Mudflows and Debris Flows

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River Mechanics and Sediment Transport
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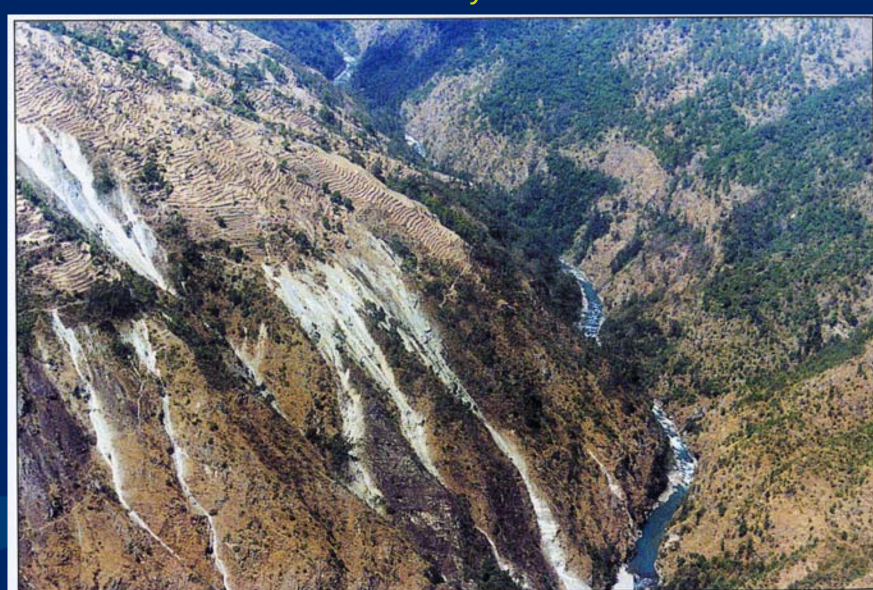
Objectives

Brief overview of examples from around the world:

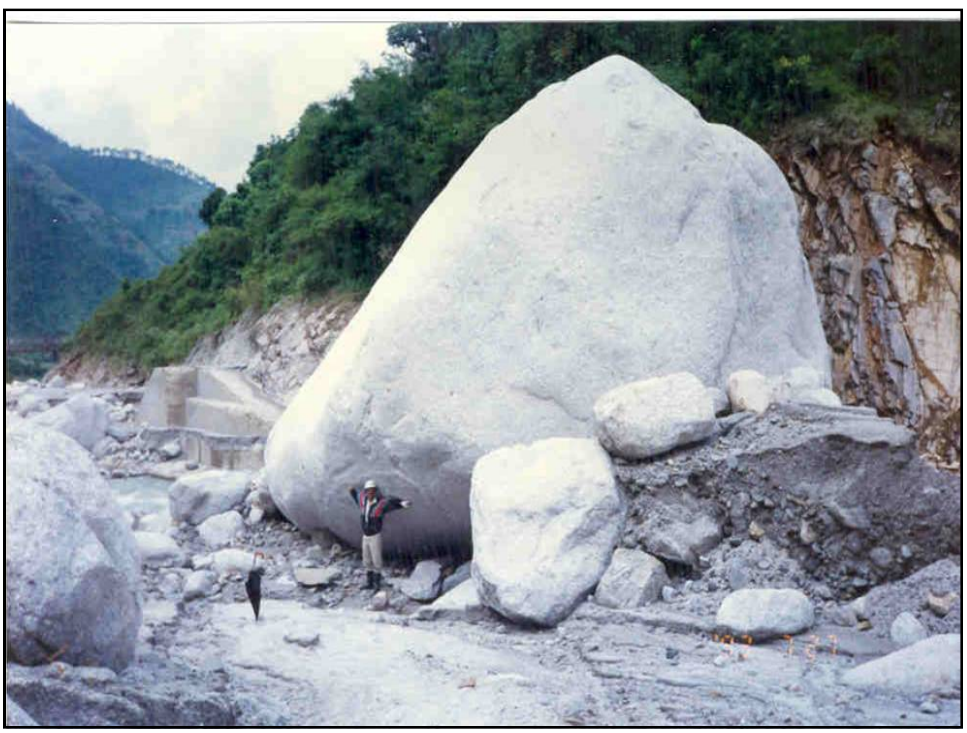
1. Landslides in the Himalayas;
2. Duksan Creek in South Korea
3. San Julian in Venezuela;
4. Sediment Plugs in New Mexico;
5. Rheology and Countermeasure Design.

1. Landslides in the Himalayas

Lesser Himalayan Area



Gullying on valley wall slopes along the Dudh Kosi, in the Lesser Himalaya.

