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JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

THE PUBLIC WORKS DEPARTMENT (JKR) MALAYSIA

THE STUDY ON SLOPE DISASTER MANAGEMENT FOR FEDERAL ROADS IN MALAYSIA

GUIDE II

GUIDE TO SLOPE INSPECTION

MARCH 2002

NIPPON KOEI CO., LTD.
OYO CORPORATION

JAPAN INTERNATIONAL
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CHAPTER 1 GENERAL

1.1 Purpose

This Guide presents a standard procedure of road slope inspection and risk evaluation for SIMS (Slope Information Management System) that has been prepared by JICA Study from November 2000 to March 2002.

The purposes of this manual are:

1) To standardise the procedure of road slope inspection

2) To standardise the hazard rating and consequence assessment of road slope

1.2 Outline of Inspection Method

1.2.1 Main Information Obtained by the Slope Inspection

The systematic inspection method is studied to provide information for policy making of slope disaster management. The following information is obtained by the slope inspection.

(1) Score of Slope Hazard
(2) Score of Effectiveness of Existing Countermeasure
(3) Total Slope Hazard Score
(4) Consequence Score
(5) Risk Rate
(6) Rough Cost Estimation of Countermeasure

(1) Score of Slope Hazard is obtained by filling the inspection sheet prepared for this manual. It shows "the level of probability of slope instability without effect of existing countermeasure".
(2) Score of Effectiveness of Existing Countermeasure is obtained by evaluating the effectiveness of existing countermeasure for the slope inspected. This score shows "The level of effectiveness of countermeasure ".
(3) Total Slope Hazard Score is defined in this slope inspection as "The level of probability of slope instability. The score is obtained by adding Score of Slope Instability to Score of Countermeasure.
(4) Consequence Score is defined as "the level of the consequential effect by the road slope disaster".
(5) Risk Rate is obtained by the following formula and shows "the priority level for treating countermeasure work".

Risk Rate = Hazard Score x 0.9 + Consequence Attribute

Where ;

Full mark of each score is as follows

Hazard Score	:	100
Score of Consequential Factor	:	10
Risk Rate	:	100

The relationship between each score is shown in the Figure 1.2.1.

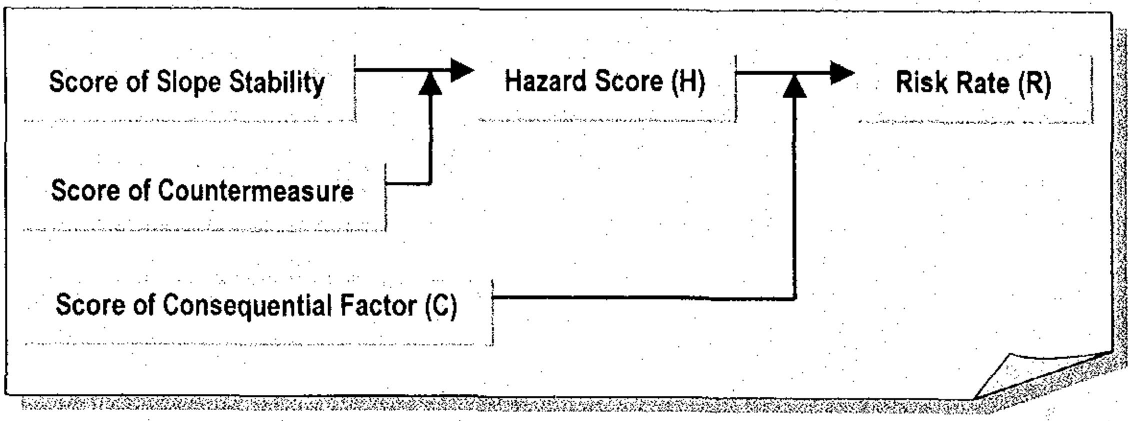


Figure 1.2.1 Determination of Risk Rate Score

(6) Rough Cost Estimation of Countermeasure is done according to the result of planning countermeasure work for the slope inspected. Unit rate of countermeasure work is arranged i.e. the average cost in Malaysia. (Refer to Table4.3.1)

1.2.2 Inspection Method and Flow

The major work items and flow mainly follow the Japanese Slope Inspection Manual prepared in 1996 that is basically the same as SPRS (Slope Priority Ranking System). General Flow of Slope Inspection is shown in the Figure 1.2.1.
The following studies are required to obtain information for road disaster management.

(1) Preparation of Inspection
Prior to the inspection at the site, it is required to collect data on slope and slope disaster of the route to be inspected. Generally the following data are collected and studied.

(2) Selection of Slopes to be Inspected ("Screening")
Observation of aerial photographs and topography maps and reconnaissance survey are carried out to select slopes to be inspected. Selection of slopes is made on the basis of the criteria listed in Section 2.2.1. The unit length of inspection section is determined in consideration of topographical and geological features, together with the conditions of the existing prevention facilities. By this work all slopes are listed and given slope ID and slopes to be inspected are selected.

(3) Slope Inspection (Including Risk Rating)
Slope inspection is carried out on the slope surface using basic tools for field survey such as measuring tape, clinometer, and camera. Inspection Sheets (Refer to Chapter 4) are used for recording data of slope inspections. The following information on slope disaster management can be obtained by filling Forms mentioned in the next Section 1.2.1-4. And evaluation of stability can be output by completing the Inspection Sheet.

(a) General information of the slopes
(b) Slope stability/hazard and consequence score
(c) Cost of countermeasures in outline

(4) Reporting and Database Creation
Result of the slope inspection is compiled according to the specification of the study. Generally, the results of preparatory work, slope selection and slope inspection are arranged with some comment and recommendation.
The data collected will be entered into a database for road slope maintenance that shall be created on the basis of the "SIMS User's Guide".

START

(1) Preparation of Inspection

<Collection of Information>
- Disaster Records
- Aerial Photographs
- Topographic Maps
- Geological Maps

(2) "Screening" Selection of Inspection Sites

<Field Work>
- Site Observation

<Desk Work>
- Observation of Aerial Photographs
- Observation of Topographic Maps

(3) Slope Inspection

<Field Work>
- Site Detail Observation (Sketch, Photograph, etc.)

<Desk Work>
- Location Map, General Slope Data etc.
- Consequence Attribute
- Hazard Rating
- Selection of Countermeasure Works

(4) Reporting and Data Creation

Figure 1.2.2 General Flow of Slope Inspection

1.2.3 Slope Inspection Form

Six kinds of inspection forms are prepared to record collected information mentioned above in the slope inspection. (Refer to Chapter 4)

- Form A: General information and Location Map (1/50,000).
- Form B: Slope Sketch Sheet.
- Form C: Photograph Sheet.
- Form D: Recording Slope Features.
- Form E: Evaluation of Slope Hazard and Existing Countermeasure (E 1 to E5 for each failure type is prepared)
- Form F: Proposed Countermeasure, Consequence Attribute score and Local Information

Six failure types for Form E are mentioned below, in Section 1.2.4.

1.2.4 Six Categories of Slope Failure Type and Form E

The type of slope failure is classified according to the following six types considering their mode of failure.

(1) Collapse (CL)

(2) Rock Fall (RF)

(3) Rock Mass Failure (RM)

(4) Landslide (LS)

(5) Debris Flow (DF)

(6) Embankment Failure (EB)

These six types of slope failure are roughly defined below and in the Table 1.2.1.

(1) Collapse (CL)

This refers to failure of loose and porous soil and rocks from slope when the loose materials are filled by water during heavy rainfall or are shaken loose by earthquake. This failure type is marked as sudden with rapid movement without prior indication. Mechanism of collapse is breakdown of loose and porous part of the slope itself. Generally, the size of failure is less than 1,000 m^3 because only the loose part of the slope surface collapses.

(2) Rock Fall: (RF)

Free fall or rolling down of a rock or few rocks individually from a steep slope or cliff. This failure type is also marked as sudden with rapid failure that is prone to occur during heavy rainfall. But this type of failure could occur sometimes with no relation to weather conditions. Generally, the size of failure is small and is less than 5 m^3.

As mentioned above and shown in the Table 1.2.2 Collapse and Rock Fall occur in similar topography/geological conditions.

(3) Rock Mass Failure(RM)

Mass failure in a rock slope such as planar slide, wedge slide, and toppling. The mechanism is closely related to geological discontinuity. Deformation of rock mass often implies a signal of final failure. Generally, size is more than 100 m^3.

(4) Landslide (LS)

Mass sliding movement of highly weathered rocks, debris and soil across a slip surface. It is characterised by its deformed slope landscape. Size is large, generally more than 5,000 m^3 and ranges to several hundred thousands of cubic metres.

