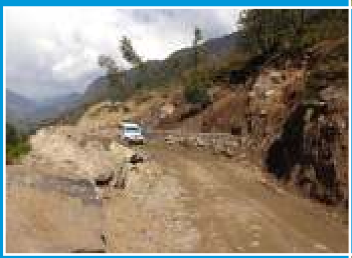
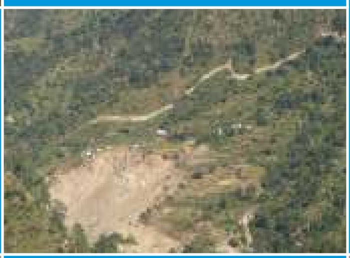
Geological investigations in Rudraprayag district with special reference to mass instability





Disaster Mitigation and Management Centre

(An Autonomous Institute of the Department of Disaster Management, Government of Uttarakhand)

Uttarakhand Secretariat, Dehradun - 248 001

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A Disaster Mitigation and Management Centre (DMMC) publication

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Uttarakhand (India)

2014

Preface

Fragility of the terrain is often reflected in the form of disasters in the state of Uttarakhand. In the previous some years, particularly in 2010, 2012 and 2013, the state has witnessed disasters induced by extreme climate events. These are often attributed to climate change.

The disaster of June, 2013 was unprecedented in many ways. The impact was extraordinarily violent and it caused heavy loss of human lives, infrastructure and property. Mandakini valley in Rudraprayag district that houses the highly revered holy Hindu shrine of Lord Shiva at Kedarnath, was the most adversely affected. Besides flash floods, heavy and continuous rains in the area induced slope instability and triggered massive mass movements in the area.

Landslide is a complex geological process and interplay of a number of factors is known to trigger these. Amongst these, geology and structural set up of the area are major contributing factors and details on these aspects are required not only for mitigation but also for vulnerability assessment. Both, geological maps and inventory of landslides on appropriate scale are however not available and therefore Disaster Mitigation and Management Centre (DMMC) initiated the task of preparing district wise geological maps and landslide inventory. Rudraprayag is the first district to be completed under this initiative. Major portion of fieldwork was undertaken in the area on the aftermath of June, 2013 disaster and this report therefore captures the devastation caused by this disaster and attempts to analyse causes of the same.

This study is envisaged to bring forth awareness amongst the masses as also policy makers on this important issue, that should rightly be the concern of one and all residing in this region for (s)he can in no way escape the consequences. This in turn is envisaged to pave way for appropriate changes and stern compliance of the techno-legal regime, introduction and proliferation of the risk transfer measures and improved disaster preparedness levels. These measures, if implemented sincerely can shield us, every one of us, against the likely devastating situation.

Hope this report helps in better understanding the geological fragility of Rudraprayag district and provide basic ground rules to the agencies engaged in reconstruction and restoration. I am sure this document would be utilized by these as also other agencies, like the previous documents of DMMC.

No study can claim to be flawless and there could well be errors in this report. We, at DMMC encourage you to share, discuss and use the results of this study so as to bring forth awareness amongst the masses on this highly important and pertinent issue. We welcome comments and quarries on the report and we value both.

This study is largely based upon observations made during the fieldwork undertaken in Rudraprayag district in 2012 and 2013. Effort has been made to acknowledge contribution of earlier workers. Omission if any, is unintentional and is regretted. Both Dr. Krishna Singh Sajwan and Sushil Khanduri are thanked for diligently undertaking geological fieldwork. Suman Ghindiyal and Chanderkala together with Ashish Rawat are thanked for incorporating field observations into GIS environment, analyzing the same and preparing maps. Administration of Rudraprayag district is thanked for extending all possible support during the fieldwork.

We acknowledge guidance and support from the Chief Secretary, Government of Uttarakhand Shri Subash Kumar, Additional Chief Secretary, Government of Uttarakhand Shri Rakesh Sharma and Secretary, Disaster Management, Government of Uttarakhand Shri Bhaskaranand. All the colleagues at DMMC are thanked; but for their commitment, support, cooperation and encouragement this work would not have been possible. Last but not the least, the effort put in by Govind Rautela in typesetting, layout and design is duly acknowledged.

10th July, 2014
Disaster Mitigation and Management Centre
Uttarakhand Secretariat
Dehradun

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Contents

Executive Summary

The hilly terrain is presently faced with the dilemma of maintaining a balance between development and environmental conservation. In the hills the land available for various developmental works is limited and its availability is further depleted by stringent environmental laws. The infrastructure development initiatives however have to keep pace with the increase in population, tourist and pilgrim inflow and consequent increase in the demand of various services that include accommodation, transport, recreation, electricity, water, sewerage and the others.

Under these mutually conflicting forces the hills are witnessing a lopsided growth whereby proliferation of hastily built, not so legal constructions with scant regard to safety measures is becoming common place and probability of major disasters is on the rise. This trend if allowed to continue unabated, is sure to result in a threatening situation.

Inherent instability of hill slopes, that is attributed to geological and tectonic setup of the terrain together with high relative relief and precipitation, is often aggravated by infrastructure development works that result in change in angle of repose of the slopes. In case adequate mitigation measures are not taken these are likely to make hills chronically prone to landslides.

This report assimilates detailed geological account of Rudraprayag district where rocks of both Lesser Himalaya and Cental Crystallines are observed to be exposed. Besides some local faults, major dislocations of the area viz., Vaikrita Thrust and Main Central Thrust (MCT) have been mapped. Geologists, particularly those interested in structural set up of the area would appreciate this effort. The report at the same time incorporates detailed inventory of as many as 290 landslides. Majority of these (34 percent) are observed to be triggered by bank erosion by streams and rivers while 29 percent are caused by change in angle of repose, largely for road construction. This inventory would provide solid foundation for landslide risk assessment and landslide forecasting studies; which we are to take up soon.

Departure from traditional pattern of settlement is also observed to be responsible for increasing loss of human lives, infrastructure and property in the previous some years. Traditionally people desisted from settling down over alluvial terraces and old slide material. They deliberately settled down in the upslope areas over firm ground even though it amounted to routine inconvenience. Their strategy of giving precedence to safety over comfort saved them not only from landslides and flash floods but also from earthquake tremors.

Habitation and infrastructure development initiatives in close proximity of streams and rivers, as also over Quaternary deposits, and unplanned disposal of excavated rock and debris are observed to aggravate the fury of both, landslides and flash floods in the region. Appropriate legislative measures, mass awareness, implementation of mitigation measures, relocation of population and infrastructure from high risk areas, compliance of techno-legal regime and review of the appropriateness of traditional mitigation measures under the present ground realities are suggested as possible solutions. Practically possible happy blend of these can be devised for reducing recurring disaster induced losses.

It needs to be understood that slope instability is strictly a geological phenomenon and any attempt to solve it without the involvement of geologists is not really going to help.

Chapter - 1

Introduction

The present study focuses on Rudraprayag district of Uttarakhand that falls in Lesser and Higher Himalayan terrain of Garhwal Himalaya (Fig. 1). Administrative boundaries of the district are delimited by 78^{0}48'46" E and 79^{0}21'45" E longitudes and 30^{0}10'36" N and 30^{0}48'50" N latitudes. Located at the confluence of Mandakini and Alaknanda rivers, Rudraprayag with population of 9,313 is the headquarter of the district and is situated at a distance of 140 kilometers from Rishikesh, on Rishikesh-Badrinath National Highway. Rishikesh is the nearest rail head while located in close proximity of Dehradun, the capital of Uttarakhand state, Jolly Grant airport is at a distance of 154 kilometers. Rudraprayag has three Tehsils; Okhimath, Jakholi and Rudraprayag and there are 688 villages in the district of which 28 are uninhabited.

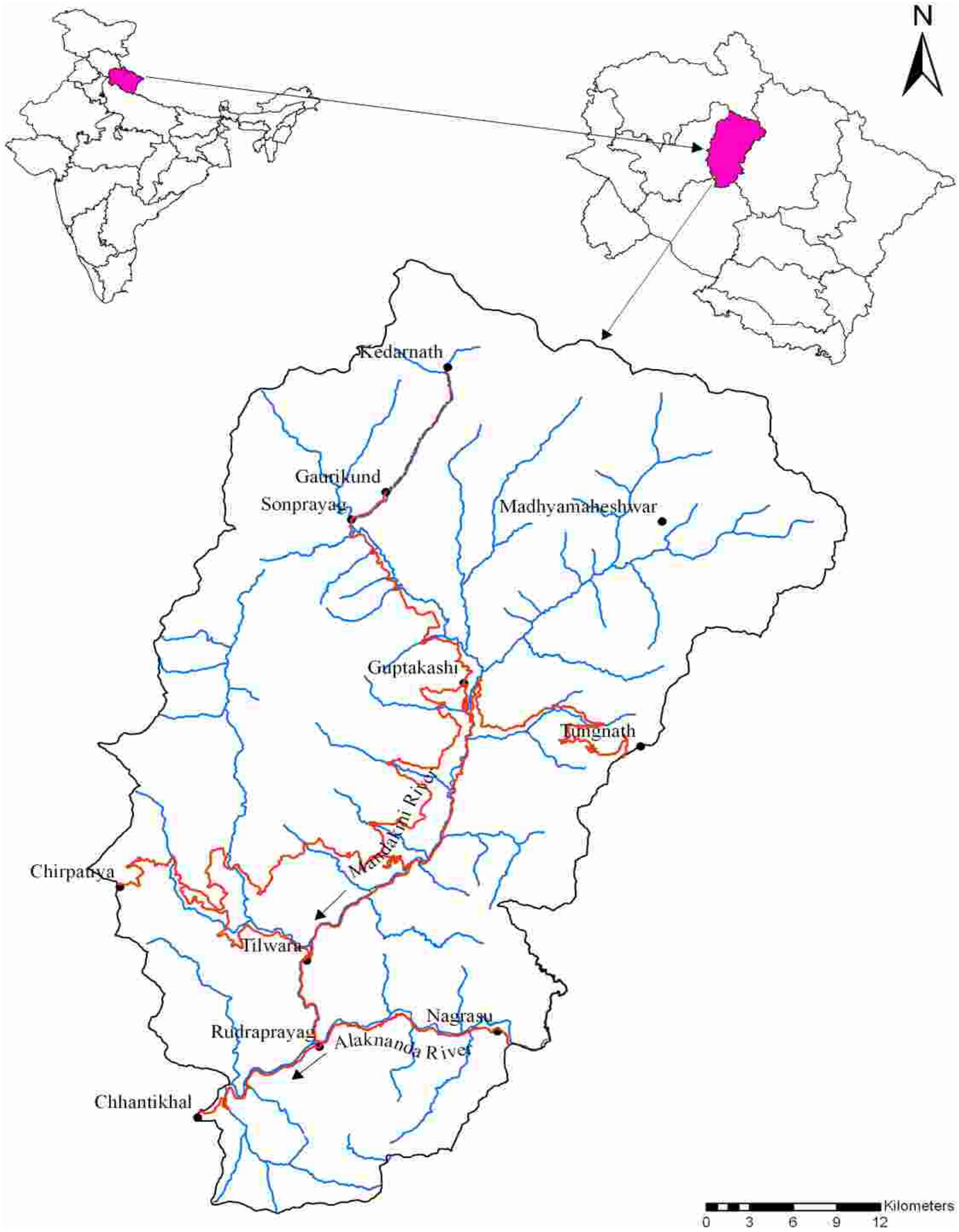


Fig. 1: Location map of the study area.

The population of the district is 2,42,285 which is 2.4 percent of the state population. Of these 1,27,696 are females and thus with regard to sex ratio, Rudraprayag with 1,114 females per 1000 males, is well above the national average of 940. Geographical area of the district is 1,987.46 sq km and the population density is 122 persons per sq km. Average literacy rate of the district is 81.30 while male and female literacy rates are 93.90 and 70.35 respectively. Child population (0 - 6 years in age) of the district is 32,046 (Census of India, 2011).

Mandakini with catchment area of 1,641.64 sq km is the major stream draining the district. It originates from Chorabari glacier (3,895 m) and is a major tributary of Alaknanda river that meets Bhagirathi river at Devprayag to form Ganga river. Located close to the origin of Mandakini river, Kedarnath (3,581 m) is a Nagar Panchayat with population of 611. It is the seat of Lord Shiva and is highly revered by Hindus. It is a major pilgrim destination and is visited by people in large numbers.

Gaurikund, situated on the right bank of Mandakini is known for its hot springs, and is the last motor head for reaching Kedarnath (Fig. 2). From there one has to trek for 16 kilometers upstream along the Mandakini to reach Kedarnath.

Fig. 2: Panaromic view of Kedarnath (camera looking south).
Abandoned channel (Saraswati) is seen to the east of the temple township.

Chapter - 2

Rudraprayag: A disaster prone district

Rudraprayag district falls in Zone V of the Seismic Zoning Map of India (IS 1893, 2002) and earthquakes of 1803 and 1842 reportedly devastated the region. Heavy losses were inflicted to residential and other structures in the areas around Jakholi, Okhimath and Rudraprayag by 1999 Chamoli Earthquake. Population of 11,500 in 34 villages was affected by this quake that caused loss of 36 human lives in the district. 176 persons were injured in this incidence that also took toll of 140 cattle.

Seismicity is however not the sole hazard to which the district is vulnerable. Landslide, cloudburst and flash flood are other common hazards in the area. Geo-tectonic configuration of the rocks and high relative relief make the area inherently unstable and prone to mass movement. A number of landslides are therefore triggered in the area, particularly during monsoon period when increased pore water pressure and downslope acting forces together with reduced frictional force provide favourable conditions for downslope mass movement. Besides landslides, localised heavy precipitation often results in flash floods in the area. In the past the district has been devastated over and again by landslides and flash floods.

The course of Mandakini river was reportedly blocked for three days due to landslides in 1857 and then again in 1976. Flash floods in Kunjya Gad, a tributary of Mandakini, inflicted heavy losses in Kontha, Chandranagar and Ajaypur in 1979. 29 human lives were lost in this incidence and the course of Mandakini was blocked near Chandrapuri. Sirwari landslide in Jakholi tehsil killed 32 persons in 1986. During the monsoons of 1998 major landslides occurred at many places in Madhyamaheshwar and Kali Ganga valleys between 11 and 19 August. In this incidence course of Madhyamaheshwar river was blocked by massive landslide at Bheti-Paundar (in the vicinity of Mansuna) for more than 24 hours causing serious concern in the downstream areas. Summary of losses in this event is given in Table 1.

Table 1. Losses incurred by landslides in Madhyamaheshwar and Kali Ganga valleys in August 1998.

Sl. No.	Head	Number
1.	Human lives lost	103
2.	Affected villages	34
3.	Affected families	1,767
4.	Affected population	9,792
5.	Cattle loss	423
6.	Houses damaged	1,276
7.	Agriculture land loss (in hectares)	411

Landslides amid abnormally heavy precipitation on 15 and 16 July, 2001 caused death of 28 persons around Phata in Okhimath tehsil. Population of 3,924 in 15 villages of the area was affected by this incidence. 52 houses were damaged / destroyed in this incidence that took toll of 62 cattle and 43 hectares of agricultural land.

04 persons were killed in the landslide around Vijaynagar in Agastmuni on 21 July, 2005. 14 houses were damaged / destroyed in this incidence. On 26 July, 2006 landslides and flash floods caused massive losses in Ladoli, Devali, Gholtir and Gursyal villages and in 2010 losses were reported from Jaili village of Jakholi tehsil. In September, 2012 landslides around Okhimath partially ruined Giriyagaon, Salami, Mangoli, Chunni, Premnagar, Brahmankholi and Jua-Kimana villages (Fig. 3). 69 human lives were lost while 15 persons were injured in these incidences. More than 70 residential houses were reportedly destroyed in these incidences that caused heavy loss of other infrastructure and facilities.

In 2013 monsoon was early to arrive and it caused massive devastation in the district, particularly in the Mandakini valley. More than 4,000 persons went missing in this incidence that caused massive loss of infrastructure and property.

Repeated devastation and losses due to natural hazards suggests that the area is inherently vulnerable and fragile. In case well-planned and scientifically sound mitigation measures are not taken, possibility of the area being affected by hazards in future cannot be ruled out.

Fig. 3: View of the landslides around Okhimath in September, 2012.

Chapter - 3

Disaster of June 2013

Geo-tectonic disposition of rocks together with physiography of the area makes Mandakini valley highly vulnerable to different hazards and the same is evident from the record of previous disasters in the valley. Variability of physical forcing factors such as rainfall often triggers these events.

15 June is a bit early for monsoon to reach Uttarakhand, but then in 2013 it reached early and started with abnormally heavy incessant rainfall all over the state. This is attributed to the convergence of the southwest monsoon trough and westerly disturbances, resulting in the formation of dense cloud over the Uttarakhand Himalaya.

According to Tropical Rainfall Measuring Mission, in the period of five days between 14 and 18 June, 2013 Uttarakhand received approximately 2,000 mm of rainfall which is more than what it receives throughout the whole monsoon season. Percentage deviation in rainfall from normal in various districts of Uttarakhand, according to IMD records, was more than 100 percent between 5 and 12 June, 2013 and more than 997 percent between 13 and 19 June, 2013. Like other parts of the state, Mandakini valley also received heavy rains during this period and the precipitation was particularly high on 16 and 17 June, 2013.

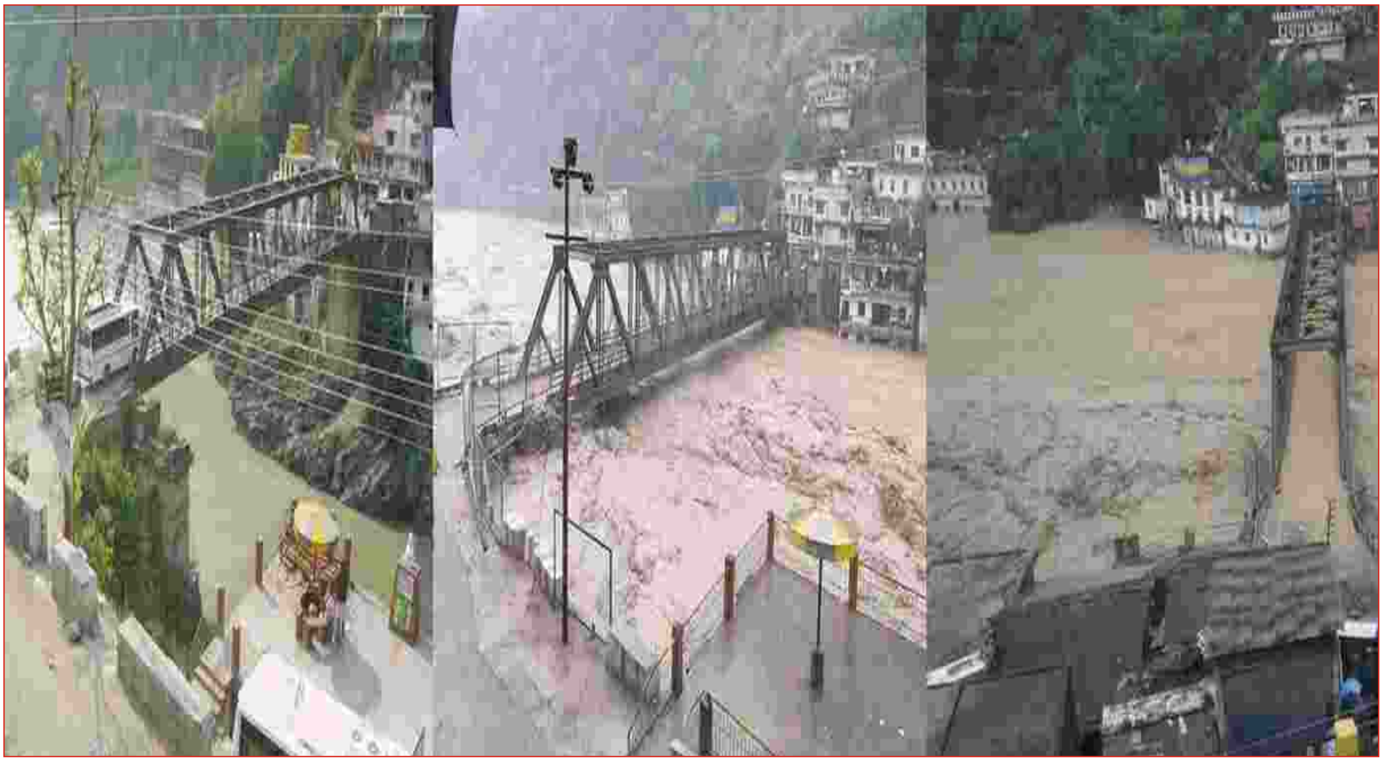


Fig. 4: Level of Alaknanda at Rudraprayag just before its confluence with Mandakini. On the left is normal water level while middle and right depict water levels on 16 and 17 June, 2013 respectively.

Heavy rainfall took place when there was still snow on the mountains and valleys. Abnormally fast melting of snow and ice due to heavy rains added to the discharge of hill torrents and streams and almost all the major rivers of the state crossed danger levels (Fig. 4). Recorded level of Mandakini on 17 June, 2013 at Rudraprayag was 633.5 meters as against the danger level of 626.0 meters (Table 2).

Prolonged heavy precipitation saturated the valley slopes and the pore water pressure crossed the threshold limits. This intermingling of heavy rainfall and rapid melting of snow thus set the stage for flooding and slope failure.

Table 2: Water level of Mandakini river at Rudraprayag between 15 and 20 June, 2013 *(Source: CWC, Dehradun).*

Date	Danger level (m above mean sea level)	Observed level (m above mean sea level)
15 June, 2013	626.00	618.12
16 June, 2013	626.00	625.00
17 June, 2013	626.00	633.50
18 June, 2013	626.00	626.65
19 June, 2013	626.00	623.00
20 June, 2013	626.00	622.48

Devastation in the Mandakini valley took place in two flood events on 16 and 17 June, 2013 and the latter was associated with the breach of Chorabari Tal that had accumulated enough water to force the moraine barrier to give way. The former event that washed off Rambara in the late evening of 16 June, 2013 was caused by the blockade of the course of Mandakini in close proximity of Kedarnath. This flooded Kedarnath, forced water into the abandoned eastern channel of Mandakini also called Saraswati and ensured that enough water was impounded to devastate Rambara and Gaurikund with sudden removal of the barrier.

Hydro - geomorphic setup of the area between Kedarnath and Rambara indicates that Dudh Ganga is the only major stream that has the potential of bringing down enough debris so as to ensure impoundment of Mandakini river. Moreover the confluence of Mandakini and Dudh Ganga is located at a place blockade over which could flood Kedarnath. Blockade at a downstream place would not affect Kedarnath because of high gradient of the river in the area.

It was this blockade of Mandakini on 16 June, 2013 that led to impoundment of the channel to the west of Kedarnath. The embankment on the left bank of the channel soon gave way and the abandoned channel of Mandakini (Saraswati) to the east of Kedarnath became active. This event resulted in washing off of some

Fig. 5: View of Kedarnath after the disaster of 16 and 17 June, 2013. Activated course of Saraswati is seen to the east of the temple with camera looking south.

people in the late evening of 16 June, 2013 from Kedarnath, that thus became water locked. Rising hydrostatic pressure due to fast increasing volume of water forced the barrier to give way and the ensuing floods devastated Rambara and Gaurikund as also pedestrian bridge over Mandakini near Kedarnath. All connectivity with the area was thus snapped.

Continuous rains caused the level of water in Chorabari Tal to rise. With the recession of the glacier the lake had a weak moraine barrier that could not withstand continuously rising hydrostatic pressure. Stage was thus set for a major disaster in Kedarnath and the barrier gave way around 0700 hrs on 17 June, 2013. The volume of water was enormous and it carried with it huge glacial boulders and outwash material that choked the western channel of Mandakini and the flow of water and debris got diverted towards Kedarnath township that was thus ravaged (Fig. 5). There was absolutely no warning and most people were taken by surprise and had no time to respond. Besides Kedarnath this event caused devastation in Rambara, Gaurikund, Sonprayag and other places.

Table 3: Rainfall data of three Tehsils of Rudraprayag district within a week; from 13 to 19 June, 2013 (Source: SDM office, Rudraprayag).

Date	Rudraprayag	Okhimath	Jakholi	Average
13 June, 2013	25.0	9.75	13.4	16.1
14 June,2013	10.0	6.25	12.8	9.7
15 June,2013	25.0	40.0	32.8	32.5
16 June, 2013	122.5	131.3	60.4	104.7
17 June, 2013	105.0	166.3	53.2	108.2
18 June,2013	50.0	80.0	33.2	54.4
19 June,2013	15.0	0.0	2.2	5.7

Chapter - 4

Disaster induced losses in 2013

Flood in the Mandakini valley caused heavy loss of human lives and property and took everyone by surprise. Losses were however not confined to Mandakini valley (Table 4). Heavy rains caused massive damage throughout the state even though the losses in Mandakni valley were mainly highlighted by the media.

Table 4: Summary of losses due to June, 2013 disaster in Uttarakhand (Source: SEOC, GoUK).

	Rudraprayag	Chamoli	Utarkashi	Tehri	Pauri	Dehradun	Haridwar	Pithoragarh	Bageshwar	Champawat	Nainital	Almora	US Nagar	Total
Dead	2	33	14	14	2	22	29	19	4	5	11	10	4	169
Missing	3998	0	0	0	0	0	0	21	0	0	2	0	0	4021
Injured	71	31	29	14	0	3	3	49	3	5	10	17	1	236
Big animals lost	1498	359	222	184	33	114	40	720	34	20	18	38	0	3280
Small animal lost	1273	760	252	200	45	47	4	4543	631	4	17	34	1	7811
Pucca houses damaged														
Fully damaged	441	565	209	169	4	44	0	647	22	6	4	8	0	2119
Severely damaged	374	646	523	633	101	25	35	318	129	28	24	164	1	3001
Partially damaged	905	2188	1961	3792	957	440	200	393	132	123	177	489	2	11759
Kuchha houses damaged														
Fully damaged	4	1	40	0	0	273	17	55	3	1	0	0	0	394
Severely damaged	0	1	4	0	0	272	59	22	1	0	1	0	0	360
Partially damaged	0	0	6	0	0	904	759	4	1	1	1	0	0	1676
Huts damaged	0	0	8	1	0	399	57	0	1	2	1	1	1	471
Cowsheds damaged	7	147	23	61	2	29	27	45	6	2	7	5	0	361
Silted agriculture land (in ha)	1	379	341	542	4	136	706	12	8	0	3	8	13	2153
Agricultural land lost (in ha)	4279	242	339	421	0	90	244	5575	234	48	0	7	2	11481
Irrigated crop loss (in ha)	0	30	96	190	90	35	321	67	25	0	2	0	14	870
Unirrigated crop loss (in ha)	8	215	7	271	0	0	48	46	3	0	3	0	0	601
Perenial crop loss (in ha)	0	0	0	3	0	37	9391	0	0	0	0	0	0	9431

169 persons were killed in these incidences in which 4,021 persons went missing. It was with great effort and diligence that the details of these persons were cross-checked and verified so as to provide death certificates to the next of kin of these persons. State wise details of the missing persons are given in Table 5.

Table 5: State wise summary of persons who went missing in the disaster of June, 2013 (Source: SEOC, GoUK).

Sl. No.	State	Missing persons			
		Male	Female	Children	Total
1.	Uttar Pradesh	602	452	96	1150
2.	Madhya Pradesh	291	221	30	542
3.	Rajasthan	253	224	34	511
4.	Delhi	104	80	32	216
5.	Maharashtra	65	76	22	163
6.	Gujarat	50	75	4	129
7.	Haryana	59	37	16	112
8.	Andhra Pradesh	24	59	3	86
9.	Bihar	34	24	0	58
10.	Jharkhand	21	17	2	40
11.	West Bengal	15	21	0	36
12.	Punjab	21	7	5	33
13.	Chattisgarh	15	12	1	28

14.	Orissa	12	10	4	26
15.	Tamil Nadu	5	9	0	14
16.	Karnataka	5	6	3	14
17.	Meghalaya	4	2	0	6
18.	Chandigarh	2	1	1	4
19.	Jammu and Kashmir	2	1	0	3
20.	Kerala	2	0	0	2
21.	Puduchery	1	0	0	1
22.	Assam	0	1	0	1
23.	Uttarakhand	645	35	166	846
	Total	2,232	1370	419	4,021
	Percentage	55.51	34.07	10.42	

Besides this there was massive loss of public infrastructure and property. Basic civic amenities were hard hit by the disaster. Electricity supply was disrupted in 3,758 habitations while 968 drinking water supply schemes were damaged or destroyed. Connectivity was disrupted all across the state and vehicular traffic was disrupted along 2,070 roads and 145 bridges were damaged or washed off. This resulted in grave hardships and more than 1.5 lakh persons were stranded at different places across the state.

Resources from all quarters were mobilized to ensure safe evacuation of the stranded persons and the rescue and evacuation operations continued for around two weeks.

Chapter - 5

Geomorphology

The area represents highly rugged and immature topography characterized by moderate to steep slopes that are intervened by narrow valleys. The topography of the region appears to be controlled by the structural and

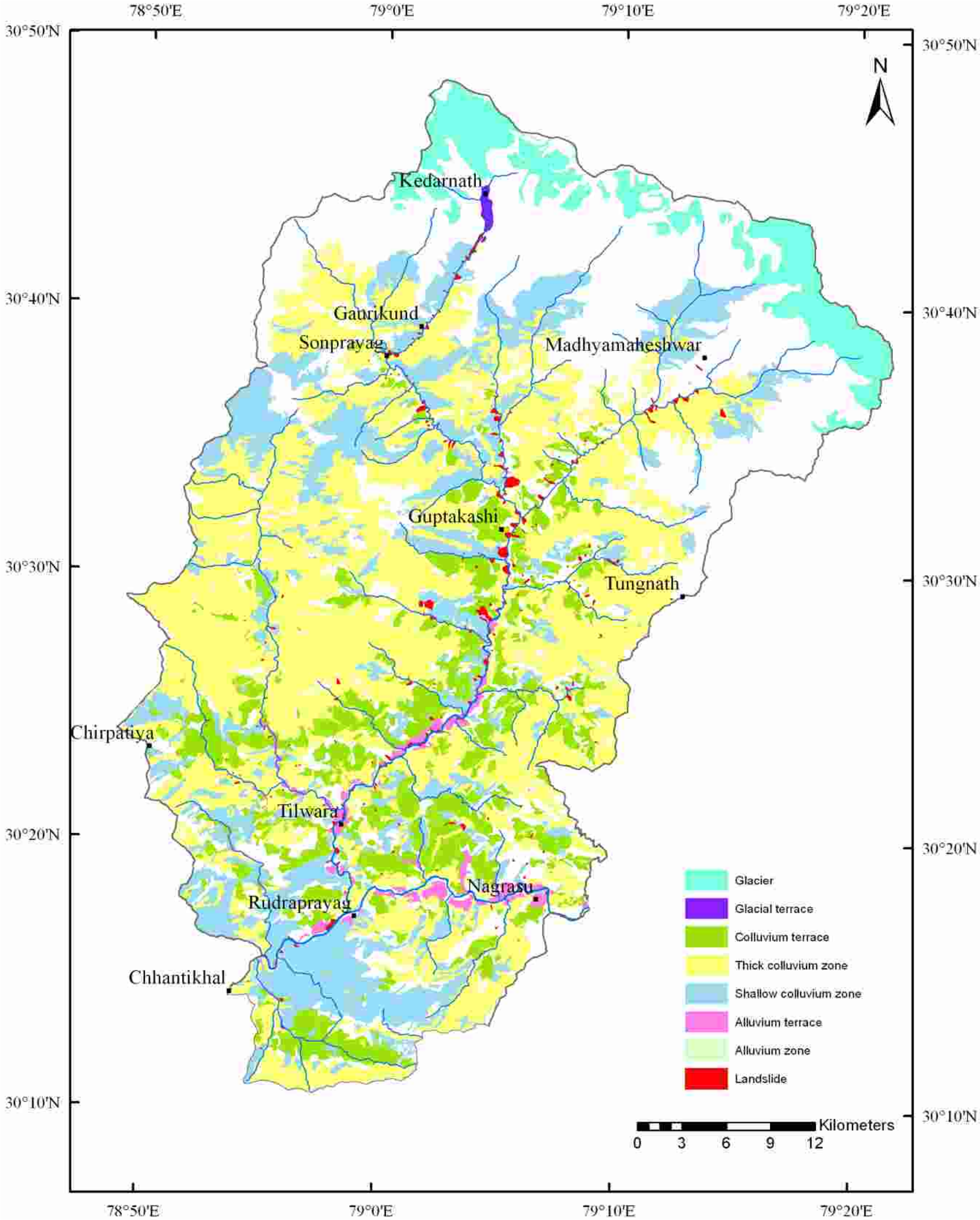


Fig. 6: Overburden map of the study area.

lithological factors. High ridges and summit surfaces of the area remain snow covered from November to March. Major ridges of the area include Bisuri Dhar (4,008 m), Khiri Dhar (3,768 m), Ragsi Dhar (2,818 m) while Sumeru Parvat (6,350 m), Bhart Khunta (6,578 m), Kedarnath (6,940 m), Mahalaya (5,970 m) and Hanuman Top (5,320 m) are some of the well-known peaks. The area thus exhibits high relative relief. Presence of overburden on steep slopes and high precipitation make this area prone to landslides.

