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Original Research Paper

Studies on Environmental Degradation By Bani and Kardoo Landslides in Jammu and Kashmir State

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ABSTRACT

Two major notorious landslides occur in the Bani-Basholi road in Kathua district of Jammu and Kashmir State. Among many other causes such as deforestation, high relief and brittle nature of rocks, the main cause of landslides revealed from the field investigation, was great water ingress present in rocks in the form of springs, nallas and snow cover by way of glaciers on top cliffs. Great water ingress is also confirmed by chemical analysis and also by thin section studies of sediments of both the landslides. The problem gets compounded during excessive rains when phyllite-slaty and quartzitic rocks develop shear joints, resulting in breaking apart big rock blocks from the main mass turning into huge scree material and finally getting accumulated on the road. For mitigation of the landslides restraining structures and shaft work at vulnerable points in the crown portion is needed. Trees with long roots in the watersheds and also vetiver grass should be grown in the whole belt from Bani to Kardoo as a soil binder to check mass wastage. Breast walls with weep holes along roadside from Bani to Kardoo are very much needed. Besides these measures for the two slides, a special method for the proper disposal of runoff in case of Kardoo landslide, where ingress of water is many times more than Bani, is suggested. Runoff in this method is disposed off by digging wells radially and correcting the same to the horizontal tunnels (Tunaki model).

INTRODUCTION

Landslides on the Himalayan terrains have always proved a menace for the people residing nearby radially on different contours. These result in mass wastage, loss of life, loss of soil and hindrance in travel and communication. The landslide aspects of environment stand directly in the way of any developmental activity of the area, which causes a lot of harm to the public property.

Two major landslides occur in Bani-Basholi road in Kathua district of Jammu and Kashmir State. One of the landslides is situated 1 km of Kardoo village, while the other one is about 2 km of Bani (Fig. 1). At both the sites, during rains, scree material and boulders get collected on the road and there is stoppage of traffic between Basholi and Bani-Sarthal areas for days together. In the present paper, these two landslides have been studied in detail to know their causes and also to suggest measures for their control. The nature of these two major landslides is slightly different.

NATURE OF THE LANDSLIDES

Kardoo landslide occurs very near to muree thrust and falls exactly in folded bed of lesser Himalayas. This landslide also has one major fault, vertical in nature, covering the outcrops of Gamir formation on one hand and the murrees on the southern end, making the rocks highly unstable. The slide occurs mainly in quartzite and phyllite mix. It is 1530 m above M.S.L. and occupies a big area mostly during rainy seasons (Fig. 2). The debris in the figure is seen coming down from high cliffs. In other photograph, big boulders of quartzite are seen rolling down towards the road (Fig. 3). The latitude of the

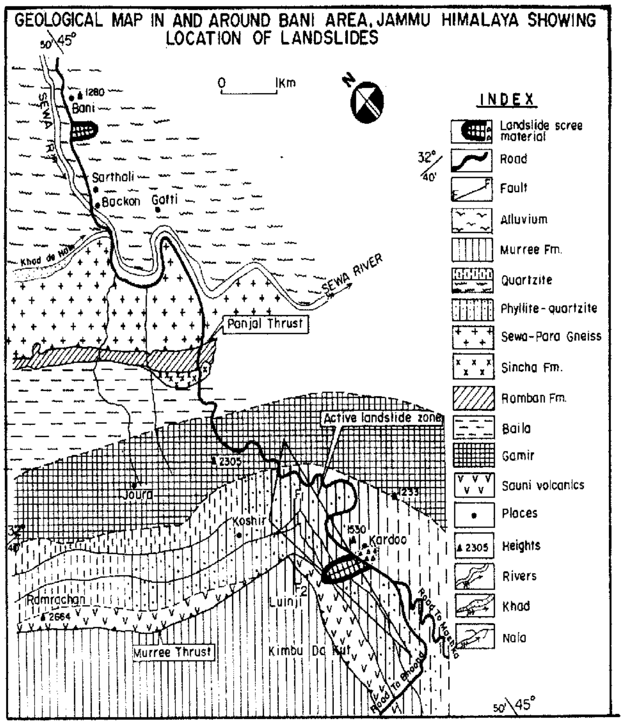

Fig. 1: Geological map in and around Bani area, Jammu Himalaya showing location of landslides.

