Ground Improvements for Landslide Prevention along the Road between Kywedatson and Wetphyuye, Mandalay Region and Shan State, Myanmar

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Abstract

The research is carried out for the ground improvement to prevent landslide along the Kywedatson-Wetphyuye car-road, Mandalay Region and Shan State. This area has mainly composed of sedimentary, metasedimentary and igneous rocks experienced four types of landslides, rockfall, debris flow, creep and slump along the road particularly during the rainy season. The rocks exposed along the road can be classified into three groups by joint density analysis such as (a) low joint density zone, (b) moderate joint density zone and (c) high joint density zone. 54 possible slope sites are selected and studied for the approved suitable landslide prevention methods. Due to Slope Mass Rating (SMR), the slope sites can be classified as (a) very low hazard zone, (b) low hazard zone, (c) medium hazard zone and (d) high hazard zone. Among them, constructing trap ditches and fence should be performed in 29 rockfall sites whilst the removal of slope debris and unstable rock overhangs is recommended. In addition, reshaping slope geometry, revegetation, installation of surface drainages and precaution signage should be done before the rainy season.

Keywords:Landslide prevention method, slope mass rating, trap ditches and fence

Introduction

The present research is carried out for selecting the suitable landslide prevention methods along the road between Kywedatson and Wetphyuye, Mandalay Region and Shan State, Myanmar (Figure 1). This area is mainly composed of sedimentary, metasedimentary and igneous rocks which include rocks of Yinmabin Metamorphics (Paleozoic), Lebyin Group (Carboniferous to Lower Permian), Plateau Limestone Group (Middle Permian to Middle Triassic), Loi-an Group (Jurassic), Pyinnyaung Formation (Upper Jurassic to Cretaceous), Kalaw Red Beds (Cretaceous), Older Alluvium (Pleistocene) and Alluvium (Holocene). The igneous rocks comprise granitic rocks, dioritic rocks, rhyolite and other igneous rocks of minor occurrence (Mesozoic) and granite gneisses (Upper Tertiary) as meta-igneous rocks.

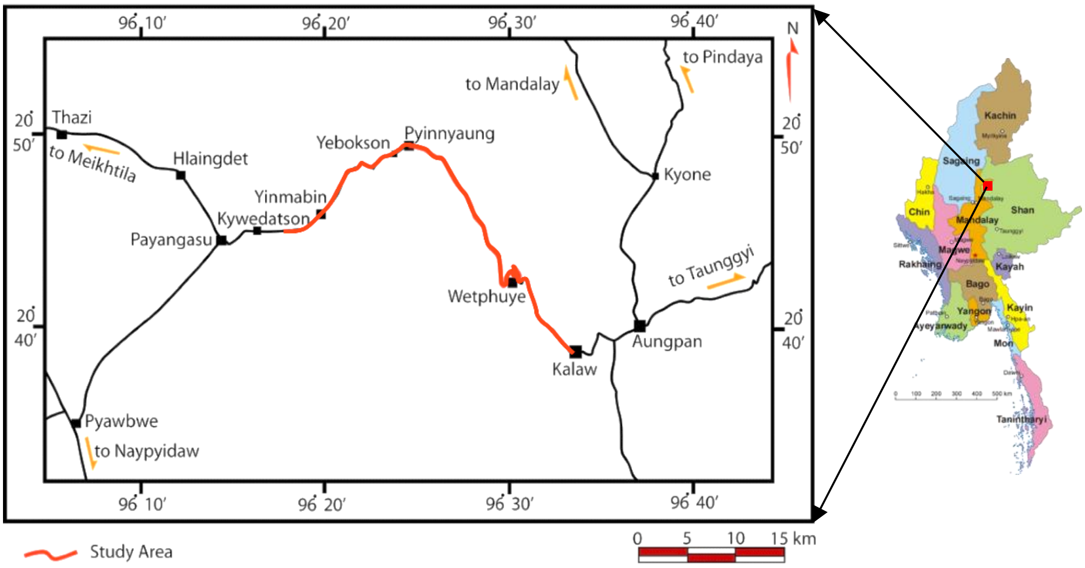

Figure (1) Location map of the research area

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Past Landslide

Landslides are common along the road particularly during the rainy season. Four types of landslides, rockfall, debris flow, creep and slump have been identified along this road which is shown in Figure (2), (3), (4) and (5). Rockfall is the common landslide type mainly occurred along the manmade road cuttings. Debris flow also occurred in the past along the road. It can be harmful, resulting undesirable consequences including fatalities, triggered by heavy and prolong rainstorm event particularly during rainy season. Erosion of rivers or stream banks may cause soil creeps during heavy rainfall.

