# Mekanisme Longsor dan Upaya Mitigasinya

Trihanyndio Rendy Satrya

# Materi Bahasan

- Sejarah Kelongsoran
- Definisi Lereng
- Jenis Lereng
- Macam Kelongsoran
- Penyebab Kelongsoran
- Tanda-tanda Kelongsoran
- Konsep Stabilitas Lereng
- Upaya Mitigasi (Pasca dan Pra-Kelongsoran)

# Sejarah Kelongsoran

Bolivia, 4 March 2003, 14 people killed, 400 houses buried

(https://faculty.ksu.edu.sa/sites/default/files/ce_481_slope_stability_ch_15_0)

# Sejarah Kelongsoran

Brazil, January 2003, 8 people killed

(https://faculty.ksu.edu.sa/sites/default/files/ce_481_slope_stability_ch_15_0)

# Sejarah Kelongsoran

Banjarnegara, Desember 2014, 108 orang meninggal tertimbun
(https://id.wikipedia.org)

# Sejarah Kelongsoran

Bandung, Februari 2010, 70 orang meninggal tertimbun
(https://www.indozone.id)

# Sejarah Kelongsoran

Agam, Sumatera Barat, Januari 2013, 20 orang meninggal tertimbun
(https://www.antaranews.com)

# Sejarah Kelongsoran

Video Longsor Terekam Kamera (https://www.youtube.com/watch?v=syhKorR3MJg)

# Sejarah Kelongsoran

*(Kelongsoran Katastropik di abad-20)*

Major slope-instability related catastrophes of the 20th century

| | | | |
|---|---|---|---|
| Kansu (China) | 1920 | Loess flow | 200,000 killed |
| Gros Ventre (Wyoming) | 1925 | Rockslide | ~40 killed |
| Madison (Montana) | 1959 | Rockslide | >100 killed |
| Vaiont (Italy) | 1963 | Rockslide | 2,600 killed |
| Aberfan (Wales) | 1966 | Debris-slide | 144 killed |
| Huascaran (Peru) | 1970 | Complex | 25,000 killed |
| Nevado del Ruiz (Colombia) | 1985 | Debris flow | 23,000 killed |
| Casitas (Nicaragua) | 1998 | Debris flow | +2,000 killed |
| Venezuela | 1999 | Complex | +20,000 killed |
| Swiss/Italian Alps | 2000 | Debris flow | 38 killed |

- Injury & loss of life
- Property damage & communication problems
- Social & economic disruption
- Loss of productive land
- Annual economic losses
  - USA >2 billion US$
  - Japan ~4 billion US$
- 1999 Venezuela debris flows ~ 50,000 dead
  - 10 billion US$
  - 10.2% of GDP
- 2000 Swiss & Italian landslides and debris flows ~ 8. 5 billion US$

# Definisi Lereng

“ adalah permukaan tanah yang terbuka dan memiliki kemiringan (sudut) terhadap bidang horizontal “

**Lereng Buatan**

- Urugan
- Bendungan Urugan
- Tanggul sungai
- Penggalian
- Timbunan Badan Jalan

**Lereng Natural**

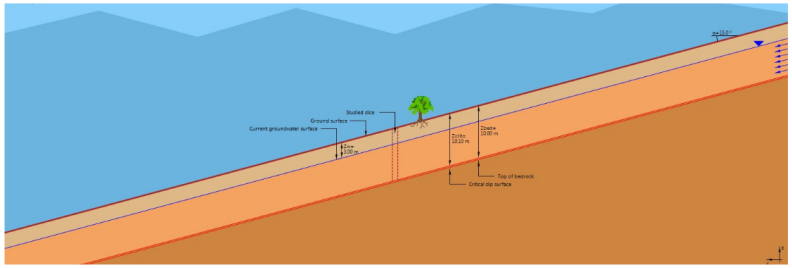
- Perbukitan
- Pengunungan
- Tangul sungai

Lereng Buatan (megas.com.my)

Lereng Alam (https://naturalresources.wales)

# Jenis Lereng

- Lereng tak hingga (infinite slope) dan Lereng hingga (finite slope)



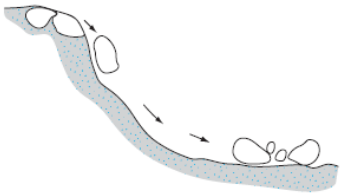

Lereng Tak Terhingga
(geoengineer.org)

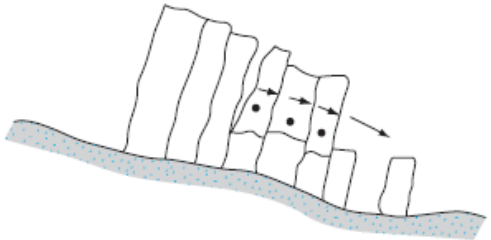
Lereng Terhingga
(geosynthetica.com)

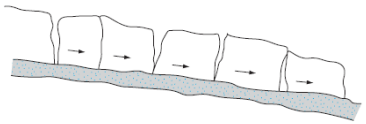
# Kelongsoran pada Lereng & Macamnya

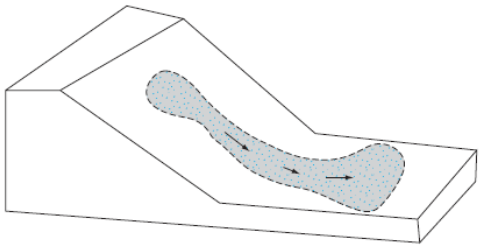
Longsor terjadi karena bidang miring yang menyebabkan komponen gravitasi tanah / batuan bergerak dari bagian yang tinggi ke bagian yang rendah.

