Rapid Recon Landslide Hazard Relative Risk Assessment

Rural Training Center-Thailand
Community-based Education Office
166 Moo 5, Ban Wangwa, Thawangpha District
Thawangpha City, Nan Province 55140
Thailand
www.neighborhoodlink.com/org/rtcth

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PREFACE

This RTC-TH Applied Geography paper uses the Geographic Systems Model in support of the RTC-TH Emergency Communications disaster preparedness community-service effort. The purpose is to train licensed amateur radio operators (Hams), interested citizens, and emergency services personnel how to quickly scout their local areas to assess potential landslide hazards.

The annual rainy season in Nan Province (and other mountainous portions of Northern Thailand) brings the potential for landslides. This rapid recon uses "windshield" surveys from vehicles. The observer can see some of the assessment criteria looking from the vehicle. Some assessment criteria require a brief stop. The idea is to identify potential trouble spots that could affect emergency relief / responders having access to or egress from an area.

The specific assessment methods have been adapted from other RTC-TH field survey methods contained in RTC-TH Publication AG-2010-2 Natural Terrain Study Guide.

Rural Training Center-Thailand: Windshield Surveys

Rapid Recon Landslide Hazard Relative Risk Assessment

c/o S. Lee, 64 Moo 2 Ban Na Fa, Jompra, Thawangpha, Nan Province, Thailand 55140
www.neighborhoodlink.com/org/rtcth E-mail: rtc2k5@gmail.com

Community-based environmental education for the self-sufficiency and sustainability of small rural family farms

ชุมชนตามสิ่งแวดล้ [illegible] เล็กครอบครัวฟาร์ม

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1.0 INTRODUCTION

The monsoonal rainy season in Nan is a time of increased flooding and landslide hazards. This technical paper is part of the RTC-TH EmComm (Rural Training Center-Thailand Emergency Communications) program of emergency preparedness. The Rapid Recon Landslide Hazard Relative Risk Assessment is a quick “windshield” survey to identify potential landslide hazards. It is not meant to replace traditional technical engineering slope stability studies.

Pinpointing potential areas of landslide risk using this low cost method helps emergency response planning. The intent is to assist emergency response planners to identify reliable access roads and safe assembly locations relatively free of possible landslide hazards. Landslides can close access roads for relief equipment and supplies. Landslides can also pose a danger to assembly and evacuation shelter areas in the mountainous areas of Nan Province.

Landslides are a particular kind of slope failure. But to most common people, landslide is the term they use when slopes fail. Mass wasting is the geo-technical term covering the wide range of slope failures. There are many forms of mass wasting. Some happen very suddenly. Others take many years. (See the summary table below.) It is the rapid sudden slope failures that are of prime concern to emergency planners.

<table>
<tr><th colspan="8">Summary Table of Mass Wasting</th></tr>
<tr><th colspan="2">Process & Sub-process</th><th>Water</th><th>Speed</th><th colspan="2">Form / Shape</th><th colspan="2">Size</th></tr>
<tr><td>Fall</td><td></td><td>No</td><td rowspan="2">Fast</td><td colspan="2">Talus slope; concave slope face</td><td colspan="2">35°-40° slope</td></tr>
<tr><td rowspan="2">Slide</td><td>Landslide</td><td rowspan="2">Some-times</td><td colspan="2">Can create natural dams and flooding hazard</td><td rowspan="3">Higher risk when slope 15° or more</td><td rowspan="5">Variable sizes</td></tr>
<tr><td>Slump</td><td rowspan="2">Medium</td><td colspan="2">Crescent shaped scars upslope</td></tr>
<tr><td rowspan="4">Flow</td><td>Earthflow</td><td rowspan="3">Yes</td><td colspan="2">Clay soils accelerate the process; slopes with little or no vegetation more susceptible</td></tr>
<tr><td>Debris flow</td><td rowspan="2">Fast</td><td rowspan="2">Common in arid regions*</td><td>Larger materials</td><td rowspan="2">Narrow canyons very dangerous</td></tr>
<tr><td>Mudflow</td><td>Smaller materials</td></tr>
<tr><td>Rock glacier</td><td>No</td><td rowspan="3">Slow</td><td colspan="2">Large, elongated in glacial areas and adjacent plains (Unlikely in Nan)</td><td colspan="2">Valley length</td></tr>
<tr><td rowspan="2">Creep</td><td>Creep</td><td rowspan="2">Yes</td><td colspan="2">Terracettes (small terraces)</td><td colspan="2" rowspan="2">Hillsides (even gentle ones)</td></tr>
<tr><td>Solifluction</td><td colspan="2">Solifluction lobes (Unlikely in Nan)</td></tr>
<tr><td colspan="8">*Mudflows may occur in areas prone to flashflooding in humid regions during heavy rains and mountainous areas.</td></tr>
</table>

1.1 The Geographic Systems Model and Landslides

A matrix using the main environmental spheres from the Geographic Systems Model and the main factors of landslides is shown below. The Atmosphere is the source of moisture. The Lithosphere provides the landform structure and processes, and slope. The movement of water on the surface is in the realm of the Hydrosphere. The vegetation on the slope is part of the Biosphere.

For any given site, the potential landslide hazard can be identified by picking factors that minimize slope instability. For example, steep slopes facing approaching storms, slopes with strata parallel to the slope, and fragmented rocks and clay soils, little or no vegetation, and saturated soils.

Key Landslide Factors and the Geographic Systems Model					
Landslide Factors		Atmosphere	Lithosphere	Hydrosphere	Biosphere
Slope Angle	Steep		X		
	Gentle				
Slope Aspect	Facing the wind	X			
	Away from wind				
Strata Dip	Parallel to slope		X		
	Into the slope				
Surface Rock Materials	Fragmented		X		
	Solid				
Slope Soil Materials	Mostly clay or sand		X		
	Loam				
Vegetative Cover	Little or no plants				X
	Dense trees				
Slope Soil Moisture	Saturated	X		X	
	Dry				

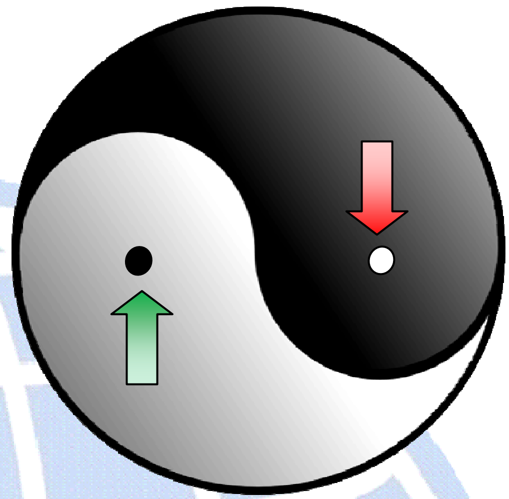
The matrix can also help identify ways to reduce landslide hazards. For any given potential landslide site, picking factors that minimize slope instability could help reduce or prevent landslides. For example, highway engineers reduce steep slopes on road cuts by grading a road cut to a lower angle or terracing. Planting bare slopes is a simple approach to get plant roots to anchor soil in place.