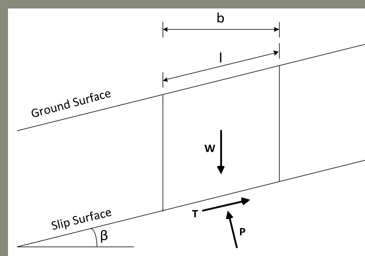


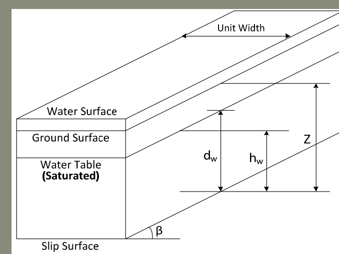

Tala HE Project

2. Duksan Creek in South Korea

Mangun mountain, South Korea

Infinite Slope Model





$$FS = \frac{Shear\ strength\ of\ the\ soil}{Shear\ stress\ along\ the\ slip\ surface}$$

$$FS = \frac{\dfrac{c\,b}{\cos\beta} + P'\tan\phi}{T + F_s}$$

$$P' = W\cos\beta = [(\gamma_{sat} - \gamma_w)\,b\,d_w + \gamma_m\,b\,(z - d_w)]\cos\beta \quad (N/m)$$

$$T = W\sin\beta = [(\gamma_{sat} - \gamma_w)\,b\,d_w + \gamma_m\,b\,(z - d_w)]\sin\beta \quad (N/m)$$

$$F_s = \sin\beta\,\gamma_w\,(b\,d_w) = \gamma_w\,b\,d_w\sin\beta \quad (N/m)$$

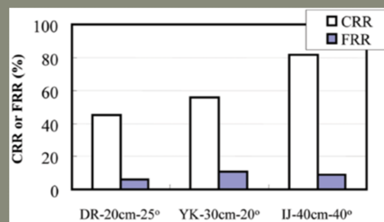
Infinite Slope Model

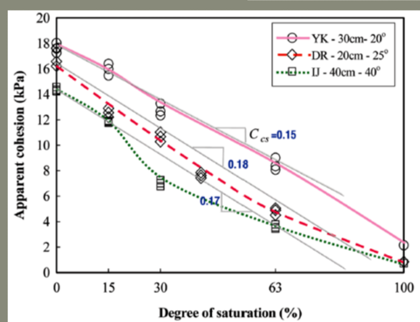
$$FS = \frac{\dfrac{c}{[(\gamma_{sat} - \gamma_w)\,d_w + \gamma_m\,(z - d_w)]\sin\beta\cos\beta} + \dfrac{\tan\phi}{\tan\beta}}{1 + \dfrac{\gamma_w\,d_w}{[(\gamma_{sat} - \gamma_w)\,d_w + \gamma_m\,(z - d_w)]}}$$

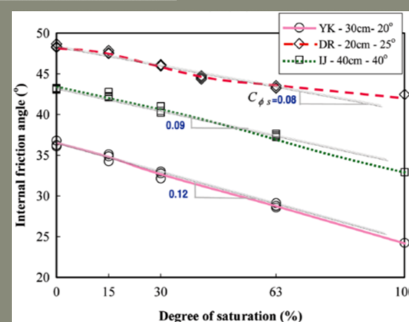
$$FS = \frac{\dfrac{c}{[(\gamma_{sat} - \gamma_w)\,d_w]\sin\beta\cos\beta} + \dfrac{\tan\phi}{\tan\beta}}{1 + \dfrac{\gamma_w}{(\gamma_{sat} - \gamma_w)}}$$

C. TREX + Infinite Slope Model

Soil cohesion and Friction angle







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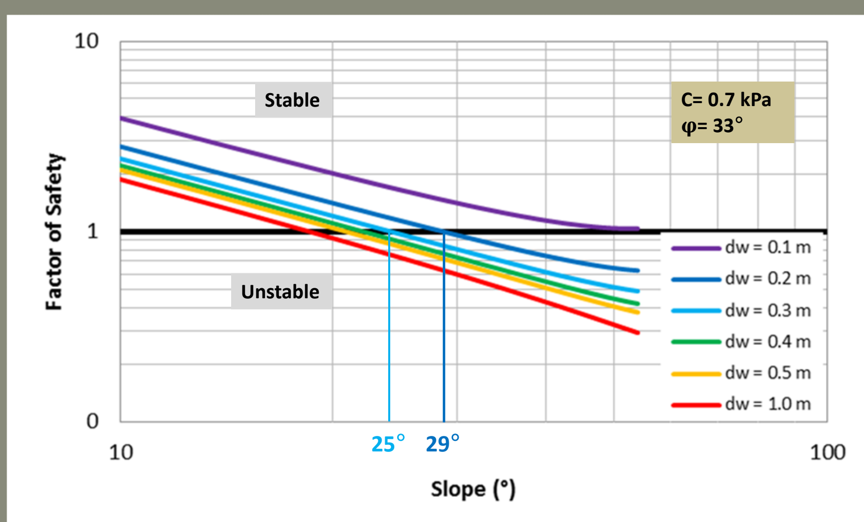
C. TREX + Infinite Slope Model

