Landslides and Slope Stability in Residual Soils

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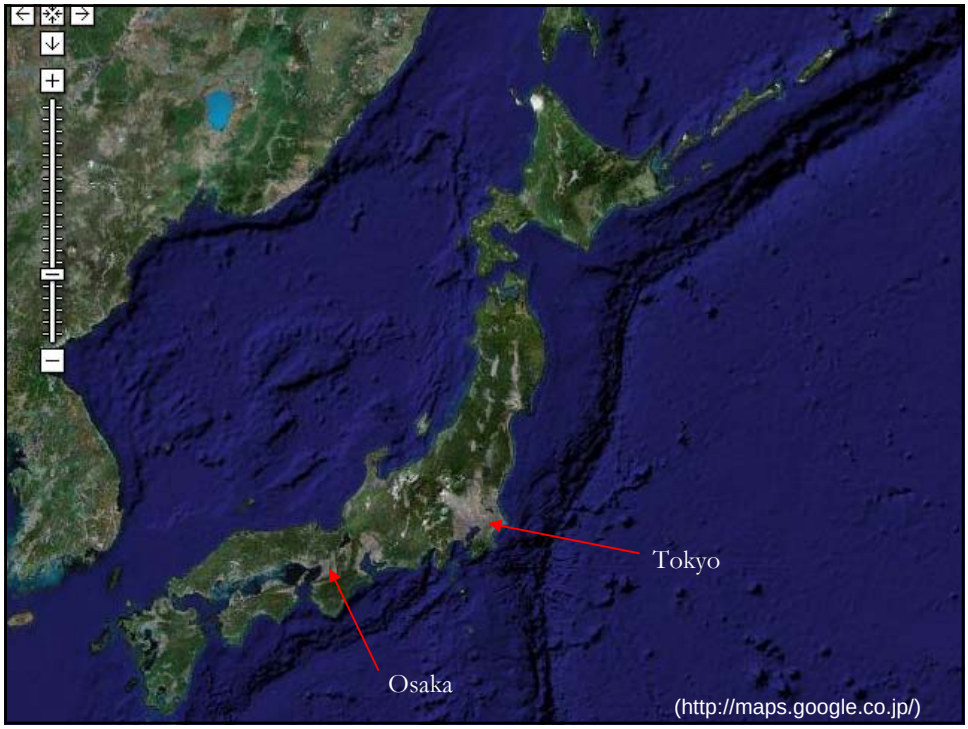
Outline of Presentation

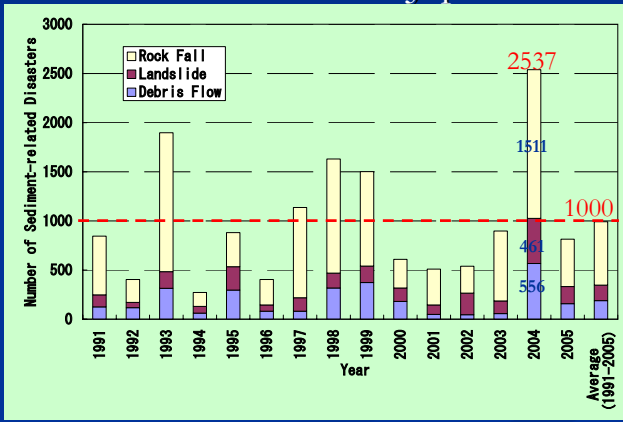
1. Landslides in Japan
2. Landslide Investigations
   - Preliminary investigations
   - Detailed investigations
3. Slope Stability Analysis
4. Landslide Mitigation Measures

Landslides in Japan



Introduction

- Sediment related disasters in Japan



Number of sediment-related disasters
(after Ministry of Land, Infrastructure and Transport, 2006 and Japan Sabo Association, 2006)