bed varies from NE 50°SW to NE 55°35'SW with slope angles from 35° to 60°. During rainy season, huge scree material and boulders come on roadside and the road gets blocked for days together. The repeated occurrence of landslides at Kardoo has resulted in slumping of the road. Kardoo area represents active debris slide zone, which is attributed to steep gradient all along together with low cohesion slope forming materials under high water saturation very near to the slide zone. The earth flow derived from failure of greyish clay horizon, reveals a viscous nature of colluvium compressing rock blocks/ fragments in clay matrix and boulders as the main slide mass. The nature of landslide reveals a southwest expansion in triggering the slide and more and more length of road getting involved, resulting in future engulfing of additional slope sediments by progressive upslope failure unless otherwise checked beforehand.

Bani is an important town in Kathua district situated on the left bank of River Sewa (Fig. 4). Bani slide, 3 km short of Bani is another landslide occurring in the area of study. It is 1280m above M.S.L. Bani slide occurs in Bhaderwah formation of late precambrian age (Sharma et al. 1973, Sharma 1975). Bhaderwah formation is composed of phyllite-slates and quartzites, but the landslide occurs in phyllite outcrops, very near to the entry bridge of Bani at 1 km distance from Sarthali. It needs to be mentioned here that Bhaderwah formation is also a part of Salkhala group of rocks of precambrian age. There is enough of gully erosion in the rocks overlying Bani succession of phyllites in the high hills. It results in splitting the phyllitic rocks at cleavage sites, finally breaking them apart. Most of


Fig. 2: Kardoo landslide with debris coming down from high cliffs.


Fig. 3: Kardoo landslide showing big boulders of quartzite rolling down towards the road.

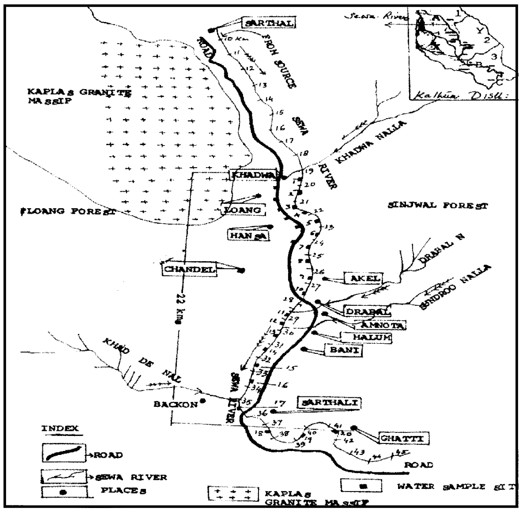

Fig. 4: Bani in Kathua district situated on the left bank of River Sewa.

the scree material gets deposited on the roadside and blocks the road for days together during rainy season. Gully erosion affects rocks at cleavage sites finally breaking apart big masses of phyllitic material (Fig. 5) . Fig. 6 shows complete view of the slide and big boulders of phyllitic material getting deposited on the roadside. During rainy season, huge scree material along with mudflows and boulders of phyllites get collected on the road, and Bani-Sarthal villages remain cut-off for days together. In Kathua district, the alteration of forest cover by people in Bani is evident by the excessive grazing of the cattle and removal of forests for fuel wood from top of the slopes making rocks barren and exposed to agents of weathering. In case of Bani landslide, slope angles vary from 20° to 60°. Geological map of the area in and around Bani is given in Fig. 7.

MATERIALS AND METHODS

The geological map of the two landslides was prepared on a scale of 1:50,000 after traversing the full area from Mashka to Sarthal. The seepages, springs and water logging conditions in the crown portion of the slides were carefully noted. The geological map of the whole area was separately prepared

Table 1: Geological succession in and around Bani area. Kathua district, Jammu & Kashmir.

