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भारत सरकार
Government of India
भारतीय भूवैज्ञानिक सर्वेक्षण
Geological Survey of India

कर्नाटक राज्य के कोडागू जिला में विराजपेट भागों के आसपास मध्य पैमाना (10,000) पर भूस्खलन संवेदनशीलता

Meso-scale (1:10,000) Landslide Susceptibility Mapping in and around Virajpet area, Kodagu district of Karnataka

टोपोशीट सं: 48 P/16;Toposheet No.: 48 P/16

एम4एलएसएसएम/एनसी/एसआर/एसयू-केजी/2020/32460
Item no.: M4LSSM/NC/SR/SU-KG/2020/32460

कार्य सत्र 2020-21 का प्रतिवेदन

Report for field season 2020-21

इ. मोहन राज, भूवैज्ञानिक/ Mohan Raj, Geologist
अचान कोन्याक, भूवैज्ञानिक /Achan Konyak, Geologist

मिशन-IV
Mission–IV

इंजीनियरिंग भूविज्ञान तथा भूस्खलन विभाग/Engineering Geology and Landslide Division
राज्य इकाई: कर्नाटक एवं गोवा/State Unit: Karnataka & Goa
बेंगलूरु/Bengaluru-560078

दिसंबर 2021/ December 2021

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GEOLOGICAL SURVEY OF INDIA

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एम4एलएसएसएम/एनसी/एसआर/ एसयू-केजी/2020/32460

इ. मोहन राज, भूवैज्ञानिक

अचान कोन्याक, भूवैज्ञानिक

सारांश

किसी दिए गए स्थान और समय में ढलान अस्थिरता स्थानीय भू-आकृति, जल विज्ञान और भूगर्भिक स्थितियों का परिणाम है। अलग-अलग आवृत्ति और वर्षा की तीव्रता और भूमि उपयोग प्रथाओं सहित भू-गतिकी प्रक्रियाओं द्वारा इन स्थितियों की बातचीत या संशोधन का विराजपेट पहाड़ियों में ढलान अस्थिरता पर असर पड़ता है। इस अध्ययन में, प्रत्येक अद्वितीय भूगर्भिक स्थितियों या डोमेन के लिए ढलान अस्थिरता के लिए जिम्मेदार अंतर्निहित कारक कारकों के विस्तृत पहलुओं को भूस्खलन तंत्र के लक्षण वर्णन और उच्च घनत्व क्षेत्र अवलोकन बिंदुओं के माध्यम से भूस्खलन के साथ संभावित भू-कारकों के कारण संबंध के मूल्यांकन के आधार पर शामिल किया गया है। अध्ययन क्षेत्र के कुल 15 किमी 2 को विभिन्न डोमेन में वर्गीकृत किया गया है, जैसे कि अर्थ स्लाइड, मलबे की स्लाइड, रॉक स्लाइड, रॉक फॉल और स्लोप कट डोमेन। मलबे की स्लाइड और मिट्टी की स्लाइड के लिए जिन भू-कारकों पर विचार किया जाता है, उनमें भू-तकनीकी, भूमि उपयोग भूमि कवर, लैंडफॉर्म और स्ट्रीम पावर इंडेक्स शामिल हैं, जबकि रॉक स्लाइड और रॉक फॉल डोमेन रॉक मास रेटिंग और किनेमेटिक विफलता मानचित्र के संदर्भ में भू-तकनीकी विषय पर विचार करते हैं। इन विषयगत कारकों के अलावा, ढलान नक्शा, रेजोलिथ मोटाई नक्शा और सापेक्ष राहत मानचित्र कट ढलान डोमेन के लिए महत्वपूर्ण विषयगत परतें हैं। इन अलग-अलग विषयों की कक्षाओं को भूस्खलन संवेदनशीलता अनुमानित रेटिंग सौंपी गई है, जिन्हें प्रत्येक डोमेन के लिए कुल अनुमानित संवेदनशीलता मान (TESV) प्राप्त करने के लिए जोड़ा जाता है और अंत में भूस्खलन की संवेदनशीलता की अलग-अलग डिग्री में वर्गीकृत किया जाता है। क्षेत्र में भूस्खलन सूची को अद्यतन करने की प्रक्रिया में, विराजपेट के इलाकों के भीतर विभिन्न आयामों के 31 भूस्खलन का दस्तावेजीकरण किया गया था। मलबे और पृथ्वी की स्लाइड प्रमुख हैं जबकि क्षेत्र में किसी भी रॉक स्लाइड का दस्तावेजीकरण नहीं किया गया है। ओवरबर्डन का सबसे बड़ा अनुपात अपरिपक्व इंसीटू मिट्टी है, जिसके बाद परिपक्व इंसीटू मिट्टी है, जबकि कोलुवियम और मिश्रित बोल्डर और मलबे के पैच को अयप्पा हिल के मध्य ढलानों और बिट्टंगला हिल के पैर ढलानों पर मैप किया गया है। भू-स्खलन का स्थानिक वितरण क्षेत्र में असमान है और 90% से अधिक भूस्खलन कट ढलान क्षेत्र के भीतर अच्छी तरह से आते हैं, यह दर्शाता है कि भूमि उपयोग या ढलान प्रोफ़ाइल संशोधन ने क्षेत्र में भूस्खलन को बढ़ा दिया है। संयुक्त भूस्खलन संवेदनशीलता मानचित्र से पता चलता है कि क्षेत्र का 74.2% कम, 19.2% मध्यम और 6.6% उच्च प्रतिशत है। संवेदनशीलता और क्षेत्र के आकलन के आधार पर, विराजपेट पहाड़ियों के भीतर संभावित उच्च जोखिम वाले क्षेत्रों की पहचान की गई है।

Meso-scale (1:10,000) Landslide Susceptibility Mapping in and around Virajpet area, Kodagu district of Karnataka

Item no.: M4LSSM/NC/SR/SU-KG/2020/32460

E Mohan Raj, Geologist

Achan Konyak, Geologist

ABSTRACT

Slope instability in any given space and time is the result of local geomorphic, hydrologic, and geologic conditions. The interaction or the modification of these conditions by geodynamic processes including the varying frequency and intensity of precipitation and land use practices have bearing on slope instability in Virajpet hillslopes. In this study, detailed aspects of inherent causative factors responsible for slope instability for each unique geologic condition or domain are incorporated based on characterization of landslide mechanism and evaluation of causal relation of potential geo-factors with landslides through high-density field observation points. A total of 15 km^2 of the study area is categorized into different domains viz, earth slide, debris slide, rock slide, rock fall, and slope cut domains. The geo-factors considered for debris slide and soil slide include geotechnical, land use/land cover, landform, and stream power index while rock slide and rock fall domain consider the geotechnical theme in terms of rock mass rating and the kinematic failure map. In addition to these thematic factors, the slope map, regolith thickness map, and relative relief maps are important thematic layers considered for the cut slope domain. The classes of these different themes have been heuristically assigned Landslide Susceptibility Estimated Ratings which are added up to derive Total Estimated Susceptibility Values (TESV) for each domain and finally classify into a varying degree of landslide susceptibility. In the process of updating the landslide inventory in the field, 31 numbers of landslides of varying dimensions were inventoried within the localities of Virajpet. The debris and earth slides are dominant while no rock slide is documented in the area. The largest proportion of overburden is immature insitu soil followed by mature insitu soil while patches of colluvium and assorted boulders and debris have been mapped on the mid slopes of Ayyappa Hill and foot slopes of Bittangala Hill. The spatial distribution of landslides is non-uniform in the area and more than 90% of the landslides fall well within the cut slope domain indicating that the land use or slope profile modification has aggravated the landslides in the area. The combined landslide susceptibility map shows a 74.2% low, 19.2% moderate, and 6.6% high percentage of the area. Based on the susceptibility and field assessments, probable high-risk areas have been identified within the Virajpet hillslopes.

1. INTRODUCTION

1.1 Background

Landslide has been one of the major geo-environmental hazards in Western parts of Karnataka and is mostly triggered during the active monsoon period (June to September). Macro-scale landslide susceptibility mapping on 1:50000 (NLSM) has been completed in FS 2019-20 for the state of Karnataka thereby helping to identify certain critical areas that need further study at a larger scale. During the monsoon of 2018 and 2019, several landslides and ground cracks have been reported in different parts of the Kodagu district, Karnataka. Ground cracks had developed in Ayyappa Hill and Nehru Nagar areas of Virajpet town while several small-scale landslide incidences had also been reported. There were losses of property, plantation, and forest land during the rainfall events of August 2018 and August 2019. In pursuance of the request from the Kodagu district administration, and keeping in view the presence of moderate and high susceptible zones as per the NLSM programme of FS 2015-16 (Ankur Kumar Srivastava & Harsha Sunder, 2016) and also to minimize the risk factor associated with the landslide affected slopes, an area of 15 km^2 was taken up for mesoscale (1:10,000) landslide susceptibility mapping.

The current Landslide Susceptibility mapping work divides the terrain into different zones according to the relative degree of susceptibility to landslides. This categorization is done through the identification of spatial areas that are likely to be affected by landslide initiation and consequently arrive at an assessment on the damage potential of the area. This has been done based on all the relevant geo-factor themes at the pertinent scale of observation (1:10,000), determining the geotechnical properties of rocks/soils and slope stability analysis at selected stretches on a relatively larger scale (1:10,000) for direct use by the concerned State Government for landslide risk mitigation. Landslide susceptibility maps are important for planning large-scale developmental works as well as essential for the quantification of landslide hazards and risk. The nature, quantum, and time of work are given in Tables 1a and 1b.

1.2 Objective

The objectives of the current study are:

i. To generate meso-scale (1:10,000) landslide susceptibility zonation map.

ii. To identify causative factors related to landslides.

iii. To suggest generic mitigation measures for unstable slopes.

iv. To update the existing landslide inventory

Table 1.1 Nature and quantum of work

Nature of Work	Target FS 2020-21	**Total** Achievement (in sq.km) 2020-2021
1. Pre field map preparation		
i. Land use/ Land cover map		**15**
ii. Drainage map		**15**
iii. Geomorphology/ Landform map	15 km²	**15**
iv. Regolith map		**15**
v. Slope Morphometry (slope angle, slope aspect, slope curvature and relative relief)		**15**
2. Field-based studies		
i. Geological-Slope Forming Material mapping (1:10 k)		**15**
ii. Geotechnical Mapping (shear parameters of overburden and rock mass characterization of slope) 1:10 k		**15**
iii. Slope forming material map	15 km²	**15**
iv. Field validation of all pre-field thematic maps.		**15**
v. Updation of landslide inventory with detailed assessment as per 42-point geo-parametric datasheet.		**28**
vi. Sample collection for determination of geotechnical parameters*	30 nos.	**33**
3. Post field studies and modelling		
i. Updation and finalization of thematic maps and landslide inventory in GIS platform.	15 km²	**15**
II. Preparation of landslide susceptibility map in GIS platform.		**15**
4. Collection of rainfall data	As per availability	
**Geotechnical properties will be determined by Geotechnical Laboratory, GSI, SR* *# Ongoing updation of field-based maps and susceptibility map in ArcGIS platform*		

Table 1.2 Man days spent on the project

Sl. No	Supervisory officer/Officers	Field initiation date	Total field days
1.	R Sajeev, Director (G)	13.12.2020	**04**
2.	E Mohan Raj, Geologist	21.11.2020	**85**
3.	Achan Konyak, Geologist	02.10.2020	**87**

1.3 Study area

Virajpet town is situated at the foothills of Ayyappa and Nehru Nagar Hills. The study area is bounded by latitude N 12° 10' 40.8" to N 12° 13' 51.6" and longitude E 75° 47' 24" to E 75° 51' 0" which falls in Toposheet No. 48 P/16. The area falls in the Kodagu district of Karnataka and is located ~33 km away from the Kodagu district headquarters, Madikeri (Fig.1). The area can be accessed from Bengaluru via NH-275 via Mysuru.

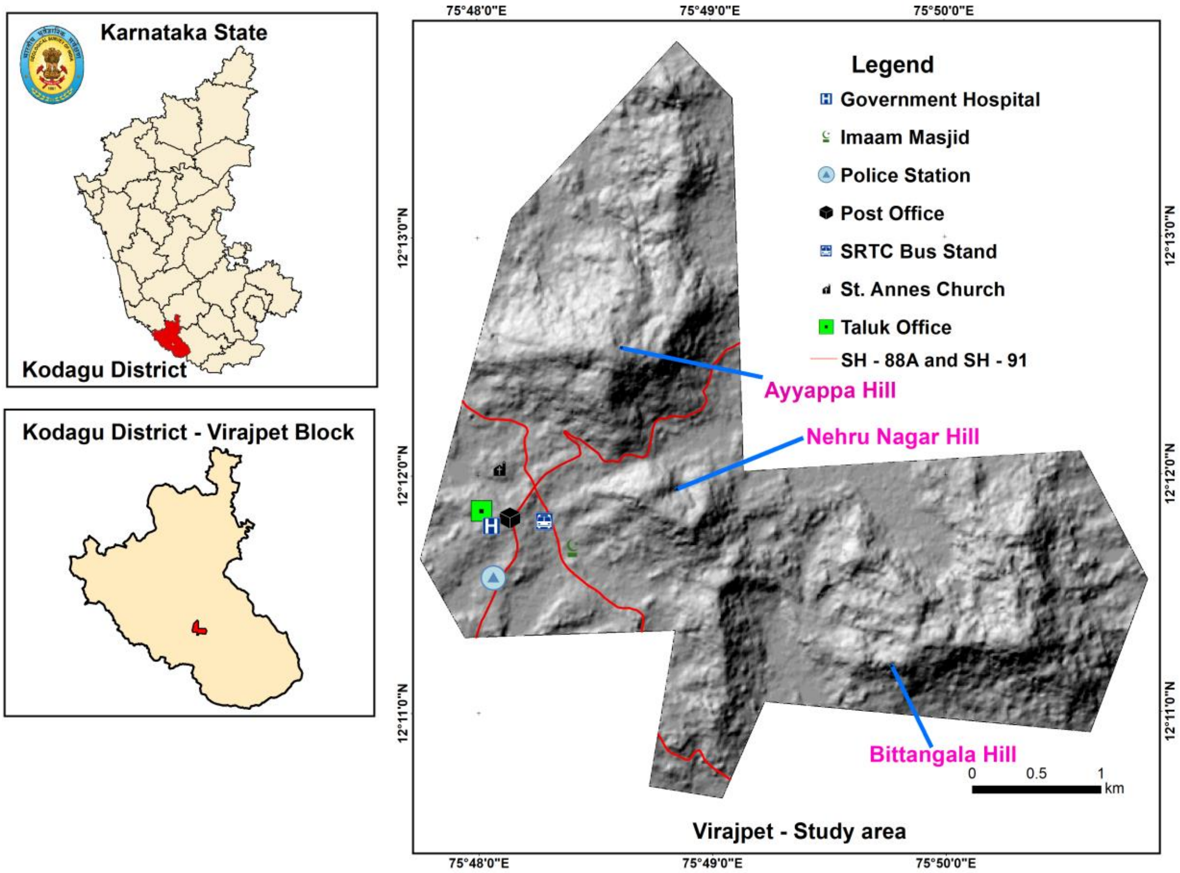

Fig. 1 Location map of Virajpet area

1.4 Physiography

The physiography of the study area represents a typical Malnad or mountainous region that forms a transition zone between the eastern plateau and the Western Ghats. The NW-SE trending hill ridges in the study area are surrounded by subdued and lowly undulating landforms. The highest elevation in the area is 1091 m above the mean sea level at Ayyappa hilltop. The relative relief of the area is about 340m. The western part of the area is represented by high rising hills of the Western Ghats. The drainage in the study area exhibits a radial pattern and shows up to the 4^{th} order stream.

1.5 Previous work on landslide studies

Earlier workers attempted Landslide susceptibility mapping adjacent to the study area along Virajpet–Madikeri–Sulya road corridor, Kodagu district, Karnataka (Maruthi and Chandran, 2013) using a modified BIS method for landslide hazard zonation wherein several facets or pockets of the road sector were mapped as highly susceptible. The study area was covered under Macro Scale (1:50,000) Landslide Susceptibility Mapping (NLSM) Programme during FS 2015-16 (Srivastava and Sunder, 2016). As per the landslide susceptibility map of 1:50,000 scale, the central and eastern parts of the area show considerable patches of high and moderate susceptibility zones, while the south-western and northern side of the area mostly falls under the low susceptibility zone. In 2019, post-disaster landslide studies (Kapil and Sunandan, 2019) were carried out after reports of landslide incidences in localities of Ayyappa and Nehru Nagar of Virajpet on the requests of the district authority. As per the report, the landslides were triggered by the monsoon rain and the anthropogenic interference on the natural slope was the primary causative factor.

These slope stability studies are taken up to cater to site-specific needs as and when landslides occur which include preliminary post-disaster studies and their inventory and also coordinating activity related to landslide hazard mitigation with district authorities. The above studies carried out by different authors are done on the different scales along selected stretches of road and also specific areas when the need arises owing to landslide incidences.

1.6 Acknowledgements

The successful completion of the project for FS 2020-21 is attributed to the concerted efforts by several individuals at various levels. The authors are grateful to Addl. Director General and HOD, GSI, SR, Hyderabad for intimating the district administration about the work to be carried out in the area. Sincere thanks are due to the Deputy Director General, SU-KG for approving all the logistics for the smooth execution of the project. The authors are grateful to Shri K.V. Maruthi, Director, under whom the project was initiated, for his guidance during the initial phase of the work. The authors are extremely thankful to Shri R. Sajeev, Director, for the overall supervision and for providing all possible logistic support and technical inputs both in the field and at headquarters. The authors would like to put on record the help, guidance, and support rendered by Sumit Kumar, Geologist and other experts from GHRM Cell, GSI, Kolkata. The authors are grateful to the colleagues of the Engineering Geology and Landslide division of Bangalore for the help rendered through mutual discussions and technical inputs in various forms.

2. GEOLOGY

2.1 Regional geology

Geologically, the southwestern part of Karnataka is occupied by rocks belonging to Sargur Group, Peninsular Gneiss-I of PGC, and Charnockite Group, which are intruded by granites, pegmatites, and dolerite dykes. The Sargur Group comprises garnet-sillimanite schist, kyanite bearing gneiss and amphibolites. The high-grade metapelites such as fuchsite quartzite, kyanite-sillimanite schist, and kyanite gneiss occur as narrow and discontinuous bands. The stratigraphic succession of the study area is given below in Table 2.1, (Misc. pub. No 30, Part VII, GSI, 2009).

Table 2.1 Generalized stratigraphic succession of South Western Karnataka.

<table>
<tr><th>Eon/Era/Epoch</th><th>Suite/Assemblage Supergroup</th><th colspan="2">Group /Formation</th><th>Lithology</th></tr>
<tr><td>Paleoproterozoic
2530-2450ma</td><td>Intrusive (Closepet granite etc.)</td><td colspan="2"></td><td>Alkali granite, monzogranite/adamellite to granodiorite</td></tr>
<tr><td colspan="5">~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~ Intrusive ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~</td></tr>
<tr><td rowspan="3">Late Archaean to
Paleoproterozoic
To
Late Archaean
2900-2600 ma</td><td rowspan="3">Dharwar Supergroup</td><td rowspan="2">Chitradurga Group
2700-2600 ma</td><td>Ranebennur Subgroup</td><td>Greywacke/BIF/ polymict conglomerate/ volcanics (Mardihalli, Bellara, Medur)</td></tr>
<tr><td>Vanivilas Subgroup</td><td>Polymict conglomerate, cross bedded quartzite, pelite, stromatolitic carbonates, biogenic chert, BIF & manganese formations (Ingaldhal volcanics-tholeiitic basalt rhyolite suite (Tekkalvatti, Jagar))</td></tr>
<tr><td colspan="2">Bababudan Group
2900-2800 ma</td><td>BIF & carbonaceous phyllite, basalt-dacite suite
(Locally pillowed) with minor ultramafics/ alternations of amygdular basalts/cross-bedded quartzites, pelite/minor BIF/basal quartz pebble conglomerate</td></tr>
<tr><td>Late Archaean
<3000 ma</td><td>Peninsular Gneiss-I</td><td colspan="2"></td><td>Tonalite-trondhjemitegranodiorite</td></tr>
<tr><td>Middle Archaean
3000 ma</td><td></td><td colspan="2">Charnockite Group</td><td>Metamorphic equivalents of earlier formed rocks</td></tr>
<tr><td>Middle Archaean</td><td></td><td colspan="2"></td><td>Ultramafic-mafic</td></tr>
</table>

>3000 ma		Sargur Group	intrusive complex (Holenarsipur-Nuggihalli)/ serpentinised komatiites, komatiitic and thoeliitic amphibolites, chert, BIF/garnet-biotite schist (with kyanite, sillimanite and staurolite)/local marble and calc-silicate/fuchsite quartzite with chromite and baryte layers

2.2 Geology of the area

As per the 1:50,000 geological map, the area shows granite gneiss of the Peninsular Gneissic Complex (PGC-I). Geological mapping over an area of 15 km^2 has been carried out on a 1:10,000 scale in the area. Two distinct rock types were observed which shows considerable variation in their texture. Granite gneiss is exposed at the lower elevation at the fringes of the hillocks. Conspicuous compositional banding of light and dark coloured minerals is observed. The predominance of micaceous minerals such as muscovite, biotite, and sericite, etc. are noticed along certain planes in the granite gneiss and appear to be manifestations of later solution activity along the weak planes. The gneissic terrain at lower elevation is marked by subdued topography and thick overburden. The second rock type is medium to coarse-grained porphyritic granite representing younger intrusive phase with mafic enclaves observed in patches at the exposures. Large phenocrysts of K-feldspars are dominant which exhibit pink to light grey colours. This massive porphyritic granite is exposed at a higher elevation towards the center of the intrusive body. The rock is massive and devoid of any persistent weak planes. No sharp contact is visible at any exposure, however, the general trend of the foliation of the granite gneiss is approximately N-S, and steep dipping is inferred to have intrusive contact.

Fig. 2.1a Porphyritic granite

Fig. 2.1b Mafic enclave within the granite

Fig. 2.1c Granite gneiss

Fig. 2.1d Micaceous minerals developed along the weak planes of granite gneiss

Fig. 2.1 Field photos of litho units of Virajpet area

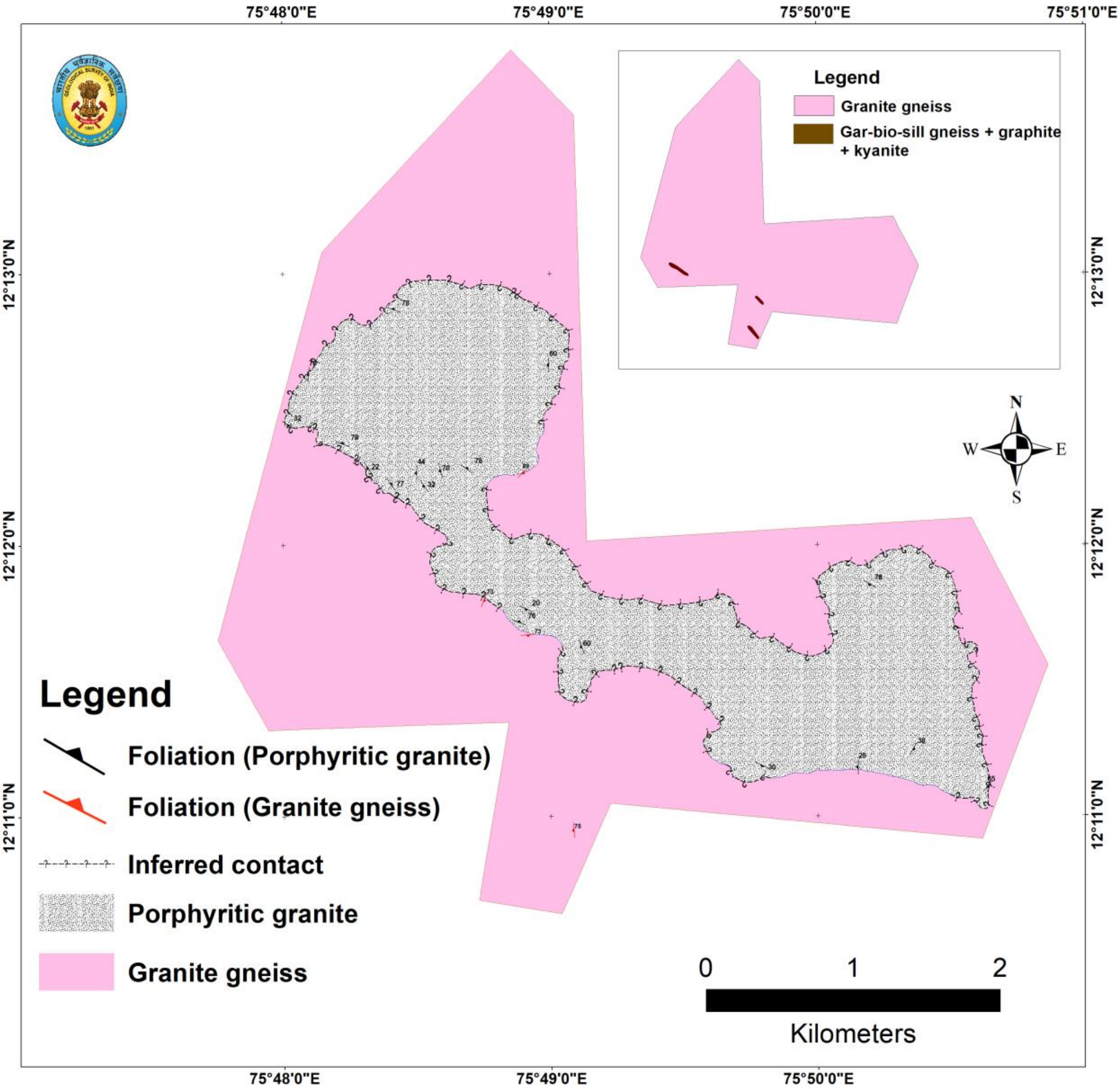

Fig. 2.2 Geological map on 1:10,000 scale of the Virajpet area (GSI legacy 50k map)

3. METHODOLOGY

In the current study, the broad guidelines outlined in standard Operating Procedure (SOP) GSI, 2021 have been followed.

3.1 Input data and maps

In absence of 1:10000 scale Survey of India Toposheet for the area, CartoDEM 10 m spatial resolution procured from National Remote sensing Centre (NRSC), Hyderabad is used to generate a topographic base map and also for the preparation of various pre-field thematic geo-factor maps for the entire Area of Interest (AOI). The multi-temporal high resolution google earth imagery is used to identify old landslide scars and other cultural features to be incorporated in the base map.

3.2 Selection of mapping unit

The term mapping unit refers to that part of the topographical surface considered to have similar geo-factor attributes significantly different from the immediate or adjacent units and thereby having definite polygonal boundaries (Guzzetti *et al*., 1999). The selection of a suitable mapping unit is the prerequisite of landslide susceptibility mapping. In the current study, pixel (10 m) from CartoDEM is used for 1: 10,000 scale because the same is easy to generate, integrate and retrieve, easy for spatial analysis, statistical/mathematical calculations, and minimum generalization. There are various mapping units adopted for the landslide hazard mapping depending on the scale of the study and the type of landslide processes involved. In the current study, a slope facet is adopted only for the slope-cut domain which is again pixelated for seamless map generation. A slope facet represents that part of the slope having similar slope inclination and azimuth. The facet map is manually prepared using a topographic map and the drainage map is generated through 10 m resolution CartoDEM.

3.3 Categorization of the study area into domains

Landslide processes are unique to every terrain. The causative factors and failure mechanisms are different for each geological terrain. Therefore, it is reasonable to categorize the hillslopes into domains based on the dominant type and processes involved in the initiation of landslides (Cruden *et al,* 1996). So, each domain in the study area represents similar or unique geologic or physiographic conditions that control the landslides in the area. The hillslopes have been categorized into the following domains: earth slide, debris slide, rockslide, rockfall, and slope cut domains.

The earth slide domain dominantly has mature soil which can either be insitu or transported while the debris slide domain has hillslopes that are covered by immature soil, colluvium, and other assorted boulders. The rocky areas have been categorized into the rock slide domain which can have both planar and wedge failure mechanisms and the rockfall domain where the slope angles are greater than 45º. Therefore, landslide inventory and characterization of landslide mechanism and evaluation of causal relation of potential geo-factors with landslides through high-density field observation points become a primary exercise to categorize the hillslopes into different domains.

In addition, any areas having water bodies, reservoirs, flatlands, etc. where obvious landslides cannot be initiated are categorized as the "No Landslide" domain. However, this does not mean that the areas marked as no landslide domain are completely devoid of landslide risks since such areas can also be along the impact path of the landslides initiated on the upslopes.

