

Sediment Transport

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River Mechanics and Sediment Transport
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Objectives

Brief overview of examples and techniques:

1. Gravel-bed Material Sampling;
2. Bedload Sampling for Gravel-bed Streams;
3. Suspended Load;
4. Reservoir Sedimentation.

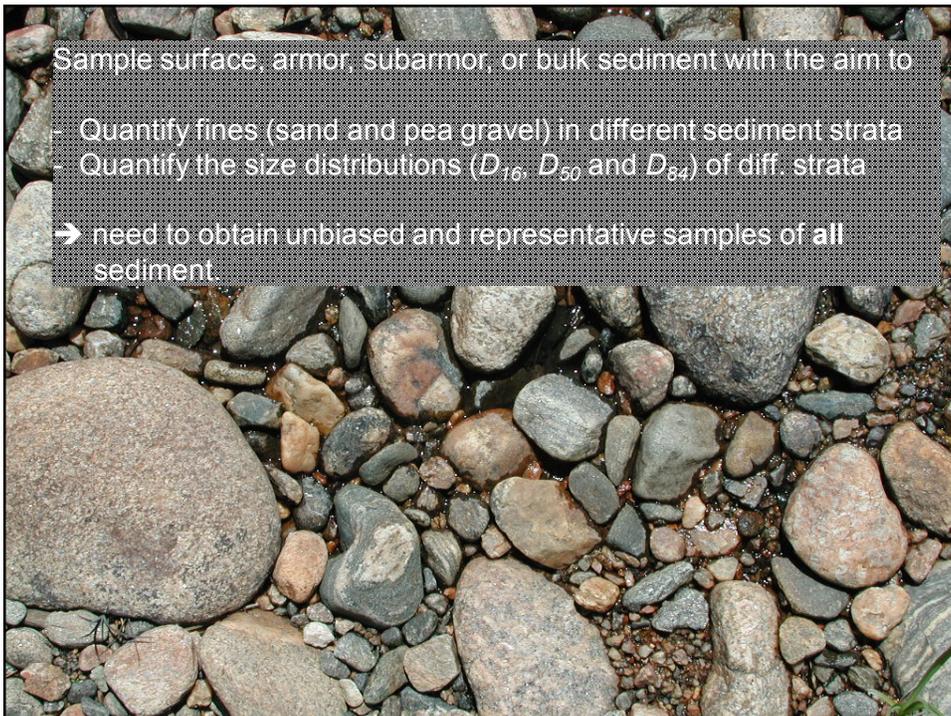
1. Gravel-bed Material Sampling

Challenges of Quantifying Bedmaterial Particle-size Distributions in Gravel-bed Streams

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Sample surface, armor, subarmor, or bulk sediment with the aim to

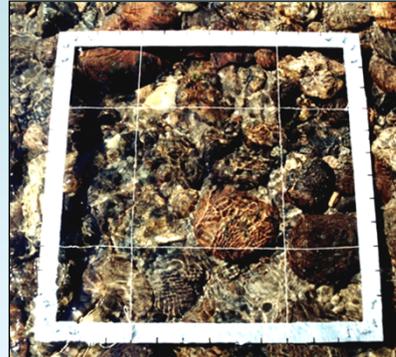
- Quantify fines (sand and pea gravel) in different sediment strata
- Quantify the size distributions (D_{16} , D_{50} and D_{84}) of diff. strata

→ need to obtain unbiased and representative samples of all sediment

Sampling Frame Technique (SFT)

- Visually selects particles under grid points (typ. spaced 0.3 m) spanned across a **Sampling Frame** to avoid observer bias in particle selection

0.6 m x 0.6 m Sampling Frame



- Advantage over heel-to toe sampling



If the bed is not clearly visible, grid intersections (close to the bed) serve to guide the finger to the particle to be selected. There is a bias against hidden fines. Use plexiglass viewer to improve visibility.

SFT uses a 0.5ϕ template to make particle size measurements in pebble counts accurate, unbiased, and reproducible

- particle sizes span 3-4 orders of magnitude

→ opening sizes that progress in log-scale and correspond to log-based **Wentworth scale** (not to arithmetically scaled ruler)



Template in 0.5 phi increments

- Comparable to sieve analysis obtained using square-hole lab sieves



How to?

Count the number of fine particles < 2 or < 6 mm under 50 grid intersections spaced by 2 inch (5 cm)

(e.g., 4 out of 50 points = 8%)

- Mind ratio of grid size of D_{max}



Gallo et al. (2005)



MT DEQ (2009)

Layers to be collected volumetrically

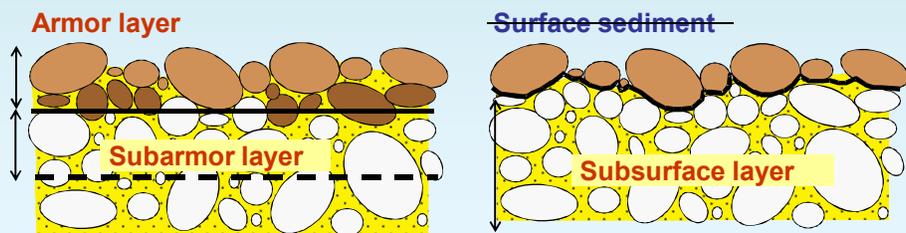
Layer/strata

Armor layer
 subarmor
 subsurface
 unstratified bulk

Thickness of sampled layer

→ critical (\approx max. embedded depth)

} less important (1 or 2 D_{max} or D_{95})



