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GOVERNMENT OF INDIA
भारतीय भूवैज्ञानिक सर्वेक्षण
GEOLOGICAL SURVEY OF INDIA

कर्नाटक राज्य के कोड़ग जिले के निडुवट्टु, मुक्कोड्लु व मेगट्टालु भागों के आसपास मध्य पैमाने (1:10,000) पर
भूस्खलन सुग्राहिता मानचित्रण पर प्रतिवेदन

REPORT ON MESO-SCALE LANDSLIDE SUSCEPTIBILITY MAPPING (1:10,000) IN AND
AROUND NIDUVATTU, MUKKODLU & MEGATTALU AREAS, KODAGU DISTRICTS OF
KARNATAKA

टोपशीट सं/Toposheet No.: 48P/10, 48P/11, 48P/14 & 48P/15

मद सं: एम4एलएसएसएम/एनसी/एसआर/एसयू-केजी/2018/26601

Item no.: M4LSSM/NC/SR/SU-KG/2018/26601

कार्य सत्र 2018-19 का अंतिम प्रतिवेदन

Final report for field season 2018-19

आईजाज़ अहमद भट्ट, वरिष्ठ भूविज्ञानी/Aijaz Ahmad Bhat, Senior Geologist

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मिशन/MISSION-IV

राज्य इकाई: कर्नाटक व गोवा/State Unit: Karnataka & Goa

दक्षिणी क्षेत्र/Southern Region

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महानिदेशक, भारतीय भूवैज्ञानिक सर्वेक्षण, कोलकाता से पूर्व में अनुमति लिए बिना इस प्रतिवेदन को पूर्णतया या अंशतया
प्रकाशित नहीं करना है।

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Item no.: M4LSSM/NC/SR/SU-KG/2018/26601

By

Aijaz Ahmad Bhat, Senior Geologist & Dr. Zameer Ahmad Shah, Geologist

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कर्नाटक राज्य के कोड़ग जिले में निडुवट्टु, मुक्कोड्लु व मेगाटलू भागों के आसपास के 1:10, 000 मध्य पैमाने पर भूस्खलन सुग्राहिता मानचित्रण

मद कूट सं.: एम4एलएसएसएम/एनसी/एसआर/एसयू-केजी/2018/26601

द्वारा

आईजाज़ अहमद भट्ट, वरिष्ठ भूवैज्ञानिक व डॉ. ज़मीर अहमद शाह, भूवैज्ञानिक

सारांश

वर्ष 2018 में वर्षा के दौरान हुए भूस्खलन घटनाओं के मुख्य कारणवाचक घटकों का पता लगाने व भूस्खलन सुभेद्यता जोखिम को न्यूनतम करने के लिए लघुकरण/सुधारात्मक उपायों को सुझाने के उद्देश्य से कर्नाटक राज्य के कोड़ग जिले के मडिकेरी तालूक में 18 वर्ग किलोमीटर क्षेत्र में 1:10,000 पैमाने पर विस्तृत भूस्खलन अन्वेषण किया गया। क्षेत्र में घटित भूस्खलनों के विभिन्न पहलुओं, भूस्खलनों की 'फेलियर' क्रियाविधि, सनातन भू-घटक मुद्दों, विभिन्न द्रोणीमय आकारमितिक मानदण्डों, वर्षा के चित्राम, ढाल 'वेरियेशन' व नमूनों के एकत्रीकरण के पश्चात उपरिभारित पदार्थ के विभिन्न भूतकनीकी मानदण्डों को अन्वेषित करने के लिए क्षेत्र सर्वेक्षण किया गया। क्षेत्र अध्ययन के दौरान कुल 112 भूस्खलन सीमांकित किए गए व भूस्खलनों के वर्गीकरण, कारण व 'फेलियर' क्रियाविधि के अनुसार अच्छी तरह से अध्ययन किए गए। क्षेत्र में किए गए 'ओब्सेर्वेशन्स', क्षेत्र में किए गए सर्वेक्षण के दौरान एकत्रित क्षेत्र संबंधी आँकड़ों के विश्लेषण व व्याख्या, कार्टोड्रैम (10 मीटर रिसल्यूशन) से किए गए अपवाह-तंत्र द्रोणी विश्लेषण, भूतकनीकी प्रयोगशाला के द्वारा विश्लेषित उपरिभारित भूतकनीकी मानदण्डों की व्याख्या, भूस्खलन सुग्राहिता स्कोर मानचित्र व मानचित्र की 'सक्सस' दर वक्र पर की गई थुगु चर्चाओं के आधार पर निष्कर्ष व सिफारिशें बनाई गई हैं।

अध्ययन क्षेत्र में भूस्खलन वर्षा ऋतु में होता है। इसके बहुत सारे कारण हैं। वर्षा भूस्खलन होने के कारण से अधिक भूस्खलन के बढ़ाव का कारण है। इसी बढ़ाव से विभिन्न प्रक्रियाएँ जैसे अपवाह-तंत्र व्यवस्था, अंतः स्यंदन, संतृप्ति, इकाई द्रव्यमान में बढ़ोत्तरी हुई है, ये सभी प्रक्रियाएँ प्रस्तुत अध्ययन क्षेत्र में निर्घर्षण, चैनल/नाली अपरदन व भूस्खलन की घटनाओं के मुख्य कारणवाचक घटक हैं। प्रस्तुत

अध्ययन क्षेत्र में जून से सितम्बर, 2018 की अवधि के दौरान 4000 मिल्लीमीटर वर्षा हुई है, जो पिछले तीन वर्षों के 2500 मिल्लीमीटर के वास्तविक वर्षा की तीव्रता से 2000 मिल्लीमीटर अधिक है। सबसे पहला व प्रमुख कारणवाचक घटक अपवाह-तंत्र संजाल समस्या है, क्योंकि 2500 मिल्लीमीटर के वास्तविक वर्षा से अधिक जब 2000 मिल्लीमीटर की अधिक वर्षा हुई, तब जल ठीक तरह से अपवाहित व अपने अनुक्रमिक धाराओं में वितरित नहीं हुआ व यह समस्या ऐसे जल विभाजक क्षेत्रों में हुई, जहाँ भूस्खलन हुए है। उपरिभारित पदार्थों के भूतकनीकी मापदण्डों के विश्लेषण से यह बात पता चली है व यह बात समर्थित हो जाती है कि इन गुणधर्म से जल दाब में बढ़ोत्तरी होने का एक रास्ता मिला है, ये पदार्थ संसंजन, घर्षण कोण, सघनता, सरंध्रता व उत्पाट आकार हैं। इन पदार्थों में जल में मिलने के कारण आगे के अपवाह-तंत्र में जल ठीक तरह से अपवाहित नहीं हुआ है। इन सभी कारणों से किसी मानवीय हस्तक्षेप के बिना ही प्राकृतिक ढलान 'फेलियर' हुआ है। इस अन्वेषण में आर्कजीआईएस प्लेटफॉर्म पर भारित बहु वर्गिक सूचक उपरिभारित पद्धति के द्वारा भूस्खलन सुग्राहिता स्कोर मानचित्र तैयार किया गया। विभिन्न सुग्राहिता वर्गों में भूस्खलन सुग्राहिता स्कोर मानचित्र को चित्रित करने के लिए आईएलडब्ल्यूआईएस सॉफ्टवेयर में उत्तरोत्तर दर वक्र तैयार किया गया। प्रस्तुत अन्वेषण में भूस्खलन सुग्राहिता स्कोर मानचित्र के लिए तैयार 'सक्सस' दर वक्र उच्च स्कोर मूल्य वाले निम्न संचयी मानचित्र क्षेत्र में (पेर्कमैप) पर ढलवाँपन दर्शाता है। इसलिए संबंधी भूस्खलन सुग्राहिता मानचित्र से भूस्खलन के लिए सबसे अधिक सुग्राही क्षेत्रों का पूर्वानुमान लगाया जा सकता है। भूस्खलन सुग्राहिता स्कोर मानचित्र से यह आकलित किया गया है कि अपवाह तंत्र संजाल समस्या एक मुख्य कारण है व इसे सही भी पाया गया है। इसी मानचित्र से अपवाह तंत्र के प्रभाव में आने वाले सभी भागों को साधारण से उच्च भूस्खलन सुग्राहिता वाले क्षेत्रों में वर्गीकृत किया गया है व अपवाह-तंत्र के प्रभाव में न आने वाले बाह्य क्षेत्र को निम्न सुग्राहिता संस्तर में वर्गीकृत किया गया है। प्रस्तुत अन्वेषित क्षेत्र के भूस्खलन सुग्राहिता स्कोर मानचित्र के सांख्यिकीय विश्लेषण से यह पता चलता है कि कुल 18 वर्ग किलोमीटर क्षेत्र में से 2.83 वर्ग किलोमीटर क्षेत्र "उच्च" भूस्खलन सुग्राहिता संस्तर में, 7.00 वर्ग किलोमीटर क्षेत्र

“साधारण” भूस्खलन सुग्राहिता संस्तर में व बाकी 8.17 वर्ग किलोमीटर क्षेत्र “निम्न” भूस्खलन सुग्राहिता संस्तर में आते हैं। ये क्षेत्र कुल मानचित्रित क्षेत्र के क्रमशः 15.73%, 38.88% व 45.39% हैं। वर्तमान में हुए भूस्खलनों में से 70% “उच्च” व “साधारण” भूस्खलन सुग्राहिता क्षेत्र में हुए हैं।



REPORT ON MESO-SCALE LANDSLIDE SUSCEPTIBILITY MAPPING (1:10,000) IN AND AROUND NIDUVATTU, MUKKODLU & MEGATTALU AREAS, KODAGU DISTRICTS OF KARNATAKA

Item no.: M4LSSM/NC/SR/SU-KG/2018/26601

By

Aijaz Ahmad Bhat, Senior Geologist & Dr. Zameer Ahmad Shah, Geologist

ABSTRACT

The detailed landslide investigation on 1:10,000 scale in Medikeri taluk, Kodagu district, Karnataka has been carried out for 18 sq.km area to find out the major causative factors of landslide occurrences during 2018 rainfall period and to suggest the mitigation/remedial measures for minimize the landslide vulnerability risk. The field survey has been carried out in the area to investigate various aspects of landslides occurred, their failure mechanism, prevailing geo-factor themes, various basin morphometric parameters, rainfall patterns, slope variations and various geotechnical parameters of overburden material after collection of samples. During field studies total 112 landslides have been demarcated and studied thoroughly in terms of their classification, causes and failure mechanism. The conclusion and recommendations have been made on the basis of thorough discussions on field observations, analysis and interpretation of field data collected during field survey, drainage basin analysis using CartoDEM (10m resolution), interpretation of geotechnical parameters of overburden analyzed by geotechnical laboratory, landslide susceptibility score map and its success rate curve.

Landslides occurred in the study area are rainfall induced caused by multiple causative factors. Rainfall was a triggering factor rather than a causative factor and it have initiated various processes related to drainage system, infiltration, saturation and increase of unit mass which became the major causative factors for scouring, channel erosion and landslide occurrences in the present study area. The present study area received more than 4000mm rainfall during June-September period 2018 which accounts 2000mm rise over 2500mm actual rainfall intensity in previous three years record. The first major causative factor was found by drainage network problem as there was poor performance to drain and distribute storage capacity (rainfall waters) in hierarchy stream orders during rainfall event with 2000mm rise over 2500mm actual rainfall intensity in landslide and channel erosion affected watersheds. The analysis of geotechnical parameters of overburden material revealed and supported the fact that certain overburden material properties (cohesion, friction angle, density, porosity and grain size) have allow the material to generate variable shear stress (pore water pressures) on saturation particularly when infiltrated water flow get stuck due to poor drainage performance and would have result natural slope failures

irrespective of any human interference. The landslide susceptibility score map was generated in this investigation by using Weighted Multiclass Index Overlay method on ArcGIS platform. A successive rate curve has been generated in ILWIS software to depict the landslide susceptibility score map in different susceptibility categories. The success rate curve generated for landslide susceptibility score map in present investigation shows steepness at lower cumulative map area percentage (permap) having highest score values, therefore the corresponding landslide susceptibility map has strong ability to predict areas that are most susceptible to landslides. The drainage network problem as a major cause has been evaluated and proved precise by landslide susceptibility score map, which has classified almost all drainage-influenced portions in moderate to high landslide susceptibility range and the area away from drainage components are classified into low landslide susceptibility zone. The statistical analysis of landslide susceptibility score map of present investigated area reveals that out of 18 sq.km area, 2.83 sq.km (15.73 cumulative map area percentage) area falls under “High” landslide susceptible zone, 7.00 sq.km (38.88 cumulative map area percentage) area falls under “Moderate” landslide susceptible zone and rest 8.17 sq.km (45.39 cumulative map area percentage) area falls under “Low” landslide susceptible zone. 70% of present landslides are falling in “High” and “Moderate” landslide susceptible zone

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Item no.: M4LSSM/NC/SR/SU-KG/2018/26601

By

Aijaz Ahmad Bhat, Senior Geologist & Dr. Zameer Ahmad Shah, Geologist

1. INTRODUCTION

1.1. General Introduction

In pursuance of a request from Deputy Commissioner, Kodagu district, Karnataka state for visiting the landslide affected areas in various parts of Kodagu district a team of officers from GSI, SU: K&G, Bengaluru office comprising *K. V. Maruthi, Aijaz Ahmad Bhat and Ankur Kumar Srivastava* visited to landslide affected areas along Madikeri-Makutta and Madikeri-Koyanad-Sulya road sections, Kodagu district, Karnataka in July 2018 and carried out preliminary investigation. In August, 2018 major landslides occurred in various parts of Kodagu district due to heavy rainfall. The landslide incidences occurred in August, 2018 have affected and devastated many settlements and agricultural land areas. Soon after this event another team of officers comprising *K. V. Maruthi, Ankur Kumar Srivastava and Sunandan Basu* visited these landslide affected areas in August, 2018 and carried out preliminary investigation. Both the teams of officers have submitted their preliminary reports to state and district authorities to minimize further damage of life and property and suggested further detail studies. On the basis of the recommendations given in the preliminary reports, the Kodagu district authorities had requested for detailed geological studies of landslide affected areas in parts of Kodagu.

In pursuance of said request a detailed geological study for 18 sq.km areas has been taken-up by GSI, SU: K&G, Bengaluru office during FS 2018-19 under a title “Meso-scale Landslide Susceptibility Mapping (1:10,000) in and around Niduvattu, Mukkodlu & Megattalu areas, Kodagu districts of Karnataka” with item no. M4LSSM/NC/SR/SU-KG/2018/26601. The objectives were to: generate landslide susceptibility map on 1:10,000; identify causative factors related to landslides; suggest mitigation/remedial measures for unstable slopes; and update the existing landslide inventory. After completion of field studies, a preliminary field note has been submitted in May, 2019 to the district authorities of Kodagu, Karnataka.

It should be noted here that as on date there are no standard operating procedure (SOP) guide lines for meso-scale susceptibility mapping on 1:0,000 scale in GSI. During the course of investigation the authors have tried lot to make a well suited landslide susceptibility model for this study and have submitted one model to GHRM Division for scrutiny but still there are various challenges to improve

that model. Keeping the necessities, priorities and requirements of district administration in consideration, the authors have adopted the landslide dependent model of NLSM for landslide susceptibility analysis in present investigation of meso-scale landslide susceptibility mapping. The said model of NLSM has been adopted after validating its prediction strength over the area and has proved best interpreted model so far for the present study area. The said model supports every observation and conclusion made during field studies and post field studies of data analysis. The authors are glad to improve and modify the landslide susceptibility analysis contents when and as the standard operating procedure (SOP) guide lines for meso-scale susceptibility mapping on 1:0,000 scale in GSI will be formulated.

1.2. Location, Communication and Physiography

The study area is situated in Kodagu/Coorg district of Karnataka (see fig. 1.1) and is part of toposheet nos. 48P/10, 48P/11, 48P/14 & 48P/15. The study area is bound by latitudes 12°29'08" to 12°31'00"N and longitudes 75°42'55" to 75°46'00"E covering parts of Niduvattu, Mukkodlu & Megattalu villages of Madikeri Taluk, Kodagu District, Karnataka. The Coorg district is bordered by Dakshina Kannada district in the north, Mysore district in the east and Kasargod district of Kerala state on the west and south.

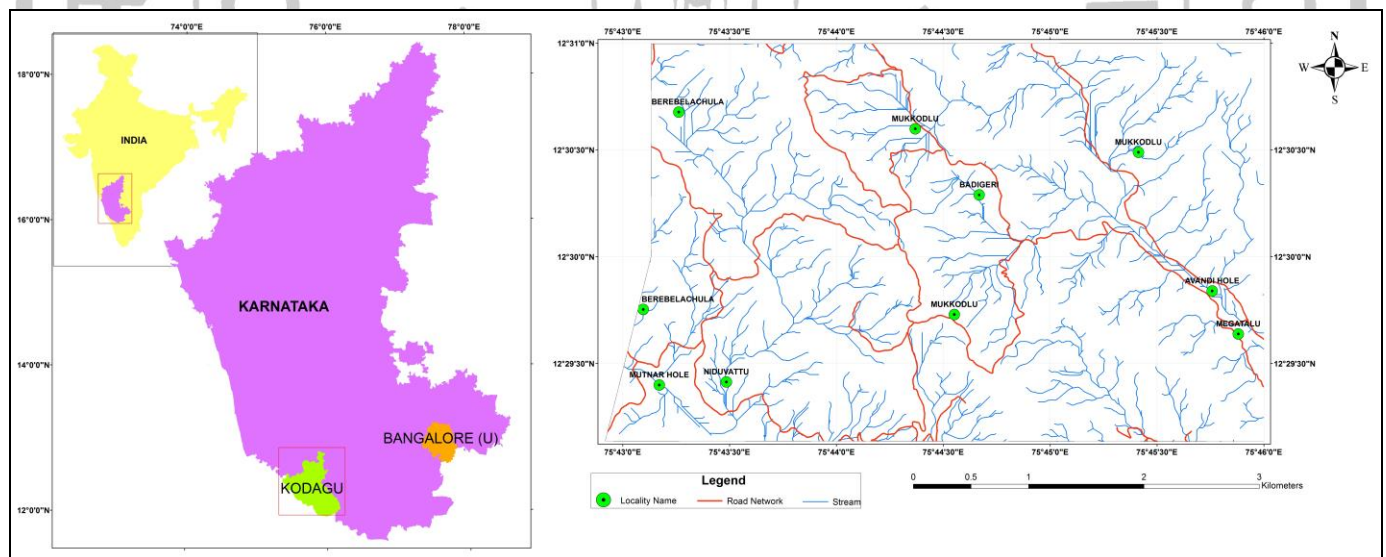


Figure-1.1: Location map of study area

The present study area is located around 20kms away in north from Madikeri town which is well connected by metaled roads. The Bangalore–Mangalore Highway (SH-88) and Mysore-Cannanore Highway (SH-88A) passes through the Coorg district. Fairly good network of roads exists in Coorg district which are connecting almost every part of rural and urban areas. Madikeri is Coorg district headquarters which is well connected by road and beyond Mysore the railway connectivity to Madikeri is

not yet been constructed. The Madikeri district headquarters is about 262 km away from Bangalore (State Capital), 128 km from Mysore and 130 km from Mangalore. The nearest Railway stations are Hassan and Mysore. Nearest Airport is located at a distance of about 130 km at Mangalore.

The Coorg district is located in the high precipitation zone with picturesque topography occupying the eastern and western slopes of the Western Ghats. The Western Ghats represent hilly range with steep escarpments parallel to the west coast of India. The topography of the area ranges from gently dipping slope plains in parts of Madikeri to rugged hilly terrains with elevation ranging upto 1300m around Nidavattu, Megatallu. The study area is marked by NW-SE trending ridges with steep slopes $>45^{\circ}$ and wide valleys along various nalas/streams having very gentle-moderately gradient slopes feasible for cultivation.

1.3. Climate and Rainfall

The Coorg district is having tropical climate characterized by slight to medium humidity due to proximity to coast (about 32km). It is known to be quite pleasant and healthy places in south India by its unique climate, weather conditions and rainfall patterns. A major part of the year consists of rainy season as the monsoon period starting in June lasts till the ends of September. Even during the post monsoon months of October and November certain parts of the district receive a significant amount of rainfall. The climate is dominated by SW monsoon starting from June ending. Because of the cloudy weather the day would be quite sultry during October and it is only during the second half of the November that the weather becomes very clear. The period from December to February is the cold season marked by a bright weather, foggy mornings and cool nights. The day temperature begins to rise sharply during March and marks the commencement of the summer season, which lasts till the end of May. The highest maximum temperature recorded at Madikeri is 35°C on the 11th of May 1902 and the lowest minimum temperature ever recorded is 8.9°C on the 20th of February 1936.

The Coorg district has recorded average annual normal rainfall 2903.1 mm and average annual actual rainfall 2539.4 mm for period 2016-2018 (KSNDMC). While the Madikeri taluk (where present study area lies) of Coorg district has recorded average annual normal rainfall 4078.6 mm and average annual actual rainfall 3416 mm for period 2016-2018 (KSNDMC). The southwest monsoon reaches usually during early of June. Generally, June-September are the months of heavy rainfall ([see fig. 1.3](#)) and the precipitation in July is incessant and very heavy. The data analysis shows a continuous increasing trend in annual actual rainfall pattern from year 2016 in Madikeri taluk ([see fig. 1.2](#)) and the highest average actual rainfall has been recorded here during June-September months of year 2018 ([see fig. 1.3](#)) which have triggered here most landslides and enhanced the channel erosion.

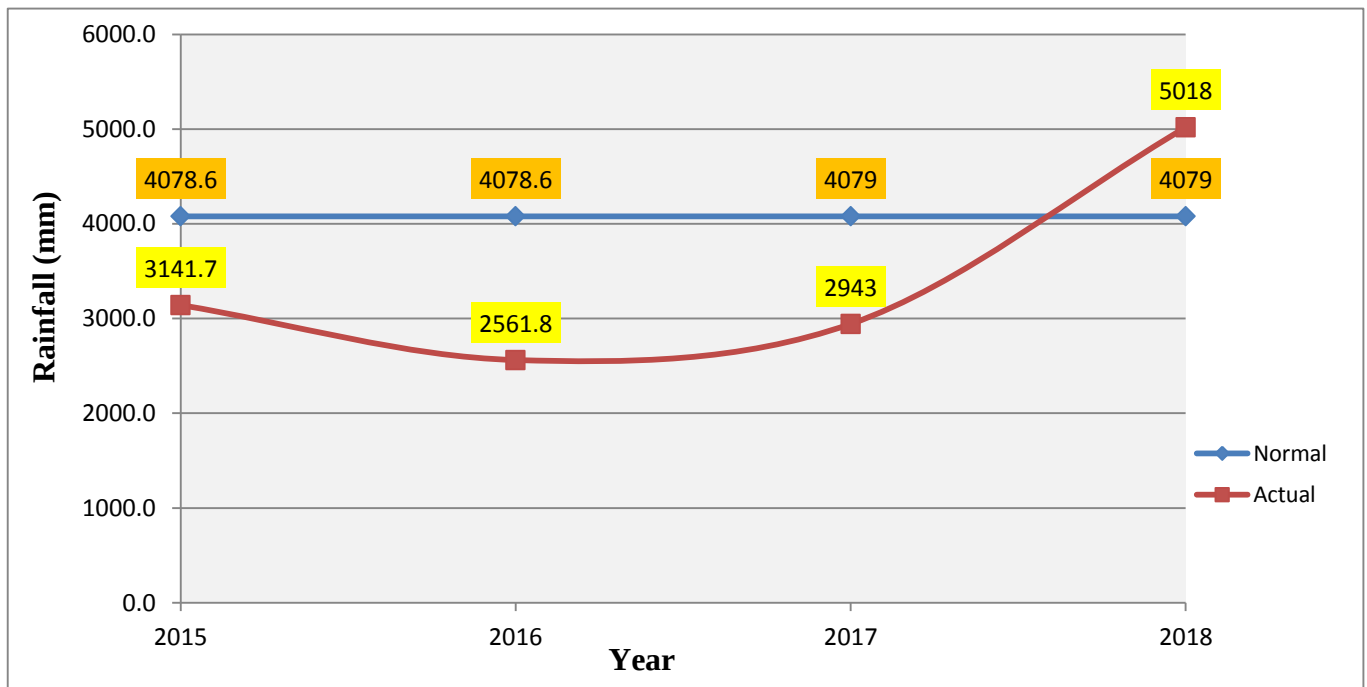


Figure-1.2: Trend of average annual normal and actual rainfall pattern in Madikeri taluk, Coorg recorded for 2015-2018 period. (Source: KSNDMC)

1.4. Previous and Present Work

In Coorg district Geological Survey of India has carried out studies on landslide subject way back 2007 by notably workers: *A. K. Mishra et al., 2008*; *K.V. Maruthi et al., 2012, 2013, 2010, 2014*; and *A.K. Srivastava et al., 2016 & 2017*. Among these *A. K. Mishra et al., K.V. Maruthi et al.,* have done landslide inventory, landslide hazard zonation and post disaster landslide studies in past years. While *A.K. Srivastava et al.,* have done Macro-scale (1:50,000) landslide susceptibility mapping (NLSM) which is a national programme launched by GSI in year 2014. The interesting thing is that the areas classified as high and moderate zone of landslide susceptibility by *A.K. Srivastava et al., 2016* were severely affected by landslides during 2018 monsoon period.

The present study is a landslide susceptibility mapping approach at meso-scale level (1:10k) by focusing on most responsible geo-factor themes and other causative factors for landslides. Extensive field work has been carried out to make best possible observations and to understand the failure mechanism, landslide material involved, causative factors and geological conditions. This assignment was one year programme with given NQT details (*see table-1.1*) and 60 field days were given mandatory. The concerned field officers have successfully achieved assigned targets and given field days more than mandatory (*see table-1.2*).

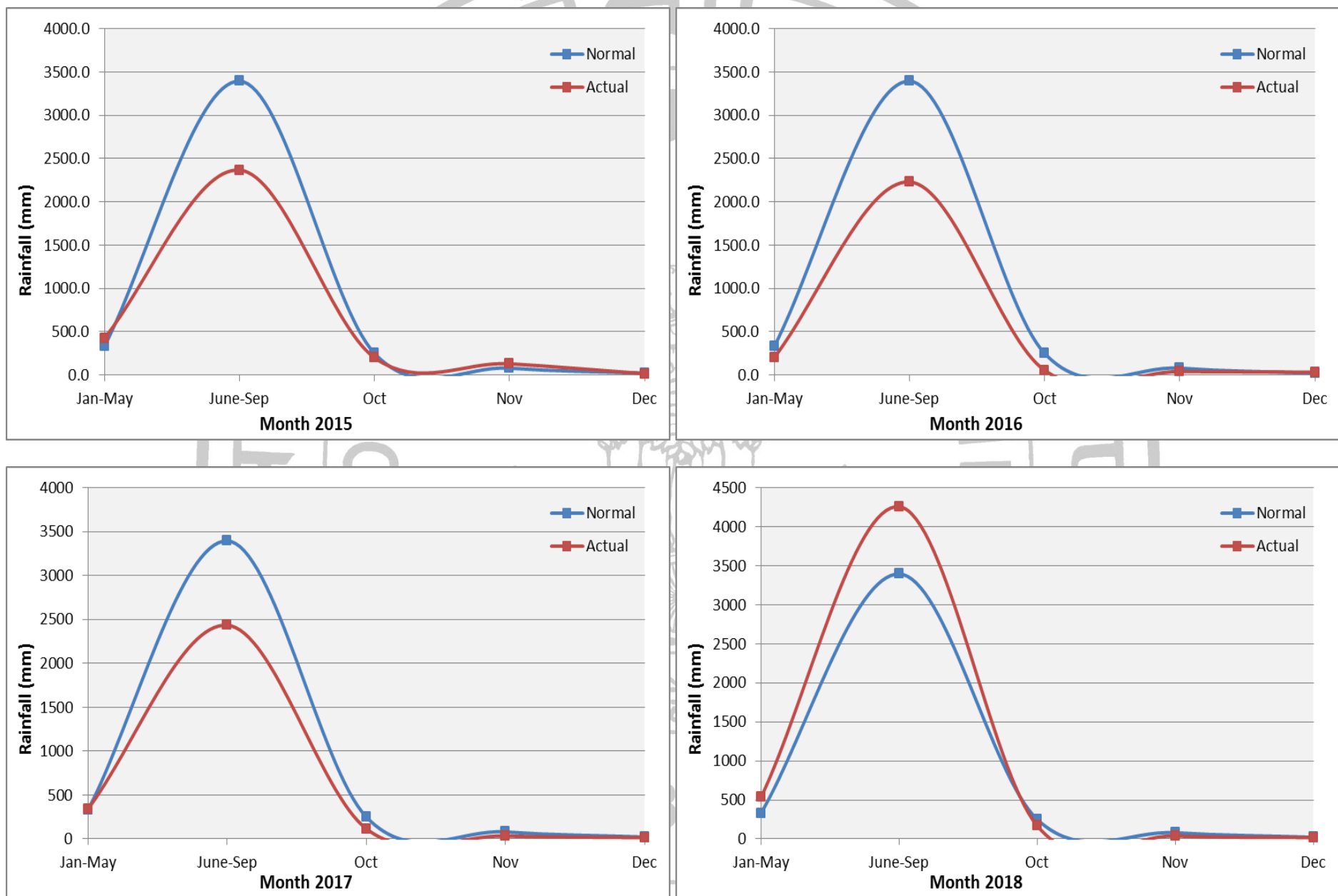


Figure-1.3: Trend of monthly average normal and actual rainfall pattern in Madikeri taluk, Coorg for years 2015-2018

Table-1.1: Nature and Quantum of Work and Time Schedule

Nature of Work	Target F.S 2018-19 (sq. km)	Achievements in sq. km
1.Pre – field studies		
Preparation of various thematic maps from remote sensing data (CartoDEM and CartoPAN 10m resolution and Google earth)	18 sq. km	18 sq. km
2. Field – based studies		
i. Geological-Slope Forming Material mapping (1:10 k)	18 sq. km	18 sq. km
ii. Geotechnical mapping - shear parameters of overburden and rock mass characterization of slope.	18 sq. km	18 sq. km
iii. Field validation of all pre-field thematic maps.	18 sq. km	18 sq. km
iv. Updation of landslide inventory with detailed assessment as per 42 point geo-parametric datasheet.	18 sq. km	18 sq. km
v. Updation of existing landslide inventory as per 41 point geo-parametric datasheet.	18 sq. km	18 sq. km
vi. Sample collection for determination of geo- technical parameters	40 nos.	41 nos.
3. Post-field studies & modeling		Model yet to be finalized with GHRM Division, Kolkata.
i. Updation and finalization of thematic maps and landslide inventory in GIS platform.	18 sq. km	18 sq. km
ii. Preparation of landslide susceptibility map in GIS platform.	18 sq. km	-
4.Collection of rainfall data	As per availability	Collected- last 5 years

Table-1.2: Total field days spent as per NQT by field officers

Name of the field officers	Field days mandatory	Total field days spent
Aijaz Ahmad Bhat Sr. Geologist	60 days	65 days
Dr. Zameer Ahmad Shah, Geologist	60 days	63 days

1.5. Acknowledgement

The authors wish to thank *Shri M. Sridhar*, Additional Director General and HOD, GSI (SR) and *Dr. I. D. Ashiya*, Dy. Director General, GSI, SU: K&G for giving opportunity to work in this project. The authors are thankful to *Shri K.V. Maruthi*, Director (Supervisory Officer) for providing facilities, guidance, support and valuable suggestions during entire project work. The authors are very grateful to *Shri J. Srihari*, Director (TC), GSI, SU: K&G for continuous moral and logistic support during the project. Last, but not least, the authors are thankful to the Kodagu district administration and local people who have rendered immense help and cooperation in various ways for successful completion of this project.



2. GENERAL GEOLOGY

2.1. Regional Geology and Stratigraphic Set Up

The area lies in Western Dharwar Craton (WDC) comprising dominantly TTG (tonalite–trondhjemite–granodiorite) or Peninsular Gneisses intercalated with highly deformed supracrustal rocks of Sargur Group having ~3.4–3.0 Ga age ([Naqvi and Rogers, 1987](#); [Jayananda et al., 2008](#)). The Mercara shear zone traverses through investigated area which is bound on the north by Western Dharwar Craton of Indian shield and to the south by Coorg Block. The Coorg Block is welded with Dharwar craton to the north by Mercara shear zone which is marked by steep gravity gradients ([Sunil et al., 2010](#)) and suggested the presence of underplated high-density material in the lower crust. The Dharwar craton comprises rocks of ancient supracrustals of 3400–3000 m.y of age range, Older and Younger Gneiss Complexes, Larger Schist belts (Dharwar type) of Late Archean age, Younger Granites (Closepet), Granulites and Younger Intrusives (Dykes) ([Aijaz et al., 2019](#)). Previous studies suggested that granulite facies rocks dominated by charnockites and mafic granulites occur as massifs in Coorg block ([Asha Manjari and Malur, 1997](#)) while others revealed that Orthopyroxene-bearing greasy green charnockites are the dominant rock types followed by TTG (tonalite–trondhjemite–granodiorite) suite and minor amphibolite/hornblende gneisses in association with bands of BIF (banded iron formation) occur sporadically, mostly along the periphery of the block. Several thick bands of granulite facies metapelites (Khondalites) with coarse garnet, sillimanite/kyanite occur along the northern and northeastern peripheries of the block where the present investigated area is located. Recent studies shows Sm–Nd whole-rock isochron ages for the charnockites, garnet granulites and migmatitic gneisses from the Coorg Block ranging from 2910 to 3700 Ma ([Peucat et al., 2013](#)) while reported U–Pb data on Zircons Mesoarchean crystallisation ages ≥ 3.3 Ga. Unlikely, GSI has done systematic mapping on 1:50k to reveal the general geology in present investigated area but has never taken further advanced or research based studies on petrology, stratigraphy, geochronology, plate tectonics, geodynamics, structural geology etc. to explore southern Indian shield and it is necessary to note here that GSI should take such advanced or research based studies in future to give its contribution to the geoscience world. The present investigated area is a part of degree sheet 48P. Based on systematic mapping, GSI has compiled the geological maps of degree sheet 48P prepared by various workers of GSI from 1949–1986 and published the second edition *Geological Quadrangle Map in 2013*. The regional stratigraphic set-up is shown in [table-2.1](#). This GQM reveals rocks of Sargur Group as oldest in the area having Archean age and are equivalent to Wyanad Group of rocks followed by Archean age rocks of Peninsular Gneissic Complex-I, Southern Granulite Complex and Peninsular Gneissic Complex-II.

Table-2.1: Regional stratigraphic set up of area covered by degree sheet 48P after *Geological Survey of India, 2013*.

Supergroup	Group	Formation	Lithology	Age
		Kadappuram/Viyyam/Periyar	Sand/Clay/Sand	Holocene
		Guruvayur	Sand	Pleistocene
			Calcrete/Laterite	Cenozoic
		Warkali	Clayey sand/Sandstone	Mio-Pliocene
			Quartz vein/Pink Granophyre/	Neoproterozoic
			Gray Granophyre/Gabbro	
			Granite/Pegmatite/Quartz vein/Dolerite	Paleoproterozoic
		Closepet Granite	Granite	Archean
		Vengad	Mica Schist	Archean
Peninsular Gneissic Complex	Peninsular Gneiss-II		Garnet-Biotite-Gneiss	Archean
Southern Granulite Complex	Charnockite		Calc Granulite	Archean
			Hornblende-Diopside Gneiss	
			Hypersthene±Cordierite Gneiss	
			Charnockite/Pyroxene Granulite	
	Khondalite		Calc Granulite with Limestone	Archean
			Garnet-Biotite Gneiss	
			Garnet-Silliminite-Kyanite Gneiss	
			Garnet-Silliminite±Graphite±Cordierite Gneiss	
			Garnet Quartzite	
Peninsular Gneissic Complex	Peninsular Gneiss-I		Mylonite	Archean
			Garnet Gneiss	
			Granodiorite Gneiss	
			Granite Gneiss	
			Grey Hornblende Biotite Gneiss	
			Anorthosite/Peridotite	Archean
	Sittampundi-Mettupalayam Complex			
	Sargur (=Wyanad)		Meta-Pyroxinite/Meta-Ultramafite/Peridotite/Banded Quartzite/Amphibolite/Pyribolite/Kyanite	Archean
			Garnet-Mica Schist/Garnet-Silliminite-Kyanite Gneiss/Garnet-Biotite-Silliminite	Magnetite Graphite
			Kyanite Cordierite Gneiss/Quartzite	

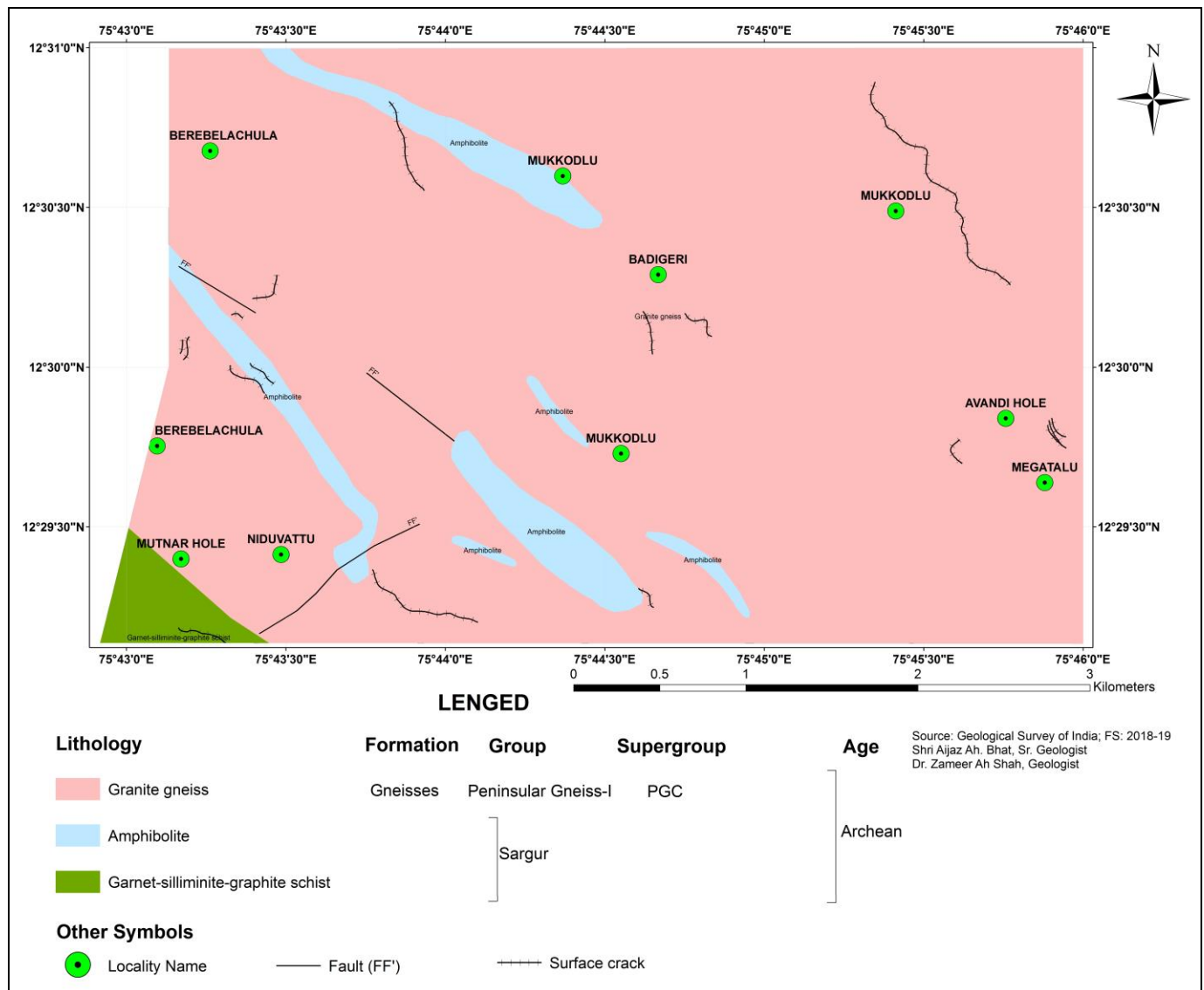


Figure-2.1: Geological map of the study area procured from Geodata Division, SU: K&G, Bangalore with some modifications done in present study

Table-2.2: Litho-stratigraphy of study area after Geological Survey of India (from 1949-2018).

Supergroup	Group	Formation	Lithology	Age
Peninsular Gneissic Complex	Peninsular Gneiss-I	Gneisses	Alluvium/Overburden	Recent
			Granite Gneiss	Archean
	Sargur (=Wyanad)		Amphibolite Garnet-Silliminite-Graphite Schist	Archean

2.2. Geology of the Study Area

The investigated area of 18 sq.km is occupied by rocks of Sargur Group followed by rocks of Peninsular Gneiss-I. The rocks from both the Groups are of Archean age but stratigraphically Sargur Group of rocks are oldest in age (*GQM Second edition, 2013, Geological Survey of India*). In the present study geological mapping has been done in 18 sq.km area on the basis of field based rock handspecimen

identification without petrographic studies (as per NQT) and few changes or modifications have been included ([see fig. 2.1](#)) in previous geological map on 1:50k by GSI.

2.2.1 Sargur Group

The Sargur Group is designated to highly deformed supracrustal sequences gone through high grade metamorphism equilibrated at ~8kbar pressure and ~700-750°C temperature around 2430 Ma in the late-Archean. Both the Sargur Group of rocks and Peninsular gneisses are overlain unconformably by rock sequences (2.9-2.5 Ga) of Dharwar Supergroup which is less deformed and less metamorphosed than the Sargur group ([Martin Guitreau et al., 2017](#)). The Sargur Group comprises the rock types as mentioned in table-3.1. Garnet-Sillimanite-Graphite Schist and Amphibolite are the dominant rock types of Sargur Group occurred in the present investigated area which are described as follows:

Garnet-Sillimanite-Graphite Schist: This rock type is highly metamorphosed seen as narrow and discontinuous patches and/or bands enclaved within Granite Gneiss (Biotite Gneiss) essentially made of quartzite, garnet and sillimanite with few flakes of graphite whereas apatite and magnetite are the accessory minerals present ([B.R.C. Iyengar, 1954](#)). This rock type is exposed in southwest of Niduvattu village, Kodagu with some discontinuous bands along foliation planes seen in Granite Gneiss. Foliation trending NW-SE direction and dipping at 35°-67° south-westerly. This rock type is highly prone to weathering and is involved most of the landslides occurred in the area of investigation during 2018 monsoon period. The weathered portions of this rock type take light pink to light red colour.

Amphibolite: This rock type is frequently associated and interbedded with schistose rocks of Sargur Group even seen as discontinuous patches along foliation planes in Granite Gneiss in the area. The most occurring variety is schistose amphibolite containing hornblende and plagioclase with few garnets. The Amphibolite's are representing ancient basaltic flows which have metamorphosed.



Figure-2.2: Amphibolite rock outcrops in Niduvattu village, Madikeri

2.2.2 Peninsular Gneissic Complex (PGC)

The recent studies on rock types of different ages occurring in Indian peninsula have gained lot to recognize the Peninsular Gneissic Complex (PGC) into Older Gneiss Complex (OGC or ~Peninsular Gneiss-I) and Younger Gneiss Complex (YGC or ~Peninsular Gneiss-II). The Older Gneiss Complex is older than 3000 m.y having mainly tonalite-trondhjemite-granodiorite (TTG) composition while Yungar Gneiss Complex is having largely reworked and mobilized gneisses of around 2600 m.y. The rock types occurring in PGC are shown in table-3.1. In the present investigated area only rock types of Older Gneiss Complex have been observed mostly Granite Gneiss.

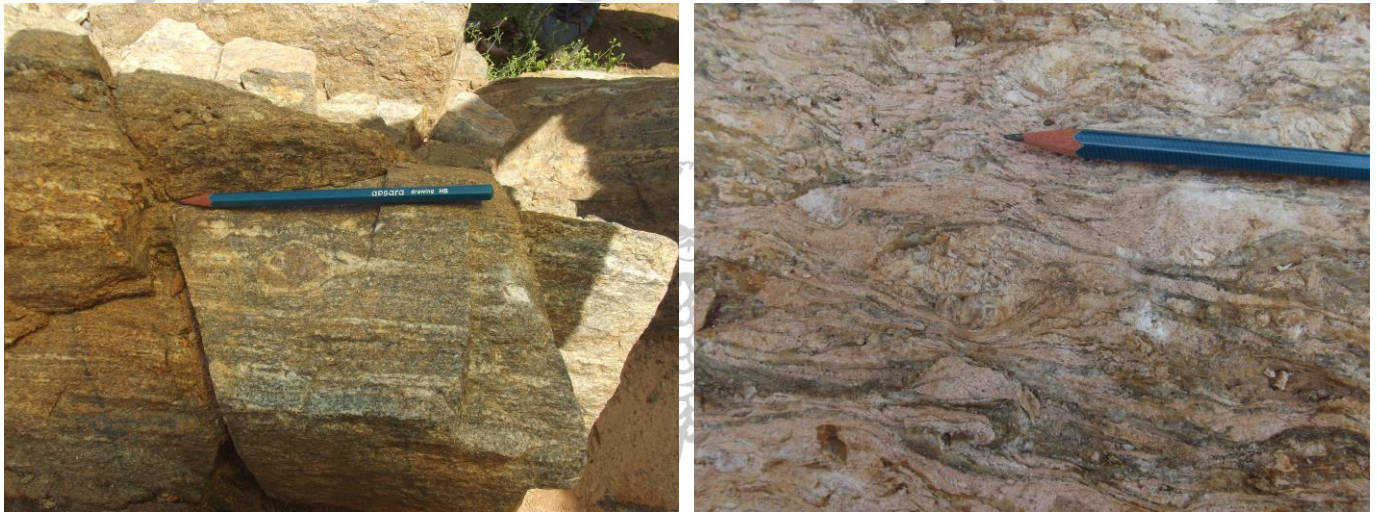


Figure-2.3: Deformed Granite Gneiss showing prominent joint planes and strong lineation features in Mukudllu village, Madikeri

Granite Gneiss: This rock type commonly known as Granite Gneiss belongs to Peninsular Gneiss-I or OGC which are coarse grained, leucocratic to mesocratic consisting quartz, plagioclase and minor amounts of mafic minerals (*T.S.S. Murthy et al., 1979, GSI*) while *B.R.C Iyengar, 1954* reported common varieties containing quartz and acid to intermediate varieties of feldspars, biotite and rarely hornblende. The accessory minerals include apatite, magnetite and mica with pink garnet widespread and frequent (*B.R.C Iyengar, 1954*) and they vary in colour from grey to pink with regional strike of foliation N25°W (*C.R. Veeraraghavan, 1961*), NNW-SSE (*B.R.C Iyengar, 1954*). However *C.R. Veeraraghavan, 1961* witnessed from its microscopic study the presence of quartz, plagioclase feldspar and biotite mica with microcline showing cross hatched twinning. In present study, various discontinuous amphibolite patches and/or bands up to tens of meters thickness have been observed occurring parallel to regional foliation NNW-SSE direction of Granite Gneiss. These amphibolite bands are standing alone in weathering and form ridges running parallel to regional foliation direction of Granite Gneiss in the area.

3. LANDSLIDE INVENTORY AND FIELD OBSERVATIONS

The area of investigation has been surveyed after exploring pre-field based studies in which various remote sensing data sources, topographic maps and literature works have studied. The field survey has been carried out in the area to investigate various aspects of landslides occurred, prevailing geo-factor themes, various basin morphometric parameters, rainfall patterns, slope variations and collection of samples for geotechnical laboratory studies.

3.1 Landslide Inventory

Geological Survey of India has prepared landslide inventory of Kodagu district from 2007 onwards and updated time to time as and when required. The previous workers ([A.K.Mishra](#); [U.K.Pradhan](#); [K.V.Maruthi](#); [K.V.Chandran](#)) of GSI have carried out landslide inventory studies in various parts of Kodagu district and among this [K.V.Maruthi](#) has dominantly updated the landslide inventory in years 2013-14. In years 2016-17, [A.K.Srivastava et al.](#) have updated the landslide inventory of parts of toposheet nos. 48P/07, P/11 & P/12, in which present investigated area lies, in their macro-scale landslide susceptibility mapping studies. In present study total 112 nos. of landslides ([see fig. 3.1](#)) have been demarcated using field inputs and remote sensing data sources ([see table-3.1](#)). Out of 112 nos. of landslides, 90 nos. of landslides were accessible which were checked and studied thoroughly with 42 point geo-parametric data sheet recordings and rest 22 nos. of landslides are located in inaccessible area which was very difficult and unsafe to reach. These 22 nos. of landslides have been validated by using landslide data of NRSC, Hyderabad. Most of landslides have reportedly occurred during 2018 monsoon rains in present study area and majority of these are earthflows. All demarcated landslides in the area are confined to overburden, except at one place, where rock slide (wedge failure) has occurred due to favorable angular relationship of foliation plane and joint planes ([see fig. 3.2k](#)). Different types of landslides were reported during field study as fig. 3.1 shows the representative field photographs of each type. This suggested that there have been acted different failure mechanisms under unique or multiple causative factors to occur these different type of landslides. Most landslides have occurred on slopes ranging from 10° to 30° gradients which are having either soil cover or weathered overburden cover of variable thickness from 1 to 7 meters (estimated values from cut slopes during field study). The basin morphometric analysis (is discussed in chapter-5) suggested that those watersheds in which most landslides have occurred, have performed very poor draining activity and made unsmooth distribution of storage capacity during incessant rainfall.

