Sherwani Landslide Complex, East District, Sikkim – A case study

Mishra, P.
Director, E.R, Geological Survey of India
Saha, S.K.
Superintending Geologist, E.R, Geological Survey of India
Pushp Lata
Superintending Geologist, EPE Division, Geological Survey of India

Abstract

Sherwani landslide in Sikkim initiated in 1984 resulted blocking of road bench due to flow of debris and damaged the retaining structures owing to subsidence and reactivation continues every year during monsoon.

Geologically, the area is represented by low grade metamorphites of Daling Group mainly comprising phyllite, quartzite and variants of these rocks. The most prominent planar fabric in the rock is foliation. Three sets of joints in the rocks have also been recorded. The slope is mainly covered with heterogeneous material derived from old slide debris consisting of huge boulders, pebbles and cobbles set in a sandy clayey matrix with sporadic rock outcrops. The area has been divided into four zones viz. C, B, A and D, from north to south depending upon the nature, intensity of hazard and mass movement/wasting. C indicates a relatively stable zone, B and D zones are moderately unstable and A is the most unstable zone.

Zone C will be under distress due to head ward movement of Zone B which is also supported by the soil properties. Catch water drains and chutes along the existing nalas would be necessary to prevent the head ward movement of zone B as well as to increase the stability of the Zone C. Zone B shows subsidence and soil creeping at places. Small rock outcrops are exposed due to removal of debris cover as a result of creeping/sliding. Main causative factors are piping, reductions of shearing strength and toe erosion by the nalas. A number of berms with retaining walls founded on rock and properly anchored have been suggested to increase slope stability. Besides, catch water drains at suitable alignment and training of nalas (chute) are required to minimise instability. Zone-A is the severely distressed zone. Toe erosion of the existing nala, piping of finer fractions by the subsurface flow, reduction of shearing strength due to saturation, development of pore water pressure at certain stretches are the main causative factors for the different instabilities at different places. Remedial measures suggested are retaining wall on rock with anchors, training of nalas, berms, catch water drains and chute. Perforated pipes at about 10°-15° inclination towards the slope, filled up with filter materials to release the pore water pressure in the western part of the distressed zone are suggested. Zone-D is located below the road bench and extends upto the Teesta River. Slided muck is dumped on this zone. Bank cutting/ toe erosion by Teesta River during high flood regime is the main causative factor for instability. The existing toe protection wall provided in stretches at present is in dilapidated condition. A continuous wall along Teesta river bank is suggested to prevent erosion. Suitable plantation in this zone is also suggested. Proper maintenance of the walls, contour drains, chutes etc. is required in regular interval, for effective functioning of the remedial measures.

1. Introduction:

Sherwani landslide in East District, Sikkim initiated in 1984 and reactivation continues affecting ~550 m of road length at about 1.2 km away from Singtam on Singtam-Dikchu Road. Singtam is about 30 km from Gangtok on NH 31A connecting Siliguri & Gangtok. Its activeness is evidenced by: (i) subsidence and movement of road culvert (ii) huge amount of debris used to come down, blocking the road and disrupting vehicular movement especially during monsoon (iii) subsidence in a portion of the road at the western extremities, i.e. towards Sherwani GREF camp/ Makha. Damaging of the culverts and retaining structures by the recurrence of slides (vi) two perennial nalas/ small waterfalls flowing over the road bench eroding the top cover of the road on the eastern extremities and central portion. The causative factors of slope instability of this huge slide complex varies from place to place which are due to (a) decrease in shearing resistance of the debris during saturation (b) piping of finer material through subsurface flow (c) bank and toe erosion by the nalas flowing over the distressed slope (d) development of pore water pressure (e) toe erosion of the Teesta River during high floods.

2. Regional Geological Set Up:

Sikkim and Darjeeling District, West Bengal forms a part of Eastern Himalaya. Rocks of this terrain are characterized by intense folding, shearing and thrusting. Rocks show an inversion of stratigraphic succession due to a number of thrust sheets. As a result, unmetamorphosed Siwaliks are overlain by Gondwanas, along Main Boundary Thrust (MBT). Similarly the low grade metamorphosed Daling Group (Phyllite-Quartzite) is overlain by high grade schist and gneiss of Darjeeling Group along Main Central Thrust (MCT). Besides the above thrusts, a number of other thrusts and faults have also sliced the rock. The contact between the underlying Gondwanas (Younger) with overlying Dalings (Older) is also thrusted. Stratigraphically, the area under study falls within Daling Group. A north-south set of fracture zone has developed across the east-west thrust sheet. This fracture zone is reported to be affected by neotectonic activities. Teesta River is flowing along one such zone.