There are no “easy” silver bullet solutions to the complex problems of slope instability and landslides. A systematic assessment of the potential landslide hazards in your local area may help reduce unpleasant surprises when emergencies occur.

1.2 Yin-Yang of Landslides

Knowing the factors that can cause a shift in the balance of forces is the key to assessing potential landslide hazards. Yin-Yang is a non-linear model describing the balance of forces in the universe. For landslides the basic balance of forces affecting landslides involves gravity (tending to pulling rock, soil, and water down slope) and resistance to the down slope movement. When the forces are balanced, the slope is stable (i.e. G = R). When resistance is greater than gravity, the slope is still stable (G < R). When gravity is greater than resistance, the slope is unstable and a landslide can occur (G > R). These are summarized in the next table.

Yin-Yang		Yin	Yang
Shading		Dark area	Light area
Traditional characteristic		soft	hard
Landslide dynamics		Gravity	Resistance
Slope Angle	Steep	+	-
	Gentle	-	+
Slope Aspect	Facing the wind	+	-
	Away from wind	-	+
Strata Dip	Parallel to slope	+	-
	Into the slope	-	+
Surface Rock Materials	Fragmented	+	-
	Solid	-	+
Slope Soil Materials	Mostly clay or sand	+	-
	Loam	-	+
Vegetative Cover	Little or no plants	+	-
	Dense trees	-	+
Slope Soil Moisture	Saturated	+	-
	Dry	-	+



1.3 The Geographic Systems Model, Yin-Yang and Landslides

The table below integrates the Geographic Systems Model and the Yin-Yang relationships. This matrix helps to systematically summarize the factors involved in assessing landslide potential.

Landslide Factors		Landslide Poten.		Atmosphere	Lithosphere	Hydrosphere	Biosphere
		High	Low				
Slope Angle	Steep	+			X		
	Gentle		+				
Slope Aspect	Facing the wind	+		X			
	Away from wind		+				
Strata Dip	Parallel to slope	+			X		
	Into the slope		+				
Surface Rock Materials	Fragmented	+			X		
	Solid		+				
Slope Soil Materials	Mostly clay or sand	+			X		
	Loam		+				
Vegetative Cover	Little or no plants	+					X
	Dense trees		+				
Slope Soil Moisture	Saturated	+		X		X	
	Dry		+				

2.0 RAPID RECON METHOD

This method uses a simple, subjective, numerical tabulation method to get a relative score of potential landslide risk. Much of the survey can be done from a vehicle (e.g. “windshield” survey). Typically, the selected road would be surveyed by driving along it. Stops can be made for measurement, observations and photographs.

A brief summary of the assessment criteria and ranking scales is presented. More detailed descriptions are given in the appendices at the end of the paper. The appendices are non-technical and brief. They are simply guides for lay people to be able to perform the recon assessment. The appendices are not intended as comprehensive references.

A field log assessment worksheet is included with the ranking scales as references are included in Appendix 1.

2.1 The Rapid Recon Survey

The kind of rapid recon survey is often called a “windshield” survey. It is done suing a moving vehicle. The idea is to quickly cover a designated area and identify potential landslide hazard areas. Once located, the idea is to determine the possible impact of the landslide on local area emergency relief operations.

2.1.1 Before the Survey: Prepare reference materials, maps, equipment, and survey forms.

References	Maps	Equipment	Survey forms
□ Recon reference sheets □ Field Survey Notes	□ Local road maps □ Aerial / satellite photos	□ hand trowel / shovel □ magnetic compass □ leveling stick □ tape measure □ water jug □ pens/pencils □ camera/batteries	□ Landslide assessment form □ field notebook
Optional Equipment:	□ GPS / batteries □ binoculars		

2.1.2 During the Survey: For each observation stop, thoroughly review the assessment form before leaving the site.

- □ Double check all measurements / observations.
- □ Complete the assessment calculation before departing.
- □ Take any and all necessary photos to document the location.
- □ Mark the map and provide as much location data as possible to make it easier for others to get back to the same location.

2.1.3 After the Survey:

- □ Secure field notes and survey data
- □ Compile and post results to data base and local area emergency planning maps
- □ Share results with relevant and interested parties (government and non-government

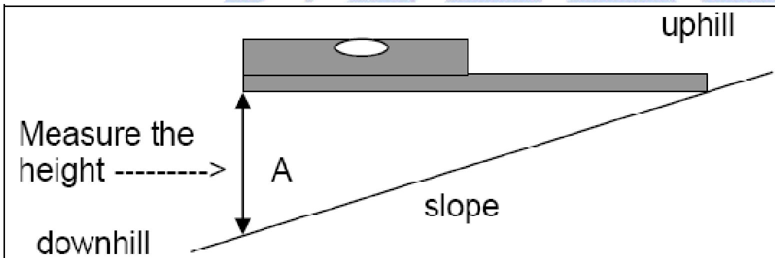
2.2 The Assessment Criteria

The items surveyed can be done quickly when make brief stops along a road or during an inspection of a possible assembly or evacuation shelter site.

2.2.1 Slope Angle *Vertical Orientation): This can be easily measured with home-made devices called a leveling stick or clinometers. Once the % slope angle is measured, an assessment number is selected from a look-up table and entered on the assessment form. Generally, steeper slopes pose greater risks than gentler slopes. But the amount of moisture, vegetation cover, and the rock / soil types, and bedding planes are also significant factors affecting slope failure. As a result, knowing the slope angle is just the start of assessing landslide risk. The ranking scale use here is "subjective" and can be endlessly debated. We tend to use this as a starting point. Over time, records for your local area will allow you to qualify and improve your "judgment" calls.

This simple spirit level on a stick with a tape measure makes slope measurements fast and easy.

The leveling stick is a simple low cost slope measuring. It can be made using bamboo and a discarded water bottle. Since we had scrap PVC and an extra spirit level, we used these materials to make a compact and easily back packable unit.



Equipment Needed:

- Leveling stick
- Short tape measure
- Note pad
- Pen or pencil

Step 1. Get the "Leveling Stick" and a tape measure with a centimeter scale.

Step 2. Assemble the "Leveling Stick" by inserting the handle into the end with the spirit level. There is a short tether to keep the two pieces together when stored.

Step 3. Use the tape measure to check the total length of the Leveling Stick is 50 cm.

Step 4. Rest the plain end of the "Level Stick" on the uphill side of the slope.

Step 5. Lift the downhill side of the "Level Stick" until the bubble in the spirit level is centered.

Step 6. Measure the height from the ground to the bottom edge of the "Level Stick" using the *centimeter* scale on your ruler. The number of centimeters multiplied by 2 is equal to the "percent" slope. This is because the "Level Stick" is made 50 cm long. "Per cent slope" is a measure of the vertical change for every 100 cm of horizontal distance. So if the height of the "A" in the diagram was 8 cm, the slope is 16%.

Note: You must multiply 8 cm X 2 because the Leveling Stick is only 50 cm long. Percent means "part of 100". So to make 50 cm = 100, you must multiply by 2. Use the table on the right to convert your slope measurements.

