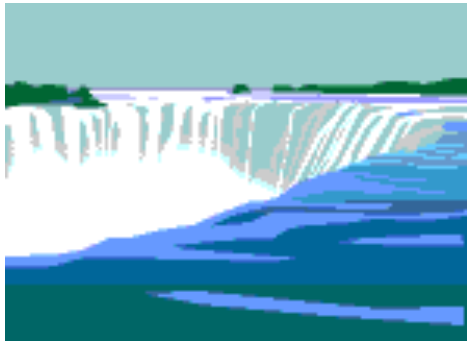
The Surface Water System: Rivers

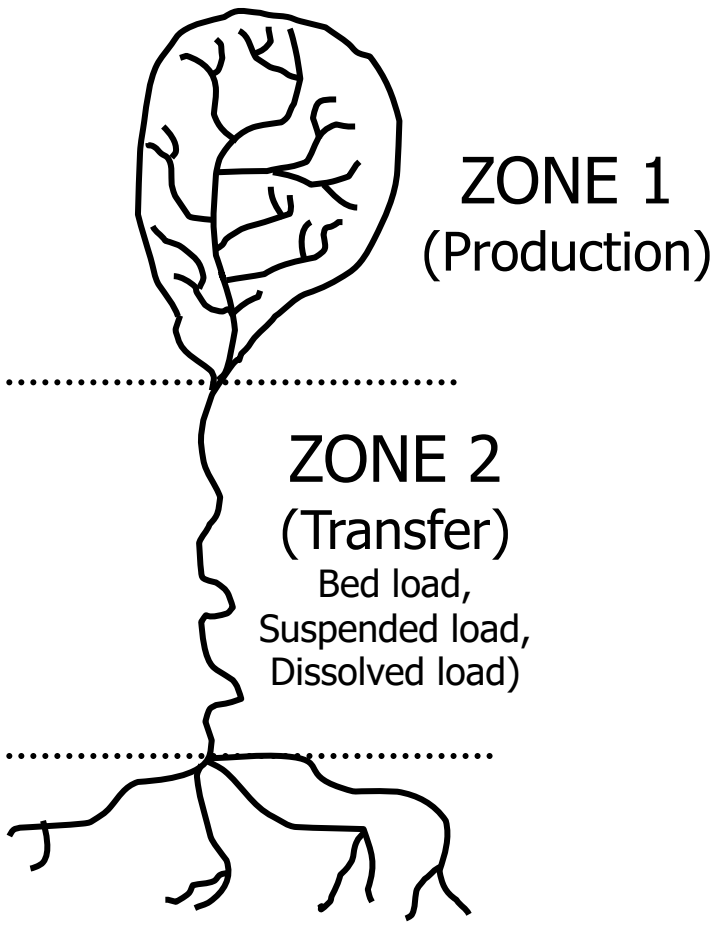
Rajiv Sinha

Department of Earth Sciences
Indian Institute of Technology
Kanpur 208016 (UP) INDIA