3. Geomorphology and Geology of the Site:

3.1 Geomorphology:

Sherwani landslide is located on the left bank of south easterly flowing Teesta River. The distressed zone is confined on the southern slope of the WNW-ESE trending hill range. This hill range is a water divide between Teesta basin located to the south and Rongni chu, a tributary of Teesta, towards north, a sub-basin of Teesta basin. A number of old and new slide scars are present at this slope (plate I), some small nalas are also present within this distressed slope flowing mainly towards SSW. The distress zone is restricted mainly along the left bank of Teesta River between EL 300m and 500m however, the top rocky main slide scar is at about El 1200m, that is, at much higher elevation of the present distress zone. The slope of the distressed zone varies from 10°-35° with local variations whereas higher slope ($\sim 45^0$) is noticed at the reactivated small slide scars and at places below the road bench (plate-II-VI). Above the distress zone slope is comparatively gentler and continuing upto the base of the main slide scar (El 1200m). At some places concave surfaces have been noticed, may be due to uneven erosional activities. A number of small nalas flow along this surface resulting due to either surface run off or fed by springs/seepages. Widening and deepening of the nalas are noticed due to bank erosion of the loose debris material present at the surface. The distressed zone is located in between two perennial nalas flowing southerly (figure 1).

3.2 Geology:

The area consists of mainly old slide debris with sporadic rock outcrops belonging to Daling Group of Precambrian age (plate I). The rock types comprise mainly quartzite, phyllite and quartz–sericite schist with quartz veins. Quartzite is medium grained, hard and compact, varies in colour from off white, dull yellow to reddish yellow with less prominent planar fabrics. Phyllite is fine grained, well cleaved, pale green to grayish white to dark grey, often altered along the joints/fractures. Foliation varies from N10°W-N30°W/30°-50°northeasterly that is, dipping into the hill. Beside foliation, the rocks are dissected by mainly three numbers of joint sets. The attitudes of major/master joints are given below.

Joint set	Attitude	Spacing	Continuity	Nature of joint
Foliation Joint	N10°-30°W/30°-50°Ely	4-30cm	>5m	Smooth undulated (phyllite), rough undulatory (quartzite)
J1	N30°W /60°-80°SW	7-40cm	>5m	Rough planar
J2	N30°E /60°NW	7-30cm	>5m	Rough planar
J3	N50°-80°E/65°-80°NW/SE	4-20cm	>5m	Rough planar

The joint set J1show a valley ward dip, whereas J2 is dipping inside the hill and generally controls the drainage. J3 makes a high angle with the slope and shows dip reversals i.e. dipping either NW/SE. Minor to mesoscopic folds are also noticed. The plunge of fold axes varies from 28°-57° towards east. At some places quartz veins have been intruded along the closure of the folds. Closely spaced fractures have developed at high angle within quartz veins. Two minor shear zones (<15 cm), trending N60°W/55°Nly and N10°E/55°Wly are observed within the rock outcrops at road cutting and the other above the road bench at eastern extremity of the distress zone. The minor folds and the shear zones do not have major role in sliding. Phyllite and quartzite often shows high weathering along the joint planes. Wide gaps have also been noticed along these joints due to erosion of softer part. Due to weathering and closely jointed nature, the rocks have been crumbled and tend to fail.

The slope debris comprises of heterogeneous material derived from the old slide debris of the above rocks consisting of huge boulders, pebbles and cobbles mixed in a silty matrix.

Photograph 1 Sherwani slide showing main slide and recent scars.

4. Geotechnical Assessment of the Landslide:

Sherwani slide/distress zone is characterized mainly by debris slide and sinking/creeping of the debris material. The top slide scar appears to be stable at present as indicated by thick vegetation. Photograph-1 shows the present active zone of the slide. At the western fringe of the scar, a portion of the slide is reactivated through which debris used to come in recent past (photograph 2, figure 1). Present subsidence/ sliding/ slow mass movement are confined from a portion of the old slide debris. This distressing is observed upto El 500m from Teesta River bed (El 300m) (plate 1). Due to sliding /mass movement from this old debris material, rocks are exposed sporadically throughout the distress slope. Wedge failure and sliding are also noticed in the exposed weathered rock mass (phyllite-quartzite).

The area is divided into four zones viz. C, B, A and D, from north to south depending upon the nature and intensity of hazard as well as mass movement. (figure 1).