Classification of Slope Movements in Japan

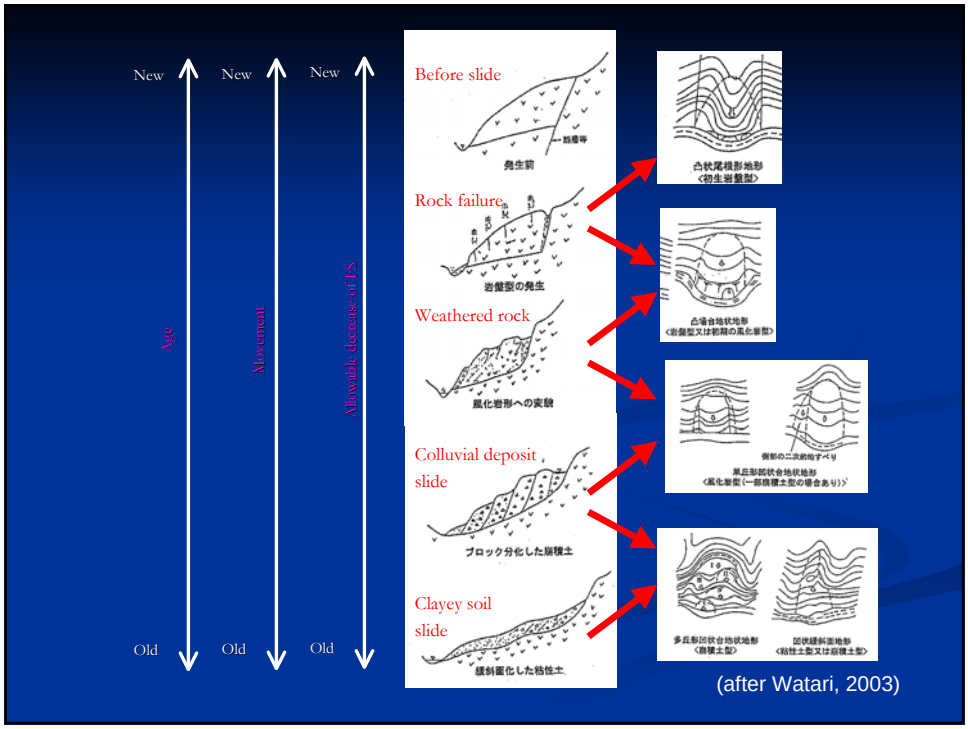
The term "landslide" describes a wide variety of processes that result in the downward and outward movement of slope-forming materials including rock, soil, artificial fill, or a combination of these.

(U.S. Geological Survey, 2004)

- **Landslide ("Jisuberi(地すべり)" in Japanese)**
- **Rapid Slope Failure / Slope Failure ("Houkai(崩壊)" in Japanese)**

Difference between Landslides and Rapid Slope Failure (Watari, 1986)

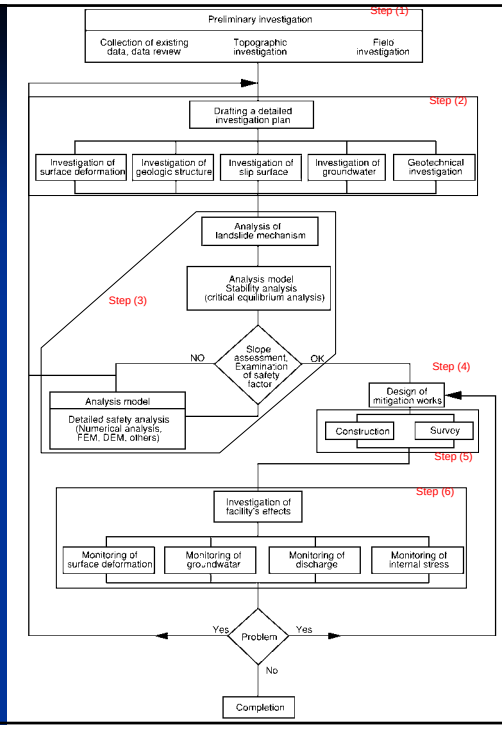
	Landslides	Rapid Slope Failures
Geology	often influenced by geology and geologic structure	little or no influenced by geology and geologic structure
Soils	moves along slip surface(s) that consists of highly plastic clay	usually involves topsoil, residual soil and (highly) weathered bedrock
Topography	occur on gentle to moderate slopes of 5 to 30° the upper slopes often have flat-plateau like topography	usually occurs on slopes steeper than 30°
Nature of movement	continuous, recurrence (repeatitive occurrence) duration of a single episode is generally long	occur suddenly short duration
Rate of movement	generally slow to very slow 0.01 to 10mm/day(most common)	very to extremely rapid 10 m/sec or faster
Nature of moving mass (blocks)	little disturbance within a sliding block often move while retaining the original shape and characteristics	incoherent move as highly disturbed mass
Causes, triggering mechanism	generally influenced by exess groundwater, elevated groundwater table	generally influenced by rainfall intensity
Size	surface area is often large ranges between 1 to 100 ha	surface area is generally small with an average volume of about 440m³
Warning signs	often develop cracks, depressions, upheavals, groundwater fluctuation, etc. prior to sliding	hardly any warning signs, almost always fail suddenly
Typical original gradient	10 to 25°	35 to 60°



(after Watari, 2003)

