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457.562 Special Issue on River Mechanics (Sediment Transport) .16 Morphodynamics of Lake and Reservoir Sedimentation

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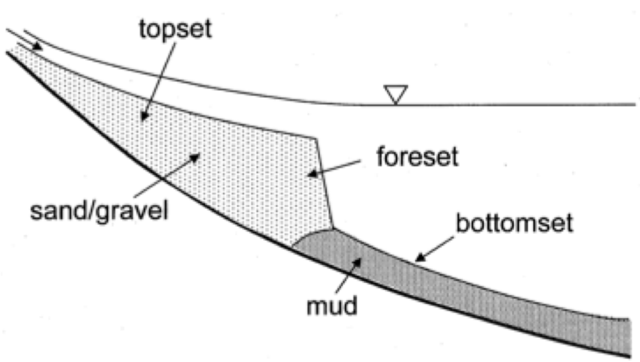
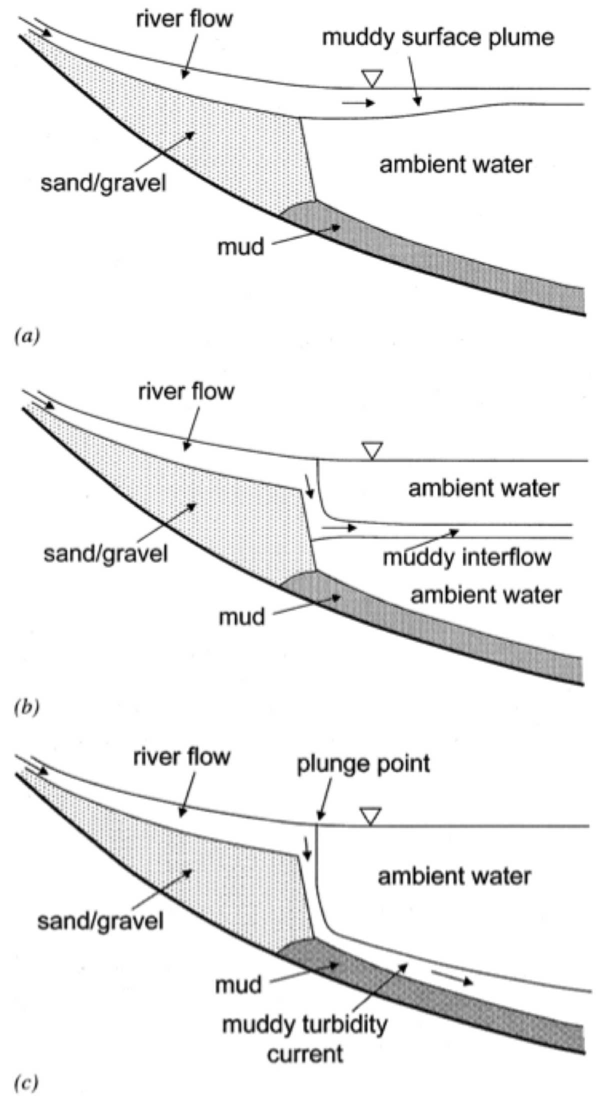
Topset, Forset, and Bottomset of Delta

- Decelerated flow drops sedime nts. This forms the delta.
- The coarser sediment deposits fluvially to form an aggrading to pset and deposit by avalanchin g to form a foreset.
- The finer sediment deposits in deeper water to form a bottoms et.





Fluvial Deposition of Topset and Foreset

- A simple one-dimensional morphodynamic model of delta t opset and foreset evolution
- Assumption
  - A river of constant width flows into a lake of the same width and infini te streamwise extent.
  - The water surface elevation in the lake is held constant.
  - The river transport sand as bed-material load (single size particle)
  - Constant fraction of the year the river is in flood, carrying a constant f lood water discharge per unit width. Otherwise the river is assumed t o be morphodynamically inactive.
  - During floods sand enters the river at x=0 at volume rate per unit wid th.