3.4 Selection of geo-factors for domain

The most relevant underlying factors in the initiation of landslides in each domain are taken into account in the current study. Since the heuristic method is employed in the current study, a reasonable assumption of the main causes of landslides in the area of interest is taken into account in selecting the most relevant geo-factors (Ghosh *et al*, 2011). Such geo-factors for landslide susceptibility analysis depend on the scale of analysis, the characteristics of the study area, and deductive knowledge of the main causes of landslides (Guzzetti *et al.*, 1999; Glade and Crozier, 2005; Van Westen *et al.*, 2008*)*. In the current study, the geo-factors considered for earth slide and debris slide include slope angle and relative relief, land use, landform, stream power index, overburden geotechnical character, Rock mass rating, and kinematic failure map.

3.5 Ratings of the classes of geo-factors

Every geo-factor theme is subdivided into classes. The ratings assigned for the classes based on the relative contributory role for landslide initiation is termed Landslide Susceptibility Estimated Ratings (LSER). Every theme will have the maximum weight assigned (Table 3.1). In the current study, the heuristic method is used to assign LSER for each class of the geo-factors. This heuristic method caters to the needs of the terrain-specific condition.

The mode of slope failure in rocky slopes and overburden-covered slopes are different. The same pre-disposing factors will have a varying contributory role for the initiation of landslides in both types of slopes. In this context, the ratings/weights to different geo-factor classes are assigned after proper field assessment of the classes and examining the landslide incidences in the given area.

The ratings are similar to the broad schema outlined by the Bureau of Indian Standards (IS-14496, Part 2), 1998 and Ghoshal *et al*., 2013 which are also knowledge-based ratings. However, in the current study, the classes and thematic geo-factors incorporated are different and based on the observations of the authors as appropriate to the terrain of the study. The LSER for the classes of any thematic geo-factor and the maximum LSER or weight assigned for any thematic geo-factor ranges from positive non-integer to "1" for each domain so that the Total Estimated Susceptibility Values (TESV) for each domain adds up to integer 1. This TESV is sub-divided into low, moderate, and high susceptible zones using the natural breaks in Arcmap 10.4 (Fig. 3.1).

Table 3.1 Maximum weight assigned to the geo-factor themes (SOP, GSI, 2021)

Rock Slide	
Geo-factors	Weights
1. Geotechnical map (GT)	0.6
2. Kinematic failure (KF)	0.4
Total Estimated Susceptibility Values (TESV)	1.0
Rockfall	
Geo-factors	Weights
1. Geotechnical map (GT)	0.4
2. Toppling failure (TF)	0.4
3. LULU	0.2
Total Estimated Susceptibility Values (TESV)	1.0
Debris slide	
Geo-factors	Weights
1. Geotechnical map (GT)	0.5
2. Landform (LF)	0.3
3. Stream Power Index (SPI)	0.1
4. LULC	0.1
Total Estimated Susceptibility Values (TESV)	1.0
Earth slide	
Geo-factors	Weights
1. Geotechnical map (GT)	0.5
2. Landform (LF)	0.3
3. Stream Power Index (SPI)	0.1
4. LULC	0.1
Total Estimated Susceptibility Values (TESV)	1.0
Cut-slope failure	
Geo-factors	Weights
1. Regolith thickness (RT)	0.2
2. Slope map(S)	0.2
3. Geotechnical map (GT)	0.4
4. Relative Relief (RR)	0.2
Total Estimated Susceptibility Values (TESV)	1.0

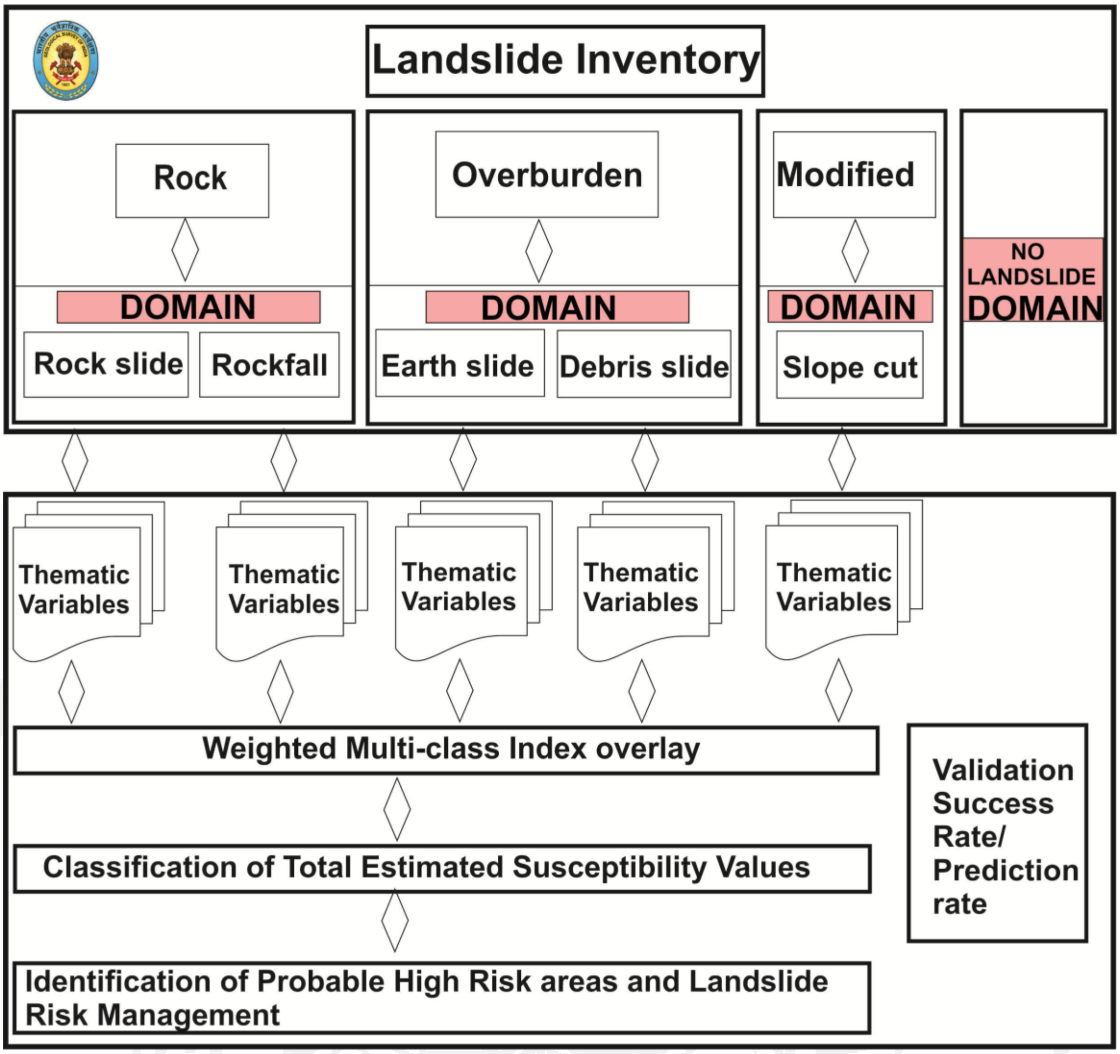

Fig. 3.1 Simplified flow chart of methodology (After SOP, GSI, 2021)

4. CAUSATIVE GEO-FACTORS

Landslides are caused by different geo-factors which have a varying degree of influence on slope stability. No one theme or factor can be singularly attributed to the initiation of slope failures because it is the combination of various geo-environmental factors that act together to initiate landslides in any given slope. These include both predisposing and triggering factors (Guzzetti *et al*., 1996). While some factors are more important than others in any given place, there is a change in various parameters from one place to another. In other words, the influence of the geo-factors will have spatial variation. In addition to this, there can be temporal variation as most landslides are triggered by a heavy downpour during monsoon which is the case in Virajpet and the Western Ghats. For each theme, the possible factor classes are considered for the preparation of geo-factor databases for the GIS-based analysis of susceptibility to land sliding. Slope stability, irrespective of the scale at which it is viewed and analyzed, is known to be influenced by causative factors such as slope morphometry, nature of slope-forming material, degree of weathering of the rock mass, relationships between the slope inclination, and attitude of discontinuities in the rock mass, land use/land cover and hydrological conditions.

Some of the geo-factor themes are categorical (e.g., land use/land cover) and others represent continuous data (e.g., geomorphon, SPI, etc.) which are prepared using CartoDEM as source data employing different geoprocessing techniques in the ArcGIS platform. The failure mechanisms in rocky slopes are different from those in overburden-covered areas and the influence of geo-factors on slope instability varies for different domains. So judicious selection of thematic geo-factors has been done for each domain pertinent to the scale and relevance of the study. Thereafter, knowledge-based assigning of ratings (LSER) is done to the classes of selected geo-factors based on their observed contributory role in landslide initiation to compute 'Total Estimated Susceptibility Values (TESV).

4.1 Landslide inventory

Historic data on landslide occurrences is a critical component of landslide susceptibility studies as it gives insight into the frequency and spatial distribution of landslides. As a result, a landslide inventory map having both the historical and present landslide locations are important for future spatial prediction and subsequent hazard analysis.

In the process of updating the landslide inventory *(Annexure-III)* in the field, 31 number landslides of varying dimensions were documented within the localities of Virajpet following Varnes' classification (Varnes, D. J., 1978) of landslides. There are 24 debris slides and 7 earth slides while no rock slide is documented in the area. Out of the 31 landslides in the database, 28 are shallow rotational earth or debris slides while 3 are shallow translational slides with a depth less than 4 m. The landslides are of varied dimension and wholly confined within the cut slope domain (Fig. 4.1). These parts of the hillslopes have undergone substantial slope profile modification primarily because of the increased construction of settlements. Several small dimension landslides are observed here due to toe cutting for building construction. The average length the landslides is 15 m with no run out distance. The maximum length of the landslide documented is about 45 m with approximately 50 m run out distance in the north facing Magulla hillslope (KG/KOD/48P16/2020-21/11, Annexure III). A few localized transverse cracks are observed on parts of these slopes which indicate a varying level of instability.

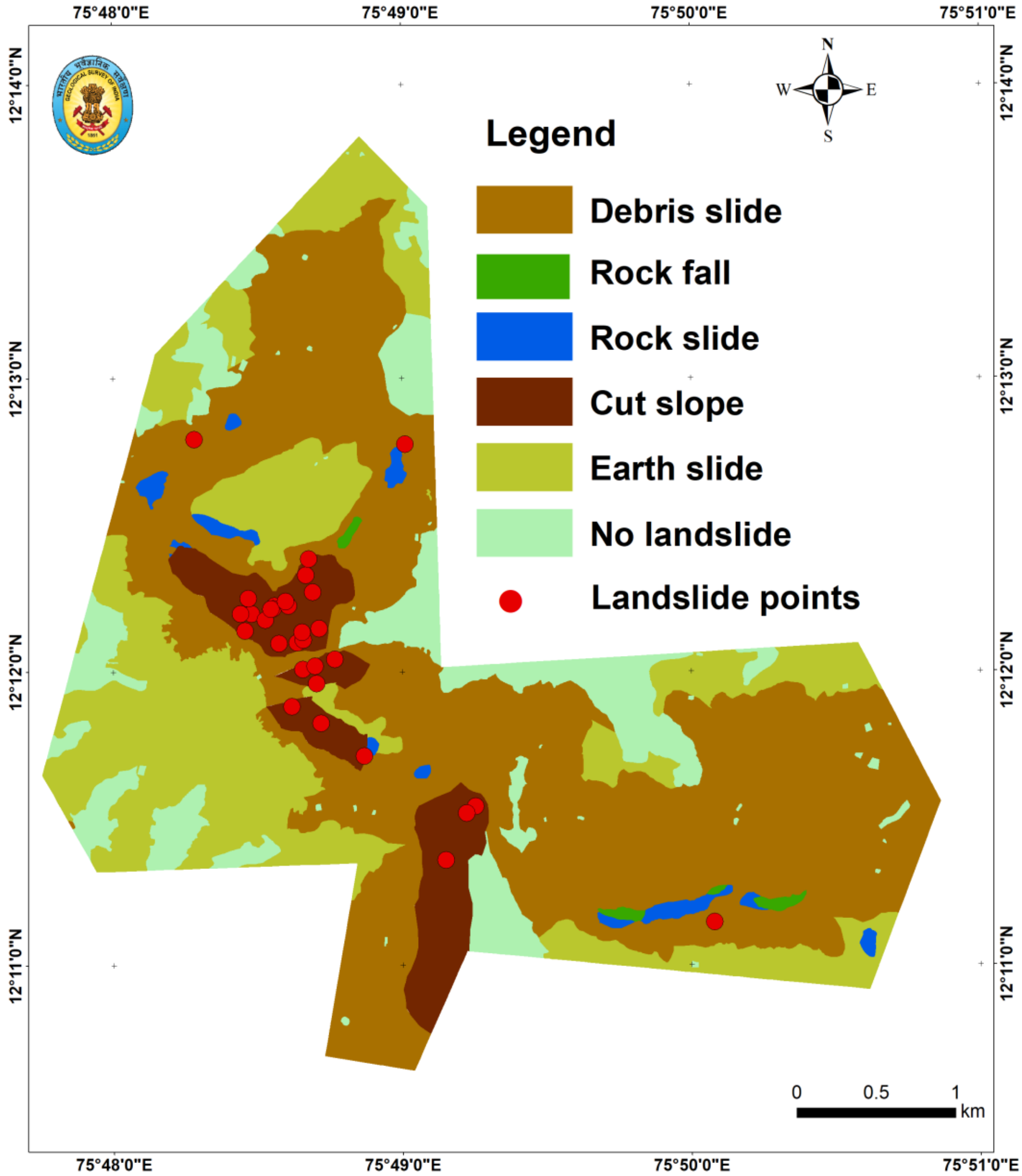

Fig. 4.1 Landslide distribution on the domain map

4.2 Rainfall as the triggering factor

In Virajpet, landsliding events of variable magnitude are mainly triggered by incessant monsoon rain between June and September. The available landslide data documented in the course of field investigation suggest direct temporal relation of landslide initiation with the prolonged rainfall. This is particularly true for the landslides that initiated during the monsoon of 2018, 2019 and 2020. However, most of the documented landslides do not have exact initiation date as the locals or the panchayat do not have the information on precise date of events. During the monsoon of 2018 there are 15 landslides while 2019 monsoon triggered about 13 landslides. Despite the lack of date and time of initiation, the analysis of South West monsoon rainfall data of 2018 and 2019 show that there were 49% and 27 % excess rainfall respectively (Table 4.1). The threshold rainfall data cannot be established for each landslide because of the non-availability of exact date of landslide event which is the primary parameter for establishing rainfall threshold.

Table 4.1 Rainfall data departure from normal for SW monsoon of 2018 and 2019 (KSNDMC)

South West Monsoon					
2018 (1st June to 30th September)			**2019 (1st June to 30th September)**		
Normal (mm)	Actual (mm)	**%DEP (+ve)**	Normal (mm)	Actual (mm)	**%DEP (+ve)**
2040	3043	**49**	2040	2585	**27**

4.3 Geo-factors in earth and debris slide domains

In soil and debris slide domains, the common thematic geo-factors considered are land use/land cover, stream power index, landform, and geotechnical maps.

4.3.1 Land use / Landcover

The prefield land use/land cover map of the Virajpet area is prepared using the high-resolution open-source google earth imagery. The imagery data for the area is taken from 2018 in the preparation of the LULC map. In the pre-field LULC map, the maximum area is observed to be thick vegetation followed by several patches of plantation. But the types of plantation could not be classified from the google earth imagery. The digitized files are saved as .kml and the features are converted into polygons in ArcGIS to be exported to Google Earth through the layer to .kml conversion for assigning names as per its LULC class.

The pre-field LULC map prepared through google earth imagery is field validated in all accessible and all necessary modifications and value addition in the boundary and name of the LULC classes are incorporated. The Virajpet area is part of the Western Ghats characterized by thick mixed vegetation. A substantial change in landscape and land use type has taken place in the Virajpet area over the years.

A substantial modification is done in the pre-field LULC map through the incorporation of coffee plantations within the mixed vegetation. Land use in terms of coffee plantations covers about 10 km^2 of the hillslopes. Coffee is not cultivated as a monoculture or under the canopy of one single tree species but grown under a diversity of native shade trees. The other major class added after field validation includes coffee plantation with silver oak. In several parts of the hillslopes around the eastern flanks of Ayyappa, Ambatty, and Nehru Nagar native trees are replaced by Grevillea *robusta* commonly known as the silver oak tree which is updated in the field-based map (Fig. 4.2). A few areas near Nehru Nagar hillslopes, acacia trees, and areca nut plantations are updated. The patches of agricultural area are confined to the low-lying valley and many of these patches are either left fallow or abandoned at the time of validation. The isolated quarries along the Western slope of Ayyappa, the eastern footslope of Ayyappa, and the Keerthi Layout Footslope have been updated. The extensive slope cut is restricted to the mid slopes sections of Ayyappa and Nehru Nagar where vertical cut sections of 2-5m are excavated for constructing settlements.

The land use theme has been observed to have a significant influence on the slope instability of the study area particularly along slope cut sections. Field study in the area reveals that extensive slope cutting has played a vital role in the initiation of several landslides along the midslopes of Ayyappa, Nehru Nagar, Magulla, and Ambatty. The upslope of such excavation becomes unstable due to the removal of the natural toe buttress of overlying overburden. The slope cuts along the settlements are classified based on slope cut heights in meters irrespective of the presence or absence of any structural mitigation measures. The presence of a breast wall or gabion wall does not necessarily prevent slope failures (Bureau of Indian Standards - IS 14458 Part - I: 1998). This slope profile modification has been duly considered in the cut slope domain. The landslide susceptibility estimated ratings (LSER) for the classes LULC are given in Table 4.2.

Table 4.2: Landslide Susceptibility Estimated Rating (LSER) for LULC classes

	Land use/Land cover (LULC)	
	Geo-factor classes	**LSER**
Earth and Debris slide domains	Waterbody	**0**
	Settlement	**0.1**
	Flat ground	**0.1**
	Cultivation	**0.2**
	Areca nut Plantation	**0.2**
	Acacia	**0.6**
	Mixed vegetation	**0.3**
	Coffee with mixed vegetation	**0.4**
	Coffee with silver oak	**0.5**
	Quarry	**0.7**
	Barren	**0.8**
	Extensive slope cut	**1**

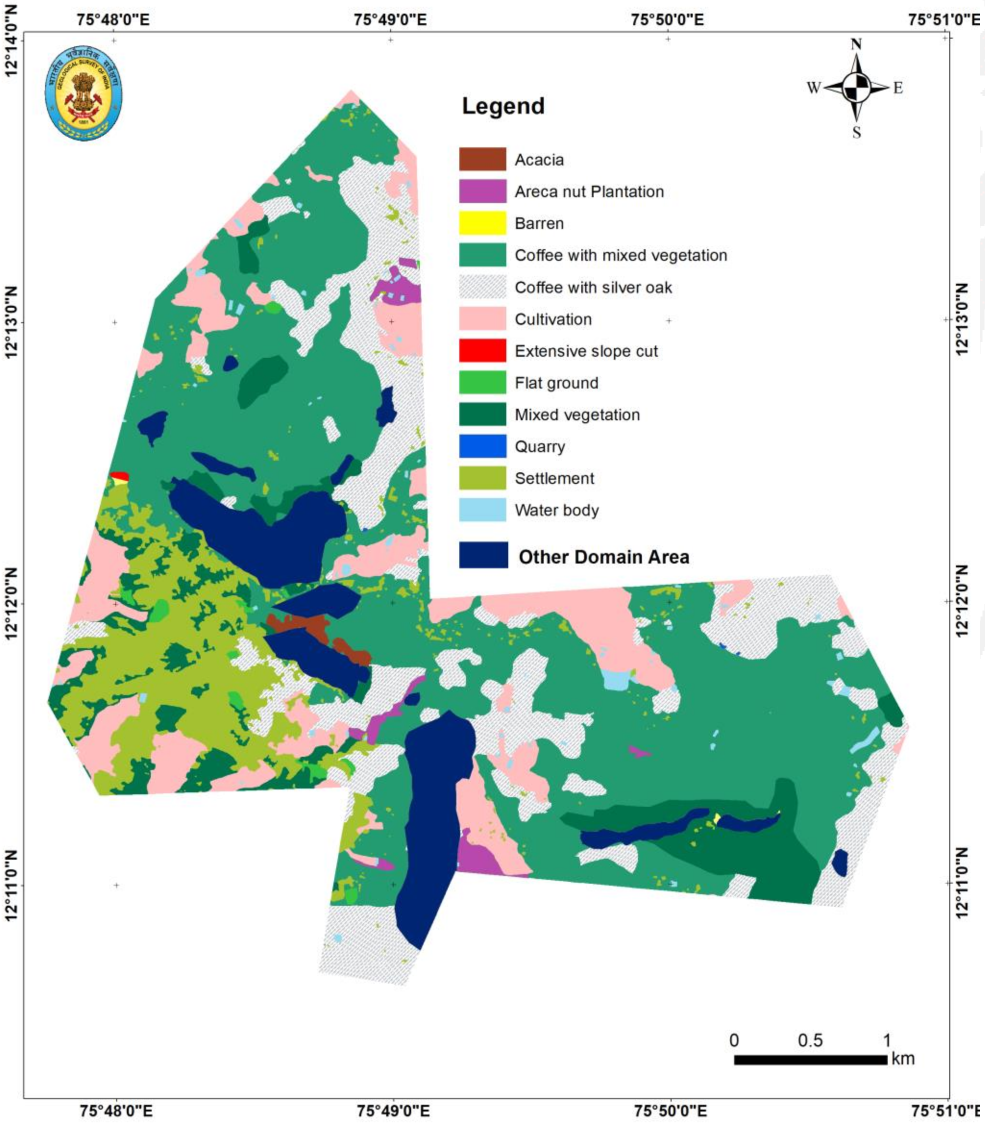

Fig. 4.2 Land use / Land cover map of earth and debris slide domains

4.3.2 Stream power Index

In the current study, stream power index (SPI) is included for earth slide and debris slide domains. The SPI is a secondary terrain attribute that accounts for the local slope gradient and catchment area and hence the proportionate discharge or erosive power of the drainage is considered for the drainages in the area.

Stream power index is expressed as $SPI = A_s \times \tan \sigma$

where, A_s is the specific catchment area represented by flow accumulation raster and σ is the slope gradient in degrees (Conforti *et al*., 2011; Shit *et al*, 2015; Gajbhiye and Konyak, 2020). It is generated using the primary terrain attributes which include the slope, flow direction, and flow accumulation through the map algebra tool in ArcGIS.

The SPI map (Fig 4.3) is an estimate of the active hydrogeological condition based on the two parameters considered. In addition, it may be noted that in the SPI map, the authors have not taken into account the ephemeral or perennial condition of the drainages. In the current study, the stream power index will adequately reflect slope erosion processes along with the erosive power of running water directly influencing slope instability.

In the current study area, the maximum relative relief is 340 m with 1st and 2nd order streams draining the larger area of the moderate to steep slopes of Virajpet. The catchment area is less and therefore the hillslopes largely exhibit SPI of 0-1 and 1-2. The 3rd or 4th order stream is confined to the lower reaches of the hillslopes. The landslide susceptibility estimated ratings (LSER) for the classes SPI are given in Table 4.3.

Table 4.3 Landslide Susceptibility Estimated Rating of stream power index

	Stream power Index (SPI)	
	Geo-factor classes	***LSER***
Earth and Debris slide domains	<0 (very low erosion)	0.2
	0-1 (low erosion)	0.4
	1-2 (moderate erosion)	0.6
	2-5 (High erosion)	0.8
	>5 (Very High erosion)	1.0

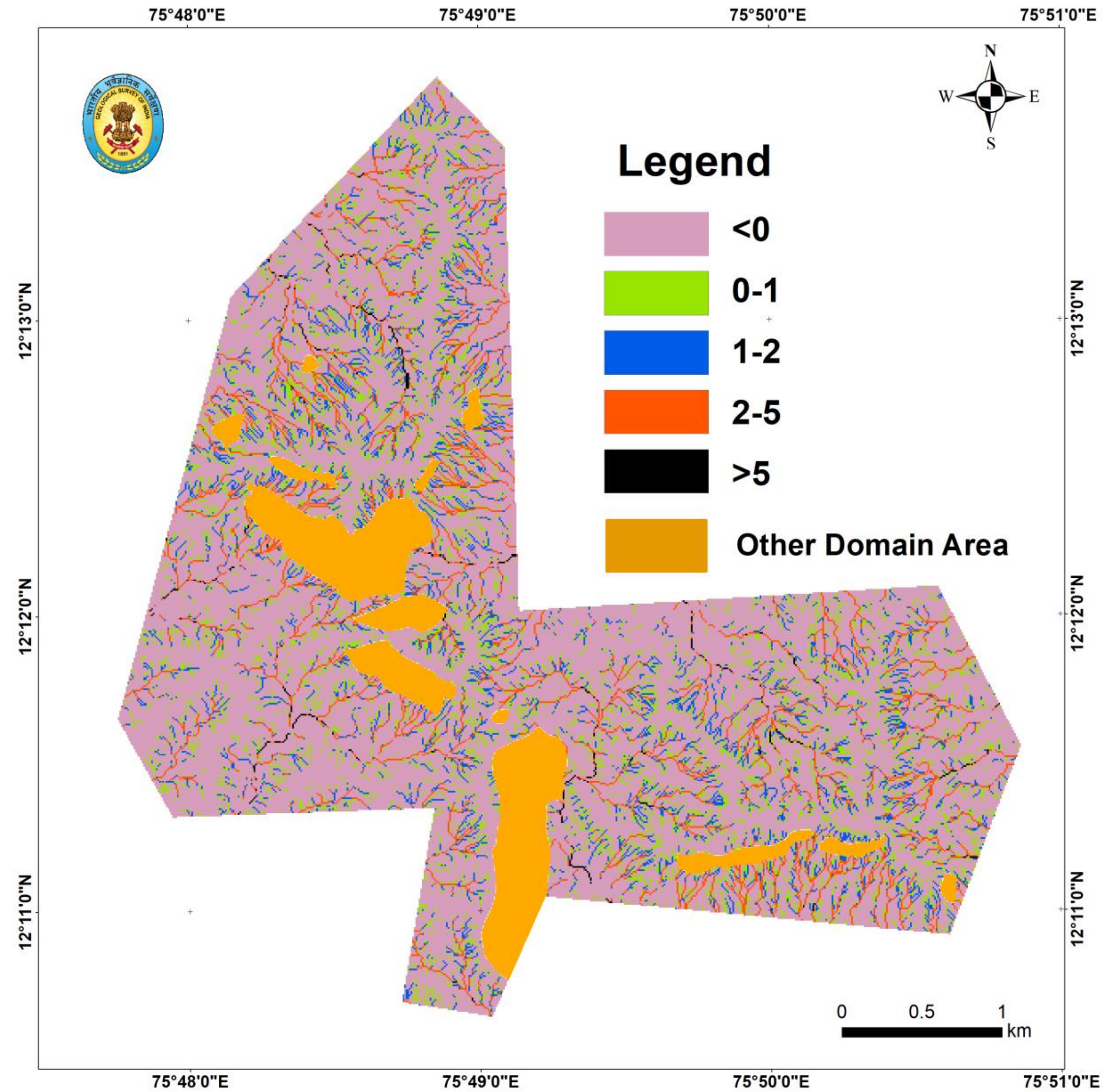

Fig. 4.3 Stream power index map of earth and debris slide domains

4.3.3. Landform map

The current work is carried out at the slope scale and it is suitable to use the DEM derived geomorphon map wherein the elementary terrain units are classified based on the morphology of surface or geomorphometric variables. The landform map is based on the concept of geomorphologic phenotype which classifies the terrain into discrete units at the slope or basin scale. Geomorphons constitute a comprehensive set of most common terrain units that are independent of the size, relief, and orientation of the actual landform (Jasiewicz and Stepinski, 2013). For the study area, the most frequent and commonly recognizable geomorphons considered are summit, ridge, shoulder, spur, slope, hollow, footslope, valley, and depression (Fig. 4.4). These classifications and processing of geomorphon are carried out in the GrassGIS platform. Geomorphon represents terrain units with attributes which is the result of the evolution of geomorphological processes. Therefore, every terrain unit is rated based on its causal relation with landslides, and the LSER is given in Table 4.4.

In the study area, out of 10 common discrete landform units, slope shows preponderance covering an area of about 40%, followed by spur 21% and hollow covering an area of 19%. The N-S and NW-SE trending linear ridges are observed on all prominent hilltops of the Virajpet area.

