



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

कर्नाटक राज्य के बेलगाम और उत्तर कन्नडा जिले एवं गोवा के दक्षिण गोवा जिले में भूआकृति संख्या 48I/8, 48I/10 और 48I/11 के कुछ हिस्सों में बृहद पैमाने पर (१: ५०,०००) भूस्खलन संवेदनशीलता का मानचित्रण

**MACRO-SCALE (1:50,000) LANDSLIDE SUSCEPTIBILITY MAPPING IN PARTS OF TOPOSHEET NOS. 48I/8, 48I/10 AND 48I/11 BELGAUM AND UTTAR KANNADA DISTRICTS, KARNATAKA AND SOUTH GOA DISTRICT, GOA**

मद संख्या: एम4एलएसएसएम/एनसी/एसआर/एसयू-केजी/ २०१८ / १८७१८  
Item no.: M4LSSM/NC/SR/SU-KG/2018/18718

कार्य सत्र २०१८-१९ का अंतिम प्रतिवेदन  
Final report for field season 2018-19

By

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मिशन-IV  
MISSION-IV

PROJECT: NLSM / परियोजना: एनएलएसएम  
STATE UNIT: KARNATAKA & GOA/ राज्य इकाई: कर्नाटक एवं गोवा

सितम्बर, 2019  
September, 2019

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(कार्य सत्र कोड संख्या: एम4एलएसएसएम/एनसी/एसआर/एसयू-केजी/ २०१८ / १८७१८)

(कार्य सत्र: २०१८-१९)

### **सारांश**

कर्नाटक राज्य के बेलगाम, उत्तर कन्नडा जिलों, और गोवा राज्य के दक्षिण गोवा के कुछ हिस्सों में उच्च रिज़ॉल्यूशन के रिमोट सेंसिंग डेटा और फ़ील्ड इनपुट का उपयोग करके वृहद पैमाने पर भूस्खलन संवेदनशीलता का मानचित्रण किया गया जिसमें कुल 1324 वर्ग किलोमीटर का क्षेत्र को मैप किया गया। अध्ययन क्षेत्र में भूस्खलन की घटनाओं की कम संख्या के कारण, एएचपी आधारित गणितीय आँकड़े प्रतिरूपण की सहायता ली गई।

भूस्खलन और कारण कारकों के बीच स्थानिक संघटन का विश्लेषण करने के लिए कुछ भूकारकों को - मौलिक धारणा के आधार पर पता लगाया गया कि वर्तमान और पिछले भूस्खलन के कारण होने वाले स्थानिक कारक भविष्य में इसी तरह के भूस्खलन का कारण बन सकते हैं। अध्ययन क्षेत्र में जाने से पहले बनाये गये मानचित्र, अर्थात्, भूमि उपयोग भूमि कवर (एल यू एल सी) मानचित्र, भूआकृति विज्ञान - मानचित्र, स्लोप फार्मिंग मटेरियल मानचित्र और रेगोलिथ मोटाई मानचित्र जीआईएस प्लेटफ़ॉर्म पर मल्टी टेम्पोरल-गूगल अर्थ इमेजरी (ओपन सोर्स) की सहायता के साथ तैयार किये गये हैं। जबकि डेम (30 मीटर रिज़ॉल्यूशन) व्युत्पन्न अर्थात् स्लोप एस्पेक्ट मानचित्र, स्लोप ग्रेडिएंट मानचित्र, स्लोप कर्वेचर मानचित्र और ड्रेनेज मानचित्र बनये गए।

क्षेत्रवार (निम्न उच्च से) एल यू एल सी को विभाजित किया गया है : जिसमें घने वनस्पति, खेती, मध्यम वनस्पति, बंजर, विरल वनस्पति, उच्च ऊँचाई के बागान (एच एच पी), कम ऊँचाई के वृक्षारोपण (एल एच पी), परती भूमि, खदान, बस्तियाँ, संशोधित ढलान पर बस्तियाँ, व्यापक कट ढलान और जल निकाय सम्मिलित हैं। अध्ययन क्षेत्र में शहरीकरण को मुख्यता घाटियों में देखा गया है। अध्ययन क्षेत्र में कृषि भूमि भी ज्यादातर घाटियों में पाया जाती है।

अध्ययन क्षेत्र में अधिकांश भूआकृति की दृष्टि- से निम्न विच्छेदित पहाड़ियों, पेडिमेंटपेडिप्लीन - कॉम्प्लेक्स, इसके बाद अत्यधिक विच्छेदित ढलान, मध्यम विच्छेदित ढलान, रोलिंग मैदान और घाटी भराव उपस्थित हैं। अध्ययन क्षेत्र में ढलान के साथ ढिली सामग्री के किसी भी प्रकार के भूस्खलन का आकलन करते समय ढलान बनाने वाली सामग्री बहुत महत्वपूर्ण कारक है, जिसको चट्टान, (जिसमें अनॉर्थोसिटिक गैब्रो, आर्जिलाइट, बी आई एफ, डोलेराइट, फेरुजिनस फ़िलाइट, ग्रेनाइट नीस, ग्रैनिटाइड, मैंगनिफेरस फ़िलाइट, मेटाबेसाल्ट, फ़िलाइट, पाइरोक्सेनाइट, क्वाटर्ज़ क्लोराइट-सिस्ट, क्वाटर्ज़ सीरीसाइट-सिस्ट, क्वाटर्ज़ाइट, अल्ट्रामैफ़ाइट, वनाडिफेरस टिटानोमैग्नेटाइट-) अपक्षययुक्त चट्टान, परिवहन मिट्टी और इनसीटू मिट्टी- में वर्गीकृत किया गया है। रेगोलिथ मोटाई, सामान्य तौर पर 0.5 मीटर से 5 मीटर से कम और कभी कभी-5 मीटर से 10 मीटर की मोटाई तक भिन्न होती है।

फील्ड कार्य के दौरान कुल 31 भूस्खलन की पहचान की गई और भूस्खलन सूची के लिए 42-बिंदुओं का जियो पैरामीट्रिक शीट में प्रलेखित किया गया। इनमें-11 मलबे की स्लाइड, 9 मलबे सह मिट्टी स्लाइड,

8 मलबे सह रॉक स्लाइड, 2 मिट्टी स्लाइड और 1 रॉक गिरावट शामिल हैं। अधिकांश स्लाइड्स को सड़क के खंडों के साथ संशोधित ढलान पर दर्ज किया गया है। इन भूस्खलन की घटनाओं के लिए प्रेरक कारक संभवतया मानवविषयक हैं यानी टो को हटाकर ढलान को अस्थिर करना, टो में उचित जल निकासी का अभाव और ढलानों पर जोड़ों और फ्रैक्चर जैसे कमजोर स्थान में पानी का जमाव होता है। अध्ययन क्षेत्र में स्लाइड्स के लिए ट्रिगरिंग कारक मुख्य रूप से वर्षा है, जिसने रॉक द्रव्यमान के दबाव में वृद्धि करने में योगदान दिया है जिसके परिणामस्वरूप कतरनी शक्ति में कमी और बाद में विफलता हुई है। स्लाइड मुख्य रूप से रोड कट तक ही सीमित हैं। गणेशगुडी जंगलबेट सड़क-पर, जोडा कुंभारवाड़ा सड़क-पर, करतोली-माला सड़कदुदलीपर, बिडोली भारदी सड़क-पर बारिश से अतिरंजित रोड कट स्लाइड के लिए कुछ आशाजनक क्षेत्र हैं। दर्ज की गई स्लाइड्स का लगभग 45% 15 ° से कम ढालन पर है और 32% स्लाइड्स 15 ° - 25 ° ढाल के बीच में और 20 % 25 ° - 35 ° ढाल के बीच में और केवल 3% में 35 ° - 45° के ढाल के बीच में हैं। लैंडयूज़ लैंडकवर के संदर्भ में व्यापक कट ढलान वाले / क्षेत्र में भूस्खलन की अधिकतम संभावना है। भूआकृति विज्ञान के संदर्भ में-, अधिकांश स्लाइड्स को कम विच्छेदित ढलानों में होने के लिए देखा गया है जहां बड़े पैमाने पर ढलान संशोधन देखा गया था। ये स्लाइड प्रकृति में मुख्य रूप से प्रतिगामी और चौड़ी हैं।

अध्ययन क्षेत्र में एएचपी द्वारा निर्मित अंतिम अतिसंवेदनशीलता मानचित्र यह दर्शाता है कि, कुल अध्ययन क्षेत्र में से, 73.5% क्रमशः निम्न सुग्राह्य में, 22.4% और 4.1% मध्यम और उच्च सुग्राह्य में आते हैं।

**MACRO-SCALE (1:50,000) LANDSLIDE SUSCEPTIBILITY MAPPING IN PARTS  
OF TOPOSHEETS NOS. 48I/8, 48I/10 AND 48I/11 BELGAUM AND UTTAR  
KANNADA DISTRICTS, KARNATAKA AND SOUTH GOA DISTRICT, GOA**

**(FSP CODE NO: M4LSSM/NC/SR/SU-KG/2018/18718)**

**Field Season: 2018-19**

By

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**ABSTRACT**

Macro scale Landslide Susceptibility Mapping was carried out with an aim to produce a seamless landslide susceptibility map using high resolution remote sensing data and field inputs in parts of Belgaum & Uttar Kannada districts of Karnataka and South Goa district, Goa for an area of 1324 sq.km. Owing to the less number of landslide incidences in the study area, use of Analytical Hierarchy Process was envisaged.

For analyzing the spatial association between the landslides and causative factors some geo-factors were delineated based on the fundamental assumption that the spatial factors that caused present and past landslides are likely to cause similar landslides in future. Pre-field maps, viz., Land Use Land Cover (LULC) map, Geomorphology map, Slope Forming Material map and Regolith thickness map were prepared on Arc-GIS platform with inputs from multi-temporal Google earth imageries (open source). Whereas DEM-derived maps, viz., Slope Aspect map, Slope Gradient map, Slope Curvature map and Drainage map were extracted from CARTO DEM (30m resolution).

The area wise (High to low) LULC is divided into: Thick vegetation, Cultivation, Moderate vegetation, Barren, Sparse vegetation, High Height Plantation (HHP), Low Height Plantation (LHP), Fallow land, Quarry, Settlements, Settlement on modified slope, Extensive Cut Slope and Water Body. Urbanization agglomerations in the study area are mainly observed in valleys. The agricultural land in the study area is mostly seen in the valleys.

The dominating geomorphic features in the area are Lowly dissected hills, Pediment-pediplain complex followed by Highly dissected slope, Moderately dissected slope, Rolling plain & valley fill.

Slope Forming Material which is very vital factor while assessing any possible movement of loose material along slope in the area can be classified into rock (including

Anorthositic gabbro, Argillite, Banded iron formation, Dolerite, Ferruginous phyllite, Granite gneiss, Granitoid, Manganiferous phyllite, Metabasalt, Phyllite, Pyroxenite, Quartz-chlorite schist, Quartz-sericite schist, Quartzite, Ultramafite, Vanadiferous titanomagnetite), weathered rock, transported soil and in-situ soil.

Regolith thickness, in general varies from less than 0.5m to 5 m and occasionally attains a thickness of 5 m to 10 m.

A total of 31 landslides were identified during field work and documented in 42-point Geo-parametric sheet for landslide inventory. These include 11 debris slides, 9 Debris cum earth slides, 8 Debris cum rock slide, 2 Earth slide and 1 rock fall. Most of the slides are recorded on modified slope along road sections. The causative factors for these landslide incidences are probably anthropogenic i.e. destabilisation of slopes by removal of toe, lack of proper drainage at toe part and on the slopes causing seepage of water into the weaker plane like joints and fractures. The triggering factor for slides in the study area is mainly rainfall which has contributed to increase in the pore pressure of the weathered rock mass resulting in reduction of shear strength and subsequent failure. The slides are mainly confined to the road cuts. Ganeshgudi-Jagalbet road section, Joida-Kumbharvada road section, Kartoli-Dudalimala road section, Bidoli-Bharadi road section are some of the promising regions for road cut slides exaggerated by rainfall. Around 45% of the recorded slides correspond to slope gradient class less than  $15^{\circ}$  & 32% slides are lies in between  $15^{\circ}$ -  $25^{\circ}$  gradient followed by 20% in  $25^{\circ}$ -  $35^{\circ}$  gradient & only 3% in  $35^{\circ}$ -  $45^{\circ}$  gradient. In terms of landuse/landcover the area having Extensive cut slopes has the maximum susceptibility to landslides. In terms of geomorphology most of the slides have been observed to occur in lowly dissected slopes where large scale slope modification was observed. These slides are mainly retrogressive and widening in nature.

Final susceptibility map produced by AHP modelling represents that, out of total study area, 73.5 % falls in Low Susceptibility zone, 22.4% and 4.1% falls in Moderate and High Susceptibility zones respectively.

# 1. INTRODUCTION

## 1.1 Background Information:

India has a colossal and significant record of the disastrous landslides causing damage to property, loss of life and economic losses. One of the most significant and disastrous landslide event in the recent past is one that occurred on 15-17 June 2013 in hilly region of Uttarakhand. Triggered by continuous heavy rainfall in higher reaches of Himalayas, it took thousands of lives and destroyed properties incurring heavy losses and shock to the nation. As fallout of the Uttarakhand disaster, GSI, the National Nodal Agency for landslides studies, took up a National Landslide Susceptibility Mapping programme, aimed at preparing seamless landslide susceptibility map for the landslide prone areas of the country on macro scale.

India has 0.42 million sq. km landslide prone area distributed in the Himalayan belt, north-eastern states and western & south-western parts of the country covering the Western Ghat ranges and adjoining coastal belt to its west. Thus a systematic approach is required to map these areas for landslide susceptibility. A thrust in this activity is imminent to match the pace of infrastructural development in these areas. Accordingly, Geological Survey of India, being the nodal agency in the country for landslide studies launched National Landslide Susceptibility Mapping (NLSM) programme with an aim to produce a seamless landslide susceptibility map of the country. To foster better progress rate and to improve the quality of landslide susceptibility mapping, along with requisite amount of field inputs, NLSM programme proposes to use very high-resolution Remote Sensing data for preparation of its landslide inventory & geo-factor database and GIS based landslide-dependent empirical techniques as well as knowledge based techniques (AHP) for data integration & landslide susceptibility modelling. The main purpose of this national programme is to prepare a nation-wide landslide inventory and susceptibility database for easy retrieval, use and updation in future whenever new events and large-scale changes in geo-environmental parameters are encountered.

Uttar Kannada & Belgaum Districts, Karnataka and South of Goa district of Goa state lies in the southern - eastern part of Western Ghats with high hills and undulating topography. These districts with their distinctive geomorphological, geological, hydrological and

meteorological characteristics have long been known for landslides in selected areas during certain months of a year. The topography of the region is sensitive and any changes in the landuse/landcover pattern causes landslides or slope failures affecting the population. Thus, the district along with its scenic beauty and pleasant climatic conditions is also becoming known for natural hazards. Infrastructural development in the form of laying new roads and widening of the existing roads that involve the modification of slopes disturb the equilibrium attained by the nature.

For the state of Karnataka landslide susceptibility mapping was proposed for entire 34,156 sq.km area and the investigations kick-started from FS 2015-16. Out of this total area, an area of 26,909 sq.km was covered by the end of FS: 2018-19 (**PLATE-1**). The prime objectives of the macro-scale landslide susceptibility mapping were: (i) Preparation of landslide inventory database using high resolution remote sensing data, archival information and field inputs; (ii) Preparation of spatial database for geo-factors of landslides on 1:50,000 scale and (iii) Categorization of hill slope in terms of landslide susceptibility using multi-class index overlay method in GIS platform.

Landslide susceptibility mapping on scale 1: 50,000 covering 1324 Sq. Km. area in parts of Uttar Kannada, Belgaum Districts, Karnataka and South Goa district, Goa was carried out under the Annual Programme of Geological Survey of India, Southern Region, vide FSP Code No: M4LSSM/NC/SR/SU-KG/2018/18718 for field season 2018-19.

## 1.2 Study area:

The study area lies in SOI Toposheet Nos. 48I/08, 48I/10 and 48I/11 in parts of Uttar Kannada and Belgaum Districts, Karnataka and South Goa district, Goa. Geographically, the area is bounded between latitudes 15°00'00" N and 15°15'00" N & longitudes 74°15'00" E and 74°30'00" E in T.S No. 48I/8 and 15°15'00" N and 15°40'26.38" N & 74°30'00" E and 74°40'07" E in parts of T.S No. 48I/10 and 48I/11 (**PLATE - 2**). The area falls on the southern part of Belgaum district and northern part of Uttar Kannada district of Karnataka and part of South Goa district, Goa. Dharwad district lies on the west of the study area.

The area has good network of roads, State Highways (SH), Main District Roads (MDR) as well as other roads. All weather metalled as well as un-metalled roads connect most of the villages located in this area. The National Highway No.4A connecting Dharwar-Panaji via

Nagargali and Gadoli in the northern part and State Highway between Belgaum-Karwar passes through the area. Dandeli-Dharwar, Joida-Belgaum is the other important roads.

Fairly good network of roads exists, connecting taluk headquarters with district headquarters.

Londa is the nearest railway junction connecting Hubli-Panaji and Hubli-Miraj section of Southwestern Railway. Dandeli, the other important place in this region is the rail terminus of the Alnavar-Dandeli branch line on the Poona-Bangalore section of the Southern Railway. Dandeli can be best reached by road either from Hubli or Dharwar, the two important rail heads on the above mentioned railway section. Supa and Dandeli are also connected by a fair-weather road to Karwar, the headquarters of North Kanara District

The area overall represents tropical to sub-tropical climate. The monsoon season extends from the mid June to middle of October where the Western Ghat ranges receive heavy rainfall. The average annual rainfall is 4232 mm.

### 1.3 Present work:

The present work includes preparation of various thematic layers on 1: 50,000 scale using Arc-GIS software and Google Earth imageries. Open Series Maps of the study area were also taken into account while preparing Landuse/Landcover, Road and Location maps. Landslide inventory prepared at headquarters was validated and updated in field. The pre field maps were validated in field and were updated in ArcGIS software at headquarters. The final landslide susceptibility map of the study area was prepared using Knowledge driven indirect method (Analytical Hierarchy Process) and then classified into low, moderate and high susceptibility zones. The nature and target of work envisaged for FS: 2018-19 and the achievements are given in **Table 1**.

Table 1: Nature, quantum of work and achievements

| <b>Nature of Work</b>                                | <b>Target F.S<br/>2018-18<br/>(Sq. Km.)</b> | <b>Achievements<br/>in Sq. Km.</b> |
|------------------------------------------------------|---------------------------------------------|------------------------------------|
| <b>1. Pre field map preparation</b>                  |                                             |                                    |
| a ) Slope forming material map                       | 1324                                        | 1324                               |
| b) Geomorphology and lineament map                   | 1324                                        | 1324                               |
| c) Slope morphometry (slope, aspect & curvature) map | 1324                                        | 1324                               |
| d) Landuse/Landcover map                             | 1324                                        | 1324                               |
| e) Drainage map                                      | 1324                                        | 1324                               |
| f) Regolith depth map                                | 1324                                        | 1324                               |
| ii) Preparation of landslide inventory map           | 1324                                        | 1324                               |

|                                                                                                                                  |                                                                                                      |                                               |
|----------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------|-----------------------------------------------|
| <b>2. Field based studies</b>                                                                                                    |                                                                                                      |                                               |
| i) Field checking of all thematic maps. Field validation of landslide inventory and collection of recent and historic landslides | 1324                                                                                                 | 1324                                          |
| ii) collection of landslide inventory and damage data as per 42 point geo – parametric sheet                                     | 1324                                                                                                 | 1324                                          |
| <b>3. Post Field studies</b>                                                                                                     |                                                                                                      |                                               |
| i) Updation of thematic and inventory maps in GIS                                                                                | 1324                                                                                                 | 1324<br>(Inventory of 31 Landslides prepared) |
| ii) Preparation of Landslide susceptibility map in GIS                                                                           | 1324                                                                                                 | 1324                                          |
| <b>4. Collection of rainfall data</b>                                                                                            | 1324<br>(Data from Uttar kannada, Belagaum & South Goa dist. have been collected for last ten years) |                                               |

#### 1.4 Physiography and Drainage:

The Western Ghats represent an orogenic mountain range with steep escarpments to the West, parallel to the west coast of India. The topography of the area ranges from gently sloping plains in the eastern part to rugged hilly terrain having elevations ranging from about 600m to 1682m above MSL in the Western and Southern part. The terrain in this part is very rugged with steeply sloping conical hills and deep valleys. These hills have a general trend of NW- SE. The central, northeastern and eastern parts are showing undulating terrain with isolated hillocks. The highest peak in the area is  $\Delta$  1043.

One of the major river of the area is Kali river. Supa Dam is built across Kali river, located at Ganeshgudi. Major drainage flows towards west and the area shows dendritic to parallel drainage pattern, while at places parallel, radial and trellis drainage patterns are also observed. Dendritic and sub-dendritic patterns are observed over the granitic terrain whereas on the top of layered igneous complexes, the drainage pattern is radial. The streams of this area flow into the Kali Nadi (river) which empties itself into the Arabian Sea at Karwar. The principal rivers and nalas apart from Kali Nadi are Pandri, Barchi, Nagihiri and Kaneri. Kaneri river flowing from northwest to southeast marks a major lineament in the area.

## 1.5 General Geology:

The area exposes rocks belonging to Peninsular Gneiss-I of PGC, Chitradurga Group of Dharwar Supergroup of Archaean age and basic intrusives of Palaeoproterozoic age. Major part of the area is made up of Chitradurga Group of rock constituting Shimoga belt, resting unconformably over granitic gneisses of PG-I with the Goa belt to the western parts and the North Kanara belt to the eastern parts.

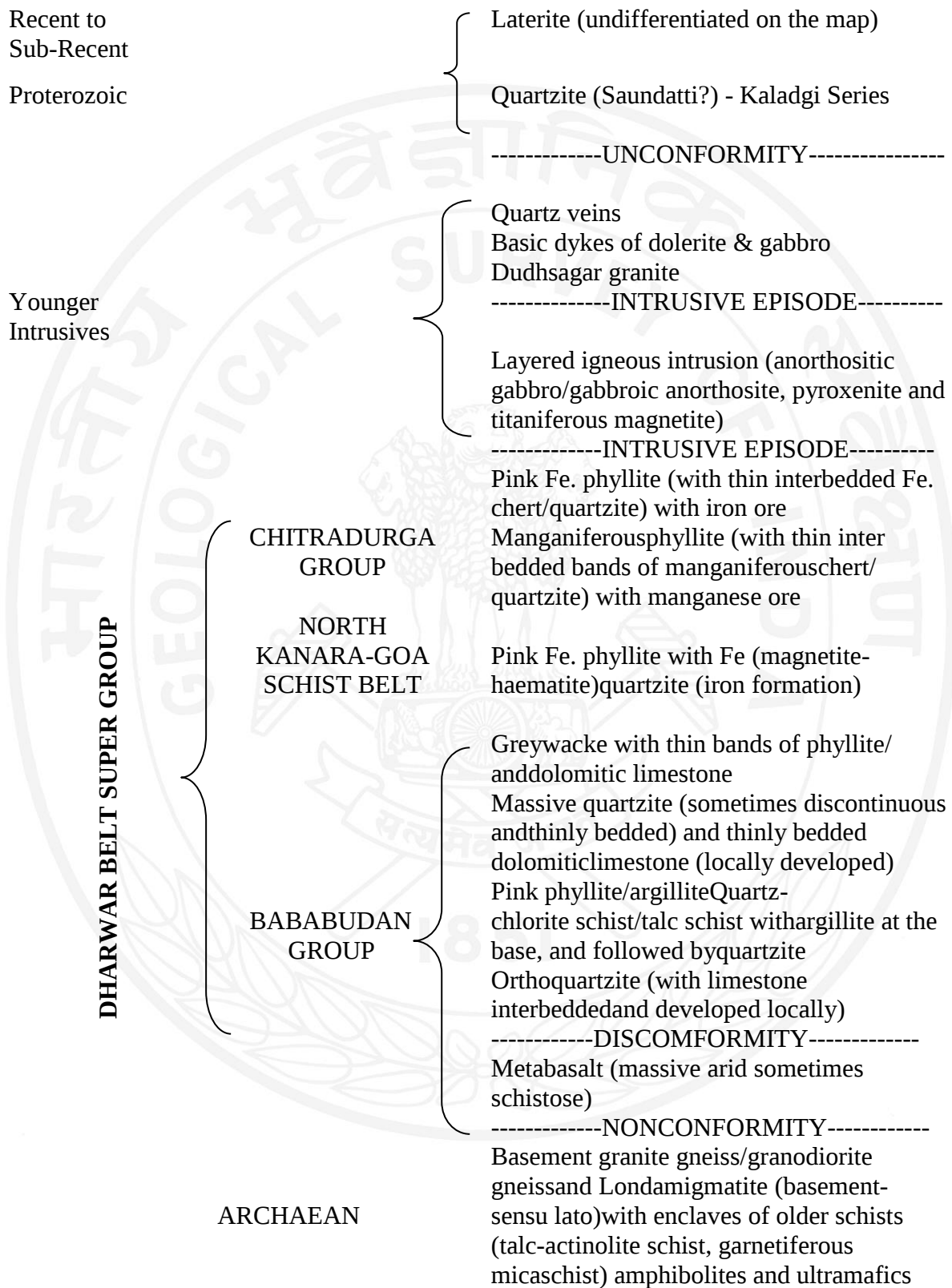
The mafic-ultramafic intrusive are exposed in the central part and the Karwar granite is exposed in the southern part. The Peninsular Gneiss-I is bordered by mangiferous phyllite and quartzite in the western part and argillite in the northern part.

PG-I is represented by granitic gneiss and migmatitic gneisses. Granitic gneiss is coarse grained, leucocratic to mesocratic consisting quartz, plagioclase and minor amounts of mafics. Goa Group of Goa belt is characterized by Barcem Formation, Sanverdem formation and Bicholim Formations equivalent to Chitradurga Group of rocks. These Formations are locally known as Goa Group. Barcem Formation is represented by a sequence of metabasalt, quartz-chlorite schist with intercalation of quartzite. This is overlain by Sanverdem Formation essentially made up of greywacke and conglomerate horizon. In the eastern part near Sahajini and Tudav isolated oval shaped exposures of manganese horizons with greywacke represents the younger Bicholim Formation of Goa Group.

The Dharwar Supergroup of Uttar Kanara belt is made up of rocks of Jhandimatti Formation which is overlain by Joldhal Formation and Ranibennur Formation of Chitradurga Group. Joida mafic-ultramafic igneous complex consists of pyroxenite, gabbro, anorthosite, titaniferous/vanadiferous magnetite occur in the central part extending over strike length of 25 km. The complex trends NE-SW. Basic dolerite/gabbro dykes are common throughout the area with varying compositions.

The regional trend of schistosity in North Kanara belt is NW-SE to NNW-SSE with moderate to steep dips towards east. The Goa belt with a few regional fold closures plunges either towards SW or western side. Bedding in quartzite and banded magnetite quartzite foliation and lineation in schist rocks and gneiss and faults in quartzite are some of the planar/linear structures observed in this area.

The regional litho-stratigraphy is as given below:



Orthoquartzite of Jhandimatti Formation is light coloured, fine grained and occurs in association with banded magnetite quartzite in the northwestern part. Joldhan Formation is represented by limestone/dolomite, which is fine grained, dark coloured consists mainly calcite and minor amounts of magnesium carbonates. This unit is exposed as lensoidal bodies exposed 4 km south of Nagargoli. Manganese phyllite is fine grained, pinkish coloured, occurring as linear folded bands along with BMQ, 2 km west of Dandeli in the south to 2 km east of Jagabet in north. The manganese/ iron ore formation is highly lateritised with residual concentrate of haematite and manganese ores associated with laterite. Argillites is fine grained, foliated, light grey and consists of quartz, plagioclase and sericite exposed as a narrow band 2 km west of Daudi for a length of 6 km in northwest direction.

Ranibennur Formation of Chitradurga Group consists of quartzite, quartz-sericite schist and greywacke-argillite. Greywacke-argillite is a major unit covering 50% of the area, mostly occupying eastern part. It is fine grained, greyish white, well foliated consisting of quartz, feldspar-chlorite and sericite. Quartzite is massive occurring as linear bands in northern part of the area. Quartz-sericite schist occur as lensoid body within grey argillite. The last phase of the igneous activities in the area is represented by basic dykes of dolerite/gabbroic in composition which trend in NW-SE, N-S and NE-SW.

## **1.6 Methodology:**

The methodology to be followed is primarily landslide dependent following a raster-based GIS modelling approach for integration of all selected and weighted thematic maps to prepare 1:50,000 scale landslide susceptibility map. For areas where a-prior knowledge of landslide is missing or scarce and/or insufficient, any one of the following approaches may be adopted as per priority or terrain conditions and/or after due discussion with the local experts/workers (**Fig.1**)

- a) Individual ratings for geofactor classes and weights of geofactors will first be determined based on a pilot study in the adjacent smaller area/ road corridor (preferably within the study area) where well-distributed landslide data are available by using various spatial association techniques. Later such ratings and weights will be used for the entire study area for model integration using the same multiclass index overlay method. In case of availability of similar or research work in adjacent and similar terrain nearby, the ratings and weights developed are used in such work and may also be used after due discussion with the local experts.

- b) Individual ratings for geofactor classes and weights of geofactors will be determined using Analytical Hierarchy Process (AHP) after preparing the pair wise qualitative comparison matrix of all factors (Saaty, 1977) after due discussion with local experts and workers.

Methodology adopted can be broadly classified as follows: -

#### **1.6.I. Pre-Field Studies:**

Total nine pre-field thematic maps were generated by using different data capturing sources. The slope morphometry maps viz. slope aspect, slope curvature, slope angle and drainage map were prepared as raster outputs from 30m CARTO DEM (Digital Elevation Model). Geomorphology and Landuse-Landcover (LULC) maps were prepared as vector products with the help of Google imageries (Multi temporal images have been used for digitization of Geomorphology layer and image generated in the period between November 2011 to March 2012 was used for digitization of LULC layer) in Arc GIS software. The Slope Forming Material (SFM) map and regolith thickness (R.T) map was generated from LULC and Geomorphology proxies in Arc-GIS software, whereas landslide inventory map was generated by collecting the data from old GSI landslide reports and field observations.

#### **1.6. II. Field Based Studies:**

As given in the Table 1.1, there were three objectives of the field studies:

- Validation of pre-field maps i.e. Geomorphology, LULC, Slope Forming Material (SFM), regolith thickness (R.T) map and Landslide Inventory map were validated in field.
- Augmentation of existing landslide database by identifying new slope failure incidences and recording field observation in 42 geo-parametric sheet at each of the identified sites. The field data recorded at field check spots (attributes of geo-factors and 42 geo-parametric points of landslides incidences) were recorded in toughpad/field device to direct upload the collected field data on OCBIS.

#### **1.6.III. Post-Field Studies:**

The post-field studies were aimed at:

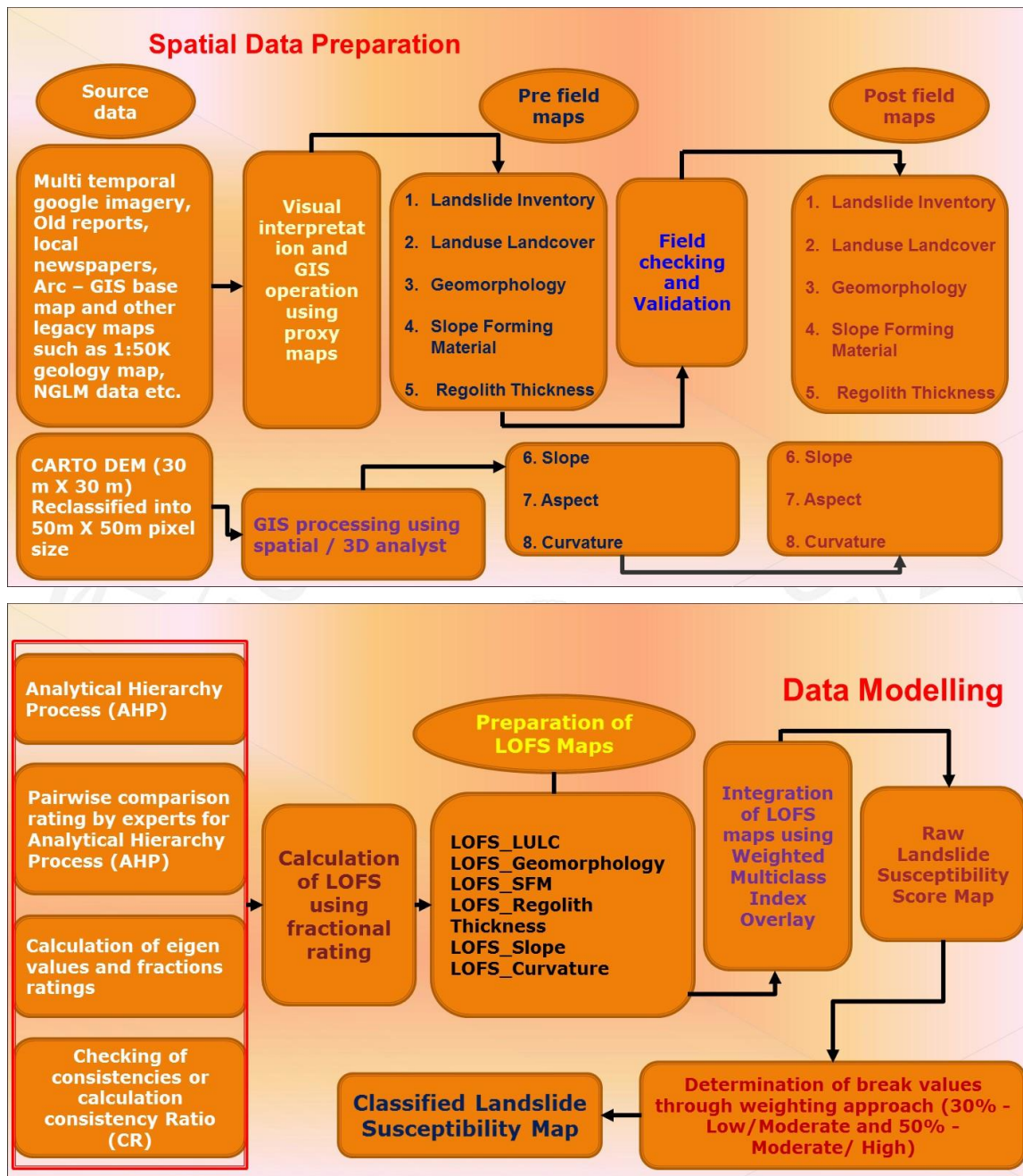
**A. Updation of Pre-field Maps:** During field validation, the modifications in the pre-field maps were done wherever required. Corrections were incorporated in ArcGIS Platform by using cut polygon method and by changing the name of the polygon of a particular class in accordance with the observations in the field. Ultimately, polygons/classes of all thematic layers viz. Geomorphology, LULC, Slope Forming Material and Regolith thickness map

were finalized.

**B. Landslide Susceptibility Modeling:** In Western Maharashtra, owing to the lesser number of landslides, Analytical Hierarchy Process (AHP) was used for landslide analysis and preparation of Landslide Susceptibility Map, instead of landslide dependent method involving Statistical Analysis of landslide incidences. The AHP is multi criteria decision making process of measurement through pair-wise comparison and it relies on the judgment of the experts to drive priority scale (Saaty 2008). The entire process of landslide susceptibility modeling is given below:

**B1. Criteria for assigning ranks to Geo-factor Classes and Maps:** Ranking of each geo-factor class was done on the basis of expert opinion, knowledge, field experience and observations by different knowledge-experts working in landslide domain in different parts of southern and western India. Similarly, average rank was assigned to every geo-factor map based on its importance in inducing a slope failure. This consensus of rankings was developed with a view to bring out the uniformity of approach in identifying landslide susceptibility zones in western India in general and Maharashtra in particular. The 9 point ranking scale, ranging from 0 (lowest ranking) to 9 (highest ranking) was finalized and each class/ geo-factor was ranked accordingly. Classes/ Maps that have higher control on inducing failures were assigned relatively higher rankings and vice-versa.

**B2. AHP Modeling:** For AHP modeling, pair-wise comparison matrix of geofactor classes was executed following calculation of eigen values, fraction rate values and Landslide Occurrence Favorability Score ratings (LOFS). After determination of LOFS ratings for each geo-factor class of a particular geo-factor map, integer weights of individual geo-factor maps were calculated. Thereafter, the integer weights were normalized by minimum weight. A raw susceptibility score map was generated using integer weights and LOFS values. The raw susceptibility score map was, finally reclassified based on the logic of providing mutual comparison expert-driven ranking of High, Moderate and Low categories/ classes. A cut off margin of 50% and 30% were used for high-moderate and moderate – low classes respectively.



**Figure 1:** Flow diagram showing process of Landslide Susceptibility Mapping

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## 2. PREVIOUS WORK ON LANDSLIDE STUDIES

Landslides and slope instabilities are major hazards to humans often causing economic losses, property damages and high maintenance costs, as well as injuries or fatalities. They can occur in natural slopes or man-modified slopes, and are triggered by various agents like rainfall, earthquakes, stream/gully erosion. Under natural slope conditions, the occurrence of landslides is mainly due to the favourable geo-environmental factors aided by rainfall or earthquakes. On the other hand, in man-made slopes, due to construction for major transportation systems and excavations which are triggered by rainfall, earthquake etc. Thus, it becomes more challenging to deal with man modified slopes for landslide susceptibility mapping.

In Karnataka, the landslide studies are mainly focused in the hilly regions of Western Ghats. The Western Ghats extend from Coorg (now Kodagu) District in the South to Uttara Kannada district in the north in Karnataka state covering an area of about 27855.45 Sq. Km. Out of the approximately 34511 Sq. Km. area of Karnataka and Goa, occupied by the Western Ghats. Several Macro scale landslide susceptibility studies and preparation of landslide inventories have been carried out along NH and SH road corridors in Karnataka and Goa states in the past decade. In Karnataka, landslides are mainly cut slope failures primarily consisting of debris and sometimes rock and are mostly located along National Highways (NH-13, 17, 48 and 206) and State Highways (SH-1, 27, 48, 50, 64, 66, 69, 88, 89, 90, 93 and 95). In Goa region, landslides are mainly cut slope failures consisting of rock as well as earth/debris, and are mostly located along National Highways (NH-4A and 17A), State Highways (SH-1, 3 and 4) and Konkan Railroad.

Landslide studies in the area have been carried out only along transportation corridors (NH & SH) in the Western Ghats. Landslides in the study area generally occur on untreated cut slopes. These are usually small in size but pose considerable risk to life and property. Several landslides are reported along roads (Highways) every year during the monsoons indicating that the triggering factor for these slides may be rainfall besides anthropogenic activities.

There were no previous work done in the study area pertains to landslide studies. Though, almost all the landslides in an area appear to have been caused due to the human inference in modifying the existing natural slopes. The steep zones along the roads in the Netravali wildlife sanctuary forest range trending NW SE are the most vulnerable zones

as far as the landslide activity is concerned. The root cause of all the slides in the area is anthropogenic involving road construction and road widening triggered mostly by rainfall.

Landslide susceptibility mapping of the road corridors have been carried out in GIS, according to the methodology prescribed by Bureau of India Standards IS 14496 (Part 2): 1998, modified by Geological Survey of India. The recommendations suggested include geometrical modification of the slope by grading / benching, bio-technical measures of slope protection and proper drainage. As per the landslide inventory along National Highway & State Highway of Ghat Roads in Coorg, Dakshina Kannada, Udupi, Shimoga and Chikmagalur Districts, Karnataka” by K. V. Maruthi and K. V. Chandran., 2013, majority of the slides seem to have occurred due to anthropogenic causes and triggered by heavy rainfall. The recommendations include proper drainage as the drainage is seen blocked or absent in around 60% of the affected areas. The water from uphill slope needs to be diverted in order to minimize sliding by providing contour drainage at the crown part & insertion of horizontal perforated pipes into the slopes which will act as weep-holes in the vertical slopes, thereby reducing the pore water pressure by draining out the excess water. This has to be given at appropriate intervals and lined drainage at the toe part are suggested. Support structures like retaining wall, stone pitching etc. are recommended as per the site condition. Bio geotechnical measures of slope protection like plantation of Vetiver grass along the slope will reinforce most of the slides.

### **3. LANDSLIDE INVENTORY**

Landslide inventories form an essential basis for landslide susceptibility, hazard and risk analysis. Landslide inventories that span a substantial period of time are one of the key requirements for landslide studies (Van Westen et al. 2008). The generation of a landslide inventory is a tedious work as landslides occur individually and have to be identified, mapped and inventoried. Each data source used to construct the new landslide inventory has its own uncertainties and limitations and therefore the details captured for each landslide entry vary in completeness and scientific content. In this study, satellite images and historical records are used as the main source for obtaining a multi-temporal landslide data.

#### **3.1 Data Source:**

Landslides leave discernible signs on slopes, most of which can be recognized, classified and mapped in the field or from photo-interpretation (Varnes, 1978). These signatures are mostly visible as morphological changes such as changes in slope type, break in slopes, hummocky surfaces, etc. These morphological signs are interpreted here to determine important landslide information such as type of failure, the surface area, cause and the run-out distance. Detailed and systematic field work was carried out to generate the 42-point attribute data for landslides.

Preparation of the landslide inventory commenced with the search of archival data sources, particularly published and unpublished reports of GSI. The SPOT images available as a base map in ESRI ArcGIS (up to the resolution of 30m) and high resolution Google Earth data of different time periods (from 2002 to 2015) were used as the main data product for generating the multi-temporal landslide inventory for this area.

#### **3.2 Inventory Mapping:**

The following steps were used for digitizing a landslide polygon in ArcGIS and building its inventory attribute.

1. In Google Earth, every segment of the study area was viewed for all available time frames. Once the landslide is identified the same is marked as a polygon. The source or the zone of depletion and the run out is marked separately.
2. The mapped polygon is then saved as kml file and later imported to Arc-GIS using “conversion” function. In Arc-GIS the kml to layer conversion is first done and then the layer

data is exported as a polygon shape file or directly to the geodatabase. In this study the WGS-84 datum and UTM projection (43N) is taken for analysis.

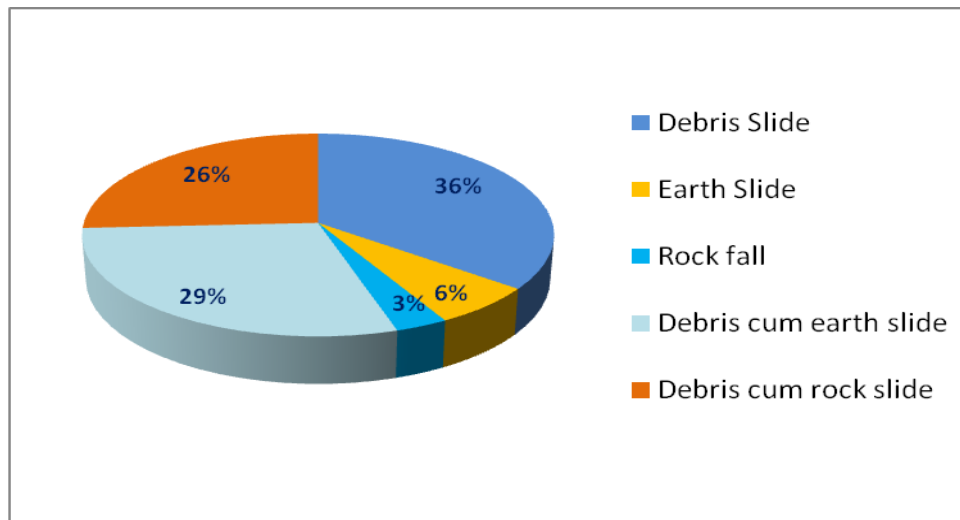
3. The landslide polygon is then corrected with the help of the ESRI base map. Any shift in the spatial location of the polygon, due to shift in the multi-temporal images of Google Earth data, is adjusted manually. Few landslides were also mapped directly from satellite imagery data and toposheet in Arc-GIS.

4. For each landslide polygon, the attributes such as name, state, district, taluk, toposheet number, initiation and reactivation year based on dates of Google Earth images, slide type, slide material, length, width, surface area, cause, land use and element at risk is attached. Archival data were used for naming and defining the cause of the landslides.

5. A systematic and detailed field check was then carried out to validate the pre-field map at all the accessible locations. The morphological signatures left by landslides on slopes were used to identify the shape of landslides.

6. The morphological parameters of the slide (landslide scar length, width and depth) are noted carefully after measuring them in the field using a meter tape. Additional data such as landslide type, run-out distance, present land use/Landcover class, regolith thickness, structure, probable cause, and damage details were also added to the inventory. Any new landslides identified were plotted in the topographic maps and were digitized as polygons or points depending upon the dimension of slide and entered in a geo-database of Arc-GIS.

During the field survey a total of 31 landslides were noted and data collected for different attributes documented in 42-point Geo-parametric sheet for landslide inventory. A total of 11 debris slides, 9 Debris cum earth slides, 8 Debris cum rock slide, 2 Earth slide and 1 rock fall are recorded. Most of the slides are recorded alongside the road cut. This is attributed to extensive slope cut and toe removal. Of all, the majority of landslides can be categorized as shallow translational with depth of slip plane being  $< 5$  m.



**Figure 2:** Spatial distribution of Landslides

The spatial distribution of mapped landslides is shown in **Annexure-II**, which gives detail inventory of 31 landslides for which 42-point inventory data were prepared.

Along the Ganeshgudi-Jagalbet road section numerous such landslides have been noted near Supa reservoir. Similar features are also noted along Joida-Kumbharvada road section, Kartoli-Dudalimala road section and Bidoli-Bharadi road section. All mapped landslides are debris/earth slides triggered by extensive slope cutting followed by spells of rain.

Numerous Debris slide/Earth slide have been recorded along the rim of Supa reservoir. These slides of different dimensions are attributed to the periodic fluctuation of the reservoir level during and after the rainy season. This leads to change in pore water pressure along the periphery of the rim and failure of the slope after the drawdown.

The Ganeshgudi-Jagalbet road section seems vulnerable to failure as loose soil and rock boulders are observed on steep slope in this area. The BIF boulders at places in the road section are highly jointed/fractured & are hanging towards the road, heavy saturation or rainfall may lead to dislodgement of these blocks. It is therefore suggested to remove those blocks and protect it using wire mesh.

Comparatively, a large dimension slide, which is reactivated, retrograded & enlargement of an old landslide observed along the Joida- Kumbharvada road section. The slide again occurred along the Granite-Metabasalt contact and consists of soil mixed with debris of weathered rock. This indicates the role of weathering in occurrence of landslide. Retaining wall is constructed on both side of the road, which has to be extended to protect the entire slide as a precautionary measure.

The locations of the recorded landslides superimposed on geology show that most of the landslide occurrences are associated with the highly weathered zone or in the vicinity of litho-contacts viz. BIF-Argillite contact, BIF- Phyllite contact & Granite-Phyllite contact. This discontinuity is controlling the stability of the slope. The mass failure has been accelerated along the litho-contact interface, after the road construction that later exaggerated by rainfall. Hence, failures are common during rains when the exposed overburden mass resting on the cut slopes slips downslope.



## 4. LANDSLIDE SUSCEPTIBILITY ANALYSIS

This chapter comprises of the materials and methods used in landslide susceptibility analysis using Analytical Hierarchy Process (AHP) for areas deficient in landslides.

### 4.1 Background Information:

Landslide susceptibility deals with the likelihood of landslide occurrence in an area on the basis of interplay of various geo-factor themes. Landslide susceptibility is the relative probability for the occurrence of landslide in an area. This does not necessarily mean that slides will essentially occur in high susceptible zones and that the low susceptible zones will not have any slides. It is only a qualitative and quantitative estimation that how a particular mapping unit, under the effect of several factors may behave in the landslide perspective. Since the study area lacks natural and sufficient number of landslides AHP method of analysis is used.

The analytical hierarchy process (AHP) is a semi-quantitative method in which decisions are taken using weights through pair wise relative comparisons without inconsistencies in the decision process (Saaty, 1980). The AHP consists of the following five steps:

- (i) Breakdown a decision problem into component factors
- (ii) Arrangement of these factors in a hierarchic order
- (iii) Assignment of numerical values (Saaty, 1977) to determine the relative importance of each factor according to their subjective relevance
- (iv) Setup of a comparison matrix and
- (v) Computation of the normalized principal Eigen vector, which gives the weight of each factor (Saaty and Vargas, 2001).

The advantages of using AHP as an expert based method in landslide susceptibility analysis (Long and DeSmedt, 2012) are : (i) all types of information related to landslides can be included in the discussion process; (ii) judgment is structured so that all information is taken into account; (iii) discussion rules are based on expert's knowledge and experience; (iv) when a consensus is reached, weights for each relevant factor are obtained automatically by eigenvector calculation of the comparison matrix; and (v) inconsistencies in the decision process were verified using consistency index values.

## **4.2 Selection of Preparatory Factors:**

For susceptibility mapping, the selection of preparatory factors for landslides depends on the scale of analysis, the characteristics of the study area, the landslide type, the failure mechanisms and the priori knowledge of the main causes of landslides (Guzzetti et al., 1999). A systematic overview of the important preparatory factors required for susceptibility mapping in different scales is given by Van Westen et al. (2008). A priori knowledge of the main causes of landslides in the area of interest is essential in selecting the most relevant factors out of the many known preparatory factors that can “theoretically” cause landslides (Ghosh and Carranza, 2010).

For susceptibility analysis six factor maps were prepared that are considered to be the main spatial causal factors for landslides in the area, out of the six maps, two are related to terrain morphometry derived from DEM and four are field based maps prepared from remote sensing data. A brief description of the significance and mapping techniques for each factor is given below.

## **4.3 Geo-factor Themes:**

In general, the factors which influence where a landslide will occur, typically include slope angle, climate, weathering, water content, vegetation, overburden, geology, and slope stability. How these factors interrelate is important in understanding what causes landslides along with an understanding of the impact humans have on these factors by altering natural processes. Mentioned below are the factors that have been taken into account for estimating landslide susceptibility in an area using GIS. As far as data model is concerned, some of the geo-factor themes are categorical (e.g., geomorphology, aspect etc.) and others represent continuous data (e.g., slope, elevation etc.). These spatial factor maps are prepared using various source data and employing different mapping techniques which are detailed below.

### **4.3.1 Slope Morphometry:**

Slope angle is one of the factor for the cause of landslides. Slope angle is formed between any part of the surface of the earth and the horizontal datum. It is a mean by which gravity induces stress in the slope rocks, flux of the water or other material: therefore, it is of great significance in hydrology and geomorphology. As the slope angle increases, then the shear stress in the soil or other consolidated material generally increases. Gentle slopes are expected to have a low frequency of landslides because of low shear stresses and associated

low gradients. Slope failures tend to increase with slope angle but when the slope becomes near vertical, land sliding is scarce or absent altogether as there is lack of soil development and debris accumulation in such topographic conditions (Selby, 1993; Derruau, 1983).

Slope morphometry is defined by slope gradient, aspect and curvature (**PLATE 3, 4, 5**). The data for these factors was derived from CARTO DEM, downloaded from BHUVAN portal, of having 30m resolution. Slope gradient and slope curvature for the study area was generated in ArcGIS software using spatial analyst tool..

**Slope gradient** map as a derivative of DEM derived from CARTO DEM (Resolution: 30m), the area was classified in to five classes ranging from  $<15^\circ$  up to  $>45^\circ$ . A large part of the area (about 78%) falls in low slope range i.e.,  $<15^\circ$  class.  $15^\circ$ - $25^\circ$  slope gradient class occupies about 17.63% of the study area. About 3.81% of the area is occupied by  $25^\circ$  to  $35^\circ$  class, which is having maximum weightage according to the ratings given in AHP. Around 45% of the recorded slides correspond to slope gradient class less than  $15^\circ$  & 32% slides are lies in between  $15^\circ$ -  $25^\circ$  gradient followed by 20% in  $25^\circ$ -  $35^\circ$  gradient & only 3% in  $35^\circ$ - $45^\circ$  gradient. The area coverage in sq.km. along with LOFS and rank is given in **Table – 2**.

**Slope curvature** is another important geo-factor in landslide susceptibility analysis. A positive curvature represents upwardly convex surface, while a negative curvature indicates that the surface is upwardly concave at a given pixel. Curvature map is classified into three classes i.e. convex, flat and concave slopes. About 10.45 of the area falls in flat slope. The Convex slope ( $>0.1$ ) class which is given the maximum weightage in the area covers about 44% of the study area while 45.5% of the area falls under Concave slope ( $<0.1$ ). The concave hill slopes are areas having high soil moisture content and receive more surface run-off. Failures can be expected to occur more frequently in those areas than the slopes that are convex along the contour

The area coverage in sq.km. along with LOFS and Rank is given in **Table – 3**. More weightage and ranking is given to convex slope class ( $>0.1$ ) and slope gradient ( $25^\circ$ - $35^\circ$ ). The convex slope is more fragile to loss of mass and  $25^\circ$ - $35^\circ$  slope are mostly influenced by anthropogenic activities and habitat in the study area.