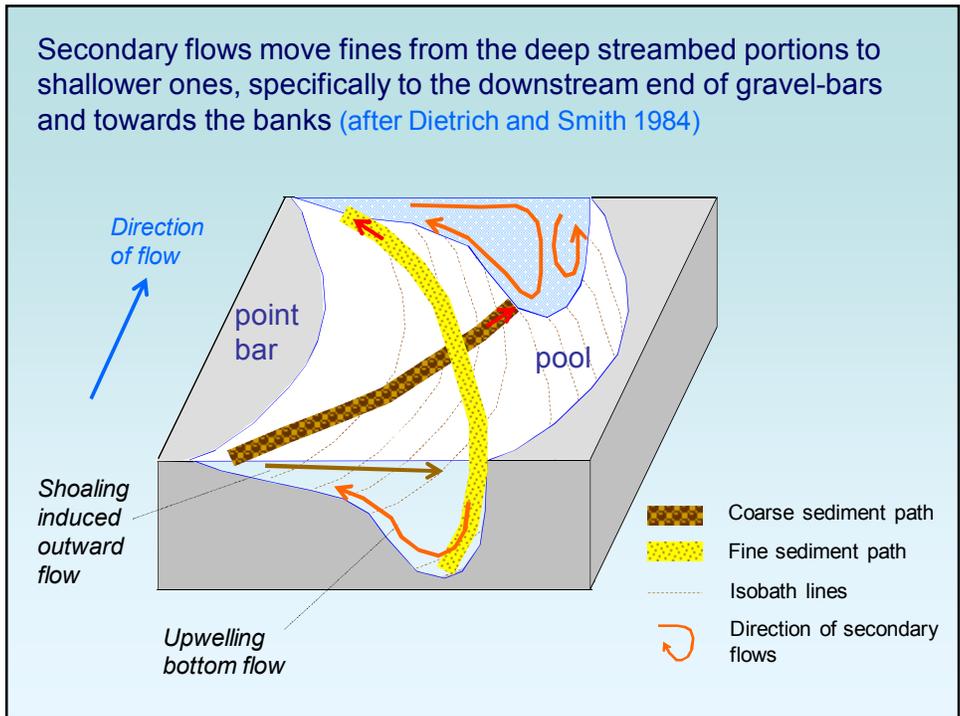
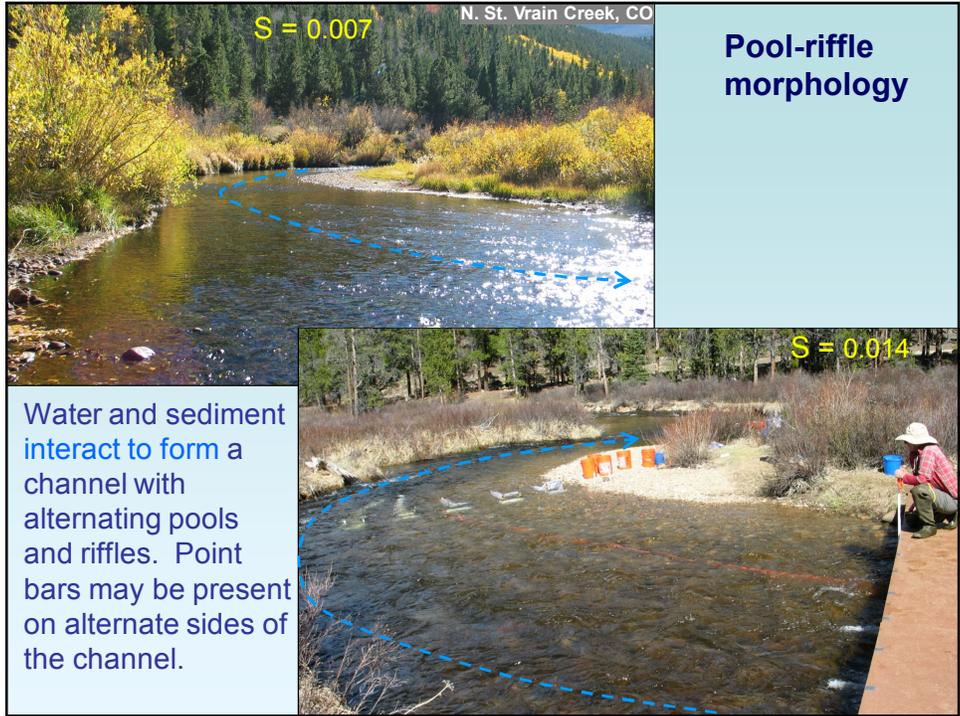
Sediment samples from individual strata



Surface + armor w/o surface = armor

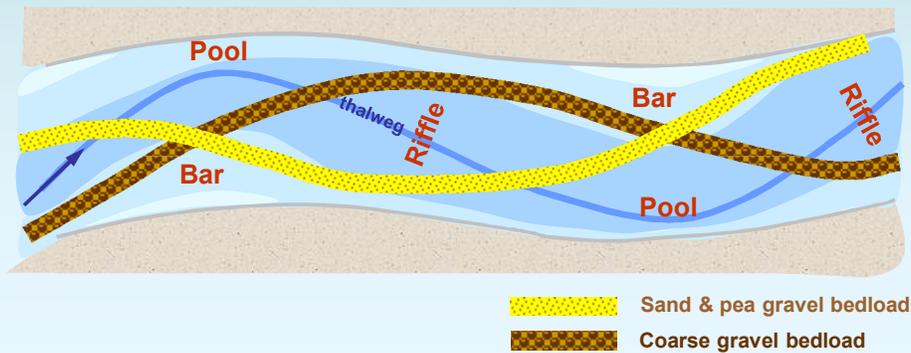
Armor w/o surface + subarmor = subsurface

- Volume of sediment sampled per locations depends on thickness of sampled layer
- Take several samples from within one habitat (or sedimentary) unit to arrive at required sample mass
- Analyze samples individually, composite mathematically (info on variability)

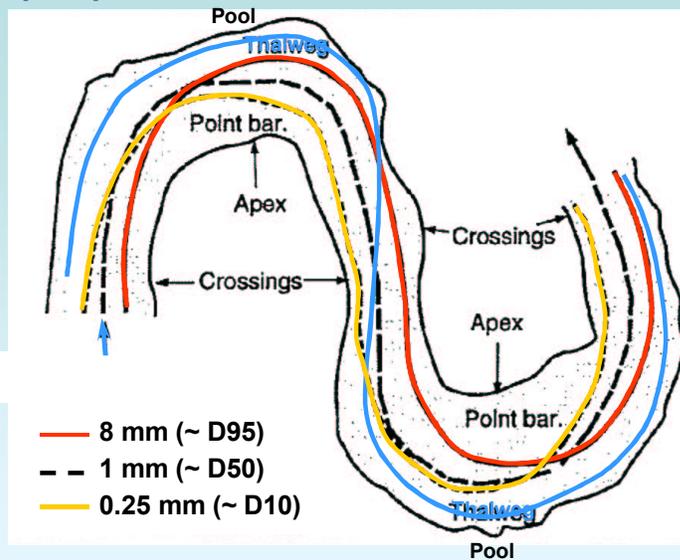


Transport paths of coarse gravel bedload and fines in pool-riffle section

Over a reach, secondary helical flows transport coarse and fine sediments downstream along specific, meandering paths that differ from the thalweg.



Transport paths for coarse and fine bedload in a meander bend



From: Julien and Anthony (2002), slightly altered

2. Bedload Sampling for Gravel-bed Streams

**Bedload traps for sampling gravel/cobble
bedload**

and what we learned from them

Kristin Bunte

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**Most commonly used
sampler in US:**

**3-inch (7.6 x 7.6 cm) Helley-
Smith sampler, flared body**

- Availability



US BL-84



HS: ease of use...

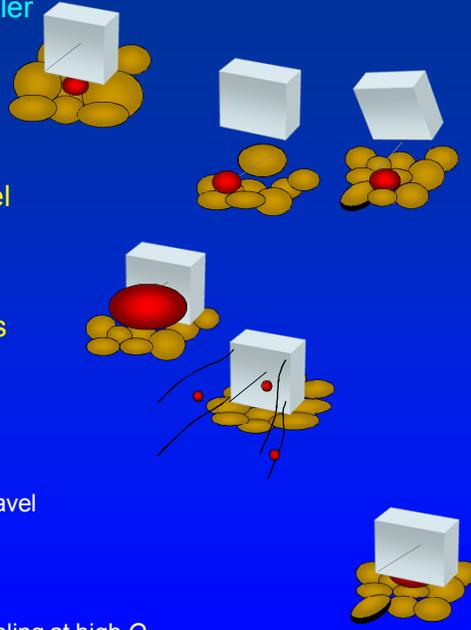


...but not
always



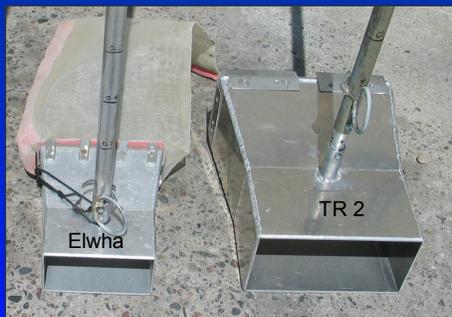
Challenges posed by HS sampler

- perched on large gravel
→ undersampling gravel
- dislocating or scooping gravel
→ oversampling gravel
- opening too small for cobbles
→ undersampling cobbles
- hydraulic efficiency > 1
→ oversampling sand and pea gravel
- short sampling time
→ oversampling at low, undersampling at high Q_B



