STANDARD PROCEDURES FOR INVESTIGATION OF POTENTIAL LANDSLIDE SITES

APRIL 1993

SABO TECHNICAL CENTRE
JAPAN INTERNATIONAL COOPERATION AGENCY

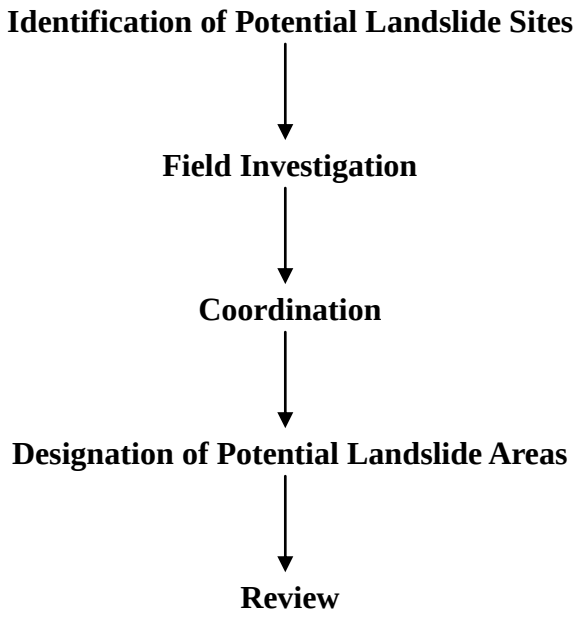
1 Standard Procedures for Investigation of Potential Landslide Sites

1.1 Scope

This manual describes standard procedures for investigation of potential landslide sites. This provides for landslide control projects under the jurisdiction of the Ministry of Public Works.

1.2 Investigation Method

1.2.1 Investigation Procedures



1.2.2 Identification of Potential Landslide Sites, Potential Landslide Areas and Potential Landslide Damage Areas.

(1) In determining Potential Landslide Sites, a group of 1) slide blocks that are considered to move independently or 2) slide blocks that are considered to affect one another during movement is regarded as a basic unit. The Potential landslide Site is defined as a set of these unit areas plus areas that could be included in future, and is determined in due consideration of desirable warning and evacuation systems and landslide control works (see Section 4.1 in Reference Section).

(2) Areas with landslide potential are identified on the basis of aerial photographs (1/5,000-1/20,000; larger-scale maps are desirable), topographic maps, geologic maps, and other records. Landslide risks and potential landslide damage areas in places that fall under (e) below need to be reviewed from time to time.

(a) Any place that has suffered damage supposed to have been inflicted by a landslide (according to ancient documents, legends, records of investigation, local residents' accounts, etc.)

(b) Any place that shows signs of ground movement (cracks, cave-in, upheaval, etc.)

(c) Any place that shows landslide topography or that is considered to have landslide potential judging from the type of rock, geological structure, etc. (based on aerial photographs, topographic maps, geological maps, etc.; to be determined according to Section 4.4 to 4.6 in Reference Section)

(d) Potential landslide areas designated according to the results of the past survey (except those that no longer have landslide potential)

(3) Potential landslide sites are indicated on topographic maps (1/25,000) issued by the Geographical Survey Institute.

(4) "Potential Landslide Areas" are designated according to the Potential Landslide Sites thus determined. A "Potential Landslide Area" consists of a Potential Landslide Site plus the zone of movement of slide blocks involved. "Potential Landslide Areas" are determined according to Section 4.2 in Reference Section. The Potential Landslide Areas thus determined are indicated on topographic maps (1/25,000) issued by the Geographical Survey Institute.

(5) For landslide areas including or adjacent to torrents, "Potential Landslide Damage Areas" are defined.

A "Potential Landslide Damage Area" consists of a Potential Landslide Area plus and area along a torrent flowing through or near the Potential Landslide area that is likely to be affected by blockage of the torrent caused by the movement of the Potential Landslide Area (see Section 4.3 in Reference Section). The "Potential Landslide Damage Areas" thus identified are indicated on topographic maps (1/25,000) issued by the Geographical Survey Institute.

(6) Considerations

In determining the Potential Landslide Sites, the following should be taken into consideration.

(a) Wherever possible, inquiries should be made at the relevant municipality to collect information on recent landslide activity prior to the interpretation of acquired data. Such inquiries might yield information on other landslide sites.

(b) During the interpretation, landslide topographies should be identified as many as possible. Those landslide topographies are classified as "clear2, "fairly clear" or "not clear". Field investigation of as many landslide topographies as possible should be conducted, giving priority to landslide topographies with higher

landslide risks.

(c) Landslides occur frequently in Tertiary landslide zones, large-scale tectonic zones, serpentine belts, crystalline schist zones, and greenstone zones.

Also landslides occur frequently in areas where there are cap rocks, intrusive rocks, fracture zones, faults, hydrothermal alteration zones (hot spring zones), and the axes of anticline and syncline.

Areas with thick layers of colluvial deposits also must be examined carefully.

(d) About 50% of the landslides in the past occurred in the vicinity of known potential landslide sites. In the process of interpretation, therefore, the known potential landslide sites and adjacent areas should be examined carefully.

(e) The planned sites of public facilities that have been made public at the time of interpretation should be examined carefully.

(f) Care must be taken so as not to mistake river and coastal terraces, lava plateaus, topographies formed by pyroclastic deposits, and other similar topographies for landslide topographies.

(g) The scale of the topographic maps used for investigation purposes should be 1/10,000 or larger.

1.2.3 Prior Coordination

The topographic maps obtained from the process described in Section 1.2.2 above are used in coordination with the related agencies. Thus, potential landslide sites that require the direct attention of the Ministry of Public Works are determined.

1.2.4 Field Investigation at Potential Landslide Sites

The potential landslide sites identified are investigated. According to the results of the investigation, the Potential Landslide Site Data Sheets (Form 1) and the Sketches of Potential Landslide Sites (Form 3) are prepared (see Section 4.6 in Reference Section for details of investigation).

The investigation should cover the following items:

(a) The names of rivers, river systems, main rivers and torrents

(b) Locations

(c) The area of each Potential Landslide Damage Area (see Section 4.3 in Reference Section)

(d) Topography

Scarps, marshes, swamps, ponds, gradient of land, etc.

(e) Geology

The age of bedrock, type of bedrock, types of rock, names of layers, geological structure, types of layers including slide blocks, dips of strata forming landslide slopes, etc.

(f) Landslide activities

Landslide activities in the past, ongoing movement of cracks, subsidence/upheaval, direction of slide movement, quantity of spring water, etc.

(g) Coverage of protection in the Potential Landslide Damage Areas (see Section 4.3 in Reference Section)

(h) Rating of potential landslide sites

(i) Others

1.2.5 Designation of Potential Landslide Sites

The results of field investigation are put together, and the potential landslide sites are determined, using topographic maps (1/25,000) and the Sketches of Potential Landslide Sites (Form 3). Finally, the potential landslide sites to be placed under the direct control of the Ministry of Public Works are determined.

1.2.6 Rating of Potential Landslide Sites (see Section 4.7 in Reference Section)

Each of the identified potential landslide sites is rated on the basis of such factors as signs of landslide activity, landslide topography, geological conditions, and landslide history, and is graded A, B or C accordingly. The landslide potential of each site is scored using the rating score sheet shown in Table 1 and is graded A, B or C according to the total scores.

