lpm during August and, as of now, its discharge starts declining from September until it reaches a minimum value of 0.59 lpm in June. It is also observed that the spring discharge started to decline 43 days after the peak rainfall recorded on 17 July 2015. This reflects that probably there is no direct relation between the rainfall and discharge fluctuation i.e., discharge is not a direct function of rainfall.

## NAUNIPANI



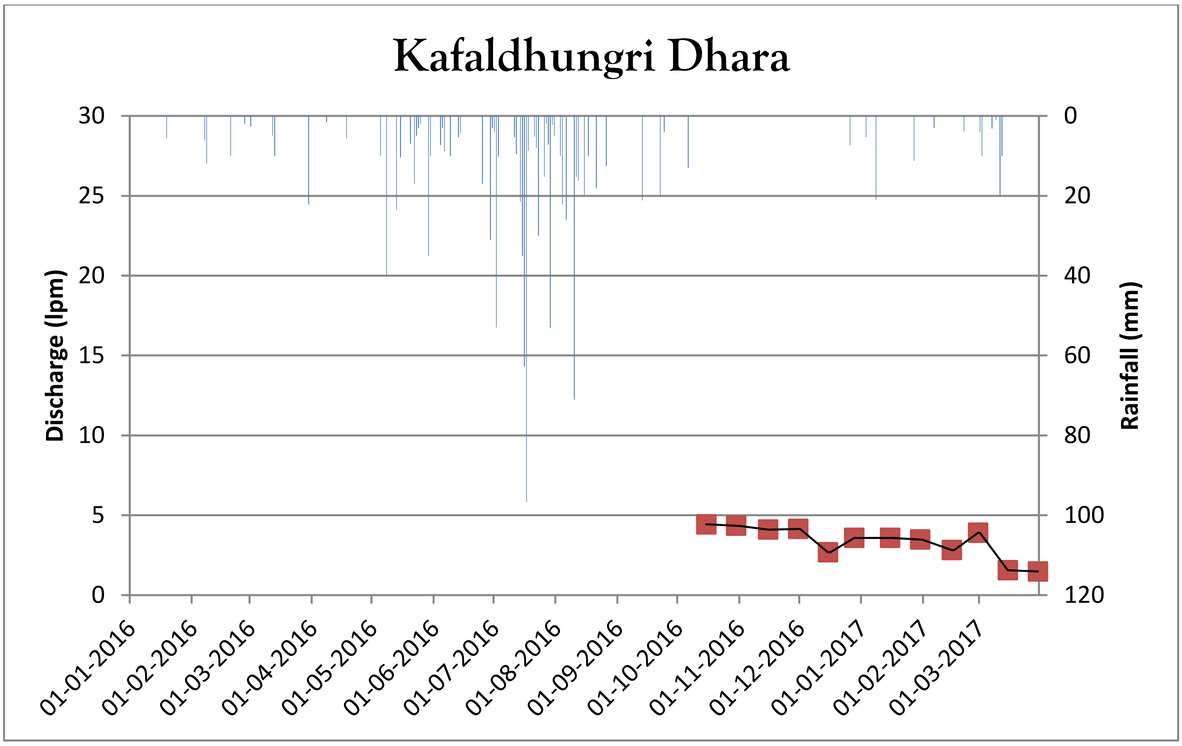

The Naunipani Dhara is a fracture spring. Though it is perennial, its discharge reduces to almost zero in summer as is evident from the fieldwork. The monitoring system was established from the month of September 2016 when the spring discharged 10 lpm groundwater. Decrease in discharge value is observed 1 lpm in September and the rainfall measured reduce to 45.2 mm. Rainfall to 13 mm in October and the discharge decreased again by 1 lpm. Since there is, no rainfall recorded the month of November the discharge also reduces by 5 units yielding only 3 lpm and remains almost constant. However, the precipitation values raised slowly from 7.4 mm of rainfall in December to 37.6 mm. in January to 7 mm. in February to 48.2 mm in March, 2017. With the advent of rainfall, a 0.5 lpm variation is observed in the spring discharge. This indicates that the Naunipani is dependent on precipitation but even then, it has maintained a bare minimum discharge of 2 lpm, which reduces to almost zero in absence of rainfall until May (as observed in the field).