Email: rsinha@iitk.ac.in



Rivers as a System

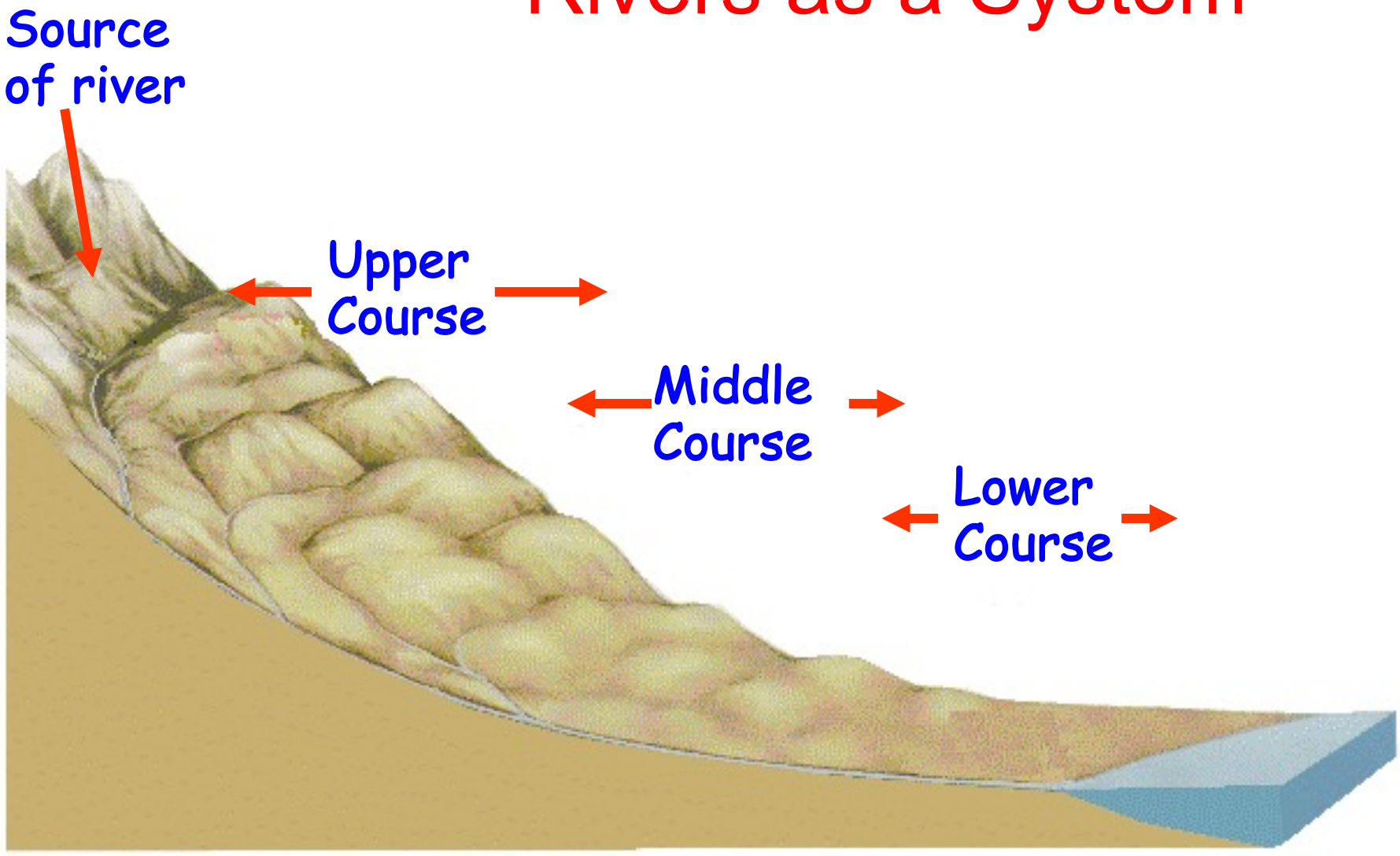


ZONE 1
(Production)

ZONE 2
(Transfer)
Bed load,
Suspended load,
Dissolved load)