- Fall
- Topple
- Slide
- Lateral Spread
- Flow
- Creep

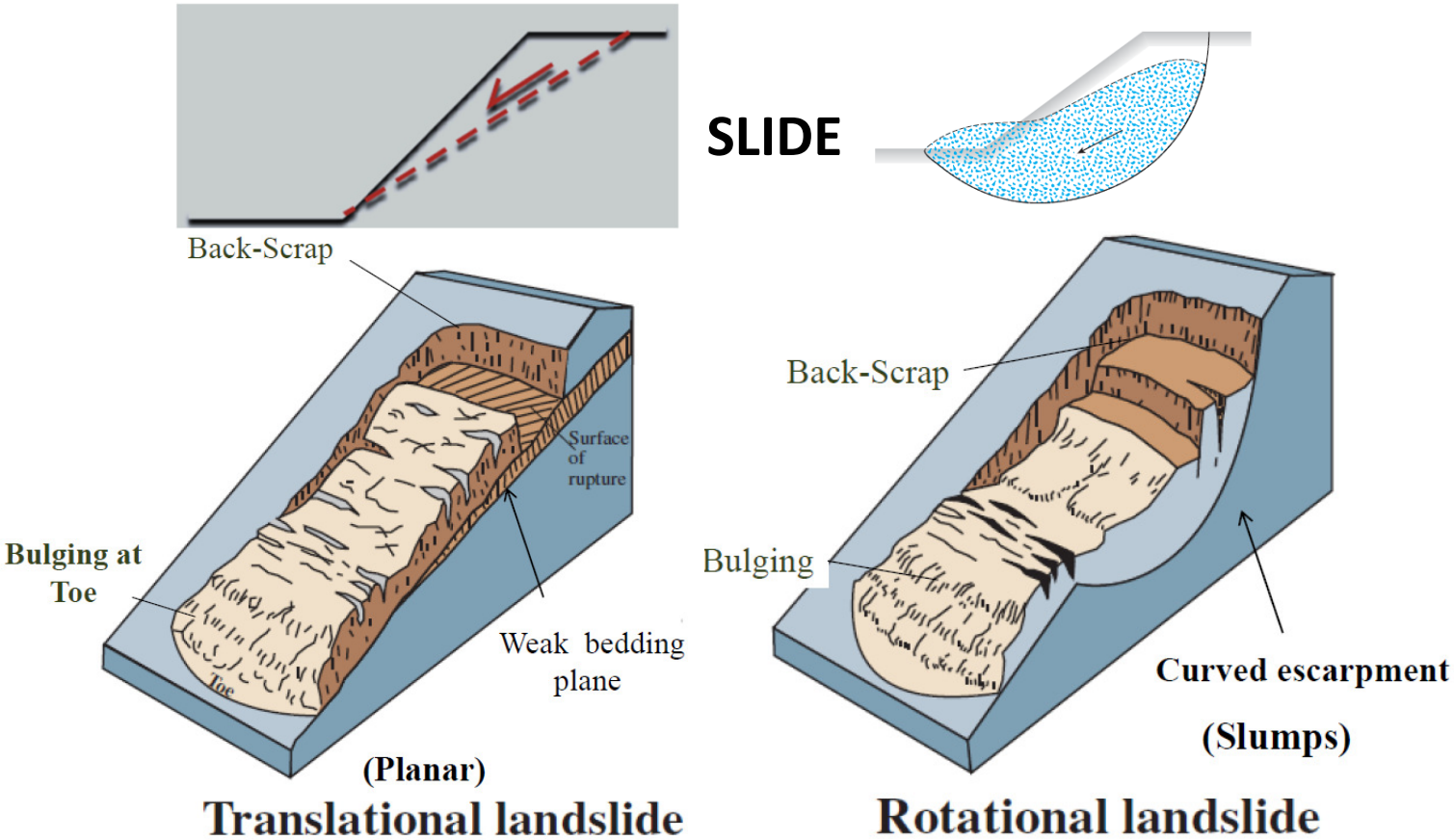






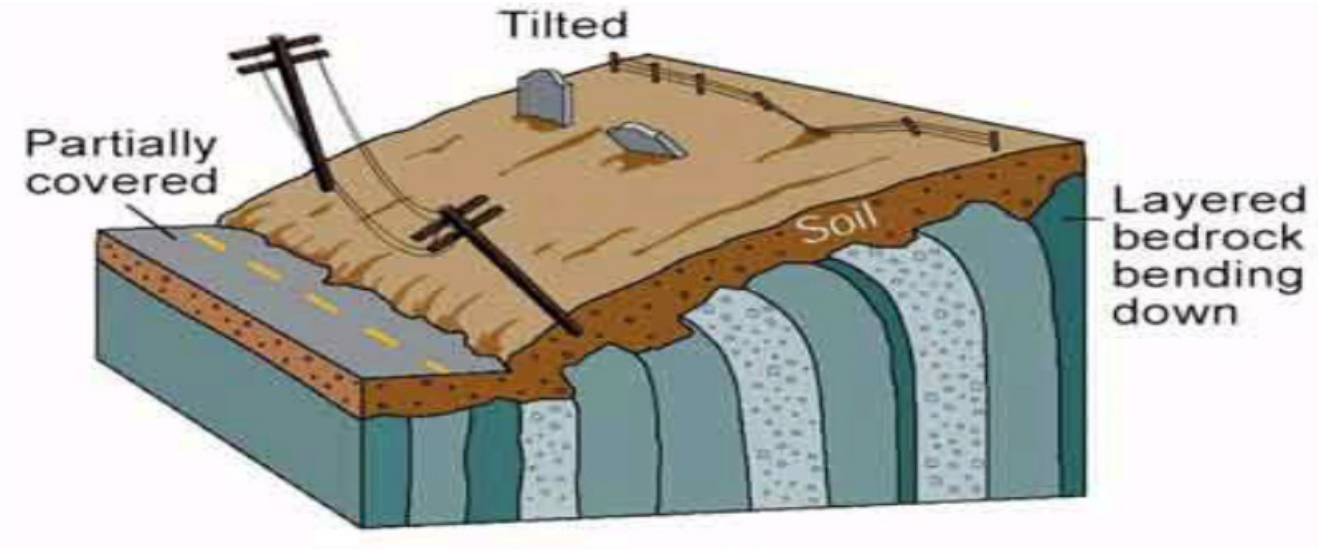


# Kelongsoran pada Lereng & Macamnya



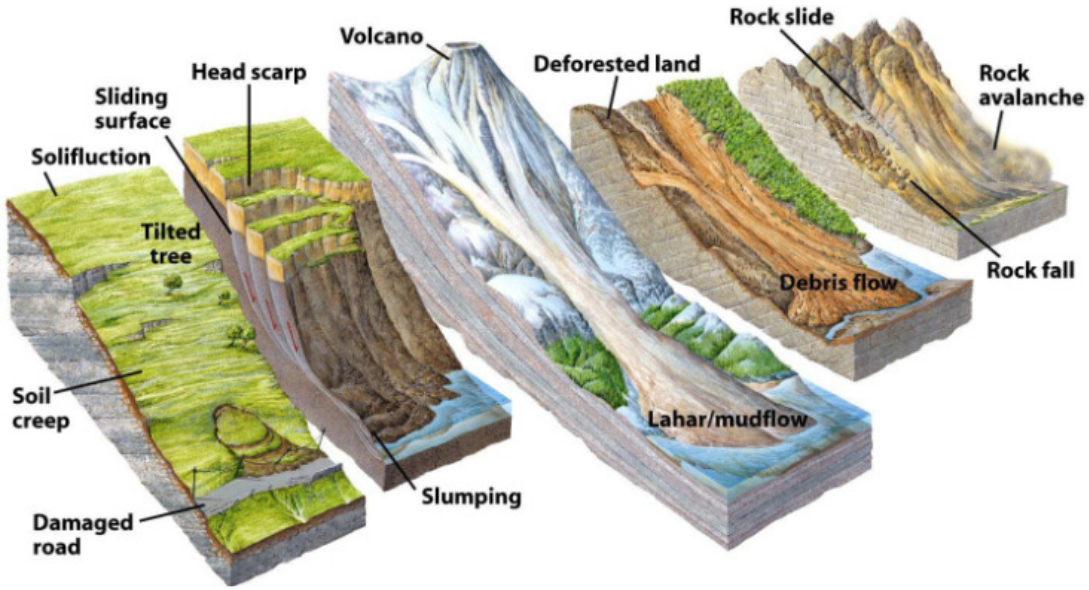

- Kelongsoran planar/datar (searah dengan lereng), terjadi pada bagian retakan/diskontinuitas atau tanah dasar yang jelek (tanah non kohesif).