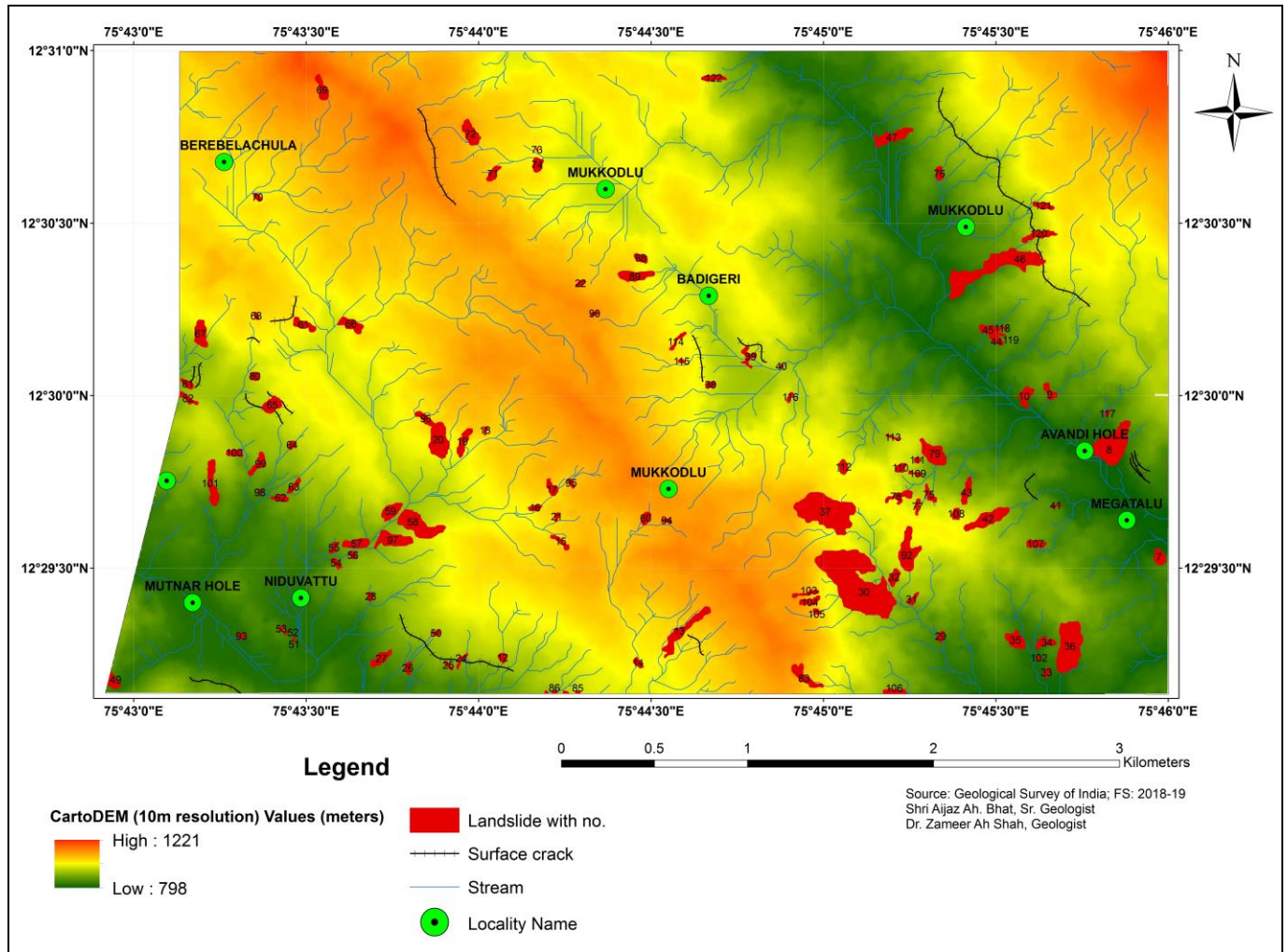


Figure-3.1: Landslide inventory map showing landslides with number and surface cracks overlapped with drainage and DEM

Table-3.1: Landslide incidences (red colour polygons in figure-5.1) with spatial coordinates.

Sl. no.	Landslide no.	Latitude (DMS)	Longitude (DMS)	Toposheet no.	Area (sq. meters)
1	84	75° 44' 15.419" E	12° 29' 7.852" N	48P/11	1435
2	85	75° 44' 17.333" E	12° 29' 8.101" N	48P/11	768
3	87	75° 44' 11.895" E	12° 29' 8.008" N	48P/11	691
4	86	75° 44' 13.363" E	12° 29' 7.915" N	48P/11	1516
5	106	75° 45' 12.447" E	12° 29' 8.303" N	48P/15	4562
6	49	75° 42' 56.187" E	12° 29' 10.675" N	48P/11	5525
7	33	75° 45' 38.875" E	12° 29' 11.830" N	48P/15	1448
8	83	75° 44' 56.946" E	12° 29' 11.239" N	48P/11	7279
9	26	75° 43' 47.789" E	12° 29' 12.578" N	48P/11	1922

10	25	75° 43' 54.742" E	12° 29' 13.019" N	48P/11	917
11	14	75° 44' 27.789" E	12° 29' 13.518" N	48P/11	1799
12	102	75° 45' 37.525" E	12° 29' 14.332" N	48P/15	518
13	12	75° 44' 4.168" E	12° 29' 14.384" N	48P/11	1852
14	24	75° 43' 57.084" E	12° 29' 13.902" N	48P/11	1628
15	27	75° 43' 43.025" E	12° 29' 14.257" N	48P/11	4906
16	51	75° 43' 27.908" E	12° 29' 17.525" N	48P/11	344
17	34	75° 45' 38.625" E	12° 29' 17.031" N	48P/15	3996
18	93	75° 43' 18.752" E	12° 29' 18.172" N	48P/11	1050
19	29	75° 45' 20.431" E	12° 29' 18.092" N	48P/15	1735
20	50	75° 43' 52.580" E	12° 29' 18.708" N	48P/11	1049
21	52	75° 43' 26.643" E	12° 29' 18.803" N	48P/11	385
22	35	75° 45' 33.411" E	12° 29' 17.530" N	48P/15	6865
23	53	75° 43' 25.709" E	12° 29' 19.449" N	48P/11	600
24	36	75° 45' 42.824" E	12° 29' 16.315" N	48P/15	28970
25	105	75° 44' 58.802" E	12° 29' 22.428" N	48P/11	962
26	13	75° 44' 35.881" E	12° 29' 18.924" N	48P/11	13510
27	104	75° 44' 57.628" E	12° 29' 24.284" N	48P/11	3215
28	28	75° 43' 41.197" E	12° 29' 25.021" N	48P/11	1343
29	31	75° 45' 15.588" E	12° 29' 24.602" N	48P/15	1946
30	103	75° 44' 56.919" E	12° 29' 25.538" N	48P/11	2334
31	32	75° 45' 12.336" E	12° 29' 28.337" N	48P/15	3803
32	54	75° 43' 35.260" E	12° 29' 30.756" N	48P/11	1764
33	56	75° 43' 38.149" E	12° 29' 32.287" N	48P/11	1344
34	30	75° 45' 5.691" E	12° 29' 27.358" N	48P/15	84630
35	7	75° 45' 58.537" E	12° 29' 31.927" N	48P/15	4295
36	55	75° 43' 34.865" E	12° 29' 33.547" N	48P/11	1859
37	107	75° 45' 36.975" E	12° 29' 34.215" N	48P/15	3519
38	57	75° 43' 38.717" E	12° 29' 34.289" N	48P/11	5988
39	15	75° 44' 14.217" E	12° 29' 34.471" N	48P/11	2566
40	97	75° 43' 45.171" E	12° 29' 34.944" N	48P/11	11210

41	92	75° 45' 14.896" E	12° 29' 33.109" N	48P/15	14770
42	94	75° 44' 32.740" E	12° 29' 38.186" N	48P/11	1059
43	21	75° 44' 13.649" E	12° 29' 38.893" N	48P/11	1029
44	60	75° 44' 29.145" E	12° 29' 38.646" N	48P/11	2641
45	58	75° 43' 49.820" E	12° 29' 37.568" N	48P/11	19220
46	108	75° 45' 23.058" E	12° 29' 39.404" N	48P/15	2313
47	42	75° 45' 28.529" E	12° 29' 38.521" N	48P/15	13040
48	16	75° 44' 9.848" E	12° 29' 40.451" N	48P/11	1696
49	41	75° 45' 40.540" E	12° 29' 40.675" N	48P/15	730
50	59	75° 43' 44.861" E	12° 29' 39.802" N	48P/11	6532
51	77	75° 45' 16.388" E	12° 29' 40.697" N	48P/15	1652
52	62	75° 43' 25.470" E	12° 29' 42.156" N	48P/11	2536
53	37	75° 45' 0.350" E	12° 29' 39.622" N	48P/11	44220
54	78	75° 45' 13.263" E	12° 29' 42.373" N	48P/15	4783
55	98	75° 43' 21.969" E	12° 29' 43.173" N	48P/11	543
56	75	75° 45' 18.621" E	12° 29' 42.892" N	48P/15	2731
57	95	75° 44' 16.133" E	12° 29' 44.720" N	48P/11	1038
58	17	75° 44' 12.775" E	12° 29' 44.002" N	48P/11	3139
59	63	75° 43' 27.882" E	12° 29' 44.284" N	48P/11	2308
60	43	75° 45' 24.903" E	12° 29' 43.390" N	48P/15	4875
61	109	75° 45' 16.009" E	12° 29' 46.448" N	48P/15	1121
62	110	75° 45' 13.430" E	12° 29' 47.424" N	48P/15	2232
63	101	75° 43' 13.784" E	12° 29' 44.785" N	48P/11	9251
64	112	75° 45' 3.488" E	12° 29' 47.565" N	48P/15	2907
65	111	75° 45' 16.379" E	12° 29' 48.778" N	48P/15	942
66	99	75° 43' 21.525" E	12° 29' 48.140" N	48P/11	4566
67	100	75° 43' 17.577" E	12° 29' 50.012" N	48P/11	2761
68	64	75° 43' 27.584" E	12° 29' 51.377" N	48P/11	1471
69	79	75° 45' 19.112" E	12° 29' 50.061" N	48P/15	11570
70	113	75° 45' 12.149" E	12° 29' 52.749" N	48P/15	984
71	19	75° 43' 57.496" E	12° 29' 51.863" N	48P/11	5703

72	18	75° 44' 1.194" E	12° 29' 53.902" N	48P/11	624
73	20	75° 43' 53.114" E	12° 29' 52.185" N	48P/11	15070
74	8	75° 45' 50.139" E	12° 29' 51.573" N	48P/15	26560
75	96	75° 43' 50.703" E	12° 29' 55.956" N	48P/11	3584
76	117	75° 45' 49.430" E	12° 29' 56.911" N	48P/15	612
77	65	75° 43' 24.111" E	12° 29' 58.400" N	48P/11	6156
78	116	75° 44' 54.246" E	12° 29' 59.705" N	48P/11	1249
79	82	75° 43' 9.484" E	12° 29' 59.513" N	48P/11	2702
80	10	75° 45' 35.209" E	12° 29' 59.765" N	48P/15	5280
81	9	75° 45' 39.430" E	12° 30' 0.671" N	48P/15	3383
82	38	75° 44' 40.393" E	12° 30' 1.889" N	48P/10	1486
83	81	75° 43' 9.336" E	12° 30' 2.034" N	48P/10	2231
84	80	75° 43' 21.073" E	12° 30' 3.350" N	48P/10	2084
85	40	75° 44' 52.670" E	12° 30' 5.101" N	48P/10	435
86	115	75° 44' 35.350" E	12° 30' 5.960" N	48P/10	673
87	39	75° 44' 46.933" E	12° 30' 6.702" N	48P/10	3601
88	44	75° 45' 30.224" E	12° 30' 9.677" N	48P/14	2333
89	114	75° 44' 34.637" E	12° 30' 9.515" N	48P/10	2065
90	119	75° 45' 30.840" E	12° 30' 10.695" N	48P/14	732
91	118	75° 45' 30.844" E	12° 30' 11.627" N	48P/14	1041
92	45	75° 45' 28.637" E	12° 30' 11.230" N	48P/14	4004
93	67	75° 43' 11.681" E	12° 30' 10.761" N	48P/10	7765
94	61	75° 43' 29.664" E	12° 30' 12.328" N	48P/10	4740
95	66	75° 43' 37.796" E	12° 30' 12.239" N	48P/10	6299
96	68	75° 43' 21.375" E	12° 30' 13.865" N	48P/10	714
97	90	75° 44' 20.206" E	12° 30' 14.270" N	48P/10	773
98	22	75° 44' 17.738" E	12° 30' 19.505" N	48P/10	1155
99	89	75° 44' 27.322" E	12° 30' 20.811" N	48P/10	8052
100	88	75° 44' 28.244" E	12° 30' 23.882" N	48P/10	2621
101	46	75° 45' 29.905" E	12° 30' 21.670" N	48P/14	40360
102	120	75° 45' 37.517" E	12° 30' 27.776" N	48P/14	5666

103	121	75° 45' 38.263" E	12° 30' 33.021" N	48P/14	3282
104	70	75° 43' 21.555" E	12° 30' 34.456" N	48P/10	1184
105	71	75° 44' 2.594" E	12° 30' 38.594" N	48P/10	3139
106	76	75° 45' 20.212" E	12° 30' 38.657" N	48P/14	2539
107	74	75° 44' 10.289" E	12° 30' 40.139" N	48P/10	3487
108	73	75° 44' 10.187" E	12° 30' 42.762" N	48P/10	196
109	47	75° 45' 12.056" E	12° 30' 44.956" N	48P/14	9735
110	72	75° 43' 58.679" E	12° 30' 45.703" N	48P/10	7868
111	122	75° 44' 40.890" E	12° 30' 55.216" N	48P/10	3335
112	69	75° 43' 32.770" E	12° 30' 53.489" N	48P/10	5109



(a) Earth slide occurred on gentle side slope of a major stream in Megatalu village



(b) Earth slide occurred in cultivated land on moderate slope by water saturation in Megatalu village



(c) Earth flow and channel erosion (no.8) occurred on moderate to high left side slopes of Avandi Hole in Megatalu village



(d) Debris slide occurred on right side high slopes of Avandi Hole in Megatalu village



(e) Channel erosion and flow along a 2nd order stream in Badigeri village



(f) Channel erosion and flow along a 1st and 2nd order stream in south Mukudlu village. The rock exposed here is Granite Gneiss with some Amphibolite layers.



(g) Earth slide occurred on moderate to high slope which have affected the local road to north-eastern Niduvatu village



(h) Earth flow occurred along 1st order stream developed on moderate slope with thick overburden cover (weathered black color material of Amphibolite rock and milky white material of Granite Gneiss) in north-eastern Niduvatu village



(i) Debris flow occurred on moderate side slope of 2nd order stream in which rock fragments of different sizes have flown down in north-eastern Niduvatu village



(j) Dewatering structures developed in the vicinity of landslide shown in (h) above. These structures are developed in very fine grained weathered rock associated with Granite Gneiss along a faulted contact in north-eastern Niduvatu village



(k) Rock slide occurred in Granite Gneiss with Amphibolite bands in north Berebelachula village



(l) Landslide debris moved by channel flow and checked with in 3rd order stream peripheries wherein few houses were buried and few damaged in south-east Mukodlu village



(m) Landslide debris material moved by channel flow of 5th order stream which is directly joined with 7th order main stream in the given watershed which has no development of 6th order streams in south-east Mukodlu village



(n) A lateral spread type of landslide occurred in south of Megatalu village. The overburden material have spread at different dimensions rather than flown, along with surface objects after might getting liquefy.

Figure-3.2: Shows field photographs of different types of landslides which were occurred during August and September 2018 rainfall period.

3.2 Field Observations

Extensive field work has been carried out to investigate the landslide affected areas in detail rather than field check and validation procedures being adopted in NLSM study. During investigation utmost efforts have been given to reach on valid classification, causative factors responsible for landslide occurrences and conclusions. Besides, the most relevant geo-factors which make a natural slope susceptible to landslides have been identified for utilizing them in assessment of slope movement susceptibility by adopting a valid model. Following observations have been made in field investigations;

- ❖ Landslides occurred in study area are rainfall induced caused by multiple causative factors. These causative factors have classified into generic and human induced. The generic causative factors include favorable slope gradient, excess and incessant rainfall, thick overburden material (SFM) due to weathering processes, saturation of overburden material, low drain out capacity of slopes subsequent to incessant rainfall, poor performance of watersheds to drain out and distribute storage capacity waters, increase of pore water pressures, increase in soil unit mass, presence of structural elements like faults, shear zone, joint systems etc., high drainage density and rise of excess water levels in higher order streams subsequently to quick runoff. The human induced causative factors include lack of proper drainage network development, blocking of natural streams by cultivation methods and settlement patterns, cut-slopes left over without proper reinforcement.
- ❖ The granite gneiss comprises alternative bands of quartz-garnet bearing rock units which are very susceptible to weathering on surface. These rock units have been frequently seen involved in landslide material with light pink to medium red coloration when weathered.
- ❖ The rise of excess water levels in higher order streams subsequently to quick runoff due to high drainage density leads to scouring and/or removal of toe material of a slope which intern induced instability in upslope material and got failure. Whereas landslides on higher slopes with or without first order streams have occurred due to low drain out capacity and increase in pore water pressures subsequent to rainwater infiltration.
- ❖ The rocks have two major joint sets which act as paths of weakness favorable for deep infiltration and deep weathering and where from movement could initiate. Among which a joint set trending regionally NE-SW direction (perpendicular to the axis of shortening of oriented mineral grains) is prominent. This joint set is dipping either in SE or NW direction. The angular relationship of this joint set with regional gneissosity/foliation is 60° - 75° . The trend of their intersection line is S15W plunging at 50° - 60° . Almost all first to second order drainage is controlled by this prominent joint set in the study area. These joint sets are allowing water to percolate very deep due to which weathering and alteration of rocks occur to deeper levels and has developed in-situ thick overburden material varying from 1m to 7m in thickness.
- ❖ Majority of landslides are earthflows occurred on moderate slopes due to water saturation which leads to loss of cohesion and finally leads to losing its shear strength and subsequently slope failure occurs.

- ❖ All the landslides occurred in the area are confined to overburden, except at one place, where rock slide (wedge failure) has occurred due to favorable angular relationship of foliation plane and joint planes.
- ❖ The large dimension landslides are confined mostly to natural slopes without any cut-slope. The main reason behind this is infiltration of rain water which could not be drained out during rainfall by low drain out capability of slopes resulting increase of pore water pressures. While the natural slopes with cut-slopes in the area particularly by road cutting have played a positive role in terms of draining the infiltration rain waters subsequent to rainfall due to which pore water pressures remain under control. Although these slopes are having small scale landslides occurred due to increase in unit mass.
- ❖ Surface cracks are developed in various parts of study area ([fig. 3.3](#)) during 2018 rainfall. These surface cracks are running parallel to contours which indicate the initiation of slope movement and material adjustment. But at places these cracks run across contours irrespective of slope gradient which indicates the localized subsurface block movement either along a concealed fault plane or most probably along penetrative joint planes. At places the rocks have undergone in high strain conditions that reflected by shearing, development of localized faults/micro faults/joint systems/fractures. The areas where rocks are pulverized without any evidence of mineral grain stretching and shear sense are mapped as brittle shear zone. These areas are mostly landslide affected areas. Due to pulverization process huge volume of non-cohesive fine grain material is produced which moved directly as earthflows during heavy rains subsequently on water saturation.
- ❖ The rocks at places have gone through brittle-ductile shear conditions which are evident from stretching of mineral grains, dextral shear sense of porphyroblasts, grain fracturing and development of faults and spaced joints, mineral grain boudins. These areas are affected by small to moderate dimensional landslides (not flows) with some lateral spread.
- ❖ Few localized faults have been demarcated during field investigation on the basis of geomorphic, structural and lithological evidences in the study area. In the vicinity of these fault lines many large scale landslides have occurred and many surface cracks have developed parallel or sub-parallel to these fault lines which indicates one of causative factor for instability of slopes in the area. Among these localized faults one fault is prominently traverses through the Berebelachula and Niduvattu villages which are more landslide affected areas and is trending in NW-SE direction parallel to sub-parallel with regional foliation planes.
- ❖ A dip-slip fault has been observed in Niduvattu village which is trending in 210° direction and dipping 21° NW. Slickensides have been recorded on fault plane trending 300° and plunging 21° .

The movement is almost layer parallel with 21° deflection from dip of foliation plane. Along this fault trend there is valley widening in Mutnar Hole which is a geomorphological evidence of this fault extension.

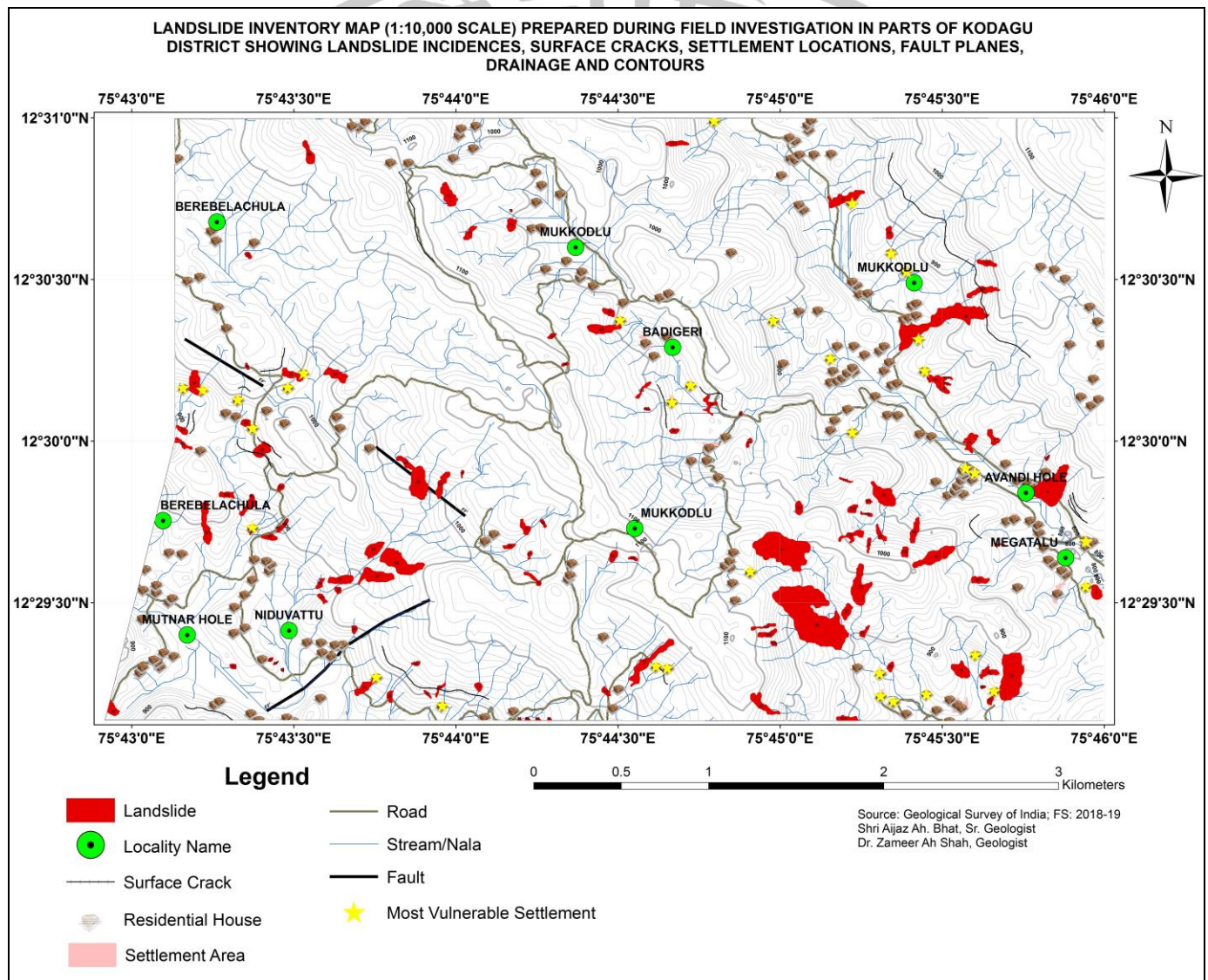


Figure-3.3: Shows landslides and surface cracks with contour, drainage, settlement, road, structural lineaments and most vulnerable settlements

4. GEO-FACTOR MAPS

Thematic map commonly known as geo-factor map is spatially prepared to show a particular theme connected with a specific geographic area. This map is of any kind of surface, subsurface or their parameter theme showing variations at smaller or larger scales which can responsible for any kind of earth's mass movement. Recent studies on landslide/mass movement have gained advanced methods of predicting slope failure vulnerability by analyzing and integrating various themes/geo-factors. Integration of various kinds of themes on a specified mapping scale by adopting precise modeling methodology leads to prepare a categorized landslide vulnerability map. In present investigation the most responsible factors for landslide cause and for susceptibility modeling have been identified by adopting various kinds of investigation procedures. These factor maps include stream watershed, drainage, slope gradient, landform, slope forming material, overburden thickness and different geotechnical parameter maps such as cohesion, friction angle, specific gravity, density, porosity and silt+clay percentage. Although there are multiple factors which have acted as subordinating roles in occurrence of landslides in the area of investigation but focus was given to most relevant and responsible factors which have acted on rainfall influx to occur the landslides and channel erosion. In a detailed sense among these most relevant and responsible factors the drainage related themes and parameters have acted major role in occurrence the landslides and channel erosion.

4.1 Stream Watershed Map

The stream watershed map has been derived from CartoDEM (10m resolution) in ArcGIS platform. For integration and modeling purpose the derived stream watershed map is reclassified in to 7 classes as there are 7 orders of streams developed in watersheds wherein present area lies ([see fig 4.1](#)). The stream watershed theme is identified most relevant for susceptibility modeling as to check which stream orders have positively responded to occur the landslides and channel erosion. The necessity to include the stream watershed theme arose after doing the drainage basin analysis as discussed in chapter-6. In drainage basin analysis it was revealed that different stream orders in watersheds wherein present area lies have poorly performed to drain and distribute storage capacity waters during rainfall intensity of >2500mm which have impacted in these watersheds to occur landslides and channel erosion. The statistics and the landslide occurrence favorability score (LOFS) ratings of stream watershed classes are shown in [table-4.1](#). The 5th order has given strong positive rating and this is because of the fact which have revealed in drainage basin analysis that in one watershed (W2) the 6th order is missing. The pressure of drainage functioning of 6th order has impacted directly the 5th order drainage functioning. The positive ratings of 2nd and 3rd stream orders reveal their poor performance during heavy rainfall.

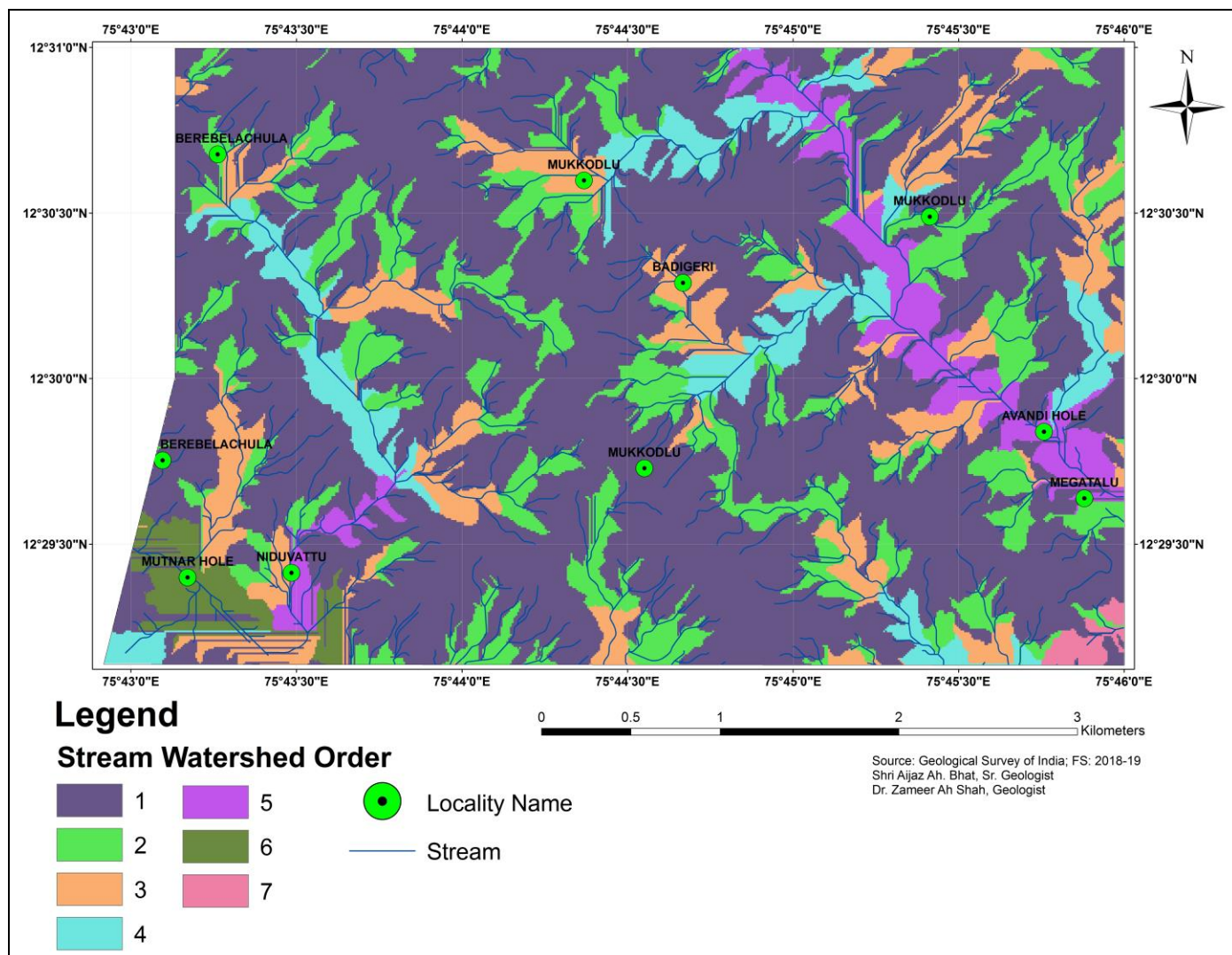


Figure-4.1: Shows stream watershed map of the study area derived from CartoDEM 10m resolution

Table-4.1: Statistics and LOFS rating of stream watershed classes

No. of Classes	Stream-Watershed Order	Pixel Count	Landslide Occupied Pixels	LOFS Rating
1	1	108693	3468	0.00
2	2	27882	1203	0.61
3	3	16771	681	0.43
4	4	11100	75	0.00
5	5	7950	432	1.00
6	6	3248	10	0.00
7	7	787	0	0.00

4.2 Slope Gradient Map

The slope gradient map has been derived from CartoDEM (10m resolution) in ArcGIS platform. For integration and modeling purpose the derived slope gradient is reclassified in to 10 classes ([see fig 4.2](#)). The slope varies up to 58° over the area of investigation. The slope gradients ranging between 10° - 35° have positively responded to occur landslides and in particular the 15° - 25° slope range has more responded in the study area. This observation rules out that landslide vulnerability increases with increasing the slope gradient and focused on the fact that slope respond is dependent on other variable geo-factors. The statistics and the landslide occurrence favorability score (LOFS) ratings of slope gradient classes is shown in [table-4.2](#).

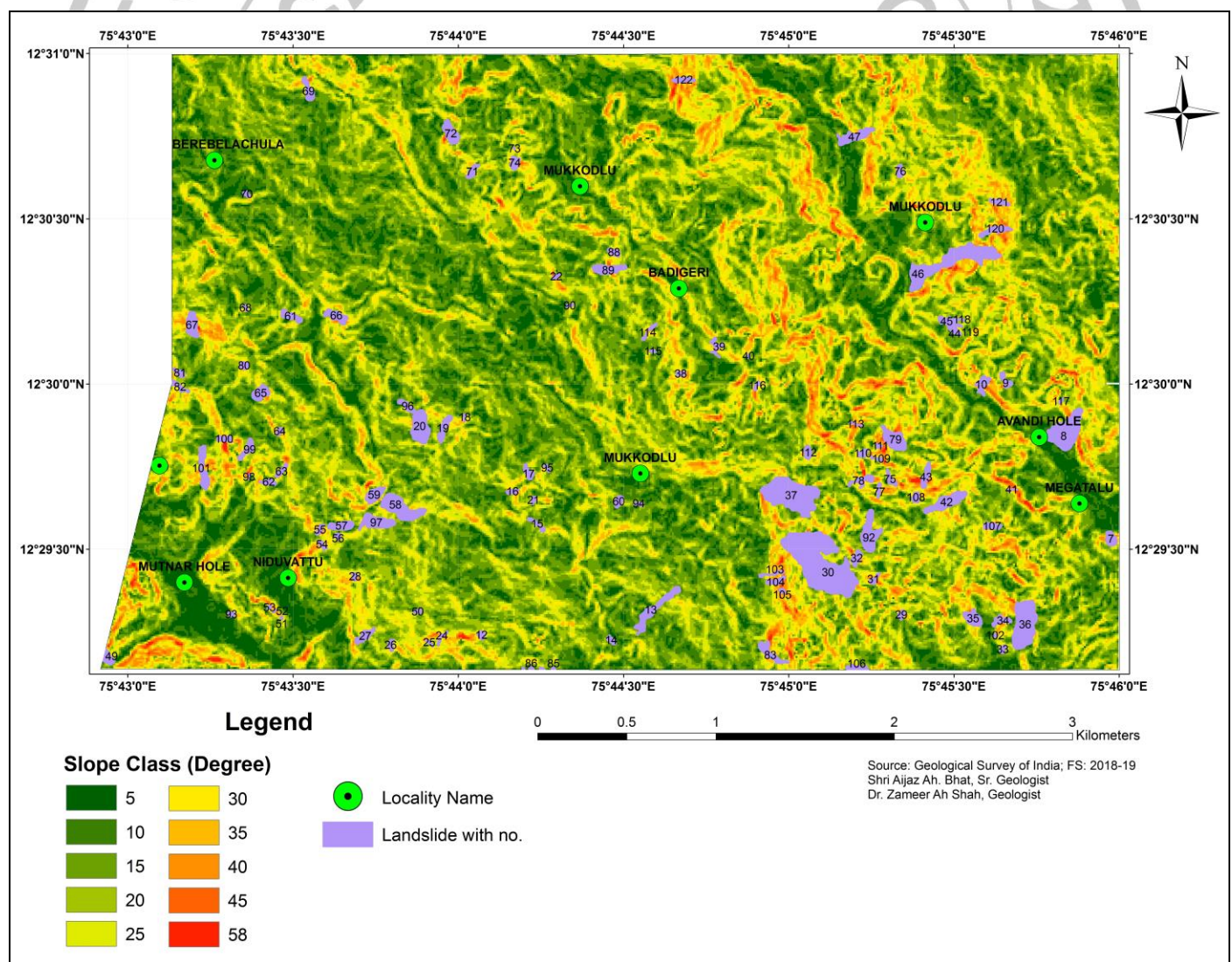


Figure-4.2: Shows slope gradient map of the study area derived from CartoDEM 10m resolution and landslide incidences occurred

Table-4.2: Statistics and LOFS rating of slope gradient classes

No. of Classes	Slope Gradient (Deg.)	Pixel Count	Landslide Occupied Pixels	LOFS Rating
1	5	13503	196	0.85
2	10	33769	677	0.00
3	15	42741	961	0.00
4	20	36060	1178	0.26
5	25	26124	1102	0.00
6	30	15724	883	0.35
7	35	8340	548	1.00
8	40	3757	315	0.77
9	45	1258	113	0.00
10	58	320	22	0.00

4.3 Drainage Map

Drainage patterns are the reflections or surface manifestations of slope, geology and different geological structures or the successive episodes by which the surface has been modified including uplift, tilting, folding, faulting, jointing, depressions (*Emilie R.Zernitz, 1932*) as well as deposition and erosional regimes. The streams form the different patterns by determining these successive episodes of modifications and form different landforms. In present investigation the drainage map has been derived from CartoDEM (10m resolution) in ArcGIS platform. Broadly there are 5 stream orders present in the study area having total stream length of 130 Km. The area broadly exhibits dendritic drainage pattern characterized by irregular branching in all directions with the tributaries joining the main stream at all angles and signifies the rocks with uniform resistance. But rectangular and parallel drainage patterns are also developed in localized zones. The rectangular pattern is characterized by right angled bends in both the main stream and its tributaries due to structural controls (*Emilie R.Zernitz, 1932*) and this drainage pattern is prominently evident in the present study area. The parallel pattern is characterized by streams flow nearly parallel to one another over a considerable area and this pattern implies either a pronounced regional slope or a slope control by successive topographic features controlled by folding or faulting (*Emilie R.Zernitz, 1932*). The present area of investigation is sharing two watersheds namely WS1 and WS2 (*see fig. 4.3*) of a parent drainage basin of 374.6 sq. km area. Attempts have been made to analyze the basin morphometry (discussed in chapter-5) of these two watersheds and their neighboring ones for understanding their drainage composition, drainage evolution and drainage response to rainfall which directly or indirectly defines evidences of structural controls, lithological variations, infiltration capacity,

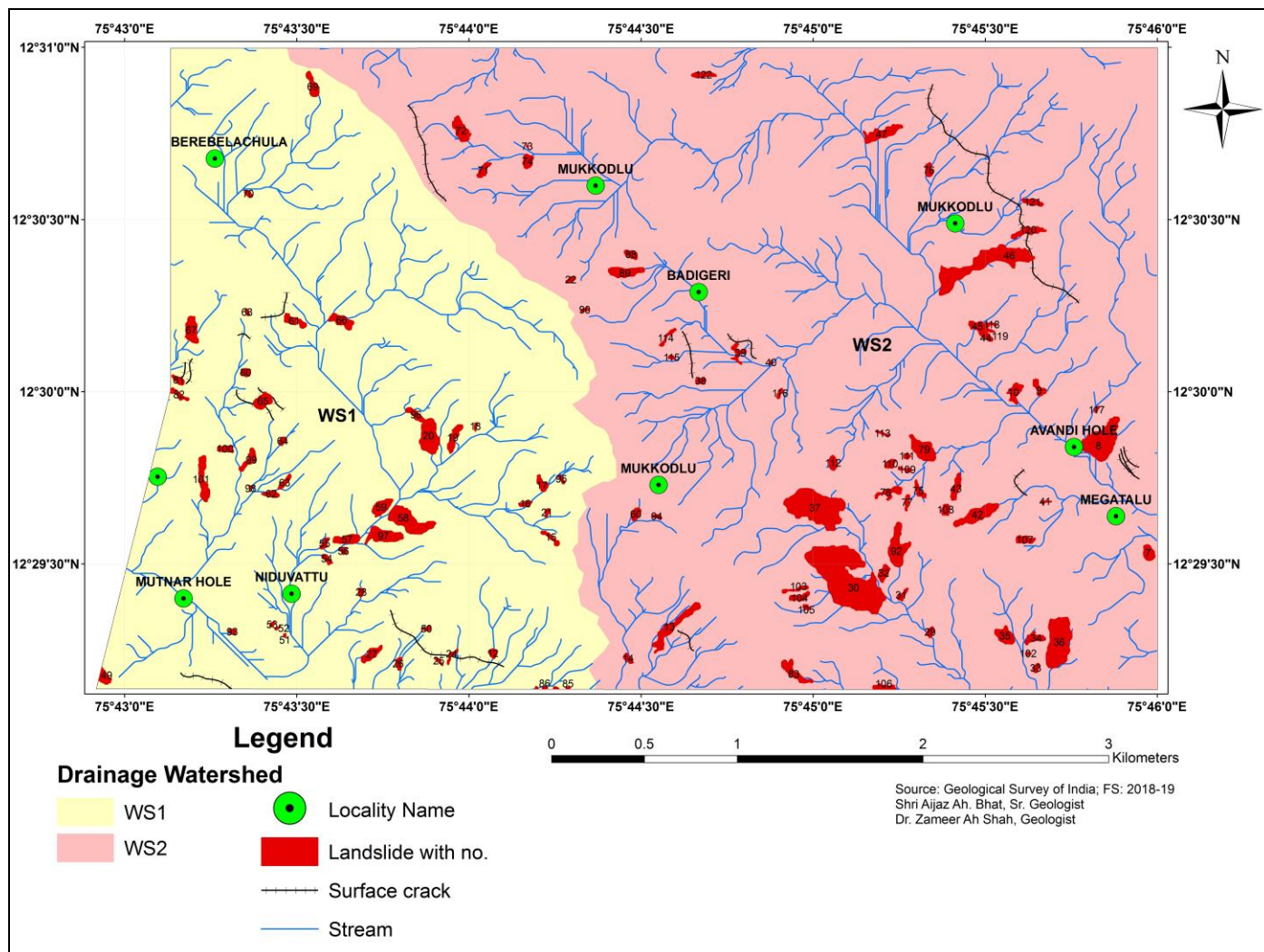


Figure-4.3: Shows drainage map of the study area with demarcation of different watersheds (drainage sub-basins) derived from CartoDEM 10m resolution overland flow, erosional levels, pervious or impervious substratum, variations in slope and relief, flood chances. Drainage is playing very significant role in landslide occurrences in the area. Many landslides have occurred on side slopes of different stream orders after removal of toe material by their flash water action during incessant rainfall (see fig. 4.4).



Figure-4.4: Shows how the overburden material has eroded and flown along the drainage of different stream orders

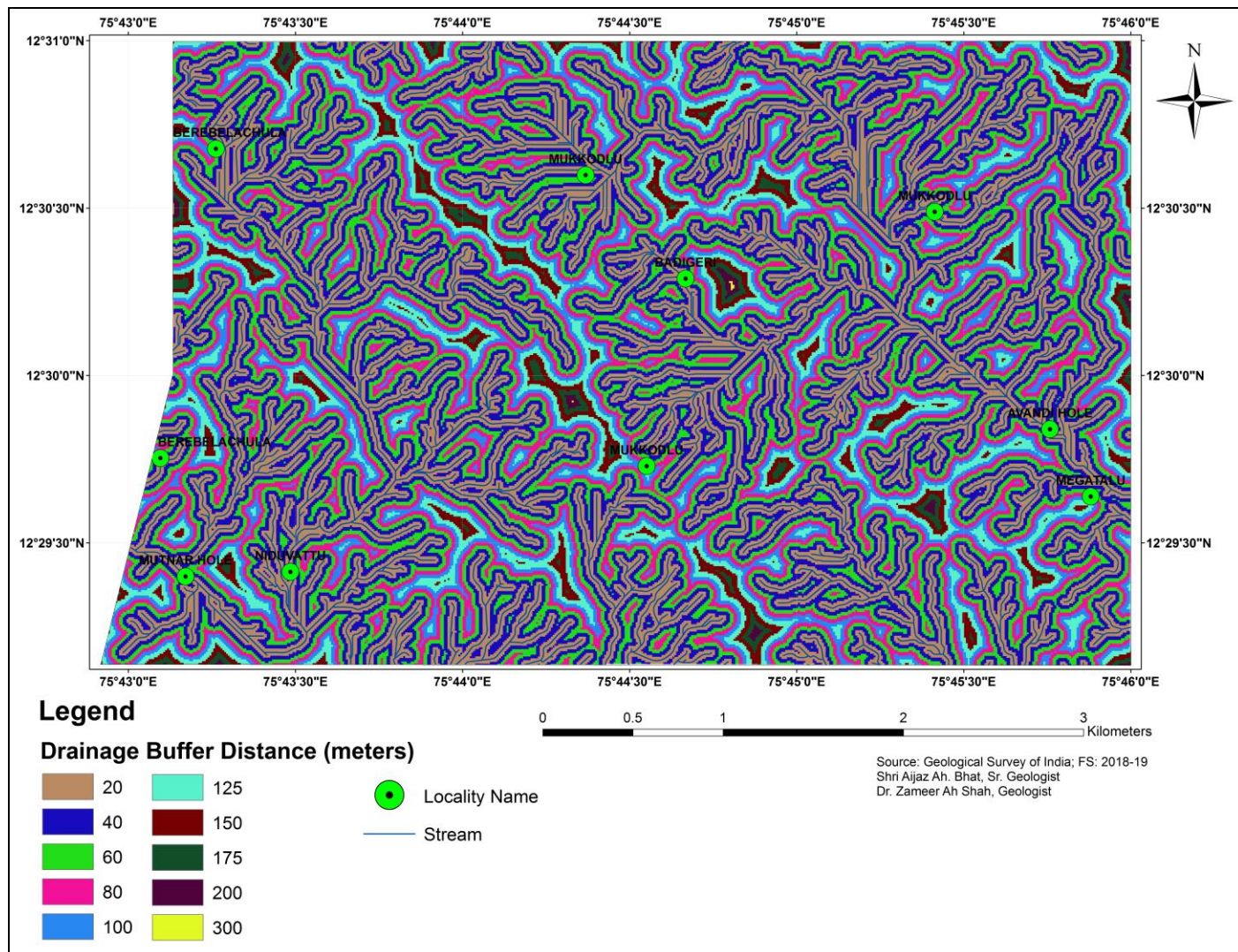


Figure-4.5: Shows multiple buffer ring drainage map derived from CartoDEM 10m resolution

Subsequently the landslide material has taken by channel flow process to higher order streams which created flood like situation in lower reaches. The drainage network has been used in susceptibility modeling in dual conceptual themes one is stream watershed which is discussed in [section 4.1](#) above and second is drainage distance theme. The drainage distance themes represent the distance of influence of water action in different stream orders during rainfall. The drainage map has been derived from CartoDEM (10m resolution) in ArcGIS platform. For integration and modeling purpose the multiple buffer rings were developed from drainage map as shown in [fig 4.5](#). The initial 60m of distance from each stream order is revealed much influenced by water action channel erosional activity during rainfall and this thing has been observed in field evidences also as shown in [fig 4.4](#). Where else the erosion activity of 60m distance from any stream order takes place subject to performance of each watershed parameter, it impacts the stability of upslope SFM during turbulent water action. Here this should be mentioned that if all the watershed parameters perform well to drain and distribute storage capacity waters then the erosion activity

and its impact on upslope SFM will minimize in hierarchy stream orders. The statistics and the landslide occurrence favorability score (LOFS) ratings of drainage distance classes are shown in [table-4.3](#) below:

Table-4.3: Statistics and LOFS rating of drainage distance classes

No. of Classes	Drainage Distance (m)	Pixel Count	Landslide Occupied Pixels	LOFS Rating
1	20	47107	1971	1.00
2	40	40403	1526	0.53
3	60	32122	1033	0.00
4	80	24831	692	0.00
5	100	17121	434	0.00
6	125	12538	238	0.00
7	150	5513	69	0.00
8	175	1602	16	0.00
9	200	347	4	0.00
10	300	20	0	0.00

4.4 Geological-Slope Forming Material Map

The slope is an integral part of the drainage system where from water and sediment reaches to streams by various transporting agencies. Slopes form with evolution of landforms and are susceptible to changes by variations in climate, lithology and structure, drainage, hydrology, deposition, erosion and mass movement etc. Some of these variables are direct responses of various controlling factors for evolution of landforms like erosion, mass movement (landslides) and deposition. If the climatic conditions change to occur more precipitation the area will be witnessed by higher drainage densities, frequent erosion and mass movements and high sediment transport.

Over the geological time scale the slopes have much evolved by various geological activities and become an independent factor of landslide occurrences. The slopes are having either rocky surface or covered with overburden of variable thickness produced by weathering or transportation. This characteristic makes the slopes vulnerable to landslides depending upon the slope angle, overburden thickness, relief, lithology and structure. Therefore, over the years researchers have taken the studies on these slope characteristics into account for analyzing their role in landslide susceptibility by preparing a map called geological-slope forming material map. This map depicts the rocky surface slopes and slopes with different types of overburden either in-situ or transported. In the present study unlike NLSM the geological-slope forming material map has been prepared ([see fig. 4.6](#)) solely by using field inputs instead

of adopting proxy geological-slope forming material map prepared by using various remote sensing based themes.