Generally, rock mass failure is also defined as "landslide". But, for the slope inspection classification for federal road in Malaysia they are divided into two categories because of the difference in mechanism and method of treatment.

(5) Debris Flow (DF)

Source area is upstream of road slope. Rapid flow of boulder, gravel, sand, silt clay mixed with a large quantity of water that is mainly generated by slope collapse and heavy rainfall. It flows down riverbed with gradient of over 20-degree gradient and stops to deposit in the riverbed with gradient of under 10 degrees.

(6) Embankment Failure (EB)

All types of slope failure such as slump or collapse of slope, settlement of road surfaces due to various causes, scouring of toe part of slope and so on.

The features of each failure type are compiled in Tables 1.2.1 to1.2.3.

The following five Form-Es are prepared for each type of slope failure (Table 4.1.1 to 4.1.10).

(a) E 1: Collapse (CL)/ Rock Fall (RF)

(b) E 2: Rock Mass Failure (RM)

(c) E 3: Landslide (LS)

(d) E 4: Debris Flow (DF)

(e)E 5: Embankment Failure (EB)

Only E1 is applied to two types of slope failure; Collapse (CL) and Rock Fall (RF), because these two types of slope failure occur commonly under similar conditions of slope.

Table 1.2.1 General Features of Six Slope Failure Types

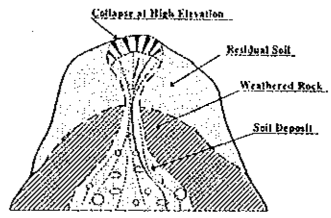
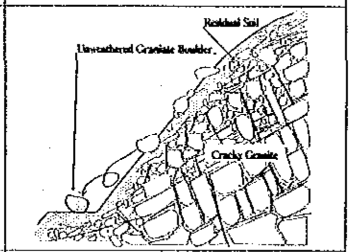
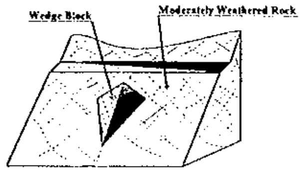
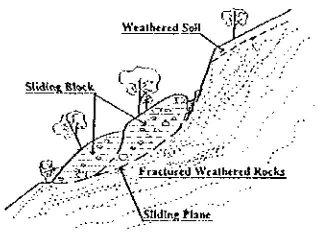
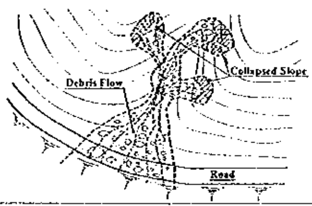
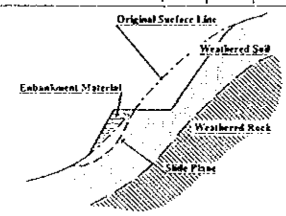
FAILURE TYPE (Inspection Sheet to be applied)	Characteristics	SCHEMATIC ILLUSTRATION
1. Collapse (CL)	- Collapsing materials are residual soils and highly weathered or jointed rocks. - Prone to occur on steep slopes. - Mostly triggered by rainfall infiltrating - Similar to slump failure in some cases. - Size is generally less than1,000 m^3	
2. Rock Fall (RF)	- Free fall or rolling down hard rocks and boulders in the slope. - Occur on steep slope and cliff. - Falls occur due to gravity and are controlled by the distribution of joints. - Size is generally less than 5 m^3.	
3. Rock Mass Failure (RM)	- Materials are hard jointed rocks. - Failure modes include wedge slide, plane slide and toppling. - Size is generally more than 2-3 m^3.	
4. Landslide (LS)	- Materials are clayey soils and highly weathered rocks. - Marked by topographic features that is gentle and deformed -Chiefly influenced by increased pore-water pressure by infiltration of heavy rainfall. -Size is generally more than 5,000 m^3.	
5. Debris Flow (DB)	- Rapid flow of boulder, gravel, sand, silt and clay mixed with big amount of water. - Occurs in a contributory areas that contains collapsible slopes	
6. Embankment Failure (EB)	All type of slope failure in embankment - Slump or collapse of slope, - settlement of road surface - Scouring of toe part	

Table 1.2.2 General Feature of Cut and Natural Slope

Failure Type	**Topography/ Geometry**	**Materials of Slope**	**Geological Structure**	**Size**	**Speed of Failure**
1) Collapse (CL)	**Steep/High Slope**	**Loose Materials** - Detritus - Residual soils - Jointed rocks	Soil slope **- no relations** Rock slope **- Jointed Rock**	**Small** (less than 1,000m^3)	**Quick**
2) Rock Fall (RF)			**Jointed Rock**	**Very Small** (less than 100m^3)	**Very Quick**
3)Rock Mass Failure (RM)		**Hard** and **Sound Rock**	**Parallel Joint** or **Daylight Joint**	**Medium** (more than 1,000m^3)	**Medium to Quick**
4) Landslide (LS)	**Gentle Slope** with **Characteristic Landform**	**Detritus** or **Highly Weathered Rocks**	**Often Planar Bed** or **Fault /Sheared**	**Big** (more than 5,000m^3 in general)	**Slow** *in general*

Table 1.2.3 General Cause for Debris Flow and Embankment Failure

5)Debris Flow (DB)	Main check point: - Slope condition of contributory area: stable or not - Earth works /Pond/ Logging activity: yes or no - Trace of debris flow	Attention shall be required for developing area
6) Embankment Failure (EB)	Main cause of slope instability - Embankment on steep slope without countermeasure - Insufficient or no culvert - Scoring at the end of culvert	Following work being put into practice -Remedial work for embankment on steep slope -Remedial work for unsuitable culvert

1.2.5 Factors for Assessment of Slope Stability

The following factors are used to assess slope stability.

(a) Topography, (b) Geometry, (c) Geological structure, (d) Geological condition, (e) Deformation of slope, (f) Surface condition,

(a) to (f) : factors mainly for Collapse, Rock Fall, Rock Mass Failure and Landslide)

(g) Cover in Source Area, f) Deformation in Source Area, h) Trace,

(g) to (h): factors only for Debris Flow)

(i) Condition of Culvert (factor only for Embankment Failure)

(j) Countermeasure (factor for each failure type)

The weighting of each instability mainly refers to the Japanese Manual and some modification is applied in consideration of the geological conditions of Malaysia. Outline of weighting for instability factors is shown in Table 1.2.4.

Table 1.2.4 Maximum Point of Instability Factor of Slope

Items	Collapse/ Rock Fall	Rock Mass Failure	Landslide	Debris Flow	Embankment Failure
Topography	5	11	50	43	0
Geometry	30	14	0	0	10
Geological Structure	14	33	10	0	0
Geological Condition	16	31	3	0	5
Deformation	15	7	32	34	26
Surface Condition	20	4	5	23	51
Others	0	0	0	0	8
Total	100	100	100	100	100

As mentioned in Section 1.2.4 and shown in Table 1.2.4, important factors of instability for each failure are as follows.

- Collapse/Rock Fall:

Collapse and rock fall is prone to occur when the surface material is loose and weak. *Therefore, the geometry of slope is given a weighting of thirty points and is the most* important factor for assessing the instability of the slope

- Rock Mass Failure

Even if the geometry of slope is steep and high, collapse or rock fall may not occur on a slope that consists of hard and sound rock. However, if geological discontinuities such as faults, sheared planes, joints, or bedding planes are present in the slope, the rock mass separated from the main rock mass by the geological discontinuity is made unstable by continuous gravity action. So, geological structure and geological condition are the most important factors to assess instability of hard and sound rock slopes. Sixty-four points out of hundred are given for the two factors.

- Landslide

Landslide is large scale slope failure under the geological condition that cannot hold the slope stable. So, an essential factor to make slope unstable is the geological condition. But, on a slope on which a landslide has occurred, it is very difficult to find evidence of bad geological condition. On the other hand, such a slope shows peculiar landform and landslide. Due to this reason, topography is given fifty points to the factor of instability for landslide failure type. One more important indicator factor for landslides is deformation. When new deformation such as tension crack or bulging at the toe of a slope is detected, it is assumed that the slope is in a critical condition and that urgent treatment is required. Thirty-two points are given for deformation.

- Debris Flow

Debris flow is the flow of soils and boulders mixed with a large quantity of water that come down from upstream. So, assessing probability of debris flow, the most important factor is topography of the upstream area, including gradient of the river crossing the road. One more important factor is "deformation" which means deformation of upstream slopes.

- Embankment Failure

The probability of embankment failure depends on the conditions of construction, of which knowledge is rarely available. To assess the instability of embankment, surface condition and deformation are selected as important factors of slope instability.