- Kelongsoran rotasional: pergerakan massa tanah pada bidang runtuh berbentuk menyerupai lingkaran (tanah kohesif)

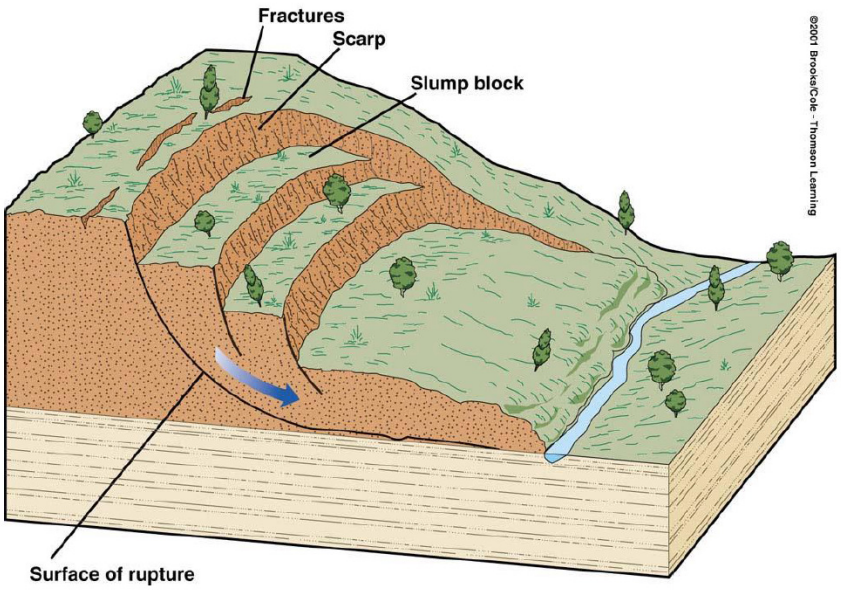
# Kelongsoran pada Lereng & Macamnya




- Kelongsoran rangkak (creep) terjadi akibat pergerakan tanah perlahan dalam periode waktu yang Panjang, biasanya terjadi pada tanah di atas lapisan batuan yang berorientasi arah vertikal.