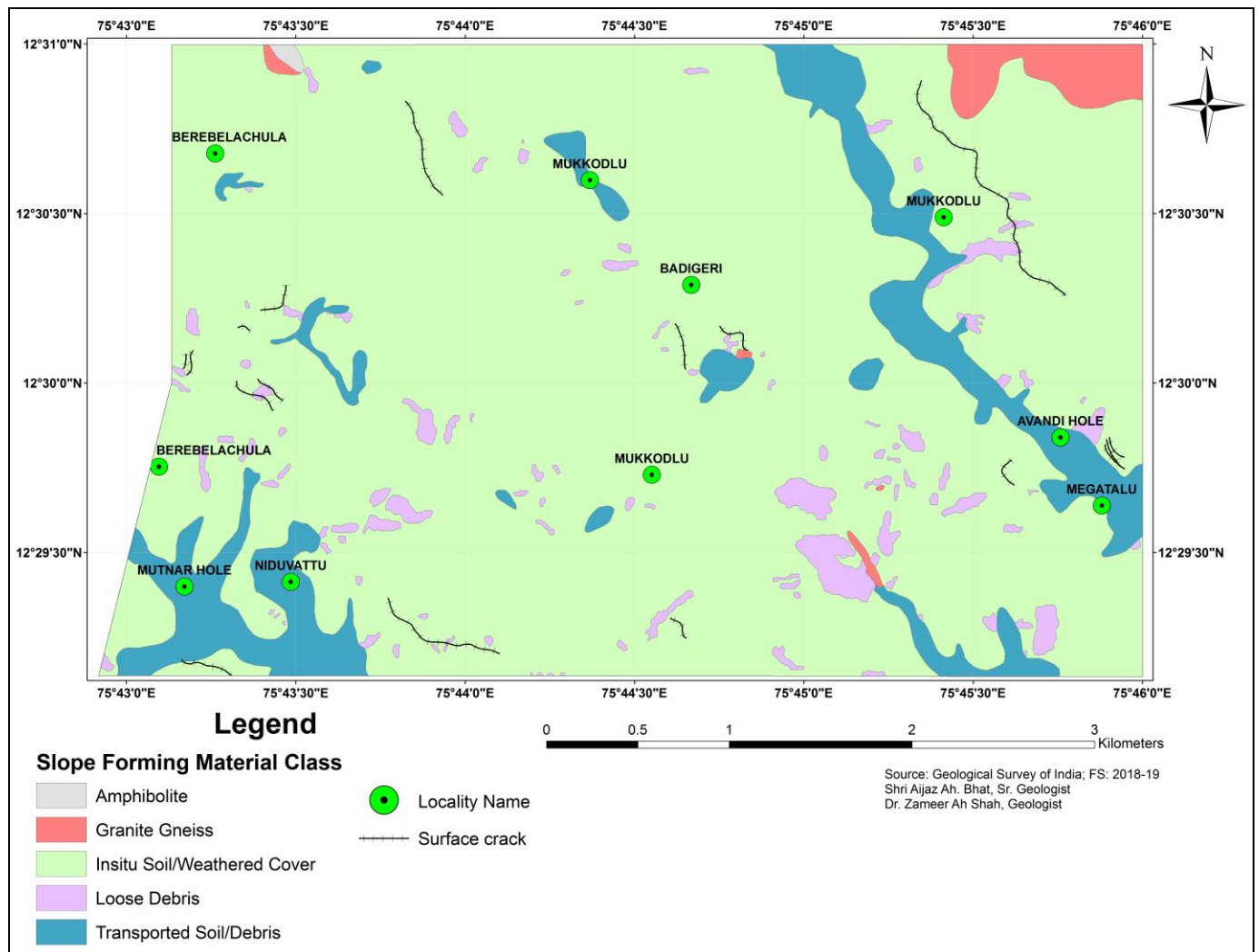


Figure-4.6: Shows geological-slope forming material map of study area on 1:10k scale prepared during field studies.

Four slope forming material classes were identified on 1:10k scale in the present study area which are; Rock, In-situ soil/weathered cover, Loose debris; and Transported soil/debris. The loose debris is located within the peripheries of landslides or any erosional material by different means and is again vulnerable to slide or erode by water action. The transported soil/debris is deposited in nearby higher order streams after short transportation particularly during rainfall periods. This class is almost less susceptible for slides because of low slope gradient but it is more vulnerable to erode or washout during quick flood events which were seen and witnessed by 2018 rainfall period. The rocky surface slopes are stable at present prevailing conditions and as such rock slides were not reported except one on the road side hill slope in north of Berebelachula village (see fig. 3.1k). Most of the slides are confined to in-situ

soil/weathered cover on slopes of varying gradients ([see fig. 4.6](#)). The in-situ soil covered slopes of 10°-35° gradients were more responded to landslides of varying dimensions. The slide down material of in-situ soil covered slope material was later eroded by rapid channel flow to higher order streams which mixed with quick flood waters and deposited over open low lying areas having cultivated lands and settlements. These cultivated lands and settlements were destroyed at many places in Kodagu district ([see fig. 3.11](#)). The loose debris class is confined to previously occurred landslide and erosion and this class is deliberately put with high LOFS rating because unlike NLSM in present study all SFM classes were let to be represented by their geotechnical parameters such as cohesion, friction angle, specific gravity, density, porosity and silt+clay percentage. Indirectly the LOFS ratings of these geotechnical parameters of overburden are signifying the impact of landslides in each SFM class.

Table-4.4: Statistics and LOFS rating of geological-slope forming material classes

No. of Classes	SFM Class	Pixel Count	Landslide Occupied Pixels	LOFS Rating
1	Amphibolite	57	0	0.00
2	Granite Gneiss	3187	19	0.00
3	Insitu Soil/Weathered Cover	155940	400	0.00
4	Loose Debris	5969	5529	1.00
5	Transported Soil/Debris	16351	35	0.00

4.5 Landform Map

Landforms are defined as specific features on the Earth's surface ranging from major types such as mountains, hills, plateaus, basins and plains to minor types such as gullies, valleys, shorelines, slopes, ridges, canyons, cliff, spur and depressions. The landforms form over a long period of time by tectonic, erosional and depositional processes. Landforms are characterized and classified by visualizing different dynamic features controlled on regional or local scale by lithology, climate, erosion, tectonic activities and to some extent by manmade activities. The study of different types of landforms has long back history ([Strahler, 1957](#)) to understand these dynamic landform features in terms of their definitions, classifications, characterizations and their significance in different fields of geoscience. Before the introduction of Digital Elevation Models (DEMs), landforms were only manually identified by means of surveys and when available through interpretation of aerial photographs ([Garbrecht J and Martz L W, 2000](#)). in the late 20th century the landform features were able to derive from Digital Elevation Models (DEMs) and described by terrain analysis methods ([Florinsky I, 2012](#)) to carry geomorphological studies. In last four decades the terrain analysis techniques have been used for topographic analysis and visualizations of land surface features which also include monitoring the slope movements ([Wieczorek G](#)

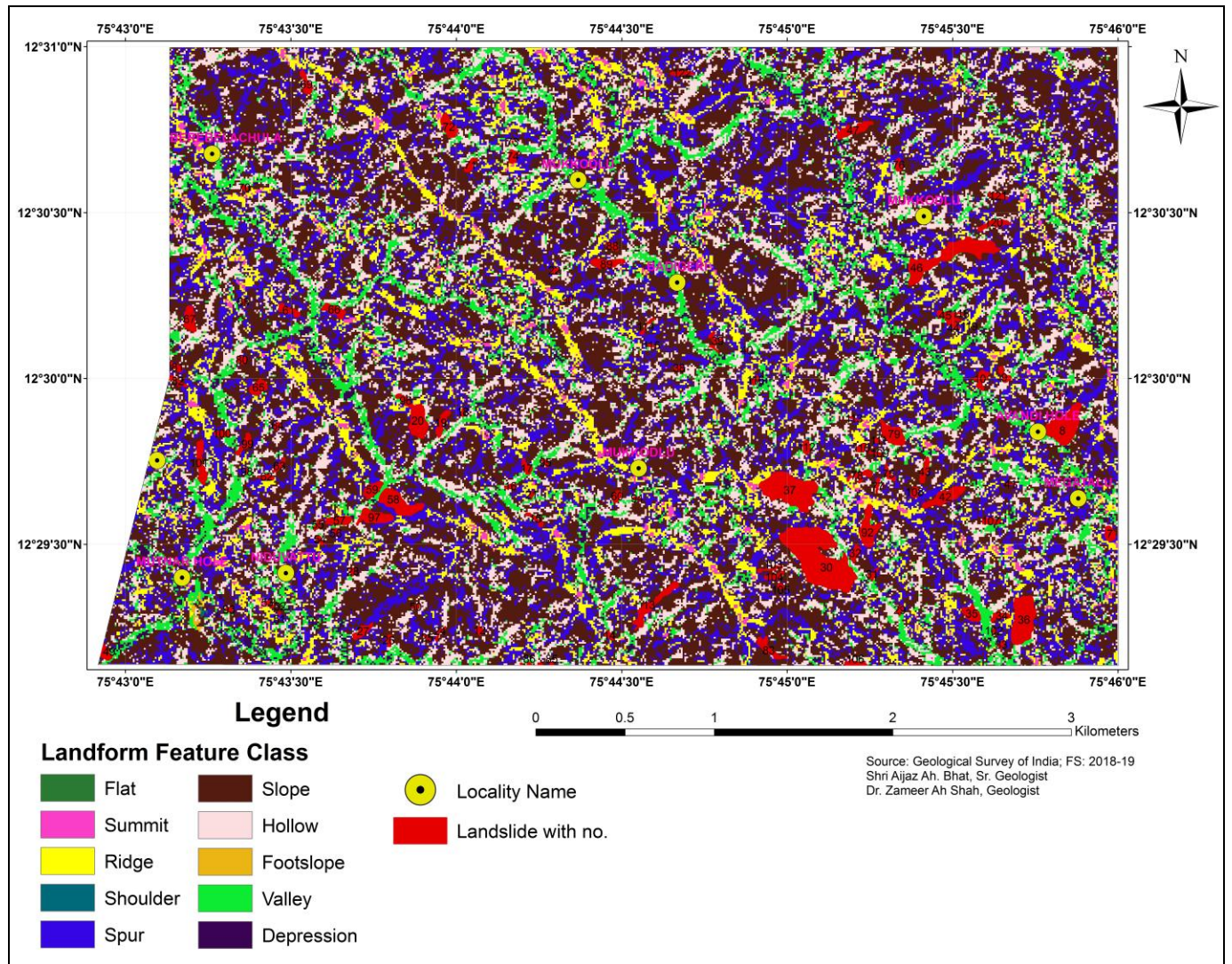


Figure-4.7: Shows landform map derived from CartoDEM 10m resolution with landslides (Snyder J B, 2009). In the present study the landform features have been derived from CartoDEM 10m resolution for the aim to analyze and quantify the role of landform features in occurrences of landslides and used in landslide susceptibility as a factor map. For integration and modeling purpose the derived landform map is reclassified in to 10 classes (see fig 4.7). In the area of investigation the slope and hollow landform features have more positively responded to landslide occurrences followed by spur and even ridges and summit features are also involved. The landslide occupied pixels in valley and depression are basically downslope extensional landslide run-out material or erosional washout material by channel flow action.

Table-4.5: Statistics and LOFS rating of landform classes

No. of Classes	Landform Class	Pixel Count	Landslide Occupied Pixels	LOFS Rating
1	Flat	2	0	0.00

2	Summit	1788	12	0.00
3	Ridge	13936	154	0.00
4	Shoulder	15	0	0.00
5	Spur	39037	943	0.00
6	Slope	75001	2799	0.69
7	Hollow	34507	1459	1.00
8	Footslope	54	1	0.00
9	Valley	15008	582	0.56
10	Depression	2255	45	0.00

4.6 SFM Thickness Map

The depth of bedrock and overburden thickness information over the years remains the most important in groundwater studies, geotechnical works, bedrock aggregate resource assessments, land use applications ([Cunhai Gao et al., 2007](#)) and landslide studies. Using the data information of drill holes penetrated in different studies, bore wells, trenches and data sources from geophysical investigations, digital elevation model analysis the depth of bedrock and overburden thickness can be measured ([Hanna Mönkkönen, 2012](#); [Cunhai Gao et al., 2007](#)). In the present investigation only overburden thickness has been taken into account and was measured during field studies from cut slopes ([see fig. 4.8](#)) wherein bedrock and overburden contact is visible. However the overburden thickness had to be measured by geophysical methods but due to unavailability of geophysical sources this could not been possible in present investigation.

The cut slopes in the study area were limited which remain a big constraint but on the scarp face of most landslides slipped along bedrock surface contact the measured thickness has been taken into consideration. Four classes of overburden thickness have been identified and mapped ([see fig. 4.9](#)) which are; 0-1m, 2-4m, 3-5m and >5m. The bedrock surface with less than or equal to 1m thick overburden has taken in 0-1m class. The hill slopes are having mostly 3-4m or >5m thick overburden cover formed due to weathering processes and low lying higher order stream areas are having 2-4m thick overburden cover deposited or aggregated by seasonal channel flow process or river action. The 2-4m and 3-4m classes could not been clubbed because the thickness measures in field is from different SFM classes in which sole 3-4m (in-situ soil SFM class) is much influenced by landslides while 2-4m (transported soil SFM class) is not much influenced by landslides. The need to keep these two classes separately which can be clubbed was for the significance of susceptibility modeling.



Figure-4.8: Shows field photographs of bedrock surface and overburden thickness sections and cut slopes in different places of study area which became very helpful to assume the overburden thickness

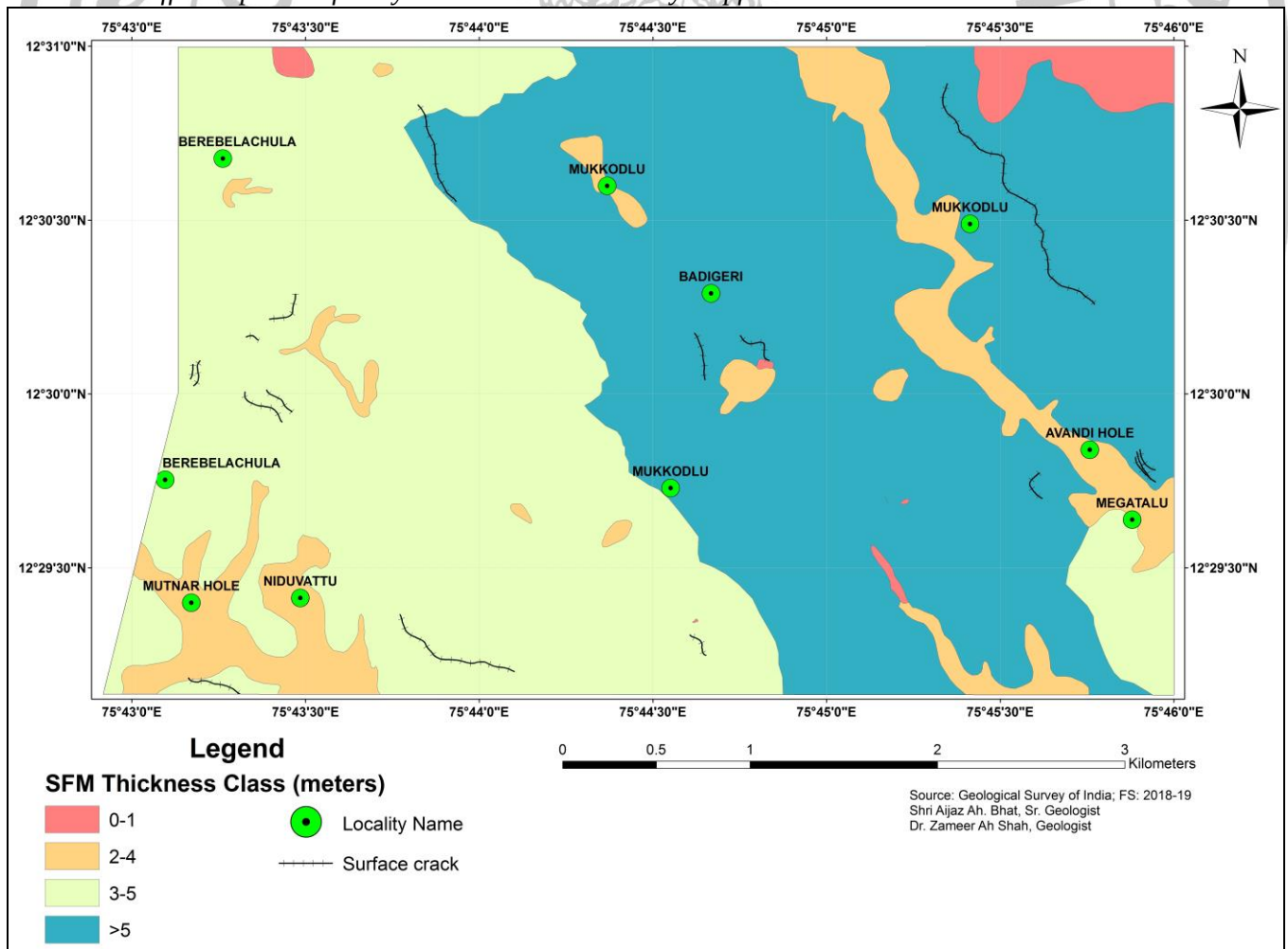


Figure-4.9: Shows SFM thickness map prepared during field studies

The hill slope overburden classes have played major role in occurrence of overburden involved landslides in the area and became the primary factor in which different hydrological processes and various mass involved forces have acted during rainfall to change different geotechnical parameters. The >5m thick overburden class is more positively responded to occur the landslides (see table-4.6) which likely signifies the fact that the stuck of infiltrated rain waters in this quite thick overburden of >5m due to poor performance of drainage network parameters (see fig. 6.2-6.4) have generated variable pore pressures which have impacted the geotechnical parameters of overburden quite strongly to occur the slope failures particularly in natural slopes without cut-slopes and where there are no interventions of human activity or stream erosion.

Table-4.6: Statistics and LOFS rating of SFM thickness classes

No. of Classes	Thickness Class (m)	Pixel Count	Landslide Occupied Pixels	LOFS Rating
1	>5m	86183	3740	1.00
2	0-1m	3347	22	0.00
3	2-4m	16753	415	0.00
4	3-5m	75321	1806	0.00

4.7 Geotechnical Parameters of Overburden Samples (Undisturbed)

In the present study the inputs of geotechnical parameters of overburden material (undisturbed) were incorporated to represent the SFM overburden classes into technical sense rather than overburden strength assumptions adopted in NLSM. The inputs of geotechnical parameters of overburden proved quite helpful in this study to identify the overburden classes in detail by varying their strength properties in almost uniformly composed weathered product on granitic rocks (see fig. 4.10-4.15). The significance revealed to this study by knowing the geotechnical parameters is that it supports the finding observed by drainage basin analysis. The increasing stable values of some geotechnical parameters as assumed such as cohesion and angle on internal friction of overburden would not been have impacted to overburden material to occur landslides in the present area but due to stuck of infiltrated rain waters in overburden by poor performance of drainage network parameters (see fig. 6.2-6.4) the pore pressures varies frequently during the heavy rainy days in which >2500mm rainfall has been recorded. This thing have impacted the geotechnical parameters along with increasing stable values of overburden quite strongly to occur the slope failures particularly in natural slopes without cut-slopes and where there are no interventions of human activity or stream erosion. The geotechnical parameters of overburden sample (undisturbed) were analyzed and an interpolation raster based theme was prepared for each parameter in ArcGIS platform to

show their spatial variation and make them incorporated in susceptibility modeling. Further on the other hand the analyzed values of overburden material (disturbed type) is supposed to be incorporated in this study to make correlated values between undisturbed and disturbed samples of overburden material. This thing would be possible when the results of all the geotechnical parameters of disturbed samples will receive from laboratory as similar to undisturbed samples. The results of geotechnical parameters of overburden material (undisturbed samples) and their correlation matrix are shown in [table-4.7 & 4.8](#).

4.7.1 Sampling Methodology of Overburden Samples

The sampling of undisturbed samples and disturbed samples has been done as per slope failure priority basis to analyze the geotechnical properties of slope overburden material. The disturbed sample was collected from slope material which has suffered the movement within landslide perimeter and undisturbed sample was taken from the same slope material which is intact outside the landslide perimeter. Likewise 41 samples including 20 nos. disturbed and 21 nos. undisturbed were collected from slopes in which landslides have occurred. The disturbed samples of approx. 6 kg in quantity were collected in plastic bags and undisturbed samples were collected in 4 inch x 16 inch iron pipes. These sample pipes were later sealed with wax on both sides. For the purpose of sample numbering the study area has been divided into 20 nos. of equal grids and numbering was given from bottom left corner to top right corner in snake pattern. The advantages of this gridding method are to simplify the identification of samples from different slopes, to avoid the repetition of sample collection from different slopes and to get the samples in a continuous fashion. The numbering format of samples was chosen in order to qualify all the area reference particulars. The format is; State name/District name/Toposheet number/Sample type/Grid number/Year of collection. The state name and district name will remain in locally standard abbreviated form e.g.; state Karnataka it will remain “KAR” and district Kodagu it will remain “KOD”.

4.7.2 Cohesion

Cohesion (c) is a type of force that attracts particles to each other in soil substratum. Cohesion creates inter-particle attraction in soil and adds to its shear strength particularly in fine grained material. Clay is a very good example of cohesive soil. In pure cohesive soils, the friction between particles does not occur and hence their shear strength is contributed by only cohesive force and not by internal friction. But in nature most of the soils are having both cohesive and frictional forces contributing to their shear strength. The cohesive property of soil reduces by saturation of water or having high moisture content which leads it to flow freely. A well compacted soil has high cohesive forces than in poorly-compacted soils and is independent of the external loads applied. In present investigated area the cohesion of overburden material varies from 0.16-0.3 kg/cm². A raster based theme has been generated from cohesion values through interpolation method in ArcGIS software. For integration and modeling purpose the raster

based theme of cohesion is reclassified in to 7 classes (see fig 4.10). Although the overburden material having high cohesion values signifies high shear strength of the material but in present study area the overburden material with high cohesion values are witnessed by high LOFS ratings (means the material has suffered lot by landslides) which should not be the case as compared to overburden material with low cohesion values. This fact reveals that the overburden material with high cohesion has lost shear strength by stuck of infiltrated rain waters due to poor performance of drainage network parameters.

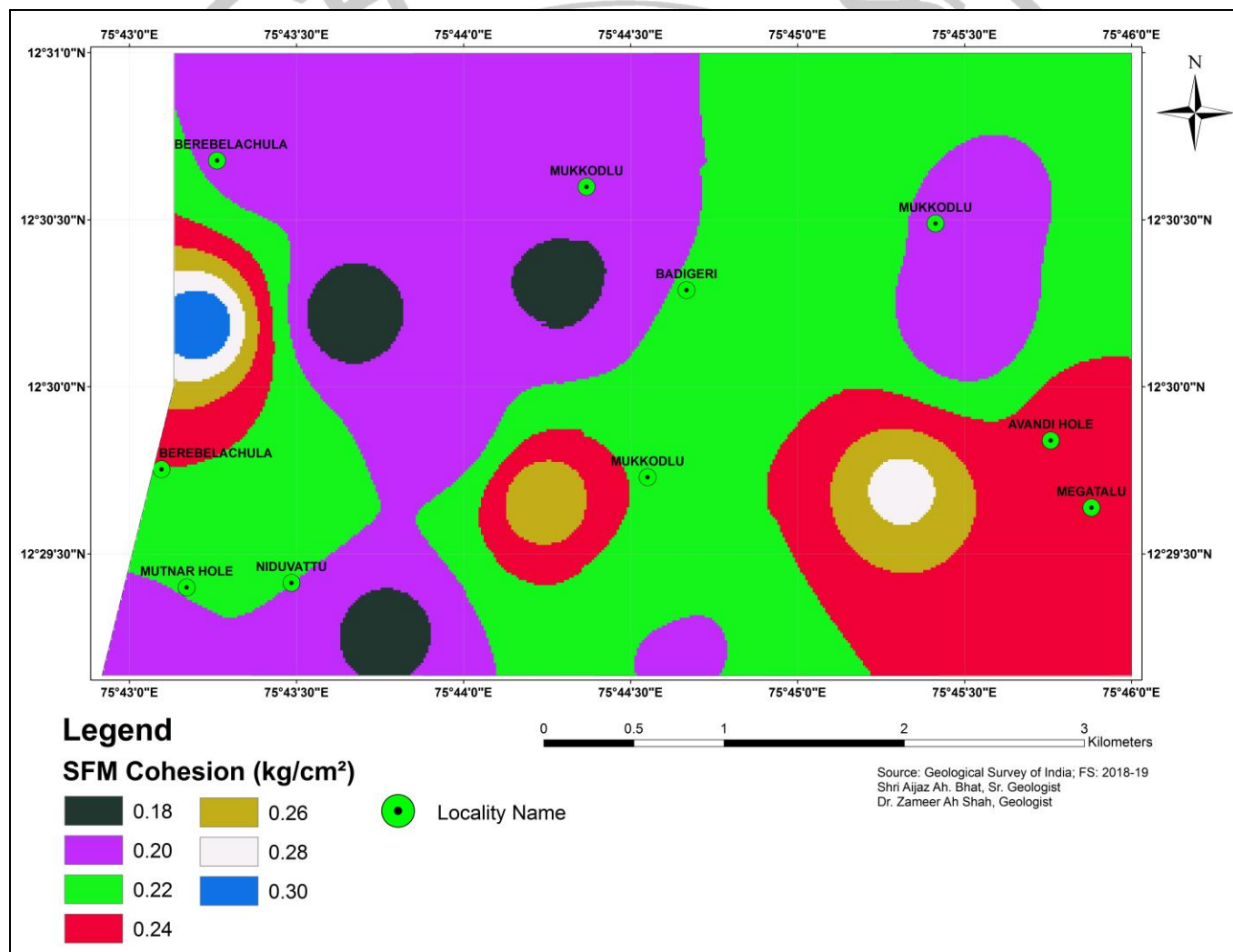


Figure-4.10: Shows spatial distribution of cohesion of overburden material of study area

Table-4.9: Statistics and LOFS rating of cohesion classes

No. of Classes	Cohesion Range	Pixel Count	Landslide Occupied Pixels	LOFS Rating
1	0.18	6166	179	0.00
2	0.2	63885	1602	0.00
3	0.22	72211	1053	0.00
4	0.24	29460	2305	1.00

5	0.26	6871	630	0.95
6	0.28	2000	150	0.73
7	0.3	972	77	0.77



Table-4.7: Results of geotechnical parameters of overburden material (undisturbed type)

S/No	Sample No/code	X	Y	Density gm/cc	Moisture Content %	Specific Gravity	Porosity (n)	Void Ratio	Gravel %	Sand %	Silt %	Clay %	Cohesion kg/cm ²	Angle of Internal Friction
1	KAR/KOD/48P11/UDS/G23/2019	75.71597222	12.4865	1.61	36	2.64	0.4	0.68	48	34	14	4	0.19	33
2	KAR/KOD/48P11/UDS/G24/2019	75.72953889	12.48786944	1.56	31	2.6	0.42	0.71	58	18	20	4	0.17	31
3	KAR/KOD/48P11/UDS/G25/2019	75.743375	12.48909722	1.52	34	2.61	0.44	0.78	27	48	17	8	0.21	27
4	KAR/KOD/48P15/UDS/G26/2019	75.76278333	12.488725	1.53	38	2.61	0.43	0.76	2	45	49	4	0.23	24
5	KAR/KOD/48P15/UDS/G27/2019	75.74403889	12.48745	2.07	41	2.57	0.23	0.3	42	35	17	6	0.19	26
6	KAR/KOD/48P11/UDS/G28/2019	75.72394167	12.49517778	1.4	42	2.63	0.44	0.79	2	22	70	6	0.22	25
7	KAR/KOD/48P11/UDS/G29/2019	75.73224167	12.49795278	1.42	33	2.62	0.47	0.9	18	62	14	6	0.18	32
8	KAR/KOD/48P11/UDS/G30/2019	75.73731944	12.49430833	1.44	26	2.63	0.47	0.88	22	40	33	5	0.26	32
9	KAR/KOD/48P15/UDS/G31/2019	75.75521944	12.49488056	1.69	36	2.4	0.38	0.6	4	42	48	6	0.27	16
10	KAR/KOD/48P15/UDS/G32/2019	75.76402778	12.49820833	1.6	32	2.64	0.41	0.69	4	41	51	4	0.23	24
11	KAR/KOD/48P10/UDS/G33/2019	75.7202	12.50310556	1.31	40	2.63	0.56	1.25	5	40	49	6	0.3	22
12	KAR/KOD/48P10/UDS/G34/2019	75.72745556	12.50352778	1.37	39	2.52	0.49	0.97	17	44	35	4	0.16	32
13	KAR/KOD/48P10/UDS/G35/2019	75.73808611	12.50523889	1.32	37	2.55	0.54	1.16	1	43	52	4	0.17	30
14	KAR/KOD/48P10/UDS/G36/2019	75.7465	12.50166111	1.39	41	2.6	0.48	0.94	7	26	57	10	0.21	27
15	KAR/KOD/48P14/UDS/G37/2019	75.7585	12.50288889	1.73	27	2.48	0.36	0.56	21	47	28	4	0.18	31
16	KAR/KOD/48P10/UDS/G38/2019	75.72328611	12.51122778	1.45	32	2.63	0.46	0.86	8	43	45	4	0.19	31
17	KAR/KOD/48P10/UDS/G39/2019	75.72837222	12.51533889	1.51	42	2.62	0.44	0.79	8	36	51	5	0.18	32
18	KAR/KOD/48P10/UDS/G40/2019	75.73616944	12.51183333	1.33	33	2.6	0.51	1.03	16	56	20	8	0.2	29
19	KAR/KOD/48P14/UDS/G41/2019	75.75421111	12.51288889	1.62	36	2.61	0.26	0.36	4	46	43	7	0.22	29
20	KAR/KOD/48P14/UDS/G42/2019	75.75834444	12.50951111	1.59	32	2.64	0.25	0.34	35	29	31	5	0.19	31
Min				1.31	26	2.4	0.23	0.3	1	18	14	4	0.16	16
Max				2.07	42	2.64	0.56	1.25	58	62	70	10	0.3	33

Table-4.8: Correlation matrix of results of geotechnical parameters of overburden material (undisturbed type)

	Density gm/cc	Moisture Content %	Specific Gravity	Porosity (n)	Void Ratio	Gravel %	Sand %	Silt %	Clay %	Cohesion kg/cm ²	Angle of Internal Friction
Density gm/cc	1										
Moisture Content %	-0.053664452	1									
Specific Gravity	-0.283365341	0.028654001	1								
Porosity (n)	-0.84425383	0.08229188	0.087390614	1							
Void Ratio	-0.851777227	0.140235541	0.11198322	0.984786926	1						
Gravel %	0.436803691	-0.301677149	0.122918875	-0.373263825	-0.38711876	1					
Sand %	-0.139437191	-0.271799165	-0.17035264	0.202980304	0.215402666	-0.32893078	1				
Silt %	-0.339915444	0.451733023	-0.020971311	0.243985493	0.246434408	-0.78630015	-0.31689	1			
Clay %	-0.133836963	0.289223426	0.05768761	0.041136437	0.076237301	-0.16685259	0.062457	0.026211	1		
Cohesion kg/cm ²	-0.088960266	0.039941167	-0.000586167	0.139399522	0.152085751	-0.39618929	0.019349	0.364909	0.242203	1	
Angle of Internal Friction	-0.164508473	-0.329122129	0.3806859	0.017755994	0.020103071	0.42842855	0.04514	-0.4377	-0.25684	-0.716965066	1

4.7.3 Angle of Internal Friction

Angle of internal friction is a measure of the ability of soil to withstand a shear stress. It is the angle (ϕ), measured between the normal force (N) and resultant force (R), that is attained when failure just occurs in response to a shearing stress (S). Its tangent (S/N) is the coefficient of sliding friction. Its value is determined experimentally. The friction angle has quite moderate positive correlation with larger grain size particles in overburden which is true in present study. In present investigated area the friction angle of overburden material varies from 16-33. A raster based theme has been generated from friction angle values through interpolation method in ArcGIS software. For integration and modeling purpose the raster based theme of friction angle is reclassified in to 8 classes (*see fig 4.11*).

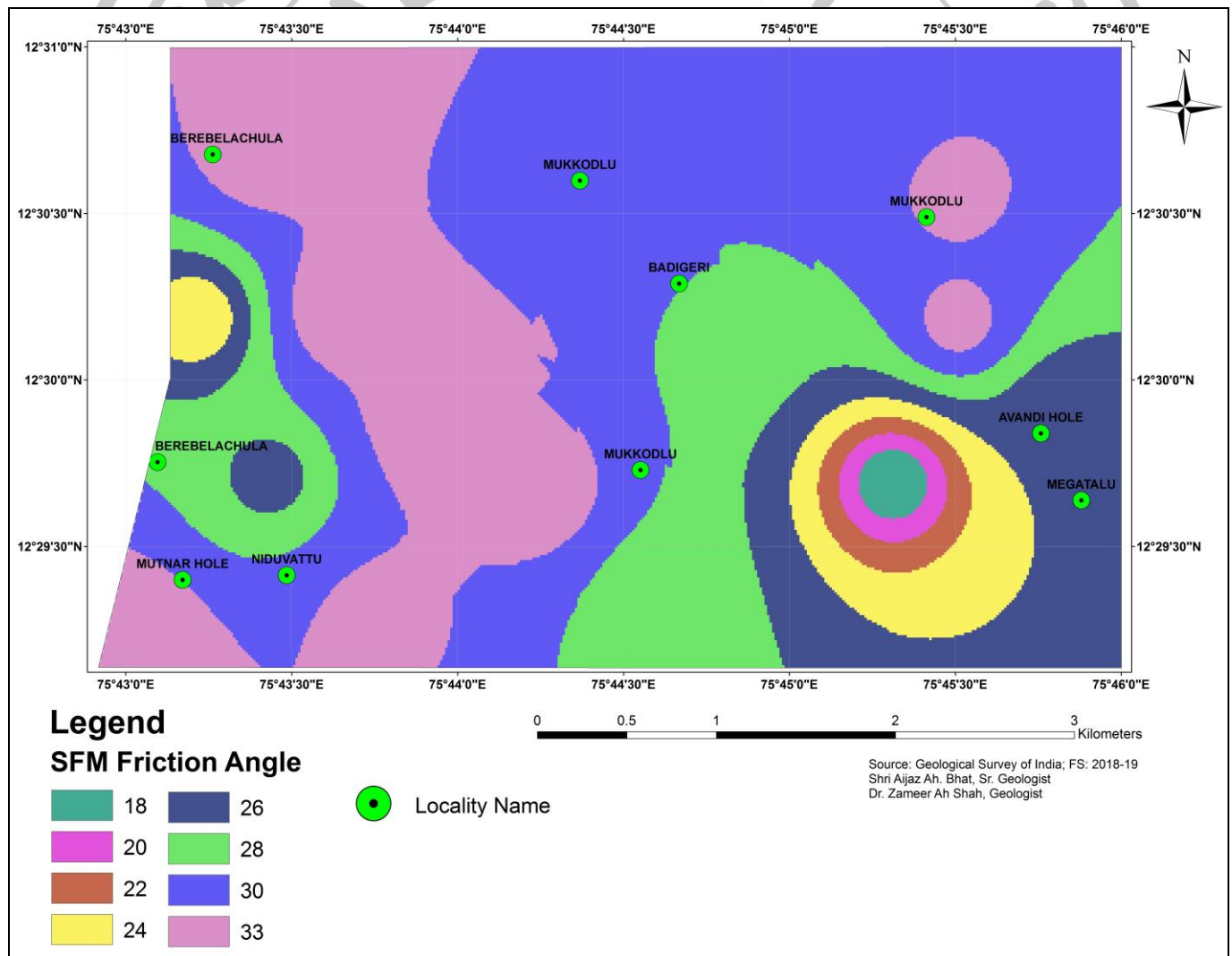


Figure-4.11: Shows spatial distribution of friction angle of overburden material of study area

The overburden material with low friction angle values experimentally proved to withstand a shear stress for short time limit as compared to the material with high friction angle values. In the present area the failures have occurred during rainfall event, hence the shear stress is likely in the form of variable pore

water pressures under which the overburden material with low friction values did not withstand for longer time limit. The overburden material with low friction angle values are witnessed high LOFS ratings which is quite relevant or true to SFM classes with fine grained material like in-situ soil with moderate to high slope gradients. As there is quite strong negative correlation between friction angle and cohesion ([see table-4.8](#)) and this thing reveals that overburden material with low friction angle and high cohesion values has got failures in the form of landslides and tensional cracks under the influence of variable pore water pressures developed by stuck of infiltrated rain waters due to poor performance of drainage network parameters.

Table-4.10: Statistics and LOFS rating of friction angle classes

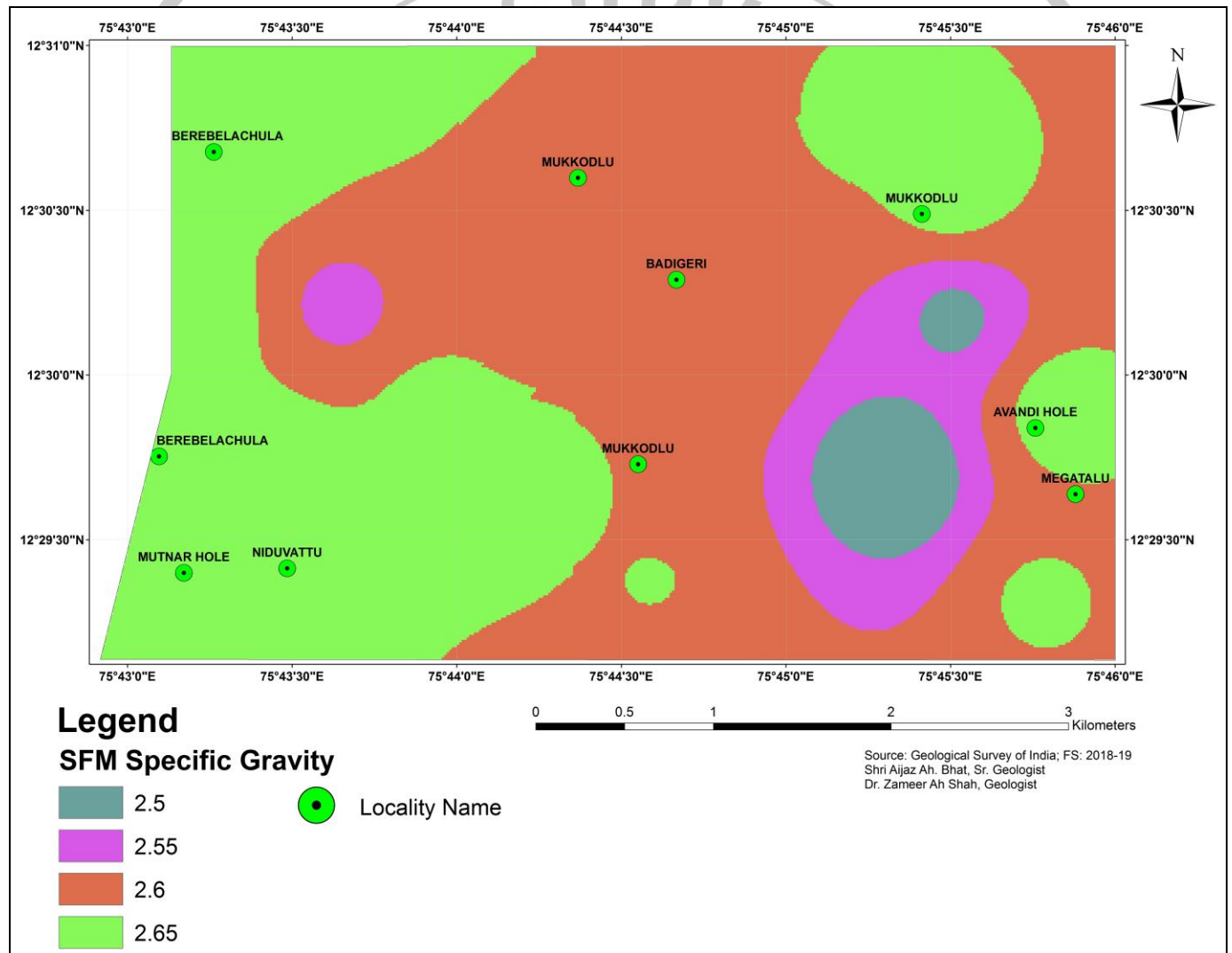
No. of Classes	Friction Angle	Pixel Count	Landslide Occupied Pixels	LOFS Rating
1	18	1122	141	0.80
2	20	1674	295	1.00
3	22	2846	213	0.50
4	24	9179	1111	0.84
5	26	21567	1355	0.46
6	28	30551	611	0.00
7	30	69783	1394	0.00
8	33	44874	876	0.00

4.7.4 Specific Gravity

Specific gravity is the ratio of the mass of soil solids to the mass of an equal volume of water. It is an important index property of soils that is closely linked with mineralogy or chemical composition ([Oyediran and Durojaiye, 2011](#)) and also reflects the history of weathering ([Tuncer and Lohnes, 1977](#)). It is relatively important as far as the qualitative behavior of the soil is concerned ([Raj, 2012](#)) and useful in soil mineral classification, for example iron minerals have a larger value of specific gravity than silica's ([Bowles, 2012](#)). In present study specific gravity shows quite moderate positive correlation with friction angle means overburden material with low specific gravity and friction angle are not able to withstand a shear stress for longer time limit and this thing is witnessed by high LOFS ratings of overburden material with low specific gravity values. In present investigated area the specific gravity of overburden material varies from 2.4-2.64. A raster based theme has been generated from specific gravity values through interpolation method in ArcGIS software. For integration and modeling purpose the raster based theme of specific gravity is reclassified in to 4 classes ([see fig 4.12](#)).

Table-4.11: Statistics and LOFS rating of specific gravity classes

No. of Classes	Specific Gravity	Pixel Count	Landslide Occupied Pixels	LOFS Rating
1	2.5	6668	731	0.97
2	2.55	15112	1555	1.00
3	2.6	87470	1295	0.00
4	2.65	72155	2415	0.02

*Figure-4.12: Shows spatial distribution of specific gravity of overburden material of study area*

4.7.5 Density

Density is the weight per unit volume of the solid portion of soil called particle density or weight per unit volume of a dry soil (volume of solids and pore spaces) called bulk density. The bulk density of a soil is always smaller than its particle density. It is measured in gm/cc. Loose and porous soils have low weights per unit volume and compact soils have high values. Bulk density normally decreases as soils

become finer in texture. Bulk density is of greater importance than particle density in understanding the physical behavior of soils. Bulk density of soil material or overburden material can reveal much about its amount of pore spaces, mineral make up, compactness, texture, structure and organic content. The variations in these factors can affect the physical behavior of soil material. In present investigated area the density of overburden material varies from 1.31-3.07 gm/cc. A raster based theme has been generated from density values through interpolation method in ArcGIS software. For integration and modeling purpose the raster based theme of density is reclassified in to 4 classes (*see fig 4.13*).

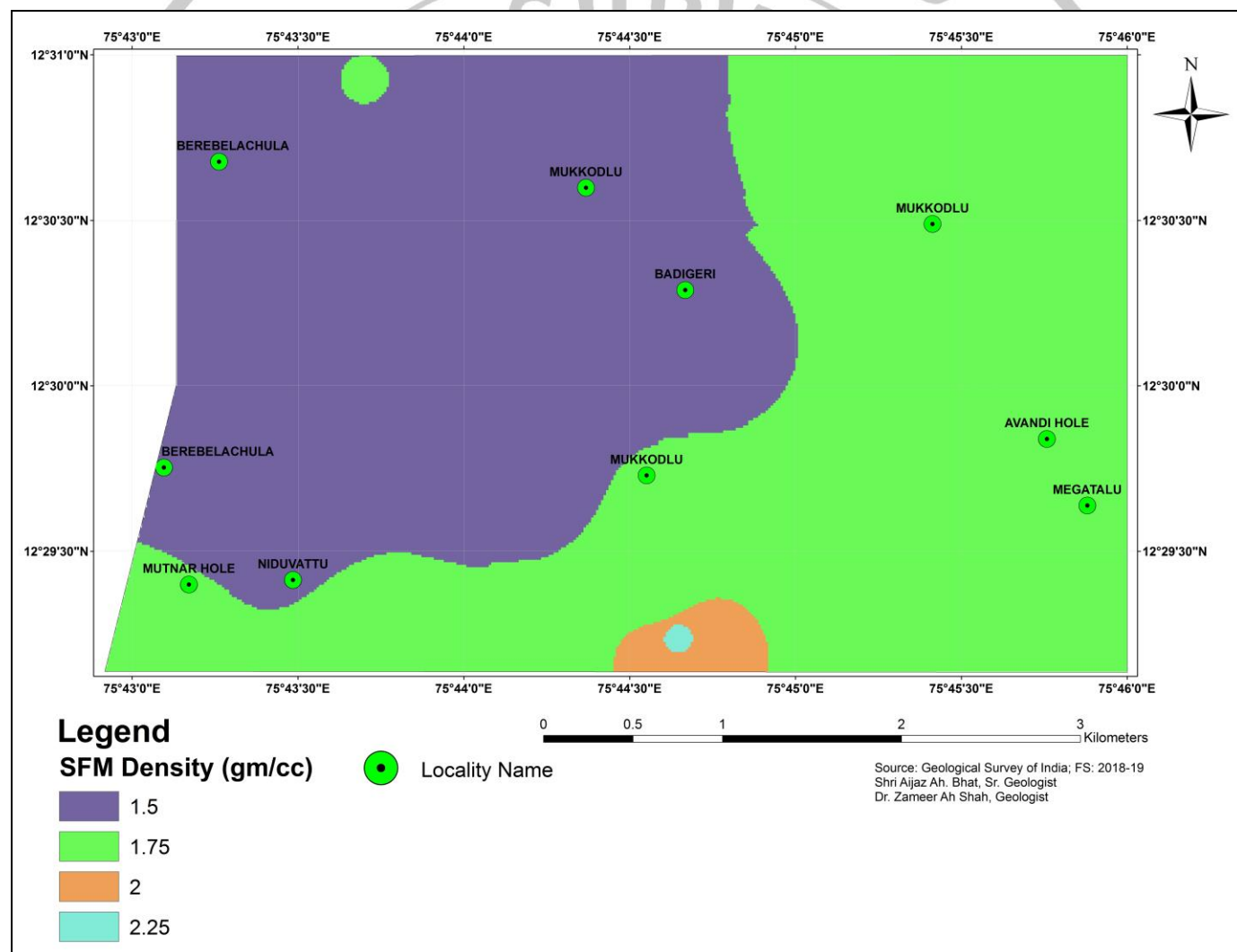


Figure-4.13: Shows spatial distribution of density of overburden material of study area

In present study the density of overburden material has strong correlation with porosity and void ratio and has quit moderate positive correlation with larger grain size particles such as gravel. The overburden material with low density values have suffered more landslides and are witnessed by high LOFS ratings as compared to overburden material with high density values. This thing reveals that overburden material with low density values is of fine texture, loose and porous with less compactness in

nature. This nature would have allow the material to generate variable pore water pressures on saturation particularly when infiltrated water flow get stuck and would have result natural slope failures irrespective of any human interference.

Table-4.12: Statistics and LOFS rating of density classes

No. of Classes	Density Range	Pixel Count	Landslide Occupied Pixels	LOFS Rating
1	1.5	85524	1844	0.00
2	1.75	93291	4116	1.00
3	2	2415	36	0.00
4	2.25	185	0	0.00

4.7.6 Porosity

Porosity is a measure of the void spaces in a material, and is a fraction of the volume of voids over the total volume, between 0 and 1, or as a percentage between 0% and 100%. Porosity of material typically decreases as particle size increases and it depends on wide range of factors such as texture, structure, compactness, depth, biological activity, grain arrangement (packing) etc. In present investigated area the porosity of overburden material varies from 0.23-0.56. A raster based theme has been generated from porosity values through interpolation method in ArcGIS software. For integration and modeling purpose the raster based theme of porosity is reclassified in to 8 classes ([see fig 4.14](#)).

Table-4.13: Statistics and LOFS rating of porosity classes

No. of Classes	Porosity Class	Pixel Count	Landslide Occupied Pixels	LOFS Rating
1	0.25	127	0	0.00
2	0.3	10136	218	0.00
3	0.35	14830	433	0.00
4	0.4	36566	2449	0.74
5	0.45	49479	1364	0.00
6	0.5	58140	1240	0.00
7	0.55	11550	215	0.00
8	0.6	609	77	1.00

In present study the porosity of overburden material has quite moderate negative correlation with larger grain size particles (gravel) as the case should be. The overburden material with increasing porosity values reveals finer material and has affected much by landslides. This thing reveals again the fact like density that high porous nature would have allow the material to generate variable pore water pressures on

saturation particularly when infiltrated water flow get stuck and would have result natural slope failures irrespective of any human interference.