Figure (2) Rockfall at the western part of Yinmabin

Figure (3) Debris flow at the eastern part of Yebokson

Figure (4) Creep by river bank erosion at the eastern part of Yinmabin

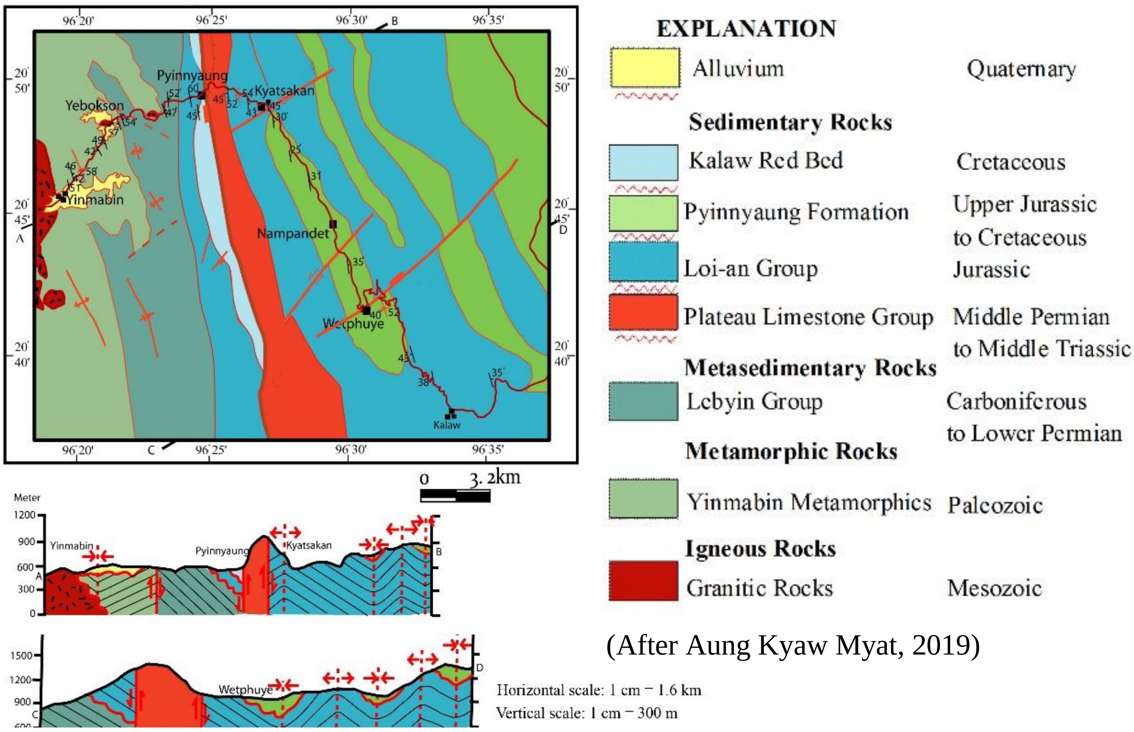
Figure (5) Slump in residual soil at the western part of Wetphyuye

Geological Investigation of the Research Area

The rocks are composed of Yinmabin Metamorphics, Lebyin Group, Plateau Limestone Group, Loi-an Group, Pyinnyaung Formation and Kalaw Red Bed. Detailed geological map with cross-section is shown in Figure (6).

The rocks of Yinmabin Metamorphics is mostly composed of sandy phyllite and calc-phyllite with igneous intrusions which is exposed at the Kywedatson and Yinmabin Areas. Metagreywacke, quartizite and phyllite comprise in Lebyin Group which is distributed in the eastern part of Yebokson Area. Brecciated limestone and micritic limestone with highly jointed and massive nature of the Plateau Limestone Group occur at the vicinity of the Pyinyaung area.

