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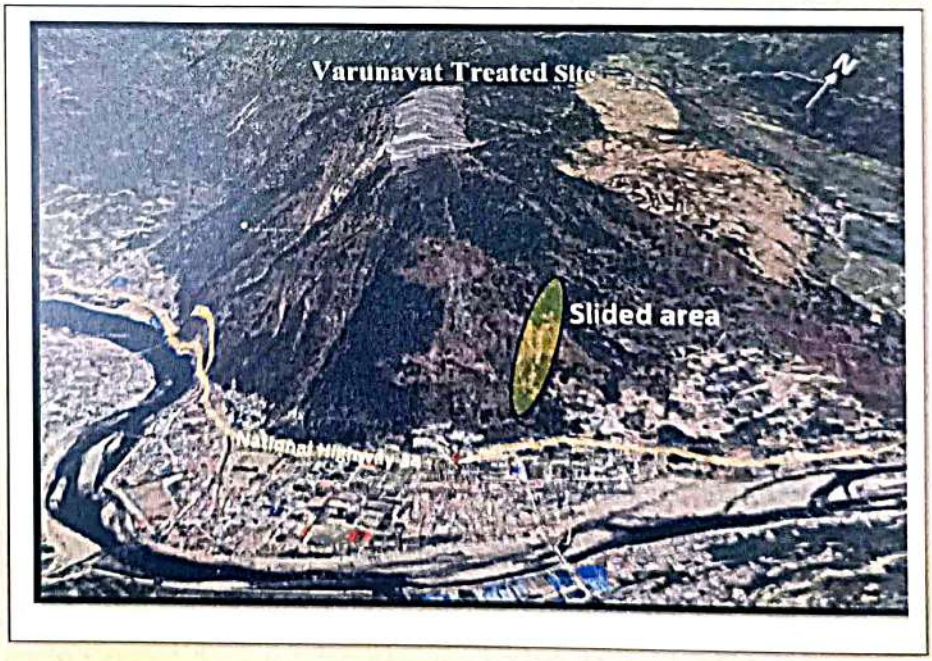
Technical Report on 27th August 2024 Gufiyara Landslide activity, Uttarkashi District, Uttarakhand

On August 27, 2024, a landslide occurred in the Gufiyara region, east of Vrunavat Hill, with no damage reported to the residential areas downhill. Given the proximity to nearby settlements and the area's history of a major landslide in 2003, a joint inspection was done by nominated persons from THDC, GSI and ULMMC to assess the situation, determine the cause, and suggest remedies.



टीएचडीसी इंडिया लिमिटेड
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Technical Report on
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1. INTRODUCTION

Uttarkashi Township, located in the Garhwal Himalayas of Uttarakhand, India, lies within the Lesser Himalayas. The town is situated in a broad valley surrounding the river Bhagirathi that flow in ENE→WSW direction in the vicinity. The area is bounded by steep ridges that rise sharply from the valleys and reach significant elevations. Varunavat Hill, located on the right side of the Bhagirathi River adjacent to Uttarkashi township, experienced a major landslide in 2003. This landslide was triggered by prolonged rainfall, which saturated the soil and weakened the already unstable rock layers, leading to a massive slope failure. The landslide caused severe damage to houses, buildings, roads, and other infrastructure as debris swept down the hill and enters into the town. Although engineering solutions, such as slope reinforcement, drainage improvements, and retaining structures, were implemented, regular monitoring of surrounding areas remains crucial in order to get earlier signs of instability, if any.

On 27th August 2024 at 11 p.m., a landslide occurred in the Gufiyara region, east of Varunavat Hill (marked in yellow in the fig1). While no damage was reported to the downhill residential areas, the proximity to settlements and the area's history of the 2003 Varunavat Hill landslide draw attention to the need for an urgent technical survey to assess the situation, determine the cause, and recommend remedial measures. A team visited the area from 6th to 8th September 2024 and following are the observation and suggestive measures of the team members

2. OBSERVATIONS

1. Location of Slided Area: The landslide area is located to the east of Varunavat Hill, above the Gufiyara Jal Sansthan colony between the lat/long of 30°44'5"N/78°27'37" E and 30°43'55"N/78°26'39"E. It is quite distant from the Varunavat treatment site and is not connected or extension of the previous landslide activity at Varunavat Hill. The crown of the landslide area is situated at an elevation of ~1,470 meters above mean sea level, while the toe is at approximately 1,230 meters. Debris cum rock failure has been reported from where the ground slope changes from 35°- 40° to 70°- 80°. Below the toe of landslide, there is a vegetated region, followed by the national highway and settlements (Fig. 2).