# Kelongsoran pada Lereng & Macamnya



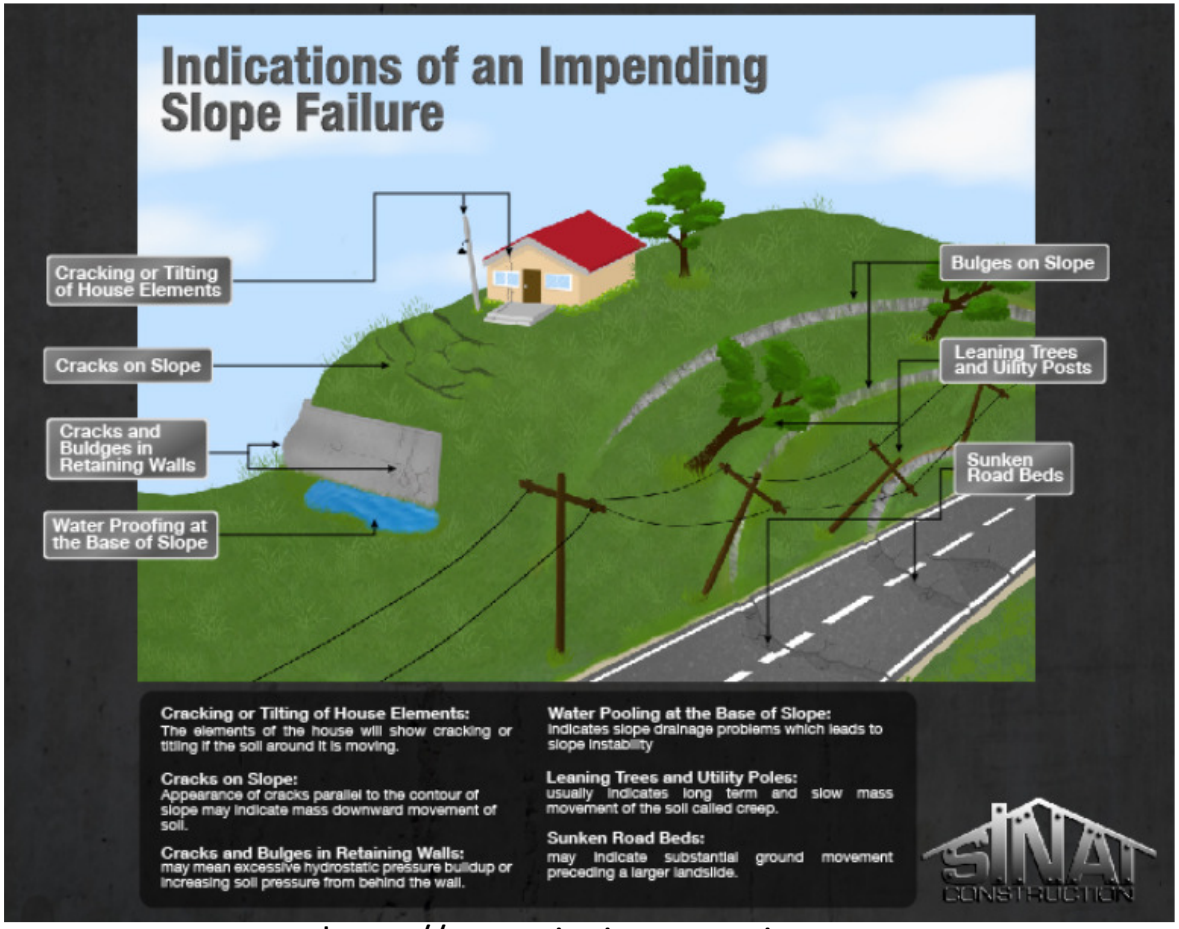

https://trailism.com/soil-and-rock/soil-mechanics-slope-stability/

# Penyebab Kelongsoran

- **Penyebab Eksternal**
  - ✓ Beban di atas lereng
  - ✓ Pengaruh cuaca
  - ✓ Peninggian timbunan atau Kemiringan lereng

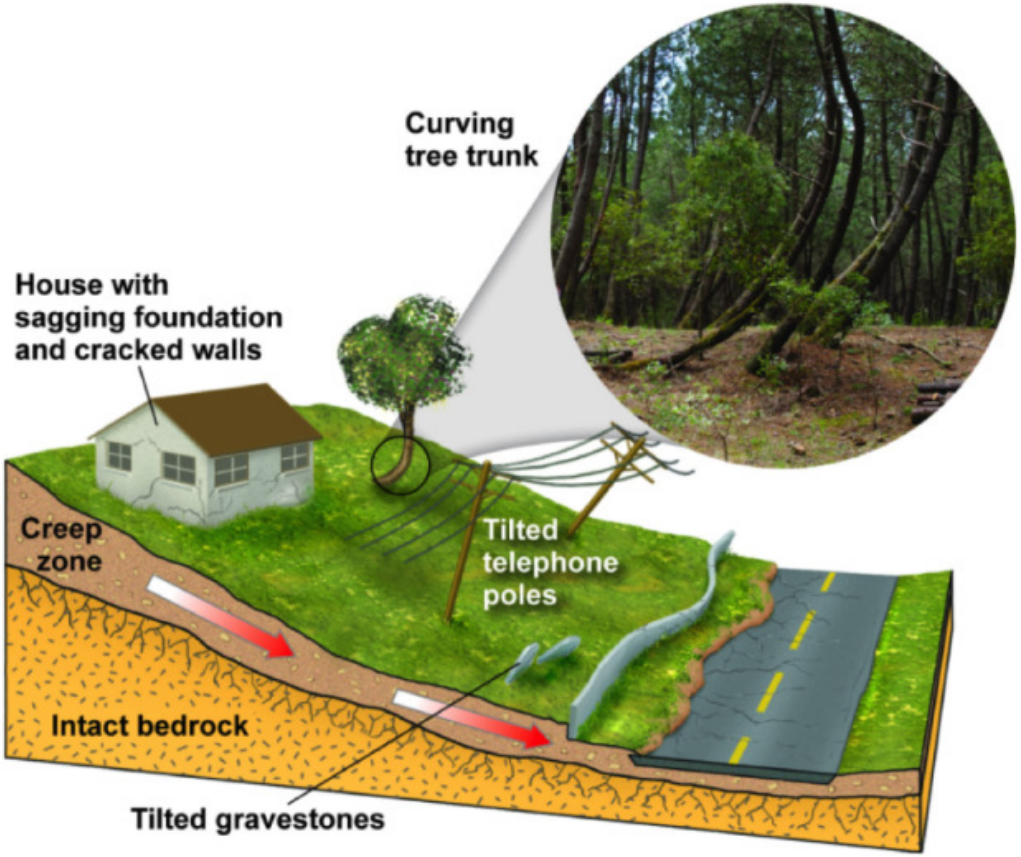
- **Penyebab Internal**
  - ✓ Peningkatan Tegangan Air Pori akibat hujan
  - ✓ Kerentanan karakteristik tanah