Critical Slope Analysis



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C. TREX + Infinite Slope Model

Critical Slope Analysis

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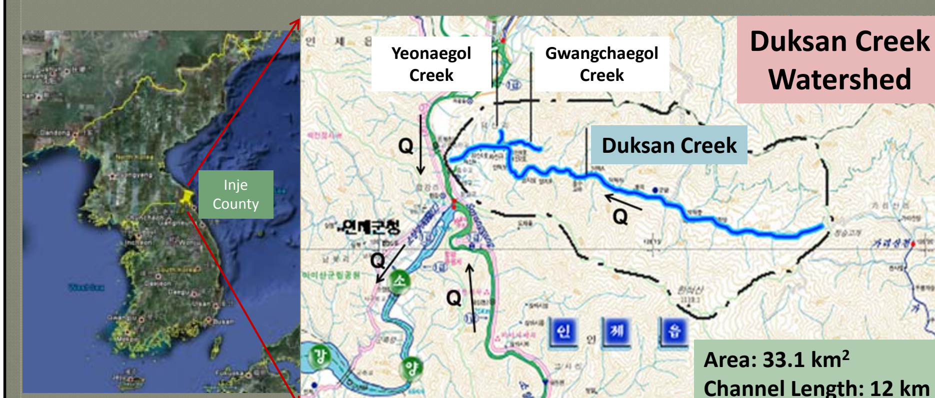
Site Description



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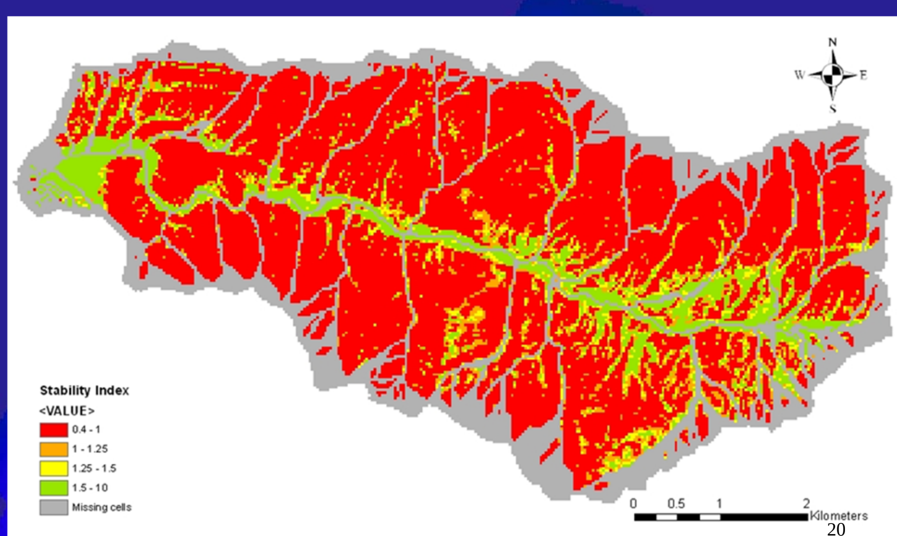
A. KFRI map

KFRI map

Class	Score Range	Degree of Hazard
1	> 181	Area with severe susceptibility to landslide
2	121 - 180	Area with moderate susceptibility to landslide
3	61 - 120	Area with little susceptibility to landslide
4	< 60	Stable Area

