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GEOLOGICAL SURVEY OF INDIA

A REPORT ON THE DETAILED SITE SPECIFIC STUDY OF BILIGERI SLIDE, SOMWARPET TALUK, COORG DISTRICT, KARNATAKA

(Progress Report for the Field Season 2006-07)

Code No.: EG/SR/KG/2006/070

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Geologist (Jr.)

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Project: ENGINEERING GEOLOGY

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कर्नाटक के कूर्ग जिले के सोमवरपेट तालूक के बिलिगेरी सर्पण क्षेत्र के विस्तृत विशिष्ट अध्ययन पर प्रतिवेदन

(क्षेत्र सत्र 2006-07 का प्रगति प्रतिवेदन)

कूट सं.:ई.जी./एस.आर./के.जी./2006/070-081

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सारांश

बिलिगेरी गाँव में, बसवेश्वरा मंदिर के पास पू.उ.पू–प.द.प. की ओर नमित पर्वत में द 10 प की ओर दिखने वाले ढाल के सर्पण क्षेत्र की प्रकृति, कारण एवं ट्रिगेरिंग क्रियाविधि को निर्धारित करने के लिए कर्नाटक के कूर्ग जिले में सोमवरपेट तालूक के बिलिगेरी क्रियाविधि के विस्तृत क्षेत्रीय भू तकनीकी अन्वेषण किया गया था. 1:1000 पैमाने पर 0.1 किमी के क्षेत्र में विस्तृत मानचित्रण किया गया एवं इस सर्पण क्षेत्र के ज्यामितीय को अनुमानित करने के लिए छह अनुप्रस्थ परिच्छेदन तैयार किए गए.

बिलिगेरे सर्पण क्षेत्र एक पुराने पुनः सक्रियित सर्पण क्षेत्र है. पुराने सर्पण क्षेत्र का क्रॉउन स्कार लगभग 10 मी ऊँचा है एवं संधित नाइसों को प्रदर्शित करते हुए लगभग अर्धाध्वर शीर्ष स्कार के साथ है. क्षेत्र में विस्तृत अध्ययन करते हुए तनाव मूलक/ अक्षीय एवं आडे दरारों एवं कंटकों के वितरण एवं पुराने सर्पण क्षेत्र के सीमाओं के स्थानिक वितरण से संस्तर को रेखांकित किया गया. अन्वेषित क्षेत्र का चट्टान प्रकार नाइस एवं डोलेराइट भित्तियों से बने है. स्थान क्षेत्र उसके पार्श्व पर दक्षिण–पश्चिम दिशा में बहने वाली दो झरनों से अपवाहित है. सर्पण क्षेत्र संस्तर के ढाल को बनाने वाली वस्तुएँ रेतीय से मृण्मय मिट्टी, गोलाश्म एवं नाइस एवं डोलेराइट शामिल मलबे से बना है.

क्षेत्र के प्राकृतिक ढाल को वेदिकायुक्त रोपण से परिशोधित किया गया है. ढाल संस्तर परिशोधित ढाल कोण 12 से 18 के बीच परिवर्तित होता है. दायिने पार्श्व में ढाल संस्तर की बाहरी सीमा ऊर्ध्वाधर रूप से प्रदर्शित डोलेराइट भित्ति के पास से गुजरता है, जो सर्पण क्षेत्र संस्तर से लगभग लंब पात में है. विस्तृत अध्ययन के आधार पर यह देखा गया है कि सर्पण क्षेत्र पुनः सक्रियित पुनक्रमणी सर्पण क्षेत्र का एक भाग है.

