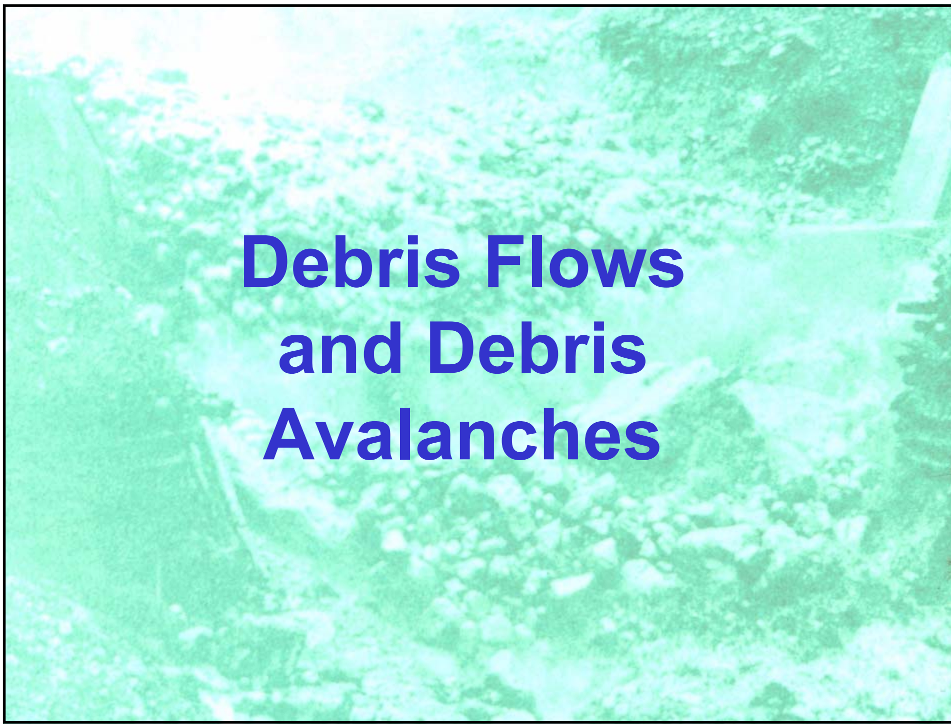
Debris Flows and Debris Avalanches



Debris Flow

Point of Initiation

Transport zone "Gorge"

Deposition zone "Fan"

~2 km

(Khumbu Valley, Nepal)

Debris Avalanche

Point of Initiation

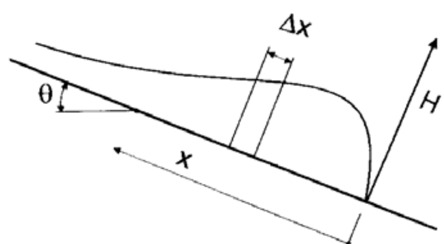
Transport zone “Trail”
(no channel!)

~700m

Deposition zone “Apron”
(no fan!)

(British Comumbia)

St. Venant Equation
- Lagrangian



$$\rho H \Delta x \frac{dV}{dt} = \rho g H \Delta x \sin\theta - T\Delta x - \frac{dp}{dx}\Delta x$$

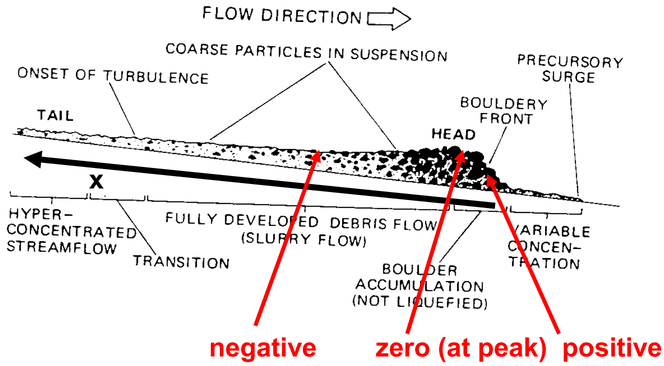
$$p = \rho g H$$

At steady state (a=0):

$$0 = \sin\theta - \frac{T}{\rho g H} - \frac{dH}{dx}$$

$$\frac{dH}{dx} = S - S_f$$

S=slope; S_f=friction slope



Boulder front

$$\frac{dH}{dx} = S - S_f$$

Turbulent surges (Jiang-jia Ravine, Chengdu, China)

$$\frac{dH}{dx} = S - S_f$$

$$\frac{dH}{dx} = S - S_f$$

At peak, dH/dx = 0

(uniform flow)