Table 4.4 Landslide susceptibility estimated rating of Landform

	Landform map	
Earth and Debris slide domains	*Geo-factor classes*	*LSER*
	Flat	0.2
	Ridge & depression	0.4
	Shoulder, Spur & foot slope	0.6
	Slope	0.8
	Hollow	1.0

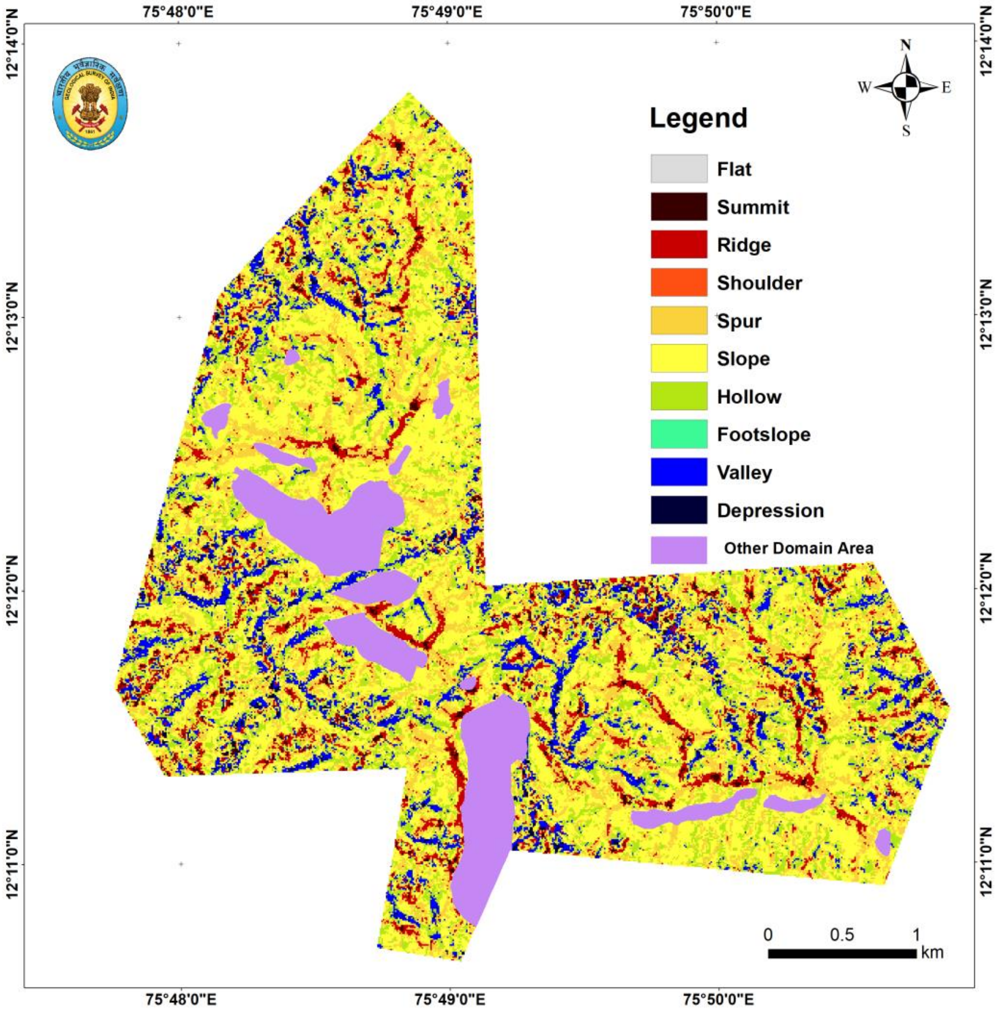

Fig. 4.4 Landform map of earth and debris slide domains

4.3.4 Geotechnical map

In the current study, the scheme of classification of overburden material has been adopted from Ghoshal *et al*., 2013 based on the genesis and their relative susceptibility to initiation of landslides. The slopes in the study area are characterized by varied slope forming material that includes bare rock at the steeper slope of Ayyappa and Bittangala, patches of colluvium, and assorted boulders and debris at the mid slopes of Bittangala and Ayyappa, and by thick immature soil spread pervasively along gentler slopes. These heterogeneous materials will have variations in the porosity and permeability influencing the overall stability condition of the slopes. Isolated pockets of slopes in these areas are strewn by assorted weathered boulders of granite or younger loose debris where past slope movement has taken place. This slope-forming material (SFM) is not directly used for assigning ratings. The samples of these SFM are collected to determine the geotechnical parameters which are then used to assign ratings (Table 4.5).

The geotechnical parameter of the overburden in terms of cohesion (C) and internal angle friction (ϕ) is an important geo-factor that determines the shear strength of the material and the ability to resist sliding. In the current study, a matrix of classes of both C and ϕ is used for assigning ratings in line with the classes defined by Ghoshal *et al*, 2013. The sampling points were selected to adequately represent all variants of the material. An attempt is made to sample following the profile elevation of the slope to acquire possible variation in material deposits due to kinematic sieving (Makse, 1999). A total of 33 numbers of soil samples were collected to determine shear parameters and the lab results reveal that the cohesion ranges from 23.54 kN/m^2 to 36.28 kN/m^2 while the angle of internal friction ranges from 20 to 29 degrees. However, it is found that all the samples fall in the "Good" geotechnical class as per the Cohesion (C)-Friction angle (ϕ) matrix (Table 4.5a). The results show minimal variation in shear strength parameters and the resultant single geotechnical class does not help to significantly classify the slopes based on susceptibility. Therefore, the workers have employed an additional simplistic relationship between shear strength in terms of peak friction angle (PFA) and the slope angle to adjust and further classify the geotechnical results (Table 4.5b). So the 'good' geotechnical class based on C - ϕ has been re-classified as 'bad' if it falls in the 'Very High' class based on peak friction angle minus slope (PFAS-S) (Roopnarine et. al, 2013). The facet map is then used to demarcate and polygonise the data and generate the geotechnical map (Fig 4.5).

Table 4.5 Landslide susceptibility estimated rating of shear parameter

	Geotechnical map	
	Geo-factor classes	*LSER*
Earth and Debris slide domains	Very good	0.2
	good	0.4
	fair	0.6
	bad	0.8
	Very bad	1.0

Table 4.5a Geotechnical class as per the cohesion and internal friction angle matrix

Cohesion (C)	**Angle of Internal Friction (ϕ)**			
	>35°	**25°-35°**	**15°-25°**	**<=15°**
<5 kN/m^2	Fair	Fair	Bad	Very Bad
5-15 kN/m^2	Fair	Fair	Bad	Bad
16 to 30 kN/m^2	Good	Good	Fair	Fair
>30 kN/m^2	Very Good	Good	Good	Fair

Table 4.5b. Geotechnical class adjusted based on Peak friction angle minus slope (After Roopnarine R, et. al 2013)

	Peak friction angle minus slope (PFAS-S)	
Geotechnical class based on Cohesion-Friction angle	**Very high**	**High**
Fair	*Very Bad*	*Bad*
Good	*Bad*	*fair*

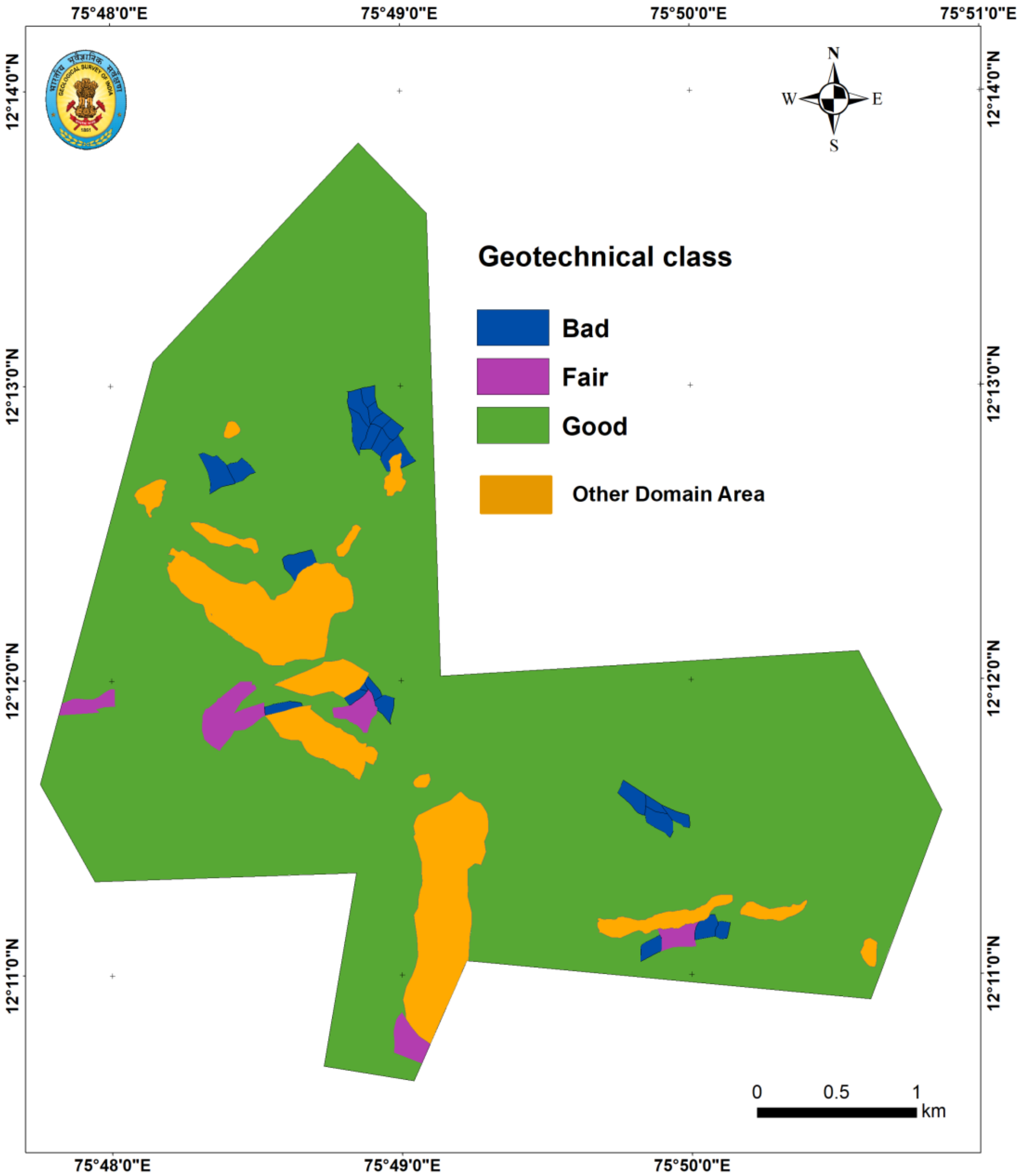

Fig. 4.5 Geotechnical map of the earth and debris slope domains of the study area

4.4 Geo-factors in rock slide and rock fall domain

The geotechnical map and kinematic failure map are two important thematic maps considered in the current study.

4.4.1 Rock mass Rating

The geomechanical characteristic of the rock mass is an important geo-factor that determines the rock slope stability. In the current study, the rock mass quality is studied using the rock mass rating (RMR_{basic}) schema provided by Bieniawski, 1989. The rock mass rating (RMR_{basic}) includes the following parameters for each structural unit:

i. Uniaxial compressive strength of intact rock material: The uniaxial compressive strength is derived using the Schmidt Rebound Hammer through non-destructive in situ tests of rock exposures.

ii. Rock quality designation (RQD): The rock quality designation is derived using the empirical equation (RQD)=115-3.3J_v, where J_v is the volumetric joint count (number of joints in 1m^3).

iii. Joint or discontinuity spacing: The joint spacing of the most vulnerable joint set is taken into account in the field.

iv. Joint condition: The joint condition is described using five parameters which include joint persistence, aperture, the roughness of the surface, type of infilling, and degree of weathering of the joint surface.

v. Groundwater condition: The hydrogeological conditions of the jointed rock mass is qualitatively described in terms of dry, damp, wet, dripping, and flowing. The condition of groundwater can change with the season and under adverse meteoric events. The qualitative observations on groundwater considered in the current study are based solely on the time/season of the fieldwork

In the study area, no rock slides have been documented and minimal rock exposures area observed within the Virajpet hillslopes. The porphyritic granite on the hillslopes is massive and devoid of persistent joints. The rock mass quality for the patches of rock slopes in Ayyappa, Nehru Nagar, and Bittangala are tabulated *(Annexure-IV)*. Since each rock exposure was accessible, the RMR_{basic} data for each rock exposure is calculated separately without using Inverse Distance Weighted interpolation (Fig 4.6). The LSER assigned for the classes of RMR_{basic} is given in Table 4.6.

Table 4.6 Landslide susceptibility estimated rating of rock mass rating

	Rock mass rating		
	Class	**RMR value**	**LSER**
Rockslide and rockfall domains	Very good (I)	>80	0.2
	Good (II)	61-80	0.4
	Fair (III)	41-60	0.6
	Poor (IV)	21-40	0.8
	Very poor (V)	≤20	1

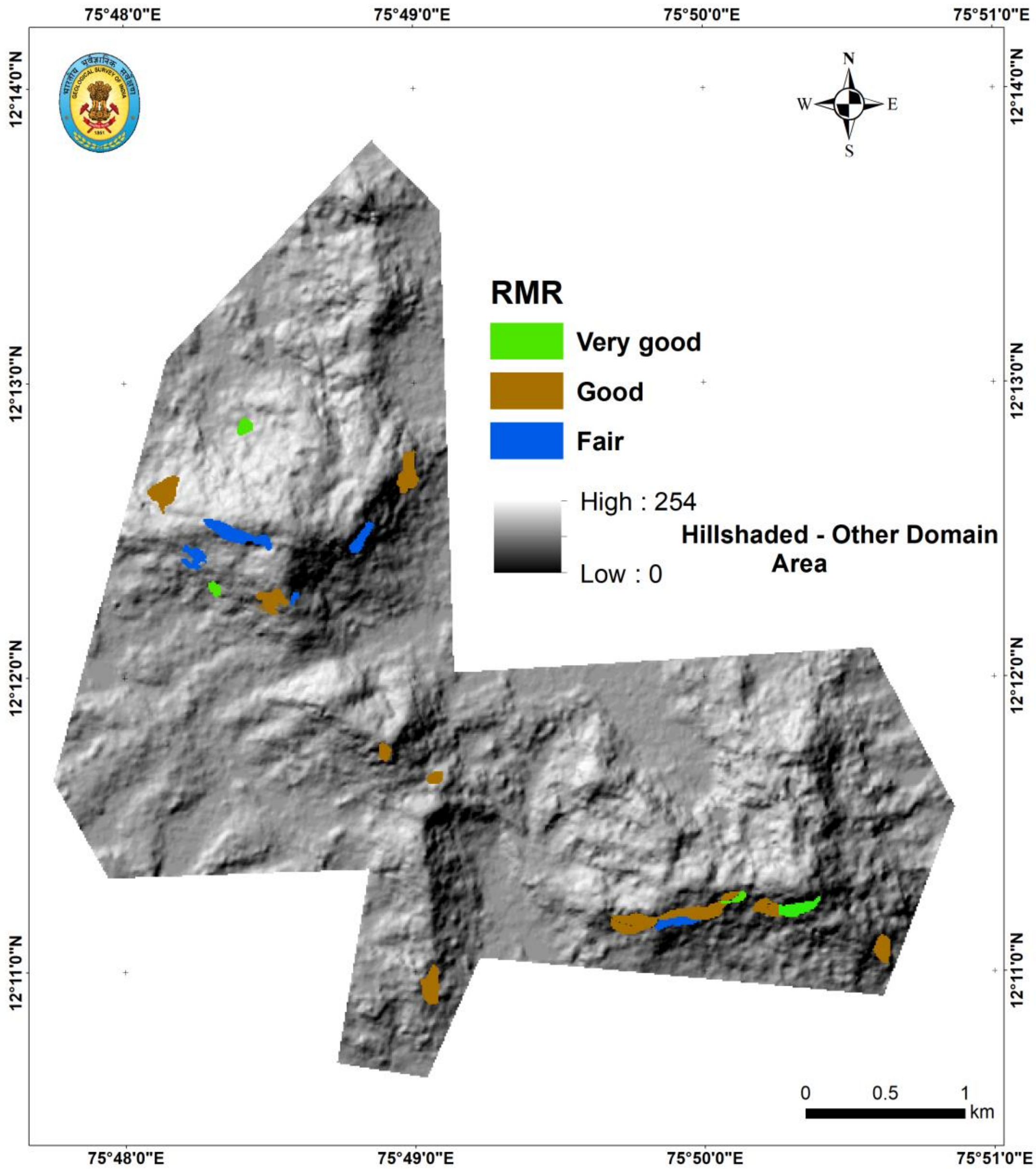

Fig. 4.6 Rock mass rating map of rockfall and rock slide domains of the study area

4.4.2. Kinematic failure map

In rocky slopes, the geometrical relation of discontinuities and the slope is an important pre-disposing factor for stability. The structures in rocks are primary and secondary discontinuities which include bedding planes, joints, foliations, faults, and thrusts (Bureau of Indian Standards - IS 14496 Part 2: 1998). Therefore, the characterization of structural setting is a basic aspect in landslide susceptibility assessment and the evaluation of the geo-structural conditions can enable assessment of slope stability where both first-time and reactivated slope failures are anticipated (Grelle *et al.*, 2011).

The structural data for patches of rock exposures are taken to establish a mutual geometrical relation with the existing slope angle. The mean vector of dip amount/plunge and dip direction/trend for each rock exposure sector is derived by plotting in the stereonet software to establish geometrical relation of the discontinuities with the slope morphometry (Ghosh and Carranza, 2010; Ghosh *et al*, 2010). In the present study, for friction angle, the lowest value in the corresponding range values of rock mass quality class as given by Bieniawski, 1989 is used assuming the worst-case scenario for stability condition. All the discontinuities data, friction angle, and slope are rasterized and the kinematic feasibility in the rockslide and the rockfall domain is processed in Arcmap 10.4.

For planar failure to occur the necessary structural conditions needed to be satisfied is ϕ <DIP<S (Hoek, E., and Bray, J. W., 1977).

Where ϕ= Angle of internal friction of the rock

DIP= Dip amount/plunge of joint

S=Slope angle

For the wedge failure, the trend and plunge of the line of intersection of the discontinuities are considered with respect to the slope and friction angle.

For the rockfall domain, the slopes greater than 45º are considered which includes the escarpment areas of Bittangala and the eastern steep slope of Ayyappa Hill. In these slopes, pervasive joint sets have formed detached blocks of rocks. The condition required to be satisfied in the rockfall is

$S \geq \phi + (90° - DIP)$

Where ϕ= angle of friction of the rock

DIP= Dip amount/plunge of joint

S=Slope angle

The presence or absence of adverse relation determines the relative stability. The characterization of these relations at different scales plays a fundamental role in understanding the landsliding mechanism in rocky slopes. As per the kinematic failure map, in Virajpet the rocky hillslopes do not show much criticality except along a few patches of the steep slope of Bittangala where critical condition of '1' is observed (Fig. 4.7). In the field, although no rock slides or rock falls are documented in the study area, a few patches of rock exposures along the mid slopes of Ayyappa exhibit orientation of joints that provide a favourable disposition to form failure mode. The landslide susceptibility estimated rating of kinematic failure conditions in the current study is given in Table 4.7.

Table 4.7 Landslide susceptibility estimated rating of kinematic failure conditions

	Kinematic failure map	
	Geo-factor classes	*LSER*
Rockslide and rockfall domains	1 critical condition	0.2
	2 critical condition	0.4
	3 critical condition	0.6
	4 critical condition	0.8
	5 critical condition	1.0

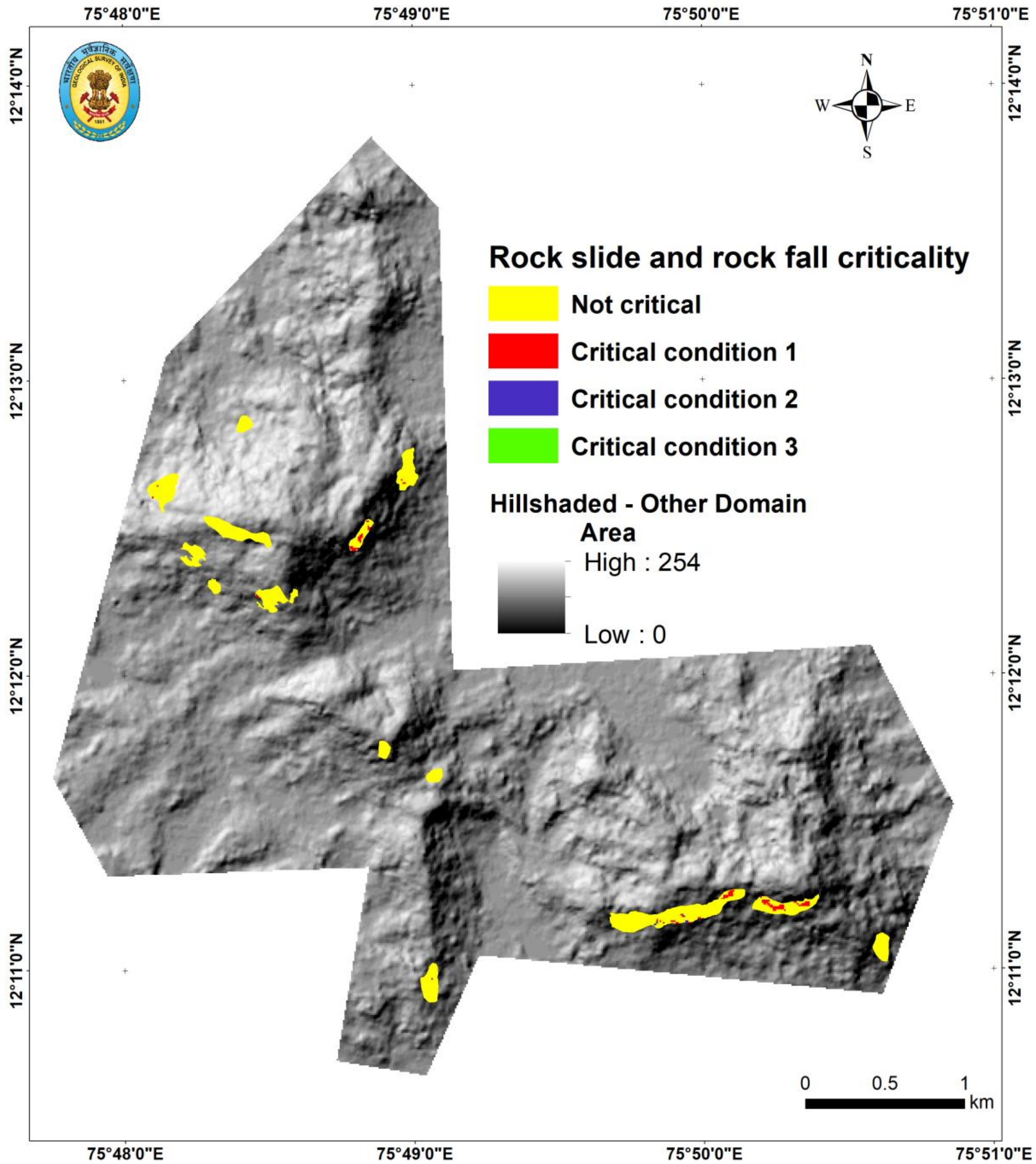

Fig. 4.7 Combined kinematic failure map for rockfall and rock slide domains

4.5 Geo-factors in cut slope domain

The slope cut domain essentially represents the slopes that have undergone partial or substantial modification through anthropogenic interference. These include slopes where slope profile has been changed due to construction of road, settlement, and other public utility structures. Partial slope profile modification through extensive slope cutting along the road is observed along the road leading up to Coorg Dental College. Intermittent slope cut heights in overburden slopes of class >2 m are observed along the settlements at Nehru Nagar, and Ayyappa midslopes.

In terms of slope forming material, these slopes can have either rock or overburden. For the rock slope falling within the cut slope domain in Ayyappa midslopes, the thematic factors RMR_{basic} and Kinematic failure map is considered. However, for the overburden cut slope domain, the thematic factors considered are slope map, regolith thickness map, a relative relief map, and geotechnical map.

4.5.1 Slope map

The slope map is generated using CartoDEM 10m resolution and reclassified into five classes (Fig. 4.8). The slope factor is invariably associated with any type of landslides. This inherent causal relationship of slope gradient in inducing slope instability makes it the most important and effective parameter to consider. Generally, landslides show a positive spatial relationship with a higher slope gradient until the maximum frequency is reached at around 35° categories followed by a decrease (Dai and Lee, 2002). In the cut slope domain area, the slope angle ranges from 0 to 46° where the slope class 15°-25° covers maximum area with about 45%, followed by 25-35°covering 26% of the area. The steeper classes 35°-45° are largely observed in sporadic clusters along the NW-SE trending hillslopes at higher reaches of Magulla, Nehru Nagar, Ambatty, and Ayyappa. The landslide susceptibility estimated ratings of slope classes of cut slope domain are given in Table 4.8.

Table 4.8 Landslide susceptibility estimated ratings of slope classes

	Slope angle	
	Classes	LSER
Cut slope domain	0-15	0.2
	15-25	0.4
	25-35	0.6
	35-45	0.8
	>45	1.0

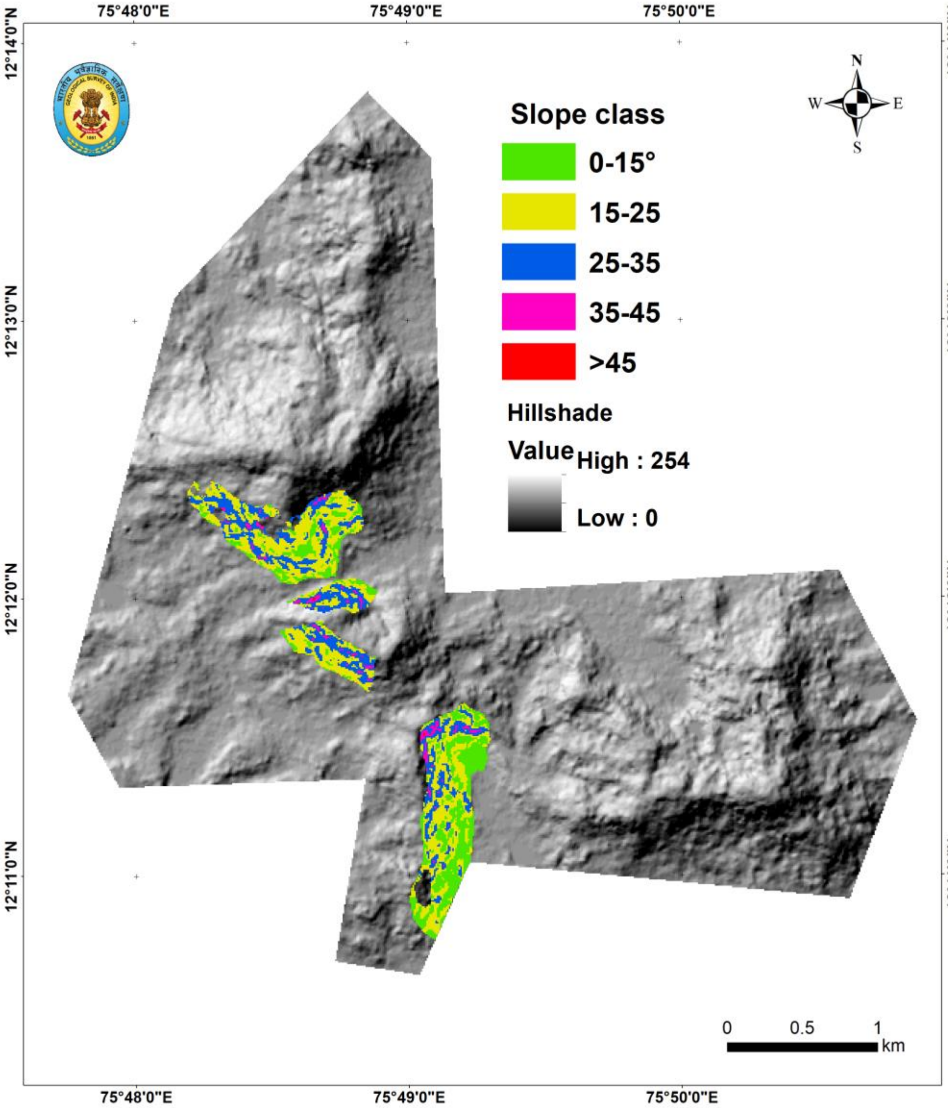

Fig. 4.8 Slope map of the cut slope domain

4.5.2. Regolith thickness map: Within the cut slope, the vertical cut sections are exposed along the settlements, roads, and quarries that help in measuring and estimating the range of regolith thickness. Generally, the cut slope with higher regolith thickness is more susceptible to landsliding at higher relief. Field observations along the cut sections show that there is extreme spatial variation in the thickness of the overburden. Limitations exist in mapping the spatial extent of overburden thickness in areas with no exposure for which reasonable interpolation based on the slope forming material type is done. In order to accommodate such uncertainty, the overburden thickness classes in the cut-slope domain area are classified into five viz. <0.5 m, 0.5-2 m, 2-4 m, and >4m (Fig. 4.9). The slopes having thicker overburden are observed to have a spatial association with landslides and the LSER are accordingly assigned (Table 4.9). The overburden thickness class 2-4 m covers a maximum area with 46% of the cut slope domain area. The overburden thickness greater than 4m is observed in the eastern facing foot slopes of the Ayyappa and Ambatty areas. The veneer cover of overburden 0.5-2 m is mostly observed along the midslopes of Ayyappa and Nehru Nagar localities.