स्थान के शर्तों एवं सर्पण क्षेत्र के लिए उत्तरदायी भूतकनीकी अनुमान के कारणों (कारणात्मक एवं ट्रिगरिंग क्रियाविधि दोनों) सम्मोच्च रेखा/कैच ड्रेन आर.एल.1253 मी पर लगा देना चाहिए ताकि बाए पार्श्व झरने में क्रॉउन में जल अंतःक्रमण को माडा जा सके एवं रोक दिया जा सके. ढाल से आ रहे अधिक जल 1150 मी सम्मोच्च स्तर पर 1 मी के अन्तराल में क्षैतिज पेरोफोरेट्ड पाइप (10 पाइप) को लगाने करने से एकत्रित किया जाता है एवं निकास जल बाये पार्श्व के झरने में छिद्र जल दाब को कम करने के लिए कैच जल लाइन्ड ड्रेन ढाल को लगाने से एकत्रित किया जाना है सपर्ण संस्तर ढलान पर 110 मी लंबे कंक्रीट धारक भित्ति उ 52 प दिशा में लगा देना चाहिए ताकि ढाल को स्थायिकृत किया जा सके. विभिन्न स्तरों पर 7 अनुसंधात्मक वेधछिद्र की सिफारिश दी गई ताकि सर्पण क्षेत्र के स्लिप वृत्त को रेखांकित किया जा सके.

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ABSTRACT

Detailed site specific geotechnical investigation of Biligeri slide, Somwarpet taluk, Coorg district, Karnataka was taken up to assess the nature, causes and triggering mechanism of the slide on the slope facing S10ºW in the ENE-WSW trending hill near Basaveshwara temple, Biligeri village. The detailed mapping of an area of about 0.1 km² on 1:1000 scale was carried out and six cross sections were prepared to evaluate the geometry of this slide.

The Biligeri slide is a reactivated old slide. The crown scar of the old slide is nearly 10 m high with near vertical head scar exposing jointed gneisses. The slide zone was delineated from the spatial distribution of the tensional/ longitudinal and transverse cracks and ridges and the old slide boundary from the detail study of the area. The rock type of the investigated area comprises of gneiss and dolerite dyke. The site area is drained by two southwesterly flowing streams at its flanks. The slope forming material in the slide zone is debris comprising of sandy to clayey soil, boulders and gravels of gneiss and dolerite.

The natural slope of the area has been modified by terraced plantation. The modified slope angle of the slide zone varies from 12º to 18º. The outer boundary of the slide zone in the right flank passes near the vertically exposed dolerite dyke, approximately perpendicular to the slide zone. Based on detailed studies the slide is found to be part of a reactivated pro-grading slide.

As per the site condition and geotechnical evaluation of the factors responsible for the slide (both of causative and triggering mechanism) contour/catch drain should be provided at the crown at RL.1235 m to divert and prevent the slope water ingression into the crown to the left flank stream. The excess water from the slope is to be collected by inserting horizontal perforated pipes (10 nos.) at 1 m spacing at the 1150 m contour level and the outlet water is to be collected by providing catch water lined drain sloping to the left flank stream to reduce the pore water pressure. A 110 m long concrete retaining wall at the toe of the slide zone is to be provided along N52ºW direction to stabilize the slope. Seven exploratory boreholes have been recommended at different levels so as to delineate the slip circle of the slide.

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1. INTRODUCTION

The serene atmosphere of the picturesque landscape of the Western Ghats draped with evergreen canopy and chirping & humming of birds draw attention even otherwise for the damaging landslides destroying life and properties, disrupting communication lines as if punishing the mankind for the unmindful exploitation of the natural slopes with least attention for sustaining equilibrium of nature. The frequent slope failures during rainy season year after year have been a concern for the public and the administration. The load/pressure on the slopes of the Western Ghats has increased with time to sustain and accommodate the increase in density of population. The unscientific modification of the slopes (slopes being graded into small localized flatland) to bring more areas under plantation and creating more space for constructing new buildings (for housing, processing plants for economic activity, roads for communication etc.) without any consideration for slope stability have increased the risk to the inhabitants and the property in these stretches.