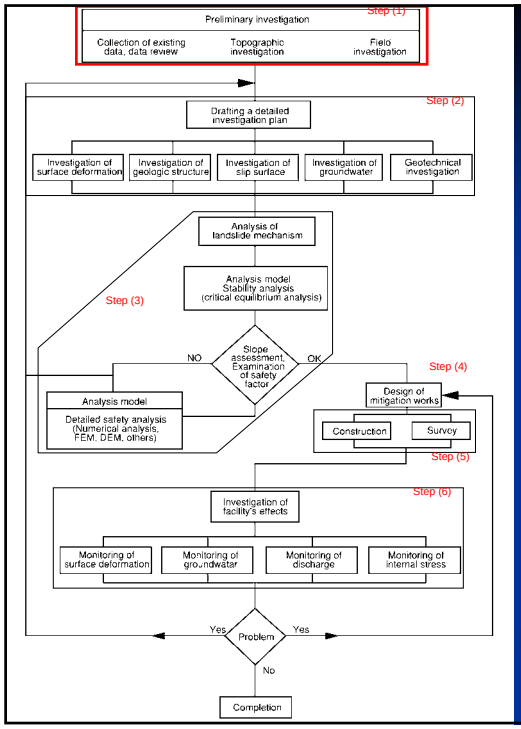
Primary Cause & Inducement

- Primary Cause
  - Geology
  - Topography
  - Strength of Geomaterials
  - Groundwater
- Inducement
  - Activities, e.g, construction
  - Rainfall
  - Earthquake



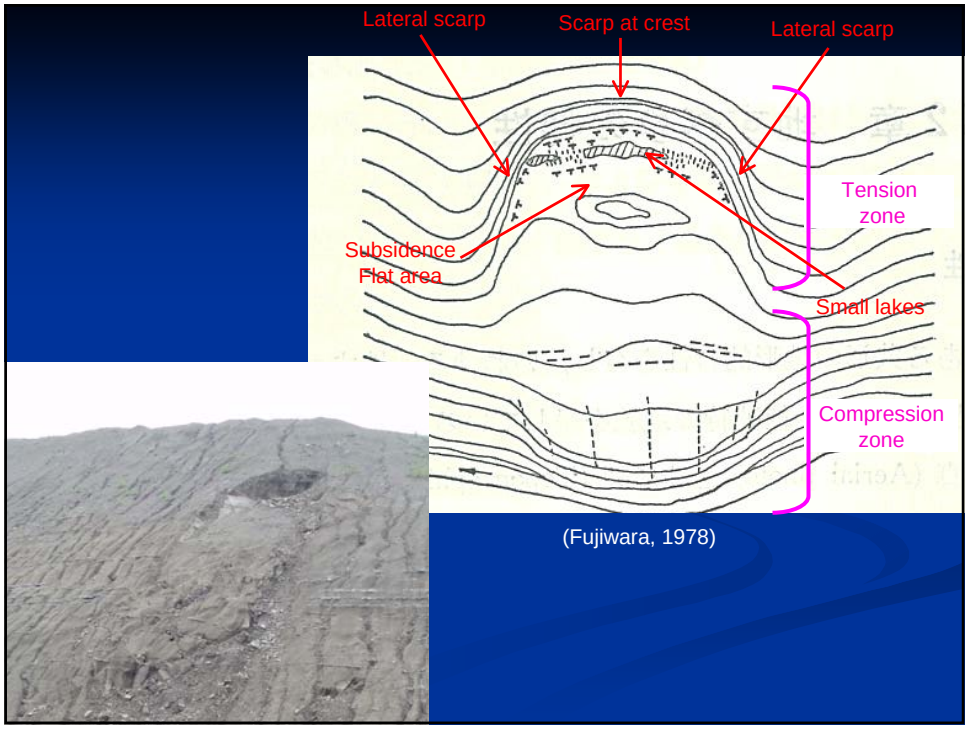
Flow chart for landslide investigation and analysis (after Japan Landslide Society and National Conference of Landslide Control, 2002)