Rock Formations	Composition	Age
Alluvium	Consisting of fluvioglacial deposits	Pleistocene and recent
Murree formation	Greyish, greenish, gritty pebbly sandstone, shales, micaceous and calcareous sandstones	Oligocene to mid-Miocene
	Murree Thrust	
Kaplas granite	Massive and foliated coarse grained granite	Lower Paleozoic
	Salkhala group	
Quartzite member	Gritty quartzite, slate partings with thin bands of limestone	Late Precambrian
Slate phyllite series	Coarse grained, grayish dirty white, brownish dark coloured slates with intercalations of phyllites	Late Precambrian
Sewa Para gneiss	Quartzite, banded streaky augen para gneiss with quartzite slate partings	Late Precambrian
	Panjal Thrust	
Sincha formation	Quartzite, dolomite limestone phyllite slate and pebbly phyllite	Early Precambrian
Ramban formation	Phyllite slate, grey and green quartzite, slaty quartzite associated with ripple marked quartzite, gritty and micaceous sandstone early precambrian	Early Precambrian
Baila and Gamir formation (undifferentiated)	Carbonaceous grey phyllites, grey and whitish limestone and brecciated quartzite	Early Precambrian
Sauni volcanics	Basaltic to andesitic	Precambrian?

Fig. 5: Gully erosion affecting rocks at cleavage sites and breaking apart big masses of phyllitic material.

having cross traverses in two-year field seasons. Soil samples were collected from crown, middle and toe portions of the two landslides in question for studying the geochemistry of the sediments of the landslides. For correctly assessing the causes of the landslides, the chemical analysis of the sediments was carried out to examine the extent of weathering in the rocks, which may be responsible for causing slope failures. Thin sections were made from the representative samples from the landslide profile. Jointing and deformation caused due to water ingress have been noted carefully with the help of microphotographs taken in the laboratory to know the exact nature of the landslides. KS and BS represented the Kardoo and Bani slides respectively.

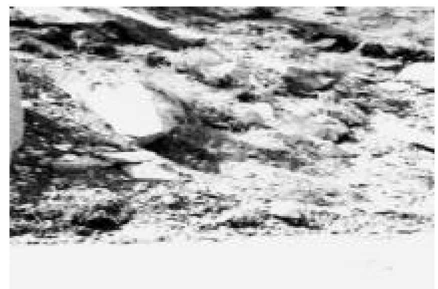

Fig. 6: Big boulders of phyllitic material getting deposited on the roadside.

GEOLOGICAL SUCCESSION

The area between Kathua and Sarthal has been mapped by a number of workers earlier. Wadia (1928), Sharma (1973, 1975), Sharma et al. (1979), Shah (1980), Janpangi et al. (1986), Bhatia & Bhatia (1973) and Karunakaran & Ranga Rao (1979) have worked out this tectonically disturbed area from Bani-Ramban-Banihal and Bani to Basantgarg. The whole area is devoid of fossils and, hence, the age of different members of Salkhala group has remained doubtful so far. It is only the varied lithology present, that different members of the succession have been incorporated by different workers from time to time in the geological succession. The geological succession in and around Bani has been worked out from the work done by earlier workers and after the field investigations by the present authors. The geology of the full area has been depicted in Fig. 7. It clearly gives the geological succession of the area of precambrian to late precambrian (Table 1).

CAUSES OF LANDSLIDES

1. There is enough surface water and subsurface water that drains the rocks of the slide area, making them cohesionless, and hence, triggering the slide.
2. In the northeast of Kardoo landslide site, there are number of springs and seepages, wherefrom oozing of water takes place. In crown portion of Bani landslide, waterlogged spots have been noticed and these have source in the northern watershed of the area that produces immense water ingress towards the landslide site. In fact, water ingress through conduit pipes percolates through the joints of the rocks in case of both the slides, but intensity is lesser in magnitude in Bani landslide in comparison to Kardoo landslide.
3. Bani landslide is nearer to Panjal thrust and Kardoo is very near to murree thrust. These two thrusts have immensely made the whole area unstable. This also is the main cause of occurrences of landslides affecting the road in both the cases. The road is narrow and for keeping the traffic on toe, cutting is usually the main practice of widening the road. This makes the rocks unstable at toe portions, and hence, due to gravity the rocks from crown portions start rolling downwards (Didwal

1980, Kachroo & Hussain 1980, Yudbir 1980, Natrajan & Gupta 1980, Prasad & Verma 1980, Singh 1991 and Fotedar et al. 2007).