Fluvial Deposition of Topset and Foreset

- Since the flood flow is assumed to be steady

$$Uh = \int_0^h \bar{u}\, dz \qquad \frac{\partial h}{\partial t} + \frac{\partial Uh}{\partial x} = 0 \qquad \frac{\partial Uh}{\partial t} + \frac{\partial U^2 h}{\partial x} = -gh\frac{\partial h}{\partial x} + ghS - C_f U^2$$

- Become

$$\frac{\partial U^2 h}{\partial x} = -gh\frac{\partial h}{\partial x} + ghS - C_f U^2 \qquad U = \frac{q}{h}$$

$$\frac{\partial q^2 / h}{\partial x} = -gh\frac{\partial h}{\partial x} + ghS_f - C_f\frac{q^2}{h^2}$$

$$-\frac{q^2}{h^2}\frac{\partial h}{\partial x} = -gh\frac{\partial h}{\partial x} + ghS_f - C_f\frac{q^2}{h^2}$$

$$\frac{q^2}{gh^3}\frac{\partial h}{\partial x} = \frac{\partial h}{\partial x} - \frac{\partial \eta}{\partial x} + C_f\frac{q^2}{gh^3}$$

$$\frac{\partial h_f}{\partial x} = \frac{-\dfrac{\partial \eta_f}{\partial x} + C_{ff} Fr^2}{1 - Fr^2}, \qquad Fr^2 = \frac{q_2^2}{gh_f^2}$$

Fluvial Deposition of Topset and Foreset

- In the backwater equation

h_f and η : flow depth and bed elevation in a fluvial zone that includes the topset and foreset regions but excludes the bottomset

Fr : Froude number of the fluvial flow

C_{ff} : bed friction coefficient in the fluvial region

- The boundary condition

$$h_f(x,t)\Big|_{x=s_{stand}} = \xi - \eta_f(x,t)\Big|_{x=s_{stand}}$$

$$(at\ a\ po\mathrm{int}\ x = s_{stand}\ where\ water\ elevation\ \xi_0\ is\ ma\mathrm{int}ained)$$

- Base on the boundary conditions, the equation solution is t he standard backwater curve. (M1 curve)

Fluvial Deposition of Topset and Foreset

- The Shields number of the fluvial flow is

$$\tau^* = \frac{\tau_b}{\rho R_s g D_s} = \frac{C_f q_w^2}{R_s g D_s h_f^2}$$

(R_s denotes the submerged specific gravity for the sand)

- Based on Engelund and Hansen, the total volume bed mat erial load per unit width of the river

$$q_t^* = \frac{q_t}{\sqrt{R_s g D_s} D_s} = \frac{0.05}{C_{ff}} \left(\tau^*\right)^{5/2}$$

- Here the friction coefficient is assumed to be a specified co nstant for simplicity.
- The bed evolution, accounting that the river is morphologic ally active only I_f fraction of the time,

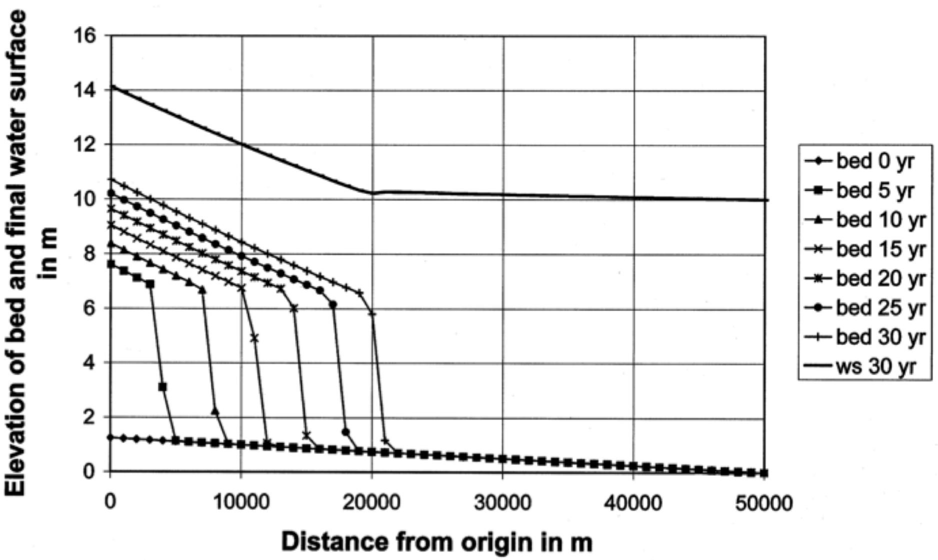
$$\left(1 - \lambda_{ps}\right)\frac{\partial \eta_f}{\partial t} = -I_f \frac{\partial q_t}{\partial x}$$