Table 4.9 Landslide susceptibility estimated rating of the classes of regolith thickness

	Regolith thickness	
	Geo-factor classes	*Landslide susceptibility estimated ratings*
Cut slope domain	0-0.5	0.2
	0.5-2	0.4
	2-4	0.7
	>4	1.0

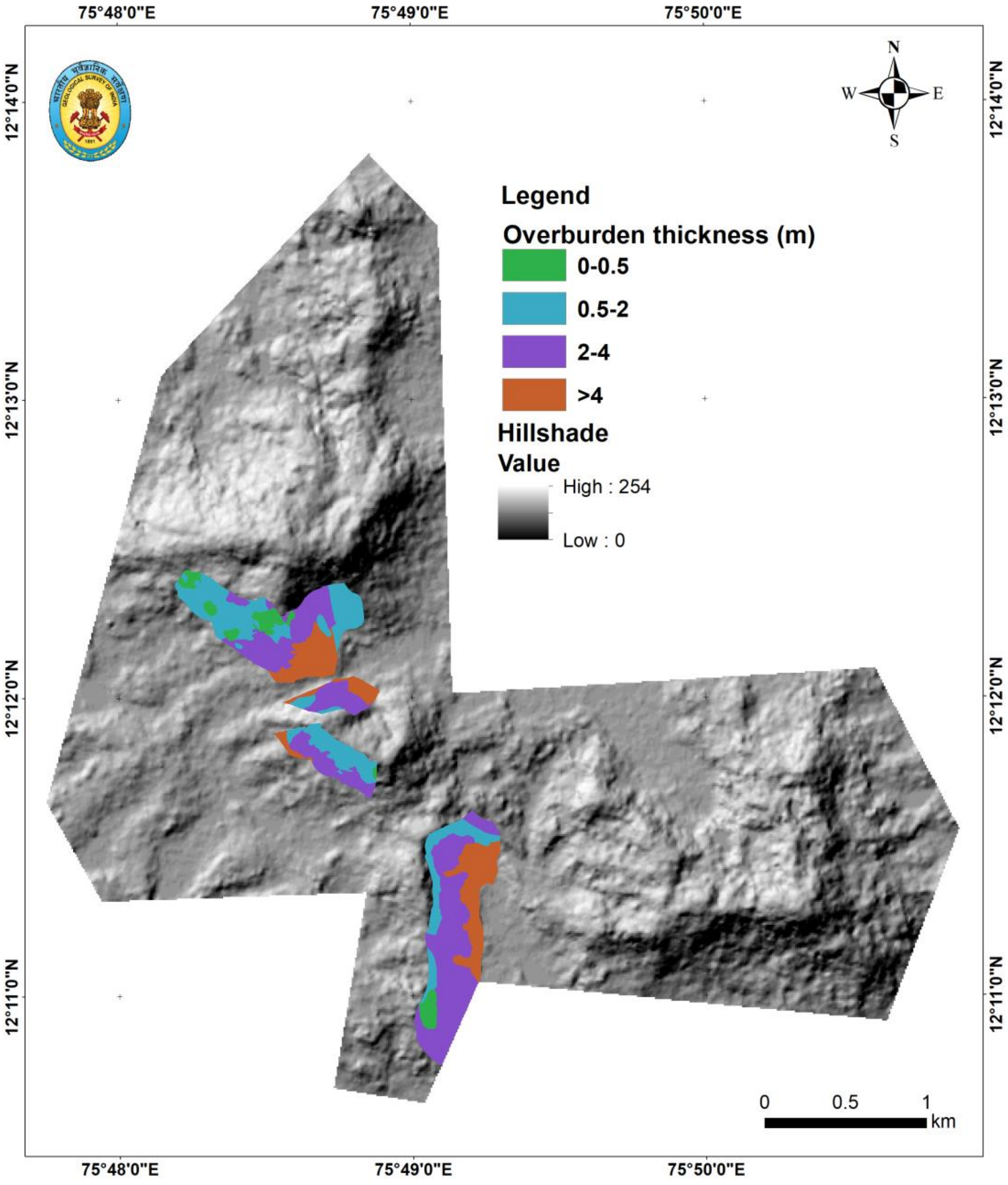

Fig. 4.9 Regolith thickness map of the cut slope domain

4.5.3. Relative relief

Relative relief is the difference between the maximum and minimum elevation in the slope unit. For the cut-slope domain, the higher the relative relief within the slope unit, the greater head load is available for inducing instability of the slope. The slope units for the cut slope domain are delineated from the topographic base map (Anbalagan, 1992) and the landslide susceptibility estimated rating of the classes are assigned (Table 4.10). The zonal statistics tool in ArcGIS is used to obtain the range of the elevation for the particular slope facet. In Ayyappa and Magulla hillslopes, low to moderate relative relief (<25 m and 25-50 m) is dominant. The higher relative relief (50-75m and 75-100m) are observed in Nehru Nagar and Ambatty hillslopes (Fig. 4.10).

Table 4.10 Landslide susceptibility estimated rating of the classes of relative relief

	Relative Relief map	
	Geo-factor classes	*LSER*
Cut slope domain	0-25 m	0.2
	25-50 m	0.4
	50-75 m	0.6
	75-100 m	0.8
	>100 m	1.0

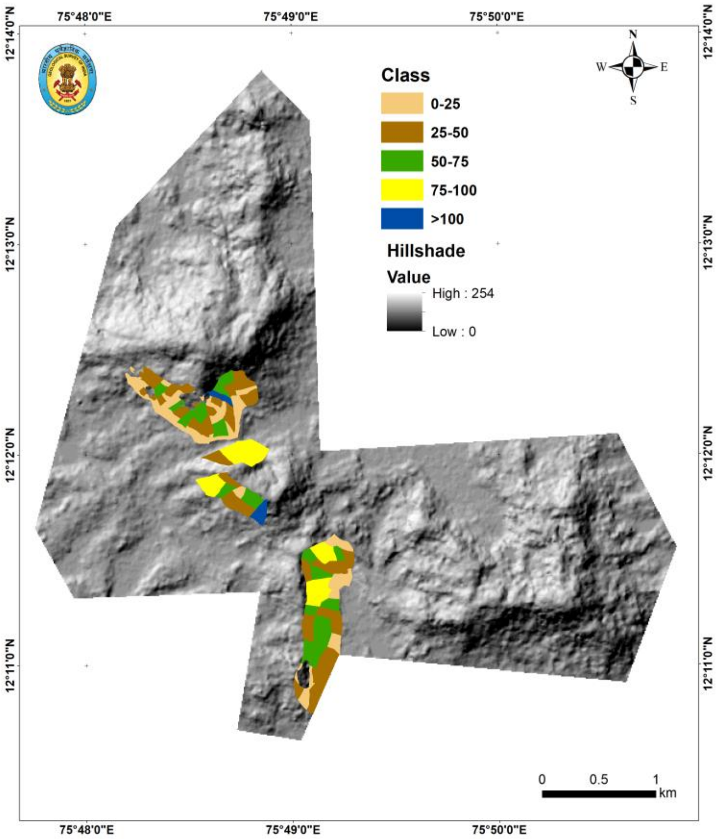

Fig. 4.10 Relative relief map of the cut slope domain

4.3.4. Geotechnical map

The geotechnical map for the cut slope domain is prepared and clipped from the same geotechnical map generated seamlessly across all the domains. For the overburden-covered part of slopes, the slope forming material type in the cut slope domain is initially mapped and the locations for the sample points are identified. The matrix of the shear parameters of the overburden material (cohesion and internal friction angle) is used to assign ratings (Ghoshal *et al*, 2013) and generate the geotechnical map as described in section 4.3.4 for earth and debris slide domain (Fig 4.11). In rocky slopes of the cut slope domain, the rock mass quality is assessed through rock mass rating (RMR_{basic}) calculation at the 14 sites (Annexure IV) following the steps described in 4.4.1.

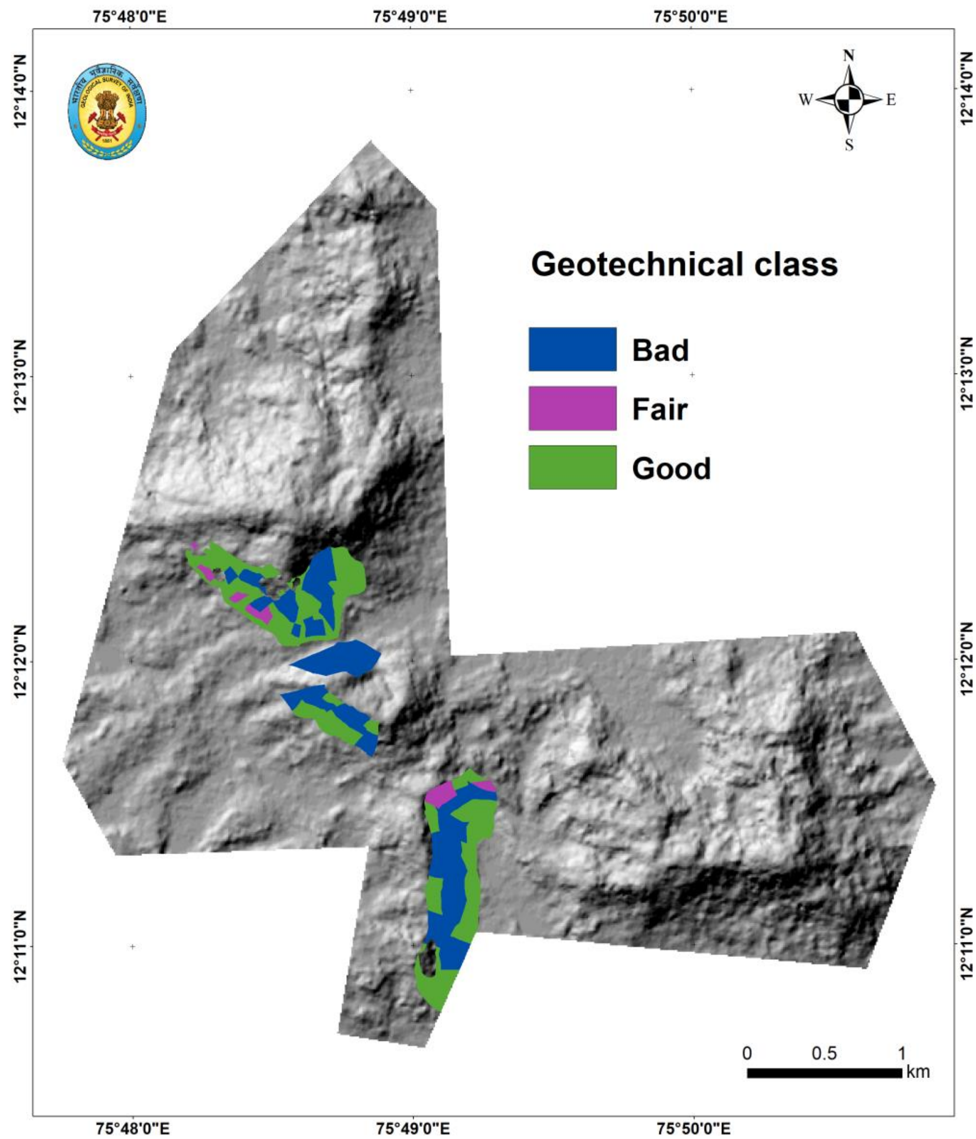

Fig. 4.11 Geotechnical map of the cut slope domain

5. LANDSLIDE SUSCEPTIBILITY MAP

A set of geo-environmental factors have been considered during the study to generate the landslide susceptibility map of the study area. The combination of geo-environmental factors and their mutual intricate relationship determine the spatial distribution of landslides. Landslide Susceptibility Estimated Ratings (LSER) of all the preparatory maps are added to obtain the Total Estimated Susceptibility Value (TESV) which is finally classified into 'high', 'moderate', and 'low' for each domain. The Total Estimated Susceptibility Value is 1 for all the domains. The value closer to 1 indicates higher susceptibility values while the lesser values indicate lesser susceptibility values. The low susceptible slopes are considered stable under the given set of geo-environmental conditions considered in the study. However, any unmethodical anthropogenic interference can still act as aggravating factor for initiating landslides.

5.1 Earth and debris slide susceptibility

The Landslide Susceptibility Estimated Ratings (LSER) of all the thematic layers for earth and debris domain are added up to derive the susceptibility score map as:

$$TESV = 0.5GT+0.3LF+0.1SPI+0.1LULC$$

Where, GT – Geotechnical map

LF – Landform

SPI – Stream Power Index

LULC – Land use land cover

In the earth and debris slide domains, it is attempted to derive the susceptibility map based on the natural break (Jenks) but it shows an unrealistic larger percentage of high and moderate classes. Therefore, in the current study, the break values for the susceptibility score have been manually done into three classes of high, moderate, and low susceptibility so that it adequately represents real field conditions. The high-class accounts for 4%, moderate class accounts for 19.2% and low susceptibility accounts for 76.8% of the earth and debris slide domains (Fig. 5.1). The map shows that the high susceptibility areas for the overburden covered areas are in parts of North facing Ayyappa hillslopes, part of Magulla and Bittangala. The moderate zones are seen along the fringes of the high zone where there are drainages.

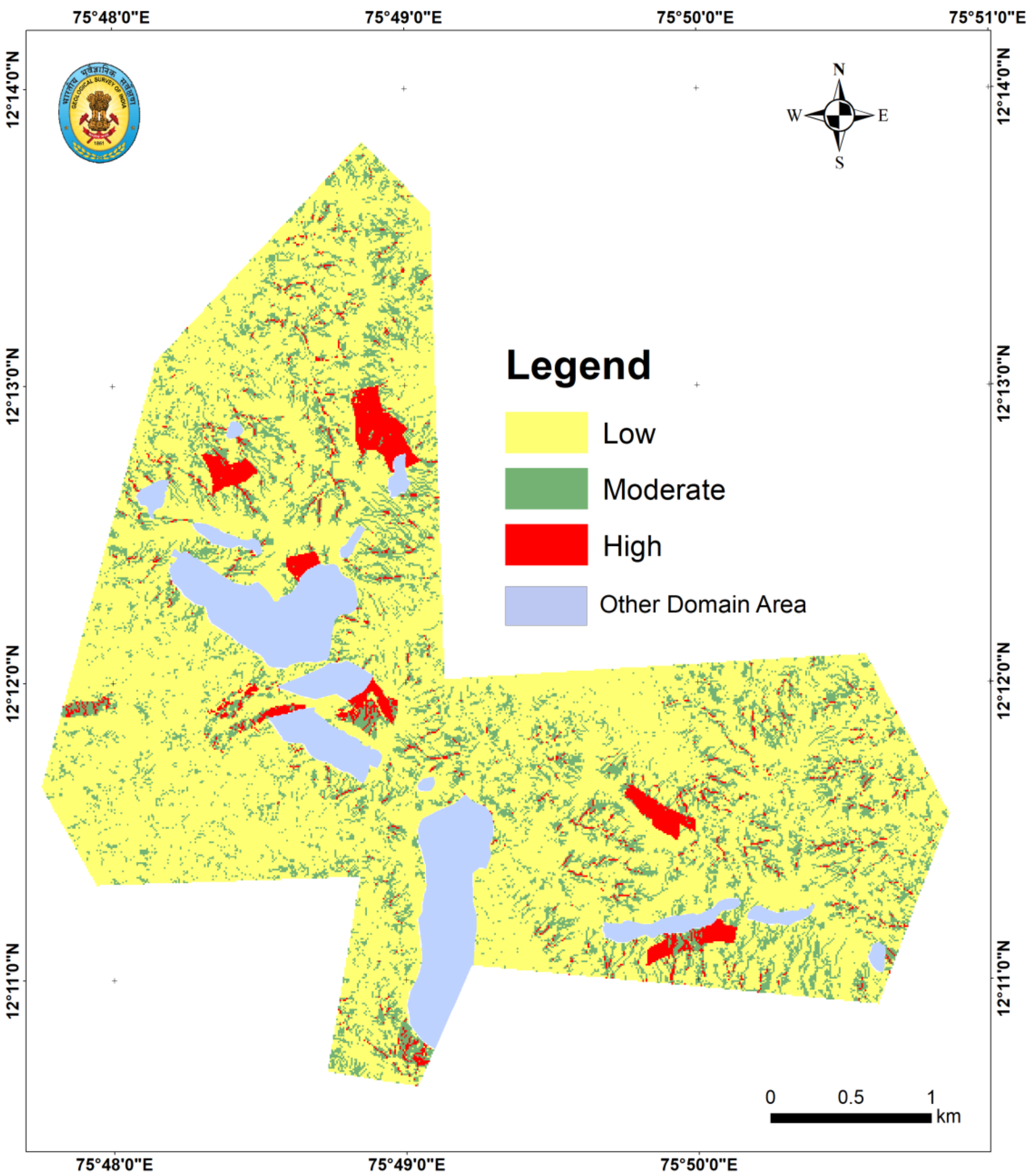

Fig. 5.1 Landslide susceptibility map of earth and debris domain

5.2 Rock slide and rock fall susceptibility

The Landslide Susceptibility Estimated Ratings (LSER) of the two geo-factors which include the Geotechnical map and Kinematic failure map are added up to arrive at the susceptibility score of rocky slopes. The parametric equation used for the rock slide susceptibility map is:

TESV=0.6GT+0.4KF

Where GT = Geotechnical map (RMR_{basic})

KF = Kinematic Failure map

Rockfall and rock slide susceptibility on the Virajpet hillslopes are observed to be minimal. The rockslide susceptibility map shows 74.1 % low, 25% moderate, and 0.9% high susceptible to rock slides (Fig. 5.2). The patch of a moderate class is seen near the south-facing Ayyapa hill midslopes while the few pixels of high and moderate susceptibility are confined to the steep slopes of Bittangala slopes.

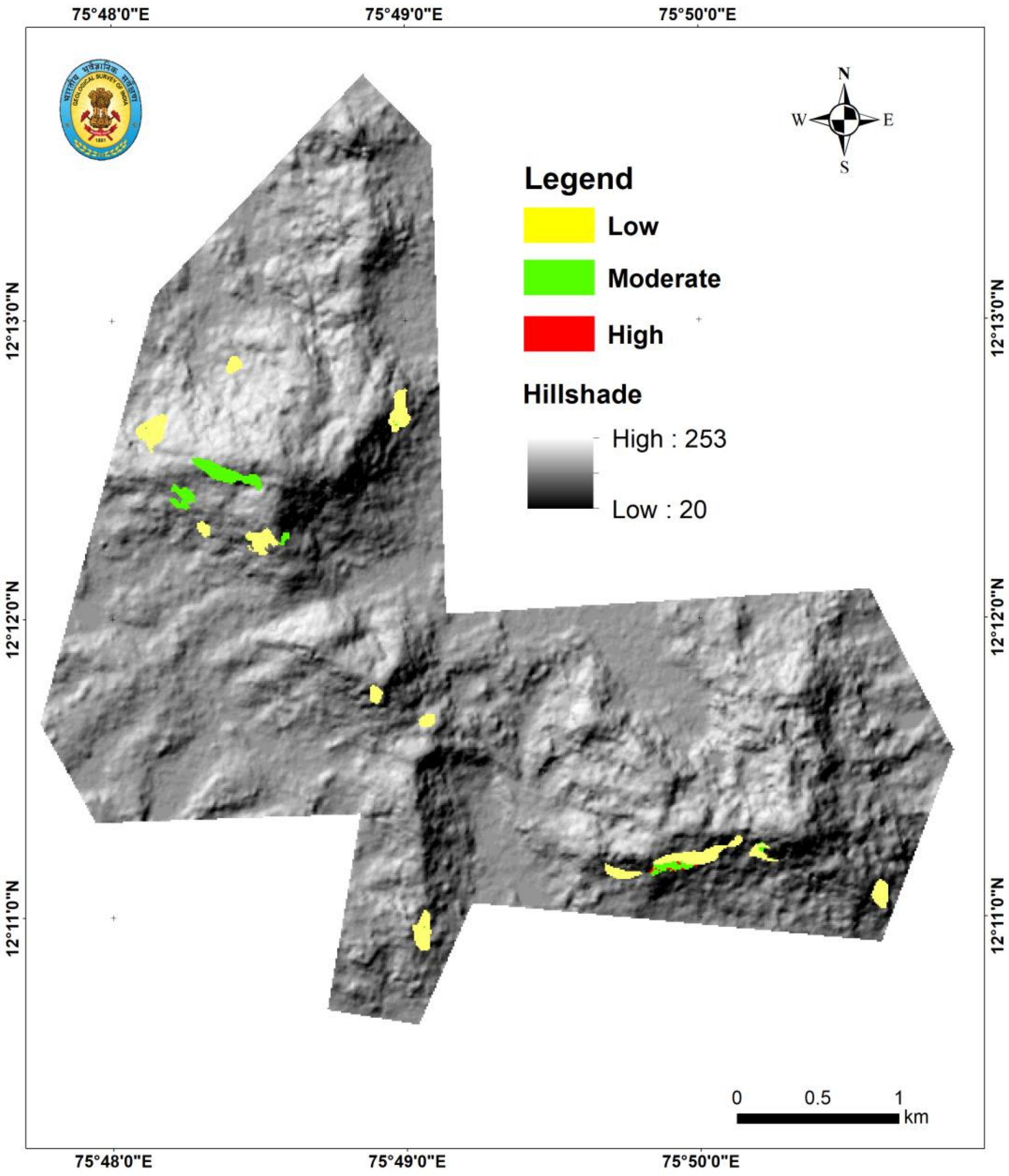

Fig. 5.2 Landslide susceptibility map of rockslide domain

The steep slopes greater than 45º are limited in the study area. The rockfall susceptibility map shows Bittangala and eastern Ayyappa hillslopes as moderate to high (Fig. 5.3). These are pockets of escarpments exposing massive bare rock.

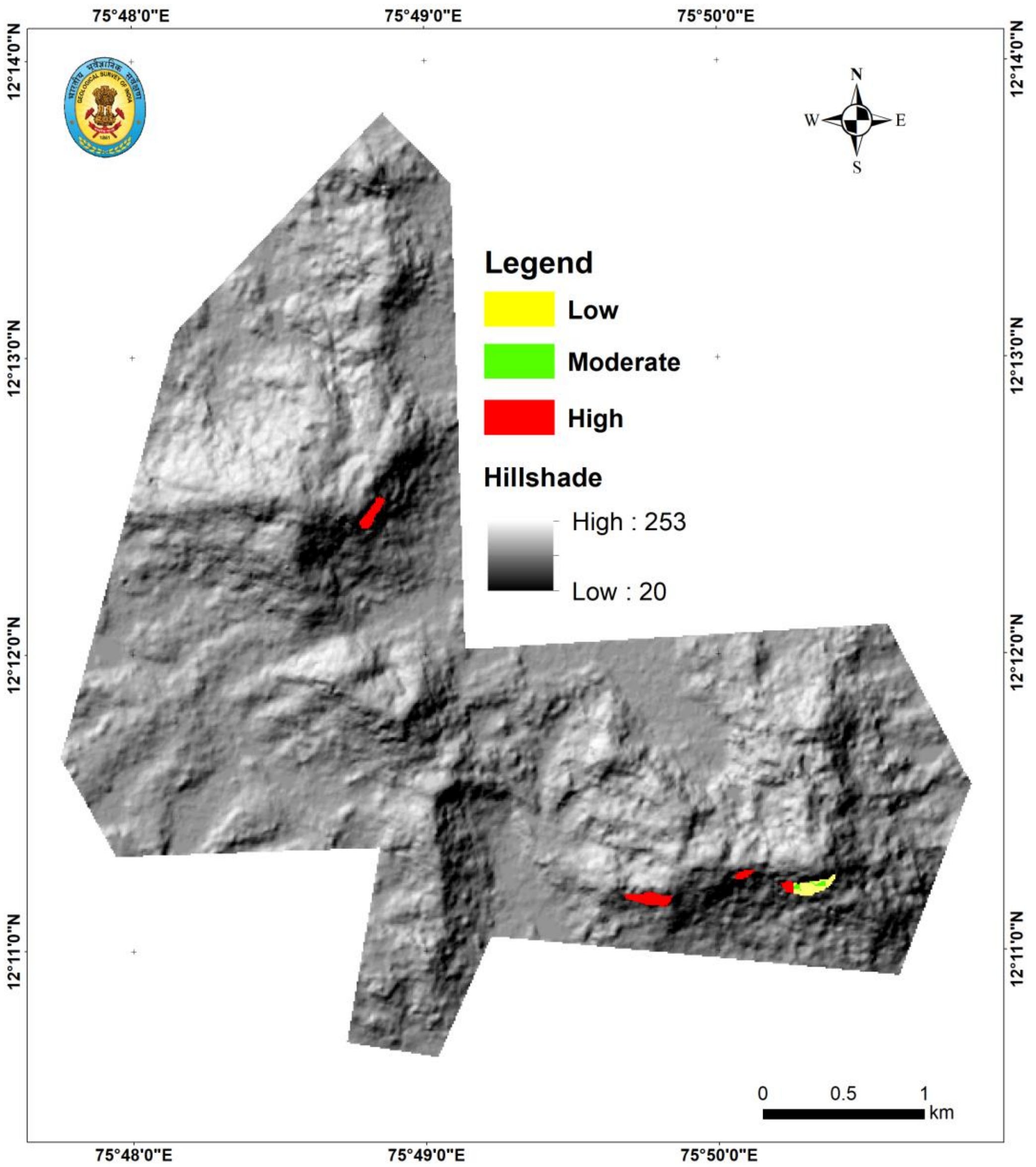

Fig. 5.3 Landslide susceptibility map of rockfall domain

5.3 Cut slope domain susceptibility

The Landslide Susceptibility Estimated Ratings (LSER) of the four geo-factors of overburden area which include the slope map, relief map, overburden thickness map and geotechnical map are added up to arrive at the susceptibility score of the cut slope domain.

The parametric equation is

TESV= 0.4GT+0.2RR+0.2RT+0.2S

Where, GT = Geotechnical map,

RR = Relative relief map,

RT = Regolith thickness map

S = Slope angle map.

The susceptibility map shows that 43.8% low, 21.8% moderate, and 34.36% high coverage of the cut slope domain. The hillslopes of the Magulla, parts of Ayyappa, and Ambatty hillslopes are categorised into moderate and high susceptible zones (Fig. 5.4).