Table 1 Landslide Potential Rating Score Sheet

Category		Check Point		Allotment	Score
Signs of movement		There is a continuous crack, upheaval or depression, or abnormality in slope stabilization works. Upheavals, cracks, etc. are observed on the road surface.		2 0	
		There are signs of a small-scale failure or local abnormality on the slope.		1 0	
		No sign observed.		0	
Landslide Topography		There is a scarp, hilly topography or gentle slope; irregularity of contour lines or bulge on a river bank is observed.	Clear	1 0	
			Fairly clear	6	
			Not clear	2	
Geology	Geological Structure	Fault/shattered zone		5	
		Volcanic alteration zone/solfataric clay		5	
		Back-slope		4	
		Stratum of opposite dip		2	
		Blocky		1	
		Others		0	
	Age and Lithology	Mesozoic and palaeozoic formation (crystalline schist, sedimentary rock)		2	
		Tertiary formation (sedimentary rock)		2	
		Green rock or serpentine distribution		2	
		Quarternary formation (sedimentary rock)		1	
		Others (volcanic rocks, igneous rocks)		0	
	Spring water under Normal Condition	Present		3	
		Absent		0	
Landslide History		Records of disasters and landslides in the past, reliable legends, etc	Present	2 0	
			Absent	0	
Total					
		Total Score			Grade
Grade		40 or above	(A)		
		20 or above and below 40	(B)		
		Below 20	(C)		

Note:

Since the check points here are evaluated relatively using qualitative indications, the resultant score does not necessarily show the current stability of the slope accurately.

1.3 Documents to be Made Out

(1) Potential Landslide Site Data Sheet 1 set

(2) Potential Landslide Site Rating Score Sheet (Form 2) 1 set

(3) Potential Landslide Site Map (1/25,000 topographic maps issued by the Geographical Survey Institute) 1 set

The landslide Prevention Areas and the Potential Landslide Sites Should be indicated distinctly using colors shown in Table 2.

(4) Location Map of Potential Landslide Sites (1/20,000 map of the prefectural territory)

(5) The Sketches of Potential Landslide Sites (Form 3) 1 set

Table 2 **Classification of Potential Landslide Sites by Color**

Area / Color	Potential Landslide Site Identified During the Past Survey (excl. Prevention Areas)	Newly Designates Potential Landslide Sites	Potential Landslide Area (excl. Potential Landslide Sites)	Potential Landslide Damage Area (excl. Potential Landslide Areas)
Periph-ery	Red broken line	Red	Brown	Blue
Inner Area	Not colored	Not colored	Shaded in light brown	Shaded in light blue

2 Directions for Filling In Potential Landslide Site Data Sheet

1) "Ref No." must be the same as the location map number

2) Fill in the blank space for "Name of Site" with the most widely used name of the site

3) Fill in the bland space for "Name of River" with the name of the river system, main river, or torrent involved.

4) Fill in the blank space for "Location" with the detailed address of the site.

5) Fill in the blank space for "Data on Potential Landslide" with approximate figures according to Fig. 4.3. All numbers must be shown in meters (distance, at 10m intervals; e.g., 50m, 70m) or hectares (area, to one decimal place; e.g., 8.3 ha, 6.2 ha).

6) Fill in the blank space for "type of Landslide" with the number corresponding to one of the following:

1. **Movement of Tertiary layer**
2. **Movement of fracture zone**
3. **Movement of hot spring area**
4. **Others**

7) Fill in the blank space for "Scarp" with the number corresponding to one of the following:

1. **Yes**
2. **No**

8) To fill in the blank space for "Gradient", draw a longitudinal section on the basis of the contours shown in the corresponding 1/25,000 map.

(1) If the upper and lower ends of the "unit of Potential Landslide Site" are not clear, measure the gradient of the line connecting the upper and lower ends of the potential landslide area. Then, indicate the direction of the cutting plane on the corresponding 1/25,000 topographic map (Fig. 2.1)

(2) If the upper and lower ends of the "unit of potential landslide site" are clear, indicate, by arrows, the upper and lower ends in a typical cross section drawing (Fig. 2.2) and measure the gradient of the line connecting the upper and lower ends.

The torrent, river or sea involved, if any, must be shown on the longitudinal section drawing.