Fluvial Deposition of Topset and Foreset

- The boundary condition of the previous equation is a specified feed rate of sand, here taken to be constant;

$$q_t\big|_{x=0} = q_{tf}$$

- The initial condition on the problem is here simplified to a bed with constant slope S_{base} and a bed elevation $\eta_f = 0$ at $x = s_{stand}$.
- Solve by numerical way, then

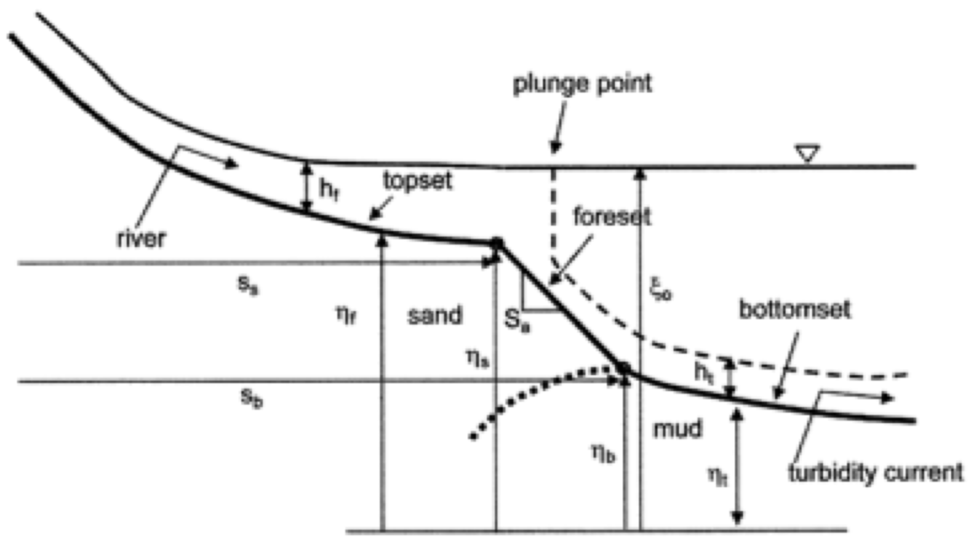


Plunging of a muddy turbidity current

- Up to now the muddy bottomset has been excluded from th e formulation.
- Since the mud does not deposit in the bed of the river, it ma y be neglected in a first model of the evolution of the topset and foreset.
- However, river meets the standing water of a lker or reserv oir, the sand is left behind on the topset-foreset and the re maining muddy water continues as a surface plume, interflo w, or bottom turbidity current.
- Now we are going to talk sufficiently dense mud flow to plu nge and form a bottom turbidity current.