# Tanda-Tanda Kelongsoran Lereng




https://www.sinaiconstruction.net

# Tanda-Tanda Kelongsoran Lereng

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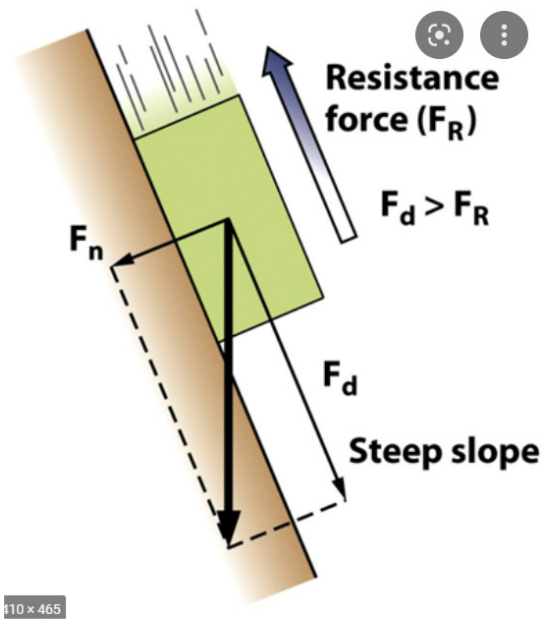
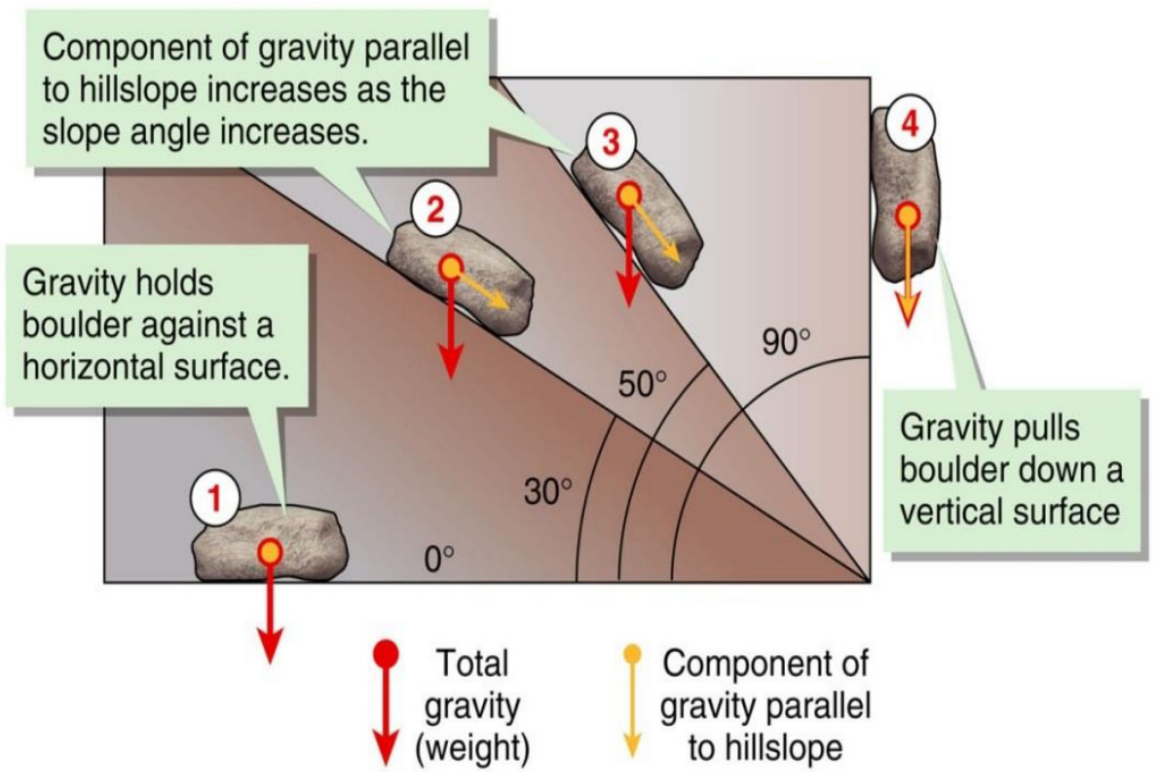
# Konsep Stabilitas Lereng

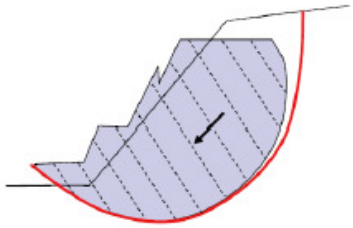


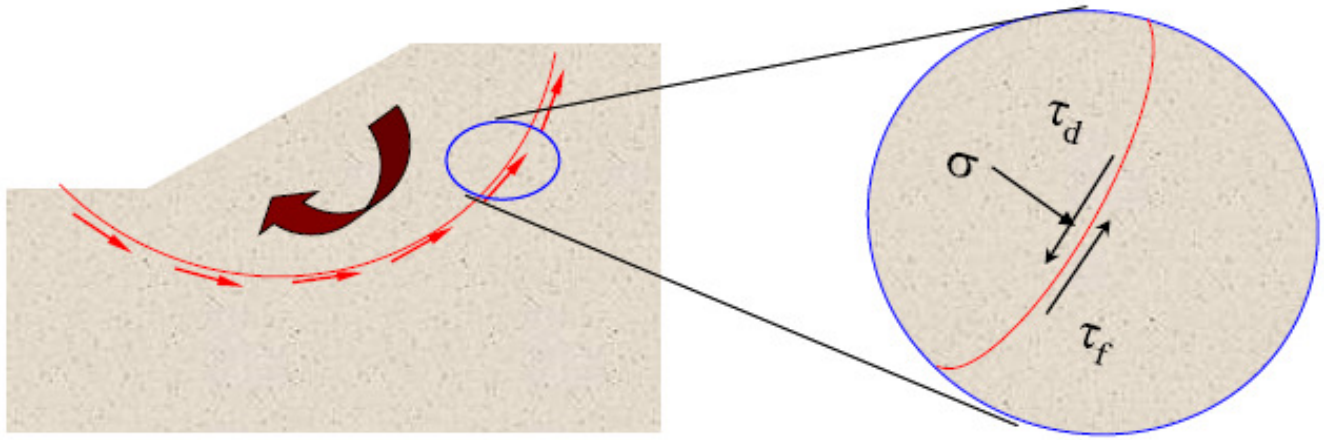
# Konsep Stabilitas Lereng

"Suatu metoda untuk menyatakan hubungan atara gaya **penahan** (resistant forces) dengan gaya **pendorong** (driving forces).

- Gaya Pendorong (Driving Forces), gaya menggerakkan material lereng ke arah bawah lereng, yang berasal dari berat material tanah, material urugan atau gedung di atas lereng.
- Gaya Penahan (Resisting Forces), gaya yang menahan pergerakan material lereng, yang berasal dari kuat geser material.



# Konsep Stabilitas Lereng




*"Kelongsoran terjadi saat **Gaya Pendorong** lebih besar dari pada **Gaya Penahan** pada bidang runtuh"*