**Slope aspect** explicates the direction that a natural slope faces. The aspect of the slope plays a role in controlling some microclimatic factors such as exposure to sunlight,

windward (wet) or leeward (dry) conditions, rainfall intensity, soil moisture and weathering, all of which control the material properties of the slope deposits (Dai et al. 2001; Cevik and Topal, 2003). The slope aspect map was derived from the 30m CARTO DEM using Arc GIS and the values were grouped into 08 directional classes with interval separation of 45°.

During the preparation of landslide susceptible map, slope aspect map has not taken into consideration.

**Table 2: Rank, LOFS and area coverage for Slope gradient of T.S Nos. 48I/8, 48I/10 and 48I/11**

| <b>CLASS</b> | <b>Rank</b> | <b>LOFS</b> | <b>Area coverage (sq.km.)</b> | <b>Area covered (%)</b> |
|--------------|-------------|-------------|-------------------------------|-------------------------|
| <15          | 2           | 0.1631      | 1010.07                       | 78                      |
| 15-25        | 4           | 0.4597      | 228.25                        | 17.63                   |
| 25-35        | 8           | 1.0000      | 49.28                         | 3.81                    |
| 35-45        | 6           | 0.2817      | 7.01                          | 0.54                    |
| >45          | 2           | 0.1631      | 0.38                          | 0.03                    |

**Table 3: Rank, LOFS map and area coverage for slope curvature map of T.S Nos 48I/8, 48I/10 and 48I/11**

#### 4.3.2 Geomorphology:

| <b>CLASS</b>   | <b>Rank</b> | <b>LOFS</b> | <b>Area coverage (sq.km.)</b> | <b>Area covered (%)</b> |
|----------------|-------------|-------------|-------------------------------|-------------------------|
| <b>Concave</b> | 4           | 0.4113      | 589.41                        | 45.51                   |
| <b>Flat</b>    | 2           | 0.1676      | 135.234                       | 10.44                   |
| <b>Convex</b>  | 6           | 1.0000      | 570.3417                      | 44.04                   |

Geomorphology, along with information on soil, water and vegetation has become one of the essential inputs in planning for various developmental activities. The scope of geomorphology has further expanded with the landform maps widely used in various fields of resource surveys, environmental analysis, hydrological studies, engineering applications and geo-technical studies.

Geomorphology map (**PLATE 7**) of the study area was prepared in Arc-GIS software through visual interpretation of multi-temporal Google Imageries of the area. The obtained

pre field map was checked and validated in field. The post field changes in Geomorphology map have been shown in Fig. 3. In terms of geomorphology the area was grouped into the following classes namely highly dissected slopes, moderately dissected slopes, lowly dissected slopes, Piedmont slope, valley fill, pediment-pediplain complex, rolling plains and alluvial plain. The dissected slopes (high, moderate or low) were mapped based on visual interpretation by taking topographic ruggedness and presence of drainage as criteria. Most of the area (about 50.68%) falls in Low dissected slopes followed by Pediment-Pediplain Complex (29.64%), highly dissected slopes (7.84%) & moderately dissected slopes (5.61%). Highly dissected slope is given maximum weightage (rating 6) using AHP method followed by lowly dissected slopes (rating 4). Most of the slides have been observed to occur in lowly dissected slopes where large scale slope modification was observed. These slides are mainly retrogressive and widening in nature.

The area coverage for each class in sq.km. LOFS and rank is given in **Table – 4**. It is observed in the study area that the anthropogenic activities like toe cutting for construction /widening of road and settlement are predominantly causative factors apart from natural causes.

The details of geomorphic features are given as follows:

**Dissected Structural Hills:** Hills, which are originated due to tectonic process and are highly dissected by the drainage lines. This can be further classified as highly, moderately and low dissection depending on the density of joints and drainage. Mostly this will be interpreted from a planimetric satellite data and the classification is highly subjective. (NGLM Manual, 2010)

**Pediment:** A broad, flat or gently sloping, rock floored erosion surface or plain of low relief, typically developed by sub aerial agents (including running water) in an arid or semiarid region at the base of an abrupt and receding mountain front or plateau escarpment, and underlain by bedrock (occasionally by older alluvial deposits) that may be bare but more often partly mantled with a discontinuous veneer of alluvium derived from the upland masses and in transit across the surface. (NGLM Manual, 2010)

**Pediplain:** Pediplain is a broad, relatively flat rock surface formed by the joining of several pediments. Pediplain is usually formed in arid or semi-arid climates and may have a thin veneer of sediments. (NGLM Manual, 2010)

**Pediment – Pediplain complex:** A complex landform where both pediplain and pediments occur and it is difficult to separate them.

**Valley fill:** The unconsolidated sediment deposited by any agent so as to fill or partly fill a valley (NGLM Manual, 2010).

**Rolling plain:** An undulating plain with rugged topography. (NGLM Manual, 2010)

**Piedmont :** Landform created at the foot of the mountain or mountains by debris deposited by shifting streams such an alluvial region in a humid climate is known as a piedmont.

**Table 4: LOFS, rank and area coverage for Geomorphology of TS nos. 48I/8, 48I/10 and 48I/11**

| <b>Class</b>                      | <b>Rank</b> | <b>LOFS</b>   | <b>Area coverage<br/>(sq.km)</b> | <b>Area covered<br/>(%)</b> |
|-----------------------------------|-------------|---------------|----------------------------------|-----------------------------|
| <b>Lowly Dissected Slope</b>      | <b>4</b>    | <b>0.1947</b> | <b>671.05</b>                    | <b>50.68</b>                |
| <b>Moderately Dissected Slope</b> | <b>6</b>    | <b>0.4020</b> | <b>74.29</b>                     | <b>5.61</b>                 |
| <b>Highly Dissected Slope</b>     | <b>8</b>    | <b>0.7279</b> | <b>103.86</b>                    | <b>7.84</b>                 |
| <b>Piedmont Slope</b>             | <b>4</b>    | <b>0.1947</b> | <b>7.87</b>                      | <b>0.59</b>                 |
| <b>Water body</b>                 | <b>0</b>    | <b>0</b>      | <b>45.46</b>                     | <b>3.43</b>                 |
| <b>Rolling Plain</b>              | <b>0</b>    | <b>0</b>      | <b>27.04</b>                     | <b>2.06</b>                 |
| <b>Valley Fill</b>                | <b>0</b>    | <b>0</b>      | <b>1.53</b>                      | <b>0.12</b>                 |
| <b>Alluvial Plain</b>             | <b>0</b>    | <b>0</b>      | <b>0.21</b>                      | <b>0.02</b>                 |
| <b>Pediment Pediplain Complex</b> | <b>0</b>    | <b>0</b>      | <b>392.36</b>                    | <b>29.64</b>                |

#### **4.3.3 Land Use and Land Cover:**

Landuse & landcover of an area refers to how the land is being used and the density of vegetation in that area. LULC is an important component in understanding the interaction of the human activities with the environment and thus it is necessary to monitor and detect the changes in LULC to maintain a sustainable environment and slope stability. Any modifications in landcover and landuse may affect the reliability of the landslide susceptibility map to a greater extent. As the requirements of the society are dynamic, the landuse- landcover too changes over a period of time. Given the dynamic character of this class and appreciable influence that the density of vegetation and different landuse practices

have over the stability of hill slopes, it is necessary to specifically mention the time frame of the data source used for making LULC map of the area under study.

The study area consists of lush green forests, followed by cultivation. The commercial plantations form a small part of landuse in this area. Settlements are observed in almost all parts of the study area. This often results in slope cut failures, mostly along road. This is augmented by heavy rainfall during monsoon. The major part of the area is occupied by plantations, which is the main source of income for the people in the study area, followed by forests and cultivated land. Human habitation has seen an increase in the past decade, since the area is a popular tourist destination; creation of holiday homes and resorts in the interior parts of the forests has also led to deforestation.

Construction of roads, railways and reservoirs has opened channels for exploitation and caused rapid changes in LULC of the area. The land use and land cover (LULC) map (**PLATE 5**) was prepared from the Google Earth data of the year 2012-time frame. Following the normal mapping procedure in Google Earth, first the polylines of different land use/cover classes were drawn and the same were imported in Arc GIS through kml to feature conversion. In Arc GIS the features were converted into polygons and then again exported to Google Earth through layer to kml conversion. Each polygon was named as per its LULC class and reconverted into a shape file through kml to layer conversion. The obtained pre-field landuse/landcover map was checked in the field at all accessible locations. The area in terms of landuse/landcover can be classified in to the following classes: Barren, cultivation, settlement, settlement on modified slope, sparse vegetated areas, moderate vegetated areas, thick vegetated areas, river, low height plantation, high height plantation, extensive cut slope and fallow land. The area along river banks is covered with alluvial material and along low lying valleys is covered with overburden material and are being used for cultivation. Major part of the area (about 71.22%) is covered with thick forest in all of the study area. The next class of highest percent is occupied by cultivation that constitutes about 11.83% of the area. Moderate vegetation covers 7.46% of the study area followed by 1.43% of sparse vegetation. Settlements and settlement on modified slopes occupy about 1 % of the area. The total plantation area covered is 1.43% & Barren part (**Photo-8**) is 1.70% of the total area. LU/LC factor class 'Extensive slope cut' is observed to be most vulnerable sites for slope failures and occupies about 0.03% of the study area. The maximum weightage is given to extensive slope cut (Photo-1,3) followed by sparse vegetation and settlement on modified slopes which

occupy about 1.43% and 0.06 % of the area respectively. The area coverage of each factor class in pixels, LOFS and rank is given in **Table – 5**.

**Thick vegetation:** Thick vegetation (forest cover) covers most parts of 48I/8 toposheet and eastern and central parts of 48I/11. The North – Western and Southern part of the study area, has been fragmented at many places by human activities. Along the road side Teak plantation has been done by the Forest division for timber.

**Plantations:** The whole area is rich in forest wealth with bamboos, teak-wood, rose-wood and other valuable timber. These include commercial plantations like rubber, coconut, arica nut, teak, silver oak etc. They mostly cover the low lying region of the area. Coconut & Teak plantations are found mostly in the study area.

**Settlements:** Due to high degree of commercialization and improvement in communication routes more and more area of the Western Ghats is being encroached upon by human settlements. Labourers from other states, who are brought in to work in plantations also live here. The study area is also a well-known tourist spot, hence to cater to the needs of the tourists, several holiday homes resorts and hotels have come up, thus increasing the urbanization index of the area.

**Settlements on Modified slope:** Slopes in and around localities such as Chandrali and south of Ganeshgudi have been modified for human use thus increasing the landslide susceptibility index of the area.

**Extensive slope cut:** Roads and railways are required for improving connectivity and communication in an area. The study area also has good road connectivity though at the cost of extensive damage to slopes. Slopes need to be cut in order to construct roads in the hilly terrains of the Western ghats. This weakens the slopes a great deal. This class has been given high rating for the same.

**Table 5: LOFS, rank and area coverage for Land-use/Land-cover of TS nos. 48I/8, 48I/10 and 48I/11**

| <b>Class</b>                        | <b>Rank</b> | <b>LOFS</b>   | <b>Area coverage (Sq.km)</b> | <b>Area covered (%)</b> |
|-------------------------------------|-------------|---------------|------------------------------|-------------------------|
| <b>Barren</b>                       | <b>1</b>    | <b>0.0626</b> | <b>22.45</b>                 | <b>1.7</b>              |
| <b>Cultivation</b>                  | <b>2</b>    | <b>0.0937</b> | <b>156.60</b>                | <b>11.83</b>            |
| <b>Extensive Slope Cut</b>          | <b>9</b>    | <b>1</b>      | <b>0.36</b>                  | <b>0.03</b>             |
| <b>Fallow Land</b>                  | <b>1</b>    | <b>0.0626</b> | <b>4.43</b>                  | <b>0.33</b>             |
| <b>Moderate Vegetation</b>          | <b>5</b>    | <b>0.2912</b> | <b>98.77</b>                 | <b>7.46</b>             |
| <b>Plantation (HHP)</b>             | <b>4</b>    | <b>0.1988</b> | <b>10.97</b>                 | <b>0.83</b>             |
| <b>Plantation (LHP)</b>             | <b>3</b>    | <b>0.1366</b> | <b>7.94</b>                  | <b>0.6</b>              |
| <b>Quarry</b>                       | <b>5</b>    | <b>0.2912</b> | <b>0.74</b>                  | <b>0.06</b>             |
| <b>Settlement</b>                   | <b>1</b>    | <b>0.0683</b> | <b>13.45</b>                 | <b>1.02</b>             |
| <b>Settlement on modified slope</b> | <b>7</b>    | <b>0.5631</b> | <b>0.75</b>                  | <b>0.06</b>             |
| <b>Thick Vegetation</b>             | <b>4</b>    | <b>0.1988</b> | <b>942.60</b>                | <b>71.22</b>            |
| <b>Sparse Vegetation</b>            | <b>7</b>    | <b>0.5631</b> | <b>18.95</b>                 | <b>1.43</b>             |
| <b>Water body</b>                   | <b>0</b>    | <b>0</b>      | <b>45.46</b>                 | <b>3.43</b>             |

#### **4.3.4 Slope Forming Material (SFM):**

The slope forming material has a great deal of bearing on the slope stability as their physio-mechanical properties depend on the climatic setup, slope gradient, aspect of the slope and slope curvature. Thus this theme is as important as other geo-factors in considering the landslide susceptibility analysis. Thus careful study of slope forming material is a must for any area. Slope Forming Material (SFM) (**PLATE 9**) map was prepared in Arc-GIS through visual interpretation of multi-temporal Google Imageries of the area and collection of data for material present on slopes. The study area in terms of Slope Forming Material (SFM) is classified in to the following classes: Rock, Weathered rock, transported soil, alluvium and in-situ soil.

On slopes as well as ridge tops, barren rock is present at places where the slope gradient in general is more than 35°, most of the study area (about 89.8%) is covered by in-situ, granitic soil (**Photo-2, 6, 11, 12**) and rock (**Photo 9, 10**) (9.11%). The factor class rock includes overburden material of  $\leq 0.5\text{m}$  thickness. For this class different rock names are taken from the geological map of the study area by GSI. The class in-situ soil and amphibolites are assigned maximum weightage because minerals present in amphibolites are highly susceptible to weathering and the loose in-situ soil has poor shear strength due to

water saturation in Western Ghats climatic conditions. The area covered in Sq.km, LOFS and rank is given in **Table – 6**.

Table 6: LOFS, rank and area coverage for Slope forming material of 48I/08, 10 and 11

| <b>CLASS</b>                         | <b>Rank</b> | <b>LOFS</b>   | <b>Area Coverage<br/>(Sq.km)</b> | <b>Area Coverage<br/>(in %)</b> |
|--------------------------------------|-------------|---------------|----------------------------------|---------------------------------|
| <b>Anorthositic gabbro</b>           | <b>1</b>    | <b>0.0682</b> | <b>13.20</b>                     | <b>1.00</b>                     |
| <b>Argillite</b>                     | <b>4</b>    | <b>0.2409</b> | <b>15.79</b>                     | <b>1.19</b>                     |
| <b>Banded iron formation</b>         | <b>1</b>    | <b>0.0682</b> | <b>2.37</b>                      | <b>0.18</b>                     |
| <b>Dolerite</b>                      | <b>1</b>    | <b>0.0682</b> | <b>4.99</b>                      | <b>0.38</b>                     |
| <b>Ferruginous phyllite</b>          | <b>4</b>    | <b>0.2409</b> | <b>0.74</b>                      | <b>0.06</b>                     |
| <b>Granite gneiss</b>                | <b>1</b>    | <b>0.0682</b> | <b>373.98</b>                    | <b>28.26</b>                    |
| <b>Granitoid</b>                     | <b>1</b>    | <b>0.0682</b> | <b>0.55</b>                      | <b>0.04</b>                     |
| <b>In-situ soil</b>                  | <b>4</b>    | <b>0.2409</b> | <b>237.92</b>                    | <b>17.98</b>                    |
| <b>Manganiferous phyllite</b>        | <b>4</b>    | <b>0.2409</b> | <b>16.64</b>                     | <b>1.26</b>                     |
| <b>Metabasalt</b>                    | <b>1</b>    | <b>0.0682</b> | <b>48.94</b>                     | <b>3.70</b>                     |
| <b>Phyllite</b>                      | <b>4</b>    | <b>0.2409</b> | <b>0.47</b>                      | <b>0.04</b>                     |
| <b>Pyroxenite</b>                    | <b>1</b>    | <b>0.0682</b> | <b>6.91</b>                      | <b>0.52</b>                     |
| <b>Quartz-chlorite schist</b>        | <b>4</b>    | <b>0.2409</b> | <b>82.25</b>                     | <b>6.21</b>                     |
| <b>Quartz-sericite schist</b>        | <b>4</b>    | <b>0.2409</b> | <b>1.75</b>                      | <b>0.13</b>                     |
| <b>Quartz vein</b>                   | <b>1</b>    | <b>0.0682</b> | <b>0.04</b>                      | <b>0.00</b>                     |
| <b>Quartzite</b>                     | <b>1</b>    | <b>0.0682</b> | <b>2.94</b>                      | <b>0.22</b>                     |
| <b>Transported Soil</b>              | <b>3</b>    | <b>0.1506</b> | <b>401.21</b>                    | <b>30.31</b>                    |
| <b>Ultramafite</b>                   | <b>1</b>    | <b>0.0682</b> | <b>0.40</b>                      | <b>0.03</b>                     |
| <b>Vanadiferous titano-magnetite</b> | <b>1</b>    | <b>0.0682</b> | <b>0.36</b>                      | <b>0.03</b>                     |
| <b>Water body</b>                    | <b>0</b>    | <b>0.0000</b> | <b>45.46</b>                     | <b>3.43</b>                     |
| <b>Weathered Rock</b>                | <b>6</b>    | <b>0.5437</b> | <b>66.65</b>                     | <b>5.04</b>                     |

#### 4.3.5 Regolith Thickness:

One of the most sensitive parameters is soil thickness (Van Westen et. al, 2008 and Page et al., 1994) to correlate sediment thickness with landslide events. Landslide is triggered due to the decrease in shear strength of the soil as a result of increase in pore water pressure on the failure surface. An increase in pore water pressure can be caused directly by percolating rainfall or indirectly by an accumulation of water at a certain depth due to changes in permeability within the soil cover (perched water tables) or by an accumulation of water at the soil – bedrock contact (Terlien, 1998).

In the study area, the variation in the thickness of soil/regolith was observed to be very erratic. Regolith, here, means material (in-situ or transported), including soil and weathered

mass, lying over the fresh country rock. The thickness depends on a large variety of factors, one important being the local variation in terrain morphology; and therefore prediction of the thickness of regolith over a large area is extremely difficult. Ideally, for thickness modeling, a large number of observations (such as drill holes, outcrops or geophysical measurements) are required. However, at a catchment scale, this approach is difficult to implement. Given the above limitations, regolith thickness map was prepared based on field observations and value judgement. During field work, regolith/overburden thickness is estimated by observing road cuts, forest trenches and nala sections wherever available. An attempt is made to get the approximate overburden depth and it is observed that in low dissected hill slope with low slope gradient, the overburden depth is relatively more (approx. 2-5 m or >5m) where as in low dissected slopes having steeper slope gradient, the overburden depth varies from 1-2m to occasionally upto 5m. In the study area, it can be classified in to three classes less than 0.5 m, 0.5m to 5 m and 5m to 10m (**PLATE 8**). Along the moderate and steep slopes depth of overburden, in general, is less while along major weathered profiles, regolith thickness is more, and these areas are more prone to landslides. Regolith depth of <0.5m depth is observed on rocky, steep slopes and is included into rock class. The map is grouped into three classes. About 42.87% of the area falls under rock cover with very thin slope wash at moderate to steep slope thus < 0.5m regolith class will be consider for the same. Another 45.57 % of the area comes under 0.5-5 m regolith thickness. The 5-10m regolith thickness comprises nearly 8% of the study area and is present mainly in the northern & north eastern part of Ganeshgudi & south of Khanapura town. The area covered by each factor class in terms of pixels, LOFS and rank is given in **Table – 7**

**Table 7: LOFS, rank and area coverage in pixels for Regolith Thickness of T.S No. 481/08, 10 and 11**

| CLASS      | Rank | LOFS    | Area coverage (Sq.km) | Area covered (%) |
|------------|------|---------|-----------------------|------------------|
| < 0.5 m    | 0    | 0       | 568.39                | 42.87            |
| 0.5 - 5 m  | 7    | 1       | 604.25                | 45.58            |
| 5 - 10 m   | 4    | 0.32296 | 105.55                | 7.96             |
| Water body | 0    | 0       | 39.83                 | 3.00             |
| River      | 0    | 0       | 7.77                  | 0.59             |

#### **4.4 Analytical Hierarchy Process (AHP):**

Landslide Susceptibility Mapping is a qualitative study of slope failures in an area with focus on identifying zones susceptible to landslides as low, moderate and high. The presence of climatic change necessitates greater focus on slope failures, identification of hillsides prone to slope failures, study of causative and triggering factors, depiction of vulnerable areas on GIS based and locality specific maps and on evolving innovative technologies for future management.

Since very few, almost negligible amount of slides are observed elsewhere in the area, the normal method of modeling cannot be used here. In this situation, ratings and inter-predictor weights can only be determined using expert or knowledge driven techniques by implementing one of the following alternatives or by combining knowledge derived from attempting all the alternatives.

##### **Alternative 1:** Finalization of ratings and weights in a smaller neighboring area-

If landslide inventory data is available in a smaller catchment or road-corridor within or adjacent to the proposed study area (or Toposheet), attempts should be made to determine terrain-specific ratings and weights of geo-factors through a pilot study in that particular pilot study area. This can be executed by employing different spatial association analysis such as determination of Yule's Co-efficient, Distance Distribution Analysis etc. The ratings and weights determined so far through that pilot study can then be utilized for the entire study area where landslide data is not available. Since NLSM aims to develop and utilize terrain-specific ratings and weights, this seems to be the best approximation of terrain-specific importance of geo-factors.

##### **Alternative 2:** Finalization of ratings and weights using expert opinion and Analytical Hierarchy Process (AHP)-

In a situation of complete non-availability of landslide inventory data, there is absolutely no remedy other than utilizing complete expert or knowledge driven ratings and weights into susceptibility modeling despite its subjectivity. However, this knowledge-driven ratings/ weights in quantitative matrices can easily be determined mathematically using AHP (Saaty, 1977; Ghosh et al., 2010), after preparing/ deciding on the qualitative pairwise importance matrix for different geo-factor classes and amongst different geo-factors for inter-predictor weights, obtained so far through discussion and comments received from local experts and landslide scientists engaged in landslide investigation of the area. The procedures of application of AHP through some examples are illustrated below.

In line of the above proposition, for determining the terrain-specific knowledge-driven ratings and weights through application of AHP, a mandate form/ questionnaire is prepared, where all the concerned landslide scientists, other geologists working in similar terrain and all experts of the concerned Region may submit their mandate/ answer in a semi-quantitative term by rating each geo-factor theme separately. While giving the semi-quantitative rating in a scale of 1-9 for each geofactor theme, the mutual relative importance for influencing/ causing a single proposition that is landsliding in this case should be taken into account. A particular geo-factor class having higher rating would be considered as more instrumental in influencing land sliding. For example, if we classify our slopes into 5 classes say 0-15, 15-25, 25-35, 35-45 and >45 and give semi-quantitative rating as 2, 4, 8, 6, 1 then it will be presumed that for land sliding, slope class 25-35 is the most important among all other classes.

#### 4.4.1 Methodology:

The Analytic Hierarchy Process (AHP), developed by Saaty (1980) is a method of structuring decision problems. The AHP consists of three levels of hierarchy. The first hierarchy level is the goal of the decision making, the second level involves how each of the existing criteria contributes to achievement of goal, and the third level is to find out how each of the alternatives contributes to each of the criteria.

The AHP method is appropriate and to be used where decisions are to be assessed quantitatively. It is assumed that human beings' natural reaction when facing a complex decision making process, is by grouping the decision elements according to common characteristics. This involves ranking the decision elements, and then comparing between each pair in each group in a form of matrix. Then inconsistency ratio and weight for each element can be measured. This provides ease in testing the data consistency. The higher consistency ratio, the assessment result becomes more inconsistent. The acceptable consistency ratio is less than or equal to 10%.

According to Taylor, Consistency Index (CI) can be calculated by using the following formula:

$$CI = \frac{\lambda_{\max} - n}{n(n-1)} \quad \text{Eq-1}$$

$$\lambda_{\max} = \sum_{i=1}^n w_i \cdot ci_i \quad \text{Eq-2}$$

The consistency ratio is then calculated as,

$$\boxed{CR = CI / RI} \dots\dots\dots \text{Eq-3}$$

Where, n is the amount of items compared,  $w_i$  is the weight,  $c_i$  is the sum of column, CR is the Consistency Ratio, CI is the Consistency Index and RI is the Random Consistency Index.

If  $CR \geq 10\%$ , the data acquired is inconsistent and If  $CR < 10\%$ , the data acquired is consistent. The ratio-scale form is used as an input. The values in the ratio are organized in a matrix, which is called the pairwise comparison matrix. In the AHP method, the scale range 1–9 is assumed. It is limited to a ratio-scale 1–9 because according to the research conducted by Miller, human beings cannot simultaneously compare more than seven objects. The Standard Preference Scale used is given in table:

Table 8: Class value and their ratings

| Preference Level                     | Numerical Value |
|--------------------------------------|-----------------|
| Equally Preferred                    | 1               |
| Equally to Moderately Preferred      | 2               |
| Moderately Preferred                 | 3               |
| Moderately to Strong Preferred       | 4               |
| Strongly Preferred                   | 5               |
| Strongly to Very Strongly Preferred  | 6               |
| Very Strongly Preferred              | 7               |
| Very Strongly to Extremely Preferred | 8               |
| Extremely Preferred                  | 9               |

Using the above Standard Preference Scale, a group of geoscientists from GSI engaged in landslide studies in India and in Western Ghats, in particular, were asked to rank the factor classes and the factor maps. The obtained score for individual factor class was used for determining the ratings for each factor class. The average score for the factor maps were ranked between 0 and 9. Matrix of pairwise ratings; estimated eigenvectors of pairwise rating matrix; and estimation of consistency vector (CV), consistency index (CI) and consistency ratio (CR) for judgment of consistency of pairwise ratings of factors, respectively for all maps was calculated. Example of LULC for calculation of LOFS is given in **table 9-12**.

Table 9: Generic Table showing mutual comparison rank of LULC factor classes

| CLASS                        | Rank | LOFS   |
|------------------------------|------|--------|
| Barren                       | 1    | 0.0626 |
| Cultivation                  | 2    | 0.0937 |
| Extensive Slope Cut          | 9    | 1.0000 |
| Fallow Land                  | 1    | 0.0626 |
| Moderate Vegetation          | 5    | 0.2912 |
| Plantation (HHP)             | 4    | 0.1988 |
| Plantation (LHP)             | 3    | 0.1366 |
| Quarry                       | 5    | 0.2912 |
| Settlement                   | 1    | 0.0683 |
| Settlement on modified slope | 7    | 0.5631 |
| Swamp                        | 0    | 0.0000 |
| Thick Vegetation             | 4    | 0.1988 |
| Sparse Vegetation            | 7    | 0.5631 |
| Water body                   | 0    | 0.0000 |
| River                        | 0    | 0.0000 |

Table 10: Table showing matrix of mutual comparison ranks of LULC classes given rank &gt;0

| LULC           | B     | CL    | ESC  | FL    | MV    | HHP   | LHP   | QR    | S     | SM   | TV    | SV   |
|----------------|-------|-------|------|-------|-------|-------|-------|-------|-------|------|-------|------|
| <b>B</b>       | 1.00  | 0.50  | 0.11 | 1.00  | 0.20  | 0.25  | 0.33  | 0.20  | 1.00  | 0.14 | 0.25  | 0.14 |
| <b>CL</b>      | 2.00  | 1.00  | 0.13 | 2.00  | 0.25  | 0.33  | 0.50  | 0.25  | 2.00  | 0.17 | 0.33  | 0.17 |
| <b>ESC</b>     | 9.00  | 8.00  | 1.00 | 9.00  | 5.00  | 6.00  | 7.00  | 5.00  | 9.00  | 3.00 | 6.00  | 3.00 |
| <b>FL</b>      | 1.00  | 0.50  | 0.11 | 1.00  | 0.20  | 0.25  | 0.33  | 0.20  | 1.00  | 0.14 | 0.25  | 0.14 |
| <b>MV</b>      | 5.00  | 4.00  | 0.20 | 5.00  | 1.00  | 2.00  | 3.00  | 1.00  | 5.00  | 0.33 | 2.00  | 0.33 |
| <b>HHP</b>     | 4.00  | 3.00  | 0.17 | 4.00  | 0.50  | 1.00  | 2.00  | 0.50  | 4.00  | 0.25 | 1.00  | 0.25 |
| <b>LHP</b>     | 3.00  | 2.00  | 0.14 | 3.00  | 0.33  | 0.50  | 1.00  | 0.33  | 3.00  | 0.20 | 0.50  | 0.20 |
| <b>QR</b>      | 5.00  | 4.00  | 0.20 | 5.00  | 1.00  | 2.00  | 3.00  | 1.00  | 5.00  | 0.33 | 2.00  | 0.33 |
| <b>S</b>       | 1.00  | 0.50  | 0.11 | 1.00  | 0.20  | 0.25  | 0.33  | 0.50  | 1.00  | 0.14 | 0.25  | 0.14 |
| <b>SM</b>      | 7.00  | 6.00  | 0.33 | 7.00  | 3.00  | 4.00  | 5.00  | 3.00  | 7.00  | 1.00 | 4.00  | 1.00 |
| <b>TV</b>      | 4.00  | 3.00  | 0.17 | 4.00  | 0.50  | 1.00  | 2.00  | 0.50  | 4.00  | 0.25 | 1.00  | 0.25 |
| <b>SV</b>      | 7.00  | 6.00  | 0.33 | 7.00  | 3.00  | 4.00  | 5.00  | 3.00  | 7.00  | 1.00 | 4.00  | 1.00 |
| <b>Sum Clm</b> | 49.00 | 38.50 | 3.00 | 49.00 | 15.18 | 21.58 | 29.50 | 15.48 | 49.00 | 6.96 | 21.58 | 6.96 |

Table 11: Table Showing Fraction rate and LOFS values

| LU LC     | B       | CL      | ESC     | FL      | MV      | HH P    | LH P    | QR      | S       | SM      | TV      | SV      | Sum rows | Frac rate | LO FS  |
|-----------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|----------|-----------|--------|
| <b>B</b>  | 0.02041 | 0.01299 | 0.03702 | 0.02041 | 0.01551 | 0.01158 | 0.0113  | 0.01292 | 0.02041 | 0.02052 | 0.01158 | 0.02052 | 0.21283  | 0.01774   | 0.0626 |
| <b>CL</b> | 0.04082 | 0.02597 | 0.04165 | 0.04082 | 0.01647 | 0.01544 | 0.01695 | 0.01615 | 0.04082 | 0.02394 | 0.01544 | 0.02394 | 0.3184   | 0.02653   | 0.0937 |

|           |      |      |      |      |      |      |      |      |      |      |      |      |       |       |     |
|-----------|------|------|------|------|------|------|------|------|------|------|------|------|-------|-------|-----|
| <b>ES</b> | 0.18 | 0.20 | 0.33 | 0.18 | 0.32 | 0.27 | 0.23 | 0.32 | 0.18 | 0.43 | 0.27 | 0.43 | 3.399 | 0.283 | 1.0 |
| <b>C</b>  | 367  | 779  | 32   | 367  | 931  | 799  | 729  | 293  | 367  | 092  | 799  | 092  | 36    | 28    | 000 |
| <b>FL</b> | 0.02 | 0.01 | 0.03 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.01 | 0.02 | 0.212 | 0.017 | 0.0 |
|           | 041  | 299  | 702  | 041  | 551  | 158  | 13   | 292  | 041  | 052  | 158  | 052  | 83    | 74    | 626 |
| <b>MV</b> | 0.10 | 0.10 | 0.06 | 0.10 | 0.06 | 0.09 | 0.10 | 0.06 | 0.10 | 0.04 | 0.09 | 0.04 | 0.989 | 0.082 | 0.2 |
|           | 204  | 39   | 664  | 204  | 586  | 266  | 169  | 459  | 204  | 788  | 266  | 788  | 89    | 49    | 912 |
| <b>HH</b> | 0.08 | 0.07 | 0.05 | 0.08 | 0.03 | 0.04 | 0.06 | 0.03 | 0.08 | 0.03 | 0.04 | 0.03 | 0.675 | 0.056 | 0.1 |
| <b>P</b>  | 163  | 792  | 553  | 163  | 293  | 633  | 78   | 229  | 163  | 591  | 633  | 591  | 86    | 32    | 988 |
| <b>LH</b> | 0.06 | 0.05 | 0.04 | 0.06 | 0.02 | 0.02 | 0.03 | 0.02 | 0.06 | 0.02 | 0.02 | 0.02 | 0.464 | 0.038 | 0.1 |
| <b>P</b>  | 122  | 195  | 76   | 122  | 195  | 317  | 39   | 153  | 122  | 873  | 317  | 873  | 39    | 7     | 366 |
| <b>QR</b> | 0.10 | 0.10 | 0.06 | 0.10 | 0.06 | 0.09 | 0.10 | 0.06 | 0.10 | 0.04 | 0.09 | 0.04 | 0.989 | 0.082 | 0.2 |
|           | 204  | 39   | 664  | 204  | 586  | 266  | 169  | 459  | 204  | 788  | 266  | 788  | 89    | 49    | 912 |
| <b>S</b>  | 0.02 | 0.01 | 0.03 | 0.02 | 0.01 | 0.01 | 0.01 | 0.03 | 0.02 | 0.02 | 0.01 | 0.02 | 0.232 | 0.019 | 0.0 |
|           | 041  | 299  | 702  | 041  | 551  | 158  | 13   | 229  | 041  | 052  | 158  | 052  | 2     | 35    | 683 |
| <b>SM</b> | 0.14 | 0.15 | 0.11 | 0.14 | 0.19 | 0.18 | 0.16 | 0.19 | 0.14 | 0.14 | 0.18 | 0.14 | 1.914 | 0.159 | 0.5 |
|           | 286  | 584  | 107  | 286  | 759  | 533  | 949  | 376  | 286  | 364  | 533  | 364  | 25    | 52    | 631 |
| <b>TV</b> | 0.08 | 0.07 | 0.05 | 0.08 | 0.03 | 0.04 | 0.06 | 0.03 | 0.08 | 0.03 | 0.04 | 0.03 | 0.675 | 0.056 | 0.1 |
|           | 163  | 792  | 553  | 163  | 293  | 633  | 78   | 229  | 163  | 591  | 633  | 591  | 86    | 32    | 988 |
| <b>SV</b> | 0.14 | 0.15 | 0.11 | 0.14 | 0.19 | 0.18 | 0.16 | 0.19 | 0.14 | 0.14 | 0.18 | 0.14 | 1.914 | 0.159 | 0.5 |
|           | 286  | 584  | 107  | 286  | 759  | 533  | 949  | 376  | 286  | 364  | 533  | 364  | 25    | 52    | 631 |

Table 12: Table showing estimation of consistency vector (CV)

| LU         | B     | CL    | ESC   | FL    | MV    | HHP   | LHP   | QR    | S     | SM    | TV    | SV    | Sum   | CV    |
|------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| LC         |       |       |       |       |       |       |       |       |       |       |       |       | rows  |       |
| <b>B</b>   | 0.017 | 0.013 | 0.031 | 0.017 | 0.016 | 0.014 | 0.012 | 0.016 | 0.019 | 0.022 | 0.014 | 0.022 | 0.219 | 12.35 |
|            | 74    | 27    | 48    | 74    | 5     | 08    | 9     | 5     | 35    | 79    | 08    | 79    | 2     | 91    |
| <b>CL</b>  | 0.035 | 0.026 | 0.035 | 0.035 | 0.020 | 0.018 | 0.019 | 0.020 | 0.038 | 0.026 | 0.018 | 0.026 | 0.322 | 12.16 |
|            | 47    | 53    | 41    | 47    | 62    | 77    | 35    | 62    | 7     | 59    | 77    | 59    | 9     | 96    |
| <b>ESC</b> | 0.159 | 0.212 | 0.283 | 0.159 | 0.412 | 0.337 | 0.270 | 0.412 | 0.174 | 0.478 | 0.337 | 0.478 | 3.717 | 13.12 |
|            | 62    | 27    | 28    | 62    | 45    | 93    | 89    | 45    | 15    | 56    | 93    | 56    | 73    | 39    |
| <b>FL</b>  | 0.017 | 0.013 | 0.031 | 0.017 | 0.016 | 0.014 | 0.012 | 0.016 | 0.019 | 0.022 | 0.014 | 0.022 | 0.219 | 12.35 |
|            | 74    | 27    | 48    | 74    | 5     | 08    | 9     | 5     | 35    | 79    | 08    | 79    | 2     | 91    |
| <b>MV</b>  | 0.088 | 0.106 | 0.056 | 0.088 | 0.082 | 0.112 | 0.116 | 0.082 | 0.096 | 0.053 | 0.112 | 0.053 | 1.049 | 12.72 |
|            | 68    | 13    | 66    | 68    | 49    | 64    | 1     | 49    | 75    | 17    | 64    | 17    | 61    | 4     |
| <b>HH</b>  | 0.070 | 0.079 | 0.047 | 0.070 | 0.041 | 0.056 | 0.077 | 0.041 | 0.077 | 0.039 | 0.056 | 0.039 | 0.698 | 12.40 |
| <b>P</b>   | 94    | 6     | 21    | 94    | 25    | 32    | 4     | 25    | 4     | 88    | 32    | 88    | 39    | 01    |
| <b>LH</b>  | 0.053 | 0.053 | 0.040 | 0.053 | 0.027 | 0.028 | 0.038 | 0.027 | 0.058 | 0.031 | 0.028 | 0.031 | 0.471 | 12.19 |
| <b>P</b>   | 21    | 07    | 47    | 21    | 5     | 16    | 7     | 5     | 05    | 9     | 16    | 9     | 82    | 21    |
| <b>QR</b>  | 0.088 | 0.106 | 0.056 | 0.088 | 0.082 | 0.112 | 0.116 | 0.082 | 0.096 | 0.053 | 0.112 | 0.053 | 1.049 | 12.72 |
|            | 68    | 13    | 66    | 68    | 49    | 64    | 1     | 49    | 75    | 17    | 64    | 17    | 61    | 4     |
| <b>S</b>   | 0.017 | 0.013 | 0.031 | 0.017 | 0.016 | 0.014 | 0.012 | 0.041 | 0.019 | 0.022 | 0.014 | 0.022 | 0.243 | 12.60 |
|            | 74    | 27    | 48    | 74    | 5     | 08    | 9     | 25    | 35    | 79    | 08    | 79    | 95    | 68    |
| <b>SM</b>  | 0.124 | 0.159 | 0.094 | 0.124 | 0.247 | 0.225 | 0.193 | 0.247 | 0.135 | 0.159 | 0.225 | 0.159 | 2.095 | 13.13 |
|            | 15    | 2     | 43    | 15    | 47    | 29    | 5     | 47    | 45    | 52    | 29    | 52    | 43    | 58    |
| <b>TV</b>  | 0.070 | 0.079 | 0.047 | 0.070 | 0.041 | 0.056 | 0.077 | 0.041 | 0.077 | 0.039 | 0.056 | 0.039 | 0.698 | 12.40 |
|            | 94    | 6     | 21    | 94    | 25    | 32    | 4     | 25    | 4     | 88    | 32    | 88    | 39    | 01    |
| <b>SV</b>  | 0.124 | 0.159 | 0.094 | 0.124 | 0.247 | 0.225 | 0.193 | 0.247 | 0.135 | 0.159 | 0.225 | 0.159 | 2.095 | 13.13 |
|            | 15    | 2     | 43    | 15    | 47    | 29    | 5     | 47    | 45    | 52    | 29    | 52    | 43    | 58    |
|            |       |       |       |       |       |       |       |       |       |       |       |       | Sum   | 151.3 |
|            |       |       |       |       |       |       |       |       |       |       |       |       | CV    | 3     |

In the same manner LOFS and consistency ratio (CR) were calculated for all the six factor maps. All the tables of the six factor maps for LOFS and consistency ratio calculations have been attached in **Annexure – I**.

Table 13: Table showing calculation of consistency index (CI) and consistency ratio (CR).

|                                                                                                                                      |   |   |      |     |      |      |      |      |      |      |
|--------------------------------------------------------------------------------------------------------------------------------------|---|---|------|-----|------|------|------|------|------|------|
| <div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div><div></div></div> |   |   |      |     |      |      |      |      |      |      |
| <i>n</i>                                                                                                                             | 1 | 2 | 3    | 4   | 5    | 6    | 7    | 8    | 9    | 10   |
| RI                                                                                                                                   | 0 | 0 | 0.58 | 0.9 | 1.12 | 1.24 | 1.32 | 1.41 | 1.45 | 1.49 |

|                                  |  |  |         |         |                                              |  |  |
|----------------------------------|--|--|---------|---------|----------------------------------------------|--|--|
| Mean CV                          |  |  |         | 12.6109 |                                              |  |  |
| Consistency Index (CI) =         |  |  |         |         | (Mean CV-number of themes)/(No of themes -1) |  |  |
| CI                               |  |  | 0.05553 |         |                                              |  |  |
| Consistency Ratio (CR) =         |  |  |         |         | CI/RI                                        |  |  |
| CR                               |  |  | 0.00463 |         |                                              |  |  |
| CR should never be more than 0.1 |  |  |         |         |                                              |  |  |

Table 14: Table showing mutual comparison of individual factor maps and weights.

| Factor Classes     |      |
|--------------------|------|
| Factor             | Rank |
| Slope              | 9    |
| Curvature          | 2    |
| SFM                | 6    |
| LULC               | 8    |
| Geomorphology      | 6    |
| Regolith Thickness | 4    |

| Factor    | Slope | Curvat | SFM  | LUL  | Geo  | RT    |
|-----------|-------|--------|------|------|------|-------|
| Slope     | 1.00  | 8.00   | 4.00 | 2.00 | 4.00 | 6.00  |
| Curvature | 0.13  | 1.00   | 0.20 | 0.14 | 0.20 | 0.33  |
| SFM       | 0.25  | 5.00   | 1.00 | 0.33 | 1.00 | 3.00  |
| LULC      | 0.50  | 7.00   | 3.00 | 1.00 | 3.00 | 5.00  |
| Geom      | 0.25  | 5.00   | 1.00 | 0.33 | 1.00 | 3.00  |
| RT        | 0.17  | 3.00   | 0.33 | 0.20 | 0.33 | 1.00  |
| Sum Clmn  | 2.29  | 29.00  | 9.53 | 4.01 | 9.53 | 18.33 |

| Factor    | Slope   | Curvature | SFM     | LULC    | Geom    | RT      | Sum rows | Frac rate | Weight  | Weight W N |
|-----------|---------|-----------|---------|---------|---------|---------|----------|-----------|---------|------------|
| Slope     | 0.43636 | 0.27586   | 0.41958 | 0.49881 | 0.41958 | 0.32727 | 2.37747  | 0.39625   | 12.8653 | 13         |
| Curvature | 0.05455 | 0.03448   | 0.02098 | 0.03563 | 0.02098 | 0.01818 | 0.18480  | 0.0308    | 1       | 1          |
| SFM       | 0.10909 | 0.17241   | 0.10490 | 0.08314 | 0.10490 | 0.16364 | 0.73807  | 0.12301   | 3.99392 | 4          |
| LULC      | 0.21818 | 0.24138   | 0.31469 | 0.24941 | 0.31469 | 0.27273 | 1.61107  | 0.26851   | 8.718   | 9          |
| Geom      | 0.10909 | 0.17241   | 0.10490 | 0.08314 | 0.10490 | 0.16364 | 0.73807  | 0.12301   | 3.99392 | 4          |
| RT        | 0.07273 | 0.10345   | 0.03497 | 0.04988 | 0.03497 | 0.05455 | 0.35053  | 0.05842   | 1.89685 | 2          |

Once the LOFS values for geofactor sub classes are determined, all the LOFS values against the sub classes are compiled in an excel sheet. Then the LOFS attributes are joined in the raster map attribute table using “join and relates” option. Finally, LOFS map of the geofactor

is prepared with the help of “Lookup” command in Arc GIS, using raster map of the geofactor as “input raster” and “geofactor\_LOFS\$LOFS” as lookup field.

For determination of Predictor Weight for the geo-factor, one comparison matrix is calculated in microsoft excel software for the pair wise qualitative comparison of all the geo-factors. In the comparison matrix, fraction weight is calculated for all the geo-factors (**Table 14**). Once all the fraction weights are determined, minimum value within the fraction ratings is identified using the “MIN” command in excel software. Then all the fraction weight values are divided with the minimum fraction weight value to determine the Predictor Weight or weight of geo-factors. In this way, as the fraction weights are divided with the minimum fraction weight value, the Predictor Weight or weight values will be one or more than one. For each geo-factor, consider the nearest whole number as its Predictor Weight or weight.

For generation of “Raw Landslide Susceptibility Score Map” in Arc – GIS, “raster calculation” command under map algebra is used. For “Raw Landslide Susceptibility Score Map” the following formula is used.

**Susc Score** = (LOFS\_Factor1\*weight of Factor1 + LOFS\_Factor2\*weight of Factor2 + LOFS\_Factor3\*weight of Factor3 + ..... + LOFS\_Factor<sub>n</sub>\*weight of Factor<sub>n</sub>) / Sum of inter – predictor weight

In this type of knowledge-driven models, classification break values can be determined on the basis of the logic applied while giving mutual comparison expert driven ranking. It is always thought by any expert that rank value for any factor class is  $\geq 5$ , and it is considered that the particular factor class has higher likelihood in influencing the landslides. This rank value of “5” in a scale of “0” to “9” comes after 50% of the absolute difference values (9-0 = 9; 50% of 9 is 4.5). That is why this 50% cut-off margin or weightage can be used to determine the break raster value between “Moderate” and “High” susceptibility classes (*BrMH*). Similarly, when rank value for any factor class is  $\leq 3$  (lower than 30% of the absolute difference value of 9), and it is considered that the particular geofactor class has lesser likelihood in influencing any landslides. Accordingly, 30% cut-off margin or weightage can be used to determine the break values between “Low” and “Moderate” susceptibility classes (*BrLM*).

Using the above logic, the required break values can be done using the above logic the required break values can be determined by solving the following formula:

$$\mathbf{BrMH} = [(Abs \text{ Diff LOFS Factor1} * 50) * \text{weight of Fcator1} + (Abs \text{ Diff LOFS Factor2} * 50) * \text{weight of Fcator2} + (Abs \text{ Diff LOFS Factor3} * 50) * \text{weight of Fcator3} + \dots + (Abs \text{ Diff LOFS Factorn} * 50) * \text{weight of Fcatorn}] / \text{Sum of inter – predictor weight}$$

$$\mathbf{BrLM} = [(Abs \text{ Diff LOFS Factor1} * 30) * \text{weight of Fcator1} + (Abs \text{ Diff LOFS Factor2} * 30) * \text{weight of Fcator2} + (Abs \text{ Diff LOFS Factor3} * 30) * \text{weight of Fcator3} + \dots + (Abs \text{ Diff LOFS Factorn} * 30) * \text{weight of Fcatorn}] / \text{Sum of inter – predictor weight}$$

Once break values (BrMH and BrLM) are calculated, Classified Landslide Susceptibility Map is prepared by reclassifying the Raw Landslide Susceptibility Score Map using reclassify command in Arc – GIS. In reclassification window, three classes are chosen and in break values, 2nd topmost value given as the first value (Class 1), 1st topmost value is given as the second value (Class 2) and third value (Class 3) is given as one. Now the Raw Landslide Susceptibility Score Map is classified into the following categories: Class 1 stands for “Low Susceptibility”, Class 2 stands for “Moderate Susceptibility” and Class 3 stands for “High Susceptibility”.

## 5. LANDSLIDE SUSCEPTIBILITY MAP

Landslide susceptibility maps are key tools for land use planning, management and risk mitigation measures. Landslide susceptibility mapping aims to differentiate a land surface into homogeneous areas according to their probability of failure caused by mass-movement at specific locations (Varnes, 1978). It relies on understanding complex mass movement processes and their controlling factors. An accurate and reliable landslide susceptibility map requires high quality data to arrive at useful decisions, and an appropriate methodology for analysis and modelling.

A Landslide susceptibility score map is thus obtained after generating LOFS maps for all the factor classes and using Weighted Multiclass Index Overlay method to generate raw susceptibility score map which is classified into low, moderate and high susceptible areas so that it can be understood easily by the common man. The susceptibility is expressed in terms of the relative likelihood of an area for initiation of landslide or slope failure in a pixel (the mapping unit) under the given geo-environmental conditions. According to the final susceptibility map obtained after AHP modelling, about 73.5% area falls under low landslide susceptibility zone while 22.4% area is categorized in moderate susceptibility zone. About 4.1 % area falls under high landslide susceptibility zone. The area on the western fringe of Kumbharvada, Dudalimala, Kundali and west of Bharadi falls under high mountains as well as deep valleys steeply sloping towards west. This area is a long NNW-SSE trending range in the Northern part of the area and N-S to NNE-SSW in the southern part contributes much of the area under high susceptible zone. This area also forms a part of thickly forested Western Ghat abounded with wild life and is inaccessible. Except a few scattered hamlets along the Goa-Karnataka border, there is no habitation in vicinity,

Most of the high susceptibility zones correspond to slope gradient class between  $12^{\circ}$  -  $25^{\circ}$ . It has been observed that most of the slides occur in this slope gradient class  $<15^{\circ}$  (14slides) ,  $15^{\circ}$  -  $25^{\circ}$  (10 slides) and  $25^{\circ}$  -  $35^{\circ}$  (6 slides) (**PLATE 13**). In terms of landuse/landcover the area having settlement on modified slopes and Extensive cut slopes has the maximum susceptibility to landslides. In terms of geomorphology, most of the slides are observed to occur in lowly dissected slopes (25 slides). It has to be noted here that most of the slides occurring in low dissected slopes are located along cut slopes where modification slope and slope disturbances are maximum.

Most of the area in toposheet no. 48I/8 falls under moderate to high susceptibility which can be attributed to two facts (i) most parts in this area/ toposheet have steep slope gradients as compared to other part of the area, and (ii) natural slopes have been excavated and modified for construction of highways, settlements rendering the slopes unstable and prone to failures. There have been many small occurrences of slope failures and road subsidences observed along the roads. Uncontrolled slope modification, removal of vegetation and blocking the natural drainage (nala) flow by constructing the road (Nujji-Karwar road) without giving culvert at road bench are few reasons for slope failure in this area.

All places where extensive cut slopes are marked are falling in high susceptibility zone. These places are vulnerable to slope failures due to removal of toe material which is being carried out without any support/ remedial measures and make these slopes unstable.

Most of the northern, central and eastern part of study area is categorised into low to moderate susceptibility zone. This may be attributed to presence of low lying planes which are abounding cultivation and low height plantations. In addition to this most of the area has slope gradients less than  $15^\circ$  which renders the area stable. Since the area has thick vegetation on the slope forming material, the site is penetrated by roots of these plants. This also provides stability to this area as far as slope failure is concerned.

