A REPORT ON

Geological Field Visit of Several Villages in Yamkeshwar Block, Pauri Garhwal

UTTARAKHAND

submitted by

UTTARAKAND LANDSLIDE MITIGATION AND MANAGEMENT CENTER

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1.0 INTRODUCTION

During the monsoon of 2023 particularly between 12th and 16th August, heavy downpour initiated many landslides and subsidence activities in various locations in Pauri Garhwal, resulted in damages at number of locations/houses and threatens the locals. In this context, Department of Disaster management, Government of Uttarakhand received a letter no 2023/1974 dated 30th September 2023 from the MLA, Yamkeshwar for executing geological field survey in various villages of Yamkeshwar, Dugadda and Dwarikhal block of Pauri Garhwal in order to find out the damage and causes of instability so that significance planning can execute to reduce the risk.

In this regard, two teams are constituent out of which team 1 has completed survey between 27th December 2023 to 2nd January 2024 in Yamkeshwar block of Pauri Garhwal. Following are the members of team 1 who have completed the field survey of 10 villages i.e. Kasaan, Tachla, Juledi, Bustola, Bukandi, Kothar, Sinduri, Udda, Bhadhni, Tallabanas (Kandakhal)

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2. Er Amit Gairola, Assistant Engineer, ULMMC

The Patwaries from Revenue department and Pradhan/Pradanpati of a particular village also joined during field work in their respective area. The following are the recommendations of the committee related to the site visit of the individual village between 27th Dec - 2nd January, 2024

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2.0 FIELD OBSERVATIONS AND RECOMMENDATION IN DIFFERENT VILLAGES

The observations, causes and recommendations for each village visited of yamkeshwar block of pauri garhwal are described hereunder

2.1 VILLAGE JULEDI

There are **four spots** identified where instability caused during August 2023.

2.1 .1 Spot 1 (Panipugri Tok): (Latitute 30°03'17.68" N, 78°21'17.6" E).

A) Observations: There are two houses includes 4 families (according to Patwari) settled in the spot 1 and experienced cracks on floor and walls of their houses during August 2023. According to resident, these cracks were first time visible in this site during monsoon of 2023 whereas previously, there were no cracks on ground and houses observed before monsoon of 2023.

Geomorphologically, the slope has several breaks i.e. at top, the slope gradient is 40°, at middle it is 20° and at base, it is 70°. The settlement that has subsidence issues lies in the mid slope of the hills sloping towards ESE. Just above this location, a metalled road is passing across and a landslide scarp is seen with 10-15 m in length and <100 m wide (Fig 1). The thickness of overburden at this spot is about 4-10 m. Six to Eight inch widen cracks oriented in direction of 311° (towards hill side) to 145° (towards valley side) are observed running oblique to road. Same trending crack (~2 m in length and <1 cm wide) is also observed in agricultural land. A rock outcrop i.e. slate is seen after 300 m ahead from this site along the road.

Presently the cracks on walls of house-1 are repaired whereas other house has not been repaired, and associated with poor construction and differential ground movement. From the distant view, it is clearly seen that landslide activity is also present at the base of hill where slope is very steep i e. >70° (Fig1a) but presently about 20-30 m horizontally away from the settlement.

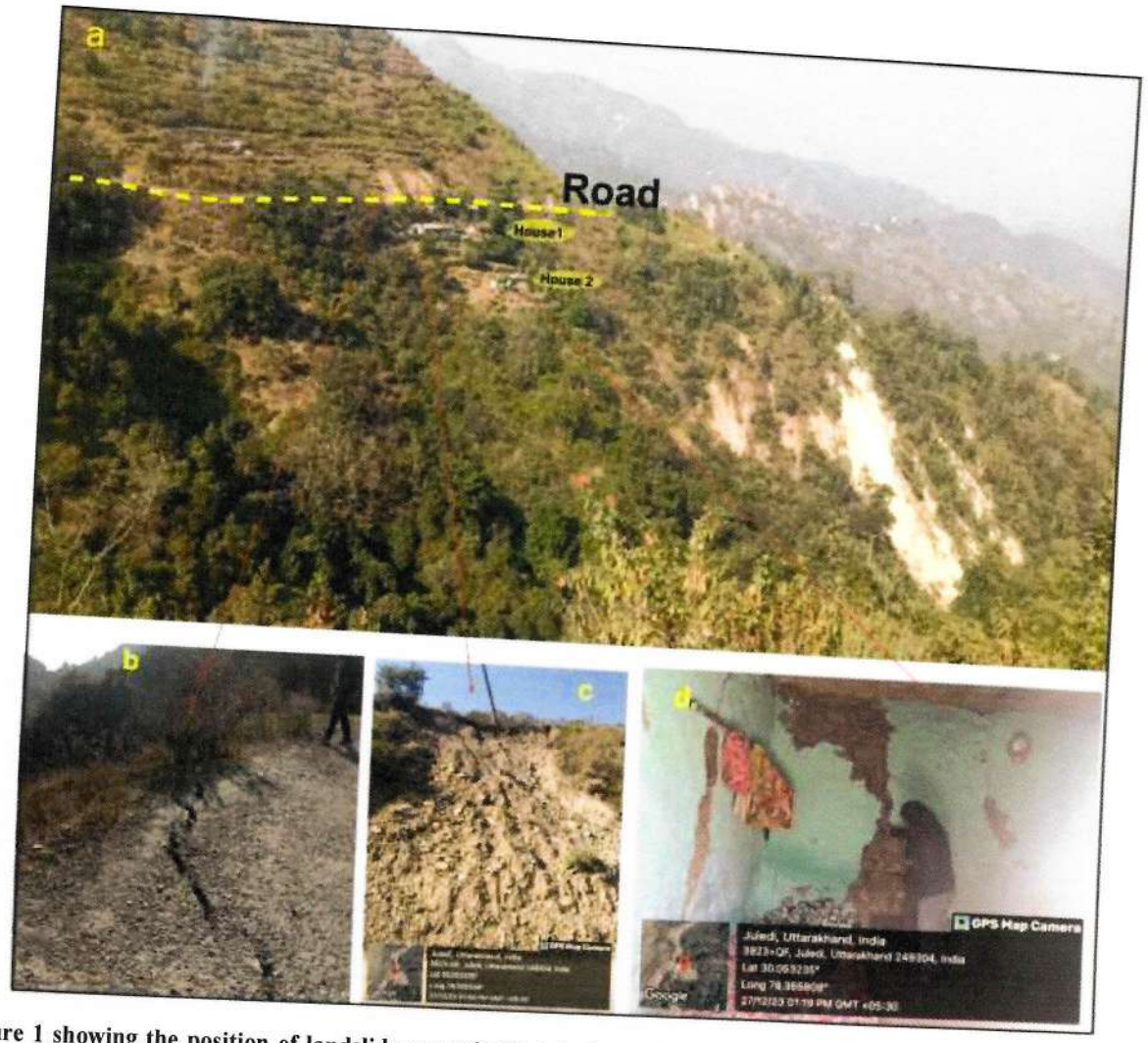

Figure 1 showing the position of landslide scarp in Spot 1 along with road cracks and poor construction of house-2 in which fallen plaster has seen

B) Cause

Due to the continuous and heavy rainfall, there were initiation of smaller scale landslide activity crown of which is above the road and settlement whereas toe of which is near agricultural lands near to house-1 (Figure 1) that causes instability/cracks in the area.