During the monsoon of 2005, the incessant rain for 11 days in Somwarpet taluk, Coorg district, Karnataka and the development of ground crack all along the slope of hill trending ENE-WSW near Basaveswara temple, Biligeri village for nearly 200 m, along the S10°W facing slope, damaged two houses on 27th July 2005. Local residents heard subterranean sound in the mid night of 26th July 2005. Cracks on ground and civil structures were noticed by the local people on 27th July 2005. The information in the print media describing it as a fissure on the ground caused due to seismicity created panic and anxiety among the residents and public. The area was visited by Shri M. M. Swamy, then Director and A. K. Mishra, Geologist (Jr.), EG Division, Op: Karnataka and Goa and was found to be a debris slide of a reactivated old slide. As

per the proposed action plan of MHA on landslide Hazard Risk and Mitigation, the detail site specific investigation of this slide was taken up to get an insight into the slide and its behavior on the slopes of Western Ghats. During FS: *2006-07* the item was taken up *as a service item no.081 (FS Code: EG/SR/KG/2006/070-081)***.**

1.1 Scope and objective: The objective of the study was to evaluate the old slide dimensions, new movement planes, crack propagation, mechanism of failure, triggering mechanism, depth and type of failure circle, stability of the slope, risk associated in the area and to propose suitable remedial measures or precautionary measure to stabilize the slope.

1.2 Geographic location: The site is located at 12° 33' 34"N latitude and 75° 48' 32"E longitude in toposheet no. 48 P/14, near Kibri coffee estate, 500 m northwest of Basaveswara temple, Biligeri village. The area is nearly 25 km southwest of Somwarpet, the taluk headquarter (12° 35' 45"N, 75° 51' 00"E) and 40 km northwest of Madikere, the district headquarter (Plate-1).

1.3 Nature and Quantum of work done:
The amount of work carried out during the period is given below:

Nature of work	Target	Achievement
1. Detailed mapping on 1:1000 scale	As necessary	0.1 Sq Km
2. Geological section		
a) Longitudinal section on 1:1000 scale	3 profiles	3 profiles
b) Cross section on 1:1000 scale	6 profiles	3 profiles
3. Drilling and SPT (to be out sourced)	350 m (At least 7 boreholes of 50m depth each	Not carried out
4.SMPL		
a) Undisturbed	20	Nil
b) Disturbed	20	5

1.4 Acknowledgements: The authors extend their sincere thanks to Shri R. Panduranga, Director, EG Division, Op. Karnataka & Goa, GSI, Bangalore for his guidance and scrutiny of the report. They also extend their thanks to the Deputy Director General, Op: Karnataka & Goa, GSI, Bangalore for his encouragement and support. Authors are thankful to the residents of Biligeri village and district authorities for rendering co-operation during the investigation.

2. PHYSIOGRAPHY AND CLIMATE

2.1 Topography: The slide slope is located on the NE-SW trending spur of the NW-SE trending hillock (Photo-1). The highest elevation in the area is 1235 m from MSL (NW corner of the hillock). The height of the slope from the water divide of the hillock to the stream (Nandimote) is nearly 1160 m with an average slope of 12°-18°. The whole slope from the water divide to Nondimote Hole has been modified during the long span of time for plantation and for making space for dwelling units (Photo-2). The modification includes terracing with eight major breaks in slopes (Photo-3, Plate – 3 to 5), flattening and grading of the slope. The steep old slide scarp is the first major break in slope of the area. The average topography is wavy with the ridges and depressions elongated parallel to the slide direction.

2.2 Drainage: The south western slope of the NW-SE trending hillock on which the slide is located has many small streams flowing in SW direction draining into the major perennial stream Nandimote Hole flowing towards SE direction. The area has sub-dendritic to trellis drainage pattern.

The site of investigation is drained by two major streams on its flanks (Photo- 4 & 5, Plate-3) running parallel for nearly 100 m and then join together draining into Nandimote Hole. A major depression/hollow extends all along the slide zone in NW-SE direction from above the crown of the old slide to the toe of the slide zone and joins the right flank stream. During rainy season when runoff is high the excess water from the slope is drained out through this major depression. The valley incisions of the streams have exposed bed rock all along their course with depth of valley incision varying from 1m to 10 m.