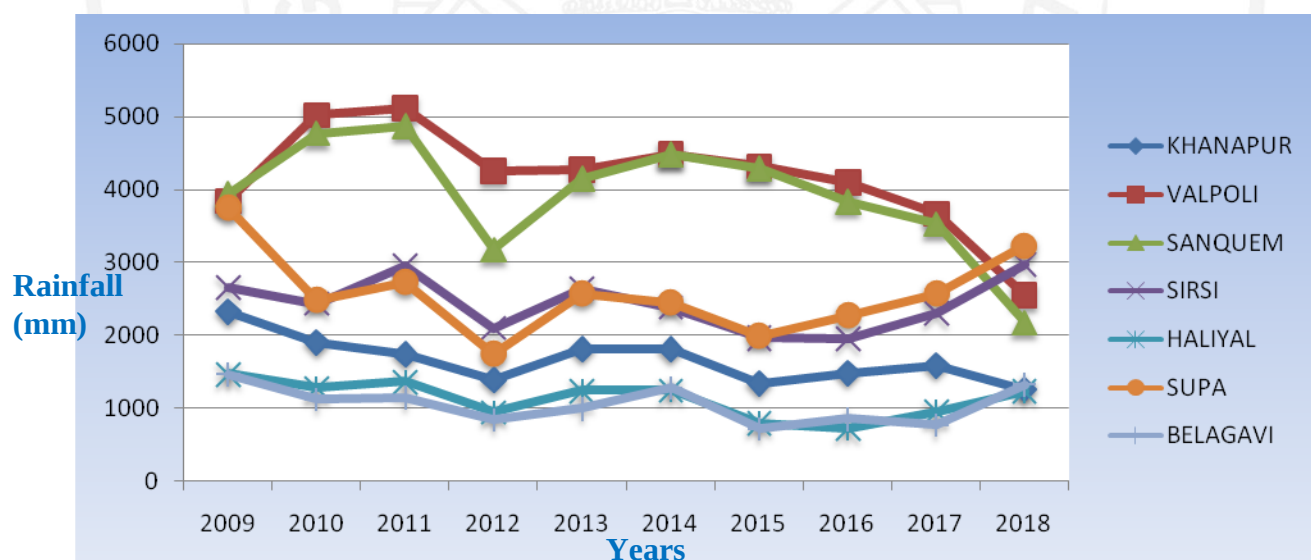
## 6. Rainfall Pattern

The tract receives rainfall mainly from southwest monsoon from June to Sept. The rainfall is more, in the west and decreases towards east. The highest rainfall is about 5000 mm at Valpoli and lowest being 726 mm in parts of Haliyal. Accordingly the type of vegetation changes from evergreen, semi evergreen to deciduous type. In the east, where rainfall is comparatively less, soil is poor and underlying rock being granite and quartzite the disintegrated soil is rather sandy. This is common in areas of Haliyal Range and Parts of Bhagawati and Sambrani Ranges. In parts of Dandeli and Virnoli Ranges rainfall is fairly good and tract is well drained.

The particulars of distribution of rainfall on year basis received from 2009 to 2018 are shown in **Annexure- III**.

It is evident that evergreen /semi evergreen forests are found in the areas, receiving rainfall more that 2000 mm and moist deciduous type of forests are in areas receiving rainfall between 1200-2000 mm. Further dry deciduous forests are found in areas receiving rainfall less than 1200 mm.

Due to increase of human activities like industrialization, urbanization, increase in road and rail traffic, destruction of trees and deforestation, etc., have an effect on climate resulting in growing atmospheric and water pollution and an increase in temperature.



**Figure 3:** Average Annual rainfall pattern of last ten years at different Rain gauge stations

The average annual rainfall distribution maps of study area from year-2009 to 2018 are given in **Plate no. 14, 15 & 16**.

## 7. CONCLUSIONS AND RECOMMENDATIONS

The susceptibility map produced on 1:50,000 scale gives the qualitative estimation how the mapping unit will be affected by a future landslide source, but the “future” here is not connected to a time frame. It only indicates the stability status of a slope irrespective of a time of an event to occur.

For a landslide to occur a number of conditions needs to be satisfied. These conditions can be classified into two broad categories, i) controlling factors (such as material properties, viz., rock/soil type, in-situ soil, bulk strength, etc. and terrain conditions, viz., slope angle, slope aspect, fracturing, cultivation, etc.) that prepare/prevent the slope to/from failure and ii) triggering events (such as earthquakes, intense rainstorms, clearing of vegetation and possibly new construction). If all these controlling factors in an area are known, it may be possible to say where landslides are most likely to occur, given a particular triggering event (McDonald et al, 1999).

All these parameters play an important role in areas experiencing failures, in the Himalayas, however, the same may not hold true for Western Ghats, where landslides are largely restricted to cut/modified slopes. Hence, for the current study pre-defined set of 6 geo-factor parameters such as slope morphometry, landuse/landcover, geomorphology, regolith thickness, drainage and slope forming material maps with region specific ranking and weight systems were considered and the landslide susceptibility map was modelled using analytical hierarchy process (AHP) and following multi-class index overlay method in GIS platform. The geographical spread of high and moderate susceptible zones in the study area shows positive spatial association with certain physiography's, slope inclinations, geomorphic forms and distribution of slope-forming material as well as landuse types.

About 4.1% (54.28 Sq. Km.) of area is grouped under High susceptibility zone. Most of this area lies along road transportation corridors and around extensive cut slope areas. Besides, hills with steep slopes are also grouped under moderate to high susceptible zones.

The susceptibility map thus obtained using Analytical hierarchy process (AHP) gives a qualitative estimation of the study area about particular mapping units (pixel in this case having 50m \* 50m resolution) being susceptible to landslide occurrence under the cumulative effect of geo factors under consideration. This does not have any time connotation and it is assumed that the same geo-environmental conditions will prevail in the future that augmented the present slope failures. These conditions may change with time and so will the

susceptibility index of the area. The areas categorised under high and moderate zones are enlisted below in brief.

The causative factors for the landslide/mass failures incidences in the area may be mainly anthropogenic i.e. destabilisation of slopes by removal of toe, lack of proper drainage at toe part and on the slopes causing seepage of water into the weaker plane like joints and fracture. The triggering factor for slides in the study area is mainly rainfall which has contributed to increase in the pore pressure in the unconsolidated loose weathered rock mass resulting in reduction of shear strength and subsequent failure.

The locations of the recorded landslides superimposed on geology show that most of the landslides occurrences are associated with the highly weathered zone or in the vicinity of different litho-contacts. This discontinuity is contributing to the stability of the slope. The mass failure has been accelerated along the litho-contact, after the road construction and later exaggerated by rainfall.

In the western part of the toposheet no. 48I/8, Western Ghat range initially runs NW-SE direction in the Northern part of area, that swirls NNE-SSW in the central part & then again rapidly swirls in NNW-SSE in the Northern part of the area. The high susceptible zones in the landslide susceptibility map also follow this pattern.

The rainfall data of the last ten years (Plates: 13,14,15) revealed that western part of the study area is coming under high rainfall region. The higher susceptibility zone in the area as evident by landslide susceptibility map is coinciding with the high rainfall affected regions. Prediction of rainfall-triggered hill slope disasters has relied mostly on the valley slope, rainfall intensity and duration that can cause hill slope failure. Therefore, the western part of the region is looking more vulnerable towards mass failures.

Road sections on Ganeshgudi-Jagalbet, Kumbharvada-Karwar, Kadagarani- Anshi have been observed to have moderate to steep slope gradients. Incidences of slope failures along these roads have been recorded due to removal of toe support for widening of the road that left behind vertical cuts with no lateral support. This subsequently leads to failure of the mass during heavy rainfall. This area also has high to moderate possibility of slope failures as indicated by susceptibility map.

At places, roads are developed cracks and showing evidence of subsidence. This is occurring due to blocking of the natural flow of drainage (nala) by road construction. Lack of proper drainage along the road resulted in seepage of water beneath the road. This subsequently leads to removing of soil underneath & thus resulted in development of

subsidence & cracks thereafter. A culvert of suitable dimensions to be constructed at the road level to facilitate smooth water/debris flow.

Preventive measures like slope stabilisation, slope contour/ chute drainage and conservation of forests need to be taken up so that the roads and associated population is kept safe from any damage.

### **Limitations:**

Every methodology tends to have its own limitations and constraints. Similarly, during the study, a few constraints in terms of the methodology adopted for this study were also identified which are enumerated below.

The mapping of, the nature and extent of, the slope forming material based on observations at accessible stretches may not depict the true picture on all studied hill slopes. Subsequently, the regolith thickness map is very subjective since the regolith thickness along a slope is visually estimated; few vulnerable sites may be explored or investigated through sub-surface exploration on the basis of its exposure in a section and extrapolated to adjacent areas considering the terrain morphology.

The assumption of the methodology that the relation/s between spatial factors and past/present landslides are relevant to the occurrence of future landslides may not always hold true in nature.

The causative factors (e.g., slope, aspect, curvature, geomorphology and drainage) are not expected to change significantly in a short time period, local morphological changes may occur due to land sliding, but this will not substantially affect the susceptibility model. However, some local changes in the land use pattern may take place, such as terracing of slope for cultivation or excavation for construction of new buildings. Such changes can induce instability “locally” and may increase or decrease the susceptibility of that slope.

The susceptibility map is only valid under the given set of geo-environmental conditions taken as input in the susceptibility modelling. Any changes in the spatial distribution of the geo-environmental factors may affect the susceptibility of the area.

Spatio-temporal prediction of a landslide is still difficult on macro-scale; hence questions can be raised about the predictive capability of a susceptibility map given the uncertainty in the occurrence of a landslide.

Limitations in understanding the terrain and its landslide characteristics thereby affecting the selection of preparatory factors are also probable.

Despite the above, the generated landslide susceptibility map of the area is the first level spatial database on regional scale which can form the basis of landslide hazard and risk evaluation indicating the vulnerability of the elements at risk.

### **Recommendations:**

Based on the evaluation of the geo-factors and understanding their relative importance that are specific to the terrain, as well as considering the scale of the study and the observations made in the field, the following generic recommendations are suggested:

The susceptibility map is generally meant for regional application because the information is shown on scale 1:50,000; however, they are still of considerable significance from the point of specific land use and urban planning. Nevertheless, it is recommended that a detailed site-specific study may be duly conducted before planning and execution of the civil construction works. Areas with high susceptibility falling under high hazard should be given due attention while executing civil constructions or may be avoided.

Landslide susceptibility mapping is useful in identifying potential landslide hazard zones but remedial measure to protect/treat the slide is of prime concern. In order to make these studies user friendly, the town planner/district administration should consult the report and landslide protection work should be undertaken in consultation with civil engineers and Engineering geologists.

It is also recommended that the susceptibility map showing the potential landslide area should not be considered as standalone map for planning; the run out of potential debris flows be also considered for the specific planning.

In the event if a disaster strikes, the loss would be immense if buildings are not safely and properly located. Awareness among people is of utmost importance to reduce the loss of lives and property. The awareness should include information about the potential danger, its identification and its communication; the physical significance of hazard and inherent uncertainties; ways to reduce landslide risk and the available local mitigation options.

Remedial measures for individual slides are given in Annexure-II in 42 points geo-parametric data sheet.

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## Locality Index

| SI. No. | Locality Name | Latitude | Longitude |
|---------|---------------|----------|-----------|
| 1       | Bharadi       | 15.01    | 74.34     |
| 2       | Bidoll        | 15.01    | 74.45     |
| 3       | Bijgami       | 15.54    | 74.57     |
| 4       | Bondeli       | 15.25    | 74.26     |
| 5       | Chennevadi    | 15.56    | 74.58     |
| 6       | Dandeli       | 15.26    | 74.61     |
| 7       | Dudalimala    | 15.24    | 74.32     |
| 8       | Ganeshgudi    | 15.28    | 74.53     |
| 9       | Gharli        | 15.42    | 74.52     |
| 10      | Ghotgali      | 15.47    | 74.57     |
| 11      | Gobral        | 15.32    | 74.6      |
| 12      | Halsi         | 15.54    | 74.59     |
| 13      | Hebbal        | 15.6     | 74.56     |
| 14      | Jagalbet      | 15.33    | 74.51     |
| 15      | Jhalavali     | 15.11    | 74.35     |
| 16      | Joida         | 15.17    | 74.48     |
| 17      | Kadagarani    | 15.02    | 74.49     |
| 18      | Kanangaon     | 15.23    | 74.41     |
| 19      | Kapoli        | 15.5     | 74.54     |
| 20      | Kartoli       | 15.2     | 74.4      |
| 21      | Khanapur      | 15.64    | 74.51     |
| 22      | Kumbharda     | 15.42    | 74.58     |
| 23      | Kumbharvada   | 15.13    | 74.4      |
| 24      | Kundal        | 15.11    | 74.29     |
| 25      | Manikvadi     | 15.57    | 74.5      |
| 26      | Mudiye        | 15.17    | 74.41     |
| 27      | Nagargali     | 15.42    | 74.61     |
| 28      | Nagoda        | 15.2     | 74.47     |
| 29      | Nandgad       | 15.58    | 74.57     |
| 30      | Shindoli      | 15.59    | 74.51     |
| 31      | Shingargaon   | 15.34    | 74.55     |
| 32      | Shisai        | 15.22    | 74.33     |
| 33      | Shivthan      | 15.47    | 74.54     |
| 34      | Talapa        | 15.03    | 74.35     |
| 35      | Tavargatti    | 15.41    | 74.66     |
| 36      | Vaijgaon      | 15.37    | 74.53     |

## SYNOPSIS OF WORK DONE

|                                                                                                                                                                                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                           |  |                                 |               |                                |              |                                    |                |                                                         |              |                              |              |                  |              |                             |              |                                              |              |                               |  |                                                                                                                                                                                     |              |                                                                                                  |                                      |                                              |  |                                                    |              |                                                         |              |                                                                    |                                               |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|---------------------------------|---------------|--------------------------------|--------------|------------------------------------|----------------|---------------------------------------------------------|--------------|------------------------------|--------------|------------------|--------------|-----------------------------|--------------|----------------------------------------------|--------------|-------------------------------|--|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------|--------------------------------------------------------------------------------------------------|--------------------------------------|----------------------------------------------|--|----------------------------------------------------|--------------|---------------------------------------------------------|--------------|--------------------------------------------------------------------|-----------------------------------------------|
| 1                                                                                                                                                                                   | Title of the report                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Macro-Scale (1: 50,000) Landslide Susceptibility Mapping in Parts of Toposheets Nos. 48I/08, 48I/10 and 48I/11, Belgaum & Uttar Kannada, Districts, Karnataka and South Goa District,Goa. |  |                                 |               |                                |              |                                    |                |                                                         |              |                              |              |                  |              |                             |              |                                              |              |                               |  |                                                                                                                                                                                     |              |                                                                                                  |                                      |                                              |  |                                                    |              |                                                         |              |                                                                    |                                               |
| 2                                                                                                                                                                                   | FSP Code No                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | M4LSSM/NC/SR/SU-KG/2018/18718                                                                                                                                                             |  |                                 |               |                                |              |                                    |                |                                                         |              |                              |              |                  |              |                             |              |                                              |              |                               |  |                                                                                                                                                                                     |              |                                                                                                  |                                      |                                              |  |                                                    |              |                                                         |              |                                                                    |                                               |
| 3                                                                                                                                                                                   | Field Season                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 2018 – 2019                                                                                                                                                                               |  |                                 |               |                                |              |                                    |                |                                                         |              |                              |              |                  |              |                             |              |                                              |              |                               |  |                                                                                                                                                                                     |              |                                                                                                  |                                      |                                              |  |                                                    |              |                                                         |              |                                                                    |                                               |
| 4                                                                                                                                                                                   | Date of Commencement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 24 <sup>th</sup> September 2018                                                                                                                                                           |  |                                 |               |                                |              |                                    |                |                                                         |              |                              |              |                  |              |                             |              |                                              |              |                               |  |                                                                                                                                                                                     |              |                                                                                                  |                                      |                                              |  |                                                    |              |                                                         |              |                                                                    |                                               |
| 5                                                                                                                                                                                   | Date of Completion                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 16 <sup>th</sup> March 2019                                                                                                                                                               |  |                                 |               |                                |              |                                    |                |                                                         |              |                              |              |                  |              |                             |              |                                              |              |                               |  |                                                                                                                                                                                     |              |                                                                                                  |                                      |                                              |  |                                                    |              |                                                         |              |                                                                    |                                               |
| 6                                                                                                                                                                                   | Officers associated with the investigation and no. of days spent in the field                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Kapil Singh, Geologist (100 days),<br>Sovesh D Muduli, Geologist (102days)                                                                                                                |  |                                 |               |                                |              |                                    |                |                                                         |              |                              |              |                  |              |                             |              |                                              |              |                               |  |                                                                                                                                                                                     |              |                                                                                                  |                                      |                                              |  |                                                    |              |                                                         |              |                                                                    |                                               |
| 7                                                                                                                                                                                   | <b>Quantum of work done</b> <table><tr><td colspan="2"><b>1. Pre-field preparation</b></td></tr><tr><td>(i) Slope Forming Material map</td><td>1324 Sq. Km.</td></tr><tr><td>(ii) Geomorphology &amp; Lineament map</td><td>1324 Sq. Km.</td></tr><tr><td>(iii) Slope Morphometry (slope, aspect &amp; curvature) map</td><td>1324 Sq. Km.</td></tr><tr><td>(iv) Landuse / Landcover map</td><td>1324 Sq. Km.</td></tr><tr><td>(v) Drainage map</td><td>1324 Sq. Km.</td></tr><tr><td>(vi) Regolith thickness map</td><td>1324 Sq. Km.</td></tr><tr><td>(vii) Preparation of Landslide Inventory Map</td><td>1324 Sq. Km.</td></tr><tr><td colspan="2"><b>2. Field-based studies</b></td></tr><tr><td>(i) Field-checking of all thematic maps. Field validation of landslide inventory and collection of recent and historic landslides (using archives, old reports, road register etc.)</td><td>1324 Sq. Km.</td></tr><tr><td>(ii) Collection of landslide inventory and damage data as per 41 point geo parametric data sheet</td><td>1324 Sq. Km. (31 nos. of landslides)</td></tr><tr><td colspan="2"><b>3. Post-field studies &amp; modelling</b></td></tr><tr><td>(i) Updation of thematic and inventory maps in GIS</td><td>1324 Sq. Km.</td></tr><tr><td>(ii) Preparation of Landslide Susceptibility Map in GIS</td><td>1324 Sq. Km.</td></tr><tr><td><b>4. Collection of rainfall data from available rain stations</b></td><td>1324 Sq. Km.<br/>(Collected data for 10 years)</td></tr></table> |                                                                                                                                                                                           |  | <b>1. Pre-field preparation</b> |               | (i) Slope Forming Material map | 1324 Sq. Km. | (ii) Geomorphology & Lineament map | 1324 Sq. Km.   | (iii) Slope Morphometry (slope, aspect & curvature) map | 1324 Sq. Km. | (iv) Landuse / Landcover map | 1324 Sq. Km. | (v) Drainage map | 1324 Sq. Km. | (vi) Regolith thickness map | 1324 Sq. Km. | (vii) Preparation of Landslide Inventory Map | 1324 Sq. Km. | <b>2. Field-based studies</b> |  | (i) Field-checking of all thematic maps. Field validation of landslide inventory and collection of recent and historic landslides (using archives, old reports, road register etc.) | 1324 Sq. Km. | (ii) Collection of landslide inventory and damage data as per 41 point geo parametric data sheet | 1324 Sq. Km. (31 nos. of landslides) | <b>3. Post-field studies &amp; modelling</b> |  | (i) Updation of thematic and inventory maps in GIS | 1324 Sq. Km. | (ii) Preparation of Landslide Susceptibility Map in GIS | 1324 Sq. Km. | <b>4. Collection of rainfall data from available rain stations</b> | 1324 Sq. Km.<br>(Collected data for 10 years) |
| <b>1. Pre-field preparation</b>                                                                                                                                                     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                           |  |                                 |               |                                |              |                                    |                |                                                         |              |                              |              |                  |              |                             |              |                                              |              |                               |  |                                                                                                                                                                                     |              |                                                                                                  |                                      |                                              |  |                                                    |              |                                                         |              |                                                                    |                                               |
| (i) Slope Forming Material map                                                                                                                                                      | 1324 Sq. Km.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                                                                                                                           |  |                                 |               |                                |              |                                    |                |                                                         |              |                              |              |                  |              |                             |              |                                              |              |                               |  |                                                                                                                                                                                     |              |                                                                                                  |                                      |                                              |  |                                                    |              |                                                         |              |                                                                    |                                               |
| (ii) Geomorphology & Lineament map                                                                                                                                                  | 1324 Sq. Km.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                                                                                                                           |  |                                 |               |                                |              |                                    |                |                                                         |              |                              |              |                  |              |                             |              |                                              |              |                               |  |                                                                                                                                                                                     |              |                                                                                                  |                                      |                                              |  |                                                    |              |                                                         |              |                                                                    |                                               |
| (iii) Slope Morphometry (slope, aspect & curvature) map                                                                                                                             | 1324 Sq. Km.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                                                                                                                           |  |                                 |               |                                |              |                                    |                |                                                         |              |                              |              |                  |              |                             |              |                                              |              |                               |  |                                                                                                                                                                                     |              |                                                                                                  |                                      |                                              |  |                                                    |              |                                                         |              |                                                                    |                                               |
| (iv) Landuse / Landcover map                                                                                                                                                        | 1324 Sq. Km.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                                                                                                                           |  |                                 |               |                                |              |                                    |                |                                                         |              |                              |              |                  |              |                             |              |                                              |              |                               |  |                                                                                                                                                                                     |              |                                                                                                  |                                      |                                              |  |                                                    |              |                                                         |              |                                                                    |                                               |
| (v) Drainage map                                                                                                                                                                    | 1324 Sq. Km.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                                                                                                                           |  |                                 |               |                                |              |                                    |                |                                                         |              |                              |              |                  |              |                             |              |                                              |              |                               |  |                                                                                                                                                                                     |              |                                                                                                  |                                      |                                              |  |                                                    |              |                                                         |              |                                                                    |                                               |
| (vi) Regolith thickness map                                                                                                                                                         | 1324 Sq. Km.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                                                                                                                           |  |                                 |               |                                |              |                                    |                |                                                         |              |                              |              |                  |              |                             |              |                                              |              |                               |  |                                                                                                                                                                                     |              |                                                                                                  |                                      |                                              |  |                                                    |              |                                                         |              |                                                                    |                                               |
| (vii) Preparation of Landslide Inventory Map                                                                                                                                        | 1324 Sq. Km.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                                                                                                                           |  |                                 |               |                                |              |                                    |                |                                                         |              |                              |              |                  |              |                             |              |                                              |              |                               |  |                                                                                                                                                                                     |              |                                                                                                  |                                      |                                              |  |                                                    |              |                                                         |              |                                                                    |                                               |
| <b>2. Field-based studies</b>                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                           |  |                                 |               |                                |              |                                    |                |                                                         |              |                              |              |                  |              |                             |              |                                              |              |                               |  |                                                                                                                                                                                     |              |                                                                                                  |                                      |                                              |  |                                                    |              |                                                         |              |                                                                    |                                               |
| (i) Field-checking of all thematic maps. Field validation of landslide inventory and collection of recent and historic landslides (using archives, old reports, road register etc.) | 1324 Sq. Km.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                                                                                                                           |  |                                 |               |                                |              |                                    |                |                                                         |              |                              |              |                  |              |                             |              |                                              |              |                               |  |                                                                                                                                                                                     |              |                                                                                                  |                                      |                                              |  |                                                    |              |                                                         |              |                                                                    |                                               |
| (ii) Collection of landslide inventory and damage data as per 41 point geo parametric data sheet                                                                                    | 1324 Sq. Km. (31 nos. of landslides)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                                                                           |  |                                 |               |                                |              |                                    |                |                                                         |              |                              |              |                  |              |                             |              |                                              |              |                               |  |                                                                                                                                                                                     |              |                                                                                                  |                                      |                                              |  |                                                    |              |                                                         |              |                                                                    |                                               |
| <b>3. Post-field studies &amp; modelling</b>                                                                                                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                           |  |                                 |               |                                |              |                                    |                |                                                         |              |                              |              |                  |              |                             |              |                                              |              |                               |  |                                                                                                                                                                                     |              |                                                                                                  |                                      |                                              |  |                                                    |              |                                                         |              |                                                                    |                                               |
| (i) Updation of thematic and inventory maps in GIS                                                                                                                                  | 1324 Sq. Km.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                                                                                                                           |  |                                 |               |                                |              |                                    |                |                                                         |              |                              |              |                  |              |                             |              |                                              |              |                               |  |                                                                                                                                                                                     |              |                                                                                                  |                                      |                                              |  |                                                    |              |                                                         |              |                                                                    |                                               |
| (ii) Preparation of Landslide Susceptibility Map in GIS                                                                                                                             | 1324 Sq. Km.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                                                                                                                           |  |                                 |               |                                |              |                                    |                |                                                         |              |                              |              |                  |              |                             |              |                                              |              |                               |  |                                                                                                                                                                                     |              |                                                                                                  |                                      |                                              |  |                                                    |              |                                                         |              |                                                                    |                                               |
| <b>4. Collection of rainfall data from available rain stations</b>                                                                                                                  | 1324 Sq. Km.<br>(Collected data for 10 years)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                           |  |                                 |               |                                |              |                                    |                |                                                         |              |                              |              |                  |              |                             |              |                                              |              |                               |  |                                                                                                                                                                                     |              |                                                                                                  |                                      |                                              |  |                                                    |              |                                                         |              |                                                                    |                                               |
| 8                                                                                                                                                                                   | <b>Expenditure</b> <table><tr><td>Wages (Rs.)</td><td>Rs. 77,313.00</td></tr><tr><td>OC (Rs.)</td><td>Rs. 37789.00</td></tr><tr><td>Total (Rs.)</td><td>Rs. 1,15102.00</td></tr></table> <p>* Outsourced vehicle used for field.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                                                                           |  | Wages (Rs.)                     | Rs. 77,313.00 | OC (Rs.)                       | Rs. 37789.00 | Total (Rs.)                        | Rs. 1,15102.00 |                                                         |              |                              |              |                  |              |                             |              |                                              |              |                               |  |                                                                                                                                                                                     |              |                                                                                                  |                                      |                                              |  |                                                    |              |                                                         |              |                                                                    |                                               |
| Wages (Rs.)                                                                                                                                                                         | Rs. 77,313.00                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                           |  |                                 |               |                                |              |                                    |                |                                                         |              |                              |              |                  |              |                             |              |                                              |              |                               |  |                                                                                                                                                                                     |              |                                                                                                  |                                      |                                              |  |                                                    |              |                                                         |              |                                                                    |                                               |
| OC (Rs.)                                                                                                                                                                            | Rs. 37789.00                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                                                                                                                           |  |                                 |               |                                |              |                                    |                |                                                         |              |                              |              |                  |              |                             |              |                                              |              |                               |  |                                                                                                                                                                                     |              |                                                                                                  |                                      |                                              |  |                                                    |              |                                                         |              |                                                                    |                                               |
| Total (Rs.)                                                                                                                                                                         | Rs. 1,15102.00                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                                                                           |  |                                 |               |                                |              |                                    |                |                                                         |              |                              |              |                  |              |                             |              |                                              |              |                               |  |                                                                                                                                                                                     |              |                                                                                                  |                                      |                                              |  |                                                    |              |                                                         |              |                                                                    |                                               |

## FIVE POINT PROFORMA

|                                                                                                                                                                                                                    |                                                                                                                                                                                                                                                                            |                |          |                    |          |              |                 |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------|----------|--------------------|----------|--------------|-----------------|
| <b>Title of the report:</b> Macro-Scale (1:50,000) Landslide Susceptibility Mapping in Parts of Toposheets Nos. 48I8, 48I/10 And 48I/11 Belgaum and Uttar Kannada Districts, Karnataka and South Goa District, Goa |                                                                                                                                                                                                                                                                            |                |          |                    |          |              |                 |
| 1. Background of the investigation at whose instance or with what particular objective in view the investigation was undertaken                                                                                    | The item was taken up as per the annual programme of GSI vide FSP Code No: M4LSSM/NC/SR/SU-KG/2018/18718 with an objective to prepare seamless Landslide Susceptibility Map of India.                                                                                      |                |          |                    |          |              |                 |
| 2. Whether the item of investigation was included in the approved programme for the year concerned. If so, particulars, such as item No. page reference etc. may be given.                                         | Yes<br>FSP Code No: M4LSSM/NC/SR/SU-KG/2018/18718                                                                                                                                                                                                                          |                |          |                    |          |              |                 |
| 3. Date of commencement of the investigation with month and year, and exact number of days spent by the officer(s) in the field in connection with the investigation.                                              | 24 <sup>th</sup> September 2018<br><table style="margin-left: auto; margin-right: auto;"> <tr> <td>1. Kapil Singh</td> <td>100 days</td> </tr> <tr> <td>2. Sovesh D Muduli</td> <td>102 days</td> </tr> <tr> <td><b>Total</b></td> <td><b>202 days</b></td> </tr> </table> | 1. Kapil Singh | 100 days | 2. Sovesh D Muduli | 102 days | <b>Total</b> | <b>202 days</b> |
| 1. Kapil Singh                                                                                                                                                                                                     | 100 days                                                                                                                                                                                                                                                                   |                |          |                    |          |              |                 |
| 2. Sovesh D Muduli                                                                                                                                                                                                 | 102 days                                                                                                                                                                                                                                                                   |                |          |                    |          |              |                 |
| <b>Total</b>                                                                                                                                                                                                       | <b>202 days</b>                                                                                                                                                                                                                                                            |                |          |                    |          |              |                 |
| 4. Brief comments by Director / Supervisory officer on the conclusion and recommendation by the author(s) with suggestion for implementing the same.                                                               | I fully agree with the conclusions drawn and recommendations made by the authors.                                                                                                                                                                                          |                |          |                    |          |              |                 |
| 5. Please state specifically how the results of the investigation were achieved compared with the objective for which it was undertaken                                                                            | The objective of the investigation is fully achieved.                                                                                                                                                                                                                      |                |          |                    |          |              |                 |
| Date:<br><br>Place: Bengaluru                                                                                                                                                                                      | Shri J. Srihari<br>Director                                                                                                                                                                                                                                                |                |          |                    |          |              |                 |



## GEOLOGICAL SURVEY OF INDIA

### Certificate of Quality of the report

**Project/ Division:** NLSM/EG Division **FSP No.:** M4LSM/NC/SR/SUKG/2018/18718  
**Mission:** IV

**Title of the report:** Macro-Scale (1: 50,000) Landslide Susceptibility Mapping in Parts of Toposheets Nos. 48I/08, 48I/10 and 48I/11, Belgaum & Uttar Kannada, Districts, Karnataka and South Goa District, Goa.

**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 required laboratory analysis, compilation and synthesis of field data, collation of the data and writing of the report as per the approved guidelines. The duration of field stay of each Officer is as against his/ her name.

| Name and designation of the Officer | Total field stay during the FSP (No. of days) | Signature with date |
|-------------------------------------|-----------------------------------------------|---------------------|
| 1. Kapil Singh, Geologist           | 100 days                                      |                     |
| 2. Sovesh Dulal Muduli, Geologist   | 102 days                                      |                     |

**Part-B:** This is to certify that drilling has been carried out and completed as per the table given below: Not Applicable

| Drilling Unit No | Date of commencement of drilling | Date of completion of drilling | Name and signature of the Director Drilling |
|------------------|----------------------------------|--------------------------------|---------------------------------------------|
| 1.               |                                  |                                |                                             |
| 2.               |                                  |                                |                                             |

**Part-C:** This is to certify that geophysical component of the item has been carried out as per the table given below: ---- Not Applicable -----

| Name(s)<br>Designation of the geophysicist | Date of commencement of work | Date of completion of work | Signature of the Geophysicist with date |
|--------------------------------------------|------------------------------|----------------------------|-----------------------------------------|
| 1.                                         |                              |                            |                                         |
| 2.                                         |                              |                            |                                         |
| Name of the Director (Geophysics)          |                              |                            |                                         |
| Signature with date                        |                              |                            |                                         |

**Part-D:** This is to certify that the chemical analysis of the geological samples has been carried out as per the table given below - Not applicable.

| Name of the Director in charge of the Laboratory | Date of receipt of samples from the Field Officer/ party | Date of providing complete analytical results to the Field Officer/ party | Signature with date |
|--------------------------------------------------|----------------------------------------------------------|---------------------------------------------------------------------------|---------------------|
|                                                  |                                                          |                                                                           |                     |

**Part -E:** This is to certify that the Supervisory Officer(s) mentioned below 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 table below. 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) and designation of the Supervisory Officers | No. of inspection visits | Total No. of days spent on inspection visit | Signature with date |
|-----------------------------------------------------|--------------------------|---------------------------------------------|---------------------|
| 1. Shri. J. Srihari, Director                       | 02                       | 05                                          |                     |

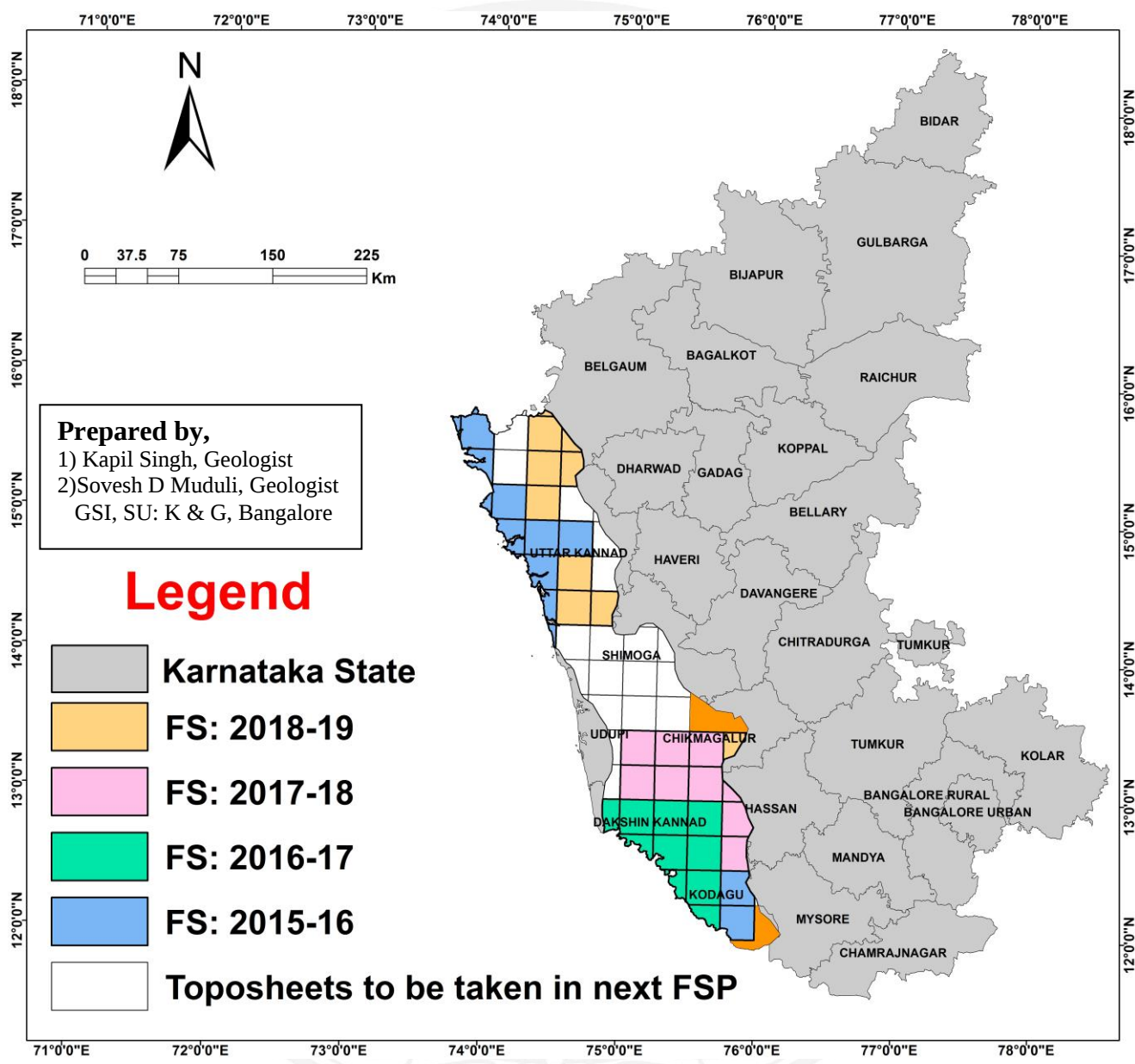
**Part-F:** This is to certify that the report has been thoroughly scrutinized at the Regional Mission Head level. The scientific contents and the quality of the report are certified. The report has been peer reviewed and the needful corrections have been attended to.

| Name and designation of the Regional Mission Head | Signature with date |
|---------------------------------------------------|---------------------|
|                                                   |                     |

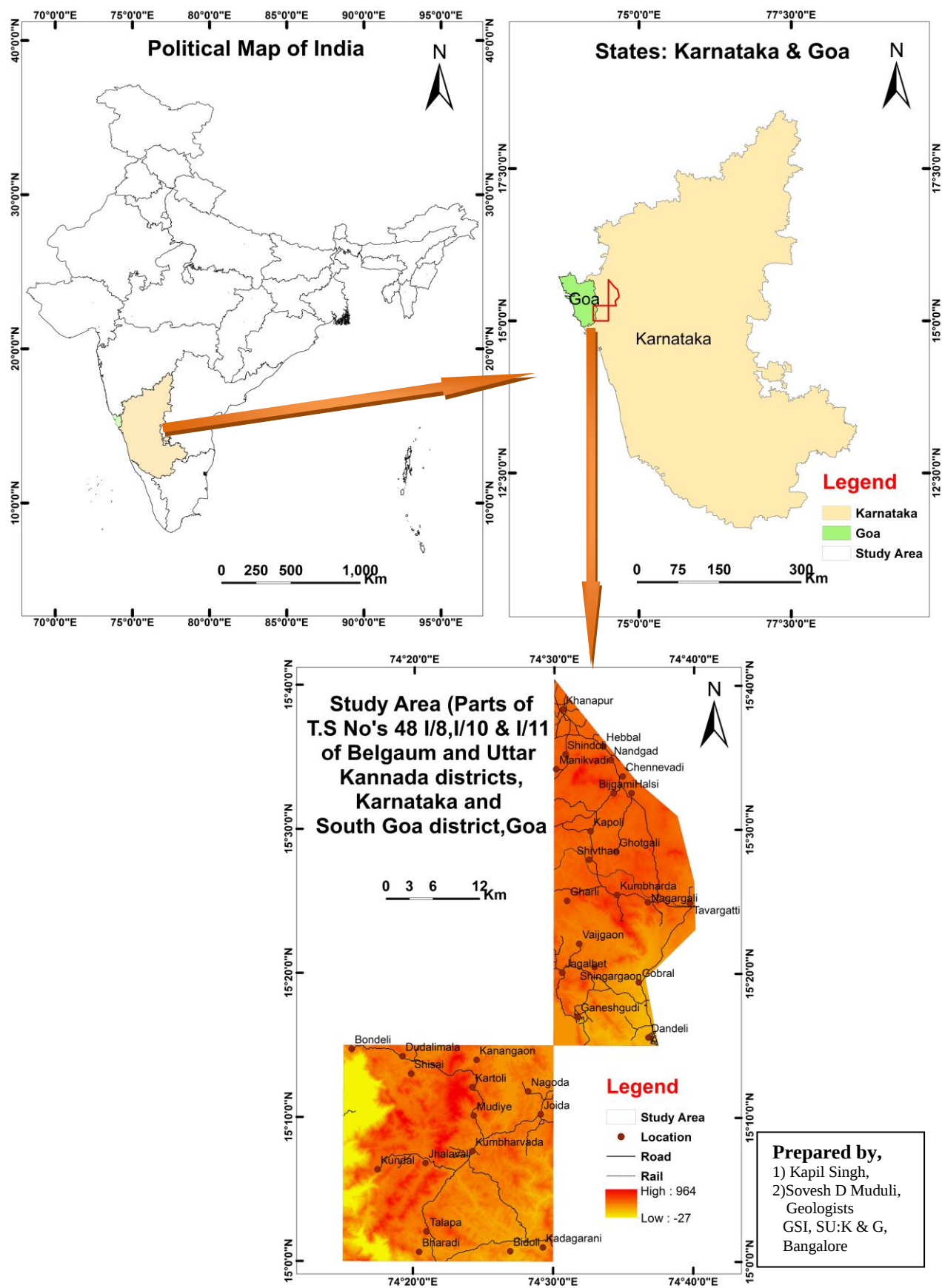
**Part-G:** This is to certify that the report has been scrutinized at various levels and has also been peer reviewed. On being satisfied regarding the scientific content and quality of the report, the undersigned has accorded approval for its circulation.

| Name and designation of the Regional HOD | Signature with date |
|------------------------------------------|---------------------|
|                                          |                     |

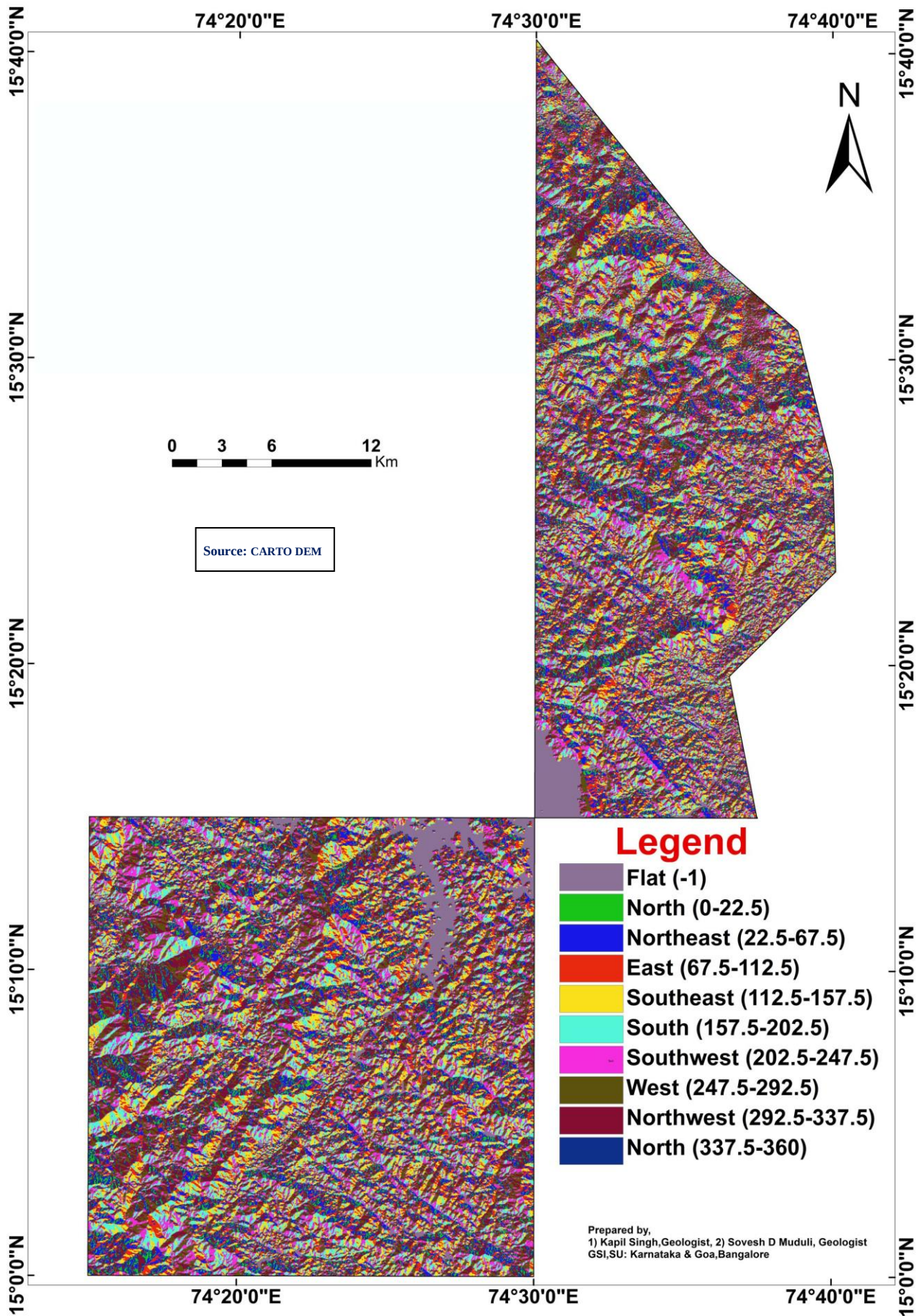
Map showing Western Ghat area mapped for landslide susceptibility under  
Karnataka for FS: 2015 to 2018 at 1:50,000 Scale



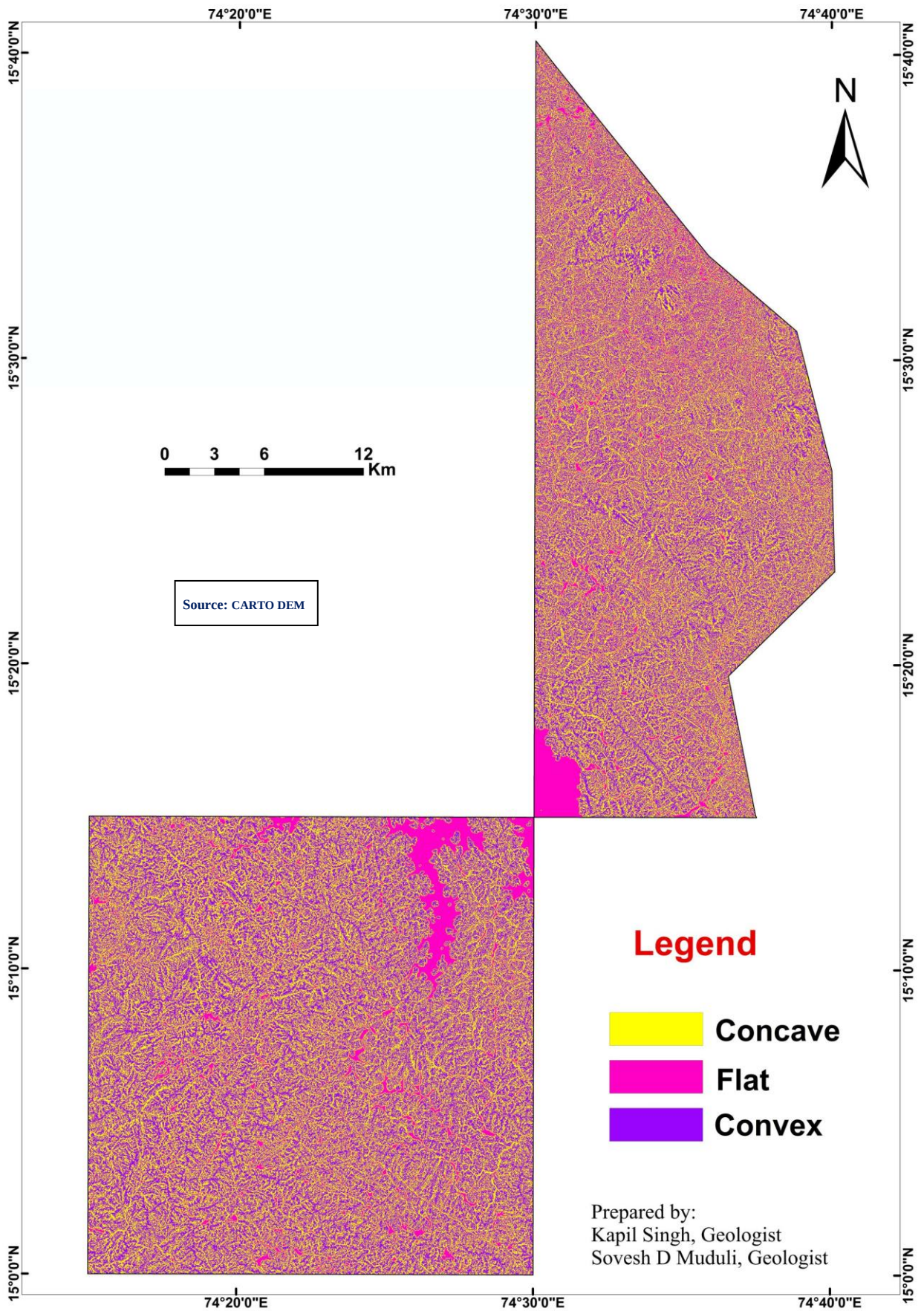
LOCATION MAP OF THE STUDY AREA



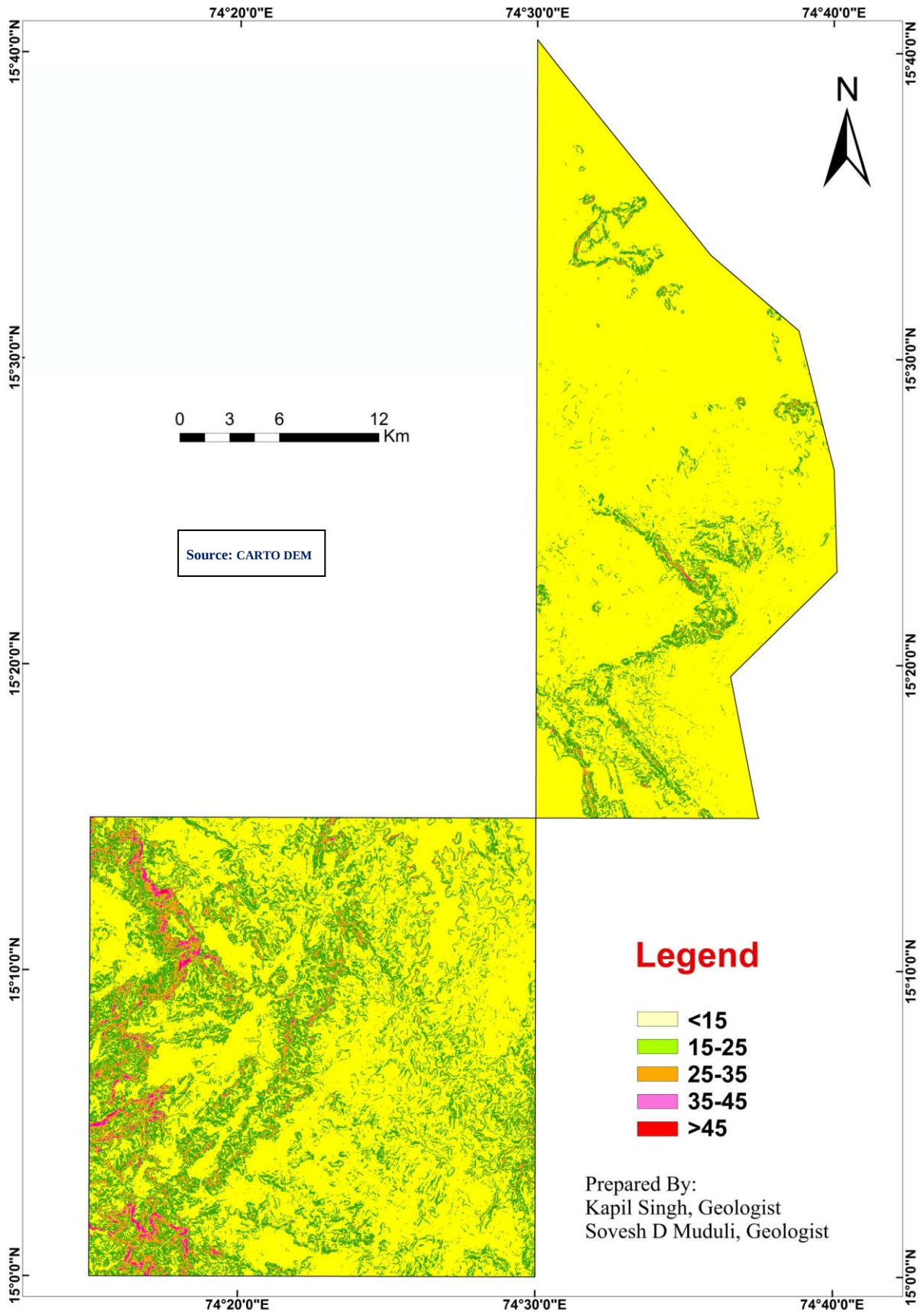
**Slope Aspect Map of Parts of Toposheet Nos. 48I/8, I/10 and I/11 in Belgaum and Uttar Kannada Districts, Karnataka and South Goa District, Goa**