C) Recommendations

Since **the risk involve is low to moderate**, therefore following recommendation is need to taken into consideration

1. A **retaining wall is needed on road** side along with **side drainage** to channelize the flow of rainwater away from this scarp in order to arrest the movement. It is also advisable to make **contour drain** with impermeable base above crown so that water may not enter in the crown of landslide scarp and able to resist further movement

2. A **sign board** is needed at the site mentioning the date/year of landslide activity and warning to people to restrict the construction in this area as its landslide prone zone.

3. **Repair and filling of cracks** with impermeable material is recommended on road site.

2.1.2 SPOT 2 Bijakhet tok (N 30°02'25.5"/ E 78°21'00.0")

A) Observations

There are irregular pattern cracks observed at 5 houses located at Bijakhet tok but two houses are severely cracked. These houses are located at an elevation of 840 msl and above a large landslide that initiated in August 2023. The landslide is 40 m in length and 10 m widen. A previous constructed concrete footpath just above the head of landslide is also ished away. There are many widen tention cracks (upto 2ft deep) still present at crown of landslide in which 1-2 ft vertical displacement is noticed (fig 2). Above the landslide scarp, the affected area in which tensional cracks on ground visible is upto 8 m. In general, the houses that are far from landslide scarp are not having cracks whereas the houses located above the landslide crown having cracks. The severity of cracks in houses depends on their distance from the landslide scarp. Since houses are not located justaposition of landslide margin or very close to crown (approx more than 10 m away) therefore there is no serious risk involved for the people but chances of more visible of cracks and ground settlements during heavy rainfall after triggering of same landslide again.

Geologically, no rock is exposed in the site and landslide debris consists of sandy clayey matrix with no rock boulders therefore the overburden at agricultural lands may expect more than 10 m.

There is possibility of increase in landslide scarp as there are many open and deep cracks present on crown portion. If water will percolate further inside the cracks in next monsoon, there may chances of reactivation of the same and more visibility of cracks on houses. As the houses construction are of poor in nature with foundation lying on loose soil and only upto 1 ft in depth.

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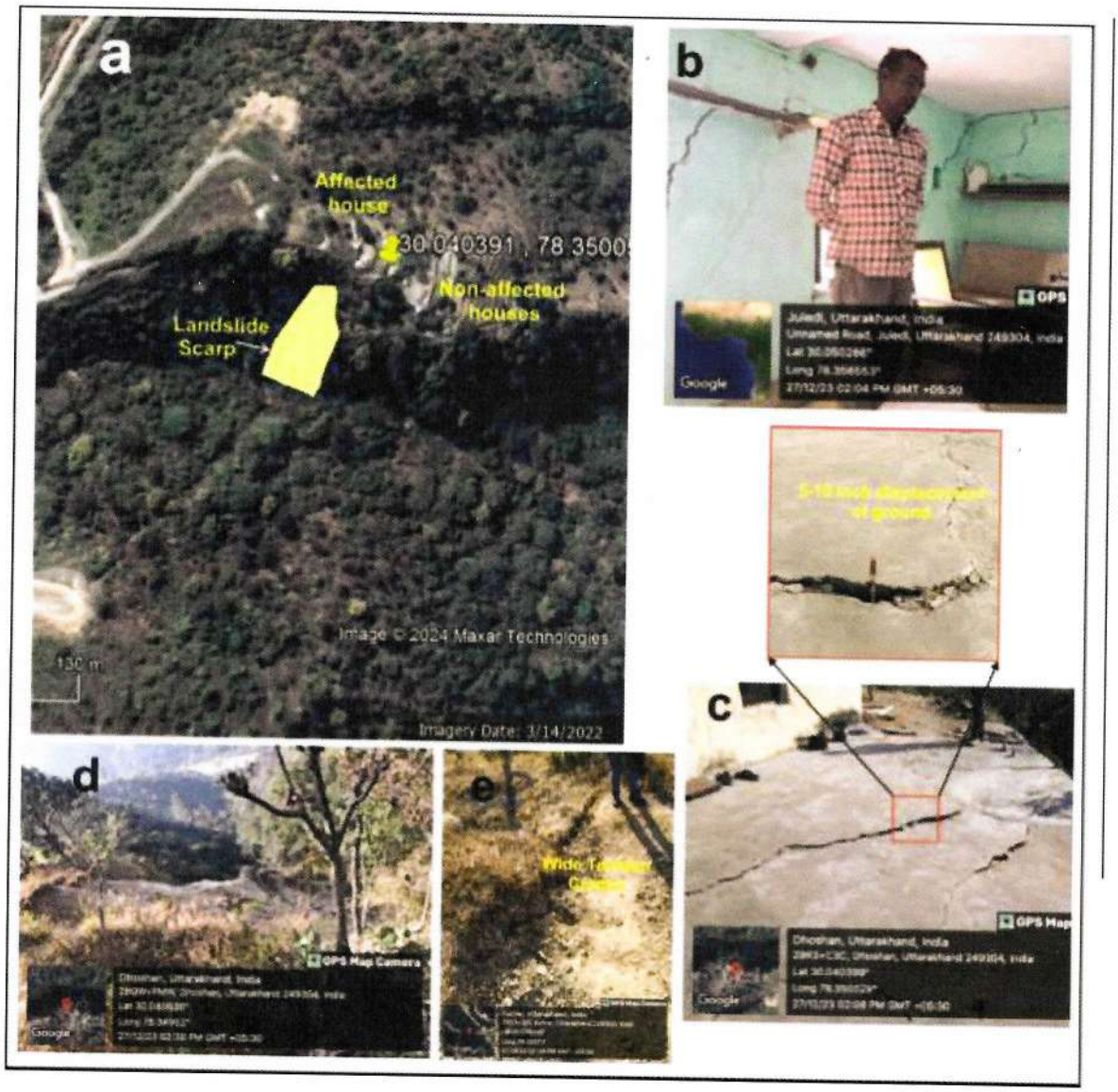

Figure 2 showing the landslide scarp as in yellow colour in satellite view along with damage in form of cracks on ground and house

B) ***Causes:*** Due to heavy rainfall of continuous five consecutive days initiated landslide and those house situated above the crown packed with substantial cracks on walls and ground

C) Recommendations/Suggestions

1. The area falls under **moderate to high** risk

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2. Since, the landslide material fallen down into the forest areas with no road and settlement below, is inaccessible and very steep (80°) therefore, providing any **mitigation measure is not possible** however **Early warning system (EWS) system** may consider in order to avoid unpleasant activity in future

3. The house that is severely affected has not been repaired therefore risk involved near future may not be monitored. It is desirable to instruct **related department to monitor whether the repair of the cracks is done or not**, if relief fund released to them as per the govt. norms otherwise repairment is advisable. It is important to monitor these cracks whether increasing or not showing any deformation in next season in order to provide safety to people and further planning which cannot be possible if repair work not be done.

2.1.3 SPOT 3 (Pani Pangdi Tok)

A) Observations

The Spot 3 is located at latitude 30.058963°N and longitude 78.356476°E at an elevation of about ± 820 m from msl and the slope faces towards SSE. At the base of the hill, a nala is present that further meets with a tributary of river Ganga i. e. Hewal nadi. The entire area is occupied by the slope ish material and the slopes, in general, are steep whereas flat (nearly horizontal) where only two houses are built. A landslide of 140 m length and 20 m width covered an area of 1658 mt^2 occurred on 16th August 2023 in which a house is completely washed out. The other house is situated justaposition of landslide scarp at an elevation of 800 m (Fig3). An another house is situated little far of this landslide site and does not show any significant cracks on wall and ground and subsidence.