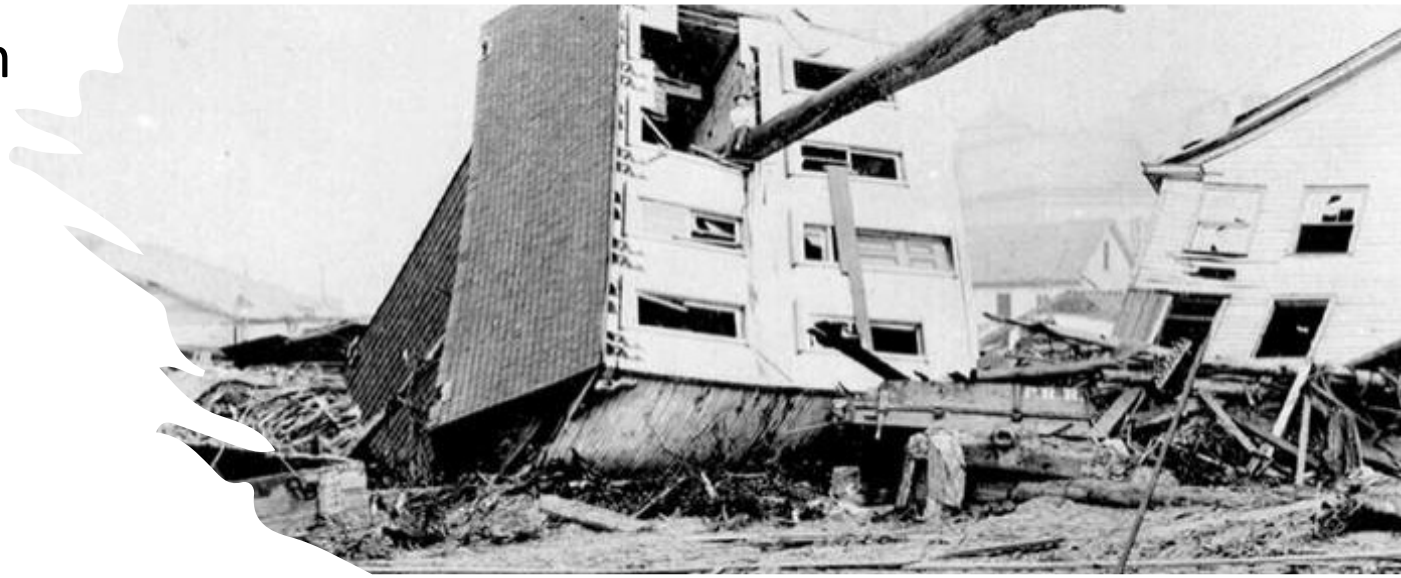
ZONE 3
(Deposition)

(Schumm, 1977)