Velocity equations:

$$V = \frac{\rho g \sin\theta}{k\upsilon}$$

Laminar (Poiseuille) flow

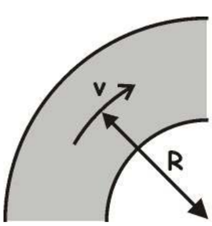
k = shape factor
(3 for wide channel, 8 for semi-circle)

υ = dynamic viscosity:
(3 kPa.s)

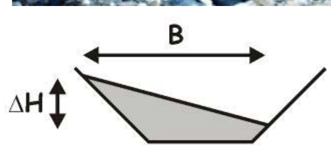
Estimation of velocity in the field

Forced Vortex Equation (superelevation)

$$\Delta H = B\frac{v^2}{Rg}$$



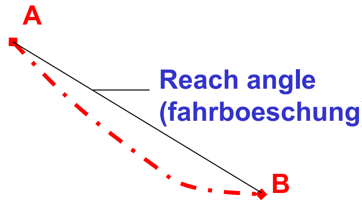
plan

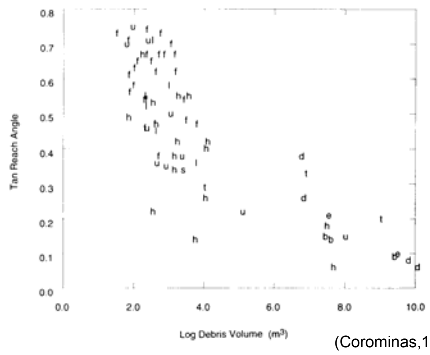


x-section

e.g.(Hungr et al. 1984)

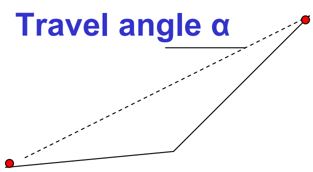
Debris flow runout:





(Corominas,1996)

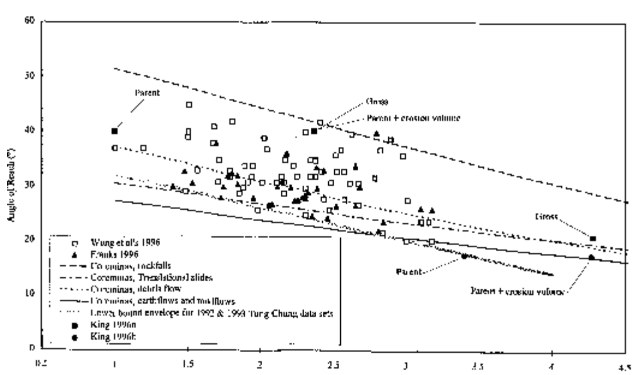
Travel angle α



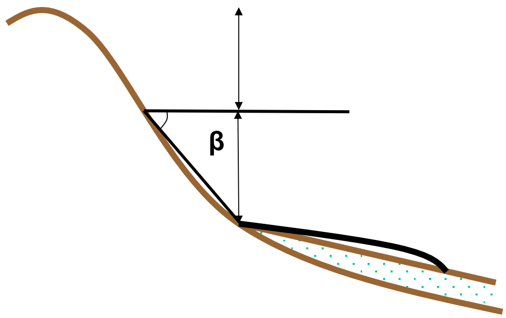
Debris flows in Hong Kong

(Wong et al., 1997)

Angle α
(deg.)