4. The landslide develops from incipient movement caused by various factors including the loss of vegetational cover, poor soil strength and presence of excessive surface for grazing of cattle and removal of firewood from top of the soil. These causes are common to both the slides.
5. There occur no deflector canals to remove large ingress of water from the site of landslides. Excessive rains for 8 months in a year and presence of glaciers on high cliffs account for great ingress of water in these areas. This is one of the main causes of triggering of the slides (Greenwood 1957).
6. Deforestation is also one of the main causes of landslides in the study area. The rocks in the watershed of both Bani and Kardoo landslides are devoid of forests and the rocks lose stability. During the preceding decades, there has been unrestrained commercial exploitation of forests by several unscrupulous elements from the Himalayan slopes resulting in denudation. The bare hill slopes not only present an ugly look but also result in soil erosion, frequent landslides and other unwanted and unfavourable changes in the region. Application of the mindset on the problems reveals that forests from which cliffs underneath maintain soil fertility and minimize the wastage of the nutrient rich soil to get washed off from vegetational farmyards. Forests are considered to regulate the environmental quality in many aspects (Chadha 1990, Aggarwal 1992). The presence of forests because of human activities, is more severe than the direct influence from submergence (Singh 1991, Zaruba & Manvel 1969, Hobest & Zojic 1983, Chowdhury 1980). Forests are closely linked to the life style of the hill people. The loss of forests is an immense material loss to the economy of the state. Notwithstanding the commendable efforts made by BEACONS and other agencies, landslide problems in the Himalayan Jammu and Kashmir State has still now eluded a lasting solution, and the main cause is deforestation. Thus, cutting of forests is the main cause at the grassroot level, which is responsible for destruction of crops on one hand and landslides on the other hand.

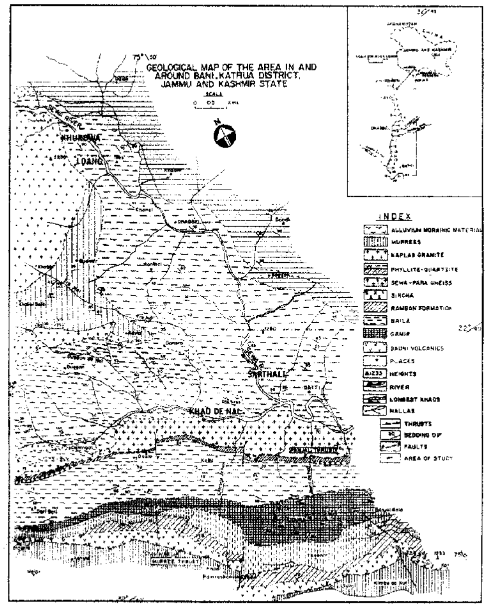

Fig. 7: The geology of the full area.