Geologically, the rock is mainly phyllite with bands of quartzite and is thinly bedded, highly fractured and sloping towards the valley side. Therefore there may be chances of activation of landslide again during heavy downpour.

B) Cause : As a prima facie, it appears that the sudden landslide is caused due to the toe erosion of steep slope due to heavy gush of water at confluence of two first order seasonal rivulet positioned at the base of hills (Fig3) at an elevation of 780 msl during 16th August 2023.

Figure 3 showing the satellite view and location of house from far to closer view that located just above the landslide scarp and falling under high risk

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C) Recommendations :

No construction in future may allow in this spot with the **resettlement** particularly the family located in the margin of landslide. After relocating, it is advisable to damage the roof of house so that it may not occupy again along with **signboard mentioning "*landslide* *risk area and restricted for any construction*"**. Although other house in the region seems stable as presently no cracks seen and located at the middle of flat portion in ridge but both side seasonal rivulets are present, therefore in extreme rainfall condition, it would be in risk again as chances of landslide activity may not be overruled in both the side. Therefore monitoring and awareness is needed for the family and reporting if any tension cracks appear.

2.1.4 SPOT 4: (at Manikut parvat homestay)

A) Observations : The Spot 4 is located at latitude 30.054857°N and longitude 78.356418°E adjacent to metalled road which is 500 m far from Jhilmil gufa pedestrian track and about 200 m far from Spot 3. A private property named Manikut parvat homestay is situated at this spot which is presently closed for visitors. The backyard of the homestay building are packed with open tension cracks of < 1 ft wide and 10-20 m in length. Highly fractured quartzite rock and chunks of rock quartzite in soil are exposed along the open tensional cracks giving the possibility of fault scarp at this site. From Google view, many older landslide scarps are also noticed in this hill slope indicating landslide activity in past also occurred. The entire area is covered with thick slope ish material giving the clue that its already weaker zone and numerous arculate open, 1 m deep and ½ m wide ground cracks is visible in the area. There are no agricultural lands all around and no settlement except a guard looking after the property.

B) Cause: There is possibility of a fault passing in the area which fractured and crumbled the rock quartzite and hence weak zone prone to landslide, hence triggered by intense rainfall activity of August 2023.

C) Recommendation

1. It is recommended to **fill the cracks with impermeable material.** Since, there is no agriculture lands and families staying there and only a guard looking after the property therefore it is advisable of **resident of any person/guard/ family must avoid during monsoon** at this site. For that, a **signboard may be mounted**

2. There is possibility of landslide occurrence in the site as having many tension cracks which are open just at backyard of the main homestay building therefore **any sort of further construction and use of place during monsoon should be avoid**.

Figure 4 Satellite view of Markut Parvat homestay that exhibits wide open cracks located at the backyard. Note that satellite view is of 2022 and many older landslide scarps are visible. The yellow highlighted portion exhibit the presence of open cracks of about 1 ft wide

2.2 BUSTOLA VILLAGE

A) Observations: The village Bustola is located at latitude N 30.057799° and longitude E78.34658° and situated towards the base of hill. It approaches through the Dweli Daman

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village road. There is one spot located towards the left of the village Bustola along Dweli Daaman road (kaccha road) where a landslide scarp (8 m wide and 30 m high) occured that damaged the agricultural field and blocked the foot track approaching the village. A thinly bedded, light greyish green phyllitic rock is exposed at the road level at N 30.05781° (Latitude) and E78.345835°(Longitude) along village road side. The rock dips 38° towards NE with 15° dip amount. The slope direction is towards west in this location. The rock have tendency to get slippery when mix with water as possibility of having talc or chlorite mineral. A house is located at crown of this landslide scarp but as per information given by Revenue officer , no family stayed there.

Figure 6 exhibiting the field condition and condition of houses/ground in the village Bustola

Further, at the other spot in the main village, there are cracks observed in 2-3 houses that are located justaposition of another instable area towards right side of village. It is observed that only 2-3 houses having cracks out of which only 1 house of Smt Uma Devi has damaged. Due to poor construction and very shallow foundation, the water percolated and soil gets heavy and settled down and thus constructed houses initiated cracks. The most damaged house is resident of Smt Uma devi in which lots of seepage occured at ground floor. The ground floor of this house is constructed partially underground and thus more seepage occured. Just adjacent to this house, a new house is build in the area which does not show any cracks having suitable construction and foundation with pillars. Therefore it appears that cracks on house are not because any landslide and prominent ground subsidence but of poor construction and differential ground movement due to heavy rain.

Further ahead, due to heavy gush of water during heavy rains, a part of land of 30-40 m length and 4-5m in height ished down and settled at base along with uprooting of few trees.

B) Cause : At first spot, the slope forming material is composed of green coloured phyllite rocks that too is weathered and weak in nature and slippery when mix with water. Extreme rainfall event for continuous 4-5 days initiated the slide . Towards the other side , soil erosion has been noticed. Only 1 house majorly experience cracks on floor and wall and falling of roof plaster and is link with and soil erosion at base and differential movement due to seepage associated with poor construction practices.

C) Recommendations:

1. The area falls under **low to moderate risk**
2. There are houses situated in middle of slope in such a fashion that blocked the natural flow of water, therefore it is recommend to **make proper cross drainage** so that water does not enter in settlement areas.
3. **Flood protection wall may be provided at the base of hill where** a perinneal nala is flowing after ensuring the presence of only loose material or fractured rocks on side of stream, for that a project proposal may initiate from the irrigation department after visiting the site. Since the road is kuchcha where landslide initiated therefore special attention should be taken in Spot 1 when the road constructed in future at this site.
4. In order to control the erosion towards the end, **geojute** is recommended.

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2.3 VILLAGE KUTHAR

A) Observations : The Kuthar village is located in Pauri tehsil of Garhwal district in Uttarakhand, India and being awarded the Deendayal Adarsh Gram Award . It is situated 6 km away from Pauri, which is both district & sub-district headquarter of Kothar village. It is located at latitude N 30°04'3.3" and longitude E78°20'47.7" at elevation of about 981 m (on road side). The slope direction is towards N20°E. A landslide having 40 m height (approx) and 15 m width (approx) occured along Neelkanth –Kothar road after the prolounged rainfall for continuous three days in August 2023 that damaged the road approaching to village, waterpipeline , agricultural lands and also threat to the houses and temple located near the crown of the hill. Four houses and a temple of Mata Bharvi Bhawani are situated just above the landslide crown poses serious threat to their stability. The drains of these houses and temple are towards the same slope. Adjacent to this landslide scarp, an another landslide scarp is also observed in which one house is located at close proximity and top of a smaller scarp with all house hold water draining towards the landslide site. As a temporary arrangement, the portion of upper disturbed slope are being covered with plastic sheets.

Geologically, no rock is exposed in the site and the entire slope is comprises of clayey silty material which is wet in nature. Geomorphologically, the slope direction is towards N20°E with landslide affected area steepness varies from 30° (middle portion) to 80° (top). Below the road, first order seasonal nala is present. The slope forming material is wet in nature and percolated water is also present on roadside as the area does not received sunrays and in shadow zone.