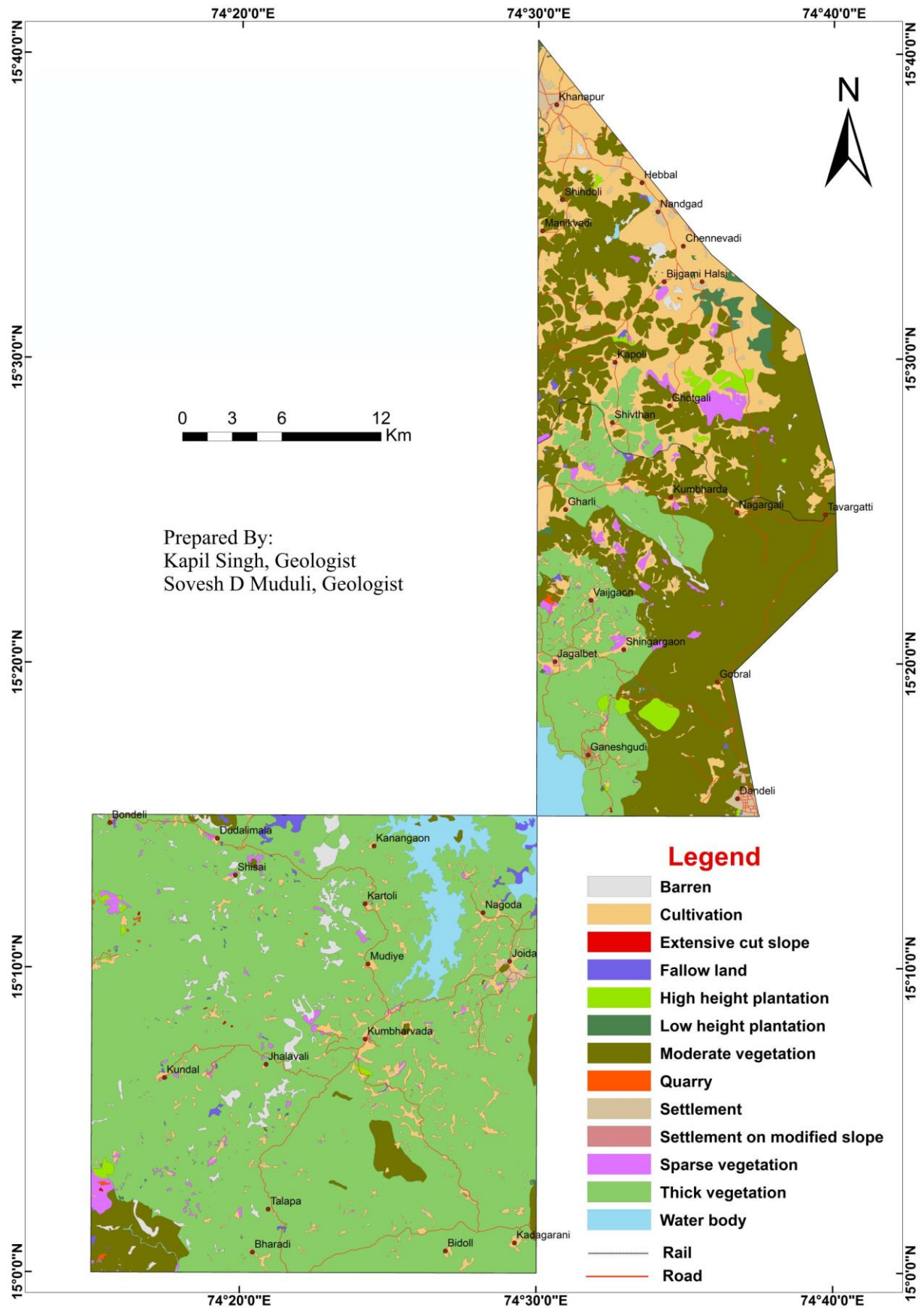
**Slope Curvature Map of Parts of Toposheet Nos. 48I/8, I/10 and I/11 in Belgaum and Uttar  
Kannada Districts, Karnataka and South Goa District, Goa**



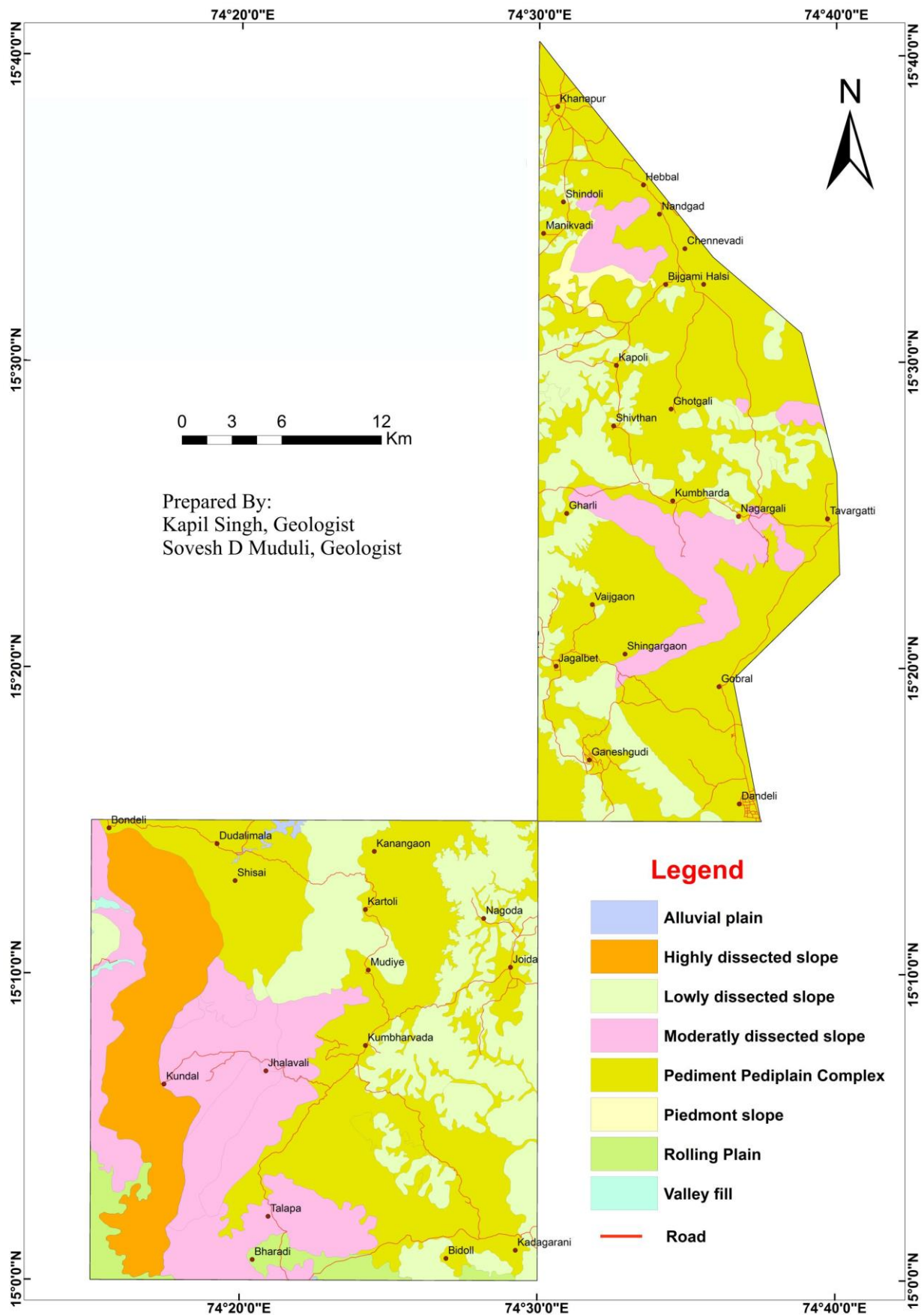
**Slope Gradient Map of Parts of Toposheet Nos. 48I/8, I/10 and I/11 in Belgaum and Uttar Kannada Districts, Karnataka and South Goa District, Goa**



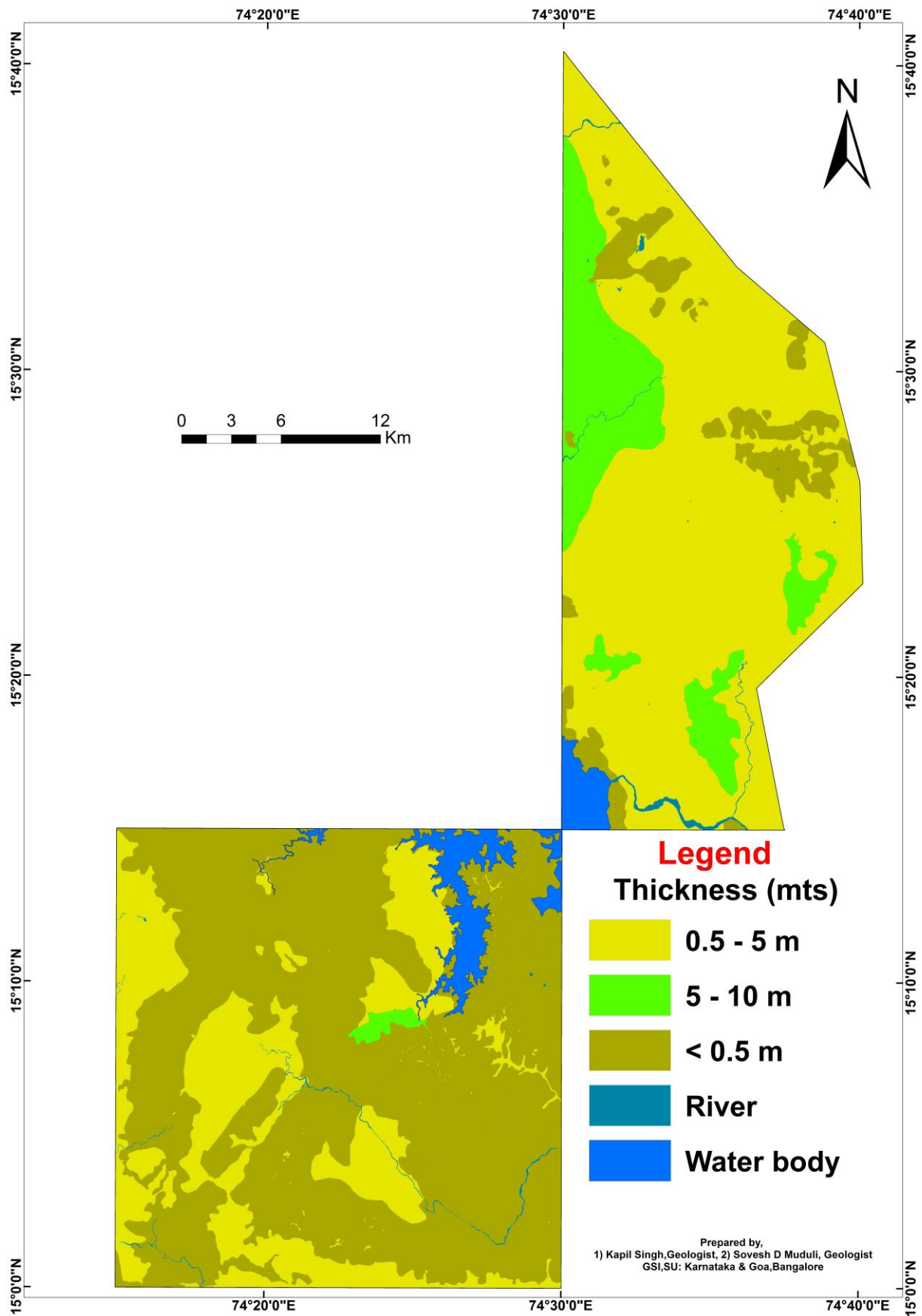
# Land Use and Land Cover Map in Parts of Toposheet Nos. 48I/8, I/10 and I/11 of Belgaum and Uttar Kannada Districts, Karnataka and South Goa District, Goa



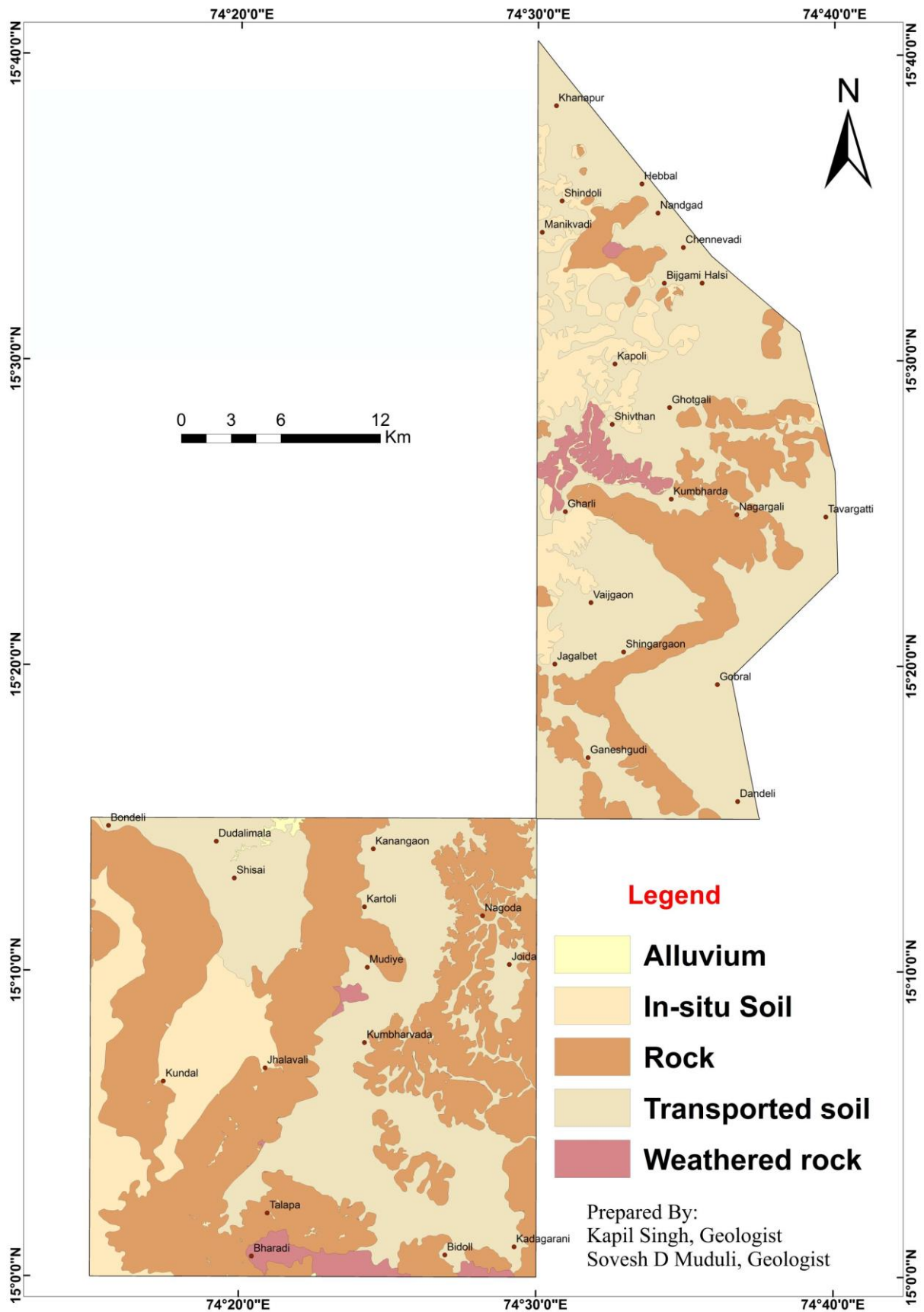
# Geomorphology Map in Parts of Toposheet Nos. 48I/8, I/10 and I/11 of Belgaum and Uttar Kannada Districts, Karnataka and South Goa District, Goa



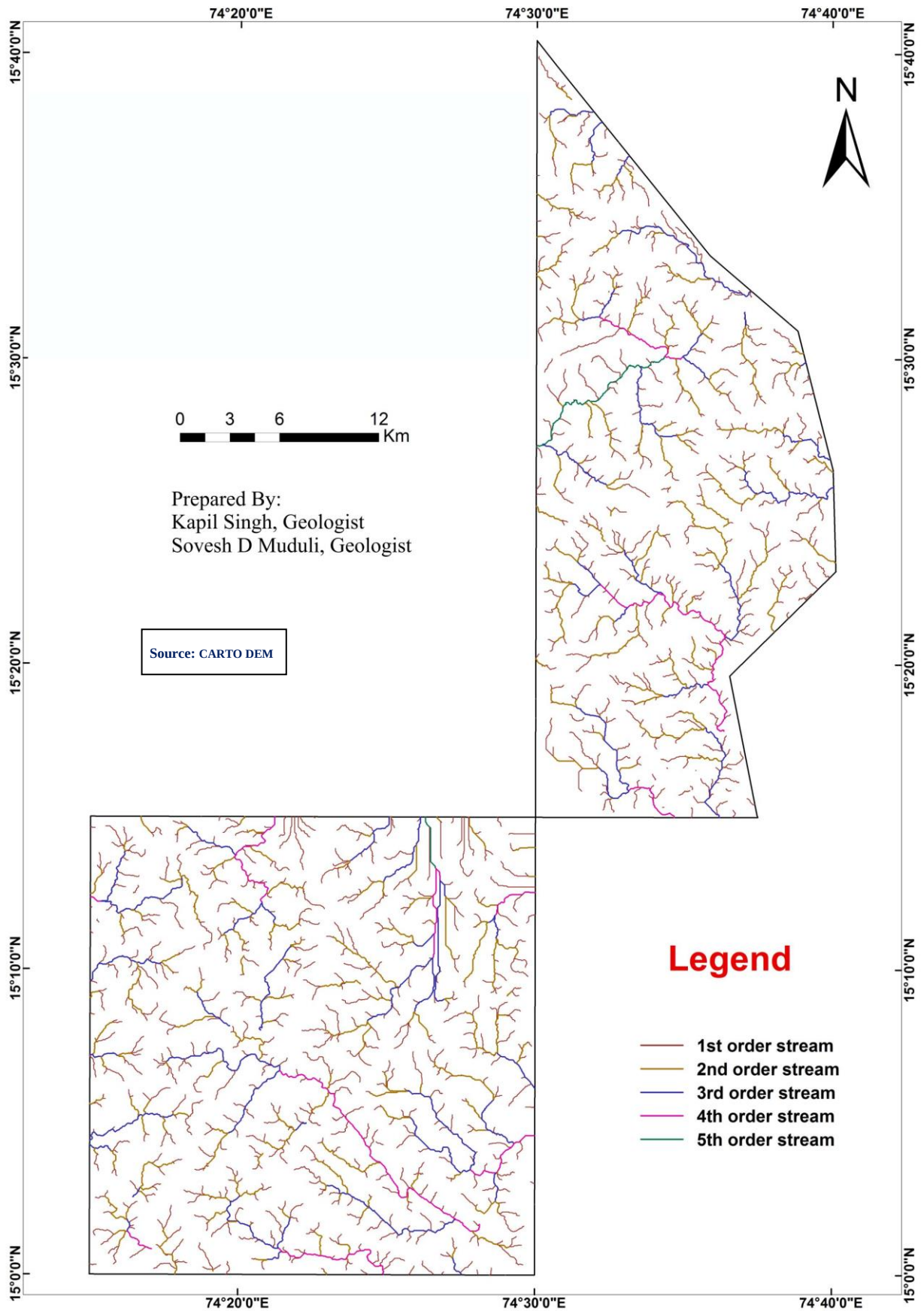
**Regolith Thickness Map in Parts of Toposheet Nos. 48I/8, I/10 and I/11 of Belgaum and Uttar Kannada Districts, Karnataka and South Goa District, Goa**



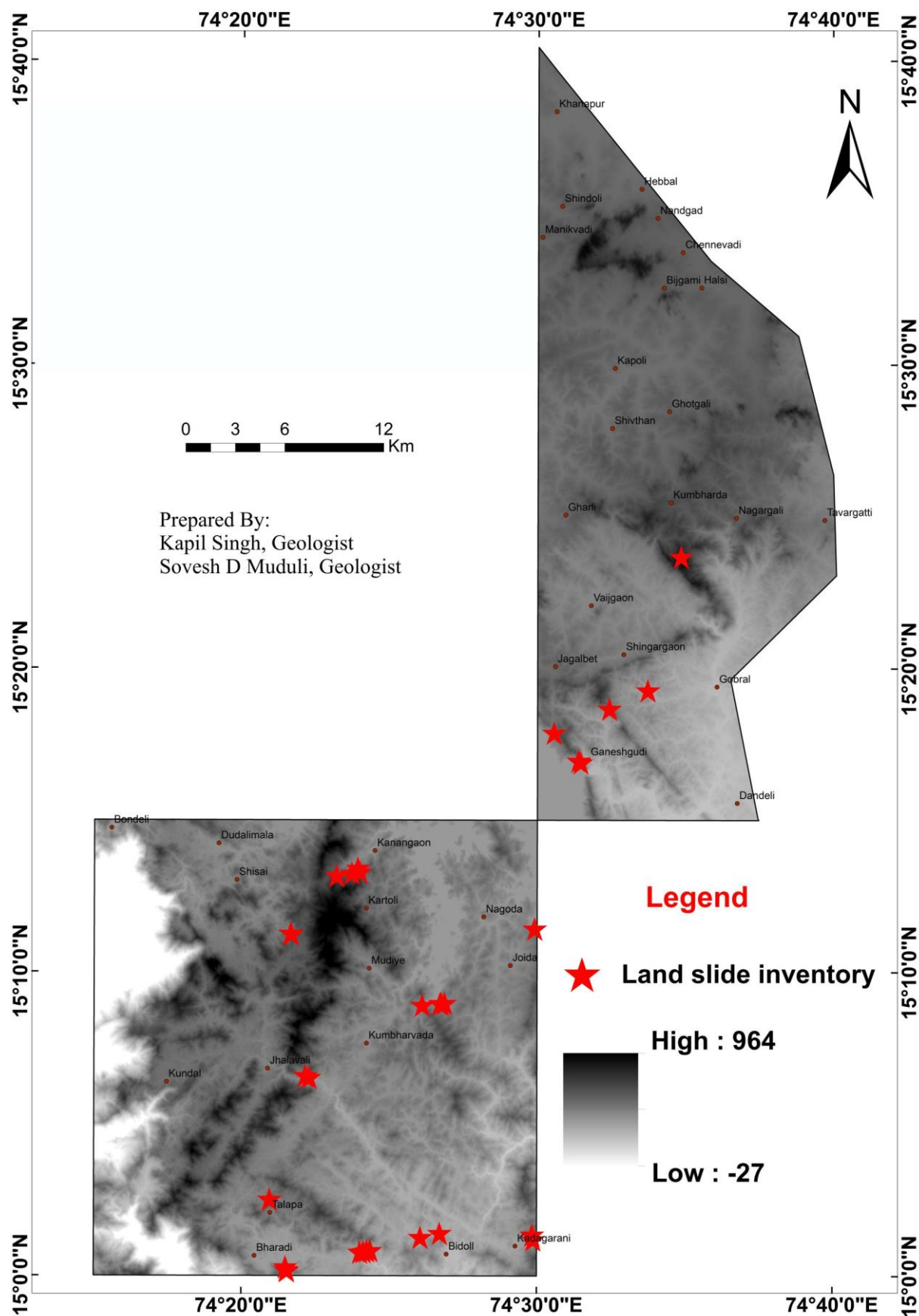
**Slope Forming Material Map in Parts of Toposheet Nos. 48I/8, I/10 and I/11 of Belgaum and Uttar Kannada Districts, Karnataka and South Goa District, Goa**



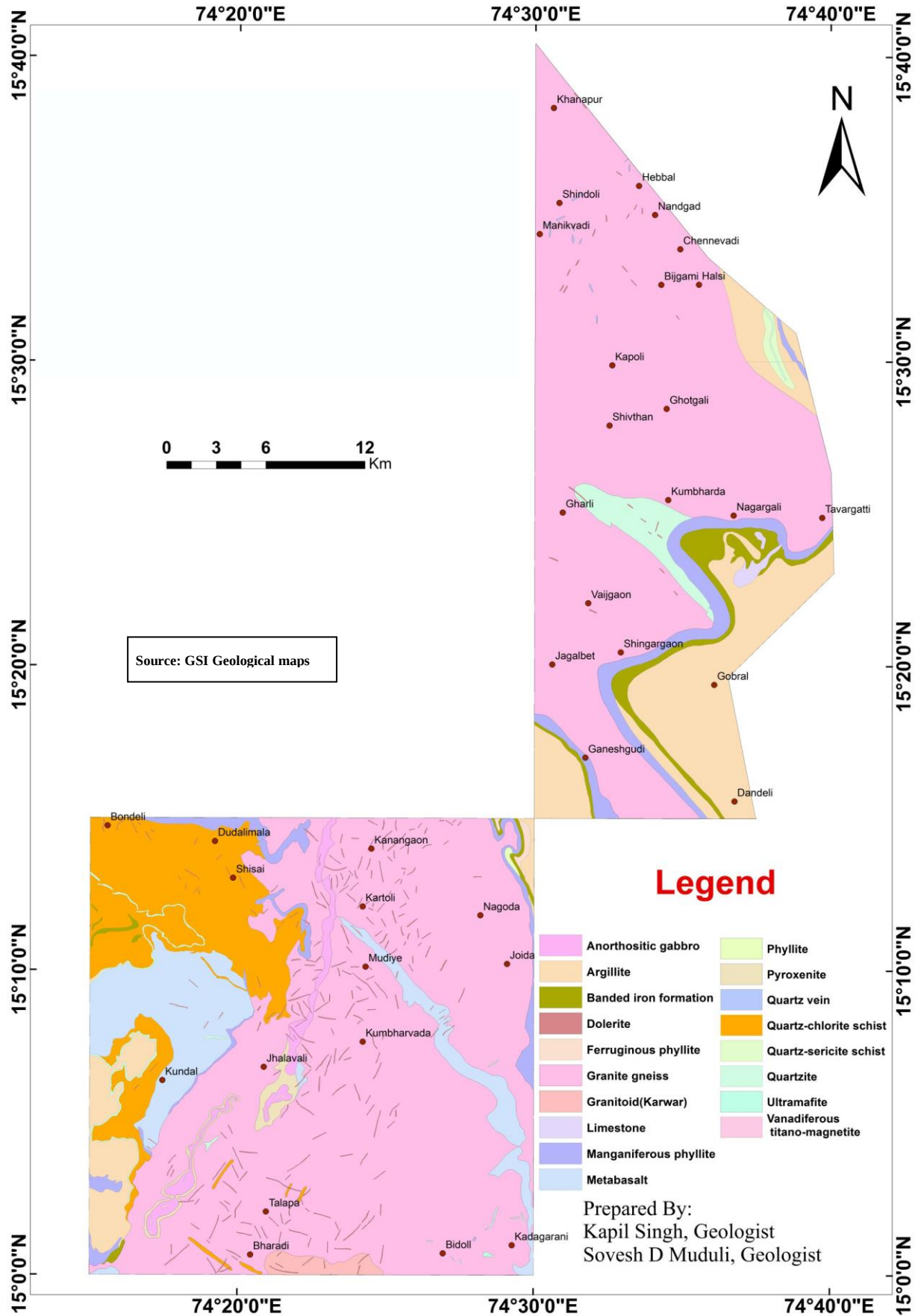
**Drainage Map in Parts of Toposheet Nos. 48I/8, I/10 and I/11 of Belgaum and Uttar  
Kannada Districts, Karnataka and South Goa District, Goa**



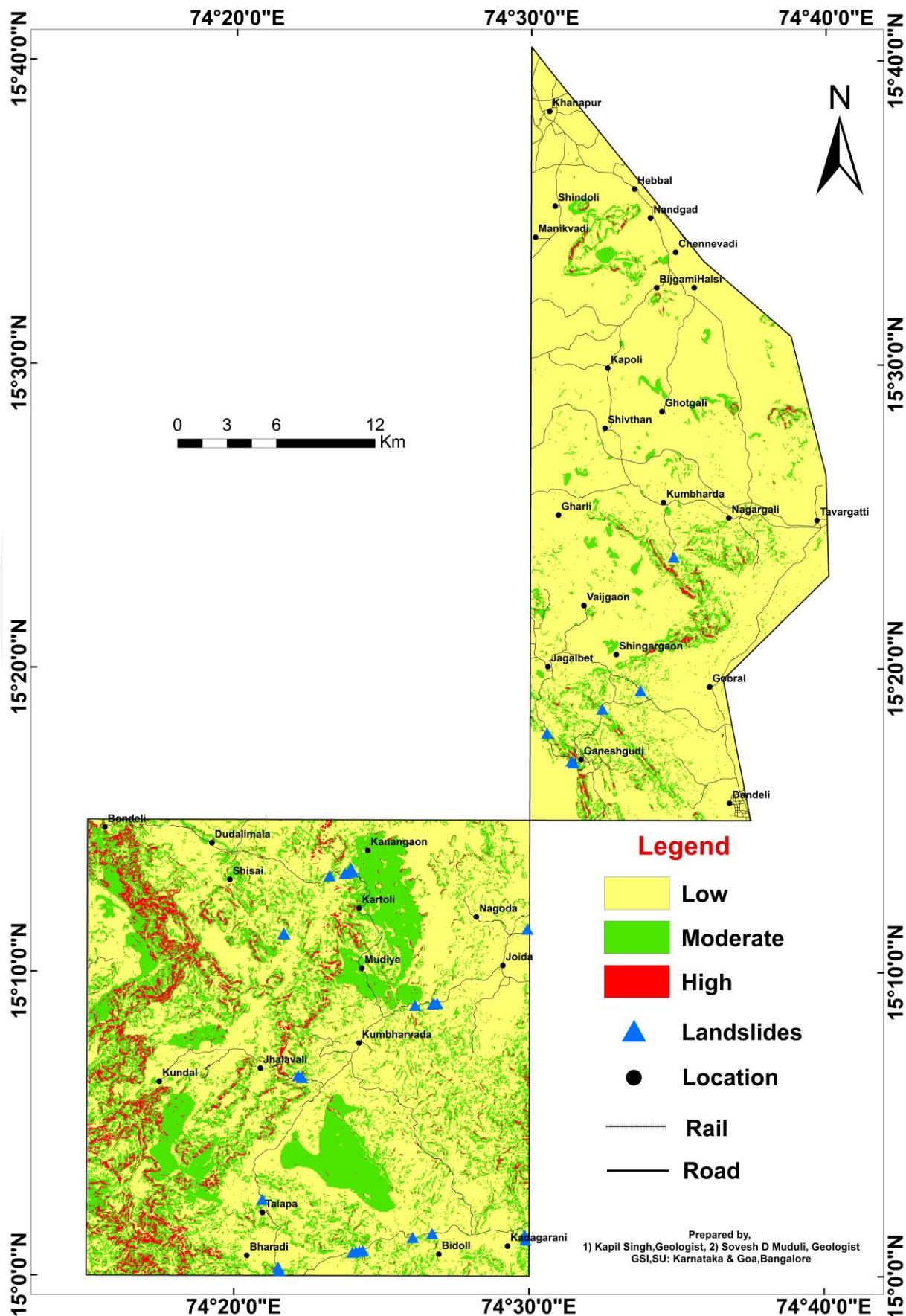
# Landslide Inventory Map in Parts of Toposheet Nos. 48I/8, I/10 and I/11 of Belgaum and Uttar Kannada Districts, Karnataka and South Goa District, Goa



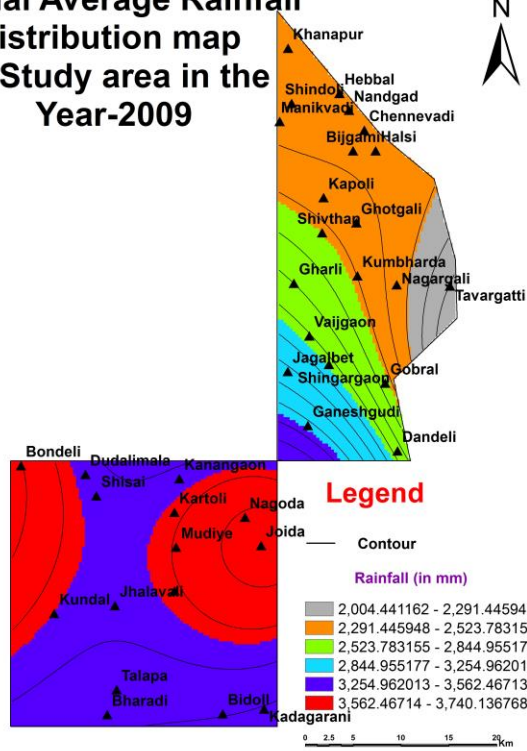
**Lithology Map in Parts of Toposheet Nos. 48I/8, I/10 and I/11 of Belgaum and Uttar  
Kannada Districts, Karnataka and South Goa District, Goa**



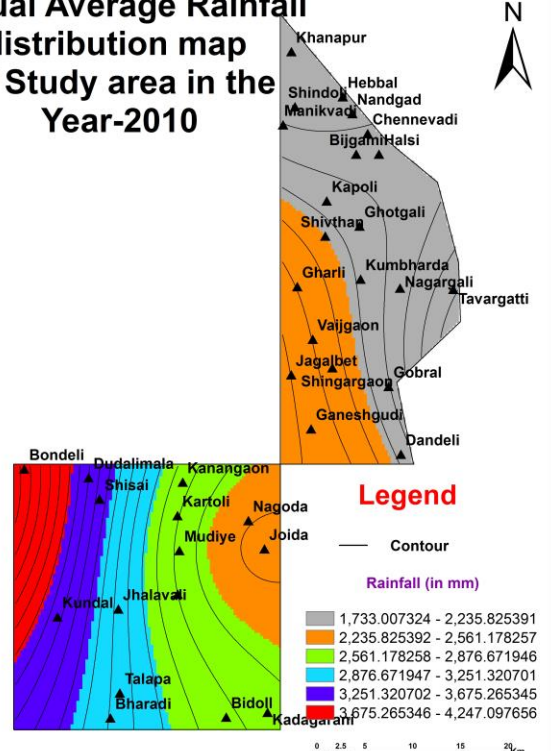
# Landslide Susceptibility Map in Parts of Toposheet Nos. 48I/8, I/10 and I/11 of Belgaum and Uttar Kannada Districts, Karnataka and South Goa District, Goa



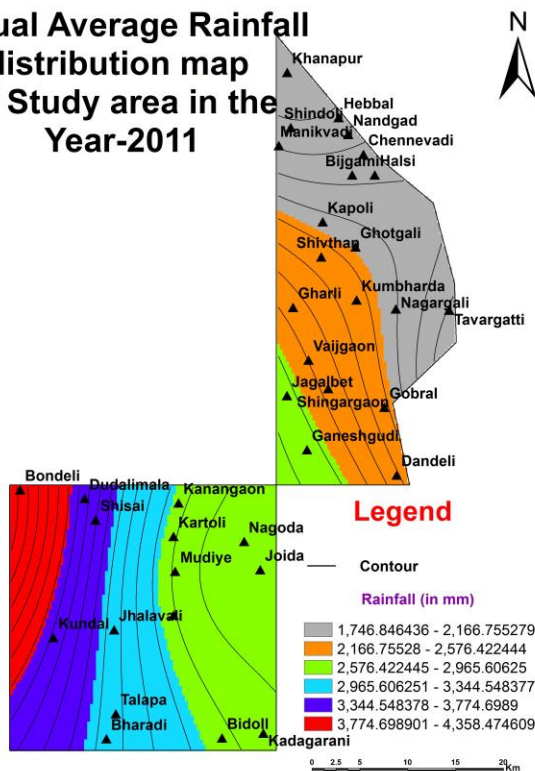
**Annual Average Rainfall  
distribution map  
of Study area in the  
Year-2009**



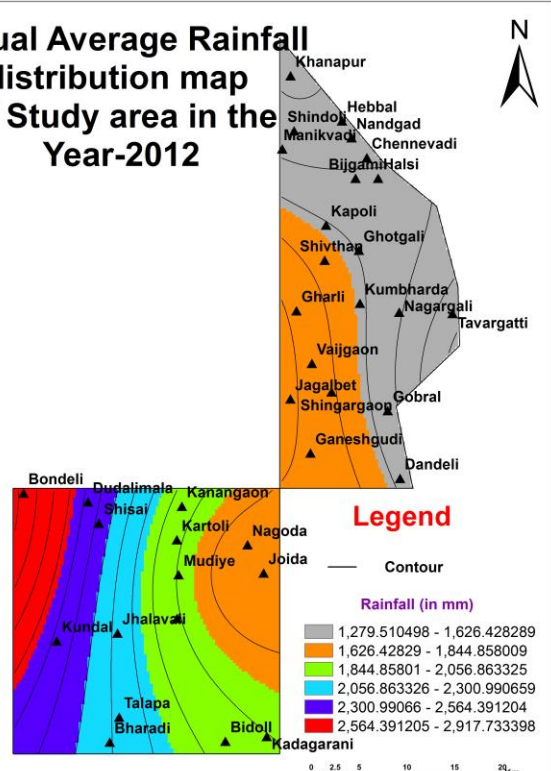
**Annual Average Rainfall  
distribution map  
of Study area in the  
Year-2010**



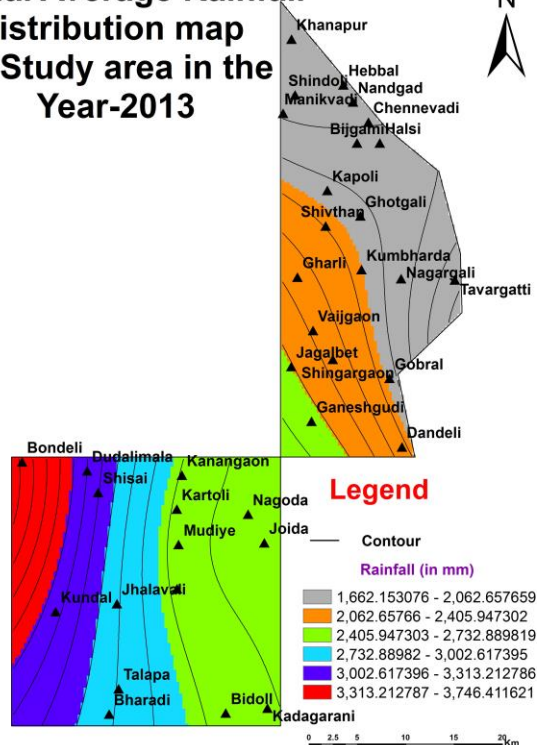
**Annual Average Rainfall  
distribution map  
of Study area in the  
Year-2011**



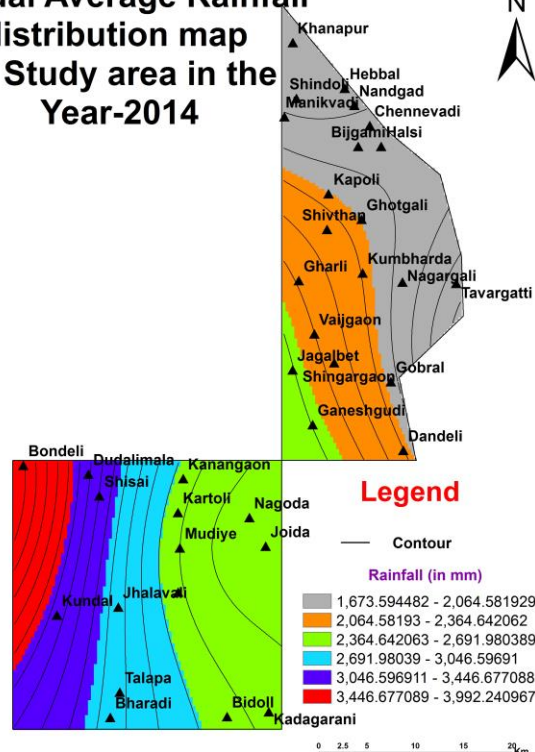
**Annual Average Rainfall  
distribution map  
of Study area in the  
Year-2012**



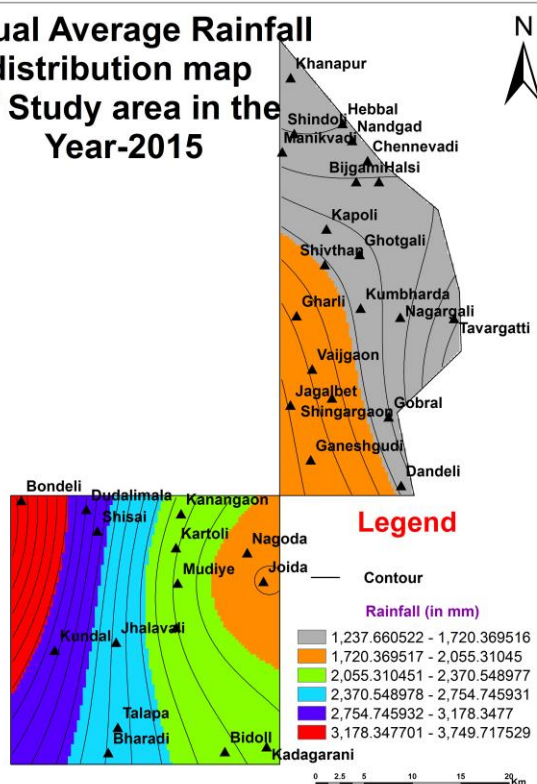
**Annual Average Rainfall  
distribution map  
of Study area in the  
Year-2013**



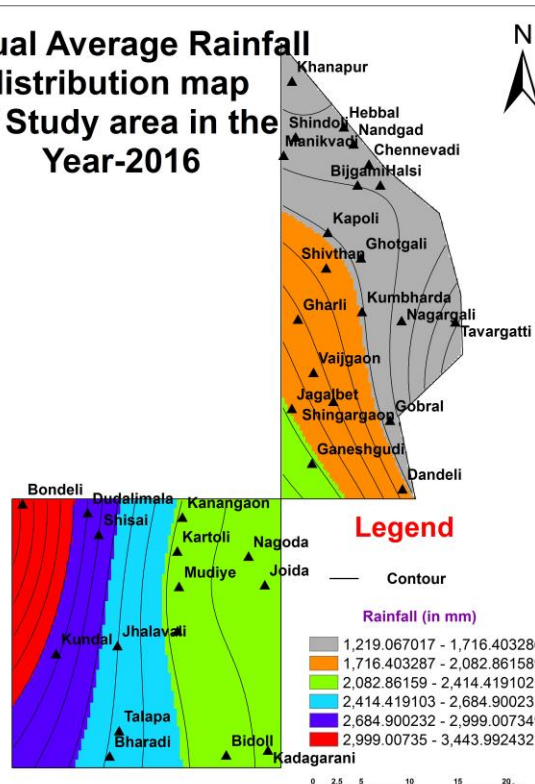
**Annual Average Rainfall  
distribution map  
of Study area in the  
Year-2014**

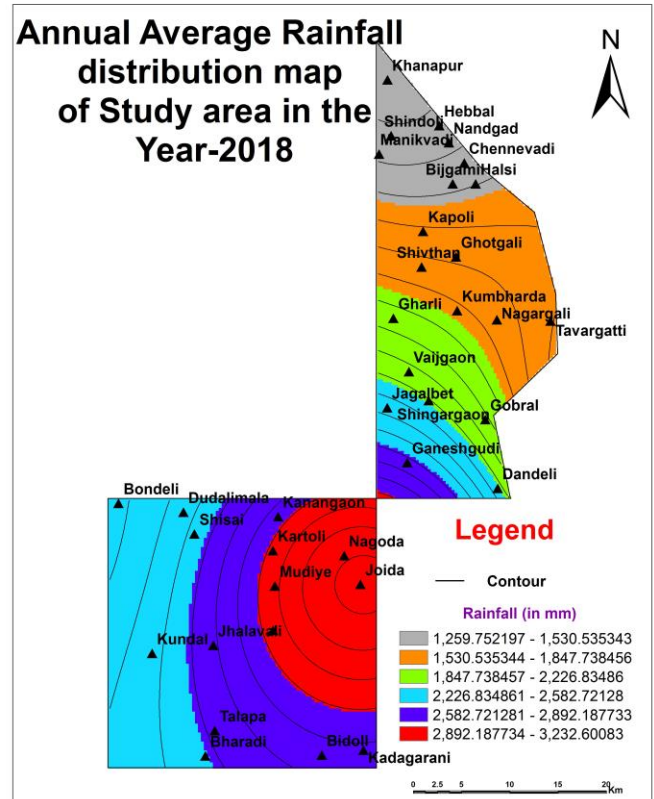
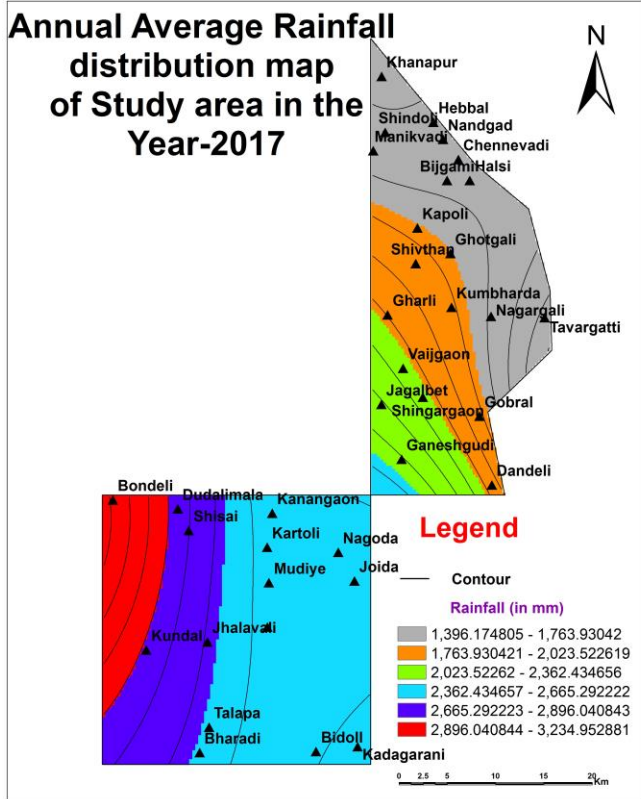


**Annual Average Rainfall  
distribution map  
of Study area in the  
Year-2015**



**Annual Average Rainfall  
distribution map  
of Study area in the  
Year-2016**





# **FIELD PHOTOGRAPHS**





**Photo 1: Extensive Cut Slope in in-situ soil. South-West of Usoda, TS No. 48I/11.**



**Photo 2: Regolith thickness (~5m), E of Jhalavali, TS No. 48I/08.**



**Photo 3: Extensive Cut Slope for making bricks & settlement, Vill. Chandrali, TS No. 48I/8.**



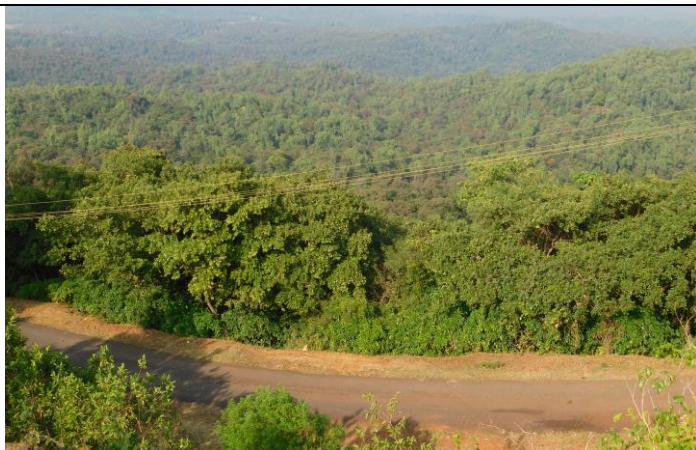
**Photo 4: Old landside scar, near Umbarpani, TS No. 48I/11.**



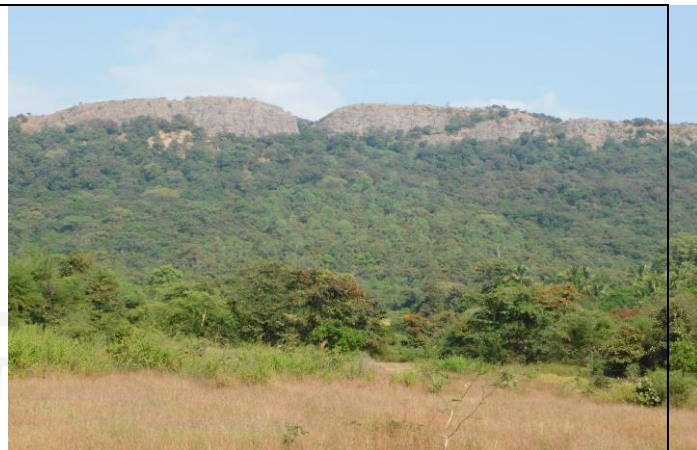
**Photo 5: Slope failure with retaining wall on both the side of road, West of Vill. Ghotaki, TS No. 48I/8**



**Photo 6: Multiple mass failures along road with regolith thickness >5m, NW of Terali, TS No. 48I/8**



**Photo 7: Reserved forest with lowly dissected hills, on the North of Kumbharda; TS No. 48I/11.**



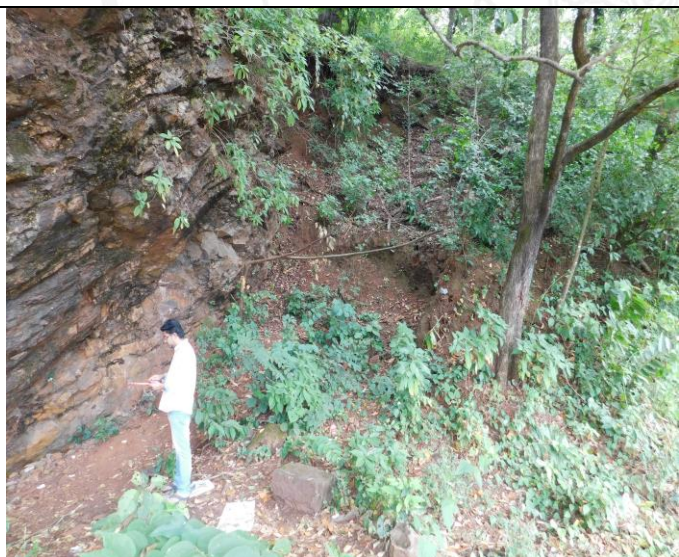
**Photo 8: Barren ridge top showing hard rock with steep slope; East of Gharli, TS No. 48I/11.**



**Photo 9: Abandoned/Old Manganese ore mine at fold closure, ESE of Dudalimala; TS No. 48I/8.**



**Photo 10: Granite Quarry, North of Kumbhal; TS No. 48I/11.**



**Photo 11: Shallow translational failure in BIF (closely jointed) occurred in contact with Phyllite, NW of Virkhol; TS No. 48I/11**



**Photo 12: Litho-Contact between Pyroxenite & weathered Gabbro. Mass Failure has been distinct along the discontinuity plane, East of Jhalavali; TS No. 48I/8.**



**Photo 13: Change in Land use Pattern, Soil excavation for construction purpose, East of Jhalavali; TS No. 48I/8.**



**Photo 14: Change in Land use Pattern, Nala has been converted into cultivation land, North of Kumbral ; TS No. 48I/11**



**Photo 15: Natural course of nala obstructed, Road cracks observed due to removal of soil underneath indicating subsidence, SW of Kanangaon; TS No. 48I/8**



**Photo 16: Transportational water Tunnel, Benching & Rock pitching provided for slope stabilization, East of Kumbharvada; TS No. 48I/8.**



**Photo 17: Extensive vertical cut slope observed in West of Kutvali; TS No. 48I/8.**



**Photo 18: Settlements on modified slope observed in Vill. Chandrali, TS No. 48I/8**

## ANNEXURE-I

Calculation of LOFS and consistency ratio (CR) for all factor maps



**Annexure – I: Calculation of LOFS and consistency ratio (CR) for all factor maps.**

**Geofactor: Geomorphology**  
**Rank of Geomorphology Classes**

| Sl No | Class Name                   | Code       | Rank |
|-------|------------------------------|------------|------|
| 1     | Denudational Slope           | DS         | 9    |
| 2     | Escarpment                   | ESC        | 2    |
| 3     | Mound                        | MOUND      | 2    |
| 4     | Colluvial Foot Slope         | CFS        | 3    |
| 5     | Lowly Dissected Slope        | LDS        | 4    |
| 6     | Moderately Dissected Slope   | MDS        | 6    |
| 7     | Highly Dissected Slope       | HDS        | 8    |
| 8     | Piedmont Slope               | PIED SLOPE | 4    |
| 9     | Ridge - top                  | RT         | 0    |
| 10    | Tidal Flat                   | TF         | 0    |
| 11    | Colluvial Plain              | CP         | 0    |
| 12    | Plateau Top (Flat)           | PT         | 0    |
| 13    | Rolling Plain                | RP         | 0    |
| 14    | Valley Fill                  | VF         | 0    |
| 15    | Alluvial Plain               | AP         | 0    |
| 16    | Beach                        | BE         | 0    |
| 17    | Pediment – Pediplain Complex | PPC        | 0    |
| 18    | Hilltop                      | HT         | 0    |
| 19    | Water body                   | WB         | 0    |