2.3 Climate and rainfall: The investigated area lies in Western Ghats and has a tropical humid climate and receives a sumptuous rainfall during monsoon with a unimodal distribution. The rainfall in this area is very high from June to September having as high as 139 rainy days in certain years with average annual rainfall of nearly 2123 mm (Annexure-I). The rainfall data from the nearest rain gauge station located at Madapura (Lat: 12° 55'N, Long: 75° 30'E, MSL 875 m) around 5 km south east of the site was collected from the local authorities and the rainfall pattern was studied (Fig.-1)

As shown in Table-1 below during the first half of July 2005 there was no rain and in the second half upto 23rd July 05 there was a maximum of 10 mm rainfall. There was a sudden

increase in the amount of rainfall from 24th to 26th (i.e 102 mm, 107 mm & 184.2 mm) and then a decrease from 27th July onwards (Fig.-2)

Table-1 Rain fall data for the 25 days prior and 7 days after the slide

Date	Rain fall in mm	Remarks
1st to 15th July 2005	No rain fall	
16th to 23rd July 2005	Maximum 10	
24th July 2005	102	
25th July 2005	107.4	
26th July 2005	183.2	
27th July 2005	134.2	Development of ground cracks reported
28th July 2005	86.8	
29th July 2005	97.4	
30th July 2005	67.0	
31st July 2005	74.4	
1st Aug 2005	78.2	
2nd Aug 2005	70.2	

***Source: PWD, Somwarpet taluk, Coorg District**

3. GEOLOGY

3.1. Regional geology: The lithounits exposed in and around the study area includes rocks of Sargur Group, Peninsular Gneissic Complex (PG-I) and Charnockite suite of rocks (Archaean), basic intrusives (Paleo-Proterozoic) and calcrete cover (Quaternary). Sargur Group is represented by hornblende schist and hornblende gneiss. Charnockite suite is represented by charnockite and pyroxene granulite occurring as irregular lensoidal bodies within PGC. This suite is exposed north and west of Somwarpet and south of Bellarimotte. Pyroxene granulite occurs as linear to tabular bands within PGC trending NW-SE and NNW-SSE directions. It is exposed throughout the area (Iyengar, 1957) (Plate -2).

3.2 Geology at site: The lithounits exposed in the slide zone are either due to valley incision of the stream or the vertical scarp formed by earlier sliding event or removal of the overburden by run off. The different type of rockmass includes gneiss, dolerite dyke and the debris & boulder unit.

3.2.1 Gneiss: The base of the slide zone rests on the gneiss which exhibit six sets of joints (Table-2). The rocks are well exposed in the crown scarp, in both the flanks in the stream beds, central part of the toe region near the right flank and as scattered outcrops on the slope at many places. It is coarse grained, light grey, foliated granite gneiss with gneissosity varying from N21°W-S21°E to N10°E-S10°W dipping vertical to 42° towards south. Boulders of gneiss are also found in the debris as float mass (Photo- 6 & 7, Plate-3 to 6).

Table-2 The joint characteristics of the 6 sets of joints in gneisses

Sl. No	Joint set	Attitude	Spacing	Filling
1	Jt1	N5°W/Vertical	50 cm	Nil
2	Jt2	N15°W/69°S	30 cm-1 m	Nil
3	Jt3	Horizontal	35 cm	Nil
4	Jt4	N64°E/vertical	single	Nil
5	Jt5	S20°W/Vertical	single	Nil
6	Jt6	N-S/42°E	single	Nil

3.2.2 Dolerite: A Dolerite dyke trending N-S is exposed near the head of the slide below Kusallappa's house and E-W in the midslope below Chittappa's house. It is fine to medium grained and dark green consisting essentially of pyroxene and plagioclase. The vertical

E-W dyke has three sets of joints (Table-3) and is acting like a retaining wall in the left flank of the midslope and also marks the left boundary of the slide zone (Photo-8, Plate-3).

Table-3 Joint characteristics in the dolerite dyke

Sl. No	Joint set	Attitude	Spacing	Filling
1	Jt1	E-W/Vertical	50 cm	Nil
2	Jt2	N-S/ Vertical	50 cm-1 m	Nil
3	Jt3	Horizontal	1-2 m	Nil

3.2.3 Debris and boulder unit: This unit consists of unconsolidated rock fragments of dyke and gneisses (gravel, cobble and boulder size) and sand, silt and clay. The rock fragments vary in size from 2 cm to 2 m. The boulders of gneiss and dolerite ranging in size from 1 to 2 m are dispersed all over the slide zone (Photo-9 & 10, Plate-3).