B) Cause : During the continuous and heavy rainfall for consequently three days during August 2023, the slope comprises of clay rich slope got oversaturated at certain and swallower depth since clay are poor in permeability and landslide triggered.

C) Recommendations:

1. The area falls under **high risk for settlement above the landslide**
2. As four families are settled just above and margin of landslide scarp, therefore **relocating the houses are recommended in order to reduce the weight** on the top of the landslide zone and for the safety of temple.
3. **Repair the damaged water pipeline** ensuring no ingress of water into slopes

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Figure 7 (A) Satellite view of Kuthar village. The yellow highlighted portion is of landslide occurred on 17 August 2023. (b) landslide view and location of temple just above the crown (c) view of landslide from the top of the crown (d) the landslide site sloping towards north hence not received sunrays for longer hours and slope material is still \wet with water on road even during winter

4. A **step retaining wall** of (1-2 m) is recommended along the road side with side drainage and considering insitu condition of foundation material.

5. Since, the debris disposed in the valley side along the road after landslide activity, therefore it is recommended **to provide the support below the road with retaining wall with weep holes below road level.**

6. Since the slope is gentler in the middle **therefore bamboos, vetiver grasses** or any other plant species that may hold soil and strengthen the slope is recommended.

Special Recommendation: The road approaching to kuthar village is unmetalled and the area is developed than any other villages of the same block. Since, It is close to neelkanth temple and other tourist places like jhilmil gufa, therefore construction of metalled road is recommended that may helpful to develop area from tourism point of view.

2.4 VILLAGE SINDURI AT VEERKHATLI TOK

A) Observations: The Veerkatli tok of Sinduri village is located at latitude N 30.052435° and longitude E 78.398048 ° at an elevation of El ± 600. The slope direction is 60° towards ENE. There is no road connectivity in the area and approached through a foot track. The agriculture is being practiced on these slopes extending from the height of 640 m till the steep slope present. Only Two houses are situated at an elevation of 600 msl in a hill sloping towards east whereas a sub tributary of river Ganga is flowing at the base at an elevation of 540 m. Along both side of sub-tributary, landslide occurred (Fig 8). Towards the left side of river, the slope comprises of debris with boulders of quartzites of 1-1/2 m dia whereas towards right side, highly fractured, fragile rock quartzite and shale is exposed dipping towards south. The slope is sub-vertical near the base of the hill whereas ~20° where two houses are situated and again slope is highly steep (~70°) on the top of hill. These houses that located at the middle of the slope are packed with cracks on walls and ground whereas their location are far from the landslide site, therefore the cracks are due to poor construction and differential ground movement during heavy downpour. An another swallower landslide occurred along the spur adjacent to house-2 however the front face of this landslide, its extend and associated degree of risk cannot be estimated due to topography of terrain and hence the width and height may not estimated.

B) Cause: The cracks are due to poor construction and little differential ground movement during heavy downpour.

C) Recommendations

1. The area falls under **low risk**
2. The house-1 may **implement necessary repairs** whereas house 2 may be shifted towards its left from present position as falls near the edge of hill/spur to the rivulet where landslide occurred in August 2024
3. Smaller bridge (may be wooden) is recommended as during extreme condition , there is no escaped route for villagers and the area is only approachable by crossing the river

Figure 8 Field conditions and condition of houses in Veerkaatli tok of Sinduri village(Red arculate portions denote landslide scarps developed in the monsoon of 2023)

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2.5 VILLAGE BUKANDI

A) Observation: Bukandi village is located on the left bank of the Tyodi gad that is sub-tributary of river Bean. It is connected by a newly constructed road in which construction is still in progress and highly disturbed in various sections. Therefore, due to the slope cutting, many landslides occurred along the entire road site. Many spots along the newly constructed road are blocked during the monsoon of 2023 and opened after the monsoon. Also, it observed that muck is disposed near valley site and at one of the spot, the muck further run towards downslope and damaged the agriculture land of villagers situated at the base near the confluence of Tyodi Gad and Tal river confluence.

There are several damaged spots in and around Bukandi village where cracks on road, houses, agriculture lands and several landslides occurred.

The first spot is located at latitude and longitude of N 30° 02'23.17" and E 78°22'7.52". At this site, 5 cm widen crack aligned in the direction of 150° – 330° is observed on road site that further runs across the primary school building located at the top. Below the road, agriculture fields and vegetation growth is present due to which the direction of the cracks cannot be traced beyond. There are no cracks seen on open ground in front of school building but cracks are present on floor and wall of school building

On the way of Spot no 2, highly weathered rocks cliff are exposed dipping towards NE (40°) with an dip amount of 60° and muck dumping towards the valley site along the road with multiple landslides and can be a direct consequence of unscientific slope cutting and improper disposal of muck.

The sub-village of Bukandi known as Katali (Spot 2 at N 29°58'15.27" & E78°20'50.71" at an elevation of 800 m from msl), where few houses settled near to highly weathered and crushed rock i.e. phyllite observed giving clue of presence of fault along the entire valley thus initiated landslide activity. The orientation of fault is parallel to Nala i.e. 160°-330°. All the houses are kachcha and build with stones with slanting roof. There are no damaged occurred in Katali as houses are located at considerable distance from faulted. however just close to slope edge, cracks are seen on ground. The landslide activities are common in both side of valley due to exposed of fault and weathered rock. It is observed that few house is either located at near to

valley side or in just contact with hill slope although lot of space are available which resulted allow the water to percolate and ooze in from the backside of houses as houses are of kuccha in nature and constructed of stone blocks.

