



कार्यालयीन प्रयोग हेतु/For official use only
विवृत फाईल प्रतिवेदन/Open file report

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

कर्नाटक राज्य के बेलगाम, उत्तर कन्नड़ जिले, कर्नाटक एवं गोवा राज्य के उत्तरी गोवा और दक्षिण गोवा जिले के भूआकृति संख्या 48I/05, 48I/06, और 48I/07 के कुछ हिस्सों में वृहद पैमाने पर (1:50,000) भूस्खलन संवेदनशीलता का मानचित्रण।

Macro-scale (1:50,000) Landslide Susceptibility Mapping in parts of Toposheets nos. 48I/05, 48I/06, & 48I/07 Belgaum, Uttar Kannada districts, Karnataka and North Goa & South Goa districts, Goa.

टोपोशीट सं./ Toposheet No.: 48I/05, 48I/06, 48I/07
मद संख्या: M4LSSM/एनसी/एस आर/SU-KG/2018/18717
Item no.: M4LSSM/NC/SR/SU-KG/2018/18717

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

नेहा कुमारी, भू-वैज्ञानिक एवं कमल कुमार, भू-वैज्ञानिक
Neha Kumari, Geologist And Kamal Kumar, Geologist

मिशन-IV
MISSION-IV

PROJECT: NLSM / परियोजना: एनएलएसएम

STATE UNIT: KARNATAKA & GOA/ राज्य इकाई: कर्नाटक एवं गोवा

सितम्बर, 2018
September, 2018

महानिदेशक, भारतीय भूवैज्ञानिक सर्वेक्षण, कोलकाता की पूर्वानुमति के बिना आंशिक या पूर्ण किसी भी रूप में उद्धरित ना किया जाये
Not to be published in part or full without prior permission of the Director General, Geological Survey of India, Kolkata

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

कर्नाटक राज्य के बेलगाम, उत्तर कन्नड़ जिले, कर्नाटक एवं गोवा राज्य के उत्तरी गोवा और दक्षिण गोवा जिले के भूआकृति संख्या 48I/05, 48I/06, और 48I/07 के कुछ हिस्सों में वृहद पैमाने पर (1:50,000) भूस्खलन संवेदनशीलता का मानचित्रण।

Macro-scale (1:50,000) Landslide Susceptibility Mapping in parts of Toposheets nos. 48I/05, 48I/06, & 48I/07 Belgaum, Uttar Kannada districts, Karnataka and North Goa & South Goa districts, Goa.

टोपोशीट सं./ Toposheet No.: 48I/05, 48I/06, 48I/07
मद संख्या: M4LSSM/एनसी/एस आर/SU-KG/2018/18717
Item no.: M4LSSM/NC/SR/SU-KG/2018/18717

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

नेहा कुमारी, भू-वैज्ञानिक एवं कमल कुमार, भू-वैज्ञानिक
Neha Kumari, Geologist And Kamal Kumar, Geologist

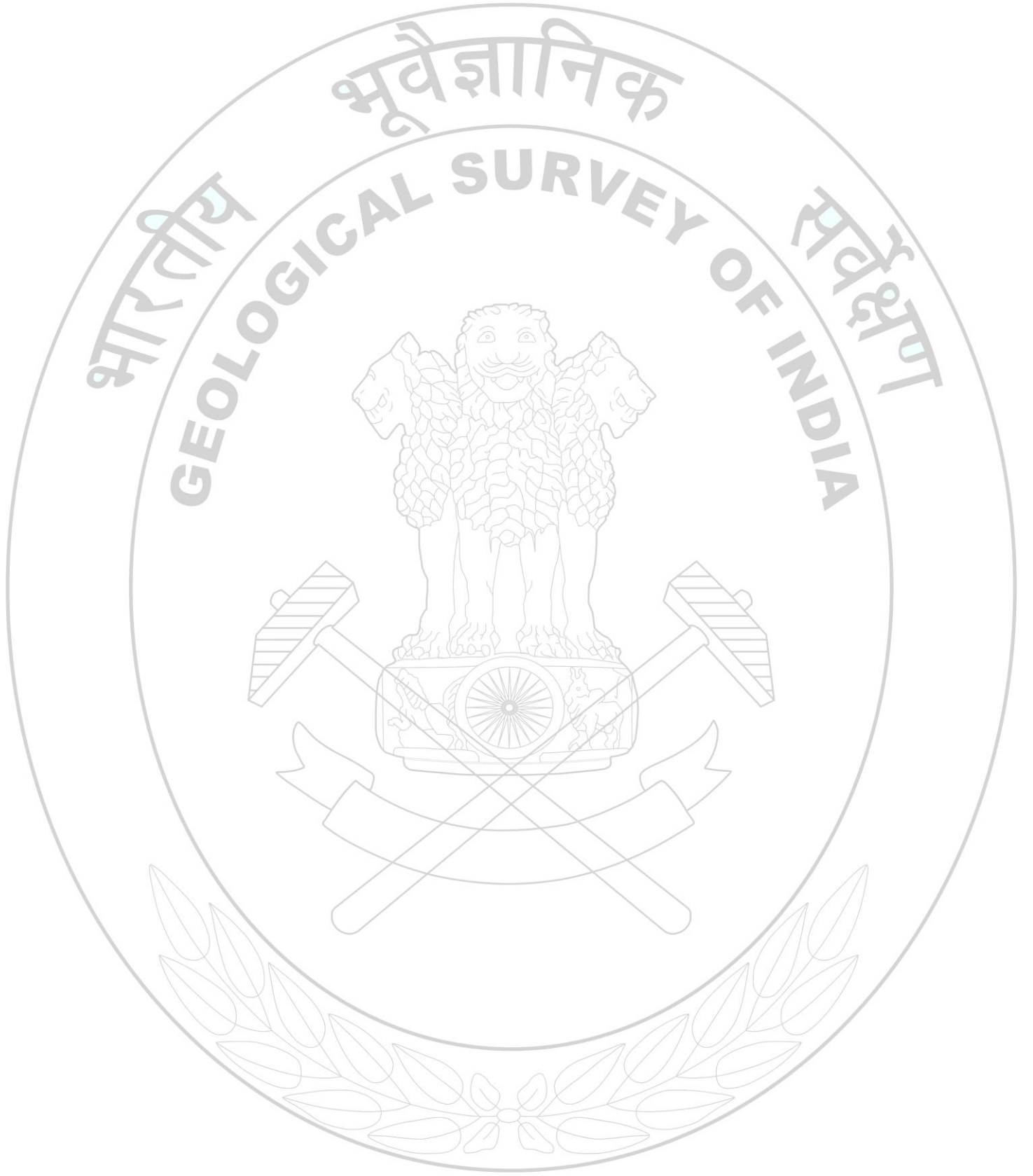
मिशन-IV
MISSION-IV

PROJECT: NLSM / परियोजना: एनएलएसएम

STATE UNIT: KARNATAKA & GOA/ राज्य इकाई: कर्नाटक एवं गोवा

सितम्बर, 2018
September, 2018

महानिदेशक, भारतीय भूवैज्ञानिक सर्वेक्षण, कोलकाता की पूर्वानुमति के बिना आंशिक या पूर्ण किसी भी रूप में उद्धरित ना किया जाये
Not to be published in part or full without prior permission of the Director General, Geological Survey of India, Kolkata



Macro-scale (1:50,000) Landslide Susceptibility Mapping in parts of Toposheets nos. 48I/05, 48I/06, & 48I/07 Belgaum, Uttar Kannada districts, Karnataka and North Goa & South Goa districts, Goa.

(FSP Code: M4LSSM/NC/SR/SU-KG/2018/18717)

Field Season: 2018-19

By

**Neha Kumari, Geologist
and
Kamal Kumar, Geologist**

CONTENTS

	Page no.
सारांश	i-iii
Abstract	iv-vi
I. INTRODUCTION	
1.1 Background Information	1-2
1.2 Present Work	2
1.3 Location and Accessibility	3
1.4 Physiography and Drainage	4
1.5 Climate and Rainfall	4-5
1.6 General Gemorphology and Soil Types	5
1.7 General Geology	6-7
1.8 Methodology	7-9
1.9 Acknowledgements	9
II. PREVIOUS WORK ON LANDSLIDE STUDIES	10-11
2.1 Review of Literature	10
2.2 Spatial distribution of Historic Landslide Incidences	11
2.2.1 History of Landslides	
III. LANDSLIDE INCIDENCES IN PRESENT SCENARIO	12-23
3.1 Spatial distribution of Landslides	
3.1.1. Major landslide incidences along Anmod-Mollem ghat road section (NH-4A) road section.	
3.1.2. Landslide incidences along Tadki-Kunang road section.	
3.1.3. Landslides along Castle rock- Dudhsagar railway station (ghat section).	
IV. LANDSLIDE SUSCEPTIBILITY ANALYSIS	23
4.1 Background	23

4.2 Selection of Preparatory factors	23-24
4.3 Geo-factor Themes	24-28
4.3.1 Slope Morphometry	
4.3.2 Landuse and Landcover	
4.3.3 Geomorphology	
4.3.4 Slope Forming Material (SFM)	
4.3.5 Regolith Thickness	
4.3.6 Structure and Drainage	
4.4 Landslide Susceptibility Analysis	34-40
4.4.1 Methodology	34
4.4.2 Selection of mapping units	35
4.5 Methods of Susceptibility Analysis	36-40
V. LANDSLIDE SUSCEPTIBILITY MAP	42-43
5.1 Interpretation of Susceptibility Map	
VI. CONCLUSIONS AND RECOMMENDATIONS	44-47
REFERENCES	
LOCALITY INDEX	
SYNOPSIS OF WORK DONE	
FIVE POINT PROFORMA	
DATASHEET ON MOVEMENT OF REPORT	
CERTIFICATE OF QUALITY OF REPORT	
LIST OF TABLES	
Table 1: Details of nature of work, quantum and achievements.	
Table 2: Chrono-stratigraphic Succession of Litho-units of the study area.	
Table 3: Details of location of historic/past landslide incidences in the study area.	
Table 4: Details of the locations showing recent and past landslides/ boulders fallen incidences between Castle rock (CLR) to Kulem (QLM) Railwayline (ghat section) under SSE/P.way/CLR jurisdiction	
Table 5: Details of location of landslide incidences recorded in the study area.	
Table 6: The unstable landslide susceptible zones and vulnerable extensive cut slopes locations along Castle rock –Dudhasagar- Kulem railway station (ghat section).	
Table 7: The Percentage distribution of Classified Slope Gradient/Angle Map of T.S Nos. 48I/5, I/6 & I/7 with their LOFS and Rank.	
Table 8: The Percentage distribution of Classified Slope Curvature Map of T.S Nos. 48I/5, I/6 & I/7 with their LOFS and Rank.	
Table 9: The Percentage distribution of Classified Slope Aspect Map of T.S Nos. 48I/5, I/6 & I/7 with their LOFS and Rank.	

Table 10: The Percentage distribution of Landuse/Landcover classes of T.S Nos. 48I/5, I/6 & I/7 with their LOFS and Rank.

Table 11: The Percentage distribution of Landuse/Landcover classes during pre-field studies and post field validation of the study area covering T.S Nos. 48I/5, I/6 & I/7.

Table 12: The Percentage distribution of Geomorphology classes for T.S Nos. 48I/5, I/6 & I/7 with their LOFS and Rank.

Table 13: The Percentage distribution of Slope Forming Material classes of T.S Nos. 48I/5, I/6 & I/7 with their LOFS and Rank..

Table 14: The Percentage distribution of Regolith Thickness classes of T.S Nos. 48I/5, I/6 & I/7 with their LOFS and Rank..

LIST OF GRAPHS

Graph 1: Graph showing frequency of different type of landslide incidences and their percentage distribution.

Graph 2: Graph showing frequency of landslides and their percentage distribution with respect to Slope Angle Class.

Graph 3: Graph showing frequency of landslides, their percentage distribution and probability of occurrence of landslides in different Slope Curvature Class.

Graph 4: Graph showing frequency of landslides, their percentage distribution and probability of occurrence of landslides in different Slope Aspect Class.

Graph 5: Graph showing frequency of landslides, their percentage distribution and probability of occurrence of landslides in different LU/LC Classes.

Graph 6: Graph showing frequency of landslides, their percentage distribution and probability of occurrence of landslides in different Geomorpholgy Classes.

Graph 7: Graph showing frequency of landslides, their percentage distribution and probability of occurrence of landslides in different litho-units.

Graph 8: Graph showing frequency of landslides, their percentage distribution and probability of occurrence of landslides in different Slope Forming Material Class.

Graph 9: Graph showing frequency of landslides, their percentage distribution and probability of occurrence of landslides in different Regolith Thickness Class.

Graph 10: Graph showing relationship between different geofactors and landslides and their percentage distribution with respect to different geofactor classes.

Graph 11: Graph showing percentage distribution of landslides and geographical area under low, moderate and high landslides susceptible zones.

LIST OF DIAGRAMS

Diagram 1: Flow diagram showing methodology adopted for Landslide Susceptibility Mapping.

LIST OF ANNEXURES

Annexure I: Geo-parametric landslide inventory database.

Annexure II: 42-point Geo-parametric landslide data inventory.

Annexure III: Tabular matrices for LOFS and consistency ratio calculations for six factor maps.

Annexure IV: Rainfall data (11 yrs) collected from different rain gauge stations of the study area.

LIST OF FIELD PHOTOGRAPHS

Photo 1A: Field Photograph showing Highly dissected hillslope of Anmod-Mollem ghat road

Photo 1B: Field Photograph showing Lowly dissected hillslope along Khanapur-Jamboti ghat road section.

Photo 2: Field Photograph showing Pediment Pediplain complex along Khanapur-Jamboti ghat road section.

Photo 3: Field Photograph showing Extensive Cut Slope along Anmod-Mollem ghat road section.

Photo 4: Field Photograph showing Extensive Cut Slope along the metalled Anmod road section.

Photo 5: Field Photograph showing Extensive Cut Slope on Lowly Dissected Hillslope along Castle Rock railway cutting.

LIST OF PLATES

Plate-1: Location map of the study area covering parts of Toposheet nos. 48I/05, 48I/06, & 48I/07 Belgaum, Uttar Kannada districts, Karnataka and North Goa & South Goa districts, Goa.

Plate-2: Geological map of Toposheet nos. 48I/05, 48I/06, & 48I/07 Belgaum, Uttar Kannada districts, Karnataka and North Goa & South Goa districts, Goa.

Plate-3: Landuse and Landcover map of Toposheet nos. 48I/05, 48I/06, & 48I/07 Belgaum, Uttar Kannada districts, Karnataka and North Goa & South Goa districts, Goa.

Plate-4: Geomorphology map of Toposheet nos. 48I/05, 48I/06, & 48I/07 Belgaum, Uttar Kannada districts, Karnataka and North Goa & South Goa districts, Goa.

Plate-5: Slope Gradient/Angle map of of Toposheet nos. 48I/05, 48I/06, & 48I/07 Belgaum, Uttar Kannada districts, Karnataka and North Goa & South Goa districts, Goa.

Plate-6: Slope Aspect map of Toposheet nos. 48I/05, 48I/06, & 48I/07 Belgaum, Uttar Kannada districts, Karnataka and North Goa & South Goa districts, Goa.

Plate-7: Slope Curvature map of Toposheet nos. 48I/05, 48I/06, & 48I/07 Belgaum, Uttar Kannada districts, Karnataka and North Goa & South Goa districts, Goa.

Plate-8: Drainage map of Toposheet nos. 48I/05, 48I/06, & 48I/07 Belgaum, Uttar Kannada districts, Karnataka and North Goa & South Goa districts, Goa.

- Plate-9:** Slope Forming Material map of Toposheet nos. 48I/05, 48I/06, & 48I/07 Belgaum, Uttar Kannada districts, Karnataka and North Goa & South Goa districts, Goa.
- Plate-10:** Regolith Thickness map of Toposheet nos. 48I/05, 48I/06, & 48I/07 Belgaum, Uttar Kannada districts, Karnataka and North Goa & South Goa districts, Goa.
- Plate-11:** Landslide Inventory map of Toposheet nos. 48I/05, 48I/06, & 48I/07 Belgaum, Uttar Kannada districts, Karnataka and North Goa & South Goa districts, Goa.
- Plate-12:** Landslide Susceptibility map of Toposheets nos. 48I/05, 48I/06, & 48I/07 Belgaum, Uttar Kannada districts, Karnataka and North Goa & South Goa districts, Goa.
- Plate-13:** Annual Rainfall Distribution map for the year 2008 to year 2011 of study area covering Toposheet nos. 48I/05, 48I/06, & 48I/07 Belgaum, Uttar Kannada districts, Karnataka and North Goa & South Goa districts, Goa.
- Plate-14:** Annual Rainfall Distribution map for the year 2012 to year 2015 of study area covering Toposheet nos. 48I/05, 48I/06, & 48I/07 Belgaum, Uttar Kannada districts, Karnataka and North Goa & South Goa districts, Goa.
- Plate-15:** Annual Rainfall Distribution map for the year 2016 to year 2018 of study area covering Toposheet nos. 48I/05, 48I/06, & 48I/07 Belgaum, Uttar Kannada districts, Karnataka and North Goa & South Goa districts, Goa.
- Plate-16:** Graph showing Annual Rainfall Distribution Curves of past 10 years rainfall data recorded in different rain gauge stations of study area covering Toposheets nos. 48I/05, 48I/06, & 48I/07 Belgaum, Uttar Kannada districts, Karnataka and North Goa & South Goa districts, Goa.

कर्नाटक राज्य के बेलगाम, उत्तर कन्नड़ जिले, कर्नाटक एवं गोवा राज्य के उत्तरी गोवा और दक्षिण गोवा जिले, के भूआकृति संख्या 48I/05, 48I/06, और 48I/07 के कुछ हिस्सों में वृहद पैमाने पर (1:50,000) भूस्खलन संवेदनशीलता का मानचित्रण I

कार्य-सत्र कोड सं:(M4LSSM/एनसी/एस आर/SU-KG/2018/18717)

कार्य-सत्र : 2018-19

द्वारा

नेहा कुमारी, भू-वैज्ञानिक

एवं

कमल कुमार, भू-वैज्ञानिक

सारांश

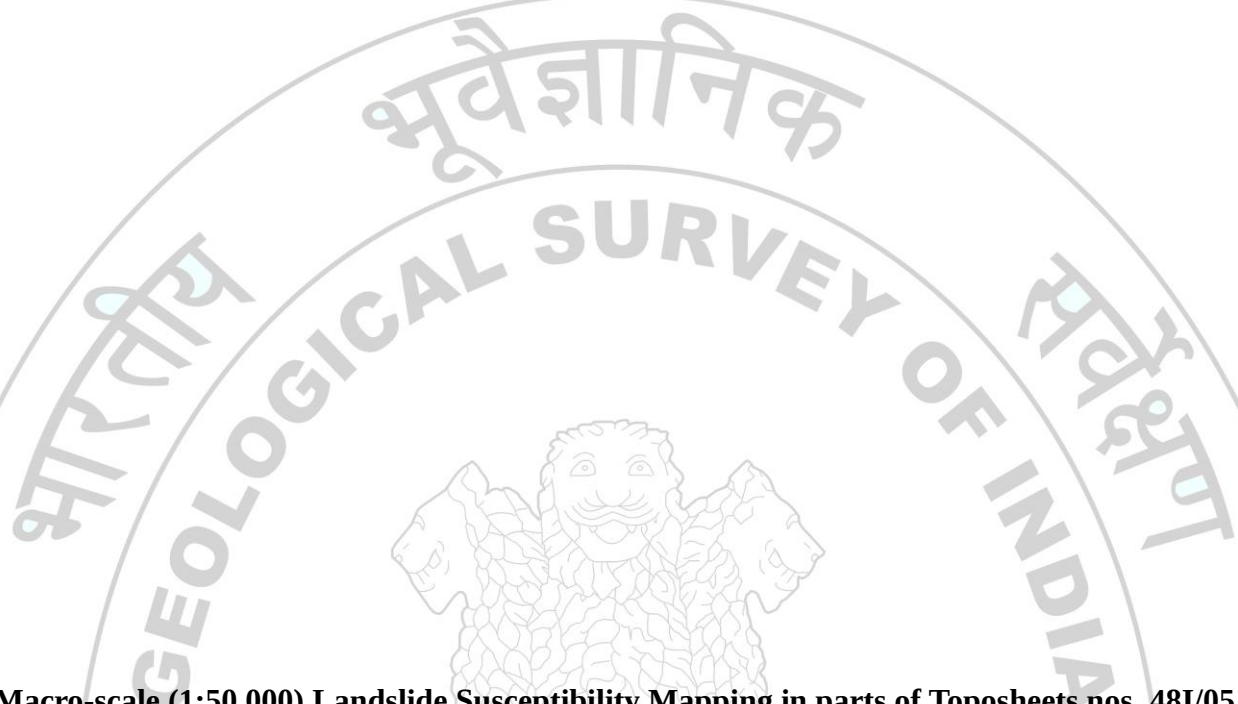
कर्नाटक राज्य के बेलगाम, उत्तर कन्नड़ जिले, कर्नाटक एवं गोवा राज्य के उत्तरी गोवा और दक्षिण गोवा जिले के भूआकृति संख्या 48I/05, I/06, और I/ 07 के कुछ हिस्सों में वृहद पैमाने 1:50,000 पर कुल 1491 वर्ग किलोमीटर के क्षेत्र का भूस्खलन संवेदनशीलता का मानचित्रण किया गया। पश्चिमी घाटों के हिस्सों का अध्ययन क्षेत्र, भू-आकृति की दृष्टि से कुल 12% क्षेत्र में अत्यधिक विच्छेदित पहाड़ियाँ हैं जिनमें चोटी और खड़ी घाटियाँ शामिल हैं, जबकि 82% क्षेत्रों में ज्यादातर मध्य और पूर्वी क्षेत्र में निम्न विच्छेदित पहाड़ियों के साथ ऊँची नीची स्थलाकृति के साथ आनिरंतरित छोटी पहाड़ी और पेडिमेंट-पेडिप्लीन कॉम्प्लेक्स उपस्थित हैं। बड़े पैमाने पर लटेराइट निम्न विच्छेदित पहाड़ियाँ पश्चिमी भाग में विच्छेदित पठारों का निर्माण करती हैं। भूमि आवरण यह दर्शाता है कि अध्ययन क्षेत्र का प्रमुख हिस्सा आरक्षित वन है, जो सागौन वृक्षारोपण के साथ घने मिश्रित जंगल से आच्छादित है। वन क्षेत्र के भीतर यूकेलिप्टस और अकेसिया के पेड़ (एच एच पी) अलग-अलग स्थानों में पाये जाते हैं और काजू के बागान (एच एच पी) लेटेराइट की निम्न ऊँचाई वाली पहाड़ियों पर पाये जाते हैं। अध्ययन क्षेत्र के उत्तरी और पूर्वी भाग में मृदा की उपरिभार 0.5-5मी., 5-10मी. और >10मी. पहाड़ियों के निचली ढलान और पेडिमेंट-पेडिप्लीन कॉम्प्लेक्स के भिन्न भिन्न स्थानों में व्याप्त है। भू-विज्ञान की दृष्टि से अम्बानेली और महाबलेश्वर समूह की चट्टान डेक्कन ट्रैप सुपर ग्रुप से बेसाल्टिक प्रवाह, क्रिटेसस से पेलियोसीन आयु के हैं। धारवाड़ सुपर ग्रुप के चित्रादुर्गा समूह की चट्टानों आर्जीलिट, मैंगनिफेरस फिलाइट, फेरुजिनस फिलाइट और आर्कियन युग के पीजीसी के ग्रेनाइट, ग्रेनाइटनिस अध्ययन क्षेत्र में उपस्थित हैं। चित्रदुर्ग समूह की चट्टानें बड़े पैमाने पर विच्छेदित पठारों का निर्माण करती हैं। लेटेराइट में लोहे, अलुमिनस और मैंगनीज अयस्क की मात्रा पाई जाती है। लौह और मैंगनिफेरस फिलाइट पर लटेराइजेसन की प्रक्रिया के परिणामस्वरूप लोहे और मैंगनीज अयस्क कुछ-कुछ भागों में प्राप्त होते हैं।

अध्ययन क्षेत्र में कुल 38 संख्या में भूस्खलन की घटनाओं को घाट सड़कों, रेलवे खंडों और अन्य प्रमुख राजमार्गों के साथ दर्ज किया गया है। कुल 63.16% भूस्खलन मलबे की स्लाइड के रूप में, रॉक स्लाइड के रूप में 10.53%, मलबे सह रॉक स्लाइड के रूप में 10.53% और 15.79% रॉक सह मलबे स्लाइड के रूप में वर्गीकृत किए गए हैं। भूस्खलन घटनाओं के स्थानिक वितरण से पता चलता है कि कुल 27 भूस्खलन की घटनाओं को उच्च विच्छेदित पहाड़ियों अनमोड-मोलेम घाट रोड (एन एच- 4ए) के अवतल और उत्तल वक्रों पर दर्ज भूस्खलन के निशान और अन्य को नीच विच्छेदित पहाड़ी ढलान पर दर्ज किया गया है, जो ढलान कोण 25°-35° और 35°-45° पर पाये गये हैं। खड़े ढाल कोण सहित विस्तृत ढाल पर भूस्खलन की घटनाओं को कैसल रॉक-द्रुधसागर-कुलेम रेलवे लाइन घाट सेक्शन पर दर्ज किया गया है। अनमोड-मोलेम घाट रोड (एन एच- 4ए) पर भूस्खलन की घटनाओं को सड़क चौड़ीकरण के लिए ढलान के काटने के कारण हुआ है और

साथ ही कैसल रॉक-दूधसागर रेलवे लाइन घाट खंड रेलवे लाइन विस्तार के लिए पहाड़ी की ढलान काटने के कारण हुआ है। दर्ज की गई भूस्खलन में से अधिकांश पुरानी और असक्रिय मलबे की स्लाइड हैं जो (< 2 मी.) उथले स्थानांतरण मलबे में वर्गीकृत है, फेलियर तल को नियंत्रित करने वाले निर्धारणात्मक भू घटक ढाल प्रवणता है। ढलान के संबंध में भूस्खलन के स्थानिक वितरण से संकेत मिलता है कि लगभग 23.68% स्लाइड $< 15^\circ$, 15-25° ढलान पर 52.63%, 25-35° ढलान पर 15.79% और 35-45° ढलान पर 7.89% स्लाइड पर हो रही है। भूस्खलन की घटनाओं के कुल 18.42% और ढलान की विफलता 70°-85° और 73.69% के बीच अलग-अलग खड़ी ढलानकोण विस्तृत कटान पहाड़ियों के ढलान पर प्रतिबंधित है, भूस्खलन की घटनाओं के कारण ढीले सामग्री (मिट्टी), अत्यधिक अपक्षय, खंडित और जोइंटेड शैल के कमजोर तल के समानंतर हो रहे हैं, जिनकी ओवरबर्डन मोटाई > 10 मीटर और 5-10 मीटर पायी गयी है। घाट सड़क के किनारे घने वनस्पतियों के साथ अत्यधिक विच्छेदित पहाड़ियों पर कुल 47.37% भूस्खलन हुआ, ढलान बनाने वाली सामग्री ढलान अस्थिरता में मुख्य भूमिका निभाती है, कुल 66.79% स्लाइड अपक्षययुक्त चट्टान पर, 15.79% लेटराइट पर, 10.52% ग्रेनाइट और ग्रेनाइट एवम 7.89% मिट्टी पर पर हुई है।

भूस्खलन की घटनाओं को प्रभावित करने वाले भू-घटक और भू-घटक वर्गों के गुणात्मक और मात्रात्मक सांख्यिकीय विश्लेषण से संकेत मिलता है, कि ढीले पदार्थ (मिट्टी) के साथ विस्तृत कटे हुए पहाड़ी ढलान, खंडित और संयुक्त चट्टानें पानी के रिसाव के लिये नया रास्ता प्रदान करती हैं। जो प्राकृतिक पहाड़ियों को भूस्खलन / भूस्खलन के लिए असुरक्षित बनाते हैं। दक्षिण-पश्चिम और पश्चिम की ओर की पहाड़ियों पर दक्षिण-पश्चिम मानसून के प्रभाव के कारण अपक्षय अधिक होता है। अपक्षय घटना के साथ दक्षिण-पश्चिम मानसून के दौरान बारिश के कारण ढलान विफलता प्रमुख भूस्खलन बढ़ाने के कारक है।

क्षेत्र के भूस्खलन संवेदनशीलता मानचित्र एएचपी आधारित गणितीय प्रतिरूपण और जीआईएस का उपयोग करके तैयार किए गए हैं। अलग-अलग विषयगत मानचित्रों को व्यवस्थित करके और इसी भूस्खलन घटना अनुकूलता स्कोर मानचित्र एल. ओ. एफ. एस. रेटिंग्स और भू-घटक वर्गों के भार का उपयोग करके बनाया गया है। विषयगत मानचित्र को एकीकृत करके बहु-श्रेणी सुची बंध तरीके का उपयोग करके भूस्खलन संवेदनशीलता मानचित्र तैयार किए गए हैं। वर्गीकृत भूस्खलन संवेदनशीलता मानचित्र यह दर्शाता है कि 2.6% क्षेत्र उच्च संवेदनशील जोन, 16.4% क्षेत्र सामान्य और 81% क्षेत्र निम्न संवेदनशील क्षेत्र में आते हैं। भूस्खलन संवेदनशील मानचित्र का सत्यापन और उपरिशासी विश्लेषण के साथ भूस्खलन वितरण मानचित्र से यह संकेत मिलता है कि भूस्खलन का 36.84% उच्च संवेदनशील क्षेत्रों में पड़ता है, जबकि 36.84% और 26.32% भूस्खलन क्रमशः मध्यम और निम्न संवेदनशील क्षेत्रों में आता है। संशोधित प्राकृतिक ढलान यानी सड़क और रेल नेटवर्क के लिए 30° - 45° से भिन्न भिन्न ढलान पर बनी विस्तृत कट ढलान मानसून के दौरान फिसलने की चपेट में है। ढलान स्थिरीकरण तकनीकों को अपनाया जाना चाहिए और पहाड़ी ढलान के दो भाग में पंक्तिदार प्रवाह तंत्र के साथ वीप जल निकासी तथा अपरदन को रोकने के लिये समर्थन प्रदान किया जाना चाहिए।



Macro-scale (1:50,000) Landslide Susceptibility Mapping in parts of Toposheets nos. 48I/05, 48I/06, & 48I/07 Belgaum, Uttar Kannada districts, Karnataka and North Goa & South Goa districts, Goa.

(FSP Code: M4LSSM/NC/SR/SU-KG/2018/18717)

(F.S. 2018-19)

By

Neha Kumari, Geologist

&

Kamal Kumar, Geologist

An area of total 1491 sq. km. was mapped in parts of 48I/05, I/06, & I/07 in Belgaum, Uttar Kannada districts, Karnataka and North Goa & South Goa districts of Goa for landslide susceptibility mapping on 1:50,000 scale. Physiographically, the study area forms part of Western Ghat. Geomorphologically, a total of 12% of the area in the western part is highly dissected hill ranges comprise of ridges and steep valleys whereas 82% of the areas in the northern, central and eastern part is lowly lying dissected hillslope with rolling topography intermittent with hillocks and Pediment-Pediplain Complex. The lowly dissected extensively lateritised hill forms the dissected plateaus in the north-western part. The land cover pattern indicates that major part of the study area is reserve forest with dense mixed jungle. The teak, eucalyptus and acacia plantation (HHP) are dispersed in isolated patches within the fringe of the forest area and cashew plantation (LHP) are

practised on low lateritic hills. The thickness of overburden soil varies from 0.5-5m, 5-10m and >10m on foot slope and Pediment-Pediplain Complex in northern and eastern part of the study area.

Geologically, the rock types exposed in the study area belong to the basaltic flow of Ambaneli and Mahabaleshwar Formation of Sahyadri Group of Deccan Trap Super Group (upper Cretaceous to Palaeocene age), rocks of Chitradurga Group i.e. Argillite, bands of Manganiferous Phyllite, Ferruginous phyllite of Joldal formation of Dharwar Super Group (Archean age) and Granite, Granite gneiss of Peninsular Gneissic complex of Archean age. The rocks of Chitradurga Group are extensively lateritised and form dissected plateaus. The laterites are ferruginous, aluminous and manganiferous in composition. The process of lateritisation on Fe/Mn phyllite has resulted in the formation of pockets/lenses rich in iron and manganese ore.

Total 38 nos. of landslide incidences are recorded along Ghat roads, railway sections and other major highways in the study area. Total 63.16% of landslides are categorised as debris slide, 10.53% as rock slide, 10.53% as debris cum rock slide and remaining 15.79% as rock cum debris slide. The spatial distribution of landslides incidences indicates that total 27 nos. of landslides are recorded on concave and convex curves of Anmod-Mollem Ghat road (NH-4A) on highly dissected hills and others are recorded on lowly dissected hill slope confined to the cut slope varying between slope angle 25°-35° and 35°-45°. The landslide incidences on extensive cut slope are recorded along Castle Rock-Dudhsagar-Kulem railway line ghat section. The landslides incidences on Anmod-Mollem Ghat road (NH-4A) are induced due to toe cutting of slope for road widening and infrastructure development triggered by heavy rainfall. Similarly, the landslides occurring on Castle Rock-Dudhsagar railway line ghat section are caused due to extensive hill slope cutting i.e. modification of natural slopes for extension of railway line. Most of the slides recorded are old and suspended debris slide of shallow (<2m) translational to rotational slope failure that can get reactivated during the torrential rainfall. Slope is the deterministic geofactor governing the failure plane.

The spatial distribution of landslides with respect to slope gradient indicates that nearly 23.68% of slides are occurring on slope <15°, 52.63% on 15-25° slope, 15.79% on 25-35° slope and 7.89% of slides are occurring on 35-45° slope. Total 18.42% of landslide incidences and slope failure are restricted on “Extensive cut slope” with steep slope angle varying between 70°-85°. Total 47.37% of landslides occurred on highly dissected hillslope along ghat road with thick vegetation cover. The slope forming material plays key role in slope destabilization. The landslide incidences are occurring on loose material (soil), laterite, highly weathered, fractured and jointed rocks. Total 66.79% of slide has occurred on weathered rock, 15.79% on laterite, 10.52% on granite and granite gneiss and 7.89% on loose soil.

Qualitative and Quantitative statistical analysis of geofactors and geofactor classes influencing landslide incidences indicates that the extensive cut on hillslope with loose material (soil), laterite, highly weathered, fractured and jointed rocks on hillslope provides new path way for water seepage and saturation along the weaker planes that makes the natural hillslope vulnerable for landslides/landslips. The southwest and west facing hillslopes are more prone to weathering due to influence of southwest monsoon. So, the slope failure due to rainfall during southwest monsoon in combination with weathering phenomenon is the major landslide triggering factors.

The final landslide susceptibility maps of the area are generated using knowledge driven data modeling method i.e. AHP in GIS platform. The different thematic maps are rasterised and corresponding Landslide Occurrence Favorability Score maps (LOFS) are generated using LOFS ratings/weights of geofactor classes. The thematic maps are integrated using multi-class index overlay method to generate landslide susceptibility map. The classified landslide susceptibility map indicates that 2.6% of the area is highly susceptible, 16.4% of the area is moderately susceptible and 81% of the area falls in low susceptible zone. The overlay analysis and validation of susceptibility map with respect to landslide distribution map indicates that 36.84% of the landslides falls in high susceptible zones, whereas 36.84% and 26.32% of landslides falls in moderate and low susceptible zones respectively. The modified natural slope i.e. extensive cut made on slope varying from 30°-45° for road, rail network and other infrastructure developments are vulnerable to sliding during monsoon. Keeping in view the development activities the slope stabilization techniques should be adopted on disturbed hillslope. Lined drainage with weep holes should be provided for toe support all along the ghat road in hilly terrain for effective drainage and to avoid toe erosion.

Macro-scale (1:50,000) Landslide Susceptibility Mapping in parts of Toposheets nos. 48I/05, 48I/06, & 48I/07 Belgaum, Uttar Kannada districts, Karnataka and North Goa & South Goa districts, Goa.

(FSP Code: M4LSSM/NC/SR/SU-KG/2018/18717)

(F.S.: 2018-19)

I. INTRODUCTION

1.1. Background Information

Large scale landslides are the major natural hazard in hilly terrain of Himalayas of extra-Peninsular India and Western Ghat region of Indian Peninsula, which accounts for considerable loss of life and damage to communication routes, human settlements, agricultural fields and forest lands in recent past. Geological Survey of India, being the Nodal Agency for Landslides in India since 2004, vigorously and swiftly implemented the NLSM programme in hilly terrain as per the action plan 2006 of the National Disaster Management Authority (NDMA) on landslide hazard as well as risk mitigation. Landslide susceptibility maps spatially depict the areas where future slope failures are likely to occur due to specific environmental & terrain conditions. The Landslide inventory mapping was first taken up during FS:2007-08 in order to prepare a landslide inventory database at various stretches along the Ghat roads in the Western Ghat belt covering districts of Coorg, Dakshina Kannada, Udupi, Shimoga, Chikmagalur of Karnataka state and North Goa & South Goa districts of Goa state. The weathering phenomenon and heavy rainfall during peak rainy season is the major triggering factor for landslides, leading to the displacement of rocks and soils causing widespread damage to infrastructure such as railway, roads as well as casualties leading to loss of life and property.

In view of the ever increasing developmental pressure, the mean of communication network like roads, railways and other construction works are progressing rapidly in hilly terrain of Western Ghats. The Landuse/Landcover changes, whether of natural origin or anthropogenic activities has influenced the susceptibility of natural slopes to landslides all along NH and SH Ghat road sections of hilly terrains of Western Ghat. Accordingly, the hillside collapse is the most commonly occurring phenomena due to human interference, heavy rainfall, ineffective drainage and high degree of weathering & erosional phenomenon in Western Ghats. The specter 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 for future management are the need of the time. Taking into account all these parameters “Macro-scale on 1:50,000 scale Landslide Susceptibility Mapping” in parts of Toposheet nos. 48I/05, 48I/06 & 48I/07 of Belgaum, Uttar Kannad districts of Karnataka and North Goa & South Goa districts of

Goa vide FSP code: M4LSSM/NC/SR/SU-KG/2018/18717 was carried out. The Landslide Susceptibility Map is generated on priority basis using knowledge-driven mathematical method and data integration technique i.e. multi-class index overlay method for geofactors thematic maps integration in Arc GIS platform. The hillslopes are categorised as high, moderate and low susceptible zones based on weightage assigned to causative geofactors incorporating AHP based mathematical data modelling method for delineating landslide susceptible zones.

1.2 Present Work

The aim of the present work was to carry out for Macro-scale (1:50,000) Landslide Susceptibility Mapping in parts of Toposheet nos. 48I/05, 48I/06 & 48I/07 of Belgaum, Uttar Kannad districts of Karnataka and North Goa & South Goa districts of Goa with the following objectives:

- (i). Preparation of landslide inventory database using high resolution remote sensing information and field inputs.
- (ii). Preparation of spatial database for geofactors of landslides.
- (iii). Categorisation of the hillslope in terms of landslide susceptibility.

Table 1: Details of nature of work, quantum and achievements.

Nature of Work	Target in (sq. km.)	Achievements in (sq. km.)
1. Pre field map preparation		
i) Preparation of Thematic maps (in GIS on scale 1:50000)		
a)Slope forming material map	1491 sq. km.	1491 sq. km.
b) Geomorphology and lineament map	1491 sq. km.	1491 sq. km.
c) Slope morphometry (slope, aspect & curvature) map	1491 sq. km.	1491 sq. km.
d) Landuse / Landcover map	1491 sq. km.	1491 sq. km.
e) Drainage map	1491 sq. km.	1491 sq. km.
f) Regolith Thickness map	1491 sq. km.	1491 sq. km.
ii) Preparation of landslide inventory map	1491 sq. km.	1491 sq. km.
2. Field based studies		
i)Field checking of all thematic maps	1491 sq. km.	1491 sq. km.
ii)Field checking and collection of landslide inventory attributes (41 point geo -parametric sheet)	1491 sq. km.	1491 sq. km. (38 nos. of Landslides)
3. Post field studies and modelling		
i) Updation of thematic and landslide inventory maps	1491 sq. km.	1491 sq. km.
ii) Landslide susceptibility modelling and finalization of landslide susceptibility map in GIS	1491 sq. km.	1491 sq. km.
4.Collection of rainfall data from available rain stations	Taluk wise 11 years rainfall data obtained from different rain gauge stations of the study area.	

1.3 Location and Accessibility

The major part of the study area falls in Belgaum & Uttar Kannada districts of Karnataka and minor part falls in North Goa & South Goa district of Goa (**Plate-1**). The area is bounded by 15°47'44.14"N-15°15'00.00"N latitudes and 74°15'00.00"E-74°30'00.00"E longitudes. The study area is highly rugged with highly dissected hill ranges comprises of ridges and steep valleys in the western part and lowly dissected hillslope with rolling topography intermittent with hillocks and Pediment-Pediplain Complex in the central and eastern part. The northern and eastern parts of the study area forms parts of Belgaum and Khanapur taluks of Belgaum district and southern and central part forms part of Joida taluk of Uttar Kannada district. A small part in the southwestern part of the area is represented by Sanguem taluk of North Goa district of Goa state.

The Dudhsagar waterfall is the famous eye catching waterfall on the hilly dissected hill range of Western Ghats. The National Highway (NH-4A) passes from study area connecting Ramnagar to Panaji and Ramnagar to Belgaum. The area is well connected by SH-04 (Jamboti-chorla ghat road) connecting Khanpur Taluk headquarter to Panaji and Panaji to Belgaum. The important major road connecting interior places are Khanapur-Jamboti and Khanapur-Anmod road sections. Three highway viz. Londa-Khanapura road, Khanapura-Talawadi road, Khanapur-Kankumbi road passes through the area. The important locality/villages are Baknur, Belvetti, Kiniye, Gunji, Jamboti, Asoga, Londa and Khanapur. The SH-54 passes through Kiniye connecting NH-4A (Panaji-Belgaum Road). The Londa-Marmagoa, Londa-Miraj, and Belgaum-Londa railway sections of south central railway connecting Bengaluru and Belgaum passes through these areas. Londa and castle rock are the important railway stations. The nearest airport is Bambolim at Vasco. Marmagoa is the nearest harbour. All the villages are connected to taluk headquarter by state highways, national highways and metalled roads. Interior parts are well connected by fairly good metalled, & all weather roads, cart and foot tracts.

1.4 Physiography and Drainage

The area is highly rugged, forms part of Western Ghats and comprises of ridges and steep valleys in the western part. The greater part of the area is lowly dissected hill slope intermittent with Pediment-Pediplain Complex and Rolling plain. The highest altitude is 962m from MSL. The area is thickly forested and forms the northeastern extension of the well-known canara forest. The inaccessible mountain ranges and hillocks is covered with dense mixed jungle.

The Malaprabha river running east is the only major perennial river, other rivers like Mahadai river, Bali nadi, Khoti nadi and Halaton nadi are tributaries joining Malaprabha river. Pandhri nala and Kali Nadi are the other important streams. The drainage is of dendritic to sub-trellis in nature.

The catchment and river basin are the important sites for determining the water saturation in the adjacent areas. The Supa reservoir is present in the Southeastern part of T.S no. 48I/7 (**Plate 8**).

1.5 Climate and Rainfall

The Uttar Kannada and Belgaum Districts experience tropical monsoon climate. The maximum temperature recorded during the summer is 41°C and during the winter is 9°C. The average rainfall in the district is 808 mm. The rainfall of different gauge station of the study area indicates that Khanapur taluk in the north eastern part and Supa taluk in south eastern part receives the maximum rainfall. The temperature rising from January to peak in May; commonly around 30°C and rise up to 38°C. The humidity is lowest during the dry season and highest during the monsoons. The winds are predominantly south-westerly during the summer monsoon and north-easterly during the winter monsoon. The district receives rainfall both from the South-West and North-West monsoon, but the area receives the major rainfall is from South-West monsoon in the month of September and October.

Goa has a tropical monsoon climate and the region is generally warm and humid throughout the year. The temperature ranges from 20°C to 34°C. Due to maritime influence, the diurnal range of temperature during the day is not large. The diurnal range is the least being 4 to 6°C during monsoon season and increases to the maximum of 10 to 20°C during December & January. May is the hottest month where the mean daily temperature increases to 30°C. January is the coolest with mean daily temperature of about 23°C. It is noted that the day temperature is the lowest in monsoon months of July and August and not in the cool winter months of December and January. The temperature is highest (around 33°C) in pre-monsoon months of April & May and again in post monsoon months of November & January.