# Konsep Stabilitas Lereng (Angka Keamanan)

**Angka Keamanan** = $\frac{\text{Gaya Penahan (resisting force)}}{\text{Gaya Pendorong (driving force)}}$

*(Factor of Safety, FS)*

$$F_s = \frac{\tau_f}{\tau_d}$$

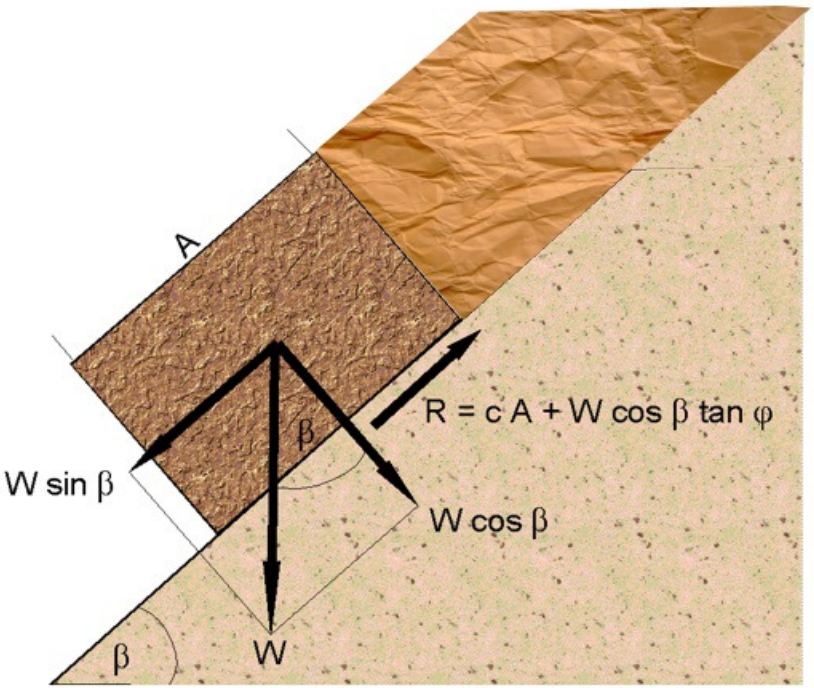
Fs < 1 ➔ Tidak Stabil / longsor

Fs = 1 ➔ Kritis

Fs > 1 ➔ Stabil

**Dalam peraturan SNI 8460:2017, FS kondisi aman adalah ≥ 1.5**

# Konsep Stabilitas Lereng (Angka Keamanan)




A : Shear surface [m2];
W : Gravitational force [N];
Wsinβ/A : **shear stress** [KPa=kN/m2];
s = c + σ tan ϕ : **shear strength**
σ = normal stress = W cos β / A
c = cohesion (KPa)
ϕ = angle of internal friction (degrees)

**Shear stress =** Wsinβ/A
**Shear strength** = cA + W cos β tan ϕ

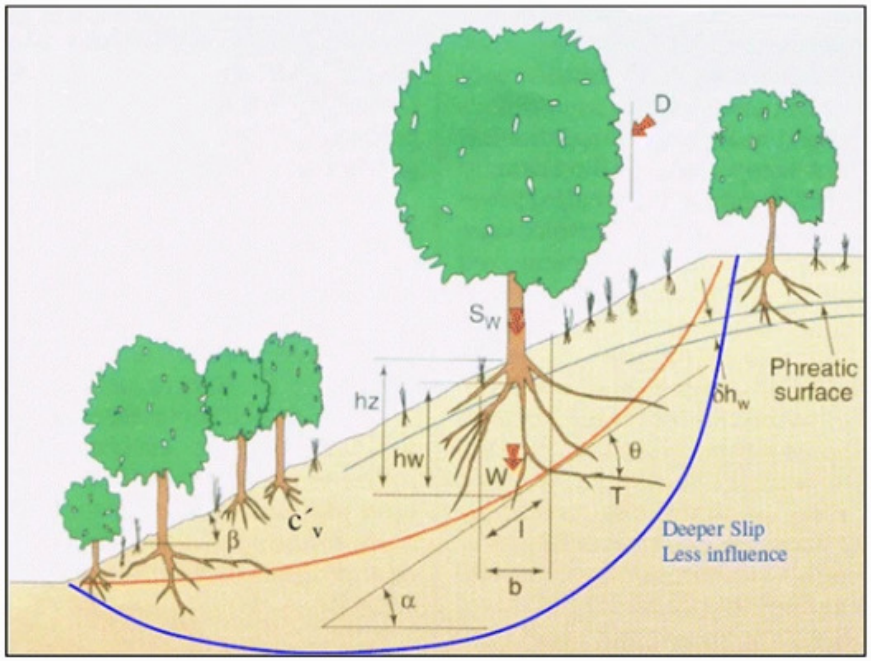
$$\textit{Factor of Safety (F)} = \frac{\textbf{Shear strength}}{\textbf{Shear stress}} = \frac{cA + W\cos\beta\tan\phi}{W\sin\beta/A}$$

https://www.cdema.org/virtuallibrary/index.php/charim-hbook/methodology/4-landslide-hazards/4-1-introduction-d89

# Upaya Mitigasi (Pasca Longsor)

- Investigasi kondisi **geoteknik** dan **geometri** lereng
- Pemetaan (**zoning**) wilayah yang rentan longsor
- Perkuatan tanah (**vegetasi**)
- Perkuatan tanah (**beton bertulang / baja**)

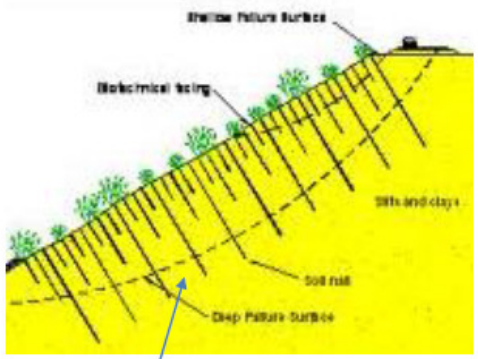
# Upaya Mitigasi (Pasca Longsor)




(Coppin and Richards 1990)

# Upaya Mitigasi (Pasca Longsor)

**Reinforcement**

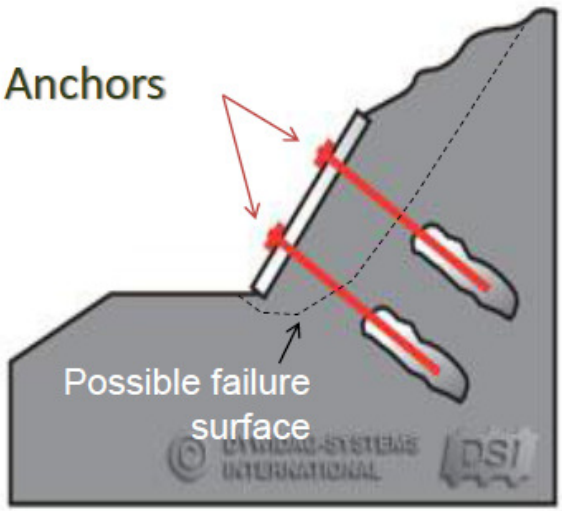


Soil nails

(https://faculty.ksu.edu.sa/sites/default/files/ce_481_slope_stability_ch_15_0)