## SEEM DHARA



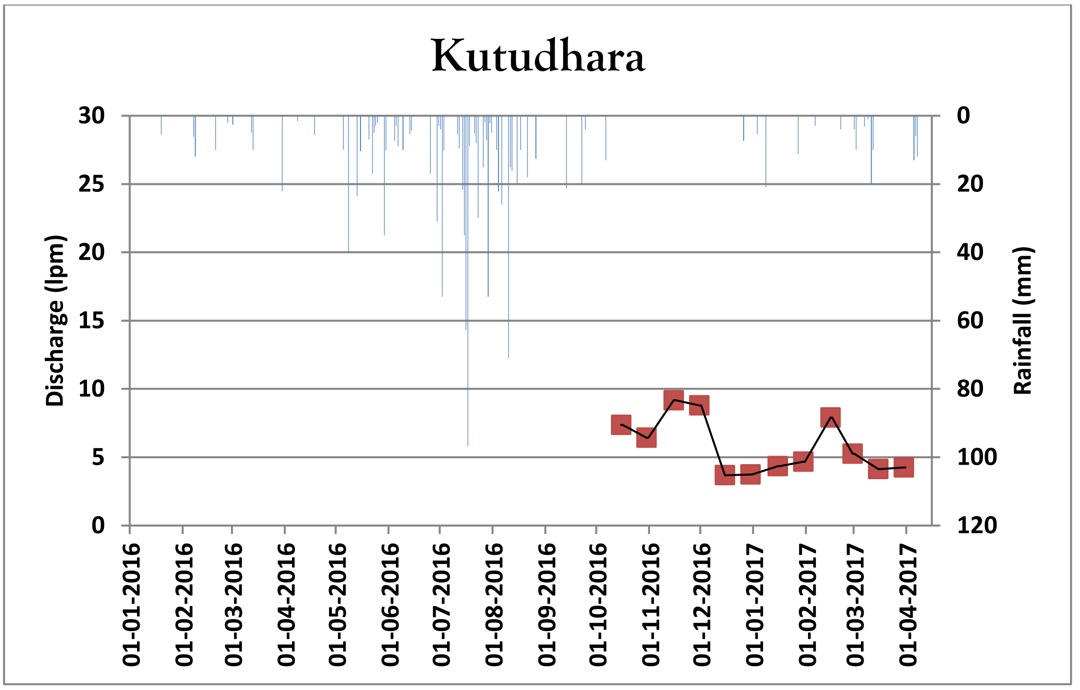

The discharge of the Seem Dhara is being monitored since May 2016 until when the discharge is 9 lpm and the region had received precipitation of 82.7 mm. The rainfall hits the region from May to August during which period the discharge increases gradually by two units i.e., 12 lpm and the region receives 909.6mm of rainfall. Moving on, in September spring discharge reduces to 9.23 lpm and rainfall is significantly reduced to 45.2mm. Since then, constant decrease in discharge (by 1 lpm per month) is observed which reaches upto 2 lpm in March 2017 lpm.  Thus, discharge of Seem Dhara declines constantly which yields a maximum discharge of 12 lpm in July to 2 lpm in December and does not fluctuate much with rainfall.

