CALCULATION OF EROSION AND LOWERING RATES

Measurement units and conversions

m = meter	1 m = 3.2808 ft	kg = kilogram	1 kg = 2.2046 lb	y = year
ft = foot	1 ft = 0.3048 m	lb = pound	1 lb = 0.4534 kg	ka = kiloannum = 1000 yr
km = kilometer	1 km = 0.6213 mi	metric ton = 1000 kg	1 metric ton = 1.1023 ton	
mi = mile	1 mi = 1.9093 km	English ton = 2000 lb	1 ton = 0.9072 metric ton	
	1 mi = 5280 ft	tonne = metric ton		
		ton = English ton		

$1\ km^2 = 0.3861\ mi^2$
$1\ mi^2 = 2.60\ km^2$
$1\ mi^2 = 27{,}878{,}400\ ft^2$

$1\ g/cm^3 = 1000\ kg/m^3 = 1\ tonne/m^3 = 62.428\ lb/ft^3$
$1\ kg/m^3 = 0.0624\ lb/ft^3$
$1\ lb/ft^3 = 0.0610\ g/cm^3 = 61.1018\ kg/m^3$

$1\ metric\ ton/km^2 = 2.855\ ton/mi^2$
$1\ ton/mi^2 = 0.3503\ metric\ ton/km^2$

quantity	symbol	dimensions	units	description
Erosion rate	E	[M/T]	kg/y metric tons/y metric tons/ka tons/y tons/ka	rate of removal of rock and soil material from the land surface of a drainage basin measured as mass removed per unit time
Unit erosion rate	r	$[M/L^2\ T]$	$kg/km^2/y$ $metric\ tons/km^2/ka$ $tons/mi^2/y$	rate of removal of rock and soil material from the land surface of a drainage basin measured as mass removed per unit area per unit time
Lowering rate (Denudation rate)	L	[L/T]	mm/y m/y m/ka ft/y	average rate of lowering of the land surface
Suspended-sediment discharge	Q_s	[M/T]	metric tons/y tons/y	average rate of suspended sediment discharge from a drainage basin
Bedload discharge	Q_b	[M/T]	metric tons/y tons/y	average rate of bedload discharge from a drainage basin
Drainage area	A	$[L^2]$	km^2 mi^2	area of drainage basin from which sediment is derived
Bedrock or soil density	ρ_b or ρ_s	$[M/L^3]$	g/cm^3 kg/m^3	mean density of bedrock or soil in the drainage basin
Bedrock or soil specific weight	γ_b or γ_s	$[F/L^3]$	N/m^3 lb/ft^3	mean specific weight of bedrock or soil in the drainage basin

Logic of lowering rate calculation:

1. Convert *mass* of sediment discharged to *volume* of material removed from drainage basin by dividing by either density or specific weight (as appropriate) of watershed substrate (bedrock or soil.)
2. Divide this volume by the drainage area to get lowering rate, being careful to convert units properly.

Data needed

a. Q_s and Q_b — Mean sediment discharge from drainage basin (preferably suspended load plus bedload, but often only suspended load data is available). The erosion rate $E = (Q_s + Q_b)$;

or

V_{sed} — Volume of sediment discharged from basin over some period of years T (e.g., sediment trapped in a reservoir) which can be converted to a mass of sediment if the density ρ_{sed} or specific weight γ_{sed} of the deposited sediment is known:

$M_{sed} = V_{sed} \cdot \rho_{sed}$ (for metric mass units -- kg or metric tons) or

$M_{sed} = V_{sed} \cdot \gamma_{sed}$ (for English force units -- lb or English tons)

This can be converted to the erosion rate E by dividing by T, the length of time in years over which volume V_{sed} was accumulated or discharged

$$E = \frac{M_{sed}}{T}$$

b. A — Area of drainage basin from which sediment was derived.

c. ρ_b or ρ_s — Mean density of either bedrock or soil in the drainage basin (if sediment discharge is in metric mass units); or

γ_b or γ_s — Mean specific weight of either bedrock or soil in the drainage basin (if sediment discharge is in English force units)

Procedure

1. Determine the unit erosion rate for the basin by dividing the sediment discharge by the drainage area: $r = \frac{E}{A} = \frac{(Q_s + Q_b)}{A}$

2. To compute the lowering rate

   a. if the sediment discharge is in metric mass units (kg or metric tons) divide the unit erosion rate by the *density* (in appropriate units) of the material for which you want to compute the lowering rate:

   bedrock lowering rate $L_b = \frac{r}{\rho_b}$

   soil lowering rate $L_s = \frac{r}{\rho_s}$

   b. if the sediment discharge is in English force units (lb or English tons) divide the unit erosion rate by the *specific weight* (in appropriate units) of the material for which you want to compute the lowering rate:

   bedrock lowering rate $L_b = \frac{r}{\gamma_b}$

   soil lowering rate $L_s = \frac{r}{\gamma_s}$

Example calculation

Compute mean bedrock lowering rate of Eel River basin upstream of Scotia, CA

Gaging site: Eel River at Scotia, CA

Drainage area: $A = 3113\ mi^2$

Suspended-sediment discharge (10/57 to 9/60): Q_s = 18, 200,000 tons/y = 36,400, 000, 000 lb/y

Estimated bedrock density: $\rho_b = 2.5\ g/cm^3$

Because the sediment discharge is in English force units (tons or pounds) we need the *specific weight* of the bedrock. To determine this we recognize:

1) The *specific gravity* , G, of a material is the ratio of its weight or mass to the weight or mass of an equal volume of water -- i.e. it's how many times heavier (or lighter) than water the material is.

2) The specific gravity of a material is *numerically* equal to its density in g/cm^3. So in this example $G_b = 2.5$, meaning that the bedrock is 2.5 times heavier than water.

3) The *specific weight* γ_b of the bedrock can be determined by multiplying the specific weight of water ($\gamma_w = 62.4\ lb/ft^3$) by the specific gravity of the bedrock, i.e.,

$$\gamma_b = G_b \cdot \gamma_w = 2.5 \times 62.4\ lb/ft^3 = 156\ lb/ft^3$$

a. Compute the unit sediment discharge r:

$$r = \frac{18200000\ tons/y}{3113\ mi^2} = 5{,}846\ tons/mi^2\text{-}y$$

b. Compute the bedrock lowering rate; note that we have to convert the tons to pounds and the square miles to square feet to keep units consistent when we divide by the specific weight

$$L_b = \frac{r}{\gamma_b} = \frac{(5846\ tons/mi^2\text{-}y)\ (2000\ lb/ton)}{(156\ lb/ft^3)\ (27878400\ ft^2/mi^2)} = 0.0027\ ft/yr = 2.7\ ft/ka = 0.8\ m/ka = 0.8\ mm/y$$