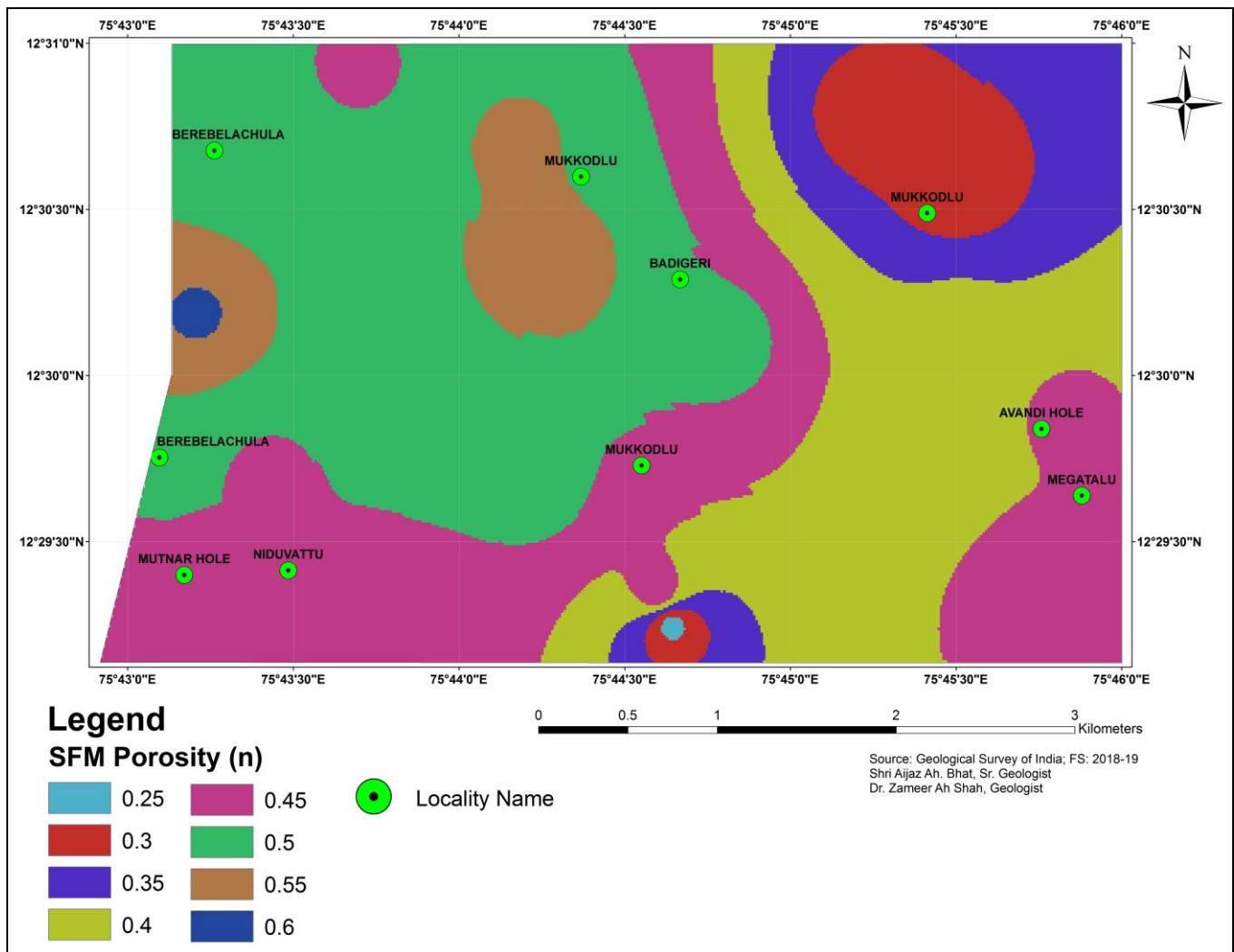


Figure-4.14: Shows spatial distribution of porosity of overburden material of study area

4.7.7 Grain Size (Silt+Clay)

Grain-size analysis is widely used in engineering classifications of soils. The standard grain-size analysis test determines the relative proportions of different grain sizes as they are distributed among certain size ranges like gravel, sand, silt and clay in descending grain size ranges. Grain sizes influences how fast or slow water or other fluid moves through a soil or overburden material. In present study the sum of finer grain size material is considered for evaluation of overburden material properties which are associated with its grain size distribution because maximum landslides have occurred in in-situ soil cover in which silt+clay percentage gave answers to various field observation rather than larger grain size. In present investigated area the silt+clay percentage of overburden material varies from 18-76%. A raster based theme has been generated from silt+clay percentage values through interpolation method in ArcGIS

software. For integration and modeling purpose the raster based theme of silt+clay percentage is reclassified in to 10 classes (see fig 4.15).

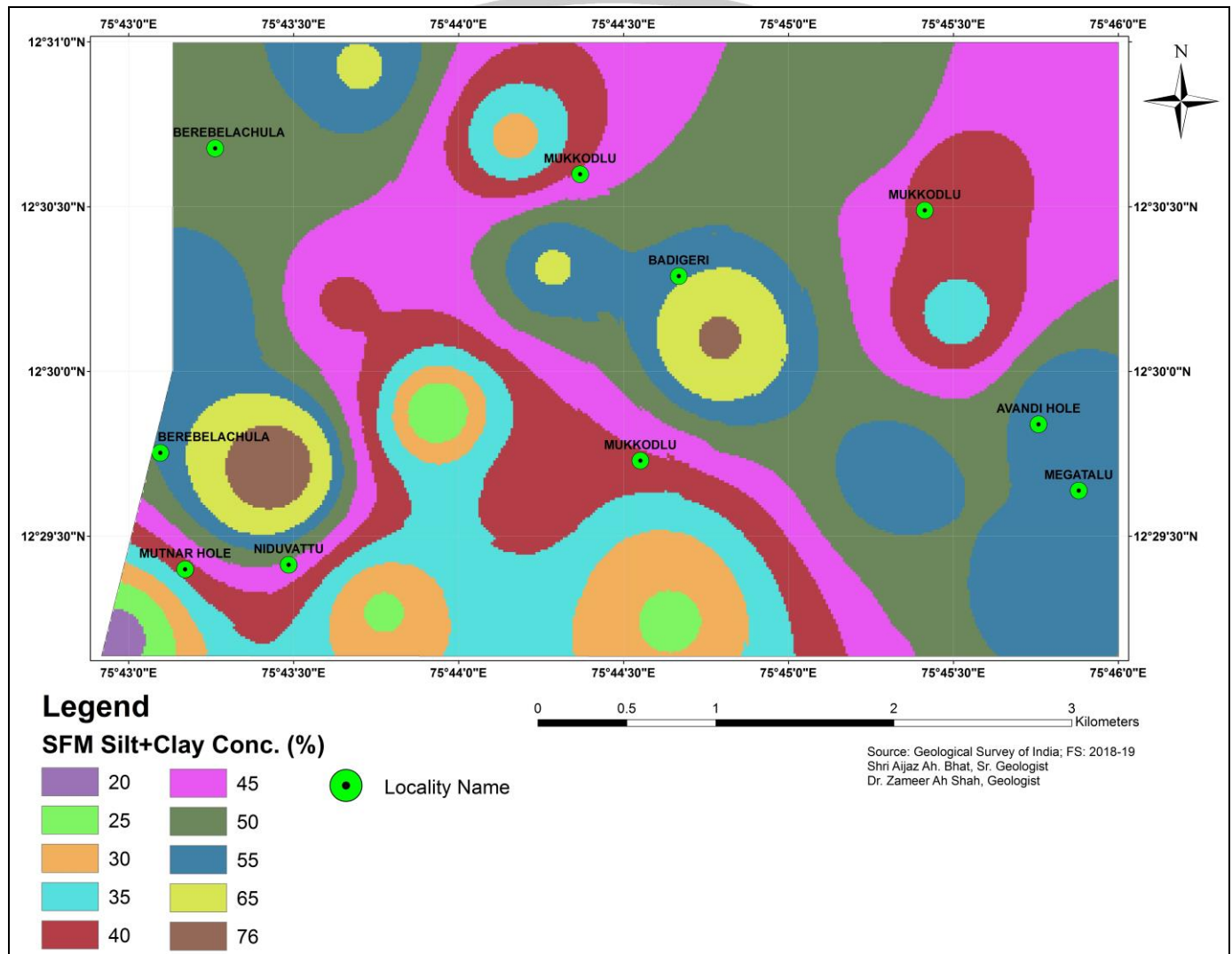


Figure-4.15: Shows spatial distribution of silt+clay percentage of overburden material of study area

The overburden material with low silt+clay percentage has witnessed by high LOFS ratings. It is basically the run-out debris reached the interpolated grain size classes with low silt+clay percentage in low lying areas where transported overburden material deposited. These overburden classes are quite vulnerable to movement during heavy rainfall. The overburden material with increasing silt+clay percentage is supported by high porosity, low density, high cohesion and low friction angle and is much influenced by landslides. This thing again reveals that overburden material with increasing silt+clay percentage and other properties discussed above have allow the material to generate variable pore water pressures on saturation particularly when infiltrated water flow get stuck and would have result natural slope failures irrespective of any human interference.

Table-4.14: Statistics and LOFS rating of silt+clay percentage classes

No. of Classes	Silt+Clay %age	Pixel Count	Landslide Occupied Pixels	LOFS Rating
1	20	479	35	0.71
2	25	2860	284	1.00
3	30	9864	257	0.00
4	35	17619	276	0.00
5	40	25549	1087	0.27
6	45	36306	1152	0.00
7	50	46991	950	0.00
8	55	31992	1648	0.51
9	65	7814	180	0.00
10	76	2180	127	0.51

5. DRAINAGE BASIN MORPHOMETRY

5.1 Drainage Basin Morphometry: Introduction

The relationship and inter-response between various natural agencies and processes involved within a drainage basin and/or watershed (a recognized dynamic natural topographic unit in geomorphology) to give different shapes to landforms, is necessary to understand by describing the basin and/or watershed parameters quantitatively. The landform development and their evolution are dependent on variations occurring in geological, hydrological, climatic and denudation (erosion and landslides) processes prevailing within a basin and/or watershed area. Since the beginning three major geomorphic and physiographic bases have been identified by researchers (*N.M Fenneman, 1914; S.W Wooldridge, 1932; R E Horton, 1945; A N Strahler, 1964*) for description and analysis of landforms which are; Geological framework of terrain, Davisian cycle and the associated denudation chronology; and the erosional drainage basin (*Geomorphology book by R J Chorley et.al, 1984*) respectively. With time the renowned researchers *R E Horton and A N Strahler* have devised and used various standard statistical methods to obtain a quantitative description of drainage basin landform which is an area limited by a drainage divide and occupied by a drainage network wherein upstream drainage basin (different watersheds) supplies water controlled by hydrological processes and sediment controlled by erosion or denudation to the lower parts which reflects its geological, hydrological and climatic characters and their equilibrium levels. These two researchers have performed basin morphometric analysis by examining different morphometric features of a drainage basin and classified later by *A N Strahler* into linear, areal and relief attributes (*Geomorphology book by R J Chorley et.al, 1984*).

In the present study an attempt has been done to do drainage basin analysis after arising the questions that why the landslides and channel erosion in Kodagu district have been occurred in selected places although the rainfall intensity was recorded almost same over Kodagu district recording stations with light variations. After doing drainage basin analysis the answer to raised questions comes with lot of understanding that it is not only the surficial geo-factor themes which are responsible factors for landslides and channel erosion but major role has been played by watershed geometry attributes to occur landslides and channel erosion wherein these geometry attributes have shown poor performance to drain and distribute storage capacity waters during 2018 rainfall event in which the annual rainfall intensity was 2000mm higher over 2500mm in previous three years record (*see fig. 1.2 & 1.3*). The 2000mm rise in rainfall intensity was recorded in June-September period 2018 and this period remains all high in rainfall in the Kodagu district. This has been revealed in present study by doing drainage basin analysis described ahead that the watersheds (WS1, WS2, WS3, WS9) suffered lot by landslides and channel erosion in 2018 rainfall event and similar to them (WS8, WS12) which have not suffered are always susceptible to

landslides, scouring and channel erosion in rainfall intensity rise from 2500mm which has been seen as a threshold limit in Kodagu district. However this was the limited area study in which only few watersheds (WS1, WS2, WS3, WS4, WS5, WS8, WS9, WS10, WS11 & WS12) of Kodagu district have been analyzed and their geometry has been understood.

5.2 Watershed Analysis and Interpretation

In the present investigation different system tools of ArcGIS have been utilized to derive various types of hydrology themes and doing their statistics by using Carto-DEM 10m resolution. Various important linear and areal attributes of watersheds (WS1, WS2) wherein present study area lies and their different neighboring watersheds (WS3, WS4, WS5, WS8, WS9, WS10, WS11 & WS12) of a big parent drainage basin have been calculated (*see fig. 5.1*) using their standard definitions by *R E Horton and A N Strahler*. The calculated values of landslide and channel erosion affected watersheds (WS1, WS2, WS3 and WS9) have been interpreted as per the descriptions published by *S Sukristiyanti et. al, 2018; In Geomorphology book by R J Chorley et.al, 1984; Drainage basin morphology book by S A Schumm. Dowden, Hutchinson & Ross, Inc.1977*) and were analyzed in comparison with well drained neighboring watersheds (WS4, WS5 and WS8, WS11 and WS12) with least evidences of landslides and channel erosion. The mean average values of various morphometric attributes of 7th order and 6th order level watersheds and values of individual stream morphometric attributes of 7th order, 6th order and 5th order were analyzed and interpreted separately (*see fig. 5.2 and 5.3*) which revealed that there was poor performance to drain and distribute storage capacity of available waters in hierarchy stream orders during precipitation in landslide and channel erosion affected watersheds (WS1, WS2, WS3 and WS9) which leads significant changes in various inherited equilibrated factors or processes acting within the watershed boundaries. These significant changes during the precipitation were responded by occurrence of channel erosion, scouring and landslides.

5.3 Mean Average Morphometric Attribute Values

The mean average values were calculated for 7th order level (WS1, WS2, WS3, WS4, WS5 and WS8) and 6th order level (WS9, WS11 and WS12) watersheds. The calculated values were later converted to logarithm scale. The converted values are graphically shown in fig. 5.3. The high drainage density (6-8 km/sq.km) of all analyzed watersheds (WS1, WS2, WS3, WS4, WS5, WS7, WS8, WS9, WS10, WS11 & WS12) revealed that drainage texture is fine (which develops in areas wherein least resistance rocks and/or overburden occurred with low permeability property), there is high risk of erosion and moderate to high relief (*S Sukristiyanti et. al, 2018*). Besides, the high drainage density results high runoff in quick hydrological response which directly influences the higher order streams to receive more waters and signals them to distribute it smoothly with high water storage capacity. Besides high drainage density (6-8

km/sq.km) with fine drainage texture of all analyzed watersheds suggested their quick hydrological response to rainfall events and high risk of flooding in higher order streams during rainfall higher than threshold which have happened in 2018 rainfall event in watersheds (WS1, WS2, WS3 and WS9).

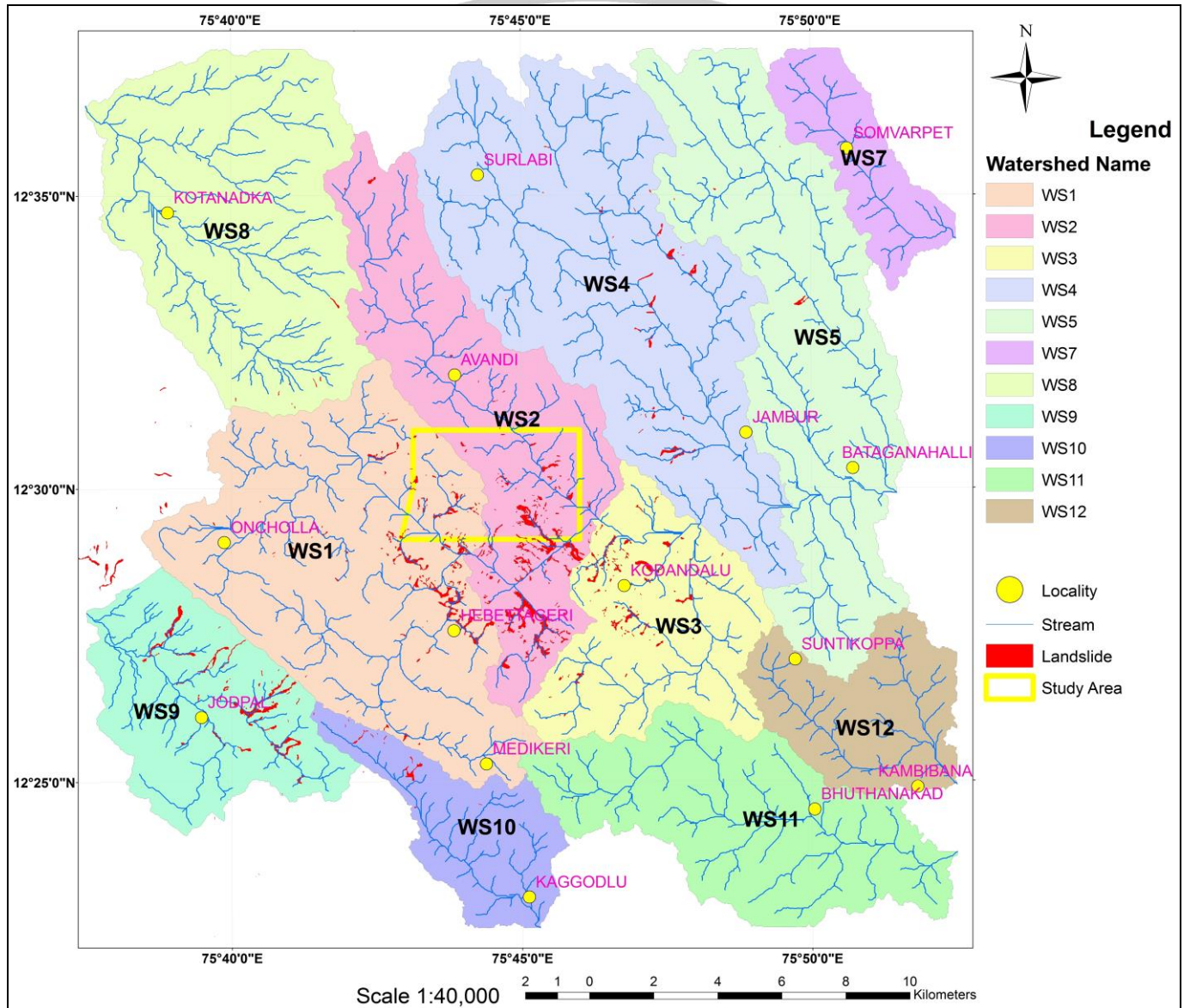


Figure-5.1: Shows different watersheds of a big parent basin wherein present study area lies

Although the mean bifurcation ratio does not indicate any structural control in the area but bifurcation ratio (>2 value) of some individual streams in various watersheds suggested that those are controlled by some minor structural lineaments such as joints, fractures, shear plans and localized faults. The stream length ratio trend of individual stream orders of almost all analyzed watersheds particularly those influenced by landslides and erosion indicated that these watersheds are having immature stage streams leading towards the maturity in which all eligible streams do incision during high precipitation. The length of overland flow is moderate (0.2 to 0.3) which indicates that there is moderate to high relief,

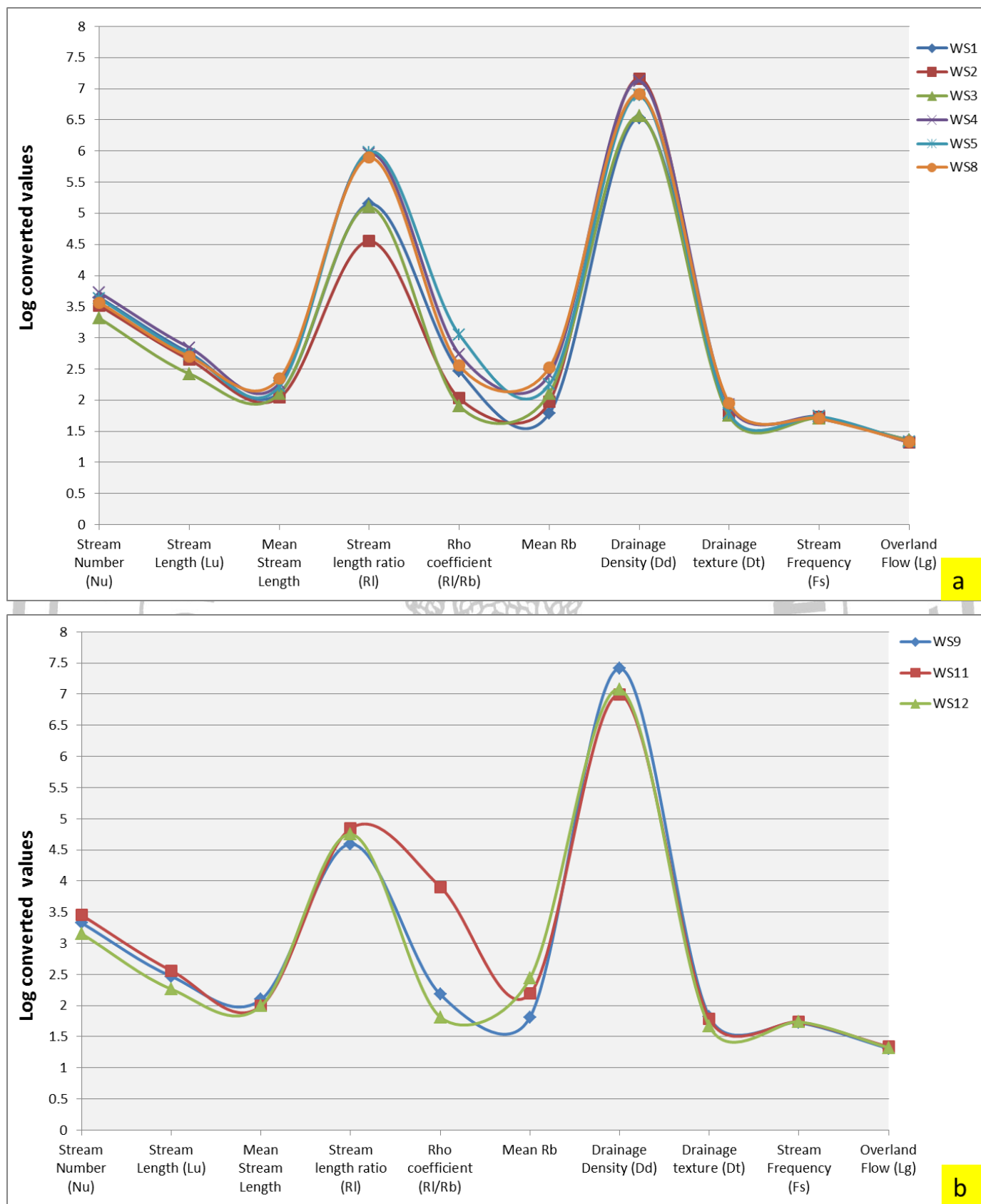


Figure-5.2: Shows mean average values of various morphometric attributes of watersheds of 7th order (a) and 6th order (b) level.

more runoff and low to moderate infiltration which leads to chances of high risk of erosion and flooding (S Sukristiyanti et. al, 2018). The stream length ratio, stream length, Rho coefficient, mean bifurcation ratio and drainage density are observed low for poorly draining watersheds (WS1, WS2, WS3) of 7th order level and WS9 of 6th order level which have suffered lot by landslides, scouring and channel erosion as compared to well drained watersheds (WS4, WS5, WS8) of 7th order level and WS11, WS12 of 6th order level (see fig. 5.2).

5.4 Individual Stream Morphometric Attribute Values

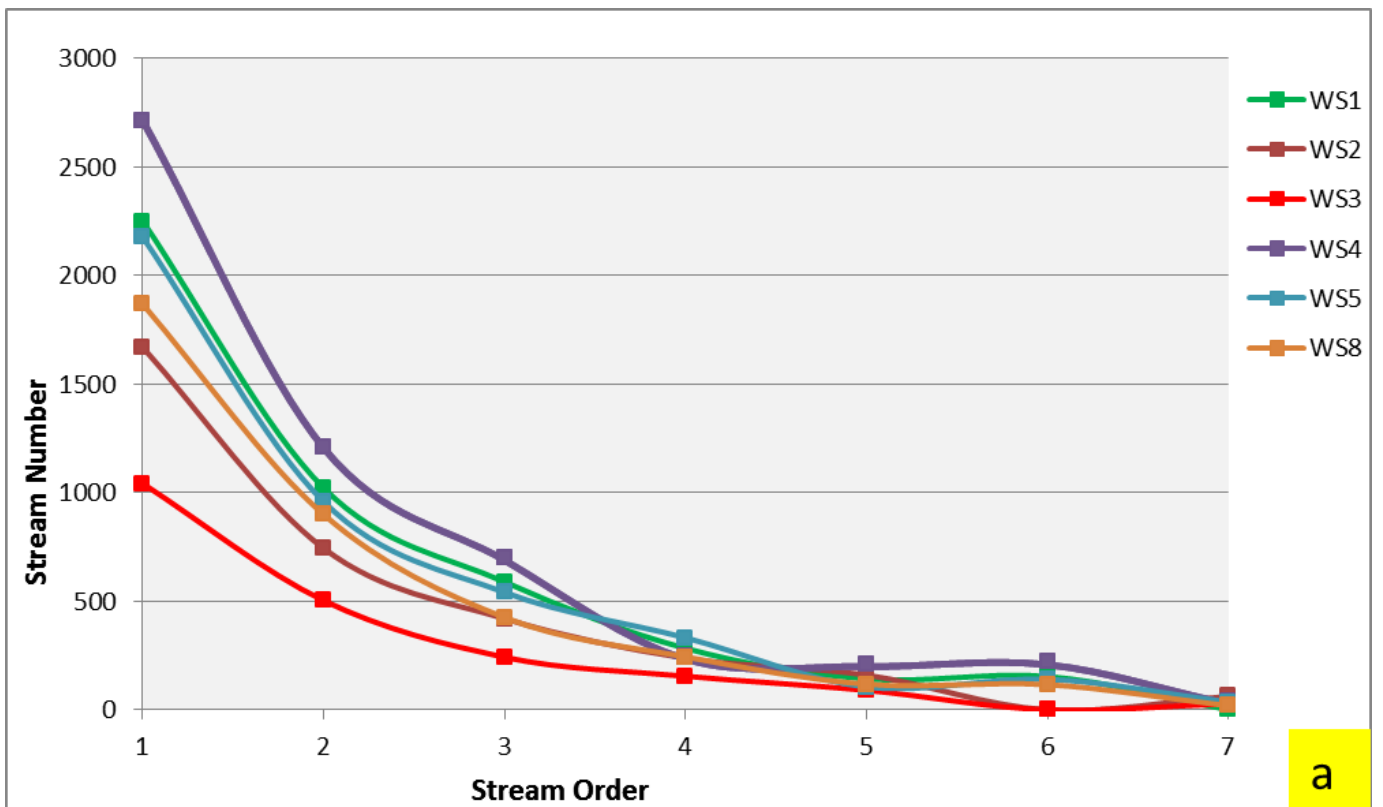
The individual stream morphometric values of attributes such as stream number (Nu), stream length (Lu), mean stream length (Lm), bifurcation ratio (Rb) and Rho coefficient were calculated in each watershed to observe that which attributes have impacted the landslide and channel erosion affected watersheds (WS1, WS2, WS3 and WS9) performance as compared to well performed watersheds to drain and distribute storage waters and what significant changes have occurred in each watershed. One major among of these changes is that the 6th order streams are not developed in watersheds (WS2, WS3) in which the poor performance happened to drain and distribute storage capacity of available waters in higher stream orders during precipitation (see fig. 5.3). The water load which has to be distributed in 6th order streams is forced to distribute in consecutive lower order streams with getting extra back water pressures from main stream (7th order) water flow as it receives waters from all neighboring watersheds. So this is revealed that this process might have put negative influence on various geotechnical properties like permeability, effective stress, cohesion etc. of overburden and/or rock. Besides, the infiltration might has gone in deep fractured rocks beneath the overburden and mobile them to failure which is witnessed by involvement of fractured rock blocks in some debris type of landslides occurred in lower order stream side slopes. The calculated values of individual stream morphometric attributes of all analyzed watersheds are shown by linear graphs (see fig.5.3 & 5.4) which are giving a clear look of various significant changes in morphometric attributes. The individual stream morphometric attributes were graphically represented for 7th order and 6th order separately in order to observe the major attribute changes in watersheds (WS1, WS2, WS3 and WS9) suffered lot by channel erosion, scouring and landslides as compared to other neighboring watersheds (WS4, WS5, WS6, WS7, WS8, WS10, WS11 & WS12) which have well performed to drain and distribute the storage capacity waters during 2018 rainfall event and were least affected by channel erosion, scouring and landslides.

The 7th order watersheds WS2, WS3 have less stream number and stream length as compared to others. However watershed WS1 has sufficient stream number and stream length to other well drained watersheds but is showing low performance in other attributes with similar attitude of 6th order watershed WS9. The mean stream length of well performed and well drained watersheds decreases gradually to the

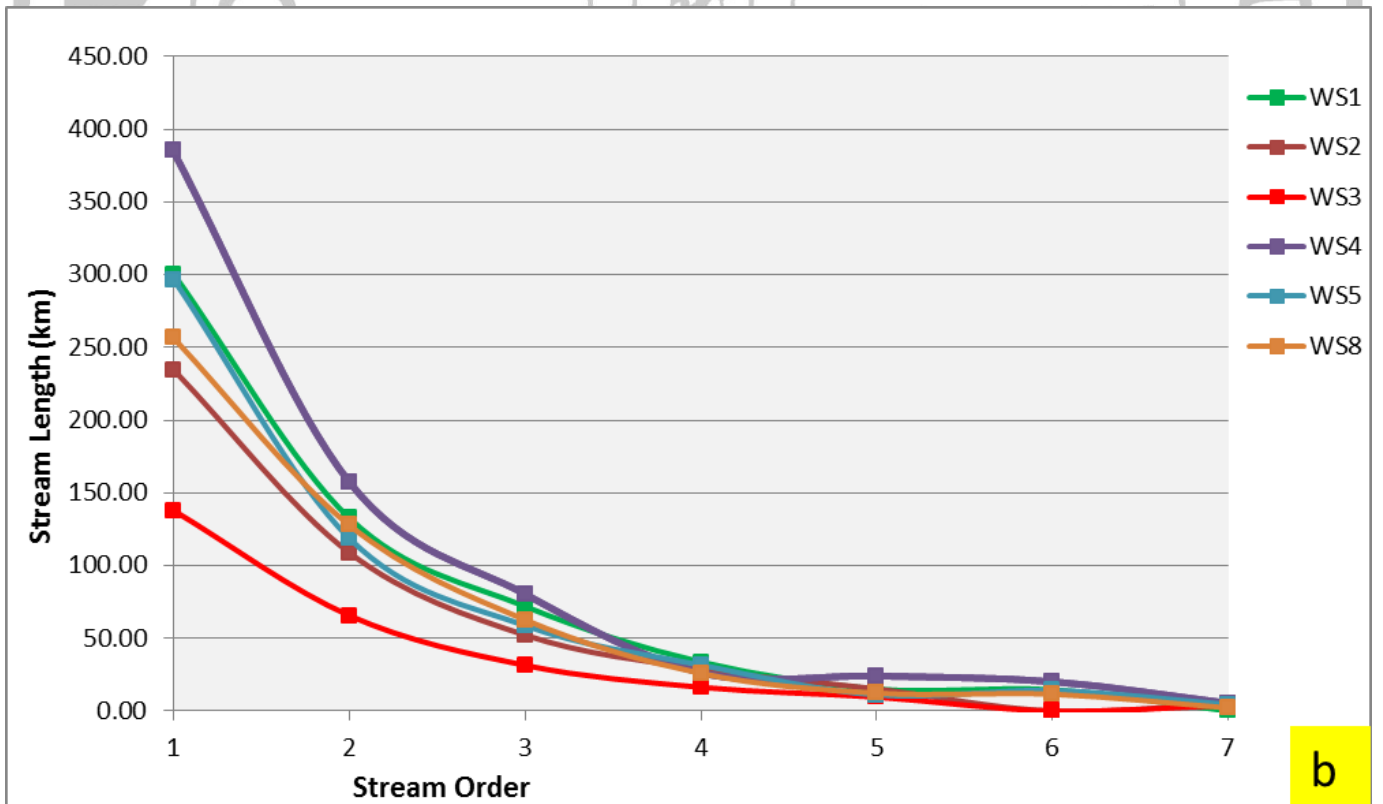
4th order then follow a regular path of slight increase with some light fluctuations to adjust their stream maturity stages and this path is considered normal path of mean stream length. The major changes or deviations from the normal path of mean stream length are shown by watersheds WS1, WS2, WS3 which have suffered lot by channel erosion, scouring and landslides. Similar changes or deviations in mean stream length are observed in 6th order watershed WS9. It means the lower order streams with no gradual decreasing trend and higher order streams with gradual or abrupt decreasing trend in mean stream length are susceptible to landslides, scouring and channel erosion and same thing has been revealed from WS1 and WS2 watersheds wherein present study area lies.

The bifurcation ratio of well performed and well drained watersheds (WS4, WS5, WS11 and WS12) shows gradual decrease in lower stream orders then follow high fluctuations in higher stream orders means an indication of a sign of well drained condition. The deviations from this indicated sign accounts poorly performance of landslide affected watersheds (WS1, WS2, WS3 and WS9) and various stream orders in watersheds WS3 and WS8. The stream length ratio of well performed and well drained watersheds (WS4, WS5, WS11 and WS12) shows steep slope increasing trend to 2nd order with a sudden decrease in 3rd order stream then follow a constant regular path of slight increasing trend with high fluctuations in water receiving main stream. This stream length ratio path is a sign of normal well performance and well drained condition. The poorly performed and landslide affected watersheds (WS1, WS2, WS3 and WS9) are following deviated trends from normal stream length ratio path of well drained condition. Even some stream orders of few watersheds (WS3 and WS8) are showing this deviated trend and they have suffered channel erosion and landslides.

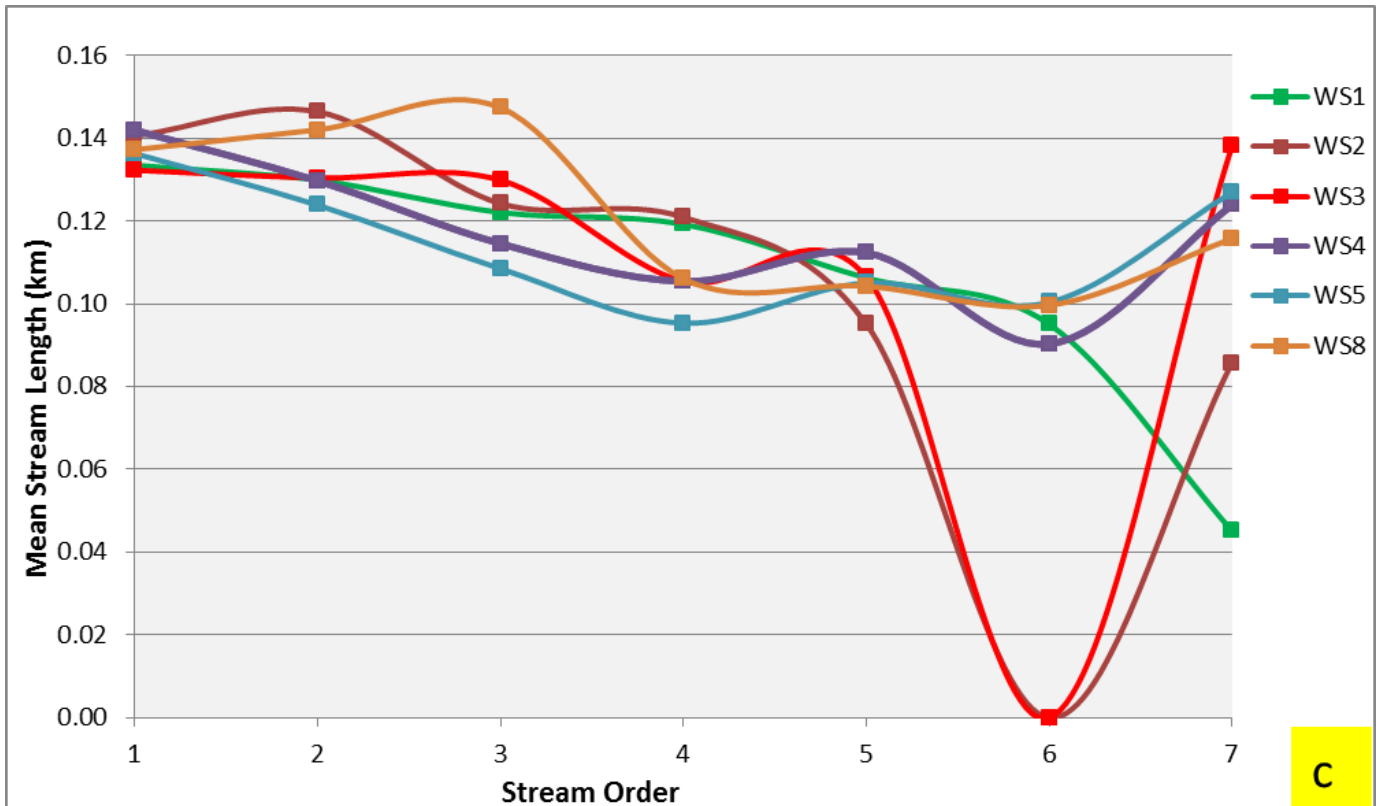
The Rho coefficient of well performed and well drained watersheds (WS4, WS5 and WS11) of both 7th and 6th order level shows gentle slope increasing trend to 2nd order with slight decrease in 3rd and/or 4th order streams then follow a steep slope increasing path and high increasing fluctuation in 5th order stream with steep slope decrease in water receiving main stream. This path is considered as Rho coefficient normal path of well drained condition. The deviations from this indicated Rho coefficient path of well drained condition accounts poorly performance of landslide affected watersheds (WS1, WS2, WS3 and WS9). The watershed WS12 is having less stream number and stream length and showing a similar deviations from Rho coefficient path of well drained condition but has not suffered landslides or channel erosion. The reason could be first the rainfall intensity was not beyond the threshold level wherein this watershed could have respond by landslide occurrence and channel erosion or second the rest of well performed attributes have overcome these deviations.



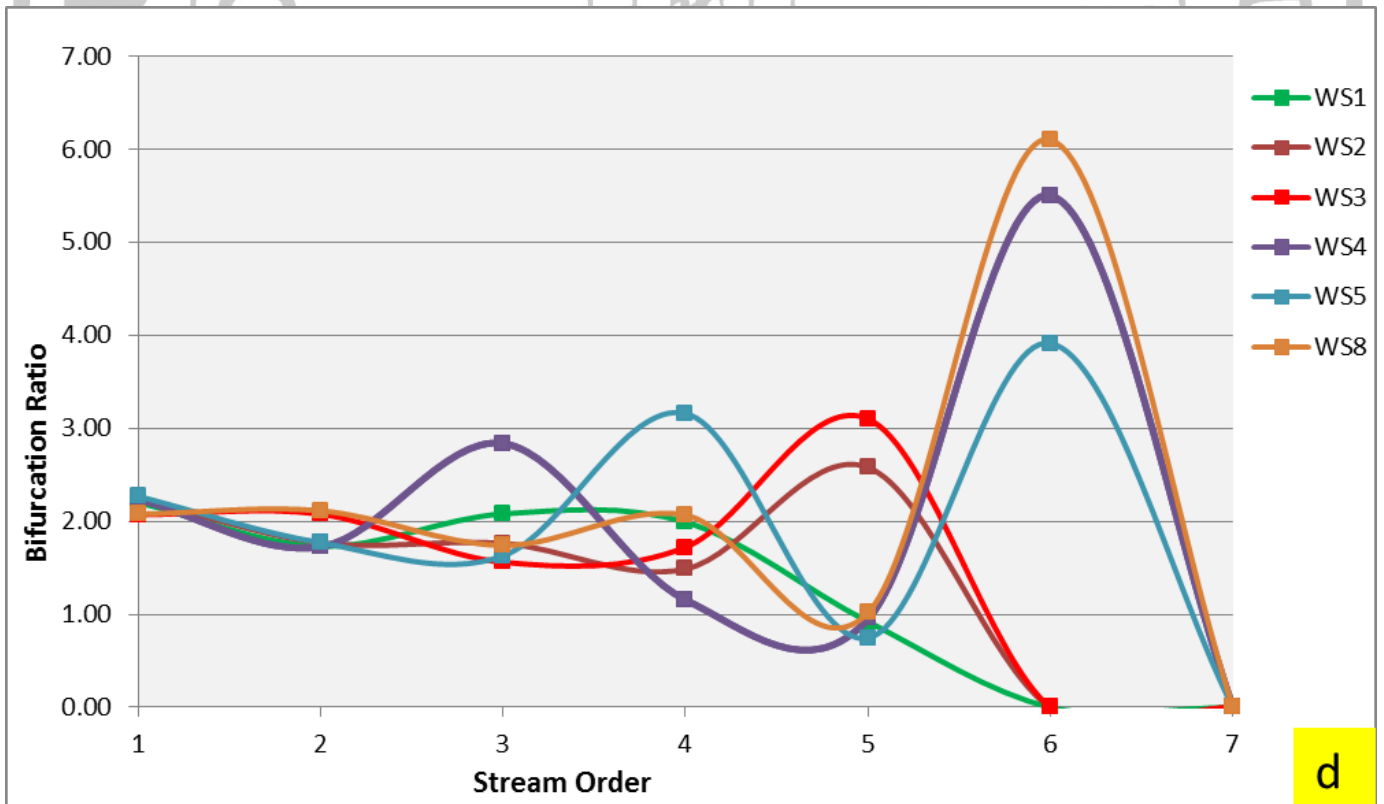
a



b



c



d

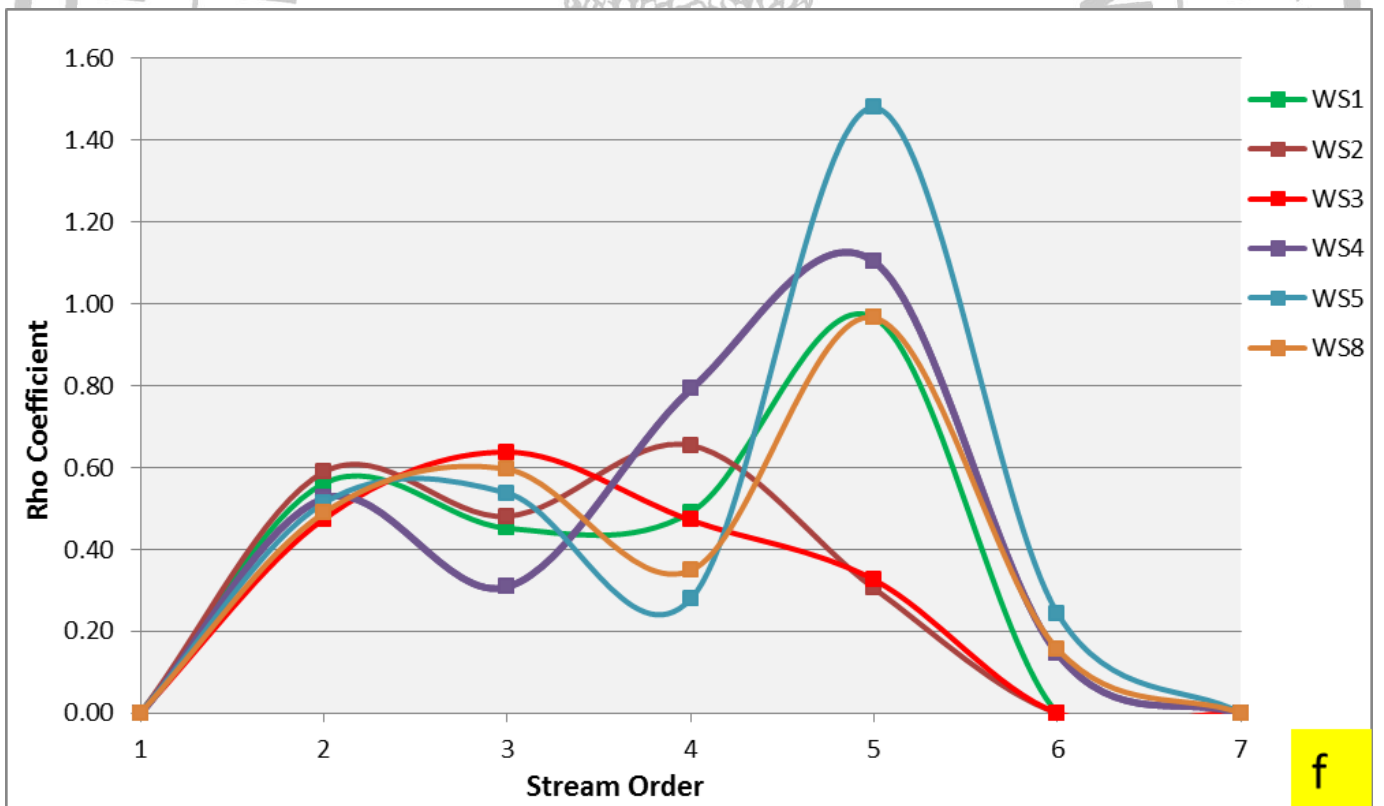
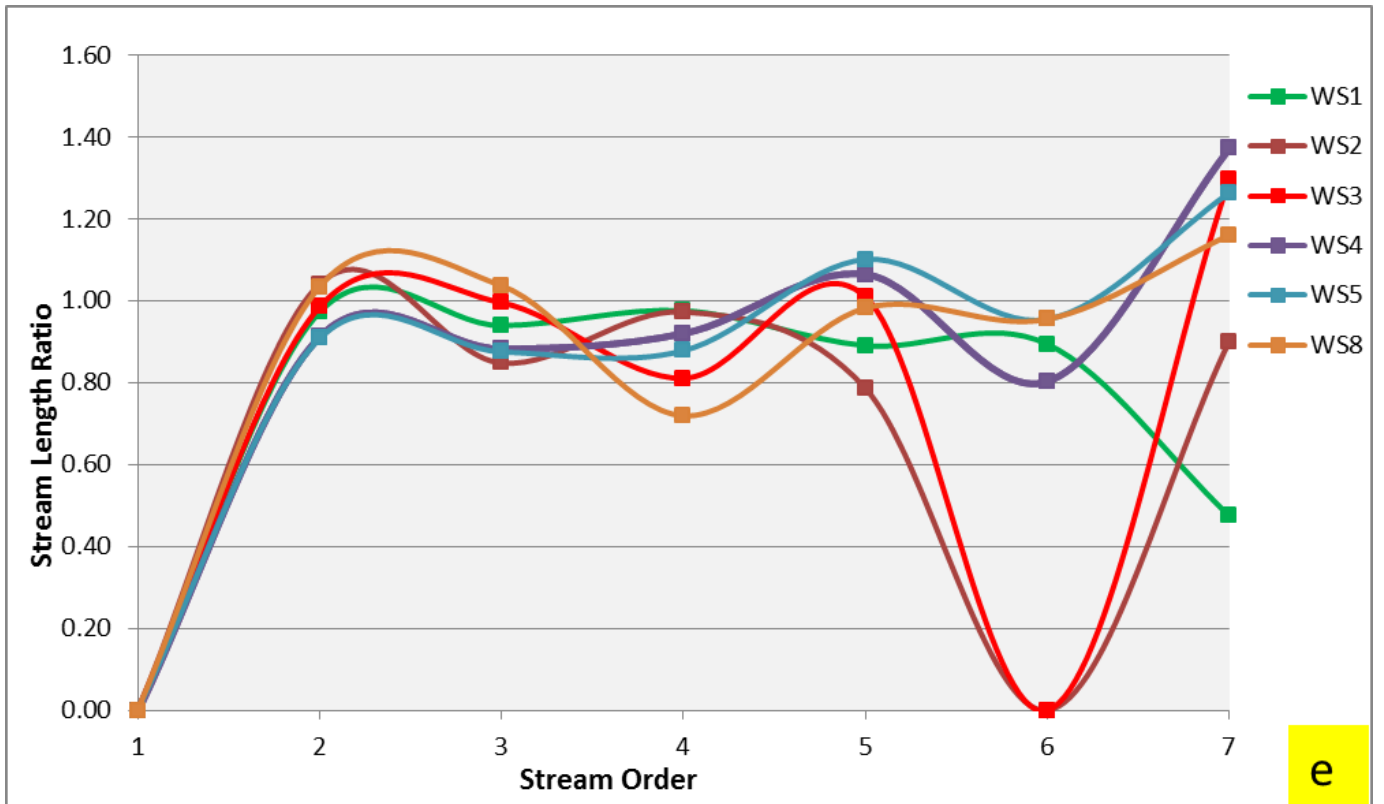
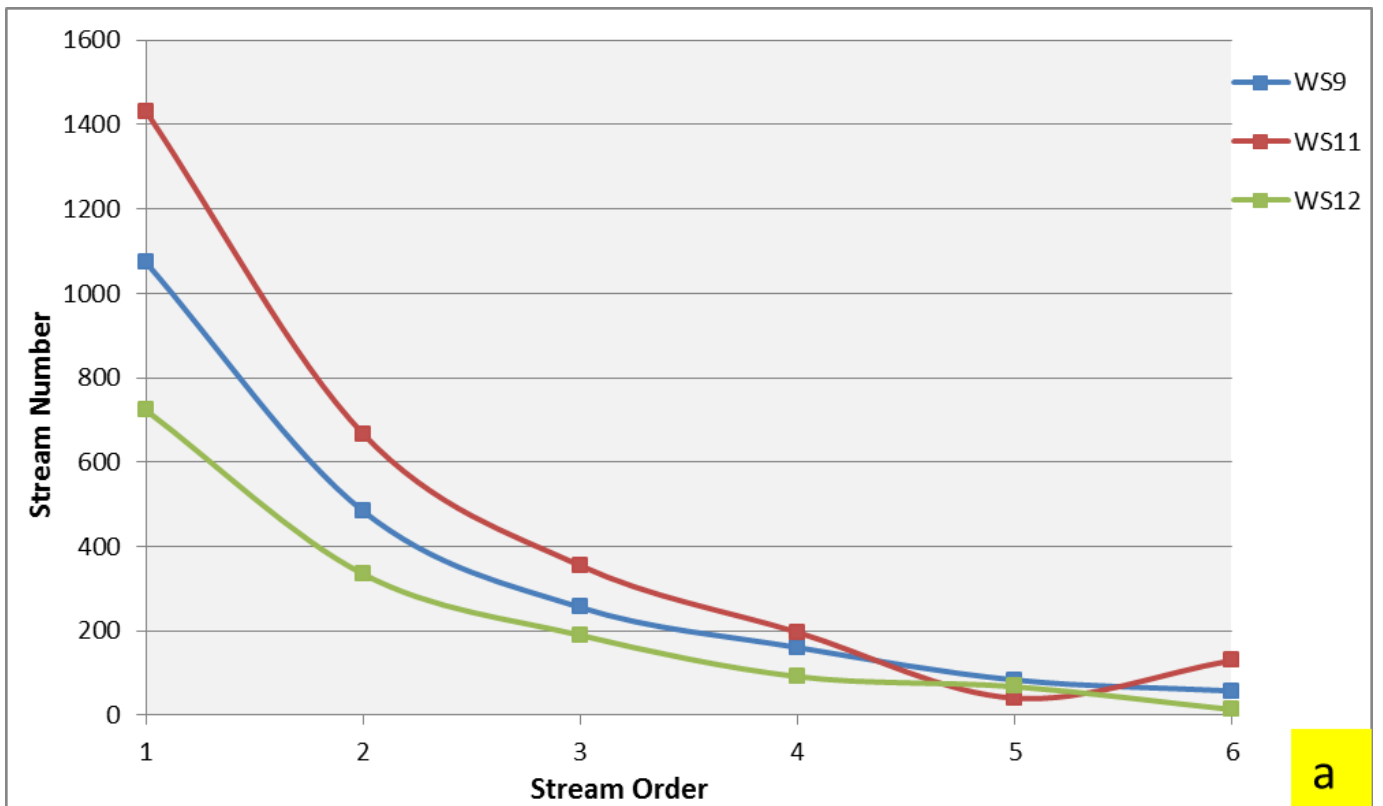
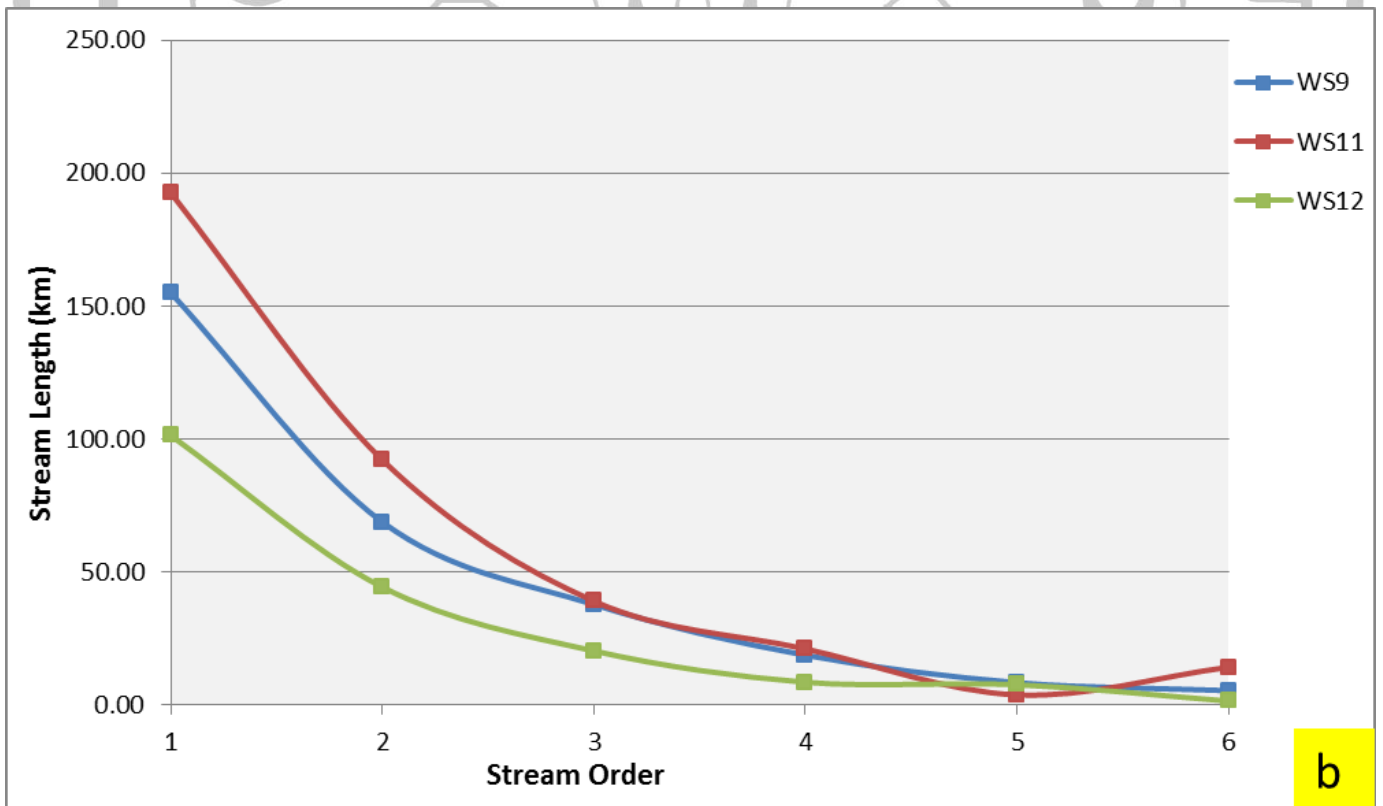