Due to proximity to the Arabian Sea, humidity throughout the year is more than 60% with highest from 80 to 90% during monsoon period. The state receives abundant rainfall from the Southwest monsoon during June to September. The average annual rainfall received in the State is about 3200mm. As a result of the orographic influence the rainfall increases progressively from the coast to the Western Ghats from about 2500 mm to over 4500 mm. Over 90% rainfall occurs during the monsoon months with Valpoi and Sanguem stations recording maximum rainfall while the remaining 10% rainfall is received during the non-monsoon months. The low lying coastal areas receive minimum rainfall while the inland hilly terrain receives maximum rainfall. Highest rainfall is received during the month of July followed by a gradual decrease in subsequent monsoon months (**Plate-13, Plate-14, Plate-15, Plate-16**).

1.6 General Gemorphology and Soil Types

Geomorphologically, major part of the uttar kanada district is covered by hilly areas belonging to lowly dissected Sahyadri hill ranges and plain table land areas on eastern most parts of the district occupying parts of Mundgod and Halyal taluks. The land mass of the district is situated between the elevations of 0 to 800 m above msl. The highest peak in the district is Darshangudda located 915m msl near the border to Goa state and the minor parts of North & South Goa districts comprises of Deeply dissected high Western Ghats denudational hills as distinct morphometric unit in the western part in parts of T.S no. 48I/6, I/7 of the study area. The Belagaum district is primarily located on the eastern side of the Western Ghats and its topography is predominantly undulating. A “rugged terrain” marks the western part of Khanapur and Belgaum taluks with deep cutting ravines on the foothills of the Western Ghats. The elevation of these hills varies from 796 to 1025m msl. Northern portion of the district is a plateau region formed by basaltic lava flows, which represents “Deccan peneplain”. The central and southern parts exhibit moderate to gently “undulating terrain” having sparsely distributed knolls and tors. In some parts, especially in Ramdurg and Saundatti taluks, hills with elevations between 686 and 783m msl are present. The remaining part of the district is in general a “plateau area”. The elevation in the plains varies from 534m in the northeastern part to 820m amsl in the southwestern part of the district. The regional slope is towards northeast.

The most rugged hilly parts of the district are covered by coarse sandy soil and surrounded by the areas covered by lateritic soil. Lateritic soil constitutes the major soil type in the study area. It is highly porous & permeable, slightly acidic with low pH values, low in organic matter, Calcium and Phosphorus. On eastern parts, the lateritic soils change to red loamy soils. The soils of Belgaum district can broadly be classified into red soils and black soils. These soils vary in depth and texture, depending on the parent rock type, physiographic settings and climatic conditions. The black soil predominates the Deccan Trap terrain and the red soils are found in the south-western and south-eastern part of the district over gneissic terrain. They are greyish to dark greyish-brown in colour varies from loamy to clayey texture. These soils have low to moderate infiltration characteristics. These soils occur on plains or lands having gentle slopes. These are derived from the weathered products of basalts and limestone and are darker in valleys than in high lands. These are derived from a wide variety of parent rock types, like traps, schists, gneisses and sedimentary rocks. They are generally transported and therefore occur in valleys and depressions Their texture varies from loam to clay, with low to moderate infiltration characteristics. Lateritic soils are red in colour and occur as pockets. They occur at high-levels as insitu in Deccan Trap terrain and at low-levels as transported in Malnad region. They are derived from Deccan traps as well as sedimentary rocks, Dharwarian Schists and peninsular gneisses. These soil have good to moderate infiltration characteristics.

1.7 General Geology

Geologically, the area has rock types belonging to Sargur Group and PGC, Goa and North Kanara schist belts of Dharwar Supergroup of Proterozoic age, metasedimentary sequence of Dharwar Supergroup of Archean age and Deccan traps of Upper Cretaceous and Palaeocene age, Arenite of Badami Group of Proterozoic age and Upper Cretaceous and Palaeocene age are exposed. Basaltic flows of Ambanelli and Mahabaleshwar Formation of Sahyadri Group belonging to Deccan Trap Super Group are found resting on this rock. Rocks of Chitradurga Group are extensively lateritised and form dissected plateaus. The Deccan trap are capped by 60-70m thick pile of laterite (**Plate-2**).

In the central part of the area, the north western extension of Shimoga schist belt which is locally referred as North Kanara schist belt. The North Kanara schist belt is represented by Jodhal Formation of Chitradurga Group of rocks essentially made up of orthoquartzite-limestone chert, maganiferous phyllite and banded haematite Quartzite. Sandstone of Kaladagi Supergroup of rocks is exposed unconformably over PGC locally called Anmod Ghat Gneiss that occupies 60% of the study area. All the above units have undergone intense lateritization to various degrees. The basement anmod ghat gneiss occurs extensively with NE & NW parts occurs as circular, elongated domal mass with overlying meta-sedimentary rocks. Dudhsagar granite is a younger intrusive granite in South western part of the study area. The meta-sedimentary sequence belonging to Barcem and Bicholem Formation of Chitradurga Group of Dharwar Super Group is represented by Cholrite Schist interbedded with Quartzite in NE, central and SW part of the area. The gneissic rock is medium to coarse grained with well defined gneissic banding. Basaltic Flows occur at the higher elevation +750 m overlying pre-existing schistose rocks as seen southwest of Kotagdi donya hills.

The Goa belt is exposed in the south western corner of the study area and are mainly of Barcem and Sanverdem Formation that consists of quart-chlorite schist with interbedded quartzite. All the litho-units have undergone intense lateritization to various degrees. The laterites are ferruginous, aluminous and manganiferous in composition. The chrono-lithostratigraphic succession of the study area is shown in (**Table 2**).

The planar structures are represented by bedding bedding in quartzite and Banded Iron Formation, foliation in schist and gneiss, joints in gneiss and granites, and overturned syncline is central part is observed in the central part of the study area (T.S no.48I/7). The regional foliation trends in NW-SE direction with steep dip towards NE. The North Kanara belt is disposed on regional scale in the form of SW plunging synclinal structure with Ranebennur Formation occupying the core and Bisgod Formation bordering the basement gneiss.

Economic minerals:

The Manganese, Iron and Laterite are the most economic minerals found in the area. The numerous abandoned open cast manganese ore mines are observed in the southern part of reserve forest south of Tadki village area and 2 nos. of abandoned open cast iron ore mine are observed on Anmod Ghat road (T.S no. 48I/7). The iron rich ferruginous laterite is occurring in and around Ivoli & Kunang village area in southern part of T.S. no. 48I/7.

Table 2: Chrono-lithostratigraphic succession of the study area (SOI T.S nos. 48I/5, I/6, & I/7)
Source: Sahasnabudhe, Saleem A. K. et. al, GSI (FS: 1989-90).

Age	Supergroup	Group	Formation	Lithology
Cenozoic				Laterite
Upper Cretaceous to Palaeocene	DeccanTrap	Sahyadri	Mahabaleshwar	Basalt Flow 28 Basalt Flow 27 Basalt Flow 26 Basalt Flow 25 Basalt Flow 24 Basalt Flow 23
			Ambaneli	Basalt Flow 22 Basalt Flow 21 Basalt Flow 20 Basalt Flow 19 Basalt Flow Undifferentiated Basalt Flow 18
Palaeoproterozoic		Younger Intrusives	Acid intrusives	Quartz vein
			Basic intrusive	Dolerite
Archean		Layered Ultramafic Complex	Motimakki Ultramafites	Anorthositic Gabbro
		Chitradurga (Goa)	Sanvardem	Quartzite
				Phyllite
				Argillite
			Bicholim	Quartzite
				Limestone
				Argillite
			Barcem	Quartzite
				Quartz-chlorite schist
		Chitradurga (Shimoga)	Ranibennur	Argillite
			Joldal	Banded Iron Formation
				Ferruginous Phyllite
				Manganiferous Phyllite
				Limestone
				Quartzite
	Peninsular Gneissic Complex	Peninsular Gneissic-I	Grey Granite	Granite (Dudhsagar)
			Gneisses	Granite Gneiss
		Sargur		Ultramafite
				Garnet-Kyanite-Sillimanite Schist

1.8 Methodology

Landslide Susceptibility Map is prepared using multi-class index overlay and AHP based mathematical data modelling method. In present study both probabilistic and heuristic-based method are used where the weightage is assigned based on knowledge of the causative factors/parameters. Due to insufficient data on landslide to support the data driven modelling, knowledge driven method is applied in the present study area. The Analytical Hierarchy Process is a multi-criteria decision making process of measurement through pair wise comparisons and relies on the judgements of the experts to derive priority scales (Saaty,2008). The Analytical Hierarchy Process operates at four levels viz. defining problems, construction of pair wise comparison matrix, determining weights and obtaining overall priority. In Landslide Susceptibility Mapping different landslide causative factors are considered as alternatives. Absolute numbers (from 1 to 9) are assigned to each landslide related parameters based on its relative importance and comparison matrices are constructed to Compute Consistency Ratio (CR), Consistency Index (CI).

Methodology followed for generating landslide susceptibility map is mentioned below:

I. Preparations of Pre-field thematic/geofactor map (in GIS on 1:50000 scale) includes:

Various geofactor thematic maps i.e. Landuse and Landcover Map, Geomorphology Map, Slope Forming Material Map, Regolith Thickness Map, Slope Morphometry (Slope, Aspect, and Curvature) Map, Drainage Map, Landslide inventory Map are prepared in Arc GIS platform with the aid of topographic sheets, Multi-temporal Google Earth Satellite Imagery and Carto DEM data.

The following thematic datasets are prepared for AHP based data modeling and analysis:

- (i) LU/LC Map and Geomorphology Map are prepared from real time Google Earth Imagery (Multi-temporal imagery).
- (ii) Slope Forming Material Map are generated with the aid of Geomorphology, Lithology (from legacy map: Geology map) and LU/LC map as proxy thematic maps.
- (iii) Regolith Thickness Map are prepared with the aid of geomorphology, LU/LC as proxy maps and developed more accuracy during field checks.
- (iv) Drainage Map and Slope Morphometry (Slope, Aspect, Curvature) Map are DEM derivative maps prepared from Carto DEM data of 30m resolution.
- (v) Landslide Inventory Map and Landslide inventory database is prepared with the help of multi-temporal data on Google Earth Imagery, historical and event based data are reported in old GSI reports and other relevant papers/articles.

II. Field based studies/Ground truthing includes:

- (i) Ground truthing/field checks and validation of all geofactor thematic maps.
- (ii) Field validation of historic landslides and collection of data on recent landslide incidences at important locations.
- (iii) Collection of landslide inventory and damage data as per 42-point geo-parametric sheet.

III. Post field studies and modelling includes:

- (i) Updation of thematic maps and landslide inventory maps based on field data in GIS platform.
- (ii) Pairwise correlation matrix calculation, determination of LOFS and Rank as per the weightage/ rating assigned to different thematic (causative factors) variables.
- (iii) AHP based data modeling and multi class overlay analysis of different rasterised thematic maps for the preparation of Landslide susceptibility map in GIS platform.

1.9 Acknowledgements

The authors feel immense pleasure in extending their sincere thanks to Shri M. Sridhar, ADG & HOD, Southern Region, Shri S. K. Tripathi, DDG & RMH-IV, Southern Region for their co-operation, technical and financial support in regulating the project. I am grateful to Shri Ishwar Dan Ashiya, Dy. DG, and Shri R. Bhaskaran, the than Dy. Director General, SU:K&G, GSI, Bengaluru for his positive attitude and necessary guidance for the successful execution of the assigned work.

I convey my thanks and feel highly debted to the supervisory officer Shri J. Srihari, Director, SU: K&G,GSI, Bengaluru for his guidance, co-operation, patience and for imparting his valuable engineering knowledge and analytical skills during his inspection visits in the field. I am grateful to him for his field efforts in generating good quality data.

The authors feel privileged in extending their sincere thanks Nodal officers of landslide division, (GHRM) Cell, CHQ, Kolkata for their support, encouragement as well as monitoring the work progress that helped in successful completion of the assignments.

The authors are especially thankful to district authorities for their co-operations in sharing rainfall data and railway authority, P-way, Hubli Division for sharing records of past landslides incidences from Castle rock-Dudhsagar-Kulem railway line ghat section and necessary guidance during the traverse along railway line section.

I extend my thanks to our colleagues, experts, senior officials and staffs for the co-operation, technical assistance and team spirit. The authors is grateful to the local residents for their co-operation, sharing their valuable experiences and informations about the past landslide incidences during the field investigations.

II. PREVIOUS WORK ON LANDSLIDE STUDIES

2.1 REVIEW OF LITERATURE:

In the first phase of the inventory of landslides, the landslides along the National Highways (NH) and State Highways (SH) of the Western Ghat section in parts of Goa state and in parts of Karnataka state in toposheets no. 48I/2, I/3, E/14, 15 & 16 and J/7, J/6, J/9, and L/13 was taken up during F.S: 2007-08 in order to develop a landslide database for future landslide zonation and modelling as a part of the action plan of the MHA on landslide Hazard and risk mitigation.

In adjacent areas Chorla Ghat road (SH-04) connecting Panaji to Belgaum recorded heavy rainfall for most part of the day that caused major landslides. Landslide inventory mapping during field season: 12-13 recorded 14 nos. landslides along SH-04 between Sattari-Chorla road sections, Sattari taluk, and North Goa district. Most of the landslides recorded are old and reactivated debris slide of shallow (<2m) translational to rotational slope failure. Total 10 nos. of landslides are recorded along Panaji-Ponda ghat road section (NH-4A) temporarily affect the road traffic. The Anmod Ghat road along NH-4A (T.S no 48I/7) is probable landslide susceptible zone. Few debris slides are recorded along Anmod-Mollem Ghat road in near past. Earlier newspaper record reveals that the traffic along the Belgaum-Goa road via Sawantwadi has been blocked due to major landslide at Amboli ghat road section. The vertical roads cut sections with steep slope angle varying from 70°-90° are prone to slope failure.

2.2 Spatial distribution of historic landslide incidences:

In order to implement the proposed action plan of NDMA on Landslide Hazard Risk Mitigation it is proposed to take up landslide inventory of Karnataka state as a precursor to the landslide hazard zonation and risk evaluation of the hilly terrains of Western Ghats.

2.2.1 History of landslides:

The landslide inventory mapping was carried along the NH and SH ghat roads in North and South Goa districts of Goa state during field season 2007-2008. According to landslide inventory database, the major landslides are recorded on road cut along NH-4A ghat road section in parts of North Goa district, Goa state. The landslides occurred on rock, weathered rock and loose materials (lateritic soil) of hillslope are classified as debris slide and rock slide. The type of landslide with location details are listed in the tabular form below in (**Table 3**). Details of the locations showing recent and past landslides/boulders fallen incidences between Castle rock (CLR) to Kulem (QLM) station (railwayline ghat section) under SSE/P.way/CLR jurisdiction appended in (**Table 4**).

Table 3: Details of location of historic/past landslide incidences in the study area (SOI T.S nos. 48I/5,I/6, & I/7).

Slide ID	Location	T.S no.	Lat (Decimal Degree)	Long (Decimal Degree)	Type of Slide
KA-01	NH-4A	48I/07	15.418889	74.269722	Debris Slide
KA-02	NH-4A	48I/07	15.416667	74.2675	Debris Slide
KA-03	NH-4A	48I/07	15.414722	74.266944	Rock Slide
KA-04	NH-4A	48I/07	15.413611	74.266944	Debris Slide
KA-05	NH-4A	48I/07	15.413333	74.266944	Debris Slide
KA-06	NH-4A	48I/07	15.4125	74.2675	Rock Slide
KA-07	NH-4A	48I/07	15.412222	74.268056	Rock Slide
KA-08	NH-4A	48I/07	15.412222	74.268333	Rock Slide
KA-09	NH-4A	48I/07	15.412222	74.268889	Rock Slide
KA-10	NH-4A	48I/07	15.411111	74.269722	Rock Slide
KA-11	NH-4A	48I/07	15.410833	74.27	Rock Slide
KA-12	NH-4A	48I/07	15.408333	74.271111	Rock Slide
KA-13	NH-4A	48I/07	15.411389	74.267778	Rock Slide
KA-14	NH-4A	48I/07	15.411389	74.266944	Rock Slide
KA-15	NH-4A	48I/07	15.410278	74.263611	Debris Slide
KA-16	NH-4A	48I/07	15.411667	74.263333	Debris Slide
KA-17	NH-4A	48I/07	15.416389	74.262222	Debris Slide
KA-18	NH-4A	48I/07	15.416667	74.260833	Debris Slide
KA-19	NH-4A	48I/07	15.416389	74.260833	Debris Slide
KA-20	NH-4A	48I/07	15.416111	74.260278	Debris Slide

Table 4: Details of the locations showing recent and past landslides/boulders fallen incidences between Castle rock (CLR) to Kulem (QLM) station (railwayline ghat section) under SSE/P.way/CLR jurisdiction (Source: P.way/CLR section/ Hubli Division, year: 2019).

Sr. No.	Km/Hm		T.S no.	Date of Occurrence	Remarks
	From	To			
1.	37/300	37/400	48I/07	26.07.13	Landsliding LH side cutting
2.	37/300	37/400	48I/07	01.08.13	Boulder fallen on the track LH side cutting
3.	43/500	43/600	48I/07	28.08.16	Boulder fallen on the track LH side cutting
4.	30/300	30/400	48I/07	12.08.18	Landsliding LH side cutting
5.	30/500	30/600	48I/07	14.08.18	Landsliding LH side cutting
6.	37/700	37/800	48I/07	21.08.18	Boulder fallen on the track LH/RH side cutting
Vulnerable locations as identified for frequent landslides and boulders fallen between CLR-QLM station in the past					
1.	37/900	38/0	48I/07	(PH) landslide cutting	
2.	38/600	38/715	48I/07	(PH) Boulder falling	
3.	39/650	40/0	48I/07	(PH) side erosion, incident of landslide	
4.	43/450	43/800	48I/07	Loose boulders and earth fallen on track during 2016	
5.	35/200	35/300	48I/07	(PH) Boulder falling on LH side	

III. LANDSLIDE INCIDENCES IN PRESENT SCENARIO

3.1 Spatial distribution of Landslides

Major slope failure are restricted to “Extensive cut slope” with steep slope angle between 70°-85° and vertical height >10m. Most of the slope failures are occurring on loose material (in-situ soil), highly weathered, fractured and jointed rocks. The water seepage and water saturation on hillslope leads to decrease in the cohesive and shear strength of slope forming material. Total 38 nos. of landslide incidences are recorded. Total 23 no. of landslides are categorised as debris slide, 05 nos. as rock cum debris slides, 03 nos. as debris cum rock slide and 07 nos. of rock slide based on sliding material. The landslides are recorded on “Highly Dissected Hillslope” and “Lowly Dissected Hillslope”. The old and recent landslides locations recorded during field investigations are listed in (Table 5).

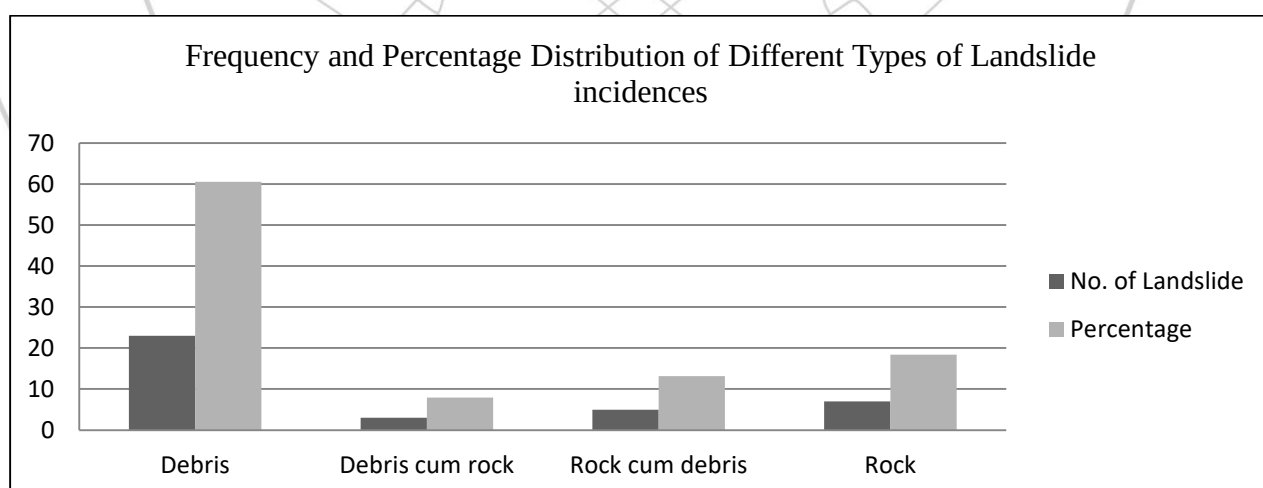
Major landslides/slope failures are recorded on following road sections:

- (a). Anmod-Mollem ghat road section (NH-4A): 32 nos. of landslides.
- (b). Tadki-Kunang-Kuvesi road section: 4 nos. of landslides.
- (c). Castle rock- Dudhsagar railway station (Ghat section): 2 nos. of landslides.

Table 5: Details of location showing landslide incidences in the study area.

Slide No.	Latitude (Decimal Degree)	Longitude (Decimal Degree)	TS no.	NH/SH/ Locality	Type of Landslide
KAR/UK/2018/01	15.438	74.300	48O/7	NH-4A	Debris Slide
KAR/UK/2018/02	15.430	74.300	48O/7	NH-4A	Debris cum rock Slide
KAR/UK/2018/03	15.432	74.291	48O/7	NH-4A	Debris Slump
KAR/UK/2018/04	15.430	74.289	48O/7	NH-4A	Rock cum debris Slide
KAR/UK/2018/05	15.430	74.286	48O/7	NH-4A	Rock cum debris Slide
KAR/UK/2018/06	15.430	74.286	48O/7	NH-4A	Debris Slide
KAR/UK/2018/07	15.429	74.286	48O/7	NH-4A	Debris Slide
KAR/UK/2018/08	15.429	74.286	48O/7	NH-4A	Rock Slide
KAR/UK/2018/09	15.428	74.286	48O/7	NH-4A	Rock Slide
KAR/UK/2018/10	15.425	74.280	48O/7	NH-4A	Debris Slide
KAR/BEL/2018/11	15.424	74.280	48O/7	NH-4A	Debris Slide
GOA/SG/2018/12	15.422	74.279	48O/7	NH-4A	Debris Slide
KAR/BEL/2018/13	15.415	74.280	48O/7	NH-4A	Debris Slide
GOA/SG/2018/14	15.419	74.271	48O/7	NH-4A	Debris cum rock Slide
GOA/SG/2018/15	15.417	74.268	48O/7	NH-4A	Debris cum rock Slide
GOA/SG/2018/16	15.415	74.267	48O/7	NH-4A	Debris Slide
GOA/SG/2018/17	15.414	74.267	48O/7	NH-4A	Debris Slide

Slide No.	Latitude (Decimal Degree)	Longitude (Decimal Degree)	TS no.	NH/SH/ Locality	Type of Landslide
GOA/SG/2018/18	15.412	74.269	48O/7	NH-4A	Debris Slide
GOA/SG/2018/19	15.414	74.267	48O/7	NH-4A	Debris Slide
GOA/SG/2018/20	15.413	74.267	48O/7	NH-4A	Rock Slide
GOA/SG/2018/21	15.412	74.267	48O/7	NH-4A	Rock cum debris Slide
GOA/SG/2018/22	15.412	74.268	48O/7	NH-4A	Rock Slide
GOA/SG/2018/23	15.411	74.270	48O/7	NH-4A	Rock cum debris Slide
GOA/SG/2018/24	15.411	74.268	48O/7	NH-4A	Rock Slide
GOA/SG/2018/25	15.411	74.266	48O/7	NH-4A	Rock Slide
GOA/SG/2018/26	15.411	74.265	48O/7	NH-4A	Rock cum debris Slide
GOA/SG/2018/27	15.411	74.265	48O/7	NH-4A	Debris Slide
GOA/SG/2018/28	15.411	74.264	48O/7	NH-4A	Debris Slide
GOA/SG/2018/29	15.416	74.262	48O/7	NH-4A	Debris Slide
GOA/SG/2018/30	15.417	74.261	48O/7	NH-4A	Debris Slide
GOA/SG/2018/31	15.416	74.261	48O/7	NH-4A	Debris Slide
GOA/SG/2018/32	15.414	74.255	48O/7	NH-4A	Debris Slide
GOA/SG/2018/33	15.333	74.306	48O/7	Dudhasagar Railway station	Rock Slide
KAR/UK/2018/34	15.399	74.338	48O/7	Castle rock railway junction	Debris Slide
KAR/UK/2018/35	15.327	74.380	48O/7	Tadki-Kunang road	Debris Slide
KAR/UK/2018/36	15.325	74.382	48O/7	Tadki-Kunang road	Debris Slide
KAR/UK/2018/37	15.348	74.349	48O/7	Kuvesi road section	Debris Slide
KAR/UK/2018/38	15.263	74.333	48O/7	Aldur village	Debris Slide



Graph 1: Graph showing frequency of different type of landslide incidences and their percentage distribution.

3.1.1. Major landslide incidences along Anmod-Mollem ghat (NH-4A) road section:

1. Location: The slide is located at latitude 15°24'51.60"N and longitude 74°16'1.80"E lies in Survey of India toposheet no. 48I/7 on NH-4A.

Slide description: The small dimension slide is classified as shallow (<2m) translational debris slide. The overburden material consists of in-situ soil and the upslope gradient is low. The rate of movement of sliding material is slow. The slide is widening, enlarging and progressive in nature. The slide is occurring on lowly dissected hill slope. In current scenario the sliding activity is suspended and stable, so the risk is low. No damage to communication lines. The old scars are present. The slide may get reactivated during monsoon. The slope forming material is in-situ soil and highly weathered rock. The morphometric parameters of slide are Length~10m, Width~25m, Height~8m and run out distance~25-30m. The slope angle of the sliding surface is gentle i.e. 15-25°.

Causes: The geo-scientific causes are weathering, erosion of loose materials due to water saturation, decrease of cohesive strength of slope forming material during heavy rainfall.

Remedial measures: The concrete lined drainage, and slope gradation is required.

Remarks: Retaining wall with weep holes of dimension 22m wide and 3m high were constructed for toe support.

2. Location: The slide is located at 15°23'55.51"N/74°20'17.64"E lies in Survey of India toposheet no. 48I/7 on NH-4A.

Slide description: The slide is classified as shallow (<=5m) translational planar rock failure at concave part of ghat road section. The sliding material consists of rock and the upslope gradient is low. The rate of movement of sliding material is slow. The slide is confined, suspended but widening in nature. The slide is occurring on lowly dissected hill slope. In current scenario the sliding activity is suspended and stable. No damage to communication lines. The old scars are present. The slide may get reactivated during monsoon. The slope forming material is in-situ soil and highly weathered rock. The morphometric parameters of slide are Length~60m, Width~30m, Height~13m. The slope angle of the sliding surface is gentle i.e. 15-25°.

Causes: The geo-scientific causes are differential weathering, erosion of loose materials due to water saturation, decrease of cohesive strength of slope forming material during heavy rainfall. The Anthropogenic activities i.e. Slope modification for road construction and widening provides new path way for water seepage and slope saturation leading to vertical road cut failure along the exsisting fracture and joints in weathered rock.

Remarks: The rock on slope is prone to weathering and failure along the weaker plane during heavy rainfall. The concrete lined drainage, and slope gradation is required.

3. Location: The slide is located at 15°24'43.90"N/74°16'6.20"E lies in Survey of India toposheet no. 48I/7 on NH-4A.

Slide description: The rock cum debris slide is classified as Shallow ($\leq 5\text{m}$) translational failure/Planar rock failure at concave part of ghat road section. The sliding material consists of rock and the upslope gradient is low. The rate of movement of sliding material is slow. The slide is confined, suspended but widening in nature. The slide is occurring on lowly dissected hill slope. In current scenario the sliding activity is suspended and stable. No damage to communication lines. The old scars are present. The slide may get reactivated during monsoon. The slope forming material is in-situ soil and highly weathered rock. The morphometric parameters of slide are $L \sim 65\text{m}$, $W \sim 75\text{m}$, $H \sim 13\text{m}$. The slope angle of the sliding surface is gentle i.e. 25-35°.

Causes: The geo-scientific causes are differential weathering, erosion of loose materials due to water saturation, decrease of cohesive strength of slope forming material during heavy rainfall. Slope modification i.e. cutting of slope for road construction leads to vertical road cut failure along the fractured and weathered rock during heavy rainfall. There is risk to communication line.

Remarks: The exposed vertical cut has provided new pathway for slope seepage and saturation. The rock on slope is prone to weathering and failure along the weaker plane during heavy rainfall.

4. Location: The slide is located at 15°24'41.20"N /74°16'3.80"E lies in Survey of India toposheet no. 48I/7 on NH-4A.

Slide description: The rock slide is classified as Shallow ($\leq 2\text{m}$) translational failure at concave part of ghat road section. The sliding material consists of rock and loose highly weathered rock and the upslope gradient is low. The rate of movement of sliding material is slow. The slide is confined, suspended at present but retrogressive in nature. The slide is occurring on lowly dissected hill slope. In current scenario the sliding activity is suspended and stable. No damage to communication lines. The old scars are present. The slide may get reactivated during monsoon. The slope forming material is in-situ soil and highly weathered rock. The morphometric parameters of slide are Rock Slide: $L \sim 65\text{m}$, $W = 155\text{m}$, $H \sim 13\text{m}$. The slope angle of the sliding surface is gentle i.e. 25-35°.

Causes: The geo-scientific causes are differential weathering, erosion of loose materials due to water saturation, decrease of cohesive strength of slope forming material during heavy rainfall. Slope modification i.e. cutting of slope for road construction leads to failure along weaker plane i.e. joints and fracture. There is risk to communication line during heavy rainfall. The rock fracture plane dipping towards road. The weathering and seepage along failure plane occurred along nala section.

Remarks: The exposed vertical cut has made new pathway for slope seepage and saturation. The rock on slope is prone to weathering and failure along the plane during heavy rainfall. Lined drainage

at toe part of hillslope should be provided to avoid toe erosion and broken part of lined drainage should be repaired.

5. Location: The slide is located at 15°24'40.60"N/74°15'58.60"E lies in Survey of India toposheet no. 48I/7 on NH-4A.

Slide description: The rock cum debris slide is classified as Shallow ($\leq 5\text{m}$) translational failure at concave part of ghat road section. The sliding material consists of rock and loose highly weathered rock and the upslope gradient is low. The rate of movement of sliding material is slow. The slide is confined, suspended at present but retrogressive in nature. The slide is occurring on lowly dissected hill slope. In current scenario the sliding activity is suspended and stable. No damage to communication lines. The old scars are present. The slide may get reactivated during monsoon. The slope forming material is in-situ soil and highly weathered rock. The morphometric parameters of slide are $L \sim 35\text{m}$, $W \sim 145\text{m}$. The slope angle of the sliding surface is gentle i.e. $35-45^\circ$.

Causes: The geo-scientific causes are differential weathering, erosion of loose materials due to water saturation, decrease of cohesive strength of slope forming material during heavy rainfall. Slope modification i.e. cutting of slope for road construction. Vertical road cut failure occurred along the fractured and weathered rock. There is risk to communication line during heavy rainfall. The fracture/failure plane dipping towards road, weathering and seepage along failure plane occurred along nala section.

Remarks: The exposed vertical cut has made new pathway for slope seepage and saturation. The rock on slope is prone to weathering and failure along the plane during heavy rainfall. Lined drainage at toe part of hillslope should be provided.

6. Location: The slide is located at 15°24'39.30"N /74°15'48.60"E Elies in Survey of India toposheet no. 48I/7 on NH-4.

Slide description: The debris slide is classified as Shallow ($\leq 5\text{m}$) translational failure at concave part of ghat road section. The sliding material consists of rock and loose highly weathered rock and the upslope gradient is low. The rate of movement of sliding material is slow. The slide is confined, suspended at present but retrogressive in nature. The slide is occurring on lowly dissected hill slope. In current scenario the sliding activity is suspended and stable. No damage to communication lines. The old scars are present. The slide may get reactivated during monsoon. The slope forming material is in-situ soil and highly weathered rock. The morphometric parameters of slide are Rock Slide: $L \sim 35\text{m}$, $W = 55\text{m}$, Vertical Height $\sim 15\text{m}$. The slope angle of the sliding surface is gentle i.e. $35-45^\circ$.

Causes: The geo-scientific causes are differential weathering, erosion of loose materials due to water saturation, decrease of cohesive strength of slope forming material during heavy rainfall. Slope

modification i.e. cutting of slope for road construction leads to vertical road cut failure along the fractured and weathered rock. There is risk to communication line during heavy rainfall.

Remarks: 1.50m high retaining wall with weep holes were constructed. The concrete lined drainage is required at toe part of hillslope is required. The drainage line should be extended upto 50m and more upto the slumping zone. The rock on slope is prone to weathering and failure during heavy rainfall.

7. Location: The slide is located at 15°24'58.90"N/74°15'43.70"E lies in Survey of India toposheet no. 48I/7 on NH-4A.

Slide description: The debris cum rock slide is classified as shallow ($\leq 5\text{m}$) translational failure at concave part of ghat road section. The sliding material consists of rock and loose highly weathered rock and the upslope gradient is low. The rate of movement of sliding material is slow. The slide is old, confined, suspended at present but widening, enlarging and retrogressive in nature. The slide is occurring on lowly dissected hill slope. In current scenario the sliding activity is suspended and stable. No damage to communication lines. The old scars are present. The slide may get reactivated during monsoon due to the saturation of the slope material. The slope forming material is in-situ soil and highly weathered rock. The morphometric parameters of slide are $L \sim 17\text{m}$, $W = 45\text{m}$, Vertical Height $\sim 15\text{m}$. The slope angle of the sliding surface is gentle i.e. 15-25°.

Causes: The geo-scientific causes are differential weathering, erosion of loose materials due to water saturation, decrease of cohesive strength of slope forming material during heavy rainfall. Slope modification i.e. cutting of slope for road construction leads to vertical road cut failure along the fractured and weathered rock. There is risk to communication line during heavy rainfall. The fracture/failure plane dipping towards road, weathering and seepage along failure plane.

Remarks: 1.50m high retaining wall with weep holes were constructed. Concrete lined drainage is required. The drainage line should be extended upto 50m and more. The rock on slope is prone to weathering and failure during heavy rainfall.

8. Location: The slide is located at 15°24'48.60"N /74°15'19.20"E lies in Survey of India toposheet no. 48I/7 on NH-4A.

Slide description: The debris cum rock slide is classified as Shallow ($\leq 5\text{m}$) translational failure at concave part of ghat road section. The sliding material consists of rock and loose highly weathered rock and the upslope gradient is low. The rate of movement of sliding material is slow. The slide is old, confined, suspended at present but widening, enlarging and retrogressive in nature. The slide is occurring on highly dissected hill slope. In current scenario the sliding activity is suspended and stable. No damage to communication lines. The old scars are present. The slide may get reactivated

during monsoon. The slope forming material is in-situ soil and highly weathered rock. The morphometric parameters of slide are L~17m, W=112m, Vertical Height~15m. The slope angle of the sliding surface is gentle i.e. 15-25°.

Causes: The geo-scientific causes are differential weathering, erosion of loose materials due to water saturation, decrease of cohesive strength/shear strength of slope forming material during heavy rainfall. Two Failure along nala section occurred, weathering and seepage along failure plane is pronounced. The vertical road cut failure occurred along the fractured and weathered rock. There is risk to communication line during heavy rainfall. The fracture/failure plane dipping towards road,

Remarks: 112m wide retaining wall with weep holes constructed should be extended upto 50m and more upto the slumping zone. The rock on slope is prone to weathering and failure during heavy rainfall.

3.1.2. Landslide incidences along Tadki-Kunang road section.

1. Location: The slide is located at 15°19'37.94"N/74°22'49.33"E lies in Survey of India toposheet no. 48I/7 Tadki-Kunang road section.

Slide description: At Long: 15°19'37.94"N/74°22'49.33"E about 400 m North of Tadki village areas old, suspended palaeo-debris flow recorded along natural course of stream occurring on lowly dissected hill slope with slope angle varies between 25°-35°. The litho-units have undergone intense lateritization and weathering. The ground evidence indicates the debris flow along the nala course brought the debris in downslope direction, however at present the stream is dry but can get reactivated during monsoon. The Debris flow occurred along the stream/nala. The rate of movement of sliding material is slow. The slide is old, confined, suspended at present but widening, enlarging and retrogressive in nature. The slide is occurring on highly dissected hill slope. In current scenario the sliding activity is suspended and stable. No damage to communication lines. The slope forming material highly weathered rock and lateritic soil. The morphometric parameters of slide are L~22m, W=28m. The litho-units have undergone intense lateritization and weathering. The ground evidence indicates the debris flow along the nala course brought the debris in downslope direction, however at present the stream is dry but can get reactivated during monsoon. The poor drainage at road bench level resulted in road subsidence.

Causes: The geo-scientific causes are differential weathering, erosion of loose materials due to water saturation, decrease of cohesive strength of slope forming material during heavy rainfall. Slope modification i.e. cutting of slope for road construction. Vertical road cut failure along along the fractured and weathered rock. The poor drainage at road bench level resulted in road subsidence.

Remedial measures: The lined drainage with box culvert should be constructed for draining the flowing water to suitable location as remedial measures to prevent road damage and water seepage and slope saturation.

Remarks: The exposed vertical cut has made new pathway for slope seepage and saturation. The rock on slope is prone to weathering and failure during heavy rainfall.

2. Location: The slide is located at 15°19'29.43"N /74°22'56.90"E lies in Survey of India toposheet no. 48I/7 Tadki-Kunang road section.

Slide description: The debris slide is classified as Shallow ($\leq 5\text{m}$) translational failure recorded on the road cut section. The sliding material consists of loose in-situ soil and highly weathered rock. The upslope gradient is low. The rate of movement of sliding material is slow. The slide is old, confined, suspended at present but widening, enlarging and retrogressive in nature. The slide is occurring on lowly dissected hill slope. The old and suspended shallow debris slide of retrogressive in nature are recorded on lowly dissected hill slope with slope angle varies between 25°-35°. The scars of landslide and crown cracks are prominent, and precarious rock boulders were hanging on top. The adjoining area is damp and quite unstable. In current scenario the sliding activity is suspended. No damage to communication lines. The old scars are present. The slide may get reactivated during monsoon. The slope forming material is in-situ soil and highly weathered rock. The morphometric parameters of slide are $L \sim 21\text{m}$, $W \sim 28\text{m}$, Vertical Height $\sim 2.5\text{m}$. The slope angle of the sliding surface is gentle i.e. 25°-35°.

Causes: The geo-scientific causes are differential weathering, erosion of loose materials due to water saturation, decrease of cohesive strength of slope forming material during heavy rainfall.

Remedial measures: The lined drainage at toe part of hillslope should be provided to prevent toe erosion and subsequent slope failure.

Remarks: The exposed vertical cut has made new pathway for slope seepage and saturation. The rock on slope is prone to weathering and failure during heavy rainfall.

3. Location: The slide is located at 15°20'51.60"N /74°20'55.60"E lies in Survey of India toposheet no. 48I/7 Kuvesi road section.

Slide description: The debris slide is classified as Shallow ($\leq 5\text{m}$) translational failure recorded along the road cut section. The sliding material consists of loose in-situ soil and highly weathered rock and the upslope gradient is low. The rate of movement of sliding material is slow. The slide is old, confined, suspended at present but widening, enlarging and retrogressive in nature. The slide is occurring on lowly dissected hill slope adjacent to 1st order drainage, loose hanging lateritic boulders. In current scenario the sliding activity is suspended and stable. No damage to communication lines.

The old scars are present. The slide may get reactivated during monsoon. The slope forming material is in-situ soil and highly weathered rock. The morphometric parameters of slide are L~17m, W=~28m, Vertical Height~14m. The slope angle of the sliding surface is gentle i.e. 25°-35°.

Causes: The geo-scientific causes are weathering, erosion of loose materials along 1st order drainage due to water saturation and decrease of cohesive strength of slope forming material during heavy rainfall.

Remedial measures: Slope re-gradation and vegetation on the slope can hold the soil to prevent soil slips.

Remarks: The exposed vertical cut has made new pathway for slope seepage and saturation. The rock on slope is prone to weathering and failure during heavy rainfall.

4. Location: The slide is located at 15°15'47.30"N /74°19'59.70"E lies in Survey of India toposheet no. 48I/7 Namsi village road section.

Slide description: The debris slide is classified as Shallow ($\leq 5\text{m}$) translational failure recorded along the road cut section. The sliding material consists of loose in-situ soil and the upslope gradient is low. The rate of movement of sliding material is slow. The slide is old, confined, suspended at present but widening, enlarging and retrogressive in nature. The slide occurred in vicinity of the 1st order nala. The slide is occurring on lowly dissected hill slope. In current scenario the sliding activity is suspended and stable. No damage to communication lines. The old scars are present. The slide may get reactivated during monsoon. The slope forming material is in-situ soil and highly weathered rock. The morphometric parameters of slide are L~28m m, W=~35m Vertical Height~12m. The slope angle of the sliding surface is gentle i.e. 25°-35°.

Causes: The geo-scientific causes are differential weathering, erosion of loose materials due to water saturation, decrease of cohesive strength of slope forming material during heavy rainfall. The exposed vertical cut has made new pathway for slope seepage and saturation. The slope failure is along the first order stream.

Remedial measures: Slope re-gradation and vegetation on the slope can hold the soil to prevent soil slips.

Remarks: The rock on slope is prone to weathering and failure during heavy rainfall.

3.1.3. Landslides along Castle rock- Dudhsagar railway station (ghat section):

The spatial distribution of landslide incidences on extensive cut slope are recorded on highly dissected hillslope along Castle Rock-Dudhsagar-Kulem railway line ghat section. The landslides and slope failures are caused due to hill slope cutting for railway line extension. Majority of the landslides and slope failures are restricted to the cut slopes having more than 10m overburden and on

quite a steep slope angle varying 70°-90° along the railway line ghat section. The unstable landslide susceptible zones and vulnerable extensive cut slopes locations along Castle rock –Dudhasagar- Kulem station (ghat section) are listed below in (Table 6).

Table 6: The unstable landslide susceptible zones and vulnerable extensive cut slopes locations along Castle rock –Dudhasagar- Kulem station (ghat section) are listed below:

Railway line ghat road section from Londa-Castle rock-Dudhsagar-Kulem upto 50km stretch/extension		
Londa Railway Junction	Starting point 0 km	Remarks
Castle Rock landslide	24km/400m	Landslide
Castle rock –Dudhasagar- Kulem station (ghat section)	25km/600m	Landslide
	29km/600m to 29km/800m	Landslide
	30km/500m	Extensive Cut Slope
	31km/100m	Extensive Cut Slope
	32km/200m	Landslide
	32km/300m	Landslide
	32km/700m	Landslide
	33km	Landslide
	33km/800m	Extensive Cut Slope
	35km to 35km/100m	Landslide
	35km/100m to 35km/200m	Landslide
	36km/100m to 36km/200m	Landslide
	36km/500m to 36km/600m	Landslide
	36km/800m to 37km	Landslide
	37km to 37km/100m	Landslide
Dudhsagar Railway Station	38km	Landslide
Sonalium Railway Station	43/0	Extensive Cut Slope
	44km/500m to 46km/500m	Landslide zone

1.Location: The slide is located at 15°23'55.51"N/74°20'17.64"E lies in Survey of India toposheet no. 48I/7 on Castle Rock railway station.

Slide description: The debris slide is classified as deep (≤ 5 m) translational failure on extensive cut slope made on Highly dissected hillslope. The sliding material consists of loose highly weathered rock and soil. The upslope gradient is low. The rate of movement of sliding material is slow. The slide is old, retrogressive in nature and can get reactivated during heavy rainfall. The slide is occurring on highly dissected hill slope. In current scenario the sliding activity is suspended and

stable. No damage to communication lines. The old scars are present. The slide may get reactivated during monsoon. The slope forming material is rock and highly weathered rock. The morphometric parameters of slide are $L \sim 50\text{m}$, $W = 110\text{m}$, Vertical Height $\sim 17\text{m}$. The slope angle of the sliding surface is gentle i.e. $25-35^\circ$. And at lat/long: $15^\circ 23' 52.85''\text{N}/74^\circ 20' 10.87''\text{E}$, the similar debris failure on vertical cut section is observed. The vertical cut section prone to slope failure is extending upto $\sim 175\text{m}$. The slope failure has occurred in successive benches made during slope gradation. The landslide is retrogressive, enlarging and widening in nature.

Causes: The geo-scientific causes are differential weathering, erosion of loose materials due to water saturation, and seepage along closely jointed and fractured rock decrease of cohesive strength of slope forming material during heavy rainfall. There is risk to communication line during heavy rainfall. The cutting of slopes and removal of soil transforms the slope and opens up new way for water seepage and runoff pattern during prolonged rainfall that destabilizes slope and leads to landslides/slope failures. The Ferruginous Phyllite of Joldal formation has undergone intense weathering and kaolinitization that triggered landslips.