Static Modeling with SINMAP



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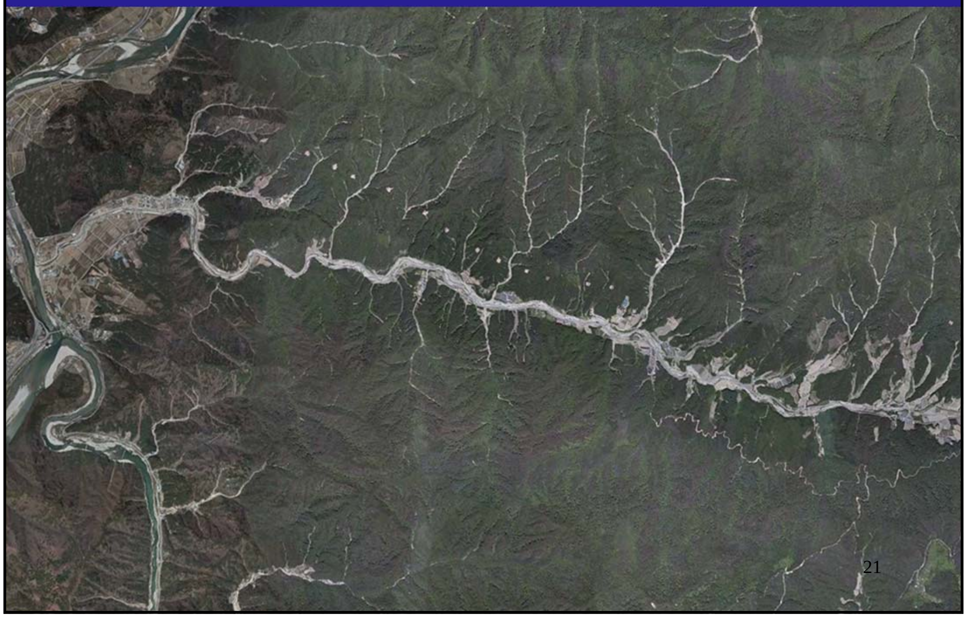
Duksan Creek, Inje Gun, SK



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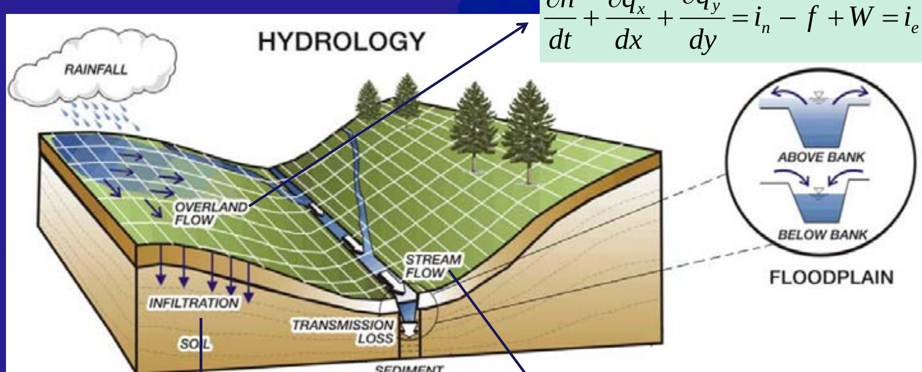
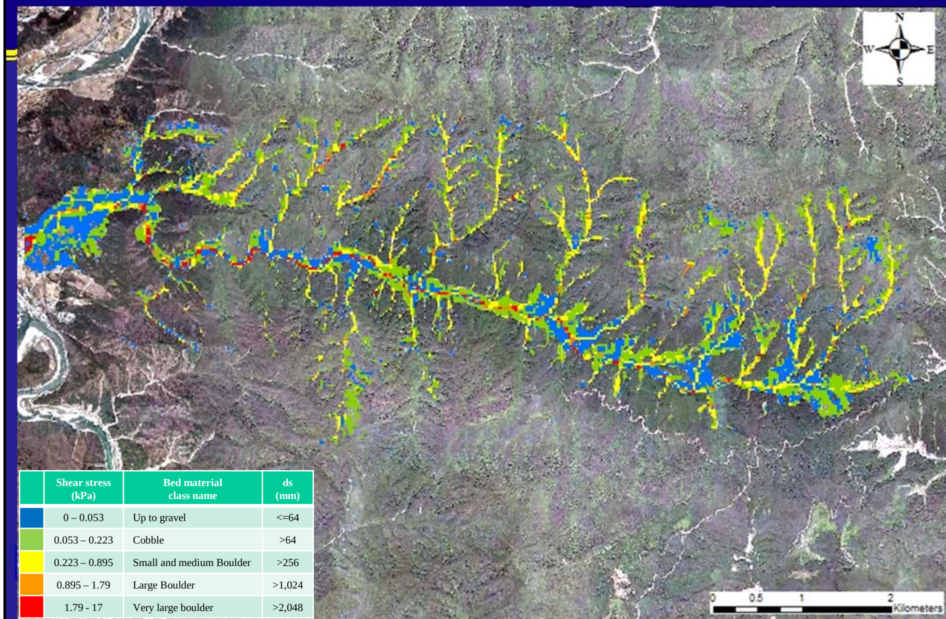
Dynamic Modeling with TREX