Helley-Smith type samplers larger than 3" x 3"

- 6-inch Helley-Smith (6" x 6"),
- Toutle River sampler (6" x 12")
- Elwha sampler (4" x 8")

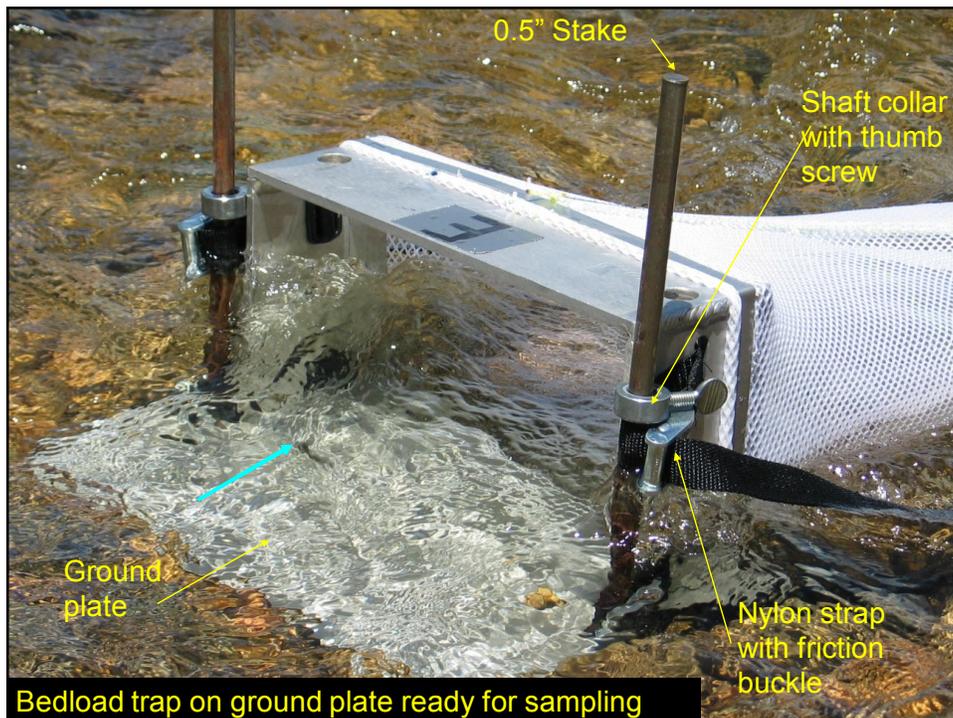


solve opening size problem, but difficult to hold at high flows; need tethers or crane; scoop particles, and sample for only 30 - 120 s



A new bedload sampler was needed
for more accurate sampling of gravel and cobble bedload
in wadeable coarse-bedded mountain streams

Design of bedload traps





- **4-mm mesh width**
 - lets sand, fine organics, and water pass freely but limits sampling to gravel transport;
 - avoids the need for a flared opening
- 0.5-mm mesh unsuitable (clogs, bulges, and ponds upstream flow)

Large sample volumes needed:

- to average over fluctuating Q_B
- to obtain representative samples, particularly of the largest mobile particles that move infrequently





Bedload traps are also used in Alpine steep streams:

Swiss WSL: Johannes Schneider, Bastian Schmidt, Jens Turowski



Foto: J. Schneider



Foto: J. Turowski

Freie Univ. Bozen: Francesco Comiti, Luca Mao



Foto: F. Comiti

Univ. BOKU Wien: Hugo Seitz, Helmut Habersack



Foto: H. Seitz



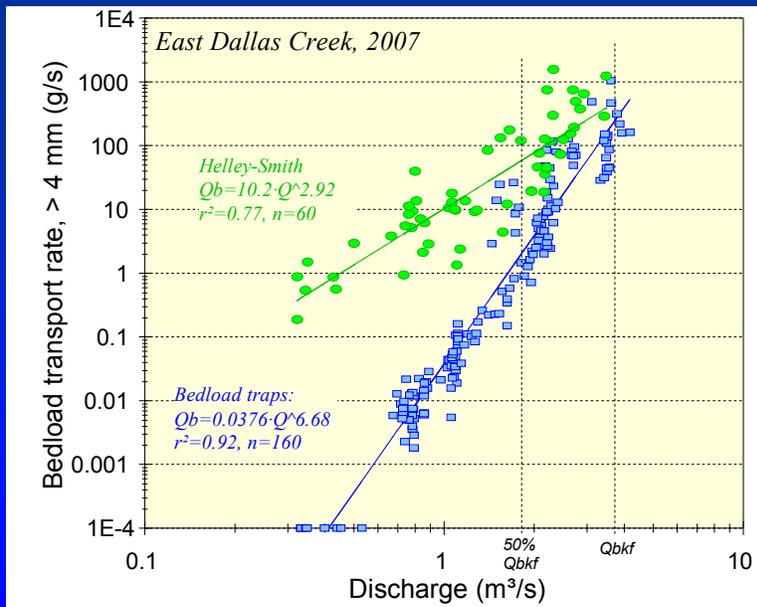
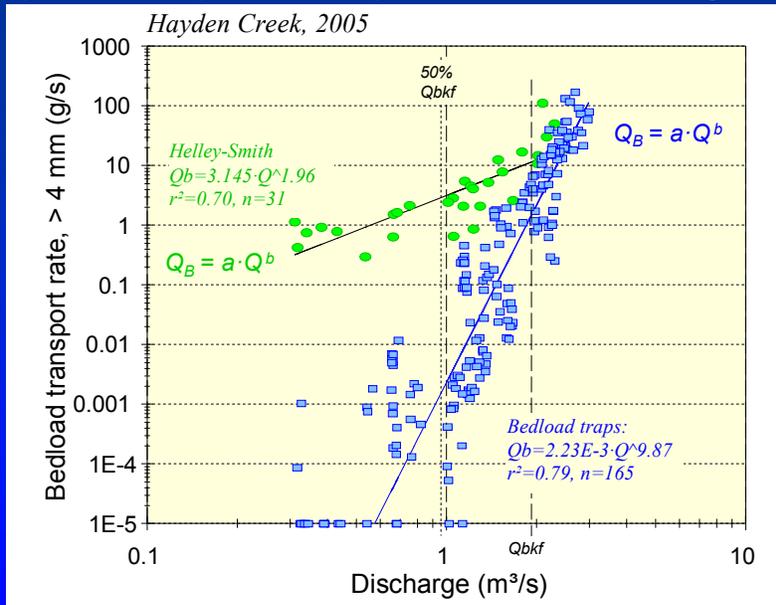
With footbridge (Halfmoon Creek 2004)