Landslide Investigations

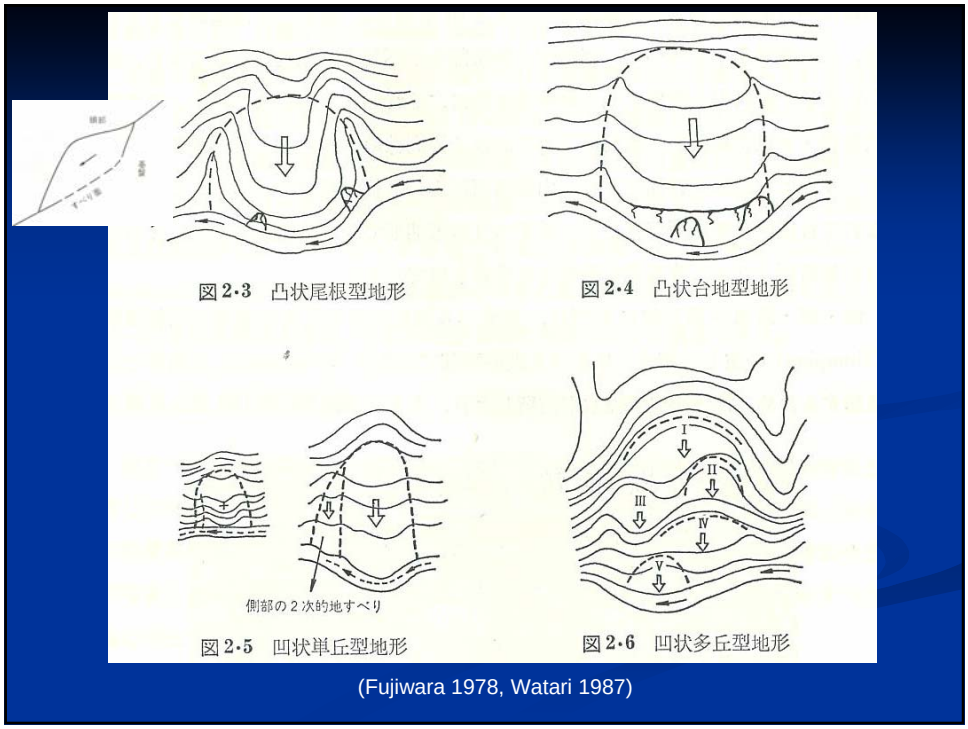


- Preliminary Investigation
  - Typically existing data is limited
  - Time is limited
  - Need to make a critical judgment with limited information
  - Refer to the similar landslide (experience)
  - Topographic investigation
  - Field investigation
  - Blueprint of following steps

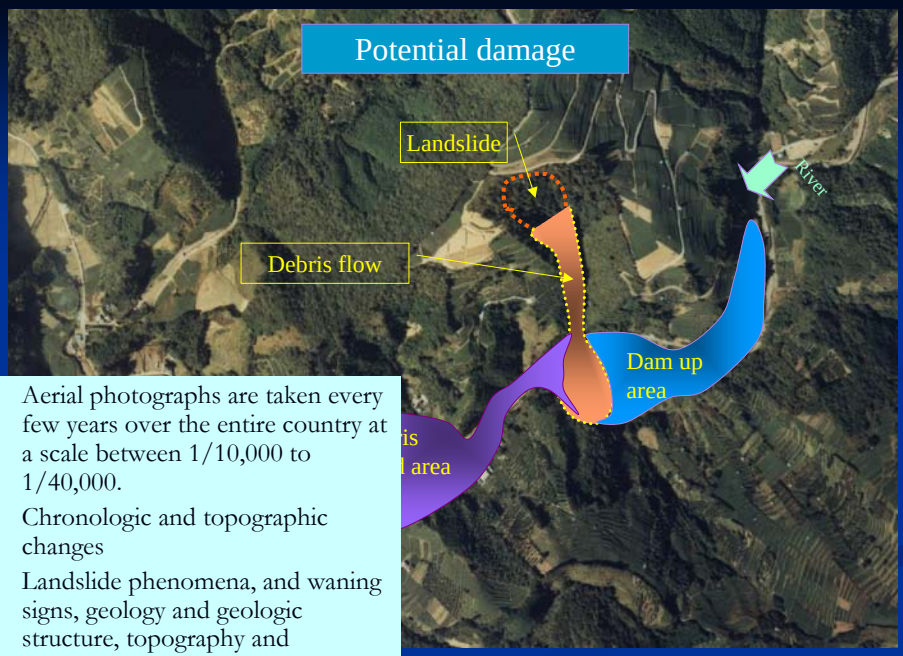
Flow chart for landslide investigation and analysis (after Japan Landslide Society and National Conference of Landslide Control, 2002)



(Fujiwara, 1978)



(Fujiwara 1978, Watari 1987)