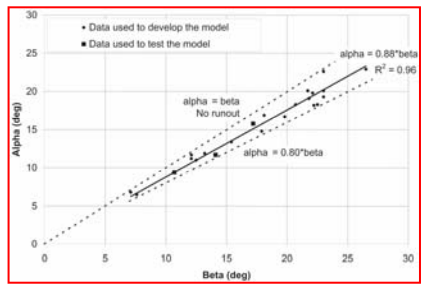
Log Initial Volume (m^3)

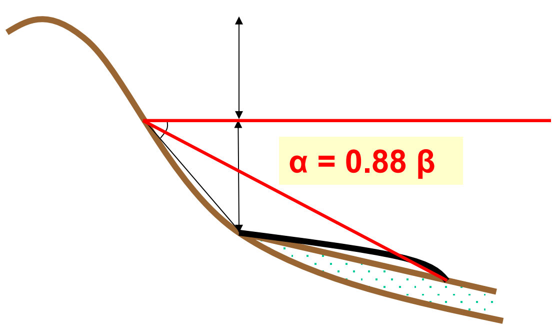


New Empirical Model

(Haneberg, Cannon, Earth Surface Processes)

in press





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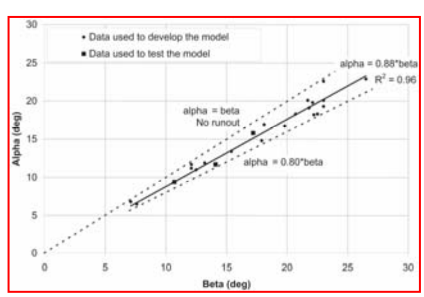
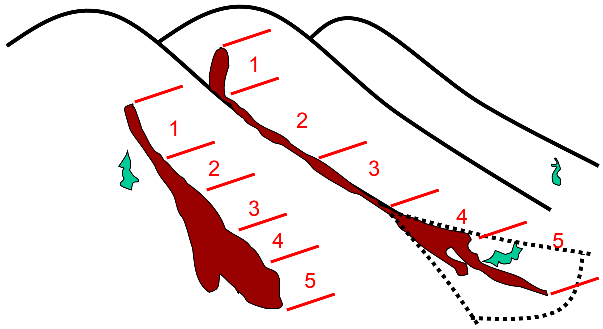
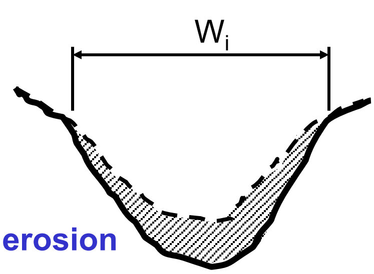


Estimation of magnitude: Yield rate concept (Hungr et al., 1984)



Channel segments ("reaches") with approximately constant channel description

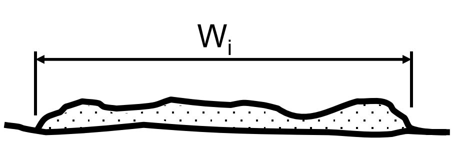


Incremental volume for reach i:

$$V_i = Y_i L_i$$

L_i = length of the reach

Y_i = Yield Rate (m^3/m)



or, alternatively:

$$V_i = d_i W_i L_i$$

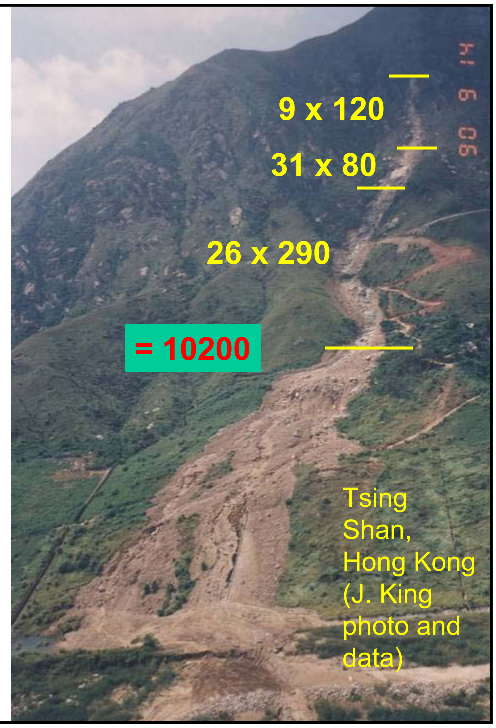
D_i = Erosion Depth (m)