The zone C is located at the northern portion and is less affected. Zone B is located south of ‘zone A’ where slow mass movement and sinking is noticed. Zone A is severely-affected where mass movement is active and is located generally south of zone B. The zone D represents the portion below the road bench to Teesta riverbed, where instability resulted due to toe erosion during high flood.

Photograph 2 Reactivation of slide with debris flow path from the main old slide scar above “Zone-C”

5. Soil Properties:

To study the soil characters, five undisturbed soil samples were collected (figure1). Sample S1 was collected above the crown portion of the slide/sinking zone, located at the western part ('C' zone). S2 from a highly slushy area located at the center of the most vulnerable sinking zone ('A' zone) present at the western part. S3 is from the same zone, above the location of S2 (~25m above the road bench). S4 represents the east-central part ('A' zone) whereas sample S5 was collected beyond the eastern margin of the Sherwani distress zone. The analysis of data is given in Table1 and 2.

Table 1
Grain size Analysis in Weight %

Sample no.	Pebbles and granules	Sand	Silt	Clay
S1	30.53	20.78	47.97	0.72
S2	33.88	22.31	42.75	1.04
S3	48.3	20.99	28.93	1.78
S4	63.41	22.08	13.99	0.53
S5	31.68	20.913	44.26	3.15

Table 2
Test Report of Soil Samples

Sample no.	LL	PL	PI	Soil Group	Saturated moisture content (%)	Shear parameters (under saturated moisture content, consolidated and undrained condition)	
						C (kg/cm^2)	φ
S1	32	27	5	ML	35.18	0.400	16^0
S2	25	19	6	ML	N.D.	N.D.	N.D.
S3	26	20	6	ML	N.D.	N.D.	N.D.
S4	n.d.	n.d.	n.d.	n.d.	16.92	0.300	23.5^0
S5	43	34	9	CI	26.16	0.395	17^0

N.D: not determined

S1 and S5 collected from the undisturbed zone shows higher percentage of finer fractions (silt dominated). Nevertheless, the silt percentage is gradually decreasing within the distress zone from north to south i.e. from less distress zone to highly distress zone indicating removal/piping of finer particles (silt and clay) from the debris material through subsurface flow.

The slushy nature of ground (western part) and the mudflow occurred after penetration of the iron tube for a few inches while collecting the sample S2 indicate that the soil has exceeded the liquid limit and is no more in plastic state. In such condition, migration of material along with water is a common phenomenon, causing instability of the soil mass. At this place, the top surface material is relatively impervious in comparison to the underlying, which is more pervious and saturated causing upward thrust. As a result, the impervious top layer has become unstable due to increased uplift pore water pressure.

The shearing resistance of the materials in the unaffected zone is very low making it susceptible to sliding in case the materials are charged with water.

6. Geotechnical Aspects of Different Zones:

6.1 Zone C

Zone C, represented by old slide debris, utilized for cultivation with a few habitats, at present is unaffected (Plate I, IV-VI). A debris flow path initiated from the top most slide scar (EL 1200m) is present at the northwestern portion of this zone, through which debris has come down (plate I).

Causative factors and remedial measures:

This zone is under the threat of distressing due to gradual headword movement the slides of Zone B & A, located in the down slope. The physical properties of soil also indicate their susceptibility to sliding. The shearing resistance (sample S1) of the materials is very low making it susceptible to sliding during saturation. A series of catch water drains, preferably at every slope break with construction of chutes along the existing nalas are suggested to improve the stability of the zone.

6.2 Zone B

It is located between Zones A and C and is mainly characterized by presence of debris with small outcrops of phyllite-quartzite (plate I, II & IV). A subsidence scar is observed at the top i.e. towards upslope direction with few small subsidence scars here and there. Sliding/creeping of the top debris material has exposed the in situ rocks at places. These rocks show weathering depending upon the composition (phyllitic/quartzitic). A few small nalas are originated in this zone mainly in southern part, due to seepages from the contact between rocks and overlying debris (photograph 3). The gabions provided to prevent rolling of boulders along the nala flow at the eastern extremities of this distress zone are completely damaged.

Photograph 3 Nala generated from seepages from debris-rock contact

Causative Factors and Remedial Measures:

Reactivation of sliding /subsidence due to reduction of shearing resistance, piping of finer particles and toe erosion along the nalas are the main causative factors. Small wedge failures are also noticed due to adversely oriented joints, though the rock outcrops have been considered relatively stable. Weathering, also play a crucial role for failure.