Remedial measures: At lat/long: $15^\circ 23' 55.51''\text{N}/74^\circ 20' 17.64''\text{E}$ gabion wall with wire mesh of dimension 113m width and 4.5m high constructed for toe support. The slope stabilization technique i.e. low height gabion wall with wire mesh is constructed in successive benches to provide toe support. The existing gabion wall constructed at toe part need to be extended upto unstable zone and long term slope stability measures i.e. drainage trench on slopes should be provided to avoid soil slips.

Remarks: The exposed vertical cut has made new pathway for slope seepage and saturation. The rock on slope is prone to weathering and failure during heavy rainfall.

2.Location: The slide is located at $15^\circ 19' 57.00''\text{N}/74^\circ 18' 22.80''\text{E}$ lies in Survey of India toposheet no. 48I/7 on Dudhasagar railway station.

Slide description: The rock slide is classified as shallow ($\leq 5\text{m}$) translational rock failure along the hill slope adjoining the railway tract at Dudhasagar railway crossing. Major rock slide occurred in August 2018. The sliding material consists of rock and weathered rock. The upslope gradient is low. The rate of movement of sliding material is slow. The slide is active, widening, enlarging, retrogressive in nature. The slide is occurring on highly dissected hill slope. In current scenario the sliding activity is active. The risk factor to communication lines i.e. railway track is very high during heavy rainfall. The morphometric parameters of slide are $L \sim 17\text{m}$, $W = 25\text{m}$, Vertical Height $\sim 22\text{m}$. The slope angle of the sliding surface is between $35-45^\circ$. The failure occurred along the major joints and fracture in rock. Two major Vertical joints along which failure occurred are trending NE-SW and NW-SE in Granitic rock.

Causes: The geo-scientific causes are differential weathering, erosion of loose materials due to water saturation, decrease of cohesive strength of slope forming material during heavy rainfall. The slope failure occurred along major joints at exposed railway cutting and boulders get dislodged along the plane of weakness triggered by heavy rainfall.

Remedial measures: High height retaining wall and wire mesh with bolting should be done on priority to avoid casualties. Slope gradation is required. Total 7m high retaining wall with weep holes were constructed for toe support.

Remarks: The rock is jointed and fractured, exposed vertical cut provide new pathway for slope seepage and saturation. The rock on slope is prone to weathering and failure during heavy rainfall.

IV. LANDSLIDE SUSCEPTIBILITY ANALYSIS

4.1 Background

Landslide occurrences in any terrain is governed by various factors, which are site/terrain specific so; multivariate analysis is required to serve the purpose. Different geofactor themes are taken into consideration which includes i) Physical state of slope/slope morphometric parameters such as slope gradient, slope aspect, and slope curvature, ii) Lithology or physical characteristics of slope forming material iii) spatial variation in thickness of slope forming material/regolith, iv) Geomorphic features, v) Geology and rock structure: orientation of planar/linear discontinuities in the rock mass in relation to topography, vi) Drainage and, vii) Landuse/Landcover including road and other physical features mappable on 1:50,000 scale. Based on the estimation of above pre-disposing geofactors, the following preparatory factors and its possible factor classes are considered for preparation of geofactor databases for the GIS-based analysis of susceptibility of hillslope to landsliding.

4.2. Selection of preparatory factors

As per data model, some of the geofactor themes are categorical (e.g., geomorphology, LU/LC etc.) and others represent continuous data (e.g., slope, elevation etc.) These spatial geo-factor maps are prepared using various source data and employing different mapping techniques:

- (i) **Geomorphology Map:** The source data for preparation of Geomorphology map is National Geomorphological and Lineament map on 1:50,000 scale and Google Earth based satellite imagery on 1:50,000 scale. The pre-field Geomorphology maps are validated in the field and necessary correction/updation in geomorphic features are made based on field data.

- (ii) **Landuse/Landcover Map:** The source data for preparation of Landuse/Landcover map is toposheet and Google Earth based satellite imagery on 1:50,000 scale. The pre-field Landuse/Landcover maps are validated in the field and necessary correction/updates are made based on field data.
- (iii) **Slope Morphometry Maps:** The Slope, Aspect and Curvature maps are DEM derived continuous data, prepared from Carto DEM data of 30m resolution.
- (iv) **Slope Forming Material Map:** The pre-field maps are prepared taking proxies from geomorphology, geology, and landuse/landcover maps and further updated based on field inputs.
- (v) **Regolith Thickness Map:** These maps are prepared with help of overburden thickness observed along road cut sections and quarry sections during field work.
- (vi) **Road, River & Water bodies:** Primary source data for preparing base map is topographic map /Google Earth Imageries.

4.3 Geofactor Themes: The geofactor thematic maps are prepared for landslide susceptibility analysis are mentioned below:

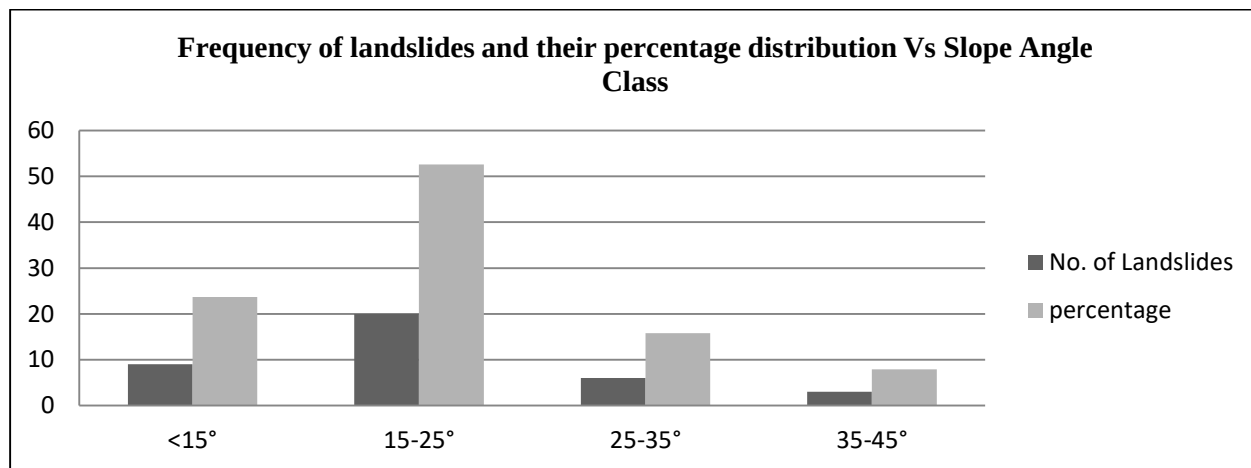
4.3.1 Slope Morphometry (Slope, Aspect, Curvature) Maps:

Raster maps of Slope (**Plate-5**), Aspect (**Plate-6**), and Curvature (**Plate-7**) are DEM derivative geofactor maps generated from Carto DEM of 30m resolution using Spatial Analyst/3D Analyst Module of Arc GIS software.

(a) **Slope Angle Map (Plate-5)** is classified into 5 classes; $<15^\circ$, $15^\circ-25^\circ$, $25^\circ-35^\circ$, $35^\circ-45^\circ$, $>45^\circ$ based on slope gradient, slope is deterministic geofactor class governing the failure plane. The slope class that has maximum LOFS is $25^\circ-35^\circ$ followed by $15^\circ-25^\circ$ slope, where the vertical cut has modified the slope with $70^\circ-90^\circ$ angle. According to the frequency distribution of landslide incidences, the slope varying from $\leq 15^\circ$ to 25° are more susceptible for landsliding and slope failure. The percentage distribution of different slope gradient classes are listed in (**Table 7**) based on classified slope map.

Table 7: The Percentage distribution of Classified Slope Gradient/Angle Map for T.S Nos. 48I/5, I/6 & I/7 with their LOFS and Rank.

CLASS	Rank	LOFS	Area in (sq. km.)	Area in (%)
$<15^\circ$	2	0.1631	1235.30	82.87
$15^\circ-25^\circ$	4	0.4597	196.40	13.18
$25^\circ-35^\circ$	8	1.0000	47.83	3.21
$35^\circ-45^\circ$	6	0.2817	9.51	0.64
$>45^\circ$	2	0.1631	1.61	0.11

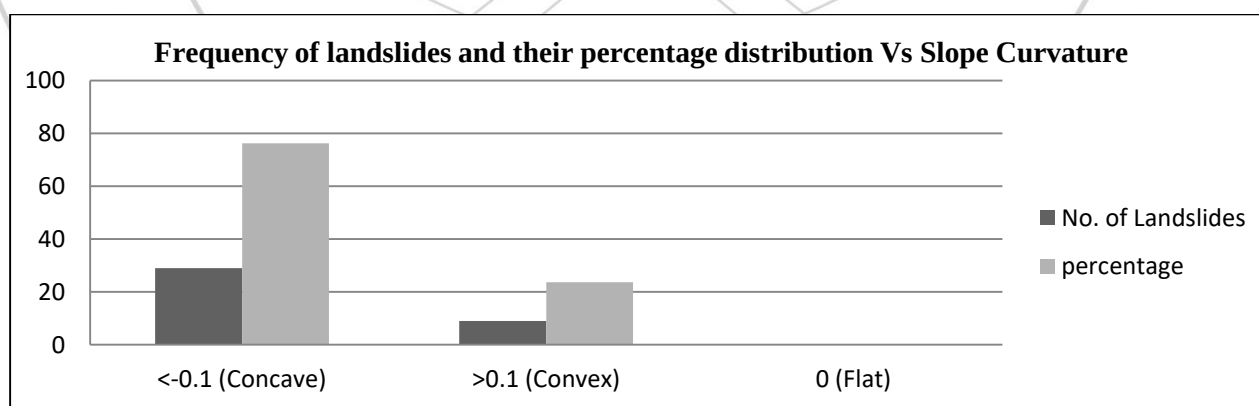


Graph 2: Graph showing frequency of landslides and their percentage distribution with respect to Slope Angle Class.

(b) **Slope Curvature Map (Plate-7)** shows negative and positive curvature values that represent concave and convex upward slopes respectively which are believed to have strong spatial correlation with landslides mapped and zero curvature shows flat surface. The percentage distribution of different slope curvature classes are listed in **(Table 8)**. Statistical analysis of on classified Curvature of the slope indicates that the probability of landslides increases as the hillsides become more concave or convex.

Table 8: The Percentage distribution of Classified Slope Curvature Map for T.S Nos. 48I/5, I/6 & I/7 with their LOFS and Rank.

CLASS	Rank	LOFS	Area in (sq. km.)	Area in (%)
Concave	4	0.4113	674.97	45.28
Flat	2	0.1676	175.83	42.93
Convex	6	1.0000	639.87	11.80

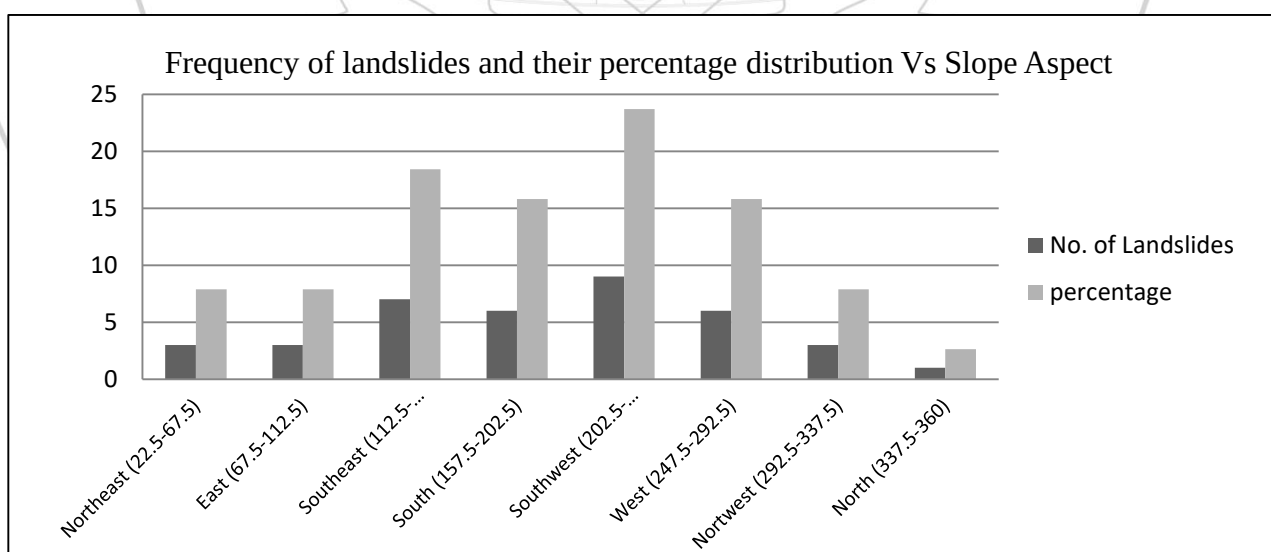


Graph 3: Graph showing frequency of landslides, their percentage distribution and probability of occurrence of landslides in different Slope Curvature Class.

(c) Slope Aspect Map: Geofactor theme aspect is categorised into 10 classes namely N, NE, E, SE, S, SW, W, NW, NW & NNW **(Plate-6)**. Raster map of Aspect are generated for analysing the Slope Morphometry. The computed aspect values are a categorical data, discretized into 10 classes extracted from Carto DEM of 30m resolution. Aspect parameter is not taken into consideration in the analysis as it has very less influence or of no affect on final Landslide Susceptibility Map. Aspect describes the maximum rate of change in the elevations or the slope direction. It is measured in positive integer degrees from 0 to 360 clockwise from North. Aspects of cells (pixels) of zero slope (flat areas) are assigned value of -1. Statistical analysis of on Aspect indicates that the South and South west facing hill facets the probability of landslides increases. Hence the South west monsoon play key role in slope saturation and weathering phenomenon.

Table 9: The Percentage distribution of Classified Slope Aspect Map for T.S Nos. 48I/5, I/6 & I/7 with their LOFS and Rank.

CLASS	Area in (sq. km.)	Area in (%)
Flat (-1)	75.17	5.15
North (0-22.5)	88.80	6.09
Northeast (22.5-67.5)	164.66	11.29
East (67.5-112.5)	164.75	11.29
Southeast (112.5-157.5)	166.83	11.44
South (157.5-202.5)	183.07	12.55
Southwest (202.5-247.5)	190.31	13.05
West (247.5-292.5)	181.50	12.44
Northwest (292.5-337.5)	166.82	11.44
North (337.5-360)	76.83	5.27



Graph 4: Graph showing frequency of landslides, their percentage distribution and probability of occurrence of landslides in different Slope Aspect Class.

4.3.2 Landuse/Landcover Map:

Pre-field landuse and landcover map is prepared through visual interpretation of Google Earth Imagery (multi-temporal real time datasets) and validated during field traverses. This thematic map is classified into some standard landuse/landcover classes (**Plate-4**). The landuse and landcover categories classified and their geographical distribution in percentage is illustrated in (**Table 10**) and pre-field and post field studies for LU/LC are illustrated in (**Table 11**).

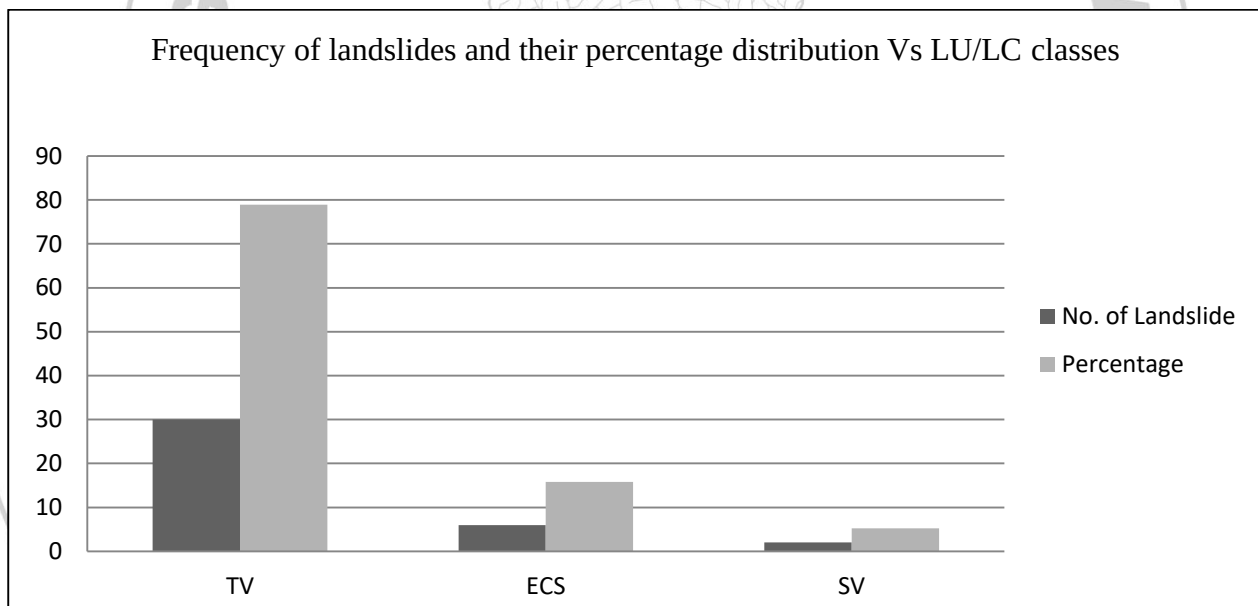
Based on geographical distribution around 65.28% and 5.77% of the study area is covered with thick vegetation and dense mixed jungle whereas .66% of the area is covered with teak, eucalyptus and acacia plantation (HHP) in the fringe of the forest area, .11% of the area has cashew plantation (LHP) practised on low lateritic hills. The agro-climatic condition is conducive for cultivation of sugarcane and paddy and other plantation crops practised on 14.76% of the study area. Total .02% of the extensive cut slope are made along the vertical road cut and railway cutting along the ghat road section. The study area is not densely populated so, the settlement and settlement on modified slope covers .71% and .03% of the study area. Statistical analysis of Landuse/Landcover indicates that the highly dissected hillslope and lowly dissected hillslope with thick and sparse vegetation along the ghat road and in the vicinity of streams and water catchment area are more prone to failure. The extensive cut slope provides new path way for water infiltration and slope saturation during rainfall that triggers landslides on the vertical cut slope.

Table 10: The Percentage distribution of different Landuse/Landcover classes for T.S Nos. 48I/5, I/6 & I/7 with their LOFS and Rank.

Class	Rank	LOFS	Area in (sq. km.)	Area in (%)
Thick Vegetation	4	0.1988	1002.86	65.28
Moderate Vegetation	5	0.2912	85.99	5.77
Sparse Vegetation	7	0.5631	50.87	3.41
Plantation (HHP)	4	0.1988	9.79	.66
Plantation (LHP)	3	0.1366	1.63	.11
Cultivation	2	0.0937	219.98	14.76
Extensive Slope Cut	9	1	0.29	0.02
Fallow Land	1	0.0626	19.02	1.28
Barren	1	0.0626	2.55	2.55
Quarry	5	0.2912	1.02	0.07
Settlement	1	0.0683	10.61	.71
Settlement on modified slope	7	0.5631	0.41	0.03
Water body	0	0	50.13	0.067694

Table 11: The Percentage distribution of different Landuse/Landcover classes during pre-field studies and post field validation of the study area covering T.S Nos. 48I/5, I/6 & I/7.

Class	Pre-field Area in (sq. km.)	Post-field Area in (%)
Thick Vegetation	1002.86	1191.20
Moderate Vegetation	85.99	44.62
Sparse Vegetation	50.87	32.36
Plantation (HHP)	9.79	41.38
Plantation (LHP)	1.63	
Cultivation	219.98	71.14
Extensive Slope Cut	0.29	0.02
Fallow Land	19.02	26.89
Barren	2.55	25.01
Quarry	1.02	0.96
Settlement	10.61	10.93
Settlement on modified slope	0.41	0.37
Water body	50.13	50.13



Graph 5: Graph showing frequency of landslides, their percentage distribution and probability of occurrence of landslides in different LU/LC Classes.

4.3.3 Geomorphology Map:

National Geomorphological and Lineament Map (NGLM) of GSI used as source map for geomorphology theme for use in landslide susceptibility map. It is one of the categorical geofactor thematic databases. The geomorphic features are mapped mostly through visual interpretation of Satellite imagery with limited field checks. The NGLM data is substantiated by reclassifying the

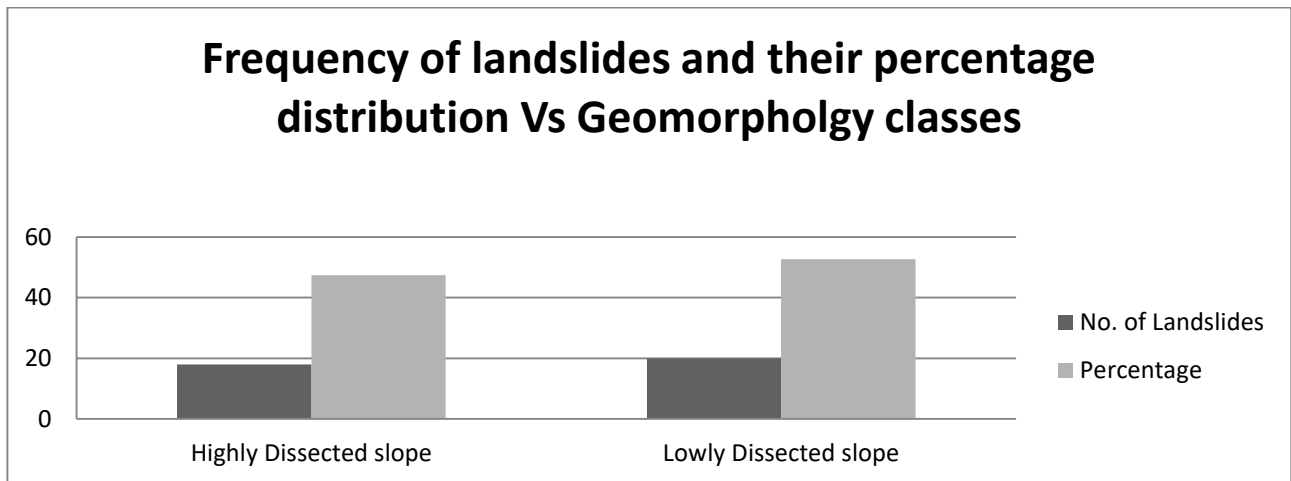
existing geomorphic features making it more useful as an evidential layer for landslide susceptibility.

Geomorphologically, the area forms a part of Western Ghats and is characterised by a highly undulating rugged topography with steep ridges and lowly dissected hill slope with intermittent narrow valley fills and Pediment-Piedplain Complex having rolling topography. The wide spread lowly dissected hill slope trending NW-SE is occupying 60.57% of the study area. The lower reaches of hill slope are categorised as Pediment-Piedplain Complex and Piedmont slope of slope angle <15%. The North-Eastern and South-Eastern parts are occupied by 10.98% of Moderately Dissected hillslope. Lithology Viz, BIF, interbedded Quartzite, and the granitoids controls the geomorphological features of the area (**Plate-4**). The folded and deformed BIF owing to its greater resistance to weathering stands out as horseshoe shaped hill range with steep escarpment. The granitic terrain is characterised by highly dissected topography.

The different geomorphic features and categories identified in the area and their geographical distribution (**Table 12**) indicates geomorphologically, 12% of the geographical area is highly dissected hills comprise of ridges and steep valleys whereas 82% of the elevated area in the central and eastern part are lowly dissected hillslope with gently undulatory topography dotted with hillocks and Pediment-Piedplain Complex. The lowly dissected extensively lateritised hill forms the dissected plateaus in the western part. Statistical analysis of Geomorphology indicates that the highly dissected hillslope and lowly dissected hillslope along the ghat road and in the vicinity of streams and water catchment area are more prone to failure.

Table 12: The Percentage distribution of different Geomorphology classes for T.S Nos. 481/5, I/6 & I/7 with their LOFS and Rank.

Class	Rank	LOFS	Area covered (in sq. km)	Area covered (%)
Escarpment	2	0.0819	0.29	.02
Hilltop	0	0	11.09	.74
Lowly Dissected Slope	4	0.1947	837.42	56.18
Highly Dissected Slope	6	0.4020	179.44	12.04
Pediment Piedplain Complex	0	0	377.69	25.34
Piedmont Slope	4	0.1947	18.28	1.23
Ridge - top	0	0	.63	0.04
Plateau Top (Flat)	0	0	10.59	0.71
Valley Fill	0	0	2.36	0.16
Water body	0	0	50.13	0.068



Graph 6: Graph showing frequency of landslides, their percentage distribution and probability of occurrence of landslides in different Geomorpholgy Classes.

4.3.4 Slope Forming Material Map:

Another important categorical data is geofactor theme of slope forming material which categorizes areas into discerning types of material occurring on slope which includes different litho-units and overburden material. The primary source maps used for the preparation of such slope forming material map are Geology Map, Geomorphology map, Landuse/Landcover and Slope maps on 1:50,000 scale. The field-based knowledge/inputs on characteristics of exposed rock masses, their weathering details, types of overburden material, depths etc, are then combined with the above source maps and subsequently, a slope forming material map can be derived as an important geofactor thematic map for use in the landslide susceptibility analysis.

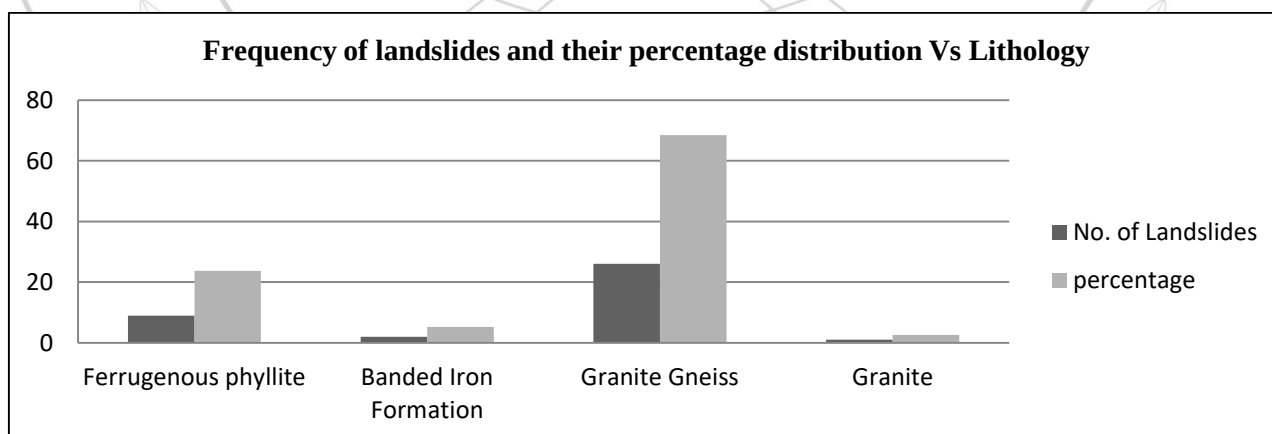
Since, on macro scale (1:50,000) it is generally difficult to classify susceptibility maps solely based on landslide types (e.g. debris and rock slides) so, the preparation of such a detailed and classified slope forming material map and using the same as an input thematic map in the landslide susceptibility modelling instead of general geology map would always be highly relevant. Statistical analysis of slope forming material indicates that the probability of landslides increases on weathered, fractured, jointed rock and loose material (soil). In the study area the litho-units i.e. ferruginous and manganeferous phyllite are more prone to weathering and susceptible to failure along the fissility plane. The major part of the ghat road, the hillslope has weathered and lateritised granite and granite gneiss that encounters maximum number of landslide and slope failure incidences during rainy season.

Total 81.58% of the landslides are occurring on the weathered rock and laterite. In the study area the slope forming material classes (**Plate-9**) are identified as rock, weathered rock, in-situ soil

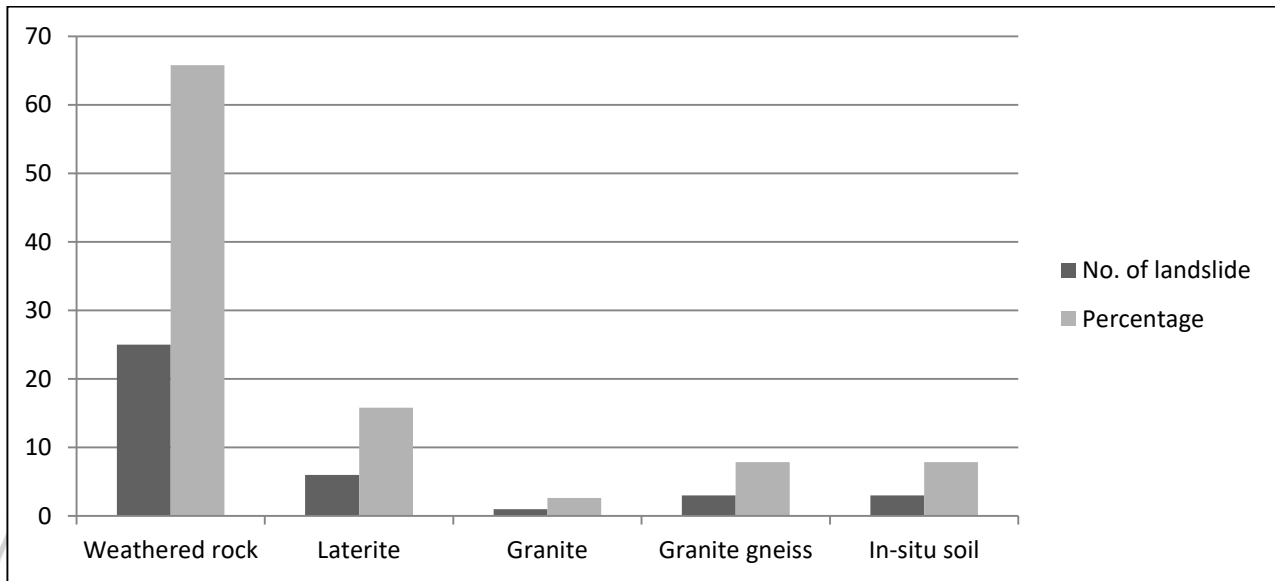
& transported soil and accordingly Rank was given to all identified 20 classes. The percentage distribution are given below in (Table 13).

Table 13: The Percentage distribution of different Slope Forming Material classes for T.S Nos. 48I/5, I/6 & I/7 with their LOFS and Rank.

CLASS	Rank	LOFS	Area in (sq. km)	Area in (%)
In-situ soil	4	0.2409	0.39	0.03
Granite	1	0.0682	98.11	6.58
Granite gneiss	1	0.0682	6.18	0.41
Quartzite	1	0.0682	9.54	0.64
Quartz vein	1	0.0682	1.51	0.10
Ultramafite	1	0.0682	50.46	3.39
Dolerite	1	0.0682	0.32	0.02
Granitoid	1	0.0682	16.57	1.11
Vanadiferous titano-magnetite	1	0.0682	179.55	12.05
Banded iron formation	1	0.0682	661.45	44.37
Limestone	1	0.0682	84.94	5.70
Anorthositic gabbro	1	0.0682	2.57	0.17
Pyroxenite	1	0.0682	28.18	1.89
Metabasalt	1	0.0682	0.69	0.05
Transported Soil	3	0.1506	45.50	3.05
Laterite	4	0.2409	11.65	0.78
Manganiferous phyllite	4	0.2409	188.87	12.67
Argillite	4	0.2409	0.48	0.03
Basalt flow	4	0.2409	51.36	3.45
Ferruginous phyllite	4	0.2409	52.26	3.51
Water body	0	0	50.13	0.068



Graph 7: Graph showing frequency of landslides, their percentage distribution and probability of occurrence of landslides in different litho-units.



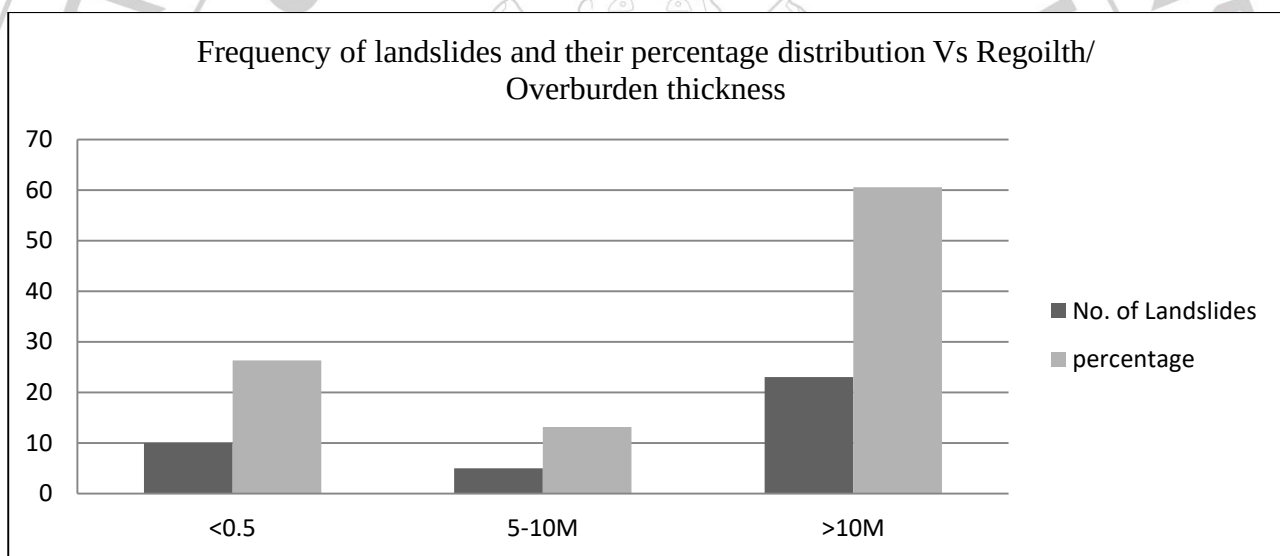
Graph 8: Graph showing frequency of landslides, their percentage distribution and probability of occurrence of landslides in different Slope Forming Material Class.

4.3.4 Regolith Thickness Map:

The Regolith Thickness map is prepared on the basis of field observation 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 rock mass, lying over the fresh country rock. The thickness depends on different factors, one important factor being the local variation in terrain morphology; therefore prediction of the thickness of regolith over a large area is extremely difficult. Ideally, for thickness modelling, a large number of observations (such as drill holes, outcrops or geophysical data) are required. However, at a catchment scale, this approach is difficult to implement. Given the above limitations, Regolith thickness map is prepared based on field observations. Assessment of depth of regolith at different sites was made by studying the exposures or cut sections along the road, streams, landslide scars and from open wells. The overburden thickness varies from <0.5m, 0-5m, 5-10m, 10-15m and their area and percentage distribution with LOFS and rank are illustrated in **Table 14**. Statistical analysis of regolith thickness indicates that the probability of landslides increases with increase of the overburden thickness of loose material (soil) on modified slope. The rock failure is occurring on weathered and jointed rock during prolonged weathering and water saturation along weaker plane. The overburden thickness of slope forming in-situ soil and transported soil the study area varies from 0.5-5m, 5-10m and >10m (**Plate-10**).

Table 14: The Percentage distribution of different Regolith Thickness classes for T.S Nos. 48I/5, I/6 & I/7 with their LOFS and Rank.

CLASS	Rank	LOFS	Area in (sq. km.)	Area covered (in %)
< 0.5 m	0	0	527.07	35.36
0.5 - 5 m	7	1	147.45	9.89
5 - 10 m	4	0.3230	502.82	33.73
>10m	2	0.1363	261.94	17.57
Water body	0	0	51.36	3.45



Graph 9: Graph showing frequency of landslides, their percentage distribution and probability of occurrence of landslides in different Regolith Thickness Class.

4.3.5. Structure and Drainage

Structures, particularly joint and fracture play an important role in defining distribution of landslides. The presence of joint and their orientation has large influence in causing landslides particularly the rock failures during rainfall. The seepage along weaker planes builds pore pressure resulting in shattering of rocks such sliding surfaces are highly prone to failure. Concerning geo-hydrological parameters, the different order of streams are extracted and classified as first order, second order and higher order streams from Carto DEM data of 30m using Strahler's (1957) ordering system. It is observed that 1st order streams cause only limited erosion including shallow landslides. So, drainage is not considered as significant parameter for landslide susceptibility mapping. Drainage map of different streams orders i.e. 1st Order, 2nd Order, 3rd Order, 4th Order

and 5th Order streams are extracted from Carto DEM data (30m resolution) in GIS platform using spatial analyst tool (**Plate-8**).

4.4 LANDSLIDE SUSCEPTIBILITY ANALYSIS

Landslide susceptibility is a qualitative estimate of the spatial distribution of landslides, which exists or potentially may occur in an area. Although it is expected that landslide will occur more frequently in the most susceptible areas, however, in the susceptibility analysis, no time frame and magnitude of event are explicitly taken into account. A susceptibility map therefore gives only the qualitative estimation that the mapping unit (e.g., a pixel, slope unit or facet) will be affected by a future landslide. “Landslide Susceptibility Analysis” is carried out on the basis of AHP method for spatial prediction of landslide-prone areas and the final susceptible map of the area is classified as low, moderate and highly susceptible areas where likelihood of landslide occurrences in near future is expected.

4.4.1 Methodology

Due to the certain limitations/constraints in present ground condition and lack of sufficient landslide datasets for data driven modelling in such a situation empirically derived terrain-specific ratings and weights can pose problems. Hence, Analytical Hierarchy Processes is considered for the preparation and generation of landslide susceptibility map.

Different methods of predictive mapping of landslide susceptibility are adopted because landsliding is a complex interactions with several geo-environmental factors. The cardinal aim of landslide susceptibility mapping is to identify locations where future landslides are likely to occur, based on the fundamental assumption that spatial factors that caused present and past landslides are likely to cause similar landslides in the future. Several knowledge-driven (heuristic) and data-driven or empirical methods of mapping landslide susceptibility are available in the literature which make use of indirect or direct spatial relations between landsliding of a certain type and relevant spatial factors.

Knowledge-driven/ Heuristic methods of landslide susceptibility can either be direct or indirect. In indirect heuristic methods, individual factors are assigned specified weight values or ratings that are solely based on subjective criteria (Hansen, 1984; BIS, 1998). In the latter method, specified factor weights are considered regardless of the existing landslide inventory maps and variations in terrain conditions and to use unique weight values for the factor in different geomorphological/geological environments. However, the most important aspect of any predictive mapping is the validation. Validating the landslide susceptibility maps by mere overlapping the landslide incidence map over landslide susceptibility map is only trivial and cannot quantitatively

assess the actual performance of any predictive model. Predictive modelling of susceptibility to sliding aims to make an estimate at every location in a study area of the future occurrence of such landslides based on known occurrence of landslides. The analysis thus assumes that the relations between spatial factors and past landslides are relevant to the occurrence of future landslides. Therefore, to effectively model the landsliding phenomenon, landslide incidences, controlling geofactors, their mutual importance in influencing landslides is taken into account.

Methodology of landslide susceptibility mapping is divided into the following main themes:

- **Identification and preparation of its landslide inventory database and maps in GIS:**
Landslides, its types and failure mechanisms are the basic and fundamental parameters required by any analyst for carrying out landslide susceptibility analysis. For this, availability of a complete landslide inventory of an area is a prime pre-requisite. To accomplish this task, landslide inventory mapping using all sorts of available and past source information such as archival data, old maps/ reports, very high-resolution remote sensing data and adequate fieldwork are carried out and landslide inventory database is generated and landslide inventory map is prepared.
- **Role of geofactors in landsliding and preparation of its related GIS-based database.**
- **Empirical selection or spatial association analysis between various geofactors and landslides for determining both ratings of factor classes and weights of the geofactor themes:**
Several empirical techniques are available in the literature for selection and weighting of geofactors using landslide inventory data through which spatial association analyses between prevalent landslides and different types of geofactor maps are carried out in a GIS. The purpose of accomplishing such quantitative spatial association analyses in any predictive modeling of landslide susceptibility is to select and use only the good predictors, which are the spatial geofactors that exhibit positive spatial associations with existing landslides. After selection of such predictors, the next step is to objectively determine their inter-predictor weights and then combine the selected predictors with their weights in a suitable susceptibility model like Weighted Multiclass Index Overlay
- **GIS-based modeling for integration of selected and weighted geofactor maps for preparation of landslide susceptibility scores, validation and classification of landslide susceptibility score maps into qualitative maps showing varying degree of landslide susceptibility.**

4.4.2 Selection of mapping unit

After the selection of appropriate preparatory factors, the next step was the selection of mapping units for the GIS based susceptibility analysis. Total 1491 sq. km. study area was converted into an equal-area grid by rasterizing the geofactor vector map using a $50\text{m} \times 50\text{m}$ pixel size. The DEM derivative maps are extracted from Carto DEM of 30m resolution for the overlay analysis of different thematic maps. Therefore, in this work, a pixel was selected as the basic mapping unit for the susceptibility modelling so, that the smallest landslide can be represented by a single pixel of $50\text{m} \times 50\text{m}$ resolution.

4.5 Methods of Susceptibility Analysis:

The flow diagram (**Flow Diagram-1**) shows the methodology followed in the present study for calculation of factor class ratings and inter-predictor weights of factor maps using pairwise comparison matrix developed by Saaty, 1977.

1. Analysis for selection and weightage of geofactors (heuristic/ knowledge-driven AHP method)

- a. Empirical landslide-dependent analysis for determining terrain-specific ratings and weights of geofactors.
- b. Analysis and discussion about spatial association between each geofactor and observed landslides in the study area.

2. Data integration and landslide susceptibility mapping

- a. Data integration procedure-e.g., Weighted Multi-class Index Overlay.
- b. Data validation.
- c. Classification and preparation of qualitative landslide susceptibility map.
- d. Utility of landslide susceptibility maps and information with specific recommendations.

3. Data Modelling using Analytic Hierarchy Process (AHP):

The Analytic Hierarchy Process (AHP) is a multi-criteria decision-making approach which was originally developed by Prof. Thomas L. Saaty (1977). It is an effective tool for dealing with complex decisions and may aid the decision maker to set priorities and make the best decision. By reducing complex decisions to a series of pair wise comparisons, and then synthesizing the results, the AHP helps to capture both subjective and objective aspects of a decision. In addition, the AHP incorporates a useful technique for checking the consistency of the decision maker's evaluations, thus reducing the bias in the decision making process. The Analytical

Hierarchy Process-AHP provides measures of consistency, derives priorities among criteria and alternatives, and simplifies preference ratings among decision criteria using pair wise comparisons to establish priorities among the elements to obtain the set of overall weights for achieving, evaluating and checking the consistency of judgements.

4. Classification of the Landslide Susceptibility Map into High, Moderate and Low Susceptible zones.

The basic procedures followed are described below:

1. Develop the ratings for each decision alternative for each criterion by • developing a pair wise comparison matrix for each criterion • normalizing the resulting matrix • averaging the values in each row to get the corresponding rating • calculating and checking the consistency ratio.
2. Calculate the weighted average rating for each decision alternative and choose the one with the highest score.

Step 1: Pair wise comparison matrix

The criteria in the row are being compared to the criteria in the column.

Step 2: Normalization

This step is to normalize the matrix by totalling the numbers in each column. Each entry in the column is then divided by the column sum to yield its normalized score. The sum of each column is 1.

Step 3: Consistency analysis

Now, calculate the consistency ratio is calculated and value is checked. The purpose for doing this is to make sure that the original preference ratings were consistent.

There are 3 steps to arrive at the consistency ratio:

1. Calculate the consistency measure
2. Calculate the consistency index (CI).
3. Calculate the consistency ratio (CI/RI where RI is a random index).

$$CI = \lambda_{\max} - n / n - 1$$

$$CR = CI / RI$$

To calculate the consistency measure, we can take advantage of Excel's matrix multiplication function = MMULT()

Approximation of the Consistency Index

1. Multiply each column of the pair wise comparison matrix by the corresponding weight.
2. Divide of sum of the row entries by the corresponding weight.

3. Compute the average of the values from step 2, denote it by $\lambda_{\max}$.

4. The approximate $CI = \lambda_{\max} - n / n - 1$

Consistency Ratio (CR)

$$CR = CI / RI$$

Random Index (RI)

The CI of a randomly-generated pair wise comparison matrix

n	1	2	3	4	5	6	7	8	9
RI	0.00	0.00	0.58	0.9	1.12	1.24	1.32	1.41	1.46

Notes: n = order of matrix, Random inconsistency indices for n = 10 (Saaty, 1980)

In the AHP method, the scale range 1–9 is assumed. The standard preference scale was used by Miller is as follows:

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

1. The calculation of the ratings for each factor classes and weights of each factor maps was performed in excel. Based on pair wise matrix comparison of each factor class for all geo-factor thematic maps, calculation of Eigen values, fraction rate values and Landslide Occurrence Favourability Score (LOFS) rating was obtained.
2. Annexure III provides the calculated LOFS ratings of all classes of six geo-factor thematic maps. The excel table is joined with the factor maps using “Table Join & Relate” function in Arc GIS.
3. Using the “Lookup” function in Reclassify tool of Arc GIS, LOFS rating map was generated for each thematic geo-factor maps, showing the spatial distribution of LOFS values.