4. WEATHERING

The type of litho units and the nature of weathering of the slope forming material determine the effective pore space, permeability, clay content, cohesion and retentivity and run off. The physic-mechanical properties of the slope forming material thus depend on the grade of weathering.

The gneissic rock exposed all along the stream section on the flanks of the slide zone is fresh to partially weathered. Dolerite dyke is fresh to partially weathered at surface. The exfoliation weathering (mechanical weathering) of this rock unit is prominent. The highly jointed nature of the rock in association with high rainfall has dislodged huge blocks of the dyke and gneiss which have rolled down and are scattered all over the slope as float mass. The fresh rock is exposed in the stream beds and moderately weathered rock outcrop is seen in the scarp. The weathering is expected to be upto a depth of 20-30 m in the slide zone (Photo-11 & 12, Plate-3).The fragments of highly weathered gneiss in a clay matrix was observed in the right flank of the slide.

5. LAND USE AND LAND COVER

In general, the area is covered with lush green to moist evergreen forest. The slope above the failed mass has moderate land cover due to coffee plantation but the slide zone in particular has scanty. Even though the natural slope of the site has been modified for plantation at the crown, near the head and upper part of the mid slope, the high shade requirement for coffee plantation has spared many forest plants with reasonably good shoot/root ratio. This has helped in binding the loose top soil but the vegetation has added more weight on the top distressed mass.

The land use pattern in the area is mainly controlled by the type of land holding, lease area and time span of the slope modification. The higher contours up above the crown scarp and the lower contours where streams of both flanks meet coffee plantation can be seen. The other major plantation crops in the slide zone are areca nut, banana, coconut, guava, cardamom, mango, silver oak etc,. In the investigated area from crown scarp to the meeting point of the streams in both flanks, twenty long wide flattened terraces are found. Nine of them lie in the slide zone with high degree of human activity. This can be judged from the fact that seven residential units, one coffee processing plant, six water tanks, a total of 40 m long masonry boundary wall (2 m high and 0.5 m wide) and two motorable roads with a total length of more than 70 m lie over an area of ~5600 m^2. Thus slope is not only highly modified but overused (Photo-13, Plate-3)

6. GROUND WATER

The composition and type of slope forming material at the site is due to the prevailing groundwater regime. The ground water table fluctuation has heightened the opening up of the joints in the jointed gneiss and dolerite leading to dislodgement of boulders, development of clay horizons, increase in depth of weathering, development of soil profile and increase in volume of the overburden and debris on the slope.

The seasonal fluctuation of the ground water table is very high in the area and is directly proportional to the variation in rainfall. June, July and August receive almost 70 to 80% of the total rainfall of the year, preceded and succeeded by comparatively dry spells.

The ground water table at the site was observed in the unlined dug well of 1 m diameter at the northwestern corner of Chittappa's house in the mid slope (Photo-14). During the time of investigation standing water in this well was at a depth of ~1.5 m indicating ground water table in general to be at a depth of 1.5 m (Photo-15). The observation could be a little erroneous as the upper contours in the slide zone were well irrigated through drip irrigation. The continuous irrigation for coffee plantation at the time of investigation might have caused the ground water table to rise to this level. However, variation in water level may not be significant as the streams flowing in the left and right flank of the slide are perennial and the unlined storage pond for water near the crown at the upper contour was observed to have water at neck level indicating a shallow water table.

7. LANDSLIDE CHARACTERISTICS

An area of about 0.1 km² was covered by detailed mapping on 1:1000 scale and six cross sections were prepared to evaluate the geometry of the slide (Plate-3 to 9). The slide zone is bounded by two southwesterly flowing streams at its flanks. Gneiss and dolerite dykes are exposed in and around the slide zone. The slope forming material in the slide zone is debris comprising of clayey soil and boulders of gneiss and dolerite. The natural slope of the area has been modified by terraced plantation. The modified slope angle of the slide zone varies from 12º-18º. The crown scar of the old slide is found to be nearly 10 m high exposing jointed gneiss. The tensional/ longitudinal and transverse cracks and ridges in the investigated area were mapped. From the crack disposition pattern the boundary of the slide zone was delineated. The outer boundary of the slide zone in the right flank extends up to the vertically exposed dolerite dyke which is approximately perpendicular to the slide zone. The details of the Biligeri slide, Somwarpet Taluk, Coorg district, Karnataka is given in Annexure-II.