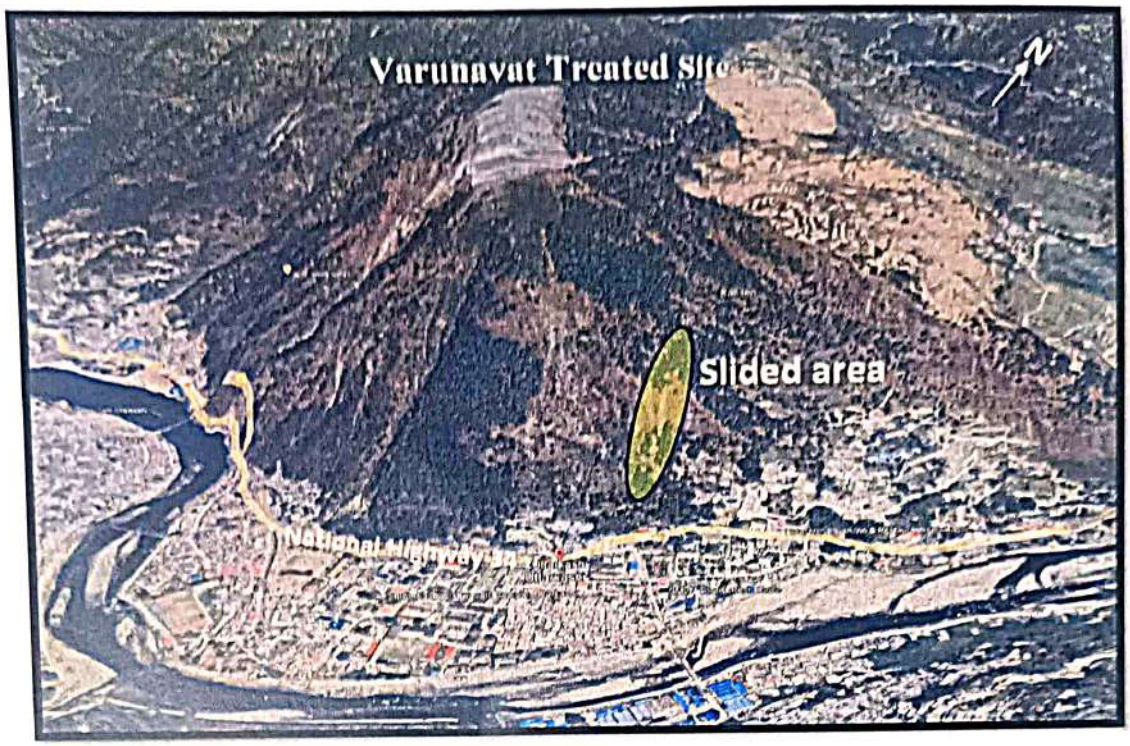


Figure 1: 3D Google view of Varunavat hill with marked recent slided area

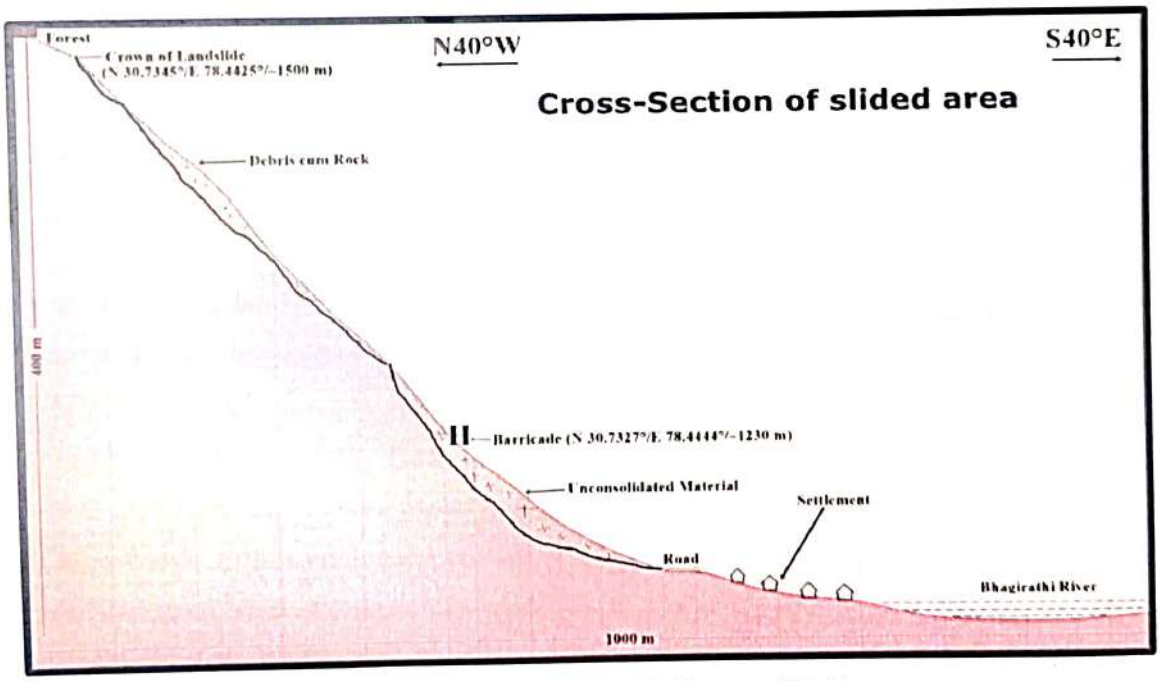


Figure 2: Cross section of Gufiyara slided area

2. Above the Crown area: The crown of the landslide is located at a slope break at about 1470 m, above which the slope is covered with thick vegetation, including grasses, cacti, and pine trees. No tensional cracks have been observed above the crown, and the slope above crown has an angle of 35-40 degree. Due to the moderate gradient, the estimated slope cover is 5-10

meters and consisting of cohesive, wet, clay-rich soil (Fig 3) above crown. No tilted trees were observed above crown.

Figure 3: Moderate slope gradient above crown with no sign of instability

3. Crown Area:

At the crown of the landslide, outcrops of quartzite and quartzitic phyllite are present. The inhomogenous and interbedded quartzite and phyllitic quartzite are well exposed in the upper and middle sections of landslide and sizes of quartzite bands ranges from several mm to few cm. (Fig 4) In contrast, highly fractured phyllitic quartzite is found on the left side of the landslide (Fig. 4b), which is more prone to failure. As a result, the possibility of the landslide expanding towards sides cannot be ruled out. The quartzite at the center is compact and sub horizontally aligned, with one prominent orthogonal sets of joints that are tight in nature but one dips towards outward direction. Due to steep slope and inaccessibility of exposed section, joint mapping could not be conducted. The width of the landslide scarp is approximately 10 meters at the top (at the crown) and 20-25 meters in the middle of the upper exposed section and depth of overburden is about 1-1.5 m at this site.