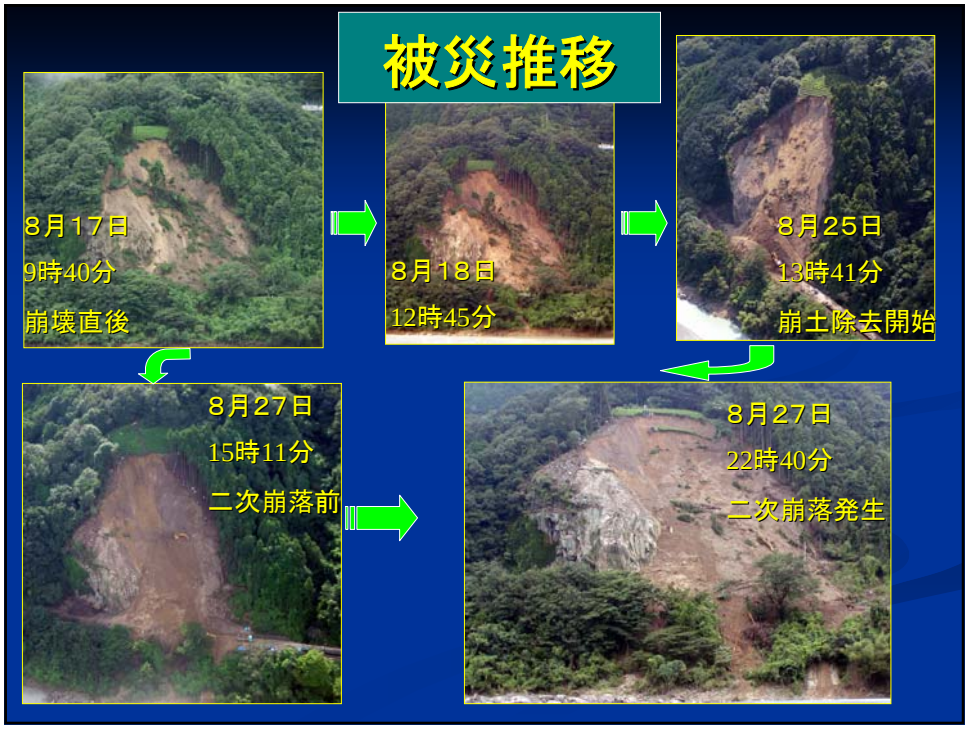


- Aerial photographs are taken every few years over the entire country at a scale between 1/10,000 to 1/40,000.
- Chronologic and topographic changes
- Landslide phenomena, and waning signs, geology and geologic structure, topography and distribution of vegetation type.

Field Investigation

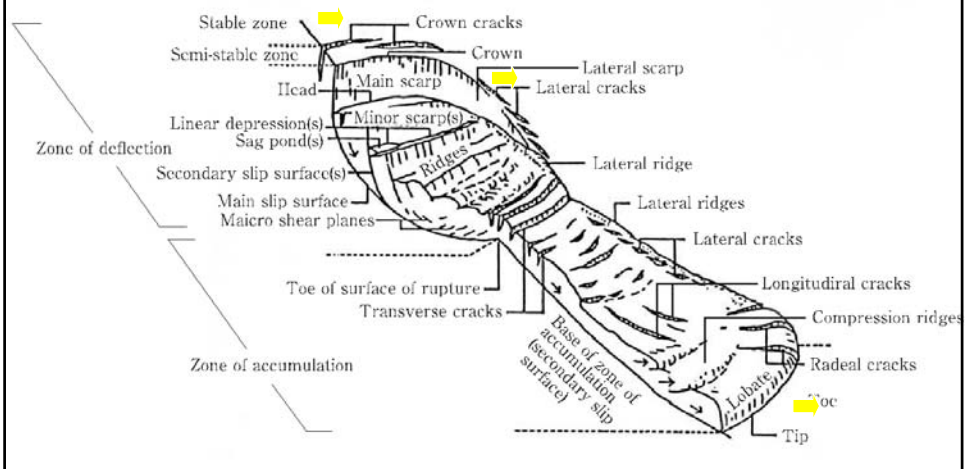
- Check points
  - Evacuation required?
  - degree of landslide damage
  - Possibility of secondary disaster ➡
  - Size of landslide (extent, depth, & volume)
  - Landslide mechanism (Cause of landslide)
  - Emergency mitigation measures required?
  - Required detailed investigation
  - Possible landslide mitigation measures


←金谷
(国)473号線
←金谷
←一級河川 大井川
神尾駅
大井川鉄道


被災推移
8月17日
9時40分
崩壊直後
8月18日
12時45分
8月25日
13時41分
崩土除去開始
8月27日
15時11分
二次崩落前
8月27日
22時40分
二次崩落発生