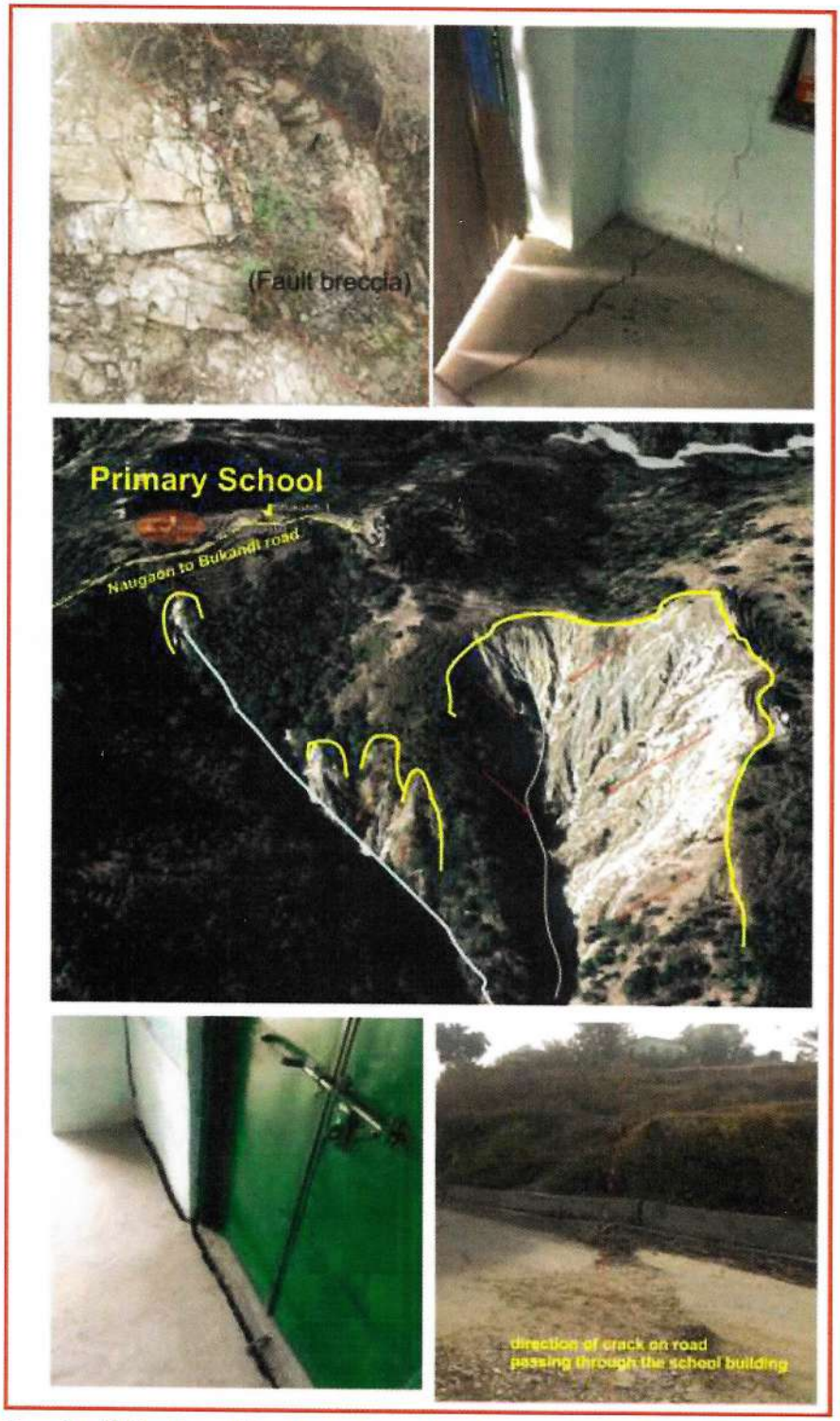

Figure 9 exhibiting the condition at spot 1 where landslide scarp can seen below the school building . A crack observed in the school building as well as on road is just extension of landslide scarp.

Figure 10 Photographs of Spot 2 of Bukhandi village

B) Cause: Due to poor and highly weathered rock, landslides scarps appeared majorly on nala sides. Many places got unstable particularly where there may be possibilities of fault as shown by few geological and geomorphological evidences.

C) Recommendations:

1. The area falls under **moderate risk**
2. Recommendation to **repair and reinforce the damaged school structures**.
3. **Instructions to construction company** to follow guidelines on **disposing muck dumping.**
4. **Awareness programs** are needed for villagers as they should know the safer and unsafer place and response during the unpleasant activity with coordination of local authorities.

2.6 VILLAGE BADHNI

A) Observations: Badhni is situated along the left bank of Tal river at N 29° 59' 00.2" (Longitude) and E 78°21'00.6" (Latitude) with considerable elevational difference from the river base. The houses are scatterily constructed on nearly flat slope with wide agriculture lands. There is no road connectivity in the area and thus vehicle moves only on river bed to approach this area. The area is isolated during the time of monsoon when Tal river having high flow rate.

A swallower ~3-4 m high landslide scarp with few uprooted trees seen in the area marked by yellow dashed line in figure 11 in the slope facing 220° (SW). The detached portion accumulated at slope break and not reached to settlement. No cracks have seen in any of the houses and agriculture field are flat and at considerable elevation from the river base. An outcrop of weathered phyllite is noticed giving clue that there is thin cover of overburden.

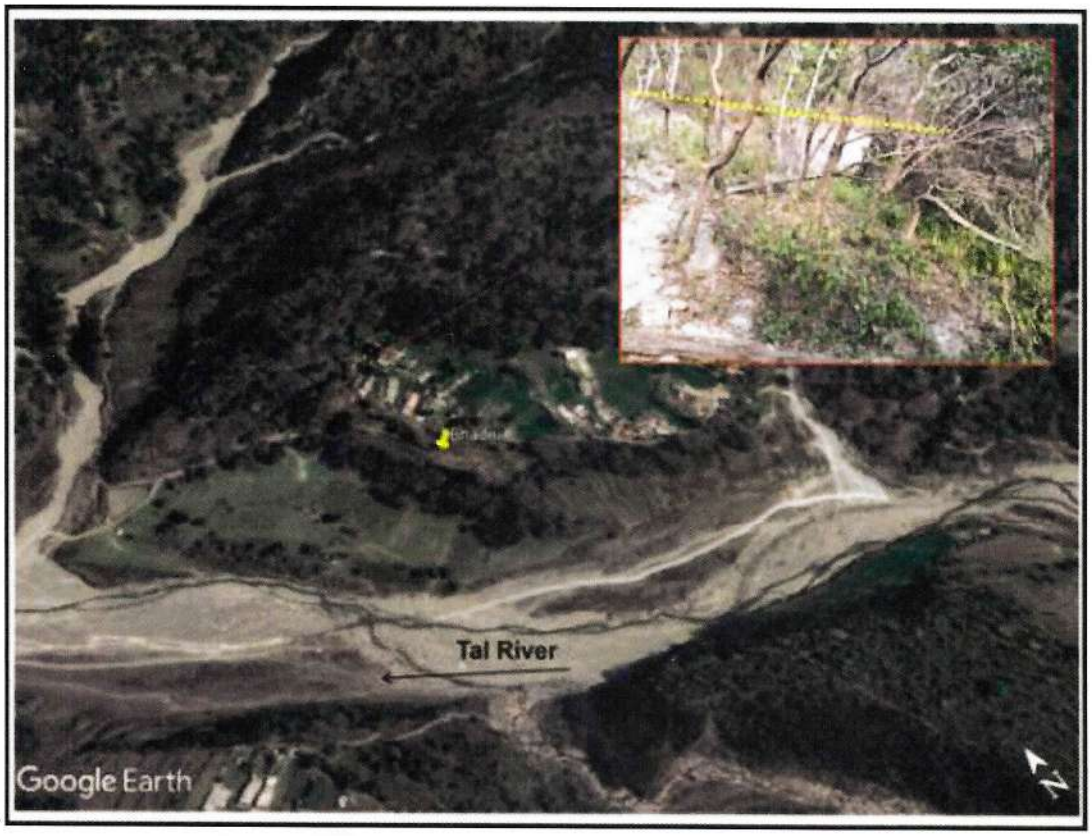

Figure 11 showing the location of Badhni village which is almost flat area having 8-10 m elevational difference from River Tal

B) Cause: The heavy rainfall in August 2023 resulted, outish of small patch of land portion in Bandani village where overburden is thin and which has not impacted on residential area.

C) Recommedations

1. The area falls under **low risk zone**
2. A wide portion may dig out **to accumulate** debris at back side of settlement ensuring the safety of houses with proper water drainout pipes and also **removal of disturbed uprooted and fallen trees** which settled just above residential houses. However, it is noticed that 1ft wide ditches are already digout to install waterline. It must be ensure that such work must complete before monsoon otherwise such dig portions may accumulated water helping to trigger the swallower landslide activity.
3. It is advisable that **construction of road and bridge** are necessary to approach the area with scientific and technical support of expertise and special attention to the fact that river bean and tributaries showing signature of active environment in form of landslides, toe cutting and sediments deposition.