**Geofactor: Geomorphology**  
**Matrix of Pairwise Ratings of Geomorphology Class**

| GEOM       | DS   | ESC   | MOUND | CFS   | LDS   | MDS  | HDS  | PIED SLOPE |
|------------|------|-------|-------|-------|-------|------|------|------------|
| DS         | 1.00 | 8.00  | 8.00  | 7.00  | 6.00  | 4.00 | 2.00 | 6.00       |
| ESC        | 0.13 | 1.00  | 1.00  | 0.50  | 0.33  | 0.20 | 0.14 | 0.33       |
| MOUND      | 0.13 | 1.00  | 1.00  | 0.50  | 0.33  | 0.20 | 0.14 | 0.33       |
| CFS        | 0.14 | 2.00  | 2.00  | 1.00  | 0.50  | 0.25 | 0.17 | 0.50       |
| LDS        | 0.17 | 3.00  | 3.00  | 2.00  | 1.00  | 0.33 | 0.20 | 1.00       |
| MDS        | 0.25 | 5.00  | 5.00  | 4.00  | 3.00  | 1.00 | 0.33 | 3.00       |
| HDS        | 0.50 | 7.00  | 7.00  | 6.00  | 5.00  | 3.00 | 1.00 | 5.00       |
| PIED SLOPE | 0.17 | 3.00  | 3.00  | 2.00  | 1.00  | 0.33 | 0.20 | 1.00       |
| Sum Column | 2.48 | 30.00 | 30.00 | 23.00 | 17.17 | 9.32 | 4.19 | 17.17      |

| GEOM       | DS     | ESC    | MOUND  | CFS    | LDS    | MDS    | HDS    | PIED SLOPE | Sum Rows | Frac Weight | LOFS   |
|------------|--------|--------|--------|--------|--------|--------|--------|------------|----------|-------------|--------|
| DS         | 0.4038 | 0.2667 | 0.2667 | 0.3043 | 0.3495 | 0.4293 | 0.4778 | 0.3495     | 2.8477   | 0.3560      | 1.0000 |
| ESC        | 0.0505 | 0.0333 | 0.0333 | 0.0217 | 0.0194 | 0.0215 | 0.0341 | 0.0194     | 0.2333   | 0.0292      | 0.0819 |
| MOUND      | 0.0505 | 0.0333 | 0.0333 | 0.0217 | 0.0194 | 0.0215 | 0.0341 | 0.0194     | 0.2333   | 0.0292      | 0.0819 |
| CFS        | 0.0577 | 0.0667 | 0.0667 | 0.0435 | 0.0291 | 0.0268 | 0.0398 | 0.0291     | 0.3594   | 0.0449      | 0.1262 |
| LDS        | 0.0673 | 0.1000 | 0.1000 | 0.0870 | 0.0583 | 0.0358 | 0.0478 | 0.0583     | 0.5543   | 0.0693      | 0.1947 |
| MDS        | 0.1010 | 0.1667 | 0.1667 | 0.1739 | 0.1748 | 0.1073 | 0.0796 | 0.1748     | 1.1447   | 0.1431      | 0.4020 |
| HDS        | 0.2019 | 0.2333 | 0.2333 | 0.2609 | 0.2913 | 0.3220 | 0.2389 | 0.2913     | 2.0729   | 0.2591      | 0.7279 |
| PIED SLOPE | 0.0673 | 0.1000 | 0.1000 | 0.0870 | 0.0583 | 0.0358 | 0.0478 | 0.0583     | 0.5543   | 0.0693      | 0.1947 |

## Geofactor: Geomorphology

### Estimation of consistency vector (CV), consistency index (CI) and consistency ratio (CR) for Geomorphology classes

[illegible]

**Geofactor: Slope Forming Material (SFM)**  
**Rank of SFM Classes**

| Sl No | Class Name            | Code    | Rank |
|-------|-----------------------|---------|------|
| 1     | Compact Slide Debris  | CSD     | 3    |
| 2     | In – situ Soil        | IS      | 4    |
| 3     | Colluvium             | CL      | 5    |
| 4     | Loose Slide Debris    | LSD     | 8    |
| 5     | Rock Class Type – I   | R - I   | 1    |
| 6     | Rock Class Type – II  | R - II  | 2    |
| 7     | Rock Class Type – III | R - III | 4    |
| 8     | Transported Soil      | TS      | 3    |
| 9     | Weathered Rock        | WR      | 6    |
| 10    | Salt                  | SL      | 0    |
| 11    | Water                 | WT      | 0    |
| 12    | Alluvium              | AL      | 0    |
| 13    | Barren Sand           | BS      | 0    |

**Geofactor: Slope Forming Material (SFM)**  
**Matrix of Pairwise Ratings of SFM Class**

| SFM        | CSD   | IS    | CL   | LSD  | R – I | R – II | R – III | TS    | WR   |
|------------|-------|-------|------|------|-------|--------|---------|-------|------|
| CSD        | 1.00  | 0.50  | 0.33 | 0.17 | 3.00  | 2.00   | 0.50    | 1.00  | 0.25 |
| IS         | 2.00  | 1.00  | 0.50 | 0.20 | 4.00  | 3.00   | 1.00    | 2.00  | 0.33 |
| CL         | 3.00  | 2.00  | 1.00 | 0.25 | 5.00  | 4.00   | 2.00    | 3.00  | 0.50 |
| LSD        | 6.00  | 5.00  | 4.00 | 1.00 | 8.00  | 7.00   | 5.00    | 6.00  | 3.00 |
| R - I      | 0.33  | 0.25  | 0.20 | 0.13 | 1.00  | 0.50   | 0.25    | 0.33  | 0.17 |
| R - II     | 0.50  | 0.33  | 0.25 | 0.14 | 2.00  | 1.00   | 0.33    | 0.50  | 0.20 |
| R - III    | 2.00  | 1.00  | 0.50 | 0.20 | 4.00  | 3.00   | 1.00    | 2.00  | 0.33 |
| TS         | 1.00  | 0.50  | 0.33 | 0.17 | 3.00  | 2.00   | 0.50    | 1.00  | 0.25 |
| WR         | 4.00  | 3.00  | 2.00 | 0.33 | 6.00  | 5.00   | 3.00    | 4.00  | 1.00 |
| Sum Column | 19.83 | 13.58 | 9.12 | 2.58 | 36.00 | 27.50  | 13.58   | 19.83 | 6.03 |

**Estimated Eigen values, fraction rate and LOFS for SFM classes**

| SFM     | CSD    | IS     | CL     | LSD    | R – I  | R – II | R – III | TS     | WR     | Sum Rows | Frac Weight | LOFS   |
|---------|--------|--------|--------|--------|--------|--------|---------|--------|--------|----------|-------------|--------|
| CSD     | 0.0504 | 0.0368 | 0.0366 | 0.0645 | 0.0833 | 0.0727 | 0.0368  | 0.0504 | 0.0414 | 0.4730   | 0.0526      | 0.1506 |
| IS      | 0.1008 | 0.0736 | 0.0548 | 0.0774 | 0.1111 | 0.1091 | 0.0736  | 0.1008 | 0.0552 | 0.7566   | 0.0841      | 0.2409 |
| CL      | 0.1513 | 0.1472 | 0.1097 | 0.0967 | 0.1389 | 0.1455 | 0.1472  | 0.1513 | 0.0829 | 1.1706   | 0.1301      | 0.3727 |
| LSD     | 0.3025 | 0.3681 | 0.4388 | 0.3869 | 0.2222 | 0.2545 | 0.3681  | 0.3025 | 0.4972 | 3.1409   | 0.3490      | 1.0000 |
| R - I   | 0.0168 | 0.0184 | 0.0219 | 0.0484 | 0.0278 | 0.0182 | 0.0184  | 0.0168 | 0.0276 | 0.2143   | 0.0238      | 0.0682 |
| R - II  | 0.0252 | 0.0245 | 0.0274 | 0.0553 | 0.0556 | 0.0364 | 0.0245  | 0.0252 | 0.0331 | 0.3073   | 0.0341      | 0.0978 |
| R - III | 0.1008 | 0.0736 | 0.0548 | 0.0774 | 0.1111 | 0.1091 | 0.0736  | 0.1008 | 0.0552 | 0.7566   | 0.0841      | 0.2409 |
| TS      | 0.0504 | 0.0368 | 0.0366 | 0.0645 | 0.0833 | 0.0727 | 0.0368  | 0.0504 | 0.0414 | 0.4730   | 0.0526      | 0.1506 |
| WR      | 0.2017 | 0.2209 | 0.2194 | 0.1290 | 0.1667 | 0.1818 | 0.2209  | 0.2017 | 0.1657 | 1.7077   | 0.1897      | 0.5437 |

### Estimation of consistency vector (CV), consistency index (CI) and consistency ratio (CR) for SFM classes

[illegible]

**Geofactor: Regolith Thickness**  
**Rank of Regolith Thickness Classes**

| Sl No | Class Name  | Code        | Rank |
|-------|-------------|-------------|------|
| 1     | < 0.5 m     | < 0.5 m     | 0    |
| 2     | 0.5 m – 5 m | 0.5 m – 5 m | 7    |
| 3     | 5 m – 10 m  | 5 m – 10 m  | 4    |
| 4     | > 10 m      | > 10 m      | 2    |

**Matrix of Pairwise Ratings of Regolith Thickness Class**

| Regolith Thickness | 0.5 – 5 m | 5 – 10 m | > 10 m |
|--------------------|-----------|----------|--------|
| 0.5 – 5 m          | 1.00      | 4.00     | 6.00   |
| 5 – 10 m           | 0.25      | 1.00     | 3.00   |
| > 10 m             | 0.17      | 0.33     | 1.00   |
| Sum Column         | 1.42      | 5.33     | 10.00  |

**Geofactor: Regolith Thickness**  
**Estimated Eigen values, fraction rate and LOFS for Regolith Thickness classes**

| Regolith Thickness | 0.5 – 5 m | 5 – 10 m | > 10 m | Sum Rows | Frac Weight | LOFS   |
|--------------------|-----------|----------|--------|----------|-------------|--------|
| 0.5 – 5 m          | 0.705882  | 0.75     | 0.6    | 2.055882 | 0.685294    | 1.0000 |
| 5 – 10 m           | 0.176471  | 0.1875   | 0.3    | 0.663971 | 0.221324    | 0.3230 |
| > 10 m             | 0.117647  | 0.0625   | 0.1    | 0.280147 | 0.093382    | 0.1363 |

**Estimation of consistency vector (CV), consistency index (CI) and consistency ratio (CR) for Regolith Thickness classes**

| Regolith Thickness                                                                               | 0.5 – 5 m | 5 – 10 m | > 10 m   | Sum Rows | CV       |
|--------------------------------------------------------------------------------------------------|-----------|----------|----------|----------|----------|
| 0.5 – 5 m                                                                                        | 0.685294  | 0.885294 | 0.560294 | 2.130882 | 3.109442 |
| 5 – 10 m                                                                                         | 0.171324  | 0.221324 | 0.280147 | 0.672794 | 3.039867 |
| > 10 m                                                                                           | 0.114216  | 0.073775 | 0.093382 | 0.281373 | 3.013123 |
| Sum CV                                                                                           |           |          |          |          | 9.162433 |
| Mean Consistency Vector (Mean CV) = Total CV/ Nos. Of factor class (9.162433/3) =                |           |          |          |          | 3.054144 |
| Consistency Index (CI) = (Mean CV - No. Of criteria/ factor class) / (No. Of factor class - 1) = |           |          |          |          | 0.027072 |
| Consistency Ratio (CR) = CI/ RI = 0.027072 / 0.58 =                                              |           |          |          |          | 0.0467   |

**Geofactor: Slope Angle**  
**Rank of Slope Angle Classes**

| Sl No | Class Name | Code      | Rank |
|-------|------------|-----------|------|
| 1     | < 15°      | < 15°     | 4    |
| 2     | 15° - 25°  | 15° - 25° | 6    |
| 3     | 25° - 35°  | 25° - 35° | 8    |
| 4     | 35° - 45°  | 35° - 45° | 5    |
| 5     | > 45°      | > 45°     | 4    |

### Matrix of Pairwise Ratings of Slope Angle Class

| Slope Class | < 15° | 15° - 25° | 25° - 35° | 35° - 45° | > 45° |
|-------------|-------|-----------|-----------|-----------|-------|
| < 15°       | 1.00  | 0.33      | 0.20      | 0.50      | 1.00  |
| 15° - 25°   | 3.00  | 1.00      | 0.33      | 2.00      | 3.00  |
| 25° - 35°   | 5.00  | 3.00      | 1.00      | 4.00      | 5.00  |
| 35° - 45°   | 2.00  | 0.50      | 0.25      | 1.00      | 2.00  |
| > 45°       | 1.00  | 0.33      | 0.20      | 0.50      | 1.00  |
| Sum Column  | 12.00 | 5.17      | 1.98      | 8.00      | 12.00 |

## Geofactor: Slope Angle

### Estimated Eigen values, fraction rate and LOFS for Slope Angle classes

| Slope Class | < 15°       | 15° - 25°   | 25° - 35°   | 35° - 45° | > 45°       | Sum Rows    | Frac Weight | LOFS   |
|-------------|-------------|-------------|-------------|-----------|-------------|-------------|-------------|--------|
| < 15°       | 0.083333333 | 0.064516129 | 0.100840336 | 0.0625    | 0.083333333 | 0.394523132 | 0.078904626 | 0.1631 |
| 15° - 25°   | 0.25        | 0.193548387 | 0.168067227 | 0.25      | 0.25        | 1.111615614 | 0.222323123 | 0.4597 |
| 25° - 35°   | 0.416666667 | 0.580645161 | 0.504201681 | 0.5       | 0.416666667 | 2.418180175 | 0.483636035 | 1.0000 |
| 35° - 45°   | 0.166666667 | 0.096774194 | 0.12605042  | 0.125     | 0.166666667 | 0.681157947 | 0.136231589 | 0.2817 |
| > 45°       | 0.083333333 | 0.064516129 | 0.100840336 | 0.0625    | 0.083333333 | 0.394523132 | 0.078904626 | 0.1631 |

### Estimation of consistency vector (CV), consistency index (CI) and consistency ratio (CR) for Slope Angle classes

[illegible]

**Geofactor: Slope Curvature**  
**Rank of Slope Curvature Classes**

| Sl No | Class Name | Code    | Rank |
|-------|------------|---------|------|
| 1     | < -0.1     | Concave | 4    |
| 2     | -0.1 – 0.1 | Flat    | 2    |
| 3     | > 0.1      | Convex  | 6    |

**Matrix of Pairwise Ratings of Slope Curvature Class**

| Slope Curvature | Concave | Flat | Convex |
|-----------------|---------|------|--------|
| Concave         | 1.00    | 3.00 | 0.33   |
| Flat            | 0.33    | 1.00 | 0.20   |
| Convex          | 3.00    | 5.00 | 1.00   |
| Sum Column      | 4.33    | 9.00 | 1.53   |

**Geofactor: Slope Curvature**  
**Estimated Eigen values, fraction rate and LOFS for Slope Curvature classes**

| Slope Curvature | Concave  | Flat     | Convex   | Sum Rows | Frac Weight | LOFS   |
|-----------------|----------|----------|----------|----------|-------------|--------|
| Concave         | 0.230769 | 0.333333 | 0.217391 | 0.781494 | 0.260498    | 0.4113 |
| Flat            | 0.076923 | 0.111111 | 0.130435 | 0.318469 | 0.106156    | 0.1676 |
| Convex          | 0.692308 | 0.555556 | 0.652174 | 1.900037 | 0.633346    | 1.0000 |

**Estimation of consistency vector (CV), consistency index(CI) and consistency ratio (CR) for Slope Angle classes**

| Slope Curvature                                                                                  | Concave  | Flat     | Convex   | Sum Rows      | CV              |
|--------------------------------------------------------------------------------------------------|----------|----------|----------|---------------|-----------------|
| Concave                                                                                          | 0.260498 | 0.318469 | 0.211115 | 0.790082      | 3.032969        |
| Flat                                                                                             | 0.086833 | 0.106156 | 0.126669 | 0.319658      | 3.011202        |
| Convex                                                                                           | 0.781494 | 0.530782 | 0.633346 | 1.945621      | 3.071973        |
|                                                                                                  |          |          |          | <b>Sum CV</b> | <b>9.116144</b> |
| Mean Consistency Vector (Mean CV) = Total CV/ Nos. Of factor class (9.116144/3) =                |          |          |          |               | <b>3.038715</b> |
| Consistency Index (CI) = (Mean CV - No. Of criteria/ factor class) / (No. Of factor class - 1) = |          |          |          |               | <b>0.019357</b> |
| Consistency Ratio (CR) = CI/ RI = 0.019357 / 0.58 =                                              |          |          |          |               | <b>0.0334</b>   |

**Factor Class**  
**Rank of Factor Classes**

| SI No | Factor Class Name      | Code | Rank |
|-------|------------------------|------|------|
| 1     | Slope                  | SLP  | 9    |
| 2     | Curvature              | CUR  | 2    |
| 3     | Slope Forming Material | SFM  | 6    |
| 4     | Land Use Land Cover    | LULC | 8    |
| 5     | Geomorphology          | GEOM | 6    |
| 6     | Regolith Thickness     | RT   | 4    |

**Matrix of Pairwise Ratings of Factor Class**

| Factor Class | SLP  | CUR   | SFM  | LULC | GEOM | RT    |
|--------------|------|-------|------|------|------|-------|
| SLP          | 1.00 | 8.00  | 4.00 | 2.00 | 4.00 | 6.00  |
| CUR          | 0.13 | 1.00  | 0.20 | 0.14 | 0.20 | 0.33  |
| SFM          | 0.25 | 5.00  | 1.00 | 0.33 | 1.00 | 3.00  |
| LULC         | 0.50 | 7.00  | 3.00 | 1.00 | 3.00 | 5.00  |
| GEOM         | 0.25 | 5.00  | 1.00 | 0.33 | 1.00 | 3.00  |
| RT           | 0.17 | 3.00  | 0.33 | 0.20 | 0.33 | 1.00  |
| Sum Column   | 2.29 | 29.00 | 9.53 | 4.01 | 9.53 | 18.33 |

**Factor Class**  
**Estimated Eigen values, fraction rate and Weight for Factor classes**

| Factor Class | SLP     | CUR     | SFM     | LULC    | GEOM    | RT      | Sum Rows | Frac Weight | Weight              |
|--------------|---------|---------|---------|---------|---------|---------|----------|-------------|---------------------|
| SLP          | 0.43636 | 0.27586 | 0.41958 | 0.49881 | 0.41958 | 0.32727 | 2.37747  | 0.396245271 | 12.86527835 ~<br>13 |
| CUR          | 0.05455 | 0.03448 | 0.02098 | 0.03563 | 0.02098 | 0.01818 | 0.18480  | 0.030799588 | 1 ~ 1               |
| SFM          | 0.10909 | 0.17241 | 0.10490 | 0.08314 | 0.10490 | 0.16364 | 0.73807  | 0.123011111 | 3.993920696 ~<br>4  |
| LULC         | 0.21818 | 0.24138 | 0.31469 | 0.24941 | 0.31469 | 0.27273 | 1.61107  | 0.268510868 | 8.718001981 ~<br>9  |
| GEOM         | 0.10909 | 0.17241 | 0.10490 | 0.08314 | 0.10490 | 0.16364 | 0.73807  | 0.123011111 | 3.993920696 ~<br>4  |
| RT           | 0.07273 | 0.10345 | 0.03497 | 0.04988 | 0.03497 | 0.05455 | 0.35053  | 0.058422051 | 1.896845233 ~<br>2  |

| CUR                                                                                                     | SFM         | LULC        | GEOM        | RT          | Sum Rows      |
|---------------------------------------------------------------------------------------------------------|-------------|-------------|-------------|-------------|---------------|
| 0.246396703                                                                                             | 0.492044445 | 0.537021735 | 0.492044445 | 0.350532308 | 2.514284907   |
| 0.030799588                                                                                             | 0.024602222 | 0.038358695 | 0.024602222 | 0.019474017 | 0.187367404   |
| 0.153997939                                                                                             | 0.123011111 | 0.089503623 | 0.123011111 | 0.175266154 | 0.763851256   |
| 0.215597115                                                                                             | 0.369033334 | 0.268510868 | 0.369033334 | 0.292110257 | 1.712407542   |
| 0.153997939                                                                                             | 0.123011111 | 0.089503623 | 0.123011111 | 0.175266154 | 0.763851256   |
| 0.092398763                                                                                             | 0.041003704 | 0.053702174 | 0.041003704 | 0.058422051 | 0.352571274   |
|                                                                                                         |             |             |             |             | <b>Sum CV</b> |
| <b>Mean Consistency Vector (Mean CV) = Total CV/ Nos. Of factor class (37.2603/6) =</b>                 |             |             |             |             |               |
| <b>Consistency Index (CI) = (Mean CV - No. Of criteria/ factor class) / (No. Of factor class - 1) =</b> |             |             |             |             |               |
| <b>Consistency Ratio (CR) = CI/ RI = 0.042009 / 1.24 =</b>                                              |             |             |             |             |               |

[illegible]

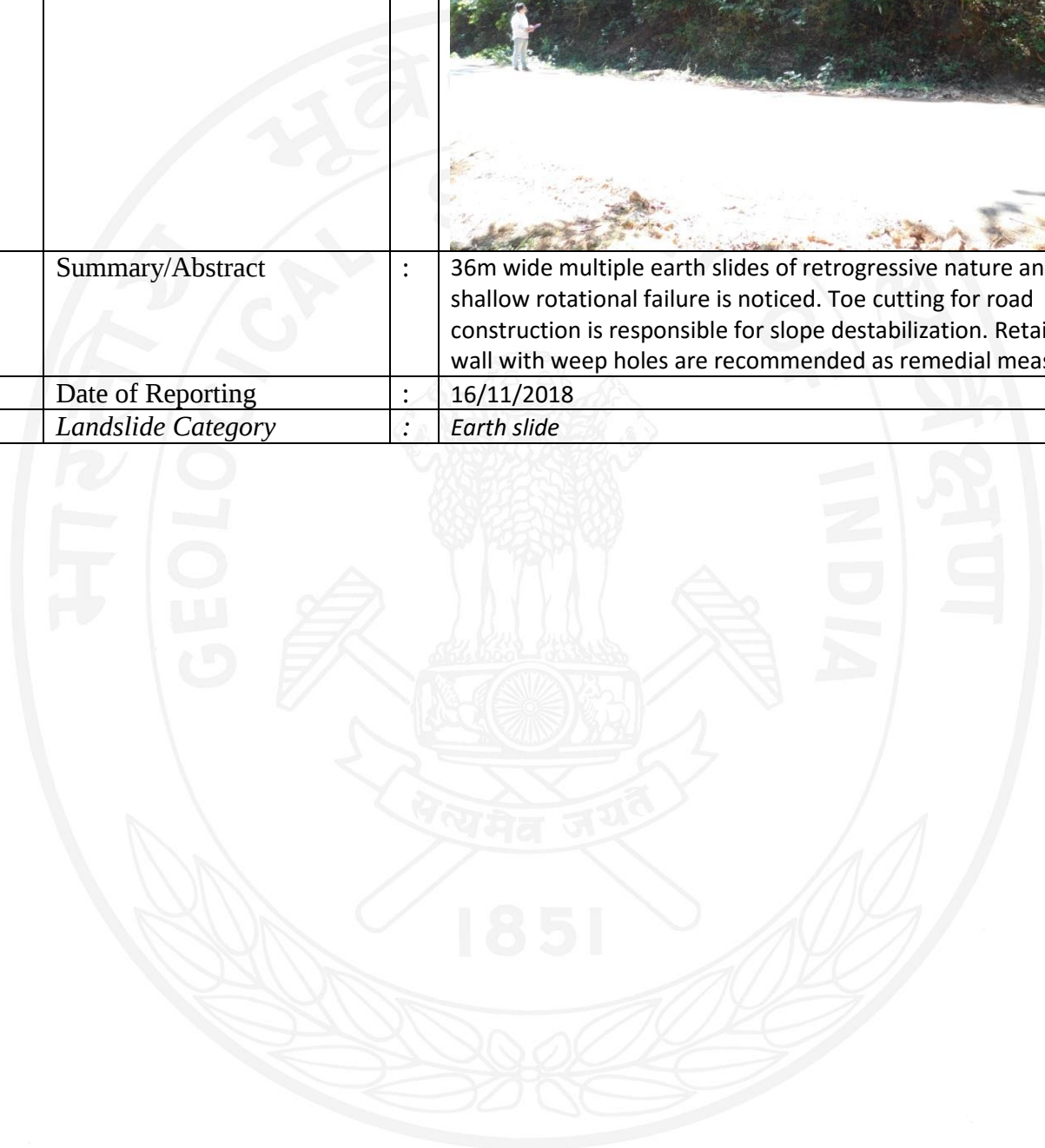
## ANNEXURE-II

### 42-Point Geo-Parametric Data Format for Landslides



| No | Field                     |   | Description                                                   |
|----|---------------------------|---|---------------------------------------------------------------|
| 1  | Slide No.                 | : | 1                                                             |
| 2  | State                     | : | Karnataka                                                     |
| 3  | District                  |   | Uttar Kannada                                                 |
| 4  | Toposheet No              | : | 48I/11                                                        |
| 5  | Name of the Slide         | : | KAR/UK/48I11/2018/01                                          |
| 6  | NH/SH/Locality            | : | 2 km SE of Shingargaon.                                       |
| 7  | Latitude (N)              | : | 15°19'16.000                                                  |
| 8  | Longitude (E)             | : | 74°33'44.700                                                  |
| 9  | Length (m)                | : | 8                                                             |
| 10 | Width (m)                 | : | 36                                                            |
| 11 | Height (m)                | : | 6                                                             |
| 12 | Area (sq m)               | : | 288                                                           |
| 13 | Depth                     | : | <=5m                                                          |
| 14 | Volume                    | : |                                                               |
| 15 | Run out distance (m)      | : | 8                                                             |
| 16 | Type of material          | : | Soil                                                          |
| 17 | Type of movement          | : | Slide                                                         |
| 18 | Rate of movement          | : | Imperceptible                                                 |
| 19 | Activity                  | : | Active                                                        |
| 20 | Distribution              | : | Retrogressive                                                 |
| 21 | Style                     | : | Multiple                                                      |
| 22 | Failure mechanism         | : | Shallow Rotational Failure                                    |
| 23 | History                   | : | Data Not Available                                            |
| 24 | Geomorphology             | : | Lowly Dissected Slope                                         |
| 25 | Geology/Lithology         | : | Argillite                                                     |
| 26 | Structure                 | : | No distinct structure                                         |
| 27 | Landuse/ Landcover        | : | Extensive Cut Slope                                           |
| 28 | Hydrological condition    | : | Damp                                                          |
| 29 | Triggering Factor         | : | Rainfall                                                      |
| 30 | Death of persons          | : | Data Not Available                                            |
| 31 | People affected           | : | Data Not Available                                            |
| 32 | Livestock Loss            | : | Data Not Available                                            |
| 33 | Communication             | : | Data Not Available                                            |
| 34 | Infrastructure            | : | Data Not Available                                            |
| 35 | Agriculture/forest/Barren | : | Forest                                                        |
| 36 | Geo-scientific Causes     | : | Anthropogenic activity (toe cutting ) in argillitic lithology |
| 37 | Remedial measures         | : | Retaining wall with weep holes is suggested                   |
| 38 | Remarks, if any           |   | Toe cutting at curve of road aggravated the slide.            |

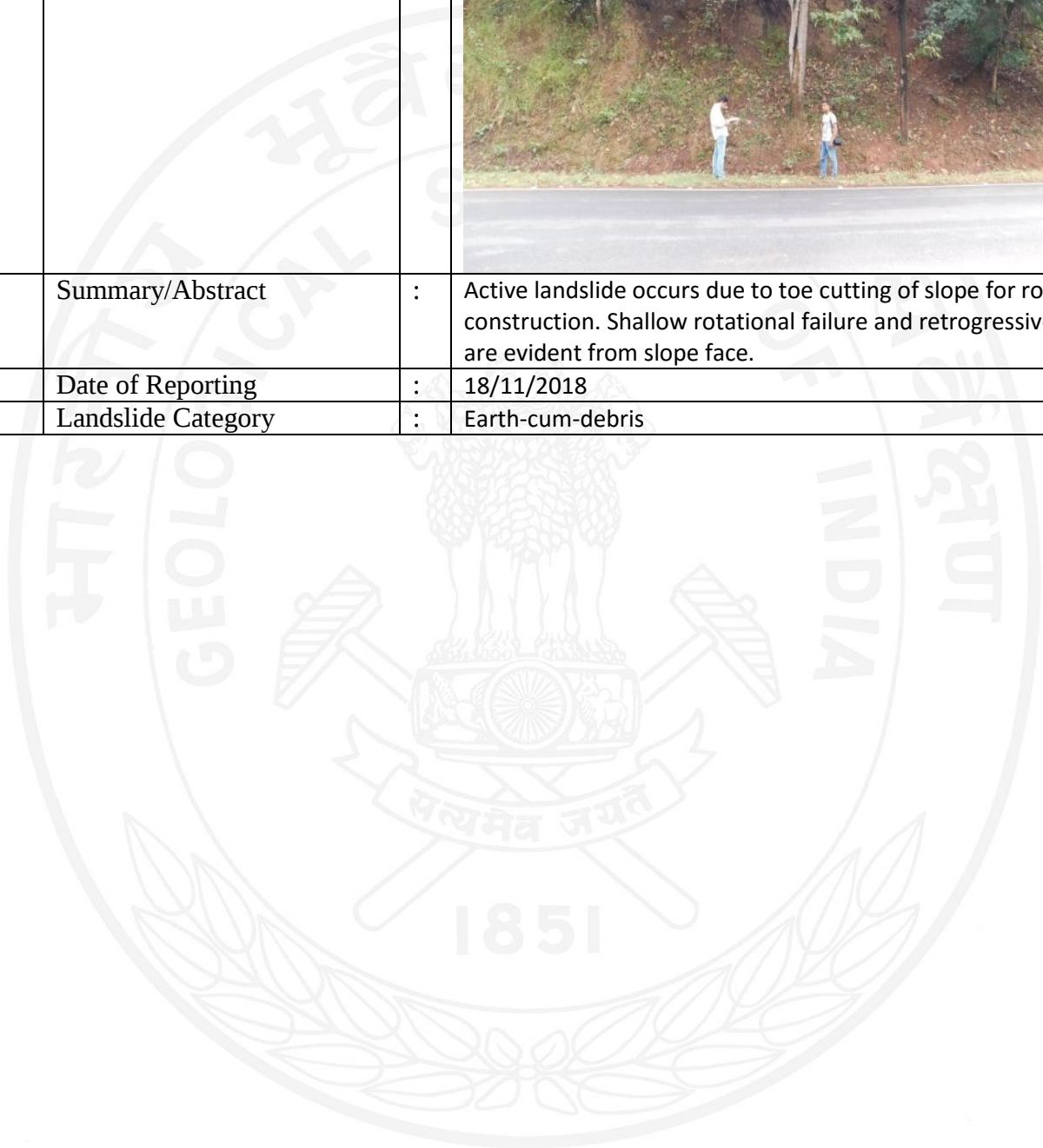
|    |                                               |   |                                                                                                                                                                                                                                                   |
|----|-----------------------------------------------|---|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 39 | Photos. Sketch of Plan & section of the slide | : |                                                                                                                                                                 |
| 40 | Summary/Abstract                              | : | 36m wide multiple earth slides of retrogressive nature and shallow rotational failure is noticed. Toe cutting for road construction is responsible for slope destabilization. Retaining wall with weep holes are recommended as remedial measure. |
| 41 | Date of Reporting                             | : | 16/11/2018                                                                                                                                                                                                                                        |
| 42 | Landslide Category                            | : | Earth slide                                                                                                                                                                                                                                       |



| No | Field                                         |   | Description                                                                                                                                                                                               |
|----|-----------------------------------------------|---|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1  | Slide No.                                     | : | 2                                                                                                                                                                                                         |
| 2  | State                                         | : | Karnataka                                                                                                                                                                                                 |
| 3  | District                                      |   | Uttar Kannada                                                                                                                                                                                             |
| 4  | Toposheet No                                  | : | 48I/11                                                                                                                                                                                                    |
| 5  | Name of the Slide                             | : | KAR/UK/48I11/2018/02                                                                                                                                                                                      |
| 6  | NH/SH/Locality                                | : | 1 km SW of Usoda, SH 28                                                                                                                                                                                   |
| 7  | Latitude (N)                                  | : | 15°19'16.001                                                                                                                                                                                              |
| 8  | Longitude (E)                                 | : | 74°32'26.700                                                                                                                                                                                              |
| 9  | Length (m)                                    | : | 6                                                                                                                                                                                                         |
| 10 | Width (m)                                     | : | 12                                                                                                                                                                                                        |
| 11 | Height (m)                                    | : | 8                                                                                                                                                                                                         |
| 12 | Area (sq m)                                   | : | 72                                                                                                                                                                                                        |
| 13 | Depth                                         | : | <=5m                                                                                                                                                                                                      |
| 14 | Volume                                        | : |                                                                                                                                                                                                           |
| 15 | Run out distance (m)                          | : | 8                                                                                                                                                                                                         |
| 16 | Type of material                              | : | Debris                                                                                                                                                                                                    |
| 17 | Type of movement                              | : | Slide                                                                                                                                                                                                     |
| 18 | Rate of movement                              | : | Imperceptible                                                                                                                                                                                             |
| 19 | Activity                                      | : | Active                                                                                                                                                                                                    |
| 20 | Distribution                                  | : | Retrogressive                                                                                                                                                                                             |
| 21 | Style                                         | : | Single                                                                                                                                                                                                    |
| 22 | Failure mechanism                             | : | Shallow Rotational Failure                                                                                                                                                                                |
| 23 | History                                       | : | Data Not Available                                                                                                                                                                                        |
| 24 | Geomorphology                                 | : | Lowly Dissected Slope                                                                                                                                                                                     |
| 25 | Geology/Lithology                             | : | Granite, Phyllite, BIF                                                                                                                                                                                    |
| 26 | Structure                                     | : | No distinct structure                                                                                                                                                                                     |
| 27 | Landuse/ Landcover                            | : | Extensive Cut Slope                                                                                                                                                                                       |
| 28 | Hydrological condition                        | : | Damp                                                                                                                                                                                                      |
| 29 | Triggering Factor                             | : | Rainfall                                                                                                                                                                                                  |
| 30 | Death of persons                              | : | Data Not Available                                                                                                                                                                                        |
| 31 | People affected                               | : | Data Not Available                                                                                                                                                                                        |
| 32 | Livestock Loss                                | : | Data Not Available                                                                                                                                                                                        |
| 33 | Communication                                 | : | Data Not Available                                                                                                                                                                                        |
| 34 | Infrastructure                                | : | Data Not Available                                                                                                                                                                                        |
| 35 | Agriculture/forest/Barren                     | : | Forest                                                                                                                                                                                                    |
| 36 | Geo-scientific Causes                         | : | Anthropogenic activity (toe cutting).Granite-Phyllite litho contact act as a path for facilitating the water infiltration & thus giving rise to increase in hydrostatic pressure leading to mass failure. |
| 37 | Remedial measures                             | : | Breast wall with weep holes is suggested                                                                                                                                                                  |
| 38 | Remarks, if any                               |   | Nil                                                                                                                                                                                                       |
| 39 | Photos. Sketch of Plan & section of the slide | : |                                                                                                                                                                                                           |

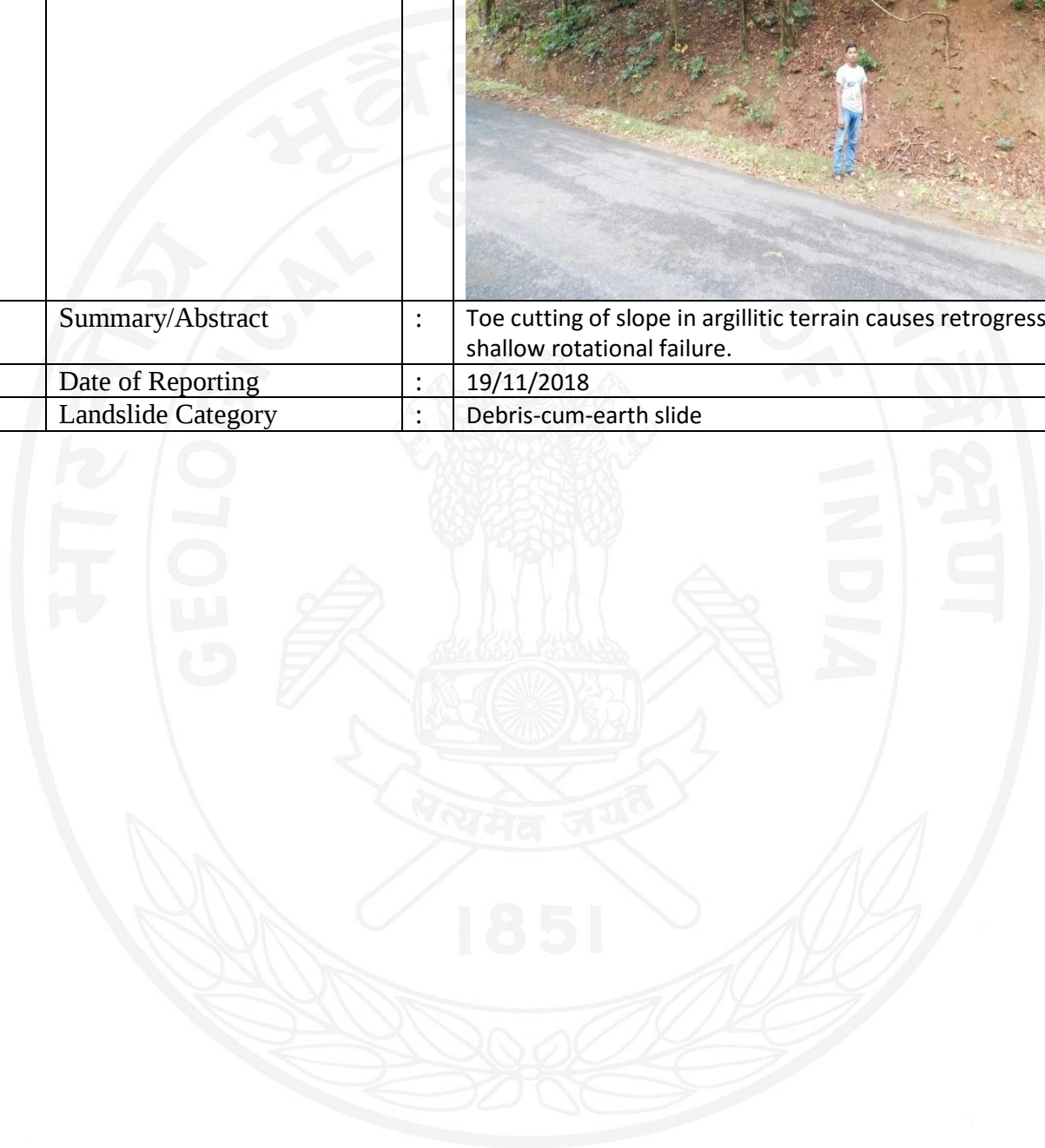


|    |                    |   |                                                                                                                                                             |
|----|--------------------|---|-------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 40 | Summary/Abstract   | : | Active landslide occurs due to toe cutting of slope for road construction. Shallow rotational failure and retrogressive nature are evident from slope face. |
| 41 | Date of Reporting  | : | 18/11/2018                                                                                                                                                  |
| 42 | Landslide Category | : | Earth-cum-debris                                                                                                                                            |



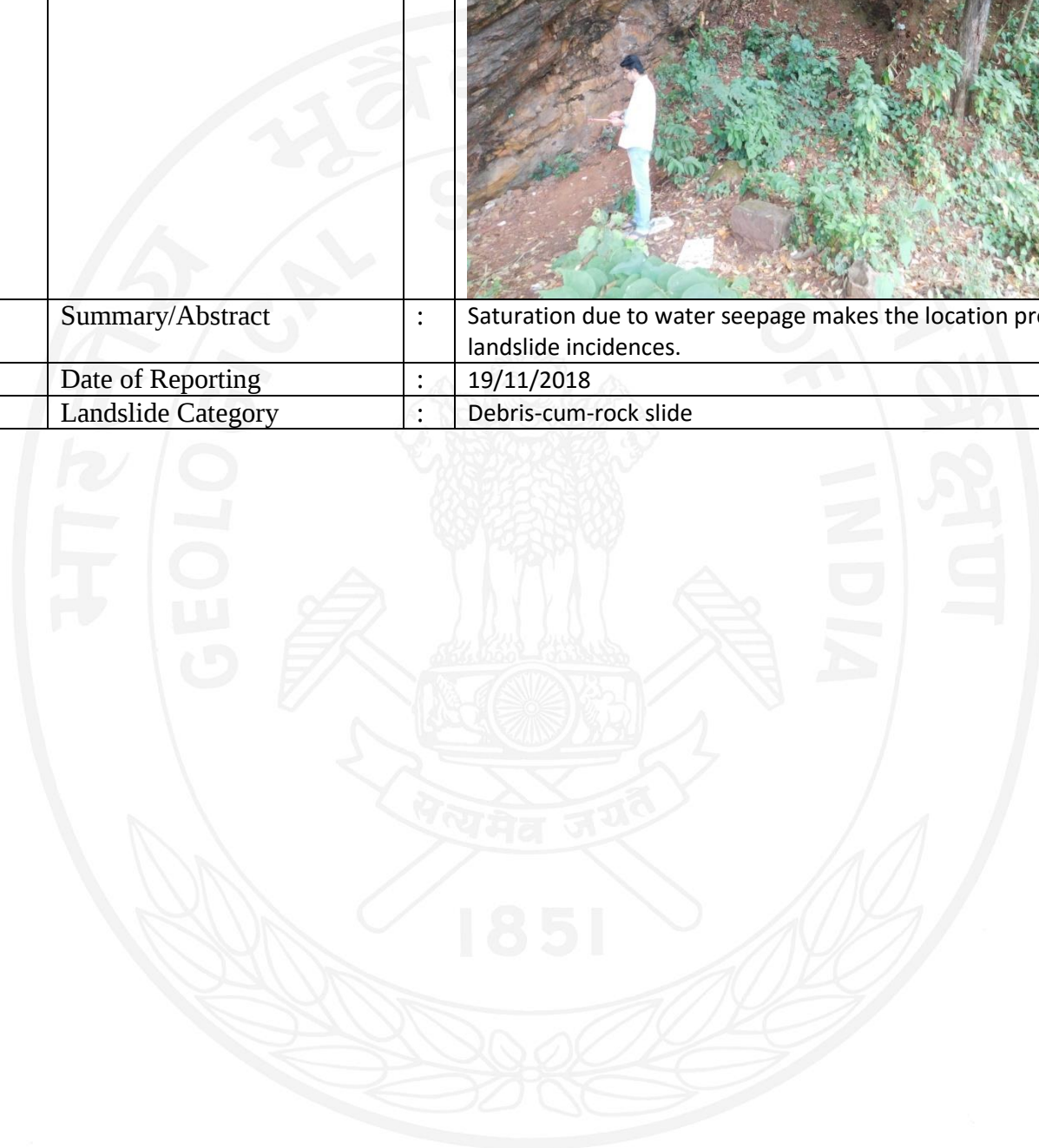
| No | Field                     |   | Description                                                         |
|----|---------------------------|---|---------------------------------------------------------------------|
| 1  | Slide No.                 | : | 3                                                                   |
| 2  | State                     | : | Karnataka                                                           |
| 3  | District                  | : | Uttar Kannada                                                       |
| 4  | Toposheet No              | : | 48I/11                                                              |
| 5  | Name of the Slide         | : | KAR/UK/48I11/2018/03                                                |
| 6  | NH/SH/Locality            | : | Near Ganeshgudi                                                     |
| 7  | Latitude (N)              | : | 15°16'53.200                                                        |
| 8  | Longitude (E)             | : | 74°31'28.500                                                        |
| 9  | Length (m)                | : | 9                                                                   |
| 10 | Width (m)                 | : | 21                                                                  |
| 11 | Height (m)                | : | 6                                                                   |
| 12 | Area (sq m)               | : | 189                                                                 |
| 13 | Depth                     | : | <=5m                                                                |
| 14 | Volume                    | : |                                                                     |
| 15 | Run out distance (m)      | : | 5                                                                   |
| 16 | Type of material          | : | Soil                                                                |
| 17 | Type of movement          | : | Slide                                                               |
| 18 | Rate of movement          | : | Imperceptible                                                       |
| 19 | Activity                  | : | Active                                                              |
| 20 | Distribution              | : | Retrogressive                                                       |
| 21 | Style                     | : | Multiple                                                            |
| 22 | Failure mechanism         | : | Shallow Rotational Failure                                          |
| 23 | History                   | : | Data Not Available                                                  |
| 24 | Geomorphology             | : | Lowly Dissected Slope                                               |
| 25 | Geology/Lithology         | : | Argillite                                                           |
| 26 | Structure                 | : | No distinct structure                                               |
| 27 | Landuse/ Landcover        | : | Extensive Cut Slope                                                 |
| 28 | Hydrological condition    | : | Damp                                                                |
| 29 | Triggering Factor         | : | Rainfall                                                            |
| 30 | Death of persons          | : | Data Not Available                                                  |
| 31 | People affected           | : | Data Not Available                                                  |
| 32 | Livestock Loss            | : | Data Not Available                                                  |
| 33 | Communication             | : | Data Not Available                                                  |
| 34 | Infrastructure            | : | Data Not Available                                                  |
| 35 | Agriculture/forest/Barren | : | Forest                                                              |
| 36 | Geo-scientific Causes     | : | Toe cutting by road construction led to slide in argillitic terrain |
| 37 | Remedial measures         | : | Retaining wall with weep holes is suggested                         |
| 38 | Remarks, if any           | : | Slide is getting widened.                                           |

|    |                                               |   |                                                                                             |
|----|-----------------------------------------------|---|---------------------------------------------------------------------------------------------|
| 39 | Photos. Sketch of Plan & section of the slide | : |           |
| 40 | Summary/Abstract                              | : | Toe cutting of slope in argillitic terrain causes retrogressive shallow rotational failure. |
| 41 | Date of Reporting                             | : | 19/11/2018                                                                                  |
| 42 | Landslide Category                            | : | Debris-cum-earth slide                                                                      |



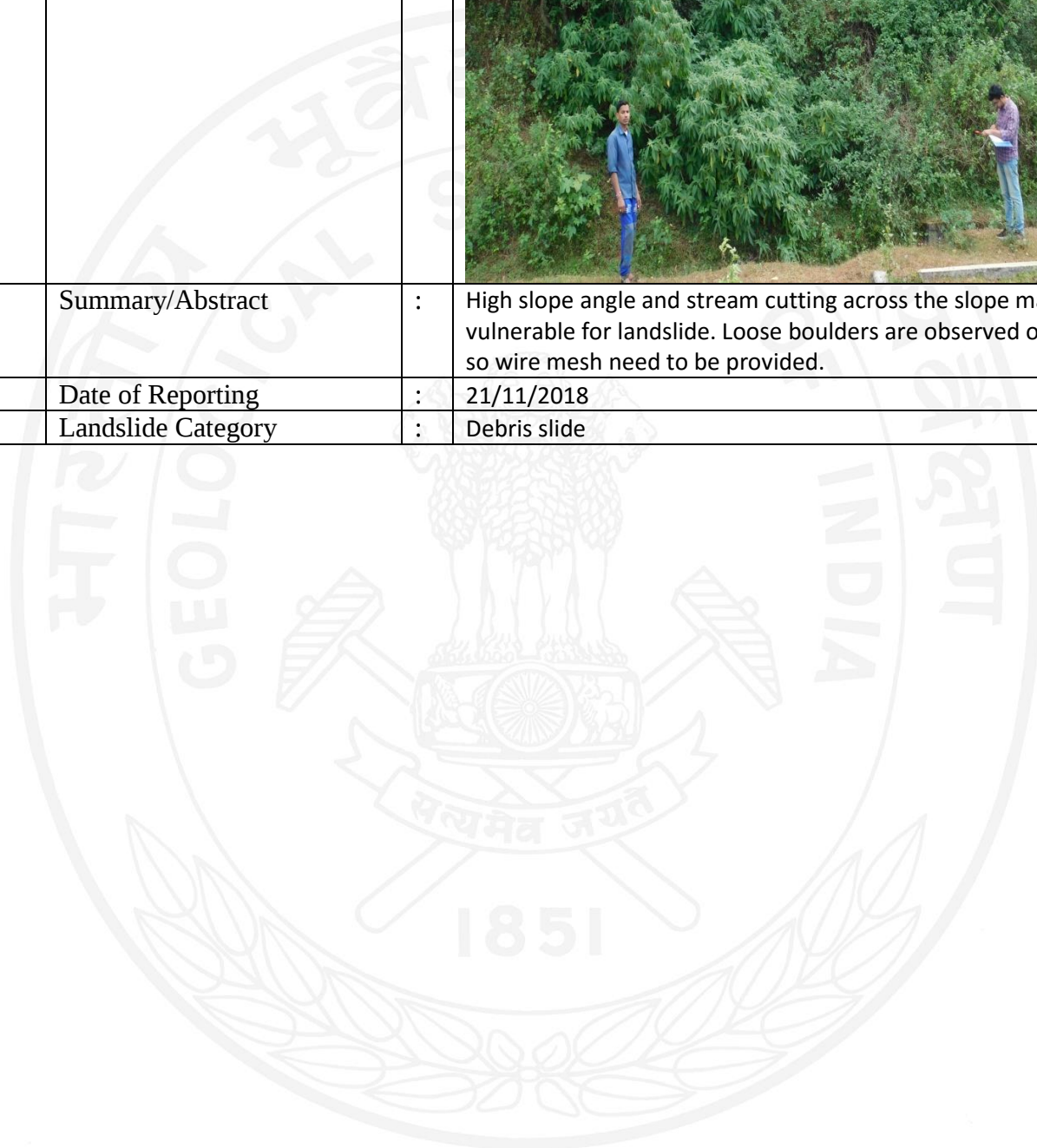
| No | Field                     |   | Description                                                                                                                                                                                                                                                                                                                       |
|----|---------------------------|---|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1  | Slide No.                 | : | 4                                                                                                                                                                                                                                                                                                                                 |
| 2  | State                     | : | Karnataka                                                                                                                                                                                                                                                                                                                         |
| 3  | District                  |   | Uttar Kannada                                                                                                                                                                                                                                                                                                                     |
| 4  | Toposheet No              | : | 48I/11                                                                                                                                                                                                                                                                                                                            |
| 5  | Name of the Slide         | : | KAR/UK/48I11/2018/04                                                                                                                                                                                                                                                                                                              |
| 6  | NH/SH/Locality            | : | 2km NW of Ganeshgudi, SH 34                                                                                                                                                                                                                                                                                                       |
| 7  | Latitude (N)              | : | 15°17'51.800                                                                                                                                                                                                                                                                                                                      |
| 8  | Longitude (E)             | : | 74°30'34.400                                                                                                                                                                                                                                                                                                                      |
| 9  | Length (m)                | : | 16                                                                                                                                                                                                                                                                                                                                |
| 10 | Width (m)                 | : | 22                                                                                                                                                                                                                                                                                                                                |
| 11 | Height (m)                | : | 12                                                                                                                                                                                                                                                                                                                                |
| 12 | Area (sq m)               | : | 352                                                                                                                                                                                                                                                                                                                               |
| 13 | Depth                     | : | <=5m                                                                                                                                                                                                                                                                                                                              |
| 14 | Volume                    | : |                                                                                                                                                                                                                                                                                                                                   |
| 15 | Run out distance (m)      | : | 10                                                                                                                                                                                                                                                                                                                                |
| 16 | Type of material          | : | Debris                                                                                                                                                                                                                                                                                                                            |
| 17 | Type of movement          | : | Slide                                                                                                                                                                                                                                                                                                                             |
| 18 | Rate of movement          | : | Imperceptible                                                                                                                                                                                                                                                                                                                     |
| 19 | Activity                  | : | Active                                                                                                                                                                                                                                                                                                                            |
| 20 | Distribution              | : | Retrogressive                                                                                                                                                                                                                                                                                                                     |
| 21 | Style                     | : | Multiple                                                                                                                                                                                                                                                                                                                          |
| 22 | Failure mechanism         | : | Shallow Rotational Failure                                                                                                                                                                                                                                                                                                        |
| 23 | History                   | : | Data Not Available                                                                                                                                                                                                                                                                                                                |
| 24 | Geomorphology             | : | Lowly Dissected Slope                                                                                                                                                                                                                                                                                                             |
| 25 | Geology/Lithology         | : | BIF                                                                                                                                                                                                                                                                                                                               |
| 26 | Structure                 | : | J1-065/80°SE, J2-225/40°NE                                                                                                                                                                                                                                                                                                        |
| 27 | Landuse/ Landcover        | : | Extensive Cut Slope                                                                                                                                                                                                                                                                                                               |
| 28 | Hydrological condition    | : | Damp                                                                                                                                                                                                                                                                                                                              |
| 29 | Triggering Factor         | : | Rainfall                                                                                                                                                                                                                                                                                                                          |
| 30 | Death of persons          | : | Data Not Available                                                                                                                                                                                                                                                                                                                |
| 31 | People affected           | : | Data Not Available                                                                                                                                                                                                                                                                                                                |
| 32 | Livestock Loss            | : | Data Not Available                                                                                                                                                                                                                                                                                                                |
| 33 | Communication             | : | Data Not Available                                                                                                                                                                                                                                                                                                                |
| 34 | Infrastructure            | : | Data Not Available                                                                                                                                                                                                                                                                                                                |
| 35 | Agriculture/forest/Barren | : | Forest                                                                                                                                                                                                                                                                                                                            |
| 36 | Geo-scientific Causes     | : | Water seepage through joints leads to dislodge the rocks & thus making the slope prone to landslide. Slide occurring in the vicinity of BIF-Phyllite contact giving rise to subsequently fail of mass due to the presence of path for facilitating the water infiltration & thus giving rise to increase in hydrostatic pressure. |
| 37 | Remedial measures         | : | Breast wall with weep holes is suggested                                                                                                                                                                                                                                                                                          |
| 38 | Remarks, if any           |   | Landslide is getting widened gently. The passing through spring can be triggered in monsoons.                                                                                                                                                                                                                                     |

|    |                                               |   |                                                                                    |
|----|-----------------------------------------------|---|------------------------------------------------------------------------------------|
| 39 | Photos. Sketch of Plan & section of the slide | : |  |
| 40 | Summary/Abstract                              | : | Saturation due to water seepage makes the location prone to landslide incidences.  |
| 41 | Date of Reporting                             | : | 19/11/2018                                                                         |
| 42 | Landslide Category                            | : | Debris-cum-rock slide                                                              |