1.3 Study Team

Slope inspection is the task of collecting information on road slope, evaluating instability and making a preliminary plan of countermeasure work. Although the most important key factor is topographical and geological information, every factor for road slope management shall be taken into consideration. So, it is required to organise the study team that has suitable ability for the study as mentioned below.(Figure 1.3.1 and Table 1.3.1)
The Study Team for the slope inspection shall be organised including the following staff.

(1) Chief Engineer

(2) Engineering Geologist

(3) Slope Design Engineer

(4) Assistant Engineer

(5) Operator

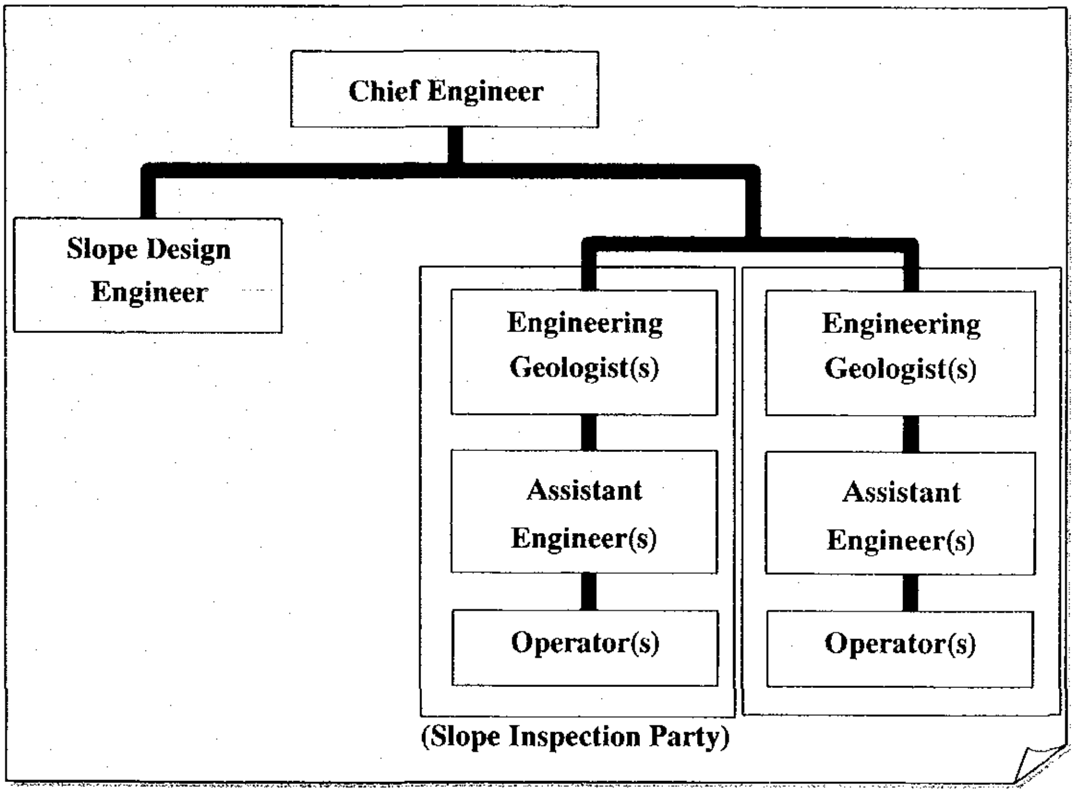


Figure 1.3.1 General Organisation of Study Team for Slope Inspection

(1) Chief engineer shall be an engineer who has ability and sufficient experience for the study. So, he shall be qualified with a doctorate or a registered engineer in at least one of the following fields:

-Engineering geology, Geo-technical engineering or Road planing/designing-

He shall manage the total work such as planning the study, preparing implementation plan, instructions for the staff, selection of slope to be inspected, check & approve results and administration of the study.

(2) Engineering geologist shall have sufficient ability to execute the inspection work mainly on field inspection and evaluation of slope instability. So, he shall be qualified as an engineer who is a graduate of geological fields and has more than three years experience in projects of engineering geology. Furthermore, he shall have completed the instruction course for the slope inspection.

(3) His main role is executing the slope inspection and assisting the chief engineer in most work items.
Slope design engineer is required to have ability to evaluate the effectiveness of existing countermeasures and to plan a suitable one for the slope. So, he should be qualified as an engineer who is graduate of civil engineering and has more than three years experience in geo-technical projects. He shall also have completed the instruction course for slope inspection. His main role is planning countermeasure work for each slope and assisting the chief engineer in civil engineering field including countermeasure work.

(4) Assistant engineer works mainly on field inspection assisting the engineering geologist. He should be qualified as a graduate in geological or civil engineering fields or be competent to perform the work.

(5) The data input operators enter the data that are obtained by the inspection into a slope inspection database. He is required to have skill of using Microsoft Word and Excel computer packages.

The number of engineering geologists, assistant engineers and operators required will differ depending on the condition of inspection work.

Table 1.3.1 Study Team for Slope Inspection

Category of Engineer	Role & Responsibility	Required Ability & Qualification	Number Of Engineer
1) Chief Engineer	- Proposal of the study - Implementation plan - Instruction for the staff - Selection of slopes - Check & approval of results - Administration of the study	Ph.D. or Registered Engineer of following Field - Engineering geology - Geo technical engineering - Road planning/designing - Competent ability for the study	1
2) Engineering Geologist	- Proposal of the slope inspection - Implementation plan of the inspection - Administration for the field work	Graduate of geological fields - Over three years experience of engineering geology project - Finished Instruction course for the slope inspection	Required number for the study
3) Slope Design Engineer	- Proposal of planning countermeasure - Implementation planning of countermeasure work - Evaluating of existing countermeasure - *Planning countermeasure for each slope* - Arrangement of report on the countermeasure planning	Graduate of geological fields - Over three years experience of geo-technical project - Finished Instruction Course for *the slope inspection*	1
4) Assistant Engineer	- Assistant for planning, field work, reporting	- Graduate of geological or civil engineering fields or being competent for the work	Required number for the study
5) Operator	- Database input for SIMS	- Ability to use Microsoft Word and Excel	

CHAPTER 2 PREPATORY WORK

2.1 General

As shown in the Figure 1.2.2 General flow of Slope Inspection Slope, the work can be divided into four stages. Prior to slope inspection on the site, existing information on the area to be inspected should be collected as far as possible. The following items and materials are important and required to obtain good results from the inspection.

1) Topographical Maps

2) Aerial Photographs

3) Geological Maps

4) Disaster Record

5) Others

Information on the route to be inspected shall be arranged for use in following stages of slope inspection work.

2.2 Arrangement of Regional Information

2.2.1 Topography Map

The following maps are published by the Department of Survey and Mapping

(a) Road maps of states in Malaysia at scales of 1/100,000 to 1/900,000

(b) Topography Map, Scale: 1/50,000

(c) Topography Map, Scale: 1/25,000

(d) Topographical digital data : Scale 1/25,000

(a) Road maps of states in Malaysia is an important material for mapping functions of SIMS and is useful to search for alternative roads when large slope disasters occur.

It is better to obtain aerial photographs for preparing digital maps that can be used as detailed location map or base maps for preparing geological maps, land use maps and hazard maps. When it is not planned to make digital maps for the inspection, one of the topography maps b), c), or d) can be selected for use as location map of slopes to be inspected. (Figure 2.2.1)