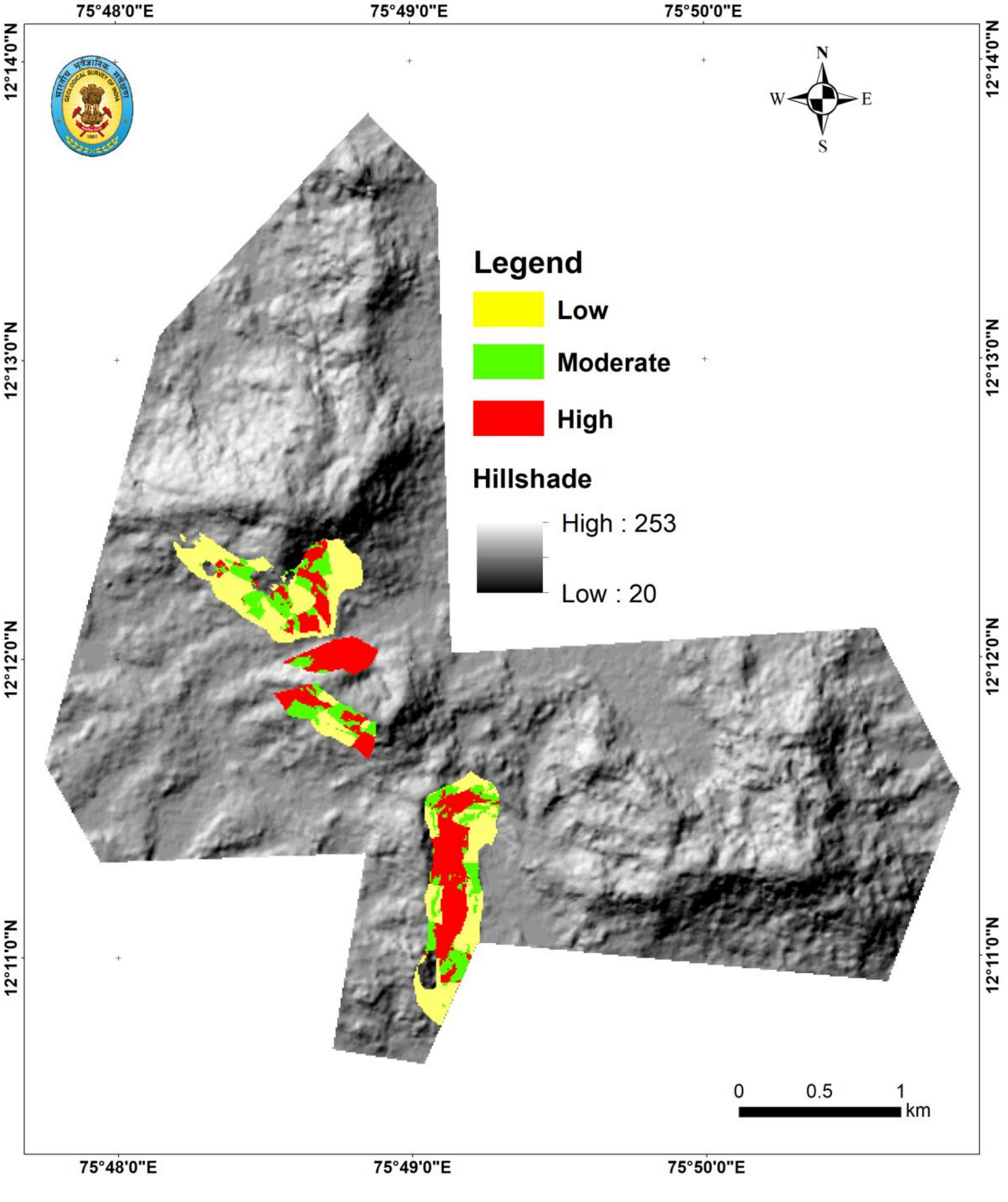

Fig. 5.4 Landslide susceptibility map of cut slope domain

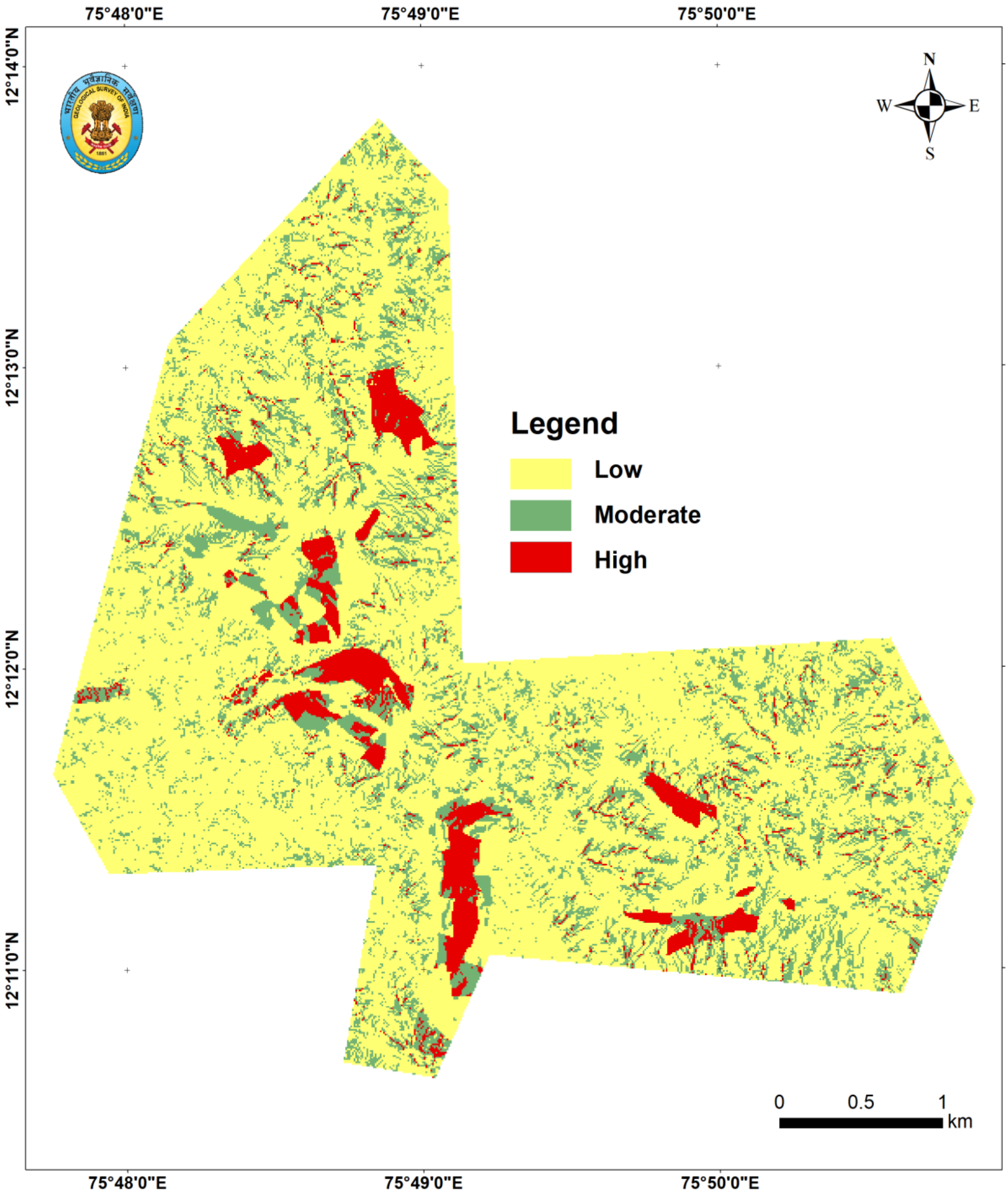

Fig. 5.5 Combined landslide susceptibility map of the study area

5.4 Validation of landslide susceptibility map

In the current study, the documented landslides are not used in deriving the susceptibility score map because of which the “success-rate curve” cannot be generated (Chung and Fabbri, 1999). Moreover, owing to want of landslide data and non-uniform spatial distribution, the prediction rate curve has been generated only for the cut slope domain from where the landslides have been documented. The prediction rate curve is able to predict fairly well where 34% of the high susceptible map area is able to classify 65% of the landslide area (Fig. 5.6).

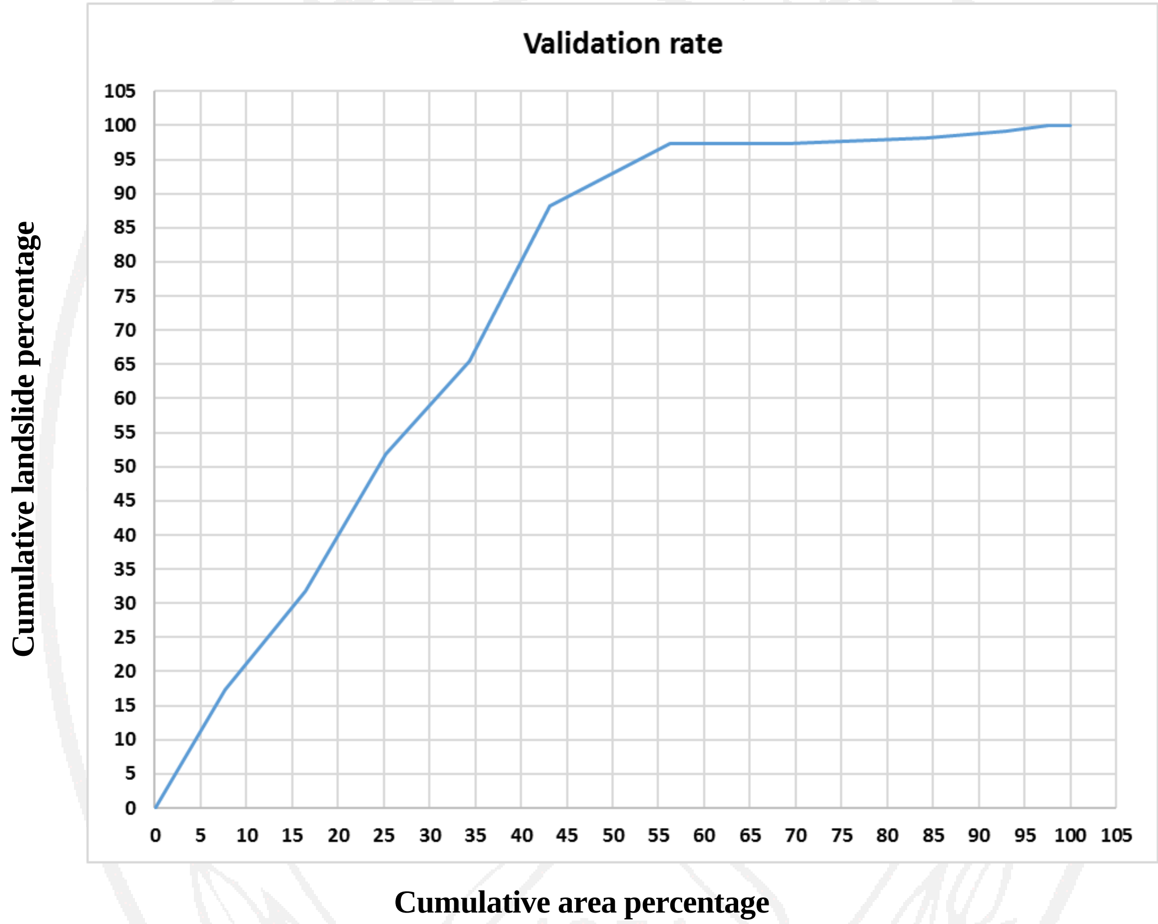

Fig. 5.6 Prediction rate curve of landslide susceptibility map of cut slope domain.

In addition to the prediction rate curve using cumulative landslide area, the number of documented landslides in the field are cross validated using simple landslide density on the susceptibility map generated for the cut slope domain. It is found that the high susceptible area accounts for 20 landslide points, the moderate susceptible zone account for 5 landslide points and the low susceptible area shows 3 landslide points (Fig. 5.7).

Table 5.1 Landslide density distribution in each susceptibility class

Class	Total pixels	Area (sq.m)	Number of known landslides	Landslide density	Landslide percent
Low	4668	466800	3	0.000643	10.71
Moderate	2325	232500	5	0.002151	17.86
High	3662	366200	20	0.005461	71.43
Total	10655	1065500	28		

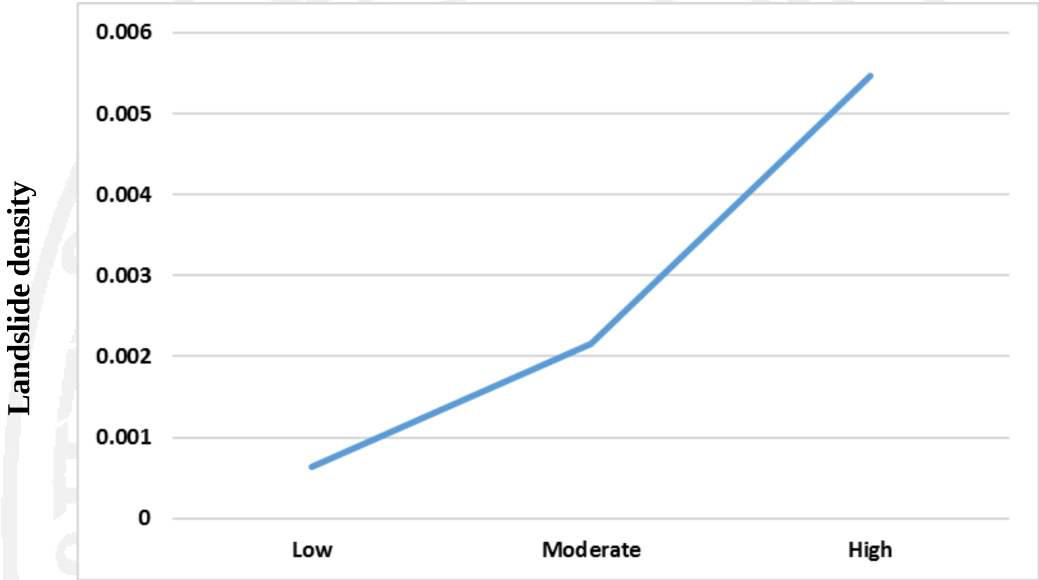

Fig. 5.7 Landslide density distribution in each susceptibility class

6. LANDSLIDE RISK MANAGEMENT

The landslide susceptibility map of the study area as obtained by using the heuristic method of ratings is a map that can be used to understand the relative stability of the study area. The map provides a fair idea of the slope susceptibility to failure of any type in response to the interaction of the considered geo-environmental factors. The susceptibility map will, therefore, give a qualitative estimation of how the specific areas will be susceptible to a potential future landslide. However, it may be categorically mentioned that the future landslide does not refer to any specific time frame or frequency of occurrence nor does it carry any connotation on the magnitude or scale of the failure. It is merely an establishment of a relationship of relevant geo-environmental causative factors with landslides for the areas of interest and based on which a qualitative assessment is derived about the slope stability.

The landslide susceptibility map generated in this work will serve as a foundational step within the larger framework of landslide risk management. The stakeholders including the local administration and Panchayat can use the output susceptibility map to establish relevant criteria for value judgments in managing risks associated with landslides in specific areas of Virajpet hillslopes.

6.1 Probable high-risk areas and mitigation measures

The landslide susceptibility shows a substantial area of the cut slope domains of Ayyappa, Magulla, and Nehru Nagar are in high susceptibility. Several settlements or public utility buildings are located on the downslope side due to which Probable High Risk (PhR) area status has been assigned to parts of slopes of Ayyappa, Nehru Nagar, Magulla, Ambatty. This assessment is primarily based on field observations on site characteristics. The assessment was done on the possible volume of material that could be mobilized if a landslide is triggered based on the dimension of the cracks and the thickness of the overburden material on these slopes. The probable direction of slope failure is derived according to the mean direction of the slope facet and based on which the feasible escape route or safe shelter has been identified for the high-risk zones.

a. Nehru Nagar, Virajpet

In Nehru Nagar, above Polling Station number 8, the settlements and buildings are located on the mid-slopes of southwestern facing slope up to an elevation of 1007m above mean sea level. A localized surface crack (12°11'42.57"N, 75°48'51.84"E) has developed at the mid-slope above the topmost settlement or building at Nehru Nagar, Virajpet (Fig. 6.1a,b). The crack is about 30 m long with an opening varying from 5-10 cm while the depth varies from 10-30 cm. The shape of the crack is curvilinear and is currently sealed using impervious material by the locals. The possible cause of the instability is the nature of the material which is immature soil. In addition, the houses are constructed on the benched slope without toe support which has aggravated minor landslides bringing down the material over the houses. The thickness of the overburden in this slope ranges from 1-2m. A first-order stream is observed on the right flank of the houses which is devoid of any impervious lining.

The approximate volume of the material that can be mobilized is 1,800 m^3 based on the length of the localized surface crack and the projected dimension of displaced material in terms of width (30m) and length (40m) and the thickness of the overburden (1.5m). If the landslide is triggered under adverse hydrological conditions, the probable direction of material movement is in the southwest direction where about 14 houses are located and serve as possible elements at risk.

The mitigation measures recommended for the eastern part of Nehru Nagar hillslope includes:

i) Masonry breast wall is observed only in the lowest bench of slope cut section near the Polling station number 8. The benched slope cut sections on the upslope settlements should be provided with a breast wall and adequate weep holes.

ii) The existing water tank near the surface crack should be abandoned/removed to minimize static loading on the distressed slope.

iii) Further slope cutting near the surface crack must be prohibited.

iv) The ephemeral streamlet on the right flank of the settlements and near the surface crack should be provided with impervious lining to prevent aggravation of slope instability.

v) The higher reaches of the central part of Nehru Nagar hillslopes are also observed to have vertical cut sections of 2-4 m height (Lat/Long:12.196529°/75.812634°) at the elevation of 1003m above MSL. The upslope of these slope cut sections is characterized by residual boulders of varying dimensions. The cut sections should be provided with either a reinforced concrete breast wall or a drystone masonry wall. In addition, further unmethodical slope cutting should be prohibited to prevent untoward displacement of detached boulders.

vi) Several cut sections without structural toe buttress are observed at the western part of Nehru Nagar (Lat/Long: 12.197102°/ 75.811939°). In addition, a settlement is constructed right on the path of the ephemeral stream without the provision of a drainage system and is currently abandoned due to slope instability. The site is characterized by a preponderance of slope wash and assorted debris and represents concave slope morphometry or hollow landform unit which has a high potential for water accumulation. Therefore, a proper drainage system with adequate lining must be provided along the hillside of the cut sections.

vii) In the event of any indicators of landslide incidence within the slope Nehru Nagar, a feasible immediate escape route is towards the southeast of Polling Station number 8 where a temporary safe shelter can be arranged (Fig 6.1c).

Fig. 6.1a. Cracks developed on the floor of houses at Nehru Nagar

Fig. 6.1b. Cracks developed on the wall of houses at Nehru Nagar

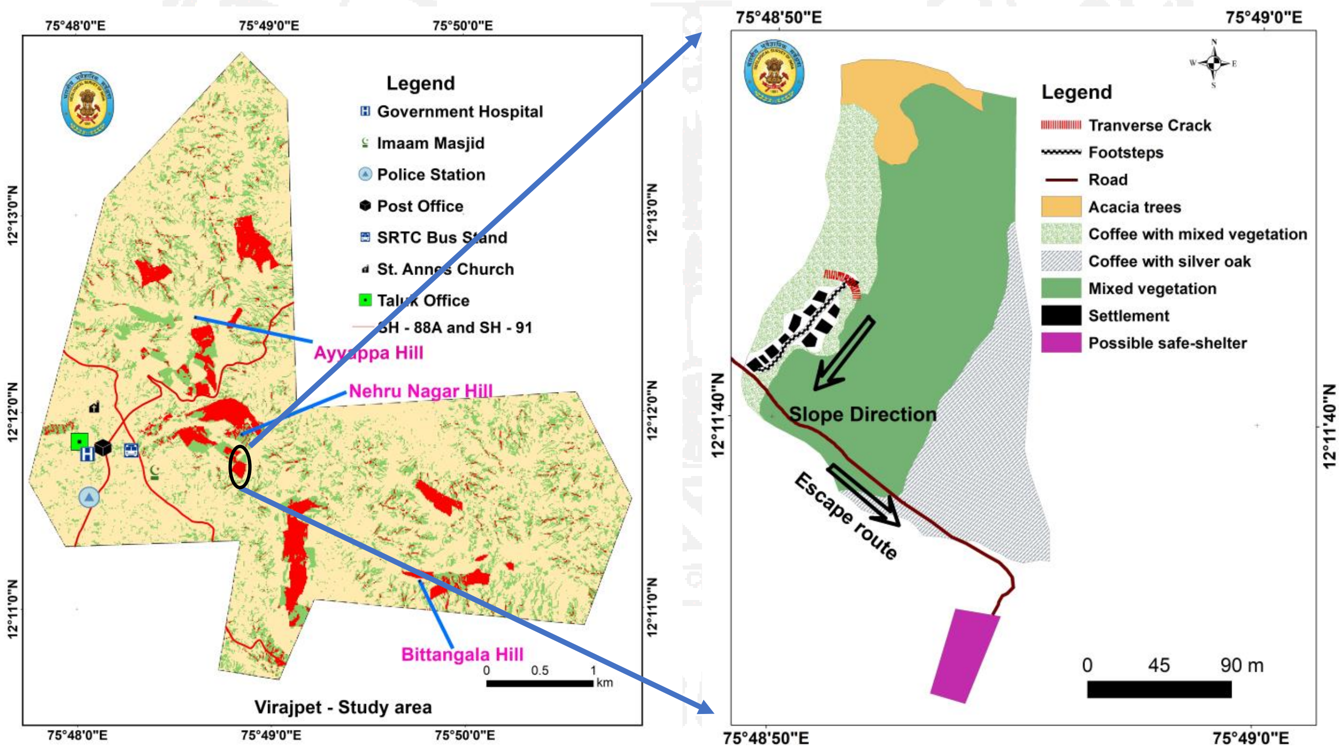

Fig. 6.1c Location map of Nehru Nagar along with Elements at Risk (EatR) and possible escape route

b. Magulla, Virajpet

In Magulla, a landslide was reported in the 2018 Monsoon, wherein a house was partially damaged (Fig. 6.2a). The landslide was initiated above the excavated steep slope where the extensive slope cut was kept unsupported at the toe. The thickness of the immature soil characterizing the slope is about 3-4m. No transverse cracks are observed on the flanks or above the landslide however a few tilted tree trunks are observed on the upslopes (Fig. 6.2b). If re-activation of the old landslide is triggered through retrogression, given the steep slope of about 35°-45° coupled with thick overburden under adverse hydrological conditions, the Magulla foot slope falls in the probable high-risk zone. The elements at risk (EatR) identified include 5 residential buildings that fall in a possible impact zone along the material movement direction. Based on the dimension of the old landslide, the possible volume of the material that can be mobilized is 3000 m^3 (Length-20m, width-50m, and thickness-3m).

As a part of the mitigative measure, it is recommended to erect a breast wall of sufficient height and weep holes at the slope cut sections. In the event of a prolonged adverse meteoric event that may aggravate instability within the slope, a feasible immediate escape route is towards the north where a temporary safe shelter can be arranged above the closest State-Highway road tri-junction about 90m away at the foot slope of Ayyappa Hill (Fig.6.2c)

	
Fig. 6.2a Old landslide in Magulla hillslope	*Fig. 6.2b Tilted tree trunks in Magulla hillslopes*

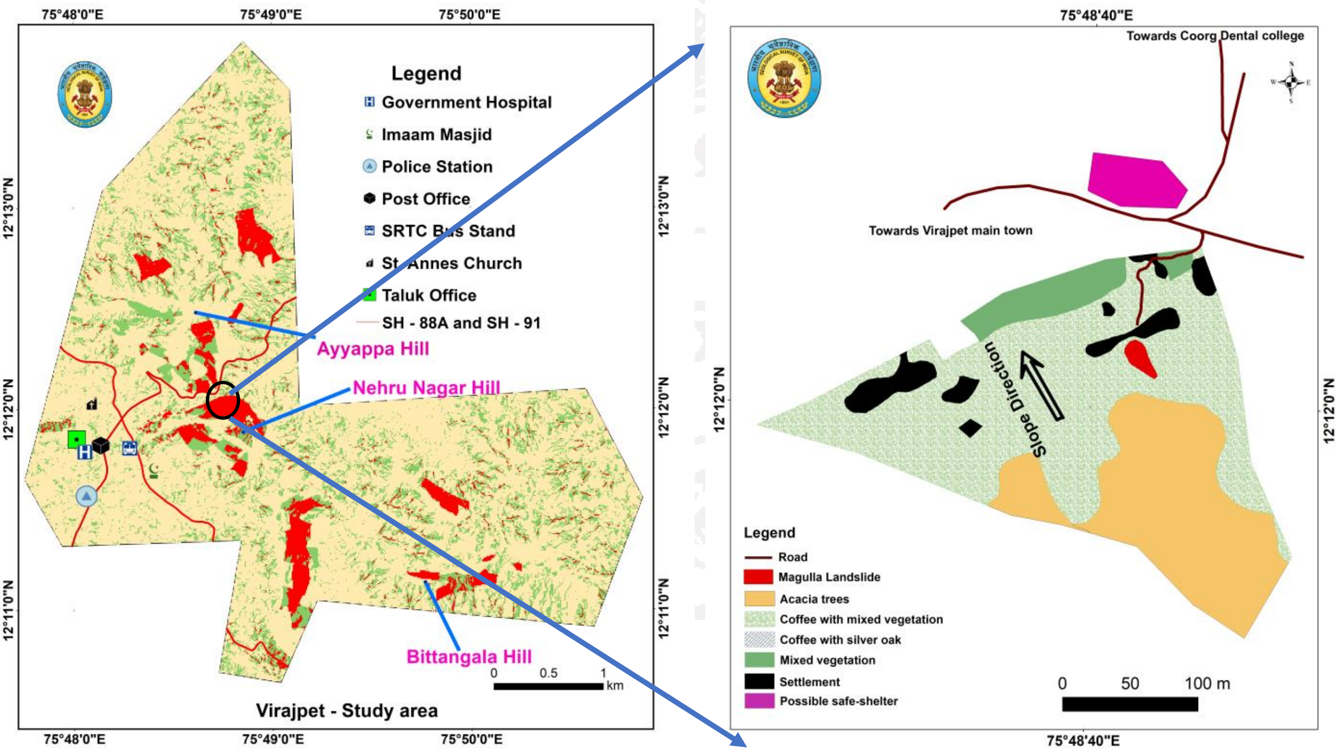

Fig. 6.2c. Location map of Magulla, Virajpet along with Elements at Risk (EatR) and possible escape route

c. Ambatty, Virajpet

Slope distress was reported at Ambatty, Virajpet near the house of Smt. Buttiayana w/o Lt. Namchappa through the development of approx. north-south trending cracks of about 15m in length and similarly aligned smaller transverse cracks at the downslope of the road (6.3a,b). The slope is relatively gentle but represents a transportational mid-slope characterized by a preponderance of assorted and compacted debris and immature in situ soil. No conspicuous displacement of material is observed in the slope. The elements at risk (EatR) include one residential building at the possible crown area and the connecting road at the downslope side. Other buildings in the downslope are close to the material movement direction but may not fall in the possible impact zone. The approximate volume of the material that can be mobilized is 1600 m^3 based on the length of the crack and projected dimension of displaced material in terms of width (20m) and length (40m) and the thickness of the overburden (2m).

As a mitigation measure, in this part of the slope, a lined contour drain at the back of the house is recommended. In the event of an adverse hydrological event giving indicators of probable landslide incidence within the slope, a feasible immediate escape route is towards the road leading south where a temporary safe shelter can be arranged 200m away from the slope distressed zone (Fig. 6.3c).

	
Fig. 6.3a Transverse crack near the house of Smt. Buttiayana w/o Lt. Namchappa	*Fig. 6.3b Transverse crack at downslope of the Ambatty road*

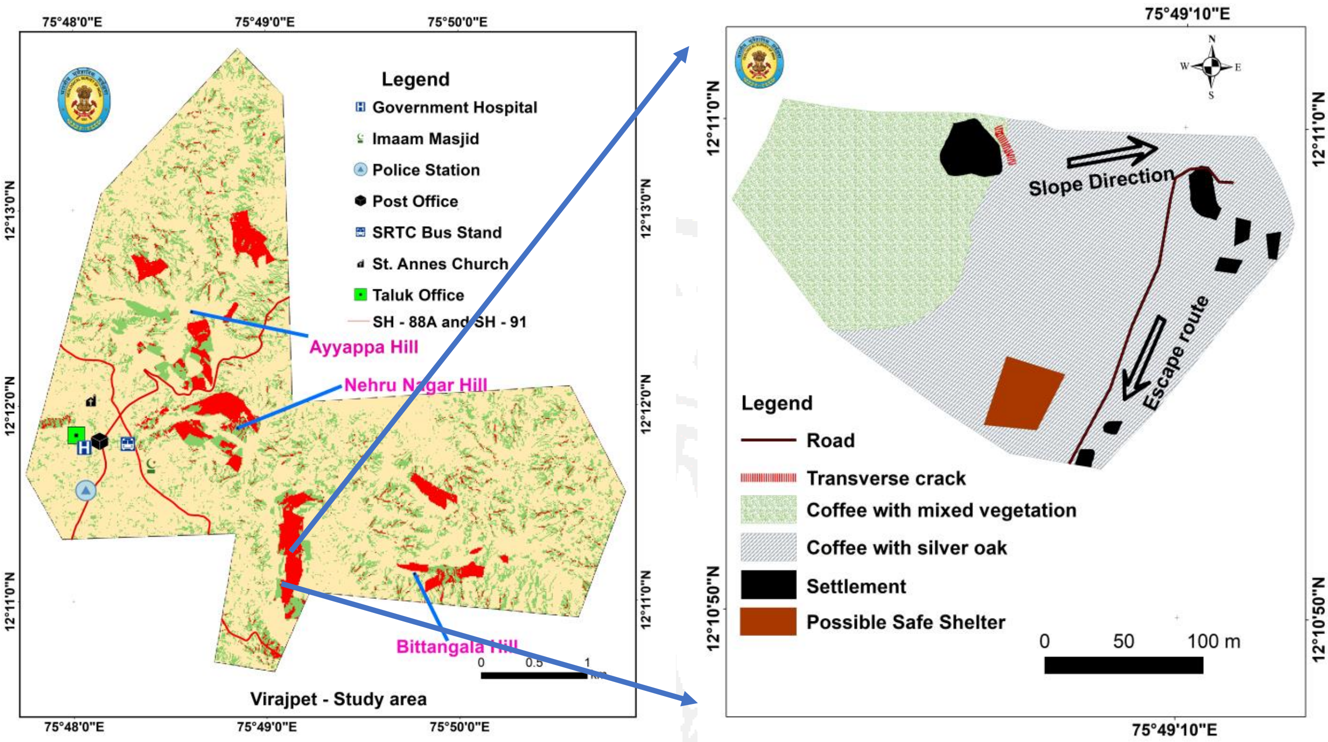

Fig. 6.3c. Location map of Ambatty, Virajpet along with Elements at Risk (EatR) and possible escape route

The probable high risk (PhR) area is a qualitative assessment that is driven by the presence of elements at risk (EatR) near the distressed slopes. The possible volume of material that can be mobilized is an approximate conservative estimation based on the observations of site characteristics. The proposed temporary safe shelter and escape route identified are of neighbouring houses representing relatively stable locations in the event of adverse incidence.