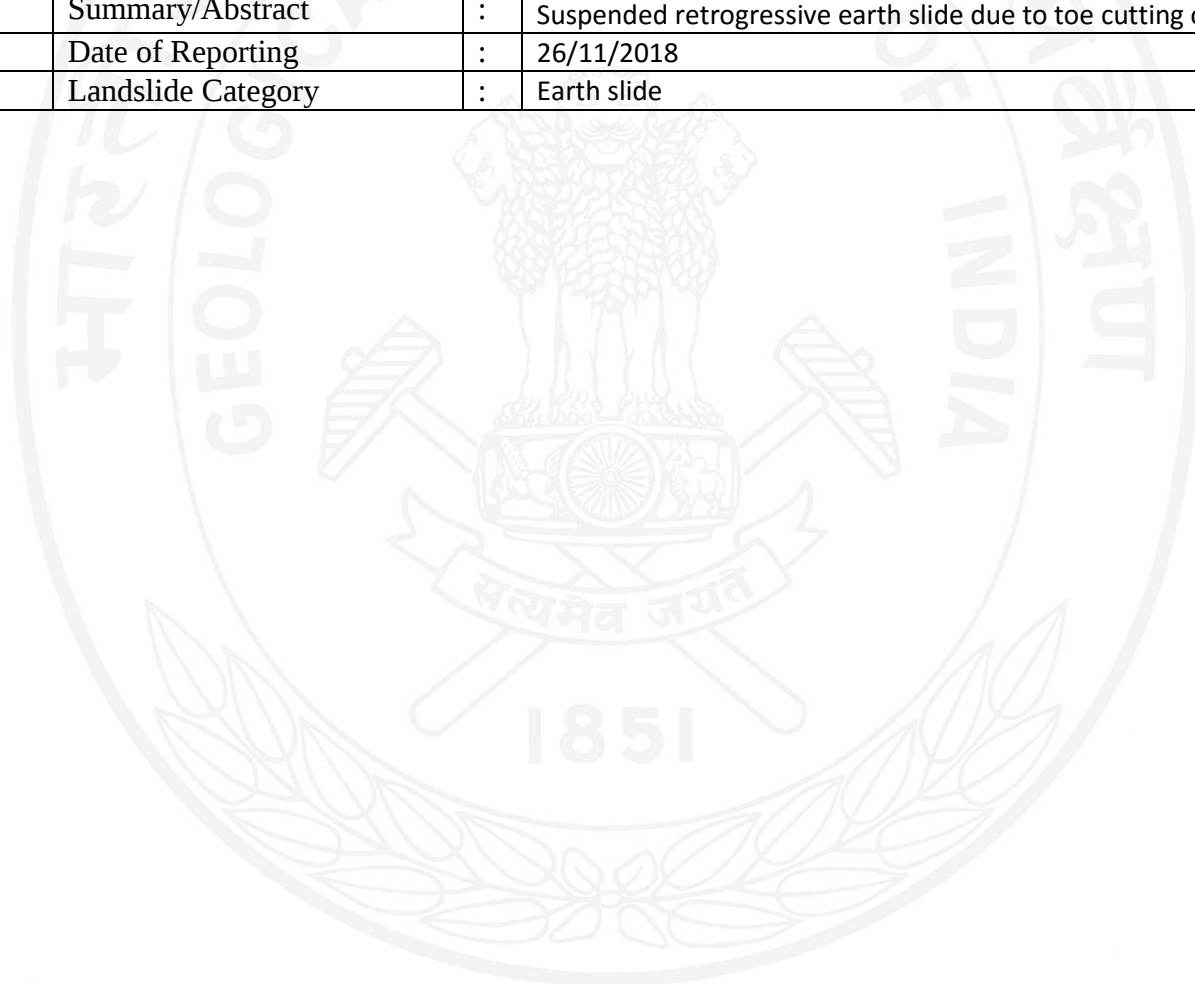
| No | Field                     |   | Description                        |
|----|---------------------------|---|------------------------------------|
| 1  | Slide No.                 | : | 5                                  |
| 2  | State                     | : | Karnataka                          |
| 3  | District                  |   | Uttar Kannada                      |
| 4  | Toposheet No              | : | 48I/11                             |
| 5  | Name of the Slide         | : | KAR/UK/48I11/2018/05               |
| 6  | NH/SH/Locality            | : | Near Handibadaganath temple        |
| 7  | Latitude (N)              | : | 15°23'39.900                       |
| 8  | Longitude (E)             | : | 74°34'51.900                       |
| 9  | Length (m)                | : | 6                                  |
| 10 | Width (m)                 | : | 8                                  |
| 11 | Height (m)                | : | 4                                  |
| 12 | Area (sq m)               | : | 48                                 |
| 13 | Depth                     | : | <=5m                               |
| 14 | Volume                    | : |                                    |
| 15 | Run out distance (m)      | : | 5                                  |
| 16 | Type of material          | : | Debris                             |
| 17 | Type of movement          | : | Slide                              |
| 18 | Rate of movement          | : | Imperceptible                      |
| 19 | Activity                  | : | Suspended                          |
| 20 | Distribution              | : | Retrogressive                      |
| 21 | Style                     | : | Single                             |
| 22 | Failure mechanism         | : | Shallow Rotational Failure         |
| 23 | History                   | : | Data Not Available                 |
| 24 | Geomorphology             | : | Lowly Dissected Slope              |
| 25 | Geology/Lithology         | : | Phyllite, BIF                      |
| 26 | Structure                 | : | No distinct structure              |
| 27 | Landuse/ Landcover        | : | Extensive Cut Slope                |
| 28 | Hydrological condition    | : | Damp                               |
| 29 | Triggering Factor         | : | Rainfall                           |
| 30 | Death of persons          | : | Data Not Available                 |
| 31 | People affected           | : | Data Not Available                 |
| 32 | Livestock Loss            | : | Data Not Available                 |
| 33 | Communication             | : | Data Not Available                 |
| 34 | Infrastructure            | : | Data Not Available                 |
| 35 | Agriculture/forest/Barren | : | Forest                             |
| 36 | Geo-scientific Causes     | : | Toe cutting                        |
| 37 | Remedial measures         | : | Retaining wall and wire mesh       |
| 38 | Remarks, if any           |   | Slide Scar covered with vegetation |

|    |                                               |   |                                                                                                                                                                |
|----|-----------------------------------------------|---|----------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 39 | Photos. Sketch of Plan & section of the slide | : |                                                                              |
| 40 | Summary/Abstract                              | : | High slope angle and stream cutting across the slope makes it vulnerable for landslide. Loose boulders are observed on slope so wire mesh need to be provided. |
| 41 | Date of Reporting                             | : | 21/11/2018                                                                                                                                                     |
| 42 | Landslide Category                            | : | Debris slide                                                                                                                                                   |



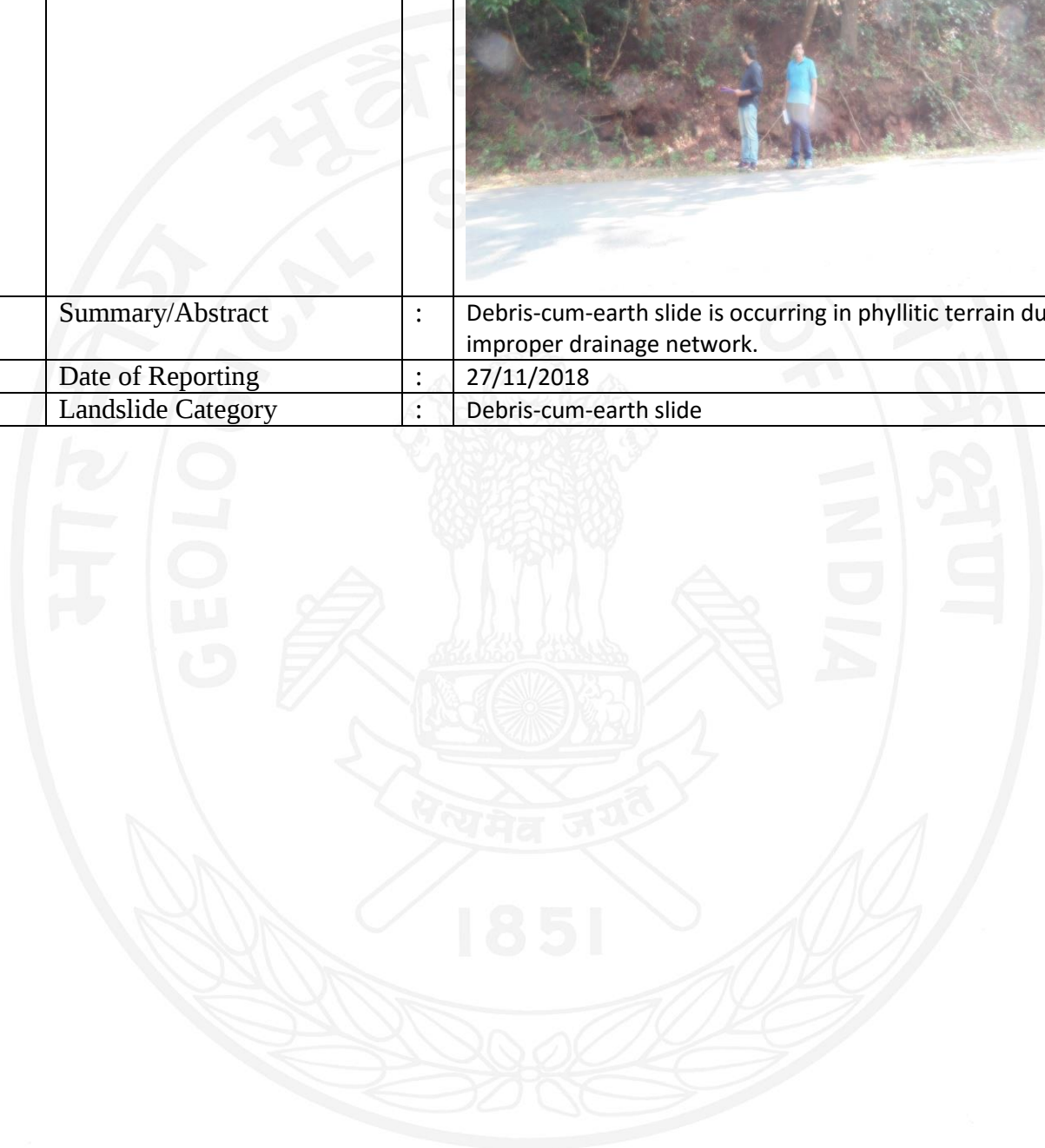
| No | Field                     |   | Description                                                                                |
|----|---------------------------|---|--------------------------------------------------------------------------------------------|
| 1  | Slide No.                 | : | 6                                                                                          |
| 2  | State                     | : | Karnataka                                                                                  |
| 3  | District                  |   | Uttar Kannada                                                                              |
| 4  | Toposheet No              | : | 48I/11                                                                                     |
| 5  | Name of the Slide         | : | KAR/UK/48I11/2018/06                                                                       |
| 6  | NH/SH/Locality            | : | 2.3 km West of Ganeshgudi, SH 34                                                           |
| 7  | Latitude (N)              | : | 15°16'56.700                                                                               |
| 8  | Longitude (E)             | : | 74°31'24.500                                                                               |
| 9  | Length (m)                | : | 8                                                                                          |
| 10 | Width (m)                 | : | 18                                                                                         |
| 11 | Height (m)                | : | 6                                                                                          |
| 12 | Area (sq m)               | : | 384                                                                                        |
| 13 | Depth                     | : | <=5m                                                                                       |
| 14 | Volume                    | : |                                                                                            |
| 15 | Run out distance (m)      | : | 6                                                                                          |
| 16 | Type of material          | : | Debris                                                                                     |
| 17 | Type of movement          | : | Slide                                                                                      |
| 18 | Rate of movement          | : | Imperceptible                                                                              |
| 19 | Activity                  | : | Suspended                                                                                  |
| 20 | Distribution              | : | Retrogressive                                                                              |
| 21 | Style                     | : | Single                                                                                     |
| 22 | Failure mechanism         | : | Shallow Rotational Failure                                                                 |
| 23 | History                   | : | Data Not Available                                                                         |
| 24 | Geomorphology             | : | Lowly Dissected Slope                                                                      |
| 25 | Geology/Lithology         | : | Argillite                                                                                  |
| 26 | Structure                 | : | No distinct structure                                                                      |
| 27 | Landuse/ Landcover        | : | Extensive Cut Slope                                                                        |
| 28 | Hydrological condition    | : | Damp                                                                                       |
| 29 | Triggering Factor         | : | Rainfall                                                                                   |
| 30 | Death of persons          | : | Data Not Available                                                                         |
| 31 | People affected           | : | Data Not Available                                                                         |
| 32 | Livestock Loss            | : | Data Not Available                                                                         |
| 33 | Communication             | : | Data Not Available                                                                         |
| 34 | Infrastructure            | : | Data Not Available                                                                         |
| 35 | Agriculture/forest/Barren | : | Forest                                                                                     |
| 36 | Geo-scientific Causes     | : | Toe cutting                                                                                |
| 37 | Remedial measures         | : | Removal of boulders from culvert thereby maintaining the flow of drainage during rainfall. |
| 38 | Remarks, if any           |   | Nala is cutting across slope and road.                                                     |

|    |                                               |   |                                                                                    |
|----|-----------------------------------------------|---|------------------------------------------------------------------------------------|
| 39 | Photos. Sketch of Plan & section of the slide | : |  |
| 40 | Summary/Abstract                              | : | Suspended retrogressive earth slide due to toe cutting of slope.                   |
| 41 | Date of Reporting                             | : | 26/11/2018                                                                         |
| 42 | Landslide Category                            | : | Earth slide                                                                        |



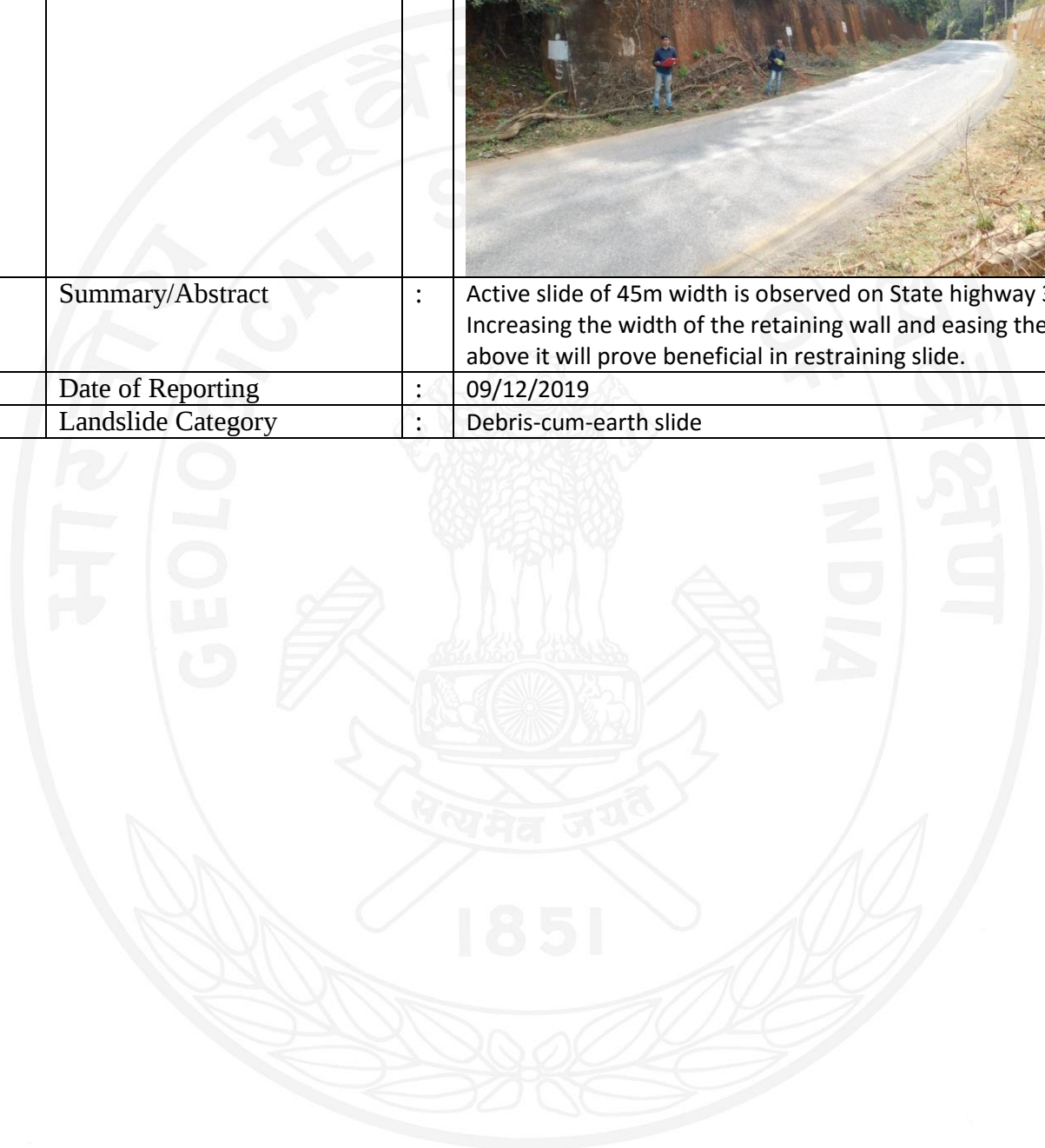
| No | Field                     |   | Description                                                                                                             |
|----|---------------------------|---|-------------------------------------------------------------------------------------------------------------------------|
| 1  | Slide No.                 | : | 7                                                                                                                       |
| 2  | State                     | : | Karnataka                                                                                                               |
| 3  | District                  |   | Uttar Kannada                                                                                                           |
| 4  | Toposheet No              | : | 48I/8                                                                                                                   |
| 5  | Name of the Slide         | : | KAR/UK/48I08/2018/07                                                                                                    |
| 6  | NH/SH/Locality            | : | 1 km NE of Chittegali                                                                                                   |
| 7  | Latitude (N)              | : | 15°11'25.000                                                                                                            |
| 8  | Longitude (E)             | : | 74°29'55.300                                                                                                            |
| 9  | Length (m)                | : | 9                                                                                                                       |
| 10 | Width (m)                 | : | 37                                                                                                                      |
| 11 | Height (m)                | : | 7                                                                                                                       |
| 12 | Area (sq m)               | : | 333                                                                                                                     |
| 13 | Depth                     | : | <=5m                                                                                                                    |
| 14 | Volume                    | : |                                                                                                                         |
| 15 | Run out distance (m)      | : | 6                                                                                                                       |
| 16 | Type of material          | : | Debris                                                                                                                  |
| 17 | Type of movement          | : | Slide                                                                                                                   |
| 18 | Rate of movement          | : | Imperceptible                                                                                                           |
| 19 | Activity                  | : | Suspended                                                                                                               |
| 20 | Distribution              | : | Retrogressive                                                                                                           |
| 21 | Style                     | : | Single                                                                                                                  |
| 22 | Failure mechanism         | : | Shallow Rotational Failure                                                                                              |
| 23 | History                   | : | Data Not Available                                                                                                      |
| 24 | Geomorphology             | : | Lowly Dissected Slope                                                                                                   |
| 25 | Geology/Lithology         | : | Phyllite                                                                                                                |
| 26 | Structure                 | : | No distinct structure                                                                                                   |
| 27 | Landuse/ Landcover        | : | Extensive Cut Slope                                                                                                     |
| 28 | Hydrological condition    | : | Wet                                                                                                                     |
| 29 | Triggering Factor         | : | Water saturation                                                                                                        |
| 30 | Death of persons          | : | Data Not Available                                                                                                      |
| 31 | People affected           | : | Data Not Available                                                                                                      |
| 32 | Livestock Loss            | : | Data Not Available                                                                                                      |
| 33 | Communication             | : | Data Not Available                                                                                                      |
| 34 | Infrastructure            | : | Data Not Available                                                                                                      |
| 35 | Agriculture/forest/Barren | : | Forest                                                                                                                  |
| 36 | Geo-scientific Causes     | : | Toe cutting by road construction, unconsolidated slope material, lack of proper drainage at toe part and on the slopes. |
| 37 | Remedial measures         | : | Retaining wall with weep holes and proper drainage                                                                      |
| 38 | Remarks, if any           |   | Uprooting of trees is observed. The same may be removed.                                                                |

|    |                                               |   |                                                                                            |
|----|-----------------------------------------------|---|--------------------------------------------------------------------------------------------|
| 39 | Photos. Sketch of Plan & section of the slide | : |          |
| 40 | Summary/Abstract                              | : | Debris-cum-earth slide is occurring in phyllitic terrain due to improper drainage network. |
| 41 | Date of Reporting                             | : | 27/11/2018                                                                                 |
| 42 | Landslide Category                            | : | Debris-cum-earth slide                                                                     |



| No | Field                     |   | Description                                                                                                                                                                                                                                                                         |
|----|---------------------------|---|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1  | Slide No.                 | : | 8                                                                                                                                                                                                                                                                                   |
| 2  | State                     | : | Karnataka                                                                                                                                                                                                                                                                           |
| 3  | District                  |   | Uttar Kannada                                                                                                                                                                                                                                                                       |
| 4  | Toposheet No              | : | 48I/8                                                                                                                                                                                                                                                                               |
| 5  | Name of the Slide         | : | KAR/UK/48I08/2018/08                                                                                                                                                                                                                                                                |
| 6  | NH/SH/Locality            | : | 0.5 km N of Devulli, SH 34                                                                                                                                                                                                                                                          |
| 7  | Latitude (N)              | : | 15°08'56.900                                                                                                                                                                                                                                                                        |
| 8  | Longitude (E)             | : | 74°26'43.400                                                                                                                                                                                                                                                                        |
| 9  | Length (m)                | : | 15                                                                                                                                                                                                                                                                                  |
| 10 | Width (m)                 | : | 46                                                                                                                                                                                                                                                                                  |
| 11 | Height (m)                | : | 10                                                                                                                                                                                                                                                                                  |
| 12 | Area (sq m)               | : | 690                                                                                                                                                                                                                                                                                 |
| 13 | Depth                     | : | <=5m                                                                                                                                                                                                                                                                                |
| 14 | Volume                    | : |                                                                                                                                                                                                                                                                                     |
| 15 | Run out distance (m)      | : | 10                                                                                                                                                                                                                                                                                  |
| 16 | Type of material          | : | Debris                                                                                                                                                                                                                                                                              |
| 17 | Type of movement          | : | Slide                                                                                                                                                                                                                                                                               |
| 18 | Rate of movement          | : | Imperceptible                                                                                                                                                                                                                                                                       |
| 19 | Activity                  | : | Active                                                                                                                                                                                                                                                                              |
| 20 | Distribution              | : | Retrogressive                                                                                                                                                                                                                                                                       |
| 21 | Style                     | : | Single                                                                                                                                                                                                                                                                              |
| 22 | Failure mechanism         | : | Shallow Rotational Failure                                                                                                                                                                                                                                                          |
| 23 | History                   | : | Data Not Available                                                                                                                                                                                                                                                                  |
| 24 | Geomorphology             | : | Lowly Dissected Slope                                                                                                                                                                                                                                                               |
| 25 | Geology/Lithology         | : | Granite                                                                                                                                                                                                                                                                             |
| 26 | Structure                 | : | No distinct structure                                                                                                                                                                                                                                                               |
| 27 | Landuse/ Landcover        | : | Extensive Cut Slope                                                                                                                                                                                                                                                                 |
| 28 | Hydrological condition    | : | Damp                                                                                                                                                                                                                                                                                |
| 29 | Triggering Factor         | : | Rainfall                                                                                                                                                                                                                                                                            |
| 30 | Death of persons          | : | Data Not Available                                                                                                                                                                                                                                                                  |
| 31 | People affected           | : | Data Not Available                                                                                                                                                                                                                                                                  |
| 32 | Livestock Loss            | : | Data Not Available                                                                                                                                                                                                                                                                  |
| 33 | Communication             | : | Data Not Available                                                                                                                                                                                                                                                                  |
| 34 | Infrastructure            | : | Data Not Available                                                                                                                                                                                                                                                                  |
| 35 | Agriculture/forest/Barren | : | Forest                                                                                                                                                                                                                                                                              |
| 36 | Geo-scientific Causes     | : | Toe cutting and water saturation. The mass failure has been accelerated along the Metabasalt-Granite litho-contact, after the road construction that later exaggerated by rainfall. Contact facilitating the water infiltration & thus increase in hydrostatic pressure.            |
| 37 | Remedial measures         | : | Extending existing retaining wall to both sides is suggested. More weep holes and easing the slope are recommended.                                                                                                                                                                 |
| 38 | Remarks, if any           |   | Many streams cut across the section, draining into the adjacent reservoir. Debris is observed at the base of slide revealing it as an active slide. Landslide occurred in the past and is maintained after construction of retaining wall & breast wall on either side of the road. |

|    |                                               |   |                                                                                                                                                                                 |
|----|-----------------------------------------------|---|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 39 | Photos. Sketch of Plan & section of the slide | : |                                                                                               |
| 40 | Summary/Abstract                              | : | Active slide of 45m width is observed on State highway 34, Increasing the width of the retaining wall and easing the slope above it will prove beneficial in restraining slide. |
| 41 | Date of Reporting                             | : | 09/12/2019                                                                                                                                                                      |
| 42 | Landslide Category                            | : | Debris-cum-earth slide                                                                                                                                                          |



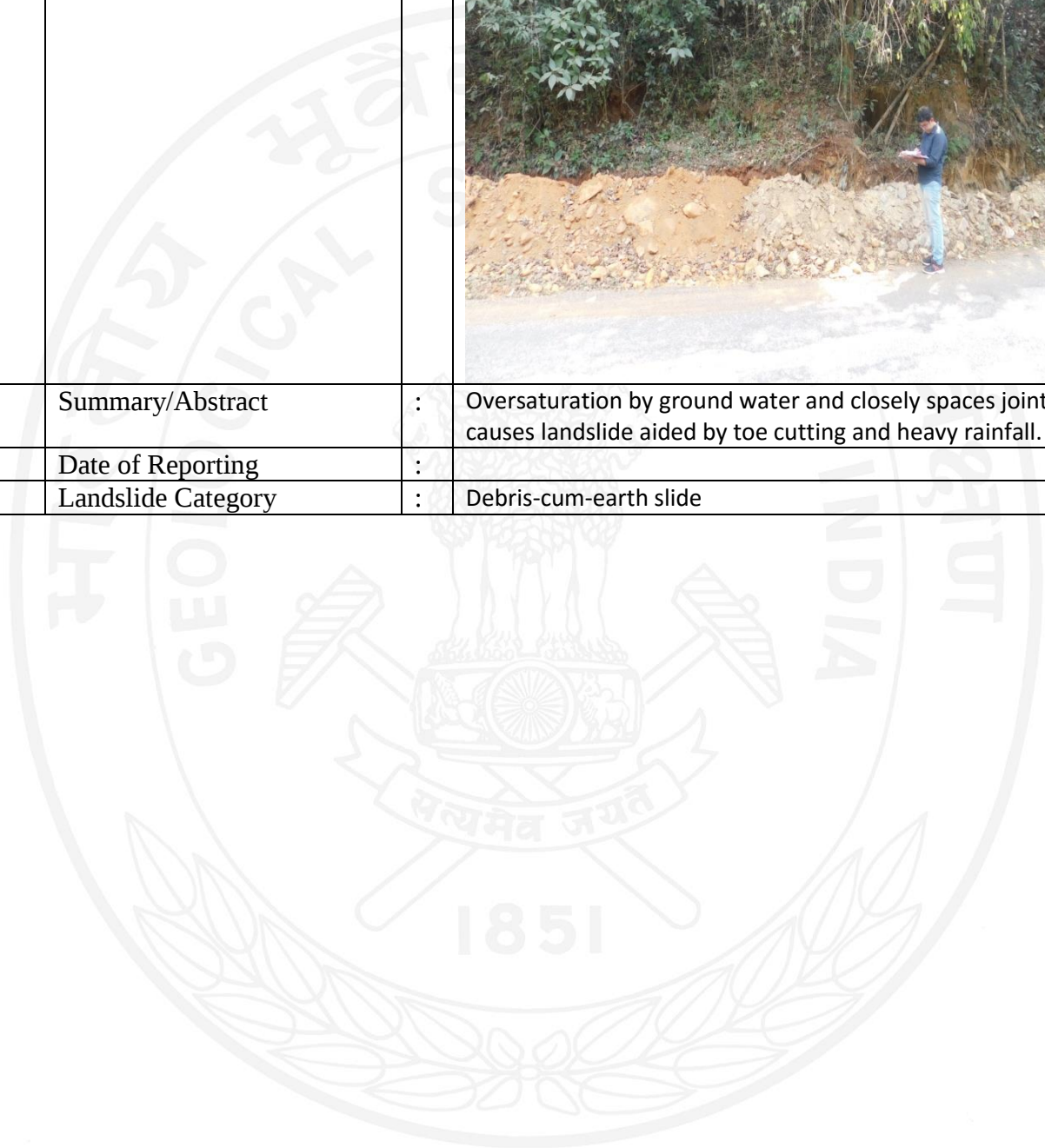
| No | Field                     |   | Description                                                                                         |
|----|---------------------------|---|-----------------------------------------------------------------------------------------------------|
| 1  | Slide No.                 | : | 9                                                                                                   |
| 2  | State                     | : | Karnataka                                                                                           |
| 3  | District                  |   | Uttar Kannada                                                                                       |
| 4  | Toposheet No              | : | 48I/8                                                                                               |
| 5  | Name of the Slide         | : | KAR/UK/48I08/2018/09                                                                                |
| 6  | NH/SH/Locality            | : | 1 km NW of Dewali                                                                                   |
| 7  | Latitude (N)              | : | 15°08'58.000                                                                                        |
| 8  | Longitude (E)             | : | 74°26'52.300                                                                                        |
| 9  | Length (m)                | : | 10                                                                                                  |
| 10 | Width (m)                 | : | 10                                                                                                  |
| 11 | Height (m)                | : | 8                                                                                                   |
| 12 | Area (sq m)               | : | 100                                                                                                 |
| 13 | Depth                     | : | <=5m                                                                                                |
| 14 | Volume                    | : |                                                                                                     |
| 15 | Run out distance (m)      | : | 5                                                                                                   |
| 16 | Type of material          | : | Debris                                                                                              |
| 17 | Type of movement          | : | Slide                                                                                               |
| 18 | Rate of movement          | : | Imperceptible                                                                                       |
| 19 | Activity                  | : | Suspended                                                                                           |
| 20 | Distribution              | : | Retrogressive                                                                                       |
| 21 | Style                     | : | Single                                                                                              |
| 22 | Failure mechanism         | : | Shallow Rotational Failure                                                                          |
| 23 | History                   | : | Data Not Available                                                                                  |
| 24 | Geomorphology             | : | Lowly Dissected Slope                                                                               |
| 25 | Geology/Lithology         | : | Granite                                                                                             |
| 26 | Structure                 | : | No distinct structure                                                                               |
| 27 | Landuse/ Landcover        | : | Extensive Cut Slope                                                                                 |
| 28 | Hydrological condition    | : | Dry                                                                                                 |
| 29 | Triggering Factor         | : | Rainfall                                                                                            |
| 30 | Death of persons          | : | Data Not Available                                                                                  |
| 31 | People affected           | : | Data Not Available                                                                                  |
| 32 | Livestock Loss            | : | Data Not Available                                                                                  |
| 33 | Communication             | : | Data Not Available                                                                                  |
| 34 | Infrastructure            | : | Data Not Available                                                                                  |
| 35 | Agriculture/forest/Barren | : | Forest                                                                                              |
| 36 | Geo-scientific Causes     | : | Removal of toe support and subsequently infiltration of water leads to mass failure and subsidence. |
| 37 | Remedial measures         | : | Retaining wall with weep holes is suggested                                                         |
| 38 | Remarks, if any           |   | Creeping of trees and hanging roots are observed.                                                   |

|    |                                               |   |                                                                                    |
|----|-----------------------------------------------|---|------------------------------------------------------------------------------------|
| 39 | Photos. Sketch of Plan & section of the slide | : |  |
| 40 | Summary/Abstract                              | : | Suspended retrogressive shallow rotational slide is observed on granitic terrain.  |
| 41 | Date of Reporting                             | : | 09/12/2018                                                                         |
| 42 | Landslide Category                            | : | Debris-cum-earth slide                                                             |



| No | Field                     |   | Description                                                                                                        |
|----|---------------------------|---|--------------------------------------------------------------------------------------------------------------------|
| 1  | Slide No.                 | : | 10                                                                                                                 |
| 2  | State                     | : | Karnataka                                                                                                          |
| 3  | District                  |   | Uttar Kannada                                                                                                      |
| 4  | Toposheet No              | : | 48I/8                                                                                                              |
| 5  | Name of the Slide         | : | KAR/UK/48I08/2018/10                                                                                               |
| 6  | NH/SH/Locality            | : | 1 km NE of Dewali                                                                                                  |
| 7  | Latitude (N)              | : | 15°08'57.900                                                                                                       |
| 8  | Longitude (E)             | : | 74°26'45.700                                                                                                       |
| 9  | Length (m)                | : | 11                                                                                                                 |
| 10 | Width (m)                 | : | 20                                                                                                                 |
| 11 | Height (m)                | : | 10                                                                                                                 |
| 12 | Area (sq m)               | : | 220                                                                                                                |
| 13 | Depth                     | : | <=5m                                                                                                               |
| 14 | Volume                    | : |                                                                                                                    |
| 15 | Run out distance (m)      | : | 8                                                                                                                  |
| 16 | Type of material          | : | Debris                                                                                                             |
| 17 | Type of movement          | : | Slide                                                                                                              |
| 18 | Rate of movement          | : | Imperceptible                                                                                                      |
| 19 | Activity                  | : | Suspended                                                                                                          |
| 20 | Distribution              | : | Retrogressive                                                                                                      |
| 21 | Style                     | : | Single                                                                                                             |
| 22 | Failure mechanism         | : | Shallow Rotational Failure                                                                                         |
| 23 | History                   | : | Data Not Available                                                                                                 |
| 24 | Geomorphology             | : | Lowly Dissected Slope                                                                                              |
| 25 | Geology/Lithology         | : | Granite                                                                                                            |
| 26 | Structure                 | : | No distinct structure                                                                                              |
| 27 | Landuse/ Landcover        | : | Extensive Cut Slope                                                                                                |
| 28 | Hydrological condition    | : | Damp                                                                                                               |
| 29 | Triggering Factor         | : | Rainfall                                                                                                           |
| 30 | Death of persons          | : | Data Not Available                                                                                                 |
| 31 | People affected           | : | Data Not Available                                                                                                 |
| 32 | Livestock Loss            | : | Data Not Available                                                                                                 |
| 33 | Communication             | : | Data Not Available                                                                                                 |
| 34 | Infrastructure            | : | Data Not Available                                                                                                 |
| 35 | Agriculture/forest/Barren | : | Forest                                                                                                             |
| 36 | Geo-scientific Causes     | : | Damp condition due to flow to adjacent reservoir                                                                   |
| 37 | Remedial measures         | : | Breast wall with weep holes is suggested. Proper drainge should be provided at downslope to avoid road subsidence. |
| 38 | Remarks, if any           |   | Nil                                                                                                                |

|    |                                               |   |                                                                                                                     |
|----|-----------------------------------------------|---|---------------------------------------------------------------------------------------------------------------------|
| 39 | Photos. Sketch of Plan & section of the slide | : |                                   |
| 40 | Summary/Abstract                              | : | Oversaturation by ground water and closely spaces jointed causes landslide aided by toe cutting and heavy rainfall. |
| 41 | Date of Reporting                             | : |                                                                                                                     |
| 42 | Landslide Category                            | : | Debris-cum-earth slide                                                                                              |



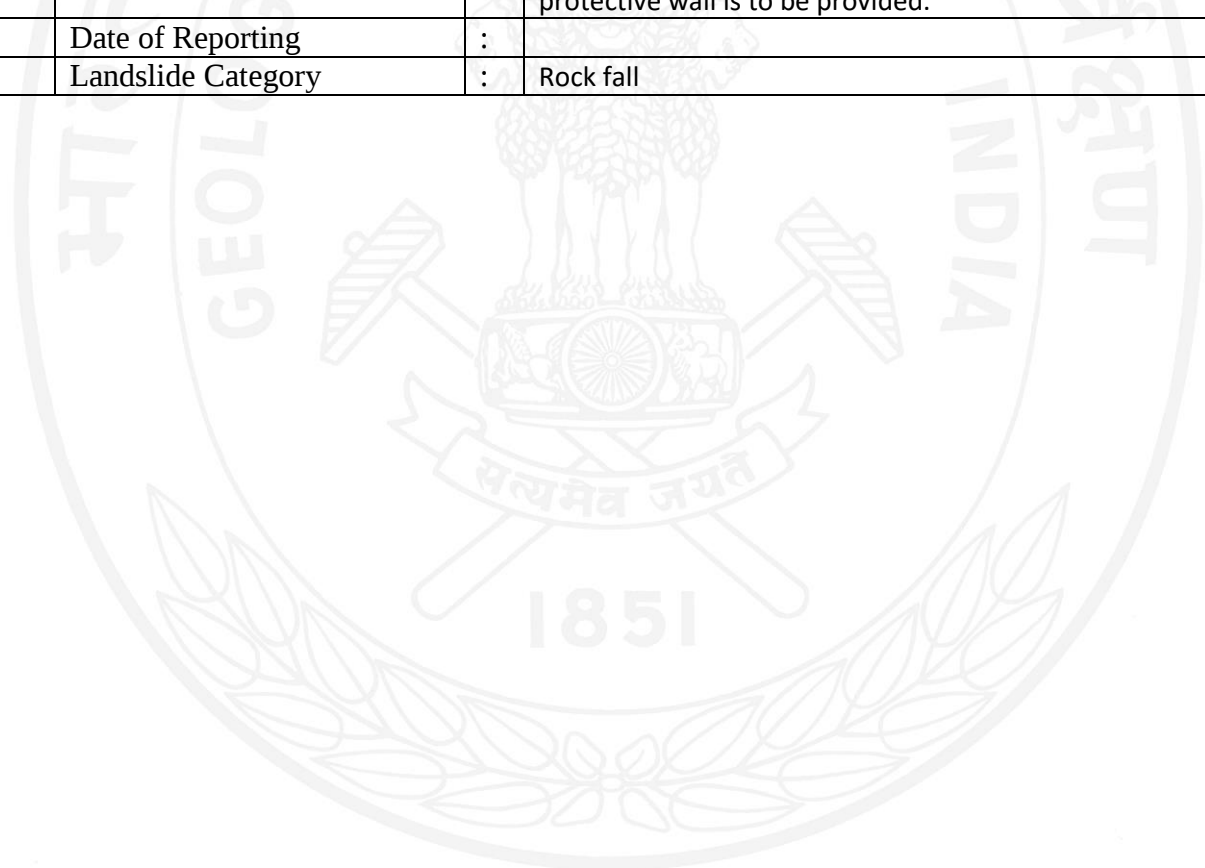
| No | Field                     |   | Description                                 |
|----|---------------------------|---|---------------------------------------------|
| 1  | Slide No.                 | : | 11                                          |
| 2  | State                     | : | Karnataka                                   |
| 3  | District                  |   | Uttar Kannada                               |
| 4  | Toposheet No              | : | 48I/8                                       |
| 5  | Name of the Slide         | : | KAR/UK/48I08/2018/11                        |
| 6  | NH/SH/Locality            | : | 2km N of Nangal                             |
| 7  | Latitude (N)              | : | 15°08'54.100                                |
| 8  | Longitude (E)             | : | 74°26'7.200                                 |
| 9  | Length (m)                | : | 8                                           |
| 10 | Width (m)                 | : | 8                                           |
| 11 | Height (m)                | : | 6                                           |
| 12 | Area (sq m)               | : | 64                                          |
| 13 | Depth                     | : | <=5m                                        |
| 14 | Volume                    | : |                                             |
| 15 | Run out distance (m)      | : | 8                                           |
| 16 | Type of material          | : | Debris                                      |
| 17 | Type of movement          | : | Slide                                       |
| 18 | Rate of movement          | : | Imperceptible                               |
| 19 | Activity                  | : | Suspended                                   |
| 20 | Distribution              | : | Retrogressive                               |
| 21 | Style                     | : | Single                                      |
| 22 | Failure mechanism         | : | Shallow Rotational Failure                  |
| 23 | History                   | : | Data Not Available                          |
| 24 | Geomorphology             | : | Lowly Dissected Slope                       |
| 25 | Geology/Lithology         | : | Metabasalt                                  |
| 26 | Structure                 | : | No distinct structure                       |
| 27 | Landuse/ Landcover        | : | Extensive Cut Slope                         |
| 28 | Hydrological condition    | : | Dry                                         |
| 29 | Triggering Factor         | : | Rainfall                                    |
| 30 | Death of persons          | : | Data Not Available                          |
| 31 | People affected           | : | Data Not Available                          |
| 32 | Livestock Loss            | : | Data Not Available                          |
| 33 | Communication             | : | Data Not Available                          |
| 34 | Infrastructure            | : | Data Not Available                          |
| 35 | Agriculture/forest/Barren | : | Forest                                      |
| 36 | Geo-scientific Causes     | : | Toe cutting                                 |
| 37 | Remedial measures         | : | Retaining wall with weep holes is suggested |
| 38 | Remarks, if any           |   | Weathered rocks are observed on slope.      |

|    |                                               |   |                                                                                    |
|----|-----------------------------------------------|---|------------------------------------------------------------------------------------|
| 39 | Photos. Sketch of Plan & section of the slide | : |  |
| 40 | Summary/Abstract                              | : | Suspended retrogressive shallow rotational slide is observed on granitic terrain.  |
| 41 | Date of Reporting                             | : |                                                                                    |
| 42 | Landslide Category                            | : | Debris-cum-earth slide                                                             |



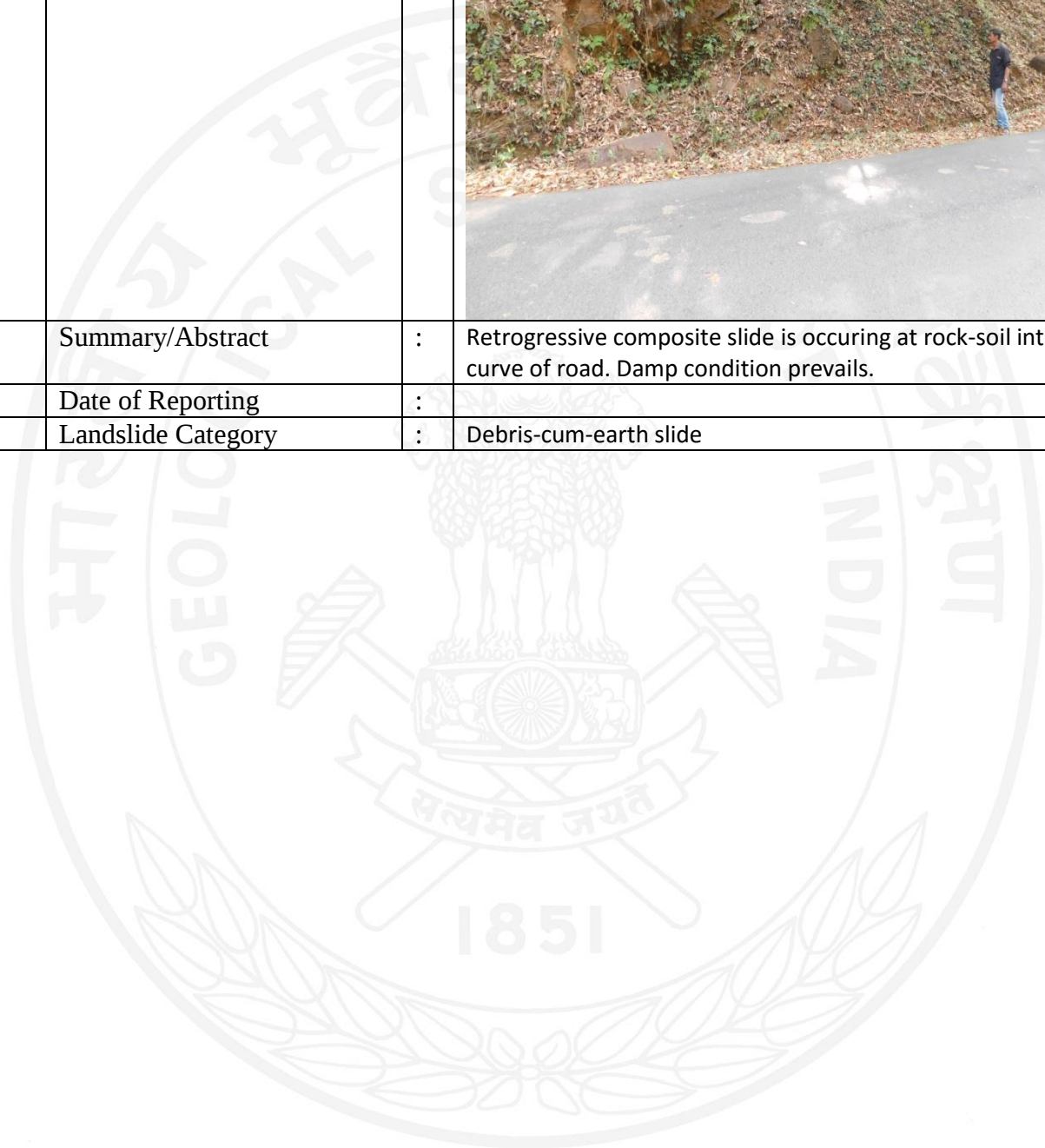
| No | Field                     |   | Description                                                                                              |
|----|---------------------------|---|----------------------------------------------------------------------------------------------------------|
| 1  | Slide No.                 | : | 12                                                                                                       |
| 2  | State                     | : | Karnataka                                                                                                |
| 3  | District                  |   | Uttar Kannada                                                                                            |
| 4  | Toposheet No              | : | 48I/8                                                                                                    |
| 5  | Name of the Slide         | : | KAR/UK/48I08/2018/12                                                                                     |
| 6  | NH/SH/Locality            | : | 0.5 km W of Dudgali                                                                                      |
| 7  | Latitude (N)              | : | 15°02'30.200                                                                                             |
| 8  | Longitude (E)             | : | 74°20'57.600                                                                                             |
| 9  | Length (m)                | : | 8                                                                                                        |
| 10 | Width (m)                 | : | 20                                                                                                       |
| 11 | Height (m)                | : | 6                                                                                                        |
| 12 | Area (sq m)               | : | 160                                                                                                      |
| 13 | Depth                     | : | <=5m                                                                                                     |
| 14 | Volume                    | : |                                                                                                          |
| 15 | Run out distance (m)      | : | 15                                                                                                       |
| 16 | Type of material          | : | Debris                                                                                                   |
| 17 | Type of movement          | : | Slide                                                                                                    |
| 18 | Rate of movement          | : | Imperceptible                                                                                            |
| 19 | Activity                  | : | Active                                                                                                   |
| 20 | Distribution              | : | Retrogressive                                                                                            |
| 21 | Style                     | : | Single                                                                                                   |
| 22 | Failure mechanism         | : | Shallow Rotational Failure                                                                               |
| 23 | History                   | : | Data Not Available                                                                                       |
| 24 | Geomorphology             | : | Lowly Dissected Slope                                                                                    |
| 25 | Geology/Lithology         | : | Granite, Dolerite                                                                                        |
| 26 | Structure                 | : | No distinct structure                                                                                    |
| 27 | Landuse/ Landcover        | : | Extensive Cut Slope                                                                                      |
| 28 | Hydrological condition    | : | Dry                                                                                                      |
| 29 | Triggering Factor         | : | Rainfall                                                                                                 |
| 30 | Death of persons          | : | Data Not Available                                                                                       |
| 31 | People affected           | : | Data Not Available                                                                                       |
| 32 | Livestock Loss            | : | Data Not Available                                                                                       |
| 33 | Communication             | : | Data Not Available                                                                                       |
| 34 | Infrastructure            | : | Data Not Available                                                                                       |
| 35 | Agriculture/forest/Barren | : | Forest                                                                                                   |
| 36 | Geo-scientific Causes     | : | Toe cutting                                                                                              |
| 37 | Remedial measures         | : | Removal of loose boulders which are present on slope and construction of protective wall are recommended |
| 38 | Remarks, if any           |   | Nil                                                                                                      |

|    |                                               |   |                                                                                                                                                               |
|----|-----------------------------------------------|---|---------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 39 | Photos. Sketch of Plan & section of the slide | : |                                                                             |
| 40 | Summary/Abstract                              | : | High slope angle and toe cutting of the slope makes it vulnerable for landslide. Loose boulders are observed on slope so a protective wall is to be provided. |
| 41 | Date of Reporting                             | : |                                                                                                                                                               |
| 42 | Landslide Category                            | : | Rock fall                                                                                                                                                     |