$$\frac{\partial h}{dt}+\frac{\partial q_x}{dx}+\frac{\partial q_y}{dy}=i_n - f + \dot{W} = i_e$$



$$f = K_h\left(1+\frac{H_c\left(1-S_e\right)\theta_e}{F}\right)$$

$$\frac{\partial A}{dt}+\frac{\partial Q}{dx}=q_l+\hat{W}_{22}$$



	Shear stress (kPa)	Bed material class name	ds (mm)
	0 – 0.053	Up to gravel	<=64
	0.053 – 0.223	Cobble	>64
	0.223 – 0.895	Small and medium Boulder	>256
	0.895 – 1.79	Large Boulder	>1,024
	1.79 - 17	Very large boulder	>2,048

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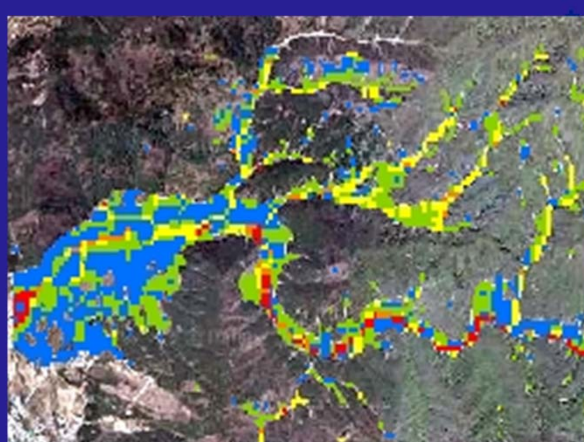
Landslides



- Steep hillslopes
- High rainfall precipitation
- Saturated yield strength ~ 1kPa
- High Infiltration


ompar
Q
Duksan
Creek
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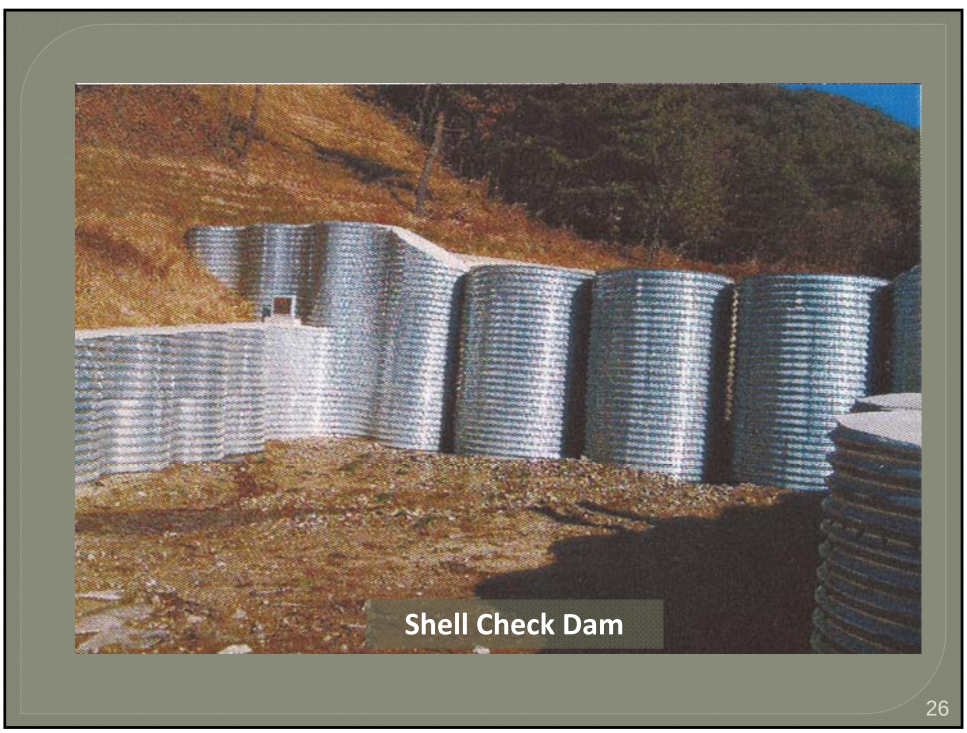
Shell Check Dam
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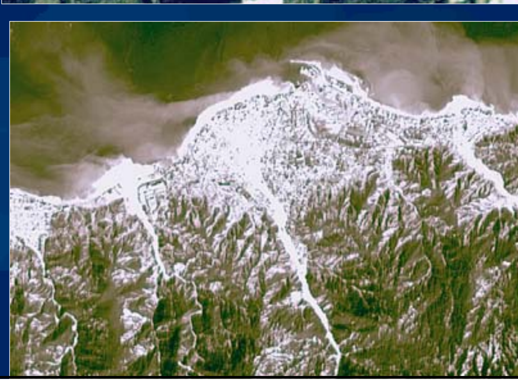
3. San Julian in Venezuela