A number of berms with retaining/breast walls may be provided at this zone. Since, rock is expected at shallow depth, the concrete retaining/ breast walls may be founded on the rock. The walls may be anchored with the rock present below and weep holes be provided. To minimize infiltration (i.e. ingress of water during heavy downpour), catch water drains above the crown, i.e. at the contact of zones B and C and inside the zone B are suggested. Besides, construction of chute along the existing nalas flowing through the distressed surfaces is also required to prevent bank/toe erosion. Training of the two nalas flowing along the eastern and western boundary of the distress zone is also required. Proper maintenance of the drains to avoid blockage and repairing of cracks should be undertaken to avoid overflowing of drains and preventing seepage through cracks, otherwise gushes of water will penetrate into the underlying natural mass, which will deteriorate the shear resistance and cause slide.

6.3 Zone A

This is the most severely affected zone, located south of Zone B and just above the road bench. Sliding of the old debris is noticed in this zone resulting to development of new slide scars with a prominent subsidence in the soil making concave topography (plate-I - VI). Evidences of creeping of soil/debris are also observed like bulging of sausage wall. It has also been observed that the hillside drains are not continuous and sometimes the water flows over the road damaging the bench and creating slope instability due to scouring. Seepage points have given rise to the formation of nalas. High pore water pressure is observed in western part of this zone. Mudflow due to excessive pore water pressure was noticed while collecting soil sample S2.

Causative Factors and Remedial Measures:

The causative factors are same as in Zone B but the intensity of the agencies responsible for failure is more. The nalas are gradually widened due to erosion on both the banks resulting slope instability. These nalas are also carrying the old debris material from the top and dumping at the road and in down slope. Reduction of shearing resistance due to saturation and piping of finer material along rock-debris contact through sub surface flow are also responsible for sliding at some places. Moreover, development of pore water pressure during super saturation at some places (western part) plays an important factor for failure as discussed in under the heading of soil character.

Remedial measures like benches, retaining wall from rock with anchors, training of nalas etc. are required as suggested in Zone B. At the western part development of pore water pressure (S2 and S3 locations) - the main causative factor of subsidence requires to be reduced. Perforated pipes filled up with filter material at about 10^0-15^0 inclined towards the slope should be required to release the pore water pressure (plate II) and the released water be guided through catch water drains. The hillside drain on the road bench should be made continuous and the water should be guided to the existing nalas to avoid flow of water over the road bench.

6.4 Zone D

This zone starts below the road bench and extends upto the left bank water edge of Teesta River (plate-I - VI). Average slope is 30^0. The area is mainly covered by dumped slided muck, which has come down on the road bench and to a lesser extent by river borne material. High and low flood levels are distinctly marked with floodwater scar and vegetation. A small retaining wall is present 30m below the main box culvert whereas a disturbed toe wall is noticed towards Makha. The water from the upslope flows through the culvert and along few untrained nalas. Subsidence is noticed in newly built retaining wall and culverts (photo-4). Seepage is noticed mainly through cracks and not through the weep holes.

Photograph 4 Subsidence cracks developed on the newly constructed box culvert on the road bench

Causative Factors and Remedial Measures:

The main causative factors are toe erosion of Teesta River. In addition, water from the upslope flows along few untrained nalas causing slope instabilities.

A toe wall along the Teesta River bank is proposed to prevent toe erosion. The earlier suggested training of nalas flowing on the distressed zone including eastern and western extremities of the Sherwani slide should be continued upto Teesta riverbed. Suitable plantation within this zone is also required.

7. Conclusions & Recommendations:

Sherwani distressed zone is causing slope stability problems like sliding, creeping, subsidence etc. since 1984. The site is mainly covered with old debris with sporadic rock exposures of mainly phyllite, quartzite and intermediaries. The rocks are dissected by foliation and other three sets of joints.

The distressed zone is characterised by sliding, subsidence and slow mass movement and has been classified as C, D, B and A, on the basis of intensity of distressing. C indicates a relatively stable zone and A is the most unstable zone.
Zone C is relatively stable, but will be under distress due to headward movement of Zone B which is also supported by the soil properties. Catch water drains and chutes along the existing nalas would be necessary to prevent the headward movement of zone B as well as to increase the stability of the Zone C.

Zone B shows subsidence and soil creeping at places. Small rock outcrops are exposed due to removal of debris cover as a result of creeping/sliding. Main causative factors are piping, reductions of shearing strength and toe erosion by the nalas. A number of berms with retaining walls founded on rock and properly anchored have been suggested to increase slope stability. Besides, catch water drains at suitable alignment and training of nalas (chute) are required to minimize instability.