Loi-an group is exposed at the eastern part of the Pyinnyaung Village which is mainly composed of yellowish brown to buff colored sandstone interbedded with thinly laminated shale, partly carbonaceous shale. Pyinnyaung Formation is mainly exposed in Pyinnyaung area which comprises thin to medium bedded sandstone alternated with thinly laminated siltstone and shale. Kalaw Red Bed is well exposed at the eastern part of the area. The rocks are reddish brown colored, medium to thick bedded asiltstone intercalated with shale.



(After Aung Kyaw Myat, 2019)

Figure (6) Geological map and diagrammatic cross-section of the study area

Aims and Objectives

This research mainly aims to select the suitable prevention methods for landslide based on geological and geotechnical data. Objectives of this study are to observe past landslide localities and possible landslide triggering localities of study area, to analyze by Slope Mass Rating (SMR), to explore the suitable slope cutting method and to select the suitable retaining structure and drained pipes.

Methodology

The landslide of the research area was identified based on landslide classification of Cruden and Varnes (1996).

Geomechanics classification of Rock Mass Rating (RMR) (Bieniawski, 1989) system has been used to find Slope Mass Rating (SMR) (Romana, 1993). The SMR is obtained from RMR by adding a factorial adjustment factor; depending on the relative orientation of joints and slopes and another adjustment factor depending on the method of rock slope excavation. Field observations and measurements of discontinuities are the main methods for finding the SMR.

Rock trap design determinations for rockfall slope sites were made by using Whiteside (1986) ditch design method.

In selection of landslide prevention method, the following reinforcement methods are suitable for slope stability such as retaining structures and slope drainage methods (After, Wyllie and Christophere, 2003).

Results and Discussion

The research area consists of hilly terrain with steep slopes and geologically unstable structure. Landslides occur in all rock types of igneous, sedimentary and metamorphic rocks which are exposed along the road between Kywedatson and Wetphyuye. Recently, there has been an increase in deforestation. Hence, natural and manmade hillside cutting will cause more landslides.

Analysis on Joint Density

The abundance of joints at a given site is described through the evaluation of joint density. Joint density can be measured and described in a number of ways: (1) average spacing of joints; (2) number of joints in a given area; (3) total cumulative length of joints in a specified area; and (4) surface area of all joints within a given volume of rock.

For this study, the joint density measurement and calculation are based on the total lengths of joints per 2 meter circular area of the slope face (Palmstrom, 1982). Joint density distribution map is shown in Figure (7).