Plunging of a muddy turbidity current

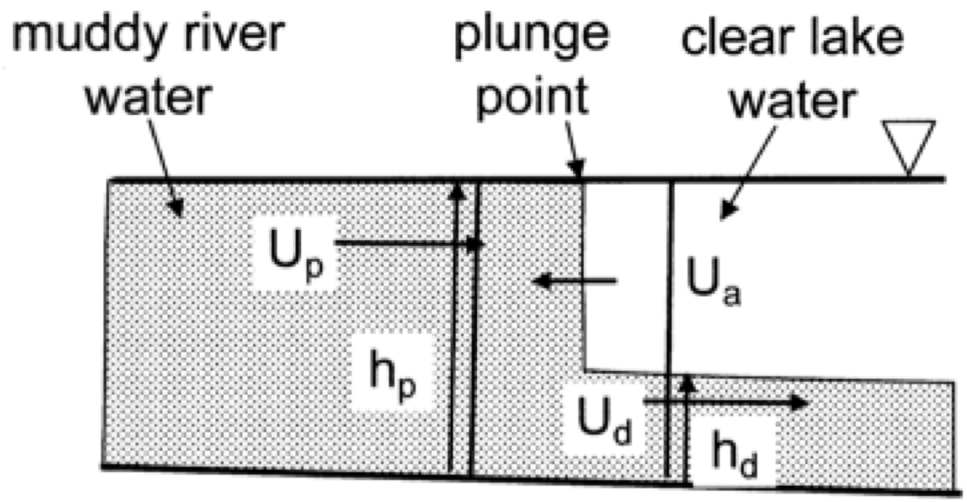
- When muddy river water is denser than lake water at every level of the lake, the river water plunges somewhere above the forest to create the bottom turbidity current.



- We will lean the treatment of Parker and Toniolo as a sampl e.

Plunging of a muddy turbidity current

- The analysis is applied to muddy water flowing into a lake with no ambient stratification.
- The flow near the plunge point is



- The flow velocity, depth and volume mud concentration in the river water just upstream of the plunge point are denoted as U_p, h_p, and C_{mp}.

Plunging of a muddy turbidity current

- The flow velocity, layer thickness and volume mud concentr ation in the turbidity current just downstream of the plunge point are denoted as U_d, h_d, and C_{md}.
- The submerged specific gravity of the mud is denoted as R_m.
- As the river flow plunges, it invariably draws into it some a mbient water from the lake. The velocity at which this ambient water enters the muddy flow is denoted as U_a.
- The coefficient of mixing of ambient water into the muddy fl ow is defined as

$$\gamma = \frac{U_a\left(h_p - h_d\right)}{U_p h_p}$$

- This value larger than 0, is required for the muddy flow to pl unge.

Plunging of a muddy turbidity current

- The flow discharge per unit width just downstream of plungi ng is related to that just upstream of plunging as

$$U_d h_d = U_p h_p \left(1+\gamma\right) = q_w \left(1+\gamma\right)$$

$$\phi = \frac{h_d}{h_p} \qquad (depth\ ratio)$$

$$Fr_{dp}^2 = \frac{U_p^2}{R_m C_{mp} g h_p} = \frac{q_w^2}{R_m C_{mp} g h_p^3} \quad (upstream\ densimetric\ Froude\ number)$$

$$Fr_{dd}^2 = \frac{U_d^2}{R_m C_{md} g h_d} \quad (downstream\ densimetric\ Froude\ number)$$

Plunging of a muddy turbidity current

- Parker and Toniolo

$$Fr_{dd}^2 = Fr_{dp}^2 \frac{(1+\gamma)^3}{\phi^3}$$

$$Fr_{dp}^2 = \frac{1}{2\gamma^2}(1-\phi)^3$$

$$\frac{1}{\gamma^2}(1-\phi)^3 - \frac{1}{\gamma^2}\frac{(1-\phi)^3}{\phi}(1+\gamma)^2 - (1-\phi)^2 + 1 - \frac{\phi^2}{(1+\gamma)} = 0$$

- Once the mixing coefficient is specified, these equations allow the determination of the plunge point and the flow below it.
- Let q_{mf} denotes the volume feed rate of mud per unit width.

Plunging of a muddy turbidity current

- Because the mud does not settle out upstream of the plunge point, the volume concentration of mud, just upsteam of the plunge point is given from the relation

$$q_{mf} = q_w C_{mp}$$

- So, the ratio of depth obtained, then we can get the upstream plunge depth, and down stream plunge depth.