## KAFALDHUNGRI DHARA



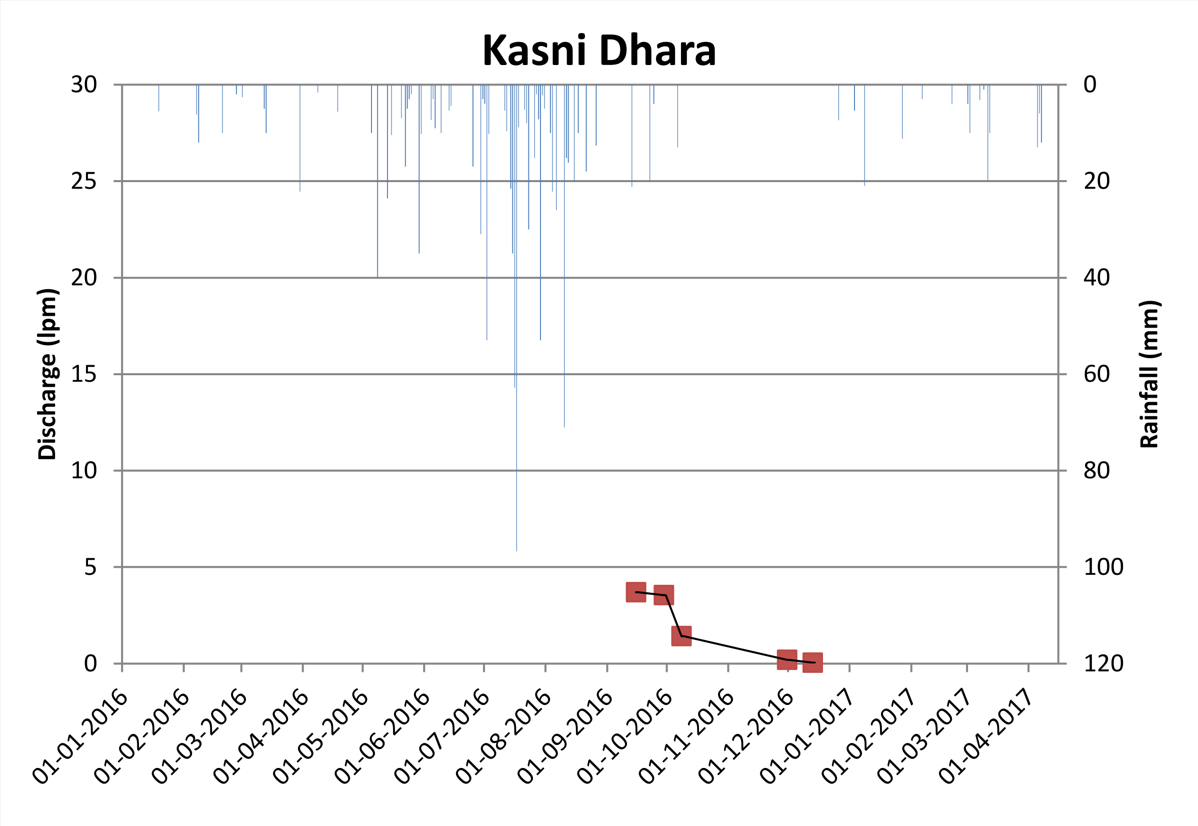

The Kafaldhungri Dhara is a perennial depression spring in Bans but its discharge reduces greatly during lean period. In comparison with Kutuadhara, its discharge is comparatively low. It discharged 4.5 lpm in October and rainfall accounts for 13mm in the month. There is no rainfall received in November and the discharge reduces by 0.03 lpm only. In December, there is increase in the discharge by 2.36 units. Rainfall received is 7.4 mm. in January 2017. Discharge decreases by 0.10 lpm and the amount of rainfall recorded is 37.6 mm. In February discharge of the spring decreases slightly by 0.66 lpm and then increases by 1.09 lpm and the rainfall received throughout the month is 7 mm.

## KUTUA DHARA




Kutuadhara spring is a perennial source for the residents of Kafaldhungri and Maitoli village. It is being monitored since September, 2016 when its discharge was 4.31 lpm and since January, 2016, the area has received precipitation of 1037.5 mm. The spring discharge decreases by 0.93 lpm at the end of the October and the rainfall recorded is 13 mm. The discharge value increases by 2.74 lpm with the onset of November whereas towards the second fortnight it decreases by 0.38 lpm and no rainfall is observed in November. The discharge value increases markedly by 5.11 lpm in first fortnight of December whereas it decreases slightly by 0.05 lpm at the end of the month and rainfall amounts to 7.4 mm. The discharge value again increases by 0.62 lpm during the first half of January 2017 and by 0.33 lpm at the end of the month and recorded rainfall is 37.6 mm. In the beginning February, the discharge value increases by 3.21 lpm and decreases by 2.63 lpm at the end of the month and the monthly rainfall is 7 mm. in the month of March the discharge value firstly decreases by 1.14 lpm at the starting of the month and then increases by 0.13 lpm at the end of the month. The recorded rainfall in the month of March is 48.2 mm.

## KASNI DHARA




As is evident from the graph above, Kasni Dhara is a seasonal spring occurring as depression as well as fracture spring in Pabhe village, which forms the springshed with Bans. Kasni Dhara spring is situated at the top of the ridge with discharge of 3.7 lpm in September. The discharge decreases by 0.16 in the second fortnight of September 2016 and the monthly rainfall received is 45.2 mm. In October there is a considerable decrease in the discharge by 3.35 lpm also the rainfall received is only 13 mm. again the discharge decreases by 1.23 lpm in November. There is no precipitation in November. December and January also mark a further reduction in the volume of Dhara. The Dhara dies completely in the second fortnight of January.

## WAY FORWARD

- Continuous monitoring of the springs will enable in developing better understanding of the resource “Aquifer” feeding them.

- Water quality assessment of the selected springs for detecting fecal contamination if any.