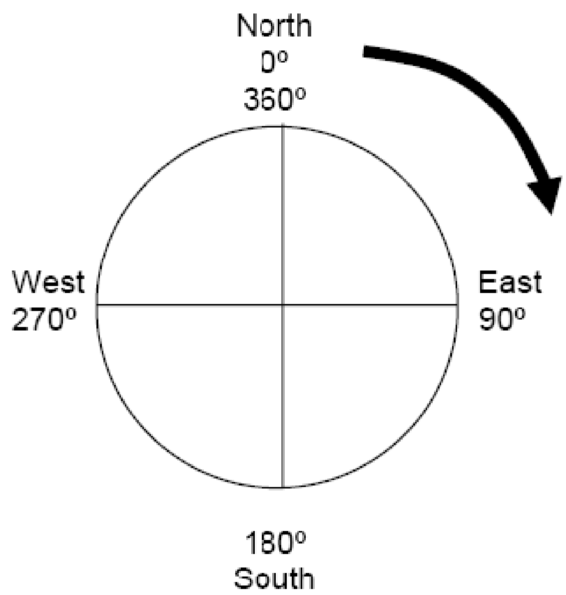
% Grade	Ratio	Degrees
100.0%	1:1	45.0º
50.0%	1:2	26.6º
33.3%	1:3	18.4º
25.0%	1:4	14.0º
20.0%	1:5	11.3º
16.7%	1:6	09.5º
14.3%	1:7	08.1º
12.5%	1:8	07.1º
11.1%	1:9	06.3º
10.0%	1:10	05.7º

Slope Angle Ranking Scores

Landslide Hazard		General slope classes			
	Rank	Simple slopes	Complex slopes	Lower %	Upper %
High	6	Very steep	Very steep	>45	
	5	Steep	Steep	20	60
	4	Moderately steep	Hilly	10	30
	3	Strongly sloping	Rolling	4	16
	2	Gently sloping	Undulating	1	8
Low	1	Nearly level	Nearly level	0	3

Slope Aspect (Horizontal Orientation)

The slope aspect is the horizontal compass direction the slope faces.



To Measure Slope Aspect:

Imagine you are standing in the middle of the circle in the picture on the left.

Step 1. Stand on the slope facing down hill.

Step 2. Aim the magnetic compass directly down slope, but keep the compass level so the needle swings freely.

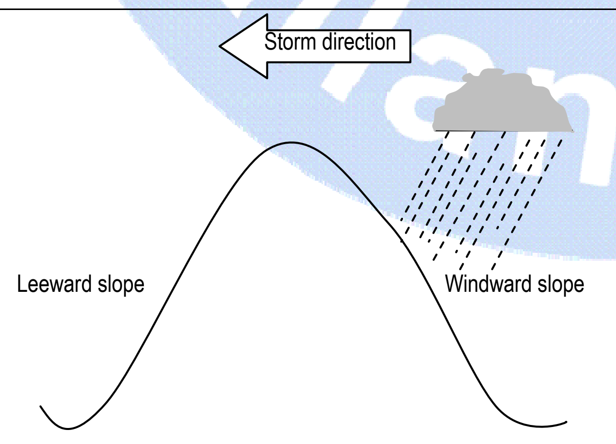
Step 3. Read off the azimuth angle in degrees ranging from 0º (starting at North) going clockwise around the circle.

Step 4. Change the azimuth number into the name of the direction using the table below. Ultra precision is not needed. The general direction is good enough.

For a site located at 33.93°N, sunlight is always coming from the south. So slopes facing this direction will get more direct sunlight than north-facing slopes.

0º & 360º = North	180º = South
45º = Northeast	225º = Southwest
90º = East	270º = West
135 – Southeast	315 = Northwest

The main concern is if the slope is facing an approaching storm. The slope facing the wind is called the “windward” slope. The opposite slope is called the “leeward” slope. Since the winds can change direction depending on the weather, it is necessary to know the compass direction a slope faces. If you know the slope aspect, then any slopes with a high potential landslide hazard will be immediately identified once you know the wind direction of a storm. Since this wind/storm direction cannot be known ahead of time, this factor is NOT applied during the rapid recon assessment. (More about this in section 2.2.6 Soil Moisture.)



Windward vs. Leeward Slopes

- Windward slopes tend to get more rain since they face the approaching storm directly.
- Leeward slopes tend to get less rain since the face away from the approaching storm.

2.2.2 Strata Dip Orientation of Slope Rock / Soil Materials: The mountains of Nan Province are formed mostly by the compression of sedimentary layers during mountain building. This means there are multiple layers of rock / soil materials that have been tilted and folded. Many road cuts in the province will have rock / soil layers that are either parallel to the slope angle or dipping into the slope. Rock layers with bedding planes parallel to the slope often fail along the bedding planes. Rock layers with bedding planes dipping into the slope may still fail, but not to the degree of severity as those with bedding planes parallel to the slope.

From this, you can readily see that weaker layers of rock / soil between stronger ones could fail to support overlying layers. This could lead to a landslide event. Again, the key point for rapid recon surveys is to identify the orientation of the layers relative to the road and / or emergency evacuation or supply assembly area.

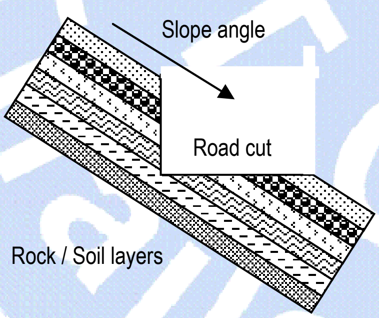
Note: In some parts of the world, earthquakes can trigger landslides. In recent times, Nam Province has a very low earthquake risk hazards. However should an earthquake occur slopes in close proximity to known geologic faults could have a higher potential for landslides.

Rock / Soil Strata Orientation to the Slope

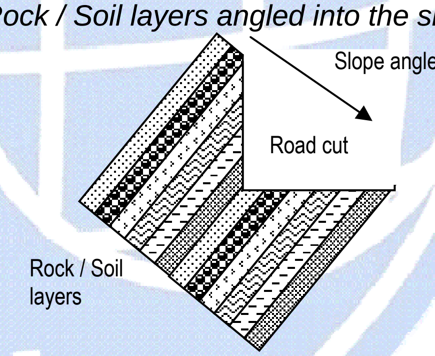
The greatest landslide potential exists when the rock / soil strata are parallel to the slope angle. Changes in the balance of forces can cause the rock / soil to move along the bedding plane resulting in a landslide. Adding moisture to the materials increases the overall weight of the materials. Water in the soil pore spaces can decrease friction making it easier for the materials to “slip” or “slide” against one another.

Under these conditions, the steeper the slope angle, the higher the potential risk for a landslide.

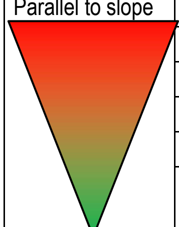
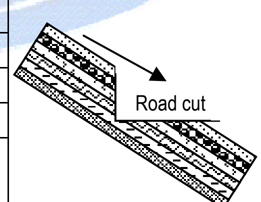
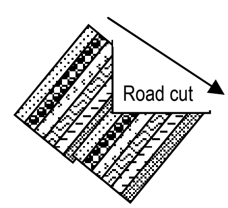
Rock / Soil layers parallel to the slope.