Zone A is the severely distressed zone. Toe erosion of the existing nala, piping of finer fractions by the subsurface flow, reduction of shearing strength due to saturation, development of pore water pressure at certain stretches are the main causative factors for the different instabilities at different places. Remedial measures suggested are retaining wall on rock with anchors, training of nalas, berms, catch water drains and chute. Perforated pipes at about 10°-15° inclination towards the slope, filled up with filter materials to release the pore water pressure in the western part of the distressed zone are suggested.

Zone D is located below the road bench and extends upto the Teesta River. Slided muck is dumped on this zone. Bank cutting/ toe erosion by Teesta River during high flood regime is the main causative factor for instability. The existing toe protection wall provided in stretches at present is in dilapidated condition. A continuous wall along Teesta river bank is suggested to prevent erosion. Suitable plantation in this zone is also suggested. Proper maintenance of the walls, contour drains, chutes etc. is required in regular interval, for effective functioning of the remedial measures.

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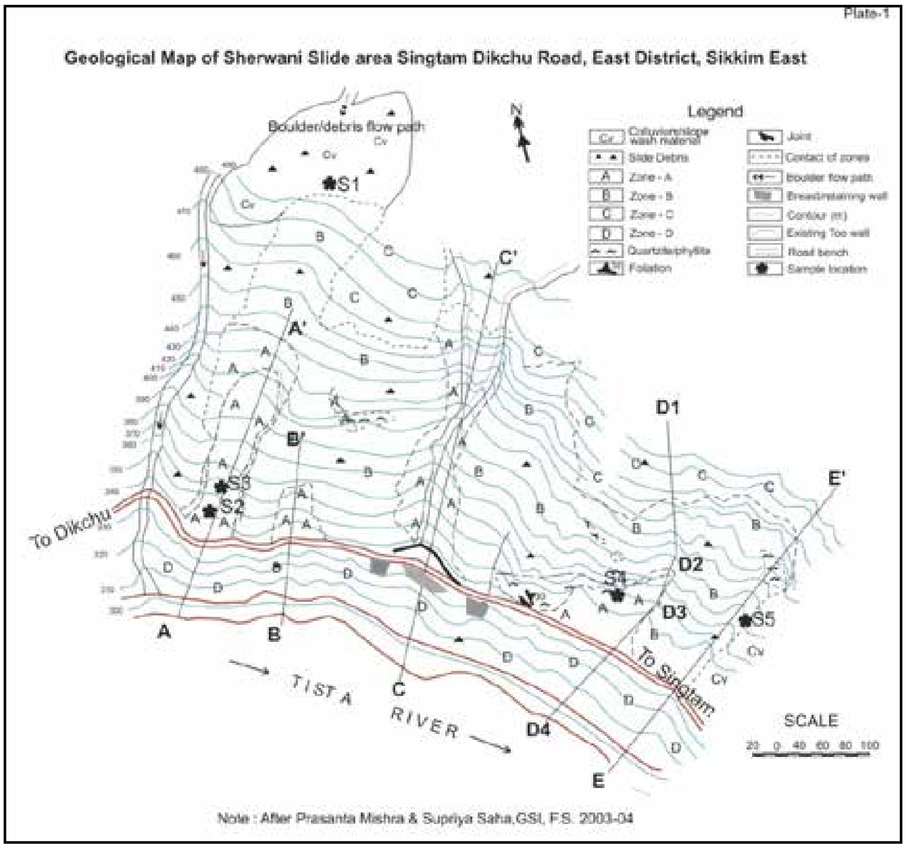
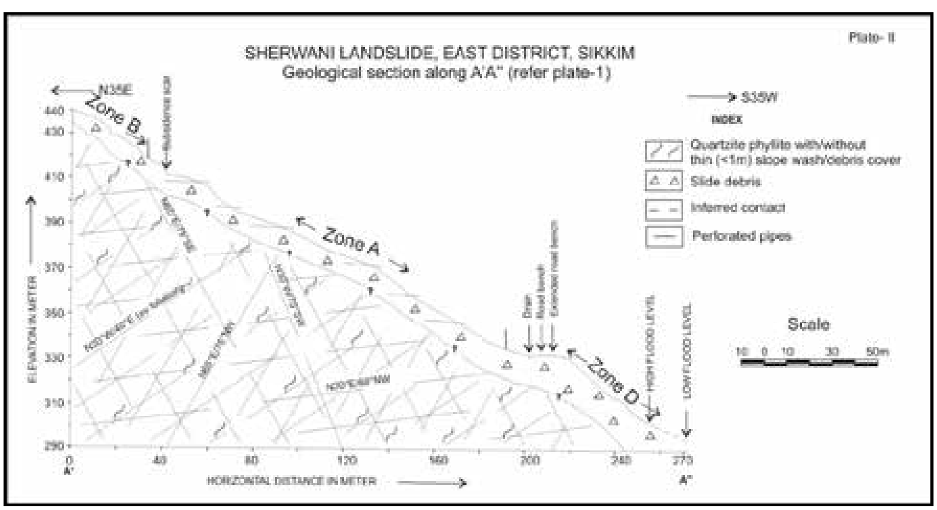