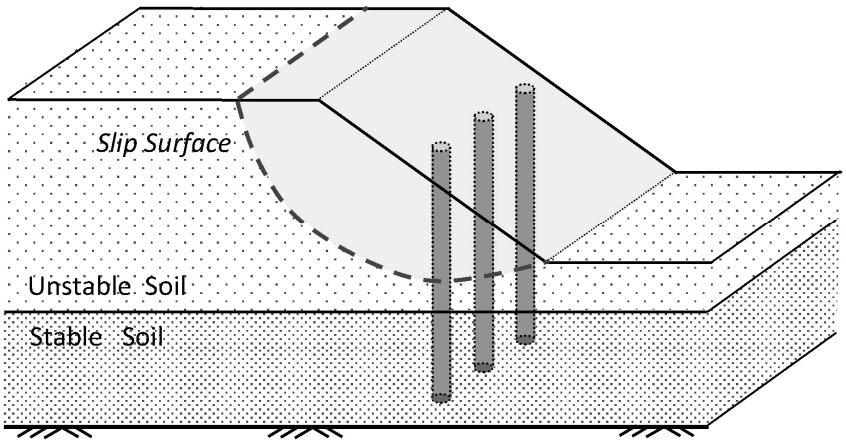
# Upaya Mitigasi (Pasca Longsor)

**Reinforcement**

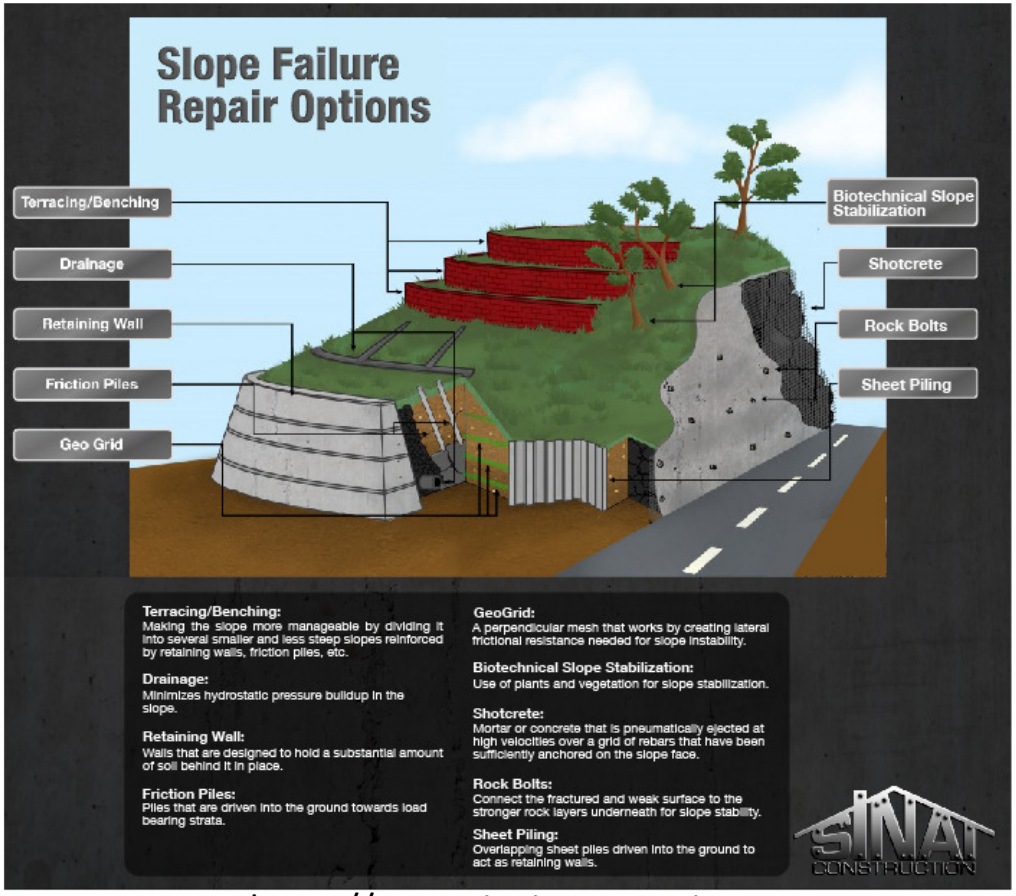


(https://faculty.ksu.edu.sa/sites/default/files/ce_481_slope_stability_ch_15_0)

# Upaya Mitigasi (Pasca Longsor)




(R. Kourkoulis et al, 2012)