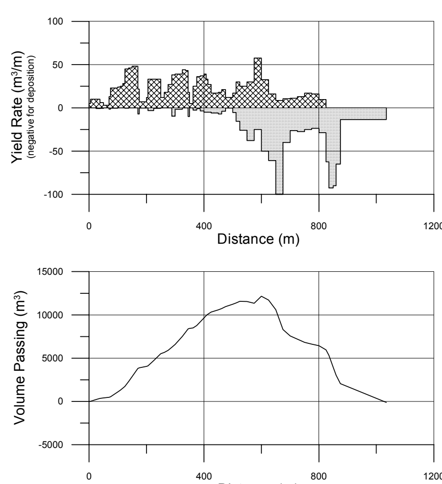
Calculate volume of debris flow:

$$V = V_{point} + \sum V_i$$

Where V_{point} is the sum of all point sources (landslides)

$$V = V_{point} + \sum Y_i L_i$$

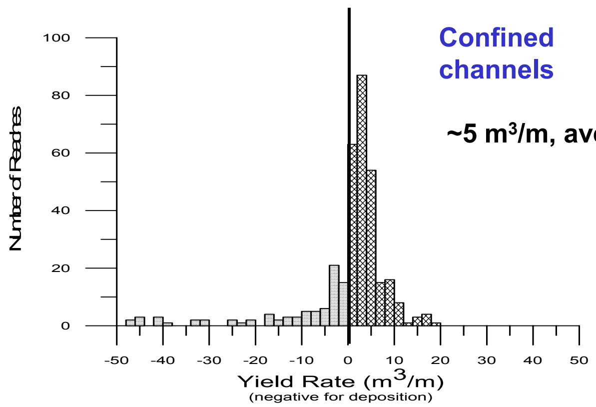




Tsing shan, HK

Yield rates, Queen Charlotte Islands, Canada

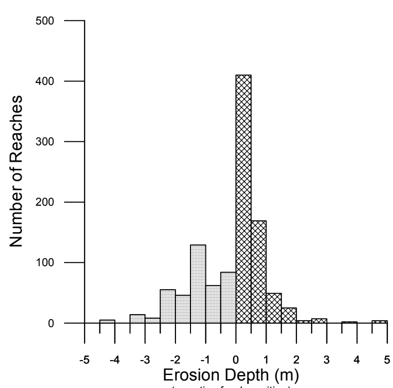
(Hungr et al., 2005. Data by (T. Rollerson)



Confined channels

~5 m^3/m, average

Erosion depths, QCI data (confined and unconfined)



~0.5 m erosion depth (average)

Debris Yield Rates, British Columbia (Hungr et al., 1984)

Channel type	Gradient (deg)	Bed material	Side slopes	Stability condition*	Channel debris yield rate† (m^3/m)
A	20–35	Bedrock	Nonerodible	Stable, practically bare of soil cover	0–5
B	10–20	Thin debris or loose soil over bedrock	Nonerodible (bedrock)	Stable	5–10
C	10–20	Deep talus or moraine	Less than 5 m high	Stable	10–15
D	10–20	Deep talus or moraine	Talus, over 5 m high	Side slopes at repose	15–30
E	10–20	Deep talus or moraine	Talus, over 20 m high	Side slopes potentially unstable (landslide area)	Up to 200 (consider as point source)

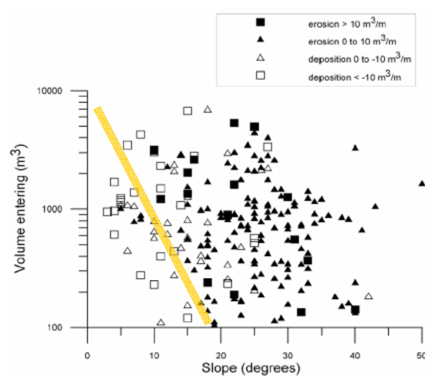
*Prior to the expected debris torrent event.
†For drainage areas of 1–3 km^2. For other drainage areas use [2].