Rock / Soil layers angled into the slope.



Rock / Soil Strata Dip Orientation Ranking Socres

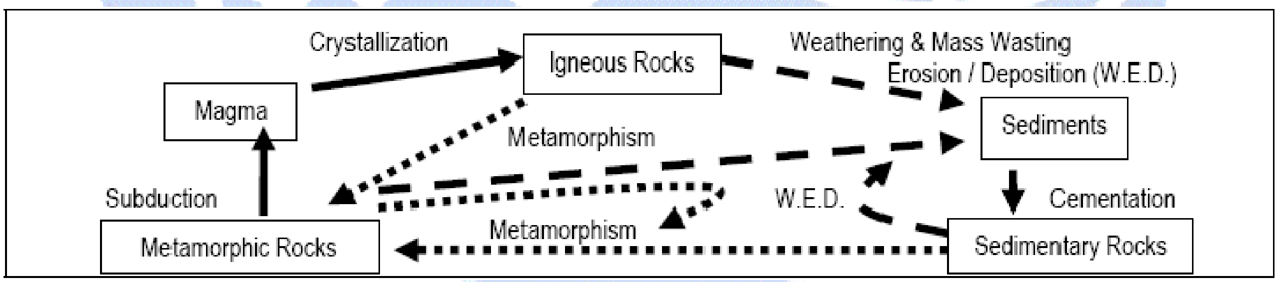
Strata Dip	Rank	Description		Angle	General Appearance	
Parallel to slope	6	Layers parallel to slope	Steep angle	>16%	Parallel to slope	Dip into slope
	5		Moderate angle	4 -16%		
	4		Gentle angle	0 – 3%		
	3	Layers dip into slope	Steep angle	>16%		
	2		Moderate angle	4 -16%		
	1		Gentle angle	0 – 3%		
Dips into slope		Layers horizontal / level with surface				

2.2.3 Surface Rocks: The rock materials on the slope become unstable when the balance of forces (i.e. gravity vs. resistance) is shifted in favor of gravity. The hardness of the rocks affects the stability of the strata. This shifts the balance toward resistance against possible down slope movement. Different kinds of rocks (without considering vegetative cover) respond differently weathering (the natural process of water and heat to breakdown rock materials to smaller pieces). This also makes it easier to move rock / soil materials down slope. Most slopes tend to be more stable when dry. But during the wet season, those same slopes could become unstable. (Soils on the slope are discussed in the next section.)

The particle sizes of rock / soil materials are standardized (see the summary chart below). For this assessment, it is not necessary to measure the particle sizes. It is useful to be familiar with the particle size terms and to recognize them in the field.

US Standard Soil Particle Size Classification					
Large---→ **Small**					
Coarse-grained material			**Fine-grained material**		
Gravel	**Sand**		**Silt**		**Clay**
More than 2-50 mm (0.08-2.0 in)	Very Coarse	1-2 mm (0.04-0.08 in)	Coarse	0.02-0.05 mm (0.0008-0.002 in)	Less than 0.002 mm (0.00008 in)
	Coarse	0.5-1 mm (0.02-0.04 in)	Medium	0.006-0.002 mm (0.00024-0.0008 in)	
	Medium	0.25-0.5 mm (0.01-0.02 in)			
	Fine	0.1-0.25 mm (0.004-0.01 in)	Fine	0.002-0.006 mm (0.00008-0.00024 in)	
	Very Fine	0.05-0.1 mm (o.002-0.004 in)			
Note: The soil sieve screen sizes you use may not coincide with the standard sizes listed in this table. Measure the sieve screens and then use the most appropriate descriptive term.					

You don't need to be a geologist, but knowing some basics about different types of rocks is useful. Different types of rocks are harder and stronger than others. Thus slopes made of these kinds of rocks may be less likely to fail. The diagram below is called "The Rock Cycle". It shows how the different kinds of rocks are made.



This summary table describes the main characteristics of the general types of rocks. All rocks exposed at the surface break down (weather) to smaller particles. Contact with rain (water) and heat (from sunlight) "weather" the rocks. This is the start of the soil making process. These smaller particles can be compacted (pressed together) making a hardened surface. The loose particles can also be cemented together making a hard surface. These hard surfaces do not let water soak into the ground. Very small particles (clay) fit together tightly due to their small size. Clay also does not let water soak into the ground. But when clay gets wet, it becomes slippery. So slopes with high amounts of clay could become susceptible to slope failure and landslides.

Main Type	Sub-Type	Description	Relative Hardness
Igneous	Intrusive	Solid, large crystals	Very Hard
	Extrusive	Solid, small crystals, some are glass-like; “ash” tends to be soft	Soft to Hard
Metamorphic	Non-foliated	Existing rocks heated by contact with magma/lava and varying degrees of pressure	Hard to Very Hard
	Foliated	Wavy layers visible; some break easily along layers; associated with mountain building	Medium to Hard

Sedimentary rocks for the third large general rock group. These can be classified in a number of ways. Two major approaches are given in the table below.

Main Type	Sub-Type		Description	Relative Hardness
Sedimentary	Clastic		Small fragments; firmly or loosely cemented together	Medium to Hard
	Non-clastic		Fine textured; chemically produced; some tightly others loosely cemented	Soft to Medium
Sedimentary	Land (Terrestrial)		High silica / aluminum content	Soft to Medium
	Water	Lacustrian	Lake sediments (fresh water)	Soft to Medium
		Marine	Oceanic sediments (salt water); high silica / magnesium content	Soft to Medium

Note: The presence of vegetation makes a difference. But for the moment we will focus on the situation of bare exposed rock materials on the slope.

Bare Slope Surface Rock Classification

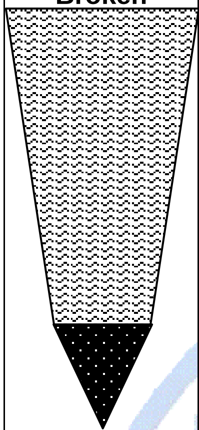
Loose, fragmented rock materials on a slope could be prime landslide materials under the right conditions. These rapid recon methods are no substitute for detailed engineering studies. The simplistic methods given here help to identify potential landslide risk areas for further study. Some added knowledge of geology may be helpful. A general reference table of rock types is on the next page.

Equipment Needed:

- Rock hammer
- Shovel or trowel
- Jug of water
- Cup / empty can to pour water

To quickly tell Silt from Clay		Silt	Clay
Dried puddle/muddy area		You can see tire tracks and / or ruts in the dried puddle area.	You can see mud cracks in the dried puddle area.
Finger Test	• Rub some of the moistened slippery soil between your thumb and index (pointing) finger. • Stop rubbing and gently lift your finger tip away from your thumb.	If the sample remains smooth (flat) between your fingers, it is silt.	If the sample is sticky or tacky (some of it lifts up making small spikes, it is clay.