4. Using “Map Algebra” function of Spatial Analyst Tool in Arc GIS rating maps were combined together to obtain landslide susceptibility score maps.

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.

$$\text{Susc Score} = (\text{LOFS_Factor1} * \text{weight of Factor1} + \text{LOFS_Factor2} * \text{weight of Factor2} + \text{LOFS_Factor3} * \text{weight of Factor3} + \dots + \text{LOFS_Factor}_n * \text{weight of Factor}_n) / \text{Sum of inter - predictor weight}$$

5. Classification break values were determined on the basis of logic of providing mutual comparison expert-driven ranking to sub-divide the score map. Considering rank value of ‘5’ in a scale of ‘0 to 9’ has higher likelihood in influencing landslides which comes after 50% of absolute difference values, similarly rank value of ‘≤3’ has least likelihood in influencing landslides comes after 30% of absolute difference value. Hence, 50% cut-off margin or weightage was used to determine the break raster value between “Moderate” and “High” susceptibility classes, while 30% cut-off margin or weightage was used between “Low” and “Moderate” susceptibility classes. In AHP based 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 ≥ 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 ≤ 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*).

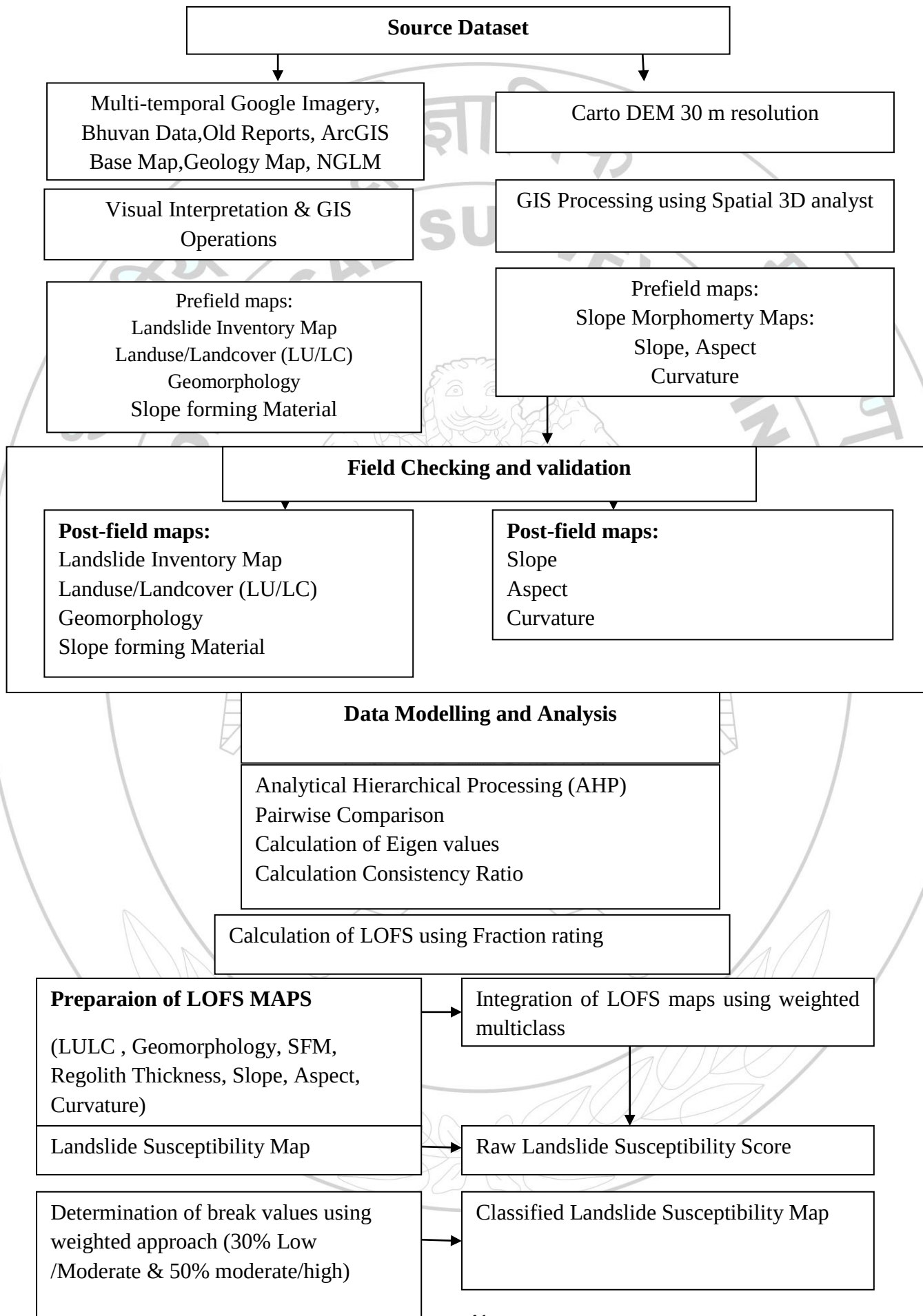
Using the above logic the required break values can be determined by using the following formula:

$$\text{BrMH} = [(\text{Abs Diff LOFS Factor1} * 50) * \text{weight of Fcator1} + (\text{Abs Diff LOFS Factor2} * 50) * \text{weight of Fcator2} + (\text{Abs Diff LOFS Factor3} * 50) * \text{weight of Fcator3} + \dots + (\text{Abs Diff LOFS Factor}_n * 50) * \text{weight of Fcator}_n] / \text{Sum of inter - predictor weight}$$

$$\text{BrLM} = [(\text{Abs Diff LOFS Factor1} * 30) * \text{weight of Fcator1} + (\text{Abs Diff LOFS Factor2} * 30) * \text{weight of Fcator2} + (\text{Abs Diff LOFS Factor3} * 30) * \text{weight of Fcator3} + \dots + (\text{Abs Diff LOFS Factor}_n * 30) * \text{weight of Fcator}_n] / \text{Sum of inter - predictor weight}$$

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 is 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”.

Figure-1: Flow diagram showing methodology for Landslide Susceptibility Mapping



V. LANDSLIDE SUSCEPTIBILITY MAP

Macro-scale (1:50,000) Landslide Susceptibility Mapping in parts of Toposheets nos. 48I/05, 48I/06, & 48I/07 Belgaum, Uttara Kannada districts, Karnataka and North Goa & South Goa districts, Goa is generated using Weighted Multiclass Index Overlay method of data integration and the AHP based knowledge driven mathematical data modelling. Landslide Occurrences Frequency Score (LOFS) are determined based on Pair wise correlation matrix and Rank as per the weightage/rating assigned to different thematic (causative factors) variables, different thematic maps are generated in GIS platform and corresponding LOFS maps are generated using LOFS ratings/weights of geofactor classes. The thematic geofactor maps are integrated in the GIS platform and overlay analysis is carried out. The output landslide susceptibility map is generated using rasterised datasets for data modelling and analysis.

The landslide investigations in present study indicates that slope gradient, landuse-landcover change, extensive cut slope, geomorphology of the terrain, type of overburden material and overburden thickness are considered to be the deterministic geofactors governing the slope failures in hilly terrain of Western Ghat region. Majority of the landslides and slope failures are restricted to the cut slopes having more than 10m overburden with quite a steep slope angle varying 70°-90° on the modified hillslope. Most of the debris and rock slides recorded are old and suspended, the failure mechanism is shallow (<2m) translational to rotational in nature. The landslide can get reactivated and triggered due to intense water saturation during prolonged heavy rainfall. The spatial distribution of landslides with respect to slope gradient indicates that nearly 23.68 % of slides are occurring on slope angle <15°, 52.63% on 15-25° slope, 15.79% on 25-35° slope and rest 7.89% on 35-45° slope. The spatial distribution of landslides incidences indicates that total 27 nos. of landslides are recorded on concave and convex curves of Anmod-Mollem Ghat road (NH-4A) on highly dissected hills and others are recorded on lowly dissected hill slope confined to the cut slope varying with slope angle 25°-35° and 35°-45° in the western part of the study area covering T.S no: 48I/7. The ghat section comprises of dissected hill ranges with steep slope are demarcated as highly susceptible to slope failure and landslide incidences if the natural slopes are disturbed in future for roads or railway connectivity. The landslide incidences on extensive cut slope are recorded along Castle Rock-Dudhsagar-Kulem railway line section. The area is demarcated as the most vulnerable and active landslide susceptible zone all along the railway cutting of Southwestern railway at the stretch of 22 km from Castle rock railway Junction to Kulem (Railwayline ghat section). The landslides incidences on Anmod-Mollem Ghat road (NH-4A) are induced due to toe cutting of slope for road construction and widening. The landslides incidences occurred along the Castle Rock-Dudhsagar railway line section are caused

due to hill slope cutting for railway line extension and good connectivity. The railway records/data are collected from Castle rock Branch of Hubli Division are listed in **(Table-10)** highlights the past and recent landslide incidences along the railway cutting that are vulnerable location that had pose threat to communication line. The extensive cut slope and landslide incidences are recorded along railway line ghat section from Castle rock-Dudhasar-Kulem station starting from Londa Junction all along the railway tract. The details of the unstable zones and landslides are recorded all along the railway tract are listed in **(Table -11)**. The railway cutting on steep slope varying from 35° - 45° are vulnerable and susceptible to sliding during heavy rainfall. The landslides are rock slide and debris slide and are active in nature. During monsoon heavy rainfall triggers these landslides in ghat section along the railway line are the great threat to life and property.

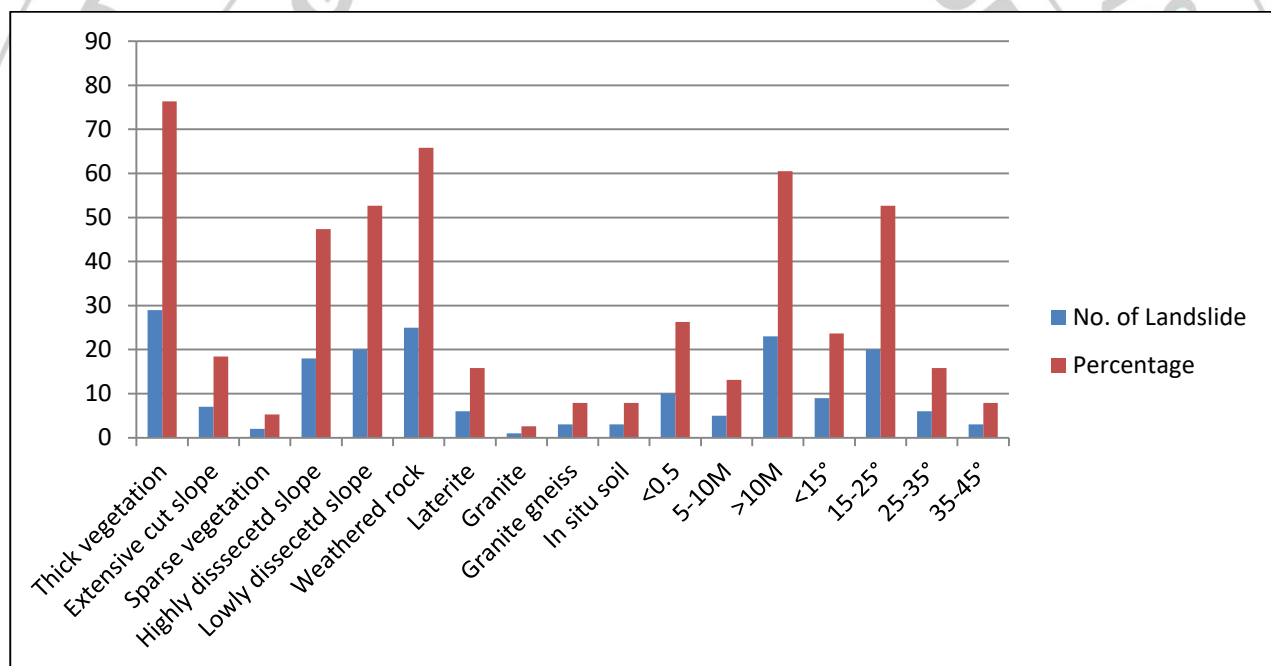
Few landslides and unstable zones are demarcated in and around the catchment of the Supa reservoir along Tadki-Kunang road section. The catchment of Supa reservoir area significantly contributes to hillslope instability due to water saturation in adjoining hill ranges. The slope failure are evident along Tadki-Kunang road section. The shallow, old and suspended debris slide are recorded along the natural course of stream/nala. The suitable mitigation measures i.e. lined drainage along the toe part of the hillslope at road bench level are suggested in these unstable zones to avoid toe erosion.

The central, eastern and northern part of the study area is a lowly dissected hillslope and pediment-pediplain complex with gently undulatory terrain. It has a slope angle $<15^{\circ}$ and 15° - 25° and overburden of $>10\text{m}$ is classified as low landslide susceptible zone. The important areas in and around the Khanapur-Jamboti (SH-4), Ramnagar-Anmod (NH-4A), Khanpur-Anmod road sections passes through Pediment-Pediplain Complex and very gentle slope of Lowly dissected hills are classified as stable and low landslide susceptible zone. The interior villages within the forest area and settlements along the road side are constructed on stable zones.

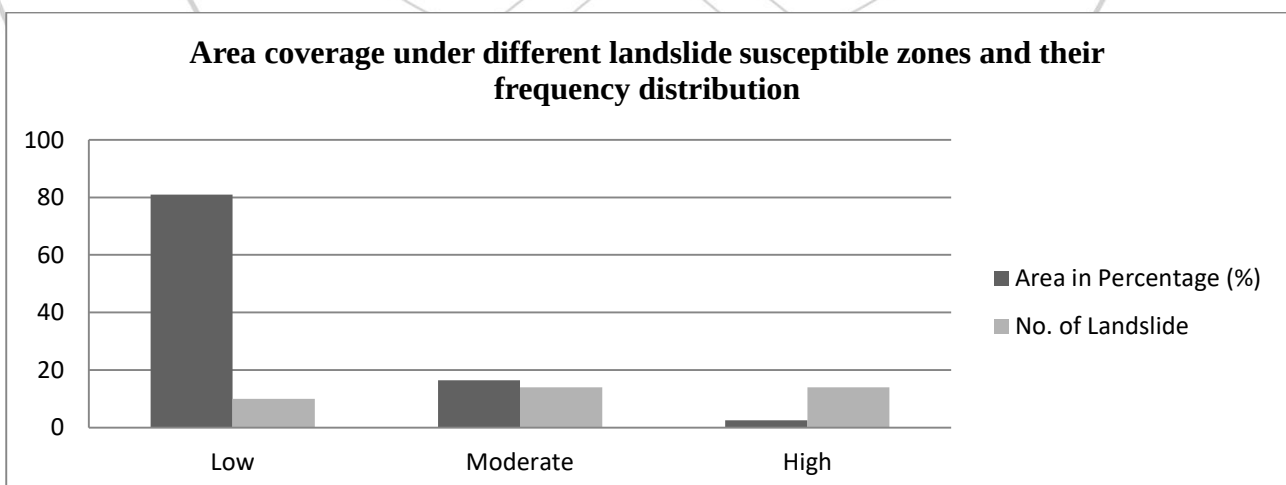
Out of 38 nos. Of landslides noted, 63.16% of landslides are categorised as debris slide, 10.53% as rock slide, 10.53% as debris cum rock slide and rest 15.79% as rock cum debris slide. Most of the landslides are old, suspended, shallow ($<2\text{m}$) translational debris slide that can get reactivated during monsoon. The highly weathered granite gneiss and laterites developed on Granite gneiss and banded ferruginous and magniferous phyllite on hillslope are more prone to slope failure..

Quantitative statistical analysis of geofactors and geofactor classes influencing landslide incidences indicates that the extensive cut slope on hill slope with thick vegetation cover and hillslope with sparse vegetation provides new path way for water seepage and saturation on exposed cut slope making the natural hillslope vulnerable for landslides/landslips incidences. The heavy rainfall during southwest monsoon and pronounced weathering phenomenon is the major

landslide triggering factors. The relationship between different geofactors and landslide incidences and their percentage distribution with respect to different geofactor classes are represented in **Graph 10** and the percentage distribution of geographical area and their probability of landslide susceptibility is determined and represented in **Graph 11**. The overlay analysis and validation of susceptibility map with respect to Landslide Distribution Map indicates that 36.84% of the landslide falls in High Landslide Susceptible Zones, whereas 36.84% and 26.32% of landslides falls in Moderate and Low Landslide Susceptible Zones respectively. The classified landslide susceptibility map indicates that 2.6% of the area is highly susceptible, 16.4% of the area is moderately susceptible and 81% of the area falls in low susceptible zones.



Graph 10: Graph showing relationship between different geofactors and landslides and their percentage distribution with respect to different geofactor classes.



Graph11: Graph showing percentage distribution of landslides and area under low, moderate and high landslides susceptible zones.

VI. CONCLUSIONS AND RECOMMENDATIONS

1. Geologically, the basaltic flow of Ambaneli and Mahabaleshwar Formation of Sahyadri Group belonging to Deccan Trap Super Group of upper cretaceous to Palaeocene age, rocks of Chitradurga Group i.e. Argillite, bands of Manganiferous Phyllite, Ferruginous phyllite of Joldal formation of Dharwar Super Group and Granite gneiss of PGC of Archean age are exposed in this area. The area has witnessed deformation in the form of folding and faulting.
2. The litho-units have undergone intense lateritization and weathering to various degrees. The laterites are ferruginous, aluminous and manganiferous in composition. The process of lateritisation on Fe/Mn phyllite has resulted in the formation of rich iron and manganese ores
3. Slope gradient, extensive cut slope, type of overburden material and overburden thickness are considered to be the deterministic geofactors governing the slope failure. The spatial distribution of landslides with respect to slope gradient indicates that nearly 23.68 % of slides are occurring on slope $<15^\circ$, 52.63% on $15-25^\circ$ slope, 15.79% on $25-35^\circ$ slope and rest 7.89% on $35-45^\circ$ slope. Major slope failure are restricted to “Extensive cut slope” with steep slope angle between 70° and 85° with vertical height $>10\text{m}$.
4. The morphological parameters governing the slope failure are slope angle, erosional activity i.e. erosion of lateral margins and sub-terrain erosions, and overburden.
5. The slope with sparse vegetation, weathered rock and loose material with slope angle between $15^\circ-25^\circ$ and $25^\circ-35^\circ$ are more susceptible to failure.
6. The slope forming material plays key role in slope destabilization, total 66.79% of slide has occurred on weathered rock, 15.79% on laterite, 10.52% on granite and granite gneiss and rest 7.89% on in-situ soil. Hence, total 73.69% of landslide incidences are occurring on loose material (in-situ soil), highly weathered, fractured and jointed rocks along weaker planes with overburden thickness $>10\text{m}$ and $5-10\text{m}$.
7. The classified landslide susceptibility map indicates that 2.6% of the area is highly susceptible, 16.4% of the area is moderately susceptible and 81% of the area falls in low susceptible zones.
8. Out of 38 nos. Of landslides noted, 63.16% of landslides are categorised as debris slide, 10.53% as rock slide, 10.53% as debris cum rock slide and rest 15.79% as rock cum debris slide. Most of the landslides are old, suspended, shallow ($<2\text{m}$) translational debris slide that can get reactivated during monsoon.
9. The landslides incidences on Anmod-Mollem Ghat road (NH-4A) are induced due to toe cutting of slope for road widening and along the Castle Rock-Dudhsagar railway line ghat section are caused due to hill slope cutting for railway line extension. The sliding activity and disturbance

on natural slope is generally observed on highly dissected hill slope of ghat road and few at lowly dissected hillslope.

10. The slides are mainly triggered by anthropogenic activities i.e. human interference with the natural slope. The main causes of landslides and slope failure in the study area are due to the vertical cut of hill slope made for the construction of road and railwayline extension.
11. Cut slope angle and height plays a major role in all the landslides. Cut slope height was included as a factor as this is found to be a major cause of the slides. Prograding of the slide is more towards both the flanks rather than towards back of the crown. The landslides are recorded on concave and convex curves of Anmod-Mollem Ghat road (NH-4A) on highly dissected hills are equally prone to landsliding and others are recorded on lowly dissected hill slope confined to the cut slope varying with slope angle 25° - 35° and 35° - 45° .
12. The anthropogenic activities are the causative factors which leads instability and slope failure. Toe cutting or slope cutting, excavation, landuse change, vibration, water leakage, barren & sparsely vegetated areas. The probable physical causes are intense rainfall, prolonged precipitation, soil pore water pressure, surface runoff etc. The geological causes are weaker plane, weathered, jointed and fissured materials, permeability contrasts and material contrast.
13. The overlay analysis and validation of susceptibility map with respect to Landslide distribution map indicates that 36.84% of the landslide falls in high susceptible zones, whereas 36.84% and 26.32% of landslides falls in moderate and low susceptible zones respectively.
14. Geomorphologically, 12% of the study area is highly dissected hills comprise of ridges and steep valleys whereas 82% of the elevated areas in the central and eastern part are lowly dissected hillslope with gently undulatory topography intermittent with hillocks and Pediment-Pediplain Complex. Major part of the study area is reserve forest covered with dense mixed jungle with teak plantation. Total 47.37% of landslides occurred on highly dissected hillslope with thick vegetation along Anmod-Mollem ghat road.

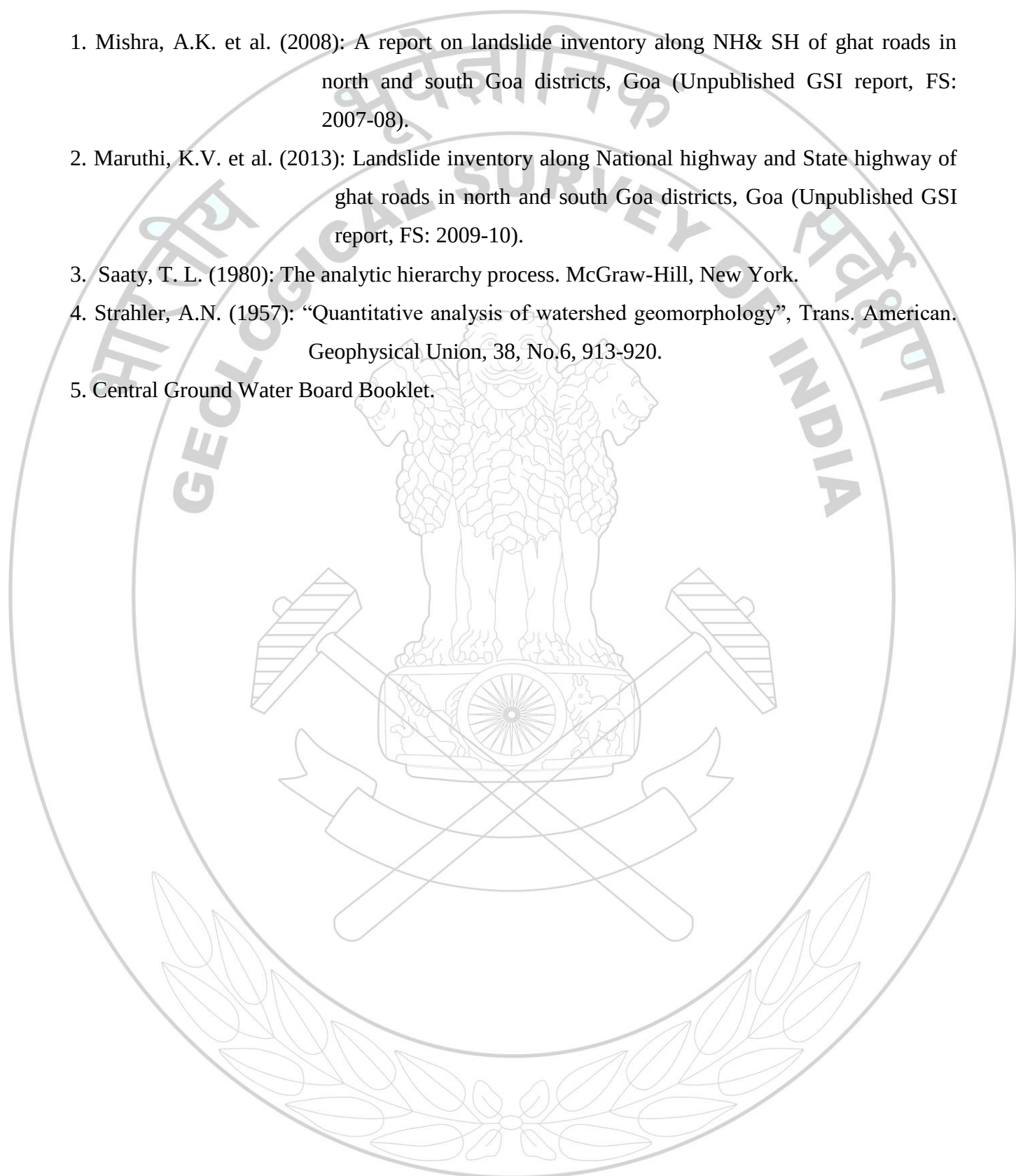
Recommendations:

1. It is suggested that the areas delineated under high and moderate susceptible zones may be avoided. Based on the landslide Susceptibility map for any development activity in order to avoid casualties due to landslips/landslides incidences.
2. The modified natural slope i.e. extensive cut slope made on slope varying from 30° - 45° for road and rail network are vulnerable to sliding during monsoon. The slope stabilization techniques should be adopted and lined drainage with weep holes should be provided at toe part of the hill slope for toe support and to avoid toe erosion.

3. The biotechnical slope protection includes biotechnical vegetation stabilization that uses mechanical elements (structures) in combination with biological elements (plants) to prevent slope failure and erosion. These slope stabilization techniques must be used to stabilize slope against excessive erosion and to mitigate the effect of landslides.
4. The unscientific way of removal of material and slope modifications for construction purposes must be avoided, if required proper scientific way of slope treatment should be adopted for long term stability of disturbed slopes. During the cutting/modifications of the slope nearby Engineering Geology Division may be consulted for attending better slope protective measures.
5. The remedial measures required to stabilize the disturbed zones are concrete retaining wall, with weep holes and lined drainage at the toe portion of hill slope, stone pitching, gabion wall, and slope re-gradation as per the site conditions are suggested.
6. Vertical cut slopes should be modified to stabilize the slope by providing benching on slope at specific interval to reduce the risk of sliding in future.
7. Indiscriminate slope cuttings have to be strictly regulated and engineering solutions such as protective walls/embankments to be made where ever required.

REFERNECES

1. Mishra, A.K. et al. (2008): A report on landslide inventory along NH& SH of ghat roads in north and south Goa districts, Goa (Unpublished GSI report, FS: 2007-08).
2. Maruthi, K.V. et al. (2013): Landslide inventory along National highway and State highway of ghat roads in north and south Goa districts, Goa (Unpublished GSI report, FS: 2009-10).
3. Saaty, T. L. (1980): The analytic hierarchy process. McGraw-Hill, New York.
4. Strahler, A.N. (1957): "Quantitative analysis of watershed geomorphology", Trans. American. Geophysical Union, 38, No.6, 913-920.
5. Central Ground Water Board Booklet.



LOCALITY INDEX

Locality Name	Latitude	Longitude	T.S No.
Anmod	15°26'9.720"N	74°18'36.627"E	48I/7
Betane	15°41'24.306"N	74°15'43.802"E	48I/6
Baknur	15°45'24.242"N	74°20'39.331"E	48I/5
CastleRock	15°23'39.330"N	74°20'5.059"E	48I/7
Chapali	15°24'5.581"N	74°27'37.744"E	48I/7
Chikhale	15°39'54.848"N	74°15'33.765"E	48I/6
Dudhsagar	15°19'1.216"N	74°18'18.978"E	48I/7
Gunji	15°32'15.989"N	74°29'22.998"E	48I/6
Hemmadaga	15°31'40.863"N	74°22'53.770"E	48I/6
Ivoli	15°20'45.502"N	74°21'21.213"E	48I/7
Jamboti	15°41'23.556"N	74°22'3.681"E	48I/6
Kamre	15°22'2.238"N	74°24'45.530"E	48I/7
Kansuli	15°40'1.345"N	74°27'11.366"E	48I/6
Kunang	15°17'27.226"N	74°22'26.697"E	48I/7
Londa	15°27'8.752"N	74°29'35.672"E	48I/7
Morab	15°45'48.655"N	74°22'6.276"E	48I/5
Ramnagar	15°25'19.369"N	74°29'24.311"E	48I/7
Shirolli	15°33'48.156"N	74°26'19.078"E	48I/6
Sindolli	15°20'48.003"N	74°29'12.744"E	48I/7
Talevadi	15°33'21.418"N	74°19'42.534"E	48I/6
Tirthakunde	15°44'21.417"N	74°26'19.391"E	48I/6
Torali	15°42'43.713"N	74°18'56.290"E	48I/6
Viranjola	15°29'26.499"N	74°16'6.691"E	48I/7

SYNOPSIS OF WORK DONE

1.	Title of the report	Macro-scale (1:50,000) Landslide Susceptibility Mapping in parts of Toposheets nos. 48I/05, 48I/06, & 48I/07 Belgaum, Uttar Kannada districts, Karnataka and North Goa & South Goa districts, Goa.	
2.	FSP Code No	M4LSSM/NC/SR/SU-KG/2018/18717	
3.	Field Season	2018 – 2019	
4.	Date of Commencement	21 th September 2018	
5.	Date of Completion	13 th March 2019	
6.	Officers associated with the investigation and no. of days spent in the field	Ms. Neha Kumari, Geologist (101days) & Mr. Kamal Kumar, Geologist (111 days)	
7.	Quantum of work done		
	1.Pre field map preparation		
	Preparation of Thematic maps (in GIS on scale 1:50000)		
	(a) Slope Forming Material map		1491 sq. km
	(b) Geomorphology & Lineament map		1491 sq. km
	(c) Slope Morphometry (slope, aspect & curvature) map		1491 sq. km
	(d) Landuse / Landcover map		1491 sq. km
	(e) Drainage map		1491 sq. km
	(f) Regolith thickness map		1491 sq. km
	(ii) Preparation of Landslide Inventory Map		1491 sq. km
	2. Field-based studies		
	(i) Field-checking of all thematic maps		1491 sq. km
	(ii)Field checking and collection of landslide inventory attributes (41 point geo -parametric sheet)		1491 sq. km (38 nos. Landslides)
	3. Post-field studies and modelling		
	i)Updation of thematic and landslide inventory maps		1491 sq. km
	ii)Landslide susceptibility modelling and finalization of landslide susceptibility map in GIS		1491 sq. km
	4. Collection of rainfall data from available rain stations	1491 sq. km (Taluk wise 11 years Monthly rainfall data obtained from different rain gauge stations.)	
8.	Expenditure in Rs.	Wages (Rs.)	70,300/-
		OC (Rs.)	57,478/-
		Total (Rs.)	1,27,778/-

FIVE POINT PROFORMA

Title of the report	Macro-scale (1:50,000) Landslide Susceptibility Mapping in parts of Toposheets nos. 48I/05, 48I/06, & 48I/07 Belgaum, Uttar Kannada districts, Karnataka and North Goa & South Goa districts, Goa.
Names of the Authors	Ms. Neha Kumari, Geologist & Mr. Kamal Kumar, Geologist
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/2018/18717 with an objective to prepare seamless Landslide Susceptibility Map on 1:50,000 scale.
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 M4LSSM/NC/SR/SU-KG/2018/18717
3. Date of commencement of the investigation with month and year, and exact number of days spent by the officers in the field in connection with the investigation.	21 st September 2018 1. Neha Kumari - 101 days 2. Kamal Kumar - 111 days
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: Place: Bengaluru Project/Division: NLSM/Engineering and Landslide Division Operation/Region: SU:K&G/Southern Region	Signature: Name: Shri J. Srihari Designation: Director



GEOLOGICAL SURVEY OF INDIA

Data sheet on report movement in connection with its scrutiny

Project / Division: NLSM/Engineering Geology and Landslide Division	FSP Code: M4LSSM/NC/SR/SUKG/2018/18717	Mission-IV: Fundamental and Multidisciplinary Geosciences
Title of the report: Macro-scale (1:50,000) Landslide Susceptibility Mapping in parts of Toposheets nos. 48I/05, 48I/06, & 48I/07 Belgaum, Uttar Kannada districts, Karnataka and North Goa & South Goa districts, Goa.		
Names of author(s) 1. Ms. Neha Kumari, Geologist 2. Mr. Kamal Kumar, Geologist	Date of submission to the Supervisory Officer	29-06-2019
	Signature of the author:	Neha Kumari
Name of the Supervisory Officer: Shri J. Srihari, Director	Date of receipt of the report:	29-06-2019
	Date of completion of scrutiny:	
	Date of handing over the report to the author after scrutiny:	12-07-2019
	Signature:	J. Srihari
Name of the author to whom the report has been handed over by the Supervisory Officer: MS. NEHA KUMARI GEOLOGIST	Date of receipt after scrutiny:	12-07-2019
	Signature:	Neha Kumari
Supervisory Officer J. SRIHARI DIRECTOR	Date of resubmission:	26-07-2019
	Signature:	Neha Kumari
	Date of receipt after modification:	26-07-2019
Name of the Internal Peer- Reviewer S.K. TRIPATHI DDG & RMH-IV	Date of handing over the report to the Project Director after peer review:	29-07-2019
	Signature:	J. Srihari
	Date of receipt of the report after Internal Peer Review:	16-09-19
Supervisory Officer J. SRIHARI DIRECTOR.	Date of handing over to the author:	16-09-19
	Signature:	J. Srihari

Name of the author MS. NEHA KUMARI GEOLOGIST	Date of receipt of the report from the Supervisory Officer:	16-09-19
	Date of resubmission to the Supervisory Officer after modification:	20-09-19
	Signature:	Neha Kumari
Name of the Supervisory Officer J. SRIHARI DIRECTOR	Date of receipt of the report after modification:	20-09-19
	Date of handing over the report to the Regional Mission Head:	20-09-19
	Signature:	J. Srihari
Name of the Regional Mission Head: S. K. TRIPATHI DDG & RMH-IV	Date of receipt of the report from the Project Director after modification:	23-09-2019
	Date of handing over the report to the HOD of the Region for approval:	27-09-2019
	Signature:	S.K. Tripathi
Name of the HOD of the Region: M. SRIDHAR ADG & HOD, SR	Date of receipt of the report for approval:	27.09.19
	Date of approval:	27.09.19
	Date of sending back report to Project Director:	
	Signature :	M. Srithar 27.9.19
Name of the Project Director: J. SRIHARI DIRECTOR	Date of receipt of the report after approval of the HOD:	30.9.19
	Date of circulation of the report	30.9.19
	Signature:	J. Srihari





GEOLOGICAL SURVEY OF INDIA
Certificate of Quality of the report

Project/ Division: NLSM/Engineering Geology and Landslide Division

Mission-IV: Fundamental and Multidisciplinary Geosciences

FSP Code: M4LSSM/NC/SR/SU-KG/2018/18717

Title of the report: Macro-scale (1:50,000) Landslide Susceptibility Mapping in parts of Toposheets nos. 48I/05, 48I/06, & 48I/07 Belgaum, Uttar Kannada districts, Karnataka and North Goa & South Goa districts, 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
Ms. Neha Kumari, Geologist	101 days	Neha Kumari 20/09/19
Mr. Kamal Kumar, Geologist	111 days	Kamal Kumar 20/09/19

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

Part-C

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

Name(s) Designation of the geophysicist	Date of commencement of work	Date of completion of work	Signature of the Geophysicist with date
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 :

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
Shri J. Srihari, Director (G)	02	04 days	S. S. Srihari 20.9.19

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
S.K. Tripathi	S.K. Tripathi

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
	M. K. Mishra 22.9.19

GEO-PARAMETRIC LANDSLIDE INVENTORY DATABASE

ANNEXURE I

Slide No.	State	TS no.	NH/SH/ Locality	Latitude	Longitude	Length	Width	Height	Type of slide	Activity	Distribution	Style	Failure mechanism	History	Geomorphology	Lithology	LU/LC	Geo- scientific Causes	Remedial measures
KAR/UK/2018/01	Uttar Kannada /Karnataka	48O/7	NH-4A	15°26'18.27"N	74°18'01.21"E	~9m	~52m	VH~10m	Debris Slide	Suspended	Confined	Successive	Shallow translational failure	Old	Lowly Dissected Slope	Ferrugenou s Phyllite	Thick Vegetation	Road cut failure	Slope regradation and easing of slope required
KAR/UK/2018/02	Uttar Kannada /Karnataka	48O/7	NH-4A	15°26'18.94"N	74°17'59.35"E	~12m	~56m	VH~10m	Debris cum rock Slide	Suspended	Confined	Multiple	Shallow translational failure	Old	Lowly Dissected Slope	Ferrugenou s Phyllite	Thick vegetation	Vertical road cut failure	Slope regradation and easing of slope required
KAR/UK/2018/03	Uttar Kannada /Karnataka	48O/7	NH-4A	15°25'54.51"N	74°17'29.15"E	~14m	~28m	VH~6m	Debris Slump	Active	Advancing	Single	Shallow translational failure	Reactivat ed	Lowly Dissected Slope	Ferrugenou s Phyllite	Thick vegetation	Vertical road cut failure	Slope regradation and easing of slope required
KAR/UK/2018/04	Uttar Kannada /Karnataka	48O/7	NH-4A	15°25'48.19"N	74°17'20.41"E	~18m	~56m	VH~11m	Rock cum debris Slide	Suspended	Retrogressive	Single	Shallow translational failure	Old	Lowly Dissected Slope	Ferrugenou s Phyllite	Thick vegetation	Vertical road cut failure	Slope regradation and easing of slope required
KAR/UK/2018/05	Uttar Kannada /Karnataka	48O/7	NH-4A	15°25'49.55"N	74°17'09.67"E	~19m	~47m	~9m	Rock cum debris Slide	Suspended	Retrogressive	Single	Shallow translational failure	Old	Lowly Dissected Slope	Ferrugenou s Phyllite	Thick vegetation	Vertical road cut failure	Slope regradation and easing of slope required
KAR/UK/2018/06	Uttar Kannada /Karnataka	48O/7	NH-4A	15°25'47.74"N	74°17'09.84"E	~12m	~38m	~15m	Debris Slide	Suspended	Retrogressive	Single	Shallow translational failure	Old	Lowly Dissected Slope	Ferrugenou s Phyllite	Thick vegetation	Vertical road cut failure	Slope regradation and easing of slope required
KAR/UK/2018/07	Uttar Kannada /Karnataka	48O/7	NH-4A	15°25'45.32"N	74°17'10.65"E	~17m	~37m	~8m	Debris Slide	Suspended	Retrogressive	Single	Shallow translational failure	Old	Lowly Dissected Slope	Ferrugenou s Phyllite	Thick vegetation	Vertical road cut failure	Slope regradation and easing of slope required
KAR/UK/2018/08	Uttar Kannada /Karnataka	48O/7	NH-4A	15°25'42.74"N	74°17'9.98"E	~18m	~32m	VH~16m	Rock Slide	Suspended	Retrogressive	Single	Shallow translational failure	Old	Lowly Dissected Slope	Banded Iron Formation	Thick vegetation	Vertical road cut failure	Slope regradation and easing of slope required
KAR/UK/2018/09	Uttar Kannada /Karnataka	48O/7	NH-4A	15°25'41.98"N	74°17'9.43"E	~12m	~42m	VH~16m	Rock Slide	Suspended	Retrogressive	Single	Shallow translational failure	Old	Lowly Dissected Slope	Banded Iron Formation	Thick vegetation	Vertical road cut failure	Slope regradation and easing of slope required
KAR/UK/2018/10	Uttar Kannada /Karnataka	48O/7	NH-4A	15°25'30.81"N	74°16'47.33"E	~17m	~57m	~7m	Debris Slide	Suspended	Retrogressive	Single	Shallow translational failure	Old	Lowly Dissected Slope	Granite gneiss	Thick vegetation	Vertical road cut failure	Slope regradation and easing of slope required
KAR/BEL/2018/11	Uttar Kannada /Karnataka	48O/7	NH-4A	15°25'25.27"N	74°16'46.41"E	~10m	~22m	~7m	Debris Slump	Suspended	Retrogressive	Single	Shallow translational failure	Old	Lowly Dissected Slope	Granite gneiss	Thick vegetation	Vertical road cut failure	Slope regradation and lined drainage with weep holes as Toe support is provided at base of the hill slope is required
GOA/SG/2018/12	Uttar Kannada /Karnataka	48O/7	NH-4A	15°25'20.93"N	74°16'46.06"E	~17m	~27m	VH~7m	Debris Slump	Suspended	Progressive and advancing	Single	Shallow translational failure	Old	Lowly Dissected Slope	Granite gneiss	Thick vegetation	Vertical road cut failure	Slope regradation and lined drainage with weep holes as Toe support is provided at base of the hill slope is required
KAR/BEL/2018/13	Uttar Kannada /Karnataka	48O/7	NH-4A	15°24'55.51"N	74°16'48.06"E	~14m	~22m	VH~7m	Debris Slide	Suspended	Retrogressive	Single	Shallow translational failure	Active	Lowly Dissected Slope	Granite gneiss	Thick vegetation	Vertical road cut failure	Slope regradation and easing of slope required
GOA/SG/2018/14	South Goa /Goa	48O/7	NH-4A	15°25'7.31"N	74°16'15.08"E	~9m	~18m	~8m	Debris cum rock Slide	Suspended	Confined	Multiple	Shallow translational failure	Old	Lowly Dissected Slope	Granite gneiss	Thick vegetation	Vertical road cut failure	Slope regradation and easing of slope required
GOA/SG/2018/15	South Goa /Goa	48O/7	NH-4A	15°25'1.36"N	74°16'3.94"E	~28m	~72m	VH~9m	Debris cum rock Slide	Suspended	Retrogressive	Single	Shallow translational failure	Old	Lowly Dissected Slope	Granite gneiss	Thick vegetation	Vertical cut slope failure along the fractured and jointed rock.	Slope regradation and lined drainage should be provided.
GOA/SG/2018/16	South Goa /Goa	48O/7	NH-4A	15°24'55.17"N	74°16'2.19"E	~10m	~25m	~12m	Debris Slide	Suspended	Progressive and advancing	Single	Shallow translational failure	Old	Highly Dissected hillslope	Granite gneiss	Thick vegetation	Vertical cut slope failure along the fractured and jointed rock.	Retaining wall of 3m height and 22 m width with weep holes were constructed. It should be extended to avoid toe erosion and to provide toe support

GEO-PARAMETRIC LANDSLIDE INVENTORY DATABASE

ANNEXURE I

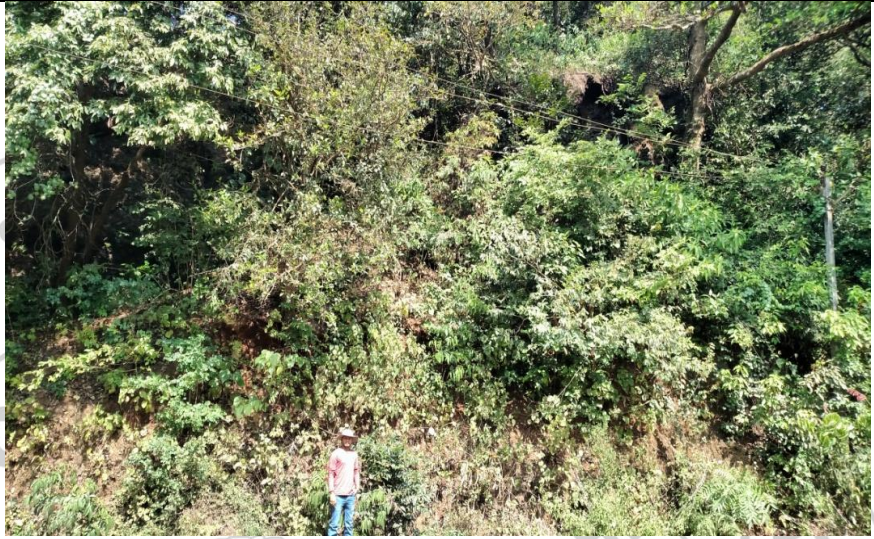
Slide No.	State	TS no.	NH/SH/ Locality	Latitude	Longitude	Length	Width	Height	Type of slide	Activity	Distribution	Style	Failure mechanism	History	Geomorphology	Lithology	LU/LC	Geo- scientific Causes	Remedial measures
GOA/SG/2018/17	South Goa /Goa	48O/7	NH-4A	15°24'51.60"N	74°16'1.80"E	~22m	~30m	VH~60m	Debris Slide	Suspended	Progressive and advancing	Single	Shallow translational failure	Old	Highly Dissected hillslope	Granite gneiss	Moderate vegetation	Road subsidence along the fractured and jointed rock.	Down slope of road subsidence high height retaining wall/breast wall with weep holes should be constructed to provide toe support and proper drainage on slope.
GOA/SG/2018/18	South Goa /Goa	48O/7	NH-4A	15°24'44.30"N	74°16'07.30"E	~14m	~35m	VH~14m	Debris Slide	Suspended	Progressive and advancing	Single	Shallow translational failure	Old	Highly Dissected hillslope	Granite gneiss	Moderate vegetation	Vertical cut slope failure along the fractured and jointed rock.	Slope regradation and easing of slope required
GOA/SG/2018/19	South Goa /Goa	48O/7	NH-4A	15°24'48.83"N	74°16'1.02"E	~10m	~22m	~7m	Debris Slide	Suspended	Progressive and advancing	Single	Shallow translational failure	Old	Lowly Dissected hillslope	Granite gneiss	Moderate vegetation	Vertical cut slope failure along the fractured and jointed rock.	Slope regradation and easing of slope required
GOA/SG/2018/20	South Goa /Goa	48O/7	NH-4A	15°24'46.97"N	74°16'0.59 "E	~12m	~25m	~11m	Rock Slide	Suspended	Retrogressive	Single	Shallow translational failure	Old	Lowly Dissected hillslope	Granite gneiss	Thick vegetation	Vertical cut slope failure along the fractured and jointed rock.	Slope regradation and lined drainage should be provided.
GOA/SG/2018/21	South Goa /Goa	48O/7	NH-4A	15°24'44.96"N	74°16'1.45"E	~12m	~25m	~12m	Rock cum debris Slide	Suspended	Retrogressive	Multiple	Shallow translational failure	Old	Lowly Dissected hillslope	Granite gneiss	Thick vegetation	Vertical cut slope failure along the fractured and jointed rock.	Slope regradation and lined drainage should be provided.
GOA/SG/2018/22	South Goa /Goa	48O/7	NH-4A	15°24'43.90"N	74°16'06.20"E	~22m	~75m	~14m	Rock Slide	Suspended	Confined	Single	Shallow translational failure	Old	Highly Dissected hillslope	Granite gneiss	Moderate vegetation	slope modification leads to vertical road cut failure & weathering along the weaker planes.	Slope regradation and lined drainage should be provided.
GOA/SG/2018/23	South Goa /Goa	48O/7	NH-4A	15°24'39.50"N	74°16'12.50 "E	~18m	~45m	VH~12m	Rock cum debris Slide	Suspended	Progressive, Widening and enlarging	Single	Shallow translational failure	Active	Highly Dissected hillslope	Granite gneiss	Thick vegetation	Vertical road cut failure	Slope regradation and easing of slope required
GOA/SG/2018/24	South Goa /Goa	48O/7	NH-4A	15°24'41.20"N	74°16'3.80"E	~22m	~155m	VH~12m	Rock Slide	Suspended	Retrogressive	Multiple	Shallow translational failure	Old	Highly Dissected hillslope	Granite gneiss	Thick vegetation	Vertical cut slope failure along the fracture and joint plane dipping towards road	Lined drainage should be provided at the entire sliding zone and broken part should be repaired.
GOA/SG/2018/25	South Goa /Goa	48O/7	NH-4A	15°24'40.60"N	74°15'58.60"E	~35m	~75m	VH~55m	Rock Slide	Suspended	Retrogressive	Multiple	Shallow translational failure	Old	Highly Dissected hillslope	Granite gneiss	Thick vegetation	Vertical cut slope failure along the fracture and joint plane.	Lined drainage should be provided at the entire sliding zone and plantatin on slope should be done.
GOA/SG/2018/26	South Goa /Goa	48O/7	NH-4A	15°24'39.40"N	74°15'53.80"E	~30m	~25m	VH~12m	Rock cum debris Slide	Active	Progressive, Widening and enlarging	Single	Shallow translational failure	Old	Highly Dissected hillslope	Granite gneiss	Thick vegetation	Vertical road cut failure	Slope regradation and easing of slope required
GOA/SG/2018/27	South Goa /Goa	48O/7	NH-4A	15°24'39.40"N	74°15'53.80"E	~17m	~35m	VH~12m	Debris Slide	Active	Progressive, Widening and enlarging	Single	Shallow translational failure	Old	Highly Dissected hillslope	Granite gneiss	Thick vegetation	Vertical road cut failure	Slope regradation and easing of slope required
GOA/SG/2018/28	South Goa /Goa	48O/7	NH-4A	15°24'39.30"N	74°15'48.60"E	~35m	~55m	~15m	Debris Slide	Suspended	Progressive, Widening and enlarging	Single	Shallow translational failure	Old	Highly Dissected hillslope	Granite gneiss	Thick vegetation	Vertical road cut failure	Concrete lined drainage required at toe partshould be extended upto 50m and more upto the disturbed zone.
GOA/SG/2018/29	South Goa /Goa	48O/7	NH-4A	15°24'58.90"N	74°15'43.70"E	~17m	~42m	VH~12m	Debris Slide	Suspended	Progressive, Widening and enlarging	Single	Shallow translational failure	Old	Highly Dissected hillslope	Granite gneiss	Thick vegetation	Vertical road cut failure	Concrete lined drainage at toe partshould be extended upto 50m and more upto the disturbed zone.
GOA/SG/2018/30	South Goa /Goa	48O/7	NH-4A	15°24'59.90"N	74°15'39.70"E	~17m	~32m	~13m	Debris Slide	Active	Retrogressive	Single	Shallow translational failure	Old	Highly Dissected hillslope	Granite gneiss	Thick vegetation	Vertical road cut failure	Slope regradation and easing of slope required.