Debris Yield Rates, worldwide (Hungr et al., 2005)

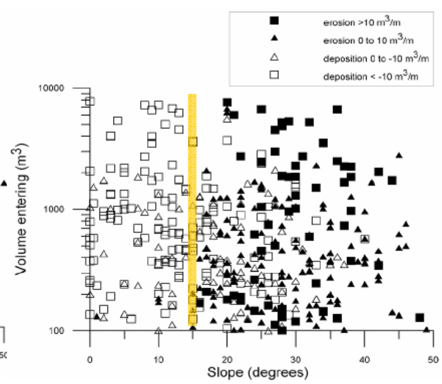
Reference	Location	No. events	Confi-nement	Erosion Depth (m)	Yield Rate (m^3/m)
Hungr et al. (1984)	B.C. Coast, Canada	5	C	-	6-18
Jakob et al. (1997)	B.C. Coast, Canada	2	C	-	(23)
Campbell and Church (2003)	B.C. Coast, Canada	37	C	0.5-1	-
Fannin and Rollerson (1993)	Queen Charlotte Isl., Canada	253 196	C U	-	(12.6) (24)
Jakob et al. (2000)	B.C. Interior, Canada	1	C	0.5-1.5	(28)
Cenderelli and Kite (1998)	The Appalachians, USA	4	U	0-2.5	0-42 (4.2)
Springer et al. (2001)	The Appalachians, USA	2	C	-	2-18
Agostino and Marchi (2003)	Southern Alps, Italy	1	C	0.1-6 (1.0)	-
Revellino et al. (2003)	Campania, Italy	17	C,U	(1,5)	-
Li and Yuan (1983)	South-west China	1	C	5-8	-
Franks (1999)	Hong-Kong	40	C	-	0.2-5 (3.6)
King (1996)	Hong Kong	1	U	0-3	0-50
Okuda et al. (1980)	The Alps, Japan	1	C	0-5	-
Rickenmann et al. (2003)	Kazakhstan	1	C	-	8-300

Erosion/deposition boundary (QCI data)

Confined reaches

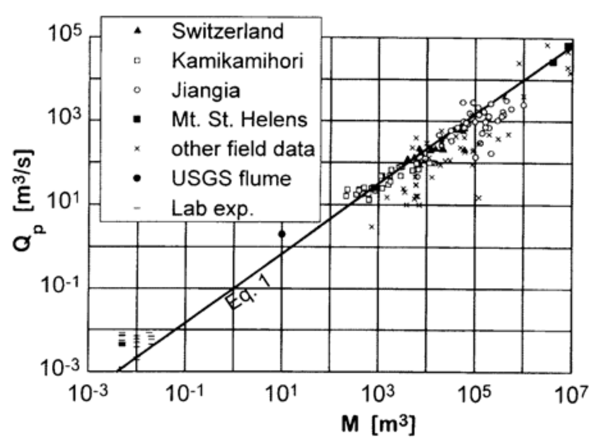


Unconfined reaches



Hypothesis: Entrainment behaviour in a given reach of the stream depends on slope and the volume of material entering the reach.