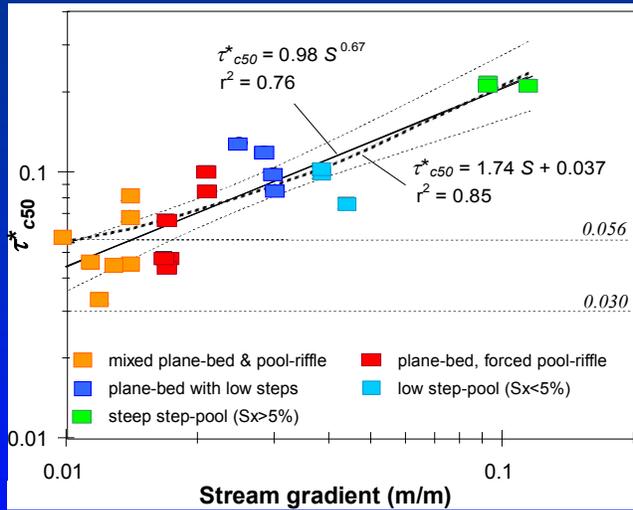
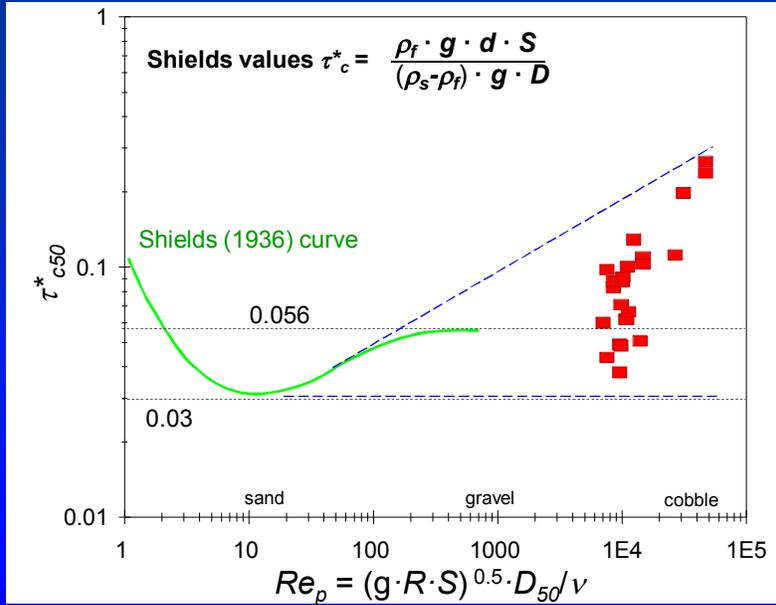
Washing samples to separate coarse organic material from bedload



Transport relationship from HS sampler covers 2-3 orders of magnitude



Incipient motion computations...

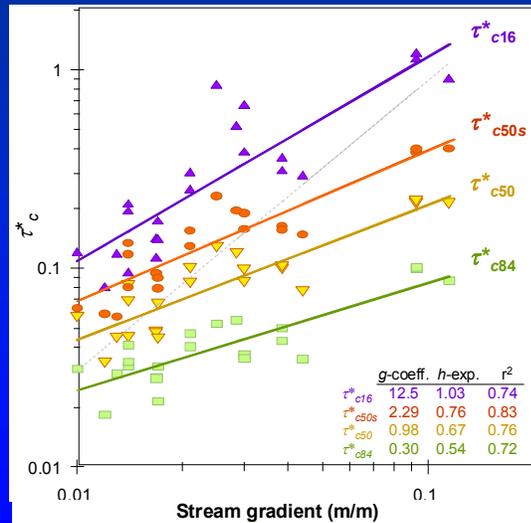


$$\tau_c^* = \frac{\rho_f \cdot g \cdot d \cdot S}{(\rho_s - \rho_f) \cdot g \cdot D_{50}}$$

- τ_c^* is strongly affected by stream gradient (10 fold diff. btw. streams)
- range of τ_c^* may be estimated for stream types

τ_c^* high for small particles and large
for small particle sizes...perhaps
simple numerical explanation

$$\tau_c^* = \frac{\rho_f \cdot g \cdot d \cdot S}{(\rho_s - \rho_f) \cdot g \cdot D}$$