Mandakini is the major stream of the study area and its N-S oriented basin is spread between Higher and Lesser Himalayas. This valley has witnessed as many as four glaciations in the previous 15,000 years and evidences of glaciation in the valley are observed till Rambara. The temple township of Kedarnath is located on glacial outwash deposits. The main shrine is located on raised middle portion of the deposit that is 20-25 meters above the level of Mandakini (3,562 m).

Chorabari Tal, breach of which caused the flash floods, was a moraine dammed lake present little downstream of the snout of Chorabari glacier. This lake was located in the depression formed in the glacial material to the west of the right lateral moraine and was fed by the seepage of the glacial melt. The lake did not have a well-defined outlet and its water used to seep out along the moraine slope to the NNW of Kedarnath. Even though the depression was around 200 meters long, 100 meters wide and 15-20 meters deep, not more than 2-3 meters water used to be there in the lake.

Originating from Chorabari glacier Mandakini encircled the glacial deposits around Kedarnath. Construction of embankment to the west of the temple along the left bank of the western channel of Mandakini however diverted most water towards this channel. In the process the eastern channel of Mandakini, also called Saraswati, was abandoned and generally carried little water seeping out of the glacial outwash slope to the north. This gave false sense of security to the inhabitants along the eastern flank of Mandakini who resorted to construction even on hitherto active river channel. Before these two channels met to the south of Kedarnath the western channel has confluence with Dudh Ganga. Thereafter till Gaurikund, Mandakini maintains a tectonically controlled NNE-SSW course. Vasuki Ganga originating from Vasuki Tal at an altitude of 4,231 meters has confluence with Mandakini at Sonprayag, 16 kilometers downstream of Kedarnath. Vasuki Ganga has a tectonically controlled NE-SW course. Mandakini joins Alaknanda river at Rudraprayag.

Landforms present in the Mandakini valley up to Rambara are observed to have distinct glacial characteristics. In this stretch the valley is characteristically 'U' shaped and outwash deposits, hanging valleys, moraines and cirques are commonly observed. Landforms to the downstream of Rambara are observed to be formed by fluvial action. From Garuriya to Munkatiya the valley, in general, is narrow and it forms a gorge between Rambara to Munkatiya.

The "U", "V" and "S" shaped meanders are generally observed all along the valley. On the upstream side valley is narrow and deep, while to the downstream side it becomes wide and sinuous; i.e. around Chandrapuri, Agastmuni and Tilwara. This is attributed to the nature of the bed rocks and bank material.

The hills on either side of the streams are observed to form high rocky surfaces that clearly reflect the action of snow and these rocky surfaces are observed to rise to the elevations of 4,500 meters. Streams are generally observed to flow with great force through steep and narrow channels which is largely responsible for excessive erosion and collapse of the banks.

Quaternary deposits are observed to be well developed all along the valley, especially around Bhiri, Chandrapuri, Agastmuni and Vijaynagar (Fig. 6). Alluvial terraces (river borne material; RBM) are observed to be well exposed and deposited on both banks of the river downstream of Kund Chatti in Mandakini valley.
Flash floods of June, 2013 in the Mandakini valley have considerably modified the original topography and geo-environment of the area. High discharge of all the tributaries of Mandakini river is observed to have resulted in excessive erosion and collapse of the banks. Due to this, a number of landslides are observed to have initiated. The failure mass of the slides washed off by the floodwaters has resulted in increased rate of sedimentation in the streams. These sediments have been dumped at various places along the river course and the river has also changed its course in many areas. This has made many areas highly vulnerable. These observations related to change in river course and deposition are summarized in Table 6.

Table 6: Details of the places where river course has changed and sedimentation has occurred.

Sl. No.	River / stream	Location	Deposited sediment thickness (in meters)	Shift in channel course (in meters)	Bank on which change in river course is observed Left bank (L/B) Right bank (R/B)
1.	Mandakini	Sonprayag	5 - 6	2 - 5	L/B
2.		Sitapur	3 - 4	5 - 7	R/B
3.		Banswara	2 - 3	8 - 10	R/B
4.		Syalsaur	1 - 2	5 - 8	R/B
5.		Chandrapuri	3 - 4	10 - 15	R/B
6.		Gabni	1 - 2	2 - 3	L/B
7.		Ganganagar	2 - 3	3 - 5	R/B
8.		Vijaynagar	4 - 5	10 - 15	L/B
9.		Rampur (just upstream)	1 - 2	2 - 4	R/B
10.		Tilwara/Sumari	2 - 3	3 - 5	R/B
11.	Madhyameheshwar	Gaundar	3 - 4	3 - 5	L/B
12.		Paundar (near iron bridge)	5 - 6	2 - 4	R/B

Major geomorphic changes have also been introduced in Kedarnath. Hitherto abandoned course of Mandakini, to the east of the temple has become active and the level of the channel to the west of the temple has been elevated due to aggradation. Relief between the temple township, that has now become waterlocked, and the river has thus been greatly reduced. Large portion of the temple township, particularly to the north has been overrun by debris and boulders. The lake to the north of the temple has vanished and instability has been induced in the entire hill slope to the north of the temple. Scarp has been formed at many places along the course of the river. General landscape of the area has thus changed.

Chapter - 6

General Geology

Two rock sequences are observed to be exposed in Rudraprayag district; sandwiched between North Almora Thrust (NAT) and Main Central Thrust (MCT) constitutes the Lesser Himalaya, while that exposed to the

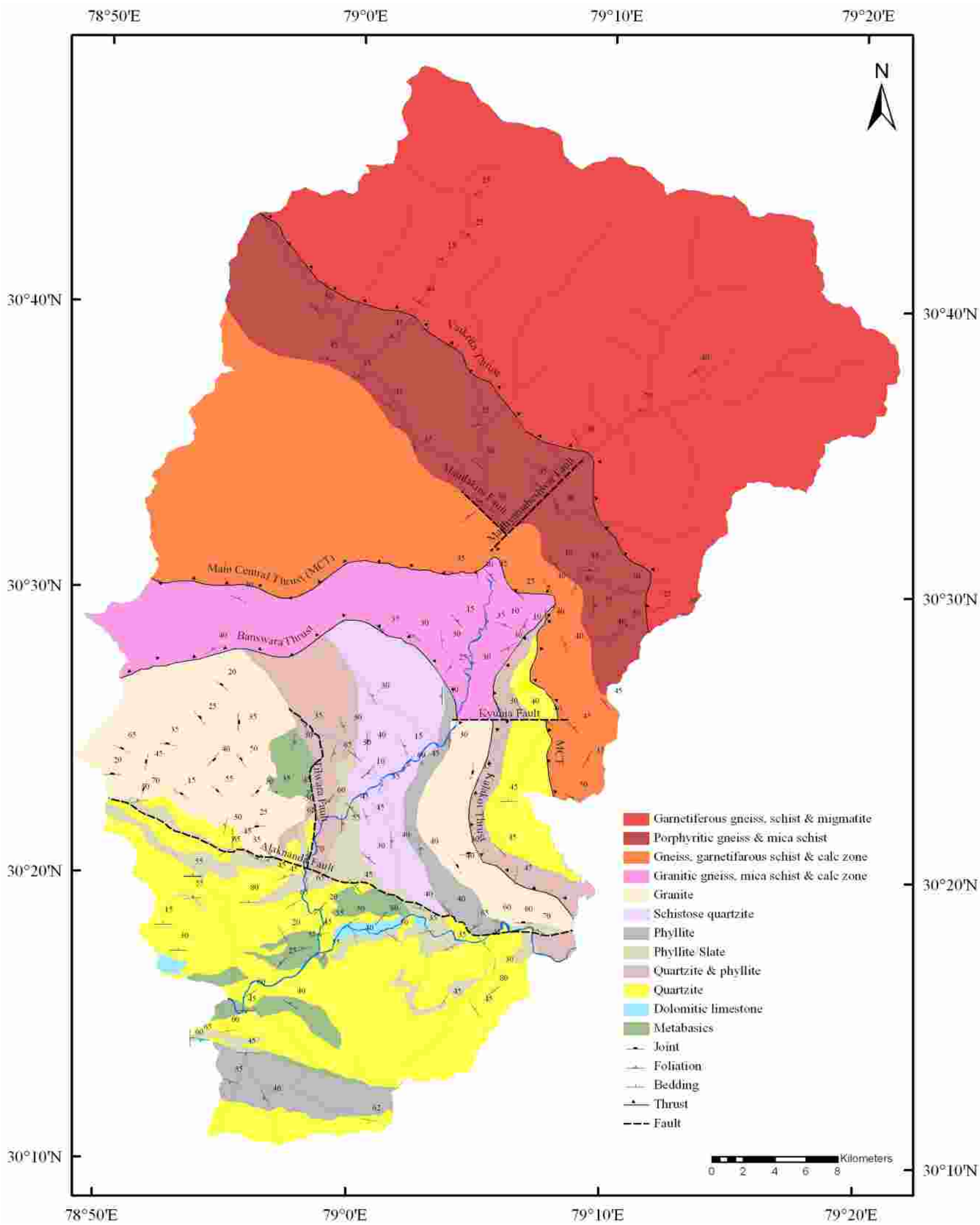


Fig. 7: Geological map of the study area.

north of MCT constitutes the Higher Himalaya (Fig. 7). Geological investigations in the Mandakini valley have been carried out by Dungarkoti and others (1976), Bist and Sinha (1980), Valdiya (1980), Naithani (2002), and Kumar (2005).

The Higher Himalayan Central Crystalline rocks are observed to comprise of low, medium and high grade rocks that have been intruded by both acidic and basic rocks. On the basis of lithology and tectonic setup, these rocks are divided into different litho-units. The main rock types observed in the area include granitic gneiss, augen gneiss, garnet mica schist, calc zone and amphibolites. At Bheembali in Mandakini valley and at Gaundar in Madhyameheshwar valley predominance of garnetiferous gneisses of Central Crystallines is observed (Figs. 8 and 9).

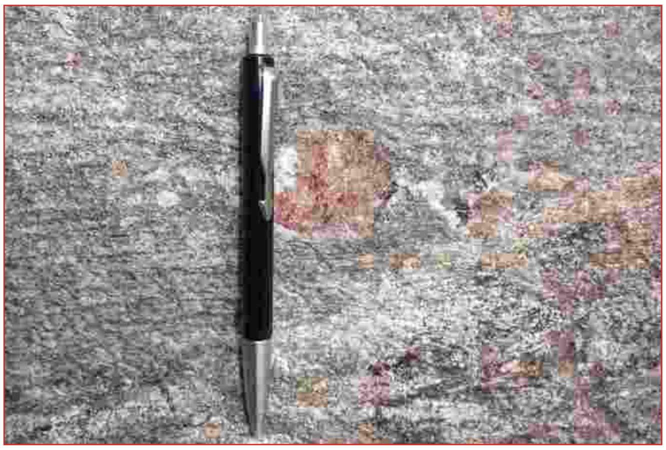


Fig. 8: View of garnetiferous gneisses at Bheembali.

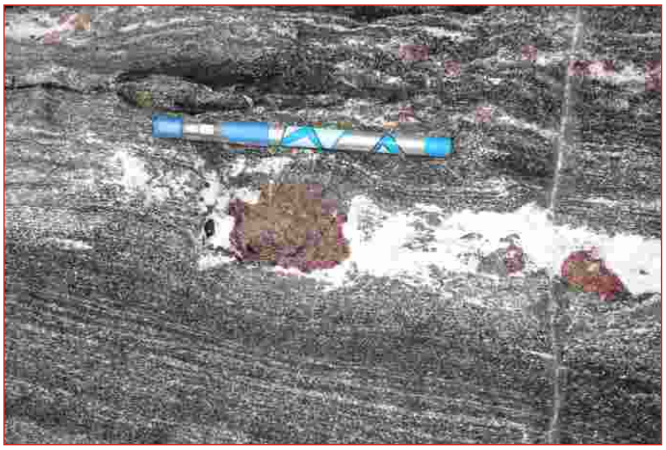


Fig. 9: View of Garnetiferous gneisses at Gaundar.

Gneisses with calc zone are observed along the Main Central Thrust (MCT) zone; mostly in the area around Kund Chatti, Parakandi, Ransi and between Bareth and Silgad in Sauri Gad catchment (Fig. 10). Downstream of Barasu near Kaladungi Nala quartzite with calc zone is observed locally (Fig. 11).

Fig. 10: View of gneisses with calc zone upstream of Ransi.

Fig. 11: Photograph depicting quartzite with calc zone.

The area is observed to be traversed by major lithotectonic groups delineated by Main Central Thrust (MCT) and Vaikrita Thrust. Besides these Banswara Thrust is observed to be a major tectonic discontinuity of the area. Rocks of Central Crystallines are observed to be thrust over the rocks of Garhwal Group along MCT. This tectonic boundary is prominently observed across the Mandakini river in close proximity of Kundchatti near Okhimath where it has almost east west trend.

In the study area high grade Central Crystalline rocks are observed to be thrust over low to medium grade Central Crystalline rocks along Vaikrita Thrust of Valdiya (1980) that is observed to the north of Gaurikund.

The areas in the proximity of tectonic boundaries are observed to be covered with large fans and cones of landslide debris. Apart from large landslides, subsidence zones are also observed around tectonic discontinuities. Lithotectonic succession of the area is given in Table 7.

Table 7: Lithotectonic succession of the study area (modified after Gopendra Kumar and others, 1971).

	Group	Formation	Member / Rock type
Higher Himalaya	Vaikrita Group	Gaurikund Formation	Garnetiferous gneiss, schist, quartzite and migmatite
	-----Vaikrita Thrust-----		
	Jutogh Group	Kalimath Formation	Porphyritic gneiss and mica schist
		Okhimath Formation	Gneiss, garnetiferous schist and calc zone
	-----Main Central Thrust (MCT) -----		
Lesser Himalaya	Garhwal Group (Pre-Cambrian to Silurian)	Patroli Formation	Patroli quartzite
		Gwanagarh Formation	Dobri dolomite, Dobri phyllite, Bhishna quartzite, Dhanpur dolomite
		Lameri Formation	Massive dolomite (Lameri C), Phyllite/slate (Lameri B), Massive dolomite (Lameri A)
		Rudraprayag Formation	Orthoquartzite-volcanic association with metabasics, phyllite and slate member.
	----- North Almora Thrust (NAT) -----		
	Dudhatoli Group (Pre-Cambrian)	Maithana Quartzite Formation Pauri Phyllite Formation	Khirsu quartzite Pauri phyllite, Bhainswara quartzite

North Almora Thrust (NAT) separates the Pauri phyllite and Khirsu quartzite of Dudhatoli Group from the Garhwal Group. This contact is observed near Koteshwar, 5 km upstream to Srinagar town.

The Garhwal Group rocks of Lesser Himalaya are observed to comprise of low grade metasediments that are intruded by acidic and basic igneous rocks. These consist of thick succession of low grade metasediments made up of quartzite along with penecontemporaneous metabasics and carbonate rocks. The main rock types observed in the area include schistose quartzite, limestone, quartzite, slate, phyllite, granite and metabasics.

Granites exposed in the area are observed to be tourmaline and at places chlorite rich and these intrude Rautgara Formation of Garhwal Group to the west of Tilwara (Fig. 12). The volcanics are largely observed to be very course grained, non - foliated and generally porphyritic. The Rautgara Formation is observed to be a sequence of massive cream coloured, purplish and brownish fine grained quartzites (Fig. 13) that are exposed along Koteshwer - Rudraprayag section in the Alaknanda valley.

Fig. 12: Field photograph of granite near Margaon village.

Fig. 13: Field photograph of purple quartzite.

Garhwal Group of rocks in the area around Rudraprayag, in both Koteshwar and Tilni sections, are characterized by massive dolomitic limestone having dislodged blocks. This rock is observed to show shrinkage features and local folding (Figs. 14 and 15).

Apart from the MCT, Vaikrita Thrust and Banswara Thrust other tectonic contacts observed in the area include Alaknanda Fault, Kaunja Fault, Laster Gad Fault, Madhyamaheshwar Fault, Mandakini Fault, Rawan Ganga Fault and Tilwara Fault. These have contributed significantly to slope instability related problems of the area.

Fig. 14: View of locally folded limestone strata at Koteshwar.

Fig. 15: View of dislodged limestone blocks at Tilni.

Alaknanda Fault

Alaknanda Fault (Kumar, 1971) offsets almost all the earlier structures and is a sub-vertical reverse fault dipping towards northeast with angle of dip varying from 25° to 40°. The Alaknanda Fault demarcates the boundary between the two litho-structural units of the area. The rocks lying to the north of the thrust are observed to be more intensely deformed and metamorphosed than those lying to its south.

Madhyamaheshwar Fault

The Crystalline rocks exposed to the north of MCT are traversed by 040°-220° trending Madhyamaheshwar Fault which is observed to extend for a distance of about 6 kilometers from Jaggi to Paundar. Apart from Jaggi - Bedula landslide, many other landslides are observed along the trace of this fault. Madhyamaheshwar Ganga exhibits sinuous morphology near Bedula along this fault. The gneisses with mica schist and granite - gneisses, garnitiferous mica schist, crystalline limestone and teromilite - actinolite schist of Okhimath and Kalimath Formations are affected by this fault.

Mandakini Fault

Evidences of a strike slip fault running parallel to the course of Mandakini river, i.e. NW - SE are observed between Narayankoti and Byung Gad. Mica schist and gneisses have been displaced against the porphyritric gneisses along this fault. A prominent escarpment appears near Devidhar, which is responsible for some scree deposits that frequently lead to landslides. The Mandakini Fault has displaced the Byung Gad Fault and therefore, it is a relatively younger tectonic feature. It continues to the east and displaces Madhyamaheshwar Fault to some extent.

Rawan Ganga Fault

East - west trending Rawan Ganga Fault is observed to follow the trace of Rawan Ganga. The straight course of Rawan Ganga to the north Salaya - Devangan together with prominent topographic break marked by a high escarpment on the northern side and low lying cultivated land on the southern side of the river are indicative of the presence of the fault.

Chapter - 7

Slope instability

Tectonic movements have resulted in intense shearing, faulting, thrusting and fracturing of the rocks observed in the area. Moreover, the terrain is characterized by predominance of high relative relief. Together these make the area very sensitive to slope failure that is facilitated by particularly high rainfall incidences during monsoon season. Various anthropogenic activities for infrastructure development further enhance the susceptibility of the area to slope failure.

Unconsolidated Quaternary deposits with relatively low less cohesion are highly susceptible to erosion. In the area these deposits are observed to be represented by old fan deposits, scree material, terrace deposits and moraines. There exists high probability of instability being initiated in these deposits. At a number of places in the field, undercutting of quaternary deposits by fluvial processes is observed to cause slope failure. Hitherto stable slopes have thus become unstable due to flooding in the streams. A number of new landslides are observed to be initiated in the area due to flooding in Mandakini and Alaknanda rivers and their tributaries. At many places old slides are observed to be reactivated. Distributions of the landslides in the area as observed in the catchments of different streams is summarized in Table 8.

Table 8: catchment wise distribution of landslides in the area.

Sl. No.	River / Stream	Number of landslides
1.	Mandakini	140
2.	Kali Ganga	13
3.	Madhyameheshwar Ganga	29
4.	Rawan Ganga	07
5.	Damar Gad	10
6.	Kakra Gad	24
7.	Kyuja Gad	04
8	Lan Gad	04
9.	Chak Gad	02
10.	Luster Gad	28
11.	Alaknanda	26
12.	Dil Nadi	03
Total		**290**

Flooding, heavy rainfall, road construction, lithological changes, presence of critical structural discontinuity and rock weathering are deducted to be the main causes of landslides observed in the area. Observed landslides have been classified on the basis of movement and rigidity of material comprising the slide mass; bed rock, debris and earth. The summary of the same is given in Table 9.

Table 9: Summary of different type of landslides observed in the area.

Sl. No.	Landslide type	Number of landslides
1.	Debris / bouldery debris slide	188
2.	Debris cum rock slide	83
3.	Rock slide / fall	15
4.	Boulder fall	04
Total		**290**

Analysis of the data pertaining to the landslides observed in the field shows that the majority (65 percent) falls in the category of debris slide. This makes it amply clear that the overburden or debris material was saturated by prolonged heavy rainfall and the same was responsible for the initiation of slides.

Landslide triggering factors

Landslide is defined as gravity driven downslope movement of rock mass and debris. In howsoever unstable position the rock mass be on the slope, Law of Inertia however mandates application of an external triggering force for initiating landslides.

Most landslides in the area are observed to be located in close proximity of roads and streams. Contribution of these in triggering landslides cannot therefore be overlooked. Discharge of streams is largely a function of the precipitation in the catchment area and erosion potential of stream water is a direct function of density and velocity of the flowing water. High gradient of mountain streams together with increased turbidity of water during spells of intense rains enhance chances of bank / toe erosion that often induces slope instability.

Similar phenomenon was experienced during June 2013 flash floods when excavated rock mass dumped along the stream and river courses by hydropower projects aggravated erosional power of the stream water. It is therefore extremely important that adequate attention be paid on safe disposal of excavated rock mass.

Moreover hill slopes have to be excavated for road construction as also for undertaking other developmental initiatives. Change in the angle of repose and absence of suitably designed stabilizing measures often trigger landslides.

For the assessment of landslide triggering factors, proximity of the landslides to roads and streams was particularly analysed together with other causative factors that include geological and structural set up of the area (Table 10).

Table 10: Summary of landslide triggering factors in the area.

Sl. No.	Triggering factors	Number of landslides
1.	Bank erosion	99
2.	Bank erosion and change in angle of repose	38
3.	Change in angle of repose	82
4.	Others	71
	Total	**290**

Majority of landslides in this area (34 percent) are observed to be triggered by bank erosion by streams and rivers while 29 percent are caused by change in angle of repose, largely for road construction. Another 13 percent is triggered jointly by bank erosion and change in angle of repose. Large proportion of the landslides (24 percent) are however also caused by other factors that include heavy rainfall, cloudburst, lithological and structural condition of the bed rocks, surface and sub-surface hydrological factors (drainage, springs) and deforestation.

Landslide incidences have severely damaged the transport infrastructure in the area. June 2013 floods have resulted in the development of a number of major landslide, particularly in the Mandakini valley. These include Gaurikund, Sonprayag, Barasu, Khat, Semi, Kund Chatti, Jaggi-Bedula, Kunjethi, Jal Talla, Nagjagai and Tilaknagar.

Blockade of river course and subsequent breach of landslide dams is a major threat posed by landslides. Creation of Gohna lake in 1893 and its breach in 1894 is a famous example of the devastating potential of landslide dams. Alaknanda valley has witnessed many incidences of similar devastation.

In the past Mandakini valley has also witnessed many instances of damming of stream course by landslides. These have often caused flash floods in the downstream areas. Nagjagai, Jagi - Bedula, Kunjethi and Jal Talla slide zones are assessed to have the potential of blocking the river course (Figs. 17 and 18).

Lake formation is observed in the field around Jagi - Bedula slide zone. It is however in an initial stage but further downslope movement of debris and rock mass has the potential of posing a serious threat. The

Fig. 17: Photograph of Nagjagai landslide.

Fig. 18: Lake formation due to Jagi-Bedula landslide.

landslides in this slide zone have huge amount of debris and debris laden water can easily erode loose portions of the slope causing further slope failure and consequently causing river blockade during monsoon period.

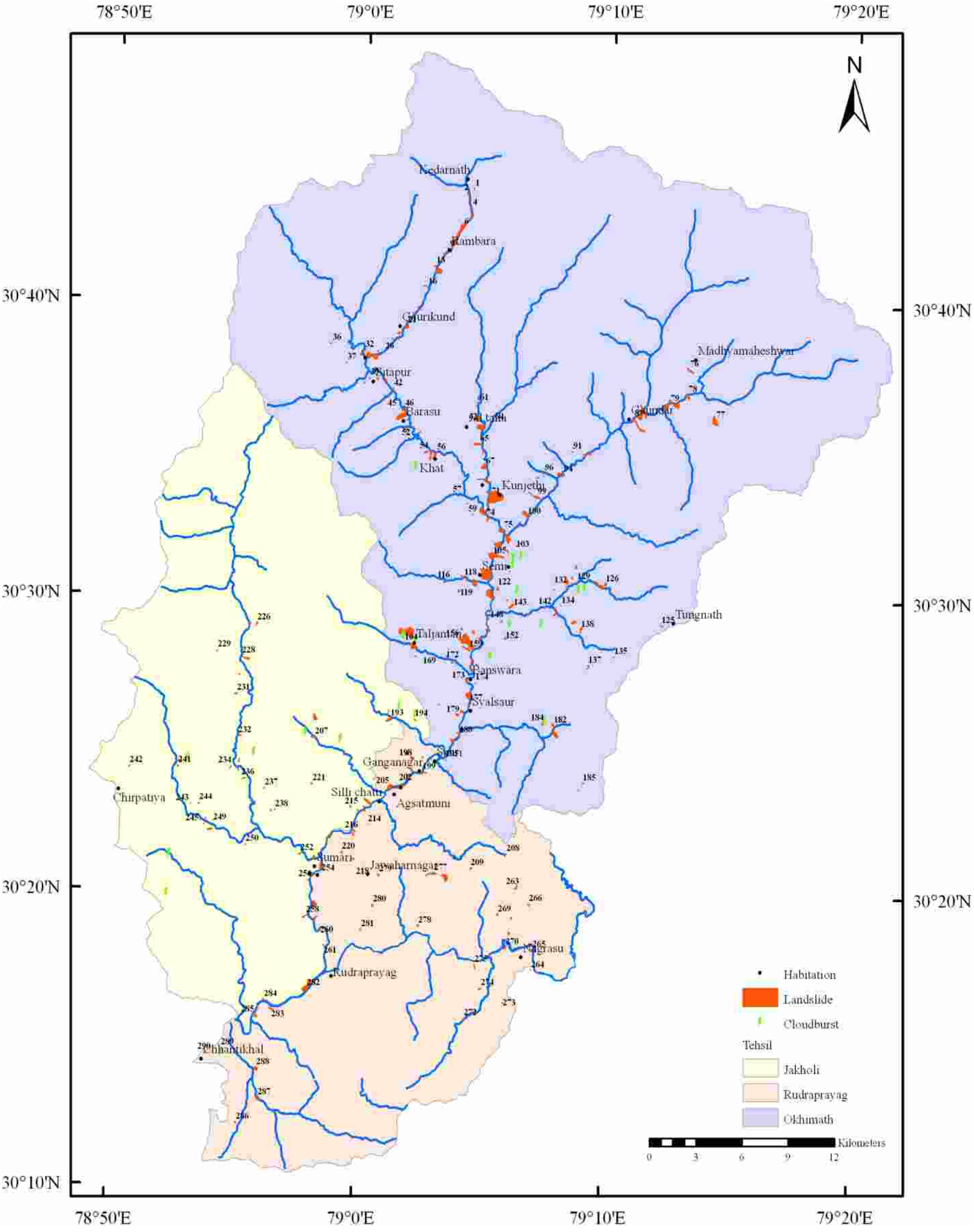


Fig. 16: Distribution of landslides in the area.
The numbers identify with the particular landslide included in the inventory.

Chapter - 8

Cloudburst incidences

High intensity rainfall of more than 100 mm / hour within a limited geographical area of a few square kilometers is defined as cloudburst (Das et al. 2006). Certain peculiar geo-morphic features that include cirque and funnel shaped valleys with high relative relief, dense forest cover; especially that of oak (banj) and rhododendron (burans), and average altitude exceeding 1,500 meters are considered to provide favorable conditions for cloudburst incidences.

Despite lack of well distributed network meteorological observatories in the hills large number of precipitation events, particularly those associated with human life loss and associated devastation, are often dubbed as being cloudburst; specially by the media. Therefore, there is bound to remain controversy as to whether or not a particular event was cloudburst. There is however no denial from any quarter that heavy localised precipitation is a natural phenomenon in the Himalaya and its frequency is observed to have increased in the previous some years. The same is often attributed to climate change.

Apart from field observations information regarding past incidences of heavy and localised rainfall events were gathered from the people. Semla, Pathali, Paldwari (Kakra Gad), Kirora Malla (Chak Gad), Kusum Gad, Phata, Panjan, Chhantikhal and Bajira were reportedly devastated by such rainfall events in the past. In September, 2012 heavy rainfall induced landslides and debris flows reportedly devastated Giriyagaon, Salami, Mangoli, Chunni, Premnagar, Brahmankholi and Jua Kimana villages around Okhimath. In the year 2013 Panjan and Bajira are observed to be devastated by cloudburst events while Taljaman, Senagarhsari, Sounda, Dhaunda, Udu, Barangali, Kimana and Khaduli are adversely affected. As many as 22 locations of cloudburst events are thus identified during the fieldwork (Fig. 16, Table 11). Most of these (41 percent) are located in Okhimath tehsil.

Sl. No.	Location /Coordinates	Landuse		Altitude (in meters)	Slope	Stream order	Valley trend	Valley shape
		Uphill side	Downhill side					
1.	Phata 30° 34' 25.988" N 79° 02' 09.176" E	Dense forest	Agriculture	1400-2200	Moderate - Steep	1	NE-SW	Funnel
2.	Salami / near Pali 30° 31' 27.409" N 79° 06' 29.758" E	Dense forest	Agriculture	1400-2200	Steep	1	NW-SE	Funnel
3.	Mangoli 30° 31' 24.852" N 79° 06' 10.784" E	Open forest	Agriculture	1400-2200	Moderate - Steep	1	NW-SE	Funnel
4.	Brahmankholi / Premnagar 30° 31' 09.173" N 79° 06' 10.150" E	Barren (rocky)	Agriculture	<1400	Moderate - Steep	-	E-W	Cirque
5.	Juakimana 30° 30' 17.991" N 79° 06' 21.482" E	Agriculture	Agriculture	1400-2200	Gentle - Moderate	1	E-W	Cirque
6.	Udu 30° 30' 23.335" N 79° 09' 05.252" E	Dense forest	Open forest	1400-2200	Moderate - Steep	2	NW-SE	Cirque
7.	Barangali 30° 30' 21.375" N 79° 08' 50.311" E	Dense forest	Agriculture	1400-2200	Moderate - Steep	1	NW-SE	Funnel

8.	Paldwari 30° 29' 10.368" N 79° 07' 22.172" E	Barren) (rocky)	Agriculture	1400-2200	Steep - Cliff	2	NW-SE	Funnel
9.	Tyung 30° 29' 07.420" N 79° 06' 04.055" E	Agriculture	Agriculture	<1400	Gentle - Moderate	-	NW-SE	Cirque
10.	Kusum Gad 30° 28' 03.515" N 79° 05' 18.146" E	Dense forest	Barren land	1400-2200	Moderate - Steep	1	E-W	Funnel
11.	Taljaman / Chhena gad 30° 28' 41.867" N 79° 01' 45.499" E	Dense forest	Open forest	1400-2200	Steep - Cliff	1	N-S	Funnel
12.	Taljaman 30° 28' 34.189" N 79° 02' 15.576" E	Barren (rocky)	Agriculture	1400-2200	Steep - Cliff	1	N-S	Funnel
13.	Senagarhsari 30° 25' 52.920" N 79° 07' 32.350" E	Barren land	Barren land	<1400	Moderate - Steep	2	NE-SW	Funnel
14.	Near Chhantikhal 30° 14' 29.786" N 78° 54' 39.873" E	Dense forest	Open forest	<1400	Moderate - Steep	1	NW-SE	Funnel
15.	Khaduli 30° 26' 19.158" N 79° 01' 39.709" E	Open forest	Agriculture	1400-2200	Moderate - Steep	2	N-S	Cirque
16.	Kimana 30° 26' 03.165" N 79° 02' 19.358" E	Dense forest	Agriculture	1400-2200	Moderate - Steep	2	NE-SW	Cirque
17.	Kirora Malla 30° 25' 11.094" N 78° 59' 16.758" E	Agriculture	Agriculture	<1400	Gentle - Moderate	1	N-S	Funnel
18.	Near Mathgaon 30° 25' 24.142" N 78° 57' 51.327" E	Dense forest	Open forest	1400-2200	Moderate - Steep	2	NW-SE	Funnel
19.	Panjan 30° 24' 41.351" N 78° 55' 46.950" E	Dense forest	Agriculture	1400-2200	Moderate - Steep	2	NE-SW	Funnel
20.	Bajira 30° 24' 28.820" N 78° 53' 06.497" E	Agriculture	Agriculture	1400-2200	Moderate - Steep	2	NE-SW	Funnel
21.	Sounda 30° 21' 12.036" N 78° 52' 25.431" E	Dense forest	Agriculture	1400-2200	Moderate - Steep	3	NW-SE	Funnel
22.	Dhaunda 30° 19' 52.247" N 78° 52' 20.955" E	Dense forest	Agriculture	1400-2200	Moderate - Steep	3	NW-SE	Funnel

Distribution of various geomorphic and physiographic factors was studied in the areas where heavy torrential rainfall events were identified. These include landuse, altitude, slope, stream order, valley trend and valley shape. There comes forth some positive correlation of some of these features.