2.7 KANDAKHAL (TALLABANAS)

***A) Observations*:** There are three spots identified in the village Kandakhal where slope instability occurred in form of presence of cracks and ground subsidence that initiated on 12th August 2023 and further accelerated.

The first spot known as Aamkatar tok in Kandakhal village located at latitude N 29° 58' 26.4" and longitude E 78°20'00.3" with scattered houses lying at the top and middle of an arc shaped ridge. The houses at spot 1 showed significant wide cracks on walls and ground indicating severe structural damage (Fig 12). This is evident in approximate 6 ft long and 3-5 cm wide cracks on floor of houses. The slope direction is towards North with major 2 ft deep tension crack orientated in direction of NE-SW appeared on agriculture field. A house is situated at latitude and longitude of 29°59'21.38" N and 78°19'2.61" E where at the back site, a scarp developed in the direction of 120°-300°. N-S oriented nala appear of extreme left of the site.

The residents are stillinhabiting in the damaged houses despite the unsafe conditions. Geologically, the spot 1 having thick soil cover of dark brown clayey soil with no rock outcrop.

The Spot 2 is located along the metalled village road where many houses are in cluster. There is no risk identified except the initial evidences of subsidence in form of tight wall cracks in few houses and settled portion of road (Fig 12).

At Spot 3, many smaller swallower landslides appeared in this site with 4-5 numbers of wide 1 m deep tension cracks appear on top of ridge. Due to occurrence of multiple landslides, a foottrack is highly damaged towards the slope direction i.e. N75° (towards East) but not affected any houses.

B) Cause: The village and houses are located on clay rich soil with many places having steep slopes and arculate shaped. Since, the clay bearing soil has low permeability therefore swallow landslides may common during heavy rainfall.

C) Recommendations:

1. The Spot 1 **falls under moderate to high risk.** Thus, resettlement and rehabilitation is recommended at Spot 1.

2. The Spot 2 have **low risk** therefore **monitoring of this area** is required.

3. The Spot 3 have **low to moderate risk,** since only 1 house located at top of the hill at Spot 3 below which landslide occurred but slightly far from landslide scarp therefore the house is not under high risk but probability of landslide may occur in this zone due to widen tension cracks. Therefore, it is suggested that if there are abnormal movement and cracks appeared then inform local authorities for further action . Presently, **no action required at this site.**

In addition EWS may install in the area to monitor the deformational changes

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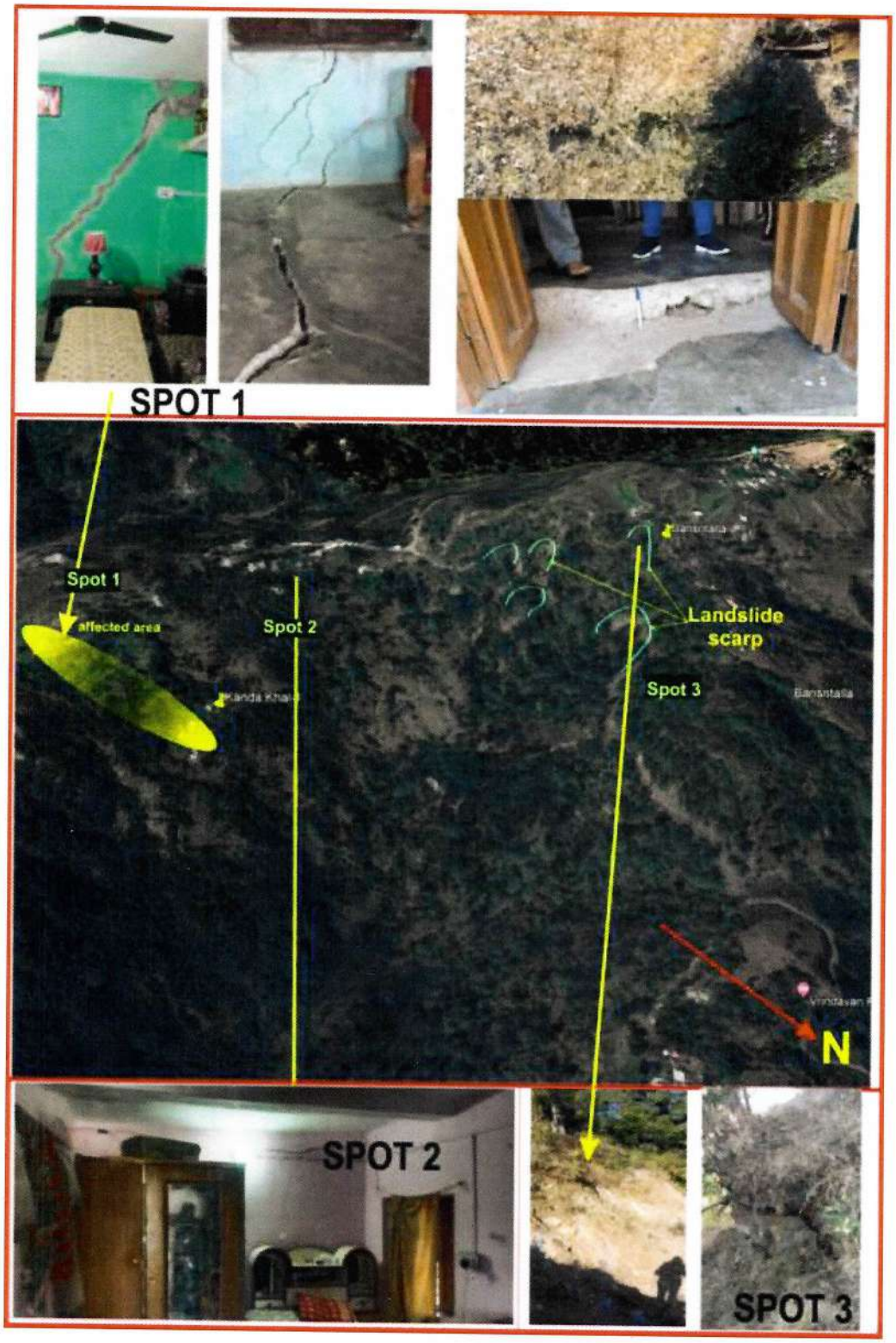

Figure 12 represents the condition of houses affected during August 2023 in three spots in Kandakhal

2.8. VILLAGE KASSAN (KIMSAR ROAD)

A) Observations: The village kassan is located at latitute N 29°48'26.57" and longitude E78°14'26.42" in moderately gentle slope facing towards NE and approached by Kimsar road. The village extends along an arculate ridge and form a small catchment (Fig 13). The entire area is covered with thick overburden without any rock outcrop and clayey soil present is wet in nature giving clue the soil is permanently having fully water saturated through out the season and over saturated during monsoon. The debris flow, subsidence and landslide problems are common in this area since many years and a major landslide occurred in 1972. In 2007, 4 people died in landslide activity in the area and again instability occurred during August 2023 . The cracks on houses appeared on 10th and 11th August 2023 and after 2 days landslide occurred. As a consequence a major crack found on road with 1 m depth and 1 ft widen in three places on road. The direction of cracks are N10°E-S10°W perpendicular to road width. The gully erosion is also commonly seen in the agriculture area.