SPOT Image.
January 18, 1999

SPOT Image.
December 25, 1999



Alluvial fan of San Julian (1998)

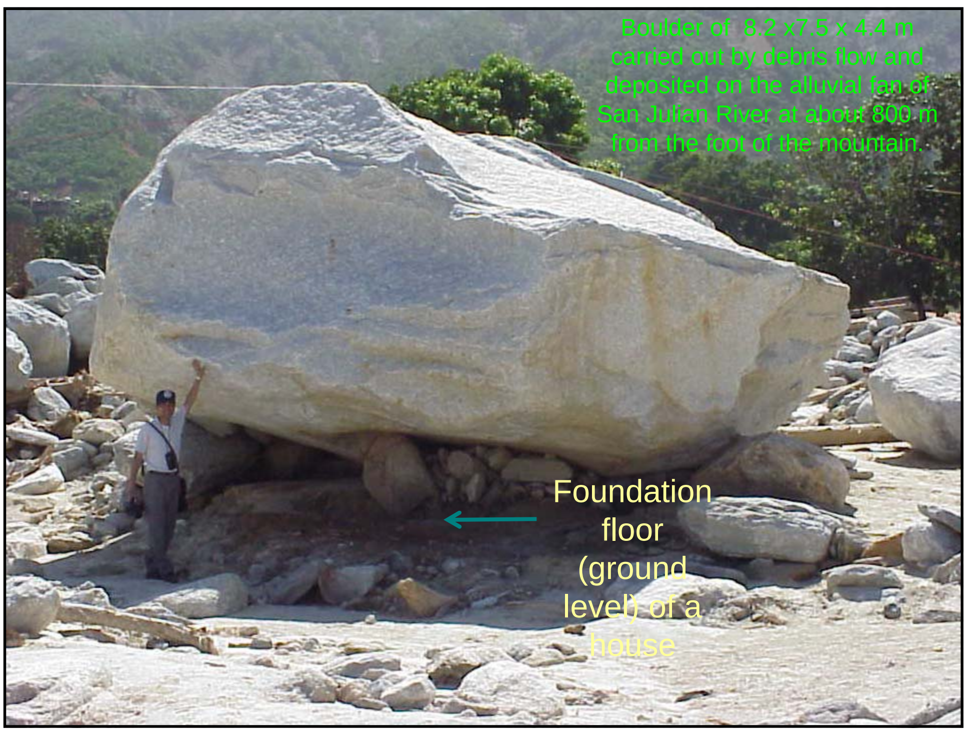
Alluvial fan of San Julian (2000)

Example: Vargas Mountains, Venezuela


LOS CORALES

Los Corales

Los Corales


Boulder of 8.2 x7.5 x 4.4 m carried out by debris flow and deposited on the alluvial fan of San Julian River at about 800 m from the foot of the mountain.
Foundation floor (ground level) of a house