滑落頭部
ボーリング足場

Landslide phenomenon

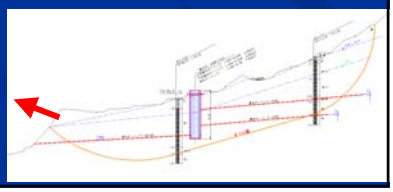


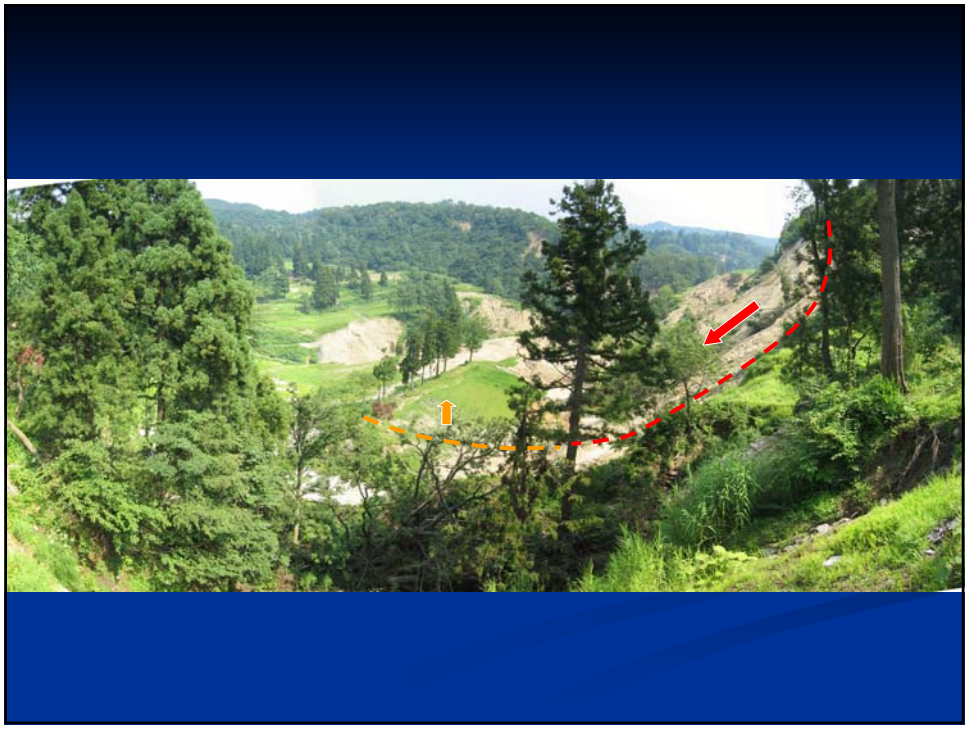
(Oyagi 1982)

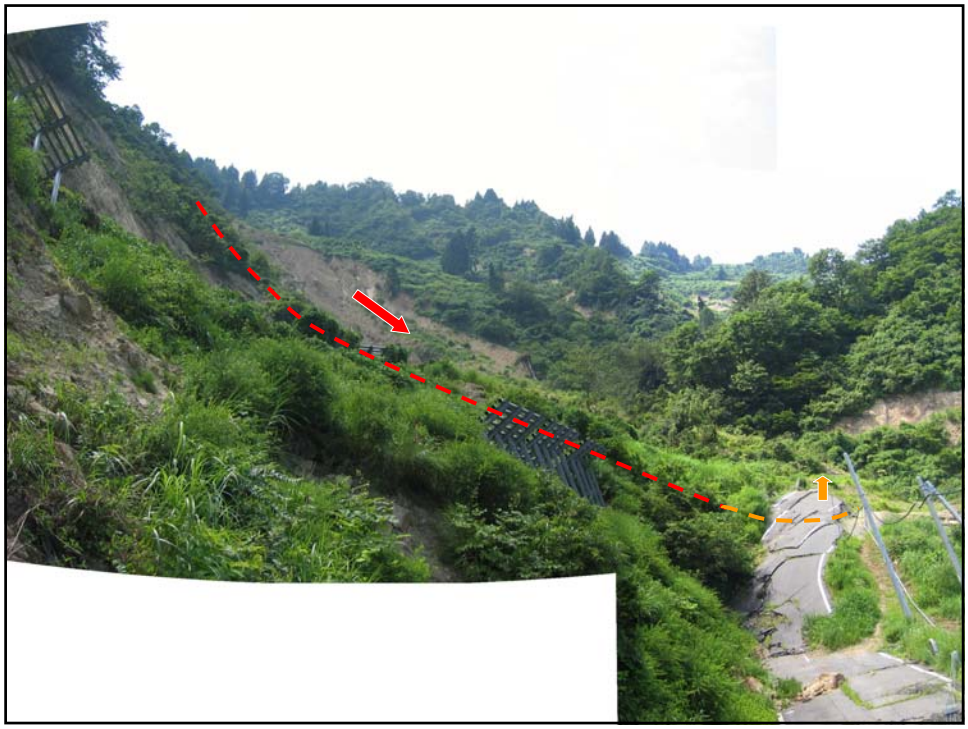
Crest

Side

Toe

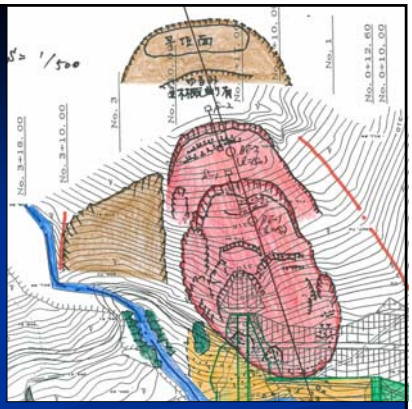


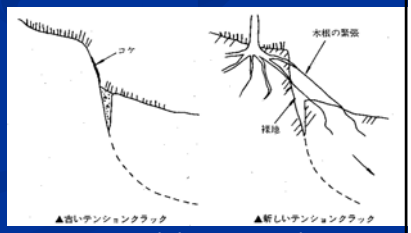




Tips

- Predict phenomenon beforehand
- Need a good map & aerial photo
- Newness of crack
- Do not concentrate on one location
- Collect information from only actual landslide site but also surrounding area
- Phenomenon at crest but may not be at toe
- Muddy groundwater
- Colluvium from the past landslide
- Small failures at toe
- Depth of slip surface
  - =1/5 – 1/8 × width (weathered rock failure)
  - =1/10 × width (colluvial deposit slide)