B) Cause: Geologically and geomorphologically, the area formed a small catchment with thick overburden comprises of clay rich soil. Since clayey soil have low permeability and due to agricultural practices, the infilteration rate of water is slow and run out is more and at certain depth the soil starts flowing after mixing with water.

C) Recommendations: The area formed small catchment, presence of clayey soil with no presence of strong rock up to greater depth, wet environment as sloping towards north which adversely impacted on instability of an area and not suitable for population, therefore may consider for **rehabilitation.**

OR

Appropriate and quick action on implementation of the mitigation plans in form of closely network subsurface and surface drainage plan and debris flow ditches are required that reduces the water in filtering considering the properties of slope forming material.

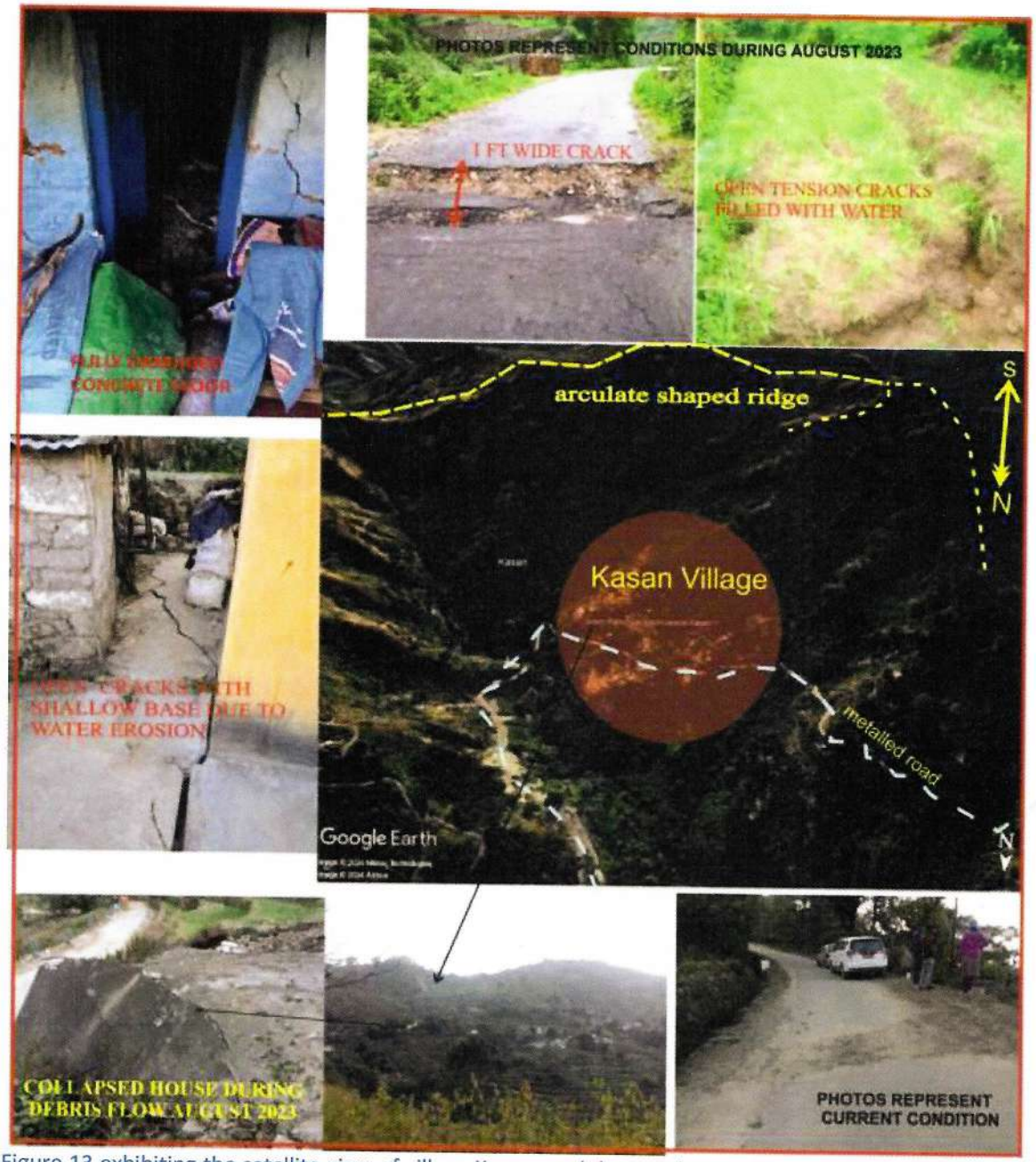

Figure 13 exhibiting the satellite view of village Kassan and damaged occurred during monsoon of 2023. Presently, the cracks on roads are temporarily repaired

2.9 VILLAGE TACHLA

A) Observations: The Tachla village is located at latitude N 29°53'42.64" and longitude E 78°24' 48.71' and settled in various clusters at different elevations. A newly aligned kaccha road named Amola Chaurani motorable road is constructed till altitude of 1028 m from msl. This approach road is constructed having very sharp turn and need to widen at turns before metallized it. A main cluster of houses are lying on top of hill where no instability caused except one house which is very old and having cracks. As a prima facie, it appears that the cracks are due to poor and old construction and not related with any ground subsidence since no cracks seen on ground. A new house is also now constructed besides this old house. Also, the trunks of 3-4 cutted trees are also noticed near house.

Figure 14 exhibiting the sites of landslide activities in Tachala village

Further, crossing the village at latitude 29°53'42.64' N and longitude 78°24'48.71'E on slope towards NE, a school is situated in which no sign of instability and subsidence occur and located at safer place. The outcrop of limestone and greenish basics rocks which are very strong strengthwise exposed in the area giving clues that thickness of overburden/soil cover at this site is not greater. Further tracking down along a foot track on NE slope, outcrop of micaceous schist exposed and 4-5 swallow landslides appeared. The debris consists of boulders of metabasics and

limestone and shiny and slippery micaceous rick clay –silt matrix. Since there is no settlement below this track, therefore no risk involved (Fig 14).

B) Cause: The multiple swallow landslide occurred due to heavy flow of rain water and surface erosion in steeper slopes (>50°) facing NE.

C) Recommendation: There is **no risk identify** along the foot track and top of hill where sparsely populated area is located. Therefore, **no measures are recommended.**

2.10 VILLAGE UDDA

A) Observations: There are three different spots identified in village Udda where instability caused in the monsoon of 2023.

The first spot is located at latitude of N 29°59′45″ and E 78° 22′ 10.6″ along Chaurani- Amola road where due to landslide activity the portion of road got damaged. The intense and prolonged precipitation on August 2023 initiated landslide at this site in which a road section of 100 meters is damaged. The debris comprises of 1-2 ft chunks of phyllite and quartzites. Geologically, the slope is covered with thin overburden with rocks dipping towards North. The percolation of water is also observed at this site (Fig 14)

The second Spot lies in the middle of east sloping hill at latitude N 29.993884° and longitude E 78.369316° having an elevation of 1100 m from msl. The under construction heavy 4storey building is established which is damaged due to the landslide activity occurred during August 2023 at this site (Fig 14). Other than this heavy building, one more house is damaged lies just above this building due to the landslide activity. Near the heavy building the weathered rock phyllite is exposed. There are presence of houses and school at top of same hill at an elevation of 1200 m from msl and imposed risk to their stability due to the hill cutting and construction of heavy structure. Further moving ahead along a foottrack towards uphill, a crack is mapped oriented at 310° -130° parallel to hill ridge above the heavy building exhibiting the slope is in stress. At the crown of landslide scarp, 1 m displacement is clearly seen near the damaged house. At the top, no cracks seen on ground and outcrop of strong rocks i.e. metabasics and quartzite are present. The rocks are dipping towards North with dip amount of 10°.