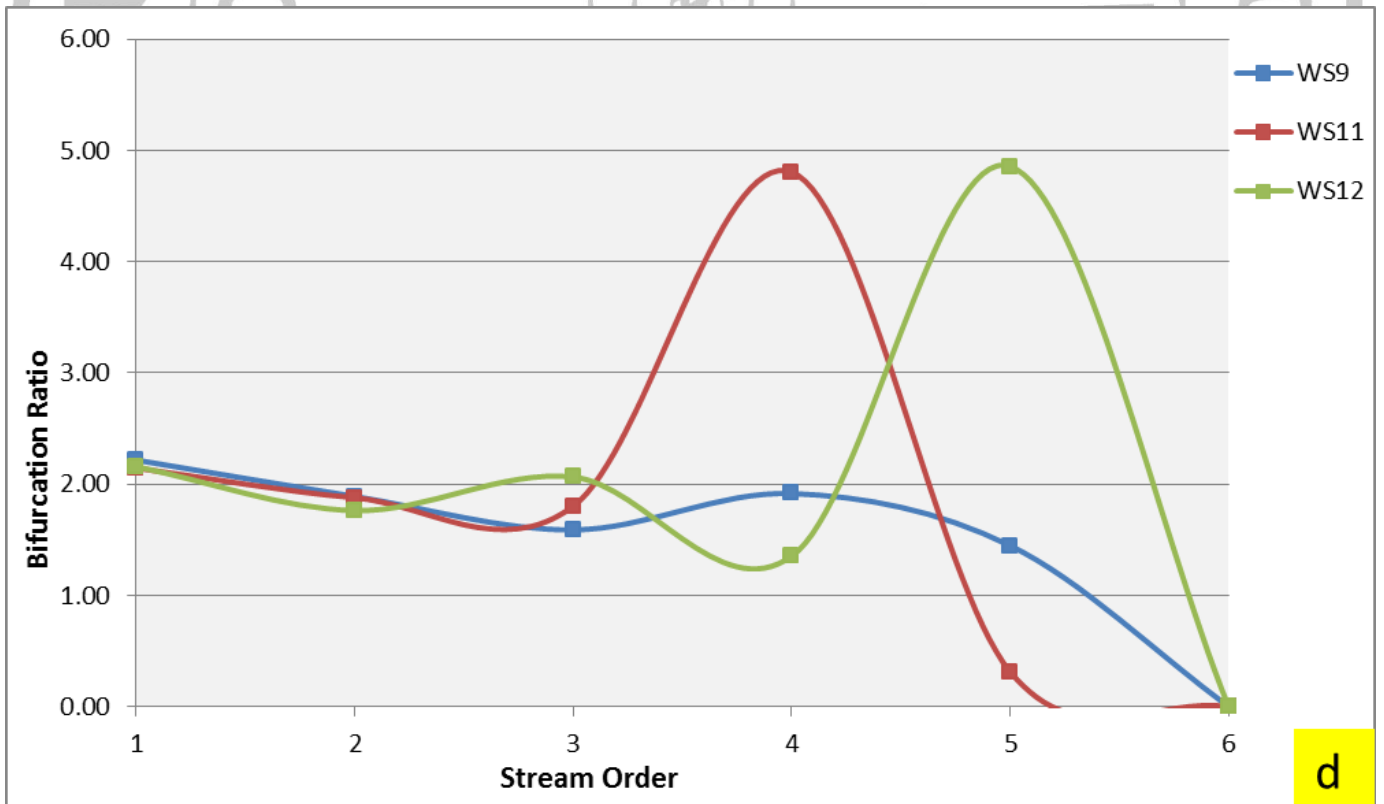
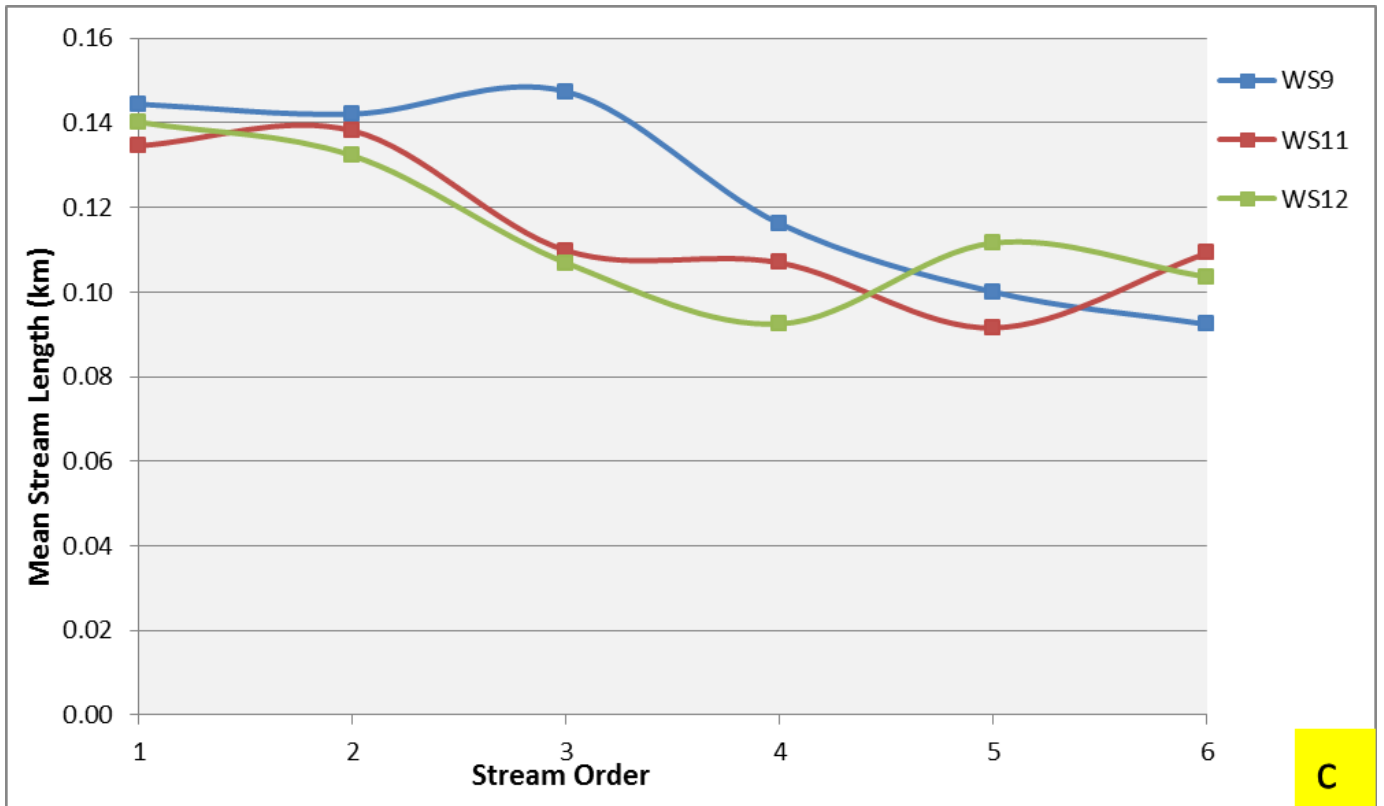
Figure-5.3(a)-(f): Shows performance of individual stream morphometric attributes of 7th order watersheds



a



b



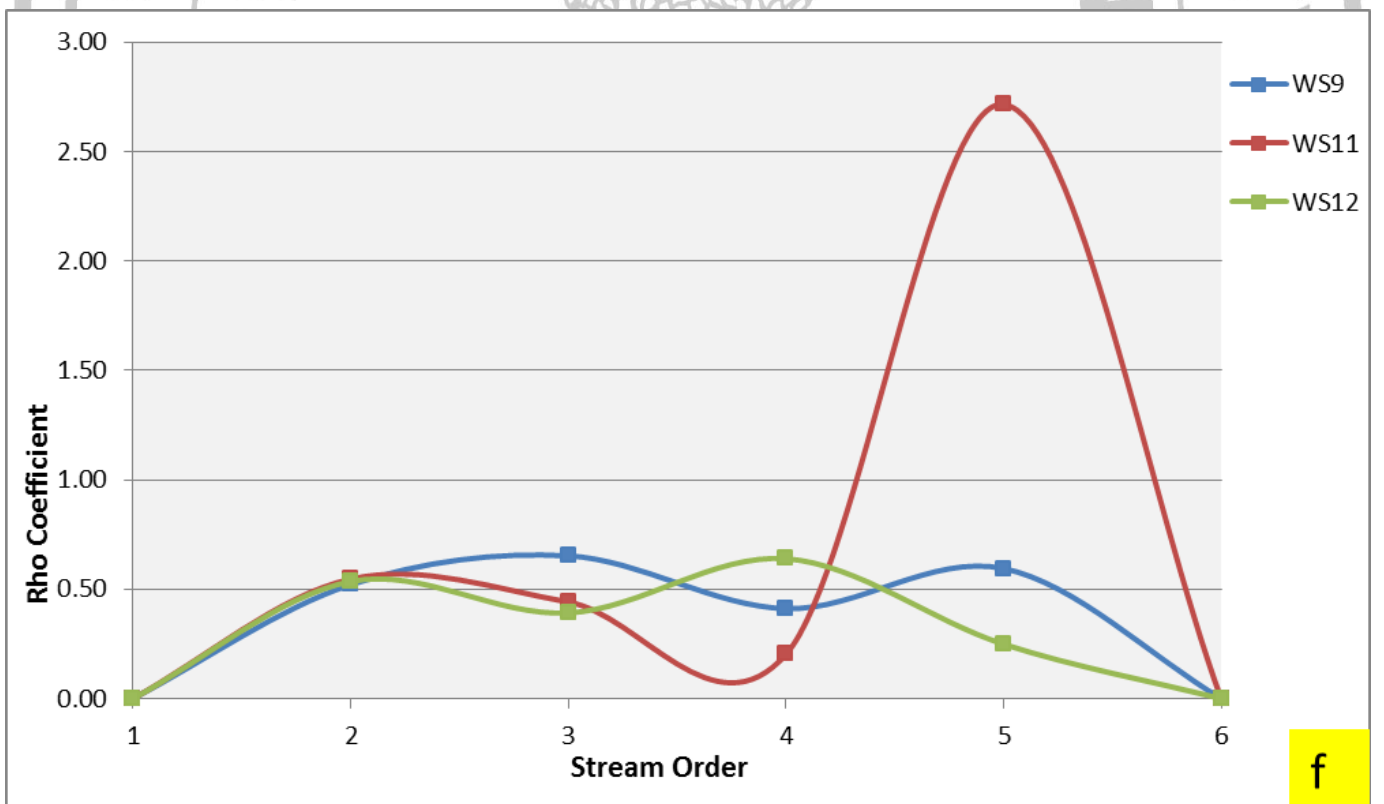
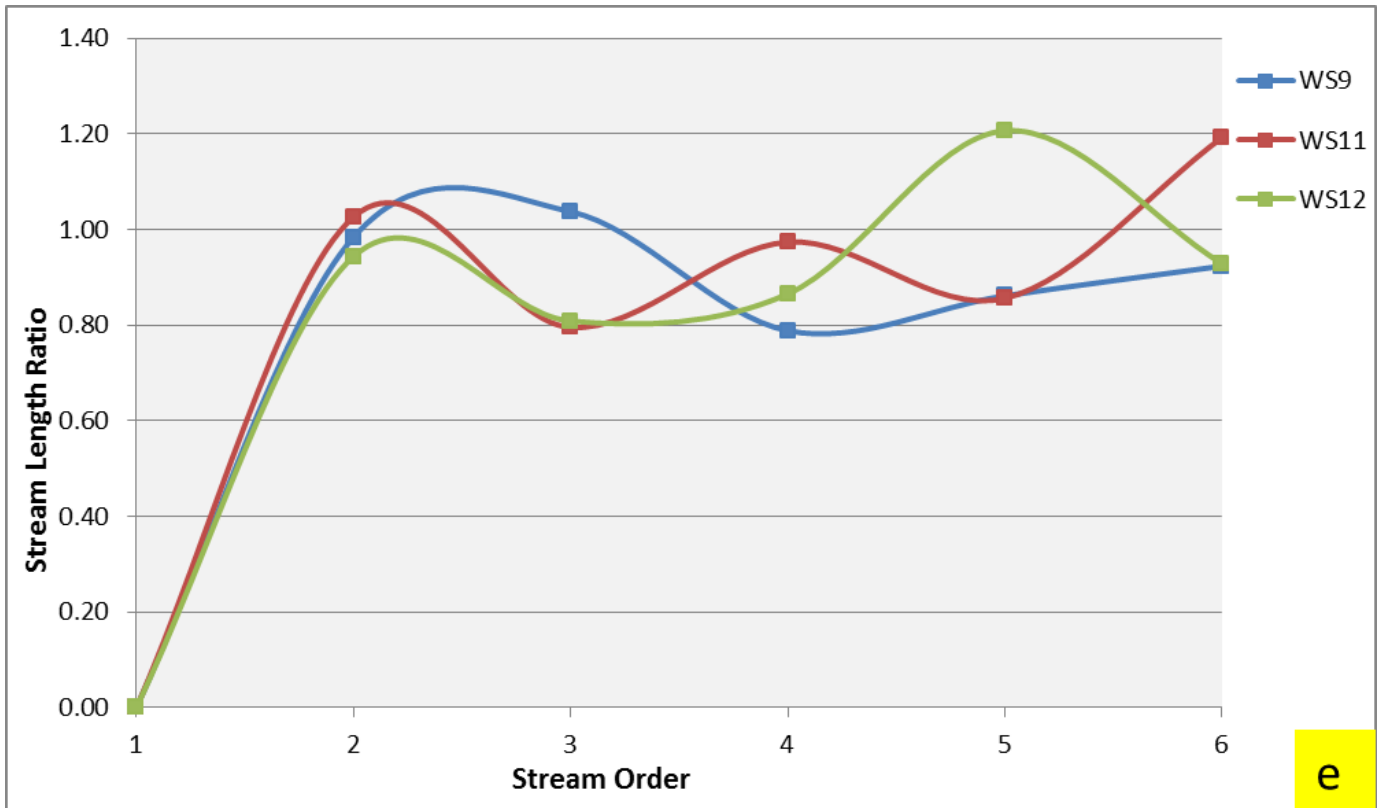


Figure-5.4(a)-(f): Shows performance of individual stream morphometric attributes of 6th order watersheds

6. LANDSLIDE SUSCEPTIBILITY ANALYSIS

6.1 Landslide Susceptibility Analysis: Introduction

Landslide susceptibility mapping is a quantitative or qualitative estimate of spatial distribution of landslides, which exist or potentially may occur in an area. Although it is expected that landslides will occur more frequently in the most susceptible areas particularly during rainfall. 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 or quantitative estimation that the mapping unit (e.g., a pixel, slope unit or facet) will be affected by a future landslide source. In GIS-based data-driven methods such as Weighted Multiclass Index Overlay, spatial factors (or layers of evidence) are integrated with a landslide inventory map (target) using various mathematical/statistical integration techniques (Bivariate, Multivariate, Artificial Neural Network etc.) that can model relationships among layers of evidence with respect to targets ([Bonham-Carter, 1994](#); [Chung et al., 1995](#); [Baeza and Corominas, 2001](#)). For landslide susceptibility mapping, the selection of preparatory factors for landsliding depends on the scale of analysis, the characteristics of the study area, the landslide type, the failure mechanisms and the priori knowledge of the main causes of landslides ([Guzzetti et al., 1999](#)). A systematic overview of the important preparatory factors required for susceptibility mapping in different scales is given by [van Westen et al. \(2008\)](#). A prior knowledge of the main causes of landslides in the area of interest is essential in selecting the most relevant factors out of the many known preparatory factors that can “theoretically” cause landslides ([Ghosh and Carranza, 2010](#)). In the present area of investigation the landslides are rainfall induced. All the landslides are confined to overburden classified either earth slides or earth flows. The most responsible and relevant geo-factors have been identified during the investigation which are causing landslides in the area and these geo-factors are discussed in [chapter-4](#). The selection of mapping unit for GIS based susceptibility analysis depends on mapping scale and available data resources. Mass movement processes (landslides and channel erosion) are highly controlled by the slope features of the terrain such as drainage, divide lines ([Carrara et al., 1991](#)) gradient, overburden etc. and therefore slope-units are best suited for a hazard analysis. Since the present investigation is a susceptibility analysis rather than a hazard analysis, therefore “pixel” is taken as a mapping unit. A pixel based mapping unit can facilitate very fast computation and processing of raster data set in GIS and it is also the commonly used unit in the raster based analysis ([Carrara et al., 1992](#)).

It should be noted here that as on date there are no standard operating procedure (SOP) guide lines for meso-scale susceptibility mapping on 1:0,000 scale in GSI. During the course of investigation the authors have tried lot to make a well suited landslide susceptibility model for this study and have

submitted one model to GHRM Division for scrutiny but still there are various challenges to improve that model. Keeping the necessities, priorities and requirements of district administration in consideration, the authors have adopted the landslide dependent model of NLSM for landslide susceptibility analysis in present investigation of meso-scale landslide susceptibility mapping. The said model of NLSM has been adopted after validating its prediction strength over the area and has proved best interpreted model so far for the present study area. The said model supports every observation and conclusion made during field studies and post field studies of data analysis. The authors are glad to improve and modify the landslide susceptibility analysis contents when and as the standard operating procedure (SOP) guide lines for meso-scale susceptibility mapping on 1:0,000 scale in GSI will be formulated.

6.2 Methodology

Landslide susceptibility is the tendency of an area to respond the prevailing climatic, lithological and tectonic conditions by different geo-factor themes. In mathematical form, landslide susceptibility is the probability of spatial occurrence of known slope failures, given a set of geo-environmental conditions (Guzzetti et al., 2005). In this study, a landslide dependent model was adopted to generate a qualitative landslide susceptibility map by using the Weighted Multi-class Index Overlay method. The landslide susceptibility modeling is divided into the following main themes:

- i) Preparation of landslide inventory and geo-factor maps with their related GIS-based database.
- ii) Establishing relation between various geo-factors and landslides for determining both ratings of factor classes and weights of the geo-factor themes.
- iii) GIS-based modeling for integration of selected and weighted geo-factor themes for preparation of landslide susceptibility score maps.
- iv) Validation and classification of landslide susceptibility score maps into qualitative maps showing varying degree of landslide susceptibility.

For validation, the resulting landslide susceptibility map was combined with the landslide inventory map. The success rate curve was prepared by plotting the cumulative percentage of all known landslide area (along y-axis) versus the cumulative percentage of the area of the susceptibility map, ordered from high to low susceptibility score values following method proposed by Chung and Fabbri (2003). If the success rate curve is steep at lower cumulative map area percentage of highest score values, then the landslide susceptibility map has strong ability to predict areas that are most susceptible to landslide. The Weighted Multiclass Index Overlay method is the improved bivariate statistical method for defining landslide susceptibility (Ghosh et al., 2011). Given that a categorical spatial factor map (f) is multi-class and a landslide occurrence map (s) is binary, the measure of the spatial association between

classes of f and s is calculated by the Yule's coefficient (YC) (Yule, 1912; Fleiss, 1991; Bonham-Carter, 1994):

$$Y_C = \frac{\sqrt{M_{fs}/M_{\bar{f}\bar{s}}} - \sqrt{M_{f\bar{s}}/M_{\bar{f}s}}}{\sqrt{M_{fs}/M_{\bar{f}\bar{s}}} + \sqrt{M_{f\bar{s}}/M_{\bar{f}s}}}, \quad \text{Eq. (1)}$$

where M_{fs} is area of 'positive match' where a factor class and landslides are both present, $M_{\bar{f}\bar{s}}$ is area of 'mismatch' where a factor class is absent but landslides are present, $M_{f\bar{s}}$ is area of 'mismatch' where a factor class is present but landslides are absent, and $M_{\bar{f}s}$ is area of 'negative match' where a factor class and landslide are both absent. The value of YC ranges between -1 and +1, just like the Pearson's correlation coefficient. A negative YC means negative spatial association, whereas a positive YC means positive spatial association.

Based on YC, for each factor class a Favorability Score or rating (F_{Ct}) is derived:

$$F_{Ct} = \begin{cases} 0 & \text{for } Y_C \leq 0 \\ Y_C/Y_{C_{\max}} & \text{for } Y_C > 0 \end{cases}, \quad \text{Eq. (2)}$$

Where, $Y_{C_{\max}}$ is the highest Y_C of all classes in a spatial factor and F_{Ct} represents the relative degree of influence of every factor class on the susceptibility to landslide occurrence in the range of 0 to 1.

Individual spatial factors can have different degrees of spatial associations with landslides. However, as landslide is related an inter-play of multiple factors, predictive modeling requires analysis of inter-predictor weights. The analysis can benefit from expert/generic knowledge of causal factors of landslides. However, expert knowledge is subjective and landslide experts are likely to assign different weights. In this section, we describe how analysis of **inter-predictor weights** can be made more objective. To determine the relative importance of every predictor, a **predictor rating (PR)** for every spatial factor theme based on their degree of spatial association with landslides can be determined:

$$PR = |SA_{\max} - SA_{\min}| / |SA_{\max} - SA_{\min}|_{\min} \quad \text{Eq. (3)}$$

Where SA is the degree of spatial association (YC for categorical variables) of classes of a spatial factor with a set of landslides. For each factor the absolute difference between the maximum and minimum SA values is calculated, which is then divided by the lowest absolute difference of all the factors to obtain the inter-predictor weights. To integrate the selected predictors for landslides, the weighted multi-class index overlay method (Bonham-Carter, 1994) can be applied. In each of the i-th ($i = 1, 2, \dots, n$ number of) predictor maps, each of the j-th ($j = 1, 2, \dots, m$ number of) predictor classes is assigned a favorability score

(F_{ji}) obtained through spatial association analysis. Every i-th predictor map is assigned an integer predictor weight, W_i , obtained through calculation shown above. Weighted predictor maps are then combined using the following equation, which calculates an average weighted score of landslide susceptibility ($\bar{S}$) for every location/ pixel (Bonham-Carter, 1994):

$$\bar{S} = \frac{\sum_i (F_{ji} \times W_i)}{\sum_i W_i} \quad \text{Eq. (4)}$$

The output map of $\bar{S}$ is a predictive model of landslide susceptibility under examination in the area. The most important aspect of any predictive mapping is the validation. For validation of landslide susceptibility maps, the landslide susceptibility score map is overlapped with the landslide inventory map. For overall validation, success/predictive rate curve can be prepared. If the success rate curve is steep at lower cumulative map area percentage of highest score values, then the corresponding landslide susceptibility map has strong ability to predict areas that are most susceptible to landslides. Success rate curve function is used to subdivide the landslide scores into three classes of different landslide susceptibility (i.e., high, moderate and low). In the present investigation the following procedures were taken for landslide susceptibility mapping:

- (a) The geo-factor themes which are most responsible for landslide occurrences in the area have been identified after carrying field as well as laboratory examinations. These geo-factor themes comprising field based maps (landslide inventory, slope forming material and overburden thickness); DEM derived maps (stream watershed, slope, landform and drainage); laboratory based overburden geotechnical parameter maps (cohesion, angle of internal friction, specific gravity, density, porosity and grain size). These different types of maps are prepared as a polygon shape-file and as a polyline shape-file then converted into raster maps of 10 m $\times$ 10 m pixel size.
- (b) The Carto DEM (10 m resolution) derivatives such as slope, drainage, stream watershed, landform were reclassified into categorical variables.
- (c) The laboratory based overburden geotechnical parameter values of cohesion, angle of internal friction, specific gravity, density, porosity and grain size were interpolated to create a variable map in raster format. The variable maps were later reclassified into categorical variables.
- (c) The number of occupancy of landslide pixels in each factor map has calculated using the “combine” function in ArcGIS platform. The tables obtained after combining the landslide inventory with each factor map provided the value of number of landslide pixels (npixd) and total pixels of a particular class of factor map (npixt). The calculation of the ratings for each class of all factor maps and their total weights has performed in Microsoft office excel tool (Table 6.1).

(d) The predictor rating (PR) for every factor map based on their degree of spatial association with landslides is calculated using Eq. (3). The obtained value is converted into integer by dividing each by the maximum value. [Table 6.1](#) shows the weight values of each factor map.

(e) For each class of all factor maps, first the Yule's coefficient (YC) is calculated in Microsoft office excel using Eq. (1). From YC, the landslide occurrence favorability score (LOFS) rating is calculated by dividing the YC value by its maximum to restrict the LOFS between 0 and 1. [Tables from 4.1 to 4.6](#) show the generated LOFS ratings of each class of all factor maps. Later the Microsoft office excel table is joined with its corresponding factor map using the "join and relates" function in ArcGIS platform.

(f) Using "lookup" function in ArcGIS platform, an attribute (LOFS rating) map is generated for each factor map showing the spatial distribution of the LOFS ratings.

(g). Using "Map Algebra" function in ArcGIS the obtained weights or LOFS maps have combined together following the Eq. (4) to obtain the raw landslide susceptibility score map.

(h) The generated raw landslide susceptibility score map has combined with the landslide inventory map and a success rate curve has generated in ILWIS software, following the method proposed by [Chung and Fabbri \(2003\)](#). The table of success rate curve has verified and the boundaries between "High" "Moderate" and "Low" landslide susceptibility zones have demarcated at pixel values of 70% and 90% of percent landslides.

Table 6.1: Predictor rating (PR) of geo-factor maps

Geo-factor map	Min Yc	Max Yc	Abs Diff	Weight	Integer weight
Stream Watershed	-0.4	0.14	0.54	0.27	3
Drainage Distance	-1	0.09	1.09	0.55	6
Slope Gradient	-1	0.13	1.13	0.57	6
Landform	-1	0.08	1.08	0.55	5
SFM	-1	0.97	1.97	1.00	10
SFM Thickness	-0.39	0.16	0.55	0.28	3
Overburden Cohesion	-0.28	0.3	0.58	0.29	3
Overburden Friction Angle	-0.18	0.44	0.62	0.31	3
Overburden Specific Gravity	-0.3	0.34	0.64	0.32	3
Overburden Density	-1	0.19	1.19	0.60	6
Overburden Porosity	-1	0.35	1.35	0.69	7
Overburden Silt+Caly	-0.2	0.29	0.49	0.25	2
Max= 1.97				Total= 57	

6.3 Landslide Susceptibility Map and Success Rate Curve

The susceptibility term expressed in terms of relative proneness to initiate a landslide in a pixel (mapping Unit) under the given geo-environmental conditions. The landslide susceptibility score map generated by using Weighted Multiclass Index Overlay method in Arc GIS platform in this investigation (see fig. 6.2) is a final product of LOFS rating of geo-factor themes comprising field based maps (landslide inventory, slope forming material and overburden thickness); DEM derived maps (stream watershed, slope, landform and drainage); laboratory based overburden geotechnical parameter maps (cohesion, angle of internal friction, specific gravity, density, porosity and grain size) which controls either individually or together the landslide occurrences. These geo-factor themes are discussed in chapter-4. The landslide susceptibility score map generated can be depicted by success rate curve (see fig. 6.1) generated by using landslide susceptibility score inputs and landslide inventory data in ILWIS software following the method proposed by Chung and Fabbri (2003). The success rate curve generated for landslide susceptibility score map in present investigation shows steepness at lower cumulative map area percentage (permap) having highest score values, therefore the corresponding landslide susceptibility map has strong ability to predict areas that are most susceptible to landslides.

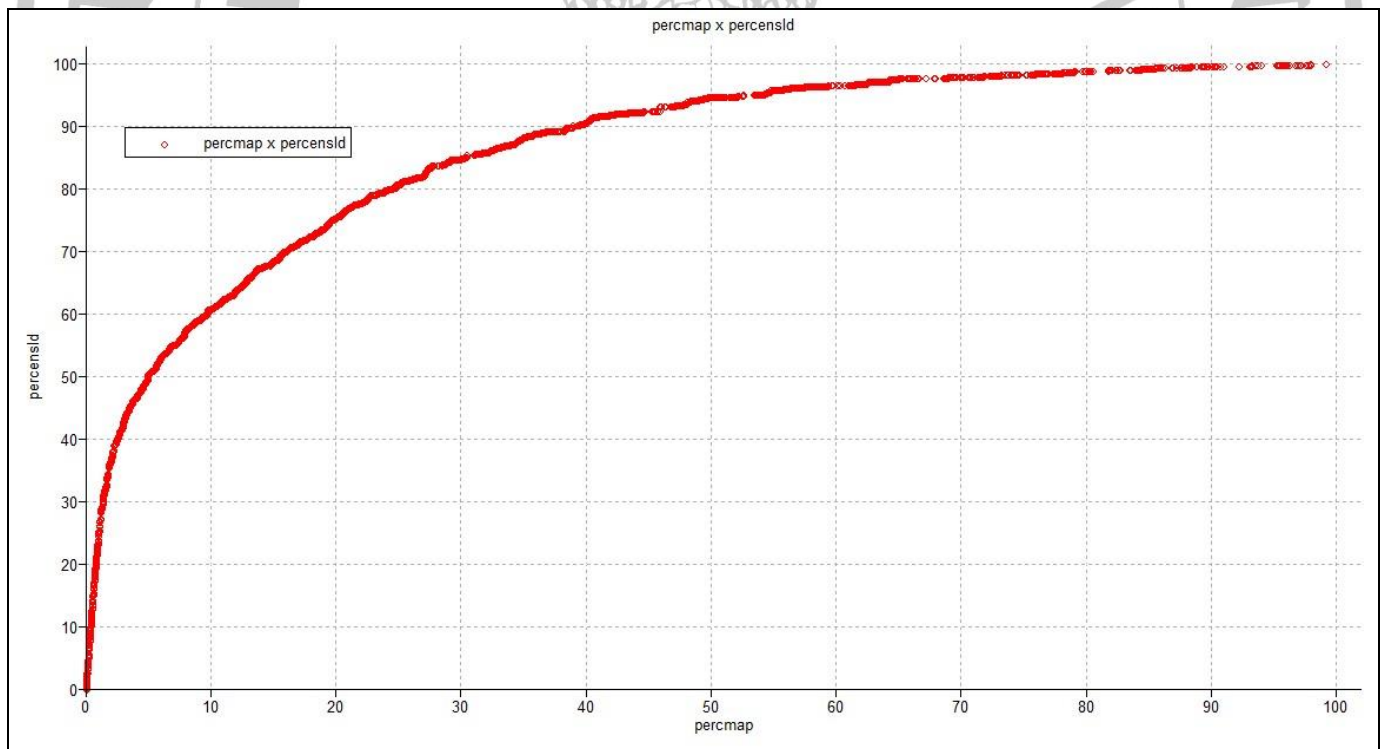


Figure-6.1: Success rate curve of landslide susceptibility score map generated for present investigated are of 18 sq. km in year 2018

The cut-off where 70.02 cumulative percent of landslides (percensld) are classified, has considered as the boundary between “High” and “Moderate” susceptibility zones. Similarly, the cut-off where 90.31 cumulative percent of landslides (percensld) are classified, has considered as the boundary between “Moderate” and “Low” susceptibility zones. The statistical attribute table of success rate curve of present area of investigation reveals that 15.73 cumulative map area percentage (percmap) falls under “High” landslide susceptible zone whereas 38.88 cumulative map area percentage (percmap) falls under “Moderate” landslide susceptible zone and rest 45.39 cumulative map area percentage (percmap) falls under “Low” landslide susceptible zone. The statistical analysis of landslide susceptibility score map of present investigated area reveals that out of 18 sq.km area, 2.83 sq.km (15.73 cumulative map area percentage) area falls under “High” landslide susceptible zone, 7.00 sq.km (38.88 cumulative map area percentage) area falls under “Moderate” landslide susceptible zone and rest 8.17 sq.km (45.39 cumulative map area percentage) area falls under “Low” landslide susceptible zone.

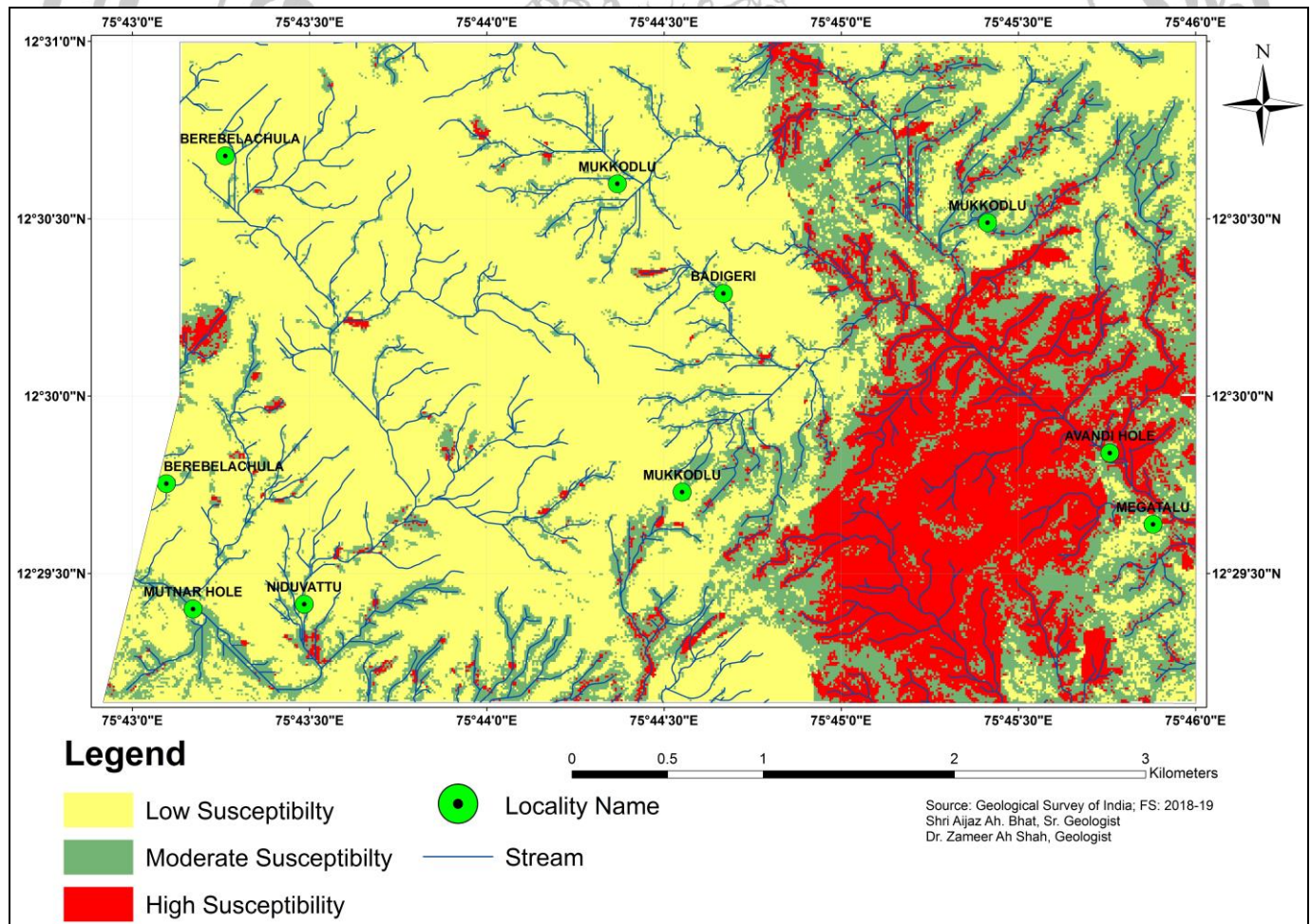


Figure-6.2: Landslide susceptibility map on 1:10,000 scale generated for present investigated area of 18 sq.km in year 2018

Although above numerical limits are strict for classification in terms of statistical analysis for each susceptibility zone but it is very difficult to strictly describe the localities in the actual area of influence in a particular zone. Some localities strictly fall in one particular zone while some would be described in range from one zone to other. The precession and accuracy of the present landslide susceptibility map can be evaluated by the actual ground realities observed during field studies. The role of drainage related parameters is proved major responsible and relevant causative factors for scouring, landslides and channel erosion in the present study area by the susceptibility map which has classified almost all drainage influenced portions in moderate to high landslide susceptibility range and the area away from drainage components are classified into low landslide susceptibility zone where any landslide if occurred is due to other relevant factors like cut-slope, pulverized zones under high strain condition etc.



7. SUMMARY & RECOMMENDATIONS

The conclusion and recommendations have been made on the basis of thorough discussions on field observations, analysis and interpretation of field data collected during field survey, drainage basin analysis, interpretation of geotechnical parameters of overburden analyzed by geotechnical laboratory, Hyderabad, landslide susceptibility score map and its success rate curve.

7.1 Summary

- ❖ The Madikeri taluk in which present study area lies, received more than 4000mm actual rainfall during June-September period 2018 which accounts 2000mm rise over 2500mm actual rainfall intensity in previous three years record (*see fig. 1.3*). This 2000mm rise in actual rainfall intensity not annually but in a particular event has resulted channel erosion and landslides during June-September period 2018 in Madikeri Taluk and its adjacent areas.
- ❖ Rainfall was a triggering factor rather than a causative factor and it have initiated various processes related to drainage system, infiltration, saturation and increase of unit mass which became the major causative factors for scouring, channel erosion and landslide occurrences in the present study area.
- ❖ The study area is a hilly terrain with landslide favorable slopes and very thick overburden cover which is developed by various weathering processes. The presence of very prominent penetrative joint sets allows deep infiltration during rainy season and processes of weathering. This hilly terrain with very thick overburden cover of in-situ type has made conditions very favorable for landslides and channel erosion during incessant rainfall which remained very high above normal.
- ❖ The first major causative factor was found by drainage network problem as there was poor performance to drain and distribute storage capacity of available waters in hierarchy stream orders during precipitation in landslide and channel erosion affected watersheds WS1 and WS2 wherein present study area lies (*see fig. 5.1*). This leads significant changes in various inherited equilibrated factors/parameters or processes acting within these watershed boundaries. These significant changes came in response after rise in actual rainfall by 2000mm not annually but eventually during June-September period 2018 and leads occurrence of channel erosion, scouring and landslides in clustering form. That is why the areas which were not witnessed by landslides or channel erosion lies in watersheds which have well performed to drain and distribute storage capacity of available waters in hierarchy stream orders during 2018 precipitation (*see fig. 5.3 & 5.4*).

- ❖ The first major causative factor related to drainage network problem has been evaluated and proved precise by landslide susceptibility score map which has classified almost all drainage influenced portions in moderate to high landslide susceptibility range and the area away from drainage components are classified into low landslide susceptibility zone where any landslide if occurred is due to other relevant factors like cut-slope, pulverized zones under high strain condition etc.
- ❖ The analysis of geotechnical parameters of overburden material revealed and supported the fact that certain overburden material properties (*discussed in chapter-4; section 4.7*) have allowed the material to generate variable shear stress (pore water pressures) on saturation particularly when infiltrated water flow get stuck due to poor drainage performance and would have resulted in natural slope failures irrespective of any human interference. Soil loses its cohesion shear strength when it reaches saturation.
- ❖ The second most responsible causative factor for landslides was found increase in unit mass due to consistent infiltration on more or less steep slopes and/or slope cuts along roads which were not withstand in incessant rainfall and got failure. The landslides occurred by this type of causative factor were found as small scale dimensional landslides.
- ❖ The lack of proper drainage networks along roads have raised chances of sufficient infiltration in moderate to high slopes, increases their unit mass and saturated the overburden slope material. These processes have increased the chances of landslides in the area.
- ❖ Besides there are other causative factors which acted as subordinated roles during the precipitation such as high slope gradient which is independent geo-factor, deformational processes in which non-cohesive pulverized rock material is produced which always remain free to flow by water action, porosity and permeability variations in overburden material depending on grain size and packing arrangements and blocking of streams by human activities.

7.2 Recommendations

1. Since the watershed configuration is a naturally controlled thing which can evolve with time depending on climate, lithology and tectonic activity. Each watershed can perform as per the natural conditions apply without any human interference. The only way to minimize the risk is that the natural streams should not be blocked by any means and all human developmental activities particularly settlements should be adopted away from natural streams.
2. Since it has been revealed that the watersheds in which present study area lies have high drainage densities with fine drainage texture. The high drainage density results high runoff in quick hydrological response which directly influences the higher order streams to receive more waters

during heavy rains. This process increases chances of flooding in main draining streams. Therefore the settlement activities should be avoided in flooding areas of higher order streams or main draining streams which receives waters from all lower hierarchy stream orders.

3. In order to find out the drainage related problems which become the major causes for landslide occurrences and flooding in hilly areas of Karnataka & Goa states, the drainage basin or watershed hydrological unit classification and their morphometric analysis with interpretation should be taken on priority basis.
4. The landslide susceptibility map of investigated 18 sq.km area is a pixel map having 10m x 10m value and comprises 174270 pixels, out of which 5790 pixels are landslide occupied under 15.73 cumulative map area percentage during year 2018. The variation in this pixel ratio would take place under given climatic, lithological, tectonic conditions and also by stabilization measures to be taken by concerned authorities. This variation in pixel ratio between map area and landslide percentage should be again analyzed and evaluated on same scale or even larger scale on the basis of relevant geo-factor themes along with drainage basin analysis after a decade for same area.
5. The areas which come under high-moderate landslide susceptibility zone (*see fig. 6.2 in which red colour denotes high landslide susceptibility zone and light green colour denotes moderate susceptibility zone*) in present investigated area should be given priority for making proper drainage arrangements and giving reinforcement measures wherein necessary such as cut-slopes, steep gradient slopes, stream or river bank eroded sections, river bridge abutments, toe of landslides etc.
6. The areas which come under high-moderate susceptibility zone should be monitored during rainfall periods and due care is needed when rainfall intensity goes above 2500mm not annually but in a particular event.
7. It is suggested to have chute or contour drainage facilities all along the slopes which are marked as vulnerable.
8. The drainage network on natural slopes having settlements or cultivation and along roads in the area should be properly maintained with cement lining to free the rainwater to drain quickly which will minimize the maximum infiltration into soil/overburden, joint, fracture and bedding planes.
9. The perforated drain holes on natural slopes having settlements or cultivation and on downward and upward slopes along roads should be installed at regular intervals to drain-out maximum infiltrated rain waters during rainfall periods.
10. The scouring and toe erosion of natural slopes at lower contours by natural waters (streams and rivers) should be controlled by constructing gabion walls on river banks.

11. The settlement and cultivation activities should be avoided in the vicinity of landslides occurred recently. An attempt has been made to identify these areas or places separately having high vulnerability or high risk in the vicinities of recently occurred landslides. These areas or places are shown in [fig-3.3](#). These areas or places should be given priority for slope stabilization after carrying out site specific slope stabilization studies for proper reinforcement treatments.
12. Since it is revealed that the watersheds in which present study area lies can perform well to drain and distribute the storage capacity (rain waters) at equal to or below 2500mm rainfall intensity in a particular event and the same watersheds will perform poorly to drain and distribute the storage capacity (rain waters) and responds by occurrences of landslides and channel erosion beyond 2500mm rainfall intensity limit in a particular event. This signature has been witnessed by June-September 2018 rainfall period. Therefore the rainfall intensity should be carefully monitored and analyzed in the area beyond 2500mm rainfall intensity limit during any particular event.
13. The movement along earlier developed surface cracks should be monitored regularly during rainfall and all these cracks especially those in the vicinity of settlements and roads should be sealed with some impervious material to control further movement along those cracks during rainfall.
14. The guidelines for slope modifications and land use should be formulated keeping the above mentioned conclusions and recommendations in consideration and those guidelines should be strictly followed by public and govt. agencies in the area.
15. The authorized geologists and civil engineers for geotechnical studies should be consulted before going for any type of construction by public and govt. agencies in the Kodagu district.
16. General social awareness programmes like seminars, work-shops and symposiums should be conducted to make people aware about the landslide causative factors, slope un-stability, area susceptibility, detection of early signs of a landslide and other safeguard measures.