GEO-PARAMETRIC LANDSLIDE INVENTORY DATABASE

ANNEXURE I

Slide No.	State	TS no.	NH/SH/ Locality	Latitude	Longitude	Length	Width	Height	Type of slide	Activity	Distribution	Style	Failure mechanism	History	Geomorphology	Lithology	LU/LC	Geo- scientific Causes	Remedial measures
GOA/SG/2018/31	South Goa /Goa	48O/7	NH-4A	15°24'59.30"N	74°15'38.70"E	~15m	~28m	VH~16m	Debris Slide	Suspended	Retrogressive	Successive	Shallow translational failure	Old	Highly Dissected hillslope	Granite gneiss	Thick Vegetation	Road cut failure	Slope regradation and easing of slope required.
GOA/SG/2018/32	South Goa /Goa	48O/7	NH-4A	15°24'48.60"N	74°15'19.20"E	~15m	~112m	VH~14m	Debris Slide	Suspended	Retrogressive	Successive	Shallow translational failure	Old	Highly Dissected hillslope	Granite gneiss	Thick Vegetation	Two Failure along nala section due to water saturation and weathering	Lined drainage should be extended upto 50m towards the slumping zone.
GOA/SG/2018/33	South Goa /Goa	48O/7	Dudhasa gar Railway station	15°19'57.00"N	74°18'22.80"E	~17m	~25m	VH~22m	Rock Slide	Active	Retrogressive	Single	Shallow translational failure	Old	Highly Dissected hillslope	Granite	Moderate vegetation	Vertical cut made for railway tract failed along the joints.	Slope regradation or easing of slope required.
KAR/UK/2018/34	Uttar Kannada /Karnataka	48O/7	Castle rock railway junction	15°23'55.51"N	74°20'17.64"E	~50m	~110m	~14m	Debris Slide	Active	Retrogressive	Single	Shallow translational failure	Reactvate d	Lowly Dissected hillslope	Ferruginous phyllite	Sparse vegetation	Vertical cut slope along the railway track to weathering induced by water saturation during rainfall.	Gabion wall with wire mesh of dimension 113m width and 4.5m high constructed for toe support should be extended upto unstable zones.
KAR/UK/2018/35	Uttar Kannada /Karnataka	48O/7	Tadki- Kunang road	15°19'37.94"N	74°22'49.33"E	~17m	~25m	VH~22m	Debris Flow	Suspended	Retrogressive	Single	Shallow translational failure	Old	Highly Dissected hillslope	Granite gneiss	Thick Vegetation	Gully erosion on upper catchment area on upsloe direction and eroded the material along the nala section.	Lined drainage with box culvert should be constructed at road bench level
KAR/UK/2018/36	Uttar Kannada /Karnataka	48O/7	Tadki- Kunang road	15°19'29.43"N	74°22'56.90"E	~18m	~28m	~13m	Debris Slide	Active	Retrogressive	Single	Shallow translational failure	Old	Highly Dissected hillslope	Granite gneiss	Thick Vegetation	weathering and erosion due to water saturation from upper catchment area	Lined drainage and slope regradation required.
KAR/UK/2018/37	Uttar Kannada /Karnataka	48O/7	Kuvesi road section	15°20'51.60"N	74°20'55.60"E	~14m	~28m	~8m	Debris Slide	Suspended	Retrogressive	Single	Shallow translational failure	Old	Highly Dissected hillslope	Granite gneiss	Sparse Vegetation	weathering and erosion due to water saturation from upper catchment area	Lined drainage and slope regradation required.
KAR/UK/2018/38	Uttar Kannada /Karnataka	48O/7	Aldur village	15°15'47.30"N	74°19'59.70"E	~17m	~28m	VH~12m	Debris Slide	Suspended	Progressive	Single	Shallow translational failure	Old	Lowly Dissected hillslope	Ferrugenou s phyllite	Sparse Vegetation	weathering and erosion due to water saturation from upper catchment area.	Lined drainage with weep holes required.

No	Field		Description
1	Slide No.	:	KAR/UK/2018/01
2	State	:	Karnataka
3	District		Uttar Kannada
4	Toposheet No.	:	48I/07
5	Name of the slide	:	Anmod-Mollem Ghat road
6	NH/SH/Locality	:	NH-4A
7	Latitude	:	15°26'18.27"N
8	Longitude	:	74°18'01.21"E
9	Length	:	~9m
10	Width	:	~52m
11	Height	:	VH~10m
12	Area	:	--
13	Depth	:	--
14	Volume	:	--
15	Run out distance	:	--
16	Type of Material	:	Debris
17	Type of movement	:	Slide
18	Rate of movement	:	Extremely slow
19	Activity	:	Suspended
20	Distribution	:	Confined
21	Style	:	Successive
22	Failure mechanism	:	Shallow translational failure
23	History	:	Old
24	Geomorphology	:	Lowly Dissected Slope
25	Geology/Lithology	:	Ferruginous Phyllite
26	Structure	:	No structure Distinct
27	Landuse/ Landcover	:	Thick Vegetation
28	Hydrological condition	:	Dry
29	Triggering Factor	:	Rainfall
30	Death of persons	:	No casualties
31	People affected	:	No casualties
32	Livestock Loss	:	No casualties
33	Communication	:	No damage
34	Infrastructure	:	Not affected
35	Agriculture/forest/ Barren	:	Forest
36	Geo-scientific Causes	:	Road cut failure.
37	Remedial measures	:	Slope regradation and easing of slope is required. Dislodged precarious rock on top of hill slope should be removed.
38	Remarks, if any		The slope failure may occur during water saturation of slope during heavy rainfall that may lead to road blockage and casualties. The electric pole nearby are at risk. The slope is in meta-stable condition.

39	Photos. Sketch of Plan & section of the slide	:	
40	Summary/Abstract	:	The debris slide occurred on lowly dissected hill slope on vertical cut slope. The slide is old and can get reactivated during monsoon. At present the area is meta-stable.
41	Date of Reporting	:	23-11-2018
42	Landslide Category	:	I

No	Field		Description
1	Slide No.	:	KAR/UK/2018/02
2	State	:	Karnataka
3	District		Uttar Kannada
4	Toposheet No.	:	48I/07
5	Name of the slide	:	Anmod-Mollem Ghat road
6	NH/SH/Locality	:	NH-4A
7	Latitude	:	15°26'18.94"N
8	Longitude	:	74°17'59.35"E
9	Length	:	~12m
10	Width	:	56m
11	Height	:	VH~10m
12	Area	:	--
13	Depth	:	--
14	Volume	:	--
15	Run out distance	:	--
16	Type of Material	:	Debris cum rock
17	Type of movement	:	Slide
18	Rate of movement	:	Very slow
19	Activity	:	Suspended
20	Distribution	:	Confined
21	Style	:	Multiple
22	Failure mechanism	:	Shallow translational failure
23	History	:	Old
24	Geomorphology	:	Lowly Dissected Slope
25	Geology/Lithology	:	Ferruginous Phyllite
26	Structure	:	No structure Distinct
27	Landuse/ Landcover	:	Thick vegetation
28	Hydrological condition	:	Dry
29	Triggering Factor	:	Rainfall
30	Death of persons	:	No casualties
31	People affected	:	No casualties
32	Livestock Loss	:	No casualties
33	Communication	:	No damage
34	Infrastructure	:	Not affected
35	Agriculture/forest/ Barren	:	Forest
36	Geo-scientific Causes	:	Slope modification i.e. cutting of slope for road construction. Vertical road cut failure.
37	Remedial measures	:	Slope regradation/easing of slope required. Dislodged precarious rock on top of hill slope should be removed.
38	Remarks, if any		The area is meta stable.

39	Photos. Sketch of Plan & section of the slide	:	
40	Summary/Abstract	:	The debris slide occurred on lowly dissected hill slope on vertical cut slope. The slide is old and can get reactivated during monsoon. At present the area is meta-stable.
41	Date of Reporting	:	23-11-2018
42	Landslide Category	:	I

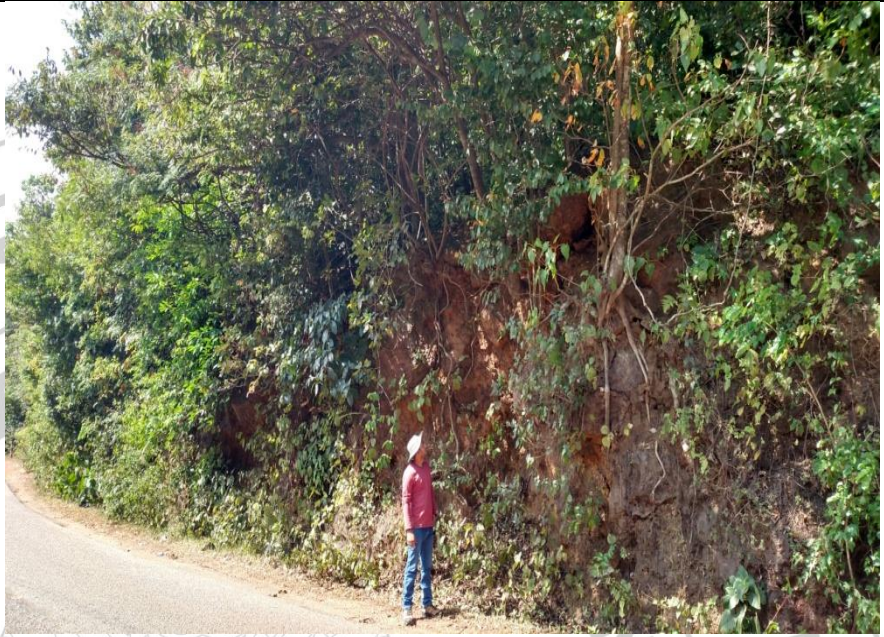
No	Field		Description
1	Slide No.	:	KAR/UK/2018/03
2	State	:	Karnataka
3	District	:	Uttar Kannada
4	Toposheet No.	:	48I/07
5	Name of the slide	:	Anmod-Mollem Ghat road
6	NH/SH/Locality	:	NH-4A
7	Latitude	:	15°25'54.51"N
8	Longitude	:	74°17'29.15"E
9	Length	:	~14m
10	Width	:	~28m
11	Height	:	VH~6m
12	Area	:	--
13	Depth	:	--
14	Volume	:	--
15	Run out distance	:	--
16	Type of Material	:	Debris (Highly weathered rock and soil)
17	Type of movement	:	Slump
18	Rate of movement	:	Very slow
19	Activity	:	Active
20	Distribution	:	Advancing/Progressive
21	Style	:	Single
22	Failure mechanism	:	Shallow translational failure
23	History	:	Reactivated
24	Geomorphology	:	Lowly Dissected Slope
25	Geology/Lithology	:	Ferruginous Phyllite
26	Structure	:	No structure Distinct
27	Landuse/ Landcover	:	Thick vegetation
28	Hydrological condition	:	Damp
29	Triggering Factor	:	Rainfall
30	Death of persons	:	No casualties
31	People affected	:	No casualties
32	Livestock Loss	:	No casualties
33	Communication	:	No damage
34	Infrastructure	:	Not affected
35	Agriculture/forest/ Barren	:	Forest
36	Geo-scientific Causes	:	Vertical road cut failure.
37	Remedial measures	:	Slope regradation/easing of slope is required. Dislodged precarious rock on top of hill slope should be removed.
38	Remarks, if any	:	Failure along fractured and weathered plane. Risk to communication line, electric pole nearby is at high risk.

39	Photos. Sketch of Plan & section of the slide	:	
40	Summary/Abstract	:	The debris slide occurred on lowly dissected hill slope on vertical cut slope. The slide is old and can get reactivated during monsoon. At present the area is meta-stable.
41	Date of Reporting	:	23-11-2018
42	Landslide Category	:	I

No	Field		Description
1	Slide No.	:	KAR/UK/2018/04
2	State	:	Karnataka
3	District	:	Uttar Kannada
4	Toposheet No.	:	48I/07
5	Name of the slide	:	Anmod-Mollem Ghat road
6	NH/SH/Locality	:	NH-4A
7	Latitude	:	15°25'48.19"N
8	Longitude	:	74°17'20.41"E
9	Length	:	~18m
10	Width	:	~56m
11	Height	:	VH~11m
12	Area	:	--
13	Depth	:	--
14	Volume	:	--
15	Run out distance	:	--
16	Type of Material	:	Rock cum debris
17	Type of movement	:	Slide
18	Rate of movement	:	Very slow
19	Activity	:	Suspended
20	Distribution	:	Retrogressive
21	Style	:	Single
22	Failure mechanism	:	Shallow translational failure
23	History	:	Old
24	Geomorphology	:	Lowly Dissected Slope
25	Geology/Lithology	:	Ferruginous Phyllite
26	Structure	:	No structure Distinct
27	Landuse/ Landcover	:	Thick vegetation
28	Hydrological condition	:	Damp
29	Triggering Factor	:	Rainfall
30	Death of persons	:	No casualties
31	People affected	:	No casualties
32	Livestock Loss	:	No casualties
33	Communication	:	No damage
34	Infrastructure	:	Not affected
35	Agriculture/forest/Barren	:	Forest
36	Geo-scientific Causes	:	Vertical road cut failure
37	Remedial measures	:	Slope regradation/easing of slope required. Dislodged precarious rock on top of hill slope should be removed.
38	Remarks, if any	:	If slope failure may occur during water saturation of slope during heavy rainfall. The road blockage and casualties may occur. Risk to communication line.
39	Photos. Sketch of Plan & section of the slide	:	

			 
40	Summary/Abstract	:	The slide is rock cum debris slide occurred on lowly dissected hill slope. At present the sliding zone is meta-stable and covered with dense vegetation.
41	Date of Reporting	:	23-11-2018
42	Landslide Category	:	I

No	Field		Description
1	Slide No.	:	KAR/UK/2018/05
2	State	:	Karnataka
3	District	:	Uttar Kannada
4	Toposheet No.	:	48I/07
5	Name of the slide	:	Anmod-Mollem Ghat road
6	NH/SH/Locality	:	NH-4A
7	Latitude	:	15°25'49.55"N
8	Longitude	:	74°17'09.67"E
9	Length	:	~19m
10	Width	:	~47m
11	Height	:	~9m
12	Area	:	--
13	Depth	:	--
14	Volume	:	--
15	Run out distance	:	--
16	Type of Material	:	Rock cum debris
17	Type of movement	:	Slide
18	Rate of movement	:	Very slow
19	Activity	:	Suspended
20	Distribution	:	Retrogressive
21	Style	:	Single
22	Failure mechanism	:	Shallow translational failure
23	History	:	Old
24	Geomorphology	:	Lowly Dissected Slope
25	Geology/Lithology	:	Ferruginous phyllite
26	Structure	:	No structure Distinct
27	Landuse/Landcover	:	Thick vegetation
28	Hydrological condition	:	Dry
29	Triggering Factor	:	Rainfall
30	Death of persons	:	No casualties
31	People affected	:	No casualties
32	Livestock Loss	:	No casualties
33	Communication	:	No damage
34	Infrastructure	:	Not affected
35	Agriculture/forest/Barren	:	Forest
36	Geo-scientific Causes	:	Water saturation along rock fractures on vertical road cut.
37	Remedial measures	:	Slope regradation/easing of slope required. Dislodged precarious rock on top of hill slope should be removed.
38	Remarks, if any	:	If slope failure may occur during water saturation of slope during heavy rainfall. The road blockage and casualties may occur. Risk to communication line and electric poles on other side of the road.

39	Photos. Sketch of Plan & section of the slide	:	
40	Summary/Abstract	:	The debris slide occurred on lowly dissected hill slope on vertical cut slope. The slide is old and can get reactivated during monsoon. At present the area is meta-stable.
41	Date of Reporting	:	23-11-2018
42	Landslide Category	:	I

No	Field		Description
1	Slide No.	:	KAR/BEL/2018/06
2	State	:	Karnataka
3	District		Uttar Kannada
4	Toposheet No.	:	48I/07
5	Name of the slide	:	Anmod-Mollem Ghat road
6	NH/SH/Locality	:	NH-4A
7	Latitude	:	15°25'47.74"N
8	Longitude	:	74°17'09.84"E
9	Length	:	~12m
10	Width	:	~38m
11	Height	:	~15m
12	Area	:	--
13	Depth	:	--
14	Volume	:	--
15	Run out distance	:	--
16	Type of Material	:	Debris (Highly weathered rock and soil)
17	Type of movement	:	Slide
18	Rate of movement	:	Very slow
19	Activity	:	Suspended
20	Distribution	:	Retrogressive
21	Style	:	Single
22	Failure mechanism	:	Shallow translational failure
23	History	:	Old
24	Geomorphology	:	Lowly Dissected Slope
25	Geology/Lithology	:	Ferruginous Phyllite
26	Structure	:	No structure Distinct
27	Landuse/ Landcover	:	Thick vegetation
28	Hydrological condition	:	Damp
29	Triggering Factor	:	Rainfall
30	Death of persons	:	No casualties
31	People affected	:	No casualties
32	Livestock Loss	:	No casualties
33	Communication	:	No damage
34	Infrastructure	:	Not affected
35	Agriculture/forest/Barren	:	Forest
36	Geo-scientific Causes	:	Water saturation along rock fractures on extensive cut slope
37	Remedial measures	:	Slope regradation/easing of slope required. Dislodged precarious rock on top of hill slope should be removed.
38	Remarks, if any		If slope failure may occur during water saturation of slope during heavy rainfall. The road blockage and casualties may occur. Risk to communication line and electric poles on other side of the road.

39	Photos. Sketch of Plan & section of the slide	:	
40	Summary/Abstract	:	The debris slide occurred on lowly dissected hill slope on vertical cut slope. The slide is old and can get reactivated during monsoon. At present the area is meta-stable.
41	Date of Reporting	:	23-11-2018
42	Landslide Category	:	I

No	Field		Description
1	Slide No.	:	KAR/BEL/2018/07
2	State	:	Karnataka
3	District	:	Uttar Kannada
4	Toposheet No.	:	48I/07
5	Name of the slide	:	Anmod-Mollem Ghat road
6	NH/SH/Locality	:	NH-4A
7	Latitude	:	15°25'45.32"N
8	Longitude	:	74°17'10.65"E
9	Length	:	~17m
10	Width	:	~37m
11	Height	:	~8m
12	Area	:	--
13	Depth	:	--
14	Volume	:	--
15	Run out distance	:	--
16	Type of Material	:	Debris
17	Type of movement	:	Slide
18	Rate of movement	:	Very slow
19	Activity	:	Suspended
20	Distribution	:	Advancing
21	Style	:	Single
22	Failure mechanism	:	Shallow translational failure
23	History	:	Old
24	Geomorphology	:	Lowly Dissected Slope
25	Geology/Lithology	:	Ferruginous Phyllite
26	Structure	:	No structure Distinct
27	Landuse/ Landcover	:	Dense Forest
28	Hydrological condition	:	Damp
29	Triggering Factor	:	Rainfall
30	Death of persons	:	No casualties
31	People affected	:	No casualties
32	Livestock Loss	:	No casualties
33	Communication	:	No damage
34	Infrastructure	:	Not affected
35	Agriculture/forest/ Barren	:	Forest
36	Geo-scientific Causes	:	Seepage, weathering and erosion along fracture plane. Cut slope failure
37	Remedial measures	:	Easing of slope required.
38	Remarks, if any	:	If slope failure may occur during water saturation of slope during heavy rainfall. The road blockage and casualties may occur. Risk to communication line.

39	Photos. Sketch of Plan & section of the slide	:	
40	Summary/Abstract	:	The debris slide occurred on lowly dissected hill slope on vertical cut slope. The slide is old and can get reactivated during monsoon. At present the area is meta-stable.
41	Date of Reporting	:	23-11-2018
42	Landslide Category	:	I

No	Field		Description
1	Slide No.	:	KAR/BEL/2018/08
2	State	:	Karnataka
3	District	:	Uttar Kannada
4	Toposheet No.	:	48I/07
5	Name of the slide	:	Anmod-Mollem Ghat road
6	NH/SH/Locality	:	NH-4A
7	Latitude	:	15°25'42.74"N
8	Longitude	:	74°17'9.98"E
9	Length	:	~18m
10	Width	:	~32m
11	Height	:	VH~16m
12	Area	:	--
13	Depth	:	--
14	Volume	:	--
15	Run out distance	:	--
16	Type of Material	:	Rock
17	Type of movement	:	Slide
18	Rate of movement	:	Very slow
19	Activity	:	Suspended
20	Distribution	:	Retrogressive
21	Style	:	Single
22	Failure mechanism	:	Shallow translational failure
23	History	:	Old
24	Geomorphology	:	Lowly Dissected Slope
25	Geology/Lithology	:	Banded Iron Formation
26	Structure	:	No structure Distinct
27	Landuse/ Landcover	:	Thick vegetation
28	Hydrological condition	:	Dry
29	Triggering Factor	:	Rainfall
30	Death of persons	:	No casualties
31	People affected	:	No casualties
32	Livestock Loss	:	No casualties
33	Communication	:	No damage
34	Infrastructure	:	Not affected
35	Agriculture/forest/ Barren	:	Forest
36	Geo-scientific Causes	:	Vertical cut slope failure
37	Remedial measures	:	Easing of slope required.
38	Remarks, if any	:	If slope failure may occur during water saturation of slope during heavy rainfall. The road blockage and casualties may occur. Risk to communication line.

39	Photos. Sketch of Plan & section of the slide	:	
40	Summary/Abstract	:	The slide is rock cum debris slide occurred on lowly dissected hill slope. At present the sliding zone is meta-stable and covered with dense vegetation. The area has undergone pronounced weathering and erosion.
41	Date of Reporting	:	23-11-2018
42	Landslide Category	:	I

No	Field		Description
1	Slide No.	:	KAR/BEL/2018/09
2	State	:	Karnataka
3	District	:	Uttar Kannada
4	Toposheet No.	:	48I/07
5	Name of the slide	:	Anmod-Mollem Ghat road
6	NH/SH/Locality	:	NH-4A
7	Latitude	:	15°25'41.98"N
8	Longitude	:	74°17'9.43"E
9	Length	:	~12m
10	Width	:	~42m
11	Height	:	VH~16m
12	Area	:	--
13	Depth	:	--
14	Volume	:	--
15	Run out distance	:	--
16	Type of Material	:	Rock
17	Type of movement	:	Slide
18	Rate of movement	:	Very slow
19	Activity	:	Suspended
20	Distribution	:	Retrogressive
21	Style	:	Multiple
22	Failure mechanism	:	Shallow translational failure
23	History	:	Old
24	Geomorphology	:	Lowly Dissected Slope
25	Geology/Lithology	:	Banded Iron Formation
26	Structure	:	No structure Distinct
27	Landuse/ Landcover	:	Thick vegetation
28	Hydrological condition	:	Damp
29	Triggering Factor	:	Rainfall
30	Death of persons	:	No casualties
31	People affected	:	No casualties
32	Livestock Loss	:	No casualties
33	Communication	:	No damage
34	Infrastructure	:	Not affected
35	Agriculture/forest/ Barren	:	Forest
36	Geo-scientific Causes	:	Vertical road cut failure
37	Remedial measures	:	Slope regradation/easing of slope required. Dislodged precarious rock on top of hill slope should be removed.
38	Remarks, if any	:	If slope failure may occur during water saturation of slope during heavy rainfall. The road blockage and casualties may occur. Risk to communication line.

39	Photos. Sketch of Plan & section of the slide	:	
40	Summary/Abstract	:	The rock slide occurred on the lowly dissected hill slope on ghat road section. The rock slide occurred due to intense weathering due to water seepage and saturation along the fracture and joints. The vertical cut slope failure is more intense during heavy rainfall.
41	Date of Reporting	:	23-11-2018
42	Landslide Category	:	I

No	Field		Description
1	Slide No.	:	KAR/BEL/2018/10
2	State	:	Goa
3	District		Uttar Kannada
4	Toposheet No.	:	48I/07
5	Name of the slide	:	Anmod-Mollem Ghat road
6	NH/SH/Locality	:	NH-4A
7	Latitude	:	15°25'30.81"N
8	Longitude	:	74°16'47.33"E
9	Length	:	~17m
10	Width	:	~57m
11	Height	:	~7m
12	Area	:	--
13	Depth	:	--
14	Volume	:	--
15	Run out distance	:	--
16	Type of Material	:	Debris (highly weathered rock)
17	Type of movement	:	slide
18	Rate of movement	:	Very slow
19	Activity	:	Active
20	Distribution	:	Retrogressive
21	Style	:	Successive
22	Failure mechanism	:	Shallow translational failure
23	History	:	Old
24	Geomorphology	:	Lowly Dissected Slope
25	Geology/Lithology	:	Granite gneiss
26	Structure	:	No structure Distinct
27	Landuse/ Landcover	:	Dense Forest
28	Hydrological condition	:	Damp
29	Triggering Factor	:	Rainfall
30	Death of persons	:	No casualties
31	People affected	:	No casualties
32	Livestock Loss	:	No casualties
33	Communication	:	No damage
34	Infrastructure	:	Not affected
35	Agriculture/forest/B arren	:	Forest
36	Geo-scientific Causes	:	Water saturation, weathering and erosion.
37	Remedial measures	:	Lined drainage at toe part of slope required.
38	Remarks, if any		If slope failure may occur during water saturation of slope during heavy rainfall. The road blockage and casualties may occur. Risk to communication line.

39	Photos. Sketch of Plan & section of the slide	:	
40	Summary/Abstract	:	The debris slide occurred on lowly dissected hill slope on vertical cut slope. The slide is old and can get reactivated during monsoon. At present the area is stable.
41	Date of Reporting	:	23-11-2018
42	Landslide Category	:	I

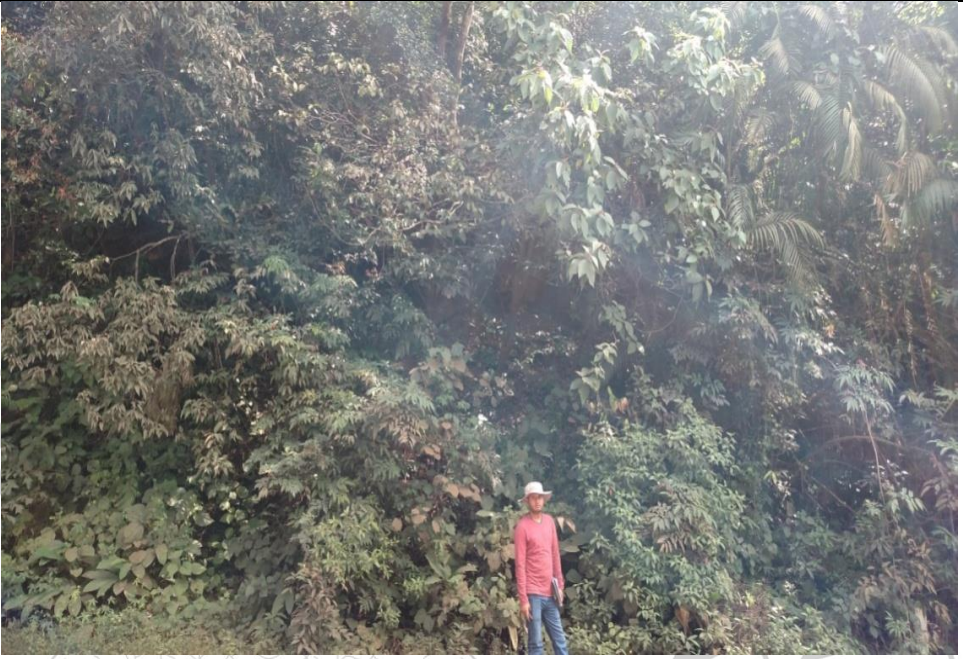
No	Field		Description
1	Slide No.	:	KAR/BEL/2018/11
2	State	:	Karnataka
3	District	:	Uttar Kannada
4	Toposheet No.	:	48I/07
5	Name of the slide	:	Anmod-Mollem Ghat road
6	NH/SH/Locality	:	NH-4A
7	Latitude	:	15°25'25.27"N
8	Longitude	:	74°16'46.41"E
9	Length	:	~10m
10	Width	:	~22m
11	Height	:	--
12	Area	:	--
13	Depth	:	--
14	Volume	:	--
15	Run out distance	:	--
16	Type of Material	:	Debris (Highly weathered rock and soil)
17	Type of movement	:	Slump
18	Rate of movement	:	Very slow
19	Activity	:	Retrogressive, Widening and Enlarging
20	Distribution	:	Retrogressive
21	Style	:	Single
22	Failure mechanism	:	Shallow rotational failure
23	History	:	Old
24	Geomorphology	:	Lowly Dissected Slope
25	Geology/Lithology	:	Granite gneiss
26	Structure	:	No structure Distinct
27	Landuse/ Landcover	:	Thick vegetation
28	Hydrological condition	:	Damp
29	Triggering Factor	:	Rainfall
30	Death of persons	:	No casualties
31	People affected	:	No casualties
32	Livestock Loss	:	No casualties
33	Communication	:	No damage
34	Infrastructure	:	Not affected
35	Agriculture/forest/B arren	:	Forest
36	Geo-scientific Causes	:	Weathering and Erosion of vertical cut slope.
37	Remedial measures	:	Slope regradation/easing of slope required. The dislodged rock boulders should be removed. The lined drainage with weep holes as Toe support is provided at base of the hill slope.
38	Remarks, if any	:	The area is meta-stable.

39	Photos. Sketch of Plan & section of the slide	:	
40	Summary/Abstract	:	The debris slide occurred on lowly dissected hill slope on vertical cut slope. The slide is old and can get reactivated during monsoon. At present the area is stable.
41	Date of Reporting	:	23-11-2018
42	Landslide Category	:	I

No	Field		Description
1	Slide No.	:	KAR/BEL/2018/12
2	State		Goa
3	District		South Goa
4	Toposheet No.	:	48I/07
5	Name of the slide	:	Anmod-Mollem Ghat road
6	NH/SH/Locality	:	NH-4A
7	Latitude	:	15°25'20.93"N
8	Longitude	:	74°16'46.06"E
9	Length	:	~17m
10	Width	:	~27m
11	Height	:	VH~7m
12	Area	:	--
13	Depth	:	--
14	Volume	:	--
15	Run out distance	:	--
16	Type of Material	:	Debris (Highly weatherd rock and soil)
17	Type of movement	:	Slump
18	Rate of movement	:	Very slow
19	Activity	:	Active
20	Distribution	:	Advancing/Progressive
21	Style	:	Single
22	Failure mechanism	:	Shallow translational failure
23	History	:	Old
24	Geomorphology	:	Lowly Dissected Slope
25	Geology/Lithology	:	Granite gneiss
26	Structure	:	No structure Distinct
27	Landuse/ Landcover	:	Thick vegetation
28	Hydrological condition	:	Damp
29	Triggering Factor	:	Rainfall
30	Death of persons	:	No casualties
31	People affected	:	No casualties
32	Livestock Loss	:	No casualties
33	Communication	:	No damage
34	Infrastructure	:	Not affected
35	Agriculture/forest/Barren	:	Forest
36	Geo-scientific Causes	:	Weathering and Erosion of vertical cut slope.
37	Remedial measures	:	Slope regradation/easing of slope required. The dislodged rock boulders should be removed.
38	Remarks, if any		At present the sliding zone is meta-stable.
39	Photos. Sketch of Plan & section of the slide	:	

			
40	Summary/Abstract	:	The debris slide occurred on lowly dissected hill slope on vertical cut slope. The slide is old and can get reactivated during monsoon. At present the area is stable.
41	Date of Reporting	:	23-11-2018
42	Landslide Category	:	I

No	Field		Description
1	Slide No.	:	KAR/BEL/2018/13
2	State	:	Karnataka
3	District	:	Belgaum
4	Toposheet No.	:	48I/07
5	Name of the slide	:	Anmod-Mollem Ghat road
6	NH/SH/Locality	:	NH-4A
7	Latitude	:	15°24'55.51"N
8	Longitude	:	74°16'48.06"E
9	Length	:	~14m
10	Width	:	~22m
11	Height	:	VH~7m
12	Area	:	--
13	Depth	:	--
14	Volume	:	--
15	Run out distance	:	--
16	Type of Material	:	Debris (Highly weatherd rock and soil)
17	Type of movement	:	Slide
18	Rate of movement	:	Very slow
19	Activity	:	Active
20	Distribution	:	Advancing/Progressive
21	Style	:	Single
22	Failure mechanism	:	Shallow translational failure
23	History	:	Old
24	Geomorphology	:	Lowly Dissected Slope
25	Geology/Lithology	:	Granite gneiss
26	Structure	:	No structure Distinct
27	Landuse/ Landcover	:	Thick vegetation
28	Hydrological condition	:	Damp
29	Triggering Factor	:	Rainfall
30	Death of persons	:	No casualties
31	People affected	:	No casualties
32	Livestock Loss	:	No casualties
33	Communication	:	No damage
34	Infrastructure	:	Not affected
35	Agriculture/forest/Barrren	:	Forest
36	Geo-scientific Causes	:	Weathering and Erosion on the vertical cut slope.
37	Remedial measures	:	Slope regradation/easing of slope required.
38	Remarks, if any	:	At present the sliding zone is meta-stable.

39	Photos. Sketch of Plan & section of the slide	:	
40	Summary/Abstract	:	The debris slide occurred on lowly dissected hill slope on vertical cut slope. The slide is old and can get reactivated during monsoon. At present the area is stable.
41	Date of Reporting	:	23-11-2018
42	Landslide Category	:	I

No	Field		Description
1	Slide No.	:	GOA/SG/2018/14
2	State	:	Goa
3	District		South Goa
4	Toposheet No.	:	48I/07
5	Name of the slide	:	Anmod-Mollem Ghat road
6	NH/SH/Locality	:	NH-4A
7	Latitude	:	15°25'7.31"N
8	Longitude	:	74°16'15.08"E
9	Length	:	~9m
10	Width	:	~18m
11	Height	:	~8m
12	Area	:	--
13	Depth	:	--
14	Volume	:	--
15	Run out distance	:	--
16	Type of Material	:	Debris cum rock slide
17	Type of movement	:	Slide
18	Rate of movement	:	Very slow
19	Activity	:	Suspended
20	Distribution	:	Confined
21	Style	:	Multiple
22	Failure mechanism	:	Shallow rotational failure
23	History	:	Old
24	Geomorphology	:	Lowly Dissected Slope
25	Geology/Lithology	:	Granite gneiss
26	Structure	:	No structure Distinct
27	Landuse/ Landcover	:	Thick vegetation
28	Hydrological condition	:	Dry
29	Triggering Factor	:	Rainfall
30	Death of persons	:	No casualties
31	People affected	:	No casualties
32	Livestock Loss	:	No casualties
33	Communication	:	No damage
34	Infrastructure	:	Not affected
35	Agriculture/forest/Barren	:	Forest
36	Geo-scientific Causes	:	Slope modification i.e. cutting of slope for road construction
37	Remedial measures	:	Lined drainage provided at toe part of hill slope.
38	Remarks, if any		If slope failure may occur during water saturation of slope during heavy rainfall. The road blockage and casualties may occur. Risk to communication line.

39	Photos. Sketch of Plan & section of the slide	:	
40	Summary/Abstract	:	The debris cum rock slide occurred on lowly dissected hill slope on vertical cut slope.
41	Date of Reporting	:	23-11-2018
42	Landslide Category	:	I

No	Field		Description
1	Slide No.	:	GOA/SG/2018/15
2	State	:	Goa
3	District	:	South Goa
4	Toposheet No.	:	48I/07
5	Name of the slide	:	Anmod-Mollem Ghat road
6	NH/SH/Locality	:	NH-4A
7	Latitude	:	15°25'1.36"N
8	Longitude	:	74°16'3.94"E
9	Length	:	~28m
10	Width	:	~72m
11	Height	:	VH~9m
12	Area	:	--
13	Depth	:	--
14	Volume	:	--
15	Run out distance	:	--
16	Type of Material	:	Debris cum rock
17	Type of movement	:	Slide
18	Rate of movement	:	Very slow
19	Activity	:	Suspended
20	Distribution	:	Retrogressive
21	Style	:	Single
22	Failure mechanism	:	Shallow translational failure
23	History	:	Old
24	Geomorphology	:	Lowly Dissected Slope
25	Geology/Lithology	:	Granite gneiss
26	Structure	:	No structure Distinct
27	Landuse/ Landcover	:	Thick vegetation
28	Hydrological condition	:	Dry
29	Triggering Factor	:	Rainfall
30	Death of persons	:	No casualties
31	People affected	:	No casualties
32	Livestock Loss	:	No casualties
33	Communication	:	No damage
34	Infrastructure	:	Not affected
35	Agriculture/forest/Barren	:	Forest
36	Geo-scientific Causes	:	Vertical cut slope failure along the fractured and jointed rock.
37	Remedial measures	:	Lined drainage should be provided to minimize toe erosion. Slope regradation/easing of slope are required. Dislodged precarious rock on top of hill slope should be removed.
38	Remarks, if any	:	The area is meta stable

39	Photos. Sketch of Plan & section of the slide	:	
40	Summary/Abstract	:	The debris cum rock slide occurred on the lowly dissected hill slope on ghat road section. The rock slide occurred due to intense weathering due to water seepage and saturation along the fracture and joints. The vertical cut slope failure is more intense during heavy rainfall. Vertical cut slope failure along the fractured and jointed rock.
41	Date of Reporting	:	23-11-2018
42	Landslide Category	:	I

Sr. No	Field		Description
1	Slide No.	:	GOA/SG/2018/16
2	State	:	Goa
3	District	:	South Goa
4	Toposheet No.	:	48I/07
5	Name of the slide	:	Anmod-Mollem Ghat road
6	NH/SH/Locality	:	NH-4A
7	Latitude	:	15°24'55.17"N
8	Longitude	:	74°16'2.19"E
9	Length	:	~10m
10	Width	:	~25m
11	Height	:	~12m
12	Area	:	--
13	Depth	:	--
14	Volume	:	--
15	Run out distance	:	--
16	Type of Material	:	Debris
17	Type of movement	:	Slide
18	Rate of movement	:	Extremely slow
19	Activity	:	Suspended
20	Distribution	:	Widening and Enlarging
21	Style	:	Single
22	Failure mechanism	:	Shallow translational failure
23	History	:	Old & Suspended
24	Geomorphology	:	Highly dissected slope
25	Geology/Lithology	:	Weathered Granite Gneiss
26	Structure	:	Indistinct
27	Landuse/ Landcover	:	Thick Vegetation
28	Hydrological condition	:	Dry
29	Triggering Factor	:	Rainfall
30	Death of persons	:	No casualties
31	People affected	:	Nil
32	Livestock Loss	:	Nil
33	Communication	:	No damage recorded
34	Infrastructure	:	No damage recorded
35	Agriculture/forest/Barren	:	Forest
36	Geo-scientific Causes	:	The water seepage and saturation on vertical cut slope leads to weathering and erosion. The loose material failed due to low cohesive strength of the slope forming material.
37	Remedial measures	:	Retaining wall of 3m height and 22 m width with weep holes were constructed to avoid toe erosion and to provide toe support.
38	Remarks, if any	:	The lined drainage should be extended upto the disturbed zone prone to slope failure.

