Estuaries and estuarine processes and morphology

Sediment dynamics and morphology

GEO3-4306; lecture 3 (part 2)

**Sediment Dynamics**

- Bedload versus suspended load
- Deposition bedload
- Dominant role of suspended load
- Behaviour of fine-cohesive sediment
- Cycle of continuous erosion, transport and deposition of sediment

**Depositional pattern mouth of estuaries** (Georgia, US)

Ongoing cycle of sediment mobility and deposition

**Shields diagram of dimensionless shear stress required to erode flat-bedded non-cohesive sand** (Using Grain Reynolds number Re*)
Erosion of sediment layers; stripping due to variability in consolidation and compaction and as a function of shear stress/velocity

Settling velocity for free-falling nearly spherical grains at 20 degrees C in still water, as function of grain diameter

Deposition and settling velocity

- Individual particles small and settling velocities also small:
  - Clay particle (1 μm): $1.0 \times 10^{-6}$ cm/s (=30 cm in 3 days !)
  - Silt particle (20 μm): 0.04 cm/s (30 cm in 10 minutes)

- Individual particles will not settle

Deposition of particles

- Particles have to flocculate or aggregate to be able to settle in estuarine/marine environment
  - Aggregates: inorganic particles strongly bound by molecular or cohesive attractive forces
  - Flocculation: inorganic particles bound by electrochemical forces
  - Agglomerate: organic or inorganic matter bound by relatively weak forces like surface tension

Factors and processes relevant for flocculation and aggregation of fine-particles

Settling velocities for different states of aggregation and dynamic flow conditions
Relationship between settling velocity, salinity and suspended sediment concentration

Variation of settling velocity with suspended concentration for mud in the Severn Estuary (UK)

Density profiles in a settling suspension with time

Relation between aggregate settling velocity and aggregate size derived from video registrations

Concentrations of suspended matter in the Severn Estuary

Vertical profiles of concentration of SPM (suspended matter); development of LUTOCLINE
Variation in thickness of the lutocline layer

Deposition rates based on $^{210}$Pb radioactive isotopes (incl. $^{137}$Cs and $^{134}$Cs)

Consolidation stages of sediment

Consolidation of sediment and critical erosion velocities

Estuarine Turbidity maximum

- Zone with concentrations 10 – 100 times greater than other parts of estuary

- Two main factors important:
  - Presence of the null-zone (settling exceeds upwards mixing)
  - Estuarine or gravitational circulation

Concentrations of SPM as function of dilution and deposition
Three models for turbidity maxima

A) Estuarine circulation and null-zone
B) Local tidal scour (effect ebb channels)
C) Tidal trapping: tidal asymmetry in combination with tidal/estuarine circulation

Development of turbidity maximum; effect of tidal asymmetry in estuary

Seaward pumping of sediment during spring tides; during neap tides most sediment stays near the bed and is subject to net landward drift

Neap-Spring cycle of suspended sediment

Turbidity maximum and effect of high and low river discharge
Transport and turbidity pattern in Chesapeake Bay

Location turbidity maximum

Estuarine trapping of sediment: other mechanisms
- Settling lag and scour lag effect
- Effect of water depth (water above shoals and tidal flats)
- Impact of mud flats on tidal flow
- Biological activity

Settling lag and scour lag principles in a tidal environment (estuaries and Wadden Coast)

3 > 4 > 5: settling lag effect
A’ > B’: scour lag effect

Estuarine morphology and sediment dispersion; modes of transport

Wave-dominated estuarine system

Wave-dominated estuary, North coast Iceland
**Tide-dominated estuarine system**

**Morphological variability tide-dominated estuaries**

**Channels and shoals in the Western Scheldt; ebb-dominated and flood-dominated channels (“eb – en vloedscharen”)**

**Morphological pattern of ebb- and flood-dominated channels**

**Secondary channels in the Western Scheldt and their origin:**

1) Short cut channel
2) Coriolis effect
3) Loss of momentum
4) Centrifugal force (curved flow pattern)

**Sediment Budget of estuary**

1) Flood-dominated system with input of sand (tidal asymmetry)
2) Development of shoals (friction !) may lead to ebb-dominated system to establish new equilibrium
3) Effect overruled due to import of fine sediment by settling lag and scour lag principle
Circulation of sediment in main and secondary channels

Sediment budgets for sections of the Western Scheldt

Dynamic patterns of bedforms on sandy shoals

Salt marshes and tidal creeks