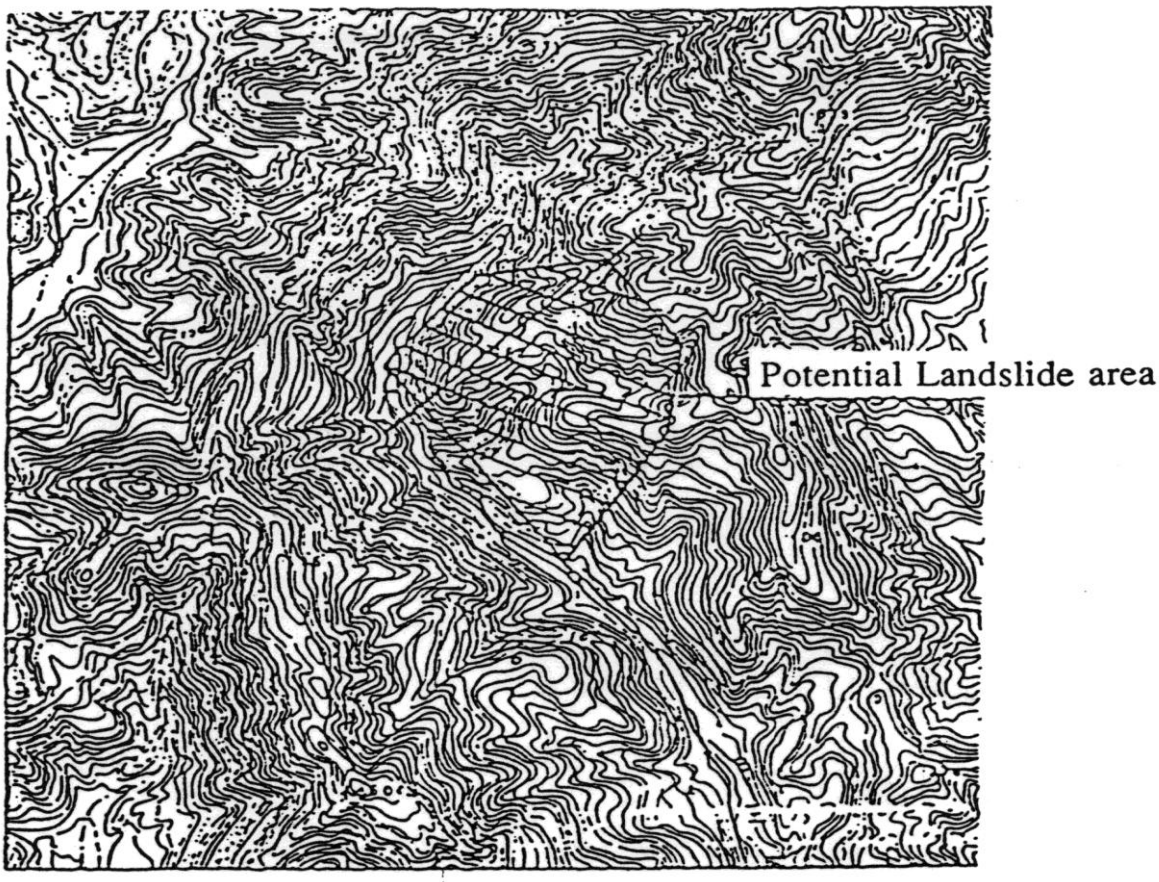


Figure **2.1**

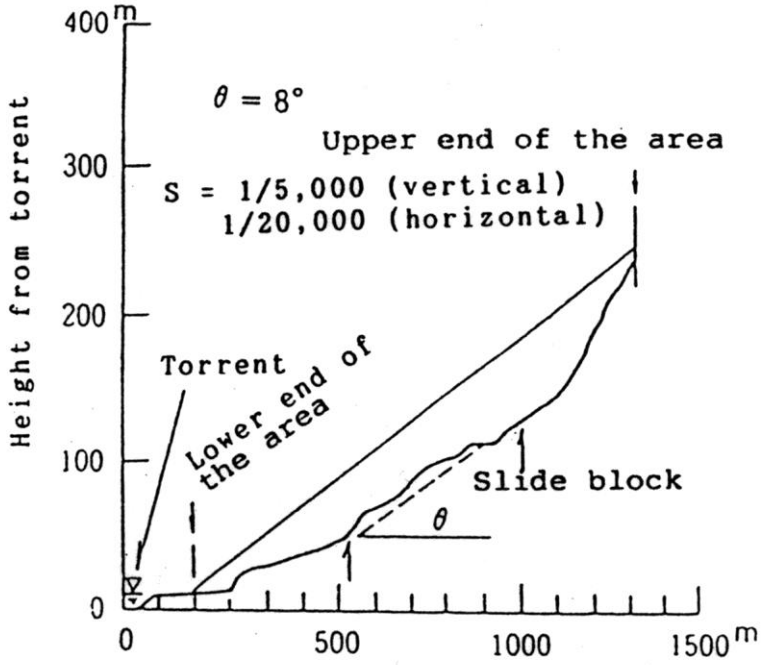


Figure **2.2**

9) Fill in the blank space for "Age of Bedrock" with the number corresponding to one of the following:

1. **Quarternary**
2. **Neogene**
3. **Paleogene**
4. **Mesozoic/Paleozoic**
5. **Not known**

10) Fill in the blank space for "Type of Bedrock" with the number corresponding to one of the following:

1. **Sedimentary rock (including green tuff)**
2. **Volcanic rock (including pyroclastic material)**
3. **Plutonic rock**
4. **Metamorphic rock**
5. **Others**
6. **Not known**

11) Fill in the blank space for "Name of Bedrock" with the type of rock, along with information on the basic unit of strata that could be involved in landslide occurrence. For the type of rock, for example, put down mudstone, shale, lutaceous schist, serpentinite, green schist, and so on. For the name of strata, put down the name of the unit stratum likely to be involved in landslide occurrence (e.g., Teradomari formation). If they are not known, put down "not known".

12) Fill in the blank space for "Geological Structure" with the number corresponding to one of the following:

For Tertiary or Quarternary formation

1. **Cap rock**
2. **Intrusive rock**
3. **Monoclinal structure**
4. **Axis of syncline**
5. **Axis of anticline**
6. **Dome structure**

For other types of formation

7. **Fault fracture zone**
8. **Regional fracture zone**
9. **Heavily weathered**
10. **Heavily altered**

11. Others

12. Not known

13) Fill in the blank space for "Moving Mass Stratum" with the number corresponding to one of the following:

1. **Cohesive soil**
2. **Sandy soil**
3. **Gravelly soil**
4. **Weathered rock**
5. **Rock**

14) Fill in the blank space for "Dip of Strata Forming the Slope" with the number corresponding to one of the following:

1. **Dip perpendicular or nearly perpendicular to landslide slope**
2. **Dip parallel or nearly parallel to landslide slope**
3. **Not known**

15) Fill in the blank space for "Crack" with the number corresponding to one of the following:

1. **Yes**
2. **No**

If yes, put down the number corresponding to one of the following:

1. Always

2. Sometimes

3. Not known

16) Fill in the blank space for "Subsidence/Upheaval" with the number corresponding to one of the following:

1. **Yes**
2. **No**

17) Fill in the Blank space for "Swamp/Marsh/Pond" with the number corresponding to one of the following:

1. **Yes**
2. **No**

18) Fill in the blank spaces for the quantity and number of places of "Spring Water" with the number corresponding to one of the following:

For the quantity of water

1. **Much (always coming out)**
2. **Little (sometimes coming out or making the site marshy)**
3. **None**

For the number of places

1. **Many (3 or more)**
2. **Few (less than 3)**
3. **None**

19) Fill in the blank spaces for "Landslide History" with the number of places and the year of the latest occurrence.

In cases where Fill in the blank space for "Occurrence in Surrounding Area" (where "Surrounding Area" refers to the area within the boundary of the same municipality) with the number corresponding to one of the following:

1. **Yes**
2. **No**

20) Fill in the blank space for "Expected Depth of Water" with the depth of diaplaced material or the maximum difference in height of the river bed and the opposite bank. Refer to "Section 4.3, Potential Landslide Damage Areas".

21) Fill in the blank space for "influence on river" with the volume of earth based on the assumed zone of landslide movement and depth of displaced material (see Section 4.3).

22) Fill in the blank space for "Population" with the total population to be protected from the potential landslides in the area. The "total population to be protected" must be shown by river system. If the Potential Landslide Damage Area overlaps other potential landslide sites, put down the simple total (above) as well as the simple total minus the overlaps in parentheses (below).

23) Fill in the blank spaces for "Number of Houses" with the quantity corresponding to each of the areas AB to E, referring to Fig. 4.3. The "Number of Houses" must be shown by river system. If the Potential Landslide Damage Area overlaps other Potential Landslide Sites, put down the simple total (above) as well as the simple total minus the overlaps in parentheses (below).

24) Fill in the blank spaces for "Type and Number of Public Facilities" with one of the following: national highway, prefectural highway, municipal road, woodland path, railway, government or other public office, school, assembly hall, and hospital. "Type and Number of Public Facilities" must be shown by river system. If the Potential Landslide Damage Area overlaps other potential landslide sites, put down the simple total (above) as well as the simple total minus the overlaps in parentheses (below).

25) Fill in the blank space for "Cultivated Land" with the quantity corresponding to each of the areas AB to E, referring to Fig. 4.3.

26) Fill in the blank space for "Progress of Work" and "Progress of Survey" with "O" if the work or investigation has already begun.

27) Fill in the blank space for the past survey with the number corresponding to one of the following:

1. **Yes, the area was investigated in the past.**
2. **No, the area was not investigated in the past.**

28) Fill in the blank space for "Designation" with the number corresponding to one of the following:

1. **Yes, the area has been designated as a Potential Landslide site.**
2. **No, the area has not been designated as Potential Landslide Site.**

29) Fill in the blank space fro "Landslide Potential" with A, B or C according to the procedure described in Section 1.2.6.

30) Fill in the blank space for "Designated under Laws" with the names of areas (e.g., sediment control areas, protection forests) under specific laws.