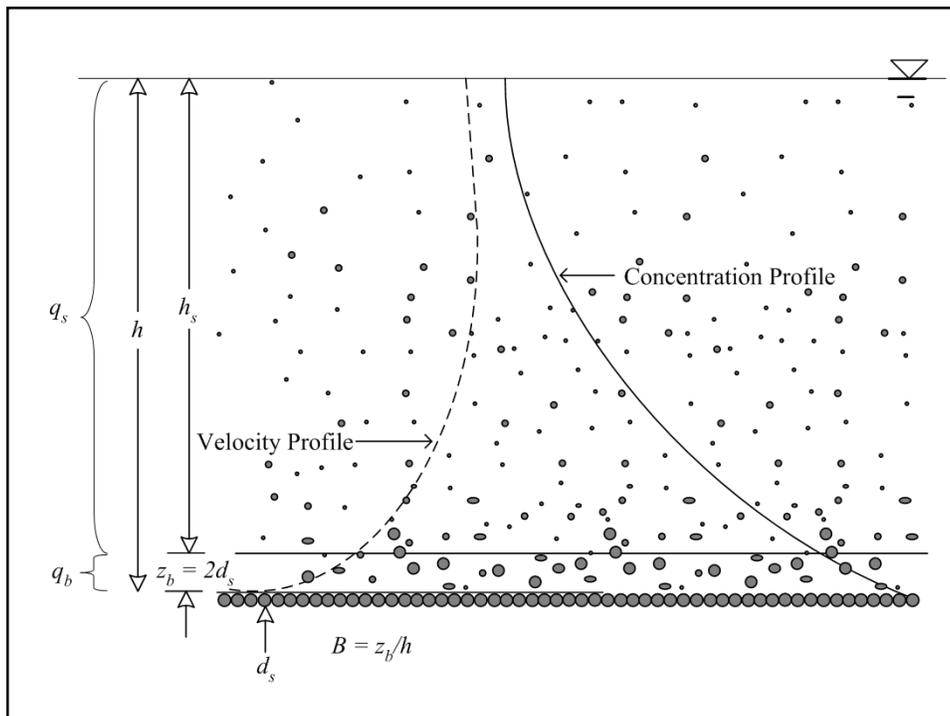


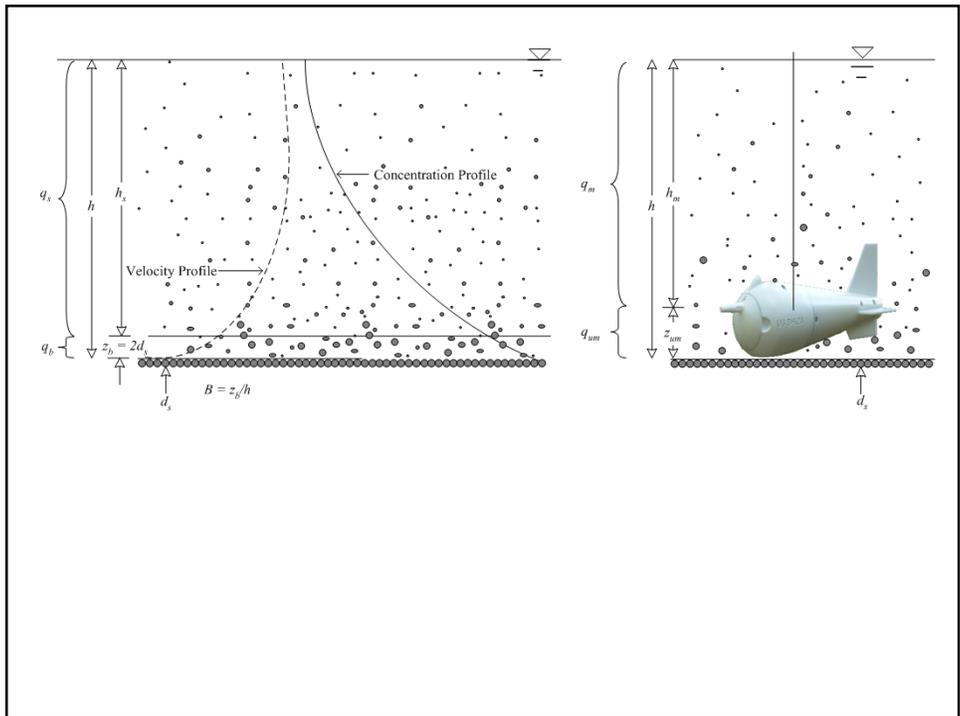
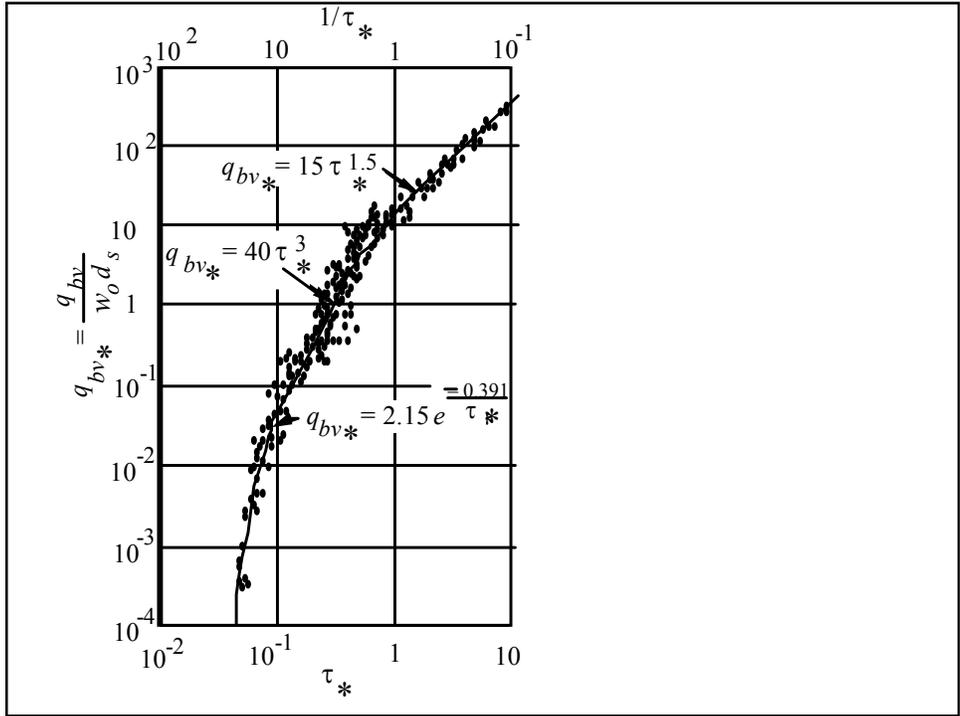
Flow depth *d* varies little
btw. moderate and high
flows (factor of ≈ 2)