Peak Discharge



Magnitude

Rickenmann, 1999

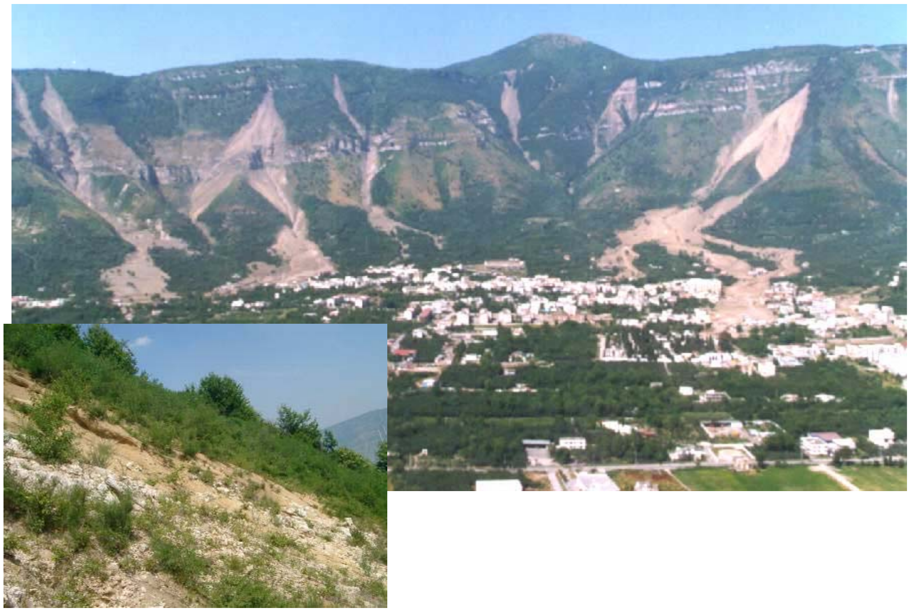
Initial slide V_i=~40x100x1 = 4 000 m^3

Y =~ 6 m^3/m

Y =~ 24 m^3/m

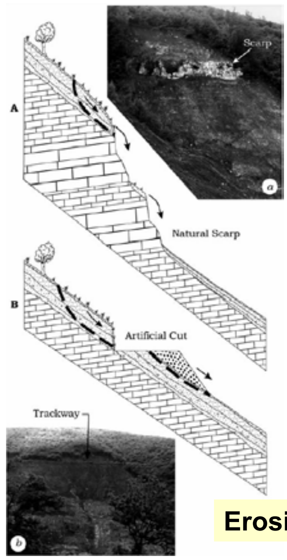
Point of deposition, slope angle = 10º

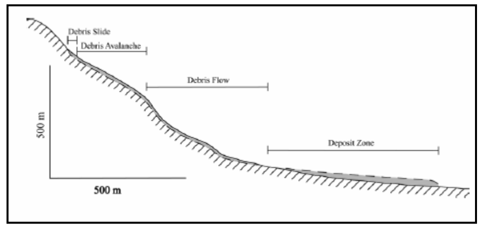
Sarno, Italy, 1999, 1.5 m depth (Revellino et al., 2003)

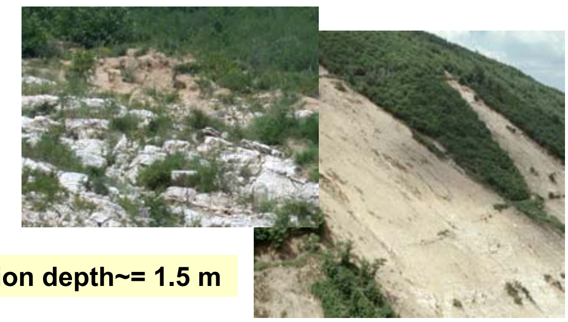


Debris avalanches, Campania, Italy

(Photos: Prof. F.Guadagno, Benevento)



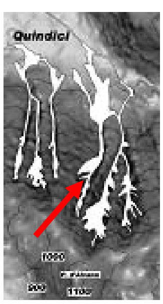


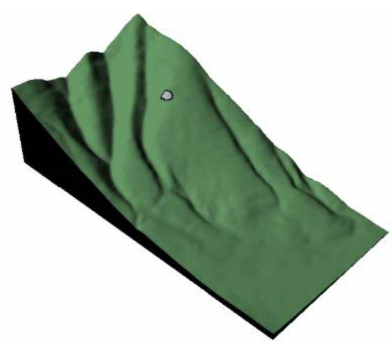


Erosion depth~= 1.5 m

Debris avalanches, Campania, Italy

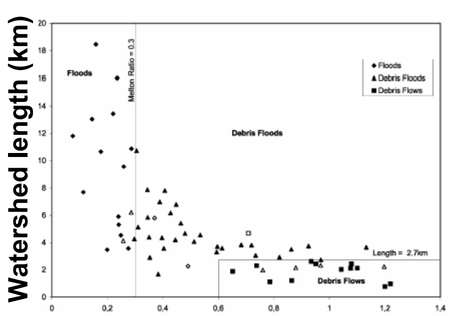
(e.g. Revellino et al., 2004)





Debris avalanche dynamic analysis: Connola Gully, Quindici, Campania

Debris flood: Peak discharge bulking factor: 1 to 2 x peak discharge of a water flood



Melton Ratio: watershed relief divided by the square root of watershed area) (Melton 1957)

Debris flood watersheds: morphological identification (Wilford et al., 2004)