Form 1-1 (1)

Province

Reference Number				
Name of Site				
Name of river	**River System**			
	Tributary			
	Torrent			
Location	**Country**			
	Town/Village			
	Section of Village			
Data on Potential Landslide Site	**Potential Landslide Site**	**A+B**	**Width**	
			Length	
			Area	
	Potential Landslide Area (excl. Potential Landslide Site)	**C**	**Width**	
			Length	
			Area	
	Potential Landslide Damage Area (excl. Potential Landslide Area)	**D**	**Length**	
			Area	
		E	**Length**	
			Area	
	Total Area of Potential Landslide Damage Area A+B+C+D+E			
Type of Landslide				
Topography/ Geology	**Scarp**			
	Gradient			
	Age of Bedrock			
	Type of Bedrock			
	Name of Bedrock			
	Geological structure			
	Moving mass stratum			
	Dip of Strata Forming the Slope (Opposite dip Back-slope)			

Form 1-1 (2)

Province

Reference Number					
Activity	**Crack**	**Occurrence**			
		Frequency			
	Subsidence and Uplift				
Swamp/Hydrology	**Marah/pond**				
	Spring water	**Quantity**			
		Number of Places			
Landslide History	**Landslide Area**	**Number of Places**			
		Occurrence Year			
	Peripheral Area				
Objects to be protected in the Area	**Probable Ponding Depth (m)**				
	Influence to River (m^3)				
	Population				
	Number of Houses		**A+B**		
			C		
			D		
			E		
			Total		
	Type and number of Public Facilities		**A+B**	**Facility**	
				Quantity	
			C	**Facility**	
				Quantity	
			D	**Facility**	
				Quantity	
			E	**Facility**	
				Quantity	
			Total	**Facility**	
				Quantity	
	Arable Land			**A+B**	
				C	
				D	
				E	
				Total	
Progress of Work					
Progress of Survey					
Survey in the Past					
Designation					
Landslide potential		**Total Score**			
		Grade			
Designation under Other Laws					

Form 2 Summation of Potential Landslide Site

Province

Landslide Potential	Number of Potential Landslide Sites	Classification of Moving Material				Designation	Sites Requiring Construction Works		Houses to be Protected on a class basis			
		Tertiary Landslide	Shattered Zone Landslide	Hot Spring Area	Others		In Progress	Planned	-4	5-9	10-19	20-
A												
B												
C												
Total												

3 Procedure for Preparation of Sketches of Potential Landslide Sites

3.1 Each Potential Landslide Site must be shown on a separate sheet.

3.2 Data to be put Down

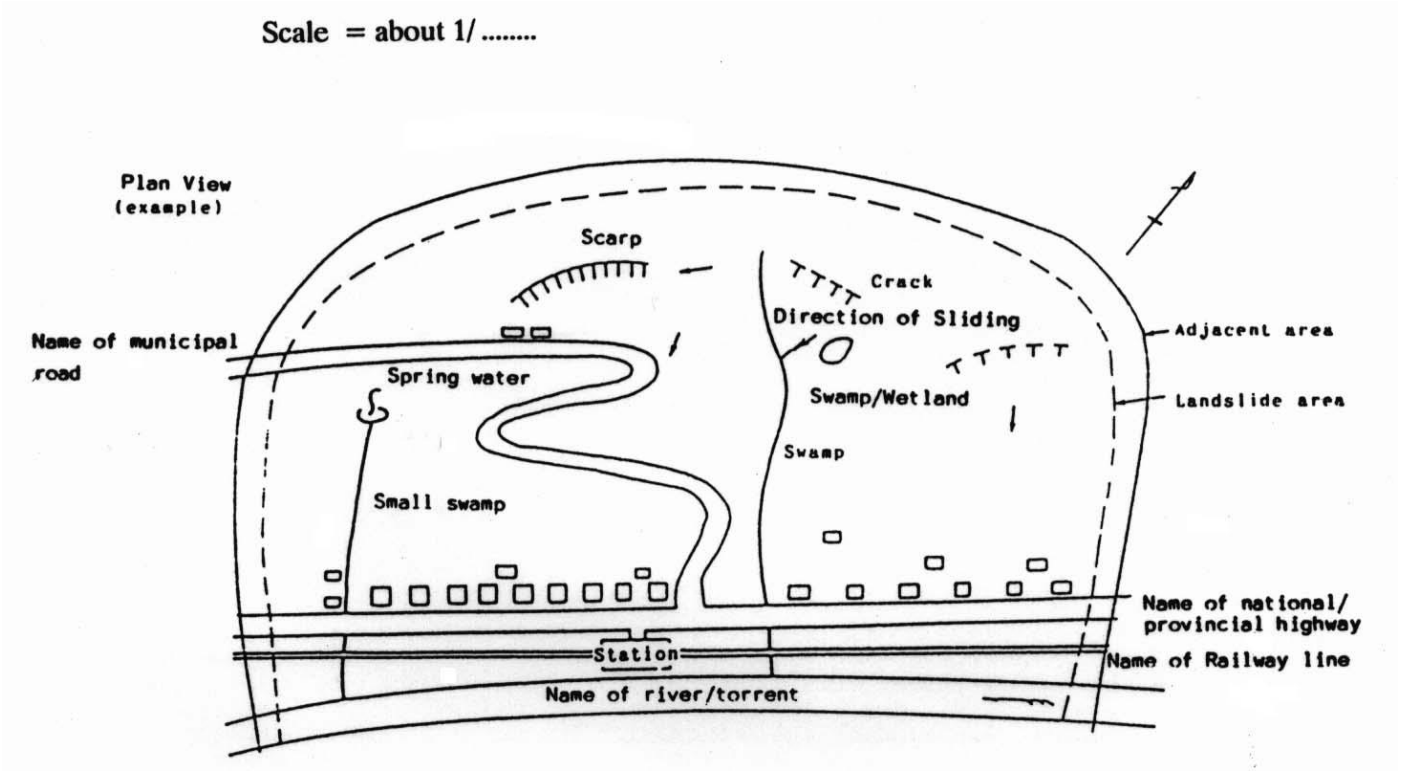
1) Reference number, name of site, location, area (outline)

2) Plan view (for the mode of representation, see the attached sheet)

- **(a) Orientation**
- **(b) Scale (approx. 1/xxx)**
- **(c) Potential landslide site: landslide area, adjacent areas**
- **(d) Activity: cracks, subsidences, upheavals, direction of slide movement**
- **(e) Property to be protected: Houses, railways, national highways, prefectural highways, municipal roads, rivers, etc.**
- **(f) Reservoirs, swamps, springs, etc.**
- **(g) Protection forests, sediment control areas, etc.**
- **(h) The names, types, tears of construction, and agencies concerned of existing conservation facilities**
- **(i) Others**

Form 3 Sketch of Potential Landslide Site

Reference number		Name of Site		Location	Area	ha



4 Reference Section

4.1 Definition of Potential Landslide Site

In defining a potential landslide site,

(1) a slide block that is considered to move as a single unit, or

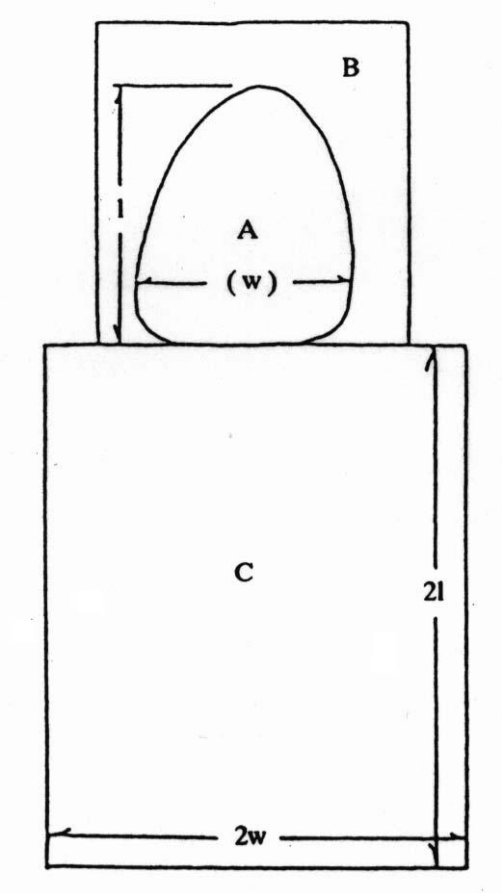
(2) a group of slide blocks that is moving or is expected to move while influencing one another

is considered to be the basic unit.