Bare Slope Rock Surface Ranking Scores

Rock / Soil	Rank	Term	Description
Broken 	6	Broken; unconsolidated: not compacted, very porous	Rock / soil of mixed materials easily sorted to gravel, sand, silt, clay particles. Easily worked with shovel. Water poured on surface soaks in quickly.
	5	Firm to Lightly compacted; not cemented	Rock / soil of mixed materials easily sorted to gravel, sand, silt, clay particles. Easily worked with shovel. Water poured on surface puddles or soaks in slowly
	4	Firm to highly compacted; not cemented	Rock / soil of uniform or cemented dissimilar material. Breaks with force with shovel or trowel.
	3	Firm (firm, but breaks easily)	Rock of uniform or well-cemented dissimilar material. Large pieces break off when struck with rock hammer.
	2	Solid (firm, breaks with force)	Rock of uniform or well-cemented dissimilar material. Small pieces break off when struck with rock hammer.
Solid	1	Solid (firm, hard; non-porous)	Rock is of uniform material. Cannot break with rock hammer.

The analysis of the strength of slope rock / soil materials to determine slope stability is a very complex engineering activity. The simplistic rapid recon methods used in this paper are not a substitute for slope engineering analyses. These simple methods can help to screen potential landslide areas to consider for planning emergency / relief activity.

2.2.4 Slope Soil Identification: Soil is a combination of weathered rock material, air, water, and decomposed organic matter. It is the primary growth medium for plants. Soil forms a good portion of the non-rock materials in landslides. Its strength to resist gravity depends on many complex factors. But generally, loam soils (a balanced mixture of sand, silt, and clay particles) are considered the best for plants. This means they hold water in a way that is easily accessible to plants. And the plants in turn help to anchor the soil on the slope.

For rapid recon purposes, we use visual and tactile methods to identify the soils. The complexity of soils makes it difficult to get fast and accurate measurement of slope stability. We use the soil ball method to get an idea of the soil type. Once the soil type is determined, the rank number is “embedded” in the table below.

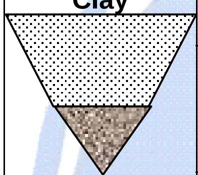
Rapid Slope Soil Identification

Visual way tell Silt from Clay	
Look for dried up puddle areas. If you can see….	
…tire tracks or ruts in a dried puddle area… ..it is probably **Silt**	…mud cracks in the dried puddle… …it is probably **Clay**

Soil Texture by Touch

	Soil Ball Method	Finger Rub Method
Check for Sand	Get some soil in your hand and squeeze your fist tight. Slowly open your fist to see if the soil formed a ball. • No ball = Sand • Ball = go to check for Silt or Clay	Get some soil and put it in the palm of your hand. Add a little water to form a small puddle. Use a finger to rub some soil in the puddle. • Gritty feeling = sandy soil • Slippery feeling = go to check for Silt or Clay
Check for Silt or Clay	Get a damp golf-ball sized soil sample and roll it between your two palms to make a "worm" or "rope" about 4 mm / 1/8 inch in diameter. Keep rolling the "worm" to see how long it will get before it breaks off from your hands. Look up the length in the table below. Then use the Finger Rub method to classify the soil.	To find out if sample is silt or clay, rub some of the moistened slippery soil between your thumb and index (pointing) finger. Stop rubbing. Then gently life your fingertip away from your thumb. • Smooth sample = silt • Tacky/sticky sample (soil forms small spikes) = clay,

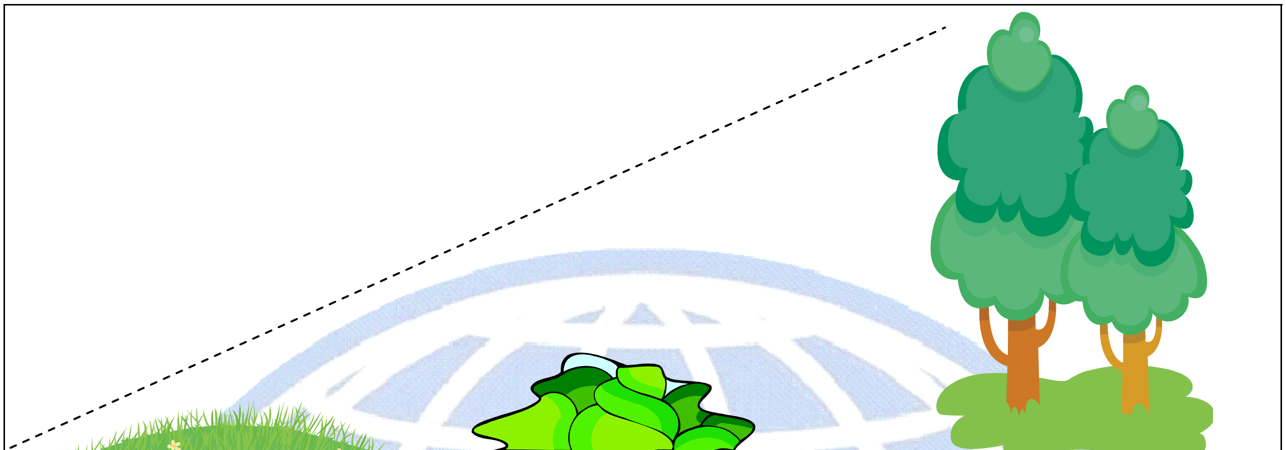
Slope Soil Ranking Scores

Soil Type		Finger rub of sample; The sample feels		Soil Ball Worm / Rope Length			
Clay				< 2.5 cm < 1 inch	2.5 – 5.0 cm 1 - <2 inch	5 – 7.5 cm 2-3 inch	>7.5 cm >3 inch
	% sand	High	Very gritty	No finger rub needed; Sand (5)	Sandy Loam (2)	Sandy Clay Loam (3)	Sandy Clay (4)
			Not gritty / not smooth		Loam (1)	Clay Loam (5)	Clay (6)
		Low	Very smooth		Silty Loam (3)	Silty Clay Loam (4)	Silty Clay (5)
Loam	Use the rank number in parenthesis for a given soil type in the form.			Low ←-------------------------- % Clay ---------------------------→ High			

The analysis of the strength of slope soil materials to determine slope stability is a very complex engineering activity. The simplistic rapid recon methods used in this paper are not a substitute for slope engineering analyses. These simple methods can help to screen potential landslide areas to consider for planning emergency / relief activity.

2.2.5 Vegetation Cover: Leave litter and mulch useful in protecting bare soil from rain drop impact (the first step in soil erosion). Vegetation cover on the slope helps to limit sheet wash (the next step in soil erosion), helps to anchor soil, and helps to manage soil moisture content (both in terms of regulating the rate of water infiltration and water removed by evapotranspiration. Trees are better than grasses. Grasses are better than barren soil. When the soil on the slope is saturated, the risk of slope failure increases.

The relative height differences for the three broad types of vegetation (e.g. trees, shrubs, grasses) makes it easy to recognize them. However, size can be deceiving. Young trees can be the height of some shrubs. Some mature shrubs can taller than some young trees. What makes the difference between the vegetation types is their structure. (See the summary table of characteristics for the different vegetation types below.)



Grasses	Shrubs	Trees
Low height; annual growth	Middle height; can be annuals or perennials	Tall height; perennial growth

Foliage Functional Definitions

The hot/dry season in Nan Province causes some plants to be drought deciduous. Grasses "die off"; some shrubs and trees drop their leaves. Fires are more likely to occur due to high fuel loads. Trees are classified by leaf structure (Broadleaf or Needleleaf). Trees on a slope can be mostly Evergreen, Deciduous, or a mixture of the two.