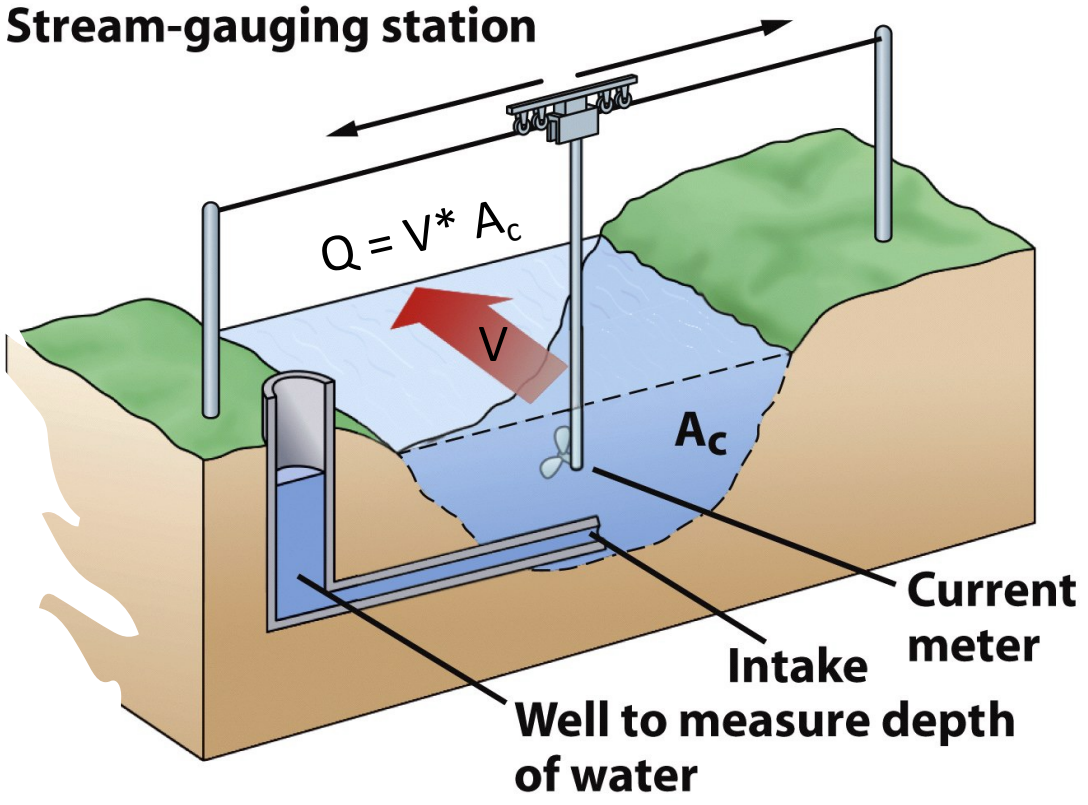
Streamflow

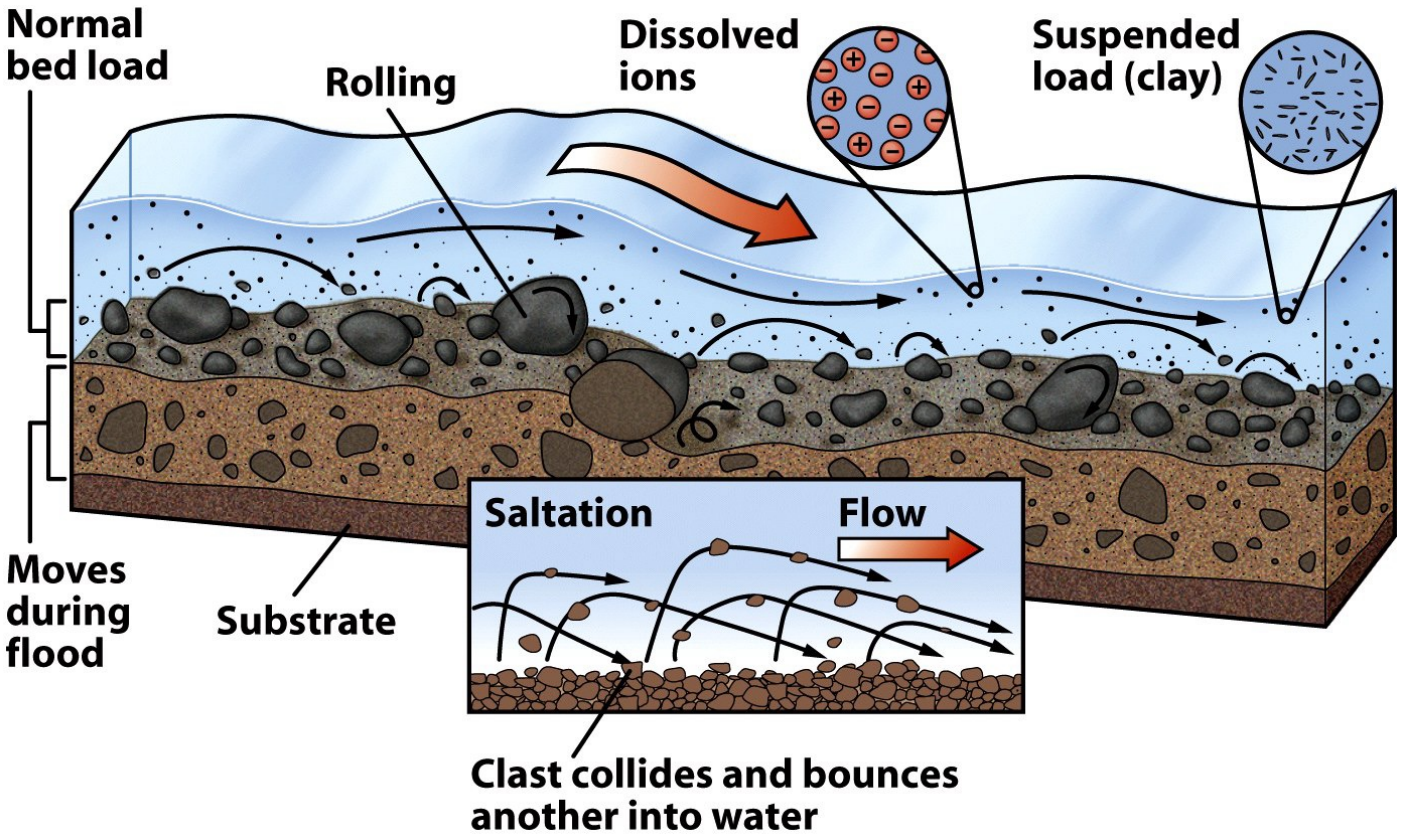
- Stream runoff is an important geomorphic agent.
  - Flowing water…
    - Erodes, transports, and deposits sediments.
    - Sculpts landscapes.
    - Transfers mass from continents to ocean basins.
  - Earth: only planet in the solar system with flowing water.
  - Without flowing water, Earth might resemble Mars.
- Stream runoff also causes many problems.
  - Flooding destroys lives and property.