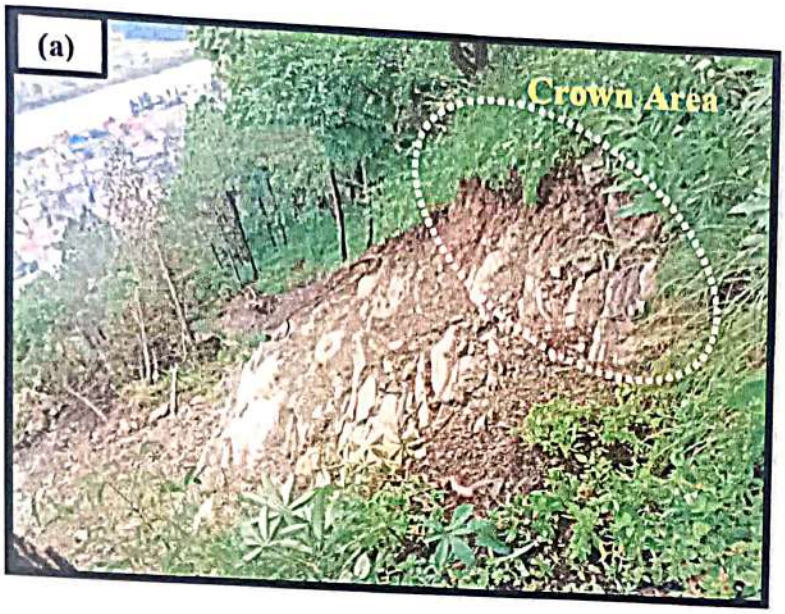
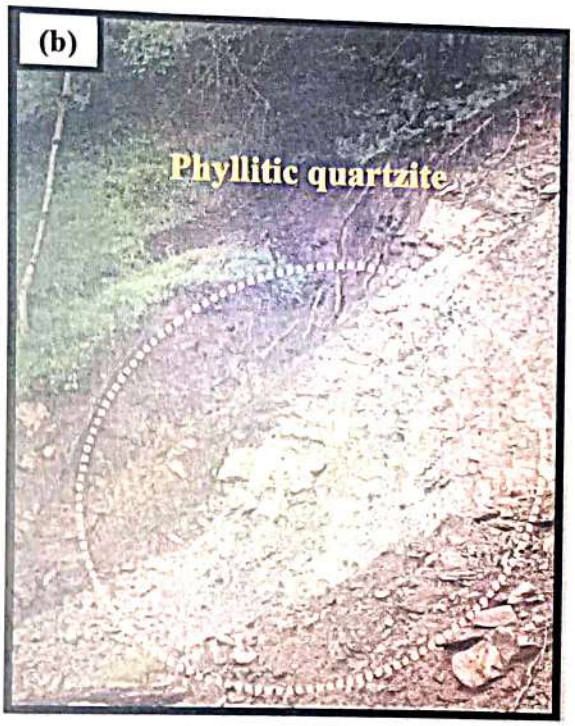


Figure 4: exhibiting middle portion of upper section where quartzite are exposed (Fig. 4a) and crushed & shattered phyllitic quartzite present at left portion (Fig. 4b) of landslide crown with hanging overburden (Fig. 4c)



4. Transported Area: Detached debris from the crown portion, consisting of quartzite boulders embedded in a sandy-silty matrix, is present throughout the slope. This debris is susceptible to further move towards downhill, especially under the influence of water during rainfall or seismic activity (Fig. 5).