		Evergreen	Mixed	Deciduous
Broadleaf	Wide leaf, network vein pattern	Leaves stay green or shed a few at a time so tree appears to be green	Mixed broadleaf / needleleaf evergreen and deciduous	Leaves dropped at specific times of the year under stressful conditions. For Nan, this is the hot dry season (~Mar-Apr)
Needleleaf	Narrow leaf, parallel veins			

Summary Characteristics of Vegetation Types

	Grasses	Shrubs	Trees
Stem	• No permanent woody stem (bamboo being a notable exception) • Soft stems bend easily in the wind	• Several woody, perennial stems that may be erect or may lay close to ground • Stem diameter not more than 7.62 cm / 3 in	• One erect, woody, perennial (living for many years) self-supporting stem (truck) • Trunk diameter at least 7.2 cm / 3 in at a point 1.37 m / 4.5 ft above the ground • Branches extend outward from trunk
Leaf	• Leaves appear to emerge from the ground • 2 part leave; sheath surrounding the stem; blade (often flat and linear)	Leaves form on stem or ends of branches. Basically a shrub looks like a shortened tree with no trunk	• Leaves form at ends of branches • Branches and leaves form the tree canopy
Shape	Generally low to the ground	Round bushy shape. Basically a shrub looks like a tree crown set on the ground.	• Stem / trunk extends vertically upward from surface • Canopy forms a definitely formed drown of foliage
Height	Generally short, (though tall grasses can be 2 m tall	Smaller than a tree (though some mature shrubs can be taller than some small trees)	Mature height at least 3.96 m / 13 ft (under adverse conditions, trees may appear to be shrub-like.

Slope Vegetation Cover Ranking Scores

Vegetation	Rank	Term	Description
Bare ground	6	Little or no vegetation	Bare soil or mostly open ground/bare soil with scattered clumps of vegetation
Grasses	5	Mostly grass	Fairly continuous grass cover
	4	Shrubs and grasses	Mixture of mostly shrubs with some grass
	3	Trees with litter/grass	Widely spaced trees (with leaf litter or grasses on ground)
	2	Trees with understory	Trees (open canopy; canopies not touching; easy to see patches of sky) with shrub understory;
Trees	1	Dense tree canopy	Trees (closed canopy; hard to see the sky) closely spaced no understory

2.2.6 Soil Moisture: Water plays a significant role in landslides. Water adds weight the rock / soil materials on the slope. This can change the balance of forces (e.g. gravity vs. friction) affecting slope stability. Water filling the pore spaces in the soil decreases friction between the soil particles. Clay can retain more moisture. Under certain conditions, wet clay materials increase the risk of landslides.

Vegetation helps control soil moisture. The tree canopy stops rain drops from directly impacting the soil. The rain water slowly seeps into the soil. The plant roots help to anchor the soil. On sunny days, evapotranspiration removes soil moisture and returns it to the atmosphere.

The manner in which the rain falls on the slope also makes a difference. The table below briefly summarizes the key difference.

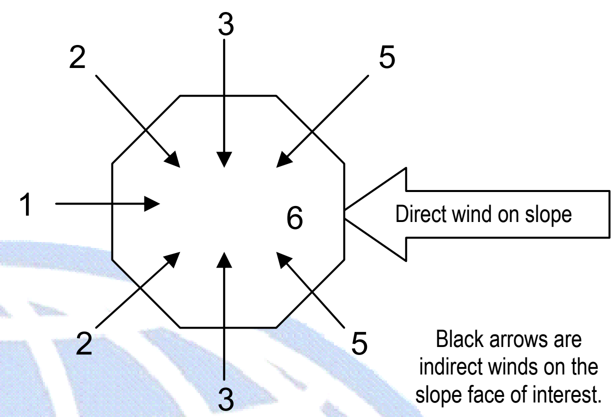
Intense heavy rain	Sudden, brief, intense thunderstorms can drop a large amount of water in a short time (often too fast to soak into the ground). The main threat for landslides results from fast flowing water (possibly flashfloods) undercutting stream banks or road cuts.
Prolonged gentle rain	Gentle, prolong rain can drop a large amount of water over a longer period of time. This lets water soak into the ground increasing the mass of the materials on the slope as well as making it easier for soil particles to slide past one another.

The direction the slope faces relative to an approaching storm also makes a difference. Storms directly approaching the windward slope will tend to put more rain on the slope. Storms obliquely approaching the windward slope will put less rain on the slope. Storms approaching parallel to the windward slope may drop less rain on the windward slope than obliquely approaching storms. Storms approaching from behind the slope of interest slope would tend to put little or no rain on the slope of interest.

Direction of the Storm	Pay particular attention to slopes that face to the SW or NE	SW	The traditional warm/wet rainy season for Nan Province is the SW monsoon (May to October). Low pressure systems over northern Thailand cause warm moist air from the Andaman Sea to move into the mountain regions. Slow moving or stalled low pressure systems bring prolonged rain (sometimes heavy rain). Slopes facing the SW will tend to get more rainfall and thus may be at more risk to slope failure.
		NE	The traditional cool/dry season for Nan Province is the NE monsoon (Nov to Feb). However, low pressure systems moving into the region could be fed with moisture from the South China Sea. Tropical storms and Tropical Depressions tracking through Vietnam / Laos typically lose strength and intensity by the time they reach Thailand. But the rainfall activity can spill over into Nan bringing increased precipitation and possible flash flooding for those in low lying areas near mountains and water courses. Slopes facing the SW will tend to get more rainfall and thus may be at more risk to slope failure.

	Slope Aspect Ranking
Rank	Wind/Storm on Slope
6	Direct on windward slope
5	Oblique on windward slope
4	
3	Perpendicular to slope aspect
2	Obliquely opposite of windward slope
1	Directly opposite Windward slope

Apply this ranking AFTER you know the direction a storm is approaching the slopes in your area.



Moving water can erode soil. Be mindful of water flowing along the road side (especially in road cuts) and roads alongside streams and rivers. Flowing water can undercut the roads causing them to collapse or limit their use.

Field Observation Tips

	Mountains	Next to Rivers /Streams	Below Dams / Reservoirs	Road Cuts
Location	• Steep mountains / slopes are higher risk • Narrow mountain valleys are prime flashflood areas	Roads along rivers / streams could be undercut by stream erosion / flash-floods or dam / reservoir failure	• Failure of the dam will result in a torrent of water capable of intense erosion • Downstream slopes could be severely undercut	• Roadside drainage ditches could undercut roadways • Culverts under roads could be undercut and cause road collapse
Things to Look for	• Look for landslide scars on mountain sides • Look for debris on / across roads indicating recent landslides that may have been cleared • Examine highway / road maintenance records for road work needed due to landslides or slope failure	• Look for signs of river bank collapse • Look for flood debris above normal water levels stuck on vegetation • Look at dry river / stream beds with assorted sizes of rocks indication flashflood occurrence	• Catastrophic dam failure makes major news and doesn't happen often • Drastic release of water to protect the dam when near capacity could result in downstream flooding • Examine dam records for past controlled releases and the downstream effects of those releases	• Look for fallen rocks and debris at the base of road cuts indication slope failure • Examine highway / road maintenance records for road work needed due to landslides or slope failure

Determining the soil moisture content can be done fairly quickly in the field using the soil ball method (see the summary chart on the next page). The soil moisture value attained applies to the day of the survey. The soil moisture content will change when rains fall on the slope.