Discharge

- The amount water flowing in a channel.
  - Volume of water passing a point per unit time ($Q = V * A_c$).
    - Cubic feet per second (ft^3/s).
    - Cubic meters per second (m^3/s).
- Given by cross-sectional area x flow velocity.
- Varies seasonally due to precipitation and runoff.



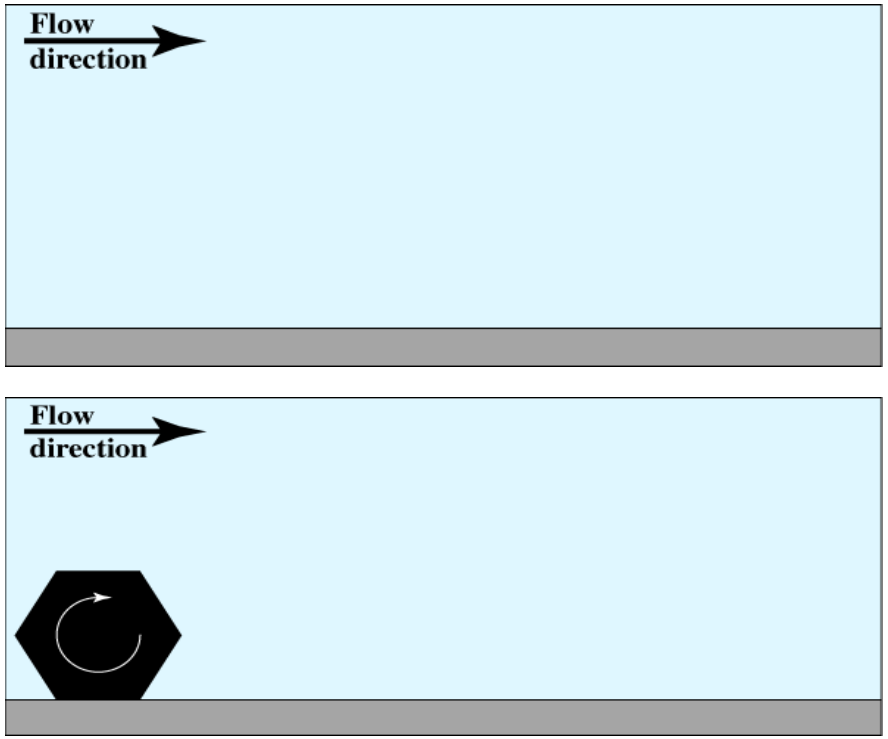


Sediment Transport

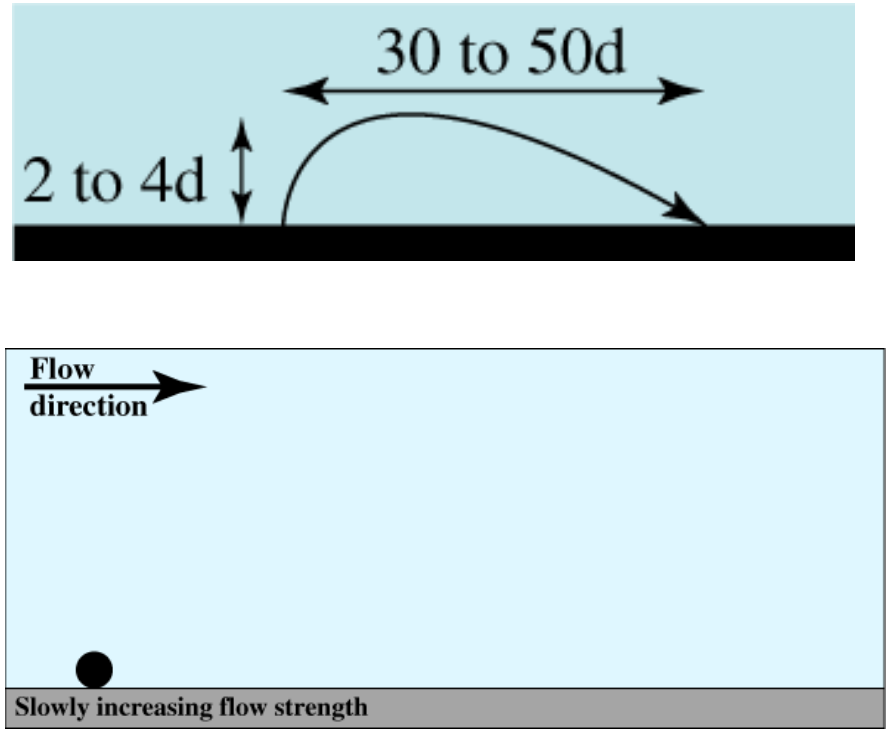
- The material moved by streams is the sediment load.
- There are 3 types of load.
  - Dissolved load – Ions from mineral weathering.
  - Suspended load – Fine particles (silt and clay) in the flow.
  - Bed load – Larger particles roll, slide, and bounce along.

Sediment transport

- *Contact load*: particles that move in contact with the bed by sliding or rolling over it.