The Potential Landslide Site is defined as a basic unit thus determined plus a surrounding or adjacent area that could become part of the landslide zone. In determining the potential landslide site, warning and evacuation methods and control work plans are taken into consideration.

4.2 Definition of Potential Landslide Area

The Potential Landslide Area is defined as a Potential Landslide Site plus the zone of movement of the slide block, as shown in Fig. 4.1. However, if the zone of movement of the slide block can be determined on the basis of actual slide movements in the past or topographic conditions, such determining factors should be given priority.



A: unit of slide block

B: area where a landslide may occur in the future

C: zone of movement of moving material

A+B: unit of potential landslide site

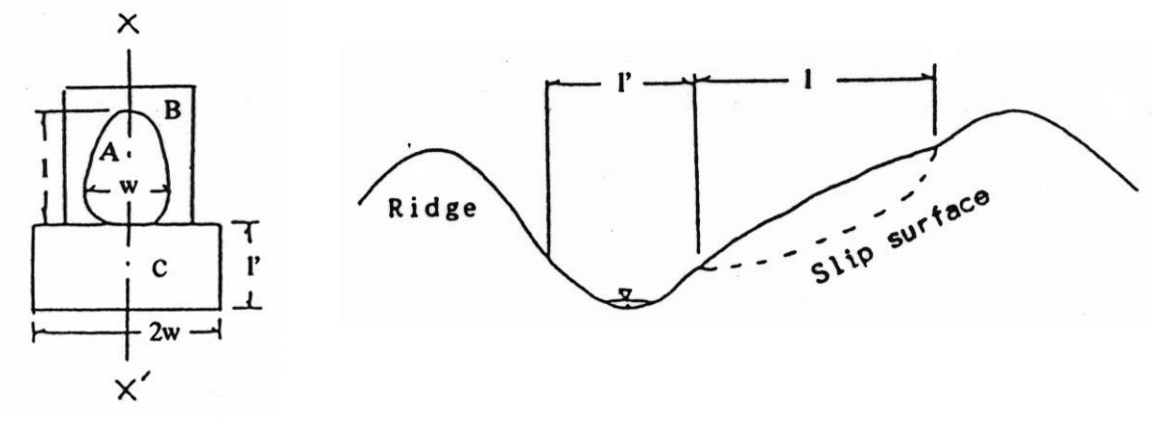
A+B+C: potential landslide area

I: horizontal length of slide block

W: maximum width of slide block

Figure 4.1 Potential Landslide Area

Plan View **X – X' section**



In cases where there is a ridge on the opposite bank, the zone of movement is estimated considering such a topographic condition to be a governing factor.

Figure 4.2 Example of the Zone of Movement of Moving Material Restricted by Topographical Condition (symbols: same as those in Fig. 4.1).

4.3 Definition of Potential Landslide Damage Area

The Potential Landslide Damage Area is defined if a potential or actual landslide is considered to occur under the influence of a torrent. The Potential Landslide Damage Area is defined as a Potential Landslide Area plus areas likely to be affected by a blockage of the river (torrent) by moving material. A Potential Landslide Damage Area is determined as shown in Fig. 4.3:

(1) In cases where moving material blocks the river channel, the depth of displaced material on the river bed is calculated as the maximum depth (h_{max}) of the slip surface of the probable landslide. For landslide sites that have not been fully investigated, the value of h_{max} is calculated as 1/7 of the width of the expected slide block (fractions to be discarded). If there is a flatland on the opposite bank, the maximum difference in height, h_1, between the river bed and the opposite bank is used in place of h_{max}.

(2) The upstream inundation area (D) in cases where moving material has blocked material determined in (1) above.

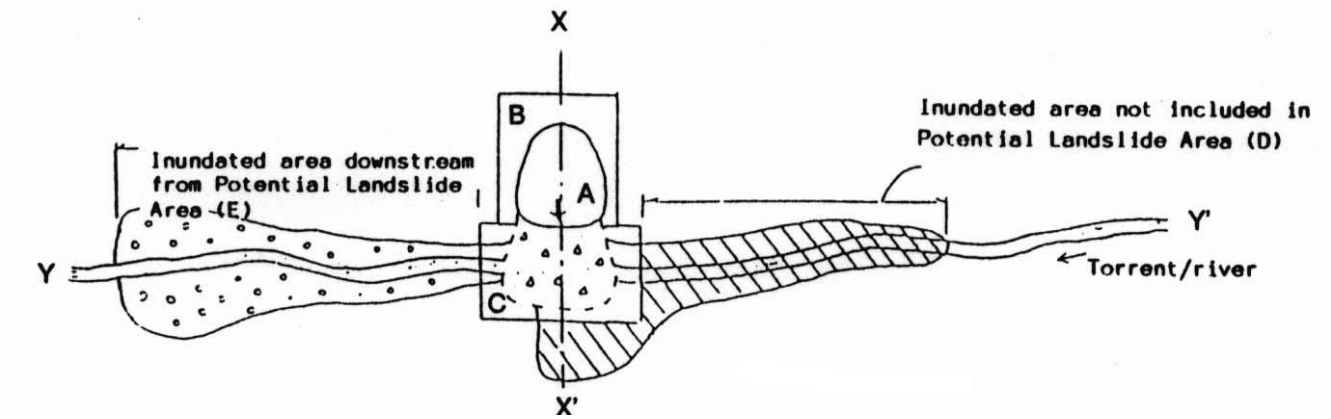
(3) In cases where moving material has blocked the river channel, if the river is a torrent prone to debris flow, the downstream inundation area (E) is usually the same as the debris flow hazard area.

(4) If the river is not a torrent prone to debris flow, the downstream inundation area (E) is usually defined as the portion of the river bed with gradients of 3^o or below plus the flat area (fan or valley bottom plain) with relative heights from the river bed of up to several meters.

(5) If the river is not a torrent prone to debris flow and if the gradient of the river bed

under the deposited material is 3^{o} or less, the downstream inundation area is determined according to the condition of the downstream area.