CHEMICAL ANALYSIS AND MICROSCOPIC EXAMINATION OF THIN SECTIONS OF THE SITES OF LANDSLIDES

Kardoo landslide: The chemical analysis of eight samples from the profile of Kardoo landslide sediment is presented in Table 2. The chemical analysis was done for various parameters namely SiO_2, Fe_2O_3 (total iron), FeO, CaO, MnO, Na_2O, and K_2O. SiO_2, ranging between 76.20 and 78.17 % in the crown portion, gets added in the toe portion revealing more erosion and weathering effects; TiO_2 and Fe_2O_3 show decline in the landslide zone. The imprints of water ingress are revealed by the leaching behaviour present in the rocks. Each mineral in the rock has been affected and this has changed the bulk chemistry. SiO_2 weight percentage in the middle and toe portion displays an increasing trend. Due to heavy runoff passing through the joints in quartzite-phyllite mix, huge amount of clay has resulted, which accounts for increase of SiO_2 in the toe portion of the profile (Pettijohn 1963). More ingress of water in the slide area has helped in this process. Besides, weathering of rock minerals is also likely to release silica in the form of H_4SiO_4 at the same time as aluminium is released. The presence of both the species in solution can be expected to give rise to silico-aluminium copolymers evolving into clays and hydro-mica in which the aluminium hydroxides and silica layers alternate in various layers (Wedepohl 1978). The aluminium dissolution is well exhibited in the last three sample (No. 6, 7 and 8) of Table 1. The iron percentage is also getting lowered due to leaching behaviour. High value of CaO in most of the samples at Kardoo may be due to close contact of quartzites with the volcanics. CaO solubility increases in the samples in the toe portions. MgO too becomes soluble in the process of rock weathering. The values of ratio MgO/CaO for quartzites have been used by a number of workers for getting an overall idea about the solubility of Mg in the soils (Wedepohl 1978). The values always are less than 1, inferring thereby that Mg solubility in sediments is far greater than Ca. In the present case also MgO/CaO values are less than 1 in all the samples, and hence, Mg solubility due to heavy ingress of water is more as compared to that of Ca. Sodium is more mobile during weathering than K.

In Kardoo landslide area Na_2O/K_2O values in all the samples are less than 1 showing more mobility of Na ions than K. Na and K are present more in feldspars of the quartzites. Due to great ingress of water, both the elements get detached from the silicate bonds, resulting in fast rate of chemical weathering witnessed by rocks. Manganese is the first element to get transported by water action among all base metals during water transport and finally increase with the reduction in the grain size. MnO weight percentage in case of Kardoo reveals the same pattern and that is how MnO percentage increases in samples at the toe end.

Fifteen thin sections from Kardoo landslide sediments, examined under research microscope, show the imprints of crushing and bending due to strain in the minerals mainly quartz and mica, and solution cavities present in the groundmass. Besides this, there is flow texture present in the chlorites. All these points portray to the large ingress of water infiltrating through the slide area mass. Fig. 8 shows the development of numerous joints and cracks in the quartz crystals. In the centre of the photograph, the quartz and chlorite crystals occupy the solution cavity created by ingress of water. Fig. 9 shows serialization of phyllite crystals in which water has played an important role. Fig. 10 shows the cracks present in mica flakes and quartz crystals. The lines of water ingress filled later by crushed quartz crystals are seen in Fig. 11.

Bani landslide: The chemical analysis of the samples from the Bani landslide sediment is given in Table 3. In case of Bani landslide, SiO_2 is increasing down profile due to bulk of clay sediments

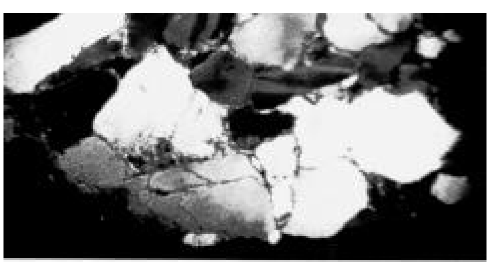

Fig. 8: Development of joints and cracks in quartz crystals.

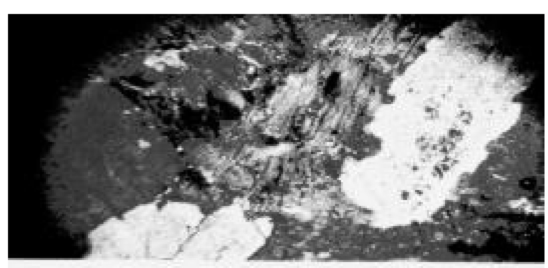

Fig. 9: Serialization of phyllite crystals by water.

Fig. 10: Cracks present in mica flakes and quartz crystals.

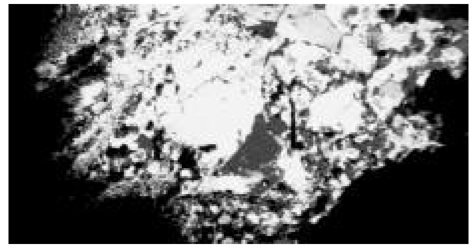

Fig. 11: Lines of water ingress filled by crushed quartz crystals.

being produced by weathering (Wedepohl 1978). The total iron is getting decreased gradually from crown to toe portion of the slide because of leaching. MgO/CaO ratios in majority of the samples is greater than 1, because of high concentration of Mg present in Bani phyllites and slates. Unlike that of Kardoo landslide sediments, Na_2O/K_2O ratios are less than 1 depicting more mobility of Na as

Table 2: Chemical analysis of Kardoo landslide sediments.