Geological Map of Sherwani Slide area Singtam Dikchu Road, East District, Sikkim East

Note : After Prasanta Mishra & Supriya Saha,GSI, F.S. 2003-04



SHERWANI LANDSLIDE, EAST DISTRICT, SIKKIM
Geological section along A'A" (refer plate-1)

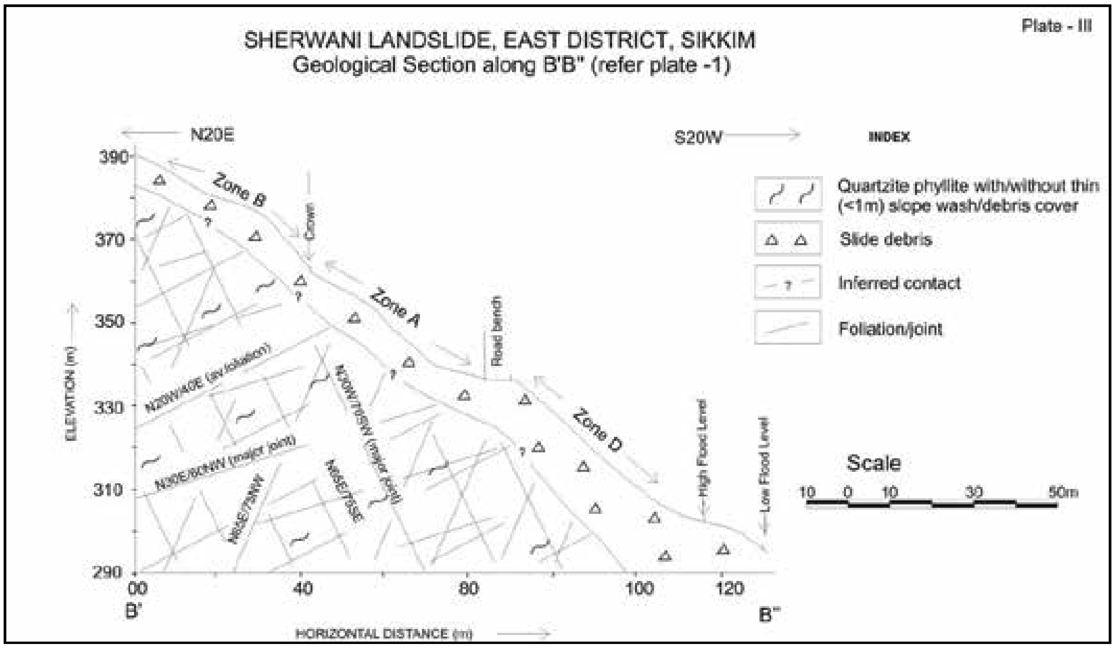


Plate - III
SHERWANI LANDSLIDE, EAST DISTRICT, SIKKIM
Geological Section along B'B" (refer plate -1)
N20E
S20W
INDEX
Quartzite phyllite with/without thin (<1m) slope wash/debris cover
Slide debris
Inferred contact
Foliation/joint
Zone B
Zone A
Zone D
Crown
Road bench
High Flood Level
Low Flood Level
N20W/40E (av.foliation)
N30E/60NW (major joint)
N70W/70SW (major joint)
N65E/75NW
N65E/75SE
Scale
ELEVATION (m)
HORIZONTAL DISTANCE (m)
B'
B"