Plan View



A: unit of slide block

B: area where a landslide may occur in the future

C: zone of movement of moving material

D: inundated area not included in potential landslide area

E: inundated area downstream from C

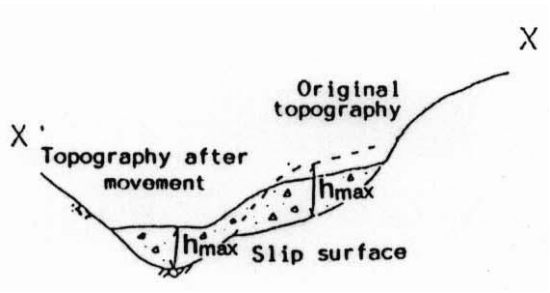
A + B + C: potential landslide area

A + B: unit of potential landslide site

A + B + C + D: potential landslide damage area

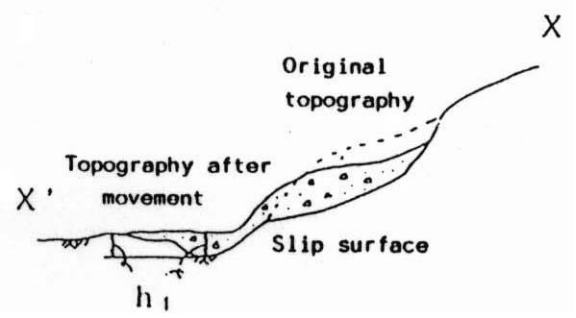
X – X' section

If the opposite bank is hillside



X – X' section

If the opposite bank is flat land



Y – Y' section

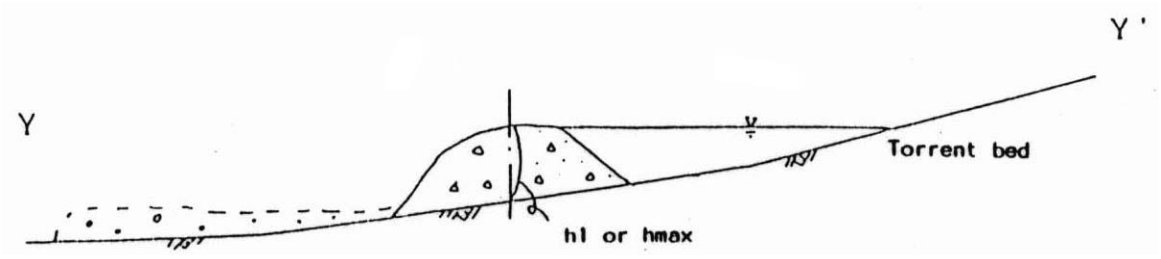


Figure 4.3 Potential Landslide Damage Area

4.4 Distribution of Landslide Sites

It is important to note that landslides often occur in areas where the conditions listed below are satisfied.

4.4.1 Type of Rock (Bedrock)

1) **Neogene mudstone or tuff**
2) **Crystalline schist or slate (green schist, lutaceous schist, black schist)along fracture zones**
3) **Greenstone**
4) **Serpentinite**
5) **Areas that have volcanic alteration rock, such as solfataric soil.**

4.4.2 Geological Structure

1) **Areas adjacent to faults with fracture zones (Fig. 4.4); areas along tectonic lines**
2) **Areas on slopes consisting of strata that are parallel or nearly parallel to the slopes (Fig. 4.4)**
3) **Areas near an axis of anticline or syncline in folds of Tertiary sandstone, mudstone, etc. (Fig. 4.5)**
4) **Areas near the boundary of intrusive igneous rock (Fig. 4.6)**
5) **Areas where there are hard cap rocks (basalt, andesite, pyroclastic material, etc.) covering soft ground (Fig. 4.7)**

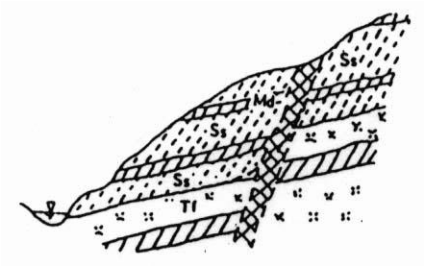


Figure 4.4 Monocline Structure (back-slope), Model of Bedrock Slide Caused by Fault

Ss: sandstone
Tf: tuff
Md: Mudstone

Fault and shattered portion

Bed rock slip surface along the upper face of tuff caused by a shattered zone

Figure 4.5 Model of Bedrock Slide and Colluvial Deposit Slide (along the lower face of colluvial deposits) Caused by Fold (anticlinal structure)

Dt: colluvial deposit
Tf: tuff
Ss: sandstone
Md: mudstone

Slip surface along the lower face of colluvial deposits

Bedrock slip surface along the upper face of mudstone

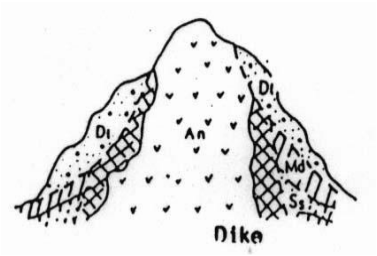


Figure 4.6 Model of colluvial Deposit Slide caused by Andesite intrusion

Dt: colluvial deposit
An: andesite
Md: mudstone
Ss: sandstone

Shattered/altered zone caused by shattering of bedrock involved in andesite intrusion

Slip surface along the lower face of colluvial deposits.

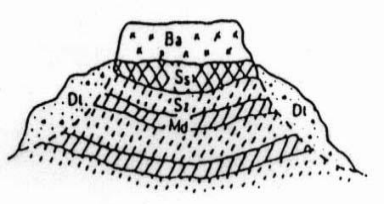


Figure 4.7 Model of colluvial Deposit Slip caused by Laccolith Cap Rocks

Dt: colluvial deposit
Ba: basalt
Sz: shattered zone
Ss: sandstone Md: mudstone

Slip surface along the upper face of colluvial deposits

(Fujiwara et al., 1979)

4.4.3 Topography

1) **Areas classified as V-shaped valleys, where planation surface is eroded downward**
2) **Areas where there are thick layers of deposits produced by collapse; buried valleys (Fig. 4.8)**
3) **Areas where there is a small depression on a hillside and there is a bulge below the depression; where a river system bypasses a block; or where a river system terminates (Fig. 4.9)**
4) **Areas where there is a water-hammered slope of rock of the type that is prone to landslides; or area on both sides of a water-hammered slope of hard rock (Fig. 4.10)**
5) **Areas where a bend in a river has an unusual bulge that is being eroded (Fig. 4.10).**

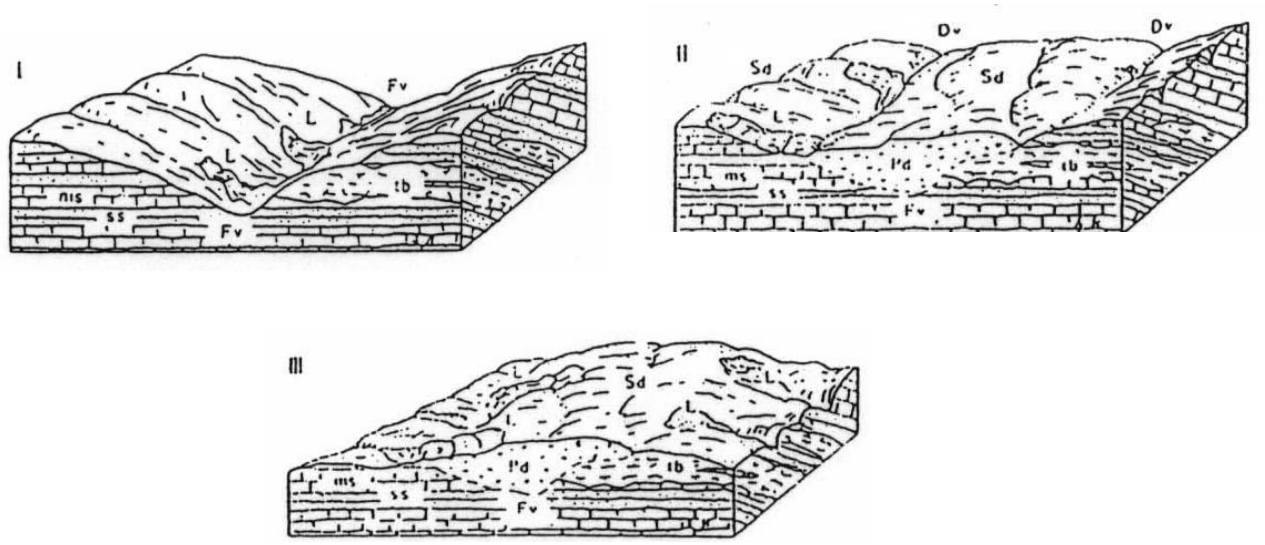
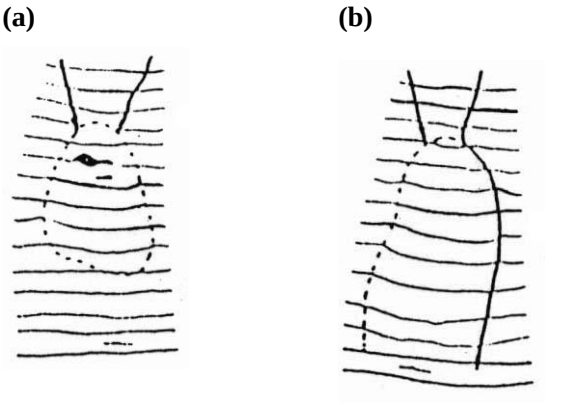