	KS-1	KS-2	KS-3	KS-4	KS-5	KS-6	KS-7	KS-8
	Crown Portion			Middle Portion			Toe Portion	
SiO_2	76.20	76.13	78.17	75.10	80.10	80.63	80.12	79.99
$A1_2O_3$	14.10	15.10	13.00	16.04	12.09	12.10	12.00	13.22
TiO_2	0.08	0.12	0.06	0.04	0.05	0.04	0.04	0.01
Fe_2O_3	1.40	1.20	1.00	1.10	1.00	0.90	0.70	0.71
FeO	1.70	1.30	1.06	1.00	2.05	1.68	1.76	0.98
CaO	2.50	2.62	4.20	3.17	1.17	1.15	1.20	1.14
MgO	0.54	0.42	0.32	0.22	0.23	0.22	0.23	0.20
K_2O	1.60	1.55	1.00	1.70	1.62	1.57	1.57	1.56
MnO	0.03	0.04	0.04	0.09	0.09	0.19	0.18	0.28
Na_2O	0.70	1.55	1.00	1.70	1.62	1.57	1.57	1.56
H_2O	1.43	1.00	1.04	0.42	0.90	0.70	0.72	0.63
Total	100.28	100.03	100.89	100.58	100.92	100.75	100.00	100.28

KS-Kardoo slide; All readings are in percentage.

Table 3: Chemical analysis of Bani landslide sediments.

	BS-1	BS-2	BS-3	BS-4	BS-5	BS-6	BS-7
	Crown Portion			Middle Portion		Toe Portion	
SiO_2	69.50	69.51	70.83	71.17	71.27	73.10	75.15
$A1_2O_3$	18.00	16.80	16.80	16.67	16.70	15.30	15.32
TiO_2	0.40	0.58	0.90	090	0.40	0.22	0.22
Fe_2O_3	1.01	1.22	1.12	1.10	1.00	0.90	0.88
FeO	1.78	1.79	1.60	1.51	1.62	1.20	1.10
CaO	1.70	2.00	1.47	1.65	1.40	1.36	1.10
MgO	2.10	1.93	1.95	1.81	1.45	1.40	1.32
K_2O	2.50	2.70	2.63	2.64	2.20	2.15	2.00
MnO	0.17	0.17	0.15	0.09	0.09	0.04	0.03
Na_2O	1.90	2.00	2.41	2.46	2.00	1.99	1.92
H_2O	1.21	1.32	1.11	0.90	1.70	1.51	1.40
Total	100.27	100.02	100.17	100.40	99.83	99.73	100.44

BS-Bani slide; All readings are in percentage.

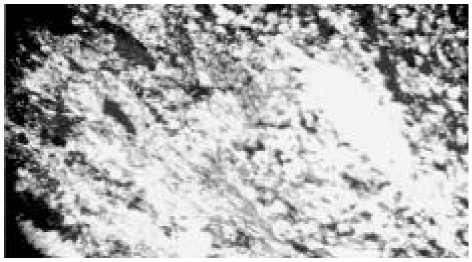

Fig. 12: Crushing behaviour of rocks.

Fig. 13: Bending of mica flakes in phyllites.

Fig. 14: Wiping off the lamellae of plagioclases.

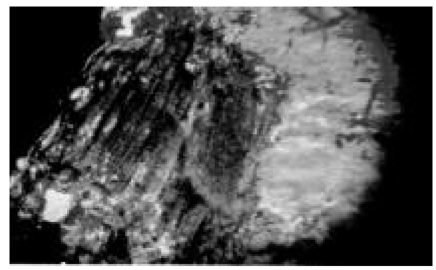

Fig. 15: A big crystal of chlorite with cracks.

compared to K. MnO gets depleted in Bani slide sediments because of fast removal of fine grained material from landslide mass. Geochemistry reveals that bulk chemistry of sediments has undergone a change because of water infiltration and stress conditions present.