39	Photos. Sketch of Plan & section of the slide	:	
40	Summary/Abstract	:	The debris slide is identified as shallow translational failure occurred on concave curve of highly dissected hillslope of ghat road (NH-4A). The upslope direction indicates the slide is progressive in nature and sliding surface is stabilized by providing proper drainage and toe support.
41	Date of Reporting	:	23-11-2018
42	Landslide Category	:	I

No	Field		Description
1	Slide No.	:	GOA/SG/2018/17
2	State	:	Goa
3	District	:	South Goa
4	Toposheet No.	:	48I/07
5	Name of the slide	:	Anmod-Mollem Ghat road
6	NH/SH/Locality	:	NH-4A
7	Latitude	:	15°24'51.60"N
8	Longitude	:	74°16'1.80"E
9	Length	:	~14m
10	Width	:	~30m
11	Height	:	VH~60m
12	Area	:	--
13	Depth	:	--
14	Volume	:	--
15	Run out distance	:	--
16	Type of Material	:	Debris
17	Type of movement	:	Slide
18	Rate of movement	:	Extremely slow
19	Activity	:	Active
20	Distribution	:	Widening and Enlarging
21	Style	:	Single
22	Failure mechanism	:	Shallow translational failure
23	History	:	New
24	Geomorphology	:	Highly dissected slope
25	Geology/Lithology	:	Granite Gneiss
26	Structure	:	Indistinct
27	Landuse/ Landcover	:	Moderate Vegetation
28	Hydrological condition	:	Dry
29	Triggering Factor	:	Rainfall
30	Death of persons	:	No casualties
31	People affected	:	Nil
32	Livestock Loss	:	Nil
33	Communication	:	No damage recorded
34	Infrastructure	:	No damage recorded
35	Agriculture/forest/Barren	:	Forest
36	Geo-scientific Causes	:	The water seepage and saturation on vertical cut slope leads to weathering and erosion. The loose material failed due to low cohesive strength of the slope forming material.
37	Remedial measures	:	In Down slope of road subsidence high height retaining wall/breast wall with weep holes should be constructed to provide toe support and proper drainage on slope.
38	Remarks, if any	:	Road subsidence occurred due to loading on upslope.

39	Photos. Sketch of Plan & section of the slide	:	
40	Summary/Abstract	:	The road subsidence has resulted in upslope and material slid in the downward direction. The high height breast wall with weep holes should be constructed for toe support with proper drainage. The subsidence of road occurred in convex curve of the road.
41	Date of Reporting	:	23-11-2018
42	Landslide Category	:	I

No	Field		Description
1	Slide No.	:	GOA/SG/2018/18
2	State	:	Goa
3	District	:	South Goa
4	Toposheet No.	:	48I/07
5	Name of the slide	:	Anmod-Mollem Ghat road
6	NH/SH/Locality	:	NH-4A
7	Latitude	:	15°24'44.30"N
8	Longitude	:	74°16'07.30"E
9	Length	:	~14m
10	Width	:	~30m
11	Height	:	VH~60m
12	Area	:	--
13	Depth	:	--
14	Volume	:	--
15	Run out distance	:	--
16	Type of Material	:	Debris
17	Type of movement	:	Slide
18	Rate of movement	:	Extremely slow
19	Activity	:	Suspended
20	Distribution	:	Widening and Enlarging
21	Style	:	Single
22	Failure mechanism	:	Shallow translational failure
23	History	:	New
24	Geomorphology	:	Highly dissected slope
25	Geology/Lithology	:	Granite Gneiss
26	Structure	:	Indistinct
27	Landuse/ Landcover	:	Moderate Vegetation
28	Hydrological condition	:	Dry
29	Triggering Factor	:	Rainfall
30	Death of persons	:	No casualties
31	People affected	:	Nil
32	Livestock Loss	:	Nil
33	Communication	:	No damage recorded
34	Infrastructure	:	No damage recorded
35	Agriculture/forest/Barren	:	Forest
36	Geo-scientific Causes	:	The water seepage and saturation on vertical cut slope leads to weathering and erosion. The loose material are likely to fail due to low cohesive strength of the slope forming material during heavy rainfall.
37	Remedial measures	:	Slope regradation is required.
38	Remarks, if any	:	At present the risk is Moderate.

39	Photos. Sketch of Plan & section of the slide	:	
40	Summary/Abstract	:	The road subsidence has resulted in upslope and material slided in the downward direction. The high height breast wall with weep holes should be constructed for toe support with proper drainage. The subsidence of road occurred in convex curve of the road.
41	Date of Reporting	:	23-11-2018
42	Landslide Category	:	I

No	Field		Description
1	Slide No.	:	GOA/SG/2018/19
2	State	:	Goa
3	District	:	South Goa
4	Toposheet No.	:	48I/07
5	Name of the slide	:	Anmod-Mollem Ghat road
6	NH/SH/Locality	:	NH-4A
7	Latitude	:	15°24'48.83"N
8	Longitude	:	74°16'1.02"E
9	Length	:	~10m
10	Width	:	~18m
11	Height	:	--
12	Area	:	--
13	Depth	:	--
14	Volume	:	--
15	Run out distance	:	--
16	Type of Material	:	Debris (Highly weatherd rock and soil)
17	Type of movement	:	Slide
18	Rate of movement	:	Very slow
19	Activity	:	Suspended
20	Distribution	:	Retrogressive and enlarging
21	Style	:	Single
22	Failure mechanism	:	Deep rotational failure
23	History	:	Old
24	Geomorphology	:	Lowly Dissected Slope
25	Geology/Lithology	:	Granite gneiss
26	Structure	:	No structure Distinct
27	Landuse/ Landcover	:	Dense Forest
28	Hydrological condition	:	Dry
29	Triggering Factor	:	Rainfall
30	Death of persons	:	No casualties
31	People affected	:	No casualties
32	Livestock Loss	:	No casualties
33	Communication	:	No damage
34	Infrastructure	:	Not affected
35	Agriculture/forest/Barren	:	Forest
36	Geo-scientific Causes	:	Intense weathering due to water seepage and saturation along the fracture and joints.
37	Remedial measures	:	Easing of slope required, lined drainage required for toe support.
38	Remarks, if any	:	If slope failure may occur during water saturation of slope during heavy rainfall. The road blockage and casualties may occur. Risk to communication line.
39	Photos. Sketch of Plan & section of the slide	:	

			
40	Summary/Abstract	:	The debris slide occurred on the lowly dissected hill slope on ghat road section. The rock slide occurred due to intense weathering due to water seepage and saturation along the fracture and joints. The vertical cut slope failure is more intense during heavy rainfall.
41	Date of Reporting	:	23-11-2018
42	Landslide Category	:	I

No	Field		Description
1	Slide No.	:	GOA/SG/2018/20
2	State	:	Goa
3	District	:	South Goa
4	Toposheet No.	:	48I/07
5	Name of the slide	:	Anmod-Mollem Ghat road
6	NH/SH/Locality	:	NH-4A
7	Latitude	:	15°24'46.97"N
8	Longitude	:	74°16'0.59 "E
9	Length	:	~12m
10	Width	:	~25m
11	Height	:	~11m
12	Area	:	--
13	Depth	:	--
14	Volume	:	--
15	Run out distance	:	--
16	Type of Material	:	Rock (Highly Weathered rock and Soil)
17	Type of movement	:	Slide
18	Rate of movement	:	Very slow
19	Activity	:	Suspended
20	Distribution	:	Retrogressive
21	Style	:	Single
22	Failure mechanism	:	Shallow translational failure
23	History	:	Old
24	Geomorphology	:	Lowly Dissected Slope
25	Geology/Lithology	:	Quartzite
26	Structure	:	No structure Distinct
27	Landuse/ Landcover	:	Dense Forest
28	Hydrological condition	:	Dry
29	Triggering Factor	:	Rainfall
30	Death of persons	:	No casualties
31	People affected	:	No casualties
32	Livestock Loss	:	No casualties
33	Communication	:	No damage
34	Infrastructure	:	Not affected
35	Agriculture/forest/ Barren	:	Forest
36	Geo-scientific Causes	:	Intense weathering due to water seepage and saturation along the fracture and joints.
37	Remedial measures	:	Slope regradation/easing of slope required. Dislodged precarious rock on top of hill slope should be removed.
38	Remarks, if any	:	If slope failure may occur during water saturation of slope during heavy rainfall. The road blockage and casualties may occur. Risk to communication line.
39	Photos. Sketch of	:	

	Plan & section of the slide		
40	Summary/Abstract	:	The rock slide occurred on the lowly dissected hill slope on ghat road section. The rock slide occurred due to intense weathering due to water seepage and saturation along the fracture and joints. The vertical cut slope failure is more intense during heavy rainfall.
41	Date of Reporting	:	23-11-2018
42	Landslide Category	:	I

No	Field		Description
1	Slide No.	:	GOA/SG/2018/21
2	State	:	Goa
3	District	:	South Goa
4	Toposheet No.	:	48I/07
5	Name of the slide	:	Anmod-Mollem Ghat road
6	NH/SH/Locality	:	NH-4A
7	Latitude	:	15°24'44.96 "N
8	Longitude	:	74°16'1.45"E
9	Length	:	~12m
10	Width	:	~25m
11	Height	:	~12m
12	Area	:	--
13	Depth	:	--
14	Volume	:	--
15	Run out distance	:	--
16	Type of Material	:	Rock cum debris
17	Type of movement	:	Slide
18	Rate of movement	:	Very slow
19	Activity	:	Suspended
20	Distribution	:	Retrogressive
21	Style	:	Multiple
22	Failure mechanism	:	Shallow translational failure
23	History	:	Old
24	Geomorphology	:	Lowly Dissected Slope
25	Geology/Lithology	:	Granite gneiss
26	Structure	:	No structure Distinct
27	Landuse/ Landcover	:	Dense Forest
28	Hydrological condition	:	Dry
29	Triggering Factor	:	Rainfall
30	Death of persons	:	No casualties
31	People affected	:	No casualties
32	Livestock Loss	:	No casualties
33	Communication	:	No damage
34	Infrastructure	:	Not affected
35	Agriculture/forest/Barren	:	Forest
36	Geo-scientific Causes	:	Road cut failure that induced weathering and erosion activity on the slopes.
37	Remedial measures	:	Lined drainage required.
38	Remarks, if any	:	If slope failure may occur during water saturation of slope during heavy rainfall. The road blockage and casualties may occur. Risk to communication line.
39	Photos. Sketch of Plan & section of the slide	:	

			
40	Summary/Abstract	:	The rock cum debris slide occurred on lowly dissected hillslope that has weathered. The slide is retrogressive in nature and the chances of landslips are more during heavy rainfall.
41	Date of Reporting	:	23-11-2018
42	Landslide Category	:	I



No	Field		Description
1	Slide No.	:	GOA/SG/2018/22
2	State	:	Goa
3	District	:	South Goa
4	Toposheet No.	:	48I/07
5	Name of the slide	:	Anmod-Mollem Ghat road
6	NH/SH/Locality	:	NH-4A
7	Latitude	:	15°24'43.90"N
8	Longitude	:	74°16'06.20"E
9	Length	:	~22m
10	Width	:	~75m
11	Height	:	~14m
12	Area	:	--
13	Depth	:	--
14	Volume	:	--
15	Run out distance	:	--
16	Type of Material	:	Rock (Weathered rock)
17	Type of movement	:	Slide
18	Rate of movement	:	Very slow
19	Activity	:	Suspended
20	Distribution	:	Confined
21	Style	:	Single
22	Failure mechanism	:	Shallow (<=5m) translational planar failure
23	History	:	Old
24	Geomorphology	:	Moderately Dissected Slope
25	Geology/Lithology	:	Granite Gneiss
26	Structure	:	Fractured and closely Jointed
27	Landuse/ Landcover	:	Dense Forest
28	Hydrological condition	:	Dry
29	Triggering Factor	:	Rainfall
30	Death of persons	:	No casualties
31	People affected	:	No casualties
32	Livestock Loss	:	No casualties
33	Communication	:	No damage
34	Infrastructure	:	Not affected
35	Agriculture/forest/Barren	:	Forest
36	Geo-scientific Causes	:	The slope modification leads to vertical road cut failure and weathering along the weaker planes.
37	Remedial measures	:	The lined drainage should be provided at the toe part.
38	Remarks, if any	:	At present the sliding zone is stable but the risk factor exist during the monsoon.
39	Photos. Sketch of Plan & section of the slide	:	

			
40	Summary/Abstract	:	The sliding zone is adjacent to the 1 st order stream. So, water seepage and saturation along the weaker plane along joints and fracture may lead to sliding of material.
41	Date of Reporting	:	05-01-2019
42	Landslide Category	:	I

No	Field		Description
1	Slide No.	:	GOA/SG/2018/23
2	State	:	Goa
3	District	:	South Goa
4	Toposheet No.	:	48I/07
5	Name of the slide	:	Anmod-Mollem Ghat road
6	NH/SH/Locality	:	NH-4A
7	Latitude	:	15°24'39.50"N
8	Longitude	:	74°16'12.50 "E
9	Length	:	~18m
10	Width	:	~45m
11	Height	:	VH~12m
12	Area	:	--
13	Depth	:	--
14	Volume	:	--
15	Run out distance	:	--
16	Type of Material	:	Rock cum debris (Highly weathered rock and soil)
17	Type of movement	:	Slide
18	Rate of movement	:	Very slow
19	Activity	:	Active, Widening and Enlarging
20	Distribution	:	Advancing/Progressive
21	Style	:	Single
22	Failure mechanism	:	Shallow (<=5m) translational failure
23	History	:	Old
24	Geomorphology	:	Lowly Dissected Slope
25	Geology/Lithology	:	Granite Gneiss
26	Structure	:	Jointed and fractured
27	Landuse/ Landcover	:	Thick vegetation
28	Hydrological condition	:	Damp
29	Triggering Factor	:	Rainfall
30	Death of persons	:	No casualties
31	People affected	:	No casualties
32	Livestock Loss	:	No casualties
33	Communication	:	No damage
34	Infrastructure	:	Not affected
35	Agriculture/forest/Barren	:	Forest
36	Geo-scientific Causes	:	The slope modification leads to vertical road cut failure and weathering along the weaker planes.
37	Remedial measures	:	The lined drainage should be provided at the toe part.
38	Remarks, if any	:	At present the sliding zone is stable but the risk factor exist during the monsoon.
39	Photos. Sketch of Plan & section of the slide	:	

			
40	Summary/Abstract	:	The sliding zone is adjacent to the 1 st order stream. So, water seepage and saturation along the weaker plane along joints and fracture may lead to sliding of material/planar failure.
41	Date of Reporting	:	05-01-2019
42	Landslide Category	:	I

No	Field		Description
1	Slide No.	:	GOA/SG/2018/24
2	State	:	Goa
3	District	:	South Goa
4	Toposheet No.	:	48I/07
5	Name of the slide	:	Anmod-Mollem Ghat road
6	NH/SH/Locality	:	NH-4A
7	Latitude	:	15°24'41.20"N
8	Longitude	:	74°16'3.80"E
9	Length	:	--
10	Width	:	~155m
11	Height	:	VH~16m
12	Area	:	--
13	Depth	:	--
14	Volume	:	--
15	Run out distance	:	--
16	Type of Material	:	Rock (Highly weathered rock and soil)
17	Type of movement	:	slide
18	Rate of movement	:	Very slow
19	Activity	:	Suspended
20	Distribution	:	Retrogressive
21	Style	:	Multiple
22	Failure mechanism	:	Shallow (<=5m) translational failure
23	History	:	Old
24	Geomorphology	:	Lowly Dissected Slope
25	Geology/Lithology	:	Granite Gneiss
26	Structure	:	Jointed and Fractured
27	Landuse/ Landcover	:	Dense Forest
28	Hydrological condition	:	Dry
29	Triggering Factor	:	Rainfall
30	Death of persons	:	No casualties
31	People affected	:	No casualties
32	Livestock Loss	:	No casualties
33	Communication	:	Risk to communication line
34	Infrastructure	:	Not affected
35	Agriculture/forest/Barren	:	Forest
36	Geo-scientific Causes	:	Slope modification i.e. cutting of slope for road construction. The fracture plane is dipping towards road, weathering and seepage along failure plane occurred along nala section.
37	Remedial measures	:	Lined drainage should be provided at the entire sliding zone and broken part should be repaired.
38	Remarks, if any	:	The successive multiple failure planes developed on the slope and during rainfall slope get saturated with water and resulted in low cohesive strength of slope forming material.

39	Photos. Sketch of Plan & section of the slide	:	
40	Summary/Abstract	:	The risk factor is high in this zone. The slope forming material is likely to slide during intense rainfall.
41	Date of Reporting	:	05-01-2019
42	Landslide Category	:	I

No	Field		Description
1	Slide No.	:	GOA/SG/2018/25
2	State	:	Goa
3	District	:	South Goa
4	Toposheet No.	:	48I/07
5	Name of the slide	:	Anmod-Mollem Ghat road
6	NH/SH/Locality	:	NH-4A
7	Latitude	:	15°24'40.60"N
8	Longitude	:	74°15'58.60"E
9	Length	:	~35m
10	Width	:	~75m
11	Height	:	VH~55m
12	Area	:	--
13	Depth	:	--
14	Volume	:	--
15	Run out distance	:	--
16	Type of Material	:	Rock cum debris
17	Type of movement	:	Slide
18	Rate of movement	:	Very slow
19	Activity	:	Suspended
20	Distribution	:	Retrogressive
21	Style	:	Single
22	Failure mechanism	:	Shallow translational failure
23	History	:	Old
24	Geomorphology	:	Highly Dissected Slope
25	Geology/Lithology	:	Granite gneiss
26	Structure	:	No structure Distinct
27	Landuse/ Landcover	:	Dense Forest
28	Hydrological condition	:	Damp
29	Triggering Factor	:	Rainfall
30	Death of persons	:	No casualties
31	People affected	:	No casualties
32	Livestock Loss	:	No casualties
33	Communication	:	No damage
34	Infrastructure	:	Not affected
35	Agriculture/forest/Barren	:	Forest
36	Geo-scientific Causes	:	Slope modification i.e. cutting of slope for road construction. The fracture plane is dipping towards road, weathering and seepage occurred along the weaker plane.
37	Remedial measures	:	Lined drainage at the toe part is required.
38	Remarks, if any	:	If slope failure may occur during water saturation of slope during heavy rainfall. The road blockage and casualties may occur. Risk to communication line.
39	Photos. Sketch of Plan & section of the slide	:	

			
40	Summary/Abstract	:	The rock cum debris slide occurred along the road cut slope. The weathered rock on slope is likely to failure during the heavy rainfall due to reduction in cohesive strength of the slope forming material due to over saturation of slope.
41	Date of Reporting	:	05-01-2019
42	Landslide Category	:	I

No	Field		Description
1	Slide No.	:	GOA/SG/2018/26
2	State	:	Goa
3	District	:	South Goa
4	Toposheet No.	:	48I/07
5	Name of the slide	:	Anmod-Mollem Ghat road
6	NH/SH/Locality	:	NH-4A
7	Latitude	:	15°24'39.40"N
8	Longitude	:	74°15'53.80"E
9	Length	:	~30m
10	Width	:	~25m
11	Height	:	VH~12m
12	Area	:	--
13	Depth	:	--
14	Volume	:	--
15	Run out distance	:	--
16	Type of Material	:	Rock cum debris
17	Type of movement	:	Slide
18	Rate of movement	:	Very slow
19	Activity	:	Suspended
20	Distribution	:	Retrogressive
21	Style	:	Single
22	Failure mechanism	:	Shallow (<=5m) translational failure
23	History	:	Old
24	Geomorphology	:	Lowly Dissected Slope
25	Geology/Lithology	:	Granite gneiss
26	Structure	:	No structure Distinct
27	Landuse/ Landcover	:	Thick vegetation
28	Hydrological condition	:	Dry nala
29	Triggering Factor	:	Rainfall
30	Death of persons	:	No casualties
31	People affected	:	No casualties
32	Livestock Loss	:	No casualties
33	Communication	:	No damage
34	Infrastructure	:	Not affected
35	Agriculture/forest/Barren	:	Forest
36	Geo-scientific Causes	:	Vertical road cut failure.
37	Remedial measures	:	Lined drainage at the toe part is required.
38	Remarks, if any	:	If slope failure may occur during water saturation of slope during heavy rainfall there is risk to communication line.

39	Photos. Sketch of Plan & section of the slide	:	
40	Summary/Abstract	:	The shallow translational rock cum debris slide occurred on the road cut that paved the new pathway for water seepage and saturation during heavy rainfall.
41	Date of Reporting	:	05-01-2019
42	Landslide Category	:	I

No	Field		Description
1	Slide No.	:	GOA/SG/2018/27
2	State	:	Goa
3	District	:	South Goa
4	Toposheet No.	:	48I/07
5	Name of the slide	:	Anmod-Mollem Ghat road
6	NH/SH/Locality	:	NH-4A
7	Latitude	:	15°24'39.40"N
8	Longitude	:	74°15'53.80"E
9	Length	:	~17m
10	Width	:	~35m
11	Height	:	VH~12m
12	Area	:	--
13	Depth	:	--
14	Volume	:	--
15	Run out distance	:	--
16	Type of Material	:	Debris
17	Type of movement	:	Slide
18	Rate of movement	:	Very slow
19	Activity	:	Suspended
20	Distribution	:	Retrogressive
21	Style	:	Single
22	Failure mechanism	:	Shallow (<=5m) translational failure
23	History	:	Old
24	Geomorphology	:	Lowly Dissected Slope
25	Geology/Lithology	:	Granite Gneiss
26	Structure	:	No structure Distinct
27	Landuse/ Landcover	:	Thick vegetation
28	Hydrological condition	:	Dry
29	Triggering Factor	:	Rainfall
30	Death of persons	:	No casualties
31	People affected	:	No casualties
32	Livestock Loss	:	No casualties
33	Communication	:	No damage
34	Infrastructure	:	Not affected
35	Agriculture/forest/Barren	:	Forest
36	Geo-scientific Causes	:	Vertical road cut failure.
37	Remedial measures	:	Slope gradation are suggested to minimise the alope failure. Lined drainage at the toe part is required for drainage.
38	Remarks, if any	:	If slope failure may occur during water saturation of slope during heavy rainfall there is risk to communication line.
39	Photos. Sketch of Plan & section of the slide	:	

			
40	Summary/Abstract	:	The shallow translational debris slide occurred on the road cut that paved the new pathway for water seepage and saturation during heavy rainfall.
41	Date of Reporting	:	05-01-2019
42	Landslide Category	:	I

No	Field		Description
1	Slide No.	:	GOA/SG/2018/28
2	State	:	Goa
3	District	:	South Goa
4	Toposheet No.	:	48I/07
5	Name of the slide	:	Anmod-Mollem Ghat road
6	NH/SH/Locality	:	NH-4A
7	Latitude	:	15°24'39.30"N
8	Longitude	:	74°15'48.60"E
9	Length	:	~35m
10	Width	:	~55m
11	Height	:	~15m
12	Area	:	--
13	Depth	:	--
14	Volume	:	--
15	Run out distance	:	--
16	Type of Material	:	Debris (Highly weathered rock and soil)
17	Type of movement	:	Slide
18	Rate of movement	:	Very slow
19	Activity	:	Suspended
20	Distribution	:	Progressive, Widening and Enlarging
21	Style	:	Single
22	Failure mechanism	:	Shallow (<=5m) translational failure
23	History	:	Old
24	Geomorphology	:	Highly Dissected Slope
25	Geology/Lithology	:	Granite Gneiss
26	Structure	:	No structure Distinct
27	Landuse/ Landcover	:	Thick vegetation
28	Hydrological condition	:	Damp
29	Triggering Factor	:	Rainfall
30	Death of persons	:	No casualties
31	People affected	:	No casualties
32	Livestock Loss	:	No casualties
33	Communication	:	No damage
34	Infrastructure	:	Not affected
35	Agriculture/forest/Barren	:	Forest
36	Geo-scientific Causes	:	Vertical road cut failure induced due to water seepage and saturation.
37	Remedial measures	:	1.50m high retaining wall with weep holes constructed upto 55m width.
38	Remarks, if any	:	Concrete lined drainage required at toe part. The drainage line should be extended upto 50m and more upto the disturbed zone.
39	Photos. Sketch of Plan & section of the slide	:	

			
40	Summary/Abstract	:	The shallow translational debris slide occurred on the road cut that paved the new pathway for water seepage and saturation during heavy rainfall.
41	Date of Reporting	:	05-01-2019
42	Landslide Category	:	I

No	Field		Description
1	Slide No.	:	GOA/SG/2018/29
2	State	:	Goa
3	District	:	South Goa
4	Toposheet No.	:	48I/07
5	Name of the slide	:	Anmod-Mollem Ghat road
6	NH/SH/Locality	:	NH-4A
7	Latitude	:	15°24'58.90"N
8	Longitude	:	74°15'43.70"E
9	Length	:	~17m
10	Width	:	~42m
11	Height	:	--
12	Area	:	--
13	Depth	:	--
14	Volume	:	--
15	Run out distance	:	--
16	Type of Material	:	Debris
17	Type of movement	:	Slide
18	Rate of movement	:	Very slow
19	Activity	:	Suspended
20	Distribution	:	Advancing
21	Style	:	Single
22	Failure mechanism	:	Shallow translational failure
23	History	:	Old
24	Geomorphology	:	Highly Dissected Slope
25	Geology/Lithology	:	Weathered Granite gneiss
26	Structure	:	No structure Distinct, highly weathered, fractured and jointed
27	Landuse/ Landcover	:	Dense Forest
28	Hydrological condition	:	Damp
29	Triggering Factor	:	Rainfall
30	Death of persons	:	No casualties
31	People affected	:	No casualties
32	Livestock Loss	:	No casualties
33	Communication	:	No damage
34	Infrastructure	:	Not affected
35	Agriculture/forest/Barren	:	Forest
36	Geo-scientific Causes	:	Seepage, weathering and erosion along fracture plane. Cut slope failure
37	Remedial measures	:	Vertical road cut failure induced due to water seepage and saturation.
38	Remarks, if any	:	The risk factor is low as the zone is stable.
39	Photos. Sketch of Plan & section of the slide	:	

			
40	Summary/Abstract	:	The sliding zone is in the convex curve of the ghat road section. At present the sliding zone is stable covered with dense vegetation.
41	Date of Reporting	:	05-01-2019
42	Landslide Category	:	I

No	Field		Description
1	Slide No.	:	GOA/SG/2018/30
2	State	:	Goa
3	District	:	South Goa
4	Toposheet No.	:	48I/07
5	Name of the slide	:	Anmod-Mollem Ghat road
6	NH/SH/Locality	:	NH-4A
7	Latitude	:	15°24'59.90"N
8	Longitude	:	74°15'39.70"E
9	Length	:	~17m
10	Width	:	~32m
11	Height	:	~13m
12	Area	:	--
13	Depth	:	--
14	Volume	:	--
15	Run out distance	:	--
16	Type of Material	:	Debris
17	Type of movement	:	Slide
18	Rate of movement	:	Very slow
19	Activity	:	Suspended
20	Distribution	:	Retrogressive
21	Style	:	Single
22	Failure mechanism	:	Shallow translational failure
23	History	:	Old
24	Geomorphology	:	Lowly Dissected Slope
25	Geology/Lithology	:	Granite gneiss
26	Structure	:	No structure Distinct
27	Landuse/ Landcover	:	Dense Forest
28	Hydrological condition	:	Dry
29	Triggering Factor	:	Rainfall
30	Death of persons	:	No casualties
31	People affected	:	No casualties
32	Livestock Loss	:	No casualties
33	Communication	:	No damage
34	Infrastructure	:	Not affected
35	Agriculture/forest/Barren	:	Forest
36	Geo-scientific Causes	:	The sliding zone is in the vicinity of 1st order stream/nala which has resulted in destabilization of slope due to weathering and erosion.
37	Remedial measures	:	Lined drainage should be provided at the toe part of the hillslope.
38	Remarks, if any	:	At present risk factor is moderate . Danger to electric pole nearby that can get damaged.
39	Photos. Sketch of Plan & section of the slide	:	

			
40	Summary/Abstract	:	The shallow translational debris slide occurred on the vertical road cut that can damage the communication line.
41	Date of Reporting	:	05-01-2019
42	Landslide Category	:	I

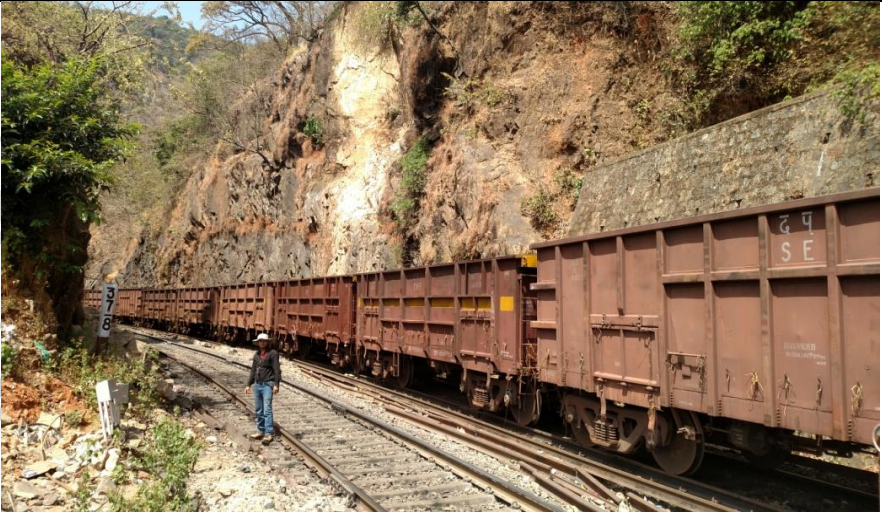
No	Field		Description
1	Slide No.	:	GOA/SG/2018/31
2	State	:	Goa
3	District	:	South Goa
4	Toposheet No.	:	48I/07
5	Name of the slide	:	Anmod-Mollem Ghat road
6	NH/SH/Locality	:	NH-4A
7	Latitude	:	15°24'59.30"N
8	Longitude	:	74°15'38.70"E
9	Length	:	~15m
10	Width	:	~28m
11	Height	:	VH~16m
12	Area	:	--
13	Depth	:	--
14	Volume	:	--
15	Run out distance	:	--
16	Type of Material	:	Debris
17	Type of movement	:	Slide
18	Rate of movement	:	Very slow
19	Activity	:	Suspended
20	Distribution	:	Retrogressive
21	Style	:	Successive
22	Failure mechanism	:	Shallow translational failure
23	History	:	Old
24	Geomorphology	:	Highly Dissected Slope
25	Geology/Lithology	:	Granite gneiss
26	Structure	:	No structure Distinct
27	Landuse/ Landcover	:	Moderate vegetation
28	Hydrological condition	:	Damp
29	Triggering Factor	:	Rainfall
30	Death of persons	:	No casualties
31	People affected	:	No casualties
32	Livestock Loss	:	No casualties
33	Communication	:	No damage
34	Infrastructure	:	Not affected
35	Agriculture/forest/Barren	:	Forest
36	Geo-scientific Causes	:	Two failures is along the nala section due to water seepage and saturation that has resulted in highly weathered zone.
37	Remedial measures	:	Lined drainage at toe part should be provided to avoid slope saturation and toe erosion.
38	Remarks, if any	:	At present the area can be demarcated as unstable zone.
39	Photos. Sketch of Plan & section of the slide	:	

			
40	Summary/Abstract	:	The shallow debris slide occurred due to weathering and erosion of the slope forming material. At present the zone is susceptible for landslips.
41	Date of Reporting	:	09-01-2019
42	Landslide Category	:	I

No	Field		Description
1	Slide No.	:	GOA/SG/2018/32
2	State	:	Goa
3	District	:	South Goa
4	Toposheet No.	:	48I/07
5	Name of the slide	:	Anmod-Mollem Ghat road
6	NH/SH/Locality	:	NH-4A
7	Latitude	:	15°24'48.60"N
8	Longitude	:	74°15'19.20"E
9	Length	:	~15m
10	Width	:	~112m
11	Height	:	~14m
12	Area	:	--
13	Depth	:	--
14	Volume	:	--
15	Run out distance	:	--
16	Type of Material	:	Debris
17	Type of movement	:	Slide
18	Rate of movement	:	Very slow
19	Activity	:	Suspended
20	Distribution	:	Retrogressive
21	Style	:	Multiple
22	Failure mechanism	:	Shallow translational failure
23	History	:	Old
24	Geomorphology	:	Highly Dissected Slope
25	Geology/Lithology	:	Granite Gneiss
26	Structure	:	No structure Distinct
27	Landuse/ Landcover	:	Dense vegetation
28	Hydrological condition	:	Damp
29	Triggering Factor	:	Rainfall
30	Death of persons	:	No casualties
31	People affected	:	No casualties
32	Livestock Loss	:	No casualties
33	Communication	:	No damage
34	Infrastructure	:	Not affected
35	Agriculture/forest/Barren	:	Forest
36	Geo-scientific Causes	:	Two Failure along nala section due to water saturation and weathering
37	Remedial measures	:	112 m wide Retaining wall with weep holes were constructed
38	Remarks, if any	:	Lined drainage should be extended upto 50m towards the slumping zone.
39	Photos. Sketch of Plan & section of the slide	:	

			 
40	Summary/Abstract	:	Multiple shallow debris slides occurred on highly dissected hill slope along NH-4A. The landslide is old, suspended and retrogressive in nature. The sliding material is in-situ soil (lateritic soil) and weathered rock covered with vegetation. The slide occurred on extensive cut slope made for road construction which got failed due to over water saturation of slope. The 2.5m high retaining wall with weep holes extending upto ~72m is constructed for providing toe support. The enlarging and widening disturbed zone indicated by debris slump in extension to present disturbed zone. So, the existing retaining wall should be extended upto the slumps.
41	Date of Reporting	:	09-01-2019
42	Landslide Category	:	I

No	Field		Description
1	Slide No.	:	GOA/SG/2018/33
2	State	:	Goa
3	District	:	South Goa
4	Toposheet No.	:	48I/07
5	Name of the slide	:	Dudhsagar landslide
6	NH/SH/Locality	:	Dudhsagar railway junction
7	Latitude	:	15°19'57.00"N
8	Longitude	:	74°18'22.80"E
9	Length	:	~17m
10	Width	:	~25m
11	Height	:	VH~22m
12	Area	:	--
13	Depth	:	--
14	Volume	:	--
15	Run out distance	:	--
16	Type of Material	:	Rock
17	Type of movement	:	Slide
18	Rate of movement	:	Moderate
19	Activity	:	Active
20	Distribution	:	Retrogressive
21	Style	:	Single
22	Failure mechanism	:	Shallow translational failure
23	History	:	New
24	Geomorphology	:	Highly dissected slope
25	Geology/Lithology	:	Granite
26	Structure	:	Jointed and fractured. Two sets of Joints trending NE-SW & NW-SE direction.
27	Landuse/ Landcover	:	Moderate vegetation
28	Hydrological condition	:	Damp
29	Triggering Factor	:	Rainfall
30	Death of persons	:	No casualties
31	People affected	:	Nil
32	Livestock Loss	:	Nil
33	Communication	:	Blockage of railway tract
34	Infrastructure	:	No damage
35	Agriculture/forest/Barren	:	Forest
36	Geo-scientific Causes	:	Vertical cut made for railway tract failed along the joints.
37	Remedial measures	:	The slope regradation is required. 7m high retaining wall with weep holes were constructed for toe support in near vicinity. The wire mesh with shotcrete is required for stabilization of slope.
38	Remarks, if any	:	The area is very unstable and the risk factor is very high.

39	Photos. Sketch of Plan & section of the slide	:	  
40	Summary/Abstract	:	The crown cracks were perfectly visible and the slope failure occurred along the cross cutting Vertical joint sets. The large chunks and boulders got dislodged along the failure plane. The zone is highly susceptible to landslide during heavy rainfall.
41	Date of Reporting	:	7-03-2019
42	Landslide Category	:	III

No	Field		Description
1	Slide No.	:	KAR/UK/2018/34
2	State	:	Karnataka
3	District	:	Uttar Kannada
4	Toposheet No.	:	48I/07
5	Name of the slide	:	Castle rock
6	NH/SH/Locality	:	Cstle rock railway junction
7	Latitude	:	15°23'55.51"N
8	Longitude	:	74°20'17.64"E
9	Length	:	~50m
10	Width	:	~110m
11	Height	:	~14m
12	Area	:	--
13	Depth	:	--
14	Volume	:	--
15	Run out distance	:	--
16	Type of Material	:	Debris
17	Type of movement	:	Slide
18	Rate of movement	:	Slow
19	Activity	:	Active
20	Distribution	:	Retrogressive
21	Style	:	Single
22	Failure mechanism	:	Shallow translational failure
23	History	:	Old and reactivated
24	Geomorphology	:	Lowly dissected slope
25	Geology/Lithology	:	Ferruginous phyllite
26	Structure	:	Not distinct
27	Landuse/ Landcover	:	Sparse vegetation
28	Hydrological condition	:	Damp
29	Triggering Factor	:	Rainfall
30	Death of persons	:	No casualties
31	People affected	:	Nil
32	Livestock Loss	:	Nil
33	Communication	:	Blockage of railway tract
34	Infrastructure	:	No damage
35	Agriculture/forest/Barren	:	Forest
36	Geo-scientific Causes	:	Vertical cut slope failed due to weathering induced by water saturation during rainfall.
37	Remedial measures	:	Gabion wall with wire mesh of dimension 113m width and 4.5m high constructed for toe support should be extended upto unstable zones.
38	Remarks, if any	:	The area is unstable

39	Photos. Sketch of Plan & section of the slide	:	
40	Summary/Abstract	:	At Castle rock railway line section, the debris slide of deep rotational failure are observed on extensive cut slope made on Lowly dissected hillslope for railway line extension are demarcated as Highly landslide susceptible zone. The slide is old, retrogressive in nature and can get reactivated during heavy rainfall. que i.e. The slope stablization techni low height gabion wallwith wire mess is constructedin successive benchesto provide toe support. And at lat/long: 15°23'52.85"N/74°20'10.87"E, the similar debris failure on vertical cut section is observed. The vertical cut section prone to slope failure is extending upto ~175m. The slope failure has occurred in successive benches made during slope gradation. The landslide is retrogressive, enlarging and widening in nature. The cutting of slopes and removal of soil transforms the slope and opens up new way for water seepage and runoff pattern during prolonged rainfall that destabilizes slope and leads to landslides/slope failures. The Ferruginous Phyllite of Joldal formation has undergone intense weathering and kaolinitization that triggers landslips. The existing gabion wall constructed at toe part need to be extended upto unstable zone and long term slope stability measures i.e. drainage trench on slopes should be provided to avoid soil slips.=
41	Date of Reporting	:	23-11-2018
42	Landslide Category	:	II

No	Field		Description
1	Slide No.	:	KAR/UK/2018/35
2	State	:	Karnataka
3	District	:	Uttar Kannada
4	Toposheet No.	:	48I/07
5	Name of the slide	:	Tadki-Kunang village
6	NH/SH/Locality	:	Tadki-Kunang road
7	Latitude	:	15°19'37.94"N
8	Longitude	:	74°22'49.33"E
9	Length	:	--
10	Width	:	
11	Height	:	
12	Area	:	--
13	Depth	:	--
14	Volume	:	--
15	Run out distance	:	--
16	Type of Material	:	Debris
17	Type of movement	:	Flow
18	Rate of movement	:	Extremely slow
19	Activity	:	Suspended
20	Distribution	:	Retrogressive
21	Style	:	Single
22	Failure mechanism	:	Shallow translational failure
23	History	:	Old
24	Geomorphology	:	Highly dissected slope
25	Geology/Lithology	:	Granite gneiss
26	Structure	:	Not distinct
27	Landuse/Landcover	:	Thick vegetation
28	Hydrological condition	:	Damp
29	Triggering Factor	:	Rainfall
30	Death of persons	:	No casualties
31	People affected	:	Nil
32	Livestock Loss	:	Nil
33	Communication	:	Blockage of railway tract
34	Infrastructure	:	No damage
35	Agriculture/forest/Barren	:	Forest
36	Geo-scientific Causes	:	The debris flow occurred due to gully erosion on upper catchment area on upslope direction and eroded the material along the nala section.
37	Remedial measures	:	Lined drainage with box culvert should be constructed for draining the flowing water diverted to suitable location as remedial measures to prevent road damage and water seepage and slope saturation.
38	Remarks, if any	:	The ground evidence indicates the debris flow along the nala course brought the debris in downslope direction, however at present the stream is dry but can get reactivated during monsoon
39	Photos. Sketch of Plan & section of the slide	:	

			
40	Summary/Abstract	:	Long: 15°19'37.94"N/74°22'49.33"E nearly 400 m North of Tadki village areas old, suspended palaeo-debris flow recorded along natural course of stream occurring on lowly dissected hill slope with slope angle varies between 25°-35°. The litho-units have undergone intense lateritization and weathering. The ground evidence indicates the debris flow along the nala course brought the debris in downslope direction, however at present the stream is dry but can get reactivated during monsoon. The poor drainage at road bench level resulted in road subsidence. So, lined drainage with box culvert should be constructed for draining the flowing water diverted to suitable location as remedial measures to prevent road damage and water seepage and slope saturation.
41	Date of Reporting	:	23-11-2018
42	Landslide Category	:	I

No	Field		Description
1	Slide No.	:	KAR/UK/2018/36
2	State	:	Karnataka
3	District	:	Uttar Kannada
4	Toposheet No.	:	48I/07
5	Name of the slide	:	Tadki-Kunang village
6	NH/SH/Locality	:	Tadki-Kunang road
7	Latitude	:	15°19'29.43"N
8	Longitude	:	74°22'56.90"E
9	Length	:	~18m
10	Width	:	~28m
11	Height	:	~VH: 21m, Crown height: 2.5m
12	Area	:	--
13	Depth	:	--
14	Volume	:	--
15	Run out distance	:	~35m
16	Type of Material	:	Debris (Weathered rock)
17	Type of movement	:	Slide
18	Rate of movement	:	Very slow
19	Activity	:	Active
20	Distribution	:	Confined
21	Style	:	Single
22	Failure mechanism	:	Shallow (≤ 5 m) translational failure
23	History	:	Old
24	Geomorphology	:	Lowly Dissected Slope
25	Geology/Lithology	:	Granite Gneiss
26	Structure	:	Not distinct
27	Landuse/ Landcover	:	Dense Forest
28	Hydrological condition	:	Damp
29	Triggering Factor	:	Rainfall
30	Death of persons	:	No casualties
31	People affected	:	No casualties
32	Livestock Loss	:	No casualties
33	Communication	:	No damage
34	Infrastructure	:	Not affected
35	Agriculture/forest/Barren	:	Forest
36	Geo-scientific Causes	:	Vertical road cut failure due to weathering and water saturation from upper catchment area.
37	Remedial measures	:	Lined drainage and slope regradation required.
38	Remarks, if any	:	The precarious lateritic boulders should be removed.

39	Photos. Sketch of Plan & section of the slide	:	
40	Summary/Abstract	:	The old and suspended shallow debris slide of retrogressive in nature are recorded on lowly dissected hill slope with slope angle varies between 25°-35°. The scars of landslide and crown cracks are prominent, and precarious rock boulders were hanging on top. The adjoining area is damp and quite unstable. The causative factor for slope failure is prolonged water seepage and saturation from higher order stream from upper catchment adjoining supra reservoir that resulted in intense lateritization and weathering of litho-units.
41	Date of Reporting	:	23-11-2018
42	Landslide Category	:	I

No	Field		Description
1	Slide No.	:	KAR/UK/2018/37
2	State	:	Karnataka
3	District		Uttar Kannada
4	Toposheet No.	:	48I/07
5	Name of the slide	:	Kuvesi village
6	NH/SH/Locality	:	Kuveshi road section
7	Latitude	:	15°20'51.60"N
8	Longitude	:	74°20'55.60"E
9	Length	:	~14m
10	Width	:	~28m
11	Height	:	~8m
12	Area	:	--
13	Depth	:	--
14	Volume	:	--
15	Run out distance	:	--
16	Type of Material	:	Debris
17	Type of movement	:	Slide
18	Rate of movement	:	Very slow
19	Activity	:	Suspended
20	Distribution	:	Retrogressive
21	Style	:	Single
22	Failure mechanism	:	Shallow translational failure
23	History	:	Old
24	Geomorphology	:	Lowly dissected hill slope
25	Geology/Lithology	:	Granite gneiss
26	Structure	:	Not distinct
27	Landuse/ Landcover	:	Sparse vegetation
28	Hydrological condition	:	Damp
29	Triggering Factor	:	rainfall
30	Death of persons	:	No casualties
31	People affected	:	No casualties
32	Livestock Loss	:	No casualties
33	Communication	:	No damage
34	Infrastructure	:	Not affected
35	Agriculture/forest/Barren	:	Forest
36	Geo-scientific Causes	:	Vertical cut slope failure along the 1st order nala due to intense weathering
37	Remedial measures	:	Slope regradation and plantation on slope ie required.
38	Remarks, if any		Adjacent to 1 st order drainage, loose hanging lateritic boulders should be removed.