7.1 Morphological parameters: The morphological parameters of the hill slope were calculated from toposheet of Survey of India on 1:50,000 scale and the slide morphometry were calculated from the plan and sections prepared on 1:1000 scale (Plate-3 to 9).

7.1.1 Hill slope morphometry:

a.	Length of the hill slope from divide to river channel	(Ls)	**:**	**~2 km**
b.	Vertical height between the heights of the divide and of the stream	(Hs)	**:**	**225 m**
c.	Plan distance of the slope from divide to stream	(HEs)	**:**	**925 mm**
d.	Mean slope angle	(Bs)	**:**	**13.67°**

7.1.2 Slide morphometry:

a.	Maximum length of the slide zone from crown to foot	(Lm)	**:**	**180 m**
b.	Maximum width of the slide zone from the left flank to the right flank boundary	(Wm)	**:**	**45 m**
c.	Maximum depth of the failed mass from the surface of the slide to the failure surface	(Dm)	**:**	**16 m**
d.	Perimeter of the slide		**:**	**585 m**
e.	Area of mass movement /Surface area of the slide zone in plan	(A)	**:**	**~5600 m²**
f.	Volume of mass above the failure surface	(V)	**:**	**~60,000 m³**
g.	Failure angle-Slope angle at which failure took place	(β)	**:**	**18º**

7.2 Type and size of slide material: The slope forming material is debris and consists of the predominant coarse (gravel, cobbles and boulders) materials with minor amount of finer material (clay, silt and sand). Loose unconsolidated to partially consolidated material excavated from the original slope seem to have been dumped in the slope of terraces. Even though the exact volume and spatial extent of this cut and fill material could not be demarcated due to the slope modification of the area by the residents for more than 50 years but dumped material was observed in patches at many locations at the break in slopes (Photo-16 to 19). The rock fragments vary in size from gravel to boulder of dyke and gneiss composition varying in sizes from 2 cm to 2 m in a clayey sand matrix (Photo-9 & 10, Plate-3).

7.3 Spatial distribution of cracks and slide characteristics: Pattern of development of cracks gives an idea about the mechanism and direction of movement. The crack development pattern is the most important character in delineating the slide zone boundary. The best fit circle to the concentric crown cracks (Plate-10, Photo-20 to 25) at the Kusallappa's house just below the old scar (main scarp) was used to calculate the crown radius, width and the point of failure. The crown width was calculated to be 45.49 m.

The head/ the bottom of the old slide scar and the outer most concentric crown crack defined the northern boundary, whereas the east and west boundary of the slide was defined as per the disposition of the outermost longitudinal cracks and the emanating cross transverse cracks in both the flanks. The southern boundary/foot of the slide was demarcated at the break in slope near the coffee processing plant where the ridge occurred.

The maximum length of the slide zone as deduced from the detailed mapping is 180 m. The depth of the failed mass was calculated using the diameter of the best fit circle of crown cracks. The best fit ellipsoid that the slide mass can be fitted into, has major and minor axes as 180 and 45.49 m respectively. The failed mass forms an ellipsoidal part of the half spheroid formed with the horizontal plane being the upper surface (i.e. the projection of the ellipsoidal mass to the horizontal). The average depth of the slide zone is projected back on to the plane dipping 18° (average slope angle of the site) and is calculated to be ≈21 m, which roughly matches the depth of the probable slip circle calculated from the sections (Plate-4 to 9).

The crown cracks near Kusallappa's house have a vertical displacement of about 8 cm and the longitudinal body cracks near the main tar road has a vertical displacement of 6 cm. The

effective horizontal and vertical displacement of cracks showed that the movement of the slide was small.