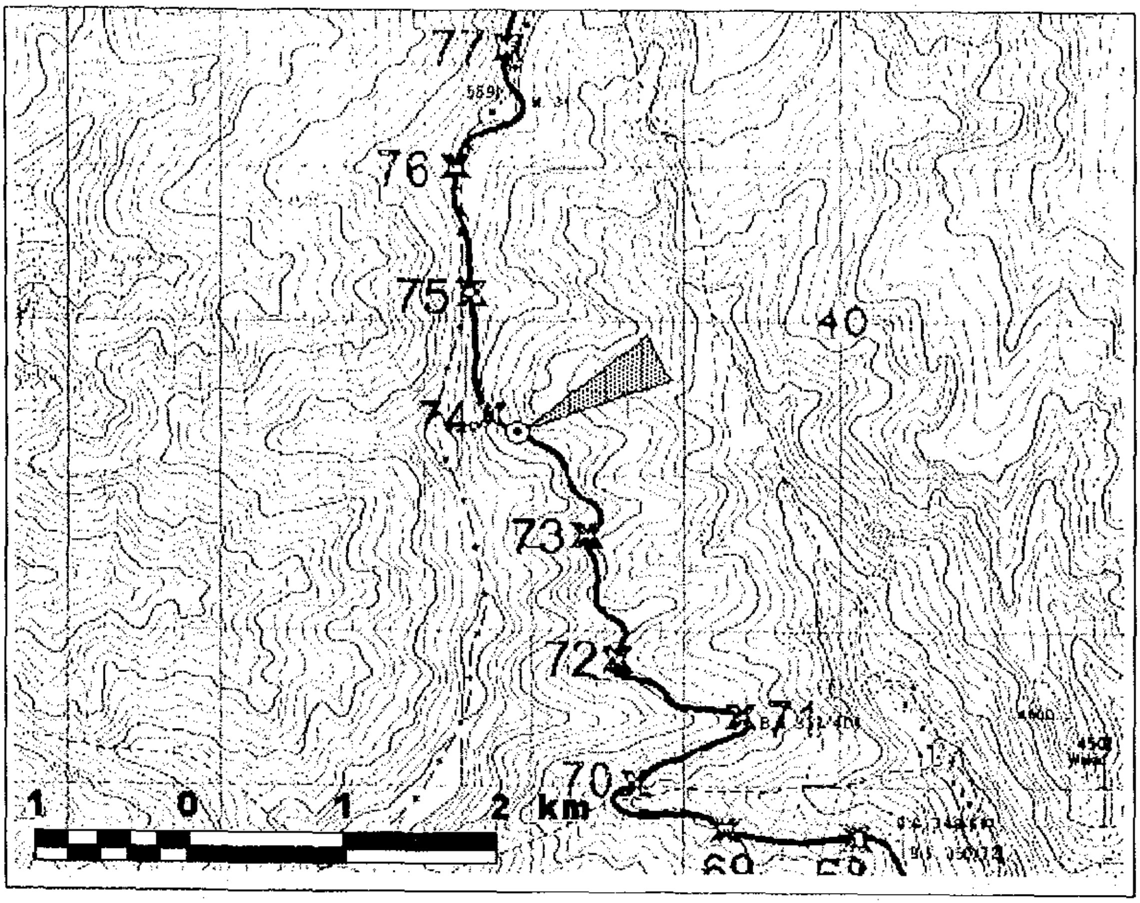


Figure 2.1.1 Example of Location Map (1/50,000 ULU TUALAN, Sabah)

2.2.2 Aerial Photograph

The Department of Survey and Mapping has prepared aerial photographs covering the entire country of Malaysia.

Observation and interpretation of aerial photograph by using a stereoscope shall be done while on inspection route to obtain the following information.

(1) Detecting landscapes that may be deformed on large scale slope failure(Landslide)

(2) Occurrence of collapsed slopes or detritus deposits in the upstream that may have contributed as the source of debris flow.

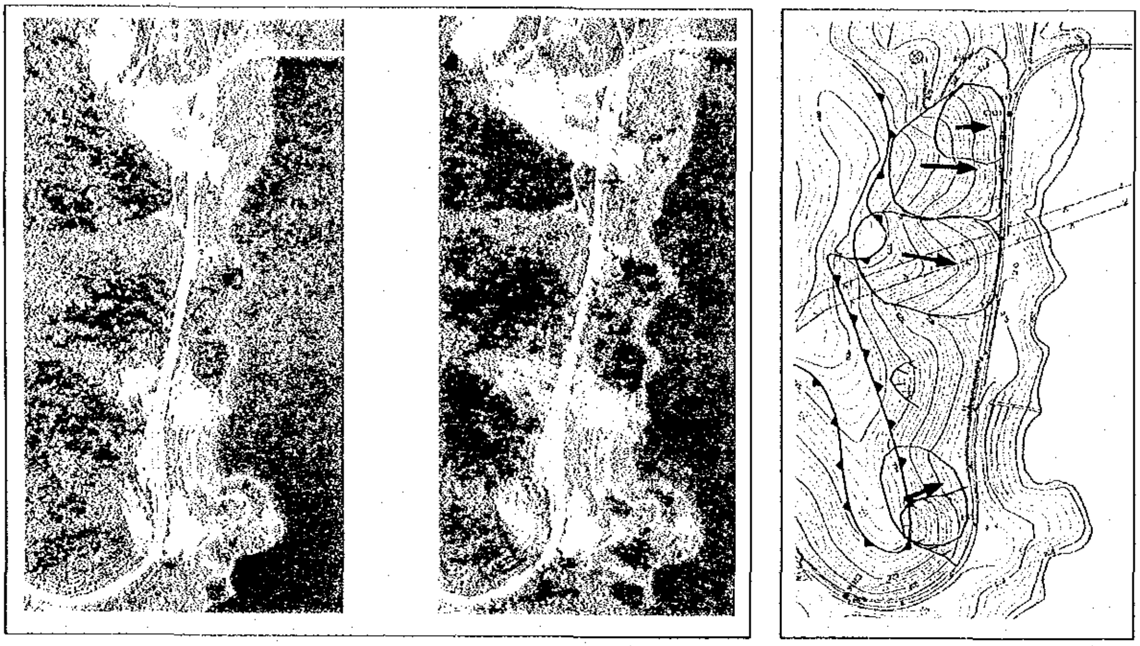
(1) Detecting Landslide Slope

Slopes with a high probability of landslide can be detected by observation and interpretation of aerial photographs by characteristic landforms mentioned in the next section. Example of aerial photograph interpretation for landslide is shown in the Table 2.2.1 and Figure 2.2.1

In this example, firstly slopes that had conspicuous large-scale landslides were observed and interpreted on aerial photographs. Final judgement of each slope was studied after site observation.

Table 2.2.1 Example of Aerial Photograph Interpretation and Judgement of Landslide (East-West Highway)

No	Slope ID	New Score ID	Type of Slope	Type of Failure	Hazard Score	Conse-quence	Risk Rating	Risk Level	Estimated Cost (RM)	Economic Indicator (V_T/C)	Final Decision
1	-	0004/071/500RC	1	4	85	8	**85**	**V.H**	2,427,500		
2	1091	0004/081/150LC	1	4	85	7	**84**	**V.H**	727,000		
3	385	0004/031/460RC	1	1	82	7	**81**	**V.H**	356,935		
4	396	0004/032/080RC	1	1	79	7	**78**	**V.H**	995,000		
5	-	0004/072/680LC	1	4	77	8	**77**	**V.H**	674,606		
6	415	0004/033/300RC	1	1	79	6	**77**	**V.H**	120,755		
7	392	0004/031/920RC	1	3	77	7	**76**	**V.H**	309,600		
8	-	0004/069/520LC	1	1	77	7	**76**	**V.H**	2,108,267		
9	647	0004/050/900RC	2	6	75	8	**76**	**V.H**	206,988		
10	432	0004/035/530LC	1	3	74	6	73	H	1,312,314		
11	441	0004/036/140LC	1	4	69	8	70	H	1,428,400		
12	332	0004/027/350RC	1	1	70	7	70	H	191,267		
13	433	0004/027/910RC	1	1	71	6	70	H	214,812		
14	474	0004/038/800RC	1	1	72	5	70	H	264,318		
15	442	0004/032/950RC	1	1	71	5	69	H	152,143		
16	468	0004/038/530LE	2	6	68	7	68	H	422,521		
17	533	0004/042/380LC	1	1	69	6	68	H	130,023		
18	1083	0004/080/700RE	2	6	70	5	68	H	115,800		
19	345	0004/028/240RC	1	1	69	5	67	H	356,250		
20	628	0004/049/680RE	2	6	65	7	66	H	95,338		
21	1019	0004/076/100LE	2	6	65	7	66	H	1,126,000		
22	435	0004/035/860LC	1	3	66	6	65	H	57,200		
23	-	0004/072/410LC	1	1	66	6	65	H	238,600		
24		0004/027/680RC	1	1	67	5	65	H	73,800		
25	452	0004/036/830LC	1	3	64	7	65	H	654,680		
26	466	0004/038/310RC	1	1	65	6	65	H	247,615		
27	537	0004/042/710LC	1	1	65	6	65	H	259,913		
									15,267,644		



(a) Aerophotos (Stereo View) (b) Results

Figure 2.2.1 Example of Ariel Photograph Observation

(2) Debris Flow

To judge probability of debris flow, the following items shall be initially checked for the upstream contributory area.

(a) Occurrence of collapse
(b) Soil work
(c) Logging
(d) Pond (natural and artificial)
(e) Trace of debris flow

In addition to this work, sites to be checked for probability of debris flow are selected according to criteria that are mentioned in Chapter 4.