It may be categorically stated that the PhR does not have time connotation in any way because of the temporal variability in the triggering factor which is primarily the monsoonal rainfall. The rainfall during the monsoon of 2018, 2019, and 2020 served as the primary triggering factor for the few landslides observed in the hillslopes of Virajpet. The adverse hydrological event and prolonged antecedent rainfall can trigger landslides of varying dimensions or re-activate the old landslides. Therefore, the common mitigation for the assessed probable high-risk area is the management of drainage through the provision of adequate lining and weep holes.

In Ayyappa midslopes, massive bare rock is exposed with thin overburden cover. There is potential for slippage of overburden over the overburden-rock interface if the percolation of water is unchecked. Therefore, it is recommended that a proper drainage system be put in place along the cut sections of the settlements. It is recommended that any extensive excavation or slope profile modification along the rocky zones in Ayyappa should be systematically carried out by strictly following engineering principles and structural support systems.

It is recommended that the local people residing in the identified hillslopes who serve as first responders need to be empowered through capacity building and imparting awareness about dealing with landslide risks such as vacating buildings during prolonged heavy rainfall of 4-5 days and avoiding unmethodical excavation of hillslopes.

6.2 Conclusion

Virajpet hillslopes have reported slope instability in recent years. Some sectors of the hillslopes have seen slope movement in the past and have currently attained a tenuous equilibrium which could be triggered and aggravated by anthropogenic interference or during an event of adverse triggering mechanisms

The landslide inventory of the recent years and the study of available rainfall data reveal that the landslides in Virajpet are triggered by prolonged or intense rainfall. However, after the field observations on the causative factors and failure mechanism involved, it is also assessed that the land use interference is aggravating slope instability in the area. The land use involving slope profile modification without methodical support system or drainage system has served as important pre-disposing factor to landslide initiation during monsoon. The landslide inventory and field investigation have corroborated this because all the landslides within the Virajpet hillslopes have documented in the cut slope domain.

The combined landslide susceptibility map shows a 74.2% low, 19.2% moderate, and 6.6% high percentage of the area. The high and moderate classes are largely seen along the hillslopes of northern Ayyappa, south east Ayyappa, Magulla, Nehru Nagar and large parts of Ambatty. Most part of these areas come under cut slope domain. The high and moderate class for the rock slide in the area is negligible. However, the rockfall susceptibility is observed along steep slope of Bittangala and Eastern Ayyappa. The landslide susceptibility map of cut slope domain has been adequately validated by the available landslides using prediction rate curve and simple landslide density curve. The landslide susceptibility map of the study area generated using heuristic method represents areas or slopes most likely to fail in response to the geo-environmental factors considered in the study. The combination of geo-environmental factors and their mutual intricate relationship determine the spatial distribution of landslides. The susceptibility map will, therefore, give a qualitative estimation of how the hillslopes within Virajpet will be susceptible to a potential future landslide.

After the field investigation, a few localities within Virajpet hillslopes are assessed to be critical which include parts of Ayyappa, Nehru Nagar, Magulla, and Ambatty. These probable high-risk areas (PhRs) require judicious management of the slope. In order to mitigate potential remobilization of the material in the slopes where a modification has taken place for construction purposes, all possible regulations at the local level must be put in place to avoid unmethodical excavation of slopes. This is particularly important because the sites investigated have spatial associations of landslides with the cut slope domain. The unsupervised anthropogenic interference can aggravate localized slope instability.

Disclaimer

1. It may be categorically mentioned that the landslide susceptibility does not refer to any specific time frame or frequency of occurrence nor does it carry any connotation on the magnitude or scale of the failure. It is merely an establishment of a relationship of relevant geo-environmental causative factors with landslides for the areas of interest and based on which a qualitative assessment is derived about their stability.
2. The susceptibility map is valid only under the given set of geo-environmental conditions taken as input in the susceptibility modeling. Any change in the spatial distribution of the geo-environmental factors considered in the modelling can affect the susceptibility of the area over a period of time.
3. Attempts have been made to sample the representative overburden variant. For sampling, as soil layers are buried and hidden from view one has to rely on samples obtained from selected depths and locations. Since there is a constraint on the number of samples that can be taken there is no guarantee that the soil parameters are truly representative of the field strata.
4. Heuristic or knowledge-driven method is employed in the current susceptibility modelling through ratings. This process caters to the terrain-specific needs; however, there is always an inclination for unintended biasness in the ratings assigned. Therefore, an earnest attempt is made to minimize biasness in assigning ratings to various factor classes and also factor weight for each theme through re-assessment of field inputs.

Locality Index		
Virajpet	12.197504°	75.800252°
Ayyappa	12.208646°	75.809240°
Magulla	12.200439°	75.811765°
Nehru Nagar	12.195625°	75.813156°
Aimangala	12.214195°	75.817234°

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Annexure-I

Geological Survey of India
Data sheet on report movement in connection with its scrutiny

Project/Division: ***EG and Landslide Division***

FSP No: M4LSSM/NC/SR/SU-KG/2020/32460 **Mission:** ***IV***

Title of the report: Meso-scale (1:10,000) Landslide Susceptibility Mapping in and around Virajpet area, Kodagu district of Karnataka

Name of author(s) 1. **Achan Konyak, Geologist** 2. . **E Mohan Raj, Geologist**	Date of submission of report to the Supervisory Officer **30 June 2021** Signature of the senior most author 30/6/21
Name of Supervisory Officer **R Sajeev, Director (G)**	Date of receipt of report: 30-06-2021 Date of completion of scrutiny 23-07-2021 Date of handing over report to the author after scrutiny Signature
Name of author(s) To whom the report has been handed over by the Supervisory Officer **Achan Konyak**	Date of receipt after scrutiny – 23rd July 2021 Signature... 23/07/21 Date of resubmission – 30th November 2021 Signature... 30/11/21
Supervisory Officer **R Sajeev, Director (G)**	Date of receipt after modification – 14th December' 21 Date of handing over report to the Regional Mission Head : 14/12/2021 Signature
Name of Regional Mission Head Shri S.K. Tripathi DY.DG	Date of receipt of report 15/12/2021 Date of handing over the report after peer review to the Project Director 29/12/2021 Signature.........S.K. Tripathi
Name of Supervisory Officer **R Sajeev, Director**	Date of receipt from the Regional Mission Head after peer review : 29-12-2021

	Date of handing over to author(s) : 29-12-2021 Signature:
Name of author(s) 1. **Achan Konyak, Geologist** 2. **E Mohan Raj, Geologist**	Date of receipt of report from Supervisory Officer 29-12-2021 Date of handing over report after modification to Supervisory Officer :31-12-2021 …………………………………… Signature…………………………
Name of Supervisory Officer **R Sajeev, Director (G)**	Date of receipt of report after modification from the author(s) ………31-12-2021 Date of handing over report to Regional Mission Head : 31-12-2021 Signature
Name of Regional Mission Head ……Shri S.K. Tripathi DY. DG	Date of receipt after modification from the Project Director..31/12/2021 Date of handing over the report to the HoD of the Region for approval …31/12/2021…………… Signature………… S.K. Tripathi
Name of the HoD of the Region …………………………………… जनार्दन प्रसाद / JANARDAN PRASAD अ.म.नि.एवं वि.अ.,भा.भू.स.,द.क्षे / ADG & HOD, GSI, SR	Date of receipt of report for approval ……31/12/2021………… Date of approval……………… Date of sending back report to Project Director……………………… Signature of the HoD……………………
Name of the Project Director **R Sajeev, Director**	Date of receipt of report after approval of HoD…………………… Date of circulation of report………….. Signature……………………………

Annexure-II

Geological Survey of India

Certificate of Quality of the report

Project/Division: *NLSM*

FSP No: M4LSSM/NC/SR/SU-KG/2020/32460 **Mission:** *IV*

Title of the report: Meso-scale (1:10,000) Landslide Susceptibility Mapping in and around Virajpet area, Kodagu district of Karnataka

Part-A

This is to certify that the following officer(s) have carried out the above mentioned FSP, and are responsible for collection of field data, carrying out the required laboratory analysis, compilation and synthesis of field data, coalition of the data and writing of the report as per the approved guidelines. The duration of field stay of each officer(s) is as against his/her name.

Name(s)/Designation of the Field Officer	Total field stay during the FSP (no. of days)	Signature with date
1 Achan Konyak, Geologist	85	
2 Mohan E Raj, Geologist	87	

Part-B

This is to certify that drilling has been carried out and completed as per the table given below:

Drilling Unit No	Date of commencement of drilling	Date of completion of drilling	Name and Signature of the Director Drilling
1. NA			
2. NA			

Part-C

This is to certify that geophysical component of the item has been carried out as per the table given below:

Name(s)/Designation of Geophysist	Date of commencement of work	Date of completion of work	Signature with date of the Geophysist
1. NA			
2. NA			
Name and signature with date of the Director (Geophysics)			

Part-D

This is to certify that the chemical analysis of the geological samples has been carried out as per the table given below:

Name of Director in charge of the Chemical Lab	Dates of receipt of samples from the field officer/party	Date of providing complete analytical results to the field officer	Signature with date of the Director Chemistry
NA			

Part-E

This is to certify that the below mentioned Supervisory Officer(s) have supervised the above item and have provided guidance to the Field Officer(s). The number of inspection visits and total duration of field visits is as per the below table. It is also certified that the work carried out under the project is of high standards, the norms of field work, lab work etc. have been followed. It is also certified that thorough scrutiny of the report for maintaining the scientific contents and its Quality has been overseen.

Name(s)/Designation of the Supervisory Officer	No. of inspection visits made to the field area	Total no. of days spent on inspection visit	Signature with date
R Sajeev, Director (G)	2	4	

Part-F

This is to certify that the report has been thoroughly scrutinized at the Regional Mission Head level. The scientific contents and the Quality of the report are certified. The report has been peer reviewed and the needful corrections have been attended to

Name(s)/Designation of the Regional Mission Head	Signature with date
Shri S. K. Tripathi, उप.म.नि	S.K. Tripathi 31/12/2021

Part-G

This is to certify that the above report has been scrutinized at various levels and has also been peer reviewed. On being satisfied regarding the scientific contents and the Quality of the report, the undersigned has accorded approval for its circulation

Name(s)/Designation of the Regional HoD	Signature with date
जनार्दन प्रसाद / JANARDAN PRASAD अ.म.नि. एवं वि.अ., भा.भू.स., द.क्षे / ADG & HOD, GSI, SR	Prasad 31/12/21

Annexure III – Landslide Inventory

No	Field	
1	Slide No (LS .No.)	KG/KOD/48P16/2020-21/1
2	State	Karnataka
3	District	Kodagu
4	Toposheet	48P16
5	Name of the slide	Saneswara Temple slide
6	NH/SH/Locality	Ayyappa Peta
7	Latitude	12°12' 11.9" N
8	Longitude	75°48' 28.6" E
9	Length	10 m
10	Width	25m
11	Height	8m
12	Area	250 sq.m
13	Depth	2 m
14	Volume	500 cu.m
15	Run out distance	0
16	Type of Material	Debris
17	Type of movement	Slide
18	Rate of movement	Rapid
19	Activity	Suspended
20	Distribution	Confined
21	Style	Single
22	Failure mechanism	Shallow translational
23	History	Initiated in August 2018
24	Geomorphology	Moderately dissected slope
25	Geology	Granite
26	Structure	Nil
27	Land use/ Land cover	Upslope Settlement
28	Hydrological condition	Damp
29	Triggering Factor	Rainfall
30	Death of persons	Nil
31	People affected	Nil
32	Live-stock loss	Nil
33	Communication	Partial drainage blockage downslope
34	Infrastructure	Nil
35	Agriculture/forest/Barren	Forested upslope

36	Geo-scientific Causes	-Thick soil and debris cover failed owing to steep slope cutting and toe removal. - Absence of the proper lined drainage at the crown resulted in the surface infiltration of the overburden material by rain water which induced slope instability.
37	Remedial measures	1. Construction of breastwall with sufficient weepholes at the toe of the landslide. 2. Construction lined hillside drain at the toe between the slide and the temple.
38	Remarks, if any	
39	Photos. Sketch of Plan & section of the slide	
40	Summary/Abstract	A shallow translational debris slide is caused due to steep cutting of the slope characterized by thick overburden/debris material at the midslope of Ayyappa hill. A breastwall construction at the toe and proper drainage maintenance is recommended.
41	Pdf	Attached
42	Landslide category	III

No	Field	
1	Slide No (LS .No.)	KG/KOD/48P16/2020-21/2
2	State	Karnataka
3	District	Kodagu
4	Toposheet	48P16
5	Name of the slide	Ayyappa Temple slide
6	NH/SH/Locality	North of Ayyappa Peta
7	Latitude	12°12' 47.6" N

8	Longitude	75°48' 16.8" E
9	Length	12m
10	Width	15m
11	Height	10m
12	Area	180 sq.m
13	Depth	2 m
14	Volume	360 cu.m
15	Run out distance	5m
16	Type of Material	Debris
17	Type of movement	Slide
18	Rate of movement	Rapid
19	Activity	Suspended
20	Distribution	Confined
21	Style	Single
22	Failure mechanism	Shallow translational
23	History	Initiated in August 2018
24	Geomorphology	Moderately dissected slope
25	Geology	Granite
26	Structure	Nil
27	Land use/ Land cover	Upslope coffee plantation with moderate vegetation
28	Hydrological condition	Damp
29	Triggering Factor	Rainfall
30	Death of persons	Nil
31	People affected	Nil
32	Live-stock loss	Nil
33	Communication	Partial drainage blockage downslope
34	Infrastructure	Nil
35	Agriculture/forest/Barren	Forested upslope
36	Geo-scientific Causes	-Low compaction of fill material on the valley side of the road and subsequent saturation of the fill material. -Absence of the proper lined drainage at the toe resulted in the toe erosion of the overburden material by rain water which induced slope instability.
37	Remedial measures	1. Construction of breastwall with sufficient weepholes at the toe of the landslide near the private local temple. 2. Construction of chute drainage along the face of the landslide along with lined hillside drain at the toe.
38	Remarks, if any	

39	Photos. Sketch of Plan & section of the slide	
40	Summary/Abstract	A shallow translational debris slide is documented which is caused due to active toe erosion by stream and slope characterized by uncompacted debris material. A breastwall construction at the toe and proper drainage maintenance is recommended.
41	Pdf	Attached
42	Landslide category	III

No	Field	
1	Slide No (LS .No.)	KG/KOD/48P16/2020-21/3
2	State	Karnataka
3	District	Kodagu
4	Toposheet	48P16
5	Name of the slide	Ayyappa slide
6	NH/SH/Locality	Central slope of Ayyappa Hill
7	Latitude	12°12'15"N
8	Longitude	75°48'28"E
9	Length	15
10	Width	12
11	Height	10
12	Area	180 sq.m
13	Depth	3 m
14	Volume	540 cu.m
15	Run out distance	5 m
16	Type of Material	Debris
17	Type of movement	Slide
18	Rate of movement	Rapid
19	Activity	Suspended
20	Distribution	Widening
21	Style	Single
22	Failure mechanism	Shallow rotational
23	History	11 August 2019
24	Geomorphology	Moderately dissected slopes
25	Geology	Granite
26	Structure	Nil
27	Land use/ Land cover	Partially Modified Slope for settlement
28	Hydrological condition	Dry
29	Triggering Factor	Rainfall
30	Death of persons	Nil
31	People affected	Nil
32	Live-stock loss	Nil
33	Communication	Nil
34	Infrastructure	One house hit and abandoned
35	Agriculture/forest/Barren	Plantation upslope

36	Geo-scientific Causes	-Highly weathered granitic rockmass overlain by thick overburden and debris. - Toe support removal due to slope cutting for settlement.
37	Remedial measures	-Construction of breast wall with weep holes and toe drain
38	Remarks, if any	-A smaller landslide/instability observed on the left flank
39	Photos. Sketch of Plan & section of the slide	
40	Summary/Abstract	A shallow rotational failure at the central part of the Ayyappa hillslope is caused by the slope cutting without any structural support at the toe. A toe support system is recommended at the toe of the slide.
41	Pdf	Attached
42	Landslide category	III

No	Field	
1	Slide No (LS .No.)	KG/KOD/48P16/2020-21/4
2	State	Karnataka
3	District	Kodagu
4	Toposheet	48P16
5	Name of the slide	Ayyappa Temple slide
6	NH/SH/Locality	Ayyappa Hill
7	Latitude	12°12'10.58''N
8	Longitude	75°48'31''E
9	Length	13
10	Width	22
11	Height	10
12	Area	286 sq.m
13	Depth	3 m
14	Volume	540 cu.m
15	Run out distance	3 m
16	Type of Material	Soil
17	Type of movement	Slide
18	Rate of movement	Rapid
19	Activity	Suspended
20	Distribution	Widening
21	Style	Single
22	Failure mechanism	Shallow rotational
23	History	Occurred in August 11, 2019
24	Geomorphology	Lowly dissected slopes
25	Geology	Granite
26	Structure	Nil
27	Land use/ Land cover	Partially Modified Slope for road
28	Hydrological condition	Dry
29	Triggering Factor	Rainfall
30	Death of persons	Nil
31	People affected	Nil
32	Live-stock loss	Nil
33	Communication	Nil
34	Infrastructure	Nil
35	Agriculture/forest/Barren	Forested upslope

36	Geo-scientific Causes	-Highly weathered granitic rockmass overlain by thick overburden and debris. - Toe support removal due to slope cutting for road widening.
37	Remedial measures	-Construction of breast wall with weep holes and toe drain -Contour drain above the crown of the slide
38	Remarks, if any	
39	Photos. Sketch of Plan & section of the slide	
40	Summary/Abstract	A soil slide is caused near the Ayyappa temple due to steep slope cutting for the widening of the road. The slope is characterized by highly weathered rock mass overlain by thick soil. It is recommended for the construction of breast wall with weep holes and toe drain and also contour drain above the crown of the slide.
41	Pdf	Attached
42	Landslide category	III

No	Field	
1	Slide No (LS .No.)	KG/KOD/48P16/2020-21/5
2	State	Karnataka
3	District	Kodagu
4	Toposheet	48P16
5	Name of the slide	North Ayyappa
6	NH/SH/Locality	Upslope of Ayyappa Temple
7	Latitude	12°12'13.56''N
8	Longitude	75°48'33.41''E
9	Length	7m
10	Width	5m
11	Height	6m
12	Area	35 sq.m
13	Depth	1.5m
14	Volume	52.5 cu.m
15	Run out distance	0
16	Type of Material	Debris
17	Type of movement	Slide
18	Rate of movement	Rapid
19	Activity	Suspended
20	Distribution	Confined
21	Style	Single
22	Failure mechanism	Shallow translational
23	History	Reportedly initiated in August 2020
24	Geomorphology	Lowly dissected slopes
25	Geology	Granite
26	Structure	Nil
27	Land use/Land cover	Partially Modified Slope/Thick vegetation
28	Hydrological condition	Dripping
29	Triggering Factor	Rainfall
30	Death of persons	Nil
31	People affected	Nil
32	Live-stock loss	Nil
33	Communication	Nil
34	Infrastructure	House foundation damaged and retaining wall collapsed
35	Agriculture/forest/Barren	Settlement upslope

36	Geo-scientific Causes	The presence of clay-rich fill material over the highly weathered granite and aggravated by poor drainage to drain the surface water.
37	Remedial measures	Construction of stepped gabion wall with a proper drainage system
38	Remarks, if any	The slope failure may reactivate subsequent to monsoon in absence of a proper drainage system.
39	Photos. Sketch of Plan & section of the slide	
40	Summary/Abstract	A minor shallow translational slide is caused by poor drainage to drain the surface water. The foundation material is clay-rich fill material over the highly weathered granite. It is recommended to install a proper drainage system to control the slope instability.
41	Pdf	Attached
42	Landslide category	III

No	Field	
1	Slide No (LS. No.)	KG/KOD/48P16/2020-21/6
2	State	Karnataka
3	District	Kodagu
4	Toposheet	48P16
5	Name of the slide	North Ayyappa
6	NH/SH/Locality	Upslope of Ayyappa Temple
7	Latitude	12°12'12.86"N
8	Longitude	75°48'33.32"E
9	Length	5
10	Width	10
11	Height	4
12	Area	50 sq.m
13	Depth	2 m
14	Volume	100 cu.m
15	Run out distance	0
16	Type of Material	Debris
17	Type of movement	Slide
18	Rate of movement	Rapid
19	Activity	Suspended
20	Distribution	Confined
21	Style	Single
22	Failure mechanism	Shallow translational
23	History	Initiated in August 2020
24	Geomorphology	Lowly dissected slopes
25	Geology	Granite
26	Structure	Nil
27	Land use/ Land cover	Partially Modified Slope for settlement
28	Hydrological condition	Damp
29	Triggering Factor	Incessant rainfall
30	Death of persons	Nil
31	People affected	Nil
32	Live-stock loss	Nil
33	Communication	Nil
34	Infrastructure	House foundation damaged and retaining wall collapsed
35	Agriculture/forest/Barren	Forested upslope

36	Geo-scientific Causes	The presence of clay-rich fill material over the highly weathered granite and aggravated by poor drainage to train the surface water.
37	Remedial measures	Construction of a stepped gabion wall with proper drainage system
38	Remarks, if any	The slope failure may reactivate subsequent to monsoon in absence of proper drainage system.
39	Photos. Sketch of Plan & section of the slide	
40	Summary/Abstract	A minor shallow translational slide is caused by poor drainage to drain the surface water. The foundation material is clay-rich fill material over the highly weathered granite. It is recommended to install a proper drainage system to control the slope instability.
41	Pdf	Attached
42	Landslide category	III

No	Field	
1	Slide No (LS. No.)	KG/KOD/48P16/2020-21/7
2	State	Karnataka
3	District	Kodagu
4	Toposheet	48P16
5	Name of the slide	North Ayyappa slide
6	NH/SH/Locality	Upslope of Ayyappa Temple
7	Latitude	12°12'12.78''N
8	Longitude	75°48'32.58''E
9	Length	5m
10	Width	6 m
11	Height	4 m
12	Area	30 sq.m
13	Depth	1 m
14	Volume	30 cu.m
15	Run out distance	0 m
16	Type of Material	Debris
17	Type of movement	Slide
18	Rate of movement	Rapid
19	Activity	Suspended
20	Distribution	Confined
21	Style	Single
22	Failure mechanism	Shallow translational.
23	History	Initiated in August 2020
24	Geomorphology	Moderately dissected slopes
25	Geology	Granite
26	Structure	Nil
27	Land use/ Land cover	Partially Modified Slope/Fill slope
28	Hydrological condition	Dry
29	Triggering Factor	Incessant rainfall
30	Death of persons	Nil
31	People affected	Nil
32	Live-stock loss	Nil
33	Communication	Nil
34	Infrastructure	Partial Road blockage
35	Agriculture/forest/Barren	Settlement upslope

36	Geo-scientific Causes	Percolation of the water into the fill slope covered with thick overburden and weathered profile of the rock which reduced the shear strength of the material.
37	Remedial measures	Breast wall with sufficient number of weep holes and channelization of the slope discharge by constructing lined drainage along the toe.
38	Remarks, if any	
39	Photos. Sketch of Plan & section of the slide	
40	Summary/Abstract	A debris slide is caused due to percolation of the water into the fill slope covered with thick overburden and weathered profile of the rock which reduced the shear strength of the material. It is recommended to construct a breast wall with a sufficient number of weep holes and channelization of the slope discharge.
41	Pdf	Attached
42	Landslide category	III

No	Field	
1	Slide No (LS. No.)	KG/KOD/48P16/2020-21/8
2	State	Karnataka
3	District	Kodagu
4	Toposheet	48P16
5	Name of the slide	Ayyappa landslide
6	NH/SH/Locality	Ayyappa
7	Latitude	12°12'06.0"N
8	Longitude	75°48'38.1"E
9	Length	7
10	Width	25m
11	Height	6 m
12	Area	42 sq.m
13	Depth	1m
14	Volume	42 cu.m
15	Run out distance	6 m
16	Type of Material	Soil
17	Type of movement	Slide
18	Rate of movement	Rapid
19	Activity	Suspended
20	Distribution	Confined
21	Style	Single
22	Failure mechanism	Shallow translational
23	History	Nil
24	Geomorphology	Lowly dissected slopes
25	Geology	Granite
26	Structure	2019
27	Land use/ Land cover	Partially Modified Slope/Cut slope for settlement
28	Hydrological condition	Dry
29	Triggering Factor	Incessant rainfall
30	Death of persons	Nil
31	People affected	Nil
32	Live-stock loss	Nil
33	Communication	Nil
34	Infrastructure	Nil
35	Agriculture/forest/Barren	Plantation upslope

36	Geo-scientific Causes	-Thick overburden of about 6 m cut beyond the angle of repose
37	Remedial measures	Moderation of the slope through benching of the upslope and provision of contour drain
38	Remarks, if any	
39	Photos. Sketch of Plan & section of the slide	
40	Summary/Abstract	The shallow translational slide is caused by the steep cutting of slope beyond the angle of repose for construction of the building. The overburden thickness is about 6 m. It is recommended to ease the slope angle through benching.
41	Pdf	Attached
42	Landslide category	III

No	Field	
1	Slide No (LS. No.)	KG/KOD/48P16/2020-21/9
2	State	Karnataka
3	District	Kodagu
4	Toposheet	48P16
5	Name of the slide	East Ayyappa slide
6	NH/SH/Locality	Ayyappa
7	Latitude	12°12'6.6"N
8	Longitude	75°48'39.4"E
9	Length	20m
10	Width	25m
11	Height	17m
12	Area	500 sq.m
13	Depth	1.0m
14	Volume	500 cu.m
15	Run out distance	Nil
16	Type of Material	Debris
17	Type of movement	Slide
18	Rate of movement	Rapid
19	Activity	Suspended
20	Distribution	Retrogressive
21	Style	Single
22	Failure mechanism	Shallow translational
23	History	Initiated in 2016
24	Geomorphology	Moderately dissected slopes
25	Geology	Granite
26	Structure	Nil
27	Land use/ Land cover	Partially Modified Slope/Thick vegetation
28	Hydrological condition	Dry
29	Triggering Factor	Incessant rainfall
30	Death of persons	Nil
31	People affected	Nil
32	Live-stock loss	Nil
33	Communication	Nil
34	Infrastructure	Temporary road blockage
35	Agriculture/forest/Barren	Forested upslope
36	Geo-scientific Causes	-Presence of concave slope morphometry augmenting the confluence of surface drainage and subsequent toe erosion

37	Remedial measures	Construction of contour drain and lined cross drain to divert the water from the crown area as well as prevent toe erosion.
38	Remarks, if any	
39	Photos. Sketch of Plan & section of the slide	
40	Summary/Abstract	The shallow translational slide is caused by the confluence of surface drainage and sustained saturation of the overburden material. Contour drainage near the crown is recommended for the site.
41	Pdf	Attached
42	Landslide category	III

No	Field	
1	Slide No (LS. No.)	KG/KOD/48P16/2020-21/10
2	State	Karnataka

3	District	Kodagu
4	Toposheet	48P16
5	Name of the slide	Magulla slide
6	NH/SH/Locality	Magulla Virajpet
7	Latitude	12°12'00.5"N
8	Longitude	75°48'39.3"E
9	Length	40
10	Width	50 m
11	Height	30 m
12	Area	2000 sq.m
13	Depth	1.5 m
14	Volume	3000 cu.m
15	Run out distance	Nil
16	Type of Material	Debris
17	Type of movement	Slide
18	Rate of movement	Rapid
19	Activity	Suspended
20	Distribution	Retrogressive
21	Style	Single
22	Failure mechanism	Shallow translational
23	History	Nil
24	Geomorphology	Moderately dissected slopes
25	Geology	Porphyritic granite
26	Structure	Nil
27	Land use/ Land cover	Coffee plantation
28	Hydrological condition	Damp
29	Triggering Factor	Rainfall
30	Death of persons	Nil
31	People affected	Nil
32	Live-stock loss	Nil
33	Communication	Nil
34	Infrastructure	Nil
35	Agriculture/forest/Barren	Settlement upslope
36	Geo-scientific Causes	Thick debris overlying the granitic rock and percolation of water along the debris-rock interface.
37	Remedial measures	Construction of breast wall and toe drain to divert the water and prevent toe erosion.
38	Remarks, if any	

39	Photos. Sketch of Plan & section of the slide	
40	Summary/Abstract	A shallow translational failure occurred due to debris overlying the granitic rock and percolation of water along the debris-rock interface
41	Pdf	Attached
42	Landslide category	III

No	Field	
1	Slide No (LS. No.)	KG/KOD/48P16/2020-21/11
2	State	Karnataka
3	District	Kodagu
4	Toposheet	48P16
5	Name of the slide	Magulla slide
6	NH/SH/Locality	Magulla Virajpet
7	Latitude	12°12'01.7"N
8	Longitude	75°48'42"E
9	Length	45 m
10	Width	30m
11	Height	35
12	Area	1350 sq.m
13	Depth	4m
14	Volume	5400 cu.m
15	Run out distance	50 m
16	Type of Material	Debris
17	Type of movement	Slide
18	Rate of movement	Rapid
19	Activity	Suspended
20	Distribution	Confined
21	Style	Single
22	Failure mechanism	Shallow translational
23	History	August 2018
24	Geomorphology	Lowly dissected slopes
25	Geology	Granite
26	Structure	Nil
27	Land use/ Land cover	Partially Modified Slope/Thick vegetation
28	Hydrological condition	Damp
29	Triggering Factor	Incessant rainfall
30	Death of persons	Nil
31	People affected	Nil
32	Live-stock loss	Nil
33	Communication	Nil
34	Infrastructure	House partially damaged
35	Agriculture/forest/Barren	Forested
36	Geo-scientific Causes	Removal of toe buttress by cutting the steep slope for settlement. Slope composed of thick overburden and highly weathered granite.