39	Photos. Sketch of Plan & section of the slide	:	
40	Summary/Abstract	:	The slide is retrogressive in nature , the lateritization indicates the water saturation, weathering and erosion of slope forming material along the 1st order nala that saturated the slope during the monsoon along the weaker section along the nala.
41	Date of Reporting	:	23-11-2018
42	Landslide Category	:	I

No	Field		Description
1	Slide No.	:	KAR/UK/2018/38
2	State	:	Karnataka
3	District	:	Uttar Kannada
4	Toposheet No.	:	48I/07
5	Name of the slide	:	Aldur village
6	NH/SH/Locality	:	Aldur village
7	Latitude	:	15°15'47.30"N
8	Longitude	:	74°19'59.70"E
9	Length	:	~17m
10	Width	:	~28m
11	Height	:	VH~12m
12	Area	:	--
13	Depth	:	--
14	Volume	:	--
15	Run out distance	:	--
16	Type of Material	:	Debris
17	Type of movement	:	Slide
18	Rate of movement	:	Very slow
19	Activity	:	Suspended
20	Distribution	:	Progressive
21	Style	:	Single
22	Failure mechanism	:	Shallow translational failure
23	History	:	Old
24	Geomorphology	:	Lowly dissected hill slope
25	Geology/Lithology	:	Ferruginous phyllite
26	Structure	:	Not distinct
27	Landuse/ Landcover	:	Sparse vegetation
28	Hydrological condition	:	Damp
29	Triggering Factor	:	rainfall
30	Death of persons	:	No casualties
31	People affected	:	No casualties
32	Livestock Loss	:	No casualties
33	Communication	:	No damage
34	Infrastructure	:	Not affected
35	Agriculture/forest/Barren	:	Forest
36	Geo-scientific Causes	:	slope failure along the 1st order nala due to intense weathering
37	Remedial measures	:	Lined drainage at toe part is required to avoid toe erosion.
38	Remarks, if any	:	Adjacent to 1 st order drainage the area has undergone intense weathering and erosion.

39	Photos. Sketch of Plan & section of the slide	:	
40	Summary/Abstract	:	The slide is retrogressive in nature; the lateritization indicates the water saturation, weathering and erosion of slope forming material along the 1st order nala that saturated the slope during the monsoon along the weaker section along the nala.
41	Date of Reporting	:	18-02-2019
42	Landslide Category	:	I

Tabular matrices for LOFS and consistency ratio calculations for six factor maps

Table 15: Slope angle classes with LOFS rating

I. Pair-wise comparison matrix of Slope Angle classes

Slope Angle	<15°	15-25°	25°-35°	35°-45°	>45°
<15°	1.00	0.33	0.14	0.20	1.00
15°-25°	3.00	1.00	0.20	0.33	3.00
25°-35°	7.00	5.00	1.00	3.00	7.00
35°-45°	5.00	3.00	0.33	1.00	5.00
>45°	1.00	0.33	0.14	0.20	1.00
Cumulative Sum	17.00	9.67	1.82	4.73	17.00

II. LOFS rating for Slope Angle class

Slope Angle	<15°	15-25°	25-35°	35-45°	>45°	Sum	Frac. Rate	LOFS rating
<15°	0.05882	0.034483	0.078534	0.042254	0.058824	0.272917	0.054583	0.1081
15-25°	0.17647	0.103448	0.109948	0.070423	0.176471	0.63676	0.127352	0.2523
25-35°	0.41176	0.517241	0.549738	0.633803	0.411765	2.524312	0.504862	1.0000
35-45°	0.29412	0.310345	0.183246	0.211268	0.294118	1.293094	0.258619	0.5123
>45°	0.05882	0.034483	0.078534	0.042254	0.058824	0.272917	0.054583	0.1081

Slope Angle class	Rank	LOFS Rating
<15°	2	0.1081
15°-25°	4	0.2523
25°-35°	8	1.0000
35°-45°	6	0.5123
>45°	2	0.1081

Tabular matrices for LOFS and consistency ratio calculations for six factor maps

Table 16: Slope Curvature classes with LOFS rating

I. Pair-wise comparison matrix of Slope Curvature classes

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
Cumulative Sum	4.33	9.00	1.53

II. LOFS rating for Slope Curvature classes

Curvature	Concave	Flat	Convex	Sum rows	Frac. rate	LOFS Rating
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

CLASS	Rank	LOFS Rating
Concave	4	0.4113
Flat	2	0.1676
Convex	6	1.0000

Tabular matrices for LOFS and consistency ratio calculations for six factor maps

Table 17: Landuse and Landcover classes with LOFS rating

I. Pair-wise comparison matrix of Landuse-Landcover classes

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

II. LOFS rating for Landuse-Landcover classes

LU /LC	B	CL	ESC	FL	MV	HHP	LHP	QR	S	SM	TV	SV	Sum rows	Frac rate	LOFS
B	0.020408	0.012987	0.037022	0.020408	0.013172	0.011583	0.011299	0.012917	0.020408	0.02052	0.011583	0.02052	0.212828	0.017736	0.0626
CL	0.040816	0.025974	0.04165	0.040816	0.016465	0.015444	0.016949	0.016146	0.040816	0.02394	0.015444	0.02394	0.318402	0.026533	0.0937
ESC	0.183673	0.207792	0.333201	0.183673	0.329308	0.277992	0.237288	0.322928	0.183673	0.430917	0.277992	0.430917	3.399356	0.28328	1.0000
FL	0.020408	0.012987	0.037022	0.020408	0.013172	0.011583	0.011299	0.012917	0.020408	0.02052	0.011583	0.02052	0.212828	0.017736	0.0626
MV	0.102041	0.103896	0.06664	0.102041	0.065862	0.092664	0.101695	0.064586	0.102041	0.04788	0.092664	0.04788	0.989888	0.082491	0.2912

Tabular matrices for LOFS and consistency ratio calculations for six factor maps

LU /LC	B	CL	ESC	FL	MV	HHP	LHP	QR	S	SM	TV	SV	Sum rows	Frac rate	LOFS
HHP	0.081633	0.077922	0.055534	0.081633	0.032931	0.046332	0.067797	0.032293	0.081633	0.03591	0.046332	0.03591	0.675857	0.056321	0.1988
LHP	0.061224	0.051948	0.0476	0.061224	0.021954	0.023166	0.033898	0.021529	0.061224	0.028728	0.023166	0.028728	0.46439	0.038699	0.1366
QR	0.102041	0.103896	0.06664	0.102041	0.065862	0.092664	0.101695	0.064586	0.102041	0.04788	0.092664	0.04788	0.989888	0.082491	0.2912
S	0.020408	0.012987	0.037022	0.020408	0.013172	0.011583	0.011299	0.032293	0.020408	0.02052	0.011583	0.02052	0.232204	0.01935	0.0683
SM	0.142857	0.155844	0.111067	0.142857	0.197585	0.185328	0.169492	0.193757	0.142857	0.143639	0.185328	0.143639	1.91425	0.159521	0.5631
TV	0.081633	0.077922	0.055534	0.081633	0.032931	0.046332	0.067797	0.032293	0.081633	0.03591	0.046332	0.03591	0.675857	0.056321	0.1988
SV	0.142857	0.155844	0.111067	0.142857	0.197585	0.185328	0.169492	0.193757	0.142857	0.143639	0.185328	0.143639	1.91425	0.159521	0.5631

CLASS	Rank	LOFS Rating
Barren	1	0.0626
Barren Sand	0	0.0000
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
Salt Pan	0	0.0000

Tabular matrices for LOFS and consistency ratio calculations for six factor maps

Table 18: Geomorphology classes with LOFS rating

I. Pair-wise comparison matrix of Landuse-Landcover classes

CLASS	DS	ESC	MOUND	CFS	LDS	MDS	HDS	PIED SLOPE
DS	1	8	8	7	6	4	2	6
ESC	0.125	1	1	0.5	0.333333333	0.2	0.142857143	0.333333333
MOUND	0.125	1	1	0.5	0.333333333	0.2	0.142857143	0.333333333
CFS	0.142857143	2	2	1	0.5	0.25	0.166666667	0.5
LDS	0.166666667	3	3	2	1	0.333333333	0.2	1
MDS	0.25	5	5	4	3	1	0.333333333	3
HDS	0.5	7	7	6	5	3	1	5
PIED SLOPE	0.166666667	3	3	2	1	0.333333333	0.2	1
Sum total	2.476190476	30	30	23	17.16666667	9.316666667	4.185714286	17.16666667

II. LOFS rating for Geomorphology classes

CLASS	DS	ESC	MOUND	CFS	LDS	MDS	HDS	PIED SLOPE	Sum Rows	Frac rate	LOFS
DS	0.403846154	0.266667	0.266666667	0.30435	0.349514563	0.429338104	0.4778157	0.34951456	2.8477102	0.35596	1
ESC	0.050480769	0.033333	0.033333333	0.02174	0.019417476	0.021466905	0.034129693	0.01941748	0.2333181	0.02916	0.08193
MOUND	0.050480769	0.033333	0.033333333	0.02174	0.019417476	0.021466905	0.034129693	0.01941748	0.2333181	0.02916	0.08193
CFS	0.057692308	0.066667	0.066666667	0.04348	0.029126214	0.026833631	0.039817975	0.02912621	0.3594079	0.04493	0.12621
LDS	0.067307692	0.1	0.1	0.08696	0.058252427	0.035778175	0.04778157	0.05825243	0.5543288	0.06929	0.19466
MDS	0.100961538	0.166667	0.166666667	0.17391	0.174757282	0.107334526	0.07963595	0.17475728	1.144693	0.14309	0.40197
HDS	0.201923077	0.233333	0.233333333	0.26087	0.291262136	0.322003578	0.23890785	0.29126214	2.072895	0.25911	0.72792
PIED SLOPE	0.067307692	0.1	0.1	0.08696	0.058252427	0.035778175	0.04778157	0.05825243	0.5543288	0.06929	0.19466

Tabular matrices for LOFS and consistency ratio calculations for six factor maps

GEOMORPHOLOGY CLASSES	Rank	LOFS Rating
Denudational Slope (DS)	9	1
Escarpment(ESC)	2	0.0819
Mound	2	0.0819
Colluvial Footslope (CFS)	3	0.1262
Lowly Dissected Slope (LDS)	4	0.1947
Moderately Dissected Slope (MDS)	6	0.402
Highly Dissected Slope (HDS)	8	0.7279
Piedmont Slope (PIED SLOPE)	4	0.1947
Ridge-top	0	0
Tidal Flat	0	0
Water body	0	0
Plateau Top (Flat)	0	0
Rolling Plain	0	0
Valley Fill	0	0
Alluvial Plain	0	0
Beach	0	0
Coastal Plain	0	0
Pediment-Pediplain Complex	0	0
Hilltop	0	0

Tabular matrices for LOFS and consistency ratio calculations for six factor maps

Table 19: Slope Forming Material map with LOFS rating

I. Pair-wise comparison matrix of Slope Curvature classes

SFM CLASSES	CSD	INSITU	COL	LSD	R (Type-1)	R (Type-2)	R (Type-3)	TS	WR
CSD	1	0.5	0.333333	0.166667	3	2	0.5	1	0.25
INSITU	2	1	0.5	0.2	4	3	1	2	0.333333
COL	3	2	1	0.25	5	4	2	3	0.5
LSD	6	5	4	1	8	7	5	6	3
R(Type-1)	0.333333	0.25	0.2	0.125	1	0.5	0.25	0.333333333	0.166667
R(Type-2)	0.5	0.333333	0.25	0.142857	2	1	0.333333333	0.5	0.2
R(Type-3)	2	1	0.5	0.2	4	3	1	2	0.333333
TS	1	0.5	0.333333	0.166667	3	2	0.5	1	0.25
WR	4	3	2	0.333333	6	5	3	4	1
SUM	19.83333	13.58333	9.116667	2.584524	36	27.5	13.58333333	19.83333333	6.033333

II. LOFS rating for Slope Forming Material classes

SFM CLASSES	CSD	INSITU	COL	LSD	R(Type-1)	R(Type-2)	R(Type-3)	TS	WR	Sum Rows	Frac rate	LOFS
CSD	0.05042	0.03681	0.036563	0.064486	0.083333333	0.072727273	0.036809816	0.050420168	0.041436	0.473006521	0.052556	0.150594949
INSITU	0.10084	0.07362	0.054845	0.077384	0.111111111	0.109090909	0.073619632	0.100840336	0.055249	0.756598876	0.084067	0.240884562
COL	0.151261	0.147239	0.109689	0.09673	0.138888889	0.145454545	0.147239264	0.151260504	0.082873	1.17063473	0.130071	0.372704538
LSD	0.302521	0.368098	0.438757	0.386918	0.222222222	0.254545455	0.36809816	0.302521008	0.497238	3.140918908	0.348991	1
R(Type-1)	0.016807	0.018405	0.021938	0.048365	0.027777778	0.018181818	0.018404908	0.016806723	0.027624	0.214309818	0.023812	0.068231567
R(Type-2)	0.02521	0.02454	0.027422	0.055274	0.055555556	0.036363636	0.024539877	0.025210084	0.033149	0.307264657	0.034141	0.097826358
R(Type-3)	0.10084	0.07362	0.054845	0.077384	0.111111111	0.109090909	0.073619632	0.100840336	0.055249	0.756598876	0.084067	0.240884562
TS	0.05042	0.03681	0.036563	0.064486	0.083333333	0.072727273	0.036809816	0.050420168	0.041436	0.473006521	0.052556	0.150594949
WR	0.201681	0.220859	0.219378	0.128973	0.166666667	0.181818182	0.220858896	0.201680672	0.165746	1.707661092	0.18974	0.543682006

Tabular matrices for LOFS and consistency ratio calculations for six factor maps

CLASS	Rank	LOFS
In-situ soil	4	0.2409
Banded magnetite quartzite	1	0.0682
Granite	1	0.0682
Granite gneiss	1	0.0682
Quartzite	1	0.0682
Quartz vein	1	0.0682
Ultramafite	1	0.0682
Dolerite	1	0.0682
Granitoid	1	0.0682
Meta-dolerite	1	0.0682
Epidiorite	1	0.0682
Gabbro	1	0.0682
Metabasalt	1	0.0682
Metagabbro	1	0.2409
Quartz porphyry	1	0.2409
Calcrete	2	0.2409
Conglomerate	2	0.2409
Transported Soil	3	0.1506
Weathered Rock	6	0.5437
Water body	0	0.0000
River	0	0.0000
Laterite	4	0.2409
Amphibolite	4	0.2409
Metapyroxenite	4	0.2409
Pyroxene granulite	4	0.2409
Carbonaceous phyllite	4	0.2409
Ferruginous phyllite	4	0.2409
Quartz-chlorite schist	4	0.2409

Tabular matrices for LOFS and consistency ratio calculations for six factor maps

Table 20: Regolith Thickness classes with LOFS rating

I. Pair-wise comparison matrix of Regolith Thickness classes

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
Sun Cumulative	1.42	5.33	10.00

II. LOFS rating for Regolith Thickness classes

Regolith Thickness	0.5 - 5 m	5 - 10 m	>10 m	Sum rows	Frac rate	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

Regolith Thickness classes (in mts)	Rank	LOFS Rating
<0.5m	0	0
0.5-5m	7	1
5-10m	4	0.322961
>10m	2	0.136266

Tabular matrices for LOFS and consistency ratio calculations for six factor maps

Table 21: Table showing Pair-wise comparison matrix of individual geofactor maps and weights.

Factor	Slope	Curvature	SFM	LULC	Geom	RT	Factor Classes	Rank
Slope	1.00	6.00	0.33	2.00	5.00	3.00	Slope	7
Curvature	0.17	1.00	0.13	0.20	0.50	0.25	Curvature	2
SFM	3.00	8.00	1.00	4.00	7.00	5.00	SFM	9
LULC	0.50	5.00	0.25	1.00	4.00	2.00	LULC	6
Geom	0.20	2.00	0.14	0.25	1.00	0.33	Geomorphology	3
RT	0.33	4.00	0.20	0.50	3.00	1.00	Regolith Thickness	5
Sum Cumulative	5.20	26.00	2.05	7.95	20.50	11.58		

Factor	Slope	Curvature	SFM	LULC	Geom	RT	Sum rows	Frac rate	Weight	Weight WN
Slope	0.19231	0.23077	0.16098	0.25157	0.24390	0.25907	1.33859	0.2230991	6.5073541	7
Curvature	0.03269	0.03846	0.06341	0.02516	0.02439	0.02159	0.20570	0.0342842	1	1
SFM	0.57692	0.30769	0.48780	0.50314	0.34146	0.43178	2.64881	0.4414679	12.876734	13
LULC	0.09615	0.19231	0.12195	0.12579	0.19512	0.17271	0.90403	0.1506721	4.3948026	4
Geom	0.03846	0.07692	0.06829	0.03145	0.04878	0.02850	0.29240	0.0487336	1.4214622	1
RT	0.06346	0.15385	0.09756	0.06289	0.14634	0.08636	0.61046	0.1017432	2.9676444	3

Factor	Slope	Curvature	SFM	LULC	Geom	RT	Sum rows	CV
Slope	0.223099109	0.205704903	0.1456844	0.3013441	0.2436681	0.3052295	1.4247302	6.3860863
Curvature	0.037926849	0.034284151	0.0573908	0.0301344	0.0243668	0.0254358	0.2095388	6.1118283
SFM	0.669297328	0.274273204	0.4414679	0.6026883	0.3411354	0.5087158	2.8375779	6.4275977
LULC	0.111549555	0.171420753	0.110367	0.1506721	0.1949345	0.2034863	0.9424302	6.254843
Geom	0.044619822	0.068568301	0.0618055	0.037668	0.0487336	0.0335752	0.2949705	6.0527105
RT	0.073622706	0.137136602	0.0882936	0.075336	0.1462009	0.1017432	0.622333	6.1167052
							Sum CV	37.349771

Rainguage Stations	Lat	Long	Annual Rainfall (in mm)										
			2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
KHANAPUR	15.64	74.517	2193.4	2329.6	1906.2	1746.8	1393.5	1816.5	1812.5	1346.7	1487	1594	1259.7
VALPOLI	15.531	74.14	4640.8	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	3776.2	3947.8	4774.8	4874.8	3177.7	4148.3	4483.3	4295.3	3842.5	3529.9	2175
SIRSI	14.618	74.835	1887.3	2644.2	2431.1	2942.7	2095.6	2641	2378.9	1972.48	1951.26	2299	2968.2
HALIYAL	15.325	74.767	1224.7	1472	1285.4	1368.4	950.6	1245	1249	802.54	726.3	954.76	1237.75
SUPA	15.172	74.488	2308.3	3747	2488.7	2732.41	1749.7	2573.4	2450.2	1998.06	2279.27	2581.52	3232.64
BELAGAVI	15.816	74.415	1326.9	1464.7	1119.9	1147.5	839	992.5	1278	715.4	850	767	1326.9

FIELD PHOTOGRAPHS

Photo1A



Photo1B



Photo 1A Field Photographs showing Highly Dissected Hillslope ghat road hill range
Photo 1B: Lowly dissected hillslope along Khanapur-Jamboti ghat section

Photo 2



Photo2: Pediment Pediplain complex along Khanapur-Jamboti ghat section

Photo 3



Photo3: Field Photographs showing Extensive Cut Slope along Anmod-mollem Ghat road NH-4A

FIELD PHOTOGRAPHS

Photo 4

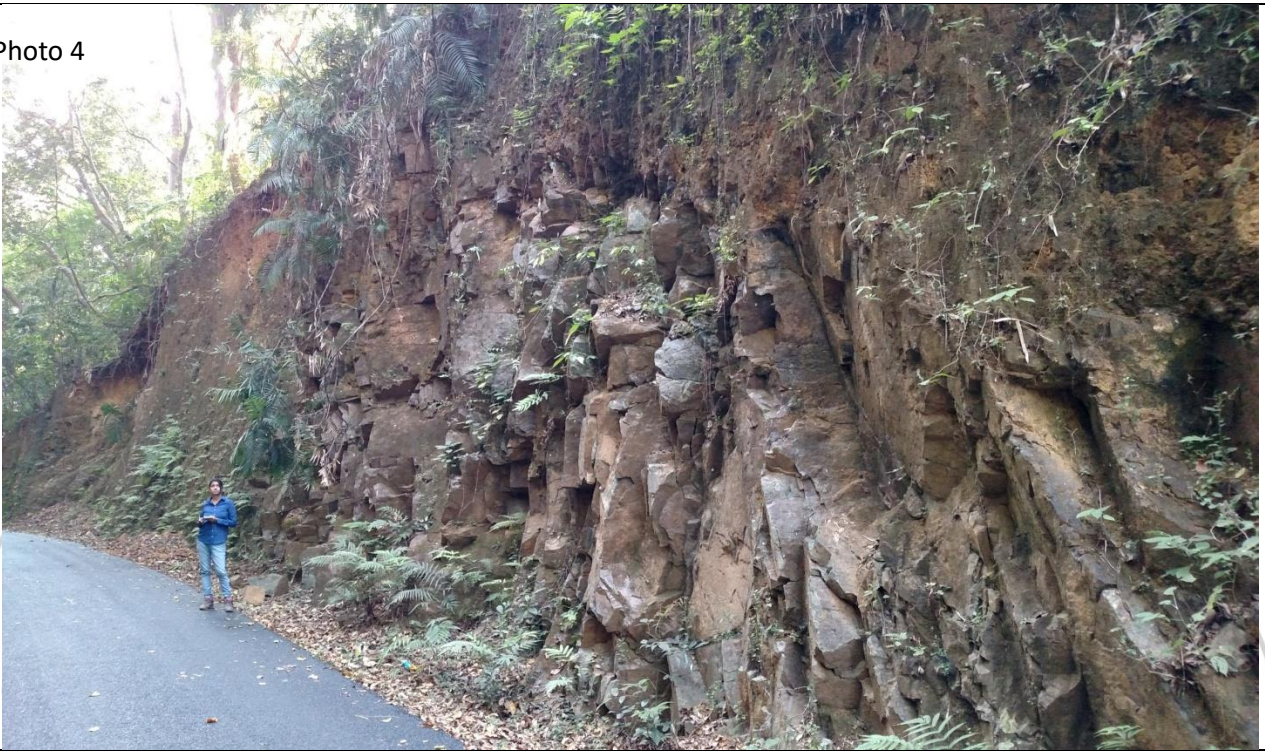
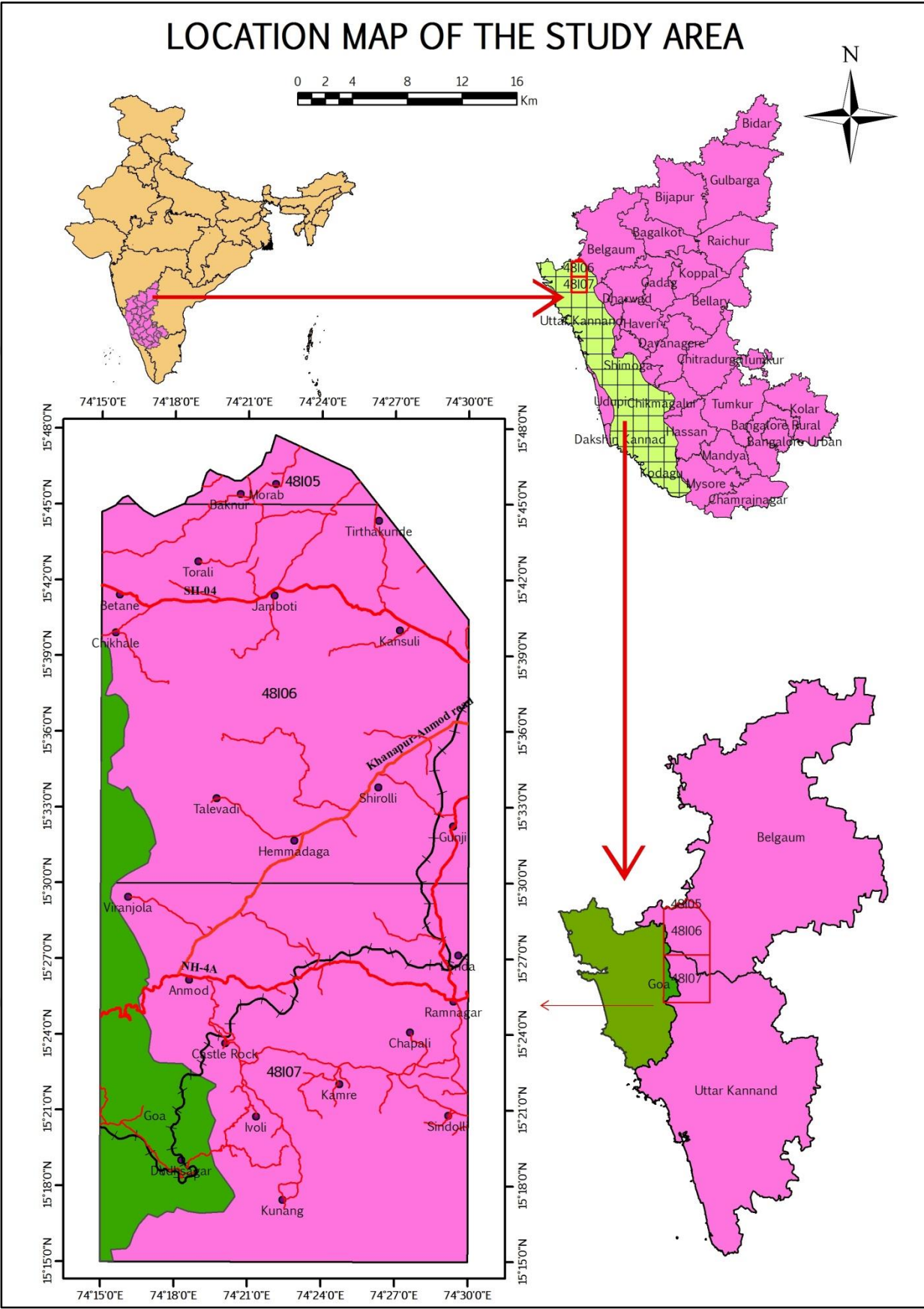


Photo 4: Field Photographs showing Extensive Cut Slope along the metallised Anmod road

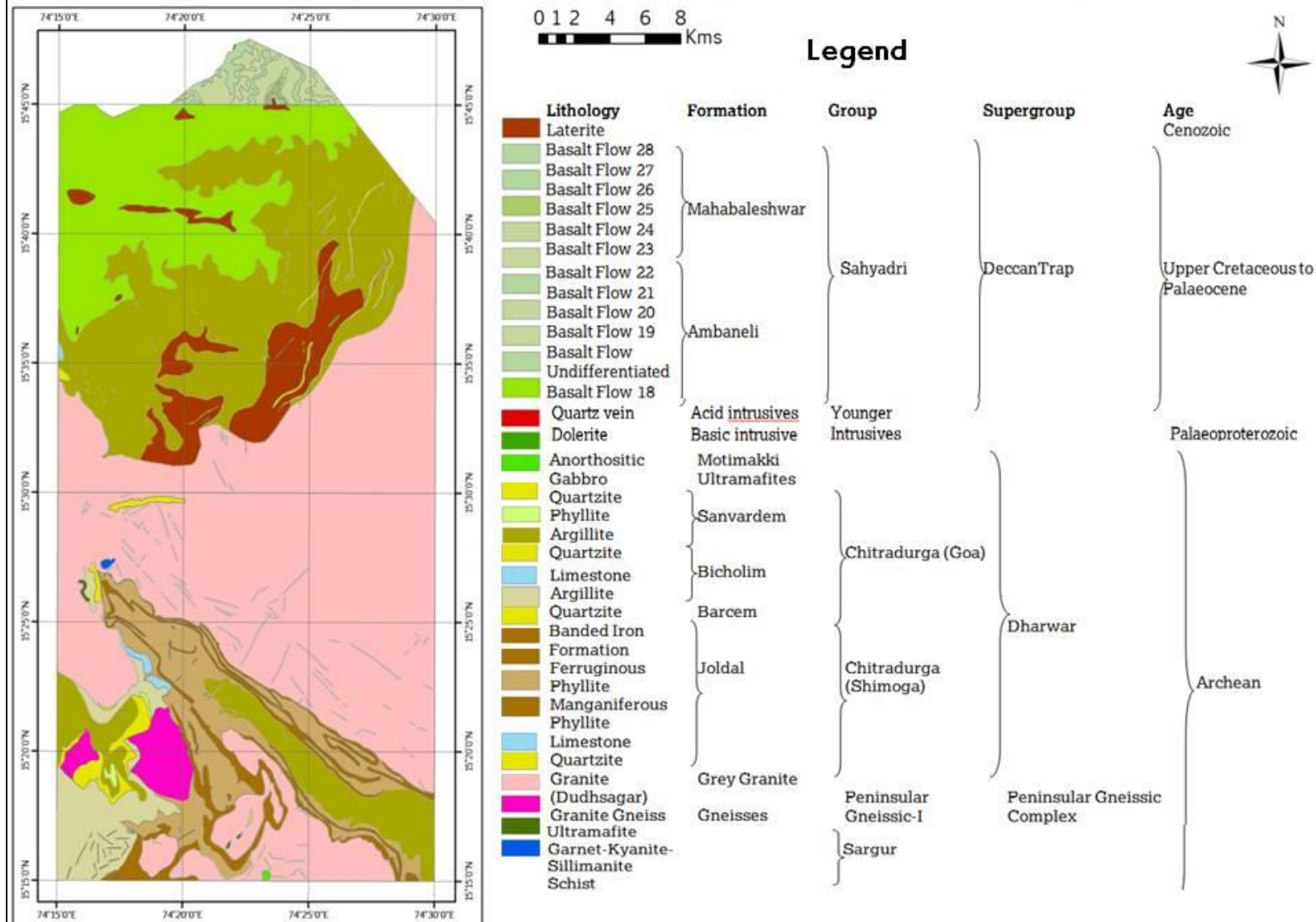


Photo 5

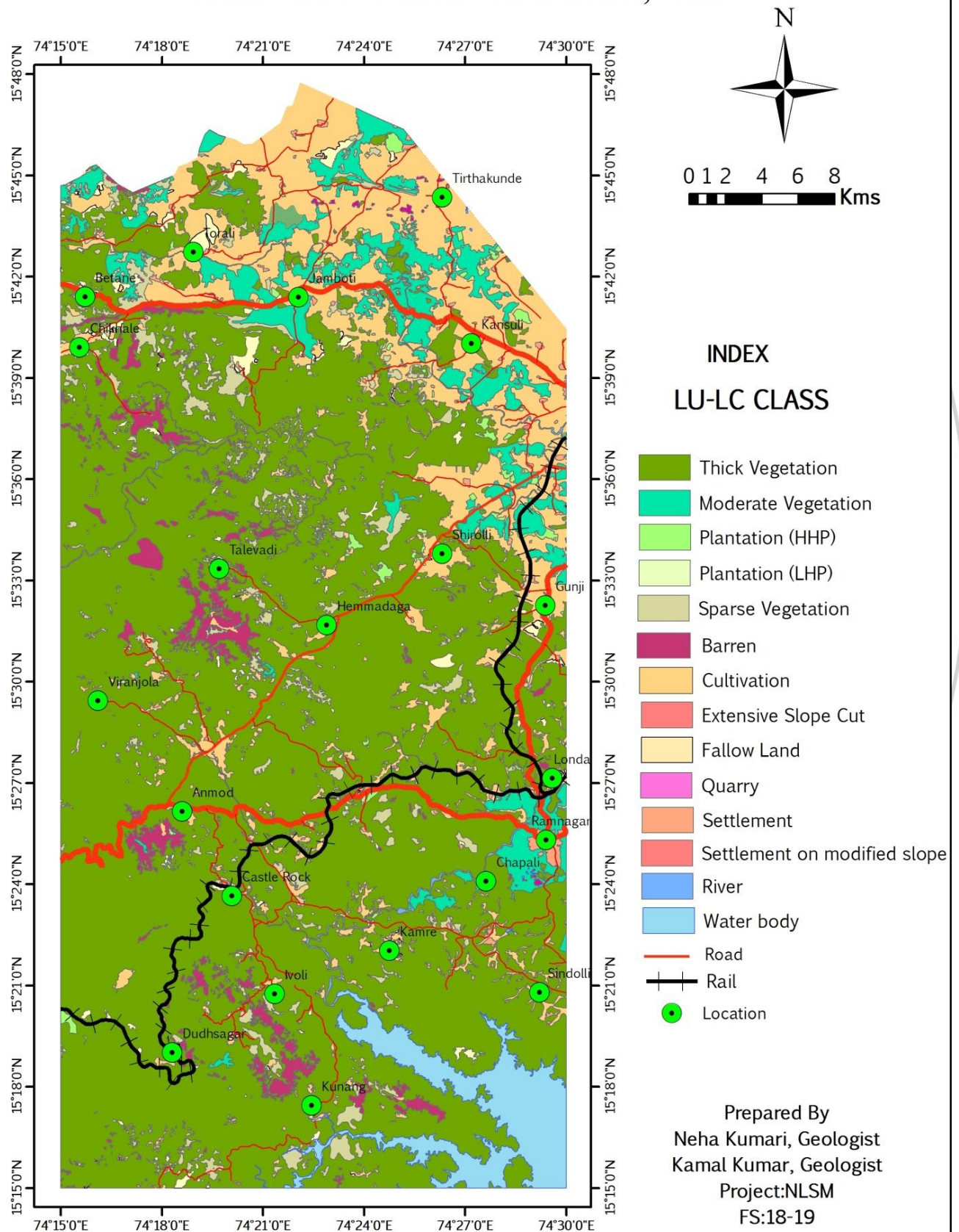
Photo 5: Field Photographs showing Extensive Cut Slope on Castle rock Railway line section



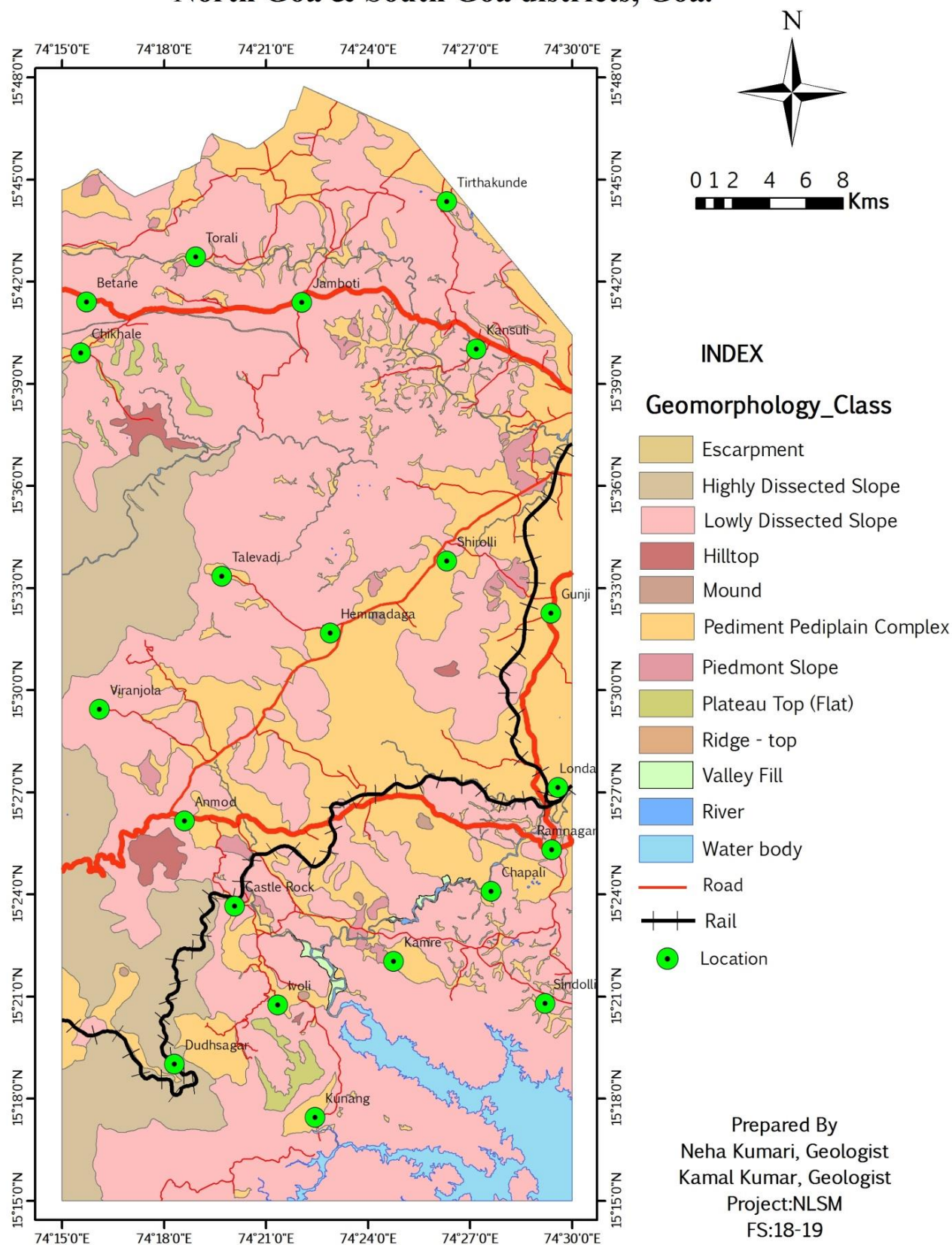
Geological Map on (1:50,000 scale) of TS Nos. 48I/5, I/6 & I/7



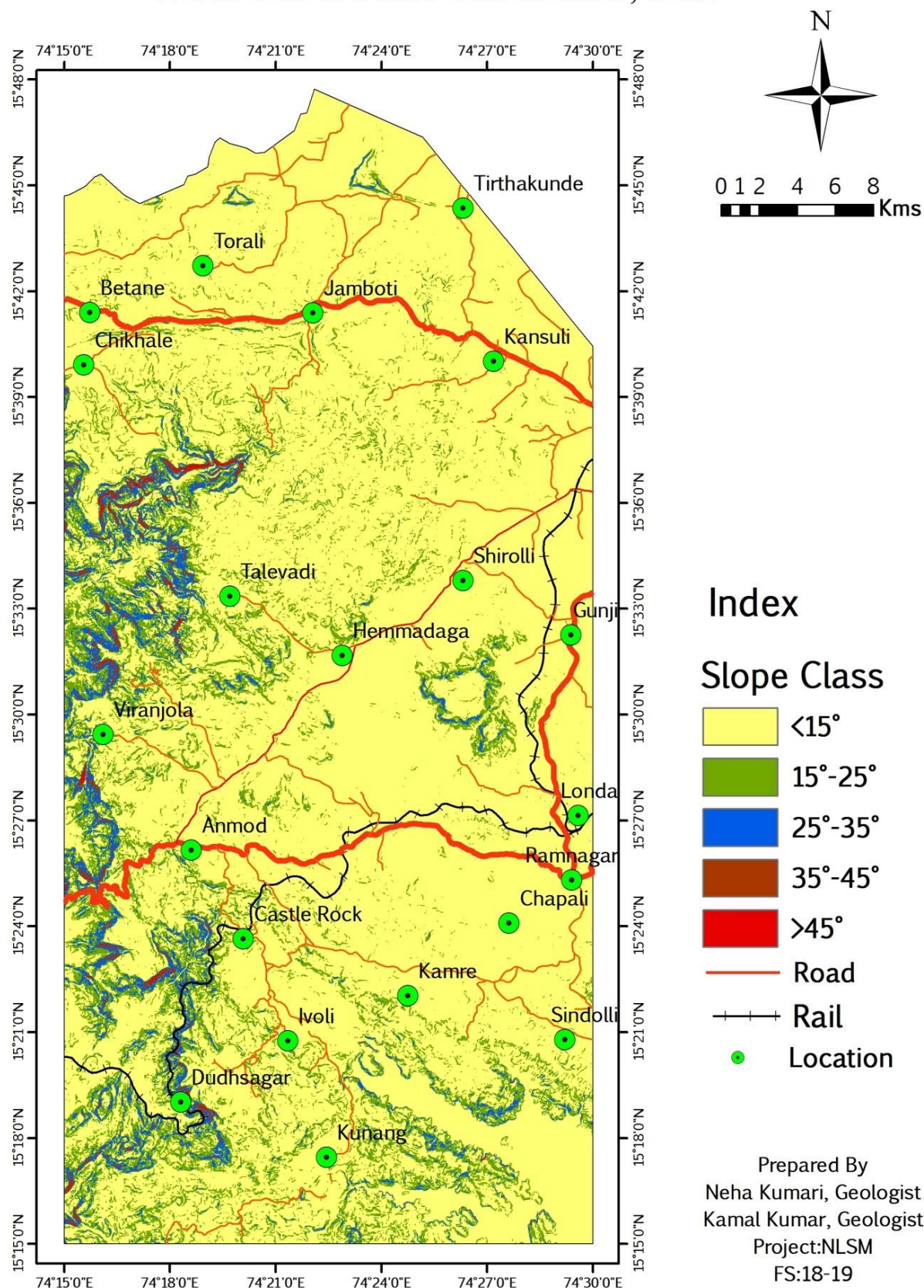
Landuse/Landcover Map of TS nos. 48I/05, I/06, & I/07 in parts of Belgaum, Uttar Kannada districts, Karnataka and North Goa & South Goa districts, Goa.



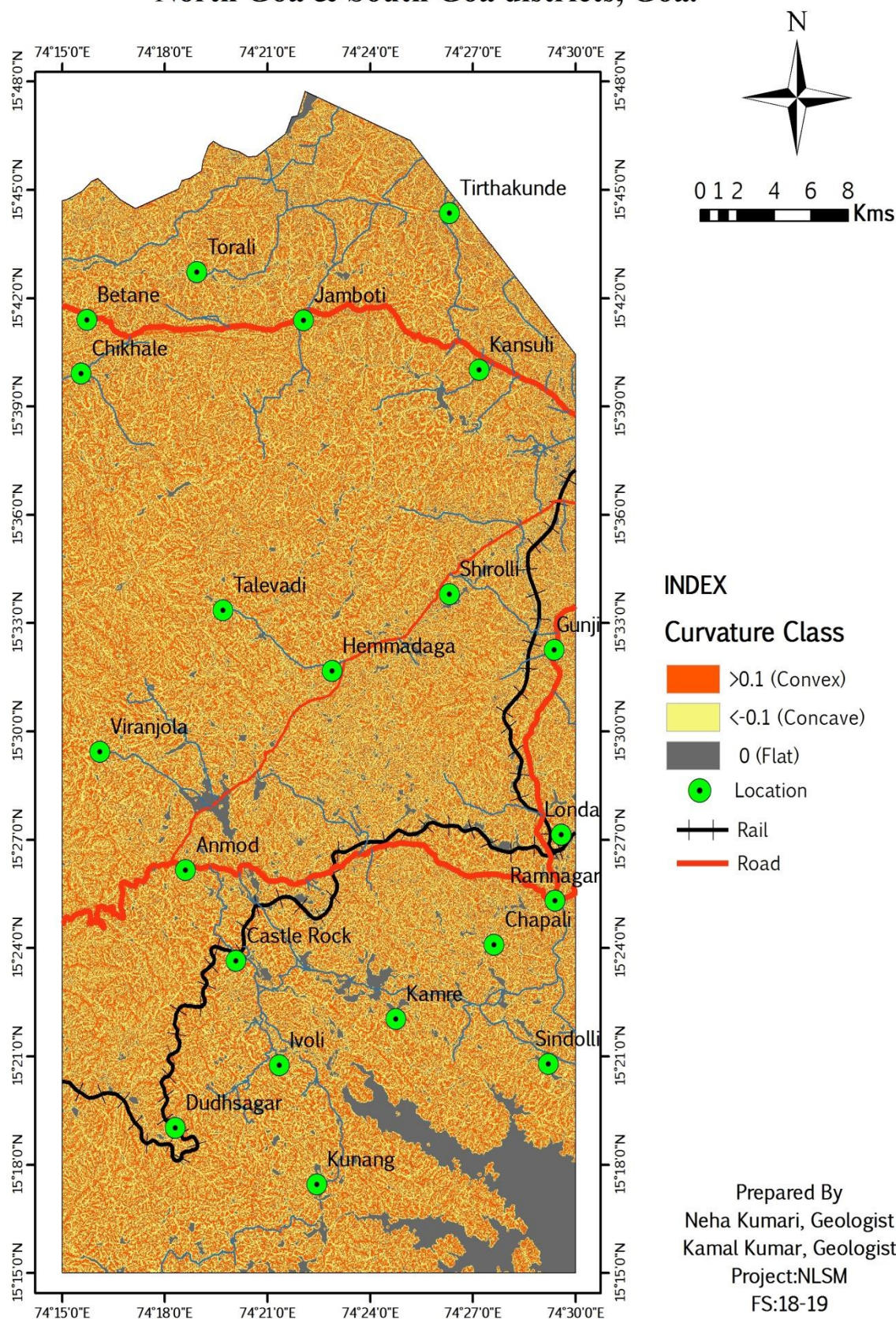
Geomorphology Map of TS nos. 48I/05, I/06, & I/07 in parts of Belgaum, Uttar Kannada districts, Karnataka and North Goa & South Goa districts, Goa.