Figure 4.8

Ⅰ: topography before the formation of a buried valley, Ⅱ: present topography, Ⅲ: part of expected topography in future, Pd: protruding deposits (in this case, colluvial deposits composed of pyroclastic material, andesite tuff breccia Strata, etc.) Sd: the portion that is so-called "landslide topography" composed of Pd, Fv: original valley aggraded by Pd, Dv: present river tunning along the periphery of Pd, Sv: a kind of subsequent valley that develops on bedrock ms and an alternation bed of ms and ss, ms: mudstone, ss: sandstone stratum, tb: pyroclastic basement material that was deposited at the same time as ms and ss and that interfingers with ms and ss, L: landslide area

(Saburo Nakamura, 1977)



(a) When there is a depression impounding water

(b) When a waterway bypasses a certain block

Figure 4.9 Landslide-Prone Areas Recognizable from the condition of water System and Topography

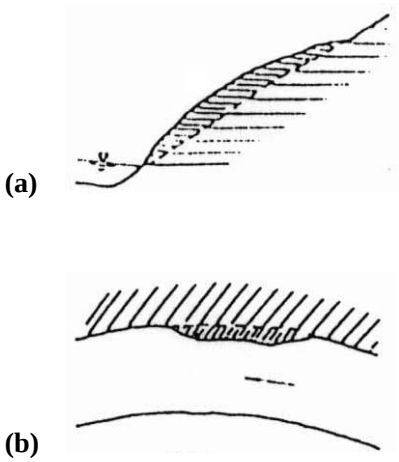


Figure 4.10 Topographically Unusual (Unstable) Slope (Takeda et al., 1976)

4.5 Characteristic of Landslide topography

It is important to note that landslide topography has the following characteristics.

1) **Contour lines have irregular shapes. Areas where contour lined are dense in the upper section, sparse in the middle section, and dense again in the lower section (Figs. 4.11 to 4.15).**
2) **There is an inverted U-shaped or rectangular scarp at the head of a slope, and the midsection forms a flat, gentle slope (Fig. 4.15); there is an isolated small hill (Fig. 4.16).**
3) **There is a concavity, depression, crack, etc. or there is a long, narrow depression in a mountain or at the top of a mountain.**
4) **There are regularly arranged ponds, swamp or marshes.**
5) **There is a marshy zone or a crack on one or both sides of a slide block (Figs. 4.17(A), (B)).**
6) **A ridge behind a landslide area has a depression (Fig. 4.18).**
7) **There are terraced paddy fields.**
8) **The foot of a slope is steep and there is an upheaval or bulge there.**
9) **A railway or road is unusually curved, or a structure is displaced.**
10) **A swamp or river is unusual curved; a river is narrower than in other areas.**

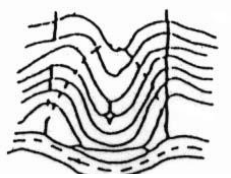


Figure 4.11 Convex Ridge Type Topography

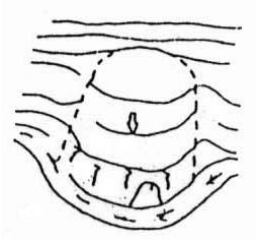


Figure 4.12 Convex Plateau Type Topography

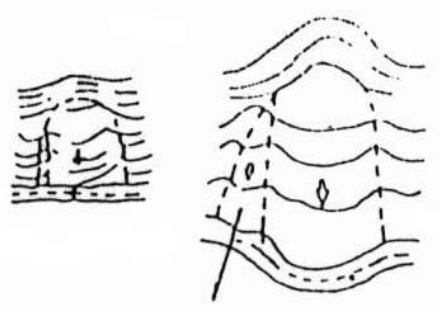


Figure 4.13 Concave Single Hill Type Topography

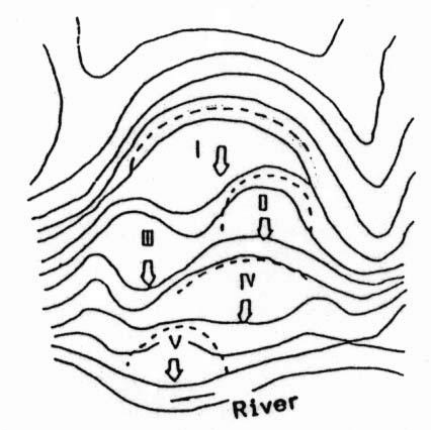


Figure 4.14 Concave Multiple Hill Type Topography

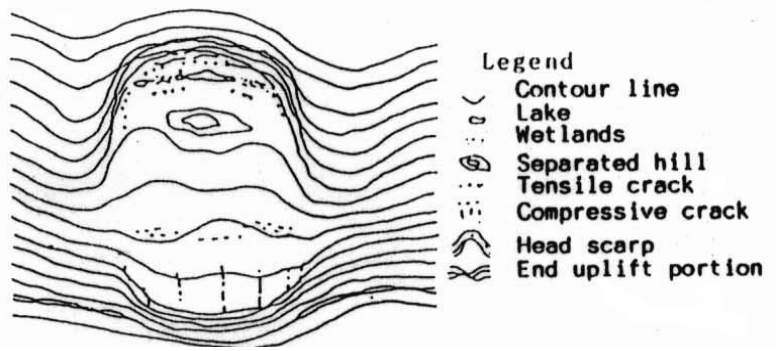
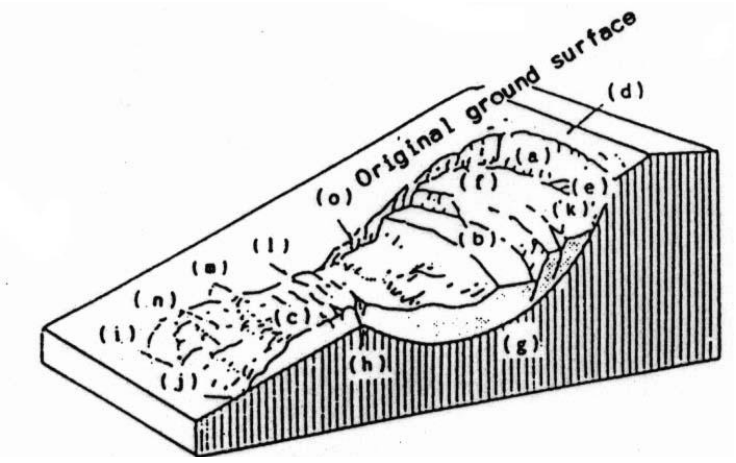


Figure 4.15 Typical Figure of Landslide (Concave Single Hill Type)

(Watari et al., 1971)



(a) Scarp
(b) Secondary scarp
(c) Tongue (d) crown
(e) Top (f) Head
(g) Slip surface
(h) Foot (i) Tip
(j) Tip of tongue
(k) Tensile crack
(l) Compressive crack
(m) Uplift
(n) Compressive crack
(o) Flank (Side)

Figure 4.16 Landslide slope

(David J. Varns, 1958)