Valley in most cases (73 percent) is observed to be funnel shaped and NW-SE (50 percent) to NE-SW oriented (88 percent). Area to the upslope of most places (64 percent) is observed to be forested. Altitude in most cases (77 percent) is observed to range between 1,400 and 2,200 meters.

Most of these areas fall in the higher reaches in the catchment of first or second order streams. Heavy downpour is observed to cause fast erosion of the agricultural lands and ensuing mud flow is largely responsible for the devastation.

These geomorphic and physiographic parameters can thus be considered as being responsible for promoting heavy and localised rains and these can in turn be utilized for identifying areas that are likely to be affected by such events. This is sure to pave way for the preparation of cloudburst vulnerability maps for the area.

Chapter - 9

Investigations around identified habitations

Besides active landslides whose details are given in the Annexure, a number of places in the study area were studied in detail. The location of these places is given in Fig. 16.

1. Kedarnath

Kedarnath is located at a distance of 16 kilometers from Gaurikund on the left bank of Mandakini river which originates from Chaurabari glacier, around 1.5 kilometers upstream of the shrine. The Kedarnath township was encircled by Mandakini and Saraswati rivers. The latter was however an abandoned channel that carried little water.

Geological set up of the area

The area is observed to be located on glacial outwash deposits and is occupied by outcrops as well as overburden. Along the valley flanks moraine deposits are observed. Rocks of Central Crystalline Group represented by augen gneisses and migmatites are observed to be exposed around Kedarnath area. Exposures of augen gneisses are observed along the footpath section to the downstream of the Kedarnath township on the left bank of Mandakini river. These rocks are medium grained, greyish in colour, moderately weathered, moderately jointed and medium to thickly foliated. These dip towards northeast to northwest at moderate angles.

Reconnaissance geological-geotechnical assessment

Heavy precipitation was received in upper Mandakini valley in June 2013. Thick pile of snow was present in the upper reaches of the area at that time. Breach of moraine dammed Chorabari Tal together with sudden melting of snow and heavy rainfall resulted in flash flood in the area. Huge volume of glacial debris along with large boulders was transported and re-deposited in this event that resulted in the activation of abandoned Saraswati channel to the east of the shrine. Due to this incidence around 1.0-2.0 meters thick pile of sediments with huge boulders got deposited on the valley floor (Figs. 19 and 20). A number of structures around the temple, particularly those to the north of it were ravaged in this incidence and the eastern wall of the temple as also many other structures were badly damaged (Fig. 21).

Fig. 19: Severely damaged structures over glacial outwash plain at Kedarnath.

Fig. 20: Large boulders around the temple.

Suggestive measures

The platform of the main shrine at Kedarnath has been completely covered by debris and boulders. The temple superstructure has also sustained damage due to the impact of rolling down mass of boulders and debris. Possibility of damage to the temple foundation cannot therefore be ruled out. No attempt should therefore be made to excavate the temple platform. This is likely to have adverse effect on the stability of the temple superstructure. Repair of the damaged portions of the temple should be carried out under personal supervision of experts.

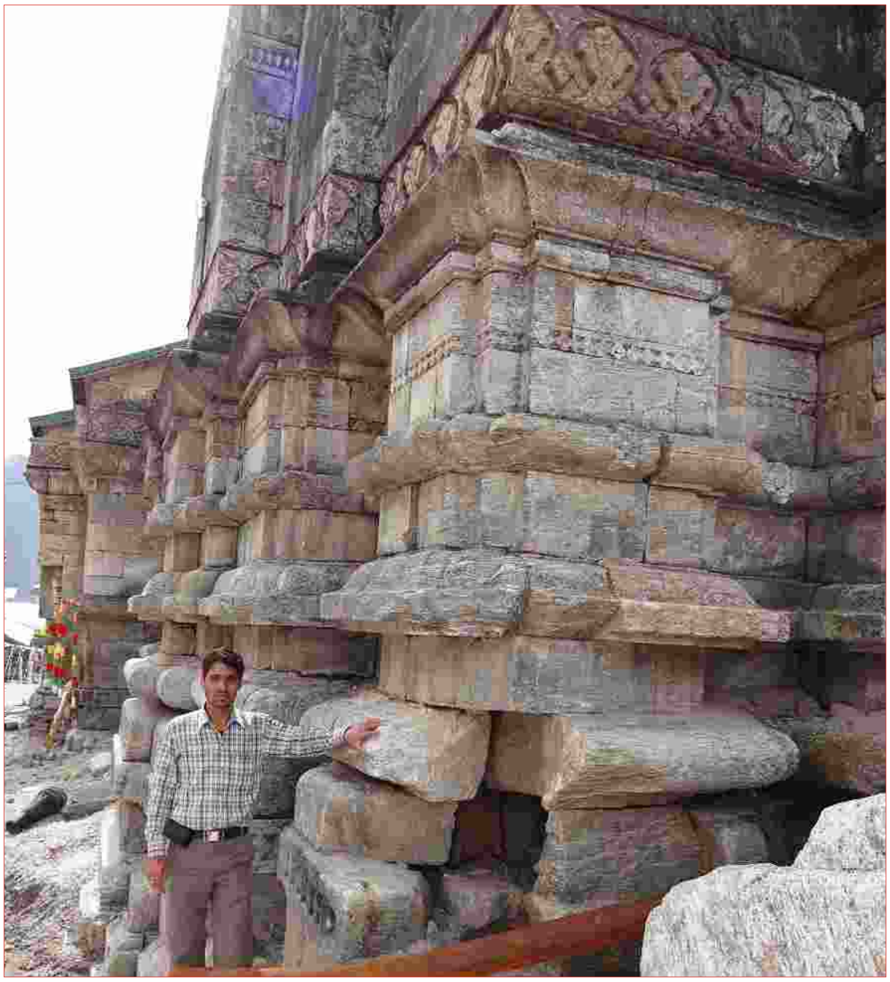


Fig. 21: Severely damaged eastern side corner wall of the main shrine at Kedarnath.

Due to the flash floods the area has witnessed major geomorphic changes. The lake (Chorabari Tal) no longer exists and the abandoned channel of Saraswati, to the east of the temple has become active. No attempt should be made to restore the original geomorphic setup. What best could be done is to let the forces of nature work and carve out new geomorphic setup.

Along the banks of the channels suitably designed toe protection walls are however required to be constructed to prevent toe cutting / bank erosion. In this process the channel course would be diverted away from the temple township. This would thus protect the temple township from subsequent erosion. To the north of the temple suitably designed semicircular guide wall can be constructed for deflecting rolling down boulders and debris.

Even though structural intervention are being recommended, it needs to be kept in mind that no structural intervention is going to be sustainable unless footed on firm foundation. Further more, it needs to be understood that Kedarnath is located over thick pile of glacial deposits and the floods of June, 2013 have added to its thickness. Finding in site rocks is therefore not going to be easy.

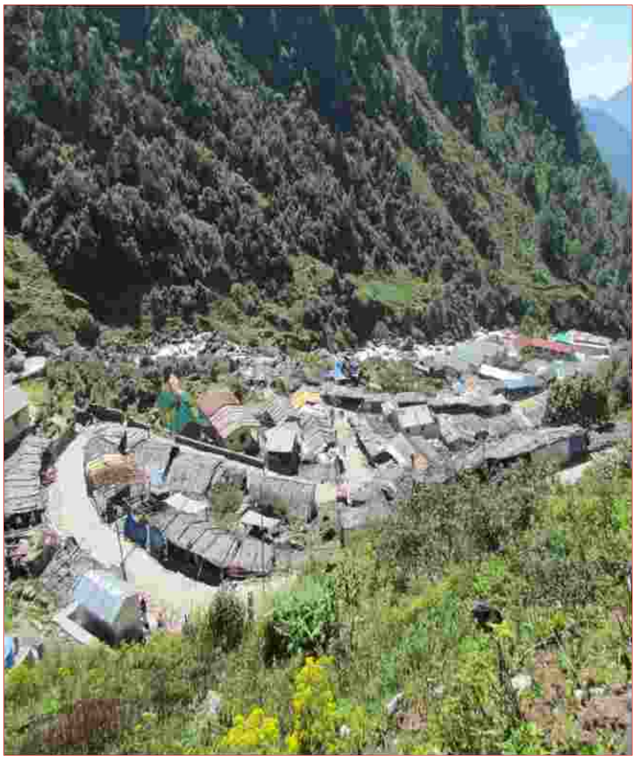
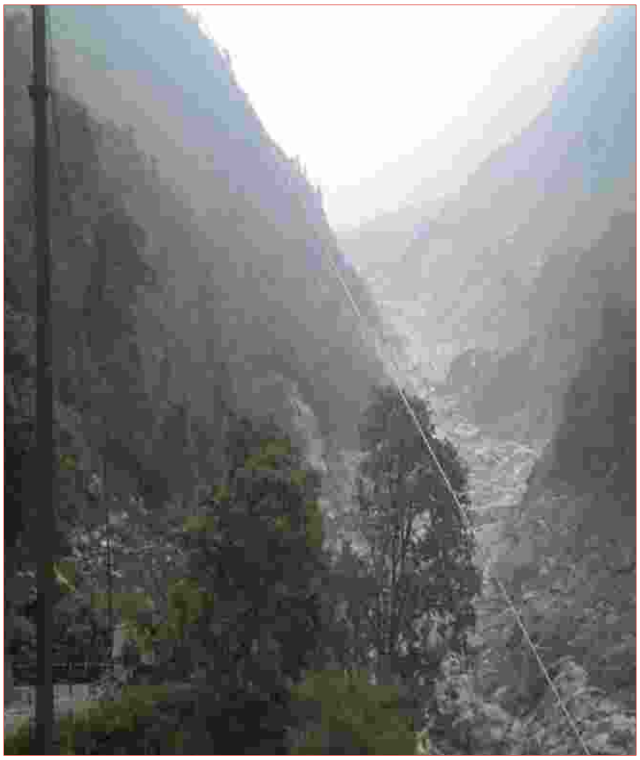
There exist a number of unsafe houses in the proximity of the temple and these are required to be demolished. Care needs to be taken to ensure minimal ground disturbance and explosives should not be used for demolition. Safe sites should then be identified for the disposal of the debris of the demolished structures. The same can be better utilized for the construction of protection walls along the stream bank.

No new constructions should be allowed in the temple township. Small and light structures can however be erected for those responsible for performing essential services related to the temple.

The temple township has freshly deposited cover of debris and boulders and any attempt to disturb these could initiate mass movement besides accelerating the pace of erosion. No attempt should therefore be made to landscape the surface.

2. Rambara

Rambara was located at a distance of 07 km from Gaurikund on the right bank of Mandakini. The place has been totally washed off in June, 2013 disaster (Fig. 22 and 23) and what exists is an active slide zone with glacial moraines visible on the scar below the in situ rock face.

Figs. 22 and 23: View of Rambara before (left) and after (right) the disaster. Camera looking south along the course of Mandakini.

Geological set up of the area

The area is observed to be located over moraines. The rocks belonging to Central Crystalline Group represented by augen gneisses are seen exposed around the area as also along the river bed. These rocks are observed to be medium grained, greyish in colour, moderately weathered, moderately jointed, and medium to thickly foliated and dipping towards northeast at moderate angles.


Figs. 24 and 25: Rambara town (left) and RCC footpath (right) were completely washed off due to flesh flood.

Reconnaissance geological-geotechnical assessment

Flooding of Mandakini river has resulted in extreme erosion on both banks around Rambara. Due to this a number of active slides have been generated (Figs. 24 and 25). The course of the river has thus become extremely wide and the slopes have come particularly steep.

Suggestive measures

Major damage has occurred around Rambara area and possibility of further instability due to toe erosion in this area cannot be ruled out. Anthropogenic intervention of any kind should be banned in this area.

Damaged footpath should be relocating on left bank of the Mandakini and the alignment of the same should be kept appreciably away from the course of the river. A bridge would be required to be constructed for crossing the river. Downstream of Rambara the river course has been rendered very wide and particularly steep. There are no in situ rock exposures in this zone for safe placement of abutments of the bridge. It is therefore recommended that the bridge be sited around 1.5 kilometers downstream of Rambara where Mandakini has carved out a gorge (Fig. 26). This site has firm rock support for placement of bridge abutments on both the banks. Moreover the course of the river is particularly narrow at this site, which would significantly reduce the span of the bridge.

Unfortunately attempts are being made to place the bridge before this point and both the abutments of this bridge are on the loose sediments and boulders (Fig. 27). Moreover the approach trek on the right bank passes through vertical cut on the moraines and is vulnerable to falling boulders .

In case of heavy rains stability of this bridge constructed on the active river bed is likely to be compromised. It is worth noting that it is the only bridge for crossing Mandakini between Gaurikund and Kedarnath and damage to the same would result in persons in Kedarnath-Linchauli area getting stranded. Emergency evacuation arrangements have to be therefore put in place for avoiding panic of any sort.

Fig. 26: Gorge downstream of the construction site where the bridge would have been constructed.

Fig. 27: Bridge being constructed on the river bed downstream of Rambara.

3. Gaurikund

Gaurikund is located at a distance of 05 km from Sonprayag on the right bank of Mandakini. It used to be the last motor head of Rishikesh - Kedarnath National Highway (NH 109), from where started pedestrian trek to Kedarnath.

Geological set up of the area

The area is observed to be located on moderate colluvium slope and river born material terrace. Exposures of Central Crystalline gneisses are observed along the footpath section both towards upstream and downstream of the town. These rocks are medium grained, greyish coloured, medium to thickly foliated and moderately to highly weathered. The rocks exposed in the area are generally observed to strike NE - SW and dip towards northwest at an angle of 45°. The joint sets are observed to dip towards SSW (65º / 210º) and ESE (70º / 110º). Presence of hot springs at Gaurikund is suggestive of its proximity to a deep-seated tectonic discontinuity. Sudden valley widening at Gaurikund is geomorphic evidence of its being located in the proximity of a tectonic contact. Vaikrita Thrust bringing high grade rocks of Vaikrita Group from those of Kalimath Formation passes in close proximity of Gaurikund.

Reconnaissance geological-geotechnical assessments

The valley to the upstream of Gurikund is particularly narrow and the stream gradient is high. Due to this sediment laden flood water attained high level and eroded even higher benches. This badly damaged the motor road up to Sonprayag, as also footpath leading to Kedarnath (Fig. 28).

Landslides are also observed on the opposite side of the market area (Fig. 29). The landslide debris has the potential of damming the river during monsoon. Bank erosion by river on its left bank has damaged a number of agricultural fields.

Fig. 28: Photograph shows damaged RCC footpath just upstream to town.

Fig. 29: View of damaged agricultural land opposite side of the market.

Suggestive measures

It is suggested that the material from slide zone be removed. Thereafter, breast wall is required to be constructed for toe protection so as to prevent further sliding. Suitably designed and appreciably high toe protection walls are recommended below the market on the right bank of the river for protecting the settlement and checking further bank erosion.

4. Sonprayag

Sonprayag is located on the right bank of Mandakini river just downstream of the confluence of Mandakini with Son Ganga. It is at a distance of 05 kilometers downstream of Gaurikund and can be approached by Rishikesh - Kedarnath National Highway (NH 109).

Geological set up of the area

The area is observed to be located on river borne material (RBM) terrace. Exposures of Central Crystalline schist are observed along the road section. These rocks are fine to medium grained, greyish coloured with thin to medium foliations and moderately to highly weathered. The rocks exposed in the area generally strike NW - SE and dip towards northeast at an angle of 30°. The joint sets dip towards SSW (80º/ 200º).

Reconnaissance geological-geotechnical assessment

Flood waters of Mandakini have eroded the terrace on its right bank and has deposited around 5 - 6 meters thick pile of sediments around the market. A number of structures together with the approach road have been badly damaged by this (Figs. 30 and 31).

Major landslide is observed between Munkatiya and Sonprayag and the same has damaged a stretch of the National Highway (NH-109). The slide is however fairly far from the Munkatiya village. The inclination of failure slope of this slide is observed to be around 45° with slope direction being northeast. The width of the failure slope is about 250 meters and vertical height of the slide is around 120 meters.

Fig. 30: View of damaged structures at Sonprayag town.

Fig. 31: View of damaged road and deposition of sediments around Sonprayag.

Suggestive measures

Suitably designed flood protection structures are required to put in place along the river bank of Mandakani for safeguarding the town and restricting bank erosion. It is recommended that the affected stretch of the National Highway (NH 109) be realigned on the uphill side.

5. Sitapur

Sitapur is located on the right bank of Mandakini river. It is a distance of around 26 kilometers from Guptkashi and can be approached by the Kedarnath National Highway (NH 109).

Geological set up of the area

The area is observed to be located amid agricultural fields and occupied by outcrops as well as overburden. This material is observed to comprise of medium grained sandy matrix with rounded boulders and cobbles. The affected area at Sitapur exhibits gentle slope and schist is observed to constitute the bedrock. Central Crystalline Group of rocks, represented mostly by schist, are observed to be exposed along the road section and river bed. Rocks exposed in the area generally strike NW- SE and dip towards northeast at an angle of 35°. The joint sets are observed to dip towards NW (50º/ 310º) and SSW (55º/ 210º).

Reconnaissance geological-geotechnical assessment

The main settlement is located on gradually sloping agricultural land that is fairly far from level of the river bed. The village is safe and presently no damage has been observed in the settlement.

River has however eroded a number of agricultural fields and has deposited around 2-3 meters thick pile of debris at Sitapur on the river bed, where river shows meandering morphology. At the same location river has also sifted 10-15 meters towards the town (Fig. 32).

Suggestive measures

For the safety of settlements, erection of suitably designed flood protection walls on the river bed along the

Fig. 32: View of deposited sediments at Sitapur on river bed.

right bank of Mandakini river is recommended.

6. Barasu Village

Barasu village is located on the right bank of Mandakini river. It is situated at a distance of 06 kilometers from Phata and can be approached by Kedarnath National Highway (NH 109).

Geological set up of the area

The area under study is observed to be located amid agricultural fields and occupied by outcrops as well as overburden. Rock exposures of tuffaceous rocks and gneisses belonging to the Central Crystalline Group are observed along the road section. The rocks exposed in the area are generally observed to strike NW - SE and dip towards northeast at angles varying around 35°. The rocks are observed to be well jointed and the details of the prominent joints observed in the field are recorded in Table 12.

Table 12: Details of the joint pattern observed in the field around Barasu village.

Joint Set	Dip amount	Dip direction	Strike trend	Remarks
I	35°	060°	150° - 330°	Foliation
II	55°	280°	010° - 190°	Prominent joint
III	85°	110°	020° - 200°	Prominent join

Reconnaissance geological-geotechnical assessment

Slopes around the area are observed to have moderate gradients whereas the overburden thickness, including weathered rock zone, is around 3.0 meters. The overburden material comprises of debris consisting of brown, fine grained silty matrix with angular fragments of gneisses and tuffeceous rocks.

Landslide is observed at the northwestern extremity of the Barasu village and the same has damaged a number of agricultural fields and a stretch of the National Highway (NH 109). The slide is however fairly far away from the village and does not pose immediate threat to the habitation.

The inclination of failure slope is observed to be around 25° - 35° and the slope direction is towards northeast. The width of failure slope is about 200 meters and vertical height of the slide is about 150 meters (Figs. 33 and 34).

Fig. 33: Panoramic view of Barasu landslide.

Fig. 34: Close view of Barasu landslide.

Suggestive measures

Suitably designed toe protection walls are required to be constructed to prevent the toe cutting / bank erosion by Mandakini river. This would protect the bank and check subsequent sliding below the habitation.

Appropriately designed retaining structures have also to be provided at the northeastern extremity of the village and below the National Highway where slope failure has taken place. This would behold the slope mass, protect the slope and help maintain the National Highway.

7. Khat village

Khat village is located at a distance of 0.8 kilometers from Phata town towards Guptkashi and is located on the right bank of southwest flowing Mandakini river. The area can be approached by Kedarnath National Highway (NH 109). The main village is around 100 meters from the National Highway on the upslope side.

Geological set up of the area

The area is observed to be occupied by outcrops as well as overburden. Exposures of Central Crystalline schist and gneisses are observed along the road section. These rocks are medium to course grained, greyish coloured with thin to medium foliations. These are moderately to highly weathered. The rocks exposed in the area generally strike NE - SW and dip towards southeast. These are observed to be well jointed and the details of the prominent joints observed in the field are recorded in Table 13.

Table 13: Details of the joint pattern observed in the field around Khat village.

Joint Set	Dip amount	Dip direction	Strike trend	Remarks
I	50°	115°	025° - 205°	Foliation
II	55°	190°	100° - 280°	Prominent joint
III	65°	320°	050° - 230°	Prominent joint

Reconnaissance geological-geotechnical assessment

A stretch of the National Highway (NH 109), downslope of Khat village, subsided on 19 November, 2013. Slope around this area is observed to have steep gradients whereas the overburden thickness, including weathered rock zone, is around 3.0 to 5.0 meters. The overburden material comprises of debris consisting of greyish brown, fine grained silty matrix with angular fragments and boulders of schist and gneisses.

Bank erosion due to floods has introduced instability in the slopes around the road below Khat village. Due to this a number of trees have been uprooted and around 100 meters long stretch of road has been damaged (Fig. 35). Primary School structures located around the crown of this slide zone have been damaged by landslide induced ground fissures (Fig. 36).

Fig. 35: View of National Highway - 109 damaged around Khat village due to landslide.

Fig. 36: View of the Primary School at Khat damaged by landslide induced fissures.

The angle of failure slope is observed to be around 45° and even more. The direction of the slope is towards north. Ground fissures in the failure slope area on road level are observed to be 3.0 - 5.0 meters long. Vertical height and width of the failure slope is 150 meters and 120 meters respectively. The critical mass lying on steep road cut has resulted in the development of NE-SW trending tension cracks in the crown portion and these are observed to be up to 1.0 meters wide and 1.5 - 2.0 meters deep.

Suggestive measures

In view of high risk due to slope instability, the Primary School structures located around the crown of the slide should be put to disuse and demolished.

In view of the risk posed to the settlement special care needs to be taken while excavating the hill slope for reconstructing the road. Suitably designed breast and retaining walls of appropriate height would then have to be constructed on both sides of the road.

8. Semi Village

Semi village is located at right bank of Mandakini river and can be approached by the Kedarnath National Highway (NH 109). It is 2.0 kilometers from Kund Chatti towards Guptkashi. It is situated on old slide zone as well as on different level of gently sloping terraces.

Geological set up of the area

The area is observed to be largely occupied by overburden material. Central Crystalline rocks comprising of schist are however exposed on the upslope side along the road section. These generally strike NW - SE and dip towards northeast. These are at the same well jointed and the details of the prominent joints observed in the field are given in Table 14.

Table 14: Details of the joint pattern observed in the field around Semi village.

Joint Set	Dip amount	Dip direction	Strike trend	Remarks
I	35°	040°	130° - 310°	Foliation
II	60°	060°	150° - 330°	Prominent joint
III	65°	175°	085° - 265°	Prominent joint

Reconnaissance geological-geotechnical assessment

In situ rocks are not generally observed around the affected village that is occupied by thick overburden material. Thickness of the overburden is observed to be around 12.0 meters. This material comprises of top soil, hill wash and debris that consists of brown and greyish, fine grained silty matrix with fragments and boulders of schist.

Slope failure is observed to have occurred on the eastern slope. The width of the failure slope is around 250 to 300 meters along the south flowing Mandakini river while the height of the slide from river bed to the crown is about 200-240 meters. The inclination of failure slope is observed to be around 25°. Entire Semi village is under high risk due to multi-level rotational slope movements and subsidence. This has damaged the National Highway and settlements (Figs. 37 and 38).

Fig. 37: View of subsidence of National Highway - 109 around Semi village.

Fig. 38: Photograph depicting semi landslide induced by bank erosion by Mandakini river.

Upper portion of the village is observed to be affected by rock / boulders fall from the higher reaches, to the upslope of Guptkashi-Jakohli motor road.

In this area the flood waters of Mandakini directly hit the base of the village resulting in continuous undercutting and erosion. Few seasonal streams drain the village and poor drainage arrangements saturate the overburden mass. These provide favourable conditions for downslope movement of thick cover of overburden material. Loading of this mass by construction has further aggravated the problems related to soil creep, subsidence and slope failure.

Suggestive measures

Semi village faces serious slope instability problem. Attempting mitigation measures would be technically challenging and financially burdensome. It is therefore advisable to shift the entire village to an alternate safe location.

It is recommended to realign the affected stretch of the National Highway (NH 109).

Appropriately designed retaining structures of suitable height with firm foundation are required to be erected at river level for checking toe cutting / bank erosion by Mandakini. This would help in gradually slowing the pace of downslope movement.

9. Gaundar village

Gaundar is located at a distance of 07 kilometers from the road head at Ransi village. It is situated on the right bank of southwest flowing Madhyameheshwar Ganga, a tributary of Mandakini river. The area can be approached by Okhimath-Mansuna-Ransi link road.

Geological set up of the area

The area is observed to be located amid agricultural fields that are occupied by both outcrops and overburden. Exposures of Higher Himalayan schist and gneisses are observed along the footpath section, as also on the stream bed below the village. These rocks are observed to be medium grained, greyish coloured, medium foliated and moderately weathered. The garnetiferous gneisses exposed in the area are generally observed to strike NE - SW and dip towards southeast. These rocks are well jointed and the details of the prominent joints observed in the field are given in Table 15.

Table 15: Details of the joint pattern observed in the field around Gaundar village.

Joint Set	Dip amount	Dip direction	Strike trend	Remarks
I	65°	120°	030° - 210°	Foliation
II	80°	205°	115° - 295°	Prominent joint
III	45°	050°	320° - 140°	Prominent joint

Reconnaissance geological-geotechnical assessment

Abnormally high sediment laden discharge of Madhyameheshwar Ganga has eroded the terrace on its right bank and deposited around 3.0 meters thick pile of sediments (Fig. 39). Some agricultural fields adjacent to the river bed, both upstream and downstream of the village, are observed to be partially wash off (Fig. 40).

Main settlement of the village is located over solid rocks and is fairly far from the stream. The village is therefore safe.

Fig. 39: Sediments deposited by Madhyameheshwar Ganga just upstream of Gaundar.

Fig. 40: View of agricultural lands washed off due to floods to the downstream of Gaundar.

Suggestive measures

Construction in the proximity of the river, particularly in low lying areas should be banned.

10. Jal Talla village

Jal Talla is located at a distance of 06 kilometers from Kalimath and is situated on the right bank of southwest flowing Kali Ganga, a tributary of Mandakini. The area can be approached by Guptkashi-Kalimath - Chaumasi link road.

Geological set up of the area

The area is observed to be located amid agricultural fields that are occupied by both, outcrops and overburden. The rock exposures of Higher Himalayan schist and gneisses are observed along the road section as also upslope of the village. These rocks are medium grained, greyish coloured with thin to medium foliations. These are observed to be moderately to highly weathered.

At places the rock mass is observed to have slumped due to fractured and jointed nature of the rocks. The rocks exposed in the area generally strike NW - SE and dip towards northeast. These rocks are observed to be well jointed and the details of the prominent joints observed in the field are given in Table 16.

Table 16: Details of the joint pattern observed in the field around Jal Talla village.

Joint Set	Dip amount	Dip direction	Strike trend	Remarks
I	25°	010°	100° - 280°	Foliation
II	70°	140°	050° - 230°	Prominent joint
III	60°	320°	050° - 230°	Prominent joint

Reconnaissance geological-geotechnical assessment

Slopes around the area have gentle - moderate gradients whereas the overburden thickness, including weathered rock zone, is around 2.0 to 5.0 meters. This overburden material comprises of debris consisting of greyish brown, fine grained silty matrix with angular fragments of schist and gneisses.

Thinly foliated and fragile nature of the schist together with overburden has resulted in the formation of landslide that is observed to facilitate movement of huge slope mass below the village. The angle of failure slope is observed to be around 25° and even more. The direction of the slope is observed to be towards east. The ground fissures in the failure slope area are observed to be 2 to 5 meters long. The vertical height and width of the failure slope are both around 150 meters (Fig. 41). The subsided material lying on gentle to moderate slopes has developed tension cracks on the road and these are observed to be up to 30 cm wide and 1.0 - 2.0 meters deep indicating active soil movement (Fig. 42).

Landslides are observed to occur uncontrollably over the entire stretch of the agricultural lands below the village. These pose threat to the houses located on the subsided portion where road has also been damaged.

Fig. 41: Slope failure around Jal Talla village.

Fig. 42: Photograph showing cracks on the road.

Suggestive measures

Hill slope should be excavated for reconstruction of the damaged road. After this suitably designed breast wall of appropriate height with weep holes should be constructed at road level.

11. Kalimath

Kalimath town is located on the right bank of Kali Ganga and is at a distance of 09 kilometers from Bhainsari on Guptkashi - Kalimath State Highway (SH 36). Kalimath has a famous temple dedicated to Goddess Kali. The town was originally known as Kobilta.

Geological set up of the area

The area is observed to be occupied by outcrops as well as overburden. The Kali temple is also located amid agricultural fields. Exposures of schist and gneisses of Central Crystalline Group of the Higher Himalaya are observed along the road section, as also on the river bed. Rocks exposed in the area are generally observed to strike NE - SW and dip towards northwest. These are well jointed and the details of the prominent joints observed in the field are given in Table 16.

Table 16: Details of the joint pattern observed in the field around Kalimath.

Joint Set	Dip amount	Dip direction	Strike trend	Remarks
I	45°	330°	060° - 240°	Foliation
II	60°	180°	090° - 270°	Prominent joint
III	60°	090°	180° - 000°	Prominent joint

Reconnaissance geological - geotechnical assessment

The area is observed to be occupied by thick pile of alluvial materials. General thickness of overburden, including weathered rock zone, is observed to be around 7.0 meters and even more. This overburden material comprises of river borne materials consisting of boulder, gravel and sand. Slope around the temple is gentle while that on the opposite side of the temple, below the Kalimath market has steep gradient.

Terraces are observed to have been cut vertically by Kali Ganga. An eroded terrace with vertical cut of around 6.0 meters is observed on the left bank of the river just below the temple. Foundation of the temple is observed to be severely damaged by toe / bank erosion of Kali Ganga on both northern and southern extremities (Figs. 43 and 44).

Figs. 43 and 44: View of severely damaged Kali temple and other structures around Kalimath.

Suggestive measures

Suitably designed toe protection structures with step ladder and deep foundation are required to be erected along the free face below the Kali temple area without disturbing the slope. This would protect the temple from stream erosion.

Appropriately designed retaining structures have also to be provided in the northern and southern extremity of temple on both the banks. This would protect the slope and the banks from stream erosion.

12. Kunjethi Village

Kunjethi village is located on the left bank of Kali Ganga and is situated 0.5 kilometers downstream of Kalimath, on Guptkashi - Kalimath State Highway. The village is situated over gently sloping colluvial terraces.

Geological set up of the area

The area is occupied by outcrops as well as overburden. The landslide zone at Kunjethi is observed to exhibit moderately steep slope and gneisses are observed to constitute the bedrock.

Central Crystalline gneisses are exposed on the right bank of Kali Ganga as also along the road section. These are medium to course grained, grey in colour, slightly to moderately weathered, moderately jointed and medium to thickly foliated. At places the rock mass is observed to have slumped due to fractured and jointed nature of the rocks, as also due to the presence of subsurface water / seepage. The rocks exposed in the area are generally observed to strike NE - SW and dip towards northwest. Details of the prominent joints observed in the field are given in Table 17.

Table 17: Details of the joint pattern observed in the field around Kunjethi village.

Joint Set	Dip amount	Dip direction	Strike trend	Remarks
I	45°	330°	060° - 240°	Foliation
II	60°	090°	000° - 180°	Prominent joint
III	60°	180°	090° - 270°	Prominent joint

Reconnaissance geological-geotechnical assessment

The overburden material comprises of top soil, hill wash and debris that consists of brown and greyish, fine grained silty matrix with fragments of gneisses. The slope failure is observed to have occurred on the western slope.