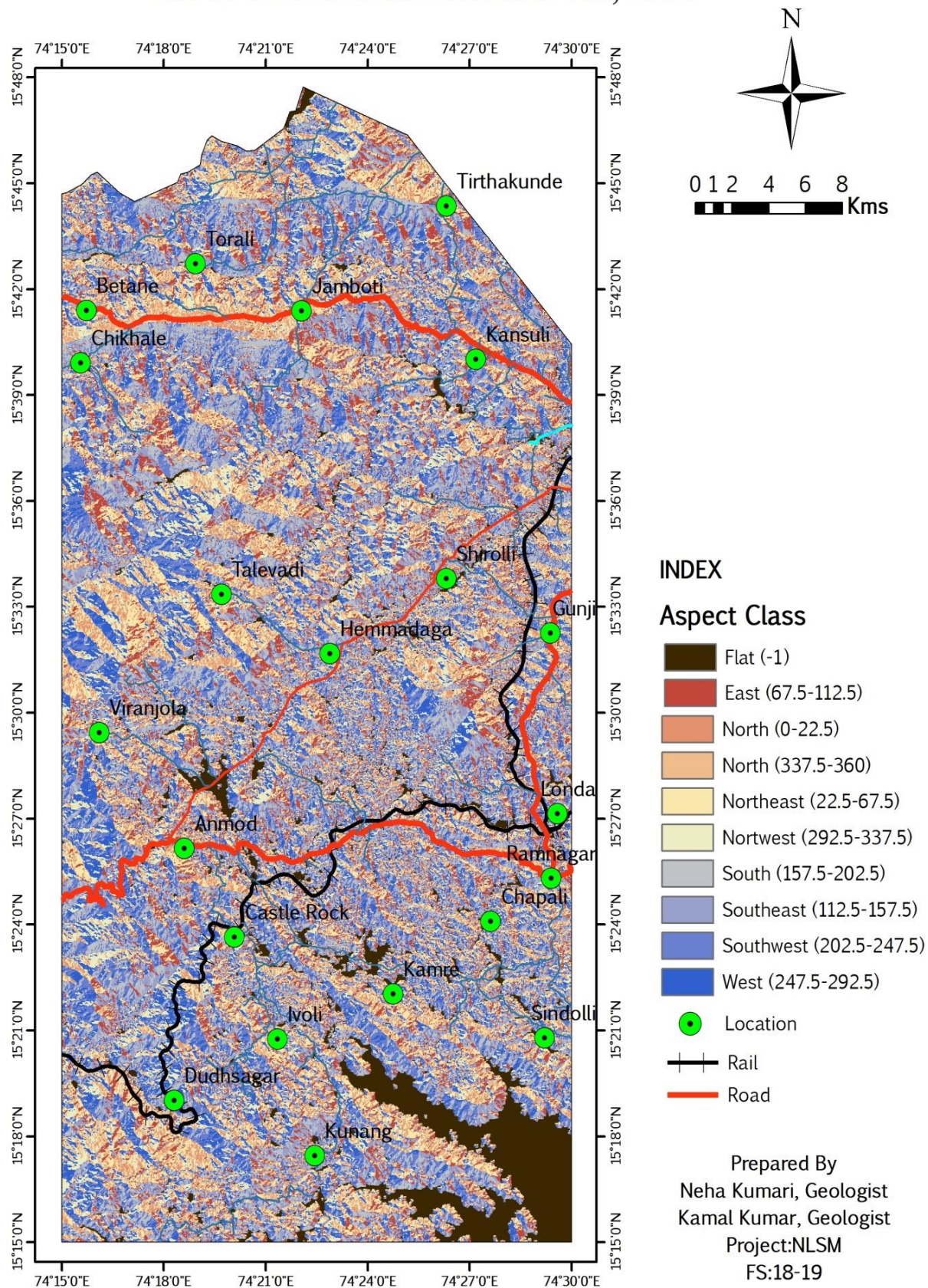
Slope Gradient Map of TS nos. 48I/05, I/06, & I/07 in parts of Belgaum, Uttar Kannada districts, Karnataka and North Goa & South Goa districts, Goa.



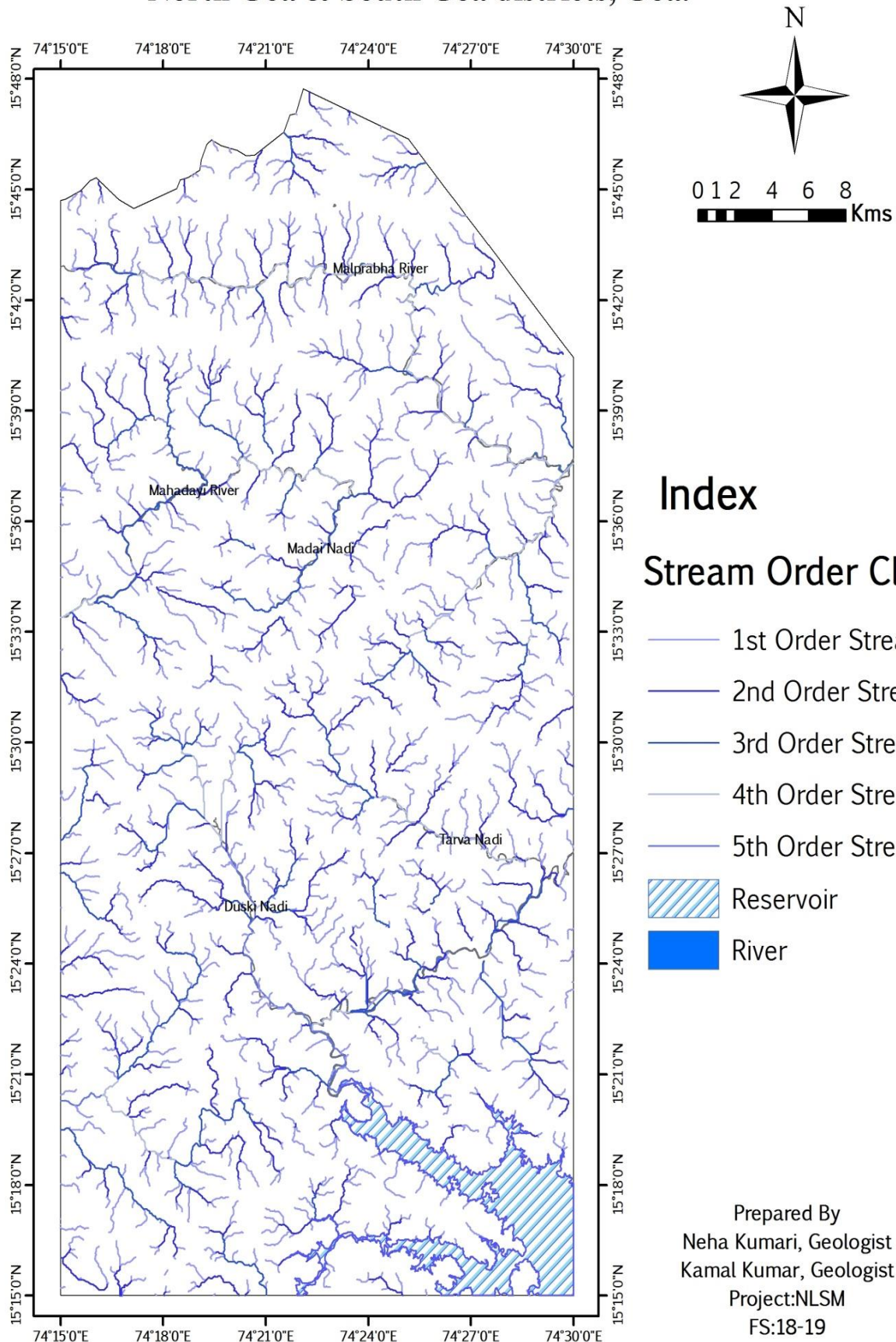
Slope Curvature Map of TS nos. 48I/05, I/06, & I/07 in parts of Belgaum, Uttar Kannada districts, Karnataka and North Goa & South Goa districts, Goa.



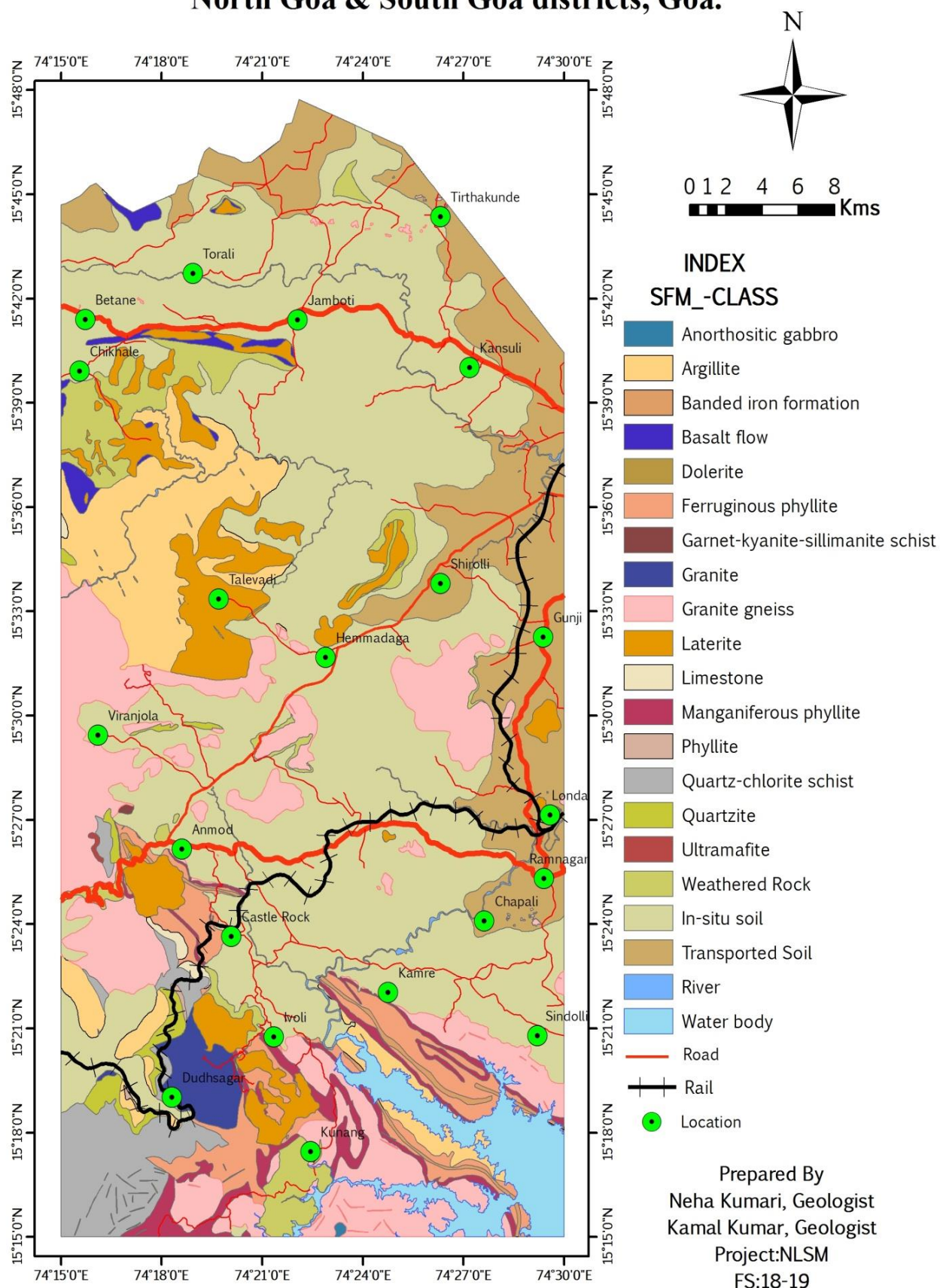
Slope Aspect Map of TS nos. 48I/05, I/06, & I/07 in parts of Belgaum, Uttar Kannada districts, Karnataka and North Goa & South Goa districts, Goa.



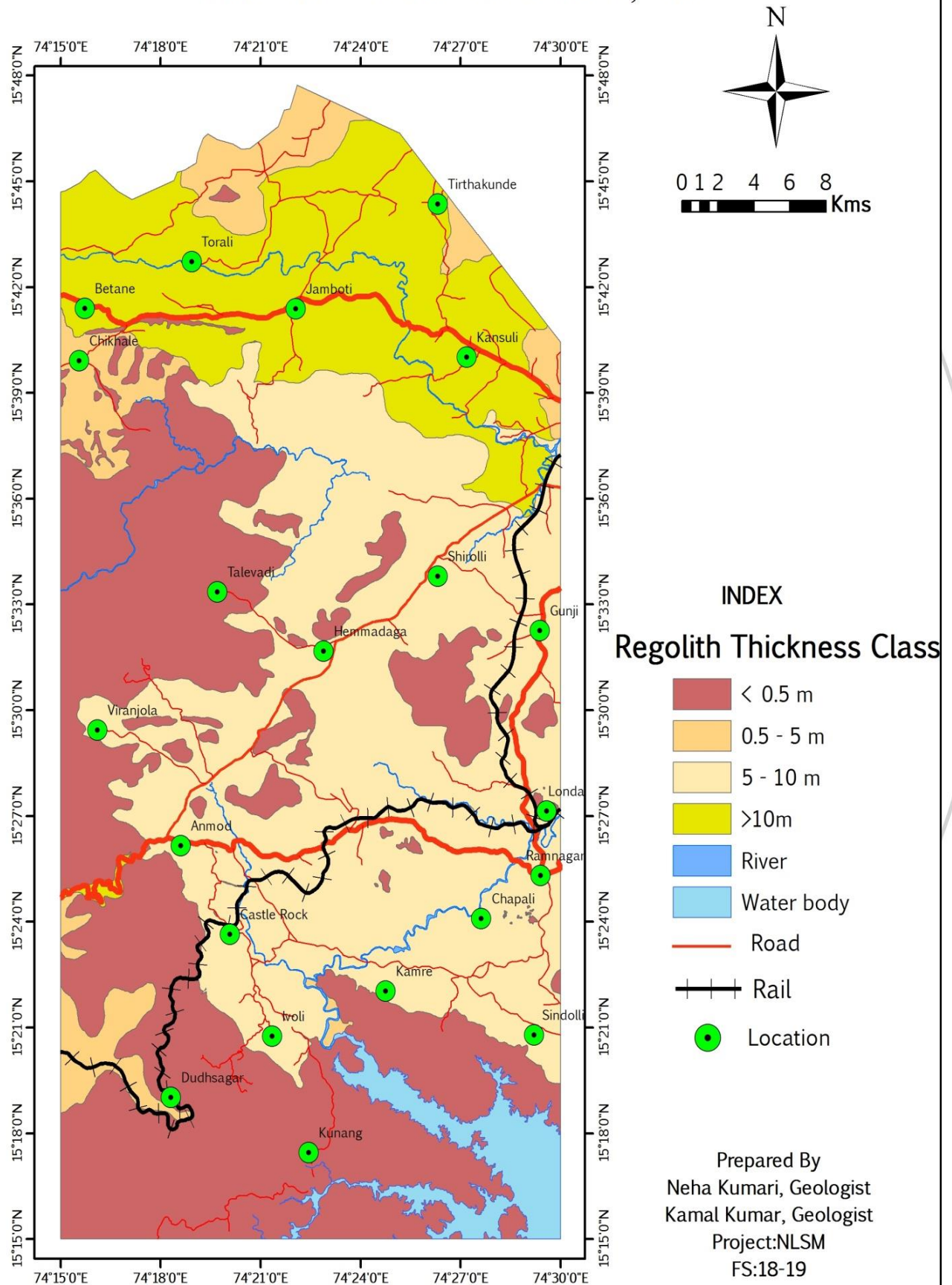
Drainage Map of TS nos. 48I/05, I/06, & I/07 in parts of Belgaum, Uttar Kannada districts, Karnataka and North Goa & South Goa districts, Goa.



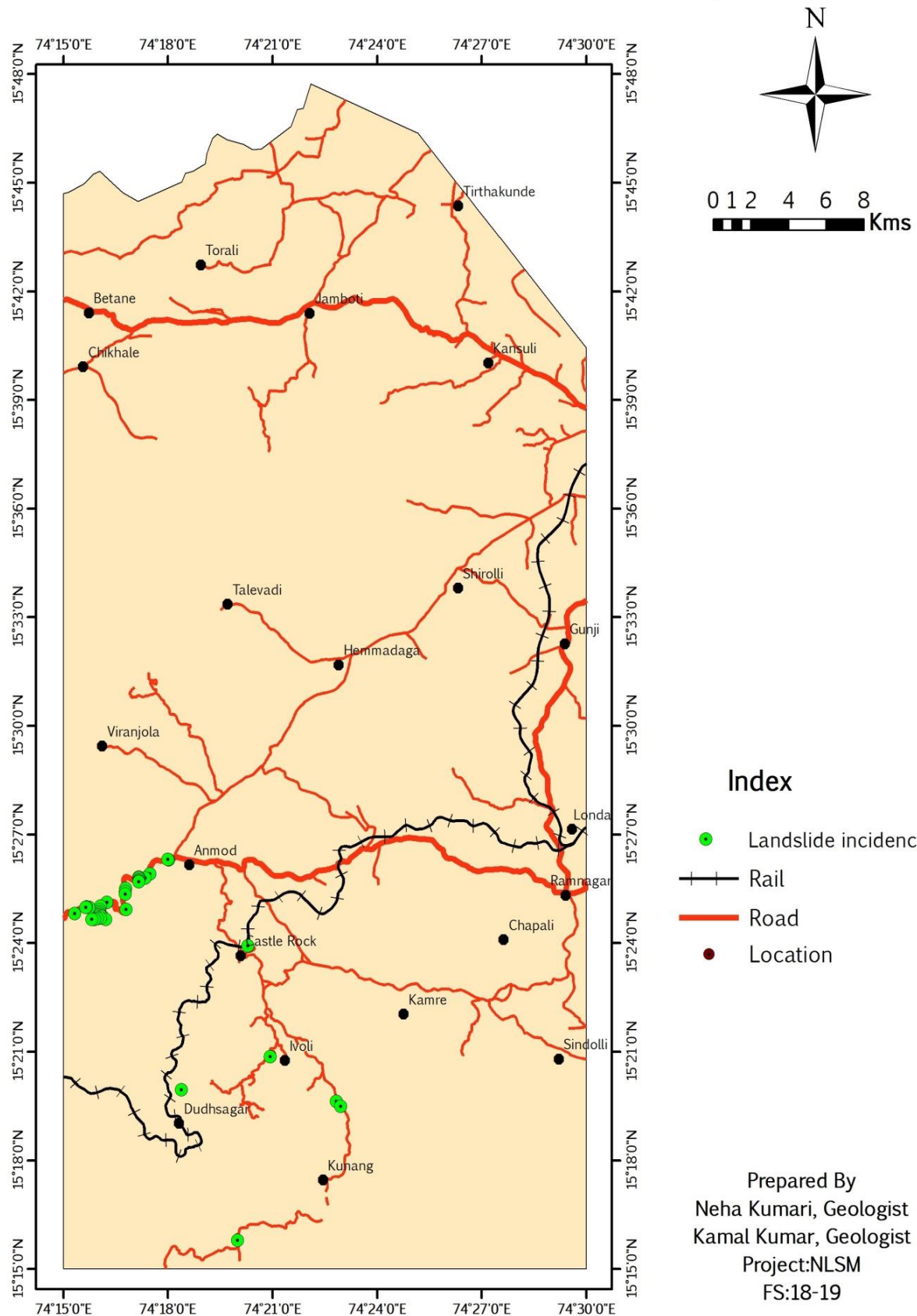
Slope Forming Material Map of TS nos. 48I/05, I/06, & I/07 in parts of Belgaum, Uttar Kannada districts, Karnataka and North Goa & South Goa districts, Goa.



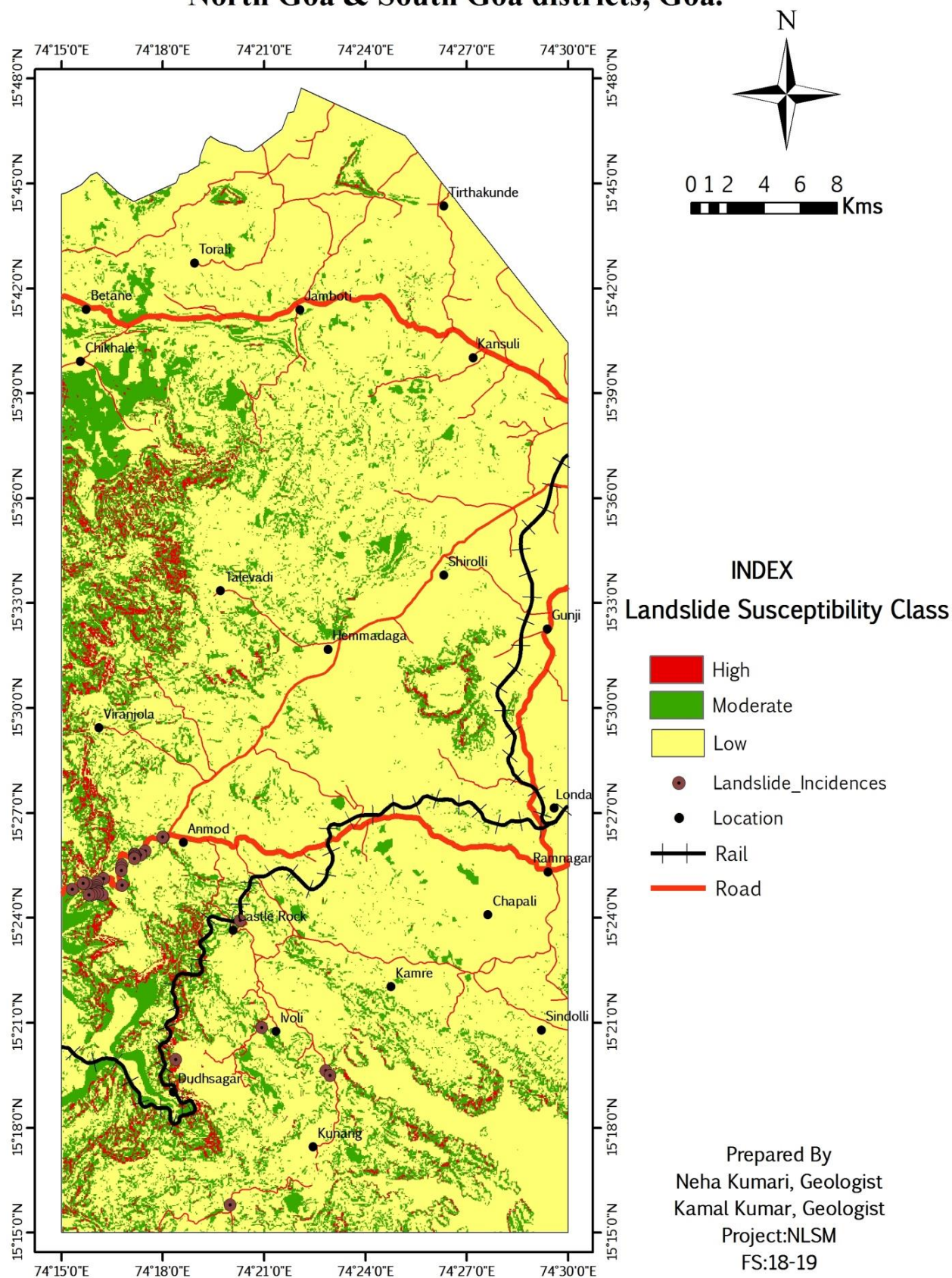
Regolith Thickness Map of TS nos. 48I/05, I/06, & I/07 in parts of Belgaum, Uttar Kannada districts, Karnataka and North Goa & South Goa districts, Goa.



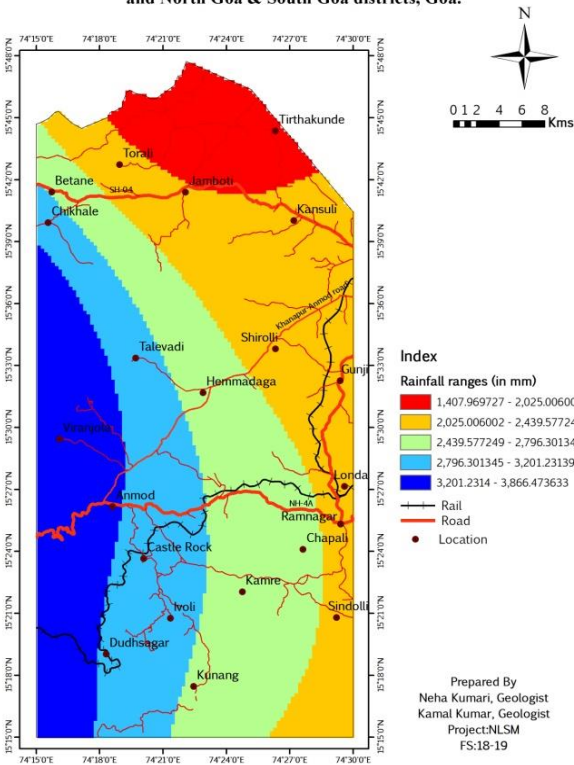
Landslide Inventory Map (1:50,000 scale) of TS nos. 48I/05, I/06, & I/07 in parts of Belgaum, Uttar Kannada districts, Karnataka and North Goa & South Goa districts, Goa.



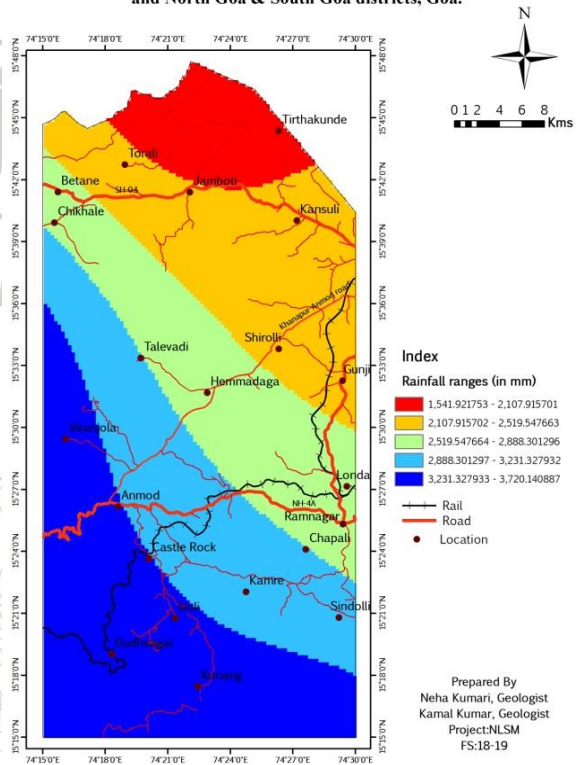
Landslide Susceptibility Map of TS nos. 48I/05, I/06, & I/07 in parts of Belgaum, Uttar Kannada districts, Karnataka and North Goa & South Goa districts, Goa.



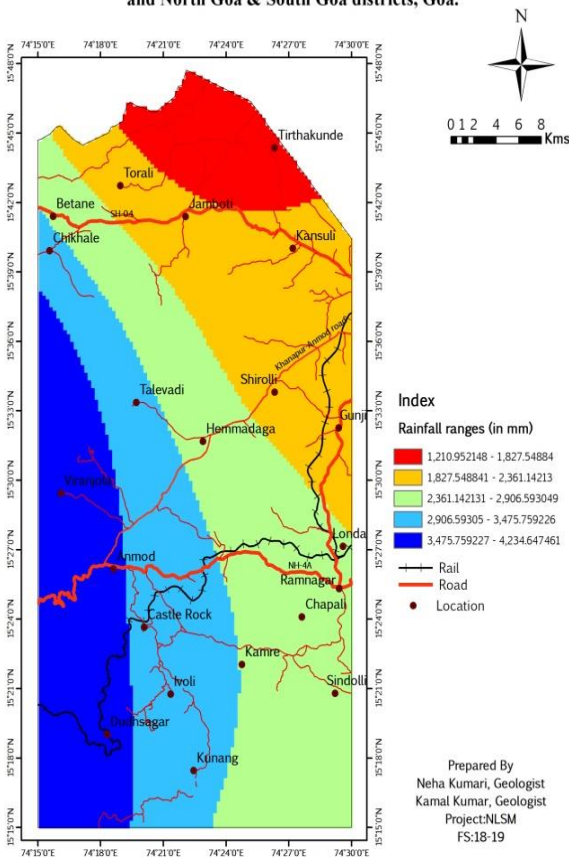
Rainfall Distribution Map for the year 2008 covering TS nos.481/05,1/06, & 1/07 in parts of Belgaum, Uttar Kannada districts,Karnataka and North Goa & South Goa districts, Goa.



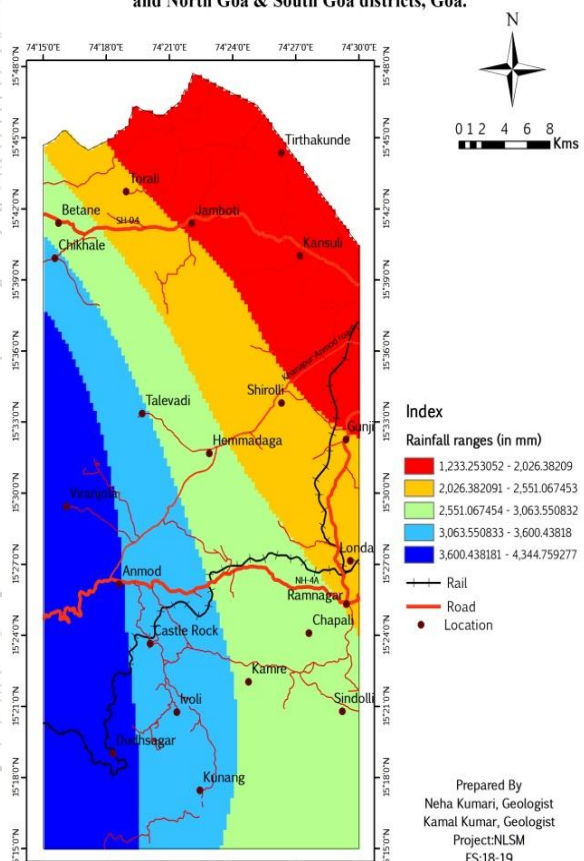
Rainfall Distribution Map for the year 2009 covering TS nos.481/05,1/06, & 1/07 in parts of Belgaum, Uttar Kannada districts,Karnataka and North Goa & South Goa districts, Goa.



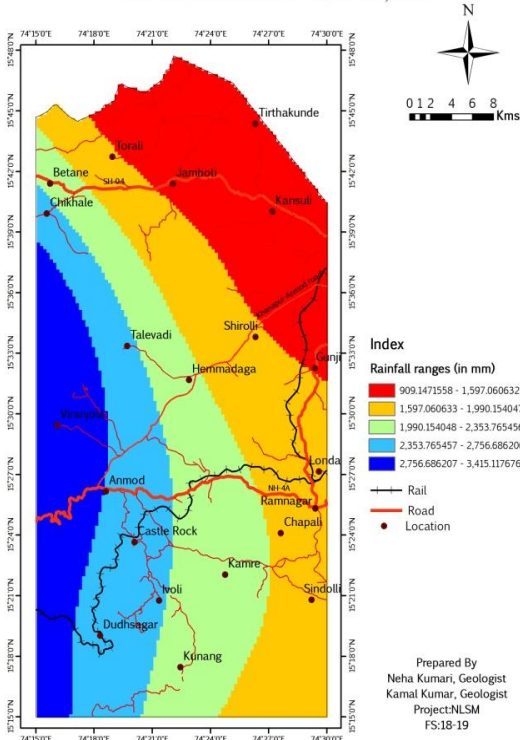
Rainfall Distribution Map for the year 2010 covering TS nos.481/05,1/06, & 1/07 in parts of Belgaum, Uttar Kannada districts,Karnataka and North Goa & South Goa districts, Goa.



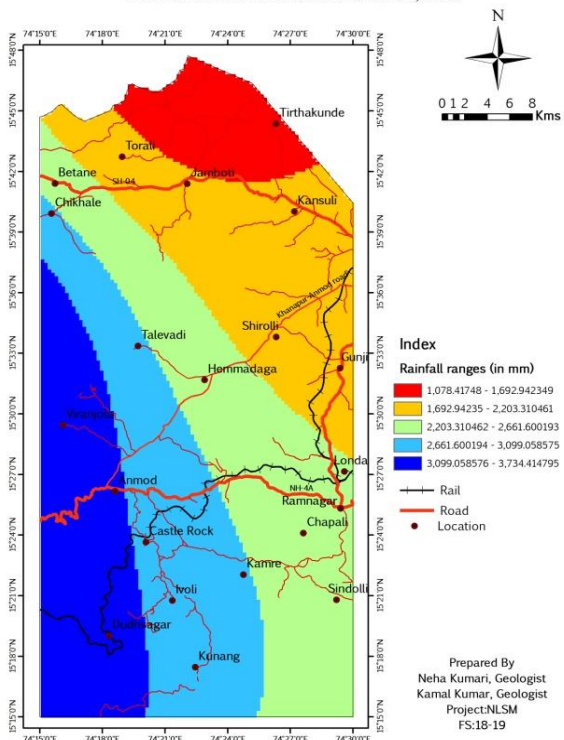
Rainfall Distribution Map for the year 2011 covering TS nos.481/05,1/06, & 1/07 in parts of Belgaum, Uttar Kannada districts,Karnataka and North Goa & South Goa districts, Goa.



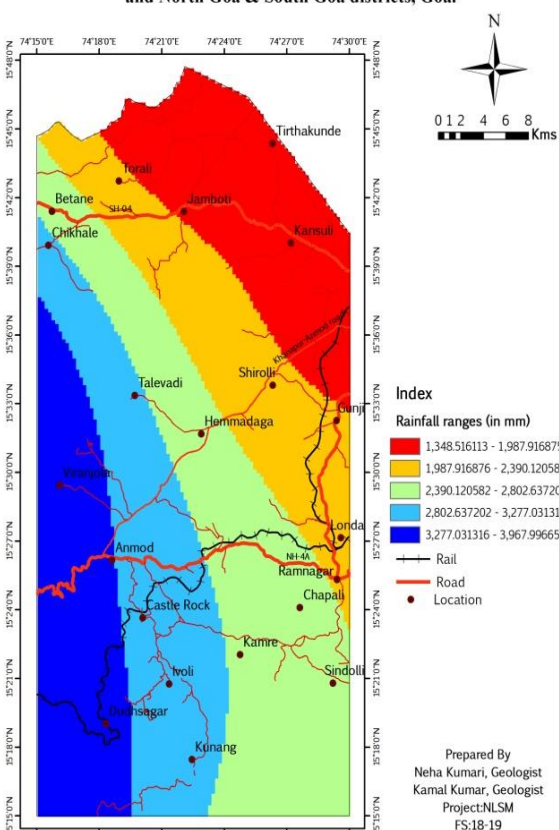
Rainfall Distribution Map for the year 2012 covering TS nos.481/05,I/06, & I/07 in parts of Belgaum, Uttar Kannada districts,Karnataka and North Goa & South Goa districts, Goa.



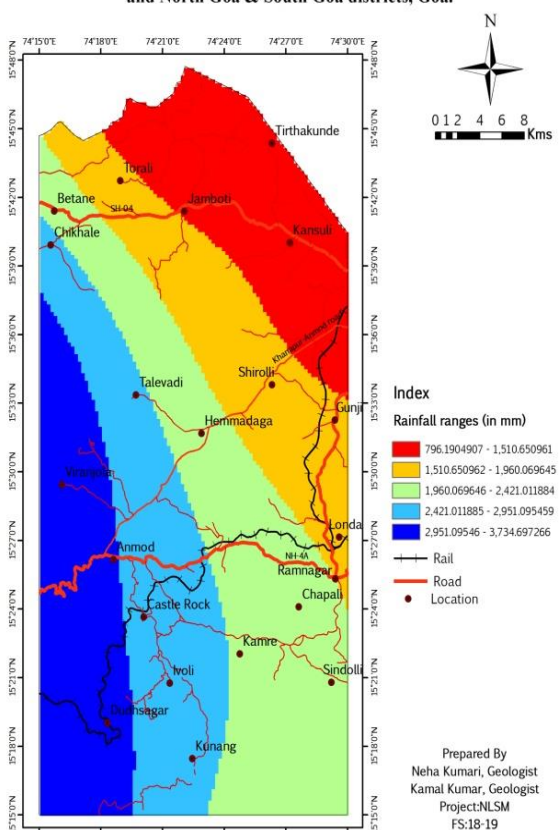
Rainfall Distribution Map for the year 2013 covering TS nos.481/05,I/06, & I/07 in parts of Belgaum, Uttar Kannada districts,Karnataka and North Goa & South Goa districts, Goa.



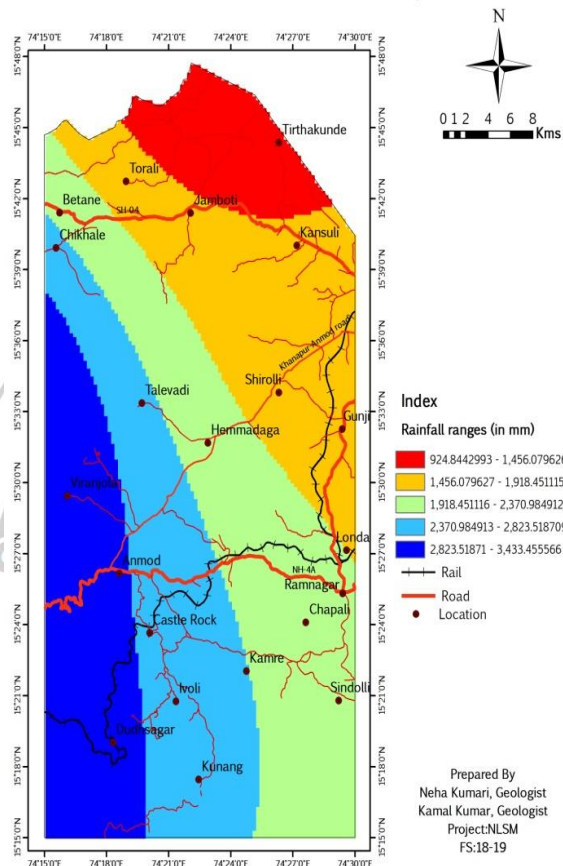
Rainfall Distribution Map for the year 2014 covering TS nos.481/05,I/06, & I/07 in parts of Belgaum, Uttar Kannada districts,Karnataka and North Goa & South Goa districts, Goa.



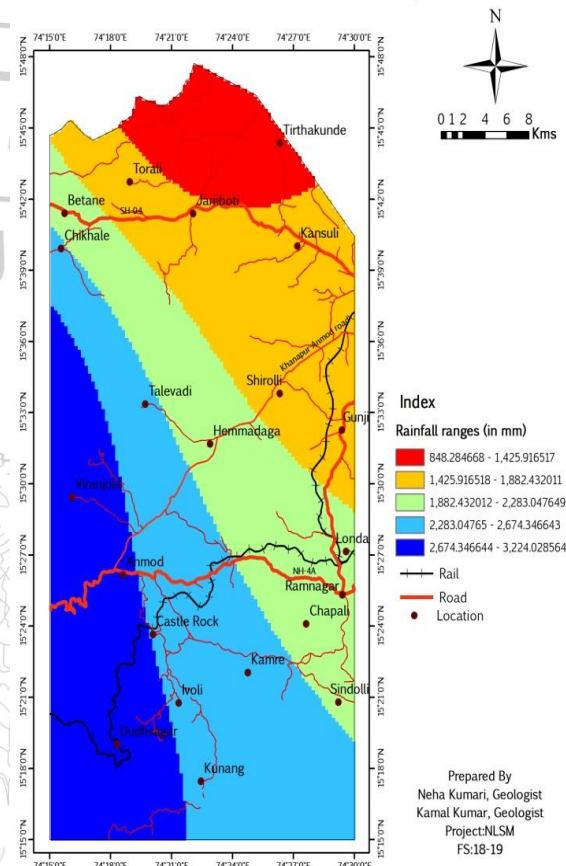
Rainfall Distribution Map for the year 2015 covering TS nos.481/05,I/06, & I/07 in parts of Belgaum, Uttar Kannada districts,Karnataka and North Goa & South Goa districts, Goa.



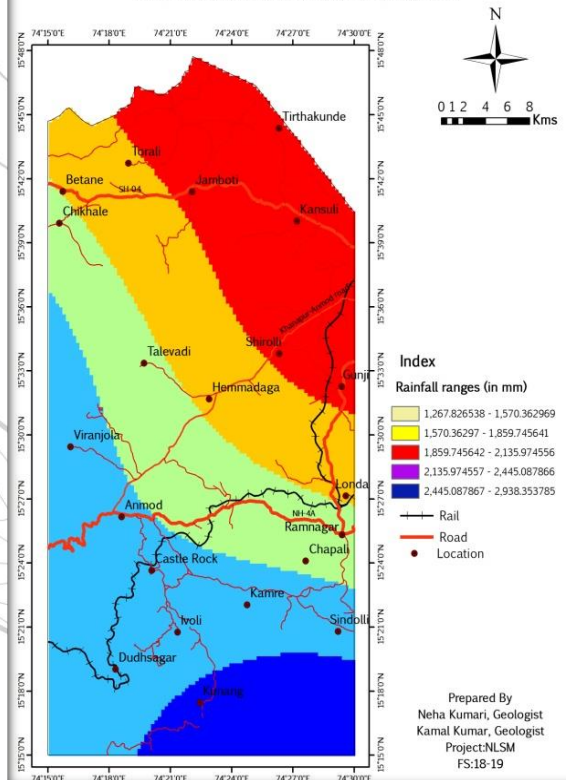
Rainfall Distribution Map for the year 2016 covering TS nos.481/05,1/06, & 1/07 in parts of Belgaum, Uttar Kannada districts,Karnataka and North Goa & South Goa districts, Goa.



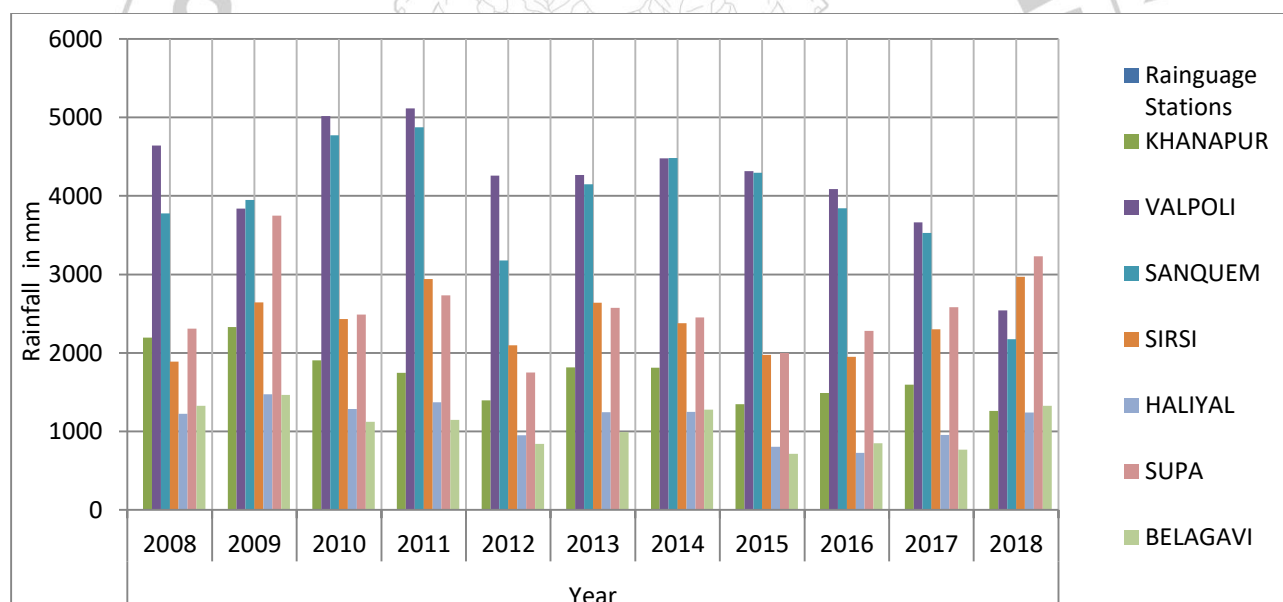
Rainfall Distribution Map for the year 2017 covering TS nos.481/05,1/06, & 1/07 in parts of Belgaum, Uttar Kannada districts,Karnataka and North Goa & South Goa districts, Goa.



Rainfall Distribution Map for the year 2018 covering TS nos.481/05,1/06, & 1/07 in parts of Belgaum, Uttar Kannada districts,Karnataka and North Goa & South Goa districts, Goa.



Graph showing Rainfall Distribution curve showing trends of 10 years total annual rainfall data recorded from different rainguage stations





Please visit us at <https://www.gsi.gov.in>