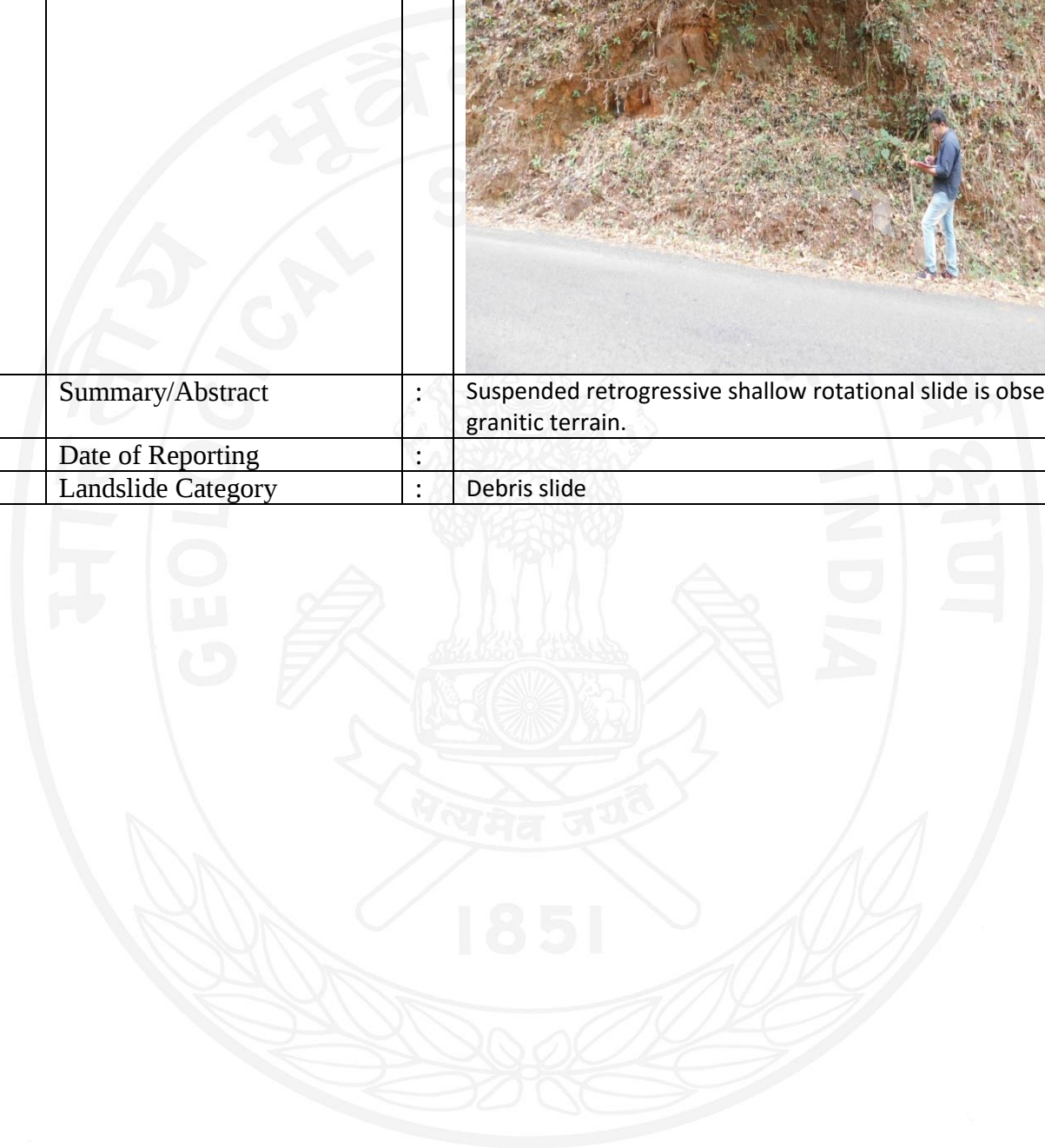
| No | Field                     |   | Description                                    |
|----|---------------------------|---|------------------------------------------------|
| 1  | Slide No.                 | : | 13                                             |
| 2  | State                     | : | Karnataka                                      |
| 3  | District                  |   | Uttar Kannada                                  |
| 4  | Toposheet No              | : | 48I/8                                          |
| 5  | Name of the Slide         | : | KAR/UK/48I08/2018/13                           |
| 6  | NH/SH/Locality            | : | 3 km N of Anshi, SH 34                         |
| 7  | Latitude (N)              | : | 15°00'16.800                                   |
| 8  | Longitude (E)             | : | 74°21'29.900                                   |
| 9  | Length (m)                | : | 8                                              |
| 10 | Width (m)                 | : | 52                                             |
| 11 | Height (m)                | : | 6                                              |
| 12 | Area (sq m)               | : | 416                                            |
| 13 | Depth                     | : | <=5m                                           |
| 14 | Volume                    | : |                                                |
| 15 | Run out distance (m)      | : | 6                                              |
| 16 | Type of material          | : | Debris                                         |
| 17 | Type of movement          | : | Slide                                          |
| 18 | Rate of movement          | : | Imperceptible                                  |
| 19 | Activity                  | : | Suspended                                      |
| 20 | Distribution              | : | Retrogressive                                  |
| 21 | Style                     | : | Composite                                      |
| 22 | Failure mechanism         | : | Shallow Rotational Failure                     |
| 23 | History                   | : | Data Not Available                             |
| 24 | Geomorphology             | : | Lowly Dissected Slope                          |
| 25 | Geology/Lithology         | : | Granite                                        |
| 26 | Structure                 | : | No distinct structure                          |
| 27 | Landuse/ Landcover        | : | Extensive Cut Slope                            |
| 28 | Hydrological condition    | : | Damp                                           |
| 29 | Triggering Factor         | : | Rainfall                                       |
| 30 | Death of persons          | : | Data Not Available                             |
| 31 | People affected           | : | Data Not Available                             |
| 32 | Livestock Loss            | : | Data Not Available                             |
| 33 | Communication             | : | Data Not Available                             |
| 34 | Infrastructure            | : | Data Not Available                             |
| 35 | Agriculture/forest/Barren | : | Forest                                         |
| 36 | Geo-scientific Causes     | : | Highly weathered rock mass and damp condition. |
| 37 | Remedial measures         | : | Breast wall with weep holes is suggested       |
| 38 | Remarks, if any           |   | Nil                                            |

|    |                                               |   |                                                                                                              |
|----|-----------------------------------------------|---|--------------------------------------------------------------------------------------------------------------|
| 39 | Photos. Sketch of Plan & section of the slide | : |                            |
| 40 | Summary/Abstract                              | : | Retrogressive composite slide is occurring at rock-soil interface at curve of road. Damp condition prevails. |
| 41 | Date of Reporting                             | : |                                                                                                              |
| 42 | Landslide Category                            | : | Debris-cum-earth slide                                                                                       |



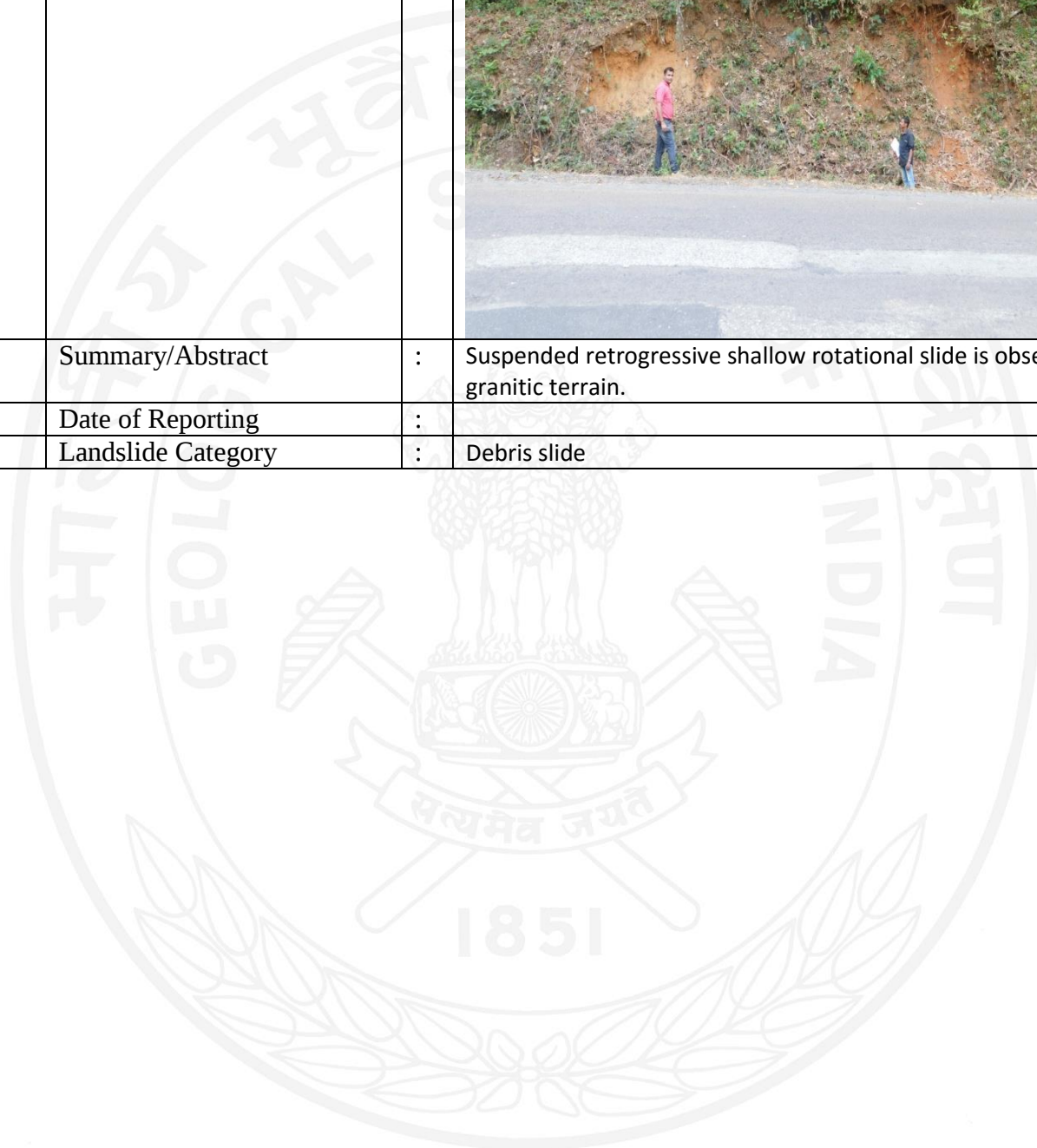
| No | Field                     |   | Description                                 |
|----|---------------------------|---|---------------------------------------------|
| 1  | Slide No.                 | : | 14                                          |
| 2  | State                     | : | Karnataka                                   |
| 3  | District                  |   | Uttar Kannada                               |
| 4  | Toposheet No              | : | 48I/8                                       |
| 5  | Name of the Slide         | : | KAR/UK/48I08/2018/14                        |
| 6  | NH/SH/Locality            | : | S of Badapohl                               |
| 7  | Latitude (N)              | : | 15°00'09.400                                |
| 8  | Longitude (E)             | : | 74°21'32.600                                |
| 9  | Length (m)                | : | 6                                           |
| 10 | Width (m)                 | : | 8                                           |
| 11 | Height (m)                | : | 5                                           |
| 12 | Area (sq m)               | : | 48                                          |
| 13 | Depth                     | : | <=5m                                        |
| 14 | Volume                    | : |                                             |
| 15 | Run out distance (m)      | : | 5                                           |
| 16 | Type of material          | : | Debris                                      |
| 17 | Type of movement          | : | Slide                                       |
| 18 | Rate of movement          | : | Imperceptible                               |
| 19 | Activity                  | : | Suspended                                   |
| 20 | Distribution              | : | Retrogressive                               |
| 21 | Style                     | : | Single                                      |
| 22 | Failure mechanism         | : | Shallow Rotational Failure                  |
| 23 | History                   | : | Data Not Available                          |
| 24 | Geomorphology             | : | Lowly Dissected Slope                       |
| 25 | Geology/Lithology         | : | Granite                                     |
| 26 | Structure                 | : | No distinct structure                       |
| 27 | Landuse/ Landcover        | : | Extensive Cut Slope                         |
| 28 | Hydrological condition    | : | Damp                                        |
| 29 | Triggering Factor         | : | Rainfall                                    |
| 30 | Death of persons          | : | Data Not Available                          |
| 31 | People affected           | : | Data Not Available                          |
| 32 | Livestock Loss            | : | Data Not Available                          |
| 33 | Communication             | : | Data Not Available                          |
| 34 | Infrastructure            | : | Data Not Available                          |
| 35 | Agriculture/forest/Barren | : | Forest                                      |
| 36 | Geo-scientific Causes     | : | Toe cutting and damp condition              |
| 37 | Remedial measures         | : | Retaining wall with weep holes is suggested |
| 38 | Remarks, if any           |   | Damp soil on slope.                         |

|    |                                               |   |                                                                                    |
|----|-----------------------------------------------|---|------------------------------------------------------------------------------------|
| 39 | Photos. Sketch of Plan & section of the slide | : |  |
| 40 | Summary/Abstract                              | : | Suspended retrogressive shallow rotational slide is observed on granitic terrain.  |
| 41 | Date of Reporting                             | : |                                                                                    |
| 42 | Landslide Category                            | : | Debris slide                                                                       |



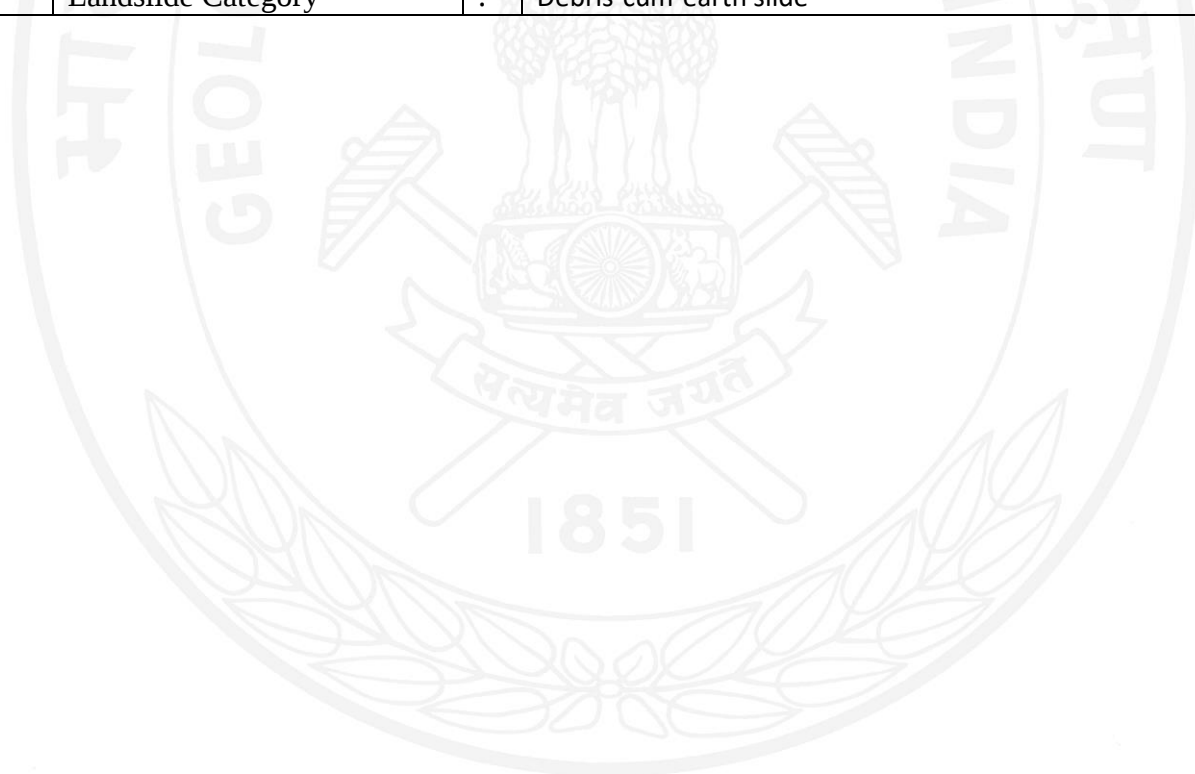
| No | Field                     |   | Description                                 |
|----|---------------------------|---|---------------------------------------------|
| 1  | Slide No.                 | : | 15                                          |
| 2  | State                     | : | Karnataka                                   |
| 3  | District                  |   | Uttar Kannada                               |
| 4  | Toposheet No              | : | 48I/8                                       |
| 5  | Name of the Slide         | : | KAR/UK/48I08/2018/15                        |
| 6  | NH/SH/Locality            | : | S of Badapohl                               |
| 7  | Latitude (N)              | : | 15°00'11.400                                |
| 8  | Longitude (E)             | : | 74°21'32.100                                |
| 9  | Length (m)                | : | 6                                           |
| 10 | Width (m)                 | : | 8                                           |
| 11 | Height (m)                | : | 5                                           |
| 12 | Area (sq m)               | : | 48                                          |
| 13 | Depth                     | : | <=5m                                        |
| 14 | Volume                    | : |                                             |
| 15 | Run out distance (m)      | : | 5                                           |
| 16 | Type of material          | : | Debris                                      |
| 17 | Type of movement          | : | Slide                                       |
| 18 | Rate of movement          | : | Imperceptible                               |
| 19 | Activity                  | : | Suspended                                   |
| 20 | Distribution              | : | Retrogressive                               |
| 21 | Style                     | : | Single                                      |
| 22 | Failure mechanism         | : | Shallow Rotational Failure                  |
| 23 | History                   | : | Data Not Available                          |
| 24 | Geomorphology             | : | Lowly Dissected Slope                       |
| 25 | Geology/Lithology         | : | Granite                                     |
| 26 | Structure                 | : | No distinct structure                       |
| 27 | Landuse/ Landcover        | : | Extensive Cut Slope                         |
| 28 | Hydrological condition    | : | Damp                                        |
| 29 | Triggering Factor         | : | Rainfall                                    |
| 30 | Death of persons          | : | Data Not Available                          |
| 31 | People affected           | : | Data Not Available                          |
| 32 | Livestock Loss            | : | Data Not Available                          |
| 33 | Communication             | : | Data Not Available                          |
| 34 | Infrastructure            | : | Data Not Available                          |
| 35 | Agriculture/forest/Barren | : | Forest                                      |
| 36 | Geo-scientific Causes     | : | Toe cutting and damp condition              |
| 37 | Remedial measures         | : | Retaining wall with weep holes is suggested |
| 38 | Remarks, if any           |   | Nil                                         |

|    |                                               |   |                                                                                    |
|----|-----------------------------------------------|---|------------------------------------------------------------------------------------|
| 39 | Photos. Sketch of Plan & section of the slide | : |  |
| 40 | Summary/Abstract                              | : | Suspended retrogressive shallow rotational slide is observed on granitic terrain.  |
| 41 | Date of Reporting                             | : |                                                                                    |
| 42 | Landslide Category                            | : | Debris slide                                                                       |



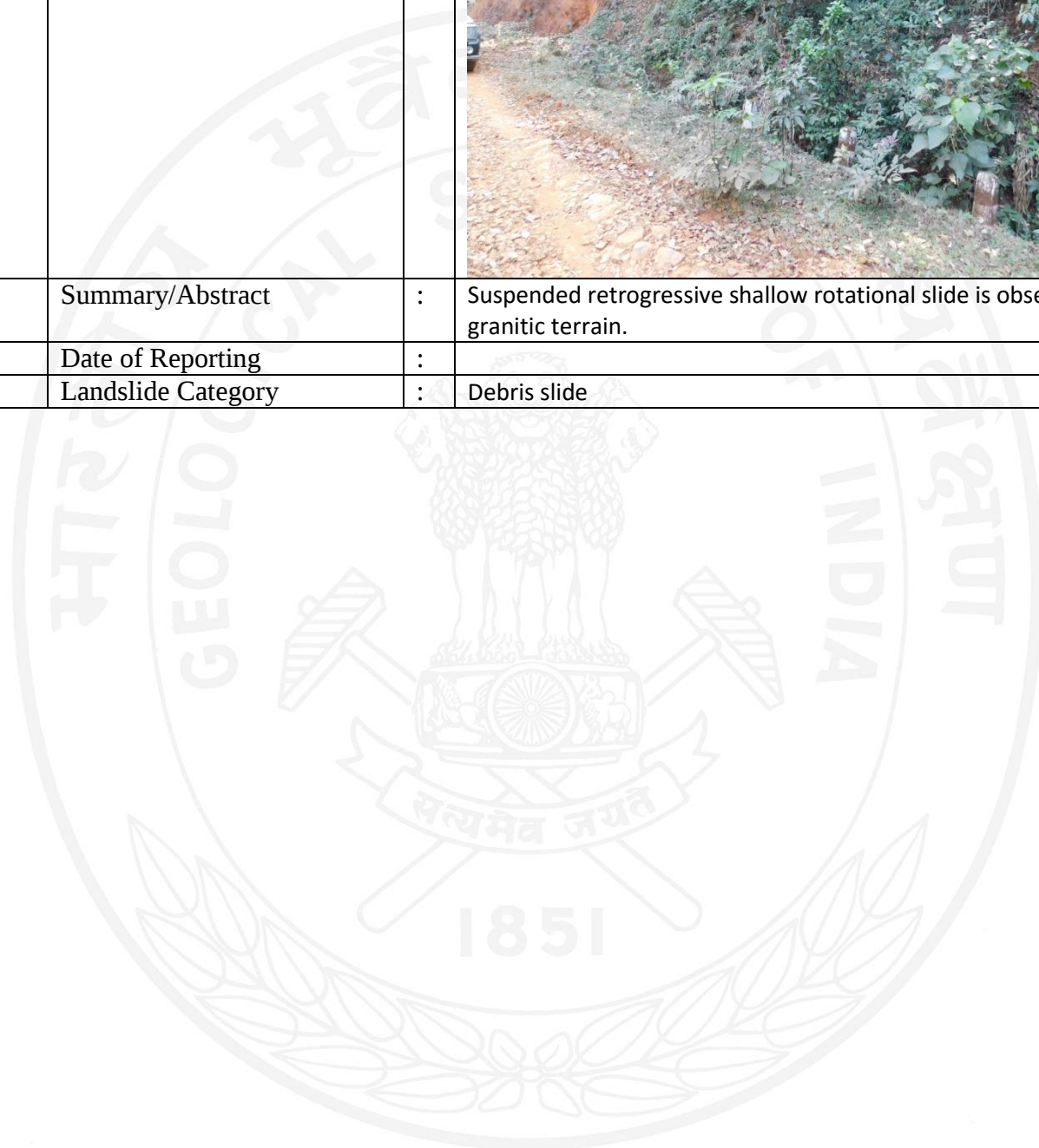
| No | Field                     |   | Description                                                                                            |
|----|---------------------------|---|--------------------------------------------------------------------------------------------------------|
| 1  | Slide No.                 | : | 16                                                                                                     |
| 2  | State                     | : | Karnataka                                                                                              |
| 3  | District                  |   | Uttar Kannada                                                                                          |
| 4  | Toposheet No              | : | 48I/8                                                                                                  |
| 5  | Name of the Slide         | : | KAR/UK/48I08/2018/16                                                                                   |
| 6  | NH/SH/Locality            | : | 2km SW of Kanangaon                                                                                    |
| 7  | Latitude (N)              | : | 15°13'16.900                                                                                           |
| 8  | Longitude (E)             | : | 74°23'59.800                                                                                           |
| 9  | Length (m)                | : | 3                                                                                                      |
| 10 | Width (m)                 | : | 18                                                                                                     |
| 11 | Height (m)                | : | 3                                                                                                      |
| 12 | Area (sq m)               | : | 54                                                                                                     |
| 13 | Depth                     | : | <=5m                                                                                                   |
| 14 | Volume                    | : |                                                                                                        |
| 15 | Run out distance (m)      | : | 7                                                                                                      |
| 16 | Type of material          | : | Debris                                                                                                 |
| 17 | Type of movement          | : | Slide                                                                                                  |
| 18 | Rate of movement          | : | Imperceptible                                                                                          |
| 19 | Activity                  | : | Suspended                                                                                              |
| 20 | Distribution              | : | Retrogressive                                                                                          |
| 21 | Style                     | : | Single                                                                                                 |
| 22 | Failure mechanism         | : | Shallow Rotational Failure                                                                             |
| 23 | History                   | : | Data Not Available                                                                                     |
| 24 | Geomorphology             | : | Lowly Dissected Slope                                                                                  |
| 25 | Geology/Lithology         | : | Granite, Metabasalt                                                                                    |
| 26 | Structure                 | : | No distinct structure                                                                                  |
| 27 | Landuse/ Landcover        | : | Extensive Cut Slope                                                                                    |
| 28 | Hydrological condition    | : | Damp                                                                                                   |
| 29 | Triggering Factor         | : | Rainfall                                                                                               |
| 30 | Death of persons          | : | Data Not Available                                                                                     |
| 31 | People affected           | : | Data Not Available                                                                                     |
| 32 | Livestock Loss            | : | Data Not Available                                                                                     |
| 33 | Communication             | : | Data Not Available                                                                                     |
| 34 | Infrastructure            | : | Data Not Available                                                                                     |
| 35 | Agriculture/forest/Barren | : | Forest                                                                                                 |
| 36 | Geo-scientific Causes     | : | Modification of drainage and toe cutting                                                               |
| 37 | Remedial measures         | : | Providing culvert and construction of retaining wall are recommended.                                  |
| 38 | Remarks, if any           |   | Obstruction of Natural course of Nala results in subsidence of road due to removal of soil underneath. |

|    |                                               |   |                                                                                                                     |
|----|-----------------------------------------------|---|---------------------------------------------------------------------------------------------------------------------|
| 39 | Photos. Sketch of Plan & section of the slide | : |                                   |
| 40 | Summary/Abstract                              | : | Oversaturation by ground water and closely spaces jointed caused landslide aided by toe cutting and heavy rainfall. |
| 41 | Date of Reporting                             | : |                                                                                                                     |
| 42 | Landslide Category                            | : | Debris-cum-earth slide                                                                                              |

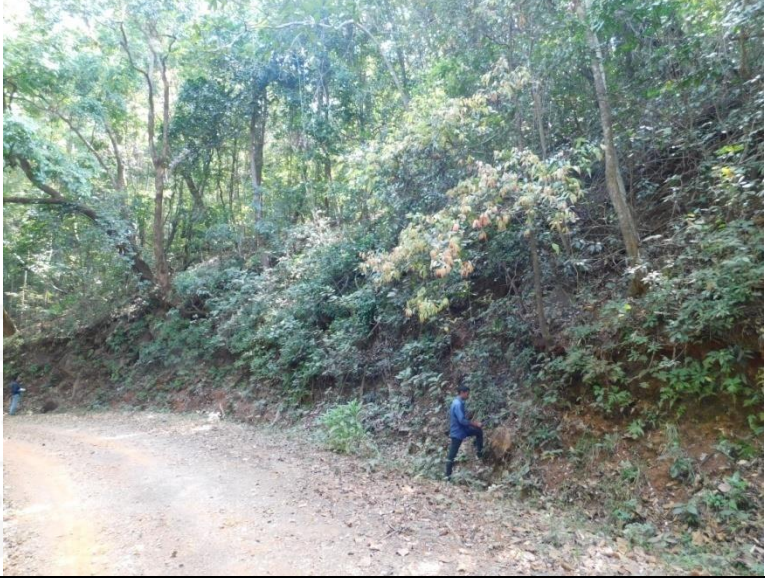


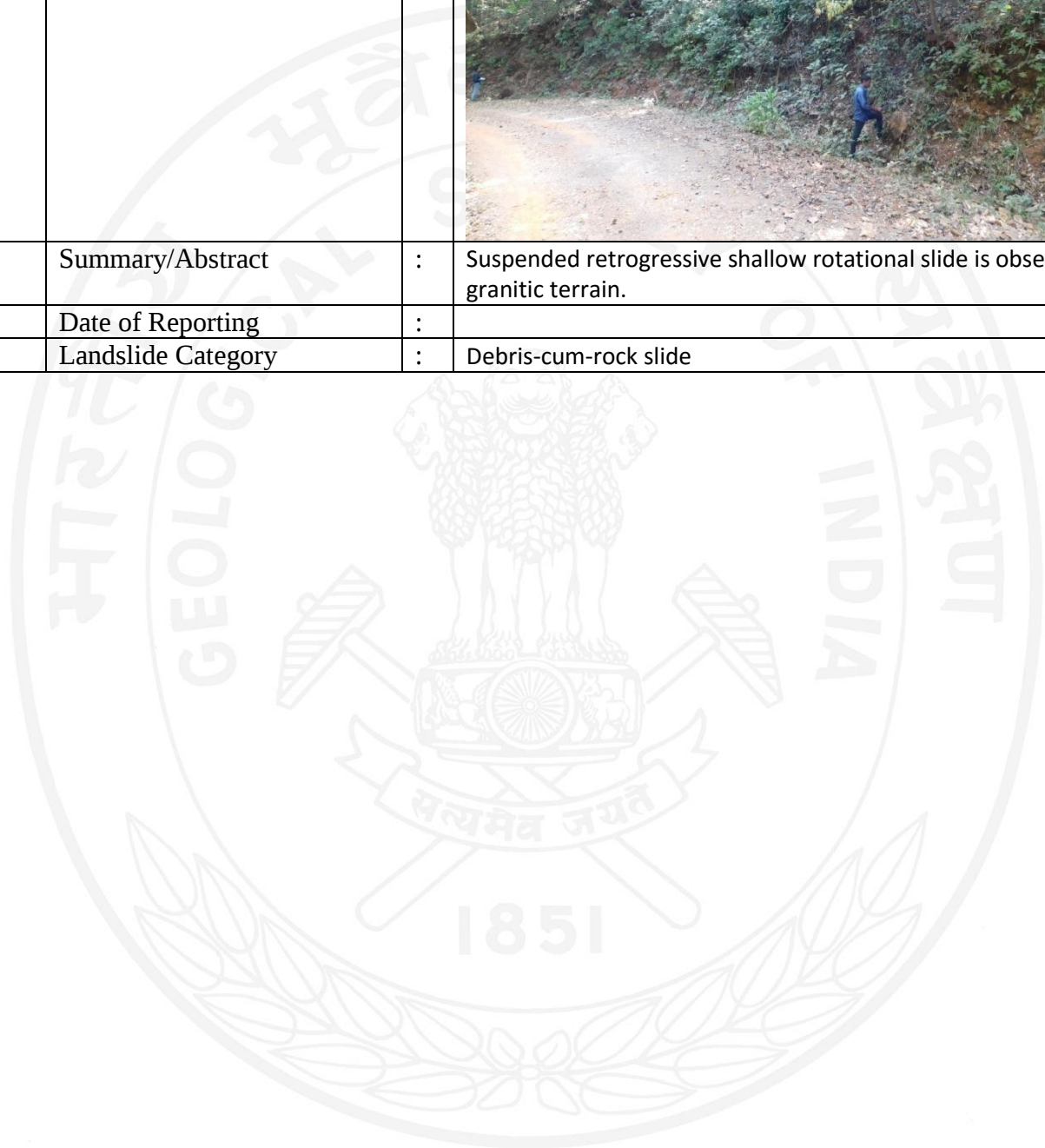
| No | Field                     |   | Description                                                      |
|----|---------------------------|---|------------------------------------------------------------------|
| 1  | Slide No.                 | : | 17                                                               |
| 2  | State                     | : | Karnataka                                                        |
| 3  | District                  |   | Uttar Kannada                                                    |
| 4  | Toposheet No              | : | 48I/8                                                            |
| 5  | Name of the Slide         | : | KAR/UK/48I08/2018/17                                             |
| 6  | NH/SH/Locality            | : | 2km SW of Kanangaon                                              |
| 7  | Latitude (N)              | : | 15°13'24.300                                                     |
| 8  | Longitude (E)             | : | 74°23'56.100                                                     |
| 9  | Length (m)                | : | 8                                                                |
| 10 | Width (m)                 | : | 12                                                               |
| 11 | Height (m)                | : | 6                                                                |
| 12 | Area (sq m)               | : | 96                                                               |
| 13 | Depth                     | : | <=5m                                                             |
| 14 | Volume                    | : |                                                                  |
| 15 | Run out distance (m)      | : | 5                                                                |
| 16 | Type of material          | : | Debris                                                           |
| 17 | Type of movement          | : | Slide                                                            |
| 18 | Rate of movement          | : | Imperceptible                                                    |
| 19 | Activity                  | : | Suspended                                                        |
| 20 | Distribution              | : | Retrogressive                                                    |
| 21 | Style                     | : | Single                                                           |
| 22 | Failure mechanism         | : | Shallow Rotational Failure                                       |
| 23 | History                   | : | Data Not Available                                               |
| 24 | Geomorphology             | : | Lowly Dissected Slope                                            |
| 25 | Geology/Lithology         | : | Granite                                                          |
| 26 | Structure                 | : | No distinct structure                                            |
| 27 | Landuse/ Landcover        | : | Extensive Cut Slope                                              |
| 28 | Hydrological condition    | : | Dry                                                              |
| 29 | Triggering Factor         | : | Rainfall                                                         |
| 30 | Death of persons          | : | Data Not Available                                               |
| 31 | People affected           | : | Data Not Available                                               |
| 32 | Livestock Loss            | : | Data Not Available                                               |
| 33 | Communication             | : | Data Not Available                                               |
| 34 | Infrastructure            | : | Data Not Available                                               |
| 35 | Agriculture/forest/Barren | : | Forest                                                           |
| 36 | Geo-scientific Causes     | : | Toe cutting                                                      |
| 37 | Remedial measures         | : | Retaining wall with weep holes and proper management of drainage |
| 38 | Remarks, if any           |   | Slided material are lying on the base of slope.                  |

|    |                                               |   |                                                                                    |
|----|-----------------------------------------------|---|------------------------------------------------------------------------------------|
| 39 | Photos. Sketch of Plan & section of the slide | : |  |
| 40 | Summary/Abstract                              | : | Suspended retrogressive shallow rotational slide is observed on granitic terrain.  |
| 41 | Date of Reporting                             | : |                                                                                    |
| 42 | Landslide Category                            | : | Debris slide                                                                       |



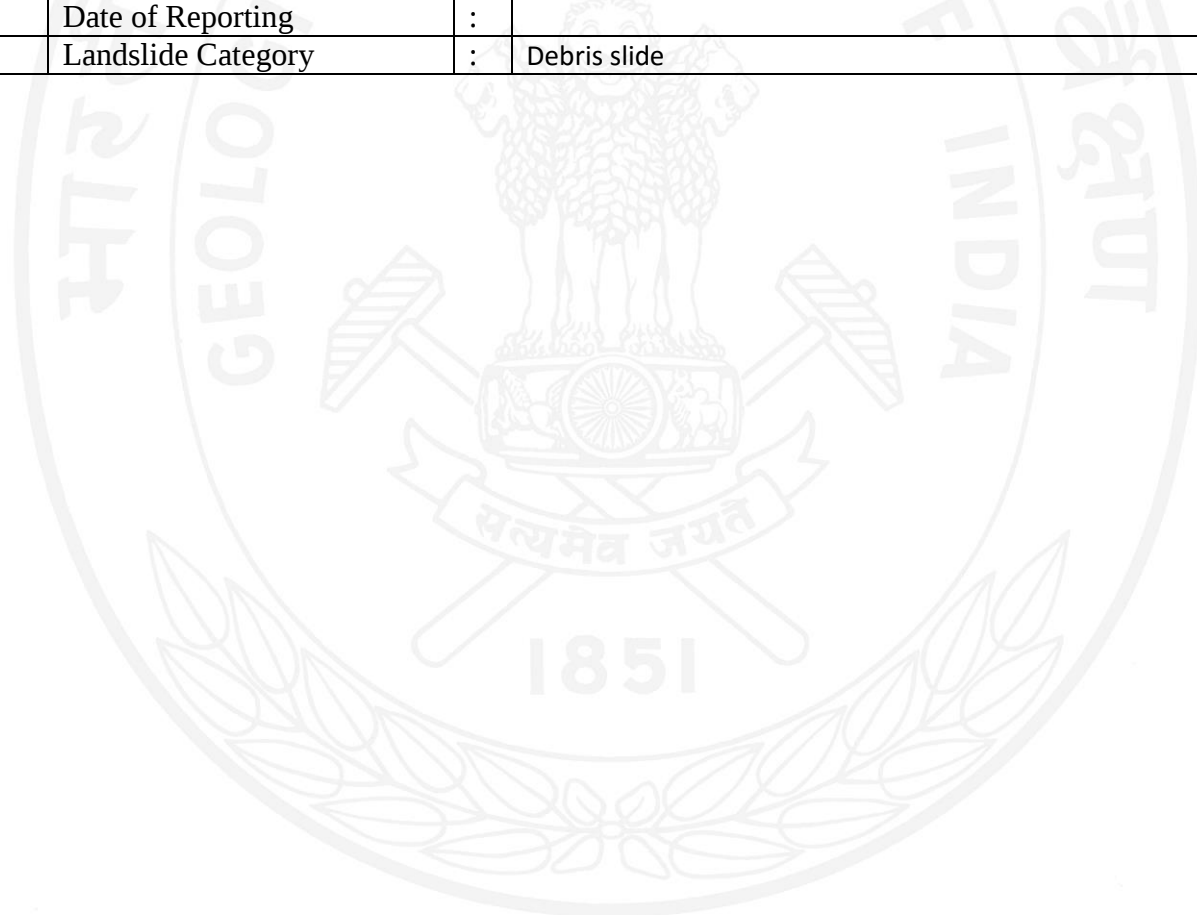
| No | Field                     |   | Description                                                                                                    |
|----|---------------------------|---|----------------------------------------------------------------------------------------------------------------|
| 1  | Slide No.                 | : | 18                                                                                                             |
| 2  | State                     | : | Karnataka                                                                                                      |
| 3  | District                  |   | Uttar Kannada                                                                                                  |
| 4  | Toposheet No              | : | 48I/8                                                                                                          |
| 5  | Name of the Slide         | : | KAR/UK/48I08/2018/18                                                                                           |
| 6  | NH/SH/Locality            | : | 2.2 km SW of Kanangaon                                                                                         |
| 7  | Latitude (N)              | : | 15°13'14.300                                                                                                   |
| 8  | Longitude (E)             | : | 74°23'43.700                                                                                                   |
| 9  | Length (m)                | : | 9                                                                                                              |
| 10 | Width (m)                 | : | 20                                                                                                             |
| 11 | Height (m)                | : | 7                                                                                                              |
| 12 | Area (sq m)               | : | 180                                                                                                            |
| 13 | Depth                     | : | <=5m                                                                                                           |
| 14 | Volume                    | : |                                                                                                                |
| 15 | Run out distance (m)      | : | 30                                                                                                             |
| 16 | Type of material          | : | Debris                                                                                                         |
| 17 | Type of movement          | : | Slide                                                                                                          |
| 18 | Rate of movement          | : | Imperceptible                                                                                                  |
| 19 | Activity                  | : | Suspended                                                                                                      |
| 20 | Distribution              | : | Retrogressive                                                                                                  |
| 21 | Style                     | : | Multiple                                                                                                       |
| 22 | Failure mechanism         | : | Shallow Rotational Failure                                                                                     |
| 23 | History                   | : | Data Not Available                                                                                             |
| 24 | Geomorphology             | : | Lowly Dissected Slope                                                                                          |
| 25 | Geology/Lithology         | : | Granite                                                                                                        |
| 26 | Structure                 | : | Jointed, J1:NS/45°W, J2:220°/60°E                                                                              |
| 27 | Landuse/ Landcover        | : | Extensive Cut Slope                                                                                            |
| 28 | Hydrological condition    | : | Damp                                                                                                           |
| 29 | Triggering Factor         | : | Rainfall                                                                                                       |
| 30 | Death of persons          | : | Data Not Available                                                                                             |
| 31 | People affected           | : | Data Not Available                                                                                             |
| 32 | Livestock Loss            | : | Data Not Available                                                                                             |
| 33 | Communication             | : | Data Not Available                                                                                             |
| 34 | Infrastructure            | : | Data Not Available                                                                                             |
| 35 | Agriculture/forest/Barren | : | Forest                                                                                                         |
| 36 | Geo-scientific Causes     | : | Toe cutting for road widening. Well-jointed granite facilitates water seepage & thus resulted in rock failure. |
| 37 | Remedial measures         | : | Retaining wall with weep holes and removal of boulders are suggested.                                          |
| 38 | Remarks, if any           |   | Boulders are lying on the other side of road.                                                                  |

|    |                                               |   |                                                                                    |
|----|-----------------------------------------------|---|------------------------------------------------------------------------------------|
| 39 | Photos. Sketch of Plan & section of the slide | : |  |
| 40 | Summary/Abstract                              | : | Suspended retrogressive shallow rotational slide is observed on granitic terrain.  |
| 41 | Date of Reporting                             | : |                                                                                    |
| 42 | Landslide Category                            | : | Debris-cum-rock slide                                                              |



| No | Field                     |   | Description                                                      |
|----|---------------------------|---|------------------------------------------------------------------|
| 1  | Slide No.                 | : | 19                                                               |
| 2  | State                     | : | Karnataka                                                        |
| 3  | District                  | : | Uttar Kannada                                                    |
| 4  | Toposheet No              | : | 48I/8                                                            |
| 5  | Name of the Slide         | : | KAR/UK/48I08/2018/19                                             |
| 6  | NH/SH/Locality            | : | Near Tadaki village                                              |
| 7  | Latitude (N)              | : | 15°13'09.400                                                     |
| 8  | Longitude (E)             | : | 74°13'12.600                                                     |
| 9  | Length (m)                | : | 7                                                                |
| 10 | Width (m)                 | : | 8                                                                |
| 11 | Height (m)                | : | 6                                                                |
| 12 | Area (sq m)               | : | 56                                                               |
| 13 | Depth                     | : | <=5m                                                             |
| 14 | Volume                    | : |                                                                  |
| 15 | Run out distance (m)      | : | 5                                                                |
| 16 | Type of material          | : | Debris                                                           |
| 17 | Type of movement          | : | Slide                                                            |
| 18 | Rate of movement          | : | Imperceptible                                                    |
| 19 | Activity                  | : | Suspended                                                        |
| 20 | Distribution              | : | Widening & Retrogressive                                         |
| 21 | Style                     | : | Composite                                                        |
| 22 | Failure mechanism         | : | Shallow Rotational Failure                                       |
| 23 | History                   | : | Data Not Available                                               |
| 24 | Geomorphology             | : | Lowly Dissected Slope                                            |
| 25 | Geology/Lithology         | : | Granite                                                          |
| 26 | Structure                 | : | No distinct structure                                            |
| 27 | Landuse/ Landcover        | : | Extensive Cut Slope                                              |
| 28 | Hydrological condition    | : | Damp                                                             |
| 29 | Triggering Factor         | : | Rainfall                                                         |
| 30 | Death of persons          | : | Data Not Available                                               |
| 31 | People affected           | : | Data Not Available                                               |
| 32 | Livestock Loss            | : | Data Not Available                                               |
| 33 | Communication             | : | Data Not Available                                               |
| 34 | Infrastructure            | : | Data Not Available                                               |
| 35 | Agriculture/forest/Barren | : | Forest                                                           |
| 36 | Geo-scientific Causes     | : | Toe cutting                                                      |
| 37 | Remedial measures         | : | Retaining wall with weep holes and proper management of drainage |
| 38 | Remarks, if any           | : | Weathered rocks are observed on slope.                           |

|    |                                               |   |                                                                                                                                                            |
|----|-----------------------------------------------|---|------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 39 | Photos. Sketch of Plan & section of the slide | : |                                                                          |
| 40 | Summary/Abstract                              | : | Suspended shallow rotational slide is observed. Slide is Widening and retrogressive in nature. Improper drainage played a major role in causing the slide. |
| 41 | Date of Reporting                             | : |                                                                                                                                                            |
| 42 | Landslide Category                            | : | Debris slide                                                                                                                                               |

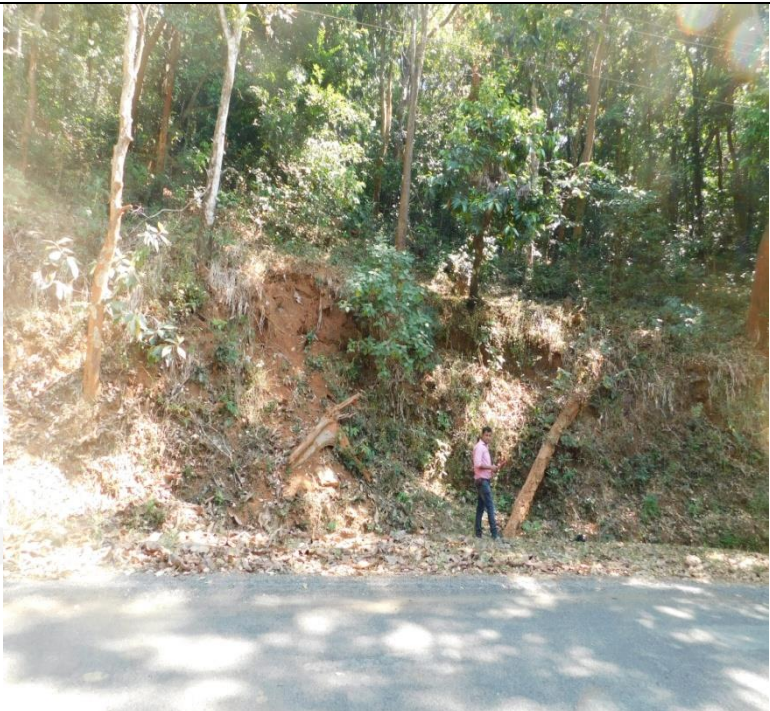


| No | Field                     |   | Description                                                   |
|----|---------------------------|---|---------------------------------------------------------------|
| 1  | Slide No.                 | : | 20                                                            |
| 2  | State                     | : | Karnataka                                                     |
| 3  | District                  |   | Uttar Kannada                                                 |
| 4  | Toposheet No              | : | 48I/8                                                         |
| 5  | Name of the Slide         | : | KAR/UK/48I08/2018/20                                          |
| 6  | NH/SH/Locality            | : | 1km NE of Kadargani                                           |
| 7  | Latitude (N)              | : | 15°01'20.700                                                  |
| 8  | Longitude (E)             | : | 74°29'50.900                                                  |
| 9  | Length (m)                | : | 8                                                             |
| 10 | Width (m)                 | : | 15                                                            |
| 11 | Height (m)                | : | 6                                                             |
| 12 | Area (sq m)               | : | 120                                                           |
| 13 | Depth                     | : | <=5m                                                          |
| 14 | Volume                    | : |                                                               |
| 15 | Run out distance (m)      | : | 5                                                             |
| 16 | Type of material          | : | Debris                                                        |
| 17 | Type of movement          | : | Slide                                                         |
| 18 | Rate of movement          | : | Imperceptible                                                 |
| 19 | Activity                  | : | Suspended                                                     |
| 20 | Distribution              | : | Retrogressive                                                 |
| 21 | Style                     | : | Single                                                        |
| 22 | Failure mechanism         | : | Shallow Rotational Failure                                    |
| 23 | History                   | : | Data Not Available                                            |
| 24 | Geomorphology             | : | Lowly Dissected Slope                                         |
| 25 | Geology/Lithology         | : | Granite, Metabasalt                                           |
| 26 | Structure                 | : | No distinct structure                                         |
| 27 | Landuse/ Landcover        | : | Extensive Cut Slope                                           |
| 28 | Hydrological condition    | : | Dry                                                           |
| 29 | Triggering Factor         | : | Rainfall                                                      |
| 30 | Death of persons          | : | Data Not Available                                            |
| 31 | People affected           | : | Data Not Available                                            |
| 32 | Livestock Loss            | : | Data Not Available                                            |
| 33 | Communication             | : | Data Not Available                                            |
| 34 | Infrastructure            | : | Data Not Available                                            |
| 35 | Agriculture/forest/Barren | : | Forest                                                        |
| 36 | Geo-scientific Causes     | : | Toe cutting at lithocontact of granite gneiss and metabasalt. |
| 37 | Remedial measures         | : | Retaining wall with weep holes is suggested                   |
| 38 | Remarks, if any           |   | Cracks are visible at the crown of slide.                     |

|    |                                               |   |                                                                                                                |
|----|-----------------------------------------------|---|----------------------------------------------------------------------------------------------------------------|
| 39 | Photos. Sketch of Plan & section of the slide | : |                              |
| 40 | Summary/Abstract                              | : | Suspended retrogressive shallow rotational slide is observed at contact zone of granite gneiss and metabasalt. |
| 41 | Date of Reporting                             | : |                                                                                                                |
| 42 | Landslide Category                            | : | Debris slide                                                                                                   |

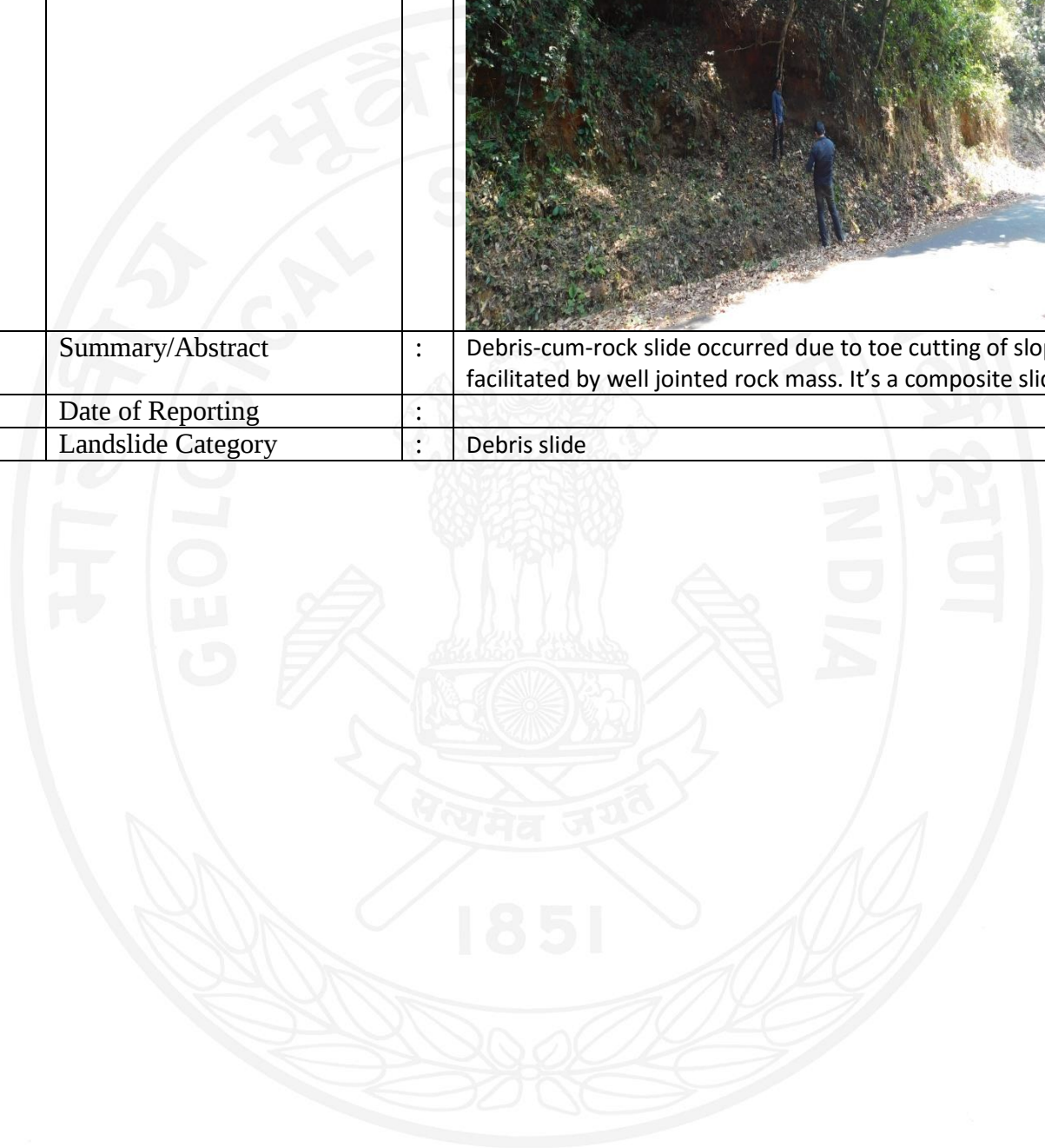


| No | Field                     |   | Description                                                      |
|----|---------------------------|---|------------------------------------------------------------------|
| 1  | Slide No.                 | : | 21                                                               |
| 2  | State                     | : | Karnataka                                                        |
| 3  | District                  |   | Uttar Kannada                                                    |
| 4  | Toposheet No              | : | 48I/8                                                            |
| 5  | Name of the Slide         | : | KAR/UK/48I08/2018/21                                             |
| 6  | NH/SH/Locality            | : | 1.2km NE of Kadargani                                            |
| 7  | Latitude (N)              | : | 15°01'11.500                                                     |
| 8  | Longitude (E)             | : | 74°29'52.800                                                     |
| 9  | Length (m)                | : | 6                                                                |
| 10 | Width (m)                 | : | 10                                                               |
| 11 | Height (m)                | : | 6                                                                |
| 12 | Area (sq m)               | : | 70                                                               |
| 13 | Depth                     | : | <=5m                                                             |
| 14 | Volume                    | : |                                                                  |
| 15 | Run out distance (m)      | : | 5                                                                |
| 16 | Type of material          | : | Debris                                                           |
| 17 | Type of movement          | : | Slide                                                            |
| 18 | Rate of movement          | : | Imperceptible                                                    |
| 19 | Activity                  | : | Suspended                                                        |
| 20 | Distribution              | : | Retrogressive                                                    |
| 21 | Style                     | : | Single                                                           |
| 22 | Failure mechanism         | : | Shallow Rotational Failure                                       |
| 23 | History                   | : | Data Not Available                                               |
| 24 | Geomorphology             | : | Lowly Dissected Slope                                            |
| 25 | Geology/Lithology         | : | Metabasalt                                                       |
| 26 | Structure                 | : | No distinct structure                                            |
| 27 | Landuse/ Landcover        | : | Extensive Cut Slope                                              |
| 28 | Hydrological condition    | : | Dry                                                              |
| 29 | Triggering Factor         | : | Rainfall                                                         |
| 30 | Death of persons          | : | Data Not Available                                               |
| 31 | People affected           | : | Data Not Available                                               |
| 32 | Livestock Loss            | : | Data Not Available                                               |
| 33 | Communication             | : | Data Not Available                                               |
| 34 | Infrastructure            | : | Data Not Available                                               |
| 35 | Agriculture/forest/Barren | : | Forest                                                           |
| 36 | Geo-scientific Causes     | : | Toe cutting                                                      |
| 37 | Remedial measures         | : | Retaining wall with weep holes and proper management of drainage |
| 38 | Remarks, if any           |   | Nil                                                              |