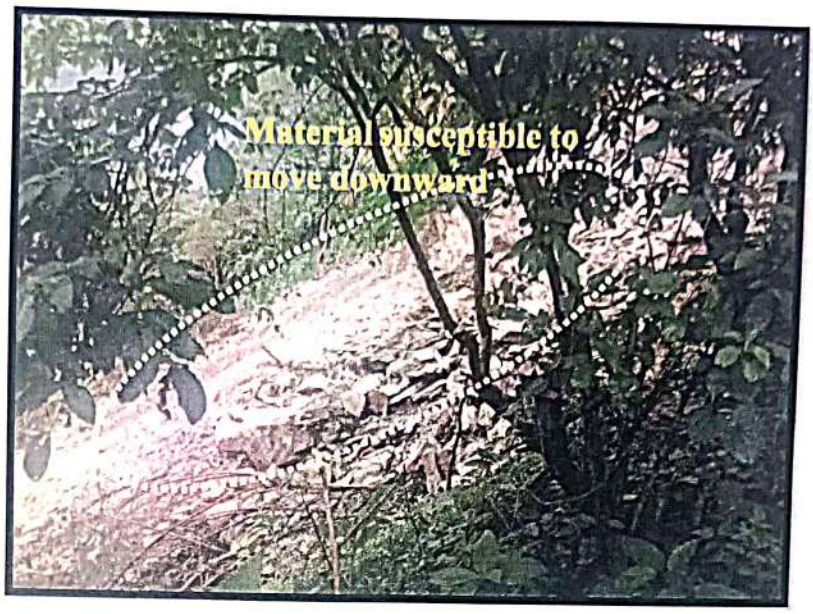


Figure 5: Loose debris consist of fine matrix with boulders of 1-3 ft rests on slopes and susceptible to move downward

5. Toe Area: The debris moved downslip was struck in barricade being constructed for the protection of downhill area (Fig. 6). The debris with boulders of medium size has been accumulated in stretch upto 1m height behind the existing barricade structure of app. 3 m height. However few boulders of size less than 1 ft and fine matrix was lying loose on the slope outside the existing steel barricade (El ± 1230) indicating the need of strengthening and expanding of protection walls/barricade for safety of downhill settlement and NH.

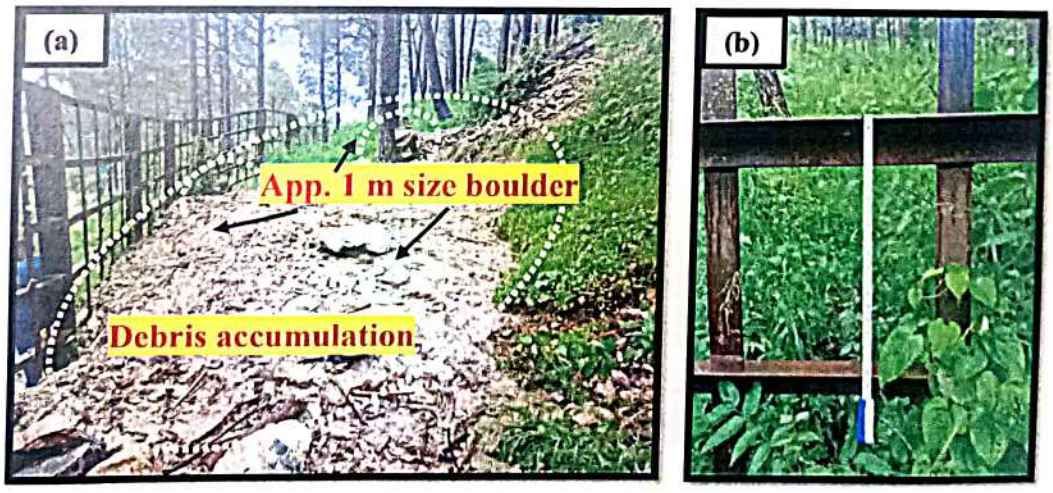


Figure 6: (a) Figure depicting the debris accumulation zone near barricade at elevation of about 1230 m and (b) size of opening of Barricade (app. 2x2 ft.)

3. ADDITIONAL COMMENTS

a. Gufiyara Nala:

- Gufiyara Nala, located approximately 100 meters from the landslide site, exhibits evidence of side cutting and poor maintenance (Fig. 7).
- The absence of proper outlets has resulted in the accumulation of loose material, which frequently obstructs the road.
- Existing retaining structures have suffered significant damage.
- Settlements in the vicinity of Gufiyara Nala are present