The width of the failure slope is about 400 meters along the road while the height of the slide from the bed of Kali Ganga to the crown is about 300 meters. The inclination of failure slope is observed to be around 25°. Continuous toe cutting by river has induced slope failure resulting in mass movement. Due to the failure, a scar has developed in the crown portion above the village (Fig. 45).

Undercutting of hill slope for reconstruction of the damaged road would remove the lateral support of the upslope material that might lead to slope failure and the same might pose a risk even for the village (Fig. 46).

Fig. 45: Photograph showing road and habitation damaged by landslides at Kunjethi.

Fig. 46: Cutting the hill slope for reconstruction of road.

Suggestive measures

In view of the risk posed to the settlement special care needs to be taken while excavating the hill slope for reconstructing the road. So far as possible excavation should be minimized and the slope material should not be disturbed. After removing the critical mass, suitably designed breast wall with weep holes should be constructed on road level.

On valley ward side, a series of wire crate retaining walls are required to be constructed across the failure slope in steps without much disturbing the slope. This would protect the critical slope and village.

13. Taljaman village

Taljaman is located on the left bank of Damar Gad and is at a distance of 25 kilometers from Guptkashi. The area can be approached by Guptkashi - Vasukedar - Jakholi motor road. The village is located downslope of the road. The area is drained by two streams at this location.

Geological set up of the area

The area is observed to be located amid agricultural fields and occupied by outcrops as well as overburden. The entire village is located on an old landslide fan. Exposures of Central Crystalline gneisses are observed along the road section around the village. These rocks are medium to course grained, greyish coloured, medium to thickly foliated and moderately weathered. Rocks exposed in the area are generally observed to strike E - W and dip towards north. The rocks are well jointed and the details of the prominent joints observed in the field are given in Table 18.

Table 18: Details of the joint pattern observed in the field around Taljaman village.

Joint Set	Dip amount	Dip direction	Strike trend	Remarks
I	30°	000°	090° - 270°	Foliation
II	65°	150°	060° - 240°	Prominent joint
III	70°	200°	110° - 290°	Prominent joint

Reconnaissance geological-geotechnical assessment

The village is located over an old landslide fan and slope around the village is observed to be gentle. A seasonal stream is observed in the area upslope of the village while a perennial stream, Damar Gad, is present below the village (Fig. 47). Both these streams have contributed to instability of the slope in this area. Around the village general thickness of the overburden material, including weathered rock zone, is observed to be around 7.0 meters.

Suggestive measures

In view of slope instability villagers are advised to stay away from both the streams and eroded zones. The households located between the old landslide and eroded zones are however required to be shifted to alternate safer locations.

14. Banswara

Banswara is located 2 kilometers upstream of Chandrapuri on Rishikesh - Kedarnath National Highway. It is on the left bank of Mandakini river.

Geological set up of the area

The area is observed to be largely occupied by river borne material (RBM) that comprises of medium grained

Fig. 47: View of terrace eroded by Damar Gad around Taljaman village.

sandy matrix with rounded boulders and cobbles. The affected area around Geeta Kutir is observed to exhibit gentle slope and schist is observed to constitute the bedrock. Biotite schist is observed to be exposed to the downstream of Geeta Kutir on the river bed. These rocks are fine to medium grained, greyish coloured, moderately weathered, moderately jointed, thinly foliated and dip towards northeast at an angle of around 55°. The joint sets are observed to dip towards SSE (80º/ 160º).

Reconnaissance geological-geotechnical assessment

The river is observed to have shifted around 10 meters towards the left bank and has eroded the terrace on its left bank. Terraces are observed to be cut vertically by the river. An eroded terrace with around 5 meters vertical cut is observed on the left bank of the river. A building and some huts on this destabilized terrace have been spared from complete destruction but the possibility of these being affected by ongoing erosion cannot be ruled out (Fig. 48).

Suggestive measures

Construction of suitably designed toe protection walls is recommended along the free face below the affected area. This would protect the affected site as also bank from stream erosion.

15. Syalsaur

Syalsaur is located on Rishikesh - Kedarnath National Highway (NH 109) around 3 kilometers upstream to Chandrapuri, on the left bank of Mandakini river.

Geological set up of the area

The area is observed to be largely occupied by river borne material (RBM) that comprises of medium grained sandy matrix with rounded boulders and cobbles. The affected area at Syalsaur is observed to exhibit gentle

Fig. 48: View of damaged structures over eroded terrace at Banswara.

slope and schist is observed to constitute the bedrock. Central Crystalline schist is observed to be exposed to the downstream side on the river bed. These are fine to medium grained, greyish coloured, moderately weathered, moderately jointed, thinly foliated and dip towards east at high angles (~ 70°). The joint sets are observed to dip towards SSW (40º/ 220º).

Reconnaissance geological-geotechnical assessment

The main settlement of this village is located upslope of Rishikesh - Kedarnath National Highway that is far away from Mandakini river. Tourist cottages of Garhwal Mandal Vikas Nigam (GMVN) are however located at the lowest level of the terrace. Flood waters of Mandakini have eroded the terrace on the left bank and has severely damaged the GMVN structures (Fig. 49), as also around 100 meters stretch of National Highway (NH 109). Three storeyed structure of Prince Hotel is also completely destroyed in this incidence (Fig. 50). The GMVN structures on this destabilized terrace have not been completely destroyed but the possibility of their being affected by continuing erosion of the terrace cannot be ruled out.

Fig. 49: View of damage GMVN cottages on the left bank of Mandakini river.

Fig. 50: View of damaged Prince Hotel just below the National Highway.

Suggestive measures

In view of future flood incidences in Mandakini river, it is recommended that the damaged GMVN structures be abandoned and demolished. Construction should be completely banned in this zone.

In order to ensure safety of the Rishikesh - Kedarnath National Highway, suitably designed flood protection wall should be constructed from the river bed level.

16. Chandrapuri

Chandrapuri market is located 4 kilometers upstream of Ganganagar on Rishikesh - Kedarnath National Highway (NH 109). It is on the left bank of Mandakini river. Chandrapuri village is located 0.5 kilometers upstream of Chandrapuri market, also on the right bank.

Geological set up of the area

The area is observed to be largely occupied by river borne material (RBM) that comprises of medium grained sandy matrix with rounded boulders and cobbles. The affected area at Chandrapuri is observed to exhibit gentle slope and gneisses constitute the bedrock. Central Crystalline gneisses are observed to be exposed upstream of the market on the river bed and on the road section. These rocks generally strike NE - SW and dip towards southeast at angles varying around 50°. The rocks are well jointed and the details of the prominent joints observed in the field are presented in Table 19.

Table 19: Details of the joint pattern observed in the area around Chandrapuri.

Joint Set	Dip amount	Dip direction	Strike trend	Remarks
I	50°	095°	005° - 185°	Foliation
II	55°	280°	010° - 190°	Prominent joint
III	75°	245°	155° - 335°	Prominent joint

Reconnaissance geological-geotechnical assessment

Flooding in Mandakini river is responsible for bank erosion in the area and the same has introduced instability in the slopes around Chandrapuri market (Fig. 51) and village (Fig. 52). River has shifted around 10 - 15 meters towards the left bank in Chandrapuri area. Flood waters of Mandakini have damaged around 300 meters long stretch of National Highway downstream of the market area on its left bank.

Fig. 51: View of the damaged settlements and road.

Fig. 52: View of flood affected Chandrapuri village on the right bank of Mandakini river.

Suggestive measures

The households living in the zone of active bank erosion are required to be shifted to alternate safe locations.

Suitably designed toe protection walls are required to be constructed along the free face below the settlement on the river bank so as to avoid further bank erosion by the river.

Realignment of the affected stretch of National Highway to the uphill side and away from the river is recommended.

17. Sauri village

Sauri is located on 3 kilometers downstream of Chandrapuri on Rishikesh - Kedarnath National Highway (NH 109), on the left bank of Mandakini river.

Geological set up of the area

The area is observed to be largely occupied by overburden material. No rock outcrop is observed in the vicinity of the village. The exposures along the Sauri Nala bed are however observed to be that of Lesser Himalayan schistose quartzite. General trend of the rocks is observed to be N - S with moderately steep dips towards east. The rocks in the area are observed to be traversed by numerous joints and the important joint sets dip at moderate to steep angles towards W and NNW (40º/ 270º and 75°/350°).

Reconnaissance geological-geotechnical assessment

The area around the village is observed to have thick overburden and its thickness is up to 8.0 meters. This overburden material comprises of river borne material that consists of grey, medium grained sandy matrix with rounded cobbles and rare boulders. Bank erosion caused by spate in Mandakini river during excessive rainfall events in this valley has contributed to the instability of the slopes in this area. An eroded terrace with vertical cut of around 6 meters is observed on the left bank of the river (Fig. 53).

Fig. 53: Photograph depicting critical state houses on eroded terrace.

Mitigation measures

Appropriately designed retaining structures of suitable height with firm foundation are required to be erected for preventing toe cutting / bank erosion by Mandakini river. This would help in protecting the affected site as well as bank of Mandakini river.

18. Pathalidhar

Pathalidahar is located on the right bank of Mandakini river. It is at a distance of 05 kilometers from Vijaynagar and can be approached by the Vijaynagar - Vasukedar - Guptkashi motor road.

Geological set up of the area

The area is observed to be occupied by outcrops as well as overburden. Exposures of Lesser Himalayan schistose quartzite are observed along the road section. These rocks are medium grained, greyish coloured, medium to thickly foliated and moderately weathered. Garhwal Group of schistose quartzite exposed in the area are generally observed to strike NE - SW and dip towards southeast at average angle of 40°. The rocks are observed to be well jointed and details of the prominent joints observed in the field are given in Table 20.

Table 20: Details of the joint pattern observed in the field around Pathalidhar.

Joint Set	Dip amount	Dip direction	Strike trend	Remarks
I	40°	095°	005° - 185°	Foliation
II	55°	280°	010° - 190°	Prominent joint
III	80°	005°	095° - 275°	Prominent joint

Reconnaissance geological-geotechnical assessment

Slopes around this area are observed to have steep gradients. The overburden thickness, including weathered rock zone, is around 2.0 to 3.0 meters. The overburden material comprises of debris consisting of greyish brown, silty - sandy matrix with angular fragments and boulders of schistose quartzite.

The angle of failure slope is observed to be around 45° and the direction of slope is towards southeast. The vertical height and width of the failure slope is around 100 meters and 50 meters respectively. The critical mass is located in between road cuts on steep slope.

Fig. 54: Panoramic view of Pathalidhar landslide.

The debris cum rock mass of Pathalidhar landslide is observed to be dangerous. It is likely to cause major problem during the monsoon season (Fig. 54). The shallow bouldery debris above the steep rocky slopes on road cuts poses threat of falling down. This could threaten the habitation below. The landslide may thus cause serious threat to a number of houses, particularly during the monsoons.

Suggestive measures

It is recommended the huge critical mass around the crown and in the detached area of landslide be removed mechanically. After removing the critical mass, suitably designed breast walls should be provided to support the failure slope on road level. The foundation of this wall has to be put on compact materials.

19. Ganganagar

Ganganagar is located on the right bank of Mandakini river. It is at a distance of around one kilometer from Vijaynagar and can be approached by the Jawahar Nagar -Vasukedar - Guptkashi link road.

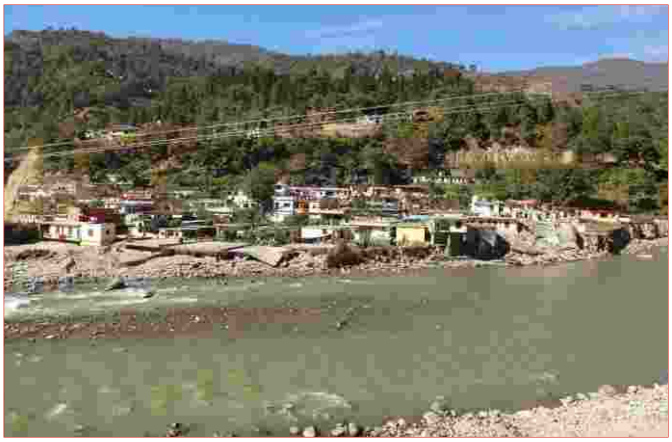
Geological set up of the area

The area is observed to be located on river borne material terrace. The terrace is composed of medium grained sandy matrix with rounded boulders and cobbles. The affected area at Ganganagar is observed to exhibit gentle slope and schistose quartzite are observed to constitute the bedrock.

schistose quartzite of Garhwal Group are continuously observed to be exposed on the upstream side along the river bed. These are medium grained, greyish coloured, medium foliated and moderately weathered. The rocks exposed in the area generally strike NW- SE and dip towards northeast at an angle of 40°. The joint sets are observed to dip towards WNW (55º/ 280º).

Reconnaissance geological-geotechnical assessment

The main settlement is located over river borne material terrace in close proximity of the river. Flood waters of Mandakini have eroded the terrace on its right bank and has severely damaged a number of structures along with around 250 meters long stretch of Jawahar Nagar - Vesukedar - Guptkashi link road located on the downstream side of the habitation (Figs. 55 and 56).



Figs. 55 and 56: Photographs shows damaged structures around Ganganagar.

Suggestive measures

Severely damaged and ruined structures should be demolished. Further construction in areas affected by floods should be banned.

Suitably designed flood protection walls should be constructed below the settlement along the river bank so as to avoid the further bank erosion.

It is recommended to realign the affected stretch of link road on uphill side and away from the river.

20. Jawaharnagar

Jawaharnagar is located on the left bank of Mandakini river. It is at a distance of around one kilometer from Vijaynagar and can be approached by the Rishikesh - Kedarnath National Highway (NH 109).

Geological set up of the area

The area is observed to be located on river borne material terrace that is composed of medium grained sandy matrix with rounded cobbles and boulders. The affected area at Jawaharnagar is observed to exhibit gentle slope and schistose quartzite is observed to constitute the bedrock.

Schistose quartzite of Garhwal Group is continuously observed to be exposed along the road section. These rocks are medium grained, greyish coloured with thin to medium foliations. These are moderately weathered. The rocks exposed in the area generally strike NE - SW and dip towards southeast at an angle of 60°. The joint sets are observed to dip towards WNW (55º/ 300º) and SSW (70º / 210º).

Reconnaissance geological-geotechnical assessment

The main settlement is observed to be located over river borne material terrace in close proximity of the river. Sediment leaden high discharge of Mandakini river has eroded the terrace on its left bank and has severely damaged the staff quarters of the Degree College, as also some personal residential houses and a numbers of agricultural fields (Fig. 57). In this area, the river has shifted around 05 - 10 meters towards the right bank.

A landslide is observed on the opposite side of the Degree College. This has damaged Ganganagar - Tilli - Mayali link road.

Fig. 57: Photograph depicting damaged structures and agricultural fields

Suggestive measures

Severely damaged and ruined structures should be demolished. Further constructions should be banned in areas that have been affected by floods.

Suitably designed flood protection walls are needed below the settlement along the river bank so as to avoid further bank erosion by the river.

It is recommended to reconstruct the damaged Tilli - Mayali link road with suitable provision of burst walls.

21. Vijaynagar

Vijaynagar is located on the left bank of Mandakini river on Rishikesh - Kedarnath National Highway (NH 109). It is located in close proximity of Agastmuni town to the upstream side. The two are around 200 meters apart.

Geological set up of the area

The area is observed to be largely occupied by river borne material (RBM) that comprises of medium grained sandy matrix with rounded boulders and cobbles. The affected area at Vijaynagar is observed to exhibit gentle slope and schistose quartzite are observed to constitute the bed rock.

Schistose quartzite of Garhwal Group are observed to be exposed towards the downstream on the river bed. These rocks are fine to medium grained, greyish coloured, moderately weathered, moderately jointed with thin to moderate foliations. These dip towards southeast at an angle of 35°. The joint sets are observed to dip towards NNW (60º/ 320º).

Reconnaissance geological-geotechnical assessment

Due to floods and ensuing erosion Mandakini river has eroded the terrace on its left bank and has shifted towards the left bank by around 15 meters. An eroded terrace with around 20 meters vertical cut is observed at this site. Temporary road measuring around 400 meters has been constructed at this place (Fig. 58). Some houses on this destabilized terrace have not been completely destroyed but the possibility of these being affected by continuing erosion of the terrace cannot be ruled out (Fig. 59). Settlement also exists above the middle portion of this stretch, which is a fan of a major nala / drainage joining Mandakini river at right angles.

Fig. 58: Photograph depicting eroded terrace and temporary road at Vijaynagar.

Fig. 59: Close view of damaged houses located over the edge of eroded terrace.

Suggestive measures

Suitably designed toe protection walls are needed along the free face below the eroded terrace so as to avoid further bank erosion by river.

Partially damaged, hanging houses located on the upper terrace pose a major risk. Therefore these houses should be demolished.

It is recommended to realign the affected stretch of National Highway (NH 109).

22. Agastmuni

Agastmuni town is located 15 km upstream of Rudraprayag, on the left bank of Mandakini river on Rishikesh Kedarnath - National Highway (NH 109). It is located over a terrace of Mandakini river.

Geological set up of the area

The area is observed to be largely occupied by river borne material (RBM) that comprises of medium grained sandy matrix with rounded cobbles and boulders. The affected area at Agastmuni is observed to exhibit gentle slope and schistose quartzite is observed to constitute the bedrock.

Schistose quartzite is exposed to the downstream of market along the road section. These rocks are observed to be fine to medium grained, greyish coloured, moderately jointed, thinly foliated and dip towards southeast at an angle of 35°. The joint sets are observed to dip towards NW (60º/ 310º).

Reconnaissance geological-geotechnical assessment

Flood waters of Mandakini have partially eroded the toe of Ramleela Ground terrace on its right bank (Fig. 60). Some of the houses constructed around the level of the river bed on the left bank have been destroyed by flood waters of Mandakini river. No damage has however occurred in the area around the market and Ramleela Ground.

Flood induced landslide is observed on the opposite side of the Ramleela Ground (Fig. 61). It has damaged a number of houses at Patiyon, Chaka, and Tilli villages along with a number of agricultural fields. The inclination of failure slope is observed to be around 40° and the slope direction is towards southeast. The width of the failure slope is about 250 meters while the vertical height of the slide is about 45 meters.

Fig. 60: View of eroded terrace of Ramlila Ground.

Fig. 61: Photograph depicting flood induced landslide.

Suggestive measures

Slope instability poses high risk in Patiyon, Chaka and Tilli villages. Severely damaged structures located along the landslide zone should therefore be put to disuse and demolished. In order to ensure safety of the settlements in these villages, detailed geological - geotechnical assessment should be carried out.

For the safety of Ramleela Ground, erection of suitably designed flood protection walls from the river bed level along the river below the Ramleela ground is recommended.

Further construction should be banned, particularly in the areas where damages have occurred as also on the river bed level and around slide zones.

23. Silli (Chaka)

It is located on the left bank of Mandakini river, approximately 2 kilometers downstream of Agastmuni on NH 109. The village is located on river borne material terrace.

Geological set up of the area

The area is observed to be occupied by outcrops as well as overburden. Exposures of Lesser Himalayan schistose quartzite are observed along the bank as also on the road section. The rocks are medium grained, greyish coloured, medium to thickly foliated and moderately weathered. These generally strike NE - SW and dip towards northeast at an angle of 35°. The joint sets are observed to dip towards WNW and NNE (50º/ 290º and 65°/30°).

Reconnaissance geological-geotechnical assessment

Flooding of Mandakini has damaged many houses in the lower portion of this village while the suspension bridge connecting Silli with Chaka (on the right bank) has been washed away.

Gully erosion is observed to the downstream of the Chaka village on the right bank of river (Fig. 62). No damage has however occurred in the Chaka village area. Landslide is observed to the downstream side of the Silli village and the same has damaged around 200 meters stretch of the National Highway (NH 109) on the left bank of Mandakini river (Fig. 63).

Fig. 62: View of gully erosion on the right bank of Mandakini.

Fig. 63: View of debris dumped on National Highway on the left bank of Mandakini.

Mitigation measures

It is recommended that flood protection wall be erected at the river level and affected part of National Highway be reconstructed after removal of debris.

24. Sumari Village

Sumari and Tilwara are located on opposite banks of Mandakini river; Sumari being on the right bank. It is well connected by Tilwara - Mayali State Highway. It is situated on two levels of gently sloping river borne material terraces.

Geological set up of the area

The area is observed to be largely occupied by river borne material that consists of grey, medium grained sandy matrix with rounded cobbles and boulders. Phyllite and basic rocks of Garhwal Group are however exposed on the river bed. These strike NE - SW and dip towards southeast at an angle of 60°. The rocks are observed to be well jointed and the details of the prominent joints observed in the field are given in Table 21.

Table 21: Details of the joint pattern observed in the area around Sumari village.

Joint Set	Dip amount	Dip direction	Strike trend	Remarks
I	60°	105°	015° - 195°	Foliation
II	65°	200°	110° - 290°	Prominent joint
III	70°	310°	040° - 220°	Prominent joint

Reconnaissance geological-geotechnical assessment

The area around Sumari is observed to have thick pile of overburden material whose thickness is as much as 20 meters. The overburden material is largely observed to comprise of river borne material that consisted of grey, medium grained sandy matrix with rounded cobbles and boulders.

Bank erosion caused by spate in Mandakini river during excessive rainfall events in this valley has contributed to the instability of the slopes in this area. The river terrace is observed to be cut vertically by the river. An eroded terrace with vertical cut around of 12 meters is observed on the right bank of Mandakini river (Figs. 64 and 65).

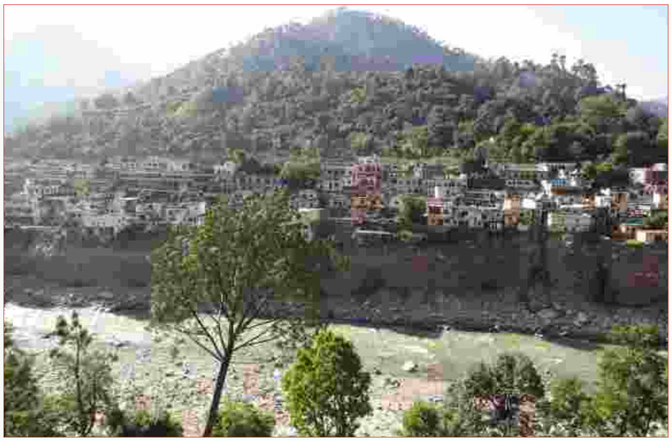


Fig. 64: View of damaged structures over eroded terrace at Sumari.

Fig. 65: Close view of damaged structures over eroded terrace.

Suggestive measures

The houses located on the lower terrace are in a highly vulnerable state and are already severely damaged. These should be demolished. Construction on this terrace should at the same time be banned.

Suitably designed retaining structures are required to be constructed along the free face below the settlement over the lower terrace so as to avoid further bank erosion by the river.

25. Tilaknagar

Tilaknagar is located on the right bank of Mandakini river. It is a distance of 1.5 kilometers from Sumari and can be approached by the Sumari - Chenagad motor road.

Geological set up of the area

The area is observed to be largely occupied by river borne material (RBM) that comprises of medium grained sandy matrix with rounded cobbles and boulders.

The affected area at Tilaknagar is observed to exhibit steep slope and quartzite, metabasics and phyllite are observed to constitute the bedrock. These rock types are also observed along the road section. Exposures of quartzite are observed on the right bank of Mandakini river as well as below the affected area. These rocks are traversed by numerous joints that comprise important structural discontinuities affecting the strength of the rock mass and stability of slopes. Phyllite exposed along the Sumari road section generally strike N - S and dip towards east at an angle of 60°. The joint sets are observed to dip towards NW (65º/ 310º).

Reconnaissance geological-geotechnical assessment

Slopes in this area have steep gradients whereas the overburden thickness, including weathered rock zone, is around 2.0 - 3.0 meters. The overburden material comprises of river borne materials consisting of sandy - silty, reddish brown soil with rounded boulders, cobbles and fragments of metabasics, quartzites and phyllites.

Below the affected site folded and heavily jointed quartzites, metabasics and phyllites are observed. The angle of failure slope is observed to be more than 45°. The direction of the slope is towards southeast. The vertical height and width of the failure slope is 100 meters and 50 meters respectively (Fig. 66). Due to landslide a number of school buildings have been damaged (Fig. 67)

The subsidence in the failure slope area at road level is observed to be of the order of 1.0 to 2.0 meters and N-S trending tension cracks are observed to be up to 0.5 meters wide and 1.0 - 2.0 meters deep. Around 50 meters long stretch of road is observed to be completely damaged.

Fig. 66: Slope failure around Government Inter Collage, Tilaknagar.

Fig. 67: Damaged school buildings due to slope failure.

Suggestive measures

It is advisable to prohibit construction in this zone and existing structures be demolished.

It is recommended to realign the affected stretch of road on hillside with appropriate design of retaining structures.

26. Tilwara

Tilwara is located on 09 km upstream of Rudraprayag on Kedarnath National Highway. It is situated on the left bank of Mandakini river.

Geological set up of the area

The area is observed to be largely occupied by overburden material. No rock outcrop is observed in the vicinity of the affected area. The exposures along the Tilwara market are however observed to be that of Lesser Himalayan phyllite and basics. General trend of the rocks is observed to be NE - SW with very steep dips towards southeast. The rocks in the area are traversed by numerous joints and important joint sets are observed to dip at moderate to steep angles towards SSW and NW (65º/ 200º and 70°/310°).

Reconnaissance geological-geotechnical assessment

The area to the downstream of Tilwara market is observed to have thick overburden material and the thickness of the same is as much as 20.0 meters. This material comprises of river borne material that consists of grey, medium grained sandy matrix with rounded cobbles and boulders. High discharge of Mandakini river during excessive rainfall events is deduced to have contributed to the instability of the slopes in this area. The river terrace is observed to be cut vertically by the river. An eroded terrace with vertical cut of around 15 meters is observed on the left bank of river along with a number of damaged structures (Figs. 68 and 69).

Fig. 68: Panoramic view of eroded terrace at Tilwara.

Fig. 69: Close view of damaged road and petrol pump.

Mitigation measures

Appropriately designed retaining structures of suitable height are required to be erected for preventing toe cutting / bank erosion by Mandakini river. This would help in protecting the affected site.

Chapter - 10

Damage to major infrastructure

Damage to hydroelectric projects

While undertaking fieldwork assessment of major losses inflicted to key infrastructure was also done. Besides road network the disaster has resulted in massive damage to Son, Phata - Byung, Singoli - Bhatwari and Kali Ganga Stage - I hydroelectric projects that are run of river schemes on Songanga, Mandakini and Kali Ganga rivers. Project wise details of damages areas given below.

Son hydroelectric project

Generation capacity of Son hydroelectric project of Uttarakhand Jal Vidyut Nigam Limited is 07 MW. The powerhouse of this project is constructed on the left bank of Songanga and about 200 meters upstream of the confluence Mandakini and Songanga. The powerhouse of this project has been severely damaged due to flood waters of Songanga (Fig. 70).

Fig. 70: View of ruined powerhouse of Son hydroelectric project at Sonprayag.

Phata - Byung hydroelectric project

The under construction Phata - Byung hydroelectric project with envisaged generation capacity of 76 MW is owned by LANCO Hydro Energy, Gurgaon (Haryana). Concrete gravity dam of this project is constructed on Mandakini river in close proximity of Sitapur town. The left abutment of this dam has been damaged due the flooding of Mandakini river.

Singoli - Bhatwari hydroelectric project

The under construction Singoli - Bhatwari Hydro Electric Project of envisaged generation capacity of 99 MW is owned by L and T Limited, Chennai. Flood waters of Mandakini river has inflicted severe damage at the barrage site at Kund Chatti, surface power house site at Ganganagar and inundated a number of components and machines of the project (Fig. 71). Located at Semi on right bank of Mandakini crasher plant of this project has also been heavily damaged (Fig. 72).

Fig. 71: View of severely damaged Barrage of Singroli - Bhatwari hydroelectric project at Kund.

Fig. 72: Photograph depicting damaged crasher plant at Semi.

Kali Ganga stage-I hydroelectric project

Kali Ganga stage-I hydroelectric project with envisaged generation capacity of 04 MW is owned by Uttarakhand Jal Vidyut Nigam Limited. High discharge in Kali Ganga is responsible for damage to the weir of this project at Jal Talla (Fig. 73). Diversion canal of this project has also been damaged due to mass movement as also toe cutting by Kali Ganga on its right bank (Fig. 74).

Fig. 73: Photograph of completely damaged Weir of Kali Ganga Stage - I hydroelectric project.

Fig. 74: View of damaged diversion canal of Kali Ganga Stage - I hydroelectric project.

Suggestive corrective measures

Powerhouse of Son hydroelectric project should be relocated and the damaged powerhouse needs to be demolished.

The management of Phata - Byung and Singoli - Bhatwari hydroelectric projects should consider revising the design of the damaged components taking into consideration the hydraulics and the sediments load expected at the dam sites. Powerhouse site of Singoli - Bhatwari hydroelectric project should be reinvestigated in the light of June, 2013 flooding of Mandakini river and appropriately designed flood protection structures should be provided for long term safety of the project.

In view of recurrence of sliding and flooding in Kali Ganga special care needs to be taken while reconstructing the damaged components of Kali Ganga Stage - I hydroelectric project.

Damage to bridges

Rudraprayag bypass bridge, Sonprayag girder bridge, Ganganagar (Phalai) girder bridge and Silli pedestal bridge have been completely washed off due to the flooding of Mandakini river. Anchoring of the abutments of the girder bridges at Kund and Ganganagar to the in situ rock is observed to be missing.

Suggestive measures

Construction of appropriately designed concrete cellular structures is recommended for fill sections between abutments and side rock areas while undertaking repair and reconstruction of Kund and Ganganagar bridges.

Damage to National and State Highways

Sonprayag - Gaurikund

This stretch of road is about 05 kilometers long and is aligned on the left bank of Songanga from its confluence with Mandakini to the UJVNL hydroelectric project after which it follows the right bank of Mandakini river.

Major landslide incidences are observed in this stretch near Munkatiya village. Most of this road stretch has been washed off together with the motor bridge over Songanga near Sonprayag.

Sonprayag - Trijuginarayan

This road stretch is of around 18 kilometers and is aligned on the right bank of Mandakini river. The main landslide incidences are observed in this road stretch above Kemana village.

Kund - Sonprayag

This road stretch is of 22 kilometers and is aligned on the right bank of Mandakini river. The main landslide incidences are observed in this road stretch at Sonprayag, Barasu, Phata, Khat, Semi and Kund Chatti.

Rudraprayag - Kund

This road stretch is about 23 kilometers long and is aligned on the left bank of Mandakini river. Main landslide incidences are observed in this road stretch at Nalupani, Silli, Vijarynagar, and just before Chandrapuri. The road alignment is hardly 5 - 6 meters above the river bed level at some locations that include Silli, Vijaynagar and Chandrapuri. Floods in Mandakini have eroded the river borne materials which resulted in the breach and collapse of the road bench.

Bhainsari - Kalimath

This road stretch is about 15 kilometers long. It is aligned on the right bank of Mandakini and Madhyamaheshwar rivers up to Vidhyapeeth after which it follows the left bank of Kali Ganga. The main landslide incidences are observed in this stretch at Kunjethi, Kalimath, Kobilta and Jal Talla villages.

Guptkashi - Vasukedar

This road stretch is about 35 kilometers long. The main landslide incidences are observed in this stretch in the vicinity of Lwani, Andrawani, Nagjagai, Taljaman, Khaduli and Bakola villages.

Kund - Okimath - Chaupta

This road stretch is about 33 kilometers long. The main landslide incidences are observed on this road section around Chunni, Karokhi, Dilmi, Mastura (below Sari) and Kathani villages.

Okhimath - Ransi

This road stretch is about 32 kilometers long. The main landslide incidences are observed in this stretch near Chajji and near the iron bridge at Paundar.

Jakholi - Vijaynagar

This road stretch is about 40 kilometers long. Major landslide incidences are observed in this stretch near Panjan, Talla, Mathgaon and Pathalidhar villages.

Mayali - Bangar

This road stretch is about 25 kilometers long. Landslides are observed in this stretch near Khaliyan village.

Mayali - Chirpatiya

This road stretch is about 35 kilometers long. Landslides are observed in this stretch near Bajira village.

Kandara - Mohankhal

This road stretch is about 30 kilometers long. The main landslide incidences are observed in this stretch near Banswara, Akhori and near Dungri villages.

Mohankhal - Koteshwar (Rudraprayag)

This road stretch is about 45 kilometers long. Landslide incidences are observed in this stretch near Kharpatiya and Jawaharnagar villages.

Koteshwar - Kande

This road stretch is about 28 kilometers long. Landslides are observed in this stretch near Banthapla village.

Nagrasu - Kaliyasaur (NH 58)

This road stretch is about 45 kilometers long. The main landslide incidences are observed in this stretch near Gholtir, Gulabrai and Kaliyasaur.