Los Corales

Los Corales

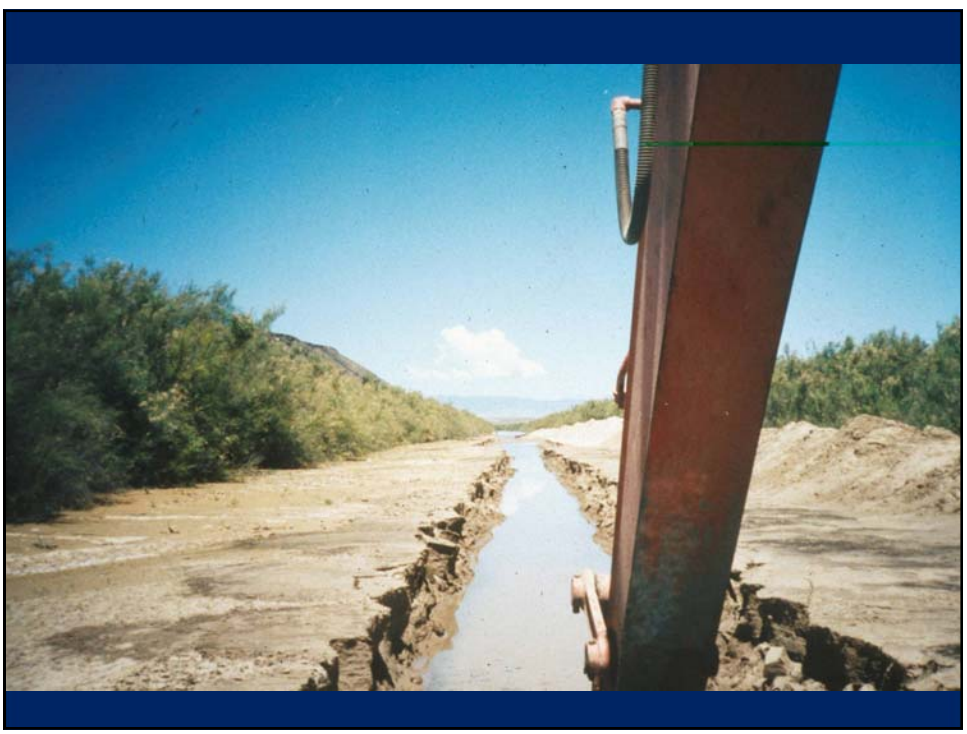

SAN JULIAN


SAN JULIAN

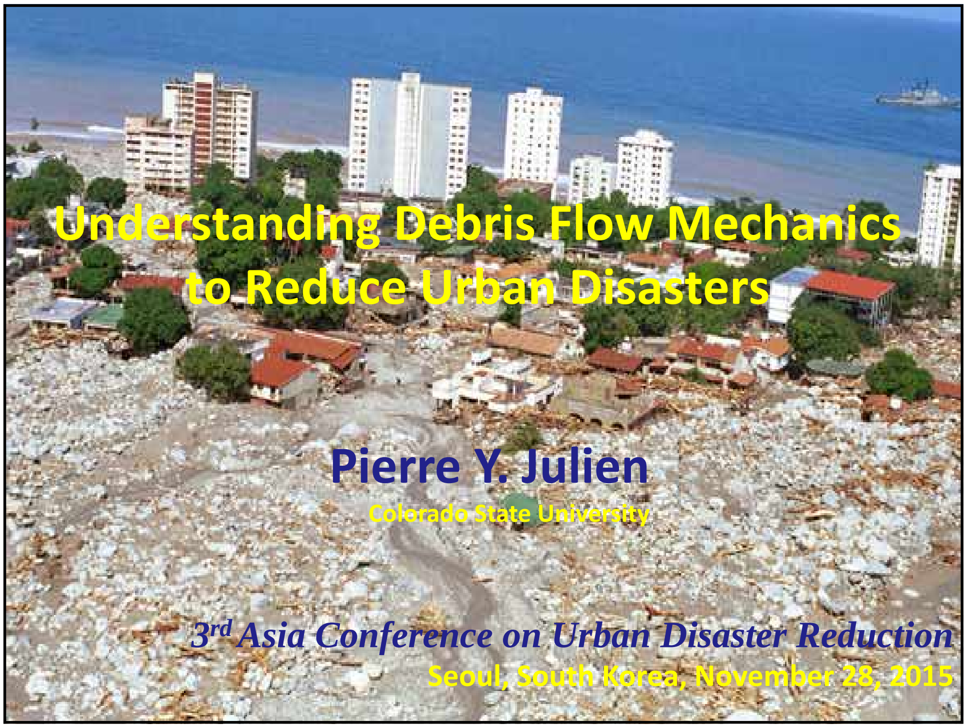

SAN JULIAN

4. Sediment Plugs in New Mexico

Sediment Plug of the Rio Grande, New Mexico



5. Rheology and Countermeasure Design



Objectives

Provide guidelines for designing mitigation countermeasures based on the type of hyperconcentrated flow

Classification and Rheology

Total shear stress :

$$\tau = \tau_y + \tau_v + \tau_t + \tau_d$$

Landslides ⟺ Yield stress

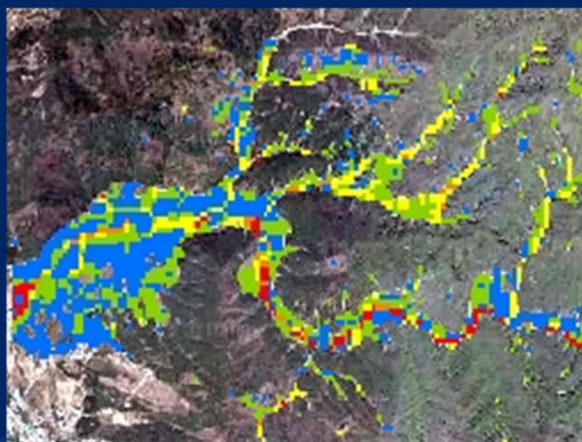
Mudflows ⟺ Viscous stress

Mudfloods ⟺ Turbulent stress

Debris flows ⟺ Dispersive stress

1. Landslides

Landslides



Duksan Creek modeling with TREX

from Dr. Jaehoon Kim, CSU and KFRI

- Yield strength
- Steep hillslopes
- High rainfall precipitation
- High Infiltration
- Saturated yield strength ~ 1kPa