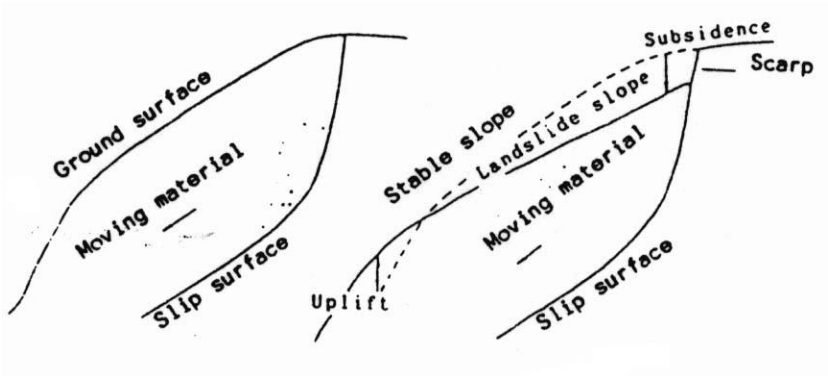
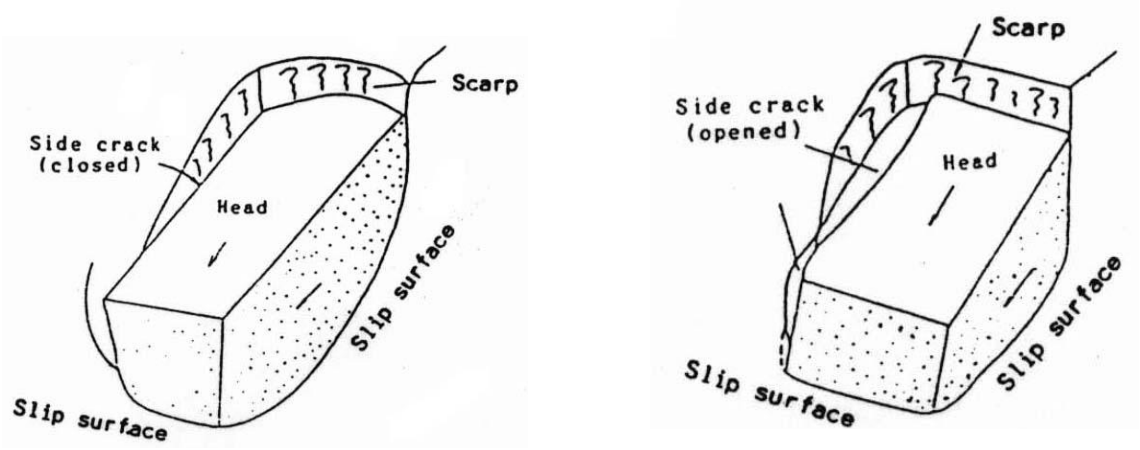


Figure 4.17 (A) Change in Side Crack



Closed Crack **Opened Crack**

Figure 4.17 (B) Side Crack

(Watari et al., 1975)

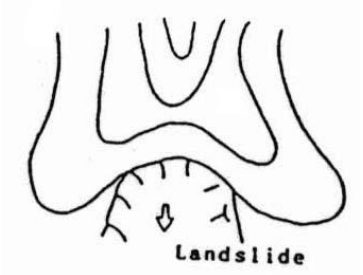


Figure 4.18 Shape of Ridge behind Landslide Area

(Yamada et al, 1971)

4.6 Field Investigation

Field investigation should be conducted to determine if there is any sign of the following phenomena because they are characteristics of landslide-prone areas.

1) **Cracks or other abnormality of roads, stone walls, stone stairways, waterways; inclination of trees, utility poles, or buildings**
2) **Repaired waterways, leakage from waterways, wells running dry, turbidity of water, spring water, marches**
3) **Upheavals at the foot of a slope, mudflow**
4) **Cracks in hillsides, slope failure, scarps**
5) **Soft rocks, fractured rocks, solfataric alteration rocks, expansible rocks, faults**

4.7 Directions for Filling in Landslide Potential Rating Score Sheet

4.7.1 Signs of Slide Movement

Signs of landslide movement are rated on three-grade scale, as shown in the rating score sheet. If more than one grade applies, take the higher one.

4.7.2 Landslide Topography

Characteristics of landslide topography have been described in Section 4.5. In filling in the rating score sheet, consider the degree of clarity of those characteristics.

4.7.3 Geology

1) Geological Structure

To evaluate factors affecting the occurrence of landslides, indicate whether the following signs are shown. You may choose more than one item here.

(1) Faults/fracture zones

Typical relative positions of fault or fracture zones and the slip surface are illustrated in Fig. 4.4. Fault or fracture zones here do not mean "fracture zone landslide" sites according to the established geological classification, but it means fault or fracture zones and the occurrence of landslides is as follows:

(a) Part of a fault surface may constitute a slip surface or form a scarp to border a landslide zone (F9g. 4.4).

(b) A fault surface or fracture zone may become a route of groundwater flow. Fault clay may cut off groundwater flow so that the rerouted groundwater governs the waterway and causes a landslide.

(c) Fault or fracture zones are prone collapse.

(2) Volcanic alteration zones and solfataric soil

In volcanic areas hot spring water deep underground causes chemical reaction of surrounding rock. Such alteration of rock is called volcanic alteration. Rock subjected to this process turns into solfataric soil, increasing the likelihood of landslide occurrence.

(3) Strata prallel or nearly parallel to the slope

Slope consisting of strata parallel or nearly parallel to the slopes are subject to landslides, particularly, tock slide type and fluidized landslides (Figs 4.4 and 4.5)

(4) Strata perpendicular or nearly perpendicular to the slope

Slope consisting of strata perpendicular or nearly perpendicular to the slopes are subject to small or medium-scale failure-type landslides.

(5) Block structure

The geological structure as described below is referred to as "block structure".

(a) Intrusive rock structure

Colluvial soil zones near intrusive rock, such as volcanic rock, are subject to landslides (Fig. 4.6).

(b) Cap rock structure

In areas that have cap rock structure where hard rock lie on weak formation, hard rock on the mountain top is highly weather-resistant and hence the likelihood of landslides or collapse is low. On the other hand, the underlying weak formation is less weather-resistant and is subject to landslides or collapse (Fig. 4.7).

2) Age and Lithology

Identify the age and lithology according to the classification given below, referring to geologic maps and other data on the area under consideration.

(1) Paleozoic/Mesozoic formation (crystalline schist, sedimentary rock):

Crystalline schist such as Minami River crystalline schist, Sangun metamorphic rock; Paleozoic/Mesozoic slate, shale, tuff, sandstone,

(2) Tertiary formation (sedimentary rock): Tertiary (Cainozoic) shale, mudstone, tuff, sandstone, etc.

(3) Greenstone/serpentinite area: Area consisting of greenstone, such as Mikabu

greenstone, and serpentinite

(4) Quarternary formation (sedimentary rock): Quarternary (Cainozoic) mudstone, tuff, sandstone, etc.

(5) Others (volcanic rock, igneous rock, etc.): rhyolite, andesite, basalt, granite, diorite, etc.

3) Spring under Normal Condition

Groundwater is a major factor affecting the occurrence of landslides. Groundwater comes in as inflow or infiltration from slopes above landslide sites or landslide slopes. The inflow or infiltration often comes out as spring water at or around the lower end of the slip surface, particularly around the lower end of either flank lf the slide block.

4.7.4 Landslide History

The objective of this survey is to trace the history of a particular landslide area. In this survey landslide records and reliable legends are collected wherever possible.