Suggestive measures

It is recommended that some stretches of the National Highways (NH 109) as also State Highways be realigned; particularly in the stretches where the road is close to the level of the stream / river bed. These stretches should be realigned towards uphill side, appreciably above the stream / river bed level.

Hill slopes should only be excavated for reconstruction of the damaged roads after construction of suitably designed retaining structures along the level of the road.

Suitably designed flood protection walls are required to be constructed towards valley side of the road to avoid further bank erosion by stream / river.

Chapter - 11

Discussion and conclusion

Rocks of Garhwal Group representing Lesser Himalaya and that of Central Crystallines representing Higher Himalaya are observed to be exposed in the area. The area is observed to be highly tectonised and the same has rendered the rocks of the area highly sheared, fractured and jointed. As many as three sets of joints are observed at most places. Banswara Thrust, Main Central Thrust (MCT) and Vaikrita Thrust are observed to traverse through the district, apart from other local tectonic contacts.

Relative relief of the area is observed to be high. The region at the same time receives appreciably high rainfall, particularly during the monsoon period when spells of heavy localized rains are common. Highly tectonised terrain, high relative relief and rainfall; together these provide favourable conditions for mass wastage.

Heavy rains often result in flash floods and sediment laden high velocity discharge causes bank erosion together with collapse of the banks and ensuing loss of infrastructure, property and human lives. A number of landslide, cloudburst and flash flood events are recorded during the field work.

The area also falls in Zone V of Seismic Zoning Map of India and has been devastated by 1999 Chamoli Earthquake. Besides causing widespread loss of human lives, infrastructure and property seismic shaking has the potential of triggering landslides along vulnerable slopes, thereby complicating the situation.

Unplanned infrastructure development and disregard of traditional disaster mitigation measures are deduced to have aggravated the devastation in the area. Various related issues are being discussed separately in the sections below.

Slope instability

Slope instability is a major cause of concern for Rudraprayag district and fieldwork carried out in the area suggests that landslides have been largely (in 76 percent cases) caused either by slope modification for infrastructure development or by toe erosion by streams and rivers, mostly during spells of high discharge. Besides zones of old landslide material, colluvium and alluvium deposits are identified as being most vulnerable to slope failure. Together with these the slopes occupied by unconsolidated material, loose soil and highly weathered, fractured and jointed rocks are also observed to be vulnerable. Structural disposition of rocks is also observed to facilitate mass movement.

Whatever the causative factors be most slides (about 90 percent) are triggered during monsoon season while the rest take place during winter rains (Thakur, 1996, Asthana and Sah, 2007). Avalanche, snow melt, cloudburst and high discharge are observed to trigger extensive slope failure and erosion. In June, 2013 precipitation in the area was significantly higher than average and large number of landslides are observed to have been triggered at various places; mostly along both the banks of Mandakini river.

Translational and circular failures are commonly observed in the area. Incidences of rockfall are however observed in the higher reaches. This is attributed to high rates of mechanical weathering by frost action.

Landslides together with bank erosion have caused severe damage to transport infrastructure in the area and the same severely hampered resue and relief on the aftermath of June 2013 disaster. Many habitations including Agastmuni, Barasu, Bhainsari, Chandrapuri, Gaurikund, Jaggi, Jal Talla, Kalimath, Khat, Kot Khal, Kunjethi, Lunyapani, Nagjagai, Pathalidhar, Rambara, Saurgarh, Sauri, Semi, Silli (Chaka), Sumari, Taljaman, Tilaknagar, Tilwara, Usara and Vijaynagar are observed to be damaged by slope instability.

Rambara no longer exists and the pedestrian route having been relocated on the left bank of Mandakini this slope is not cause of immediate concern and would ultimately be stabilised by nature in course of time. Semi village is however facing a major threat and is required to be rehabilitated as treating this slope would not be economically viable. Avoiding anthropogenic intervention in this slope and providing toe support at the river bed level are recommended. Some portions of Sumari, Agastmuni, Vijaynagar, Jawaharnagar, Ganganagar, Chandrapuri and Taljaman are also required to be relocated.

All damaged structures in the areas affected by slope instability must be demolished and construction in these areas should be banned. Happy blend of various structural and non structural restoration measures is required to be designed and implemented after detailed geo technical investigation of individual landslide zones.

Slides around Jal Talla, Khat, Kunjethi and Tilaknagar have developed tension cracks in crown and middle portions. Suitably designed concrete breast walls and wire mesh gabion structures are recommended for these slides together with planting of suitable species with high root - shoot ratio. The vegetative cover is known to reduce the action of various climatic agents on the slope mass, thereby favouring slope stabilisation. Vegetal cover also decreases erosion by shielding the surface from the action of rainwater, wind and thermal radiation.

Slides around Gaurikund, Jaggi, Jal Talla, Kunjethi and Nagjagai are observed to have potential of blocking the river course and thereby threatening safety of human habitations and infrastructure in downstream areas. Special attention is therefore required to be paid for monitoring these and other major slide zones along the river banks. Geological and geotechnical investigation of such zones should be carried out on a scale of 1:5,000 / 2,000.

The perceived threat should at the same time be communicated to the villagers in the vicinity of these slides who would communicate information regarding lake formation to the local administration.

Slope stabilisation measures

The problem of mass wastage or slope instability is often accorded importance only when it starts to affect structures and other human interests. It is a must to understand that treating the problem of slope instability may call in both engineering and non - engineering solutions but it is essentially a geological problem. Unless the problem and its causes are not analysed in detail and well understood, any solution; engineering or non - engineering, is not going to work. It is therefore a must to involve geologists and geotechnical engineers in all landslide mitigation works, right from the planning stage.

The strategy observed in the field for the treating or stabilising landslides suggests that a standardized tailor made solution is being perceived to be the solution of all landslides. It needs to be understood that every single landslide initiates under a combination of unique conditions and has a distinct character of its own. General solutions are therefore not going to work for the treatment of slides. Every landslide should therefore to be studied individually and separate strategy should to be worked out for its treatment.

It is therefore very strongly recommended that detailed geological / geotechnical investigations must be carried out soon after every slope instability incidence and all restoration works should be based upon the outcome of these. Geological / geotechnical investigations should at the same time be made mandatory for all slope modification works.

Debris disposal policy

In the hills almost all infrastructure development initiatives result in excavated rock and muck. In the absence of clear guidelines to the contrary, the excavated material is routinely disposed off along the hill slopes. Sliding down along the slope this material often overruns agricultural fields and water sources besides causing significant loss of vegetation cover on vulnerable hill slopes. This at the same time initiates new landslides.

The rolling down debris ultimately reaches the river bed and reservoirs causing problem of aggredation and reduced reservoir capacity. As is observed during the floods of June, 2013 intermingling of the excavated material with the stream water enhances its erosional potential by manifold and thus resulted in heavy devastation.

It is therefore a must to formulate a sound, effective and implementable debris disposal policy that ensures that all excavated material of all kind is mandatorily disposed off at the sites earmarked for the same. At the same time provision for covering the cost of debris disposal has to be incorporated in the budget of all infrastructure development initiatives. It is a must to understand that this is an investment that would reduce major recurring expenses and at the same time provide immense indirect benefits.

River side constructions and aggradation

At the outset it needs to be remembered that the river is sure to reclaim its channel and both aggaradation and degradation are processes that operate in all fluvial systems and therefore any fluvial channel is sure to hit back for encroachment in its regime.

At a number of places in the area constructions are observed on the river borne material in close proximity of the river and even at levels nearing river bed level. It is this kind of constructions that have sustained most damage during the floods of June, 2013. It is therefore not unjust to deduce that the losses would have been significantly less if the constructions in the proximity of streams and rivers were regulated.

Construction of any kind should therefore necessarily be banned in the proximity of the rivers and streams and in fact infrastructure development over colluvium and alluvium terraces, overburden material and old slides should be restricted if not totally banned. Provisions of the Uttarakhand Flood Plain Zoning Act, 2012 should be invoked for doing so, in addition to those provided in Disaster Management Act, 2005. Where necessary adequate legislative measures can be resorted to.

Hazard zonation exercise followed by mass awareness for risk communication drive has to be resorted to for ensuring voluntary compliance of these measures. Appropriately designed awareness drive is highly recommended for persuading people to maintain a respectable distance from streams and rivers when deciding to settle down. As a rule of thumb, message has to be sent across that the structures should be sited at lest 50 meters from river bank in case rock exposures are available at the chosen site. Otherwise minimal safe distance of 100 - 200 meters should be maintained. Besides this the structures should be sited at lest 15- 20 meters above the level of the stream. These however depend on the specific site conditions.

The course of Mandakini river is observed to have shifted towards the left bank by approximately 10 to 15 meters due to erosion of the river borne materials around Banswara, Chandrapuri and Vijaynagar. It is recommended that the river banks, especially in the proximity of areas where the river course has shifted and the banks have collapsed or have been eroded, be provided with suitable bank stabilization and strengthening measures. Rather than going for structural measures alone, the option of applying vegetative measures should be kept open while planning to do so.

Flash floods and ensuing debris laden high density high velocity discharge has resulted in massive erosion in the catchment and the transported debris has been deposited in the downstream areas. This has resulted in abnormal rise of the river bed. The river bed level is observed to have raised by around 5 meters at Sonprayag, 3 to 4 meters at Sitapur, 3 to 4 meters at Gaundar, 5 to 6 meters near Paundar, 3 to 4 meters at Chandrapuri and 4 to 5 meters at Vijayanagar. This rise of the river bed has made many hitherto safe areas vulnerable to floods.

There is thus a pressing need to remove the transported debris and channelize the water. This is however a challenging task and should only be undertaken after detailed study of the river hydraulics.

Restoration of Kedarnath

The disaster of June, 2013 has induced major geomorphic changes in the proximity of Kedarnath. The palaeochannel of Saraswati to the east of the temple has been rejuvinated and Chorabari Tal to the north of the temple has ceased to exist. Already unconsolidated thick pile of glacial outwash deposit around the temple has been disturbed and thick mass of glacial debris and boulders has been heaped over it. Forces of nature have thus carved out new geomorphic setup in the area and these would take some years to stabilise the geomorphology of the area.

It is not easy to accept changes and thus attempts to regress towards the previous stage are not uncommon. Inability to do so is often, wrongly so, potrayed as being human failure. Therefore natural human urge is to restore pre - disaster geomorphic conditions in Kedarnath. It however needs to be understood that disturbing the freshly deposited unconsolidated deposits at Kedarnath would only add to instability. This however does not rule out possibility of structural works of any sort in the area but these should be undertaken with caution ensuring minimal ground disturbance. Various issues around Kedarnath are being dealt with separately in the sections below.

The temple: Kedarnath temple is the most important structure in the area and safety of the same is of prime concern. To the north of the temple nature has already provided maze of huge boulders that continue for an appreciable distance (Fig. 75). There is thus little possibility of water and rolling down boulders and debris hitting the temple directly.

Moreover breach of Chorabari Tal has already removed a major hazard to the north of the temple. Rejuvenation of this lake is not likely in near future, as accumulation of clay and silt at the bottom of any depression is a precondition for water retention over highly porous glacial deposits and the same is a slow and long drawn process.

Fig. 75: View of large boulders stacked haphazardly to the north of the temple.

Placement of structural barrier to the north of the temple is a logical solution for further ruling out any possibility of water, debris and boulders hitting the temple. It however needs to be kept in mind that any such barrier would be placed over heap of loose material as it is not practically possible to reach the valley floor. In such a condition howsoever strong the barrier be, it would move with the glacial debris and boulders when forces of nature decide to make them move. The structural barrier to the north of the temple should therefore be appropriately designed.

But for minor damages the superstucture of Kedarnath temple has survived the impact of water and rolling down debris and boulders. Possibility of the temple foundation being disturbed and damaged cannot however be ruled out. The temple platform is now covered with debris and the same adds to the stability of the superstucture. No attempt should be made to expose the temple platform.

To the extent possible the restoration works in the area around the temple should be done manually. If mechanical excavation becomes a compulsion, it should be ensured that there are no major ground vibrations as the same might have adverse impact on the stability of temple superstructure.

Stream diversion: The disaster of June 2013 has resulted in the rejuvenation of Saraswati to the east of the temple. This is suggestive of the simple fact that the changes in the geomorphology of Kedarnath area have resulted in a new geomorphic low through which most water is presently getting discharged.

Attempts to divert water from this geomorphic low towards the old course of Mandakini by creating structural barriers is sure to initiate subsurface flow of water towards this geomorhic low (Fig. 76). This envisaged east - southeastward subsurface flow of water from Mandakini to Saraswati, in that situation, would result in piping action due to washing away of fines from the matrix of the glacial outwash deposits on which is located Kedarnath temple. It is to be kept in mind that removal of fines is likely to induce ground subsidence in the glacial outwash deposits and the same may jeopardise the safety of structures built over it, including the temple.

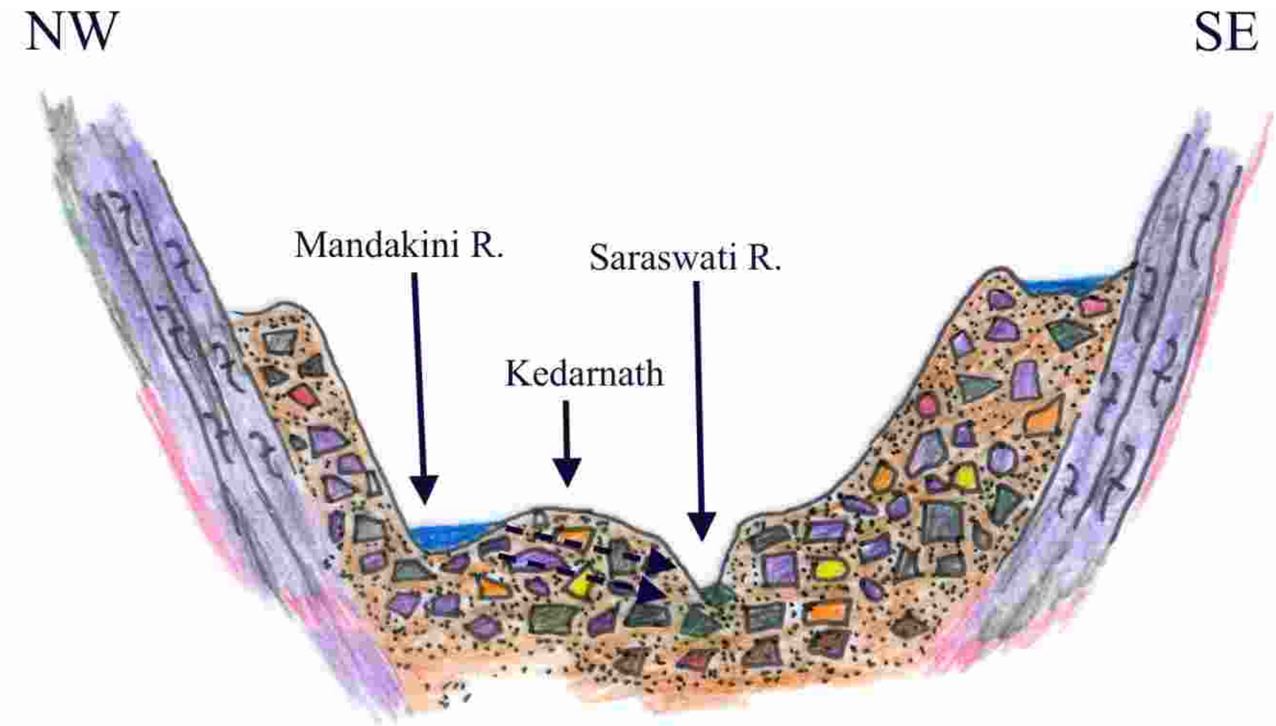


Fig. 76: Schemetic diagram depicting subsurface flow of water towards the geomorphic low.

Similar piping action was responsible for severe ground subsidence in Chain village in Chamoli district where subsurface flow of water from Dharmangar nala towards Rauldhar nala resulted in major ground subsidence in 2007 (Nawani et al., 2007).

Logical solution of this problem, if in case it is decided to divert the water towards the old course of Mandakini, is to excavate and create a new geomorphic low along that course. This is however not an easy task and would result in extensive ground disturbance and safe disposal of vast volume of excavated debris and boulders would pose a major challenge. This option is thus ruled out.

Forced diversion of water of Saraswati towards Mandakini is identified as a risk prone venture and not advised. Before undertaking any such action detailed investigations should be carried out and this issue should be deliberated, discussed and debated in the presence of experts.

Bank stabilisation and demolition of structures: In order to rule out any possibility of bank erosion, appropriately designed bank stabilisation measures should be put in place along the right bank of Saraswati and left bank of Mandakini. Stabilisation measures should also be taken at places where the opposite banks are getting eroded.

Large number of structures at Kedarnath have either been damaged or filled with debris. Besides posing threat to passers by, these are not aesthetically pleasing. These should therefore be demolished and no fresh construction should be allowed in this area. Appropriate provisions of Disaster Management Act, 2005 can be invoked for doing this.

To the extent possible, debris of the demolished structures should be utilised for bank protection works and the rest should be appropriately disposed off.

Helipad and GMVN site: On the left bank of Mandakini, little downstream of the temple, steep morainic ridge is observed to run north south. On the glacial terrace at the base of this ridge is located Kedarnath helipad. After the disaster the pilgrim traffic passes through this terrace and Garhwal Mandal Vikas Nigam (GMVN) has pitched tents and erected pre - fabricated huts over this terrace for providing various services to the pilgrims.

It needs to be noted that there exists a major elongated north south running depression between the morainic ridge and valley wall (Fig. 77). This depression is just to the east northeast of the helipad and GMVN facilities and there is usually significant impoundment of water in this depression, particularly during the monsoon period. Water from this depression is observed to flow down from as many as three places along the morainic ridge (Fig. 78).

Fig. 77: Depression between the left lateral morainic ridge and the valley wall to the east of the helipad at Kedarnath.

Fig. 78: Water flowing down the left lateral morainic ridge on the left bank of Mandakini to the east of the helipad at Kedarnath.

Breach of this depression is likely to destabilise the morainic ridge and bring down huge volume of debris and boulders. This site is therefore deduced to be not that safe and therefore no permanent structures should be erected at this site. This site should also not be used for overnight stay of pilgrims and others.

Boulders should at the same time not be collected from this ridge for foundation works of the temporary structures being constructed around the helipad. This is likely to induce instability in the moraines that might have disastrous consequences.

Water level in the depression, which is technically a moraine dammed lake like Chorabari Tal, should be continuously monitored and self draining pumps should be installed for keeping the water level within threshold limits.

Landscaping and river training: No major landscaping and river training works are suggested in the area around Kedarnath as these would further disturb the unconsolidated material. Moreover safe disposal of the excavated material is going to be a major challenge and if excavated material is not disposed off properly it might induce new problems that might be hard to manage.

Garurchatti: Rock exposures are observed in the area around Garurchatti that has been spared by the disaster of June, 2013. That area on the right bank of Mandakini prima facie looks safe. Possibilities of developing this location for establishing permanent structures should be explored.

Transport network

It is a must to create sound and reliable transport infrastructure in the area. Besides effective delivery of services and goods this would ensure prompt and effective response on the aftermath of any disaster. It however needs to be remembered that the construction of roads, particularly in the hills changes the angle of repose of the slope and in case well designed lateral support and provision of draining out rainwater are not provided slope modification for road construction is sure to initiate mass wastage. Slope protection and drainage works should therefore necessarily accompany road construction. Provision of same has to be therefore provided in the budget approved for road construction.

Roads in the area are observed to be aligned in close proximity of the river; either over the river borne material terrace or over an excavated bench. In case the banks are not adequately protected there exists high probability of such roads being disrupted during high floods. It is therefore recommended that the roads be realigned at places these traverse chronic slip zones or zones of subsidence. The new alignment should maintain respectable distance from the streams. Where alignment in the proximity of the streams becomes a compulsion adequately designed bank protection works should necessarily be provided.

In the field abutments of the bridges are observed to be placed over both active river bed and unconsolidated material. High flood levels should necessarily be considered while designing any bridge and the abutments should always be placed over in situ rocks.

Congestion in the proximity of road side is a common observation in the area. Illusion of better economic opportunity in the proximity of roads together with ease of access seem to induce people to settle down by the road side. At many places encroachments are observed on the road itself and very often major portion of the road is used for parking purposes. Besides hindering drainage this is observed to disrupt free and smooth passage of traffic. Traffic jams and delays due to this could prove to be crucial during emergencies. It is therefore recommended that the provisions of Roadside Land Control Act, 1945 be promulgated to ensure that there are no encroachments on the road. At the same time parking spaces should be developed near habitations and parking of vehicles on the roads should not be allowed.

The constructions close to the road at the same time obstruct valley ward view thereby reducing aesthetic value of travel in the hills. Appropriate legislative measures should be taken to ensure that constructions hindering valley ward view are not permitted. Similar measures were taken during the British rule to ban construction by the lake side in Nainital.

Warning generation and dissemination

Abnormally high rainfall, fast thawing of glacial ice and snow and breach of Chorabari lake resulted in the devastation of June, 2013. As a precautionary measure inventory of glacial lakes should be prepared and efforts should be made for their regular monitoring. Collaboration to this regard with some scientific organization can help the State Government in achieving this end.

In view of the devastation of June, 2013 detailed flood and landslide hazard mapping of the area should be undertaken. For this high resolution topographic mapping of the area should be prepared using state of art technology. The population living in areas likely to be affected by floods should thereafter be informed of the likely risk and advised to shift to alternate safer locations. Special incentives can be planned for those opting to do so voluntarily.

Generation of timely warning, its timely dissemination in the area likely to be affected and prompt and effective response hold the key to saving lives and the same has been demonstrated during Phalin Cyclone of September, 2013. Meteorological observation network in the area however needs to be strengthened for the generation of site specific warnings.

Landslide and flood / flash flood are both induced by atmospheric precipitation and can well be predicted in case real time data on rainfall is available and thresholds are worked out for different catchments based upon slope, geology, distribution of Quarternary deposits, catchment area and land use.

Catchment wise rainfall thresholds for triggering landslides and flood / flash flood can be worked out based upon past records as also the analysis and integration of data collected routinely. Establishing a network of automatic weather stations (AWS) and river discharge gauges (RDG) capable of transmitting real time data to State Emergency Operations Centre (SEOC) is however a major precondition for this. A module capable of indicating differential probability of landslides and flood / flash flood in based upon rainfall and river discharge inputs has then to be developed. This module has to have capability of generating hydrographs and flood scenarios with the passage of warning lead time.

It is to be noted that majority of the new landslides in the area are observed in the Quarternary deposits. There can thus be a major breakthrough in landslide prediction in case the distribution of Quarternary deposits is mapped.

At the same time warning dissemination capabilities of SEOC have to be strengthened. Apart from other measures collaboration with various mobile service providers can be sought for this. The warning related information can also be displayed through a network of centrally controlled electronic display boards.

Managing Yatra

Despite disasters people would be travelling in large numbers to various holy shrines located in remote areas of the state. A system has therefore to be put in place for regulating and managing the pilgrim traffic.

The people travelling to remote areas should be made aware of the likely hazards and should be persuaded to carry essential clothing, foot ware, raincoat, umbrella, medicines and the like. Health check up and registration should at the same time be made mandatory for both pilgrims and tourists.

Earthquake safety

The area falls in Zone V of Seismic Zoning Map of India and is highly vulnerable to earthquakes. Besides initiating mass movement major earthquake can cause large scale devastation in the area.

Despite government orders restricting building height to 12 meters in the hilly parts of the state, a number of six to seven storeyed buildings are observed in the area. Defiance of earthquake safe construction norms is also observed to be rampant. It is therefore highly recommended that special care be taken for ensuring safety of the built environment and defiance of norms should not be allowed.

Disaster of June 2013 and relevance of traditional practices

Close scrutiny of the losses incurred by June 2013 floods brings forth the dilemma of development being faced currently by the region. It needs to be remembered that what happened in 2013 is no new phenomenon for this region and the inhabitants of this region have been traditionally taking recourse to measures that have ensured minimal losses from such incidences. Besides framing rules for ensuring disaster safety they traditionally ensured compliance of the same by intelligently integrating these with the precepts of little tradition, culture and religion.

What happened in Uttarakhand in 2010, 2012 and then in 2013 is thus attributed to continous neglect, ignorance and even defiance of traditional practices. It therefore becomes pertinent and worthwhile to review various disaster mitigation practices of the region and assess their relevance in present times.

Landslides and floods: The people residing in the hills clearly understood the correlation between excessive rains, saturation of soil mass and occurrence of landslides. So, in order to restrict the build up of pore water pressure, particularly in the vulnerable locations they resorted to disposal of rainwater into drainage channels located in close proximity through a network of jungle guls (canals) constructed and maintained for this very purposes in the upper reaches of these identified vulnerable locations. Remnants of the jungle guls can be seen around Ransi and other places in Madhyamaheshwar and Kali Ganga valleys.

Though done primarily for augmenting agriculture area and perhaps with scant regard to landslide mitigation, terracing of hill slopes has improved the stability of the hill slopes.

The people traditionally left the far flung agricultural terraces, that are hard to manage during monsoons, without bunds. This is part of the planned strategy of the people of this region to rule out possibility of stagnation of water in these and thus to avoid chances of landslides.

Despite the economy of the region being traditionally dependent upon pastoralism and agriculture that are mainly practiced in upper and lower valley slopes, people traditionally never settled down in the proximity of streams and rivers. They always settled down over firm ground in the upper and middle slopes even though both the source of water and agricultural lands were located on middle and lower slopes of the valley. The people thus intentionally preferred to settle down at higher locations that were safe from both landslides and flash floods and at the same time provided strategic advantage. This clearly reflects their preference for safety over comfort and convenience.

Seismicity: The decision to settle down over stable and firm ground at the same time minimized losses during an earthquake. Together with this the people based upon their accumulated knowledge, experience and experimentation devised a set of rules for site selection and construction of structures so as to ensure safety of these during an earthquake event. Without this construction of multi storeyed houses that are quite common in Uttarakhand, which is testified by the existence of four separate words for four storeys of the house in both the local dialects of the region (Kumauni and Garhwali), would not have been possible.

The inhabitants of this region had developed the art of assessing suitability of the site selected for construction by physical examination of the soil of the proposed site of construction. This is akin to adjudging bearing capacity of the soil and is in practice even today.

Rules were also put in place for the foundation of the structures. The foundation was dug until firm in situ rock was reached and the same was left exposed for some rainy seasons. This ensured ground settlement and kept the structures free of settlement cracks.

Layout of the structure, that is an important consideration for earthquake safety, was kept simple rectangular or square and the size of the openings was kept small and their number was limited. Besides earthquake safety this ensured energy conservation.

For ensuring safe transfer of earthquake forces to the ground and to ensure ductility in the structures provision of wooden beams was provided in the structures.

Drought: Besides earthquake, flash flood and landslide the region is vulnerable to droughts as agriculture in the region is dependent upon atmospheric precipitation. Traditional distributed landholding pattern of the region ensured that the household have minimal returns in case of crop failure in a particular area.

Moreover the people developed crop varieties that could sustain prolonged spells of water deficit. The people at the same time developed animal breeds that could sustain the rigors of nature and survive sustainably on bare minimal input.

Present scenario: The inhabitants of this region thus set ground rules for disaster mitigation that ensured flourishing of human settlements in this region despite adversities put forth by nature. We were in fact fortunate to have inherited this accumulated knowledge of generations. Overview of the disasters that have become frequent in this region shows that the traditional rules are being flouted.

In the previous some decades we have forgotten these rules or, may be, burgeoning economic compulsions have forced us to forego these. With clear disregard to the threat of floods and landslides we have consciously chosen to initiate developmental initiatives over river terraces and low lying areas that were hitherto reserved only for cultivation. This decision judiciously saved the cost of site development and material transportation but then it was a major compromise on safety.

In case sustainable management of disasters in the region is intended one has to take detailed stock of the traditional practices of the region and amalgamate it with modern knowledge so as to put forth locally relevant practical solutions. Appeal to little tradition of the people can help in popularization of these measures.