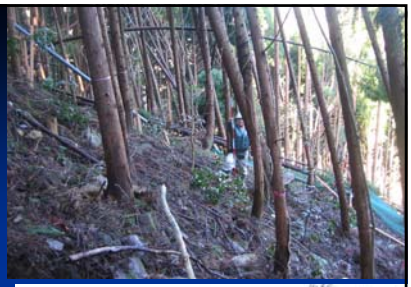


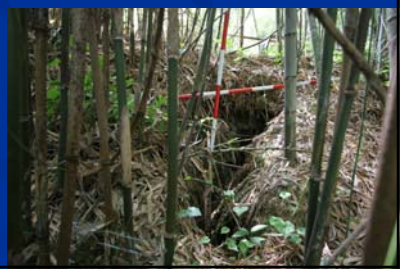


(Okusono 2000)

Tips

- Leaning of trees
- Geological structures (dip, strike, etc)
- Slope surface angle = slip surface angle (?)
- Bamboo
  - Abundant groundwater
  - Many small failures
  - Weak geomaterials
  - Slope angle is gentle
- Steep slopes
  - (Thin layer of soil) + Hard rock
  - Strong geomaterials
  - No groundwater(?)
- Phenomenon on structures





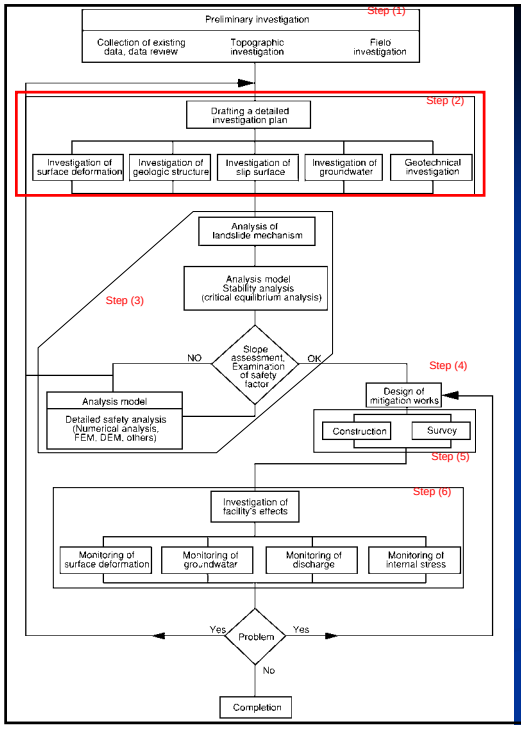
- Phenomenon on structures





（主）掛川川根線　被災状況写真
小段水路工の屈曲、沈下
終点側頭部開口キレツ
法すべり頭部滑落崖
起点側頭部滑落崖
縦水路工の破損
起点側縦水路工の破損
縦水路工の折れ
起点側サイドからの落石
被災地全景
終点側から被災範囲を望む
のり面下部の押し出し・縦水路の折れ
ブロック積に発生した水平キレツ
起点側から被災範囲を望む


（主）掛川浜岡線　菊川西方地区　被災状況写真
起点側から被災範囲を望む
終点側から地すべり範囲を望む
被災のり面全景
ブロック積擁壁に発生した水平キレツ
ブロック積擁壁に発生した縦キレツ（剥離跡あり）
ブロック積擁壁に発生した縦キレツ（開口7.5mm）
S－1付近頭部滑落崖（落差約25cm）
モルタル吹付のり面の小段に発生したキレツ
（地山との間に空隙が認められる）
モルタル吹付のり面に発生した開口キレツ
終点側地すべりサイドに発生した小崩壊
－ 27 －

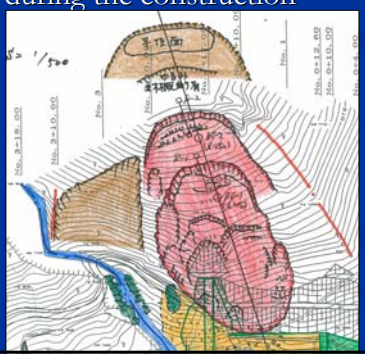


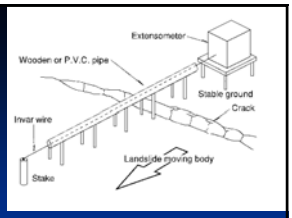
- Detailed Investigation
  - Surface deformation
    - Extensometer
    - GPS
    - Laser survey
  - Geological structure
    - Borings
  - Slip surface
    - Inclinometer
    - Pipe strain gauge
  - Groundwater
    - Groundwater level
    - Groundwater logging
  - Geotechnical Investigation

Flow chart for landslide investigation and analysis (after Japan Landslide Society and National Conference of Landslide Control, 2002)

Tips!