Landslide Countermeasures

Effective Solution ➡ **Slope reduction, drain, vegetation**

- **Terraces**
- **Drainage**

2. Mudflows

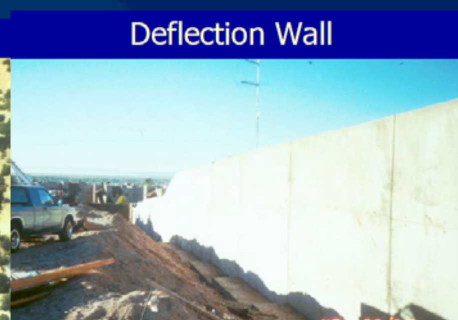
Mudflow

- Viscous
- High concentration of silts and clays
- $45\% < C_v < 55\%$
- Low velocity and Froude number
- Large flow depth and pressure
- No abrasion

Mudflow Countermeasures

Effective Solution ➡ **Store, Deflect, Spread**

- Storage basins
- Deflection walls



Rudd Creek, Utah

from Dr. Jim O'Brien

3. Mudfloods

Mud Flood

- Turbulent
- Non-cohesive particles
- Sands and silts
- Cv as high as 40%
- High velocity and Froude Number
- Abrasive

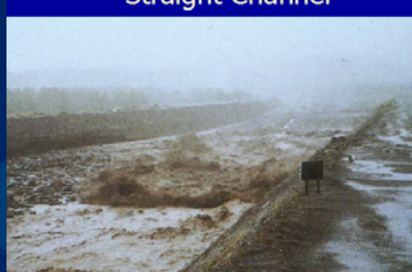
Mudflood Countermeasures

Effective Solution ➡ **Increased conveyance**

- **Straight channel**
- **Lined canal**
- **Berm and levee**
- **Drop structure**

Lined canal with drop structures

Straight Channel

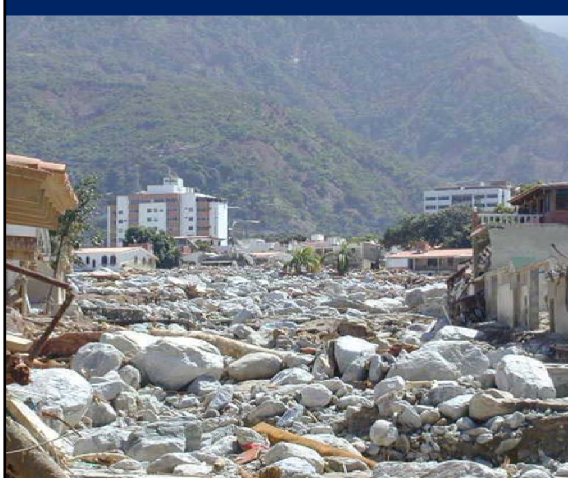


4. Debris Flows

Los Corales, Venezuela

Los Corales

Debris Flow



- Dispersive
- Large rocks
- Non cohesive
- Low viscosity
- High velocity
- Destructive impact force

Debris flow Countermeasures

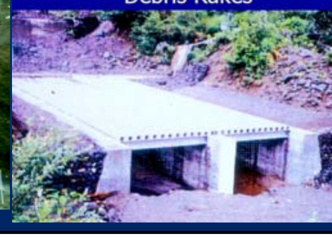
Effective Solution ➡ **Retain large rocks**
Drain water

- **Concrete sabo dams**
- **Steel Frames**
- **Debris Racks**

Sabo Dam and Steel Frames

Sabo Dam Construction

Debris Rakes



5. Example Mt Umyeon


특집 뉴스라인
집중호우 강타

Conclusions

- Mitigation structures for mudflows
  - » Detention basins
  - » Deflection walls
- Mitigation structures for mud floods
  - » Straight channels
  - » Lined canals, berm and levee channels
  - » Drop structures, energy dissipators
- Mitigation structures for debris flows
  - » Concrete Sabo dams
  - » Steel frames and debris rakes


Muchas
Gracias!
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