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ANNEXURE

Inventory of landslides in Rudraprayag district

Sl. No.	**Location / Coordinate**	**Materials** Rock type/ Overburden type/ slide type	**Rock weathering** Low Moderate High Very High	**Details of discontinuities** Foliation (F) Bedding (Bd) Joint (Jt)	**Slope type** Anaclinal Cataclinal Orthoclinal Orthoanaclinal Orthocataclinal	**Slope dip (0-15, 16-25, 26-35, 36- 45 >45) (N, NE, NW, S, SE, SW, E, W) Slope Morphology** Straight, Convex, Concave	**Vertical height (H) Width (W) of slide (Approx)**	**Geomorphology** Low dissection Moderate diss. High diss. **Landuse** Habitated area Forested area Barren land Cultivated land	**Landslide Status** Old, Old reactive, Active **Landslide potential** High Medium Low	**Remarks** (Destablising factors, instability indicators, causes of landslide, etc)	**Damaged infrastructures** (Helipad Footpath Road House Building, etc.)
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11)**
1.	L/B of Mandakini river, downstream to Kedarnath temple area 30° 43' 51.539" N 79° 4' 21.284" E	Gneiss Debris (Glacial sediments)	-	-	-	35°, S80°W, straight	H- 10 W- 20	Low diss., Barren land	Active	Washout shallow soil cover due to rain	Helipad
2.	R/B of Mandakini river, downstream to Dudh Ganga 30° 43' 42.075" N 79° 4' 6.643" E	Gneiss Debris (Glacial sediments)	-	-	-	>45°, N 70°E, straight	H-40 W- 100	High diss., Barren land	Active	Heavy rainfall, flooding	Footpath
3.	L/B of Mandakini river, 150m downstream to Dudh Ganga 30° 43' 27.901" N 79° 4' 12.342" E	Gneiss Debris (Glacial sediments)	-	-	-	>45°, S20°E, Straight	H- 30 W- 50	Moderate diss., Barren land	Active	Heavy rainfall, flooding	Nil
4.	L/B of Mandakini river, end of medial moraine 30° 43' 12.250" N 79° 4' 16.135" E	Gneiss Debris (Glacial sediments)	-	-	-	>45°, S60°W, straight	H- 35 W- 50	Moderate diss., Barren land	Active	Heavy rainfall, flooding	Nil
5.	R/B of Ma ndakini river, opposite side to perennial stream 30° 42' 55.641" N 79° 4' 15.434" E	Gneiss Debris (Glacial sediments)	-	-	-	>45°, S60°E, straight	H- 40 W- 70	Moderate diss., Barren land	Active	Heavy rainfall, flooding	Nil
6.	L/B of Mandakini river, Just upstream to slide No.6 30° 42' 32.705" N 79° 3' 55.893" E	Gneiss Debris (Glacial sediments)	Moderate	F- 25/N35°E Jt- 65/N70°W Jt- 65/S30°W	Orthclinal	45°, N80°W, straight	H- 20 W- 35	Moderate diss. Barren land	Active	Heavy rainfall, flooding	Nil

7.	R/B of Mandakini river, near Ghindurpani 30° 42' 16.222" N 79° 3' 42.188" E	Gneiss Debris (Glacial sediments)	-	-	-	>45°, S60°E, straight	H -20 W - 250	Moderate diss. Barren land	Active	Heavy rainfall, flooding	Footpath
8.	L/B of Mandakini river, 30° 42' 2.324" N 79° 3' 40.514" E	Gneiss Debris (Glacial sediments)	Moderate	F- 45/N50°E Jt- 60/W Jt- 80/S70°E	Orthoclinal	45°, N70°W, straight	H-30 W- 50	Moderate diss. Barren land	Active	Heavy rainfall, flooding	Nil
9.	R/B of Mandakini river, 30° 41' 47.351" N 79° 3' 22.594" E	Gneiss Debris (Glacial sediments)	Moderate	55/N60°E	Orthocataclinal	>45°, S80°E, straight	H-35 W- 45	High diss., Barren land	Active	Heavy rainfall, flooding	Footpath
10.	L/B of Mandakini river, 30° 41' 44.545" N 79° 3' 28.120" E	Gneiss Debris	Moderate	55/N60°E	Orthocataclinal	>45°, N10°E, concave	H-15 W- 20	High diss., Forested area	Active	Heavy rainfall, flooding	Footpath
11.	L/B of Mandakini river, along seasonal water course, at Rambara 30° 41' 43.604" N 79° 3' 23.505" E	Gneiss Debris	High	F- 15/N30°E	Orthoclinal	>45°, N50°W, straight	H- 45 W-45	Low diss., Barren land	Active	Heavy rainfall, flooding	Nil
12.	R/B of Mandakini river, near Rambara 30° 41' 38.952" N 79° 3' 10.796" E	Gneiss Rock slide	Moderate	F- 35/N30°E Jt- 30/S40°E Jt- 45/S 40°W Jt- 65/N20°W	Orthoclinal	>45°, S50°E, straight	H- 20 W-100	Low diss., Forested area	Active	Poor rock strength and slope forming material	Footpath
13.	R/B of Mandakini river, 30° 41' 13.319" N 79° 2' 48.945" E	Gneiss Debris cum rock	Moderate	F- 45/N30°W Jt- 60/N55°E Jt- 40/S15°E	Orthoanaclinal	45°, S80°E, straight	H- 10 W-15	Low dissection, Forested area	Active	Washout shallow soil cover due to rain and poor rock strength	Footpath
14.	L/B of Mandakini river, opposite side to water fall, at Bhimbali 30° 41' 3.512" N 79° 2' 57.939" E	Gneiss Debris	-	Not visible	-	>45°, N40°W, straight	H- 50 W- 35	Moderate diss., Forested area	Active	Heavy rainfall, flooding	Nil
15.	R/B of Mandakini river, R/B of nala, at Jangalchatti 30° 40' 32.689" N 79° 2' 25.114" E	Gneiss Debris	Moderate	F- 25/N10°E Jt- 70/S35°E Jt- 65/N10°W Jt- 80/S60°W	Orthoclinal	45°, N80°E, straight	H- 85 W- 20	Moderate diss., Forested area	Low	Poor rock strength and slope forming material	Nil

16.	R/B of Mandakini river, just downstream to Jangalchatti 30° 40' 29.843" N 79° 2' 30.295" E	Gneiss Debris	Moderate	F- 25/N10°E Jt- 70/S35°E Jt- 65/N10°W Jt- 80/S60°W	Cataclinal	45°, N40°E, straight	H -15 W- 25	Moderate diss. Forested area	Active	Low shear strength of slope forming material and road cut	Footpath
17.	R/B of Mandakini river, about 2.0 km upstream to Gaurikund 30° 39' 50.363" N 79° 2' 8.837" E	Gneiss Rock fall	Moderate	F- 35/N10°E Jt- 65/S60°E Jt- 35/N80°E	Orthocataclinal	>45°, N70°E, straight	H- 15 W- 20	Low diss., Forested area	Low	Poor rock strength and jointed rock.	Footpath
18.	L/B of Mandakini river 30° 39' 46.000" N 79° 2' 14.173" E	Gneiss Debris cum rock	-	Not visible	-	50°, N70°W, straight	H- 50 W- 40	High diss., Forested area	Active	Heavy rainfall, flooding	Nil
19.	R/B of Mandakini river, about 1.5 km upstream to Gaurikund 30° 39' 35.845" N 79° 1' 57.778" E	Gneiss Debris cum rock	Moderate	F- 35/N50°E Jt- 70/S60°W Jt- 55/S15°E	Orthocataclinal	>45°, S80°E, straight	H- 40 W- 100	Moderate diss., Forested area	Active	Heavy rainfall, flooding	Footpath
20.	R/B of Mandakini river, just upstream to Gaurikund 30° 39' 20.602" N 79° 1' 41.701" E	Gneiss Rock slide	Moderate	F- 45/N10°W Jt- 70/S70°E Jt- 65/S30°W	Orthoclinal	45°, N65°E, straight	H- 30 W-30	Moderate diss., Barren land	Active	Low shear strength of rock and jointed rock	Footpath
21.	L/B of Mandakini river, just opposite side to GMVN at Gaurikund 30° 39' 10.797" N 79° 1' 42.328" E	Gneiss Debris	-	Not visible	-	35°, N40°E, straight	H- 45 W-75	High diss., Agriculture & forest lands	Active	Low shear strength of slope forming material in soil	Nil
22.	R/B of Mandakini river about 250 m downstream to Gaurikund 30° 38' 56.540" N 79° 1' 24.198" E	Gneiss Debris	High	F- 40/N70°E Jt- 75/S30°W Jt- 80/N30°W	Cataclinal	45°, S80°E, straight	H- 45 W-25	Moderate diss., Forested area	Active	Low shear strength of slope forming material in soil	Footpath
23.	L/B of Mandakini river 30° 38' 44.930" N 79° 1' 21.757" E	Gneiss Debris cum rock	-	Not visible	-	45°, N15°W, straight	H- 45 W-35	Medium diss., Forested area	High	Heavy rainfall, flooding	Nil

24.	R/B of Mandakini river 30° 38' 44.432" N 79° 1' 7.311" E	Gneiss Debris	High	F- 35/N20°E Jt- 65/S60°E Jt- 75/S20°W	Orthoanaclinal	45°, S10°E, straight	H- 20 W-25	Medium diss., Forested area	Active	Low shear strength of slope forming material in soil	Footpath
25.	L/B of Mandakini river 30° 38' 30.492" N 79° 1' 3.954" E	Gneiss Debris cum rock	-	Not visible	-	45°, N60°W, straight	H-35 W-45	Moderate diss., Forested area	Active	Mass wastage due to heavy rainfall and flooding	Nil
26.	L/B of Mandakini river 30° 38' 16.918" N 79° 0' 48.170" E	Gneiss Debris cum rock	-	Not visible	-	45°, N60°W, straight	H- 25 W-20	Moderate diss., Forested area	Active	Loose material over rock.	Nil
27.	L/B of Mandakini river, opposite side to Munkatiya village 30° 38' 7.802" N 79° 0' 27.263" E	Gneiss Debris	-	Not visible	-	45°, N05°W, straight	H- 100 W-80	High diss., Forested area	Active	Mass wastage due to heavy rainfall and flooding	Nil
28.	R/B of Mandakini river, 50 m upstream to Munkatiya village 30° 38' 18.902" N 79° 0' 32.603" E	Gneiss Debris	-	F- 35/N30°E Jt- 80/S Jt- 80/W	Orthoclinal	45°, W, straight	H- 20 W-10	Medium diss., Forested area	Active	Low shear strength of slope forming material in soil	Footpath
29.	On road (R/B of Mandakini river, below Munkatiya village) 30° 38' 12.929" N 79° 0' 17.414" E	Gneiss Debris	-	F- 30/N45°E 65/S05°W 85/N40°W	Orthoanaclinal	35°, S, straight	H-40 V-30	Low diss., Forested area	Medium potential	Low shear strength of slope forming material in soil and road cut	Road
30.	On road (R/B of Mandakini river, near Munkatiya village and just upstream to confluence of Mandakini & Songanga) 30° 38' 11.424" N 79° 0' 9.842" E	Gneiss Debris cum rock	Moderate	F- 40/N50°E Jt- 55/S15°W	Orthoclinal	45°, S30°E, straight	H- 120 W-250	High diss., Forested area	Active	Many rock blocks (detached and fractured) in steep slope cut due to heavy rainfall and flooding	Road
31.	R/B of Songanga, opposite side of UJVNL power house at Sonprayag 30° 38' 11.608" N 78° 59' 51.743" E	Gneiss Debris	Moderate	F- 35/N30°E Jt- 65/S70°E Jt- 55/S10°W	Cataclinal	35°, N60°E, straight	H- 65 W-85	High diss., Forested area	Active	Loose overburden mass on steep slope and bank erosion by Son Ganga.	Nil

32.	On road (L/B of Songanga, just upstream to UJVNL power house at Sonprayag) 30° 38' 19.877" N 78° 59' 59.603" E	Gneiss Debris cum rock	Moderate	F- 30/N50°E Jt- 70/S Jt- 70/E	Orhtoanaclinal	45°, N70°W, straight	H- 50 W- 20	Moderate diss., Forested area	Active	Jointed & fractured rock	Road
33.	On road (R/B of Mandakini river, just downstream to confluence at Sonprayag) 30° 38' 1.653" N 79° 0' 0.835" E	Gneiss Debris cum rock	Moderate	F- 35/N15°E Jt- 70/S Jt- 45/S50°W	Orthocataclinal	45°, N70°E, straight	H_ 20 W- 35	Low diss., Barren land	Active	Loose soil and boulders in steep slope cut above rock and road cut	Road
34.	On road (R/ B of Mandakini river, just downstream to slide No. 33) 30° 37' 59.362" N 79° 0' 0.882" E	Gneiss Debris cum rock	Moderate	F- 35/N15°E Jt- 70/S Jt- 45/S50°W	Orhtoclinal	45°, S20°E, straight	H-15 V-20	Low diss., Barren land	Active	Loose soil and boulders in steep slope cut above rock and road cut	Road
35.	At Trijuginarayan (under construction road of Trijuginarayan to Tosi village) 30° 38' 33.190" N 78° 58' 35.968" E	Gneiss Debris	Moderate	F- 35/N30°E Jt- 65/S10°W Jt- 80/N40°W Jt- 75/S45°E	Cataclinal	25°, N20°E, straight	H- 35 W- 20	Low diss., Agriculture & habitated lands	Active	Low shear strength of slope forming material in soil and road cut	Road
36.	At Trijuginarayan (under construction road of Trijuginarayan to Tosi village), Just upstream to slide No. 35 30° 38' 33.650" N 78° 58' 38.730" E	Gneiss Debris	Moderate	F- 35/N30°E Jt- 65/S10°W Jt- 80/N40°W Jt- 75/S45°E	Cataclinal	35°, Due N, straight	H- 25 W- 30	Low diss., Habitated and Agriculture lands	Active	Low shear strength of slope forming material in soil and road cut	Road
37.	On road (3 km from Trijuginarayan towards Sonprayag) 30° 37' 54.705" N 78° 59' 16.474" E	Gneiss & schist Debris	High	F- 35/N15°E 75/N10°E 55/N35°W	Orthoclinal	35°, E, straight	H- 35 W- 50	Low diss., Forested area	Medium potential	Loose soil, seasonal water course and heavy rainfall	Road
38.	R/B of Mandakini river, right bank of nala at Sitapur 30° 37' 15.125" N 79° 0' 0.965" E	Gneiss Rock fall	High	F-35/N15°E Jt- 60/S20°E Jt- 60/S80°E	Cataclinal	>45°, N20°E, straight	H- 30 W- 15	Low diss., Agriculture land and Habitated area	Low potential	Jointed & fractured rock in steep slope cut	Nil

39.	On road (R/B of Mandakini river, at Sitapur village) 30° 37' 24.113" N 79° 0' 13.234" E	Schist Debris	High	F- 35/N05°E Jt- 50/N50°W Jt- 55/S30°W	Cataclinal	>45°, N20°W, straight	H -20 W-30	Moderate diss., Agriculture land and Habitated area	Active	Low shear strength of slope forming material in soil and road cut	Road
40.	On road (R/B of Mandakini river, 300 m upstream to Rampur village) 30° 37' 23.311" N 79° 0' 33.378" E	Schist Debris cum rock	Moderate - High	F- 30/N40°W Jt- 45/N70°E Jt- 65/S10°W	Orthoclinal	>25°, N50° E, straight	H -15 W-10	Moderate diss., Agriculture land and Habitated area	Active	Low shea r strength of slope forming material and road cut	Road
41.	L/B of Mandakini river, opposite side to Rampur village 30° 37' 20.551" N 79° 0' 52.705" E	Schist & gneiss Debris	-	Not visible	-	>45°, S10°W, straight	H- 40 W-50	Moderate diss., Forested area	Active	Heavy rainfall and flooding	Nil
42.	L/B of Mandakini river, just before confluence of Mandakini river and Kaladungi nala 30° 37' 2.792" N 79° 1' 10.210" E	Schist & gneiss Debris	-	Not visible	-	>45°, S40°W, straight	H- 45 W-40	Moderate diss., Forested area	Active	Heavy rainfall and flooding	Nil
43.	On road (R/B of Mandakini river, just upstream to Kaladungi nala) 30° 36' 47.222" N 79° 0' 50.442" E	Gneiss & schist Debris	High	F- 15/N10°E Jt- 70/S20°W Jt- 85/S80°E	Orhtoanaclinal	>35°, S50°E, straight	H- 20 W- 20	Low diss., Forested area	Low potential	Low shear strength of slope forming material and road cut	Road
44.	On road (R/B of Mandakini river, about 4.5 km downstream to Soneprayag) 30° 36' 49.266" N 79° 0' 51.303" E	Gneiss & schist Debris cum rock	Moderate - High	F- 40/N40°E Jt- 65/S30°W Jt- 40/N40°W	Cataclinal	>45°, N70°E, straight	H -15 W- 20	Moderate diss., Forested area	Low potential	Loose overburden mass over rock and road cut	Road

45.	On road (R/B of Kaladungi nala) 30° 36' 46.715" N 79° 0' 58.736" E	Schist Debris	High	F- 40/N30°E Jt- 80/N40°W	Orthoclinal	45°, N60°W, straight	H- 25 W- 35	Moderate diss., Forested area	Active	Loose overburden mass over rock and road cut	Road
46.	R/B of Mandakini River, near Badalpur village 30° 36' 21.879" N 79° 1' 38.766" E	Gneiss Debris	-	Not visible	-	>35°, N65°E, straight	H- 85 W- 75	Moderate diss., Near agriculture land	Active	Loose overburden mass over rock and road cut	Nil
47.	On road (R/B of Mandakini river, at Barasu) 30° 36' 9.690" N 79° 1' 36.766" E	Calcarious gneiss Debris cum rock	Moderate	F- 35/N60°E Jt- 85/S70°E Jt- 75/N50°E Jt- 55/N80°W	Cataclinal	>35°, N70°E, straight	H- 150 W- 200	High diss., Agriculture land and habitated area	Active	Dip slope, heavy rainfall and flooding	Road and houses
48.	R/B of Mandakini river, Below Barasu village 30° 36' 1.081" N 79° 1' 47.074" E	Calcarious gneiss Debris	-	Not visible	-	>45°, E, straight	H -100 W- 30	Moderate diss., Below agriculture land and habitated area	Active	Heavy rainfall and flooding	Nil
49.	On road (R/B of Mandakini river, Below kholi village, R/B of Godwa nala) 30° 35' 38.847" N 79° 1' 46.239" E	Schist Debris	High	F- 25/N20°E Jt- 65/S Jt- 50/N30°W Jt- 50/N70°E	Orthocataclinal	>45°, N30°W, straight	H- 50 W- 35	Moderate diss., Below habitated area	Active	Poor shear strength of slope forming material	Road
50.	On road (R/B of Mandakini river, 1 km downstream to Godwa nala) 30° 35' 30.540" N 79° 1' 50.974" E	Calcarious quartzite Debris cum rock	High	Bd- 45/N30°E Jt- 75/S60°E	Cataclinal	45°, N30°E, straight	H -30 W -85	Moderate diss., Forested area	Active	Poor shear strength of rock forming material and road cut	Road
51.	L/B of Mandakini river, just downstream to confluence of Godwa nala and Mandakini river 30° 35' 45.619" N 79° 2' 1.372" E	Gneiss Debris	-	Not visible	-	45°, S10°W, straight	H -100 W- 45	High diss., Forested area	Active	Heavy rainfall and flooding	Nil

52.	On road (R/B of Mandakini river) 30° 35' 22.956" N 79° 1' 51.555" E	Gneiss Rock fall	High	F- 40/N40°E Jt- 75/S	Orthoanaclinal	>45°, S, straight	H- 40 W- 45	Low diss., Forested area	Active	Tuffeceous rock and road cut	Road
53.	L/B of Mandakini river 30° 35' 34.067" N 79° 2' 16.054" E	Gneiss Debris	High	Not visible	-	>45°, S50°W, straight	H- 75 W- 40	Medium diss., Forested area	Active	Heavy rainfall and flooding	Nil
54.	R/B of Mandakini river, L/B of nala below Phata town 30° 34' 56.398" N 79° 2' 35.541" E	Gneiss and schist Debris	High	F- 30/N60°W Jt- 55/N70°E Jt- 75/S	Orthoanaclinal	45°, N80°E, straight	H- 35 W- 25	Medium diss., Forested area	Active	Washout shallow soil cover above rock due to rainfall and bank erosion by nala	Nil
55	On road (R/B of Mandakini river, 100 m downstream to Phata) 30° 34' 55.550" N 79° 2' 46.901" E	Gneiss Debris cum rock	Moderate - High	F- 50/E Jt- 60/N35°W Jt- 60/N Jt- 50/W	Orthoclinal	>45°, Due N, straight	H- 200 W- 100	Medium diss., Forested area	Active	Fractured, jointed rock, steep slope and road cut	Road
56	On road (R/B of Mandakini river, near Khat) 30° 34' 54.611" N 79° 2' 58.371" E	Gneiss Debris cum rock	Moderate - High	F- 50/S65°E Jt- 75/S35°W Jt- 65/N40°W	Orthoclinal	>45°, Due N, straight	H- 150 W- 120	High diss., Forested area	Active	Fractured, jointed rock, steep slope and road cut	Road and Primary school building
57	R/B of Mandakini river, R/B of Byung Gad on agriculture land below Khumera village 30° 33' 28.880" N 79° 3' 38.431" E	Gneiss Debris	Moderate	F- 45/N35°E Jt- 60/S20°E Jt- 40/N35°W	Cataclinal	>25°, N20°E, straight	H- 45 W- 75	Medium diss., Forested area	Active	Bank erosion by nala/Gad	Nil
58	On road (R/B of Mandakini river, near Jurani) 30° 33' 11.953" N 79° 4' 15.630" E	Gneiss Debris	High	F- 45/N5°E Jt- 65/S Jt- 70/N10°E	Cataclinal	>25°, N10°E, straight	H- 15 W- 100	Low diss., Forested area	Medium potential	Loose material and heavy rain	Road
59	On road (R/B of Mandakini river, just upstream to Narayankoti village) 30° 32' 49.914" N 79° 4' 30.386" E	Schist Debris cum rock	High	F- 25/N40°W Jt- 65/S10°E Jt- 65/S70°E	Anaclinal	>45°, S60°E, straight	H- 25 W- 10	Low diss., Forested area	Medium potential	Thinly laminated, jointed and weathered rock and road cut	Road

60	R/B of Mandakini river, at confluence (Kali Ganga & Mandakini 30° 32' 57.864" N 79° 4' 53.911" E	Schist Debris	High	F- 25/N40°W Jt- 65/S10°E Jt- 65/S70°E	Orthoclinal	>35°, N40°E, straight	H- 50 W- 300	High diss., Forested area and agriculture land	Active	Loose material on steep slope cut, heavy rainfall and flooding	Temple
61	Below Chaumasi village 30° 36' 36.421" N 79° 4' 40.866" E	Gneiss Debris	High	F- 30/N40°E Jt- 60/N40°W Jt- 70/S40°E	Orthoclinal	>30°, S30°E, straight	H- 50 W- 30	Low diss., Forested area	Old reactive	Heavy rainfall and flooding	Nil
62	R/B of Kali Ganga, upstream to Jal Talla village (at UJVNL stage - I Weir site) 30° 36' 6.252" N 79° 4' 40.478" E	Gneiss Debris cum rock	Moderate	F- 30/N40°E Jt- 60/N40°W Jt- 70/S40°E	Cataclinal	>45°, N55°E, straight	H- 120 W- 100	High diss., Forested area	Active	Fractured jointed rock, road cut, heavy rainfall and flooding	Weir and diversion canal
63	On road (R/B of Kali Ganga, At Jal Talla village) 30° 35' 48.709" N 79° 4' 48.797" E	Gneiss and schist Debris cum rock	Moderate to High	F- 25/N10°E Jt- 70/S40°E Jt- 60/N40°W	Orthoclinal	>35°, E, Slightly concave	H- 150 W- 150	High diss., agriculture land and habitated area	Active	Fractured jointed rock, road cut, heavy rainfall and flooding	Road, house and UJVNL project staff buildings
64	R/B of Meru Gad, near Kotmaheshwari Temple 30° 36' 3.651" N 79° 5' 17.457" E	Gneiss and schist Debris		-	-	45°, N30°W, straight	H- 40 W- 50	Moderate diss., Forested area	Active	Loose soil over rock and bank erosion by Gad	Nil
65	On road (R/B of Kali Ganga, just upstream to Kotma village) 30° 35' 12.926" N 79° 4' 42.789" E	Gneiss Debris	Moderate	F- 25/N10°E Jt- 75/S20°E Jt- 55/S30°W	Cataclinal	>35°, S75°E, Slightly concave	H- 45 W- 40	Low diss., Forested area	Active	Loose soil and seasonal water course	Road
66	R/B of Kali Ganga, below Kotma village 30° 34' 59.193" N 79° 4' 55.088" E	Gneiss Debris	Moderate	F- 25/N10°E Jt- 75/S20°E Jt- 55/S30°W	Orthocataclinal	35°, N50°E, Slightly concave	H- 25 W- 50	Low diss., agriculture land	Active	Loose soil and bank erosion	Nil
67	R/B of Kali Ganga, below Kobelta village 30° 34' 27.661" N 79° 4' 57.570" E	Gneiss Debris	Moderate	F- 25/N25°E Jt- 75/S50°E Jt- 60/S20°W	Orthoclinal	35°, E, Slightly concave	H- 85 W- 200	High diss., agriculture land	Active	Loose wet soil, road cut and flooding	Road

68	R/B of Kali Ganga, 300 m upstream to Kalimath 30° 34' 0.018" N 79° 4' 59.400" E	Gneiss Debris cum rock	Moderate	F- 40/N45°E Jt- 55/S30°E Jt- 60/S25°W	Orthocataclinal	45°, S80°E, Slightly concave	H- 100 W- 300	High diss., Forested area	Active	Loose soil above rock, road cut and flooding	Road
69	L/B of Kali Ganga, just upstream to Kalimath 30° 33' 55.946" N 79° 5' 10.526" E	Schist Debris	High	F- 50/N65°E Jt- 80/N10°E	Orthoanaclinal	40°, S10°W, straight	H- 100 W- 300	High diss., Forested area	Active	debris on steep slope and road cut	Road
70	R/B of Kali Ganga, at Kalimath (downstream to Kalimath temple area) 30° 33' 36.772" N 79° 5' 6.708" E	Schist Debris cum rock	Moderate - High	F- 50/N30°W Jt- 60/S Jt- 60/E	Orthoclinal	40°, N50°E, Slightly concave	H- 65 W- 85	High diss., Agriculture and habitated area	Active	Unconsolidated material on moderate slope cut and flooding	Houses
71	On road (L/B of Kali Ganga, 500 m downstream to Kalimath, below Kunjethi village) 30° 33' 26.333" N 79° 5' 12.645" E	Gneiss & schist Debris cum rock	High	Not visible	-	>35°, N60°W, Slightly concave	H- 300 W- 400	Low diss., Agriculture and habitated area	Active	Detached rock mass together with loose soil over road on steep slope cut and toe cutting	Road and cracks in Houses
72	R/B of Kali Ganga, just downstream to opposite side of slide no 71 30° 33' 9.391" N 79° 5' 4.310" E	Gneiss & schist Debris cum rock	High	F- 50/N30°W Jt- 60/S Jt- 60/E	Cataclinal	>35°, N60°W, Straight	H- 65 W- 85	High diss., Agriculture and habitated area	Active	Moderately to highly Jointed rock and flooding	Nil
73	On road (L/B of Kali Ganga) 30° 33' 0.112" N 79° 5' 6.868" E	Schist Debris cum rock	Moderate	F- 50/N75°E Jt- 55/S30°E Jt- 65/N40°W	Orthoclinal	45°, N30°W, Straight	H- 60 W- 50	Moderate diss., Forested area	Active	Loose soil above rock, road cut and flooding	Road
74	R/B of Mandakini river, below Hiun village 30° 32' 43.427" N 79° 5' 7.755" E	Schist Debris cum rock	-	Not visible	-	45°, N15°E, Straight	H- 90 W- 100	Moderate diss., Forested area	Active	Washout shallow soil cover due to rain and flooding	Nil
75	R/B of Mandakini river 30° 32' 18.666" N 79° 5' 43.747" E	Schist Debris	-	Not visible	-	45°, N70°E, Straight	H- 35 W- 200	Moderate diss., Forested area	Active	Loose soil, heavy rain and flooding	Nil

76	On footpath (downstream to Madhyamaheswer temple, along seasonal water course) 30° 37' 51.033" N 79° 13' 11.610" E	Gneiss Debris	High	F- 40/N30°W Jt- 80/N55°E	Orthoanaclinal	35°, S70°E, Straight	H- 50 W- 15	Low diss., Forested area	Active	Shallow soil cover eroded by seasonal water course	Footpath
77	L/B of Madhyamaheshwar Nala, south east of temple 30° 36' 8.596" N 79° 14' 17.475" E	Gneiss Debris	-	Not visible	-	35°, N30°E, Straight	H- 25 W- 50	High diss., Forested area	Active	Bank erosion by nala	Nil
78	L/B of Bantoli Gad 30° 36' 59.531" N 79° 13' 8.259" E	Gneiss Debris	-	Not visible	-	45°, N10°E, Straight	H- 45 W- 50	Moderate diss., Forested area	Active	Heavy rainfall and bank erosion by stream	Nil
79	L/B of Bantoli Gad 30° 36' 40.766" N 79° 12' 41.340" E	Gneiss Debris	-	Not visible	-	>45°, N10°W, Straight	H- 50 W- 15	Moderate diss., Forested area	Active	Heavy rainfall and bank erosion by stream	Nil
80	R/B of Bantoli Gad, below Nanugad village 30° 36' 45.011" N 79° 12' 26.845" E	Gneiss Debris	Moderate	F- 40/N30°W Jt- 80/N55°E	Anaclinal	45°, S30°E, straight	H- 35 W- 45	Low diss., Forested area	Active	Heavy rainfall and flooding	Nil
81	L/B of Bantoli Gad, opposite to Nanugad 30° 36' 37.945" N 79° 12' 15.842" E	Gneiss Debris	-	Not visible	-	>45°, N15°E, straight	H- 40 W- 45	Medium diss., Forested area	Active	Heavy rain and flooding	Nil
82	L/B of Bantoli Gad 30° 36' 21.325" N 79° 11' 27.428" E	Gneiss Debris	-	Not visible	-	45°, N45°E, straight	H- 75 W- 40	Medium diss., Forested area	Active	Heavy rain and flooding	Nil
83	R/B of Bantoli Gad, just upstream of Bantoli village 30° 36' 24.881" N 79° 11' 25.355" E	Gneiss Debris	Moderate	F- 70/N10°W Jt- 68/S50°E Jt- 70/S80°W	Anaclinal	>45°, S75°W, straight	H- 25 W- 35	Low diss., Forested area	Active	Heavy rain and flooding	Nil

84	R/B of Markanda Gad, 100 m upstream to confluence of Bantoli and Markanda Gads 30° 36' 30.485" N 79° 11' 20.132" E	Gneiss Debris	Moderate	F- 70/N10°W Jt- 68/S50°E Jt- 70/S80°W	Anaclinal/ Orthoanaclinal	45°, S40°E, straight	H- 45 W- 20	Low diss., Forested area	Active	Heavy rain and flooding	Nil
85	R/B of Madhyamaheshwar Ganga, Just downstream to confluence of Bantoli Gad and Marakanda Gad 30° 36' 23.226" N 79° 11' 14.387" E	Gneiss Debris cum rock	Moderate	F- 80/N40°W Jt- 35/N50°E Jt- 65/S45°W	Anaclinal	45°, S55°E, straight	H- 25 W- 35	Low diss., Forested area	Active	Shallow debris washout due to heavy rain and flooding	Footpath
86	L/B of Madhyamaheshwar Ganga, at confluence of Bantoli and Marakanda Gads 30° 36' 17.464" N 79° 11' 12.607" E	Gneiss Debris	-	Not visible	-	45°, N20°W, straight	H- 35 W- 45	Medium diss., Forested area	Active	Heavy rain and flooding	Nil
87	L/B of Madhyamaheswer Ganga, opposite site to Gaundar village 30° 36' 8.723" N 79° 10' 58.380" E	Gneiss Debris	-	Not visible	-	45°, N80°W, straight	H- 65 W- 35	Medium diss., Forested area	Active	Heavy rain, seasonal water course and flooding	Nil
88	L/B of Madhyamaheswer Ganga, 30° 34' 59.386" N 79° 9' 11.689" E	Gneiss Debris	-	Not visible	-	45°, N50°E, straight	H- 40 W- 50	Medium diss., Forested area	Active	Heavy rain and flooding	Nil
89	R/B of Madhyamaheswer Ganga 30° 34' 54.216" N 79° 8' 59.667" E	Gneiss Debris cum rock	High	F- 10/S70°E Jt- 60/N65°E	Cataclinal	45°, E, straight	H- 35 W- 40	Low diss., Near agriculture land	Active	Low shear strength of rock with soil cover and flooding	Nil
90	On road (R/B of Madhyamaheswer Ganga, just downstream to Ransi village) 30° 35' 8.809" N 79° 8' 33.382" E	Gneiss Debris	High	F- 45/N70°E Jt- 55/S20°W	Cataclinal	45°, E, straight	H- 30 W- 60	Low diss., Agriculture area	Active	Low shear strength of slope forming material, heavy rainfall and road cut	Road

91	On road (R/B of Madhyamaheswer Ganga, downstream to slide No. 90) 30° 35' 0.839" N 79° 8' 30.117" E	Schist Debris	High	F- 45/N70°E Jt- 55/S20°W	Cataclinal	45°, E, straight	H- 30 W- 60	Low diss., Agriculture area	Active	Heavy rainfall and road cut	Road
92	On road (L/B of Uniyana Gad) 30° 34' 45.615" N 79° 7' 44.639" E	Schist Debris	Moderate-High	F- 20/N75°E Jt- 75/S30°W Jt- 75/N30°W Jt- 55/S80°E	Orthocataclinal	>35°, S75°E, straight	H- 20 W- 15	Low diss., Agriculture land area	Active	Low shear strength of slope forming material and road cut	Road
93	R/B of Madhyamaheswer Ganga, at Paundar village 30° 34' 14.581" N 79° 7' 57.768" E	Gneiss Debris	Moderate	F- 35/N40°E Jt- 65/S15°W Jt- 80/N40°W	Orthoanaclinal	45°, S, straight	H- 20 W- 100	Medium diss., Near habitated area	Active	Bank erosion by river	Nil
94	L/B of Madhyamaheswer Ganga, Opposite side of Paundar village 30° 34' 13.741" N 79° 8' 8.197" E	Gneiss Debris	Moderate	F- 40/N85°E Jt- 55/S20°W Jt- 55/W	Orthoanaclinal	45°, N60°W, Slightly concave	H- 150 W- 100	Medium diss., Forested area	Old reactive	Bank erosion by river	Nil
95	On road (R/B of Kharsora Gad, near Uniyana village) 30° 34' 25.093" N 79° 7' 24.061" E	Gneiss Debris	Moderate	F- 20/N75°E Jt- 75/S30°W Jt- 75/N30°W Jt- 55/S80°E	Cataclinal	45°, S85°E, straight	H- 25 W- 15	Low diss., Forested area	Active	Loose material, heavy rain and road cut	Road
96	On road (R /B of Madhyamaheswer Ganga) 30° 34' 16.211" N 79° 7' 21.806" E	Gneiss Debris cum rock	Moderate	F- 40/N70°E Jt- 75/S30°E Jt- 80/N	Cataclinal	45°, N55°E, straight	H- 35 W- 85	Low diss., Barren land	Active	Fractured, jointed rock and road cut	Road
97	On road (R/B of Madhyamaheswer Ganga) 30° 34' 10.429" N 79° 7' 21.813" E	Gneiss Debris cum rock	Moderate	F- 40/N70°E Jt- 75/S30°E Jt- 80/N	Orthocataclinal	>45°, S45°E, straight	H- 20 W- 35	Low diss., Barren land	Active	Loose material on steep slope, heavy rain and road cut	Road
98	On road (Near Raunlake village) 30° 34' 6.719" N 79° 7' 6.355" E	Schist Debris	Moderate-High	F- 35/N40°E Jt- 65/S15°W Jt- 80/N40°W	Cataclinal	40°, N10°E, straight	H- 35 W- 50	Low diss., Agriculture land	Active	Loose wet soil failure due to road cut and seasonal nala	Road