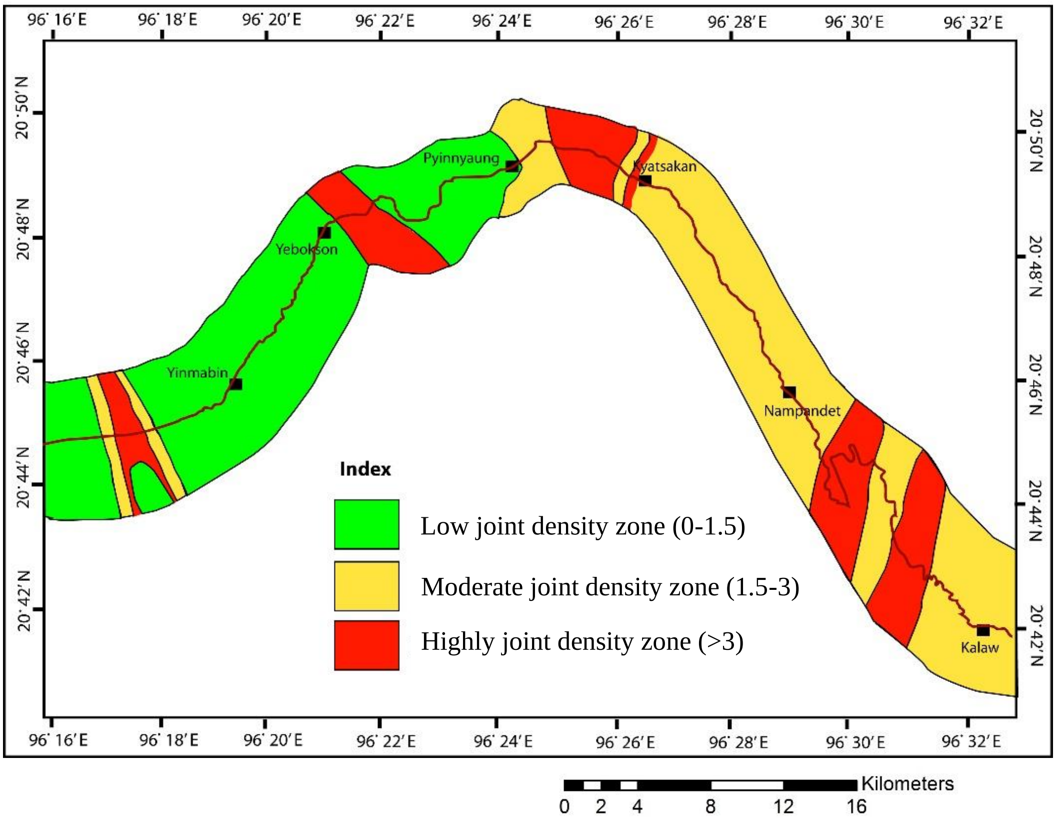


Figure (7) Joint density map of the research area

According to the joint density study, the rocks exposed along road can be classified into three groups;

(a) low joint density zone,

(b) moderate joint density zone and

(c) high joint density zone.

Some phyllite units of the Yinmabin Metamorphics, some sandstone and shale alternate units of the Loi-an Group and some red siltstone units of Kalaw Red Bed have high joint density. Most of the rocks exposed along the road have moderate joint density, understandability it has a lower probability of hazard than highly jointed area. On the other hand, some igneous rocks units of Yinmabin area, limestone unit of Plateau Limestone Group and red conglomerate unit of Kalaw Red Bed have low joint density that exhibits strong rock mass condition reflecting stable condition. The study area lies in the structurally complex Shan Scarp Fault Zone. Therefore, most of the slopes in this area are prone to landslide hazard.

Analysis on Geotechnical Parameters

In this study, 54 possible slope sites are selected to choose the landslide prevention methods. Using the collected field data, Slope Mass Rating values distribution map was built to classify the hazard zone which is shown in Figure (8). Four slope conditions have been identified based on SMR values as (a) Very low hazard zone, (b) Low hazard zone, (c) Medium hazard zone and (d) High hazard zone.

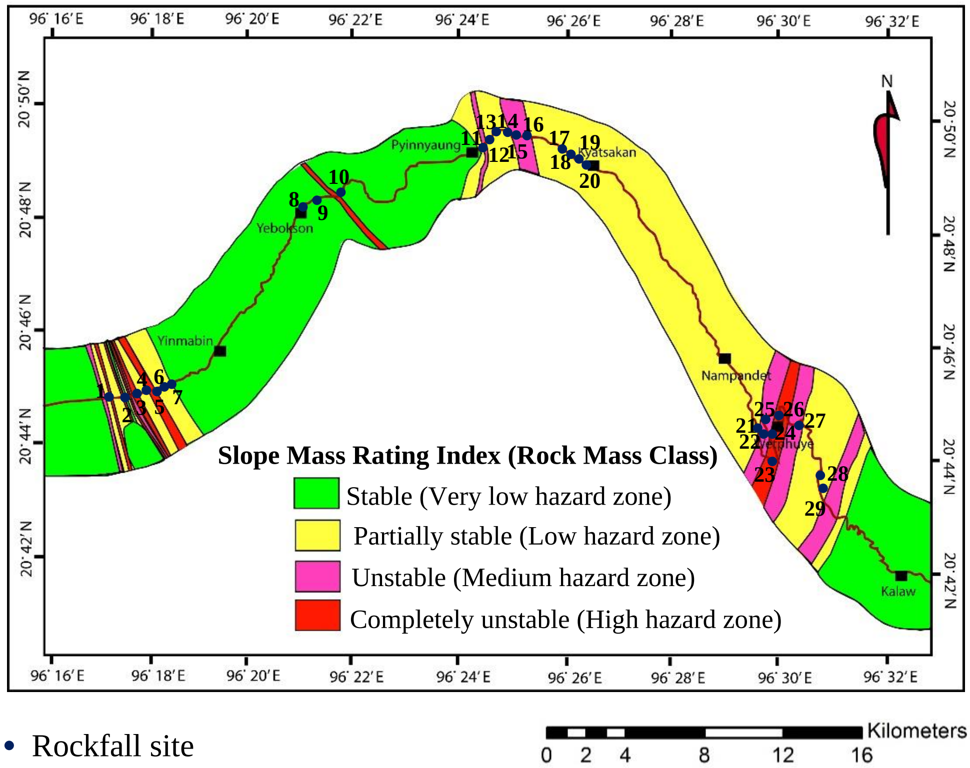


Figure (8) Slope Mass Rating distribution map with rockfall sites

According to this map, some western part of Yinmabin, eastern part of Yebokson and Wetphyuye areas lie in high hazard zone. Therefore, appropriate supporting systems such as retaining structures with slope drainage for slope stability need to be considered as soon as possible.