D_{16} to D_{84} sizes differ
about 6-10 fold in
mountain streams

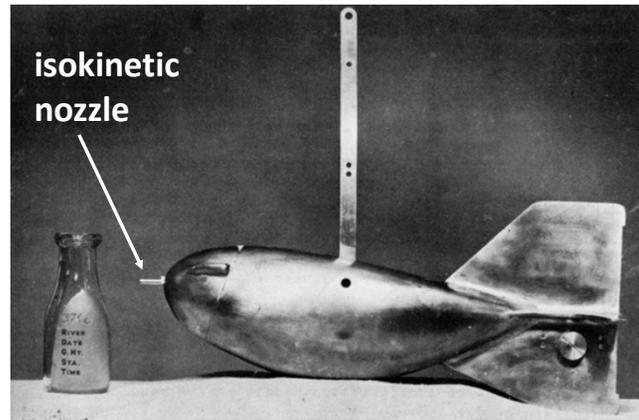
3. Suspended Load

Sediment Transport



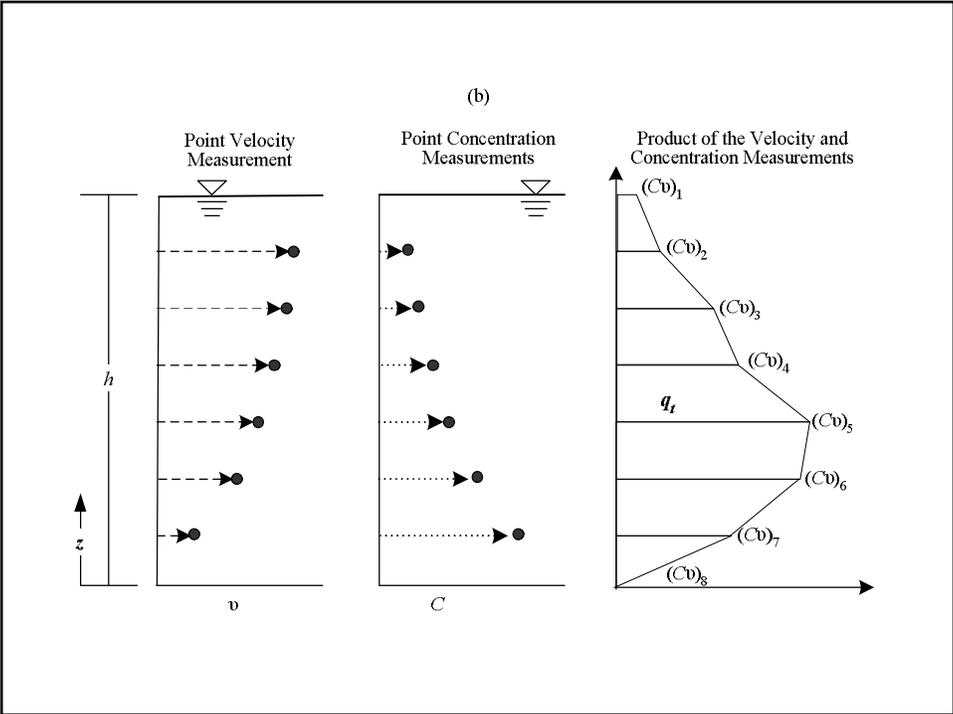


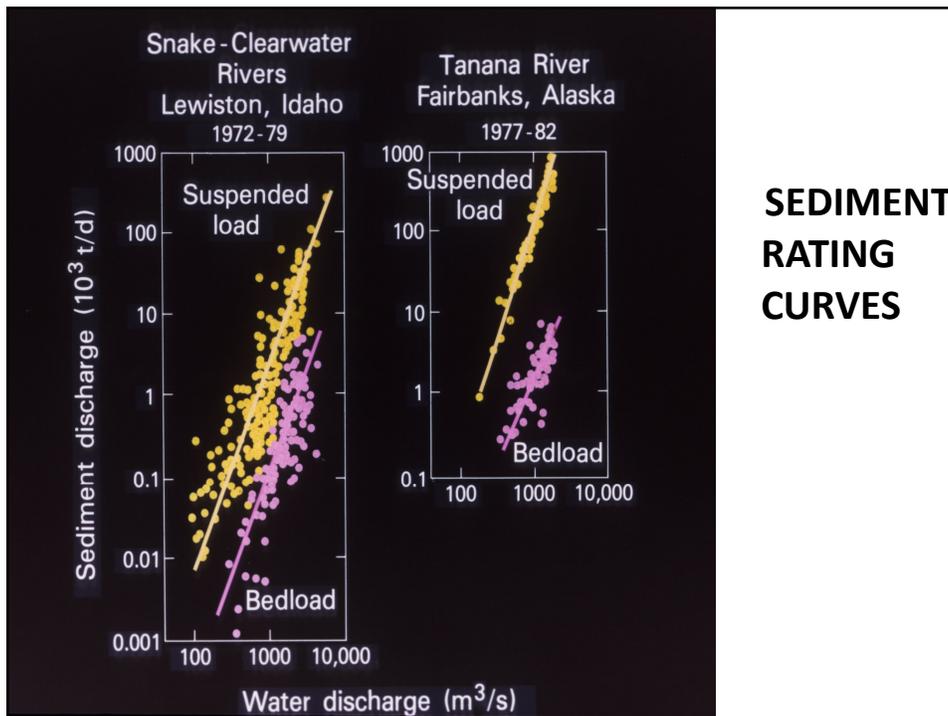
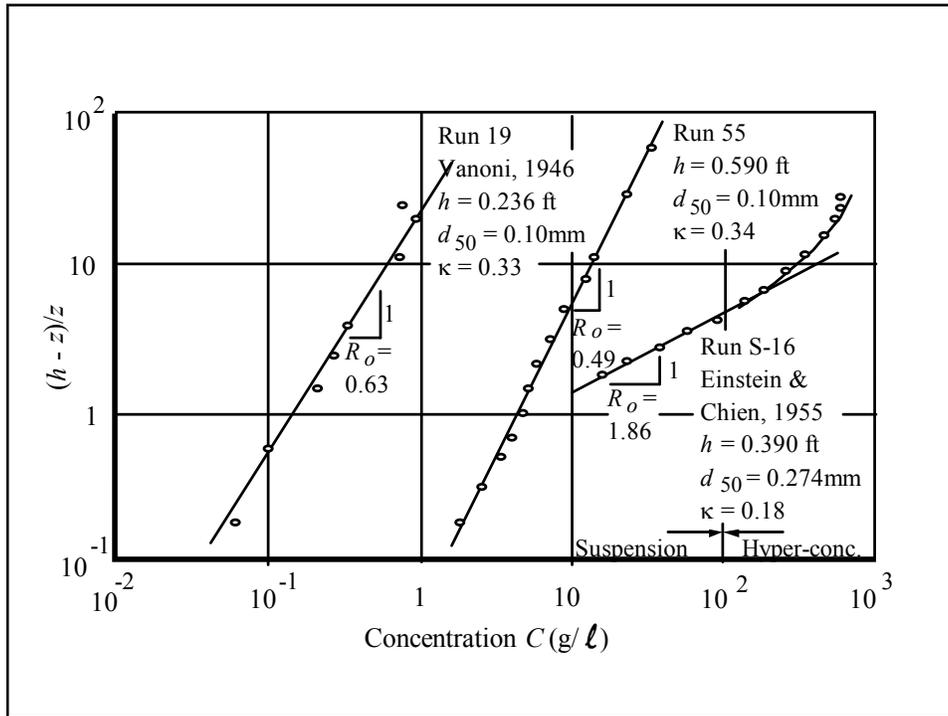
Isokinetic Depth-integrating Sampler