99	L/B of Madhyamaheswer Ganga, along nala below Pari village 30° 33' 27.493" N 79° 7' 4.662" E	Schist Debris	Moderate-High	F- 35/N75°E Jt- 65/S50°W Jt- 80/S10°E	Orthocataclinal	35°, S70°E, straight	H- 85 W- 10	Medium diss., Agriculture land	Active	Unconsolidated material eroded by seasonal water course	Nil
100	R/B of Madhyamaheswer Ganga, at Jagi village 30° 32' 51.248" N 79° 6' 42.681" E	Gneiss Debris	High	Not visible	-	45°, S50°E, Slightly concave	H- 220 W- 200	High diss., Forested area	Old reactive	Heavy rainfall and flooding	Nil
101	R/B of Madhyamaheshwar Ganga, below Bedula village 30° 32' 35.844" N 79° 6' 24.668" E	Schist & gneiss Debris	High	Not visible	-	35°, S20°W, straight	H- 25 W- 35	Medium diss., Agriculture land	Active	Bank erosion	Nil
102	On road (L/B of Madhyamaheswer Ganga, 200 m upstream to Pali village) 30° 31' 53.106" N 79° 6' 28.132" E	Gneiss Debris	High	F- 30/N85°E Jt- 65/N50°W Jt- 65/S30°W	Anaclinal	35°, W, straight	H- 35 W- 20	Medium diss., Forested area	High	Heavy rain and loose soil	Road and Bus stoppage
103	On road (L/B of Madhyamaheswer Ganga, at Salami village) 30° 31' 47.832" N 79° 6' 15.613" E	Gneiss Debris	Moderate	F- 30/N15°E Jt- 70/N50°W Jt- 30/N60°E	Orthocataclinal	30°, N20°W, straight	H- 45 W- 30	Low diss., Agriculture land	Low	High discharge in nala and heavy rain	Road and houses
104	L/B of Madhyameheshwar Ganga, just upstream to confluence (Madhyameheshwar & Mandakini river) 30° 32' 6.116" N 79° 5' 54.336" E	Gneiss Debris	Moderate	F- 30/N30°W Jt- 55/S20°W Jt- 60/N60°W	Orthoclinal	45°, N45°E, straight	H- 85 W- 70	High diss., Forested area	Active	Heavy rainfall and flooding	Nil
105	L/B of Mandakini river, below road (near Chunni village) 30° 31' 51.420" N 79° 5' 36.302" E	Gneiss Debris	Moderate	F- 40/N55°E Jt- 70/S30°W Jt- 60/N60°W	Anaclinal	45°, S80°W, straight	H- 40 W- 65	High diss., Forested area	Active	Heavy rainfall and flooding	Nil

106	R/B of Mandakini river, 50m upstream to Kund Vidhyapeeth 30° 31' 49.621" N 79° 5' 33.784" E	Gneiss and schist Debris	Moderate	F- 40/N50°E Jt- 40/N80°W Jt- 75/S30°W	Orthocataclinal	45°, S80°E, straight	H- 75 W- 200	High diss., Agriculture land	Active	Heavy rainfall and flooding	Road
107	L/B of Mandakini river, in between Chunni & Mangoli villages 30° 31' 37.149" N 79° 5' 56.183" E	Gneiss Debris	Moderate	F- 40/N55°E Jt- 50/S85°W Jt- 70/S30°W	Orthoanaclinal	45°, S, straight	H- 20 W- 15	High diss., Agricultural land area	Active	Excessive rainfall, high discharge in nala	Road and Houses
108	L/B of Mandakini river, near Chunni village 30° 31' 43.017" N 79° 5' 35.082" E	Gneiss Debris	Moderate	F- 40/N55°E Jt- 50/S85°W Jt- 70/S30°W	Orthoanaclinal	45°, S, straight	H- 20 W- 15	High diss., Agricultural land	Active	High rainfall	Road
109	L/B of Mandakini river, just below Chunni village (R/B of nala) 30° 31' 35.316" N 79° 5' 30.640" E	Gneiss Debris	Moderate	F- 45/N80°E Jt- 75/S10°W Jt- 65/N10°W	Orthoanaclinal	45°, N50°W, straight	H- 35 W- 50	Medium diss., Agricultural land	Active	High rainfall	Road
110	L/B of Mandakini river, downstream of Chunni village along seasonal nala 30° 31' 27.858" N 79° 5' 27.150" E	Gneiss Debris	Moderate	F- 45/N80°E Jt- 75/S10°W Jt- 65/N10°W	Orthoanaclinal	45°, S80°W, straight	H- 150 W- 100	High diss., Agricultural land	Active	Excessive rainfall and stream erosion	Road
111	R/B of Mandakini river, below Bhansari village 30° 31' 26.016" N 79° 5' 21.517" E	Gneiss Debris	Moderate - High	F- 30/N50°E Jt- 40/N80°W Jt- 75/S30°W	Orthocataclinal	45°, S80°E, slightly concave	H- 50 W- 150	Medium diss., Forested area	Active	High rainfall and flooding	Nil
112	On Mansuna road, just upstream to Ukhimath Bus stand (at R/B of nala) 30° 30' 56.552" N 79° 6' 0.801" E	Schist Debris cum rock	High	F- 20/N30°E Jt- 65/N60°W	Orthoclinal	45°, N60°W, straight	H- 25 W- 15	High diss., Forested area	Active	High rainfall and poor rock mass strength	Road

113	R/B of Mandakini river, just uphill to Semi village 30° 30' 58.113" N 79° 4' 54.781" E	Gneiss and schist Debris cum rock	Moderate	F- 30/N40°E Jt- 65/S05°E	Orthocataclinal	>45°, E, straight	H- 75 W- 50	Low diss., Forested area	Medium	Heavy rainfall and road cut	Road
114	R/B of Mandakini river, at Semi village 30° 30' 50.369" N 79° 5' 16.000" E	Schist Debris	High	F- 30/N40°E Jt- 65/S05°E	Orthocataclinal	>20°, E, slightly concave	H- 200 W- 300	High diss., Agricultural land	Active	Heavy rainfall and flooding	Road, buildings, houses etc.
115	L/B of Rawan ganga 30° 30' 45.724" N 79° 3' 26.666" E	Gneiss Rock slide	Moderate	F- 30/N40°E Jt- 65/S05°E	Orthocataclinal	>45°, S, straight	H- 20 W- 10	Low diss., Forested area	Active	Poor rock mass strength	Nil
116	R/B of Rawan Ganga 30° 30' 34.568" N 79° 3' 24.322" E	Gneiss Debris	High	Not visible	-	>35°, N60°E, straight	H- 45 W- 50	Moderate diss., Agriculture land	Active	Loose soil, local stream and bank erosion	Road
117	L/B of Rawan Ganga 30° 30' 45.791" N 79° 4' 4.292" E	Gneiss Rock fall	Moderate - High	F- 30/Due N Jt- 55/S	Orthoclinal	>45°, S, slightly concave	H- 35 W- 30	Low diss., Barren land	Active	Poor rock strength and road cut	Road
118	R/B of Rawan Ganga, near Lwara village 30° 30' 41.460" N 79° 4' 9.510" E	Gneiss Debris	High	Not visible	-	35°, N10°W, straight	H- 30 W- 35	Low diss., agriculture land	Active	Low shear strength of slope forming materials and bank erosion by Rawan Ganga	Nil
119	At Andrawari 30° 30' 15.794" N 79° 4' 0.316" E	Schist and gneiss Debris	Moderate - High	F- 35/N20°W Jt- 65/S30°E Jt- 65/S80°W	Orthoclinal	>25°, E, slightly concave	H- 35 W- 30	Low diss., agriculture land	Active	Loose soil, erosion by local stream and road cut	Road
120	R/B of Rawan Ganga, below Lwara village 30° 30' 38.499" N 79° 4' 17.167" E	Schist and gneiss Debris	Moderate	F- 35/N20°E Jt- 70/S10°E Jt- 50/S50°W	Orthocataclinal	>25°, N60°E, slightly concave	H- 35 W- 30	Moderate diss., agriculture land	Active	Thick overburden on steep slope, local drainage, erosion by Rawan Ganga	Nil
121	R/B of Rawan Ganga, below Singoli village 30° 30' 33.291" N 79° 4' 37.858" E	Schist Debris	High	Not visible	-	>30°, N30°E, slightly concave	H- 45 W- 50	Low diss., agriculture land	Medium	Shallow soil cover over rock on moderate slope, erosion by Rawan Ganga	Nil
122	At Sansari village, L/B of nala 30° 30' 22.686" N 79° 5' 32.543" E	Schist Debris	Moderate - High	F- 35/N50°E	Orthoclinal	20°, N40°W, slightly concave	H- 45 W- 20	High diss., Agriculture land	Active	Incessant rain and stream erosion	Nil

123	R/B of Mandakini river, at Kund chatti 30° 30' 11.416" N 79° 5' 17.939" E	Schist Debris cum rock	Moderate - High	F- 35/N50°E Jt- 78/S30°E Jt-60/W	Orthocataclinal	45°, E, slightly concave	H- 150 W- 200	High diss., Forested area	Active	Fractured, jointed rock, loose soil, rainfall and flooding	Road, partially bridge
124	L/B of Madakini river, 1 km upstream to Kakara Gad 30° 29' 34.513" N 79° 5' 15.003" E	Gneiss Debris	Moderate	F- 35/N70°E Jt- 60/S15°W Jt-60/S70°E	Orthoanaclinal	45°, N80°W, straight	H- 35 W- 170	High diss., Forested area	Active	Loose overburden and flooding	Road
125	At Chopta, above road 30° 29' 10.193" N 79° 12' 12.978" E	Gneiss & schist Rock/boulder	Moderate	F- 20/N10°W Jt- 60/E Jt-70/S	Orthoclinal	45°, N70°W, straight	H- 50 W- 45	High diss., Forested area	Low	Fractured, jointed rock	Nil
126	Near Kathani, R/B of Sigot Gad 30° 30' 32.231" N 79° 9' 55.582" E	Gneiss Debris cum rock	Moderate - High	F- 50/Due N Jt- 65/S60°W Jt-50/S	Anaclinal	45°, S15°W, straight	H- 40 W- 45	High diss., Forested area	Active	Fractured, jointed rock and road cut	Road
127	R/B of Sigot Gad, below Kathani 30° 30' 33.483" N 79° 9' 35.238" E	Gneiss Debris	Moderate - High	F- 50/Due N Jt- 65/S60°W Jt-50/S	Orthoanaclinal	45°, S30°W, straight	H- 45 W- 200	High diss., Agriculture & forested area	Active	Bank erosion	Nil
128	On road (1.0 km from Sari towards Chaupta) 30° 31' 5.068" N 79° 8' 43.809" E	Gneiss Boulder fall	Moderate	F- 40/N35°E Jt- 45/S20°W	Orthocataclinal	40°, S20°E, straight	H- 60 W- 50	Low diss., Forested area	Low	Boulders on steep slope	Nil
129	R/B of Sigot Gad, below Mastura 30° 30' 35.718" N 79° 8' 45.375" E	Gneiss Ddebris	Moderate - High	F- 30/N60°E Jt- 75/S20°W	Anaclinal	45°, S20°W, straight	H- 25 W- 40	High diss., Forested area	Active	Heavy rainfall and bank erosion	Nil
130	On road (below Sari village, at Mastura) 30° 30' 44.321" N 79° 8' 34.675" E	Gneiss Debris cum rock	Moderate - High	F- 30/N60°E Jt- 75/S20°W	Orthoclinal	>35°, S50°E, Slightly concave	H- 55 W- 90	Moderate diss., Agriculture area	Active	Unconsolidated material on moderately steep slope, heavy rain and road cut	Road and school buildings
131	On road, at Dilmi 30° 30' 36.001" N 79° 8' 19.823" E	Gneiss Bouldery debris	High	Not visible	-	45°, S20°E, straight	H- 120 W- 100	Moderate diss., Agriculture area	Active	Critical slope mass over rock, heavy rainfall and road cut	Road

132	Below road, around 300 m downstream to Dilmi 30° 30' 28.231" N 79° 8' 20.550" E	Gneiss Rock fall	Moderate	F- 30/N60°E Jt- 75/S20°W	Orthoclinal	>45°, S10°E, straight	H- 45 W- 20	Moderate diss., Agriculture area	Active	Poor strength of rock mass & surface drainage	Nil
133	On road, 1 km upstream to Karokhi village 30° 30' 19.483" N 79° 7' 50.286" E	Gneiss Boulder fall	Moderate	F- 40/N55°E Jt- 75/S10°W Jt- 55/S85°W	Orthoclinal	>45°, S25°E, straight	H- 40 W- 50	Moderate diss., Barren land	Active	Critical boulders over steep slope and surface drainage	Road
134	On road ,1.5 km from Gwar village towards Tala 30° 29' 48.054" N 79° 8' 7.926" E	Gneiss Debris cum rock	High	F- 40/E Jt- 85/N Jt- 75/S50°W	Orthoanaclinal	45°, S50°E, straight	H- 20 W- 40	Low diss., Barren land	Active	Fractured rock & road cut	Road
135	L/B of nala, on road, before Charibakhor 30° 28' 5.171" N 79° 10' 18.426" E	Gneiss Bouldery debris	High	F- 40/N15°W Jt- 80/S40°W	Cataclinal	45°, N35°W, straight	H- 25 W- 15	Moderate diss., Forested land	Active	Road cut & steam erosion	Road
136	R/B of nala, near Pab village 30° 27' 41.527" N 79° 9' 12.636" E	Gneiss Debris	High	F- 40/N70°E Jt- 65/S Jt- 75/S40°W	Anaclinal	35°, W, straight	H- 20 W- 70	High diss., Forested land	Active	Debris materials on steep slope and road cut	Nil
137	R/B of nala, near Pab village 30° 27' 46.955" N 79° 9' 16.185" E	Gneiss Debris	High	F- 40/N70°E Jt- 65/S Jt- 75/S40°W	Orthoclinal	>25°, N20°W, slightly concave	H- 50 W- 40	High diss., Forested land	Active	Loose soil & road cut	Road
138	R/B of Ragsi Gad, around 200 m upstream side opposite to Makkumath 30° 28' 59.060" N 79° 8' 56.809" E	Gneiss Bouldery debris	High	F- 28/E Jt- 80/N10°W Jt- 60/W	Orthoclinal	45°, S80°W, straight	H- 70 W- 20	High diss., Forest land	Active	Low shear strength of slope forming material along local stream	Nil
139	R/B of Ragsi Gad, along nala in between Gwar & Dilmi villages 30° 29' 14.354" N 79° 8' 38.693" E	Gneiss Bouldery debris	High	Not visible	-	>35°, S60°W, straight	H- 40 W- 20	Moderate diss., Forested land	Old	Critical boulders on steep slope & local stream	Nil

140	L/B of Ragsi Gad, about 4 km downstream to Makku 30° 29' 33.782" N 79° 7' 55.813" E	Gneiss Debris	Moderate	F- 40/N55°E Jt- 50/S60°W Jt- 80/S05°E	Orthocataclinal	>35°, Due N, straight	H- 40 W- 35	High diss., Forested land	Active	Loose soil & bank erosion by Gad	Road
141	R/B of Ragsi Gad, 200 m downstream to slide No. 140 30° 29' 41.975" N 79° 7' 53.223" E	Gneiss Debris	High	Not visible	-	45°, S60°W, straight	H- 50 W- 40	High diss., Forested land	Active	Loose soil & bank erosion by Gad	Nil
142	L/B of Kakra Gad 500 m below Kakra & Ragsi Gad confluence 30° 29' 44.574" N 79° 7' 28.227" E	Gneiss Bouldery debris	High	Not visible	-	>35°, N30°E, concave	H- 40 W- 45	High diss., agriculture land	Active	Unconsolidated material & bank erosion by Gad	Nil
143	On Vasukedar road, above Semla village 30° 29' 49.182" N 79° 6' 47.872" E	Gneiss & schist Rock fall	Slight - Moderate	F- 40/N45°E Jt- 70/S40°W	Orthoanaclinal	>75°, S10°E, straight	H- 25 W- 45	Low diss., Barren land	High	Fractured, jointed rock & road cut	Nil
144	R/B of Kakara Gad, below Semla village 30° 29' 31.173" N 79° 6' 48.395" E	Gneiss & schist Debris	Moderate	F- 40/N45°E Jt- 70/S40°W	Orthoclinal	45°, S50°E, straight	H- 45 W- 100	Moderate diss., Barren land & agriculture area	Active	Heavy rainfall, and toe cutting	Nil
145	On road, uphill side to Dunger village 30° 29' 56.746" N 79° 6' 18.000" E	Schist Debris	Moderate - High	F- 30/N30°E Jt- 70/S10°W	Orthoanaclinal	>25°, S10°E, straight	H- 20 W- 45	Moderate diss., Barren land	Active	Loose soil & road cut	Nil
146	Near Pathali, below road 30° 29' 43.931" N 79° 6' 4.684" E	Gneiss Debris	Moderate - High	F- 20/N65°E Jt- 75/N20°W	Anaclinal	45°, S50°W, straight	H- 45 W- 50	Moderate diss., Agriculture land	Active	Low shear strength of slope forming materials on steep slope and heavy rainfall	Nil
147	On road, above Pathali village 30° 29' 57.926" N 79° 5' 56.973" E	Gneiss Debris	High	F- 20/N65°E Jt- 75/N20°W	Orthoclinal	>35°, S20°E, straight	H- 15 W- 50	Low diss., Agriculture land	Active	Heavy rainfall and road cut	Nil

148	L/B of Kakara Gad, near Parkandi 30° 29' 15.800" N 79° 5' 43.540" E	Gneiss Debris	High	F- 25/N50°E Jt- 65/S80°W	Orthoclinal	25°, N15°W, straight	H- 25 W- 35	Moderate diss., Agriculture land	Active	Loose soil & heavy rainfall	Nil
149	L/B of Mandakini river, on road (50 m downstream to Kakara Gad) 30° 29' 19.734" N 79° 5' 10.966" E	Gneiss Debris cum rock	Moderate-High	F- 30/E Jt- 70/N10°E Jt- 80/W	Anaclinal	45°, W, straight	H- 40 W- 250	Moderate diss., Forested land	Active	Fractured, jointed rock with debris on steep slope, road cut & flooding	Road
150	R/B of Mandakini river, opposite to slide No. 149 30° 28' 57.705" N 79° 5' 8.410" E	Gneiss Debris	High	Not visible	-	45°, S15°E, straight	H- 35 W- 50	Moderate diss., Forested land	Active	Loose soil and flooding	Nil
151	L/B of Mandakini river, on road 30° 28' 55.994" N 79° 5' 12.563" E	Gneiss Debris cum rock	Moderate-High	F- 35/E Jt- 70/N50°E Jt- 75/S60°W	Orthoclinal	35°, W, straight	H- 40 W- 200	Moderate diss., Forested land	Active	Loose mixed materials on moderate slope, road cut and flooding	Road
152	At Govt. Intermediate college, Parkandi (2 km upslope of village Parkandi) 30° 28' 40.135" N 79° 5' 53.093" E	Gneiss & schist Debris	Moderate-High	F- 20/Due N Jt- 65/N80°W Jt- 70/N20°W	Orthoclinal	>35°, W, straight	H- 35 W- 50	High diss., Barren land	Old	Shallow debris over rock and local streams	School building
153	On road, near Nagjagai 30° 28' 57.750" N 79° 4' 7.542" E	Calc gneiss Bouldery debris	High	F- 15/N50°E Jt- 70/S Jt- 75/N40°E	Orthoanaclinal	>35°, S10°E, straight	H- 35 W- 20	Moderate diss., barren land	Active	Critical overburden mass over road cut slope	Nil
154	At Phegu, on agriculture land 30° 28' 51.689" N 79° 4' 37.520" E	Gneiss Debris	High	Not visible	-	25°, S80°E, concave	H- 120 W- 50	High diss., Agriculture land	Old reactive	Loose soil and stream erosion	Nil
155	R/B of Mandakini river, near Tamariya village 30° 28' 38.495" N 79° 4' 52.763" E	Gneiss Debris cum rock	Moderate-High	Not visible	-	45°, E, slightly concave	H- 35 W- 150	Moderate diss., agriculture land	Active	Loose overburden materials & flooding	Nil
156	On road, near Nagjagai 30° 28' 36.953" N 79° 4' 0.448" E	Gneiss Debris	High	F- 30/N80°E Jt- 55/S30°W	Cataclinal	>25°, S70°E, slightly concave	H- 35 W- 100	Low diss., barren land	Active	Loose soil and road cut	Road

157	R/B of Mandakini river, just below Nagjagai village (along nala) 30° 28' 39.492" N 79° 4' 18.227" E	Gneiss Debris	High	Not visible	-	>45°, S45°E, straight	H- 75 W- 50	Low diss., Agriculture land	Old reactive	Loose soil & toe erosion by nala	Nil
158	R/B of Mandakini river, below Nagjagai (opposite to Bhiri) 30° 28' 32.508" N 79° 4' 22.351" E	Gneiss Debris	High	Not visible	-	>45°, S60°E, slightly concave	H- 350 W- 150	High diss., Agriculture land & forested area	Old reactive	Thick overburden on steep slope & toe erosion by river	Nil
159	R/B of Mandakini river, just upstream to Damar Village 30° 28' 15.851" N 79° 4' 25.206" E	Gneiss Debris	High	Not visible	-	45°, S40°E, straight	H- 250 W- 40	Low diss., Agriculture land	Old stabilize	Stream erosion	Nil
160	R/B of Mandakini river 30° 27' 51.518" N 79° 4' 34.552" E	Gneiss Debris	High	Not visible	-	90°, E, straight	H- 20 W- 75	Low diss., Agriculture land	Active	River borne materials terrace eroded by river	Nil
161	L/B of Mandakini river, just downstream to Bhiri 30° 27' 45.730" N 79° 4' 45.376" E	Gneiss debris cum rock	Moderate	F- 30/E Jt- 60/S60°W Jt- 75/N40°W	Orthoanaclinal	>45°, N35°W, straight	H- 40 W- 05	Moderate diss., Agriculture land	Active	Fractured, jointed rock & surface drainage	Nil
162	R/B of Mandakini river, 500 m upstream to Damar Gad 30° 27' 35.831" N 79° 4' 30.191" E	Gneiss Debris	High	Not visible	-	90°, N70°E, straight	H- 35 W- 150	Moderate diss., Agriculture land	Active	River borne materials terrace eroded by river	Nil
163	Near Taljaman, above road 30° 28' 47.146" N 79° 1' 38.377" E	Gneiss Rock fall	Moderate	F- 30/Due N Jt- 70/S20°W Jt- 65/S30°E	Orthoanaclinal	>45°, S20°W, straight	H- 220 W- 100	Low diss., Forested land	Old stabilized	Fractured jointed rock	Nil
164	L/B of Damar Gad, near iron bridge at Chhenagad 30° 28' 27.643" N 79° 1' 47.450" E	Gneiss Bouldery debris	Moderate	F- 25/N05°E Jt- 75/S80°W Jt- 65/N70°E	Anaclinal	>35°, S, straight	H- 50 W- 20	High diss., Forested land	Active	Boulders on steep slope along local stream	Road

165	On road, above Taljaman village 30° 28' 45.060" N 79° 2' 1.486" E	Gneiss Rock fall	Moderate	F- 30/Due N Jt- 70/S20°W Jt- 75/N Jt- 65/S30°E	Anaclinal	>50°, S, slightly concave	H- 350 W- 50	Moderate diss., Forested land	Old reactive	Fractured, jointed rock, heavy rainfall & local stream	Houses
166	L/B of Damar Gad, below Taljaman village 30° 28' 22.933" N 79° 2' 9.143" E	Gneiss Debris	Moderate	F- 30/Due N Jt- 70/S20°W Jt- 75/N Jt- 65/S30°E	Anaclinal	>35°, S, straight	H- 20 W-250	Moderate diss., Agriculture land	Active	Old landslide fan material terrace eroded by Damar Gad	Nil
167	R/B of Damar Gad, at Patiyon village 30° 28' 18.941" N 79° 2' 9.608" E	Gneiss Debris	High	Not visible	-	>25°, N50°E, slightly concave	H- 100 W-80	Low diss., Agriculture land	Active	Loose soil subsidized due to heavy rainfall	Road
168	On road, near Badeth village 30° 28' 0.806" N 79° 2' 16.800" E	Gneiss Bouldery debris	High	Not visible	-	>25°, S80°E, straight	H- 25 W-30	Moderate diss., barren land	Active	Unconsolidated material on road cut slope	Nil
169	R/B of Damar Gad, below Badeth 30° 28' 5.611" N 79° 2' 50.116" E	Gneiss Bouldery debris	High	Not visible	-	45°, Due N, straight	H- 35 W-15	Low diss., Agriculture land	Active	Unconsolidated material on steep slope & toe erosion by river	Nil
170	L/B of Damar Gad, on road, below Tinsoli village 30° 28' 16.947" N 79° 3' 36.423" E	Gneiss Rock fall	Moderate	F- 30/N80°E Jt- 55/S30°W	Orthoclinal	45°, S, straight	H- 50 W-40	Low diss., barren land	Active	Fractured, jointed rock & road cut	Nil
171	L/B of Damar Gad, below road 30° 27' 57.852" N 79° 3' 33.121" E	Gneiss Debris	Moderate	F- 30/N80°E Jt- 55/S30°W	Orthoclinal	45°, S30°E, straight	H- 55 W- 45	Moderate diss., barren land	Active	Shallow soil cover over rock on steep slope and bank erosion by Damar Gad	Nil
172	R/B of Damar Gad, below Basti village 30° 27' 52.546" N 79° 3' 47.228" E	Gneiss Debris	High	Not visible	-	>35°, N20°E, slightly concave	H- 50 W-60	High diss., agriculture land	Active	Thick overburden on steep slope and bank erosion by Gad	Nil
173	R/B of Mandakini river, at Banswara 30° 27' 15.547" N 79° 4' 20.613" E	Quartzite Debris cum rock	Moderate	F- 10/S40°W Jt- 70/N10°W Jt- 75/N60°E	Orthoclinal	>45°, S50°E, straight	H- 55 W-70	Moderate diss., Forested land	Active	Fractured jointed rock, heavy rainfall & flooding	Nil

174	On road, about 1.5 Km form Banswara towards Kandara 30° 27' 8.245" N 79° 4' 42.015" E	Granitic gneiss & schist Debris	High	F- 55/N70°E Jt- 45/S30°W Jt- 85/N40°E	Orthoclinal	35°, S70°W, slightly concave	H- 35 W-120	High diss., Forested land	Active	Low shear strength of slope forming materials, seepage and road cut	Road
175	R/B of Mandakini river, just opposite to Gair Gad 30° 26' 42.050" N 79° 4' 29.144" E	Schist Debris cum rock	Moderate - High	F- 65/W Jt- 45/N45°E	Anaclinal	45°, N75°E, straight	H- 150 W-350	High diss., Forested land	Active	Fractured, jointed rock and flooding	Nil
176	On road, near Vasukedar 30° 26' 23.869" N 79° 3' 14.295" E	Phyllite/schist Debris	High	F- 15/S20°W Jt- 45/E Jt- 80/S40°E	Orthoanaclinal	35°, N50°E, slightly concave	H- 45 W-40	Moderate diss., Agriculture land	Active	Loose soil, heavy rainfall and road cut	Partially road damage
177	R/B of Mandakini River, below Pali village 30° 26' 26.183" N 79° 4' 27.836" E	Schist Bouldery debris	Moderate - High	F- 65/W Jt- 45/N45°E	Orthoclinal	45°, S30°E, straight	H- 10 W-75	Moderate diss. Agriculture land	Active	Loose overburden, heavy rainfall and flooding	Nil
178	R/B of Mandakini river, below Ryansu village 30° 26' 9.003" N 79° 4' 14.510" E	Schist Debris	Moderate - High	F- 70/W Jt- 55/S Jt-40/N50°W	Anaclinal	>35°, S80°E, concave	H- 45 W-85	High diss. Agriculture land	Active	Debris materials on steep slope, heavy rainfall and flooding	Nil
179	Above Chandrapuri village 30° 26' 2.635" N 79° 4' 1.861" E	Granitic gneiss & schist Debris	Moderate	F- 40/N65°E Jt- 45/S40°W	Orthoclinal	>45°, S50°E, straight	H- 55 W-50	High diss. Forested land	Active	Shallow debris cover over rock on steep slope and rainfall	Nil
180	R/B of Mandakini river, downstream to Chandrapuri village 30° 25' 41.092" N 79° 4' 4.719" E	Granitic gneiss & schist Debris	High	Not visible	-	85°, S80°E, straight	H- 20 W-100	High diss. Agriculture land	Active	Loose materials and flooding	Nil
181	R/B of Nil Gad, below Akhori village 30° 25' 55.756" N 79° 8' 8.185" E	Gneiss Debris cum rock	Moderate	F- 40/N30°E Jt- 85/S20°E Jt-55/S70°E	Orthoanaclinal	45°, S, straight	H- 100 W-45	High diss., Forested land	Active	Upslope road cut materials on steep slope	Nil

182	On road, below Senagarsari 30° 25' 44.531" N 79° 7' 54.201" E	Gneiss Debris cum rock	Moderate	F- 30/N10°E Jt- 60/E Jt-80/S20°E	Anaclinal	>35°, S, slightly concave	H- 75 W-50	Low diss., Forested land	Old stabilized	Road cut and stream erosion	Nil
183	Below Bhanajgwar village 30° 25' 30.157" N 79° 7' 55.784" E	Gneiss Debris cum rock	High	Not visible	-	45°, W, slightly concave	H- 120 W-50	High diss., Agriculture & Forested lands	Old stabilized	Poor rock strength and surface drainage	Nil
184	At Garpunga 30° 25' 48.313" N 79° 7' 28.497" E	Quartzite & gneiss Bouldery debris	Moderate	F- 40/N25°E Jt- 75/S60°E Jt-65/S80°W	Anaclinal	45°, S, straight	H- 120 W-50	High diss., Agriculture land	Active	Heavy rainfall and High discharge through local drainage	Nil
185	On road (2 km from Chandranagar towards Mohanakhal), uphill side to Rawa village 30° 25' 48.313" N 79° 7' 28.497" E	Gneiss Debris	Moderate High	F-15/N60°E Jt- 55/N	Anaclinal	>25°, S60°W, straight	H- 60 W-50	Moderate diss., Agriculture & forested lands	Active	Heavy rainfall and unconsolidated material	Road
186	L/B of nala, below Kinjyani village 30° 23' 34.158" N 79° 8' 57.296" E	Gneiss Debris	High	Not visible	-	45°, S50°E, straight	H- 40 W-20	Moderate diss., agriculture land	Active	Shallow debris on steep slope and stream erosion	Nil
187	R/B of Mandakini river, opposite to Chandrapuri Market 30° 25' 25.905" N 79° 4' 3.302" E	Gneiss Debris	Moderate	F- 45/S80°E Jt- 85/N15°W	Cataclinal	45°, S70°E, straight	H- 60 W-40	Low diss., Agriculture & barren lands	Active	Shallow debris over rock on steep slope and local stream erosion	Nil
188	L/B of Mandakini river, just downstream to Chandrapuri Market 30° 25' 21.612" N 79° 4' 6.612" E	Gneiss Debris	Moderate	F- 35/S85°E Jt- 55/S40°W Jt-60/E	Anaclinal	90°, N60°W, straight	H- 20 W-200	High diss., Habitated area	Active	River borne materials terrace eroded by river	Road
189	R/B of Mandakini river, opposite to Gabni village 30° 25' 10.658" N 79° 3' 49.809" E	Phyllite Debris	Moderate	F- 55/E Jt- 70/N20°W Jt- 20/W	Orthocataclinal	>35°, S40°E, slightly concave	H- 60 W-100	High diss., Agriculture land	Active	Heavy rainfall and flooding	Nil
190	L/B of Mandakini river, opposite to Lan Gad 30° 24' 41.970" N 79° 3' 40.425" E	Phyllite Debris	High	F- 30/E Jt- 75/N05°E	Anaclinal	>35°, S75°W, straight	H- 15 W-50	Moderate diss., Forested land	Active	Heavy rainfall, flooding and road cut	Road

191	On road, above Khaduli village 30° 26' 9.289" N 79° 1' 12.802" E	Schistose quartzite Debris	Moderate	F- 40/N80°E Jt- 60/S20°W Jt- 38/N80°W	Orthoclinal	45°, S, straight	H- 40 W-100	High diss., Forested land	Active	Heavy rainfall and road cut	Road
192	L/B of Badhani Gad, below Khaduli 30° 26' 1.609" N 79° 1' 11.803" E	Schistose quartzite Debris	Moderate	F- 40/N80°E Jt- 60/S20°W Jt- 38/N80°W	Orthoclinal	45°, S, concave	H- 80 W-40	Moderate diss., Agriculture land	Active	Loose soil and toe erosion by Badhani Gad	Nil
193	R/B of nala, on road (near Bakola village) 30° 25' 52.358" N 79° 1' 16.989" E	Calcareous Schistose quartzite Debris cum rock	Moderate-High	F- 40/N80°E Jt- 80/N80°W Jt- 85/S20°W	Cataclinal	45°, N50°E, straight	H- 100 W-200	High diss., Forested area & barren land	Active	Road cutting and fractured jointed rock	Nil
194	Below Road, near Dankot village 30° 25' 52.487" N 79° 2' 16.058" E	Schistose quartzite Debris cum rock	High	F- 35/E Jt- 70/S75°W Jt- 85/N20°W Jt- 87/N25°E	Anaclinal	>45°, W, slightly concave	H- 35 W-15	High diss., Barren land	Active	Low shear strength of slope forming materials, heavy rainfall and erosion by nala	Nil
195	R/B of Mandakini River, on road (below Ginwala village) 30° 24' 31.929" N 79° 3' 31.967" E	Phyllite Bouldery debris	High	F- 30/E Jt- 75/N05°E	Anaclinal	45°, W, straight	H- 25 W-35	Moderate diss., Agriculrtue land	Active	Unconsolidated materials on steep slope and road cut	Nil
196	L/B of Mandakini river, on road (just upstream to Sauri village) 30° 24' 33.454" N 79° 2' 58.256" E	Phyllite Debris cum rock	High	F- 35/S80°E Jt- 55/S30°W Jt- 65/E	Orthoanaclinal	>35°, N30°W, slightly concave	H- 35 W-20	High diss., Forested land	Active	Poor rock strength and road cut	Road
197	On road, near Rari village 30° 24' 35.764" N 79° 2' 37.312" E	Schistose quartzite Bouldery debris	High	Not visible	-	45°, S, straight	H- 25 W-40	High diss., Agriculture land & forested area	Active	Critical mass on steep slope and road cut	Road
198	R/B of Mandakini river, on road (below Pathali Dhar) 30° 24' 32.694" N 79° 2' 14.599" E	Schistose quartzite Debris cum rock	Moderate	F- 40/S85°E Jt- 55/N80°W Jt- 80/N05°E	Orthocataclinal	45°, S50°E, straight	H- 100 W-50	High diss., Forested land	Active	Shallow debris over fractured, jointed rock, heavy rainfall and road cut	Road