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LOCALITY INDEX

Locality Name	Latitude (X)	Longitude (Y)
AVANDI HOLE	75°45' 45.483" E	12°29' 50.363" N
BADIGERI	75°44' 40.073" E	12°30' 17.367" N
BEREBELACHULA	75°43' 5.761" E	12°29' 45.191" N
BEREBELACHULA	75°43' 15.732" E	12°30' 40.630" N
MEGATALU	75°45' 52.814" E	12°29' 38.297" N
MUKKODLU	75°44' 22.113" E	12°30' 35.912" N
MUKKODLU	75°45' 24.788" E	12°30' 29.328" N
MUKKODLU	75°44' 33.083" E	12°29' 43.751" N
MUTNAR HOLE	75°43' 10.258" E	12°29' 23.966" N
NIDUVATTU	75° 43' 29.091" E	12°29' 24.797" N

ANNEXURE-I: Geo-parameters of landslides demarcated and studies after 2018 June-Sep rainfall event in Madikeri Taluk

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P15/2019/07
State	Karnataka
District	Kodagu
Toposheet	48 P/15
Name of the slide	1.5 km ahead of Hematallu
NH/SH/Locality	Avandi road
Latitude	12° 29' 31.927" N
Longitude	75°45' 58.537" E
Length	90 m
Width	50 m
Height	40 m
Area	
Depth	
Volume	
Run out distance	50 m
Type of Material	Soil
Type of movement	Flow
Rate of movement	Rapid
Activity	Active
Distribution	Retrogressive
Style	Single
Failure mechanism	Deep planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Weathered Granite Gneiss
Structure	
Land use/ Land cover	Paddy Geo-parameters with some Plantation (Coffee)
Hydrological condition	Dry
Triggering Factor	Rainfall
Death of persons	
People affected	
Livestock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture

Geo-scientific Causes	Here the underlying rock is weathered with fractures that lead to the movement of the overlying material.
Remedial measures	Toe support at proper contour lines.
Remarks, if any	-
Photos. Sketch of Plan & section of the slide	
Summary/Abstract	<i>Here slope, high percolation due to slight convexity of the slope which lead to the increase in mass and gravity pull, oversaturation of the overlying material caused the movement of the overburden along contact of underlying rock and overburden material.</i>
Date of Reporting	17th August 2018, late hours
Landslide category	<i>II</i>

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P15/2019/08
State	Karnataka
District	Kodagu
Toposheet	48 P/15
Name of the slide	Near Avandi
NH/SH/Locality	Avandi road
Latitude	12° 29' 51.573" N
Longitude	75° 45' 50.139" E
Length	80 m
Width	120 m
Height	60 m
Area	
Depth	
Volume	
Run out distance	40 m
Type of Material	Debris
Type of movement	Flow
Rate of movement	Moderate
Activity	Active
Distribution	Retrogressive
Style	Single
Failure mechanism	Shallow planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite Gneiss
Structure	
Land use/ Land cover	Mixed HHP and LHP
Hydrological condition	Flowing
Triggering Factor	Rainfall
Death of persons	
People affected	
Livestock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture
Geo-scientific Causes	Pore water pressure, reduction of strength on super saturation.

Remedial measures	Proper drainage maintenance
Remarks, if any	-
Photos. Sketch of Plan & section of the slide	
Summary/Abstract	
Date of Reporting	17th August 2018
Landslide category	III

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P15/2019/09
State	Karnataka
District	Kodagu
Toposheet	48 P/15
Name of the slide	Near Avandi
NH/SH/Locality	Avandi road
Latitude	12° 30' 0.671" N
Longitude	75° 45' 39.430" E
Length	70 m
Width	20 m
Height	30 m
Area	
Depth	
Volume	
Run out distance	25 m
Type of Material	Soil
Type of movement	Slide
Rate of movement	Rapid
Activity	Active
Distribution	Retrogressive
Style	Single
Failure mechanism	Deep planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite Gneiss
Structure	
Land use/ Land cover	Coffee plantation
Hydrological condition	Flowing
Triggering Factor	Rainfall
Death of persons	
People affected	
Livestock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture
Geo-scientific Causes	Pore-water pressure, reduction of strength on super saturation.

Remedial measures	Proper drainage maintenance
Remarks, if any	-
Photos. Sketch of Plan & section of the slide	
Summary/Abstract	<i>Here the rock weathering is deep and penetrative. Overburden zone is thick containing fine sediments with some weathered rock fragments.</i>
Date of Reporting	16th August 2018
Landslide category	III

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P15/2019/10
State	Karnataka
District	Kodagu
Toposheet	48 P/15
Name of the slide	1.2 km ahead of Avandi
NH/SH/Locality	Mukudlu-Avandi road
Latitude	12° 29' 59.765" N
Longitude	75° 45' 35.209" E
Length	90 m
Width	50 m
Height	30 m
Area	
Depth	
Volume	
Run out distance	20 m
Type of Material	Earth
Type of movement	Slide
Rate of movement	Rapid
Activity	Active
Distribution	Retrogressive
Style	Single
Failure mechanism	Deep planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite Gneiss
Structure	
Land use/ Land cover	Coffee plantation
Hydrological condition	Dry
Triggering Factor	Rainfall
Death of persons	
People affected	
Livestock loss	-
Communication	Road
Infrastructure	
Agriculture/forest/Barren	Agriculture
Geo-scientific Causes	Reduction of shear strength due to super saturation

Remedial measures	Proper toe support, Nailing, Drainage arrangements, support at defined contour levels.
Remarks, if any	-
Photos. Sketch of Plan & section of the slide	
Summary/Abstract	<i>Here the plane exposed in middle part of slide shows some indications of shearing in the form of sheared fabric (pyroblast) showing dextral movement. The role of this shearing in promoting slide cannot be ruled out as both slide and shear are trending in the same direction.</i>
Date of Reporting	16th August 2018
Landslide category	III

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P15/2019/11
State	Karnataka
District	Kodagu
Toposheet	48P15
Name of the slide	
NH/SH/Locality	
Latitude	12° 30' 07.29" N
Longitude	75° 45' 33.88" E
Length	40 m
Width	10 m
Height	30 m
Area	
Depth	
Volume	
Run out distance	
Type of Material	Earth
Type of movement	Flow
Rate of movement	Moderate
Activity	Active
Distribution	Enlarging
Style	Single
Failure mechanism	Shallow planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite Gneiss
Structure	Foliated, jointed, folded rocks with some shearing indications.
Land use/ Land cover	Coffee plantation
Hydrological condition	Dry
Triggering Factor	Rainfall
Death of persons	
People affected	
Livestock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture

Geo-scientific Causes	High slope, weathered material, oversaturation and loss of cohesion.
Remedial measures	Steeping of slope, toe support
Remarks, if any	-
Photos. Sketch of Plan & section of the slide	
Summary/Abstract	
Date of Reporting	16th August 2018
Landslide category	III



Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P11/2019/12
State	Karnataka
District	Kodagu
Toposheet	48 P/11
Name of the slide	Near Nidavattu
NH/SH/Locality	Nidavattu
Latitude	12° 29' 14.384" N
Longitude	75° 44' 4.168" E
Length	30 m
Width	50 m
Height	25 m
Area	
Depth	
Volume	
Run out distance	
Type of Material	Debris
Type of movement	Flow
Rate of movement	Rapid
Activity	Active
Distribution	Enlarging
Style	Single
Failure mechanism	Shallow planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite Gneiss
Structure	Foliated, jointed, folded rocks with some shearing indications.
Land use/ Land cover	Plantation
Hydrological condition	Flowing
Triggering Factor	Rainfall
Death of persons	
People affected	
Livestock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture

Geo-scientific Causes	High slope, weathering and erosion of loose material, oversaturation and loss of cohesion.
Remedial measures	Steeping of slope, toe support
Remarks, if any	-
Photos. Sketch of Plan & section of the slide	
Summary/Abstract	<i>Here the rock is crushed and shows some signs of deformation (grain stretch and reorientation). Quartz veins have intruded and there is mica development, water oozing out at the contact of overburden and underlying rock.</i>
Date of Reporting	16th August 2018
Landslide category	<i>II</i>

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P11/2019/13
State	Karnataka
District	Kodagu
Toposheet	48 P/11
Name of the slide	Near Nidavattu
NH/SH/Locality	Nidavattu village
Latitude	12° 29' 18.924" N
Longitude	75° 44' 35.881" E
Length	250 m
Width	50 m
Height	20 m
Area	
Depth	
Volume	
Run out distance	
Type of Material	Debris
Type of movement	Flow
Rate of movement	Rapid
Activity	Active
Distribution	Enlarging
Style	Single
Failure mechanism	Shallow planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite Gneiss
Structure	Foliation, Joints
Land use/ Land cover	Plantation (Coffee, Cardamom)
Hydrological condition	Dripping
Triggering Factor	Rainfall
Death of persons	
People affected	
Livestock loss	-
Communication	Road
Infrastructure	
Agriculture/forest/Barren	Agriculture

Geo-scientific Causes	High slope, weathering and erosion of loose material, oversaturation and loss of cohesion.
Remedial measures	Construction of concrete culvert near road, Nailing.
Remarks, if any	-
Photos. Sketch of Plan & section of the slide	
Summary/Abstract	<i>Here the slide seems to be the outcome of lubrication along the contact of overburden and underlying rock. A pinkish rock containing mafic layers along foliation planes is susceptible to weathering. The resultant weathered material has flown on hard rock contact.</i>
Date of Reporting	16th August 2018
Landslide category	II

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P11/2019/14
State	Karnataka
District	Kodagu
Toposheet	48 P/11
Name of the slide	Near Nidavattu
NH/SH/Locality	Nidavattu village
Latitude	12° 29' 13.518" N
Longitude	75° 44' 27.789" E
Length	40 m
Width	50 m
Height	20 m
Area	
Depth	
Volume	
Run out distance	
Type of Material	Earth
Type of movement	Slide
Rate of movement	Rapid
Activity	Active
Distribution	Enlarging
Style	Single
Failure mechanism	Shallow planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite Gneiss
Structure	Foliation, Joints
Land use/ Land cover	Plantation
Hydrological condition	Dry
Triggering Factor	Rainfall
Death of persons	
People affected	
Livestock loss	-
Communication	Un metalled Road
Infrastructure	
Agriculture/forest/Barren	Agriculture

Geo-scientific Causes	High slope, weathering and erosion of loose material, oversaturation and loss of cohesion.
Remedial measures	Concrete culvert of suitable size to accommodate large boulders during high downpour, Slope easing.
Remarks, if any	-
Photos. Sketch of Plan & section of the slide	
Summary/Abstract	<i>Here a stream is flowing at the base of the slide, so toe cutting cannot be over-ruled. The slide has occurred on a very steep slope.</i>
Date of Reporting	16th August 2018
Landslide category	II

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P11/2019/15
State	Karnataka
District	Kodagu
Toposheet	48 P/11
Name of the slide	Near Mandalpadi
NH/SH/Locality	Mandalpadi-Mukudlu road
Latitude	12° 29' 34.471" N
Longitude	75°44' 14.217" E
Length	120 m
Width	75 m
Height	55 m
Area	
Depth	
Volume	
Run out distance	
Type of Material	Earth
Type of movement	Flow
Rate of movement	Rapid
Activity	Active
Distribution	Enlarging
Style	Single
Failure mechanism	Shallow planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite Gneiss
Structure	Foliation, Joints
Land use/ Land cover	Plantation
Hydrological condition	Dry
Triggering Factor	Rainfall
Death of persons	
People affected	
Livestock loss	-
Communication	Road
Infrastructure	
Agriculture/forest/Barren	Agriculture

Geo-scientific Causes	High slope, weathering and erosion of loose material, oversaturation and loss of cohesion.
Remedial measures	Drainage maintenance, Slope easing
Remarks, if any	-
Photos. Sketch of Plan & section of the slide	
Summary/Abstract	<i>The two main factors responsible here are steep slope and thick overburden. The strength of the overburden material was reduced due to super saturation.</i>
Date of Reporting	17th August 2018
Landslide category	II

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P11/2019/16
State	Karnataka
District	Kodagu
Toposheet	48 P/11
Name of the slide	Nidavattu Slide
NH/SH/Locality	Near Nidavattu
Latitude	12° 29' 40.451" N
Longitude	75° 44' 9.848" E
Length	75 m
Width	80 m
Height	45 m
Area	
Depth	
Volume	
Run out distance	20
Type of Material	Debris
Type of movement	Slide
Rate of movement	Moderate
Activity	Active
Distribution	Retrogressive
Style	Single
Failure mechanism	Shallow planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite Gneiss
Structure	
Land use/ Land cover	Coffee Plantation
Hydrological condition	Dry
Triggering Factor	Rainfall
Death of persons	
People affected	
Livestock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture

Geo-scientific Causes	High slope, weathering and erosion of loose material, oversaturation and loss of cohesion.
Remedial measures	Drainage maintenance, Slope easing
Remarks, if any	-
Photos. Sketch of Plan & section of the slide	
Summary/Abstract	
Date of Reporting	16th August 2018
Landslide category	II

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P11/2019/17
State	Karnataka
District	Kodagu
Toposheet	48 P/11
Name of the slide	Nidavattu Slide
NH/SH/Locality	Near Nidavattu
Latitude	12° 29' 44.002" N
Longitude	75° 44' 12.775" E
Length	80 m
Width	30 m
Height	20 m
Area	
Depth	
Volume	
Run out distance	30
Type of Material	Debris
Type of movement	Slide
Rate of movement	Moderate
Activity	Active
Distribution	Retrogressive
Style	Single
Failure mechanism	Shallow planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite Gneiss
Structure	
Land use/ Land cover	Coffee Plantation
Hydrological condition	Flowing
Triggering Factor	Rainfall
Death of persons	
People affected	
Livestock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture

Geo-scientific Causes	High slope, weathering and erosion of loose material, oversaturation and loss of cohesion.
Remedial measures	Drainage maintenance, Slope easing
Remarks, if any	-
Photos. Sketch of Plan & section of the slide	
Summary/Abstract	<i>The movement here is confined to insitu overburden soil. The toe cutting during high down pour cannot be ruled out due to the presence of stream at the base of the slide</i>
Date of Reporting	16th August 2018
Landslide category	I

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P11/2019/18
State	Karnataka
District	Kodagu
Toposheet	48 P/11
Name of the slide	Nidavattu Slide
NH/SH/Locality	Near Nidavattu
Latitude	12° 29' 53.902" N
Longitude	75° 44' 1.194" E
Length	70 m
Width	20 m
Height	35 m
Area	
Depth	
Volume	
Run out distance	
Type of Material	Debris
Type of movement	Slide
Rate of movement	Moderate
Activity	Active
Distribution	Retrogressive
Style	Single
Failure mechanism	Shallow planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite Gneiss
Structure	
Land use/ Land cover	Mixed Plantation
Hydrological condition	Flowing
Triggering Factor	Rainfall
Death of persons	
People affected	
Livestock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture

Geo-scientific Causes	High slope, weathering and erosion of loose material, oversaturation and loss of cohesion.
Remedial measures	Drainage maintenance, Slope easing
Remarks, if any	-
Photos. Sketch of Plan & section of the slide	
Summary/Abstract	<i>The material on the slide plane is highly crushed indicating shearing. The stream flowing at the base has played a vital role by toe cutting.</i>
Date of Reporting	16th August 2018
Landslide category	II

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P11/2019/19
State	Karnataka
District	Kodagu
Toposheet	48 P/11
Name of the slide	Nidavattu Slide
NH/SH/Locality	Near Nidavattu
Latitude	12° 29' 51.863" N
Longitude	75° 43' 57.496" E
Length	130 m
Width	50 m
Height	40 m
Area	
Depth	
Volume	
Run out distance	
Type of Material	Debris
Type of movement	Slide
Rate of movement	Rapid
Activity	Active
Distribution	Enlarging
Style	Single
Failure mechanism	Shallow planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite Gneiss
Structure	
Land use/ Land cover	Mixed Plantation
Hydrological condition	Flowing
Triggering Factor	Rainfall
Death of persons	
People affected	
Livestock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture
Geo-scientific Causes	High slope, over saturation and loss of cohesion.

Remedial measures	Drainage maintenance, Slope easing
Remarks, if any	-
Photos. Sketch of Plan & section of the slide	
Summary/Abstract	<i>Here some indications of shearing were observed in the form of elongated grains.</i>
Date of Reporting	16th August 2018
Landslide category	<i>II</i>

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P11/2019/20
State	Karnataka
District	Kodagu
Toposheet	48 P/11
Name of the slide	
NH/SH/Locality	
Latitude	12° 29' 52.185" N
Longitude	75° 43' 53.114" E
Length	320 m
Width	110 m
Height	50 m
Area	
Depth	
Volume	
Run out distance	
Type of Material	Rock
Type of movement	Slide
Rate of movement	Rapid
Activity	Active
Distribution	Widening
Style	Single
Failure mechanism	Deep planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite Gneiss with mafic intrusions
Structure	Brittle shear, Faulting, Jointing
Land use/ Land cover	Mixed Plantation (Coffee dominant)
Hydrological condition	Damp
Triggering Factor	Rainfall
Death of persons	
People affected	
Livestock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture
Geo-scientific Causes	High slope, over saturation and loss of cohesion.

Remedial measures	Drainage maintenance, Nailing
Remarks, if any	-
Photos. Sketch of Plan & section of the slide	
Summary/Abstract	<i>Here the material is pulverized under brittle shear. Pillow like structures (probably de-watering structures) were observed along with pseudotachylite. Some pseudotachylites were observed along fault planes</i>
Date of Reporting	16th August 2018
Landslide category	II

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P11/2019/21
State	Karnataka
District	Kodagu
Toposheet	48 P/11
Name of the slide	Near Nidavattu
NH/SH/Locality	Nidavattu road
Latitude	12° 29' 38.893" N
Longitude	75° 44' 13.649" E
Length	60 m
Width	40 m
Height	18 m
Area	
Depth	
Volume	
Run out distance	
Type of Material	Soil
Type of movement	Flow
Rate of movement	Rapid
Activity	Active
Distribution	Widening
Style	Single
Failure mechanism	Shallow planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite Gneiss with Quartz veins and mafic layers along foliation planes.
Structure	Brittle shear, Jointing
Land use/ Land cover	Coffee Plantation
Hydrological condition	Dry
Triggering Factor	Rainfall
Death of persons	
People affected	
Livestock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture

Geo-scientific Causes	Weathering, Presence of loose pulverized material, Oversaturation and loss of cohesion.
Remedial measures	Drainage maintenance, Nailing
Remarks, if any	-
Photos. Sketch of Plan & section of the slide	
Summary/Abstract	<i>Here the underlying rock, Granite gneiss is highly pulverized. The super saturation of this loose material including the weathered material has failed during the slide.</i>
Date of Reporting	16th August 2018
Landslide category	<i>II</i>

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P10/2019/22
State	Karnataka
District	Kodagu
Toposheet	48 P/10
Name of the slide	Near Nidavattu
NH/SH/Locality	Nidavattu road
Latitude	12° 30' 19.505" N
Longitude	75° 44' 17.738" E
Length	50 m
Width	350 m
Height	7 m
Area	
Depth	
Volume	
Run out distance	
Type of Material	Debris
Type of movement	Slide
Rate of movement	Rapid
Activity	Active
Distribution	Retrogressive
Style	Single
Failure mechanism	Shallow planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite Gneiss with Quartz veins
Structure	Jointing
Land use/ Land cover	Mixed Plantation
Hydrological condition	Dry
Triggering Factor	Rainfall
Death of persons	
People affected	
Livestock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture

Geo-scientific Causes	Weathering, Presence of loose pulverized material, Oversaturation and loss of cohesion.
Remedial measures	Drainage maintenance, Nailing
Remarks, if any	-
Photos. Sketch of Plan & section of the slide	
Summary/Abstract	<i>Here the slide seems to be the combined outcome of rock and overburden. Although the overburden is less than 0.5m but the steep slope and slight depression has favoured the percolation of more water leading to the pore water pressure.</i>
Date of Reporting	16th August 2018
Landslide category	II

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P11/2019/23
State	Karnataka
District	Kodagu
Toposheet	48 P/11
Name of the slide	Near Nidavattu
NH/SH/Locality	Nidavattu road
Latitude	12° 31' 07.95" N
Longitude	75° 43' 25.83" E
Length	40 m
Width	100 m
Height	45 m
Area	
Depth	
Volume	
Run out distance	
Type of Material	Rock
Type of movement	Slide
Rate of movement	Rapid
Activity	Active
Distribution	Retrogressive
Style	Single
Failure mechanism	Shallow planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite Gneiss
Structure	
Land use/ Land cover	Forest cover
Hydrological condition	Dry
Triggering Factor	Rainfall
Death of persons	
People affected	
Livestock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Forest
Geo-scientific Causes	
Remedial measures	Rock bolting
Remarks, if any	-

Photos. Sketch of Plan & section of the slide	
Summary/Abstract	<i>Here the slide is rock slide. The boulders lying on the road (10x07x08m) show some planes which indicate the detachment of these boulders along some planes..</i>
Date of Reporting	16th August 2018
Landslide category	II

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P11/2019/24
State	Karnataka
District	Kodagu
Toposheet	48 P/11
Name of the slide	Near Nidavattu
NH/SH/Locality	Nidavattu road
Latitude	12° 29' 13.902" N
Longitude	75° 43' 57.084" E
Length	50 m
Width	25 m
Height	15 m
Area	
Depth	
Volume	
Run out distance	
Type of Material	Rock
Type of movement	Slide
Rate of movement	Rapid
Activity	Active
Distribution	Retrogressive
Style	Single
Failure mechanism	Shallow planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite Gneiss with Quartz veins
Structure	
Land use/ Land cover	Mixed plantation
Hydrological condition	Flowing
Triggering Factor	Rainfall
Death of persons	
People affected	
Livestock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture
Geo-scientific Causes	
Remedial measures	Drainage maintenance

Remarks, if any	-
Photos. Sketch of Plan & section of the slide	
Summary/Abstract	<i>Here toe cutting very clear at the base of the slide.</i>
Date of Reporting	16th August 2018
Landslide category	<i>II</i>

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P11/2019/25
State	Karnataka
District	Kodagu
Toposheet	48 P/11
Name of the slide	Near Nidavattu
NH/SH/Locality	Nidavattu road
Latitude	12° 29' 13.019" N
Longitude	75° 43' 54.742" E
Length	50 m
Width	50 m
Height	18 m
Area	
Depth	
Volume	
Run out distance	7 m
Type of Material	Debris
Type of movement	Slide
Rate of movement	Rapid
Activity	Active
Distribution	Retrogressive
Style	Single
Failure mechanism	Shallow planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite Gneiss
Structure	
Land use/ Land cover	Mixed plantation
Hydrological condition	Flowing
Triggering Factor	Rainfall
Death of persons	
People affected	
Livestock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture
Geo-scientific Causes	Toe cutting
Remedial measures	Drainage diversion, Nailing
Remarks, if any	-

Photos. Sketch of Plan & section of the slide	
Summary/Abstract	
Date of Reporting	16th August 2018
Landslide category	II

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P11/2019/26
State	Karnataka
District	Kodagu
Toposheet	48 P/11
Name of the slide	Near Nidavattu
NH/SH/Locality	Nidavattu road
Latitude	12° 29' 12.578" N
Longitude	75° 43' 47.789" E
Length	70 m
Width	50 m
Height	30 m
Area	
Depth	
Volume	
Run out distance	
Type of Material	Earth
Type of movement	Flow
Rate of movement	Rapid
Activity	Active
Distribution	Retrogressive
Style	Single
Failure mechanism	Shallow planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite Gneiss
Structure	
Land use/ Land cover	Mixed plantation
Hydrological condition	Flowing
Triggering Factor	Rainfall
Death of persons	
People affected	
Livestock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture
Geo-scientific Causes	Toe cutting
Remedial measures	Drainage maintenance, Slope easing, Nailing

Remarks, if any	-
Photos. Sketch of Plan & section of the slide	
Summary/Abstract	
Date of Reporting	16th August 2018
Landslide category	II

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P11/2019/27
State	Karnataka
District	Kodagu
Toposheet	48 P/11
Name of the slide	
NH/SH/Locality	
Latitude	12° 29' 14.257" N
Longitude	75° 43' 43.025" E
Length	120 m
Width	70 m
Height	
Area	
Depth	
Volume	
Run out distance	
Type of Material	Earth
Type of movement	Flow
Rate of movement	Rapid
Activity	Active
Distribution	Retrogressive
Style	Single
Failure mechanism	Shallow planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite Gneiss
Structure	
Land use/ Land cover	Mixed plantation
Hydrological condition	Dry
Triggering Factor	Rainfall
Death of persons	
People affected	
Livestock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture
Geo-scientific Causes	Toe cutting
Remedial measures	Drainage maintenance, Slope easing, Nailing

Remarks, if any	-
Photos. Sketch of Plan & section of the slide	
Summary/Abstract	<i>Here the crown of the slide marks a home stay under construction. The movement has mostly occurred here along the first order stream.</i>
Date of Reporting	16th August 2018
Landslide category	II

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P11/2019/28
State	Karnataka
District	Kodagu
Toposheet	48 P/11
Name of the slide	
NH/SH/Locality	
Latitude	12° 29' 25.021" N
Longitude	75° 43' 41.197" E
Length	50 m
Width	30 m
Height	45 m
Area	
Depth	
Volume	
Run out distance	
Type of Material	Debris
Type of movement	Flow
Rate of movement	Rapid
Activity	Active
Distribution	Retrogressive
Style	Single
Failure mechanism	Shallow planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite Gneiss and Amphibolite
Structure	
Land use/ Land cover	Mixed plantation
Hydrological condition	Dry
Triggering Factor	Rainfall
Death of persons	
People affected	
Livestock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture
Geo-scientific Causes	Toe cutting

Remedial measures	Drainage maintenance, Drainage diversion
Remarks, if any	-
Photos. Sketch of Plan & section of the slide	
Summary/Abstract	
Date of Reporting	16th August 2018
Landslide category	II

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P15/2019/29
State	Karnataka
District	Kodagu
Toposheet	48 P/15
Name of the slide	
NH/SH/Locality	Chanapanda, Megatallu
Latitude	12° 29' 18.092" N
Longitude	75° 45' 20.431" E
Length	50 m
Width	50 m
Height	20 m
Area	
Depth	
Volume	
Run out distance	10
Type of Material	Earth
Type of movement	Slide
Rate of movement	Rapid
Activity	Active
Distribution	Widening
Style	Single
Failure mechanism	Shallow planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite Gneiss
Structure	
Land use/ Land cover	Coffee plantation
Hydrological condition	Wet
Triggering Factor	Rainfall
Death of persons	
People affected	
Livestock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture
Geo-scientific Causes	Reduction of strength on super-saturation, pore water pressure building

Remedial measures	Drainage maintenance, Drainage diversion
Remarks, if any	-
Photos. Sketch of Plan & section of the slide	
Summary/Abstract	
Date of Reporting	16th August 2018
Landslide category	II

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P15/2019/30
State	Karnataka
District	Kodagu
Toposheet	48 P/15
Name of the slide	
NH/SH/Locality	
Latitude	12° 29' 27.358" N
Longitude	75° 45' 5.691" E
Length	
Width	
Height	
Area	
Depth	
Volume	
Run out distance	
Type of Material	Debris
Type of movement	Flow
Rate of movement	Rapid
Activity	Active
Distribution	Widening
Style	Multiple
Failure mechanism	Deep rotational failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite Gneiss
Structure	
Land use/ Land cover	Forest cover
Hydrological condition	Wet
Triggering Factor	Rainfall
Death of persons	
People affected	
Livestock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture
Geo-scientific Causes	Reduction of strength on super-saturation, pore water pressure building

Remedial measures	Drainage maintenance, Drainage diversion
Remarks, if any	-
Photos. Sketch of Plan & section of the slide	
Summary/Abstract	<i>The material involved in slide contains rock fragments show some shear signatures. The material seems to have been sheared, pulverized before movement along the slope.</i>
Date of Reporting	16th August 2018
Landslide category	II

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P15/2019/31
State	Karnataka
District	Kodagu
Toposheet	48 P/15
Name of the slide	
NH/SH/Locality	
Latitude	12° 29' 24.602" N
Longitude	75° 45' 15.588" E
Length	
Width	
Height	
Area	
Depth	
Volume	
Run out distance	
Type of Material	Earth
Type of movement	Flow
Rate of movement	Rapid
Activity	Active
Distribution	Widening
Style	Multiple
Failure mechanism	Deep planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite Gneiss
Structure	
Land use/ Land cover	Coffee plantation
Hydrological condition	Dry
Triggering Factor	Rainfall
Death of persons	
People affected	
Livestock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture
Geo-scientific Causes	Reduction of strength on super-saturation, pore water pressure building

Remedial measures	Drainage maintenance, Drainage diversion
Remarks, if any	-
Photos. Sketch of Plan & section of the slide	
Summary/Abstract	<i>The material has flown along rock and overburden plane. The material involved is sheared and pulverized</i>
Date of Reporting	16th August 2018
Landslide category	II

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P15/2019/32
State	Karnataka
District	Kodagu
Toposheet	48 P/15
Name of the slide	
NH/SH/Locality	
Latitude	12° 29' 28.337" N
Longitude	75° 45' 12.336" E
Length	
Width	
Height	
Area	
Depth	
Volume	
Run out distance	
Type of Material	Earth
Type of movement	Flow
Rate of movement	Rapid
Activity	Active
Distribution	Widening
Style	Multiple
Failure mechanism	Deep planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite Gneiss
Structure	
Land use/ Land cover	Coffee plantation
Hydrological condition	Dry
Triggering Factor	Rainfall
Death of persons	
People affected	
Livestock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture
Geo-scientific Causes	Reduction of strength on super-saturation, pore water pressure building

Remedial measures	Drainage maintenance, Drainage diversion
Remarks, if any	-
Photos. Sketch of Plan & section of the slide	
Summary/Abstract	<i>The material has flown along rock and overburden plane. The material involved is sheared and pulverized</i>
Date of Reporting	16th August 2018
Landslide category	<i>II</i>

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P15/2019/33
State	Karnataka
District	Kodagu
Toposheet	48 P/15
Name of the slide	
NH/SH/Locality	South of Megatallu
Latitude	12° 29' 11.830" N
Longitude	75°45' 38.875" E
Length	60 m
Width	30 m
Height	10 m
Area	
Depth	
Volume	
Run out distance	10 m
Type of Material	Earth
Type of movement	Slide
Rate of movement	Rapid
Activity	Active
Distribution	Widening
Style	Single
Failure mechanism	Deep planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite Gneiss
Structure	
Land use/ Land cover	Coffee plantation
Hydrological condition	Dry
Triggering Factor	Rainfall
Death of persons	
People affected	
Livestock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture

Geo-scientific Causes	Reduction of strength on super-saturation, pore water pressure building
Remedial measures	Drainage maintenance, Drainage diversion
Remarks, if any	-
Photos. Sketch of Plan & section of the slide	
Summary/Abstract	<i>The material has been sheared and pulverized. The quartz grains in rocks are stretched and some shear fabric has been developed. The sheared and pulverized material has flown along the rock and overburden contact.</i>
Date of Reporting	16th August 2018
Landslide category	II

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P15/2019/34
State	Karnataka
District	Kodagu
Toposheet	48 P/15
Name of the slide	
NH/SH/Locality	South of Megatallu
Latitude	12° 29' 27.358" N
Longitude	75° 45' 5.691" E
Length	100 m
Width	50 m
Height	15 m
Area	
Depth	
Volume	
Run out distance	20 m
Type of Material	Earth
Type of movement	Slide
Rate of movement	Rapid
Activity	Active
Distribution	Widening
Style	Multiple
Failure mechanism	Deep planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite Gneiss
Structure	
Land use/ Land cover	Coffee plantation
Hydrological condition	Dry
Triggering Factor	Rainfall
Death of persons	
People affected	
Livestock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture
Geo-scientific Causes	Reduction of strength on super-saturation, pore water pressure building

Remedial measures	Drainage maintenance, Drainage diversion
Remarks, if any	-
Photos. Sketch of Plan & section of the slide	
Summary/Abstract	<i>The material has been sheared and pulverized. The fragments show stretched Quartz and feldspar grains. Some rock boulders had cut down along joint planes. Weathered overburden is of moderate thickness and contains pulverized rock fragments.</i>
Date of Reporting	16th August 2018
Landslide category	II

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P15/2019/35
State	Karnataka
District	Kodagu
Toposheet	48 P/15
Name of the slide	
NH/SH/Locality	South of Megatallu
Latitude	12° 29' 17.530" N
Longitude	75° 45' 33.411" E
Length	100 m
Width	60 m
Height	20 m
Area	
Depth	
Volume	
Run out distance	10 m
Type of Material	Earth
Type of movement	Slide
Rate of movement	Rapid
Activity	Active
Distribution	Widening
Style	Multiple
Failure mechanism	Deep planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite Gneiss
Structure	Jointed, Fractured and Pulverized
Land use/ Land cover	Coffee plantation
Hydrological condition	Dry
Triggering Factor	Rainfall
Death of persons	
People affected	
Livestock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture
Geo-scientific Causes	Reduction of strength on super-saturation, pore water pressure building

Remedial measures	Drainage maintenance, Drainage diversion
Remarks, if any	-
Photos. Sketch of Plan & section of the slide	
Summary/Abstract	<i>The material has been sheared and pulverized. The fragments show stretched Quartz and feldspar grains. Some rock boulders had cut down along joint planes. Weathered overburden is of moderate thickness and contains pulverized rock fragments.</i>
Date of Reporting	16th August 2018
Landslide category	II

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P15/2019/36
State	Karnataka
District	Kodagu
Toposheet	48 P/15
Name of the slide	
NH/SH/Locality	
Latitude	12° 29' 16.315" N
Longitude	75° 45' 42.824" E
Length	
Width	
Height	
Area	
Depth	
Volume	
Run out distance	
Type of Material	Earth
Type of movement	Lateral spread
Rate of movement	Rapid
Activity	suspended
Distribution	Widening
Style	Complex
Failure mechanism	Deep planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite Gneiss
Structure	Jointed, Fractured and Pulverized
Land use/ Land cover	Coffee plantation
Hydrological condition	Dry
Triggering Factor	Rainfall
Death of persons	
People affected	
Livestock loss	-
Communication	
Infrastructure	2 to 3 houses damaged.
Agriculture/forest/Barren	Agriculture

Geo-scientific Causes	Oversaturation of overburden, liquefaction due to ground motion. Reduction in strength of overburden due to oversaturation and ground motion.
Remedial measures	Drainage maintenance, Drainage diversion
Remarks, if any	-
Photos. Sketch of Plan & section of the slide	
Summary/Abstract	
Date of Reporting	16th August 2018
Landslide category	<i>II</i>

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P11/2019/37
State	Karnataka
District	Kodagu
Toposheet	48 P/11
Name of the slide	
NH/SH/Locality	
Latitude	12° 29' 39.622" N
Longitude	75° 45' 0.350" E
Length	250 m
Width	150 m
Height	70 m
Area	
Depth	
Volume	
Run out distance	100 m
Type of Material	Earth
Type of movement	Flow
Rate of movement	Very Rapid
Activity	Active
Distribution	Enlarging
Style	Multiple
Failure mechanism	Deep planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite Gneiss
Structure	Jointed, Fractured and foliated
Land use/ Land cover	Coffee plantation
Hydrological condition	Dry
Triggering Factor	Rainfall
Death of persons	
People affected	
Livestock loss	-
Communication	
Infrastructure	2 to 3 houses damaged.
Agriculture/forest/Barren	Agriculture

Geo-scientific Causes	Oversaturation of overburden, liquefaction due to ground motion. Reduction in strength of overburden due to oversaturation and ground motion.
Remedial measures	Drainage maintenance, Drainage diversion
Remarks, if any	Sheared, pulverized non-cohesive rock material under high strain conditions, Oversaturation of overburden material.
Photos. Sketch of Plan & section of the slide	Image corrupted
Summary/Abstract	
Date of Reporting	16th August 2018
Landslide category	II

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P10/2019/38
State	Karnataka
District	Kodagu
Toposheet	48 P/10
Name of the slide	
NH/SH/Locality	
Latitude	12° 30' 1.889" N
Longitude	75° 44' 40.393" E
Length	20 m
Width	30 m
Height	10 m
Area	
Depth	
Volume	
Run out distance	05 m
Type of Material	Earth
Type of movement	Slide
Rate of movement	Rapid
Activity	Active
Distribution	Widening
Style	Single
Failure mechanism	Deep planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite Gneiss
Structure	Jointed, Fractured and foliated
Land use/ Land cover	Forest cover
Hydrological condition	Dry
Triggering Factor	Rainfall
Death of persons	
People affected	
Livestock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture

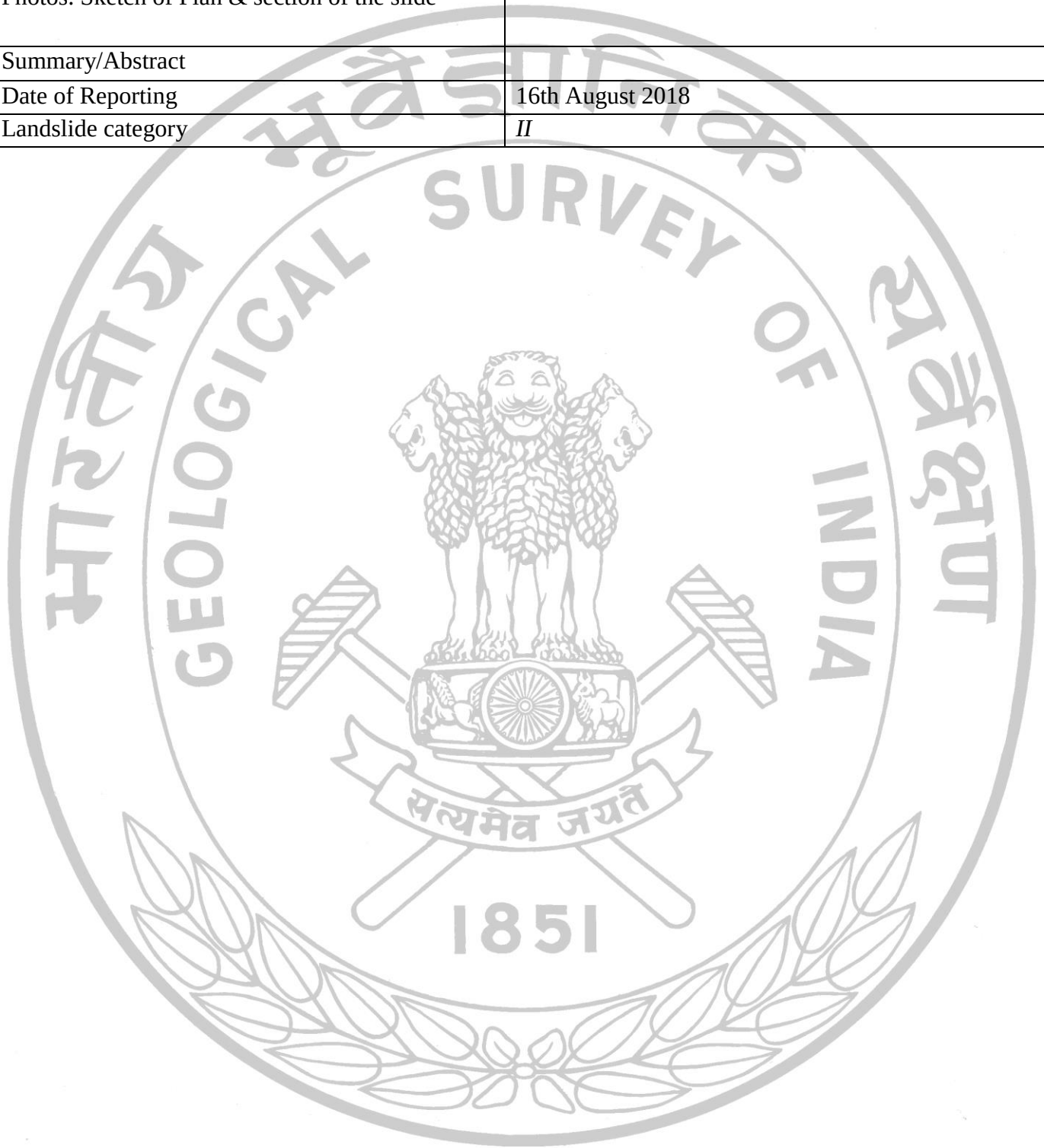
Geo-scientific Causes	Oversaturation of overburden, liquefaction due to ground motion. Reduction in strength of overburden due to oversaturation and ground motion.
Remedial measures	Drainage maintenance, Drainage diversion
Remarks, if any	Sheared, pulverized non-cohesive rock material under high strain conditions, Oversaturation of overburden material.
Photos. Sketch of Plan & section of the slide	Image corrupted
Summary/Abstract	
Date of Reporting	16th August 2018
Landslide category	II

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P10/2019/39
State	Karnataka
District	Kodagu
Toposheet	48 P/10
Name of the slide	
NH/SH/Locality	
Latitude	12° 30' 6.702" N
Longitude	75° 44' 46.933" E
Length	50 m
Width	100 m
Height	10 m
Area	
Depth	
Volume	
Run out distance	05 m
Type of Material	Earth
Type of movement	Slide
Rate of movement	Rapid
Activity	Active
Distribution	Widening
Style	Multiple
Failure mechanism	Deep planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite Gneiss with mafic layers
Structure	Jointed, Fractured and foliated
Land use/ Land cover	Forest cover
Hydrological condition	Dry
Triggering Factor	Rainfall
Death of persons	
People affected	
Livestock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture

Geo-scientific Causes	Oversaturation of overburden, liquefaction due to ground motion. Reduction in strength of overburden due to oversaturation and ground motion.
Remedial measures	Drainage maintenance, Drainage diversion
Remarks, if any	The rock shows grain stretching and development of micaceous minerals. Thick overburden, oversaturation of overburden, movement along overburden and rock contact may be due to pore-water pressure.
Photos. Sketch of Plan & section of the slide	Image corrupted
Summary/Abstract	
Date of Reporting	16th August 2018
Landslide category	II

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P10/2019/40
State	Karnataka
District	Kodagu
Toposheet	48 P/10
Name of the slide	
NH/SH/Locality	
Latitude	12° 30' 5.101" N
Longitude	75° 44' 52.670" E
Length	30 m
Width	40 m
Height	20 m
Area	
Depth	
Volume	
Run out distance	10 m
Type of Material	Earth
Type of movement	Slide
Rate of movement	Rapid
Activity	Active
Distribution	Widening
Style	Single
Failure mechanism	Shallow planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite Gneiss
Structure	
Land use/ Land cover	Forest cover
Hydrological condition	Dry
Triggering Factor	Rainfall
Death of persons	
People affected	
Livestock loss	-
Communication	Road
Infrastructure	
Agriculture/forest/Barren	Agriculture
Geo-scientific Causes	High slope, Thick overburden, Oversaturation of overburden material.

Remedial measures	Drainage maintenance, Drainage diversion
Remarks, if any	
Photos. Sketch of Plan & section of the slide	
Summary/Abstract	
Date of Reporting	16th August 2018
Landslide category	II



Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P15/2019/41
State	Karnataka
District	Kodagu
Toposheet	48 P/15
Name of the slide	
NH/SH/Locality	2 km North of Megatallu
Latitude	12° 29' 40.675" N
Longitude	75° 45' 40.540" E
Length	50 m
Width	40 m
Height	20 m
Area	
Depth	
Volume	
Run out distance	
Type of Material	Debris
Type of movement	Slide
Rate of movement	Rapid
Activity	Active
Distribution	Retrogressive
Style	Single
Failure mechanism	Shallow planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite Gneiss
Structure	
Land use/ Land cover	Paddy at the base of the slide with spices cultivation on and above slide.
Hydrological condition	Dry
Triggering Factor	Rainfall
Death of persons	
People affected	
Livestock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture

Geo-scientific Causes	Reduction in strength of overburden due to oversaturation.
Remedial measures	Drainage maintenance, Drainage diversion
Remarks, if any	
Photos. Sketch of Plan & section of the slide	
Summary/Abstract	
Date of Reporting	16th August 2018
Landslide category	II

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P15/2019/42
State	Karnataka
District	Kodagu
Toposheet	48 P/15
Name of the slide	
NH/SH/Locality	NW of Megatallu
Latitude	12° 29' 38.521" N
Longitude	75°45' 28.529" E
Length	200 m
Width	60 m
Height	30 m
Area	
Depth	
Volume	
Run out distance	
Type of Material	Debris
Type of movement	Flow
Rate of movement	Rapid
Activity	Active
Distribution	Retrogressive
Style	Single
Failure mechanism	Shallow planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite Gneiss and Amphibolite
Structure	
Land use/ Land cover	Forest cover
Hydrological condition	Dry
Triggering Factor	Rainfall
Death of persons	
People affected	
Livestock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Forest
Geo-scientific Causes	Reduction in strength of overburden due to oversaturation.

Remedial measures	Drainage maintenance, Drainage diversion
Remarks, if any	
Photos. Sketch of Plan & section of the slide	
Summary/Abstract	
Date of Reporting	16th August 2018
Landslide category	II

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P15/2019/43
State	Karnataka
District	Kodagu
Toposheet	48 P/15
Name of the slide	
NH/SH/Locality	Mukudlu village
Latitude	12° 29' 43.390" N
Longitude	75° 45' 24.903" E
Length	80 m
Width	40 m
Height	
Area	
Depth	
Volume	
Run out distance	
Type of Material	Earth
Type of movement	Flow
Rate of movement	Rapid
Activity	Active
Distribution	Retrogressive
Style	Single
Failure mechanism	Shallow planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite Gneiss and Amphibolite
Structure	
Land use/ Land cover	Coffee plantation
Hydrological condition	Dry
Triggering Factor	Rainfall
Death of persons	
People affected	
Livestock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture
Geo-scientific Causes	Oversaturation of overburden, Increase in mass gravity pull, Movement along rock and overburden contact and high slope are main factors.