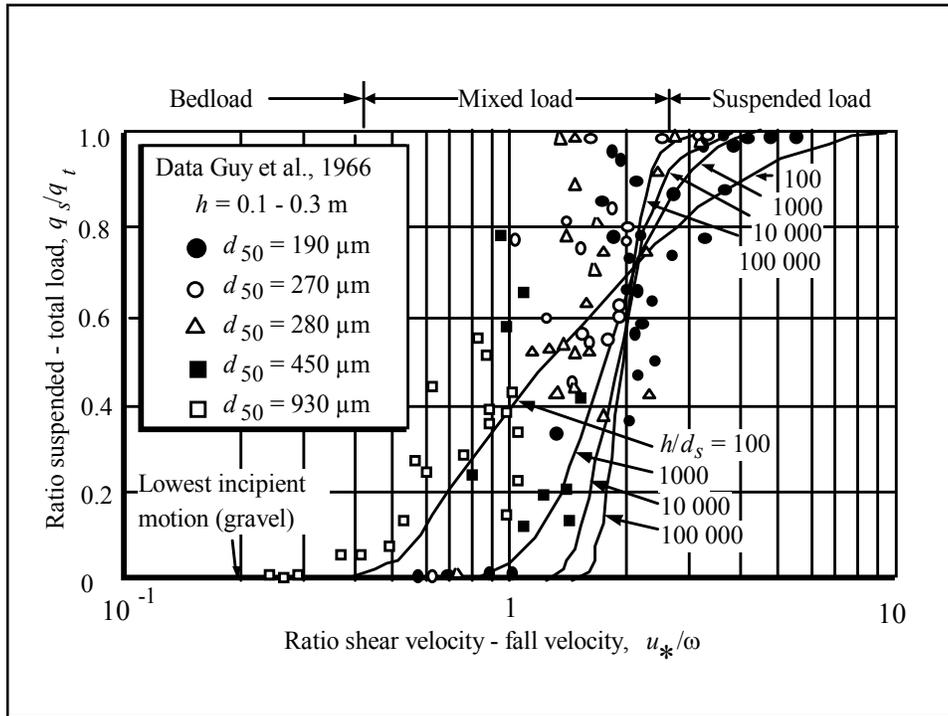


Collapsible-bag sampler array

As used in:
Amazon
Orinoco
Mississippi







4. Reservoir Sedimentation



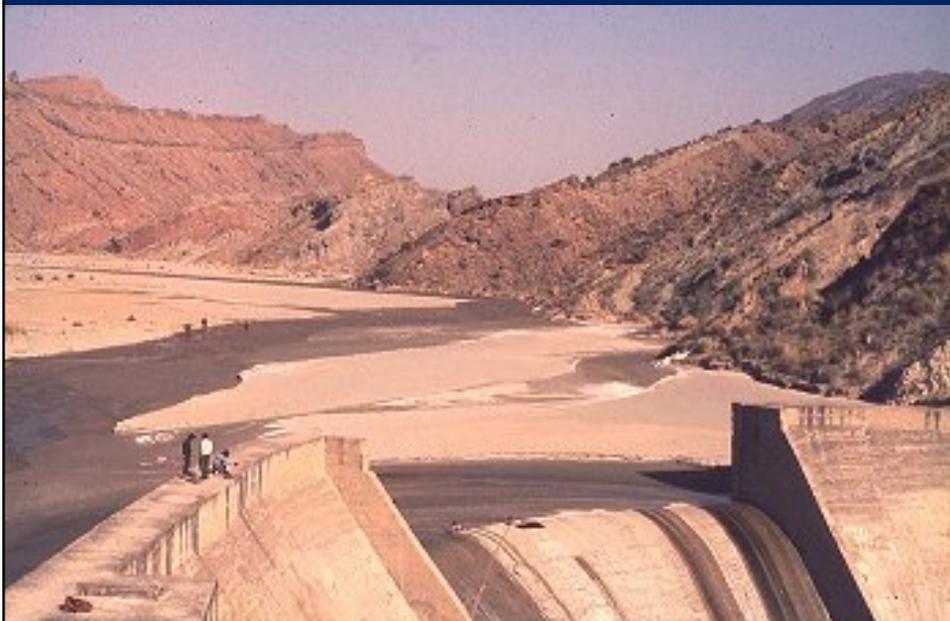
Imha reservoir

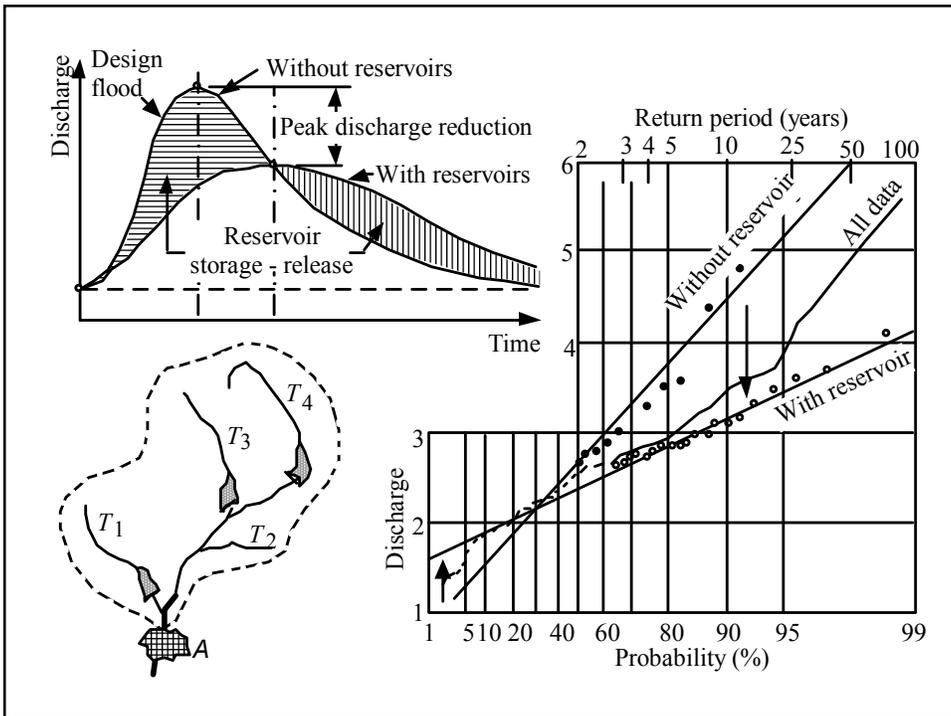


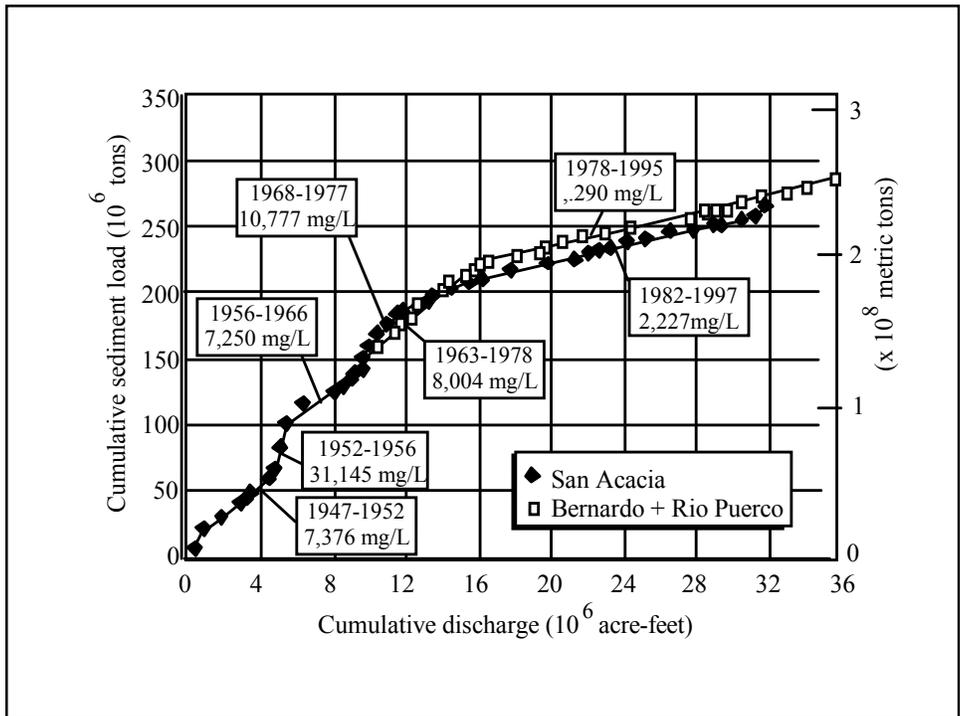
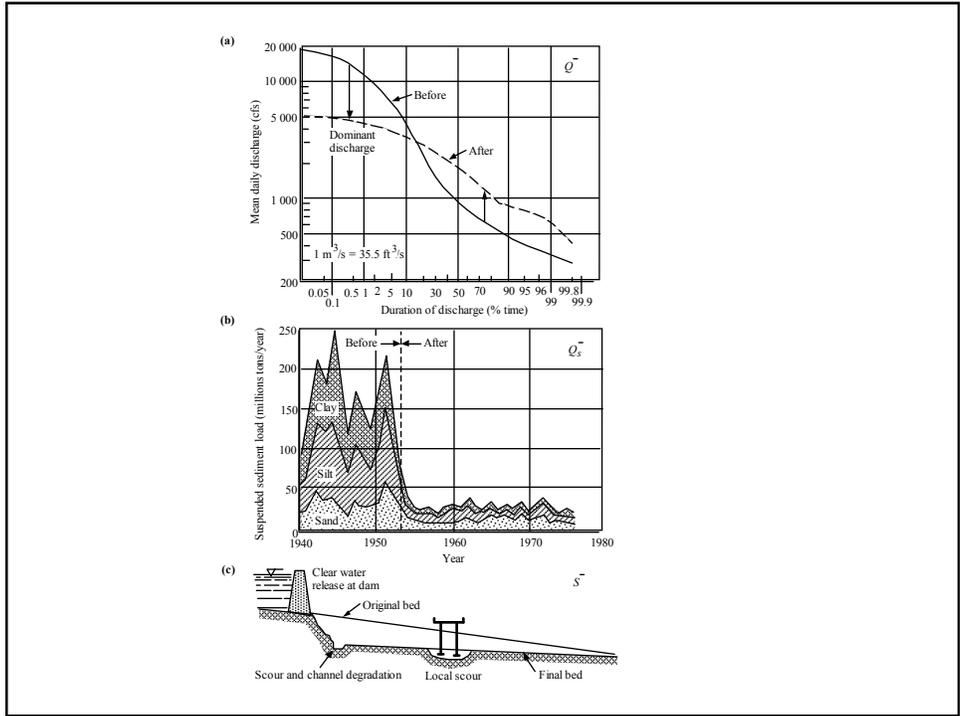
Fuensanta reservoir of the river Segura in Spain