7.4 Classification of slide: The factors used to classify landslides mainly are type of material involved, geomorphic attributes of the slope, landslide geometry, type of movement, climate, water content of the slided material, speed of movement of the slide, triggering mechanism etc. The slide at Biligeri is classified as a deep seated debris slide (Verne, 1978). The field observation indicates this slide to be a reactivated old slide. As per the rate of movement classification (WP/WLI, 1995) it is an extremely slow-slow slide (Jakob, 2005). As per the size classification (Fell, 1994) it is a medium landslide.

8. CAUSES AND TRIGGERING MECHANISM

The instability of this slope has increased over a period of time and due to various factors affecting simultaneously like slope modification, type of slope forming material, depth of weathering, ground water table variation etc. which either has increased the shear stress or decreased the shearing resistance of the material for the slope to fail. The causes for increasing the susceptibility of the slope to fail without actually initiating the slide can be classified as external and internal.

8.1 External causes:

8.1.1 Removal of slope support and modification of slope geometry: The slopes is being drained by two streams and a major mid section depression or hallow which joins the south easterly flowing stream near the toe of the slide zone. These streams have undercut the valley exposing the fresh bed rock and enhancing erosion, transportation of material from the slope and hence disturbing the natural equilibrium of the slope. The modification of slope geometry for plantation, excavation for buildings and roads in long term has increased susceptibility of the slope to landslide.

8.1.2 Increased loading of the crest and slope and transient effects: The investigated slope has been loaded at three distinct levels i.e. the head/crest, mid slope and toe. The old dormant slide was not identified earlier and heavy constructions at the crest, mid slope and toe were carried out. The weight/load of the constructions at the crown helped in aggravating the hazard by increasing the stress on the slope material. The residential buildings and the major tar road along the midslope are partially resting on the debris/dumps of the modified slope. The major road through Biligeri village passes exactly in the mid slope of this slide zone. The vehicular traffic even if meager has added instability to the slope.

8.1.3 Drainage: The main cause of the slope saturation is water. The developmental activity in the slope is haphazard by which the natural drainage has been blocked intermittently at all levels. No drainage network exists to divert the excess water from irrigation or the runoff during the rain. An unmetalled road running in the mid section of the slope (Plate-3) to the flat land on the head/crest allowed a lot of stagnation and infiltration of water during rain. The poor/ absence of drainage aggravated the slope instability by increasing the unit weight by infiltration into the loose slope material. The leakage of water from the storage tanks inside the slide zone cannot be ruled out. As draining of excess water from the slope is low and the

accumulation/infiltration of water into the slope material is high, there was a rise in pore water pressure.

8.2 Internal causes: Decrease in strength of slope material due to the fluctuation in the ground water level has reduced the cohesion and the shear strength of the material. The physical and chemical weathering of soils caused loss of strength (apparent cohesion and friction). Lower permeability of the slope material (observed in the constant head method at three sites inside the slide zone, Plate-3) may be due to clay content which was responsible for high pore pressure causing the failure Table-4.

Table- 4: Permeability test carried out in the slide zone BG-1 in the toe region, BG-2 and 3 in the mid slope region, BG-4 at the crown

Test hole nos.	**BG1**	**BG1**	**BG2**	**BG2**	**BG3**	**BG4**
Diameter	21.5 cm	21.5 cm	9 cm	9 cm	22 cm	22 cm
Depth	23.5 cm	23.5 cm	32 cm	32 cm	24 cm	24 cm
K value(liters/min)	1.255	1.95	4.019	8.842	2.712	2.26

8.3 Triggering mechanism: The antecedent and precedent rainfall in the area during the monsoon of 2005 shows a sharp rise and have a positive correlation with the slope failure. The high saturation of the slope material during heavy precipitation and the seepage of water along the earlier weak plane of the old slide caused the sliding. The high rainfall is the immediate trigger for this slide.

9. CONCLUSIONS AND RECOMMENDATIONS

9.1 Conclusions: Detailed site specific study of Biligeri slide, Somwarpet taluk, Coorg district, Karnataka was taken up to study the behaviour of the slide in the S10°W facing slope of the ENE-WSW trending hill near Basaveshwar temple, Biligeri village. The Detail mapping in 1: 1000 scale was carried out in the slide zone and the unstable zone was delineated. As proposed, drilling of the seven boreholes could not be taken up for want of approval. The slide was studied and the approach of morphometric analysis was carried out with the spatial distribution of cracks and their disposition. After detailed study of the site the following conclusions could be drawn.