The third spot showing multiple smaller scars generated during heavy rainfall as both the side of Spot 3, seasonal rivulet are present.

B) Cause: Due to heavy rainfall during August 2023, landslides occured Spot 1 and Spot 2 of Udda village whereas new swallower landslide scarps developed at spot 3 without affecting the settlement but may be critical in future.

C) Recommendations: Based on our field investigation, the following recommendations are proposed to address the immediate and long-term consequences of the landslide:

1. **At Spot 1, Retaining wall with weep holes** are required with adequate drainage arrangements along the road side and also below the road level as part of road width is already affected due to landslide.

2. Geologically, **Spot2 appeared not safe** as due to highly weathered rock i.e. phyllite exposed and

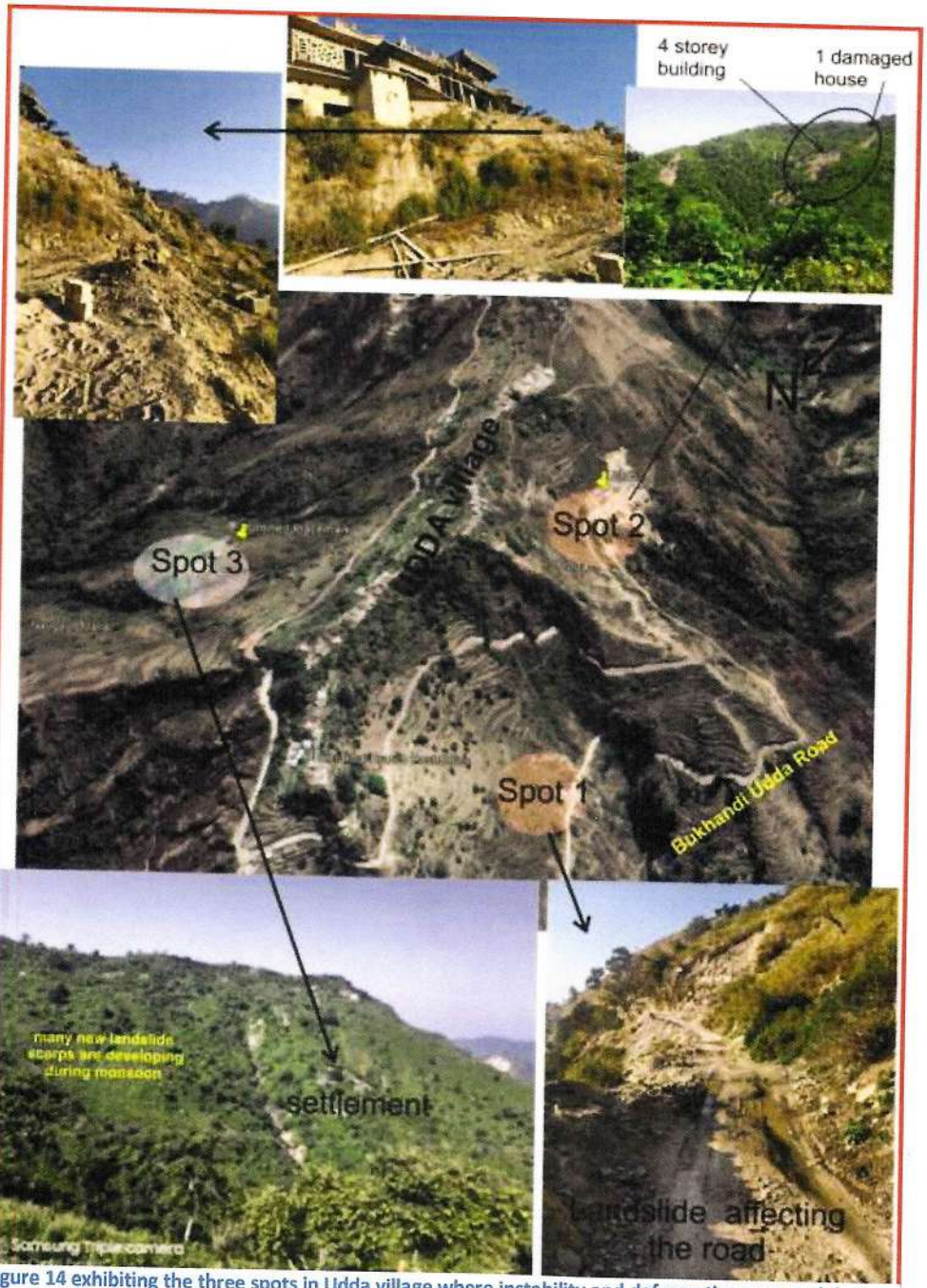

Figure 14 exhibiting the three spots in Udda village where instability and deformation occurred during monsoon of 2023

vertical ground cutting for construction of 4 storey building. Therefore, it should be instructed to the private owner to submit the **geological report duly signed with Govt official from Geological Survey of India** ensuring commenting the status of stability of the area and risk involved to the settlement above the hill along with resettlement of house located just above this heavy structure.

3. Spot 3 require monitoring and **installation of EWS** is recommended.

3.0 Additional comments

In addition to the location wise observations and suggestion given above, it has been observed that major of the villages are situated right and left side of the tributaries and subtributaries of River Ganga. At many places, there is no road connectivity in the area respecxially villages close to river Bean and its tributaries. A famous vidhyvasini temple is also located in the area. During the monsoon, the entire river is heavily flooded that causes the landslide activity in the area and erosion and deposition of high suspended particles. A debris carried out by river is large in amount therefore the base of the river is continuous filling up by river born material. There are trees whose truck are totally buried under the RBM, therefore the level of HFL is continuous increasing in abrupt rate according to villagers (Fig 15). Geomorphologically, it has noticed that many villages are in risk of flood. Therefore necessary steps should be taken to **frame the policy and planning of scientifically dredging of RBM** in this area which will support the revenue for the state and also reduces the risk for villages and agricultural land from

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flood. Ignoring of such sites may harm several villages in future.

Figure 15 buried trees under RBM

Figure 16 muck dumping along valley side

Figure 17 exhibiting the erosion and wrong constructional practices

Secondly **road connectivity is essentia**l in the area . Presently there is no road connectivity and villagers use to move on river bed only for several kms to approach one village to another situated along riverside. During the time of disaster, there is no escaped route for the villagers. Therefore, **the developemental activities like road and a bridge construction** is recommended in the area.

Also, a road constructed from Naugaon to bhukhandi dumped the muck in the valleyside, during rainfall, these loose debris flowed towards further downslope and adversily affected the agriculture lands lying on the base of valley and damaged occurred. Such construction activities should be properly monitored otherwise secondary cause of damaging environment and also affecting livelihood.

Any new road alignment/ construction in this area should be done after survey, consultation of n of experts like geologist, geotech engineers as many regional as well as local faults are present in the area otherwise facing post constructional issues ***(Figs 16 and 17)*** *affected adversely our environment.*