199	At Ganganagar Petrol Pump (below Sra) 30° 24' 5.270" N 79° 2' 44.350" E	Schistose quartzite Bouldery debris	Moderate - High	F- 45/S80°E Jt- 55/N60°W Jt-60/N	Orthoanaclinal	45°, N40°W, slightly concave	H- 35 W-45	High diss., Forest land	Active	Unconsolidated material and road cut	Nil
200	L/B of Mandakini river, opposite to Ganganagar 30° 24' 3.478" N 79° 2' 38.273" E	Schistose quartzite Debris	Moderate	F- 45/S80°E Jt- 55/N60°W Jt-60/N	Orthoclinal	>45°, N05°E, straight	H- 25 W- 45	Moderate diss., Barren land	Active	Heavy rainfall and flooding	Partially damaged road and Petrol Pump
201	R/B of Mandakini river, on road at Ganganagar 30° 24' 5.865" N 79° 2' 31.359" E	Schistose quartzite Debris	Moderate	F- 25/N80°E Jt- 40/W Jt- 75/N10°W	Orthoclinal	90°, S, straight	H- 35 W- 100	Moderate diss., Agriculture area	Active	River borne materials terrace eroded due to flooding	Road and houses
202	R/B of Mandakini river, opposite to Agastmuni Degree college 30° 30' 44.321" N 79° 8' 34.675" E	Schistose quartzite Debris cum rock	High	Not visible	-	45°, S60°E, straight	H- 80 W- 40	Moderate diss., Forest land	Active	Unconsolidated material on moderately steep slope, heavy rain and road cut	Road
203	R/B of Mandakini river, below Chamrada village 30° 23' 57.901" N 79° 2' 2.276" E	Schistose quartzite Debris	High	Not visible	-	35°, S60°E, straight	H- 100 W- 350	Moderate diss., Agriculture land and forested area	Active	Road cutting and toe erosion	Nil
204	L/B of Mandakini river, at Vijaynagar 30° 30' 44.321" N 79° 8' 34.675" E	Schistose quartzite Debris	Moderate - High	F- 35/S75°E Jt- 65/N20°W	Orthoanaclinal	90°, N30°W, straight	H- 20 W- 300	Moderate diss., Habitated area	Active	Heavy rainfall and flooding	Road, houses, commercial buildings
205	R/B of Mandakini river, opposite side to Agastmuni Ground (At Chaka village) 30° 23' 34.907" N 79° 1' 19.819" E	Schistose quartzite Debris cum rock	High	Not visible	-	40°, S35°E, Slightly concave	H- 45 W- 250	Moderate diss., Agriculture land	Active	Heavy rainfall and flooding	Houses
206	Uphill side to Kirora village 30° 25' 49.861" N 78° 58' 14.654" E	Phyllite Debris cum rock	Moderate - High	F- 45/E Jt- 40/N70°W	Orthoclinal	>35°, S, slightly concave	H- 85 W- 100	Low diss., Forested land	Active	Heavy rainfall and unconsolidated materials on steep slope	Nil

207	On road, near mathgaon village 30° 25' 13.079" N 78° 58' 14.021" E	Quartzite Debris cum rock	High	Not visible		45°, N60°E, straight	H- 40 W- 35	High diss., Forested land	Active	Road cut and stream erosion	Road
208	On road, at Kot Khal 30° 21' 22.231" N 79° 6' 4.036" E	Quartzite Debris cum rock	Low - Moderate	Bd- 45/N15°E Jt- 45/N70°W Jt- 65/S30°E	Cataclinal	35°, N30°E, slightly concave	H- 20 W- 50	Moderate diss., Forested land	Active	Road cutting	Partially Road damage
209	Above Kanda village, on road 30° 20' 51.816" N 79° 4' 38.007" E	Basics Bouldary debris	Moderate	F- 30/N10°W Jt- 55/ W Jt- 75/S30°E	Orthoclinal	45°, S65°W, straight	H- 35 W- 60	Low diss., Forested land	Low	Fractured, jointed rock and road cut	Nil
210	R/B of Mandakini river, along nala at Chaka village 30° 23' 1.721" N 79° 0' 29.168" E	Schistose quartzite Debris	Moderate	F- 35/S70°E Jt- 50/N70°W Jt- 65/N30°E	Cataclinal	>35°, S40°E, straight	H- 100 W- 40	Moderate diss., Forested land	Active	Thick colluviums mixed with RBM on steep slope, stream erosion and flooding	Nil
211	R/B of Mandakini river, just upstream to Budoli village 30° 22' 52.131" N 79° 0' 17.067" E	Phyllite Debris	High	Not visible		45°, S35°E, slightly concave	H- 45 W- 100	Moderate diss., Forested land	Active	Loose soil over steep slope, heavy rainfall and flooding	Nil
212	L/B of Mandakini river, on road at Silli Chatti 30° 22' 47.322" N 79° 0' 18.980" E	Schistose quartzite Debris	Moderate	F- 35/S70°E Jt- 50/N70°W Jt- 65/N30°E	Anaclinal	45°, N50°W, straight	H- 85 W- 120	Moderate diss., Forested land	Active	Heavy rainfall, stream erosion, road cut and flooding	Road
213	R/B of Mandakini river, below Budoli village 30° 22' 44.528" N 79° 0' 4.044" E	Phyllite Debris	Moderate	F- 35/S70°E Jt- 50/N70°W Jt- 70/N25°E	Cataclinal	>35°, S80°E, straight	H- 40 W- 85	Moderate diss., Forested land	Active	Fractured, jointed rock with shallow debris on steep slope and flooding	Nil
214	Above Benji village, on road 30° 22' 17.370" N 79° 0' 25.960" E	Phyllite Debris	Moderate - High	F- 45/N70°E Jt- 70/N	Orhtoanaclinal	>25°, N80°W, slightly concave	H- 20 W- 50	Low diss., Agriculture land	Low	Loose soil, road cut and heavy rainfall	Partially damaged road
215	R/B of Mandakini river, uphill side to Budoli village (along nala) 30° 22' 52.729" N 78° 59' 44.447" E	Phyllite Debris	High	Not visible		40°, S20°E, straight	H- 70 W- 40	Low diss., Agriculture land & forest area	Active	Shallow soil cover on steep slope and heavy rainfall	Nil

216	L/B of Mandakini river, at Gangtal village (Dangi) 30° 22' 3.915" N 78° 59' 53.391" E	Phyllite Debris	Moderate - high	F- 45/N50°E Jt- 50/S10°E Jt- 50/W	Orthoanaclinal	>35°, W, slightly concave	H- 35 W- 100	Moderate diss., Forest land	Active	Unconsolidated material on moderate slope and seepage in flowing condition	Road
217	L/B of Mandakini river, 500 m upstream to Rampur village 30° 21' 57.859" N 78° 59' 50.407" E	Phyllite Debris cum rock	Moderate	F- 45/N80°E Jt- 65/S Jt- 45/N70°W	Orthoanaclinal	>35°, N55°W, straight	H- 40 W- 35	Low diss., Forest land	Active	Shallow debris over moderate slope and flooding	Road
218	L/B of nala, near Bamoli village 30° 20' 55.693" N 79° 0' 18.905" E	Phyllite Debris	High	F- 25/N55°E Jt- 65/S Jt- 55/N35°W	Orthocataclinal	35°, N, straight	H- 30 W- 25	Low diss., Forest land	Active	Low shear strength of slope forming materials and stream erosion	Nil
219	At Kandhar, on road 30° 21' 8.124" N 78° 59' 52.451" E	Phyllite Debris	High	F- 25/N55°E Jt- 65/S Jt- 55/N35°W	Orthoclinal	>25°, N45°W, Slightly concave	H- 20 W- 40	Low diss., Agriculture land	Active	Loose soil and heavy rainfall	damaged road and a house
220	L/B of major nala, near Kandhar 30° 21' 20.693" N 78° 59' 24.215" E	Quartzite Bouldary debris	Moderate	Bd- 70/Due N Jt- 80/W Jt- 55/S10°W	Orthoanaclinal	>35°, S50°E, straight	H- 30 W- 45	Moderate diss., Forested land	Active	Jointed, fractured rock and road cut	Road
221	Above Tat village 30° 21' 20.693" N 78° 59' 24.215" E	Phyllite & Basic Debris cum rock	Moderate	F- 35/N40°E Jt- 75/N Jt- 70/S30°E	Anaclinal	45°, S65°W, straight	H- 45 W- 25	Low diss., Agriculture land	Active	Detached rock mass over steep slope	Nil
222	L/B of Mandakini river, just downstream to Rampur village 30° 21' 56.708" N 78° 58' 58.461" E	Phyllite Debris	Moderate - High	F- 45/N80°E Jt- 65/S Jt- 45/N70°W	Anaclinal	90°, W, straight	H- 35 W- 50	Moderate diss., Barren land	Active	River borne materials on steep road cut and flooding	Partially road damaged
223	L/B of Mandakini river, on road 30° 21' 51.620" N 78° 58' 54.532" E	Phyllite Debris	High	F-45/E Jt- 70/N20°E Jt- 25/W	Orthoanaclinal	>45°, N50°W, straight	H- 25 W- 200	Low diss., Barren land	High	River borne materials over rock and road cut	Nil

224	R/B of Mandakini river, at Sisaunu village 30° 21' 49.629" N 78° 58' 47.363" E	Phyllite Debris	High	Not visible	-	90°, E, straight	H- 15 W- 50	Moderate diss., Agriculture land	Active	River borne materials terrace cut by flooding	Nil
225	R/B of Mandakini river, 100 m upstream to Lustar Gad 30° 21' 16.790" N 78° 58' 30.565" E	Phyllite Debris	High	F- 80/S50°E	Orthocataclinal	45°, E, straight	H- 35 W- 40	Moderate diss., Forest land	Active	River borne materials over steep slope and bank erosion by stream	Road
226	Opposite side to San village, along nala 30° 29' 2.170" N 78° 55' 48.808" E	Granitic gneiss Debris	Moderate	Not visible	-	>35°, S50°W, straight	H- 40 W- 10	Moderate diss., Forest land	Active	Unconsolidated material and bank erosion by stream	Nil
227	L/B of Luster Gad, opposite side to San village 30° 28' 59.954" N 78° 55' 31.746" E	Granitic gneiss Debris cum rock	High	Not visible	-	45°, S60°W, straight	H- 50 W- 45	Low diss., Agriculture area & forest land	Active	Shallow debris over steep slope and bank erosion	Nil
228	Along Sirwari nala 30° 27' 54.481" N 78° 55' 13.322" E	Granitic gneiss Debris	Moderate - High	F- 30/N55°E Jt- 70/S10°W	Orthoanaclinal	>35°, N80°W, straight	H- 200 W- 20	Moderate diss., Agriculture land	Low	Stream erosion and road cut	Road
229	L/B of Gad, 1 km before Khaliyan village 30° 28' 5.877" N 78° 54' 13.508" E	Granitic gneiss Debris	Moderate - High	F- 40/N30°W Jt- 75/S	Anaclinal	40°, S, straight	H- 30 W- 100	Moderate diss., Agriculture land	High	Loose soil and heavy rainfall	Nil
230	Below Khliyan village 30° 27' 18.883" N 78° 55' 8.819" E	Granite Debris	Moderate	Jt-25/N55°E Jt-75/W	-	>15°, Due N, slightly concave	H- 35 W- 20	Moderate diss., Agriculture land	Active	Loose soil and heavy rainfall	Nil
231	1 km downstream to Khliyan towards Mayali 30° 26' 38.973" N 78° 55' 1.849" E	Granite Debris	Moderate - High	Jt-25/N55°E Jt- 90/E Jt- 75/W	-	>25°, E, Slightly concave	H- 70 W- 60	Low diss., Forested land	Active	Loose soil, local stream and seepage	Road

232	L/B of Luster Gad, 500m upstream to Panjan village 30° 25' 12.682" N 78° 55' 6.733" E	Granite Debris	Moderate	Jt-35/E Jt- 75/N70°W Jt- 80/S20°W	-	45°, W, Slightly concave	H- 35 W- 40	Low diss., Forested land	Active	Unconsolidated material and heavy rainfall	Nil
233	L/B of Luster Gad, at Panjan 30° 24' 22.639" N 78° 55' 10.821" E	Granite Debris	Moderate	Jt-45/S80°E Jt- 60/N50°W Jt- 50/S80°W	-	>25°, S, Slightly concave	H- 85 W- 50	Moderate diss., Agriculture land	Active	Erosion by stream	Road
234	R/B of Luster Gad, opposite side to Panjan village 30° 24' 11.236" N 78° 54' 52.070" E	Granite Debris	High	Not visible	-	45°, E, straight	H- 45 W- 35	Moderate diss., Forest land	Active	Shallow soil cover over rock on steep slope	Nil
235	R/B of Luster Gad, below Jainti village 30° 24' 8.273" N 78° 55' 9.548" E	Granite Debris cum rock	High	Not visible	-	40°, Due N, slightly concave	H- 85 W- 50	High diss., Forested land	Active	Heavy rainfall and bank erosion by tributary	Nil
236	R/B of Luster Gad, at Rar village 30° 23' 47.667" N 78° 55' 24.087" E	Granite Bouldary debris	High	Not visible	-	>45°, N50°E, straight	H- 75 W- 10	High diss., Agriculture land	Active	Heavy rainfall and surface drainage	Nil
237	Near Margaon village 30° 23' 28.101" N 78° 56' 13.267" E	Granite Rock cum Debris	High	Jt-30/S50°E Jt- 25/S60°W Jt- 85/W	-	45°, S20°W, straight	H- 20 W- 45	High diss., Barren land	Active	Fractured, jointed rock and road cut	Nil
238	300 m before Talla towards Vasukedar 30° 22' 44.259" N 78° 56' 39.290" E	Grainte Boulder fall	Moderate	Jt- 40/N70°E Jt- 50/S50°W Jt- 70/N75°E	-	>45°, S40°W, straight	H- 80 W- 20	Low diss., Forested land	Active	Poor strength of rock and heavy rainfall	Nil
239	1.5 km before Talla towards Vasukedar 30° 22' 42.904" N 78° 56' 31.282" E	Grainte Debris	Moderate - High	Jt- 40/N70°E Jt- 50/S50°W Jt- 70/N75°E	-	>45°, S10°E, slightly concave	H- 30 W- 35	Moderate diss., Forest land	Active	Thinly laminated, jointed rock and road cut	Road

240	Near Bajira, along nala 30° 24' 20.812" N 78° 52' 41.094" E	Granite Bouldery debris	Moderate	Jt- 25/S30°E Jt- 65/S30°W	-	>35°, W, straight	H- 200 W- 50	High diss., Agriculture and barren lands	Active	High discharge through stream	Road
241	50 m downstream to Bajira village 30° 24' 10.079" N 78° 52' 42.478" E	Granite Debris	Moderate	Jt- 25/N30°E Jt- 65/S30°W	-	25°, W, slightly concave	H- 20 W- 30	Highly diss., Agriculture land	Active	Loose soil and seepage	Nil
242	Near Palakurali, on Chirptiya road 30° 24' 8.690" N 78° 50' 44.691" E	Granite Bouldary debris	High	Jt- 55/N30°W Jt- 70/N05°E Jt- 45/S20°W	-	45°, N75°E, straight	H- 20 W- 30	Moderate diss., Forested land	Active	Low shear strength of slope forming materials and road cut	Road
243	Above Dumli village, on road 30° 22' 53.174" N 78° 53' 14.150" E	Basics Debris cum rock	High	F- 15/N30°E Jt- 70/S	Anaclinal	45°, S40°W, slightly concave	H- 35 W- 100	Moderate diss., Forest land	High	Highly jointed and fractured rock mass	Nil
244	Below Mayali village 30° 22' 55.446" N 78° 53' 34.464" E	Basic Debris	High	Not visible	-	>35°, S50°E, slightly concave	H- 25 W- 30	Moderate diss., Barren land	Active	Low shear strength of slope forming materials and road cut	Road
245	R/B of Helaun Gad, 500 m upstream to Harinagar 30° 22' 20.955" N 78° 53' 39.231" E	Granite Bouldery debris	High	Jt- 50/N45°E Jt- 60/S Jt- 45/N40°W	-	45°, N45°E, straight	H- 20 W- 30	Moderate diss., Forested land	Active	Shallow debris on steep slope and road cut	Nil
246	L/B of Helaun Gad 30° 22' 24.501" N 78° 53' 52.030" E	Granite Debris cum rock	Moderate	Jt- 50/N05°W Jt- 50/S Jt- 60/N50°W	-	45°, S50°W, straight	H- 25 W- 20	Low diss., Forested land	Active	Fractured, jointed rock and heavy rainfall	Nil
247	R/B of Helaun Gad 30° 22' 14.552" N 78° 53' 48.915" E	Granite Debris	Moderate - High	Jt- 50/N45°E Jt- 60/S Jt- 45/N40°W	-	45°, N20°E, straight	H- 12 W- 10	Low diss., Forested land	Active	Highly weathered rock and road cut	Nil

248	R/B of Helaun Gad, 500m upstream to Harinagar 30° 22' 3.087" N 78° 54' 5.890" E	Granite Boulder fall	Moderate - High	Jt- 50/N50°E Jt- 60/N30W	-	40°, E, straight	H- 85 W- 70	Moderate diss., Forested land	Active	Fractured, jointed rock and road cut	Road
249	L/B of Helaun Gad 30° 22' 20.328" N 78° 54' 9.280" E	Granite Bouldary debris	Moderate - High	Jt- 40/N05°W Jt- 50/S Jt- 60/N50°W	-	45°, S25°E, straight	H- 25 W- 50	Low diss., Barren land	Active	Detached mass over steep slope	Nil
250	R/B of Helaun Gad, below Birongaon village 30° 21' 32.725" N 78° 55' 29.945" E	Granite & basics Rock fall	Moderate	Jt- 50/N15°E Jt- 70/W	-	45°, S65°W, straight	H- 20 W- 25	Moderate diss., Forested land	Active	Poor rock strength and road cut	Nil
251	R/B of Luster Gad, near Barsari village 30° 21' 48.306" N 78° 56' 0.351" E	Granite Debris	Moderate	Jt- 25/N10°W Jt- 75/S80°E	-	40°, E, straight	H- 20 W- 25	Low diss., Forested land	Active	Loose soil and road cut	Nil
252	3 km upstream to Tilwara towards Mayali 30° 21' 15.982" N 78° 57' 43.101" E	Granite Debris cum rock	High	Jt- 35/W Jt- 79/S85°E Jt- 55/S80°W	-	45°, E, straight	H- 55 W- 45	Moderate diss., Forested land	Active	Loose soil and road cutting	Nil
253	L/B of Luster Gad, near Sumari, (500 m upstream to confluence) 30° 21' 8.630" N 78° 58' 17.389" E	Quartzite Debris cum rock	Moderate	Bd- 70/S70°E Jt- 30/N60°W Jt- 55/S30°W	Orthoclinal	>45°, S20°W, slightly concave	H- 80 W- 50	Moderate diss., Forested land	Active	Fractured jointed rock and road cut	Road
254	R/B of Madakini river, at Sumari village 30° 20' 52.915" N 78° 58' 34.641" E	Basic & Phyllite Debris	Moderate	F- 60/S75°E Jt- 65/N20°W Jt- 70/N50°W	Cataclinal	90°, E, straight	H- 20 W- 350	Moderate diss., Habitated area	Active	River borne materials terrace eroded by flooding	Number of houses and buildings

255	R/B of Mandakini river, at Tilaknagar Govt. Inter College 30° 20' 36.045" N 78° 58' 10.833" E	Phyllite, Quartzite & Basic Debris cum rock	High	F- 70/W Jt- 65/N50°W	Orthoclinal	40°, S40°E, concave	H- 75 W- 100	High diss., Forested land and habitated area	Active	River born materials on steep slope and flooding	School buildings and road
256	R/B of Mandakini river 30° 20' 23.793" N 78° 58' 5.664" E	Phyllite & Basic Debris cum rock	High	F- 70/W Jt- 65/N50°W	Anaclinal	45°, E, Slightly concave	H- 35 W- 50	Moderate diss., Agriculture land and forested area	Active	Poor strength of rock and flooding	Nil
257	L/B of Mandakini river, near Bhatwarisain 30° 19' 33.919" N 78° 58' 17.610" E	Basic Debris cum rock	Moderate	F- 55/N60°W Jt- 55/S20°W Jt- 55/S80°E	Cataclinal	45°, W, straight	H- 40 W- 150	Low diss., Barren land	Active	Road cut and flooding	Road
258	R/B of Mandakini river, just opposite to Maidanpur 30° 19' 10.981" N 8° 57' 59.357" E	Quartzite Debris	High	Not visible	-	>35°, N45°E, straight	H- 25 W- 50	Low diss., Barren land	Active	Toe cutting due to flooding	Nil
259	L/B of Mandakini river, along local stream, near Medanpur 30° 19' 5.333" N 78° 58' 20.635" E	Quartzite Debris cum rock	Moderate	Not visible	-	45°, S30°W, straight	H- 55 W- 30	Moderate diss., Barren land	Active	Shallow soil cover over rock on steep slope and high discharge through local stream during high rain	Road
260	R/B of Mandakini river, 30° 18' 10.766" N 78° 58' 48.081" E	Quartzite Debris	High	Not visible	-	>35°, N10°W, straight	H- 20 W- 50	Moderate diss., Forested land	Active	Heavy rainfall, & flooding	Nil
261	R/B of Mandakini river, 30° 18' 1.499" N 78° 58' 43.350" E	Quartzite Debris	High	Not visible	-	45°, E, straight	H- 60 W- 20	Low diss., Agriculture land	Active	Shallow debris on steep slope and heavy rainfall	Nil
262	On road (about 4 km from Kankchauri towards Koteshwar) 30° 18' 9.837" N 78° 58' 46.355" E	Quartzite Debris	Moderate	Bd- 35/S70°E Jt- 75/N65°W Jt- 60/N15°E	Orthoclinal	45°, E, straight	H- 35 W- 20	Low diss., Barren land	Active	Shallow debris on steep slope and heavy rainfall	Nil

263	Near Jagtoli along nala 30° 21' 58.395" N 79° 6' 21.420" E	Phyllite Debris cum rock	High	F- 35/N35°E Jt- 65/S50°E Jt- 50/S40°W	Orthoclinal	>35°, S80°E, slightly concave	H- 35 W- 100	Moderate diss., Barren land	Active	Stream erosion and rainfall	Nil
264	L/B of Alaknanda river, just upstream to Nagrasu 30° 20' 15.167" N 79° 6' 29.234" E	Phyllite Debris cum rock	Moderate	F- 30/N25°E Jt- 75/S10°E	Orthoclinal	<35°, N40°W, straight	H- 35 W- 50	Moderate diss., Barren land	Active	Road cut and rainfall	Road
265	L/B of Alaknanda river, At Nagrasu, below agriculture land 30° 17' 28.839" N 79° 7' 8.019" E	Basics Debris (RBM)	-	Not visible	-	90°, E, straight	H- 25 W- 50	Moderate diss., Agriculture land	Active	River born materials terrace eroded by river	Nil
266	Near Kande 30° 18' 8.040" N 79° 7' 11.056" E	Phyllite Debris	Moderate - High	F- 45/N10°E Jt- 75/S60°E Jt- 60/N50°E	Orthoanaclinal	>35°, S45°E, straight	H- 40 W- 70	Low diss., Barren land	Active	Road cutting	Road
267	R/B of Alaknanda river, opposite side to Gholtir (Convent school) 30° 19' 41.073" N 79° 7' 1.218" E	Quartzite Debris cum rock	High	Not visible	-	>45°, S40°E, straight	H- 85 W- 10	Low diss., Barren land	Active	Local stream and rainfall	Nil
268	On road (at Vanthapla) 30° 18' 40.264" N 79° 6' 12.574" E	Quartzite Debris cum rock	Moderate	Bd- 45/N50°E Jt- 70/N80°W	Orthoanaclinal	45°, S20°W, straight	H- 25 W- 45	Moderate diss., Barren land	Active	Critical mass on steep slope and road cut	Road
269	On road, R/B of local nala 30° 19' 11.900" N 79° 6' 19.742" E	Granitic gneiss Debris	High	F- 45/N35°E Jt- 45/N60°W Jt- 50/S50°E	Orthoanaclinal	>45°, S70°W, straight	H- 20 W- 35	Low diss., Barren land	Active	Shallow debris over rock on steep slope and road cut	Nil
270	L/B of Alaknanda river, at Gholtir, below agriculture land 30° 19' 18.698" N 79° 5' 45.660" E	Quartzite Debris (RBM)	High	Not visible	-	90°, N60°E, straight	H- 25 W- 150	Low diss., Agriculture land	Low	River born materials terrace eroded by river	Nil

271	R/B of Alaknanda river, below Kotki village 30° 18' 12.369" N 79° 6' 5.051" E	Quartzite Debris (RBM)	High	Not visible	-	>75°, S65°W, straight	H- 15 W- 85	Low diss., Barren land	Active	River born materials terrace eroded by river	Nil
272	L/B of Gholtir Gad, below Nail village 30° 17' 57.969" N 79° 5' 26.660" E	Quartzite Debris	Moderate	Bd- 45/N50°E Jt- 70/N80°W	Orthoclinal	>35°, S40°E, straight	H- 25 W- 45	Moderate diss., Agriculture land	Old reactive	Loose soil on steep slope and bank erosion	Nil
273	R/B of nala, on road 30° 15' 46.993" N 79° 4' 26.653" E	Quartzite Bouldary debris	Moderate	Bd- 45/S60°E Jt- 85/S10°W Jt- 65/N40°W	Orthoclinal	45°, S60°E, straight	H- 15 W- 25	Moderate diss., Barren land	Active	Shallow debris on steep slope and stream erosion	Nil
274	L/B of Gholtir Gad, north to Kot Talla 30° 15' 46.993" N 79° 4' 26.653" E	Quartzite Debris cum rock	Moderate	Not visible	-	>45°, S40°W, slightly concave	H- 150 W- 85	Low diss., Forested land	Old stabilized	Fractured and jointed rock	Nil
275	L/B of Alaknanda river, 500 downstream to Gholtir Market 30° 16' 48.708" N 79° 5' 7.157" E	Quartzite Debris cum rock	Moderate	Bd- 45/N60°E Jt- 60/S40°E Jt- 60/S40°W	Cataclinal	>45°, N75°E, straight	H- 35 W- 15	Low diss., Barren land	High	Boulder on critical slope and erosion by local stream	Nil
276	On road (2 km from Khadpatiya towards Koteshwar) 30° 17' 36.543" N 79° 4' 51.067" E	Granitic gneiss Rock fall	Moderate	F- 35/E Jt- 80/S40°W Jt- 75/N40°W	Orthoclinal	>45°, N15°W, straight	H- 45 W- 200	Low diss., Forested land	High	Fractured, jointed rock and road cut	Nil
277	At Lodala village below agriculture land 30° 20' 34.793" N 79° 3' 36.636" E	Granitic gneiss Debris	High	Not visible	-	45°, S30°W, slightly concave	H- 35 W- 250	Low diss., Agriculture & barren land	Old	Shallow soil cover on steep slope and stream erosion	Nil
278	On road, below Bhainsari 30° 20' 41.117" N 79° 3' 9.096" E	Phyllite Debris	High	F- 40/N80°E Jt- 25/N10°E Jt- 60/N40°W	Anaclinal	45°, S70°W, straight	H- 20 W- 30	Low diss., Barren land	Active	Extremely poor rock strength and road cut	Nil

279	At Jawaharnagar below road 30° 18' 53.419" N 79° 2' 32.552" E	Phyllite Debris cum rock	High – Very high	F- 45/N25°E Jt- 45/S60°W Jt- 55/S30°E	Orthoclinal	>35°, S, slightly concave	H- 75 W- 50	High diss., Forested land	Active	Exceptionally poor rock strength and stream erosion	Nil
280	Opposite side to Syund village 30° 20' 35.591" N 79° 0' 55.210" E	Quartzite Debris cum rock	High	Bd- 30/N40°E Jt- 55/N70°W Jt- 55/S80°W	Orthocataclinal	>35°, E, slightly concave	H- 65 W- 45	Moderate diss., Barren land	Active	Fractured jointed rock and surface drainage	Nil
281	Near Syupuri 30° 19' 34.272" N 79° 0' 41.471" E	Phyllite Debris cum rock	High	Bd- 45/N50°E Jt- 50/N30°W Jt- 70/N80°W	Cataclinal	45°, N70°E, straight	H- 55 W- 70	Moderate diss., Barren land	Active	Thinly laminated and weathered rock	Nil
282	R/B of Alaknanda river, opposite to Gulabrai Ground 30° 18' 44.003" N 79° 0' 14.085" E	Basic & quartzite Debris cum rock	High	-	-	>35°, S50°E, straight	H- 60 W- 100	High diss., Barren land	Active	Heavy rainfall, flooding and road cut	Road
283	L/B of Alaknanda river, on road 30° 16' 42.801" N 78° 58' 5.160" E	Quartzite Debris	Moderate	Bd- 70/N70°E Jt- 75/N30°W Jt- 35/S40°E	Orthocataclinal	45°, S60°E, straight	H- 45 W- 200	Moderate diss., Barren land	Old reactive	Critical mass on steep slope and road cut	Nil
284	R/B of Alaknanda river, 30° 15' 59.649" N 78° 56' 38.156" E	Quartzite Debris cum rock	High	Not visible	-	>45°, Due N, straight	H- 60 W- 70	Low diss., Forested land	Active	Poor strength of rock & toe cutting by river	Nil
285	On road, 500 m upstream to Narkota 30° 16' 18.587" N 78° 56' 20.694" E	Basics Debris cum rock	High	F- 70/E Jt- 50/W Jt- 80/N10°E	Orthoclinal	45°, S05°E, slightly concave	H- 35 W- 50	Low diss., Barren land	Active	Fractured, jointed rock and road cut	Nil
286	R/B of Kalu Gad, near Nawasu village 30° 15' 46.269" N 78° 56' 0.150" E	Phyllite Debris cum rock	Moderate	F- 60/S30°E Jt- 65/N70°W Jt- 30/N10°W	Orthoclinal	45°, N40°W, straight	H- 45 W- 100	Moderate diss., Forested land	Active	Low shear strength of slope forming material on steep slope and road cut	Road

287	L/B of Bachhan Gad, below Gahar 30° 12' 8.597" N 78° 55' 17.235" E	Phyllite Debris	Not visible	-	-	45°, S, straight	H- 35 W- 50	Low diss., Agriculture land	Old	Loose material on slope and stream erosion	Nil
288	L/B of Dill Nadi, just opposite to Fatehpur 30° 12' 58.684" N 78° 56' 9.565" E	Phyllite Debris	High	Not visible	-	45°, N50°E, straight	H- 35 W- 45	Moderate diss., Forested land	Active	Thick overburden over steep slope and erosion by Dil Nadi	Nil
289	On road, 1 km upstream to Kaliyasaur landslide 30° 13' 59.990" N 78° 56' 5.339" E	Quartzite Debris	Moderate	Bd- 30/S30°E Jt- 75/S10°W	Orthoclinal	>35°, N40°E, slightly concave	H- 30 W- 60	Moderate diss., Forested land	Active	Loose soil on moderate slope and road cut	Nil
290	Kaliyasaur 30° 14' 38.273" N 78° 54' 37.981" E	Quartzite Debris cum rock	Moderate	Bd-35/S Jt- 65/N60°W Jt- 65/N20°E	Orthoanaclinal	45°, N55°W, straight	H- 200 W- 250	Moderate diss., Forested land	Active	Fractured, jointed rock, road cut and toe erosion by river	Road

Disaster Mitigation and Management Centre
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