1. The slide was a reactivated slide.
2. The depth of failure is approximately calculated to be at 15 m.
3. The failure is found to be a base failure from the field observation and the model prepared.
4. Surface fracture pattern and their spatial distribution were used to arrive at the slide geometry.
5. The topographic depression extending from the crown of the old slide has been modified or graded for coffee and spice plantation thus obstructing the natural drainage, thus high infiltration and positive pore pressure development.
6. The high monthly rainfall of >600 mm in average for the month of July from 1970-2000 deteriorated the conditions though did not cause any slope failure. But during 2005 ~100 mm rainfall caused the slope failure.

9.2. Recommendations: The Biligeri slide is a reactivated prograding deep slide. As per the site condition and evaluation of the factors responsible for the slide (both causes and triggers) the following remedial measures are proposed:

1. Horizontal perforated pipes (10 nos.) at 1m interval at the 1150 m contour level with catch water lined drain to the left flank stream to drain out the excess water from the slope to reduce the pore water pressure (Plate-3 to 6).
2. Providing contour drainage at the crown following 1205 m and to divert the slope water to the left flank stream so as not to charge the crown with excess water (Plate-3). Intermediate drainage should be provided at the foot of each terrace. The blockade of the natural drainage hollow is to be modified so as to channelize the excess run off during rain.

3. Further construction in the slide zone should be avoided.
4. Construction of retaining wall of 110 m long below the coffee processing plant in N52ºW direction at the toe.
5. Providing inclined piles at the toe (Plate-3 & 4).
6. Though the slide is prominent and the movement is slow, the rainfall pattern of the area can trigger the slide to become a hazardous landslide in future. So the residents in this zone should be vacated as it is not safe for habitation.
7. Seven bore holes are proposed (Plate-1) to confirm the depth of weathering, subsurface geological condition, physic-mechanical properties of lithounits and the probable slip circle. The location and specifications of each borehole are given in Table-5.

Table- 5: Proposed borehole locations in the slide zone:

Borehole no.	Location	R.L. in m	Proposed depth (m)
BH-1	In front of Kusallappa's house near the crown	1185	15
BH-2	Near the house in the midslope, where the estate road takes left turn	1170	30
BH-3	Behind Chittappa's house	1160	30
BH-4	On the flat land below the road SE of Chittappa's house	1150	30
BH-5	Behind the labourers quarter near the water tank	1150	30
BH-6	In the depression zone below Kusallappa's house	1180	15
BH-7	Near the water tank NW of Chittappa's house	1155	30

8. SPT (Standard Penetration Test) and geotechnical properties are to be determined for undisturbed samples (UDS) at 3 m interval and disturbed samples of the debris at different depth to accurately bring out the slip circle/failure plane.
9. Constant monitoring by installing crack recorder, tensiometers, and inclinometers in the slide zone may give insight to the behavior of the modified slope of this area. The settlement pillars are to be installed to know the subsidence rate of the slope.

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SYNOPSIS OF WORK DONE

1.	Title of the report	**"REPORT ON DETAILED SITE SPECIFIC STUDY OF BILIGERI SLIDE, SOMWARPET TALUK, COORG DISTRICT, KARNATAKA"**
2.	Item No.	RP/ SR/KG/2006/O70
3	Field Season	2004-05 & 2005-06
4	Date of commencement	2004-05
5	Date of completion	2005-06
6	Officers Associated with investigation and No. of days spent in the field	R. Dharuman, Geologist (Sr.) A.K. Mishra, Geologist (Jr.)
7	Quantum of work done (i) Detailed Mapping 1:1,000 scale (ii)Longitudinal sections (iii)Cross sections	0.1 Sq. km 3 nos. 3 nos.
10.	Expenditure (1) POL (2) Wages (3) Misc.	 Rs 2,526.00 Rs 3,000.00 Rs 787.00
11.	Other information if any	----

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