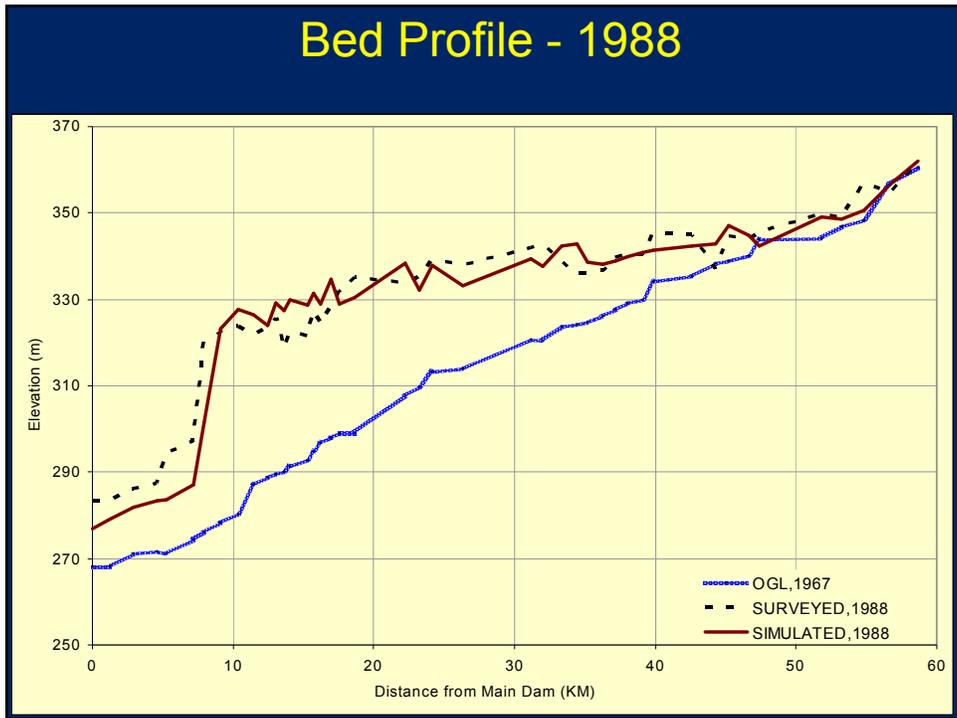
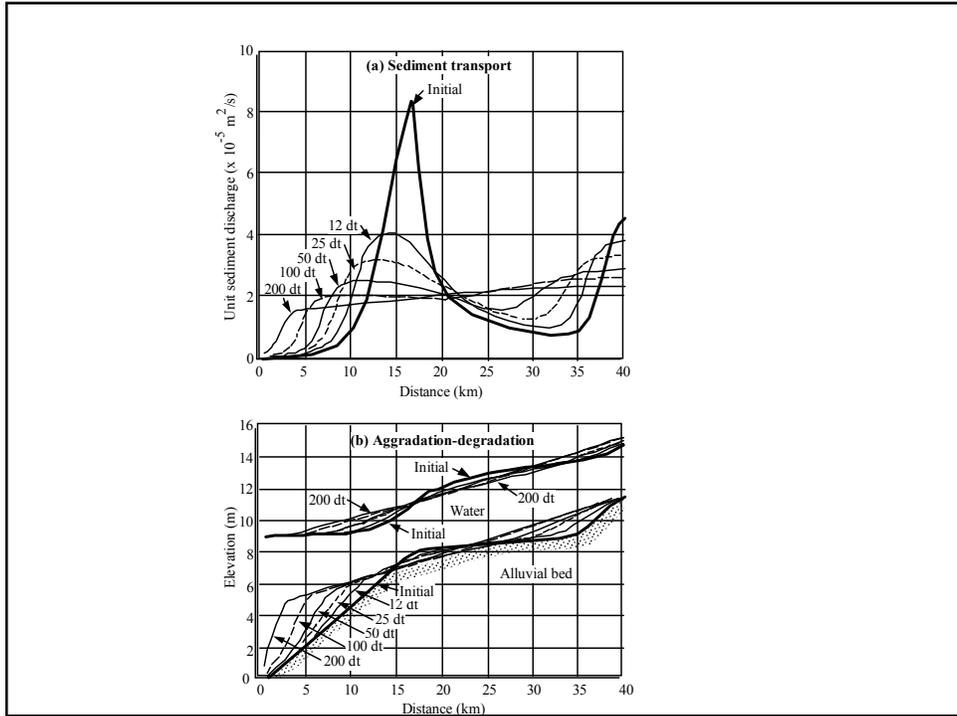


Bengal and Indus









Trap Efficiency

Defined as the percentage of the total inflowing sediment that is retained in the reservoir

$$TE = \frac{Y_s(in) - Y_s(out)}{Y_s(in)}$$

- $Y_s(in)$: sediment yield in inflow
- $Y_s(out)$: sediment yield in outflow

TE equations

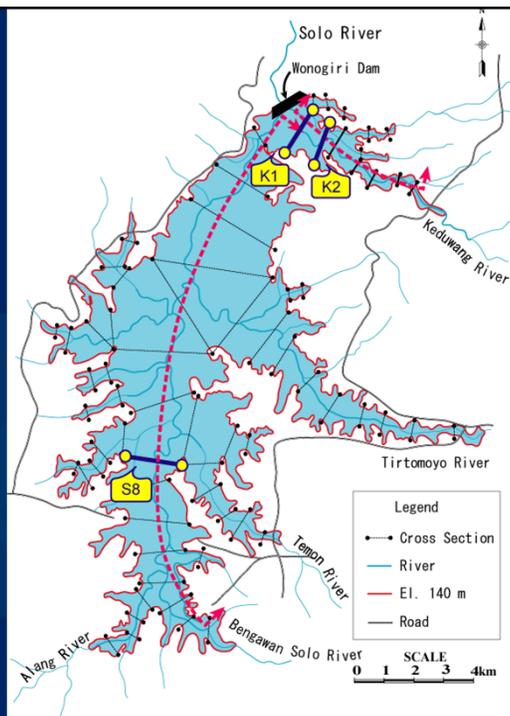
Julien (1998): $TE = 1 - e^{-\frac{X \omega_i}{Vh}}$ - $Vh = q$ (unit discharge)

Brown (1943): $TE = 1 - \left[\frac{1}{1 + KC / W} \right]$

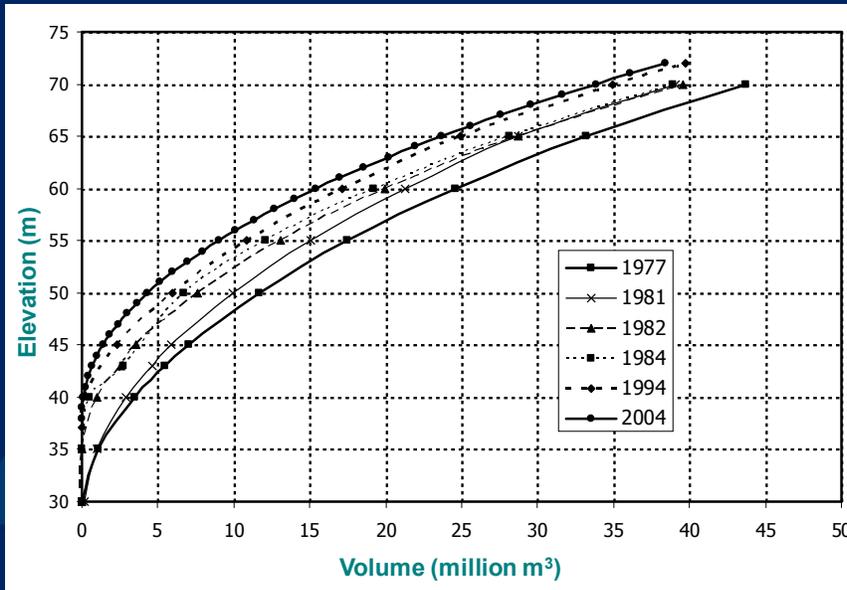
Brune (1953): $TE = 0.97^{0.19 \log \left(\frac{C}{I} \right)}$

- K : coefficient k ranges from 0.046 to 1.0
- C : reservoir capacity (acre-ft)
- W: watershed area (miles²), I : inflow rate (acre-ft/year)

Wonogiri survey paths



Reservoir storage capacity of Sempor Dam



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