Moreover, some slope sites at the western part of Yinmabin, eastern part of Pyinnyaung and Wetphyuye areas lie in medium hazard zone. These sites are also required the long-term stabilization such as shotcrete with wire mesh, slope drainage and rockbolt, or a combination of those supporting systems which are deemed suitable.

The identified low hazard sites can be assessed in the western part of Yinmabin, Pyinnyaung, Kyatsakan, Nampandet and Wetphyuye areas, whereby, removable slope debris and unstable rock overhangs, reshaping slope geometry, revegetation, surface drainages and precaution signage prior to the rainy season. The rest of the sites are stable.

Rock Trap Design Determinations for Selected Rockfall Sites

There are 29 rock slope sites possible to happen rockfall along the road where the stability of rock slopes is sensitive to the slope height, behavior of rock types, weathering rate and vegetation. Most of the slope inclinations of the research area can be identified as extremely steep and sub-vertical slope in accordance with Burt (2007). These sites experienced minor to major rockfall throughout the year particularly in the rainy season. Hence, hazard reduction is essential. One of the low-cost hazard reduction measures which the author considered suitable for those rockfall sites is to construct rock trap ditches. In due course, Whiteside (1986) ditch design method is used for the design measures of the rockfall sites in the study area (Table 1), and the schematic diagram of typical ditch is presented in Figure (9).

Table (1) Slope measurements and typical rock trap measures

Site No.	Slope angle (°)	Slope Height (m)	Description	Design Consideration	Ditch depth and width	
1	55	15	Extre. Steep	Reinforce design	1.25m	2.5 m
2	50	15	Extre. Steep	Reinforce design	1.25m	2.0 m
3	69	9	Subvertical	Wall design	1.25 m	2.0 m
4	55	24	Extre.Steep	Reinforce design	1.25 m	2.5 m
5	65	32	Extre. Steep	Reinforce design	1.75 m	4.0 m
6	60	24	Extre. Steep	Reinforce design	1.25 m	2.0 m
7	67	31	Subvertical	Wall design	1.75 m	4.0 m
8	62	15	Extre. Steep	Reinforce design	1.25 m	2.5 m
9	67	30	Subvertical	Wall design	1.75 m	4.0 m
10	60	24	Extre. Steep	Reinforce design	1.5 m	3.0 m
11	70	15	Subvertical	Wall design	1.25 m	2.5 m
12	65	24	Extre. Steep	Reinforce design	1.5 m	3.0 m
13	65	20	Extre. Steep	Reinforce design	1.5 m	3.0 m
14	60	24	Extre. Steep	Reinforce design	1.5 m	3.0 m
15	63	24	Extre. Steep	Reinforce design	1.5 m	3.0 m
16	68	22	Subvertical	Wall design	1.5 m	3.0 m
17	57	25	Extre. Steep	Reinforce design	1.5 m	3.0 m
18	62	27	Extre. Steep	Reinforce design	1.75 m	4.0 m
19	57	33	Extre. Steep	Reinforce design	1.75 m	4.0 m
20	46	13	Extre. Steep	Reinforce design	1.25 m	2.0 m
21	60	8	Extre. Steep	Reinforce design	1.25 m	2.0 m
22	85	18	Subvertical	Wall design	1.25 m	3.5 m
23	70	19	Subvertical	Wall design	1.5 m	3.0 m
24	60	23	Extre. Steep	Reinforce design	1.5 m	3.0 m
25	60	25	Extre. Steep	Reinforce design	1.5 m	3.0 m
26	55	7	Extre. Steep	Reinforce design	0.75 m	1.5 m
27	50	15	Extre. Steep	Reinforce design	1.25m	2.0 m
28	50	20	Extre. Steep	Reinforce design	1.25 m	2.5 m
29	50	15	Extre. Steep	Reinforce design	1.25m	2.0 m