37	Remedial measures	Construction of breast wall with weep holes and contour drain to divert the surface water away from the excavated area.
38	Remarks, if any	
39	Photos. Sketch of Plan & section of the slide	
40	Summary/Abstract	Thick soil overlying the highly weathered granitic rock and aggravated by removal toe buttress through excavation. It is recommended for the construction of a breast wall with weep holes and contour drain to divert the surface water away from the excavated area.
41	Pdf	Attached
42	Landslide category	III

No	Field	
1	Slide No (LS. No.)	KG/KOD/48P16/2020-21/12
2	State	Karnataka
3	District	Kodagu
4	Toposheet	48P16
5	Name of the slide	Magulla hilltop slide
6	NH/SH/Locality	Magulla Virajpet
7	Latitude	12°11'57.6"N
8	Longitude	75°48'42.1"E
9	Length	40m
10	Width	35m
11	Height	30m
12	Area	1400 sq.m
13	Depth	3 m
14	Volume	4200 cu.m
15	Run out distance	60 m
16	Type of Material	Debris
17	Type of movement	Slide
18	Rate of movement	Rapid
19	Activity	Suspended
20	Distribution	Retrogressive
21	Style	Single
22	Failure mechanism	Shallow rotational
23	History	Initiated during 1960
24	Geomorphology	Lowly dissected slopes
25	Geology	Porphyritic Granite
26	Structure	Nil
27	Land use/ Land cover	Thick vegetation
28	Hydrological condition	Dry
29	Triggering Factor	Incessant rainfall
30	Death of persons	Nil
31	People affected	Nil
32	Live-stock loss	Nil
33	Communication	Nil
34	Infrastructure	Nil
35	Agriculture/forest/Barren	Forested upslope

36	Geo-scientific Causes	-Steep slope with the presence of thick overburden and drainage above the crown flowing over the slope face and saturating the overburden
37	Remedial measures	-Proper management of the vegetation on the slope through avoiding unplanned cutting of tress and avoiding digging pits for coffee plantation
38	Remarks, if any	
39	Photos. Sketch of Plan & section of the slide	
40	Summary/Abstract	An old debris slide is reportedly triggered by the rainfall in 1960's along the steep slope of Magulla characterized by thick overburden. It is recommended to avoid unplanned deforestation on the slope.
41	Pdf	Attached
42	Landslide category	III

No	Field	
1	Slide No (LS. No.)	KG/KOD/48P16/2020-21/13
2	State	Karnataka
3	District	Kodagu
4	Toposheet	48P16
5	Name of the slide	Ayyappa slide
6	NH/SH/Locality	Ayyappa
7	Latitude	12°12'8.11"N
8	Longitude	75°48'39.12"E
9	Length	10
10	Width	22
11	Height	5
12	Area	220 sq.m
13	Depth	1 m
14	Volume	220
15	Run out distance	Nil
16	Type of Material	Debris
17	Type of movement	Slide
18	Rate of movement	Rapid
19	Activity	Suspended
20	Distribution	Confined
21	Style	Single
22	Failure mechanism	Shallow translational
23	History	Initiated in Agust 2018
24	Geomorphology	Lowly dissected slopes
25	Geology	Granite
26	Structure	Nil
27	Land use/ Land cover	Partially Modified Slope for settlement
28	Hydrological condition	Dry
29	Triggering Factor	Incessant rainfall
30	Death of persons	Nil
31	People affected	Nil
32	Live-stock loss	Nil
33	Communication	Nil
34	Infrastructure	Nil
35	Agriculture/forest/Barren	Forested upslope

36	Geo-scientific Causes	-Highly weathered granite with about 2m thick overburden/residual soil -Steep cutting of overburden covered slope for settlement without proper toe buttress.
37	Remedial measures	-Construction of contour drain at the crown area to divert the surface water along the appropriate place. -In addition, a chute drain along the face of the landslide and at the toe should be constructed.
38	Remarks, if any	Breast wall already constructed but with insufficient weep holes and inadequate height.
39	Photos. Sketch of Plan & section of the slide	
40	Summary/Abstract	The shallow translational slide in Ayyappa is caused by the steep cutting of the slope characterized by thick overburden resting on the highly weathered rock mass. A contour drain near the road upslope or the crown area and a chute drain over the face or the flanks of the slide are recommended.
41	Pdf	Attached
42	Landslide category	III

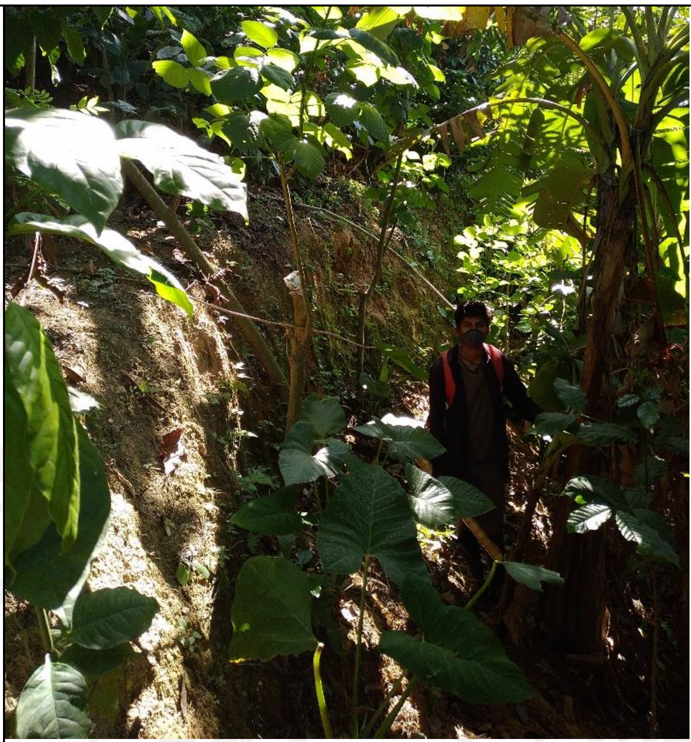
No	Field	
1	Slide No (LS. No.)	KG/KOD/48P16/2020-21/14
2	State	Karnataka
3	District	Kodagu
4	Toposheet	48P16
5	Name of the slide	Ayyappa slide
6	NH/SH/Locality	East Ayyappa
7	Latitude	12°12'13.4"N
8	Longitude	75°48'36.4"E
9	Length	15 m
10	Width	18m
11	Height	10m
12	Area	270 sq.m
13	Depth	4 m
14	Volume	1080 cu.m
15	Run out distance	4m
16	Type of Material	Debris
17	Type of movement	Slide
18	Rate of movement	Rapid
19	Activity	Suspended
20	Distribution	Confined
21	Style	Single
22	Failure mechanism	Shallow rotational
23	History	Initiated in August 2019
24	Geomorphology	Lowly dissected slopes
25	Geology	Granite
26	Structure	Nil
27	Land use/ Land cover	Partially Modified Slope/Thick vegetation
28	Hydrological condition	Dry
29	Triggering Factor	Incessant rainfall
30	Death of persons	Nil
31	People affected	Nil
32	Live-stock loss	Nil
33	Communication	Nil
34	Infrastructure	Partial damage of makeshift
35	Agriculture/forest/Barren	Forested upslope

36	Geo-scientific Causes	-Highly weathered granite with about 4 m thick overburden/residual soil -Steep cutting of overburden covered slope for settlement without proper toe buttress.
37	Remedial measures	-Construction of breast wall with sufficient weep holes and lined drainage to be provided on the hillside along with chute drain on the flanks to prevent possible widening through erosion.
38	Remarks, if any	
39	Photos. Sketch of Plan & section of the slide	
40	Summary/Abstract	The shallow rotational slide in Ayyappa is caused due to steep cutting of an overburden-covered slope for settlement without proper toe buttress. The slope is characterized by highly weathered granite forming core-stones with about 4 m thick overburden/residual soil. It is recommended to construct a breast wall with sufficient weep holes and lined drainage to be provided on the hillside along with a chute drain on the flanks to prevent possible widening through erosion.
41	Pdf	Attached
42	Landslide category	III

No	Field	
1	Slide No (LS. No.)	KG/KOD/48P16/2020-21/15
2	State	Karnataka
3	District	Kodagu
4	Toposheet	48P16
5	Name of the slide	Ayyappa slide
6	NH/SH/Locality	East Ayyappa
7	Latitude	12°12'14.4"N
8	Longitude	75°48'35.8"E
9	Length	10m
10	Width	12 m
11	Height	8m
12	Area	120 sq.m
13	Depth	3 m
14	Volume	360 cu.m
15	Run out distance	5m
16	Type of Material	Debris
17	Type of movement	Slide
18	Rate of movement	Rapid
19	Activity	Suspended
20	Distribution	Confined
21	Style	Single
22	Failure mechanism	Shallow rotational
23	History	Initiated in August 2019
24	Geomorphology	Lowly dissected slopes
25	Geology	Granite
26	Structure	Nil
27	Land use/ Land cover	Partially Modified Slope for settlement
28	Hydrological condition	Dry
29	Triggering Factor	Incessant rainfall
30	Death of persons	Nil
31	People affected	Nil
32	Live-stock loss	Nil
33	Communication	Nil
34	Infrastructure	Nil
35	Agriculture/forest/Barren	Settlement upslope

36	Geo-scientific Causes	-Highly weathered granite with about 2m thick overburden/residual soil -Steep cutting of overburden covered slope for settlement without proper toe buttress.
37	Remedial measures	-Construction of breast wall with sufficient weep holes and lined drainage to be provided on the hillside along with chute drain on the flanks to prevent possible widening through erosion.
38	Remarks, if any	
39	Photos. Sketch of Plan & section of the slide	
40	Summary/Abstract	The shallow rotational slide in Ayyappa is caused due to steep cutting of an overburden-covered slope for settlement without proper toe buttress. The slope is characterized by highly weathered granite forming core-stones with thick overburden/residual soil. It is recommended to construct breast wall with sufficient weep holes and lined drainage to be provided on the hillside along with a chute drain on the flanks to prevent possible widening through erosion.
41	Pdf	Attached
42	Landslide category	III

No	Field	
1	Slide No (LS. No.)	KG/KOD/48P16/2020-21/16
2	State	Karnataka
3	District	Kodagu
4	Toposheet	48P16
5	Name of the slide	Ayyappa slide
6	NH/SH/Locality	South Ayyappa
7	Latitude	12°12'11.9"N
8	Longitude	75°48'26.4"E
9	Length	40m
10	Width	50m
11	Height	25m
12	Area	2000 sq.m
13	Depth	4 m
14	Volume	8000 cu.m
15	Run out distance	30
16	Type of Material	Debris
17	Type of movement	Slide
18	Rate of movement	Rapid
19	Activity	Suspended
20	Distribution	Confined
21	Style	Single
22	Failure mechanism	Shallow translational
23	History	Nil (Old slide)
24	Geomorphology	Lowly dissected slopes
25	Geology	Granite
26	Structure	Nil
27	Land use/ Land cover	Coffee plantation
28	Hydrological condition	Dry
29	Triggering Factor	Incessant rainfall
30	Death of persons	Nil
31	People affected	Nil
32	Live-stock loss	Nil
33	Communication	Nil
34	Infrastructure	Nil
35	Agriculture/forest/Barren	Forested upslope
36	Geo-scientific Causes	-Thick overburden and highly weathered granite boulders -Water accumulation and active toe erosion
37	Remedial measures	-Contour draining can prevent water infiltration
38	Remarks, if any	

39	Photos. Sketch of Plan & section of the slide	
40	Summary/Abstract	The shallow translational slide in Ayyappa is caused due active toe erosion and water infiltration over the thick overburden. It is recommended to construct a contour drain over the crown area to prevent surface water infiltration.
41	Pdf	Attached
42	Landslide category	III

No	Field	
1	Slide No (LS. No.)	KG/KOD/48P16/2020-21/17
2	State	Karnataka
3	District	Kodagu
4	Toposheet	48P16
5	Name of the slide	Ayyappa slide
6	NH/SH/Locality	South Ayyappa
7	Latitude	12°12'5.8"N
8	Longitude	75°48'34.3"E
9	Length	15
10	Width	30
11	Height	10 m
12	Area	450
13	Depth	3 m
14	Volume	1350 cu.m

15	Run out distance	Nil
16	Type of Material	Debris
17	Type of movement	Slide
18	Rate of movement	Rapid
19	Activity	Suspended
20	Distribution	Confined
21	Style	Single
22	Failure mechanism	Shallow rotational
23	History	Initiated in August 2018
24	Geomorphology	Lowly dissected slopes
25	Geology	Granite
26	Structure	Nil
27	Land use/ Land cover	Partially Modified Slope/Thick vegetation
28	Hydrological condition	Dry
29	Triggering Factor	Cut slope (Anthropogenic)
30	Death of persons	Nil
31	People affected	Nil
32	Live-stock loss	Nil
33	Communication	Nil
34	Infrastructure	Nil
35	Agriculture/forest/Barren	Forested upslope
36	Geo-scientific Causes	-Highly weathered granite with about 2m thick overburden/residual soil -Steep cutting of overburden covered slope for settlement without proper toe buttress.
37	Remedial measures	-Construction of breast wall with sufficient weep holes and lined drainage to be provided on the hillside along with chute drain on the flanks to prevent possible widening through erosion.
38	Remarks, if any	
39	Photos. Sketch of Plan & section of the slide	
40	Summary/Abstract	The shallow rotational slide in Ayyappa is caused due to steep

		cutting of an overburden-covered slope for settlement without proper toe buttress. The slope is characterized by thick overburden/residual soil. It is recommended to construct a breast wall with sufficient weep holes and lined drainage to be provided on the hillside.
41	Pdf	Attached
42	Landslide category	III

No	Field	
1	Slide No (LS. No.)	KG/KOD/48P16/2020-21/18
2	State	Karnataka
3	District	Kodagu
4	Toposheet	48P16
5	Name of the slide	Ayyappa slide
6	NH/SH/Locality	South Ayyappa
7	Latitude	12°12'8.4"N
8	Longitude	75°48'27.3"E
9	Length	20m
10	Width	45 m
11	Height	18 m
12	Area	900 sq.m
13	Depth	1m
14	Volume	900 cu.m
15	Run out distance	Nil
16	Type of Material	Debris
17	Type of movement	Slide
18	Rate of movement	Rapid
19	Activity	Suspended
20	Distribution	Confined
21	Style	Single
22	Failure mechanism	Shallow translational
23	History	August 2018
24	Geomorphology	Lowly dissected slopes
25	Geology	Granite
26	Structure	Nil
27	Land use/ Land cover	Partially Modified Slope for road
28	Hydrological condition	Dry
29	Triggering Factor	Incessant rainfall
30	Death of persons	Nil

31	People affected	Nil
32	Live-stock loss	Nil
33	Communication	Nil
34	Infrastructure	Temporary road blockage
35	Agriculture/forest/Barren	Forested upslope
36	Geo-scientific Causes	-Highly weathered granite with about 2m thick overburden/residual soil -Steep cutting of overburden covered slope for settlement without proper toe buttress.
37	Remedial measures	-Construction of a breast wall with sufficient weep holes and a lined drainage to be provided on the hillside along with a chute drain on the flanks to prevent possible widening through erosion.
38	Remarks, if any	
39	Photos. Sketch of Plan & section of the slide	
40	Summary/Abstract	The shallow translational slide in south Ayyappa is caused due to steep cutting of overburden-covered slope for road widening. The slope is characterized by thick overburden/residual soil. It is recommended to construct a breast wall with sufficient weep holes and lined drainage to be provided on the hillside.
41	Pdf	Attached
42	Landslide category	III

No	Field	
1	Slide No (LS. No.)	KG/KOD/48P16/2020-21/19
2	State	Karnataka
3	District	Kodagu
4	Toposheet	48P16

5	Name of the slide	Ayyappa slide
6	NH/SH/Locality	East Ayyappa
7	Latitude	12°12'8.9"N
8	Longitude	75°48'42.7"E
9	Length	30m
10	Width	25m
11	Height	20 m
12	Area	750 sq.m
13	Depth	4 m
14	Volume	3000 cu.m
15	Run out distance	Nil
16	Type of Material	Soil
17	Type of movement	Slide
18	Rate of movement	Rapid
19	Activity	Suspended
20	Distribution	Confined
21	Style	Single
22	Failure mechanism	Shallow rotational
23	History	August 2018
24	Geomorphology	Moderate dissected hills
25	Geology	Granite
26	Structure	Nil
27	Land use/ Land cover	Partially Modified Slope
28	Hydrological condition	Dry
29	Triggering Factor	Incessant rainfall
30	Death of persons	Nil
31	People affected	Nil
32	Live-stock loss	Nil
33	Communication	Nil
34	Infrastructure	House partially damaged
35	Agriculture/forest/Barren	Forested
36	Geo-scientific Causes	- Thick overburden/residual soil over the steep slope -Steep cutting of overburden covered slope for settlement without proper toe buttress.
37	Remedial measures	-Breast wall needs to be constructed and lined drainage to prevent toe erosion
38	Remarks, if any	

39	Photos. Sketch of Plan & section of the slide	
40	Summary/Abstract	The shallow rotational slide in Ayyappa is caused due to steep cutting of an overburden-covered slope for settlement without toe support systems. The slope is characterized by thick overburden/residual soil. It is recommended to construct a breast wall with sufficient weep holes and lined drainage to be provided on the hillside.
41	Pdf	Attached
42	Landslide category	III

No	Field	
1	Slide No (LS. No.)	KG/KOD/48P16/2020-21/20
2	State	Karnataka
3	District	Kodagu
4	Toposheet	48P16
5	Name of the slide	Ayyappa slide
6	NH/SH/Locality	East Ayyappa
7	Latitude	12°12'16.3"N
8	Longitude	75°48'41.3"E
9	Length	20 m
10	Width	18 m
11	Height	18m
12	Area	3600 sq.m
13	Depth	4m
14	Volume	14,400 cu.m
15	Run out distance	Nil
16	Type of Material	Soil
17	Type of movement	Slide
18	Rate of movement	Rapid
19	Activity	Suspended

20	Distribution	Widening and retrogressive
21	Style	Single
22	Failure mechanism	Shallow rotational
23	History	August 2018
24	Geomorphology	Highly dissected slopes
25	Geology	Granite
26	Structure	Nil
27	Land use/ Land cover	Partially Modified Slope/Thick vegetation
28	Hydrological condition	Dry
29	Triggering Factor	Rainfall
30	Death of persons	Nil
31	People affected	Nil
32	Live-stock loss	Nil
33	Communication	Nil
34	Infrastructure	Nil
35	Agriculture/forest/Barren	Forested
36	Geo-scientific Causes	1. The slope forming material is largely immature soil. The granite is observed to be highly weathered. 2. Concave slope morphometry along the slope within which water converge to augment pore water pressure has aggravated instability.
37	Remedial measures	-Breast wall needs to be constructed and lined drainage to prevent toe erosion
38	Remarks, if any	
39	Photos. Sketch of Plan & section of the slide	
40	Summary/Abstract	The shallow translational slide in east Ayyappa is caused due to steep cutting of an overburden-covered slope for road widening. The slope is characterized by thick

		overburden/residual soil. It is recommended to construct a breast wall with sufficient weep holes and lined drainage to be provided on the hillside.
41	Pdf	Attached
42	Landslide category	III

No	Field	
1	Slide No (LS. No.)	KG/KOD/48P16/2020-21/21
2	State	Karnataka
3	District	Kodagu
4	Toposheet	48P16
5	Name of the slide	Aimangala slide
6	NH/SH/Locality	Aimangala
7	Latitude	12°12'46.5"N
8	Longitude	75°49'0.6"E
9	Length	40m
10	Width	30m
11	Height	30m
12	Area	1200 sq.m
13	Depth	4 m
14	Volume	4800 cu.m
15	Run out distance	Nil
16	Type of Material	Soil
17	Type of movement	Slide
18	Rate of movement	Rapid
19	Activity	Suspended
20	Distribution	Widening
21	Style	Single
22	Failure mechanism	Shallow translational
23	History	August 2019
24	Geomorphology	Lowly dissected hills
25	Geology	Granite
26	Structure	Nil
27	Land use/ Land cover	Coffee plantation
28	Hydrological condition	Dry
29	Triggering Factor	Rainfall
30	Death of persons	Nil
31	People affected	Nil
32	Live-stock loss	Nil

33	Communication	Nil
34	Infrastructure	Coffee plantation partial damage
35	Agriculture/forest/Barren	Forested
36	Geo-scientific Causes	1. The slope forming material is largely immature soil. The granite is observed to be highly weathered. 2. Concave slope morphometry along the slope within which water converges to augment pore water pressure has aggravated instability.
37	Remedial measures	-Channelization of the surface water away from the crown area and provision of chute drain along the flanks to prevent widening by erosion.
38	Remarks, if any	
39	Photos. Sketch of Plan & section of the slide	
40	Summary/Abstract	The shallow translational slide in the Aimangala Coffee plantation is caused due to infiltration of surface runoff into the overburden-covered slope. The slope is characterized by thick immature overburden/residual soil. It is recommended to construct a contour drain over the crown area and the flanks to divert water away from the slide area.
41	Pdf	Attached
42	Landslide category	III

No	Field	
1	Slide No (LS. No.)	KG/KOD/48P16/2020-21/22
2	State	Karnataka
3	District	Kodagu
4	Toposheet	48P16
5	Name of the slide	Nehru Nagar slide
6	NH/SH/Locality	Nehru Nagar Virajpet
7	Latitude	12°11'42.6"N

8	Longitude	75°48'52.0"E
9	Length	30m
10	Width	20m
11	Height	20m
12	Area	600 sq.m
13	Depth	3 m
14	Volume	1800 cu.m
15	Run out distance	Nil
16	Type of Material	Debris
17	Type of movement	Slide
18	Rate of movement	Rapid
19	Activity	Suspended
20	Distribution	Confined
21	Style	Single
22	Failure mechanism	Shallow rotational
23	History	August 11 2019
24	Geomorphology	Lowly dissected hills
25	Geology	Granite
26	Structure	Nil
27	Land use/ Land cover	Partially Modified Slope/Thick vegetation
28	Hydrological condition	Dry
29	Triggering Factor	Anthropogenic
30	Death of persons	Nil
31	People affected	Nil
32	Live-stock loss	Nil
33	Communication	Nil
34	Infrastructure	2 houses abandoned
35	Agriculture/forest/Barren	Forested
36	Geo-scientific Causes	1. The slope forming material is largely immature soil. The granite is observed to be highly weathered. 2. Concave slope morphometry along the slope within which water converges to augment pore water pressure has aggravated instability.
37	Remedial measures	-Channelization of the surface water away from the crown area
38	Remarks, if any	

39	Photos. Sketch of Plan & section of the slide	
40	Summary/Abstract	The shallow rotational slide in Nehru Nagar is caused due to steep cutting of an overburden-covered slope for construction of houses without any toe support systems. The slope is characterized by thick overburden/residual soil. It is recommended to construct a breast wall with sufficient weep holes and lined drainage to be provided on the hillside.
41	Pdf	Attached
42	Landslide category	III

No	Field	
1	Slide No (LS. No.)	KG/KOD/48P16/2020-21/23
2	State	Karnataka
3	District	Kodagu
4	Toposheet	48P16
5	Name of the slide	Magulla slide
6	NH/SH/Locality	Magulla
7	Latitude	12°12'2.6"N
8	Longitude	75°48'45.9"E
9	Length	25m
10	Width	30
11	Height	20
12	Area	7500 sq.m
13	Depth	3
14	Volume	22500 cu.m
15	Run out distance	Nil
16	Type of Material	Debris
17	Type of movement	Slide
18	Rate of movement	Rapid
19	Activity	Suspended

20	Distribution	Confined
21	Style	Single
22	Failure mechanism	Shallow translational
23	History	August 2019
24	Geomorphology	Lowly dissected hills
25	Geology	Granite
26	Structure	Nil
27	Land use/ Land cover	Partially Modified Slope/Thick vegetation
28	Hydrological condition	Dry
29	Triggering Factor	Rainfall
30	Death of persons	Nil
31	People affected	Nil
32	Live-stock loss	Nil
33	Communication	Nil
34	Infrastructure	Nil
35	Agriculture/forest/Barren	Plantation upslope
36	Geo-scientific Causes	-Highly weathered rock (W5) and overlain by thick immature soil. -Toe cutting of the steep slope with thick overburden induced slope instability.
37	Remedial measures	-Construction of benched gabion wall can prevent the re-activation of the landslide
38	Remarks, if any	.
39	Photos. Sketch of Plan & section of the slide	
40	Summary/Abstract	The shallow translational slide in Magulla is caused due to steep cutting of an overburden-covered slope for the road widening. The slope is characterized by thick overburden/residual soil. It is recommended to construct a breast wall with sufficient weep holes and lined drainage to be provided on the hillside.
41	Pdf	Attached

42	Landslide category	III

No	Field	
1	Slide No (LS .No.)	KG/KOD/48P16/2020-21/24
2	State	Karnataka
3	District	Kodagu
4	Toposheet	48P16
5	Name of the slide	Ambatty slide
6	NH/SH/Locality	Ambatty
7	Latitude	12°11'21.5"N
8	Longitude	75°49’8.9"E
9	Length	20m
10	Width	20m
11	Height	14m
12	Area	400 sq.m
13	Depth	2m
14	Volume	800 cu.m
15	Run out distance	Nil
16	Type of Material	Soil
17	Type of movement	Slide
18	Rate of movement	Rapid
19	Activity	Suspended
20	Distribution	Confined
21	Style	Single
22	Failure mechanism	Shallow rotational
23	History	August 2018
24	Geomorphology	Moderately dissected hills
25	Geology	Granite
26	Structure	Nil
27	Land use/ Land cover	Coffee plantation
28	Hydrological condition	Dry
29	Triggering Factor	Rainfall
30	Death of persons	Nil
31	People affected	Nil
32	Live-stock loss	Nil
33	Communication	Nil
34	Infrastructure	Nil
35	Agriculture/forest/Barren	Forested