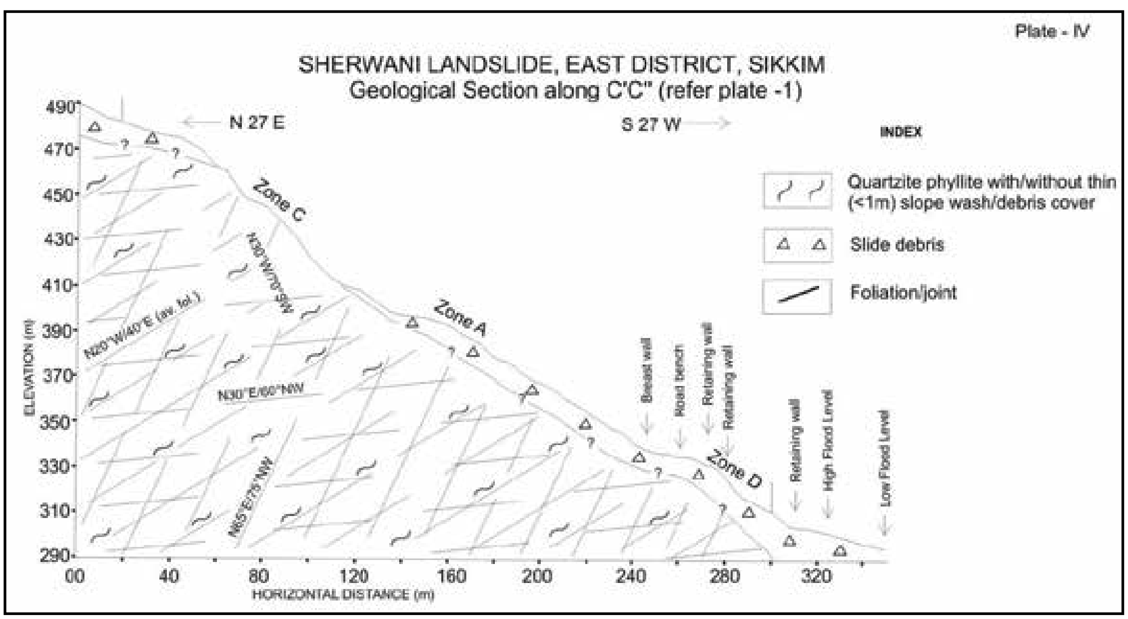


Plate - IV
SHERWANI LANDSLIDE, EAST DISTRICT, SIKKIM
Geological Section along C'C" (refer plate -1)
N 27 E
S 27 W
INDEX
Quartzite phyllite with/without thin (<1m) slope wash/debris cover
Slide debris
Foliation/joint
Zone C
Zone A
Zone D
N30°W/70°SW
N20°W/40°E (av. fol.)
N30°E/60°NW
N65°E/75°NW
Breast wall
Road bench
Retaining wall
Retaining wall
Retaining wall
High Flood Level
Low Flood Level
ELEVATION (m)
HORIZONTAL DISTANCE (m)