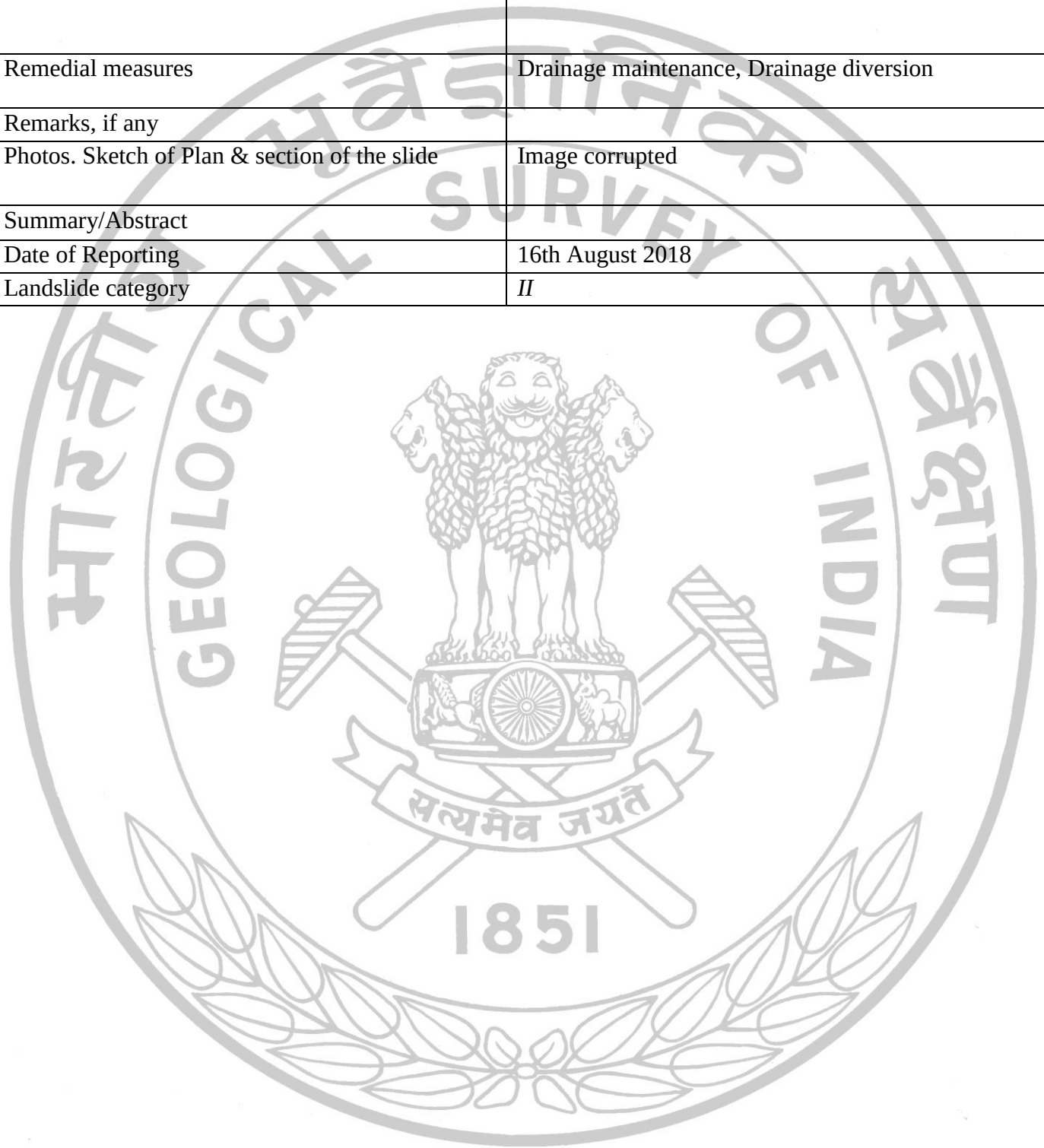
Remedial measures	Drainage maintenance, Drainage diversion
Remarks, if any	
Photos. Sketch of Plan & section of the slide	
Summary/Abstract	
Date of Reporting	16th August 2018
Landslide category	II

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P14/2019/44
State	Karnataka
District	Kodagu
Toposheet	48 P/14
Name of the slide	
NH/SH/Locality	Mukudlu village
Latitude	12° 30' 9.677" N
Longitude	75° 45' 30.224" E
Length	120 m
Width	80 m
Height	
Area	
Depth	
Volume	
Run out distance	
Type of Material	Earth
Type of movement	Flow
Rate of movement	Rapid
Activity	Active
Distribution	Enlarging
Style	Multiple
Failure mechanism	Shallow planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite Gneiss and Amphibolite
Structure	
Land use/ Land cover	Coffee plantation
Hydrological condition	Dry
Triggering Factor	Rainfall
Death of persons	
People affected	
Livestock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture

Geo-scientific Causes	Oversaturation of overburden, Increase in mass gravity pull, Movement along rock and overburden contact and high slope are main factors.
Remedial measures	Drainage maintenance, Drainage diversion
Remarks, if any	
Photos. Sketch of Plan & section of the slide	
Summary/Abstract	
Date of Reporting	16th August 2018
Landslide category	II

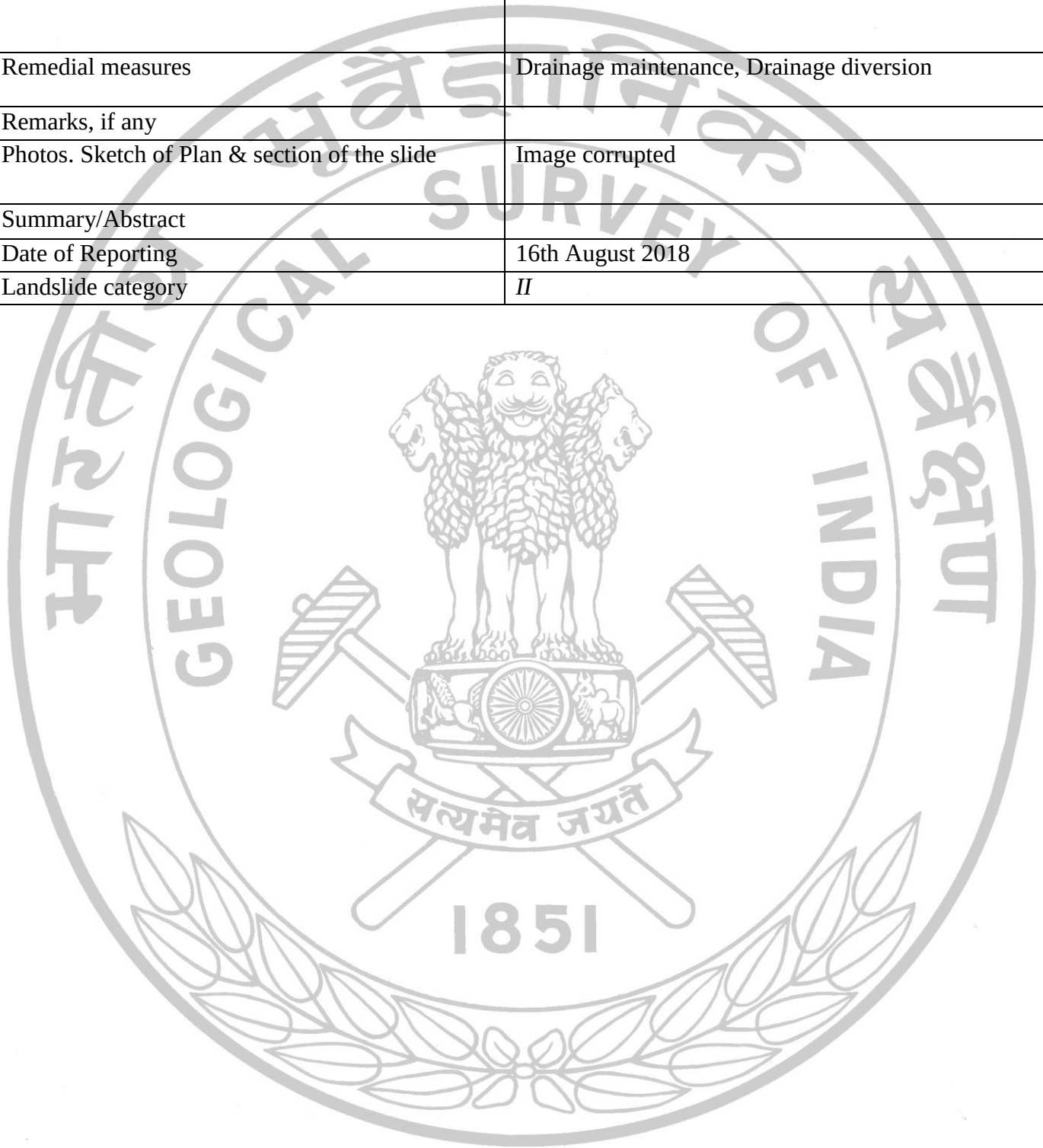
Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P14/2019/45
State	Karnataka
District	Kodagu
Toposheet	48 P/14
Name of the slide	
NH/SH/Locality	Mukudlu village
Latitude	12° 30' 11.230" N
Longitude	75° 45' 28.637" E
Length	70 m
Width	50 m
Height	20 m
Area	
Depth	
Volume	
Run out distance	
Type of Material	Earth
Type of movement	Flow
Rate of movement	Rapid
Activity	Active
Distribution	Widening
Style	Single
Failure mechanism	Shallow planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite Gneiss
Structure	
Land use/ Land cover	Coffee plantation
Hydrological condition	Dry
Triggering Factor	Rainfall
Death of persons	
People affected	
Livestock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture

Geo-scientific Causes	Sheared and pulverized material, non-cohesive material, Oversaturation leading to the movement along contact between overburden and rock contact.
Remedial measures	Drainage maintenance, Drainage diversion
Remarks, if any	
Photos. Sketch of Plan & section of the slide	Image corrupted
Summary/Abstract	
Date of Reporting	16th August 2018
Landslide category	II



Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P14/2019/46
State	Karnataka
District	Kodagu
Toposheet	48 P/14
Name of the slide	
NH/SH/Locality	Mukudlu village
Latitude	12° 30' 21.670" N
Longitude	75° 45' 29.905" E
Length	180 m
Width	80 m
Height	
Area	
Depth	
Volume	
Run out distance	300 m
Type of Material	Debris
Type of movement	Flow
Rate of movement	Rapid
Activity	Active
Distribution	Enlarging
Style	Single
Failure mechanism	Shallow planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite Gneiss
Structure	
Land use/ Land cover	Coffee plantation
Hydrological condition	Dry
Triggering Factor	Rainfall
Death of persons	
People affected	10
Livestock loss	-
Communication	
Infrastructure	one house partially damaged
Agriculture/forest/Barren	Agriculture

Geo-scientific Causes	Sheared and pulverized material, incohesive material, Oversaturation leading to the movement along contact between overburden and rock contact.
Remedial measures	Drainage maintenance, Drainage diversion
Remarks, if any	
Photos. Sketch of Plan & section of the slide	Image corrupted
Summary/Abstract	
Date of Reporting	16th August 2018
Landslide category	II



Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P14/2019/47
State	Karnataka
District	Kodagu
Toposheet	48 P/14
Name of the slide	
NH/SH/Locality	Mukudlu village
Latitude	12° 30' 44.956" N
Longitude	75°45' 12.056" E
Length	170 m
Width	60 m
Height	
Area	
Depth	
Volume	
Run out distance	70 m
Type of Material	Debris
Type of movement	Flow
Rate of movement	Rapid
Activity	Active
Distribution	Retrogressive
Style	Single
Failure mechanism	Shallow planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite Gneiss
Structure	
Land use/ Land cover	Coffee plantation
Hydrological condition	Dry
Triggering Factor	Rainfall
Death of persons	
People affected	
Livestock loss	-
Communication	
Infrastructure	one house fully and one partially damaged
Agriculture/forest/Barren	Agriculture

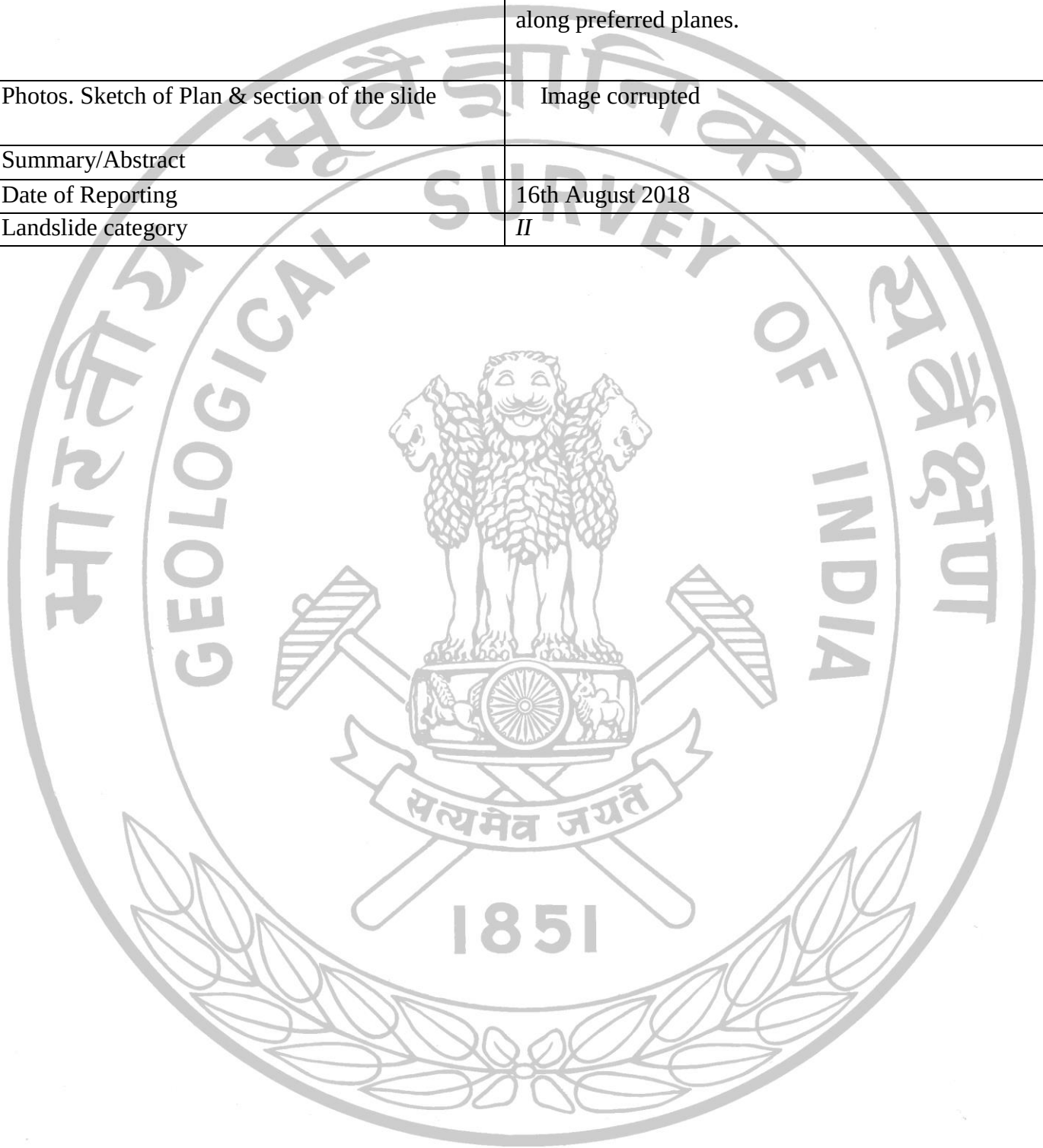
Geo-scientific Causes	Sheared and pulverized material, incohesive material, Oversaturation leading to the movement along contact between overburden and rock contact.
Remedial measures	Drainage maintenance, Drainage diversion
Remarks, if any	Here the rock exposed on the slide surface highly weathered. The slide seems to be the outcome of disintegration of incompetent rock with some evidences of shear under high shear conditions. Here the anthropogenic role is also visible as the road leading to the house and slide has destabilized the slope.
Photos. Sketch of Plan & section of the slide	
Summary/Abstract	
Date of Reporting	16th August 2018
Landslide category	<i>II</i>

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P14/2019/48
State	Karnataka
District	Kodagu
Toposheet	48P14
Name of the slide	Avandi-Mukudlu slide
NH/SH/Locality	Avandi-Mukudlu road
Latitude	12° 30' 36.50" N
Longitude	75° 45' 20.45" E
Length	40 m
Width	25 m
Height	20 m
Area	
Depth	
Volume	
Run out distance	09 m
Type of Material	Debris
Type of movement	Flow
Rate of movement	Rapid
Activity	Active
Distribution	Retrogressive
Style	Single
Failure mechanism	Shallow planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite Gneiss
Structure	
Land use/ Land cover	Coffee plantation
Hydrological condition	Flowing
Triggering Factor	Rainfall
Death of persons	
People affected	
Livestock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture
Geo-scientific Causes	Oversaturation of overburden material, High slope.

Remedial measures	Drainage maintenance, Drainage diversion, House at the base of the slide need to be relocated.
Remarks, if any	
Photos. Sketch of Plan & section of the slide	
Summary/Abstract	
Date of Reporting	16th August 2018
Landslide category	II

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P11/2019/49
State	Karnataka
District	Kodagu
Toposheet	48 P/11
Name of the slide	Nidavattu
NH/SH/Locality	Nidavattu road
Latitude	12° 29' 10.675" N
Longitude	75° 42' 56.187" E
Length	140 m
Width	100 m
Height	
Area	
Depth	
Volume	
Run out distance	70 m
Type of Material	Earth
Type of movement	Flow
Rate of movement	Rapid
Activity	Active
Distribution	Retrogressive
Style	Complex
Failure mechanism	Deep planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Garnet-Sillimanite graphite Schist
Structure	
Land use/ Land cover	Forest cover
Hydrological condition	Flowing
Triggering Factor	Rainfall
Death of persons	
People affected	
Livestock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Forest
Geo-scientific Causes	Oversaturation of overburden material, High slope.

Remedial measures	Drainage maintenance, Drainage diversion,
Remarks, if any	Here the joint and foliation planes trend in the same direction thus favour the detachment of rock boulders along preferred planes.
Photos. Sketch of Plan & section of the slide	Image corrupted
Summary/Abstract	
Date of Reporting	16th August 2018
Landslide category	II



Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P11/2019/50
State	Karnataka
District	Kodagu
Toposheet	48 P/11
Name of the slide	Nidavattu
NH/SH/Locality	Nidavattu road near home saty Hill top
Latitude	12° 29' 18.708" N
Longitude	75° 43' 52.580" E
Length	90 m
Width	40 m
Height	15 m
Area	
Depth	
Volume	
Run out distance	40 m
Type of Material	Earth
Type of movement	Flow
Rate of movement	Rapid
Activity	Active
Distribution	Retrogressive
Style	Single
Failure mechanism	Shallow planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite gneiss
Structure	
Land use/ Land cover	Coffee plantation
Hydrological condition	Flowing
Triggering Factor	Rainfall
Death of persons	
People affected	
Livestock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture
Geo-scientific Causes	Oversaturation of overburden material, High slope.

Remedial measures	Drainage maintenance, Drainage diversion,
Remarks, if any	Pulverization of material with some stretching of some grains is visible. Some white material perhaps Kaolin has developed which acts as a lubricating agent during failure. Mica has developed along some foliation planes.
Photos. Sketch of Plan & section of the slide	Image corrupted
Summary/Abstract	
Date of Reporting	16th August 2018
Landslide category	II



Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P11/2019/51
State	Karnataka
District	Kodagu
Toposheet	48 P/11
Name of the slide	Nidavattu
NH/SH/Locality	Near Nidavattu
Latitude	12° 29' 17.525" N
Longitude	75° 43' 27.908" E
Length	15 m
Width	30 m
Height	08 m
Area	
Depth	
Volume	
Run out distance	05 m
Type of Material	Debris
Type of movement	Slide
Rate of movement	Moderate
Activity	Active
Distribution	Retrogressive
Style	Single
Failure mechanism	Shallow planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite gneiss
Structure	
Land use/ Land cover	Coffee plantation
Hydrological condition	Flowing
Triggering Factor	Rainfall
Death of persons	
People affected	
Livestock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture
Geo-scientific Causes	Oversaturation of overburden material, High slope.

Remedial measures	Drainage maintenance, Drainage diversion,
Remarks, if any	The underlying rock contains white loose band, probably Kaolin, which act as a lubricating agent during failure. Here no grain stretching was found except Quartz vein fragmentation.
Photos. Sketch of Plan & section of the slide	Image corrupted
Summary/Abstract	
Date of Reporting	16th August 2018
Landslide category	II



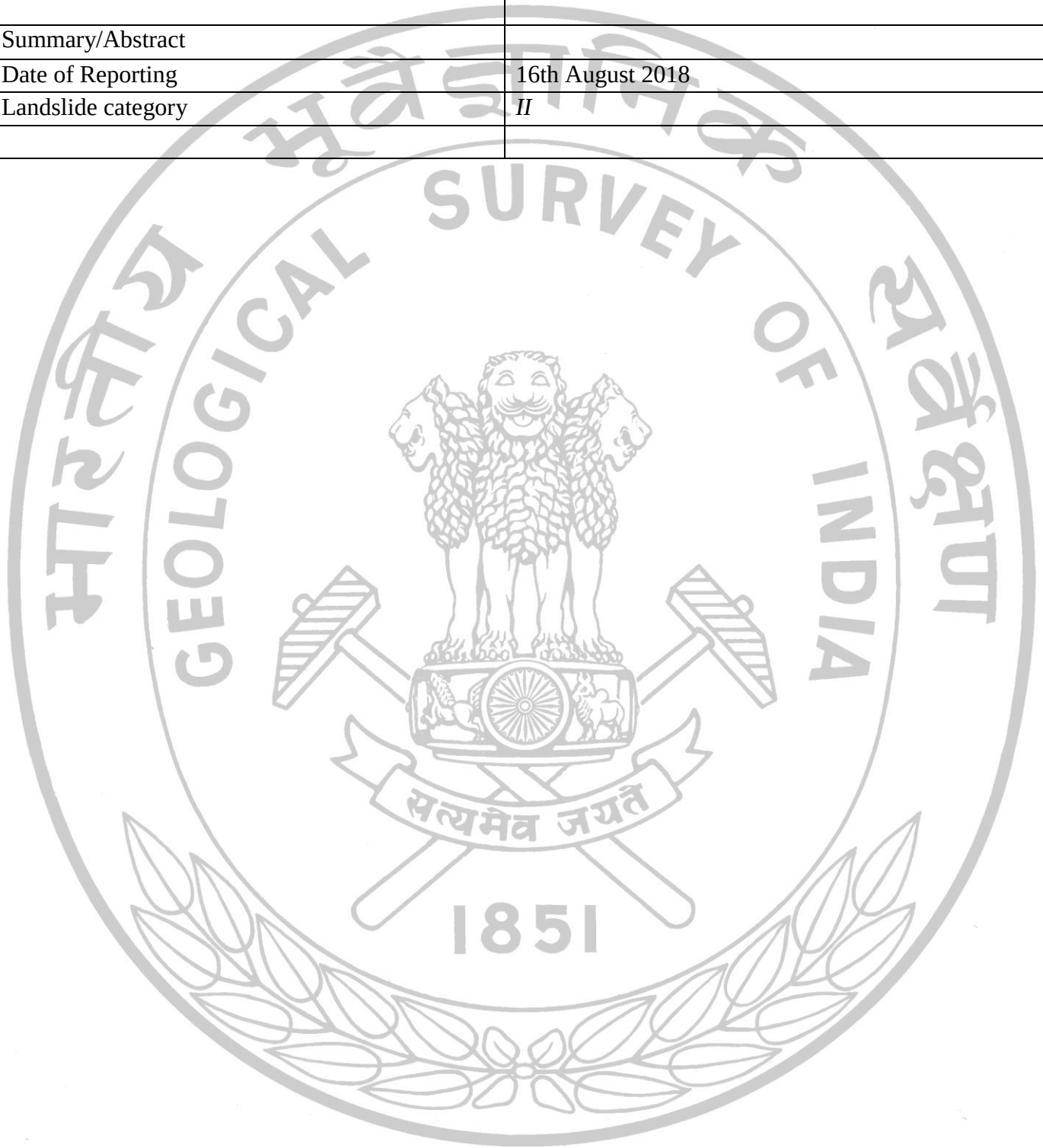
Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P11/2019/52
State	Karnataka
District	Kodagu
Toposheet	48 P/11
Name of the slide	Nidavattu
NH/SH/Locality	Near Nidavattu
Latitude	12° 29' 18.803" N
Longitude	75° 43' 26.643" E
Length	20 m
Width	10 m
Height	05 m
Area	
Depth	
Volume	
Run out distance	05 m
Type of Material	Earth
Type of movement	Flow
Rate of movement	Rapid
Activity	Active
Distribution	Enlarging
Style	Multiple
Failure mechanism	Shallow planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite gneiss with mafic rock intrusions
Structure	
Land use/ Land cover	Coffee plantation
Hydrological condition	Flowing
Triggering Factor	Rainfall
Death of persons	
People affected	
Livestock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture

Geo-scientific Causes	Presence of fractured material, under high strain, oversaturation of material and loss of cohesion.
Remedial measures	Drainage maintenance,
Remarks, if any	
Photos. Sketch of Plan & section of the slide	Image corrupted
Summary/Abstract	
Date of Reporting	16th August 2018
Landslide category	II



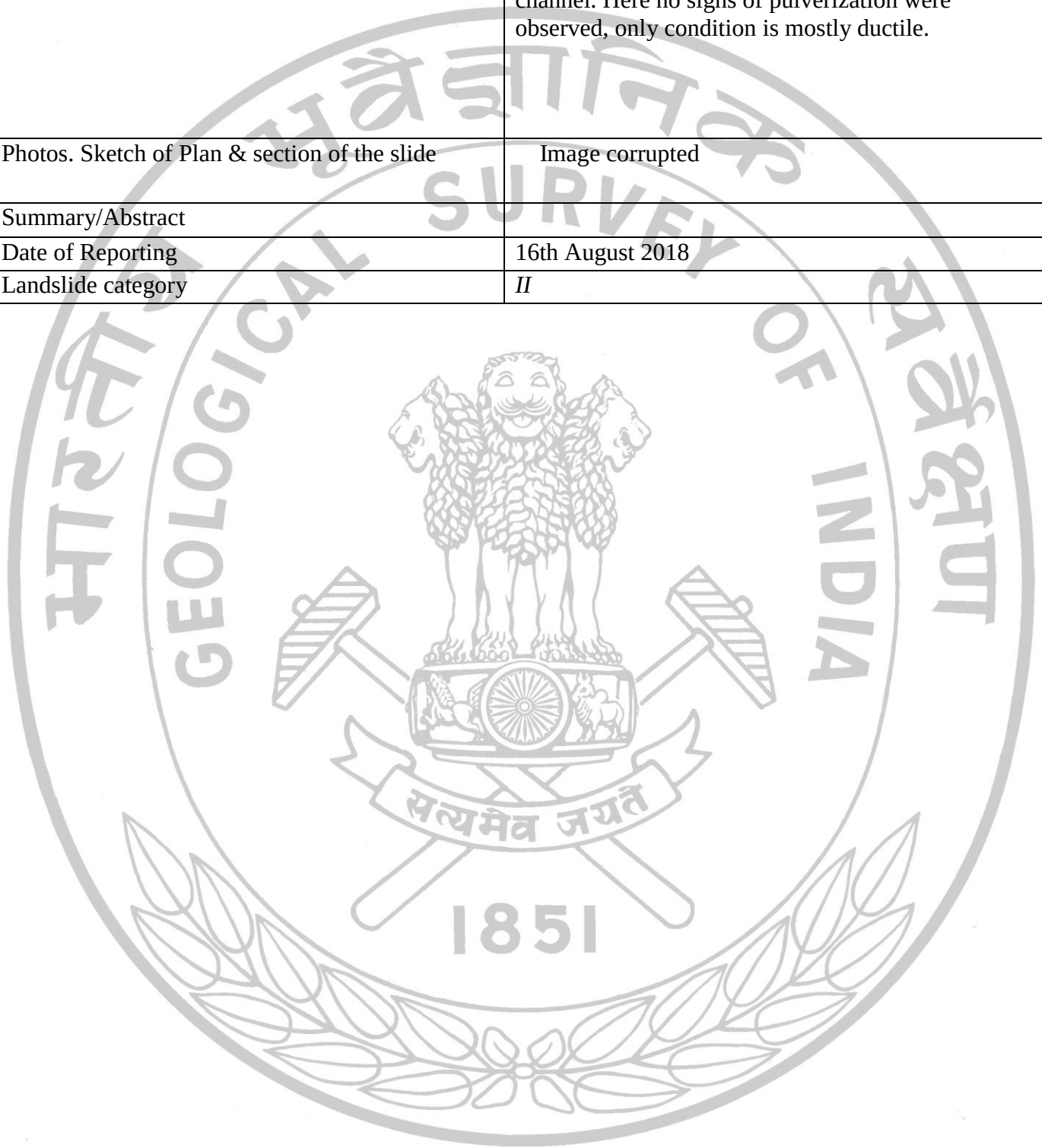
Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P11/2019/53
State	Karnataka
District	Kodagu
Toposheet	48 P/11
Name of the slide	Nidavattu
NH/SH/Locality	Near Nidavattu
Latitude	12° 29' 19.449" N
Longitude	75° 43' 25.709" E
Length	30 m
Width	20 m
Height	12 m
Area	
Depth	
Volume	
Run out distance	10 m
Type of Material	Earth
Type of movement	Flow
Rate of movement	Rapid
Activity	Active
Distribution	Retrogressive
Style	Single
Failure mechanism	Shallow planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite gneiss
Structure	
Land use/ Land cover	Coffee plantation
Hydrological condition	Dry
Triggering Factor	Rainfall
Death of persons	
People affected	
Live stock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture
Geo-scientific Causes	Oversaturation of overburden, non-cohesion of the material.

Remedial measures	Drainage maintenance,
Remarks, if any	
Photos. Sketch of Plan & section of the slide	Image corrupted
Summary/Abstract	
Date of Reporting	16th August 2018
Landslide category	II



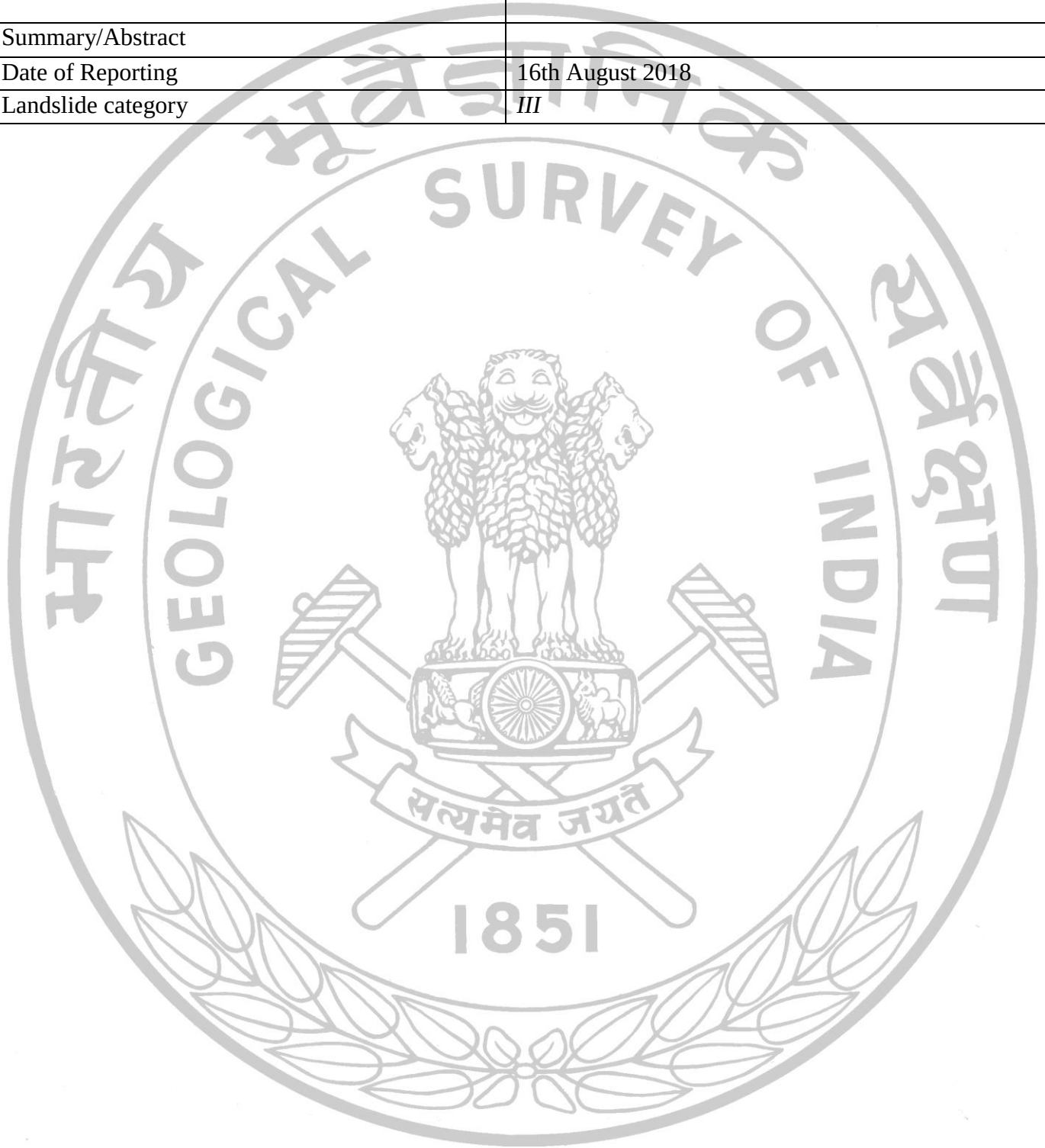
Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P11/2019/54
State	Karnataka
District	Kodagu
Toposheet	48 P/11
Name of the slide	Nidavattu
NH/SH/Locality	Near Nidavattu
Latitude	12° 29' 30.756" N
Longitude	75° 43' 35.260" E
Length	70 m
Width	40 m
Height	15 m
Area	
Depth	
Volume	
Run out distance	25 m
Type of Material	Earth
Type of movement	Flow
Rate of movement	Moderate
Activity	Active
Distribution	Retrogressive
Style	Single
Failure mechanism	Shallow planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite gneiss
Structure	
Land use/ Land cover	Coffee plantation
Hydrological condition	Flowing
Triggering Factor	Rainfall
Death of persons	
People affected	
Live stock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture
Geo-scientific Causes	Oversaturation of overburden, non-cohesion of the material.

Remedial measures	Drainage maintenance,
Remarks, if any	Here the hard rock is overlain by weathered material which on oversaturation has flown towards the channel. Here no signs of pulverization were observed, only condition is mostly ductile.
Photos. Sketch of Plan & section of the slide	Image corrupted
Summary/Abstract	
Date of Reporting	16th August 2018
Landslide category	II



Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P11/2019/55
State	Karnataka
District	Kodagu
Toposheet	48 P/11
Name of the slide	Nidavattu
NH/SH/Locality	Near Nidavattu
Latitude	12° 29' 33.547" N
Longitude	75° 43' 34.865" E
Length	70 m
Width	50 m
Height	20 m
Area	
Depth	
Volume	
Run out distance	18 m
Type of Material	Earth
Type of movement	Flow
Rate of movement	Moderate
Activity	Active
Distribution	Retrogressive
Style	Single
Failure mechanism	Shallow planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite gneiss
Structure	
Land use/ Land cover	Coffee plantation
Hydrological condition	Flowing
Triggering Factor	Rainfall
Death of persons	
People affected	
Live stock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture
Geo-scientific Causes	Oversaturation of overburden, incohesion of the material.

Remedial measures	Drainage maintenance,
Remarks, if any	
Photos. Sketch of Plan & section of the slide	Image corrupted
Summary/Abstract	
Date of Reporting	16th August 2018
Landslide category	III



Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P11/2019/56
State	Karnataka
District	Kodagu
Toposheet	48 P/11
Name of the slide	Nidavattu
NH/SH/Locality	Near Nidavattu along Nalla
Latitude	12° 29' 32.287" N
Longitude	75° 43' 38.149" E
Length	50 m
Width	25 m
Height	14 m
Area	
Depth	
Volume	
Run out distance	18 m
Type of Material	Debris
Type of movement	Slide
Rate of movement	Moderate
Activity	Active
Distribution	Retrogressive
Style	Single
Failure mechanism	Shallow planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite gneiss
Structure	
Land use/ Land cover	Coffee plantation
Hydrological condition	Flowing
Triggering Factor	Rainfall
Death of persons	
People affected	
Live stock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture
Geo-scientific Causes	Oversaturation of overburden, non-cohesion of the material.

Remedial measures	Drainage maintenance,
Remarks, if any	
Photos. Sketch of Plan & section of the slide	
Summary/Abstract	
Date of Reporting	16th August 2018
Landslide category	<i>III</i>

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P11/2019/57
State	Karnataka
District	Kodagu
Toposheet	48 P/11
Name of the slide	Nidavattu
NH/SH/Locality	Near Nidavattu near Nalla
Latitude	12° 29' 34.289" N
Longitude	75° 43' 38.717" E
Length	30 m
Width	140 m
Height	
Area	
Depth	
Volume	
Run out distance	
Type of Material	Earth
Type of movement	Flow
Rate of movement	Rapid
Activity	Active
Distribution	Retrogressive
Style	Single
Failure mechanism	Shallow planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite gneiss
Structure	
Land use/ Land cover	Coffee plantation
Hydrological condition	Flowing
Triggering Factor	Rainfall
Death of persons	
People affected	
Live stock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture
Geo-scientific Causes	Oversaturation of overburden, non-cohesion of the material.

Remedial measures	Drainage maintenance,
Remarks, if any	The overburden material has moved along contact along rock and overlying loose material. Some rock boulders lying below the stream seem to have detached along some preferred weak planes.
Photos. Sketch of Plan & section of the slide	
Summary/Abstract	
Date of Reporting	16th August 2018
Landslide category	<i>II</i>

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P11/2019/58
State	Karnataka
District	Kodagu
Toposheet	48 P/11
Name of the slide	Nidavattu
NH/SH/Locality	Near Nidavattu near Nalla
Latitude	12° 29' 37.568" N
Longitude	75° 43' 49.820" E
Length	220 m
Width	250 m
Height	45 m
Area	
Depth	
Volume	
Run out distance	120 m
Type of Material	Rock
Type of movement	Slide
Rate of movement	Moderate
Activity	Active
Distribution	Retrogressive
Style	Multiple
Failure mechanism	Shallow planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Amphibolite and Granite gneiss
Structure	
Land use/ Land cover	Coffee plantation
Hydrological condition	Flowing
Triggering Factor	Rainfall
Death of persons	
People affected	
Live stock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture
Geo-scientific Causes	Oversaturation of overburden, non-cohesion of the material.

Remedial measures	Drainage maintenance,
Remarks, if any	Here the disintegration of the mafic component lead to the movement along contact of Granite gneiss and Amphibolite.
Photos. Sketch of Plan & section of the slide	
Summary/Abstract	
Date of Reporting	16th August 2018
Landslide category	II

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P11/2019/59
State	Karnataka
District	Kodagu
Toposheet	48 P/11
Name of the slide	Nidavattu Slide
NH/SH/Locality	Near Nidavattu near Nalla
Latitude	12° 29' 39.802" N
Longitude	75° 43' 44.861" E
Length	50 m
Width	120 m
Height	
Area	
Depth	
Volume	
Run out distance	
Type of Material	Earth
Type of movement	Flow
Rate of movement	Moderate
Activity	Active
Distribution	Retrogressive
Style	Multiple
Failure mechanism	Deep planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Amphibolite and Granite gneiss
Structure	
Land use/ Land cover	Coffee plantation
Hydrological condition	Flowing
Triggering Factor	Rainfall
Death of persons	
People affected	
Live stock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture
Geo-scientific Causes	Toe cutting and over saturation of the overburden material

Remedial measures	Drainage maintenance,
Remarks, if any	
Photos. Sketch of Plan & section of the slide	
Summary/Abstract	
Date of Reporting	16th August 2018
Landslide category	II

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P11/2019/60
State	Karnataka
District	Kodagu
Toposheet	48 P/11
Name of the slide	Mukudlu near pond
NH/SH/Locality	Mukudlu
Latitude	12° 29' 38.646" N
Longitude	75° 44' 29.145" E
Length	80 m
Width	35 m
Height	15 m
Area	
Depth	
Volume	
Run out distance	30 m
Type of Material	Debris
Type of movement	Slide
Rate of movement	Moderate
Activity	Active
Distribution	Retrogressive
Style	Single
Failure mechanism	Shallow planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Weathered Granite gneiss
Structure	
Land use/ Land cover	Forest cover.
Hydrological condition	Damp
Triggering Factor	Rainfall
Death of persons	
People affected	
Live stock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Forest

Geo-scientific Causes	over saturation of the overburden material, Lubrication along contact of overburden and underlying rock. Moreover, weathered material had favoured the percolation of water.
Remedial measures	Drainage maintenance,
Remarks, if any	
Photos. Sketch of Plan & section of the slide	
Summary/Abstract	
Date of Reporting	16th August 2018
Landslide category	II

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P10/2019/61
State	Karnataka
District	Kodagu
Toposheet	48 P/10
Name of the slide	Kallur Barebellachur slide
NH/SH/Locality	Kalur
Latitude	12° 30' 12.328" N
Longitude	75° 43' 29.664" E
Length	90 m
Width	40 m
Height	15 m
Area	
Depth	
Volume	
Run out distance	60 m
Type of Material	Debris
Type of movement	Slide
Rate of movement	Rapid
Activity	Active
Distribution	Retrogressive
Style	Single
Failure mechanism	Shallow planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite gneiss
Structure	
Land use/ Land cover	Coffee plantation
Hydrological condition	Damp
Triggering Factor	Rainfall
Death of persons	
People affected	
Live stock loss	-
Communication	
Infrastructure	2 houses were partially damaged.
Agriculture/forest/Barren	Agriculture

Geo-scientific Causes	Over saturation of the overburden material, Lubrication along contact of overburden and underlying rock.
Remedial measures	Slope easing, Drainage maintenance,
Remarks, if any	
Photos. Sketch of Plan & section of the slide	
Summary/Abstract	
Date of Reporting	16th August 2018
Landslide category	III

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P11/2019/62
State	Karnataka
District	Kodagu
Toposheet	48 P/11
Name of the slide	Kallur Barebellachur slide
NH/SH/Locality	Kalur
Latitude	12° 29' 42.156" N
Longitude	75° 43' 25.470" E
Length	20 m
Width	80 m
Height	15 m
Area	
Depth	
Volume	
Run out distance	
Type of Material	Earth
Type of movement	Slide
Rate of movement	Moderate
Activity	Active
Distribution	Retrogressive
Style	Multiple
Failure mechanism	Shallow planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite gneiss
Structure	
Land use/ Land cover	Coffee plantation
Hydrological condition	Dry
Triggering Factor	Rainfall
Death of persons	
People affected	
Live stock loss	-
Communication	Road
Infrastructure	
Agriculture/forest/Barren	Agriculture

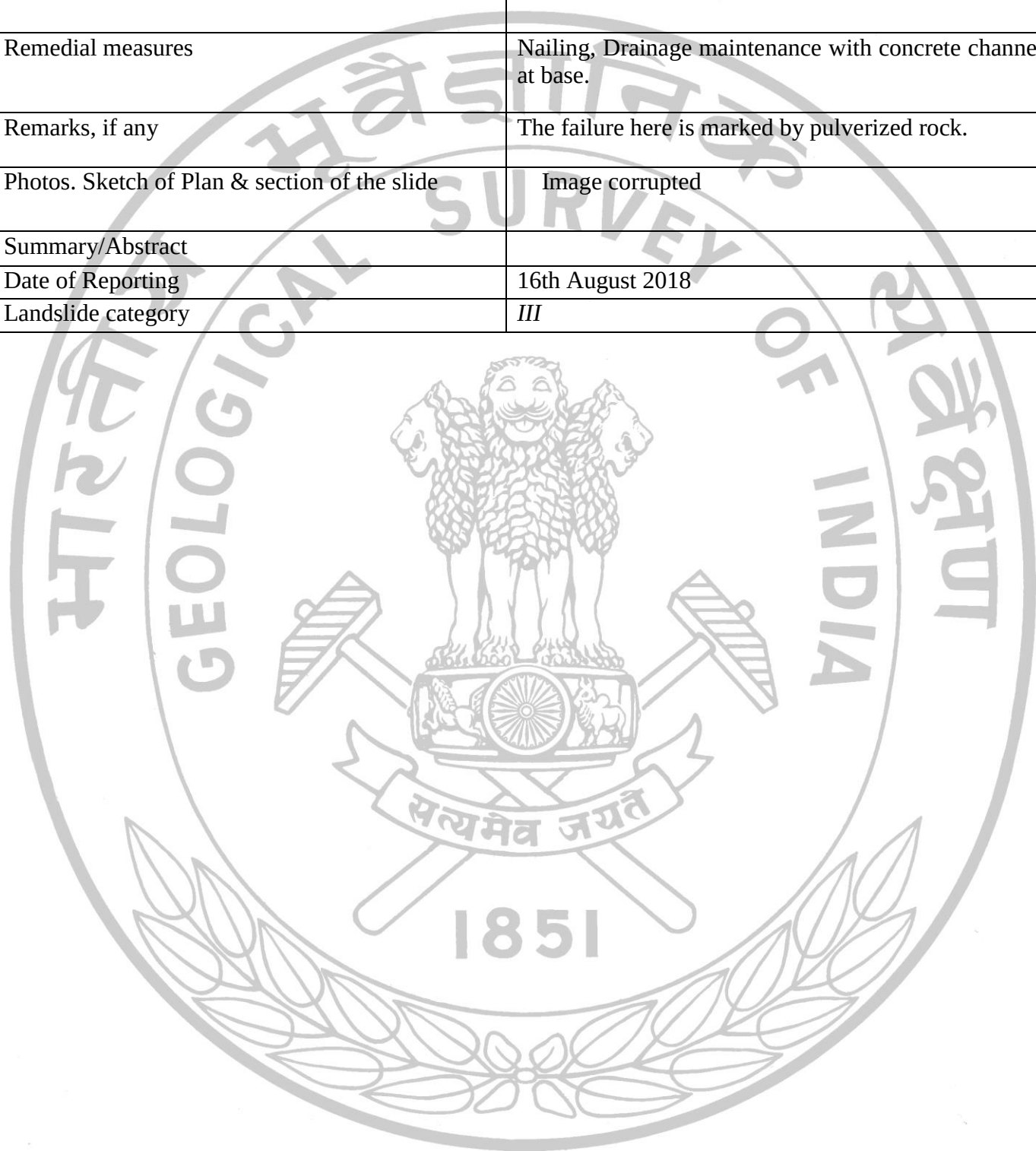
Geo-scientific Causes	Over saturation of the overburden material, Anthropogenic involvement is quite visible in the form of undammed loose material near the road bend.
Remedial measures	Slope easing, Drainage maintenance,
Remarks, if any	The slide seems to be due to the unplanned road cutting, leaving behind humps of loose material at the bend which has failed in the form of steps during rainy season.
Photos. Sketch of Plan & section of the slide	
Summary/Abstract	
Date of Reporting	16th August 2018
Landslide category	<i>III</i>

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P11/2019/63
State	Karnataka
District	Kodagu
Toposheet	48 P/11
Name of the slide	
NH/SH/Locality	
Latitude	12° 29' 44.284" N
Longitude	75° 43' 27.882" E
Length	110 m
Width	20 m
Height	
Area	
Depth	
Volume	
Run out distance	
Type of Material	Earth
Type of movement	Slide
Rate of movement	Moderate
Activity	Active
Distribution	Retrogressive
Style	Single
Failure mechanism	Shallow planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite gneiss
Structure	
Land use/ Land cover	Coffee plantation
Hydrological condition	Dry
Triggering Factor	Rainfall
Death of persons	
People affected	
Live stock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture

Geo-scientific Causes	Over saturation of the overburden material, Anthropogenic processes like road cutting and road widening also play some role.
Remedial measures	Toe cutting, Drainage coverage and Nailing.
Remarks, if any	
Photos. Sketch of Plan & section of the slide	
Summary/Abstract	
Date of Reporting	16th August 2018
Landslide category	<i>III</i>

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P11/2019/64
State	Karnataka
District	Kodagu
Toposheet	48 P/11
Name of the slide	Nidavattu Barebellachur road
NH/SH/Locality	Nidavattu
Latitude	12° 29' 51.377" N
Longitude	75° 43' 27.584" E
Length	50 m
Width	30 m
Height	15 m
Area	
Depth	
Volume	
Run out distance	40 m
Type of Material	Earth
Type of movement	Flow
Rate of movement	Moderate
Activity	Active
Distribution	Retrogressive
Style	Single
Failure mechanism	Shallow planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite gneiss
Structure	
Land use/ Land cover	Coffee plantation
Hydrological condition	Dry
Triggering Factor	Rainfall
Death of persons	
People affected	
Live stock loss	-
Communication	Road
Infrastructure	
Agriculture/forest/Barren	Agriculture

Geo-scientific Causes	The oversaturation with moderate to high slope and to some extent toe cutting for road construction played a vital role in the failure.
Remedial measures	Nailing, Drainage maintenance with concrete channel at base.
Remarks, if any	The failure here is marked by pulverized rock.
Photos. Sketch of Plan & section of the slide	Image corrupted
Summary/Abstract	
Date of Reporting	16th August 2018
Landslide category	III



Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P11/2019/65
State	Karnataka
District	Kodagu
Toposheet	48 P/11
Name of the slide	
NH/SH/Locality	Nidavattu
Latitude	12° 29' 58.400" N
Longitude	75° 43' 24.111" E
Length	100 m
Width	60 m
Height	20 m
Area	
Depth	
Volume	
Run out distance	
Type of Material	Earth
Type of movement	Spread
Rate of movement	Moderate
Activity	Active
Distribution	Moving
Style	Single
Failure mechanism	Shallow planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite gneiss
Structure	
Land use/ Land cover	Coffee plantation
Hydrological condition	Dry
Triggering Factor	Rainfall
Death of persons	
People affected	
Livestock loss	-
Communication	Road
Infrastructure	
Agriculture/forest/Barren	Agriculture

Geo-scientific Causes	The oversaturation with moderate to high slope and to some extent toe cutting for road construction played a vital role in the failure.
Remedial measures	Nailing, Drainage maintenance with concrete channel at base, Crack filling with some impervious material
Remarks, if any	Here cracks were found in stepped form. The cracks run upto the hill top and diminish near stream.
Photos. Sketch of Plan & section of the slide	Image corrupted
Summary/Abstract	
Date of Reporting	16th August 2018
Landslide category	II

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P10/2019/66
State	Karnataka
District	Kodagu
Toposheet	48 P/10
Name of the slide	Barebellachur kalur slide

NH/SH/Locality	Barebellachur
Latitude	12° 30' 12.239" N
Longitude	75° 43' 37.796" E
Length	60 m
Width	60 m
Height	30 m
Area	
Depth	
Volume	
Run out distance	20 m
Type of Material	Debris
Type of movement	Slide
Rate of movement	Rapid
Activity	Active
Distribution	Retrogressive
Style	Single
Failure mechanism	Shallow planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite gneiss
Structure	
Land use/ Land cover	Coffee and Spice plantation
Hydrological condition	Dry
Triggering Factor	Rainfall
Death of persons	
People affected	
Live stock loss	
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture
Geo-scientific Causes	The oversaturation with moderate to high slope and to some extent toe cutting for cultivation purposes.
Remedial measures	Drainage maintenance and avoid toe cutting of the slopes
Remarks, if any	Here cracks were found in stepped form. The cracks run up to the hill top and diminish near stream.