2.2.3 Geological Map

Geological Map of Peninsular Malaysia (8th edition, 1985; Scale 1/2,000,000), Geological Map of Sarawak and Sabah (5th edition, 1992; Scale 1/3,300,000) and "Geology of the Malay Peninsula" (by D.J.Gobbett and C.S.Hutchison) have been published and are suitable to understand the general geology and geological structure of Malaysia. In addition to these maps and references, regional data and references shall be collected as far as possible and studied. This work will assist in judging the geological condition of the slope.

2.2.4 Disaster Record

The study team shall collect disaster records on the route to be inspected by the following two methods.

(a) Papers on slope disaster record of the route

(b) Interview of personnel who have information on slope disaster on route.

Following items shall be collected and arranged for each disaster.

(a) Place of slope disaster (chainage on the route)

(b) Date and time of occurrence

(c) Condition of damage (personal, vehicle, building, public facilities, etc)

(d) Failure type (collapse/rock fall/rock mass failure/ landslide/debris flow embankment failure)

(e) Rainfall data before disaster

(f) Method and cost of rehabilitation work

(g) Others on the disaster

CHAPTER 3 SELECTION OF SLOPE

3.1 General

In this work, all slopes (cut slope, embankment, natural slope) along the route shall be listed and the slopes to be inspected shall be selected on the basis of the criteria described below.

As this work is a key step in the slope inspection, the chief engineer with full support of the engineering geologist shall do it.

The following matters on slope inspection shall be decided and the results shall be arranged for inspection of each slope.

(1) Decision of slope unit and JKR ID

(2) Decision of Slopes to inspect

(3) Judgement of failure type for each slope

3.2 Decision of Slope Unit and Slope ID

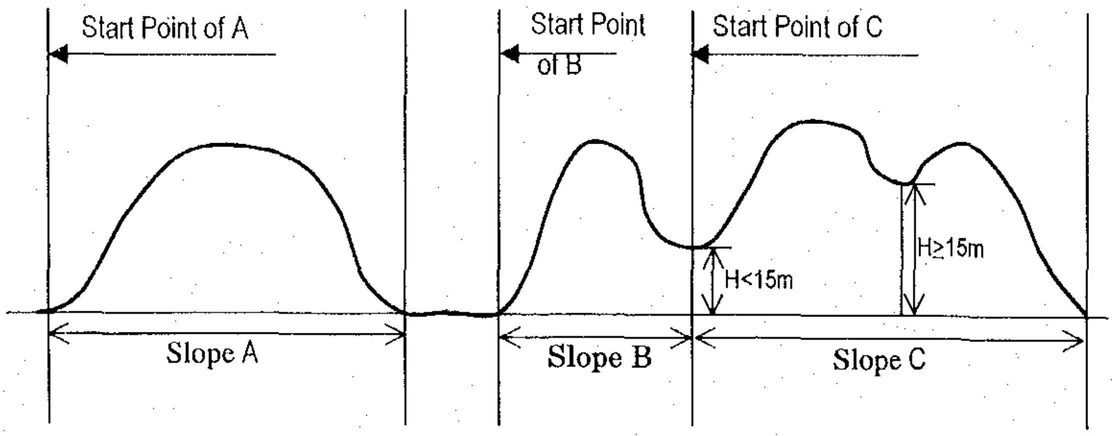
Following data shall be arranged by doing a route survey

a) Decision of slope unit
b) Decision of slope ID
c) Creation of slope map

3.2.1 Decision of Slope Unit

At first, the slope unit shall be decided based on following criteria.

(1) Decision of cut slope unit
(a) Simple slope; One slope is one unit (Figure 3.2.1(a))
(b) Compound unit (Figure 3.2.1(b))
(i) Height of lowest point < 15m ; slope unit shall be divided
Height of lowest point ≧ 15m ; slope unit shall not be divided



(a) One slope is one slope unit (b) One slope is divided into multiple slope units

Figure 3.2.1 Slope Unit

(2) Natural slope:

Continuous natural slope is one slope until it meets the valley or cut slope.

(3) Embankment slope:

Mountain side and riverside slope is one slope unit respectively

3.2.2 Decision of Slope ID

(1) Decision of JKR ID

JKR slope ID is defined based on federal road number, chainage, side, and slope feature. For example the right side cut slope of E-W Highway (route 4) chainage between 27.350 m to 27.580 m is defined as follows;

<u>0004</u> / <u>027</u> / <u>350</u> <u>R</u> <u>C</u>
a) b) c) d) e)

a) **0004**: Federal Road Route 4, route number is given in <u>four figures</u>.

b) **027**: <u>starting</u> chainage (km) is given in <u>three figures</u>.

c) **350**: <u>starting</u> chainage (m)

d) **R**: right side of road, (or **L**: left side of road)

e) **C**: cut slope, (or **E**: embankment, **N**: natural slope)

(2) Field ID

Naming of field ID is free. For example following naming indicates order of both roadsides.

R 0001; first slope of right side

L 0001; first slope of left side

3.2.3 Creation of Slope Map

Slope map is created based on route survey. This map contains road, location and slope shape. Larger scale is better (1/5000 or more) because this will be base map of GIS in SIMS.

3.3 Criteria for Selection of Slope

Following three-items (a) to (c) are major criteria for slope selection for inspection.

(a) The slope has obvious factors leading to a road slope disaster.

(b) The previous slope disaster records imply necessity for inspection.

(c) Appointed slopes by road administrator.

Detailed criteria for selection of slope to be inspected differ in respect of each failure type that are mentioned in following Section 3.3.1 to 3.3.5.

3.3.1 Collapse (CL) and Rock Fall (RF)

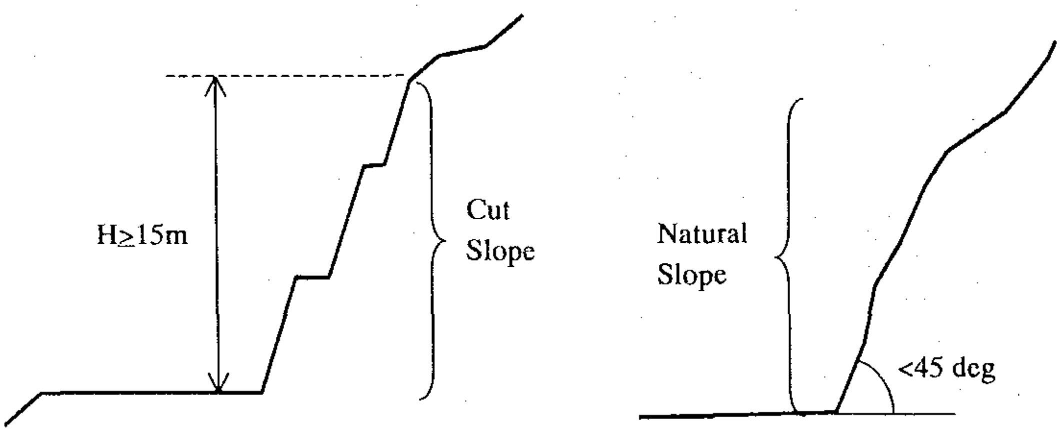
When slope failure type is Rock fall or Collapse, slopes that meet at least one of the following items shall be selected for inspection.

(a) A cutting or natural slope of over 15 m high, or a natural slope with a gradient of over 45 degrees (Figure 3.3.1)

(b) The slope contains soil, rocks susceptible to collapse (Figure 3.3.2)

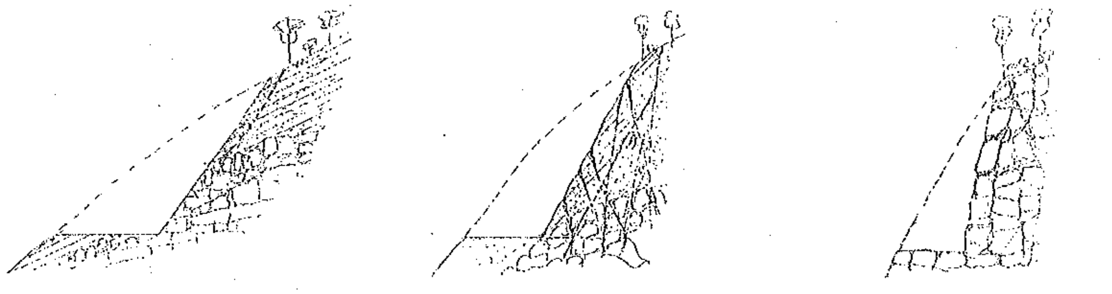
(c) Loose rocks or boulders on the slope surface (Figure 3.3.3)

(d) The existing countermeasure works are deteriorating.