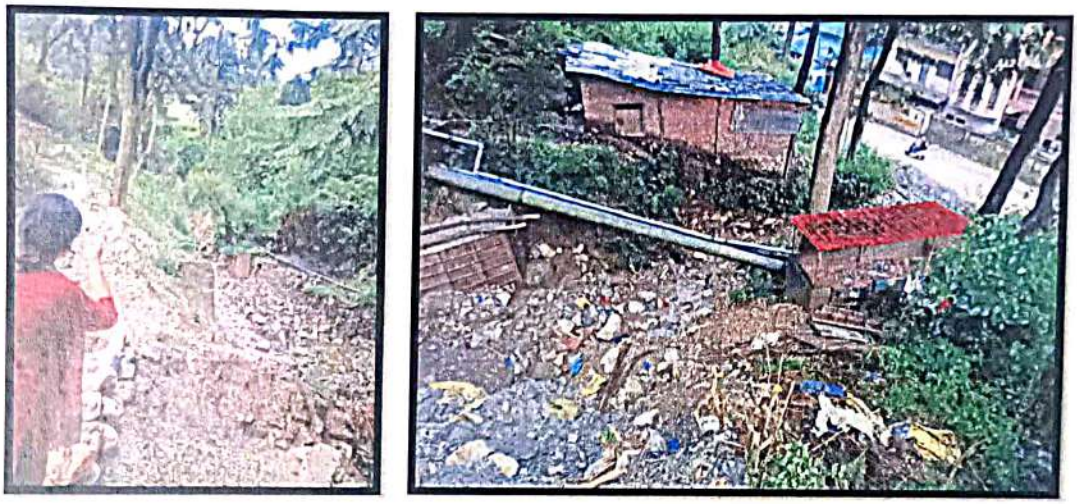


Figure 7: Condition of Gufiyara Nala

b. Varunavat Mitigation Site:

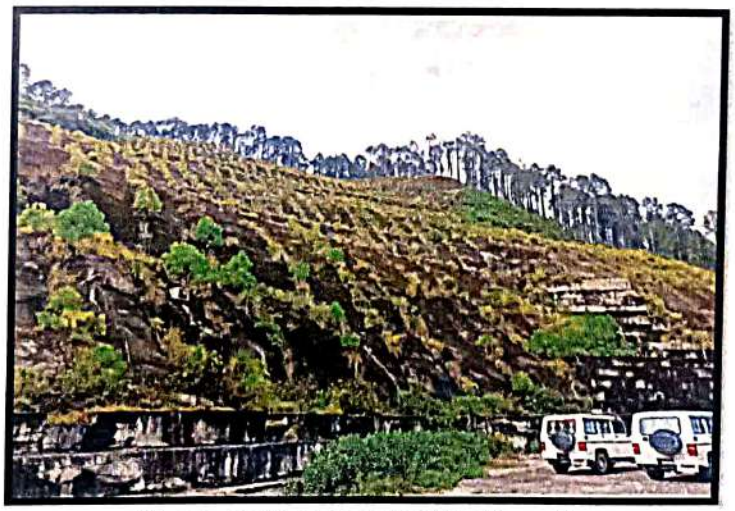


Figure 8: Varunavat mitigation site

To assess potential linkages between the earlier landslide site at Varunavat Top and the current landslide activity at Gufiyara, the site was visited and followings are the findings (Fig. 8):

- The toe contour drain was found chocked with pine leaves and vegetation (Fig. 9).
- The vegetation/pine are grown in the longitudinal groves between shotcrete and in contour drains (Fig. 10)
- MS drainage pipes provided at EL±1670 and EL±1660 for diverting rain discharge collected at toe catch drain were found chocked (Fig. 11).
- Construction material (sand) and some loose boulders were left by Tambakhani Chute treatment work contractor at edge of bench EL ±1660M (Fig. 12).

Figure 9: Chocked catch drain

Figure 10: Vegetation/small pine plants growing in the longitudinal groves

Figure 11: The catch drain is choked require to be opened at platform at EL ± 1660m.

Figure 12: Construction materials sand and boulders were left at the edge of the bench. It has to be removed

4. SUGGESTIVE MEASURES:

The following recommendations have been provided by the committee at the Gufiyara landslide site:

A. Short Term Measures: Following are the immediate treatment needed at Gufiyara landslide site as short-term measures

1. **Removal of Loose Material**: Immediate removal of loose debris/ hanging material with cautions from the landslide area, particularly from the crown, is necessary. Care should be taken during this process to avoid triggering additional landslides. Accumulated debris and boulders behind steel barricading at EL±1230 required to be removed for making free space to arresting fresh slide if any.
2. **Strengthening of Barricades**: Existing barricade at EL± 1230m needs to be strengthen by welding and installing a slanting ISMB (300x140mm) with vertical post (Fig. 13).