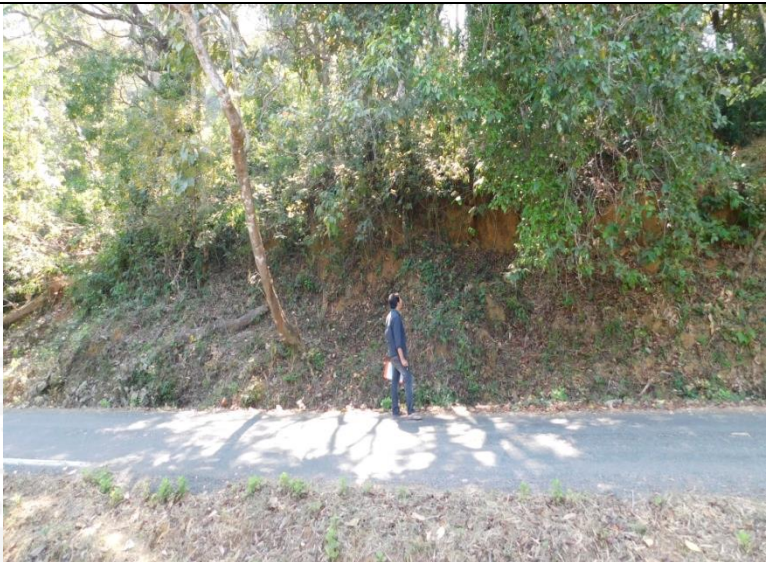
|    |                                               |   |                                                                                       |
|----|-----------------------------------------------|---|---------------------------------------------------------------------------------------|
| 39 | Photos. Sketch of Plan & section of the slide | : |     |
| 40 | Summary/Abstract                              | : | Suspended retrogressive shallow rotational slide is observed on schistose metabasalt. |
| 41 | Date of Reporting                             | : |                                                                                       |
| 42 | Landslide Category                            | : | Debris slide                                                                          |

| No | Field                     |   | Description                                              |
|----|---------------------------|---|----------------------------------------------------------|
| 1  | Slide No.                 | : | 22                                                       |
| 2  | State                     | : | Karnataka                                                |
| 3  | District                  |   | Uttar Kannada                                            |
| 4  | Toposheet No              | : | 48I/8                                                    |
| 5  | Name of the Slide         | : | KAR/UK/48I08/2018/22                                     |
| 6  | NH/SH/Locality            | : | 2 km SE of Pasoli                                        |
| 7  | Latitude (N)              | : | 15°01'23.700                                             |
| 8  | Longitude (E)             | : | 74°26'43.000                                             |
| 9  | Length (m)                | : | 8                                                        |
| 10 | Width (m)                 | : | 28                                                       |
| 11 | Height (m)                | : | 7                                                        |
| 12 | Area (sq m)               | : | 224                                                      |
| 13 | Depth                     | : | <=5m                                                     |
| 14 | Volume                    | : |                                                          |
| 15 | Run out distance (m)      | : | 6                                                        |
| 16 | Type of material          | : | Debris                                                   |
| 17 | Type of movement          | : | Slide                                                    |
| 18 | Rate of movement          | : | Imperceptible                                            |
| 19 | Activity                  | : | Suspended                                                |
| 20 | Distribution              | : | Retrogressive                                            |
| 21 | Style                     | : | Composite                                                |
| 22 | Failure mechanism         | : | Shallow Rotational Failure                               |
| 23 | History                   | : | Data Not Available                                       |
| 24 | Geomorphology             | : | Lowly Dissected Slope                                    |
| 25 | Geology/Lithology         | : | Granite                                                  |
| 26 | Structure                 | : | No distinct structure                                    |
| 27 | Landuse/ Landcover        | : | Extensive Cut Slope                                      |
| 28 | Hydrological condition    | : | Damp                                                     |
| 29 | Triggering Factor         | : | Rainfall                                                 |
| 30 | Death of persons          | : | Data Not Available                                       |
| 31 | People affected           | : | Data Not Available                                       |
| 32 | Livestock Loss            | : | Data Not Available                                       |
| 33 | Communication             | : | Data Not Available                                       |
| 34 | Infrastructure            | : | Data Not Available                                       |
| 35 | Agriculture/forest/Barren | : | Forest                                                   |
| 36 | Geo-scientific Causes     | : | Toe cutting at road bend.                                |
| 37 | Remedial measures         | : | Retaining wall with weep holes is suggested              |
| 38 | Remarks, if any           |   | Uprooting of trees is observed. The same may be removed. |

|    |                                               |   |                                                                                                                           |
|----|-----------------------------------------------|---|---------------------------------------------------------------------------------------------------------------------------|
| 39 | Photos. Sketch of Plan & section of the slide | : |                                         |
| 40 | Summary/Abstract                              | : | Debris-cum-rock slide occurred due to toe cutting of slope facilitated by well jointed rock mass. It's a composite slide. |
| 41 | Date of Reporting                             | : |                                                                                                                           |
| 42 | Landslide Category                            | : | Debris slide                                                                                                              |



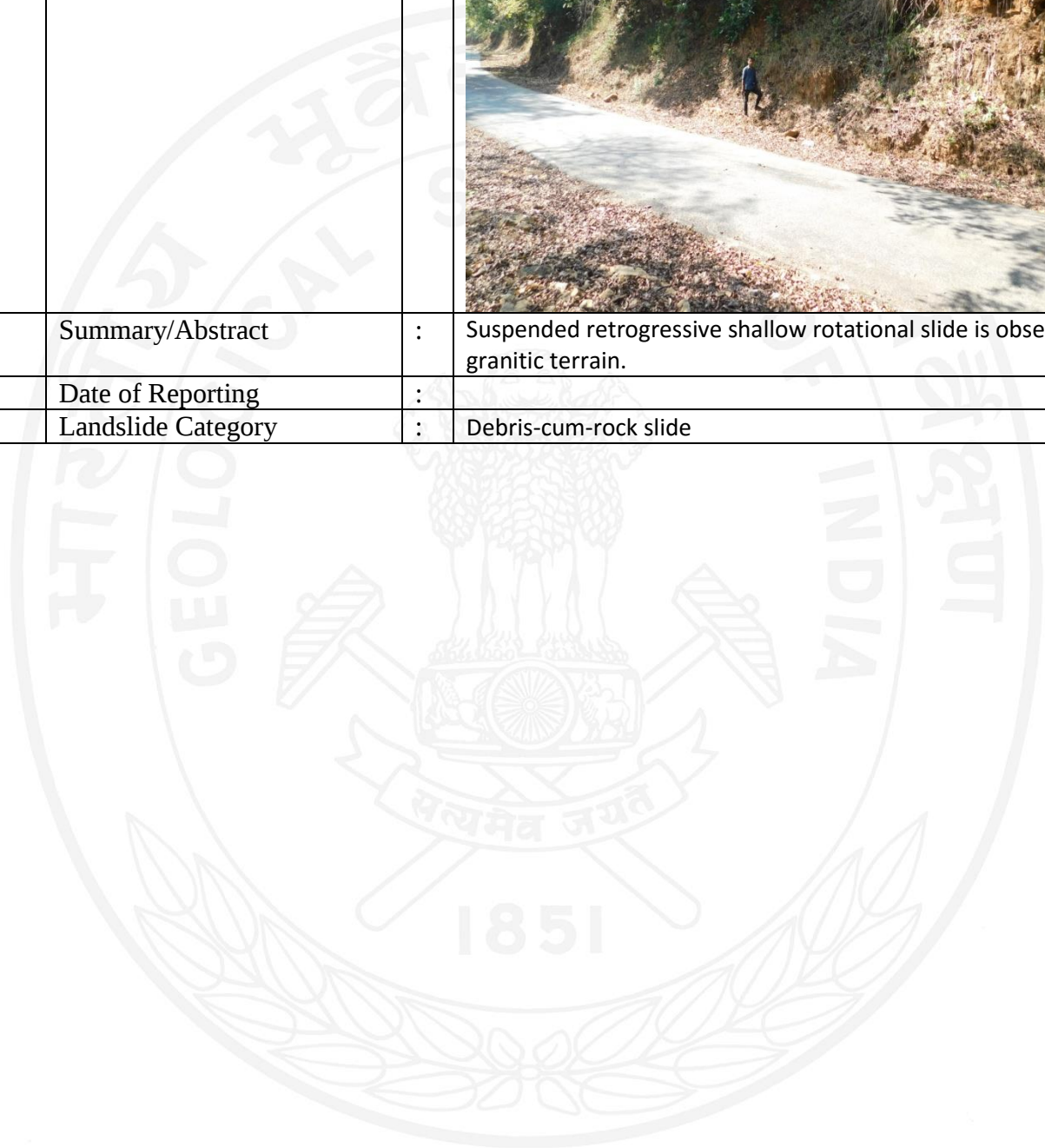
| No | Field                     |   | Description                                 |
|----|---------------------------|---|---------------------------------------------|
| 1  | Slide No.                 | : | 23                                          |
| 2  | State                     | : | Karnataka                                   |
| 3  | District                  |   | Uttar Kannada                               |
| 4  | Toposheet No              | : | 48I/8                                       |
| 5  | Name of the Slide         | : | KAR/UK/48I08/2018/23                        |
| 6  | NH/SH/Locality            | : | 1 km W of Khamshetadi                       |
| 7  | Latitude (N)              | : | 15°01'15.600                                |
| 8  | Longitude (E)             | : | 74°26'3.700                                 |
| 9  | Length (m)                | : | 7                                           |
| 10 | Width (m)                 | : | 10                                          |
| 11 | Height (m)                | : | 6                                           |
| 12 | Area (sq m)               | : | 70                                          |
| 13 | Depth                     | : | <=5m                                        |
| 14 | Volume                    | : |                                             |
| 15 | Run out distance (m)      | : | 5                                           |
| 16 | Type of material          | : | Debris                                      |
| 17 | Type of movement          | : | Slide                                       |
| 18 | Rate of movement          | : | Imperceptible                               |
| 19 | Activity                  | : | Suspended                                   |
| 20 | Distribution              | : | Retrogressive                               |
| 21 | Style                     | : | Single                                      |
| 22 | Failure mechanism         | : | Shallow Rotational Failure                  |
| 23 | History                   | : | Data Not Available                          |
| 24 | Geomorphology             | : | Lowly Dissected Slope                       |
| 25 | Geology/Lithology         | : | Granite                                     |
| 26 | Structure                 | : | No distinct structure                       |
| 27 | Landuse/ Landcover        | : | Extensive Cut Slope                         |
| 28 | Hydrological condition    | : | Dry                                         |
| 29 | Triggering Factor         | : | Rainfall                                    |
| 30 | Death of persons          | : | Data Not Available                          |
| 31 | People affected           | : | Data Not Available                          |
| 32 | Livestock Loss            | : | Data Not Available                          |
| 33 | Communication             | : | Data Not Available                          |
| 34 | Infrastructure            | : | Data Not Available                          |
| 35 | Agriculture/forest/Barren | : | Forest                                      |
| 36 | Geo-scientific Causes     | : | Toe cutting                                 |
| 37 | Remedial measures         | : | Retaining wall with weep holes is suggested |
| 38 | Remarks, if any           |   | Creeping of trees are observed.             |

|    |                                               |   |                                                                                    |
|----|-----------------------------------------------|---|------------------------------------------------------------------------------------|
| 39 | Photos. Sketch of Plan & section of the slide | : |  |
| 40 | Summary/Abstract                              | : | Suspended retrogressive shallow rotational slide is observed on granitic terrain.  |
| 41 | Date of Reporting                             | : |                                                                                    |
| 42 | Landslide Category                            | : | Debris slide                                                                       |



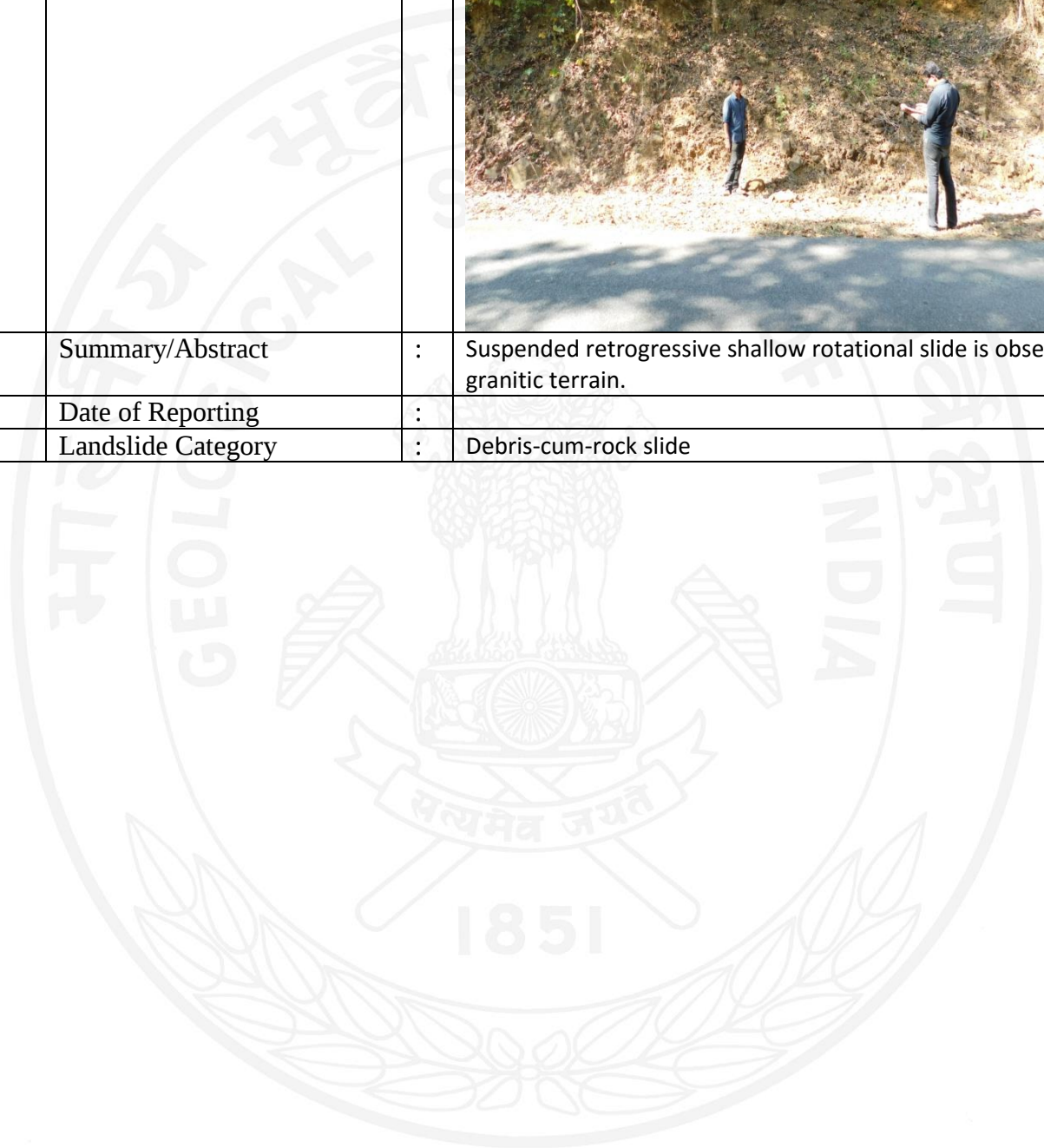
| No | Field                     |   | Description                                 |
|----|---------------------------|---|---------------------------------------------|
| 1  | Slide No.                 | : | 24                                          |
| 2  | State                     | : | Karnataka                                   |
| 3  | District                  |   | Uttar Kannada                               |
| 4  | Toposheet No              | : | 48I/8                                       |
| 5  | Name of the Slide         | : | KAR/UK/48I08/2018/24                        |
| 6  | NH/SH/Locality            | : | 2km W of Kodgali                            |
| 7  | Latitude (N)              | : | 15°00'49.500                                |
| 8  | Longitude (E)             | : | 74°24'22.200                                |
| 9  | Length (m)                | : | 8                                           |
| 10 | Width (m)                 | : | 8                                           |
| 11 | Height (m)                | : | 7                                           |
| 12 | Area (sq m)               | : | 64                                          |
| 13 | Depth                     | : | <=5m                                        |
| 14 | Volume                    | : |                                             |
| 15 | Run out distance (m)      | : | 7                                           |
| 16 | Type of material          | : | Rock                                        |
| 17 | Type of movement          | : | Slide                                       |
| 18 | Rate of movement          | : | Imperceptible                               |
| 19 | Activity                  | : | Suspended                                   |
| 20 | Distribution              | : | Retrogressive                               |
| 21 | Style                     | : | Multiple                                    |
| 22 | Failure mechanism         | : | Shallow Rotational Failure                  |
| 23 | History                   | : | Data Not Available                          |
| 24 | Geomorphology             | : | Lowly Dissected Slope                       |
| 25 | Geology/Lithology         | : | Granite                                     |
| 26 | Structure                 | : | No distinct structure                       |
| 27 | Landuse/ Landcover        | : | Extensive Cut Slope                         |
| 28 | Hydrological condition    | : | Dry                                         |
| 29 | Triggering Factor         | : | Rainfall                                    |
| 30 | Death of persons          | : | Data Not Available                          |
| 31 | People affected           | : | Data Not Available                          |
| 32 | Livestock Loss            | : | Data Not Available                          |
| 33 | Communication             | : | Data Not Available                          |
| 34 | Infrastructure            | : | Data Not Available                          |
| 35 | Agriculture/forest/Barren | : | Forest                                      |
| 36 | Geo-scientific Causes     | : | Toe cutting                                 |
| 37 | Remedial measures         | : | Retaining wall with weep holes is suggested |
| 38 | Remarks, if any           |   | Cracks are visible at the crown of slide.   |

|    |                                               |   |                                                                                    |
|----|-----------------------------------------------|---|------------------------------------------------------------------------------------|
| 39 | Photos. Sketch of Plan & section of the slide | : |  |
| 40 | Summary/Abstract                              | : | Suspended retrogressive shallow rotational slide is observed on granitic terrain.  |
| 41 | Date of Reporting                             | : |                                                                                    |
| 42 | Landslide Category                            | : | Debris-cum-rock slide                                                              |



| No | Field                     |   | Description                                   |
|----|---------------------------|---|-----------------------------------------------|
| 1  | Slide No.                 | : | 25                                            |
| 2  | State                     | : | Karnataka                                     |
| 3  | District                  |   | Uttar Kannada                                 |
| 4  | Toposheet No              | : | 48I/8                                         |
| 5  | Name of the Slide         | : | KAR/UK/48I08/2018/25                          |
| 6  | NH/SH/Locality            | : | 3.5km SW of Nergali                           |
| 7  | Latitude (N)              | : | 15°00'48.700                                  |
| 8  | Longitude (E)             | : | 74°24'15.200                                  |
| 9  | Length (m)                | : | 8                                             |
| 10 | Width (m)                 | : | 12                                            |
| 11 | Height (m)                | : | 6                                             |
| 12 | Area (sq m)               | : | 96                                            |
| 13 | Depth                     | : | <=5m                                          |
| 14 | Volume                    | : |                                               |
| 15 | Run out distance (m)      | : | 7                                             |
| 16 | Type of material          | : | Debris                                        |
| 17 | Type of movement          | : | Slide                                         |
| 18 | Rate of movement          | : | Imperceptible                                 |
| 19 | Activity                  | : | Suspended                                     |
| 20 | Distribution              | : | Retrogressive                                 |
| 21 | Style                     | : | Single                                        |
| 22 | Failure mechanism         | : | Shallow Rotational Failure                    |
| 23 | History                   | : | Data Not Available                            |
| 24 | Geomorphology             | : | Lowly Dissected Slope                         |
| 25 | Geology/Lithology         | : | Granite                                       |
| 26 | Structure                 | : | No distinct structure                         |
| 27 | Landuse/ Landcover        | : | Extensive Cut Slope                           |
| 28 | Hydrological condition    | : | Dry                                           |
| 29 | Triggering Factor         | : | Rainfall                                      |
| 30 | Death of persons          | : | Data Not Available                            |
| 31 | People affected           | : | Data Not Available                            |
| 32 | Livestock Loss            | : | Data Not Available                            |
| 33 | Communication             | : | Data Not Available                            |
| 34 | Infrastructure            | : | Data Not Available                            |
| 35 | Agriculture/forest/Barren | : | Forest                                        |
| 36 | Geo-scientific Causes     | : | Toe cutting and weathered rock mass on slope  |
| 37 | Remedial measures         | : | Retaining wall with weep holes is suggested   |
| 38 | Remarks, if any           |   | Stream is flowing on down slope side of road. |

|    |                                               |   |                                                                                    |
|----|-----------------------------------------------|---|------------------------------------------------------------------------------------|
| 39 | Photos. Sketch of Plan & section of the slide | : |  |
| 40 | Summary/Abstract                              | : | Suspended retrogressive shallow rotational slide is observed on granitic terrain.  |
| 41 | Date of Reporting                             | : |                                                                                    |
| 42 | Landslide Category                            | : | Debris-cum-rock slide                                                              |



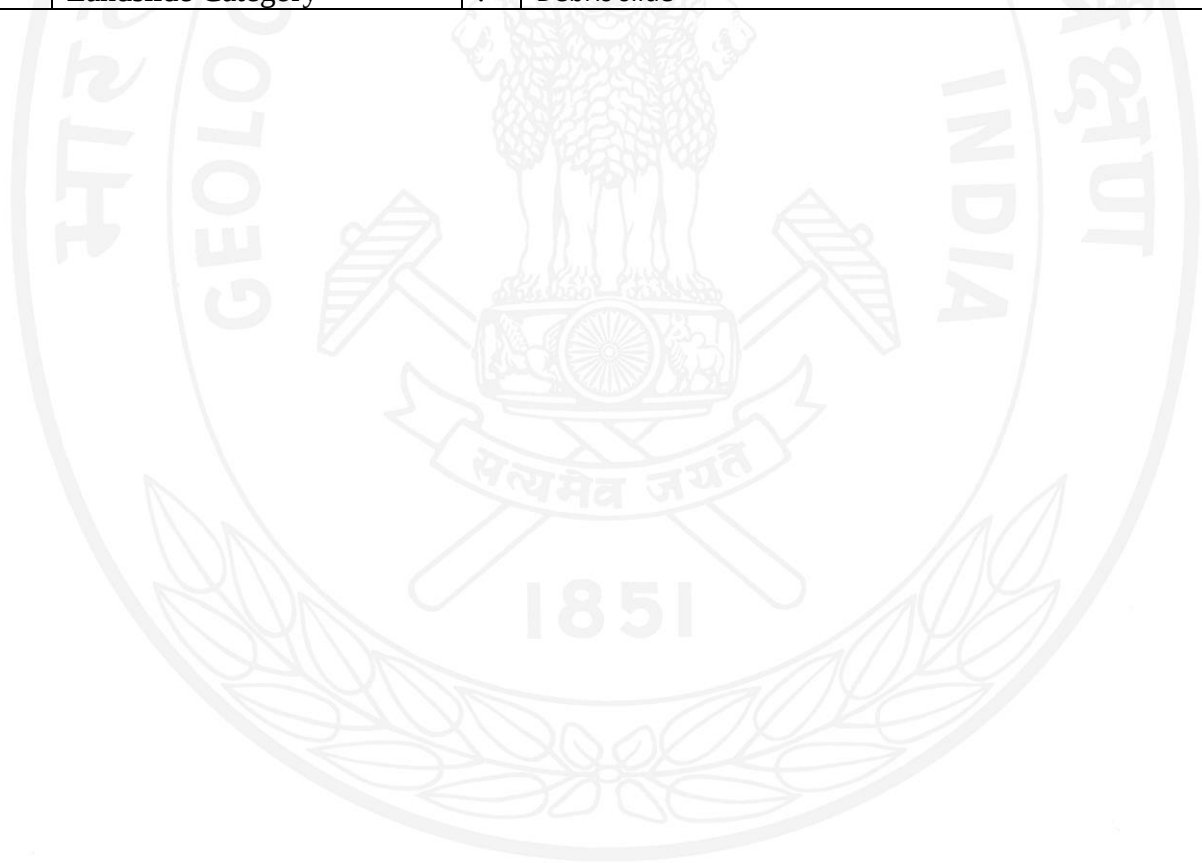
| No | Field                     |   | Description                                   |
|----|---------------------------|---|-----------------------------------------------|
| 1  | Slide No.                 | : | 26                                            |
| 2  | State                     | : | Karnataka                                     |
| 3  | District                  |   | Uttar Kannada                                 |
| 4  | Toposheet No              | : | 48I/8                                         |
| 5  | Name of the Slide         | : | KAR/UK/48I08/2018/26                          |
| 6  | NH/SH/Locality            | : | Anshi-Ulavi Road                              |
| 7  | Latitude (N)              | : | 15°00'47.200                                  |
| 8  | Longitude (E)             | : | 74°24'8.300                                   |
| 9  | Length (m)                | : | 9                                             |
| 10 | Width (m)                 | : | 14                                            |
| 11 | Height (m)                | : | 8                                             |
| 12 | Area (sq m)               | : | 126                                           |
| 13 | Depth                     | : | <=5m                                          |
| 14 | Volume                    | : |                                               |
| 15 | Run out distance (m)      | : | 8                                             |
| 16 | Type of material          | : | Debris                                        |
| 17 | Type of movement          | : | Slide                                         |
| 18 | Rate of movement          | : | Imperceptible                                 |
| 19 | Activity                  | : | Suspended                                     |
| 20 | Distribution              | : | Retrogressive                                 |
| 21 | Style                     | : | Single                                        |
| 22 | Failure mechanism         | : | Shallow Rotational Failure                    |
| 23 | History                   | : | Data Not Available                            |
| 24 | Geomorphology             | : | Lowly Dissected Slope                         |
| 25 | Geology/Lithology         | : | Granite                                       |
| 26 | Structure                 | : | No distinct structure                         |
| 27 | Landuse/ Landcover        | : | Extensive Cut Slope                           |
| 28 | Hydrological condition    | : | Damp                                          |
| 29 | Triggering Factor         | : | Rainfall                                      |
| 30 | Death of persons          | : | Data Not Available                            |
| 31 | People affected           | : | Data Not Available                            |
| 32 | Livestock Loss            | : | Data Not Available                            |
| 33 | Communication             | : | Data Not Available                            |
| 34 | Infrastructure            | : | Data Not Available                            |
| 35 | Agriculture/forest/Barren | : | Forest                                        |
| 36 | Geo-scientific Causes     | : | Toe cutting                                   |
| 37 | Remedial measures         | : | Retaining wall with weep holes is suggested   |
| 38 | Remarks, if any           |   | Stream is flowing on down slope side of road. |

|    |                                               |   |                                                                                                   |
|----|-----------------------------------------------|---|---------------------------------------------------------------------------------------------------|
| 39 | Photos. Sketch of Plan & section of the slide | : |                 |
| 40 | Summary/Abstract                              | : | Debris-cum-rock Suspended retrogressive shallow rotational slide is observed on granitic terrain. |
| 41 | Date of Reporting                             | : |                                                                                                   |
| 42 | Landslide Category                            | : | Debris-cum-rock slide                                                                             |



| No | Field                     |   | Description                              |
|----|---------------------------|---|------------------------------------------|
| 1  | Slide No.                 | : | 27                                       |
| 2  | State                     | : | Karnataka                                |
| 3  | District                  |   | Uttar Kannada                            |
| 4  | Toposheet No              | : | 48I/8                                    |
| 5  | Name of the Slide         | : | KAR/UK/48I08/2018/27                     |
| 6  | NH/SH/Locality            | : | Anshi-Ulavi Road                         |
| 7  | Latitude (N)              | : | 15°00'46.000                             |
| 8  | Longitude (E)             | : | 74°24'1.200                              |
| 9  | Length (m)                | : | 6                                        |
| 10 | Width (m)                 | : | 18                                       |
| 11 | Height (m)                | : | 5                                        |
| 12 | Area (sq m)               | : | 108                                      |
| 13 | Depth                     | : | <=5m                                     |
| 14 | Volume                    | : |                                          |
| 15 | Run out distance (m)      | : | 3                                        |
| 16 | Type of material          | : | Debris                                   |
| 17 | Type of movement          | : | Slide                                    |
| 18 | Rate of movement          | : | Imperceptible                            |
| 19 | Activity                  | : | Suspended                                |
| 20 | Distribution              | : | Retrogressive                            |
| 21 | Style                     | : | Single                                   |
| 22 | Failure mechanism         | : | Shallow Rotational Failure               |
| 23 | History                   | : | Data Not Available                       |
| 24 | Geomorphology             | : | Lowly Dissected Slope                    |
| 25 | Geology/Lithology         | : | Granite                                  |
| 26 | Structure                 | : | No distinct structure                    |
| 27 | Landuse/ Landcover        | : | Extensive Cut Slope                      |
| 28 | Hydrological condition    | : | Damp                                     |
| 29 | Triggering Factor         | : | Rainfall                                 |
| 30 | Death of persons          | : | Data Not Available                       |
| 31 | People affected           | : | Data Not Available                       |
| 32 | Livestock Loss            | : | Data Not Available                       |
| 33 | Communication             | : | Data Not Available                       |
| 34 | Infrastructure            | : | Data Not Available                       |
| 35 | Agriculture/forest/Barren | : | Forest                                   |
| 36 | Geo-scientific Causes     | : | Toe cutting                              |
| 37 | Remedial measures         | : | Breast wall with weep holes is suggested |
| 38 | Remarks, if any           |   | Nil                                      |

|    |                                               |   |                                                                                          |
|----|-----------------------------------------------|---|------------------------------------------------------------------------------------------|
| 39 | Photos. Sketch of Plan & section of the slide | : |        |
| 40 | Summary/Abstract                              | : | Suspended retrogressive shallow rotational debris slide is observed on granitic terrain. |
| 41 | Date of Reporting                             | : |                                                                                          |
| 42 | Landslide Category                            | : | Debris slide                                                                             |



| No | Field                     |   | Description                                                                                                                       |
|----|---------------------------|---|-----------------------------------------------------------------------------------------------------------------------------------|
| 1  | Slide No.                 | : | 28                                                                                                                                |
| 2  | State                     | : | Karnataka                                                                                                                         |
| 3  | District                  |   | Uttar Kannada                                                                                                                     |
| 4  | Toposheet No              | : | 48I/8                                                                                                                             |
| 5  | Name of the Slide         | : | KAR/UK/48I08/2018/28                                                                                                              |
| 6  | NH/SH/Locality            | : | 2km NW of Terali                                                                                                                  |
| 7  | Latitude (N)              | : | 15°11'15.600                                                                                                                      |
| 8  | Longitude (E)             | : | 74°21'39.700                                                                                                                      |
| 9  | Length (m)                | : | 14                                                                                                                                |
| 10 | Width (m)                 | : | 40                                                                                                                                |
| 11 | Height (m)                | : | 12                                                                                                                                |
| 12 | Area (sq m)               | : | 560                                                                                                                               |
| 13 | Depth                     | : | <=5m                                                                                                                              |
| 14 | Volume                    | : |                                                                                                                                   |
| 15 | Run out distance (m)      | : | 10                                                                                                                                |
| 16 | Type of material          | : | Debris                                                                                                                            |
| 17 | Type of movement          | : | Slide                                                                                                                             |
| 18 | Rate of movement          | : | Imperceptible                                                                                                                     |
| 19 | Activity                  | : | Active                                                                                                                            |
| 20 | Distribution              | : | Retrogressive & Widening                                                                                                          |
| 21 | Style                     | : | Multiple                                                                                                                          |
| 22 | Failure mechanism         | : | Shallow Rotational Failure                                                                                                        |
| 23 | History                   | : | Data Not Available                                                                                                                |
| 24 | Geomorphology             | : | Lowly Dissected Slope                                                                                                             |
| 25 | Geology/Lithology         | : | Quartz Chorite Schist                                                                                                             |
| 26 | Structure                 | : | Jointed, J1:210/76°SE, J2:010°/40°W                                                                                               |
| 27 | Landuse/ Landcover        | : | Extensive Cut Slope                                                                                                               |
| 28 | Hydrological condition    | : | Damp                                                                                                                              |
| 29 | Triggering Factor         | : | Rainfall                                                                                                                          |
| 30 | Death of persons          | : | Data Not Available                                                                                                                |
| 31 | People affected           | : | Data Not Available                                                                                                                |
| 32 | Livestock Loss            | : | Data Not Available                                                                                                                |
| 33 | Communication             | : | Data Not Available                                                                                                                |
| 34 | Infrastructure            | : | Data Not Available                                                                                                                |
| 35 | Agriculture/forest/Barren | : | Forest                                                                                                                            |
| 36 | Geo-scientific Causes     | : | Toe cutting and saturated condition of soil enhancing pore water pressure thereby reducing of shear strength on super-saturation. |
| 37 | Remedial measures         | : | Breast wall with weep holes is suggested                                                                                          |
| 38 | Remarks, if any           |   | Jointed rocks are present.                                                                                                        |

|    |                                               |   |                                                                                                                                                                                                                            |
|----|-----------------------------------------------|---|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 39 | Photos. Sketch of Plan & section of the slide | : |                                                                                                                                          |
| 40 | Summary/Abstract                              | : | Active slide of 40m width occurred due to toe cutting on high slope gradient .Quartz chlorite schist is the underlying lithology which is observed to be highly jointed. Multiple failures observed at different interval. |
| 41 | Date of Reporting                             | : |                                                                                                                                                                                                                            |
| 42 | Landslide Category                            | : | Debris-cum-rock slide                                                                                                                                                                                                      |

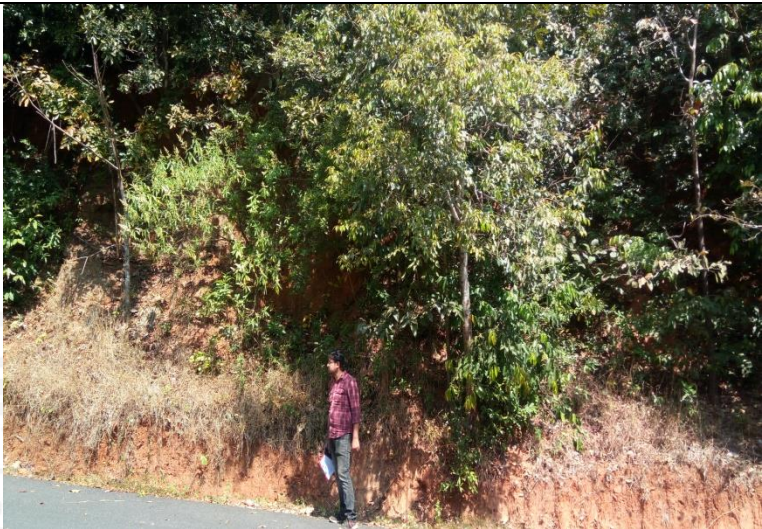


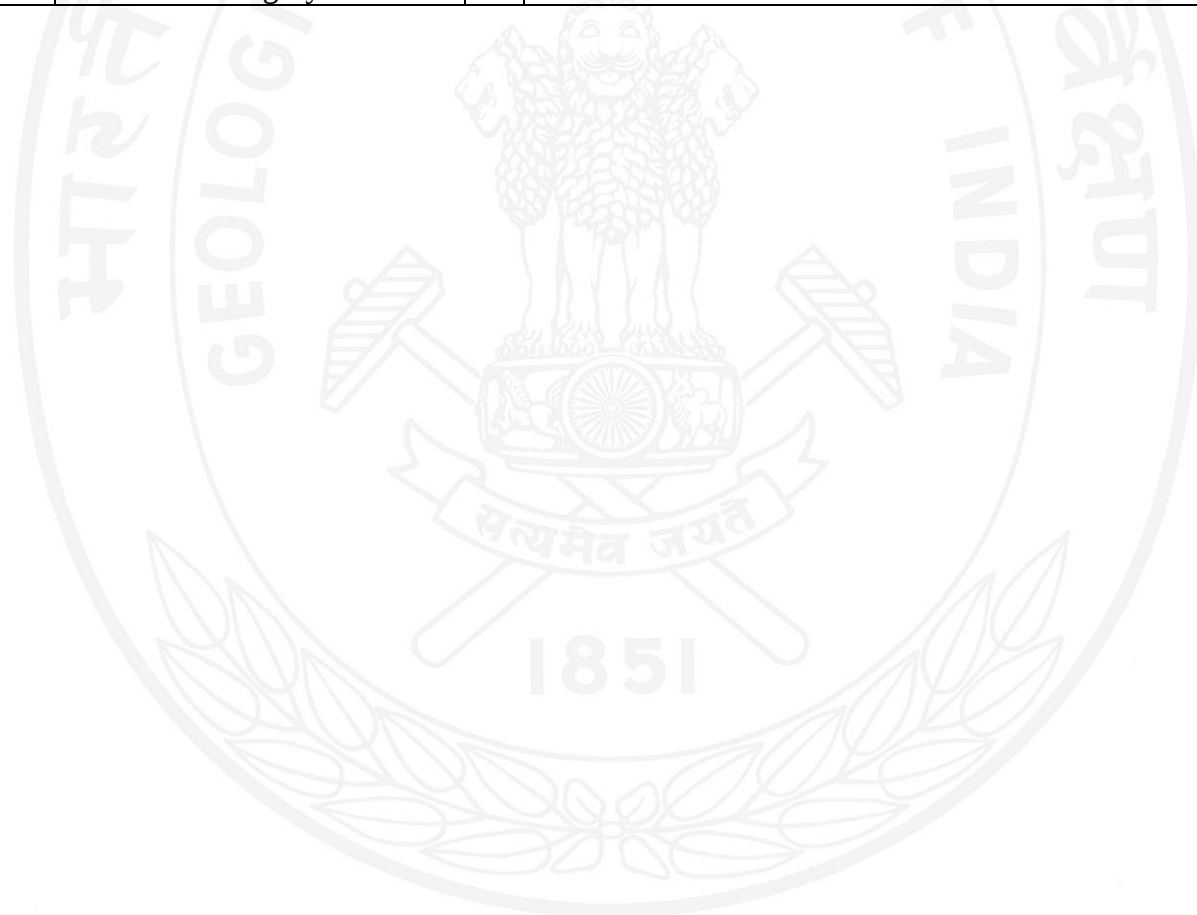
| No | Field                     |   | Description                                  |
|----|---------------------------|---|----------------------------------------------|
| 1  | Slide No.                 | : | 29                                           |
| 2  | State                     | : | Karnataka                                    |
| 3  | District                  |   | Uttar Kannada                                |
| 4  | Toposheet No              | : | 48I/8                                        |
| 5  | Name of the Slide         | : | KAR/UK/48I08/2018/29                         |
| 6  | NH/SH/Locality            | : | 2km NW of Terali                             |
| 7  | Latitude (N)              | : | 15°11'14.400                                 |
| 8  | Longitude (E)             | : | 74°21'41.000                                 |
| 9  | Length (m)                | : | 13                                           |
| 10 | Width (m)                 | : | 28                                           |
| 11 | Height (m)                | : | 11                                           |
| 12 | Area (sq m)               | : | 364                                          |
| 13 | Depth                     | : | <=5m                                         |
| 14 | Volume                    | : |                                              |
| 15 | Run out distance (m)      | : | 12                                           |
| 16 | Type of material          | : | Debris                                       |
| 17 | Type of movement          | : | Slide                                        |
| 18 | Rate of movement          | : | Imperceptible                                |
| 19 | Activity                  | : | Active                                       |
| 20 | Distribution              | : | Retrogressive & Widening                     |
| 21 | Style                     | : | Composite                                    |
| 22 | Failure mechanism         | : | Shallow Rotational Failure                   |
| 23 | History                   | : | Data Not Available                           |
| 24 | Geomorphology             | : | Lowly Dissected Slope                        |
| 25 | Geology/Lithology         | : | Quartz Chorite Schist                        |
| 26 | Structure                 | : | No distinct structure                        |
| 27 | Landuse/ Landcover        | : | Extensive Cut Slope                          |
| 28 | Hydrological condition    | : | Damp                                         |
| 29 | Triggering Factor         | : | Rainfall                                     |
| 30 | Death of persons          | : | Data Not Available                           |
| 31 | People affected           | : | Data Not Available                           |
| 32 | Livestock Loss            | : | Data Not Available                           |
| 33 | Communication             | : | Data Not Available                           |
| 34 | Infrastructure            | : | Data Not Available                           |
| 35 | Agriculture/forest/Barren | : | Forest                                       |
| 36 | Geo-scientific Causes     | : | Toe cutting and fractured rock mass.         |
| 37 | Remedial measures         | : | Retaining wall with weep holes is suggested  |
| 38 | Remarks, if any           |   | Loose debris are observed at crown of slide. |

|    |                                               |   |                                                                                                   |
|----|-----------------------------------------------|---|---------------------------------------------------------------------------------------------------|
| 39 | Photos. Sketch of Plan & section of the slide | : |                 |
| 40 | Summary/Abstract                              | : | Debris-cum-rock slide occurred due to toe cutting of slope facilitated by well jointed rock mass. |
| 41 | Date of Reporting                             | : |                                                                                                   |
| 42 | Landslide Category                            | : | Debris-cum-rock slide                                                                             |



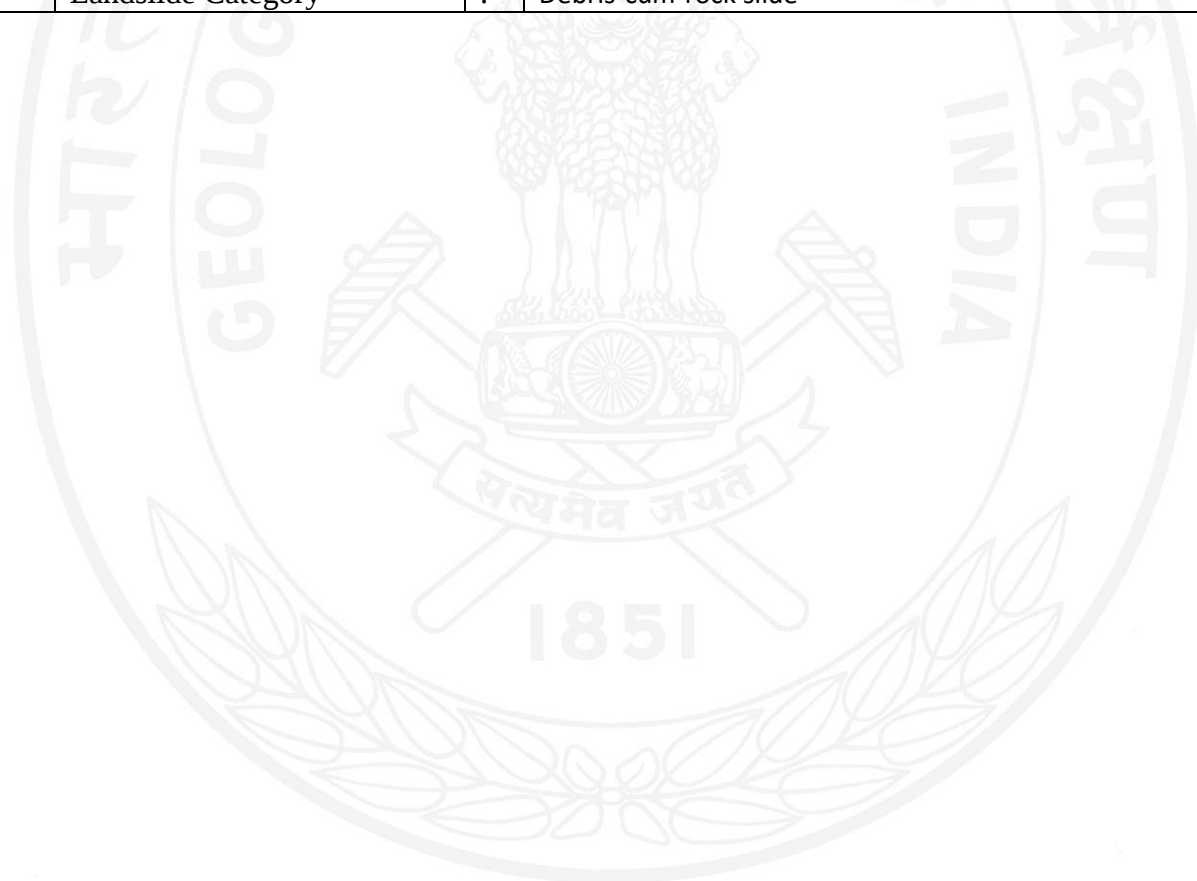
| No | Field                     |   | Description                                                                                                                                                                                                                 |
|----|---------------------------|---|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1  | Slide No.                 | : | 30                                                                                                                                                                                                                          |
| 2  | State                     | : | Karnataka                                                                                                                                                                                                                   |
| 3  | District                  |   | Uttar Kannada                                                                                                                                                                                                               |
| 4  | Toposheet No              | : | 48I/8                                                                                                                                                                                                                       |
| 5  | Name of the Slide         | : | KAR/UK/48I08/2018/30                                                                                                                                                                                                        |
| 6  | NH/SH/Locality            | : | 3km E of Jhalavat                                                                                                                                                                                                           |
| 7  | Latitude (N)              | : | 15°06'31.100                                                                                                                                                                                                                |
| 8  | Longitude (E)             | : | 74°22'17.600                                                                                                                                                                                                                |
| 9  | Length (m)                | : | 9                                                                                                                                                                                                                           |
| 10 | Width (m)                 | : | 18                                                                                                                                                                                                                          |
| 11 | Height (m)                | : | 7                                                                                                                                                                                                                           |
| 12 | Area (sq m)               | : | 162                                                                                                                                                                                                                         |
| 13 | Depth                     | : | <=5m                                                                                                                                                                                                                        |
| 14 | Volume                    | : |                                                                                                                                                                                                                             |
| 15 | Run out distance (m)      | : | 10                                                                                                                                                                                                                          |
| 16 | Type of material          | : | Debris                                                                                                                                                                                                                      |
| 17 | Type of movement          | : | Slide                                                                                                                                                                                                                       |
| 18 | Rate of movement          | : | Imperceptible                                                                                                                                                                                                               |
| 19 | Activity                  | : | Suspended                                                                                                                                                                                                                   |
| 20 | Distribution              | : | Retrogressive                                                                                                                                                                                                               |
| 21 | Style                     | : | Multiple                                                                                                                                                                                                                    |
| 22 | Failure mechanism         | : | Shallow Rotational Failure                                                                                                                                                                                                  |
| 23 | History                   | : | Data Not Available                                                                                                                                                                                                          |
| 24 | Geomorphology             | : | Lowly Dissected Slope                                                                                                                                                                                                       |
| 25 | Geology/Lithology         | : | Granite, Metabasalt, Qtz-chlorite schist                                                                                                                                                                                    |
| 26 | Structure                 | : | No distinct structure                                                                                                                                                                                                       |
| 27 | Landuse/ Landcover        | : | Extensive Cut Slope                                                                                                                                                                                                         |
| 28 | Hydrological condition    | : | Dry                                                                                                                                                                                                                         |
| 29 | Triggering Factor         | : | Rainfall                                                                                                                                                                                                                    |
| 30 | Death of persons          | : | Data Not Available                                                                                                                                                                                                          |
| 31 | People affected           | : | Data Not Available                                                                                                                                                                                                          |
| 32 | Livestock Loss            | : | Data Not Available                                                                                                                                                                                                          |
| 33 | Communication             | : | Data Not Available                                                                                                                                                                                                          |
| 34 | Infrastructure            | : | Data Not Available                                                                                                                                                                                                          |
| 35 | Agriculture/forest/Barren | : | Forest                                                                                                                                                                                                                      |
| 36 | Geo-scientific Causes     | : | Debris slide occurring at bend of road. Litho-contacts of granite, metabasalt, quartzite & dolerite facilitating the flow of water. This enhancing pore water pressure & thus reducing shear strength on super- saturation. |
| 37 | Remedial measures         | : | Retaining wall with weep holes is suggested                                                                                                                                                                                 |
| 38 | Remarks, if any           |   | Stream is flowing on downslope side of road.                                                                                                                                                                                |

|    |                                               |   |                                                                                                                                           |
|----|-----------------------------------------------|---|-------------------------------------------------------------------------------------------------------------------------------------------|
| 39 | Photos. Sketch of Plan & section of the slide | : |                                                         |
| 40 | Summary/Abstract                              | : | The failure occurred on weathered Quartzite. Retrogressive and widening landslide is occurring with shallow rotational nature of failure. |
| 41 | Date of Reporting                             | : |                                                                                                                                           |
| 42 | Landslide Category                            | : | Debris slide                                                                                                                              |



| No | Field                     |   | Description                                                                                  |
|----|---------------------------|---|----------------------------------------------------------------------------------------------|
| 1  | Slide No.                 | : | 31                                                                                           |
| 2  | State                     | : | Karnataka                                                                                    |
| 3  | District                  |   | Uttar Kannada                                                                                |
| 4  | Toposheet No              | : | 48I/8                                                                                        |
| 5  | Name of the Slide         | : | KAR/UK/48I08/2018/31                                                                         |
| 6  | NH/SH/Locality            | : | 4 km SW of Kumbharwada                                                                       |
| 7  | Latitude (N)              | : | 15°19'16.030                                                                                 |
| 8  | Longitude (E)             | : | 74°22'9.800                                                                                  |
| 9  | Length (m)                | : | 8                                                                                            |
| 10 | Width (m)                 | : | 18                                                                                           |
| 11 | Height (m)                | : | 7                                                                                            |
| 12 | Area (sq m)               | : | 144                                                                                          |
| 13 | Depth                     | : | <=5m                                                                                         |
| 14 | Volume                    | : |                                                                                              |
| 15 | Run out distance (m)      | : | 8                                                                                            |
| 16 | Type of material          | : | Debris                                                                                       |
| 17 | Type of movement          | : | Slide                                                                                        |
| 18 | Rate of movement          | : | Imperceptible                                                                                |
| 19 | Activity                  | : | Active                                                                                       |
| 20 | Distribution              | : | Retrogressive                                                                                |
| 21 | Style                     | : | Multiple                                                                                     |
| 22 | Failure mechanism         | : | Shallow Rotational Failure                                                                   |
| 23 | History                   | : | Data Not Available                                                                           |
| 24 | Geomorphology             | : | Lowly Dissected Slope                                                                        |
| 25 | Geology/Lithology         | : | Metabasalt                                                                                   |
| 26 | Structure                 | : | No distinct structure                                                                        |
| 27 | Landuse/ Landcover        | : | Extensive Cut Slope                                                                          |
| 28 | Hydrological condition    | : | Dry                                                                                          |
| 29 | Triggering Factor         | : | Rainfall                                                                                     |
| 30 | Death of persons          | : | Data Not Available                                                                           |
| 31 | People affected           | : | Data Not Available                                                                           |
| 32 | Livestock Loss            | : | Data Not Available                                                                           |
| 33 | Communication             | : | Data Not Available                                                                           |
| 34 | Infrastructure            | : | Data Not Available                                                                           |
| 35 | Agriculture/forest/Barren | : | Forest                                                                                       |
| 36 | Geo-scientific Causes     | : | Toe cutting and jointed rock mass enhancing pore water pressure and reducing shear strength. |
| 37 | Remedial measures         | : | Breast wall with weep holes is suggested                                                     |
| 38 | Remarks, if any           |   | Dolerite dyke has intruded metabasalts at the location.                                      |

|    |                                               |   |                                                                                                |
|----|-----------------------------------------------|---|------------------------------------------------------------------------------------------------|
| 39 | Photos. Sketch of Plan & section of the slide | : |              |
| 40 | Summary/Abstract                              | : | Suspended retrogressive shallow rotational slide is observed. Jointed metabasalts are present. |
| 41 | Date of Reporting                             | : |                                                                                                |
| 42 | Landslide Category                            | : | Debris-cum-rock slide                                                                          |



## Average Rainfall pattern in the area from 2009 to 2018.

| Rainuage Stations | Lat    | Long   | 2009   | 2010   | 2011    | 2012   | 2013   | 2014   | 2015    | 2016    | 2017    | 2018    |
|-------------------|--------|--------|--------|--------|---------|--------|--------|--------|---------|---------|---------|---------|
| KHANAPUR          | 15.64  | 74.517 | 2329.6 | 1906.2 | 1746.8  | 1393.5 | 1816.5 | 1812.5 | 1346.7  | 1487    | 1594    | 1259.7  |
| VALPOLI           | 15.531 | 74.14  | 3839.1 | 5017.8 | 5114.6  | 4257.3 | 4267.7 | 4480.1 | 4314.8  | 4088.95 | 3663.1  | 2542.9  |
| SANQUEM           | 15.229 | 74.152 | 3947.8 | 4774.8 | 4874.8  | 3177.7 | 4148.3 | 4483.3 | 4295.3  | 3842.5  | 3529.9  | 2175    |
| SIRSI             | 14.618 | 74.835 | 2644.2 | 2431.1 | 2942.7  | 2095.6 | 2641   | 2378.9 | 1972.48 | 1951.26 | 2299    | 2968.2  |
| HALIYAL           | 15.325 | 74.767 | 1472   | 1285.4 | 1368.4  | 950.6  | 1245   | 1249   | 802.54  | 726.3   | 954.76  | 1237.75 |
| SUPA              | 15.172 | 74.488 | 3747   | 2488.7 | 2732.41 | 1749.7 | 2573.4 | 2450.2 | 1998.06 | 2279.27 | 2581.52 | 3232.64 |
| BELGAUM           | 15.816 | 74.415 | 1464.7 | 1119.9 | 1147.5  | 839    | 992.5  | 1278   | 715.4   | 850     | 767     | 1326.9  |