Thin section petrography of Bani reveals crushing behaviour of the rocks (Fig. 12). Fig. 13 shows bending of mica flakes in phyllites. Fig. 14 portrays wiping off the lamellae of plagioclases present. Chlorite ground mass is infiltrating through the joints of the crystals resulting in the serialization of the plagioclases. Fig. 15 shows a big crystal of chlorite having developed cracks due to moving waters through the landslide mass. Thin section petrography and geochemistry reveals that the rocks at Bani landslide have been affected by water ingress, but unlike Kardoo landslide, the water infiltration is lesser in Bani area.

METHODS OF CONTROL FOR BANI AND KARDOO LANDSLIDES

1. Due to great water ingress present at the sites of both the landslides sites, deflectory canals are required to take water underneath from the crown portion to a position much lower to the toe of the slide. These deflector canals are joined at a single site far away the slide area and usually go below the roads without the rocks getting affected by water to saturate them (Fotedar et al. 2007, Tikoo 2004).
2. Restraining structures, shaft work at vulnerable points in the crown portion of the slide is needed in case of both the slides. Reinforced earth in the crown portion of the slide is also suggested to be taken in hand where there are sufficient joints present and the areas where water logging exists.
3. Anchoring at vulnerable points in the crown portions of the slides would be best suited on the lines suggested by Zaruba & Manvel (1969), Hobest & Zojic (1983) and Chowdhury (1980).
4. As far as vegetation is concerned, trees with long roots, as suggested by Natrajan & Gupta (1980) in the watershed areas, would best serve the purpose to control the slide. Moreover, recently Vetiver grass technology is becoming popular in checking mass wastage in many parts of Himalaya

(Lavania 2004). Vetiver grass should be grown abundantly in the whole belt from Bani to Kardoo area, which will bind the soil together and will prove helpful in controlling erosion, mass wastage and contamination in water bodies of the region (Tikoo 2004, Fotedar et al. 2007).

5. There exist a few breast walls on the vulnerable sites of landslides. Most parts of the Kardoo area have not even a single breast wall. The breast walls may be constructed on sound foundation having weep holes and raised to a reasonable height, capable of checking scree material rolling down from the face of the slide.

The above mentioned methods are suited for both Bani and Kardoo landslides, but because of greater ingress of water present in the crown portion of the Kardoo landslide, better arrangement is required for mitigating the menace of large ingress of water. The method adopted by Tunaki (1993) is well suited to drain harmful water quickly which otherwise causes slope failure. This method proved satisfactory in the Kamenose landslide area in Japan, where it was carried over by drilling wells 3.5 m in diameter at proper intervals in the slide area. From these wells horizontal holes, 6.6 cm in diameter with average length of 50 meters, were bored radially. A total of 36 drainage wells were constructed. Water by drainage wells was drained into drainage tunnels, which were bored in the landslide layer below the slip surface.

In case of Kardoo landslide such wells need to be constructed radially from 30^{th} milestone from Bani to the point where road bifurcates to Mashka. The wells need to be dug at proper spacing as has been done in Japan. The wells further need to be connected to horizontal tunnels for leading the runoff effectively away from the slide zone area.

Presently below the slide, National Hydroelectric Power Corporation (NHPC) at Bani and at Khaire (H.P) has constructed a road, which is 14 km long, to reach Mashka. It is a zigzag road having terrace type topography. There are so many small villages, where farmlands exist. Farmers raise a few crops in these fields, but for years together these fields were affected severely by landslides from the top cliffs at Kardoo. But now, in case the method outlined above totally controls the landslide, all the villagers can raise at least three crops, i.e., rice, wheat and maize. Besides threes three crops, apple trees can be gown abundantly in these farmlands at the periphery because the soils and climate are best suited for the same (Fotedar 2006). Another advantage of controlling the landslide at Kardoo is that the hydroelectric power station, Sewa-U, will be better monitored from Gatti to Masnka. The basic approach as given above, is hoped to be more rational and sustainable for mitigation of Kardoo landslide.

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