This is a relative ranking system. So once the survey is completed, you can rank the various slopes along an evacuation route by their average score. If rain comes to the area, and you can assume the soil will be saturated. Based on the storm direction relative to the slope aspect, you can quickly calculate the score for particular slopes and see the results. To see how to make this adjustment and recalculation, see the example on the next page.

For example, slope A has an average score of 4. We can recalculate storm's effect on Slope A storm for winds directly (perpendicular to the slope) and winds parallel to the slope. The red numbers in the table below would be the appropriate values used.

		Initial Survey	Rain Event Recalculation: Direct Rain	Rain Event Recalculation: Parallel Rain
Page Ref	Assessment Item	Score	Score	Score
4-5	Slope Angle Measured	6	6	6
7	Strata Dip rank	4	4	4
8-10	Rock Type rank	3	3	3
10-11	Soil Type rank	5	5	5
11-13	Vegetation rank	4	4	4
13-15	Soil Moisture rank	2	6	6
	Subtotal	24		
	Average	4		
6, 13-15	Rain event recalculation: Slope Aspect rank		6	3
	Rain event recalculation: Revised Subtotal		34	31
	Rain event recalculation: Updated Average		4.8	4.4

This example shows the effect of wind/rain direction on the same slope. The red numbers in the table are the adjusted values used for a Rain Event recalculation for the slope.

Step 1. Assume the soil will be saturated.

Step 2. Use the slope aspect ranking score.

Step 3. Get the revised subtotal.

Step 4. Divide by 7 to get the updated Average score.

Rapid Slope Soil Moisture Assessment

Soil moisture is a major factor in many landslides in Nan. Moisture adds weight to the slope materials tipping the balance of forces in favor of gravity pulling materials down slope. As water fills the pore spaces of the soil, friction is decreased, reducing resistance to gravity. Clay materials are finer and may "slip" easier than coarser materials.

Equipment Needed:
- Hand trowel or small shovel
- Tape measure
- Small bottle of water

Instructions:
- Follow the steps in the table below.
- Rank values: Use ranks from table below.

Step 1: Get soil sample from about 15 cm / 6 inches below the surface.

Step 2. Take a handful of soil and form a ball. Gently squeeze it in your hand and match the results to the descriptions in the table below.

Step 3. To make a soil ribbon: Start with a soil ball. Then use your thumb to push the soil ball out of your hand against the side of your index finger.

Slope Soil Moisture Ranking Scores

Soil Moisture	Rank	Available Soil Moisture	Light Texture Sandy	Medium Texture Loamy	Heavy Texture Clayey
Saturated	6	Saturated	Water appears on surface of soil ball and hand when squeezing soil ball.		
	5	100%	No free water appears when squeezing soil ball, but leaves wet outline on hand.		
	4	75-100%	Forms a weak ball; breaks easily; does not feel slick	Forms a ball; very pliable; feels slick if high in clay	Easily ribbons out between fingers; feels slick
	3	50-75%	Forms ball under pressure but seldom holds shape	Forms a ball; somewhat plastic; at times feels slick (silty/clayey) under pressure	Forms a ball; ribbons out between fingers
	2	25-50%	Look dry; will not form ball	Somewhat crumbly but holds together from pressure	Somewhat pliable; forms ball under pressure
Dry	1	0-25%	Dry; loose; flows between fingers	Powdery dry; if crusty can be easily broken into powder	Hard baked; cracked; may have crumbs on surface

Rural Training Center-Thailand

Rapid Recon Landslide Hazard Potential Assessment Survey Form

c/o U. Suttisan, 84 Moo 2 Ban Na Fa, Jompra, Thawangpha, Nan Province, Thailand 55140 www.neighborhoodlink.com/org/rtcth E-mail: rtc2k5@gmail.com

Location	Province:			Date:
	District:			Survey by:
	Sub-district:			
	Lat N	Long E	Elev. asml	Slope Aspect
	Hwy/Rd #	Between distance marker and		
	Additional detailed location notes:			

Page Ref	Assessment Item		Score	Rain Score	Brief Reminder	Rank Chart page
4-5	Slope Angle Measured				Leveling stick measure	5
7	Strata Dip rank				Observe; photo documentation	7
8-10	Rock Type rank				Observe; compaction test	10
10-11	Soil Type rank				Soil ball test	11
11-13	Vegetation rank				Observe; photo documentation	13
13-15	Soil Moisture rank			6	Soil ball test; for Rain event recalculation, assume rank of 6	15
		Subtotal			Add all rank scores for all items	
		Average			Divide subtotal by 6	
6, 13-15	Rain event recalculation	Slope Aspect rank			Winds relative to slope aspect	14
		Revised Subtotal			Add all rank scores for all items	
		Updated Average			Divide subtotal by 7	

(The following pages can be printed for use a quick field reference charts.)

Rural Training Center-Thailand

Rapid Recon Landslide Hazard Relative Risk Assessment

c/o U. Suttisan, 84 Moo 2 Ban Na Fa, Jompra, Thawangpha, Nan Province, Thailand 55140 www.neighborhoodlink.com/org/rtcth E-mail: rtc2k5@gmail.com

Landslide hazard potential assessment is a very technical engineering challenge. This rapid recon assessment is relative and subjective. It is meant as a screening tool to quickly identify possible sites where more detailed technical studies could be done. It is NOT intended to replace field engineering assessments of land slide hazards. Lay people can use this method to identify sites to avoid when constructing trails, roads, structures. In emergency planning, this method can help select "safe" areas for temporary relief shelter areas and assess the suitability of evacuation / relief supply access roads. This kind of fore knowledge can be used to plan the pre-positioning or staging of equipment, supplies, and personnel for more effective response in times of emergencies.

Definitions of slope classes					Environmental Sphere									
Landslide Hazard	General slope classes		Slope limits		Lithosphere						Biosphere		Atmosphere	
	Simple slopes	Complex slopes	Lower %	Upper %	Strata Dip		Surface Rock / Soil		Soil Type		Vegetation Cover		Soil Moisture	
High	Very steep	Very steep	>45		6	With Slope	6	Broken	6	Weathered	6	Bare ground	6	Saturated
	Steep	Steep	20	60	5		5		5		5	Grasses	5	
	Moderately steep	Hilly	10	30	4		4		4		4		4	
	Strongly sloping	Rolling	4	16	3		3		3		3		3	
	Gently sloping	Undulating	1	8	2		2		2		2		2	
Low	Nearly level	Nearly level	0	3	1	Into slope	1	Solid	1	Unweathered	1	Trees	1	Dry
						Rocks / soil strata parallel to the slope tend to move along bedding planes down slope. Bedding planes against the slope (going into the slope) tend to resist down slope movement.		Broken / fragmented rocks are less consolidated and weakened relative to consolidated rocks of the same type. Sedimentary and some metamorphic rocks are weaker than most igneous rocks.		Highly weathered / decomposed rocks and soil (clays) are less consolidated than similar unweathered materials. Vegetation helps to anchor unconsolidated materials.		If bare ground, look carefully at Lithosphere factors to determine the easy for water to penetrate and soak into the soil and the general overall stability of the slope to resist failing.		Slow, steady, prolonged rainfall tends to saturate soils more than intense heavy rainfall (which may erode and undercut to cause collapse). (In rain event use slope aspect data.)