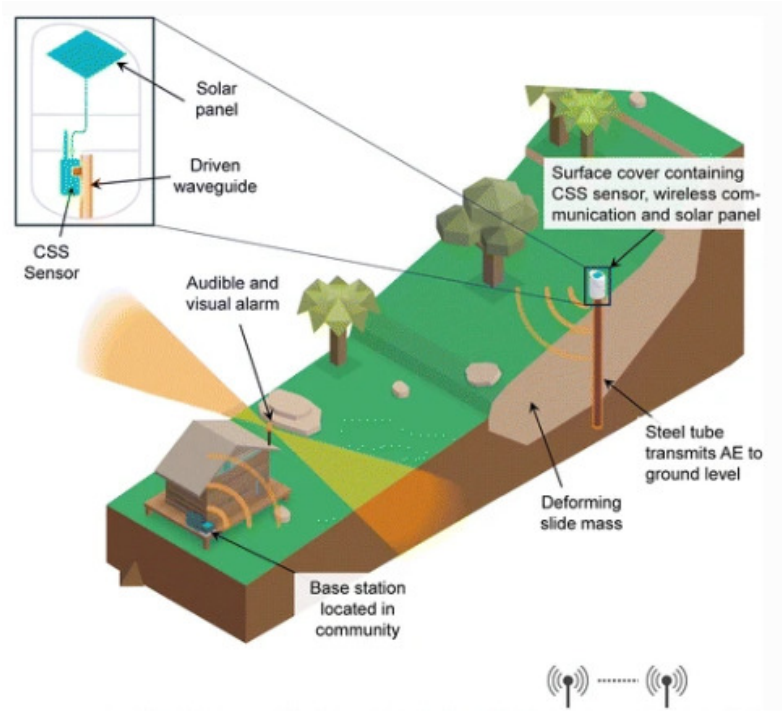



https://www.sinaiconstruction.net

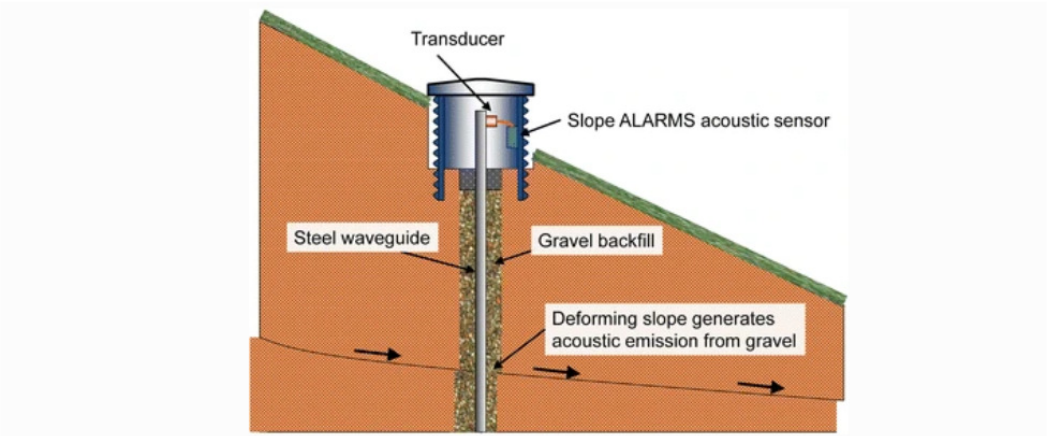
# Upaya Mitigasi (Pra-Longsor)

- Sosialisasi mengenai tanda kelongsoran lereng dan prosedur evakuasi
- Inisiasi Early Warning System untuk evakuasi
- Monitoring kondisi lereng

# Upaya Mitigasi (Pra-Longsor)

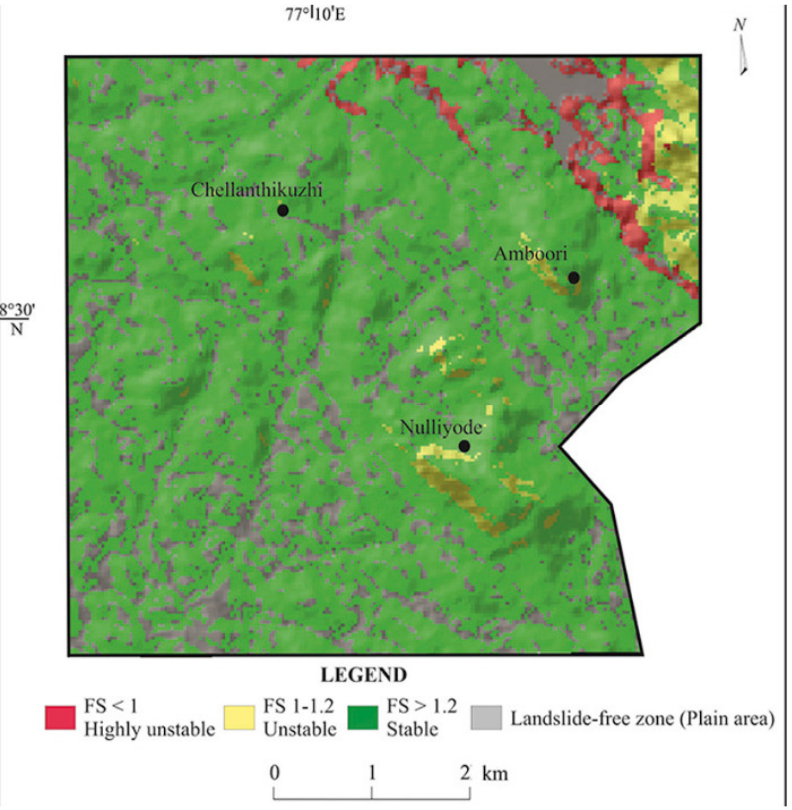


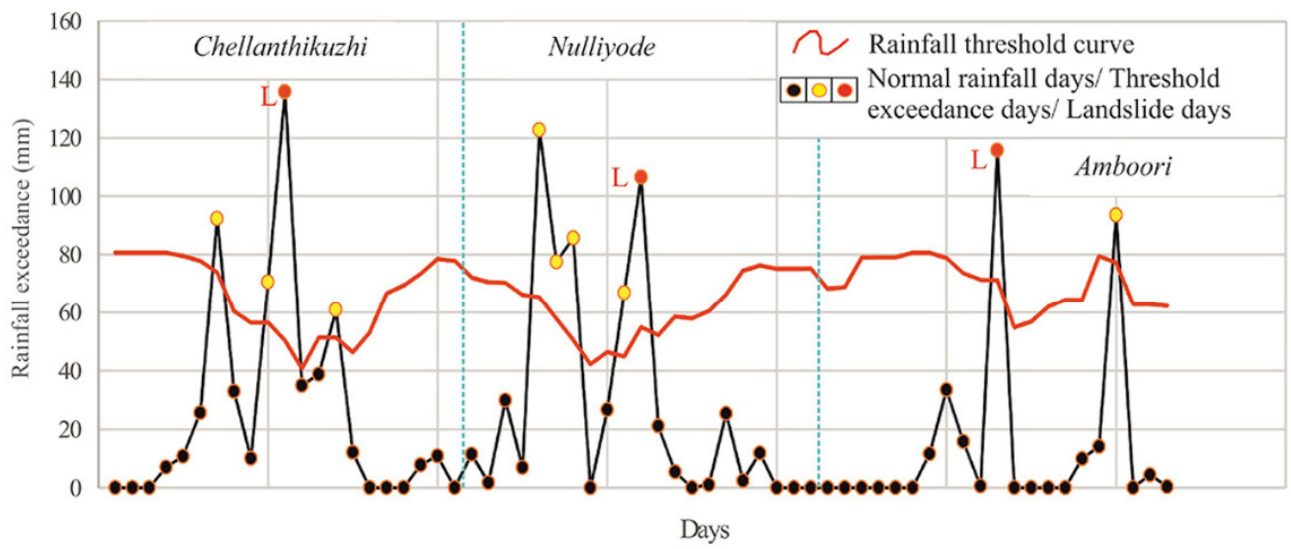

N. Dixon et al, 2018




Slope ALARMS AE monitoring approach incorporating an active waveguide (Dixon et al. 2015)

# Upaya Mitigasi (Pra-Longsor)




Shruti Naidu et al, 2018

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