36	Geo-scientific Causes	-Highly weathered rock (W5) and overlain by thick immature soil. -Toe cutting of the steep slope with thick overburden induced slope instability.
37	Remedial measures	Construction of benched gabion wall can prevent the reactivation of the landslide
38	Remarks, if any	
39	Photos. Sketch of Plan & section of the slide	
40	Summary/Abstract	The shallow rotational slide in Ambatty is caused due to steep cutting of an overburden-covered slope for road widening without toe support. The slope is characterized by thick overburden/residual soil. It is recommended to construct a gabion wall with sufficient weep holes and lined drainage to be provided on the hillside.
41	Pdf	Attached
42	Landslide category	III

No	Field	
1	Slide No (LS.No.)	KG/KOD/48P16/2020-21/25
2	State	Karnataka
3	District	Kodagu
4	Toposheet	48P16
5	Name of the slide	Ambatty slide
6	NH/SH/Locality	Ambatty
7	Latitude	12°11'32.5"N
8	Longitude	75°49’15.1"E
9	Length	40m
10	Width	15m
11	Height	30m
12	Area	600 sq.m
13	Depth	2m

14	Volume	1200 cu.m
15	Run out distance	Nil
16	Type of Material	Soil
17	Type of movement	Slide
18	Rate of movement	Rapid
19	Activity	Suspended
20	Distribution	retrogressive
21	Style	Single
22	Failure mechanism	Shallow translational
23	History	August 2018
24	Geomorphology	Lowly dissected hills
25	Geology	Granite
26	Structure	Nil
27	Land use/ Land cover	Coffee plantation
28	Hydrological condition	Dry
29	Triggering Factor	Rainfall
30	Death of persons	Nil
31	People affected	Nil
32	Live-stock loss	Nil
33	Communication	Nil
34	Infrastructure	Temporary road blockage
35	Agriculture/forest/Barren	Forested
36	Geo-scientific Causes	1. Toe cutting of the steep slope for construction of settlement without any structural support.
37	Remedial measures	Construction of drainage at the flanks of the depleted zone and construction of retaining wall at the toe.
38	Remarks, if any	
39	Photos. Sketch of Plan & section of the slide	
40	Summary/Abstract	The shallow translational slide in east Ambatty is caused due

		to steep cutting of an overburden-covered slope for road widening. The slope is characterized by thick overburden/residual soil. It is recommended to construct a breast wall with sufficient weep holes and lined drainage to be provided on the hillside.
41	Pdf	Attached
42	Landslide category	III

No	Field	
1	Slide No (LS .No.)	KG/KOD/48P16/2020-21/26
62	State	Karnataka
3	District	Kodagu
4	Toposheet	48P16
5	Name of the slide	Ambatty
6	NH/SH/Locality	Ambatty slide
7	Latitude	12°11'31.1"N
8	Longitude	75°49’13.2"E
9	Length	35m
10	Width	30 m
11	Height	30 m
12	Area	1050 sq.m
13	Depth	2m
14	Volume	2100 cu.m
15	Run out distance	Nil
16	Type of Material	Debris
17	Type of movement	Slide
18	Rate of movement	Rapid
19	Activity	Suspended
20	Distribution	Retrogressive
21	Style	Single
22	Failure mechanism	Shallow translational
23	History	August 2018
24	Geomorphology	Lowly dissected hills
25	Geology	Granite
26	Structure	Nil
27	Land use/ Land cover	Partially Modified Slope for construction of settlement
28	Hydrological condition	Dry
29	Triggering Factor	Rainfall and alteration of steep slope.
30	Death of persons	Nil
31	People affected	Nil
32	Live-stock loss	Nil
33	Communication	Nil
34	Infrastructure	House partially damaged

35	Agriculture/forest/Barren	Forested
36	Geo-scientific Causes	1. Toe cutting of the steep slope for construction of settlement without any structural support.
37	Remedial measures	Construction of retaining wall and easing of the slope.
38	Remarks, if any	
39	Photos. Sketch of Plan & section of the slide	
40	Summary/Abstract	The shallow translational slide in east Ambatty is caused due steep cutting of overburden covered slope for house construction without toe support. The slope is characterized by thick overburden/residual soil. It is recommended to construct breast wall with sufficient weep holes and lined drainage to be provided on the hillside.
41	Pdf	Attached
42	Landslide category	III

No	Field	
1	Slide No (LS .No.)	KG/KOD/48P16/2020-21/27
2	State	Karnataka
3	District	Kodagu
4	Toposheet	48P16
5	Name of the slide	Nehru Nagar slide
6	NH/SH/Locality	West Nehru Nagar
7	Latitude	12°11'52.90"N
8	Longitude	75°48'36.97"E
9	Length	10m
10	Width	12m
11	Height	8m
12	Area	120 sq.m
13	Depth	1m
14	Volume	120 cu.m
15	Run out distance	0
16	Type of Material	Debris
17	Type of movement	Slide
18	Rate of movement	Very rapid
19	Activity	Suspended
20	Distribution	Widening
21	Style	Single
22	Failure mechanism	Shallow translational
23	History	August 2018
24	Geomorphology	highly dissected hills
25	Geology	Granite
26	Structure	Nil
27	Land use/ Land cover	Partially Modified Slope for construction of settlement
28	Hydrological condition	Dry
29	Triggering Factor	Rainfall and alteration of the steep slope.
30	Death of persons	Nil
31	People affected	Nil
32	Live-stock loss	Nil
33	Communication	Nil
34	Infrastructure	Nil
35	Agriculture/forest/Barren	Forested
36	Geo-scientific Causes	1. Toe cutting of the steep slope for construction of settlement without any structural support.

37	Remedial measures	Construction of drystone wall with hillside drainage and easing of the slope.
38	Remarks, if any	
39	Photos. Sketch of Plan & section of the slide	
40	Summary/Abstract	The shallow translational slide in West Nehru Nagar is caused due to steep cutting of an overburden-covered slope for house construction. The slope is characterized by thick overburden/residual soil. It is recommended to construct a breast wall with sufficient weep holes and lined drainage to be provided on the hillside.
41	Pdf	Attached
42	Landslide category	III

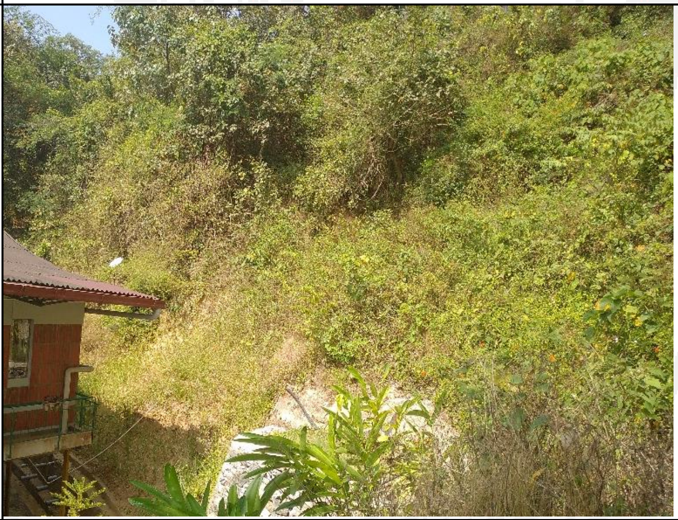
No	Field	
1	Slide No (LS. No.)	KG/KOD/48P16/2020-21/28
2	State	Karnataka
3	District	Kodagu
4	Toposheet	48P16
5	Name of the slide	Dental College slide
6	NH/SH/Locality	Near Coorg Dental College, Virajpet
7	Latitude	12°12'19.81"N
8	Longitude	75°48'39.88"E
9	Length	25 m
10	Width	30m
11	Height	22m
12	Area	750 sq.km
13	Depth	1.5m
14	Volume	1125 cu.m
15	Run out distance	Nil
16	Type of Material	Debris
17	Type of movement	Slide

18	Rate of movement	Rapid
19	Activity	Suspended
20	Distribution	Retrogressive
21	Style	Single
22	Failure mechanism	Shallow translational
23	History	Initiated in August 2019
24	Geomorphology	Highly dissected hills
25	Geology	Granite
26	Structure	Nil
27	Land use/ Land cover	Partially Modified Slope/Thick vegetation
28	Hydrological condition	Dry
29	Triggering Factor	Rainfall
30	Death of persons	Nil
31	People affected	Nil
32	Live-stock loss	Nil
33	Communication	Nil
34	Infrastructure	Nil
35	Agriculture/forest/Barren	Forested
36	Geo-scientific Causes	Steep slope cut without any structural toe support
37	Remedial measures	Construction of retaining wall with weep holes
38	Remarks, if any	
39	Photos. Sketch of Plan & section of the slide	
40	Summary/Abstract	The shallow translational slide near Coorg Dental college is caused due steep cutting of overburden covered slope for road widening and sustained toe erosion by the stream. The slope is characterized by thick overburden/residual soil. It is recommended to construct a gabion wall with sufficient weep holes and lined drainage to be provided on the hillside.
41	Pdf	Attached
42	Landslide category	III

No	Field	
1	Slide No (LS. No.)	KG/KOD/48P16/2020-21/29
2	State	Karnataka
3	District	Kodagu
4	Toposheet	48P16
5	Name of the slide	Nehru Nagar
6	NH/SH/Locality	Nehru Nagar, Virajpet
7	Latitude	12°11'49.56"N
8	Longitude	75°48'43.01"E
9	Length	10 m
10	Width	8 m
11	Height	7 m
12	Area	80 sq.km
13	Depth	1.5m
14	Volume	120 cu.m
15	Run out distance	Nil
16	Type of Material	Debris
17	Type of movement	Slide
18	Rate of movement	Rapid
19	Activity	Suspended
20	Distribution	Retrogressive
21	Style	Single
22	Failure mechanism	Shallow translational
23	History	Initiated in August 2019
24	Geomorphology	Moderately dissected hills
25	Geology	Granite
26	Structure	Nil
27	Land use/ Land cover	Partially Modified Slope/Thick vegetation
28	Hydrological condition	Dry
29	Triggering Factor	Rainfall
30	Death of persons	Nil
31	People affected	Nil
32	Live-stock loss	Nil
33	Communication	Nil
34	Infrastructure	Nil
35	Agriculture/forest/Barren	Forested
36	Geo-scientific Causes	Steep slope cut without any structural toe support
37	Remedial measures	Construction of retaining wall with weep holes
38	Remarks, if any	

39	Photos. Sketch of Plan & section of the slide	
40	Summary/Abstract	The shallow translational slide near midslope of Nehru Nagar is caused due steep cutting of overburden covered slope for house construction and sustained toe erosion by the stream. The slope is characterized by thick overburden/residual soil. It is recommended to construct a gabion wall with sufficient weep holes and lined drainage to be provided on the hillside.
41	Pdf	Attached
42	Landslide category	III

No	Field	
1	Slide No (LS. No.)	KG/KOD/48P16/2020-21/30
2	State	Karnataka
3	District	Kodagu
4	Toposheet	48P16
5	Name of the slide	Bittangala
6	NH/SH/Locality	Bittangala, Virajpet
7	Latitude	12°11'49.56"N
8	Longitude	75°48'43.01"E
9	Length	12 m
10	Width	9 m
11	Height	7 m
12	Area	108 sq.km
13	Depth	1 m
14	Volume	108 cu.m
15	Run out distance	Nil
16	Type of Material	Debris
17	Type of movement	Slide

18	Rate of movement	Rapid
19	Activity	Suspended
20	Distribution	Retrogressive
21	Style	Single
22	Failure mechanism	Shallow translational
23	History	Initiated in 2019
24	Geomorphology	Moderately dissected hills
25	Geology	Granite
26	Structure	Nil
27	Land use/ Land cover	Partially Modified Slope/Thick vegetation
28	Hydrological condition	Dry
29	Triggering Factor	Rainfall
30	Death of persons	Nil
31	People affected	Nil
32	Live-stock loss	Nil
33	Communication	Nil
34	Infrastructure	Nil
35	Agriculture/forest/Barren	Forested
36	Geo-scientific Causes	Steep slope cut without any structural toe support
37	Remedial measures	Construction of retaining wall with weep holes
38	Remarks, if any	
39	Photos. Sketch of Plan & section of the slide	
40	Summary/Abstract	The shallow translational slide near midslope of Bittangala is caused due steep cutting of overburden covered slope for building construction and sustained toe erosion by the stream. The slope is characterized by thick overburden/residual soil. It is recommended to construct a gabion wall with sufficient weep holes and lined drainage to be provided on the hillside.
41	Pdf	Attached
42	Landslide category	III

No	Field	
1	Slide No (LS. No.)	KG/KOD/48P16/2020-21/31
2	State	Karnataka
3	District	Kodagu
4	Toposheet	48P16
5	Name of the slide	Coorg Dental College
6	NH/SH/Locality	Coorg Dental College, Virajpet
7	Latitude	12°12'23.12"N
8	Longitude	75°48'40.53"E
9	Length	13 m
10	Width	10 m
11	Height	10 m
12	Area	130 sq.km
13	Depth	1 m
14	Volume	130 cu.m
15	Run out distance	Nil
16	Type of Material	Debris
17	Type of movement	Slide
18	Rate of movement	Rapid
19	Activity	Suspended
20	Distribution	Retrogressive
21	Style	Single
22	Failure mechanism	Shallow translational
23	History	Initiated in 2019
24	Geomorphology	Moderately dissected hills
25	Geology	Granite
26	Structure	Nil
27	Land use/ Land cover	Partially Modified Slope/Thick vegetation
28	Hydrological condition	Dry
29	Triggering Factor	Rainfall
30	Death of persons	Nil
31	People affected	Nil
32	Live-stock loss	Nil
33	Communication	Nil
34	Infrastructure	Nil
35	Agriculture/forest/Barren	Forested
36	Geo-scientific Causes	Steep slope cut without any structural toe support
37	Remedial measures	Construction of retaining wall with weep holes
38	Remarks, if any	

39	Photos. Sketch of Plan & section of the slide	
40	Summary/Abstract	The shallow translational slide near upslope of Coorg Dental College is caused due steep cutting of overburden covered slope for building construction. The slope is characterized by thick overburden/residual soil. It is recommended to construct a gabion wall with sufficient weep holes and lined drainage to be provided on the hillside.
41	Pdf	Attached
42	Landslide category	III

Annexure – IV - Rock Mass Rating (RMR_{Basic} Calculation)

Sl no	Lat/Long	Rock type	RMR_{basic}		Range of values	Ratings	Rock mass class
1	12° 12' 38''/75° 48' 5.4''	Porphyritic granite	Uniaxial Compressive strength		51 Mpa	7	II
			RQD		98%	20	
			Spacing of joints		1m	15	
			Condition of Discontinuities	Persistence	8m	2	
				Aperture	>5mm	0	
				Roughness	Rough	5	
				Infilling	Soft <5mm	2	
				Weathering	Slightly weathered	5	
				Groundwater	Completely dry	15	
			Total			**71**	
2	12° 12' 52.6''/75° 48' 24.8''	Porphyritic granite	Uniaxial Compressive strength		55 Mpa	7	I
			RQD		95%	20	
			Spacing of joints		>2m	20	
			Condition of Discontinuities	Persistence	2m	4	
				Aperture	>5mm	0	
				Roughness	Rough	5	
				Infilling	None	6	
				Weathering	Slightly weathered	5	
				Groundwater	Completely dry	15	
			Total			**82**	
3	12° 12' 23.6''/75° 48' 13.3''	Porphyritic granite	Uniaxial Compressive strength		47 MPa	4	
			RQD		95%	20	
			Spacing of joints		30cm	10	
			Condition of	Persistence	8m	2	
				Aperture	>5mm	0	
				Roughness	Rough	5	
				Infilling	Soft >5mm	0	

			Discontinuities	Weathering	Slightly weathered	5	**III**
				Groundwater	Damp	10	
			Total			**56**	
4	12° 12' 25.1''/75° 48' 14.1''	Porphyritic granite	Uniaxial Compressive strength		58 Mpa	7	**I**
			RQD		95%	20	
			Spacing of joints		>2m	20	
			Condition of Discontinuities	Persistence	9m	2	
				Aperture	None	6	
				Roughness	Rough	5	
				Infilling	None	6	
				Weathering	Unweathered	6	
				Groundwater	Damp	10	
			Total			**82**	

Sl no	**Lat/Long**	**Rock type**	**RMR$_{basic}$**		**Range of values**	**Ratings**	**Rock mass class**
5	12° 12' 16.5''/75° 48' 29.2''	Porphyritic granite	Uniaxial Compressive strength		41 Mpa	4	**II**
			RQD		91%	20	
			Spacing of joints		40cm	10	
			Condition of Discontinuities	Persistence	8m	2	
				Aperture	>5mm	0	
				Roughness	Rough	5	
				Infilling	Soft >5mm	0	
				Weathering	Slightly weathered	5	
				Ground water	Completely dry	15	
			Total			**61**	
	12° 12' 16.5''/75° 48' 24.8''		Uniaxial Compressive strength		58 Mpa	7	
			RQD		88.6 %	17	
			Spacing of joints		50cm	10	
				Persistence	9m	2	

6		Porphyritic granite	Condition of Discontinuities	Aperture	>5mm	0	**III**
				Roughness	Rough	5	
				Infilling	Soft <5mm	2	
				Weathering	Slightly weathered	5	
				Groundwater	Damp	10	
			Total			**58**	
7	12° 12’ 42’’/75° 48’ 59’’	Porphyritic granite	Uniaxial Compressive strength		54 Mpa	7	**II**
			RQD		95%	20	
			Spacing of joints		1m	15	
			Condition of Discontinuities	Persistence	9m	2	
				Aperture	>5mm	0	
				Roughness	Slightly rough	3	
				Infilling	None	6	
				Weathering	Slightly weathered	5	
				Groundwater	Damp	10	
			Total			**68**	

Sl no	**Lat/Long**	**Rock type**	**RMR$_{basic}$**		**Range of values**	**Ratings**	**Rock mass class**
8	12° 11’ 10.9’’/75° 49’ 47’’	Porphyritic granite	Uniaxial Compressive strength		45 Mpa	4	**II**
			RQD		95.2%	20	
			Spacing of joints		80cm	15	
			Condition of Discontinuities	Persistence	2m	4	
				Aperture	>5mm	0	
				Roughness	Rough	5	
				Infilling	Soft <5mm	2	
				Weathering	Slightly weathered	5	
				Groundwater	Completely dry	15	
			Total			**70**	
	12° 11’		Uniaxial Compressive strength		60 Mpa	7	

9	6''/75° 50' 37.8''	Porphyritic granite	RQD		98%	20	II
			Spacing of joints		60cm	15	
			Condition of Discontinuities	Persistence	7m	2	
				Aperture	>5mm	0	
				Roughness	Rough	5	
				Infilling	Hard>5mm	2	
				Weathering	Slightly weathered	5	
				Groundwater	Completely dry	15	
			Total			**71**	
10	12° 11' 14''/75° 50' 21.5''	Porphyritic granite	Uniaxial Compressive strength		62 MPa	7	I
			RQD		98%	20	
			Spacing of joints		>2 m	20	
			Condition of Discontinuities	Persistence	7m	2	
				Aperture	>5mm	0	
				Roughness	Rough	5	
				Infilling	None	6	
				Weathering	Slightly weathered	5	
				Groundwater	Completely dry	15	
			Total			**80**	
11	12° 11' 10.6''/75° 49' 53.3''	Porphyritic granite	Uniaxial Compressive strength		47 Mpa	4	III
			RQD		88%	17	
			Spacing of joints		70 cm	15	
			Condition of Discontinuities	Persistence	5m	2	
				Aperture	3mm	1	
				Roughness	Sightly rough	3	
				Infilling	Soft <5mm	2	
				Weathering	Slightly weathered	5	
				Groundwater	Damp	10	
			Total			**59**	

Sl no	Lat/Long	Rock type	RMR$_{basic}$		Range of values	Ratings	Rock mass class
12	12° 10' 57.1''/75° 49' 4.6'' (Ambatty)	Porphyritic granite	Uniaxial Compressive strength		48 Mpa	4	II
			RQD*		95%	20	
			Spacing of joints		70cm	15	
			Condition of Discontinuities	Persistence	8m	2	
				Aperture	>5mm	0	
				Roughness	Rough	5	
				Infilling	Hard>5mm	2	
				Weathering	Slightly weathered	5	
				Groundwater	Completely dry	15	
			Total			**68**	
13	12° 11' 43.6'/75° 48' 52.6'' (Nehru Nagar)	Porphyritic granite	Uniaxial Compressive strength		50 Mpa	4	II
			RQD		98%	20	
			Spacing of joints		60cm	15	
			Condition of Discontinuities	Persistence	7m	2	
				Aperture	>5mm	0	
				Roughness	Rough	5	
				Infilling	Hard>5mm	2	
				Weathering	Slightly weathered	5	
				Groundwater	Completely dry	15	
			Total			**68**	

	75.807574/ 12.207594		Uniaxial Compressive strength	42 Mpa	4	
			RQD	91.9%	20	

14	(Ayyappa Top left)	Porphyritic granite	Spacing of joints		50cm	10	**III**
			Condition of Discontinuities	Persistence	9m	2	
				Aperture	>5mm	0	
				Roughness	Rough	5	
				Infilling	Soft <5mm	2	
				Weathering	Slightly weathered	5	
				Groundwater	Damp	10	
			Total			**58**	

Annexure – V – Geotechnical Results

भू-तकनीकी प्रयोगशाला / **Geotechnical Laboratory**
भारतीय भूवैज्ञानिक सर्वेक्षण / **Geological Survey of India**
दक्षिणी क्षेत्र, हैदराबाद / **Southern Region, Hyderabad**

Lab. Reference No.	**39/SM-9793**
Sender's Name:	Shri Achan Konyak , Geologist
Description and Location:	Virajpet Area, Kodagu District of Karnataka
Reference No.	Lr. No: 01/AK/SU:KG/Soil/GT/2020-21, Dated: 17.03.2021.
Tests Done:	Moisture content, Specific gravity, Density, Void ratio, Porosity, Cohesion, Angle of Internal friction (Φ), Grain Size analysis and Atterberg limits.
F.S.Code No. & Title:	Item code: M4LSSM/NC/SR/SU-KG/2020/32460, FS:2020-21. Meso-scale (1:10,000) Landslide Susceptibility Mapping in and around Virajpet Area, Kodagu District of Karnataka.

TEST RESULTS

Sr. No.	Sample Number/Code	Moisture content %	Specific gravity	Density gm/cm³	Void ratio (e)	Porosity (n)	Grain Size				Cohesion (Kgf/cm²)	Angle of Internal friction (Ø)	Liquid Limit %	Plastic Limit %	Plasticity Index	Shrinkage Limit %
							Gravel %	Sand %	Silt %	Clay %						
1	KG/32460/UDS/01	14.5	2.67	1.40	0.91	0.48	0	28	62	10	0.29	23	44	33	11	19
2	KG/32460/UDS/02	11.5	2.67	1.47	0.82	0.45	2	31	61	6	0.30	22	38	28	10	10
3	KG/32460/UDS/03	10.9	2.70	1.39	0.94	0.48	3	24	64	9	0.30	21	44	32	12	17
4	KG/32460/UDS/04	6.5	2.60	1.48	0.76	0.43	1	34	55	10	0.25	28	40	30	10	14
5	KG/32460/UDS/05	13.3	2.70	1.40	0.93	0.48	28	36	25	11	0.27	22	44	32	12	19
6	KG/32460/UDS/06	18.0	2.71	1.41	0.92	0.48	0	24	70	6	0.28	21	35	28	7	10
7	KG/32460/UDS/07	13.2	2.64	1.43	0.85	0.46	5	24	62	9	0.27	20	36	27	9	15
8	KG/32460/UDS/08	11.3	2.63	1.53	0.72	0.42	15	28	47	10	0.26	21	44	32	12	14
9	KG/32460/UDS/09	14.4	2.63	1.41	0.87	0.47	1	28	61	10	0.29	22	44	31	13	18
10	KG/32460/UDS/10	12.8	2.64	1.39	0.90	0.47	11	26	56	7	0.34	23	39	29	10	11
11	KG/32460/UDS/11	15.4	2.57	1.55	0.66	0.40	2	34	56	8	0.30	24	40	30	10	14
12	KG/32460/UDS/12	12.5	2.70	1.47	0.84	0.46	8	24	59	9	0.29	22	42	31	11	16
13	KG/32460/UDS/13	14.9	2.69	1.45	0.86	0.46	15	31	47	7	0.30	25	38	29	9	9
14	KG/32460/UDS/14	9.3	2.61	1.37	0.91	0.48	6	31	54	9	0.26	29	42	32	10	15
15	KG/32460/UDS/15	11.9	2.68	1.57	0.71	0.42	7	22	63	8	0.28	28	38	29	9	14

R.V. Gopalakrishnan
21.10.21

Sr. No.	Sample Number/Code	Moisture content %	Specific gravity	Density gm/cm^3	Void ratio (e)	Porosity (n)	Gravel %	Sand %	Silt %	Clay %	Cohesion (Kgf/cm^2)	Angle of Internal friction (Ø)	Liquid Limit %	Plastic Limit %	Plasticity Index	Shrinkage Limit %
16	KG/32460/UDS/16	9.2	2.63	1.46	0.80	0.44	4	55	31	10	0.30	21	42	32	10	15
17	KG/32460/UDS/17	16.2	2.64	1.46	0.81	0.45	6	41	45	8	0.24	23	37	28	9	17
18	KG/32460/UDS/18	19.1	2.67	1.41	0.89	0.47	4	40	49	7	0.37	22	35	25	10	14
19	KG/32460/UDS/19	13.1	2.57	1.56	0.65	0.39	1	46	46	7	0.25	29	35	26	9	16
20	KG/32460/UDS/20	11.7	2.62	1.42	0.85	0.46	0	51	41	8	0.31	23	36	25	11	13
21	KG/32460/UDS/21	5.2	2.61	1.38	0.89	0.47	7	54	30	9	0.31	22	41	29	12	15
22	KG/32460/UDS/22	7.0	2.54	1.40	0.81	0.45	14	41	36	9	0.25	24	42	29	13	18
23	KG/32460/UDS/23	13.6	2.64	1.39	0.90	0.47	5	39	48	8	0.26	26	40	30	10	16
24	KG/32460/UDS/24	7.4	2.61	1.38	0.89	0.47	1	56	34	9	0.25	28	41	29	12	14
25	KG/32460/UDS/25	9.9	2.62	1.42	0.85	0.46	2	32	56	10	0.35	20	43	30	13	15
26	KG/32460/UDS/26	5.2	2.64	1.48	0.78	0.44	1	66	26	7	0.25	28	37	27	10	13
27	KG/32460/UDS/27	11.2	2.62	1.44	0.82	0.45	2	47	45	6	0.32	25	36	25	11	10
28	KG/32460/UDS/28	11.0	2.66	1.44	0.85	0.46	12	51	29	8	0.26	29	38	28	10	12
29	KG/32460/UDS/29	8.9	2.67	1.62	0.65	0.39	14	51	25	10	0.25	28	42	33	9	13
30	KG/32460/UDS/30	8.3	2.65	1.47	0.80	0.44	3	57	31	9	0.27	29	40	31	9	16
31	KG/32460/UDS/31	19.4	2.57	1.38	0.86	0.46	7	35	48	10	0.25	25	42	29	13	17
32	KG/32460/UDS/32	20.9	2.63	1.47	0.79	0.44	4	33	53	10	0.26	26	43	30	13	15
33	KG/32460/UDS/33	13.1	2.65	1.55	0.71	0.42	0	48	44	8	0.25	29	39	28	11	13
34	KG/32460/UDS/34	7.1	2.62	1.41	0.86	0.46	1	51	41	7	0.28	28	37	28	9	14
35	KG/32460/UDS/35	9.4	2.63	1.52	0.73	0.42	1	59	32	8	0.26	29	38	27	11	15

B.V.Gopala Krishna 21/10/21
(B. Venu Gopala Krishna)
Geologist

Shailendra 21/10/2021
(Shailendra Kumar Singh)
Senior Geologist

Approved By
21/10/2021.
(B. Ajaya Kumar)
Director

बी.अजय कुमार
B. AJAYA KUMAR
निदेशक / DIRECTOR,
अभियान्त्रिकी भूविज्ञान प्रभाग
ENGINEERING GEOLOGY DIVISION
भारतीय भूवैज्ञानिक सर्वेक्षण, दक्षिणी क्षेत्र
GEOLOGICAL SURVEY OF INDIA,S.R.
हैदराबाद /HYDERABAD -500068

PLATE I - Landslide susceptibility map of Virajpet