(a) Selection by slope height (b) Selection by slope angle

Figure 3.3.1 Criteria of Height and Gradient for Slope Selection
(For cut and natural slope)



(a) Residual soil (b) Structural relict in the residual soil (c) loosened rock in the cliff

Figure 3.3.2 Soil and Rock Prone to Collapse

(a) Rock fall from soil slope (b) Unstable rock in the residual soil

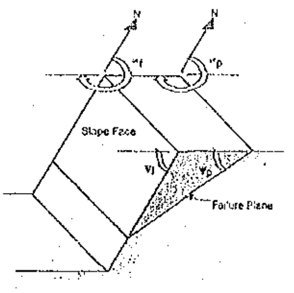
(c) Rock fall from deformed rock mass (d) Isolated boulder

Figure 3.3.3 Loose Rock or Boulders in the Slope (Ref.*12)

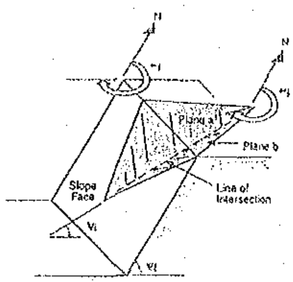
3.2.2 Rock Mass Failure (RM)

Rock mass failure is defined as "Mass failure in the rock slope such as planar slide, wedge slide, toppling". Typical rock mass failure and schematic features are shown in the Figure 3.3.4 (a to d).

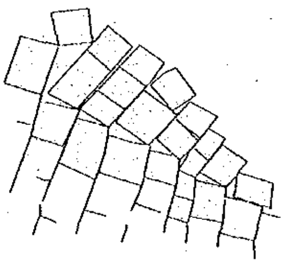
Inspection sites for Rock Mass failure are the cutting or natural rock slopes of over 15 meters high, regardless of implementation of countermeasure work.



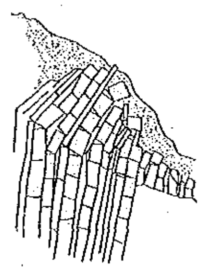
(a) Planar Slide



(b) Wedge Slide



(c) Block Toppling



(d) Block Flexure Toppling

Figure 3.3.4 Type and Feature of Rock Mass Failure (Ref.*9)

3.3.3 Landslide (LS)

The following sites or areas shall be selected as landslide failure type.

(a) The area or slope where occurrence of large scale landslide is found

(b) The area or slope where deformed topography and landslide is suspected

(c) Sites where evidence of landslide activity is clear.

Generally, rock mass failure mentioned in the former section is also defined as "landslide". But in this guide, landslide is defined as "a large mass movement of highly weathered rocks, debris or soils down a slope". Factors of instability differ from each other as shown in Tables 1.2.1 and 1.2.2. Schematic block diagram is shown in Figure 3.3.5 after Varnes (1978). And more detailed feature of landslide is mentioned in Section 3.4.

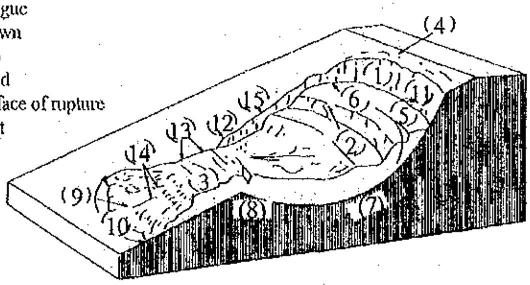


Figure 3.3.5 Schematic diagram of Landslide
(after Varnes,1978)

3.3.4 Debris flow (DF)

It is necessary to check topography maps and observations on aerial photograph for judging the probability of debris flow occurrence. The place that meets one of the conditions mentioned below shall be selected for inspection as "Debris Flow".

(a) Occurrence of collapse in the upstream contributory

(b) Area under development with soil work in the upstream contributory area

(c) Logging work in the upstream contributory area

(d) Existence of natural or artificial pond in the upstream contributory area

(f) Trace or record of debris flow in the site

3.3.5 Embankment Failure (EB)

Embankments that are over 5 m in height and meet one of the following condition shall be selected.

(a) Embankment on the landslide slope

(b) Embankment on the talus slope

(c) Embankment on the steep slope (over 40 degrees)

(d) Steep geometry of embankment (steeper than 1: 1.6)

(e) Embankment near the river

(f) Drainage or culvert in dilapidated condition

3.4 Judgement of Failure Type

3.4.1 General Flow of Slope Selection

Preliminary judgement of failure type shall be done for each slope selected that meets slope selection criteria. Chief engineer shall do this work because it requires experienced knowledge to judge the failure type. By this work, inspection sheets are selected for each failure type (E 1 to E5).

The general flow of selecting inspection sheet, which also means the judgement of failure type, is shown in Figure 3.4.1. As shown in the figure, slope types can be divided into Embankment and Cut/Natural slope.

(1) When the slope is an embankment, slope failure type is Embankment Failure
(Select Inspection Sheet E 5)

(2) Selection of debris flow shall be made according to the selection criteria as mentioned in 3.2.4 by interpretation of aerial photographs and topography maps. When it meets the selection criteria for debris flow, the place is selected as Debris Flow.
(Select Inspection Sheet E 4)

(3) For a cut or natural slope, at first, the probability of landslide shall be checked by aerial photograph interpretation and field observation. When the slope has features shown in the next section 3.4.2, the slope is judged as Landslide.
(Select Inspection Sheet E 3)

(4) When judged, there is no probability of landslide, most likely the failure type for the slope shall be selected from among "Rock Mass Failure", "Collapse" or "Rock Fall".

(a) Rock slope

When feature of "planar slide", "wedge slide" or "toppling" are found, most likely failure type in the slope is "Rock Mass Failure" (Figure 3.2.4).
(Select Inspection Sheet E 2)

When probability of rock mass failure is not found, the most likely failure type in the slope is "Rock Fall" or "Collapse". (Select Inspection Sheet E 1)

Collapse is prone to occur in slopes with numerous joint developments and are loosened to some extent. (Figure 3.2.2 (c)) (Select Inspection Sheet E 1)

Rock Fall is the most likely failure type when the loosened area is limited to a few meters and scattered. (Figure 3.2.3 (c), (d)) (Select Inspection Sheet E 1)

(b) Soil slope

Failure type in the soil slope is collapse or rock fall when landslide feature is not found in the slope. (Select Inspection Sheet E 1)

Collapse is the most likely failure type when the slope exhibits the following conditions.

- the slope consists of detritus or debris deposit

- the slope surface is highly weathered (grade V, VI) and loosened Rock Fall is the most likely failure type when the slope has the following conditions.
- boulders in the residual soil are in an unstable condition (see Figure 3.2.3 (a))
- boulders on the slope surface are in an unstable condition