- Extensometer
  - Extensometer
    - Location
    - Only measures movement of slope surface
    - Tension & Compression
    - Analogue vs Digital
    - Landslide prediction
    - Monitoring during the construction





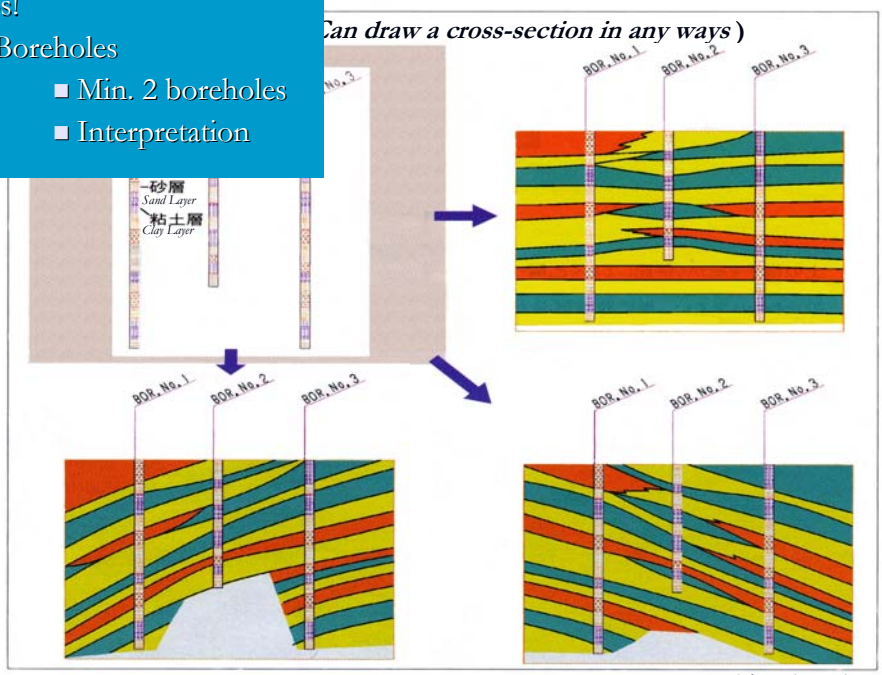
(Japan Landslide Society and National Conference of Landslide Control, 2002)

伸縮計設置の例（警報機連動）

変動が激しい伸縮計の記録例（24時間巻き）
（70mm以上／16時間）

Tips!

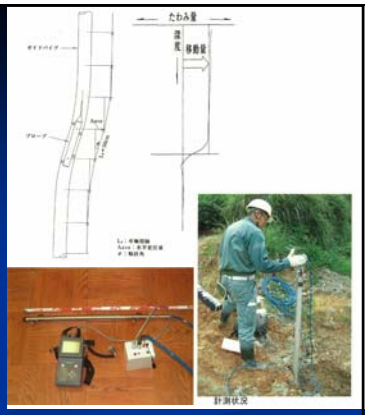
- Boreholes
  - Min. 2 boreholes
  - Interpretation

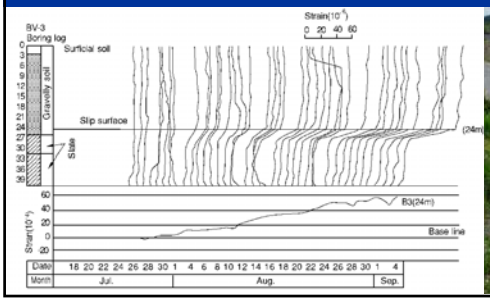


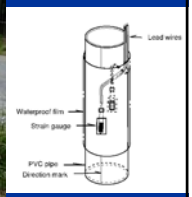
Ohta (2002)

Tips!

- Inclinometer & Pipe Strain Gauge
  - Inclinometer or pipe strain gauge?
  - Inclinometer
    - Degree of movement
    - Accumulation of error
    - Coefficient of sensor
  - Pipe strain gauge
    - Life of sensor
    - Cables
    - Switch box







(Japan Landslide Society and National Conference of Landslide Control, 2002)