Photos. Sketch of Plan & section of the slide	Image corrupted
Summary/Abstract	
Date of Reporting	16th August 2018
Landslide category	II



Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P10/2019/67
State	Karnataka
District	Kodagu
Toposheet	48 P/10
Name of the slide	
NH/SH/Locality	
Latitude	12° 30' 10.761" N
Longitude	75° 43' 11.681" E
Length	100 m
Width	40 m
Height	30 m
Area	
Depth	
Volume	
Run out distance	40 m
Type of Material	Earth
Type of movement	Flow
Rate of movement	Rapid
Activity	Active
Distribution	Widening
Style	Single
Failure mechanism	Shallow planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite gneiss and Metapelite
Structure	
Land use/ Land cover	Coffee and Spice plantation
Hydrological condition	Dry
Triggering Factor	Rainfall
Death of persons	
People affected	
Live stock loss	-
Communication	
Infrastructure	One house of Mr Kallapa was fully damaged.
Agriculture/forest/Barren	Agriculture

Geo-scientific Causes	The oversaturation of overburden, toe cutting at base by stream, and deep weathering.
Remedial measures	Drainage should not be disturbed keeping the high gradient of the slope under consideration. Any kind of construction at the base and on the slope should be avoided.
Remarks, if any	Here cracks were found in stepped form. The cracks run up to the hill top and diminish near stream.
Photos. Sketch of Plan & section of the slide	Image corrupted
Summary/Abstract	
Date of Reporting	28th August 2018
Landslide category	II

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P10/2019/68
State	Karnataka
District	Kodagu
Toposheet	48 P/10
Name of the slide	Barebellachur
NH/SH/Locality	Nidavattu-Mandalpaddi road
Latitude	12° 30' 13.865" N
Longitude	75° 43' 21.375" E
Length	50 m
Width	30 m
Height	
Area	
Depth	
Volume	
Run out distance	20 m
Type of Material	Earth
Type of movement	Slide
Rate of movement	Rapid
Activity	Active
Distribution	Retrogressive
Style	Single
Failure mechanism	Shallow planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite gneiss
Structure	
Land use/ Land cover	Coffee plantation
Hydrological condition	Dry
Triggering Factor	Rainfall
Death of persons	
People affected	
Live stock loss	-
Communication	Road
Infrastructure	
Agriculture/forest/Barren	Agriculture

Geo-scientific Causes	The oversaturation of overburden, toe cutting at base by stream, and deep weathering.
Remedial measures	Drainage maintenance, Nailing
Remarks, if any	Here the slope ranges from 35 to 40°. The slide has occurred at road bend where the role of slope cutting for road widening cannot be ruled out.
Photos. Sketch of Plan & section of the slide	
Summary/Abstract	
Date of Reporting	16th August 2018
Landslide category	II

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P10/2019/69
State	Karnataka
District	Kodagu
Toposheet	48 P/10
Name of the slide	Barebellachur
NH/SH/Locality	Nidavattu-Mandalpaddi road
Latitude	12° 30' 53.489" N
Longitude	75° 43' 32.770" E
Length	60 m
Width	30 m
Height	40 m
Area	
Depth	
Volume	
Run out distance	100 m
Type of Material	Debris
Type of movement	Flow
Rate of movement	Rapid
Activity	Active
Distribution	Retrogressive
Style	Single
Failure mechanism	Shallow planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite gneiss
Structure	
Land use/ Land cover	Coffee plantation
Hydrological condition	Dry
Triggering Factor	Rainfall
Death of persons	
People affected	
Live stock loss	-
Communication	Road
Infrastructure	
Agriculture/forest/Barren	Agriculture with some Reserve forest on other side of the hill.

Geo-scientific Causes	The oversaturation of overburden, more percolation along weak planes and detachment along same planes.
Remedial measures	Drainage maintenance, Nailing
Remarks, if any	Here the rock is highly pulverized showing brittle shear conditions. The rock is traversed by prominent joint set trending 25°/vertical causes the fragmentation.
Photos. Sketch of Plan & section of the slide	
Summary/Abstract	
Date of Reporting	16th August 2018
Landslide category	II

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P10/2019/70
State	Karnataka
District	Kodagu
Toposheet	48 P/10
Name of the slide	Barebellachur
NH/SH/Locality	
Latitude	12° 30' 34.456" N
Longitude	75°43' 21.555" E
Length	30 m
Width	20 m
Height	10 m
Area	
Depth	
Volume	
Run out distance	05 m
Type of Material	Earth
Type of movement	Slide
Rate of movement	Rapid
Activity	Active
Distribution	Retrogressive
Style	Single
Failure mechanism	Shallow planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite gneiss
Structure	
Land use/ Land cover	Mixed plantation
Hydrological condition	Dry
Triggering Factor	Rainfall
Death of persons	
People affected	
Live stock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture with some forest cover

Geo-scientific Causes	The oversaturation of overburden, more percolation along weak planes and detachment along same planes.
Remedial measures	Drainage maintenance
Remarks, if any	The slide is the outcome of the toe cutting by a stream at the base including the oversaturation of the material at the top.
Photos. Sketch of Plan & section of the slide	
Summary/Abstract	
Date of Reporting	16th August 2018
Landslide category	II

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P10/2019/71
State	Karnataka
District	Kodagu
Toposheet	48 P/10
Name of the slide	
NH/SH/Locality	
Latitude	12° 30' 38.594" N
Longitude	75° 44' 2.594" E
Length	80 m
Width	80 m
Height	20 m
Area	
Depth	
Volume	
Run out distance	40 m
Type of Material	Debris
Type of movement	Slide
Rate of movement	Rapid
Activity	Active
Distribution	Retrogressive
Style	Single
Failure mechanism	Shallow planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite gneiss
Structure	
Land use/ Land cover	Spices cultivation
Hydrological condition	Dry
Triggering Factor	Rainfall
Death of persons	
People affected	
Live stock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture

Geo-scientific Causes	The oversaturation of overburden, more percolation along weak planes and detachment along same planes.
Remedial measures	Drainage maintenance, Nailing, Maintaining free flow of the water.
Remarks, if any	The main factors responsible here include high slope, over saturation of the overburden and highly weathered nature of the rock.
Photos. Sketch of Plan & section of the slide	
Summary/Abstract	
Date of Reporting	16th August 2018
Landslide category	II

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P10/2019/72
State	Karnataka
District	Kodagu
Toposheet	48 P/10
Name of the slide	Mukudlu Slide
NH/SH/Locality	Mukudlu village
Latitude	12° 30' 45.703" N
Longitude	75° 43' 58.679" E
Length	100 m
Width	80 m
Height	40 m
Area	
Depth	
Volume	
Run out distance	50 m
Type of Material	Debris
Type of movement	Slide
Rate of movement	Moderate
Activity	Active
Distribution	Retrogressive
Style	Multiple
Failure mechanism	Shallow planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite gneiss
Structure	
Land use/ Land cover	Spices mostly pepper plantation
Hydrological condition	Dry
Triggering Factor	Rainfall
Death of persons	
People affected	
Live stock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture
Geo-scientific Causes	The oversaturation of overburden, non-cohesion of the material.

Remedial measures	Drainage maintenance, Nailing, Maintaining free flow of the water.
Remarks, if any	The main factors responsible here include high slope, over saturation of the overburden and highly weathered nature of the rock.
Photos. Sketch of Plan & section of the slide	
Summary/Abstract	
Date of Reporting	16th August 2018
Landslide category	III

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P10/2019/73
State	Karnataka
District	Kodagu
Toposheet	48 P/10
Name of the slide	Mukudlu Slide
NH/SH/Locality	Mukudlu village
Latitude	12° 30' 42.762" N
Longitude	75° 44' 10.187" E
Length	10 m
Width	10 m
Height	05 m
Area	
Depth	
Volume	
Run out distance	
Type of Material	Earth
Type of movement	Slide
Rate of movement	Moderate
Activity	Active
Distribution	Retrogressive
Style	Single
Failure mechanism	Shallow planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite gneiss
Structure	
Land use/ Land cover	Coffee plantation
Hydrological condition	Dry
Triggering Factor	Rainfall
Death of persons	
People affected	
Live stock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture

Geo-scientific Causes	Removal of toe support during road construction, Increase of soil mass due to oversaturation
Remedial measures	Drainage maintenance, Nailing, Maintaining free flow of the water.
Remarks, if any	
Photos. Sketch of Plan & section of the slide	
Summary/Abstract	
Date of Reporting	16th August 2018
Landslide category	<i>II</i>

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P10/2019/74
State	Karnataka
District	Kodagu
Toposheet	48 P/10
Name of the slide	Mukudlu Slide
NH/SH/Locality	Mukudlu village
Latitude	12° 30' 40.139" N
Longitude	75° 44' 10.289" E
Length	80 m
Width	60 m
Height	
Area	
Depth	
Volume	
Run out distance	
Type of Material	Earth
Type of movement	Slide
Rate of movement	Moderate
Activity	Active
Distribution	Widening
Style	Single
Failure mechanism	Shallow planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite gneiss
Structure	
Land use/ Land cover	Coffee plantation
Hydrological condition	Dry
Triggering Factor	Rainfall
Death of persons	
People affected	
Livestock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture

Geo-scientific Causes	Slip along contact between overburden and underlying rock, Increase in soil mass weight.
Remedial measures	Drainage maintenance, Nailing, Maintaining free flow of the water.
Remarks, if any	
Photos. Sketch of Plan & section of the slide	
Summary/Abstract	
Date of Reporting	17th August 2018
Landslide category	II

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P15/2019/75
State	Karnataka
District	Kodagu
Toposheet	48 P/15
Name of the slide	Megatallu slide
NH/SH/Locality	Megatallu
Latitude	12° 29' 42.892" N
Longitude	75° 45' 18.621" E
Length	50 m
Width	50 m
Height	20 m
Area	
Depth	
Volume	
Run out distance	10 m
Type of Material	Earth
Type of movement	Slide
Rate of movement	Rapid
Activity	Active
Distribution	Retrogressive
Style	Single
Failure mechanism	Shallow planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite gneiss
Structure	
Land use/ Land cover	Coffee plantation
Hydrological condition	Dry
Triggering Factor	Rainfall
Death of persons	
People affected	
Livestock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture

Geo-scientific Causes	Weathered rock and thick overburden, Saturation of overburden during rains, Slip along bed rock plane, Steep slope, High stretching of mineral grains under ductile conditions and initiation of shear planes.
Remedial measures	Drainage maintenance, Nailing, Maintaining free flow of the water.
Remarks, if any	
Photos. Sketch of Plan & section of the slide	
Summary/Abstract	
Date of Reporting	17th August 2018
Landslide category	II

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P14/2019/76
State	Karnataka
District	Kodagu
Toposheet	48 P/14
Name of the slide	Mukudlu slide
NH/SH/Locality	Mukudlu
Latitude	12° 30' 38.657" N
Longitude	75° 45' 20.212" E
Length	50 m
Width	40 m
Height	
Area	
Depth	
Volume	
Run out distance	
Type of Material	Earth
Type of movement	Slide
Rate of movement	Rapid
Activity	Active
Distribution	Retrogressive
Style	Single
Failure mechanism	Shallow planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite gneiss wit Quartz veins
Structure	
Land use/ Land cover	Coffee plantation
Hydrological condition	Dry
Triggering Factor	Rainfall
Death of persons	
People affected	
Live stock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture

Geo-scientific Causes	Saturation of overburden, Exposure of rock along nalla with frequent discontinuities favoured the detachment during high down pour and loose material lying on the flanks of the stream.
Remedial measures	Drainage maintenance, Nailing, Maintaining free flow of the water.
Remarks, if any	
Photos. Sketch of Plan & section of the slide	Image corrupted
Summary/Abstract	
Date of Reporting	17th August 2018
Landslide category	II



Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P15/2019/77
State	Karnataka
District	Kodagu
Toposheet	48 P/15
Name of the slide	Mukudlu slide
NH/SH/Locality	Mukudlu
Latitude	12° 29' 40.697" N
Longitude	75° 45' 16.388" E
Length	100 m
Width	30 m
Height	40 m
Area	
Depth	
Volume	
Run out distance	20 m
Type of Material	Earth
Type of movement	Flow
Rate of movement	Rapid
Activity	Active
Distribution	Retrogressive
Style	Single
Failure mechanism	Shallow planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite gneiss wit Quartz veins
Structure	
Land use/ Land cover	Coffee plantation
Hydrological condition	Dry
Triggering Factor	Rainfall
Death of persons	
People affected	
Live stock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture

Geo-scientific Causes	Saturation of overburden, Exposure of rock along nalla with frequent discontinuities favoured the detachment during high down pour and loose material lying on the flanks of the stream.
Remedial measures	Drainage maintenance, Nailing, Maintaining free flow of the water.
Remarks, if any	
Photos. Sketch of Plan & section of the slide	
Summary/Abstract	
Date of Reporting	17th August 2018
Landslide category	II

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P15/2019/78
State	Karnataka
District	Kodagu
Toposheet	48 P/15
Name of the slide	Mukudlu slide
NH/SH/Locality	Mukudlu
Latitude	12° 29' 42.373" N
Longitude	75° 45' 13.263" E
Length	100 m
Width	40 m
Height	50 m
Area	
Depth	
Volume	
Run out distance	20 m
Type of Material	Debris
Type of movement	Slide
Rate of movement	Moderate
Activity	Active
Distribution	Retrogressive
Style	Single
Failure mechanism	Shallow planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite gneiss wit Quartz veins
Structure	
Land use/ Land cover	Coffee plantation
Hydrological condition	Dry
Triggering Factor	Rainfall
Death of persons	
People affected	
Livestock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture

Geo-scientific Causes	Over saturation of the overburden, lubrication of the loose overburden material along contact between rock and overlying material
Remedial measures	Drainage maintenance, Nailing, Maintaining free flow of the water.
Remarks, if any	
Photos. Sketch of Plan & section of the slide	
Summary/Abstract	
Date of Reporting	17th August 2018
Landslide category	<i>II</i>

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P15/2019/79
State	Karnataka
District	Kodagu
Toposheet	48 P/15
Name of the slide	Mukudlu slide
NH/SH/Locality	Mukudlu
Latitude	12° 29' 50.061" N
Longitude	75° 45' 19.112" E
Length	100 m
Width	30 m
Height	
Area	
Depth	
Volume	
Run out distance	
Type of Material	Debris
Type of movement	Slide
Rate of movement	Moderate
Activity	Active
Distribution	Retrogressive
Style	Single
Failure mechanism	Shallow planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite gneiss wit Quartz veins
Structure	
Land use/ Land cover	Coffee plantation
Hydrological condition	Dry
Triggering Factor	Rainfall
Death of persons	
People affected	
Live stock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture
Geo-scientific Causes	High slope and over saturation of overburden material

Remedial measures	Drainage maintenance, Nailing, Slope easing, Maintaining free flow of the water.
Remarks, if any	
Photos. Sketch of Plan & section of the slide	
Summary/Abstract	
Date of Reporting	17th August 2018
Landslide category	II

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P10/2019/80
State	Karnataka
District	Kodagu
Toposheet	48 P/10
Name of the slide	Barebellachur slide
NH/SH/Locality	
Latitude	12° 30' 3.350" N
Longitude	75° 43' 21.073" E
Length	50 m
Width	30 m
Height	10 m
Area	
Depth	
Volume	
Run out distance	08 m
Type of Material	Debris
Type of movement	Slide
Rate of movement	Moderate
Activity	Active
Distribution	Retrogressive
Style	Single
Failure mechanism	Shallow rotational failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite gneiss
Structure	
Land use/ Land cover	Coffee plantation
Hydrological condition	Dry
Triggering Factor	Rainfall
Death of persons	
People affected	
Livestock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture
Geo-scientific Causes	Oversaturation of the overburden, lubrication of overburden along contact between overburden and underlying rock.

Remedial measures	Drainage maintenance, Nailing, Slope easing, Maintaining free flow of the water.
Remarks, if any	
Photos. Sketch of Plan & section of the slide	
Summary/Abstract	
Date of Reporting	16th August 2018
Landslide category	II

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P10/2019/81
State	Karnataka
District	Kodagu
Toposheet	48 P/10
Name of the slide	Barebellachur slide
NH/SH/Locality	
Latitude	12° 30' 2.034" N
Longitude	75°43' 9.336" E
Length	60 m
Width	30 m
Height	40 m
Area	
Depth	
Volume	
Run out distance	15 m
Type of Material	Earth
Type of movement	Slide
Rate of movement	Moderate
Activity	Active
Distribution	Retrogressive
Style	Single
Failure mechanism	Shallow rotational failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite gneiss
Structure	
Land use/ Land cover	Coffee plantation
Hydrological condition	Dry
Triggering Factor	Rainfall
Death of persons	
People affected	
Livestock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture
Geo-scientific Causes	Very steep slope (80 to 85°), Saturation of overburden.

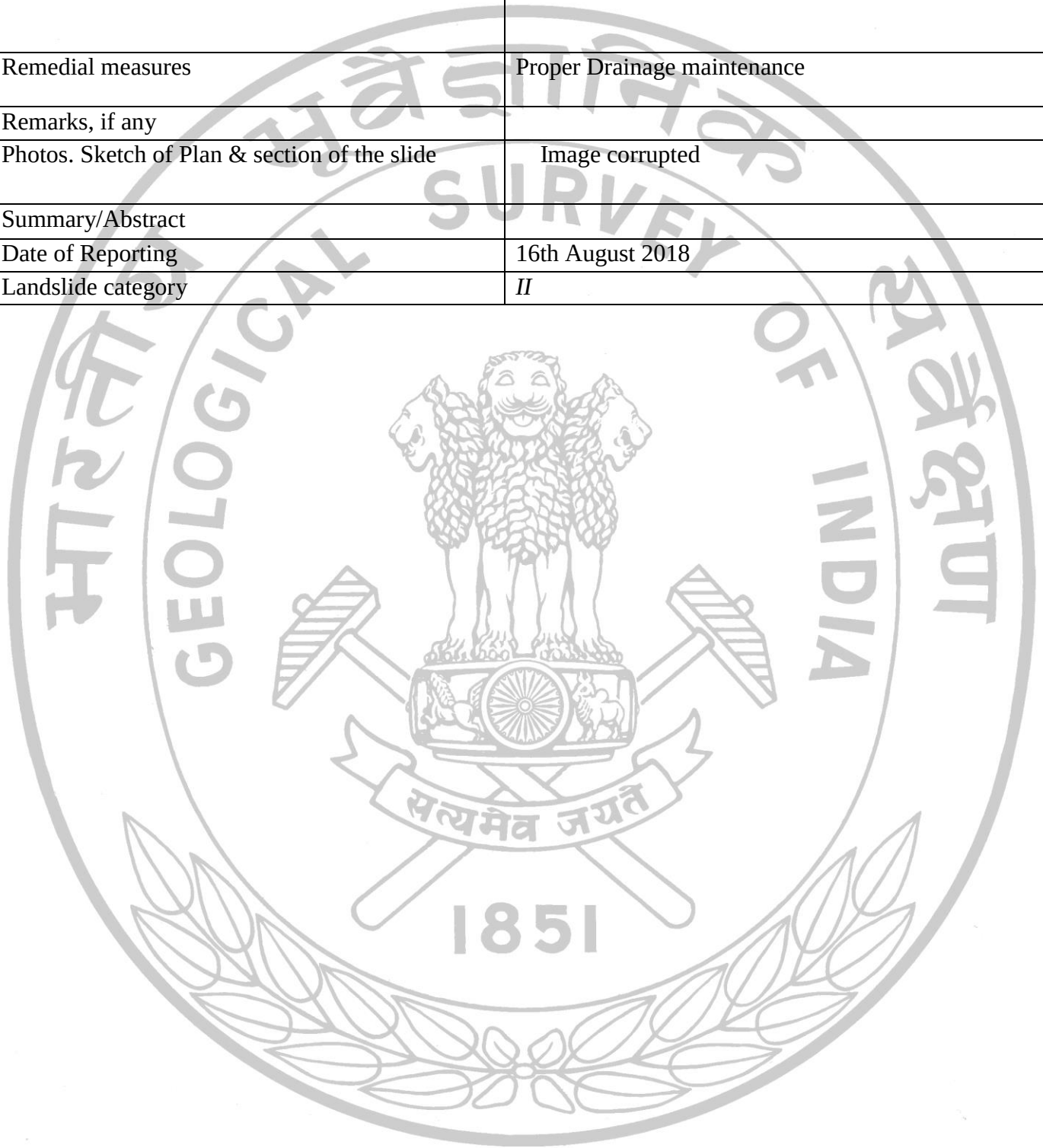
Remedial measures	Drainage maintenance, Nailing, Slope easing, Maintaining free flow of the water.
Remarks, if any	
Photos. Sketch of Plan & section of the slide	
Summary/Abstract	
Date of Reporting	16th August 2018
Landslide category	II

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P11/2019/82
State	Karnataka
District	Kodagu
Toposheet	48 P/11
Name of the slide	Barebellachur slide
NH/SH/Locality	
Latitude	12° 29' 59.513" N
Longitude	75° 43' 9.484" E
Length	100 m
Width	40 m
Height	20 m
Area	
Depth	
Volume	
Run out distance	40 m
Type of Material	Earth
Type of movement	Flow
Rate of movement	Rapid
Activity	Active
Distribution	Retrogressive
Style	Single
Failure mechanism	Shallow rotational failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite gneiss
Structure	
Land use/ Land cover	Coffee plantation
Hydrological condition	Dry
Triggering Factor	Rainfall
Death of persons	
People affected	
Livestock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture

Geo-scientific Causes	Partially weathered underlying rock Saturation of overburden and high slope
Remedial measures	Drainage maintenance, Nailing, Slope easing, Maintaining free flow of the water.
Remarks, if any	
Photos. Sketch of Plan & section of the slide	
Summary/Abstract	
Date of Reporting	16th August 2018
Landslide category	<i>II</i>

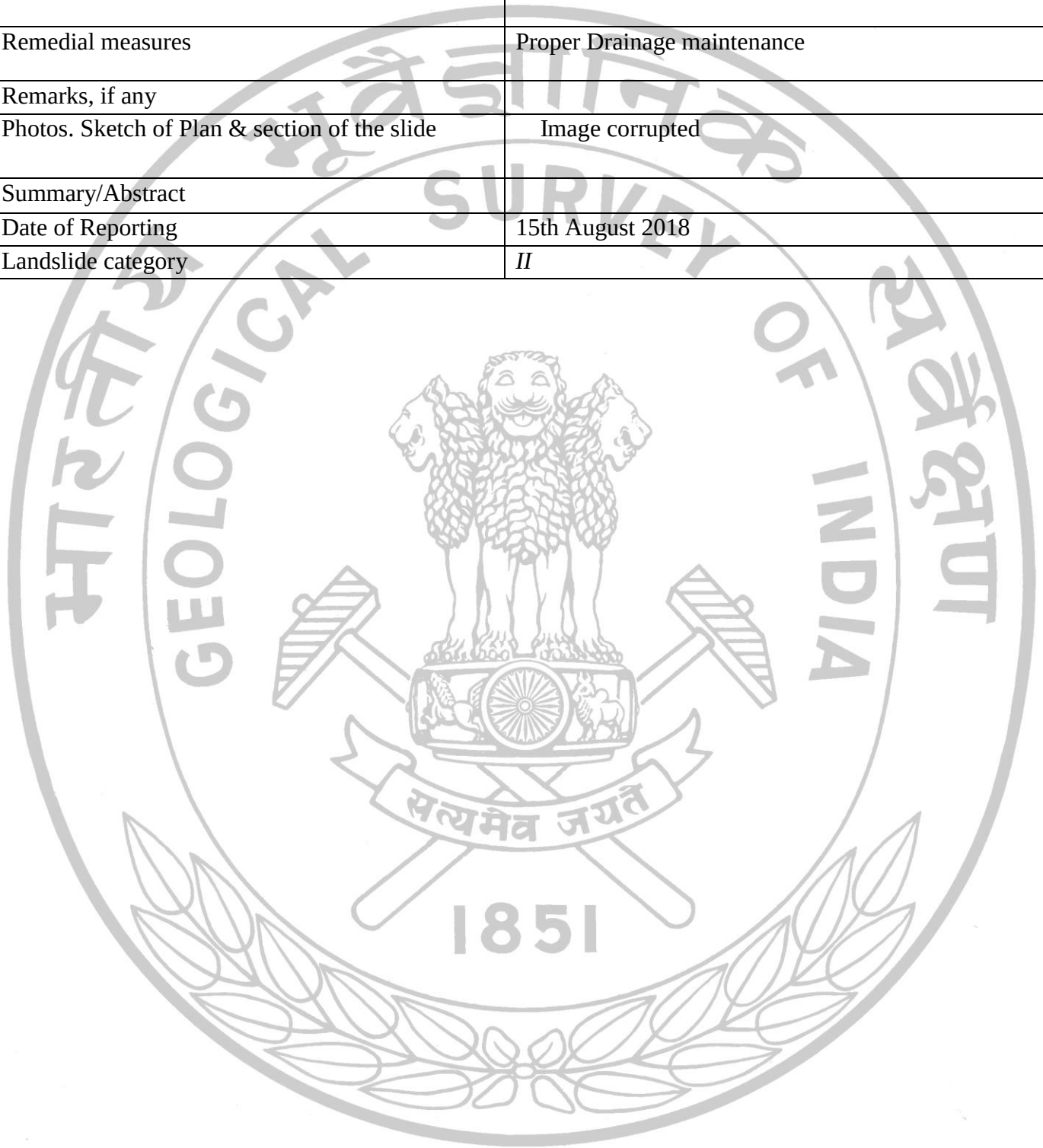
Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P11/2019/83
State	Karnataka
District	Kodagu
Toposheet	48 P/11
Name of the slide	Megatallu Slide
NH/SH/Locality	
Latitude	12° 29' 11.239" N
Longitude	75° 44' 56.946" E
Length	100 m
Width	15 m
Height	20 m
Area	
Depth	
Volume	
Run out distance	40 m
Type of Material	Debris
Type of movement	Slide
Rate of movement	Rapid
Activity	Active
Distribution	Retrogressive
Style	Single
Failure mechanism	Shallow translational failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite gneiss
Structure	
Land use/ Land cover	Coffee plantation
Hydrological condition	Dry
Triggering Factor	Rainfall
Death of persons	
People affected	
Livestock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture

Geo-scientific Causes	Toe cutting on flanks of the slopes on the sides of streams leading to collateral collapse, holding capacity of the stream exceeded during high rainfall
Remedial measures	Proper Drainage maintenance
Remarks, if any	
Photos. Sketch of Plan & section of the slide	Image corrupted
Summary/Abstract	
Date of Reporting	16th August 2018
Landslide category	II



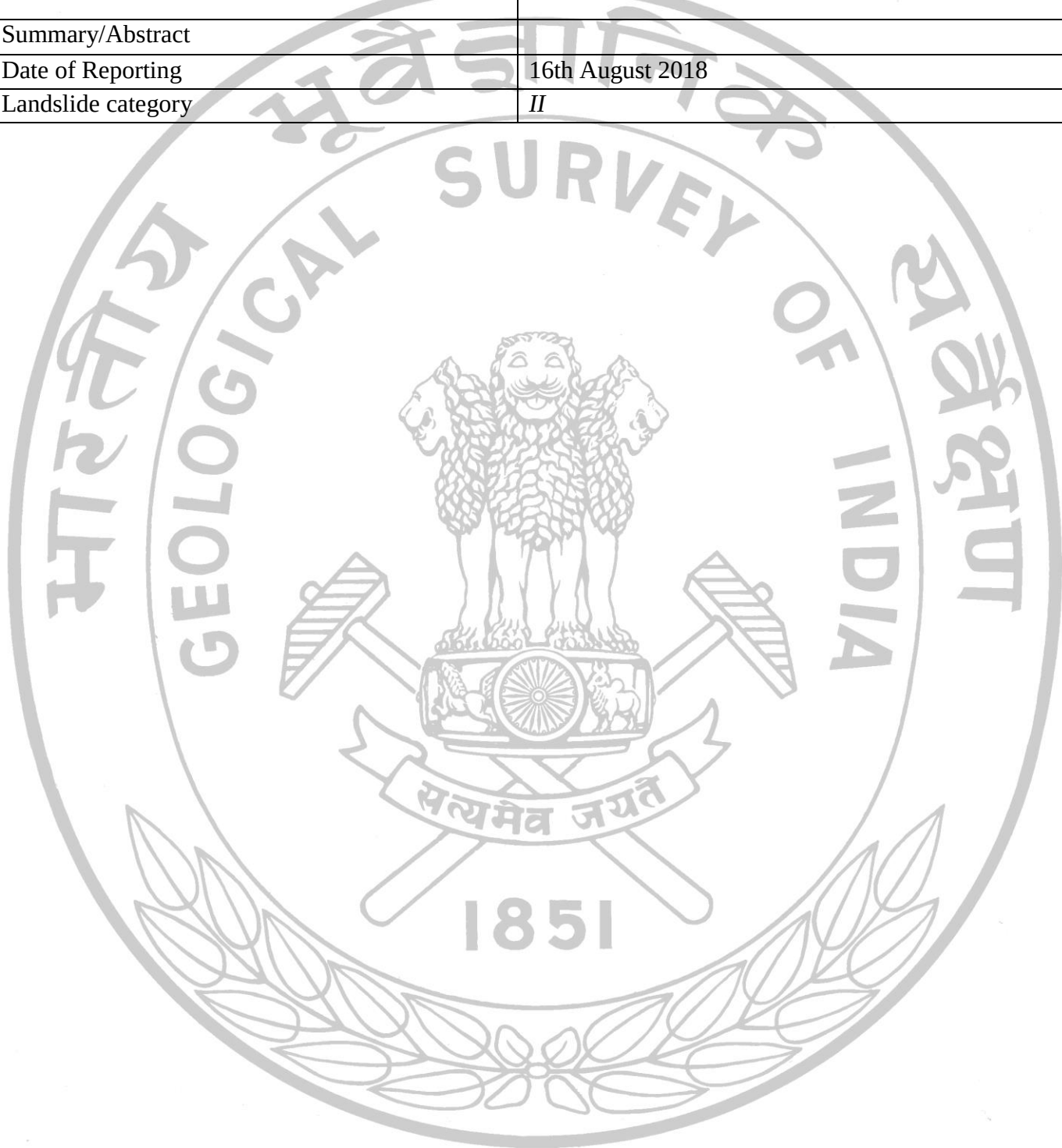
Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P11/2019/84
State	Karnataka
District	Kodagu
Toposheet	48 P/11
Name of the slide	Nidavattu Slide
NH/SH/Locality	Nidavattu
Latitude	12° 29' 7.852" N
Longitude	75° 44' 15.419" E
Length	60 m
Width	30 m
Height	20 m
Area	
Depth	
Volume	
Run out distance	15 m
Type of Material	Debris
Type of movement	Slide
Rate of movement	Moderate
Activity	Active
Distribution	Retrogressive
Style	Single
Failure mechanism	Shallow translational failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite gneiss
Structure	
Land use/ Land cover	Coffee plantation
Hydrological condition	Dry
Triggering Factor	Rainfall
Death of persons	
People affected	
Live stock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture

Geo-scientific Causes	Toe cutting, Saturation of loose material on slopes and high slope are the main contributing factors for the failure
Remedial measures	Proper Drainage maintenance
Remarks, if any	
Photos. Sketch of Plan & section of the slide	Image corrupted
Summary/Abstract	
Date of Reporting	15th August 2018
Landslide category	II



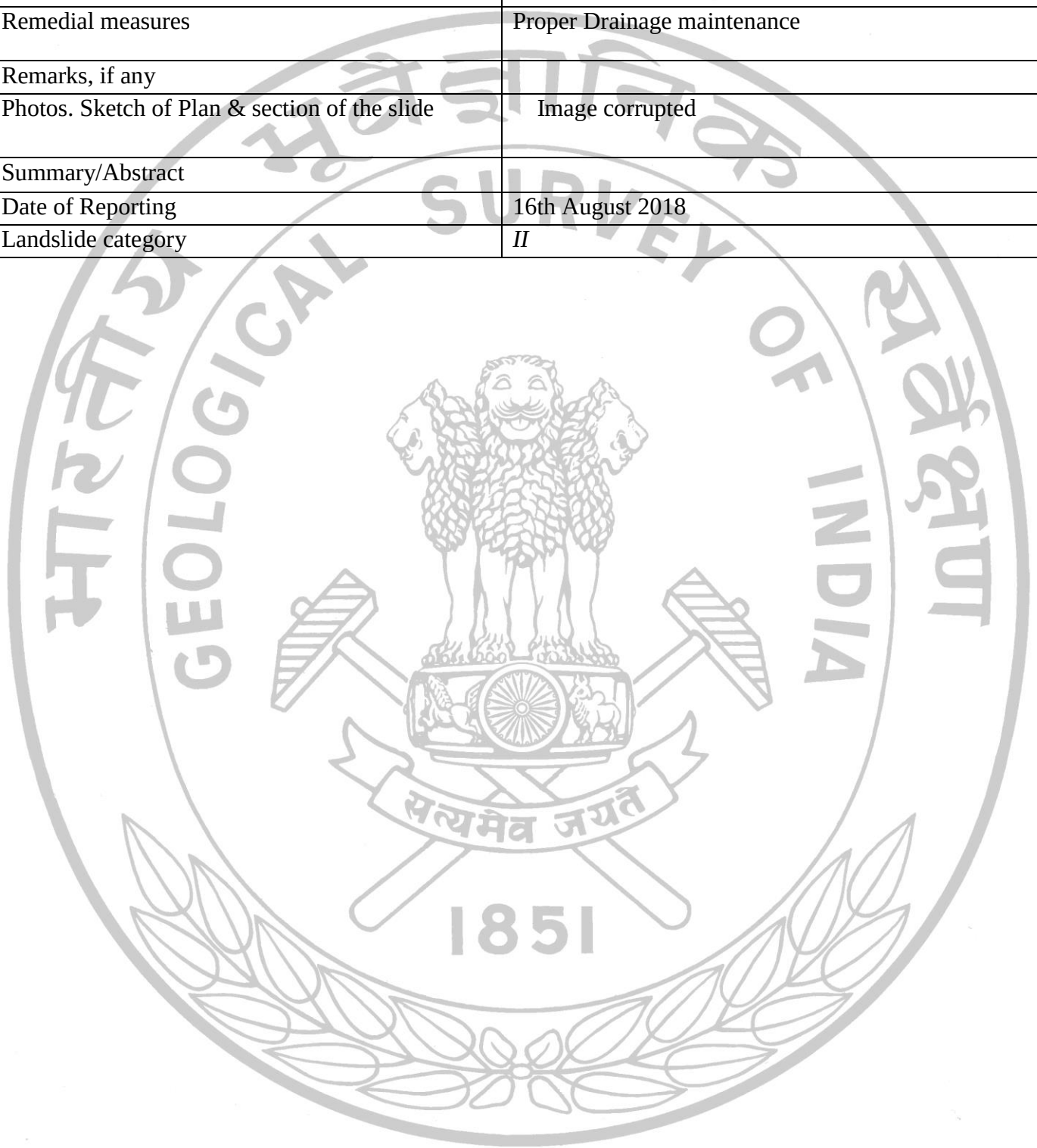
Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P11/2019/85
State	Karnataka
District	Kodagu
Toposheet	48 P/11
Name of the slide	
NH/SH/Locality	
Latitude	12° 29' 8.101" N
Longitude	75° 44' 17.333" E
Length	60 m
Width	30 m
Height	15 m
Area	
Depth	
Volume	
Run out distance	20 m
Type of Material	Debris
Type of movement	Slide
Rate of movement	Rapid
Activity	Active
Distribution	Retrogressive
Style	Single
Failure mechanism	Shallow translational failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite gneiss
Structure	
Land use/ Land cover	Coffee plantation
Hydrological condition	Dry
Triggering Factor	Rainfall
Death of persons	
People affected	
Livestock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture
Geo-scientific Causes	Toe cutting, Saturation of overburden and high slope.

Remedial measures	Proper Drainage maintenance
Remarks, if any	
Photos. Sketch of Plan & section of the slide	Image corrupted
Summary/Abstract	
Date of Reporting	16th August 2018
Landslide category	II



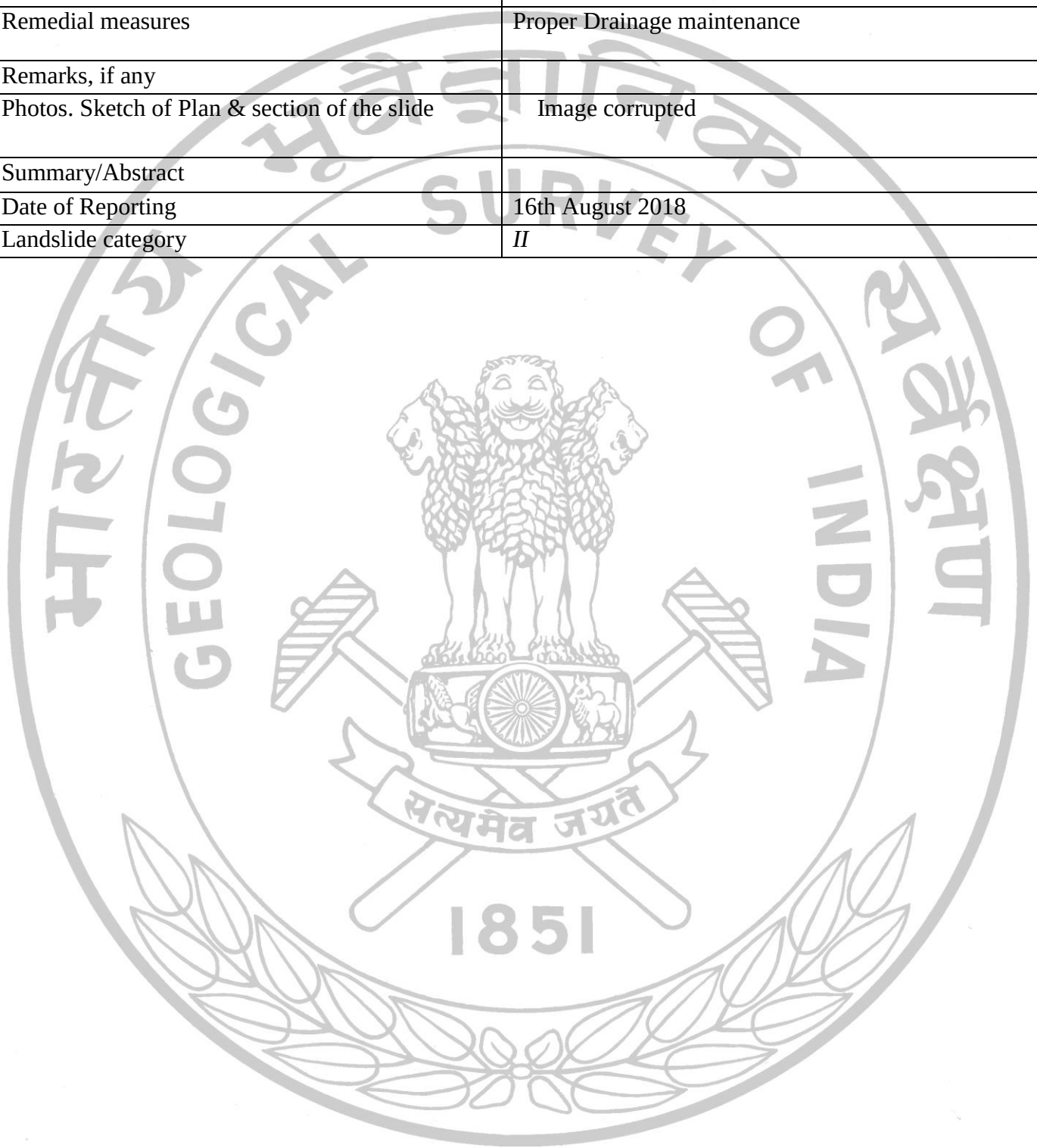
Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P11/2019/86
State	Karnataka
District	Kodagu
Toposheet	48 P/11
Name of the slide	
NH/SH/Locality	Nidavattu
Latitude	12° 29' 7.915" N
Longitude	75° 44' 13.363" E
Length	40 m
Width	30 m
Height	06 m
Area	
Depth	
Volume	
Run out distance	08 m
Type of Material	Debris
Type of movement	Slide
Rate of movement	Moderate
Activity	Active
Distribution	Widening
Style	Single
Failure mechanism	Shallow translational failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite gneiss
Structure	
Land use/ Land cover	Coffee plantation
Hydrological condition	Dry
Triggering Factor	Rainfall
Death of persons	
People affected	
Live stock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture

Geo-scientific Causes	Toe cutting, Saturation of overburden high flow in the first order stream, moderate slope.
Remedial measures	Proper Drainage maintenance
Remarks, if any	
Photos. Sketch of Plan & section of the slide	Image corrupted
Summary/Abstract	
Date of Reporting	16th August 2018
Landslide category	II



Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P11/2019/87
State	Karnataka
District	Kodagu
Toposheet	48 P/11
Name of the slide	
NH/SH/Locality	
Latitude	12° 29' 8.008" N
Longitude	75° 44' 11.895" E
Length	70 m
Width	40 m
Height	30 m
Area	
Depth	
Volume	
Run out distance	20 m
Type of Material	Debris
Type of movement	Slide
Rate of movement	Rapid
Activity	Active
Distribution	Retrogressive
Style	Single
Failure mechanism	Shallow translational failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite gneiss
Structure	
Land use/ Land cover	Coffee plantation
Hydrological condition	Dry
Triggering Factor	Rainfall
Death of persons	
People affected	
Live stock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture

Geo-scientific Causes	Toe cutting, Saturation of overburden high flow in the first order stream, moderate slope.
Remedial measures	Proper Drainage maintenance
Remarks, if any	
Photos. Sketch of Plan & section of the slide	Image corrupted
Summary/Abstract	
Date of Reporting	16th August 2018
Landslide category	II



Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P10/2019/88
State	Karnataka
District	Kodagu
Toposheet	48 P/10
Name of the slide	
NH/SH/Locality	Mukudlu village
Latitude	12° 30' 23.882" N
Longitude	75° 44' 28.244" E
Length	100 m
Width	80 m
Height	20 m
Area	
Depth	
Volume	
Run out distance	20 m
Type of Material	Earth
Type of movement	Slide
Rate of movement	Moderate
Activity	Active
Distribution	Retrogressive
Style	Single
Failure mechanism	Shallow rotational failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite gneiss
Structure	
Land use/ Land cover	Coffee plantation
Hydrological condition	Dry
Triggering Factor	Rainfall
Death of persons	
People affected	
Livestock loss	-
Communication	
Infrastructure	House of N K Somaya was partially damaged with cracks in almost all rooms of the house
Agriculture/forest/Barren	Agriculture

Geo-scientific Causes	Toe cutting, Saturation of overburden high flow in the first order stream, moderate slope.
Remedial measures	The foundation of the house should be built on sound rock
Remarks, if any	The house affected exhibit steep scarp on back side, the cracks in the house run from nalla near the house, the existence of house on scarp make it more vulnerable for future failures.
Photos. Sketch of Plan & section of the slide House with cracks	
Summary/Abstract	
Date of Reporting	15th August 2018
Landslide category	II

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P10/2019/89
State	Karnataka
District	Kodagu
Toposheet	48 P/10
Name of the slide	
NH/SH/Locality	Mukudlu village
Latitude	12° 30' 20.811" N
Longitude	75° 44' 27.322" E
Length	100 m
Width	40 m
Height	30 m
Area	
Depth	
Volume	
Run out distance	60 m
Type of Material	Debris
Type of movement	Slide
Rate of movement	Moderate
Activity	Active
Distribution	Retrogressive
Style	Single
Failure mechanism	Shallow planar failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite gneiss
Structure	
Land use/ Land cover	Coffee plantation
Hydrological condition	Dry
Triggering Factor	Rainfall
Death of persons	
People affected	
Live stock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture
Geo-scientific Causes	Toe cutting, Saturation of overburden.

Remedial measures	Proper drainage maintenance, allow free flow of water without any obstruction along the channel
Remarks, if any	
Photos. Sketch of Plan & section of the slide	
Summary/Abstract	
Date of Reporting	15th August 2018
Landslide category	I

Geo-parameter	Details
Slide No (LS .No.)	KAR/KOD/48P10/2019/90
State	Karnataka
District	Kodagu
Toposheet	48 P/10
Name of the slide	
NH/SH/Locality	Mukudlu village
Latitude	12° 30' 14.270" N
Longitude	75° 44' 20.206" E
Length	40 m
Width	20 m
Height	15 m
Area	
Depth	
Volume	
Run out distance	20 m
Type of Material	Debris
Type of movement	Slide
Rate of movement	Moderate
Activity	Active
Distribution	Retrogressive
Style	Single
Failure mechanism	Shallow translational failure
History	Nil
Geomorphology	Moderately Dissected slope
Geology/ Lithology	Granite gneiss
Structure	
Land use/ Land cover	Coffee plantation
Hydrological condition	Dry
Triggering Factor	Rainfall
Death of persons	
People affected	
Live stock loss	-
Communication	
Infrastructure	
Agriculture/forest/Barren	Agriculture
Geo-scientific Causes	Toe cutting, Saturation of overburden, toe cutting for road widening

Remedial measures	Proper drainage maintenance, allow free flow of water without any obstruction along the channel
Remarks, if any	
Photos. Sketch of Plan & section of the slide	
Summary/Abstract	
Date of Reporting	15th August 2018
Landslide category	I



GEOLOGICAL SURVEY OF INDIA

CERTIFICATE OF QUALITY OF THE REPORT

Project/Division: Engineering and Landslide

Item Code No.: M4LSSM/NC/SR/SU-KG/2018/26601

Mission: IV

FSP: 2018-19

Title of the report: Meso-scale Landslide Susceptibility Mapping (1:10 k) in and around Niduvattu, Mukkodlu & Megattalu areas, Kodagu districts of Karnataka.

Part – A:

This is to certify that the following Officer(s) have carried out the above mentioned FSP and are responsible for collection of field data, obtaining 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 Officer	Total field stay during the FSP	Signature with date
Aijaz Ahmad Bhat, Sr. Geologist	65 days	
Dr. Zameer Ahmad Shah, Geologist	63 days	

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

Drilling Unit No	Date of commencement of drilling	Date of completion of drilling	Name and signature of the Director Drilling
NA			

Part-C

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

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

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

Part -E

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

Name(s) and designation of the Supervisory Officers	No. of inspection visits	Total No. of days spent on inspection visit	Signature with date
K V Maruthi Director (G)	01	03	<i>K.V.</i> 31/10/19

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.

Name and designation of the Regional Mission Head	Signature with date
S.K. Tripathi Dy.DG, RMH-IV	Sk. Tripathi 31/10/19

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. Snidhan	M. Snidhan 31.10.19



GEOLOGICAL SURVEY OF INDIA

DATA SHEET ON REPORT MOVEMENT IN CONNECTION WITH ITS SCRUTINY

Project/Division: Engineering and Landslide		Item Code No.: M4LSSM/NC/SR/SU-KG/2018/26601
Mission: IV		FSP: 2018-19
Title of the report: Meso-scale Landslide Susceptibility Mapping (1:10 k) in and around Niduvattu, Mukkodlu & Megattalu areas, Kodagu districts of Karnataka.		
Names of author(s) Aijaz Ahmad Bhat Sr. Geologist	Date of submission to the Supervisory Officer with Signature of the author	01-10-2019 <i>[Signature]</i>
Name of the Supervisory Officer: K.V. MARUTHI DIRECTOR	Date of receipt of the report:	01.10.2019
	Date of completion of scrutiny:	08.10.2019
	Date of handing over the report to the author(s) after scrutiny:	09.10.2019
	Signature:	<i>[Signature]</i> K.V.
Name of the author to whom the report has been handed over by the Supervisory Officer: Aijaz Ahmad Bhat Sr. Geologist	Date of receipt after scrutiny:	09-10-2019
	Date of resubmission:	18-10-2019
	Signature:	<i>[Signature]</i>
Supervisory Officer:	Date of receipt after modifications:	18.10.19
	Date of handing over the report to the Regional Mission Head:	18.10.19
	Signature:	<i>[Signature]</i> K.V.
Name of the Regional Mission Head: S.K. Tripathi; Dy.D.G., RMH-IV	Date of receipt of the report:	21-10-19
	Date of handing over the report to the Project Director after peer review:	
	Signature:	<i>[Signature]</i> S.K. Tripathi

Supervisory Officer: K.V. MARUTHI DIRECTOR	Date of receipt of the report from the Regional Mission Head after peer review:	30-10-19
	Date of handing over to the author(s):	30-10-19
	Signature:	M. Maruthi. K.V.
Name of the author(s): AIJAZ AHAMAD BHAT SENIOR GEOLOGIST	Date of receipt of the report from the Supervisory Officer:	30-10-19
	Date of resubmission to the Supervisory Officer after modification:	31-10-19
	Signature:	
Supervisory Officer: K.V. MARUTHI DIRECTOR	Date of receipt of the report after modifications:	31-10-19
	Date of handing over the report to the Regional Mission Head:	31-10-19
	Signature:	M. Maruthi. K.V.
Name of the Regional Mission Head: S.K. Tripathi Dy. D.G., RMH-TV	Date of receipt of the report from the Project Director after modification:	31-10-19
	Date of handing over the report to the HOD of the Region for approval:	31-10-19
	Signature:	S.K. Tripathi
✓ Name of the HOD of the Region: M. Sridhar	Date of receipt of the report for approval:	31-10-19
	Date of approval:	31-10-19
	Date of sending back report to Project Director:	
	Signature : M. Sridhar 31/10/19	
Name of the Project Director:	Date of receipt of the report after approval of the HOD:	
	Date of circulation of the report:	
	Signature:	



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