Relative Scale Subjective Field Assessment

- Measure the slope angle using whatever means you have available. Actual measurement is better than an estimate.
- For each location of interests, use the relative scale numbers to rate the environmental factors that affect the landslide hazard.
- Add the rankings and divide the sum by 5 to get an average score. The higher the score, the higher the potential landslide risk.

Tips / Hints:

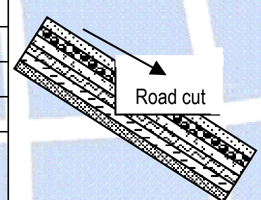
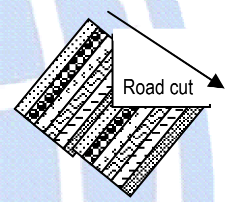
- Site Location: Use maps, aerial / satellite photos, GPS, highway / road mileage posts, vehicle odometer, and relative positions (e.g. 2 km N of Jct 1180/1072, east side of road) to identify the potential landslide hazard site. Without a good location, the value identification of the potential hazard is greatly diminished.
- Photo Documentation: Take photos not only of the potential landslide hazard site, but significant landscape features associated with it (e.g. nearby highway / road markers, signage, prominent landscape features, bends in the road, etc.) to aid field workers to easily find and identify the site. Make good notes about the azimuth direction of the photos; so make sure you have a magnetic compass with you).
- Landslide Evidence: Freshly fallen rocks and soil are obvious things to look for after storms in your areas. But keep an eye out for and photograph any evidence of past landslides. Older landslide scars (e.g. exposed soil/rock on slopes) and "out of place" patches of vegetation are landscape clues to long past landslides.
- Local Interviews: Ask local area residents if they know of or can recall any landslides in the area. Never assume they don't know anything of value. Talk with highway and road maintenance workers about the roads under their jurisdiction.
- Potential Risk: A landslide may not have occurred yet in the area; but that doesn't mean it can't happen. Preparing a potential landslide hazard assessment helps to minimize "surprises" during an actual emergency / relief operation and increases the odds of an effective emergency response.

(This page and the next can be printed for use a quick field reference charts.)

Slope Angle Ranking Scores

Landslide Hazard	General slope classes				
	Rank	Simple slopes	Complex slopes	Lower %	Upper %
High	6	Very steep	Very steep	>45	
	5	Steep	Steep	20	60
	4	Moderately steep	Hilly	10	30
	3	Strongly sloping	Rolling	4	16
	2	Gently sloping	Undulating	1	8
Low	1	Nearly level	Nearly level	0	3

Rock / Soil Strata Dip Orientation Ranking Scores

Strata Dip	Rank	Description		Angle	General Appearance	
Parallel to slope	6	Layers parallel to slope	Steep angle	>16%	Parallel to slope	Dip into slope
	5		Moderate angle	4 -16%		
	4		Gentle angle	0 – 3%		
	3	Layers dip into slope	Steep angle	>16%		
	2		Moderate angle	4 -16%		
	1		Gentle angle	0 – 3%		
Dips into slope		Layers horizontal / level with surface				

Slope Rock / Soil Surface Materials Ranking Scores

Rock / Soil	Rank	Term	Description
Broken	6	Broken; unconsolidated: not compacted, very porous	Rock / soil of mixed materials easily sorted to gravel, sand, silt, clay particles. Easily worked with shovel. Water poured on surface soaks in quickly.
	5	Firm to Lightly compacted; not cemented	Rock / soil of mixed materials easily sorted to gravel, sand, silt, clay particles. Easily worked with shovel. Water poured on surface puddles or soaks in slowly
	4	Firm to highly compacted; not cemented	Rock / soil of uniform or cemented dissimilar material. Breaks with force with shovel or trowel.
	3	Firm (firm, but breaks easily)	Rock of uniform or well-cemented dissimilar material. Large pieces break off when struck with rock hammer.
	2	Solid (firm, breaks with force)	Rock of uniform or well-cemented dissimilar material. Small pieces break off when struck with rock hammer.
Solid	1	Solid (firm, hard; non-porous)	Rock is of uniform material. Cannot break with rock hammer.

(This page t can be printed for use a quick field reference chart.)

Slope Soil Ranking Scores

Soil Type		Finger rub of sample; The sample feels		Worm / Rope Length			
Clay				< 2.5 cm < 1 inch	2.5 – 5.0 cm 1 - <2 inch	5 – 7.5 cm 2-3 inch	>7.5 cm >3 inch
	% sand	High	Very gritty	No finger rub needed; Sand (5)	Sandy Loam (2)	Sandy Clay Loam (3)	Sandy Clay (4)
			Not gritty or smooth		Loam (1)	Clay Loam (5)	Clay (6)
		Low	Very smooth		Silty Loam (3)	Silty Clay Loam (4)	Silty Clay (5)
Loam	Use the rank number in parenthesis for a given soil type in the form.			Low ←-------------------------- % Clay --------------------------→ High			

Slope Vegetation Cover Ranking Scores

Vegetation	Rank	Term	Description
Bare ground	6	Little or no vegetation	Bare soil or mostly open ground/bare soil with scattered clumps of vegetation
Grasses	5	Mostly grass	Fairly continuous grass cover
	4	Shrubs and grasses	Mixture of mostly shrubs with some grass
	3	Trees with litter/grass	Widely spaced trees (with leaf litter or grasses on ground)
	2	Trees with understory	Trees (open canopy; canopies not touching; easy to see patches of sky) with shrub understory;
Trees	1	Dense tree canopy	Trees (closed canopy; hard to see the sky) closely spaced no understory

Slope Soil Moisture Ranking Scores

Soil Moisture	Rank	Available Soil Moisture	Light Texture Sandy	Medium Texture Loamy	Heavy Texture Clayey
Saturated	6	Saturated	Water appears on surface of soil ball and hand when squeezing soil ball.		
	5	100%	No free water appears when squeezing soil ball, but leaves wet outline on hand.		
	4	75-100%	Forms a weak ball; breaks easily; does not feel slick	Forms a ball; very pliable; feels slick if high in clay	Easily ribbons out between fingers; feels slick
	3	50-75%	Forms ball under pressure but seldom holds shape	Forms a ball; somewhat plastic; at times feels slick (silty/clayey) under pressure	Forms a ball; ribbons out between fingers
	2	25-50%	Look dry; will not form ball	Somewhat crumbly but holds together from pressure	Somewhat pliable; forms ball under pressure
Dry	1	0-25%	Dry; loose; flows between fingers	Powdery dry; if crusty can be easily broken into powder	Hard baked; cracked; may have crumbs on surface