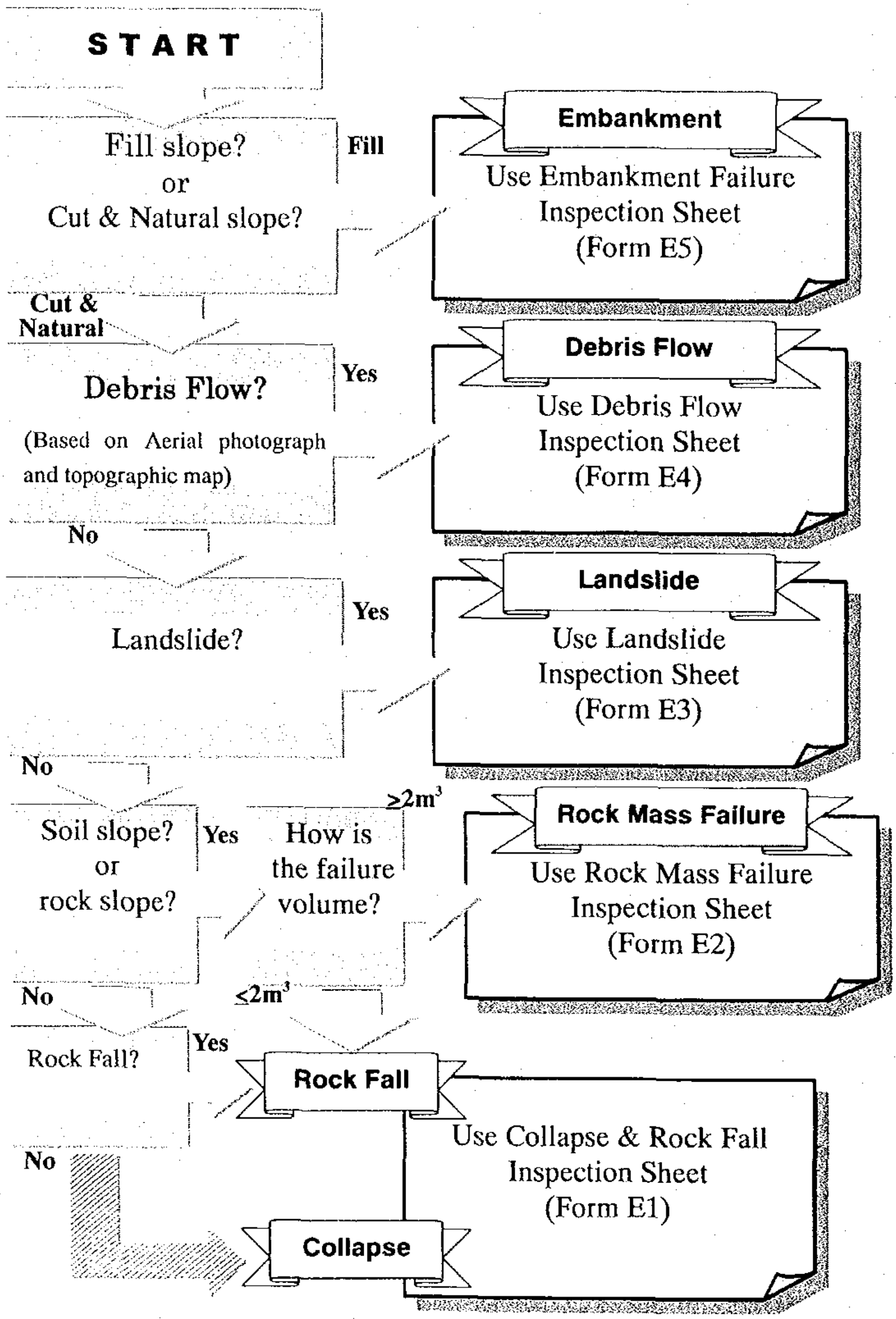


Figure 3.4.1 Schematic diagram shows selection of Form E (E1 to E5).

3.5 Features of Landslide

Landslides have the following topographical and geological features.

3.5.1 Topographic Features

Natural landslides have topographical features as shown in the Figure 3.5.1. These topographic features can be detected by observation of topography map, aerial photograph and field work.

(1) Contour lines have irregular shapes. Typically, these contour lines are dense at the upper part, sparse at the middle part and dense again at the lower part. (Figure 3.5.1 (a) to (c)).
(2) Commonly, the upper part of slope shows a horseshoe-shape or rectangular scarp, and the middle part is a flat to gentle slope. (Figure 3.5.1(c)). In some cases, an isolated small hill exists.(Figure 3.5.1 (a))
(3) There are concavities, depressions, cracks, etc. or there is a long and narrow depression in the hill slope or at the top of mountain (Figure 3.5.1(a))
(4) Existence of ponds, swamps and marshes that often shows linear distribution in the slope. (Figure 3.5.1(a))
(5) Marshy zones or cracks are often formed on one or both sides of a landslide block
(6) A ridge behind a landslide area often has a depression.
(7) Slope where a river flows down along the side of block or disappears at the top of slope.
(8) The foot of a slope is often steep where an upheaval and bulge takes place.
(9) Often occurs in a meandering part of river course on the eroded side.(Figure 3.5.1(c))

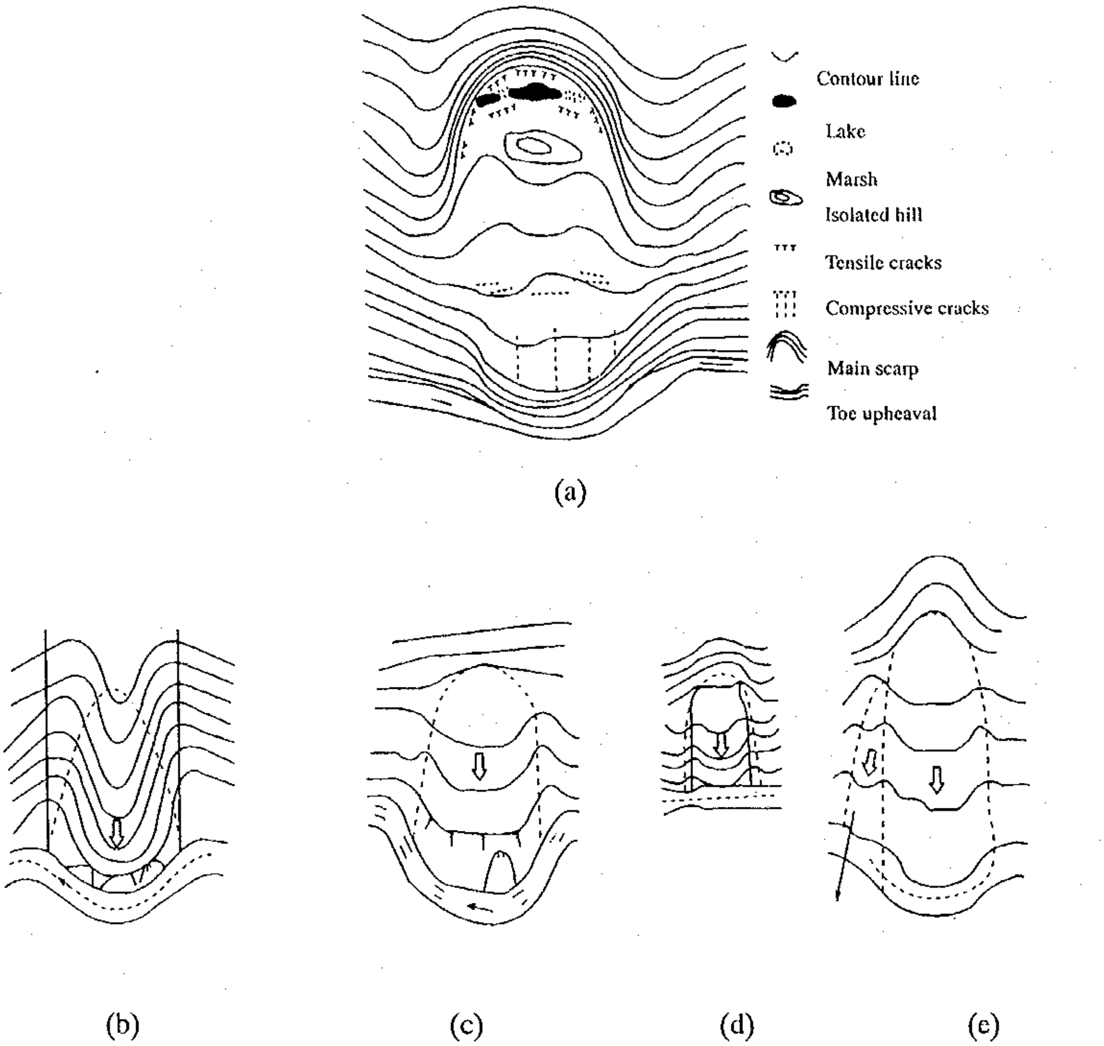


Figure 3.5.1 Typical Topographical features of Landslide (Ref. *1)

3.5.2 Geological Features in Landslide Area

Natural landslide commonly occurs in similar geological formations since the formation has geological conditions that could cause landslides. Generally, landslides occur in the following geological conditions.

(1) Geological Structure

Generally, natural landslides develop in an area that has geological defects such as fractured zones, alteration zones.

(a) Fault and Sheared Zone

Figure 3.5.2 shows the relationship between fault and a landslide. Fault surface forms a scarp to border the landslide area. Furthermore, a fault surface or a fractured zone may become a route for groundwater flow. Fault clay may cut off groundwater flow, leading to landslide due to the rise of pore water pressure. Figure 3.5.3 shows a schematic landslide near an anticline that often makes bedrock fragile.

(b) Alteration zone

Hydrothermal alteration in the geological process and hot spring water causes chemical alteration of surrounding rocks in volcanic areas. When subjected to this process, rocks turn into clay, and the slope is prone to slides.

(c) Dip slope

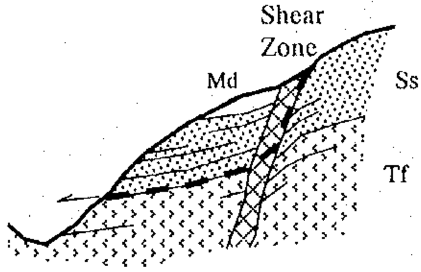
Slopes consisting of strata parallel or nearly parallel to the slope are prone to landslide.