    - High tensile chain-link fabric (50x50mm) needs to be welded behind the existing barricade to arrest debris/boulders of smaller size and needs to be extended towards Gufiyara nala by ± 100m approx. in stretch length (Fig. 14). Small gaps in between two barricades at regular interval is recommended

- Another Steel barricading structures of 3m height at EL ±1240 (near existing damaged stone wall) and EL± 1260 approx. on way of existing slide above the existing steel barricade needs to be constructed along with extension of existing barricade till settlement on left of Landslide site.

Figure 13: The existing barricade needs to be strengthened by welding by slanting ISMB.

Figure 14: Design of chain link fabric to be welded behind the existing barricade.

3. **Gabion stepped vertical surface drain** (3m x1.5m) need to be constructed and connect to road side drain a NH-108 (Uttarkashi to Gangotri) at Gufiyara nala or further connected with river or main drain. Catch drain outside barricade need to be constructed and connected either Gufiyara nala or direct to road side drain.

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4. **Bioengineering Measures**: Given that the surrounding area near the landslide exhibits shallow scarps, particularly where there is a slope break, it is recommended to implement erosion control through the spraying of seeds/ planting of dedonia/vetiver grass and bamboo. These species should be placed near the toe and around landslide and in other topographically feasible areas to stabilize the soil and reduce erosion.

B. Mid Term Measures: In addition to the immediate measures, continuous monitoring of the slope is essential due to its close proximity to the settlement. The following mid-term measures are recommended:

1. **Regular Debris Removal**: Regularly, removal of debris from the toe area is necessary to prevent the accumulation of material and restrict further flipping of material
2. **Monitoring System**: A monitoring system particularly webcam can be installed at the crown of the landslide area to track any movement or monthly physical survey is required to inspect area for the formation of tension cracks, tilted trees, or any other signs of instability. If such conditions are observed, long-term mitigation measures should be considered.

C. Suggestive Measures (Varnavat Parvat):

1. The toe contour drain should be cleaned periodically.
2. The Vegetation/small pine plants from the longitudinal groves between shotcrete and treated area should be periodically cleaned in order tofacilitate smooth discharge from slope and to release pore pressure.
3. MS drainage pipes provided at EL±1670 and EL±1660 required to be opened to prevent flooding of rainy water towards Tambakhani chute.
4. Construction material and loose boulders left at bench EL ± 1660M need to be removed.
5. Regular cleaning of drains and grooves at treated area of Varunavat Parvat crown are essentially required. It must be carried out especially during rainy season. It must not be ignored for long time.

D. Long-Term Mitigation:

Anthropogenic interference/ disturbance at the toe of Varunavat Parvat in the Buffer Zone area may aggravate the stability of up slope in the long run. Therefore, further expansion of settlement should be controlled / restricted for implementation of long-term stability of slope following required to be initiated:

a) Topographical and Geological survey at larger scale. of landslide area
b) Geophysical investigation of landslide area at toe and crown.
c) Geotechnical survey at toe to find the exact depth of competent rock
d) Selection of suitable long term treatment measures after finding the details of all above investigations
e) Design of treatment measures.
f) Implementation of long-term scheme.

5. CONCLUSIONS:

The Varunavat Mitigation site does not exhibit any direct linkage to the recent Gufiyara landslide. However, immediate short term measures are required in order to provide protection to settlement followed by monitoring the area. In addition to this Gufiyara Nala's poor maintenance and erosion of sides needs construction of civil structures. Removal of pine trees and unwanted plant species are important at Varunavat mitigated site. Addressing these issues is essential for mitigating future risks.

Note:

1. A detailed geological assessment report of the Gufiyara landslide, prepared by the Geological Survey of India (GSI), is enclosed with this document.
2. The short-term mitigation measures designed by THDC are also included in this report.
3. This document provides a summary of the observations and suggestions regarding the Gufiyara landslide, by the team from ULMMC, GSI, and THDC.

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