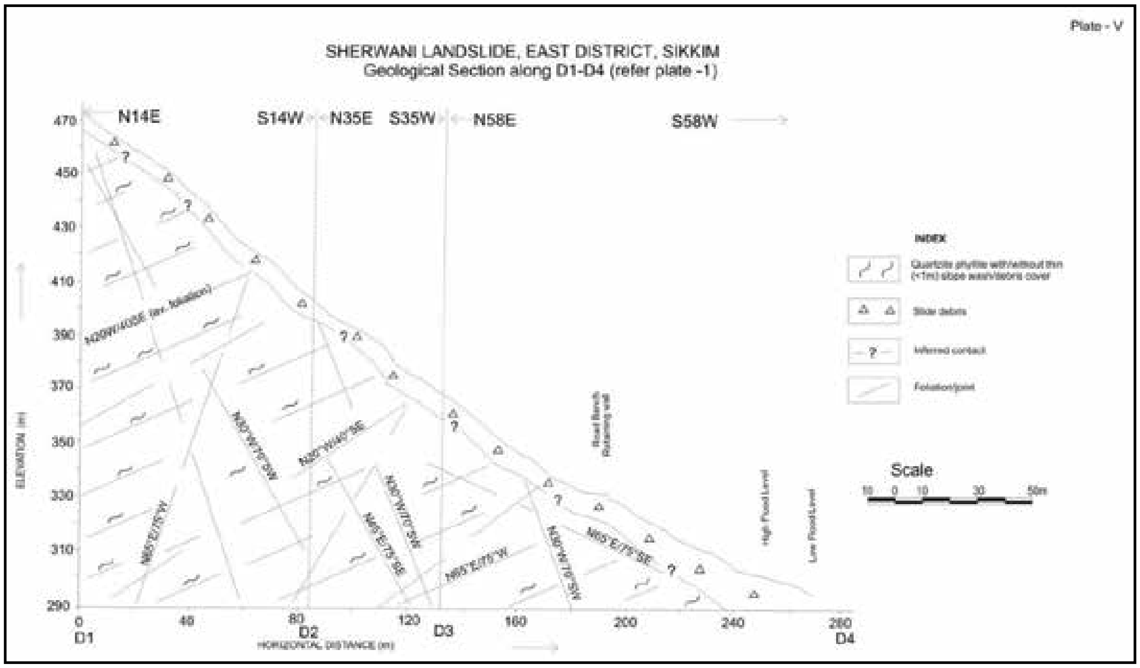


Plate - V
SHERWANI LANDSLIDE, EAST DISTRICT, SIKKIM
Geological Section along D1-D4 (refer plate -1)
N14E
S14W
N35E
S35W
N58E
S58W
470
450
430
410
390
370
350
330
310
290
ELEVATION (m)
0
40
80
120
160
200
240
280
D1
D2
D3
D4
HORIZONTAL DISTANCE (m)
N20W/40SE (av. foliation)
N30°W/70°SW
N30°W/40°SE
N30°W/70°SW
N65°E/75°SE
N65°E/75°W
N65°E/75°W
N30°W/70°SW
N65°E/75°SE
Road Bench
Retaining wall
High Flood Level
Low Flood Level
INDEX
Quartzite phyllite with/without thin (<1m) slope wash/debris cover
Slide debris
Inferred contact
Foliation/joint
Scale
10
0
10
30
50m

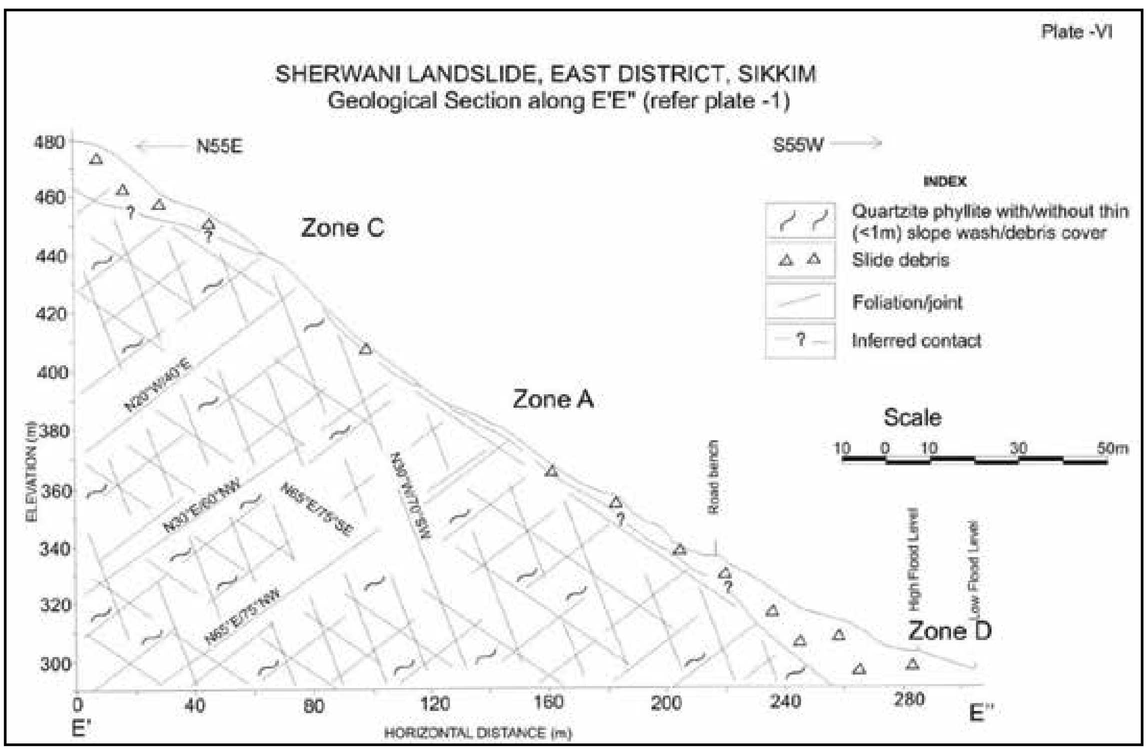


Plate -VI
SHERWANI LANDSLIDE, EAST DISTRICT, SIKKIM
Geological Section along E'E" (refer plate -1)
N55E
S55W
Zone C
Zone A
Zone D
480
460
440
420
400
380
360
340
320
300
ELEVATION (m)
0
40
80
120
160
200
240
280
E'
E''
HORIZONTAL DISTANCE (m)
N20°W/40°E
N30°E/60°NW
N65°E/75°SE
N65°E/75°NW
N30°W/70°SW
Road bench
High Flood Level
Low Flood Level
INDEX
Quartzite phyllite with/without thin (<1m) slope wash/debris cover
Slide debris
Foliation/joint
Inferred contact
Scale
10
0
10
30
50m