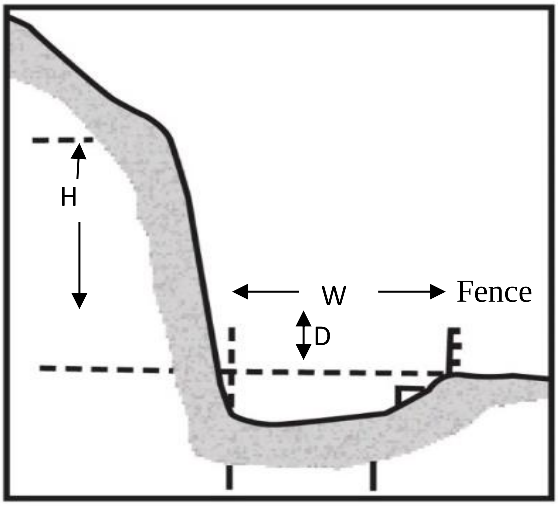


Figure (9) Designed criteria for shaped ditches to catch falling rock
(After Ritchie, 1963, and Piteau and Peckover, 1978)

Preventive Measures for Slope Stabilization

Unstable slopes are practically mitigated by introducing active and passive support.

Active support is said to act in a manner to decrease the driving force. For example, grouted tiebacks, tensioned cables or rockbolts are active support as they exert a force on the sliding mass before any movement has taken place.

On the other hand, passive support increases the resisting force. Soil nails and geotextile are the good examples of passive support, as they only develop a resisting force after some movement within the slope has taken place.

Drainage

There are lack of systematic surface drainage and underground drainage pipes in this area. Thus, the systematic drainage pipes with designing layout of surface treatment for long-term access should be built in most of the slopes along the road (Figure 10).

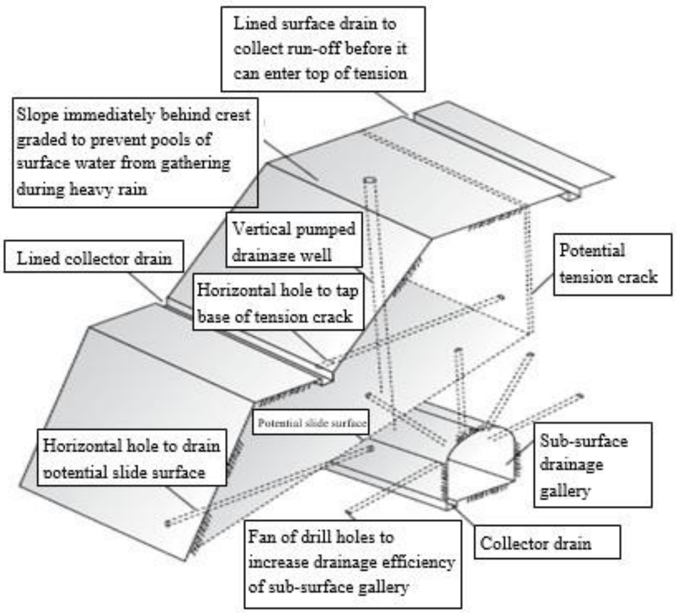


Figure (10) Slope drainage methods (After Wyllie and Christophere, 2003)

Conclusion and Recommendations

The research road located between Kywedatson and Wetphyuye is composed of sedimentary, igneous and metamorphic rocks. Four types of landslide occur along the road which is mainly triggered in rainy season. According to Slope Mass Rating analysis, the research road can be divisible for landslide into (a) very low hazard zone, (b) low hazard zone, (c) medium hazard zone and (d) high hazard zone.

29 rockfall sites have been identified out of 54 sites and hazard reduction could be achieved by constructing trap ditches and fence (if required).

Rock trap ditches may not be adequate to control the rockfall. In such situation, additional preventive measures such as rockbolt, wire mesh and subsurface drainage may be needed.

In the composite slopes containing soil and rocks, wire mesh and rockbolt should be installed superimposing the existing retaining structures to protect further rocks and debris falling over the present retaining structures.

In the area adjacent to stream bank which is located immediately close to the road, the suitable mitigation measures would be gabion wall designated with systematic drainage system.

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