(d) Opposite-Dip Slope (strata perpendicular to the slope)

Flexural toppling often occurs in slopes consisting of strata perpendicular or nearly perpendicular to the slope.

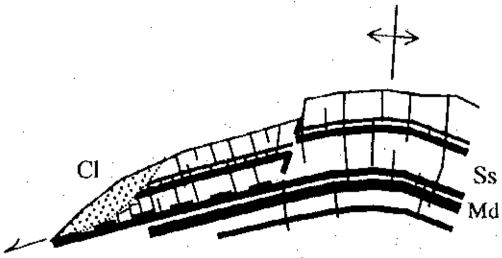
(e) Intrusive Structure

Landslides frequently occur in the colluvial zones around a volcanic intrusive rock



Ss : Sandstone
Md : Mudstone

Figure 3.5.2 Landslide caused by Fault and Monocline Bed



Cl : Colluvium
Ss : Sandstone
Md : Mudstone

Figure 3.5.3 Landslide occurring near Anticline

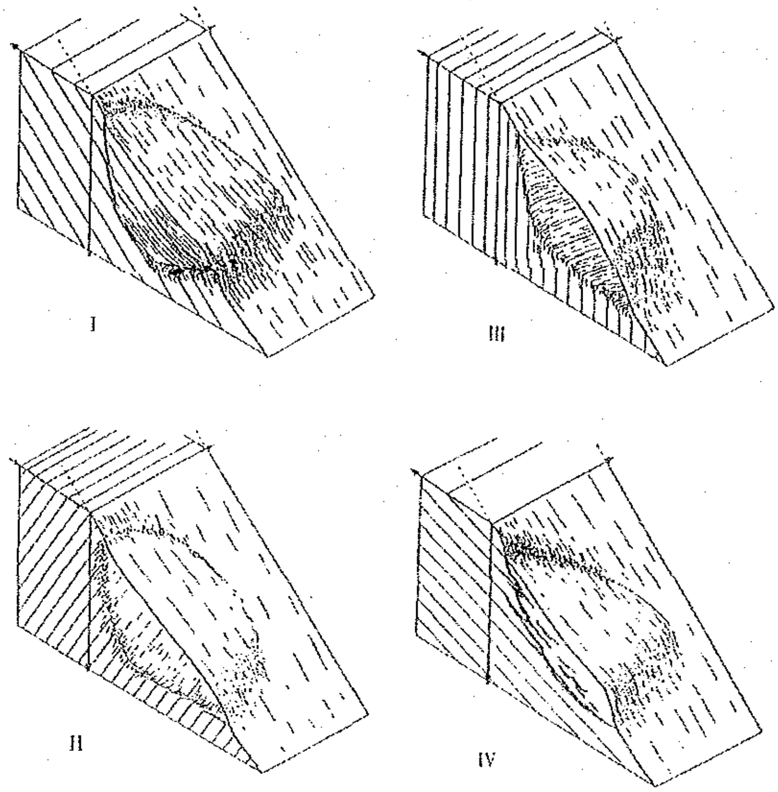


Figure 3.5.4 Landslide Symptoms in Dip Slope and Opposite Dip Slope
(I, IV: Dip Slope, II, III: Opposite Dip Slope, Ref.*11)

(2) Geological Materials

Landslides frequently occur in bedrock such as mudstone, shale, tuff, serpentine, phylite and graphite schist. These rocks contain clayey mineral or minerals that easily change into clay minerals due to weathering.

(3) Spring Water

Groundwater is a major factor that accelerates landslides. Groundwater comes in as inflow or infiltration from slope above the landslide site or landslide slope. The inflow or infiltration frequently comes out as spring water at the lower elevations of surface of slope, especially around the lower end of both sides of landslide block.

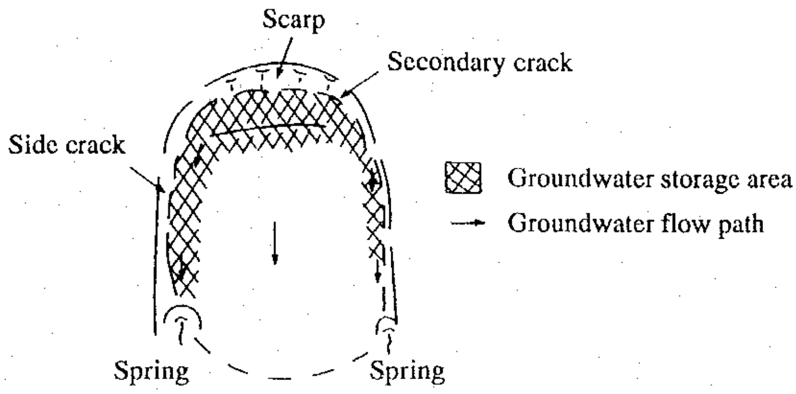


Figure 3.5.5 Groundwater Flow in Landslide Area (Ref. *1)

(4) Deformation

An active landslide shows small deformation on ground surface of the landslide block, such as bulge, depression, and cracks and so on. These features are signs of a landslide that is ready to occur. They provide clues to determining or identifying landslide activity, shapes of rupture, and direction of movement.

Deformation of countermeasure works such as joints, drainage ditch, bulge, and road settlement also show evidences of landslide activities.

3.6 Arrangement of Slope Selection Work

Results of slope selection work shall be recorded on the Inspection Sheet Form A. Following items shall be recorded at this stage.

(1) Most likely failure type
   (a) Collapse/Rock Fall, (b) Rock Mass Failure, (c) Landslide, (e) Debris Flow, (f) Embankment Failure (g)No Action Needed
(2) Chainage: Start(km) – End(km)
(3) Type of Slope: Cut/Embankment/Natural
(4) Side of Road: Right/Left
(5) JKR Slope ID
(6) Field ID
(7) Route Name
(8) District Name
(9) Realignment Event
(10) Disaster Record
(11) Location Map(1/50,000)

Example is shown in the Figure 3.6.1.

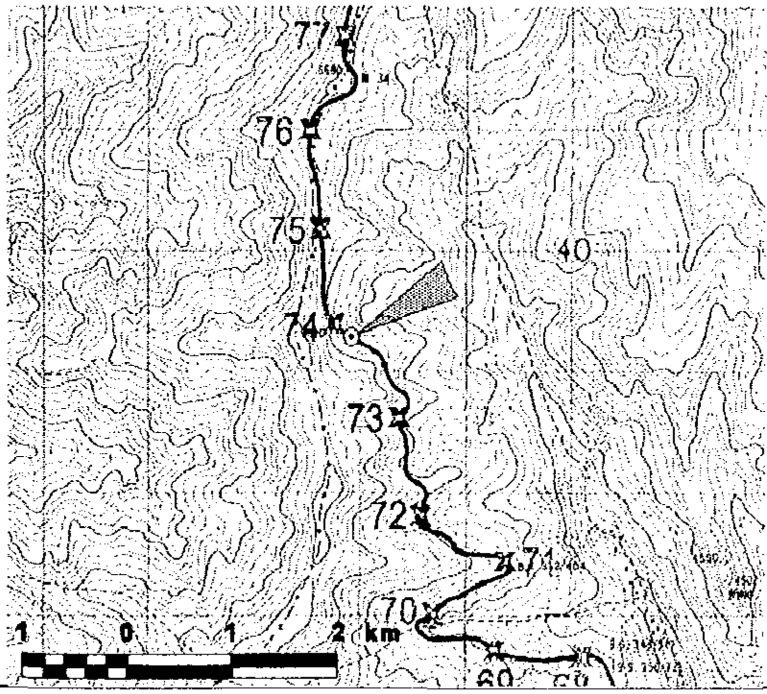
SLOPE INSPECTION SHEET

input FORM A
GENERAL SLOPE DATA

General Slope Data

Type of Slope Failure	1. Collapse / Rock Fall 2. Rock Mass Failure (3. Landslide) 4. Debris Flow 6. Embankment Failure 6. No Action Needed (Form A only)		
Chainage	Start: 73.800km - End: 73.850km	Type of Slope	Cut (Embankment) Natural
Side of Road	(Right) Left	Distance from Road Centre-Line	10 m
JKR Slope ID		Date Inspected	14-Aug-01
Field ID	S01	Inspected by	WATIN m. (JWGC)
Route Name	Tambunan - Penampang Road	Date Checked	19-Oct-01
District Name / State Name	Tambunan / Sabah	Checked by	TANAKA k. (JICA Study Team)
Realignment Event (Description)	Yes (No) (If 'yes', describe)		
Disaster Record			

Location Map (1:50,000)



Date Entered in SIMS	/ /
Entered by	

Figure 3.6.1 Example of Slope Selection Record