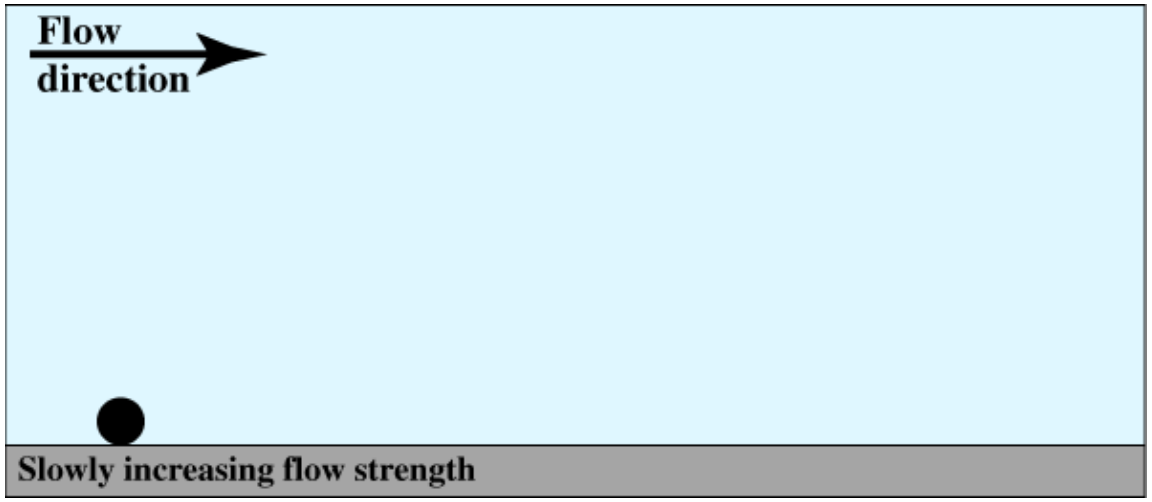


- *Saltation load*: movement as a series of "hops" along the bed, each hop following a ballistic trajectory.



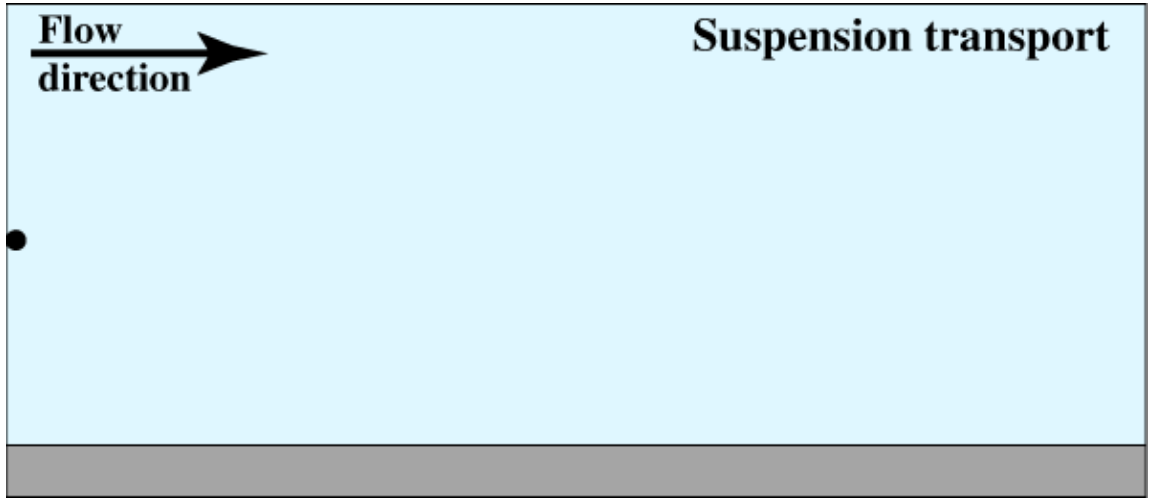
Sediment transport

- When the ballistic trajectory is disturbed by turbulence the motion is referred to as *Suspensive saltation*



- *Intermittent suspension load*: carried in suspension by turbulence in the flow.

- "Intermittent" because it is in suspension only during high flow events and otherwise resides in the deposits of the bed.

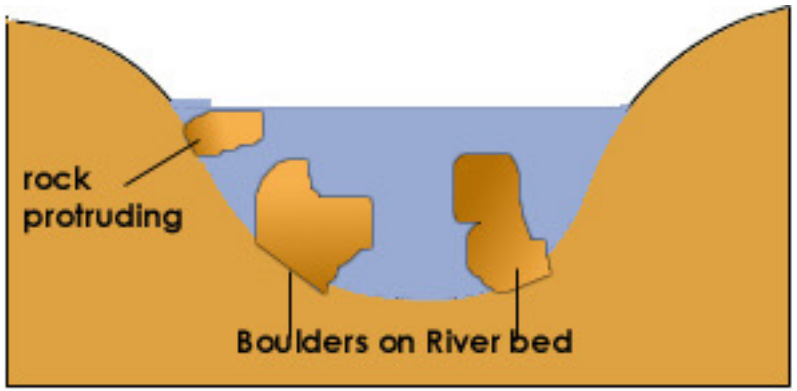


- Bursting is an important process in initiating suspension transport.

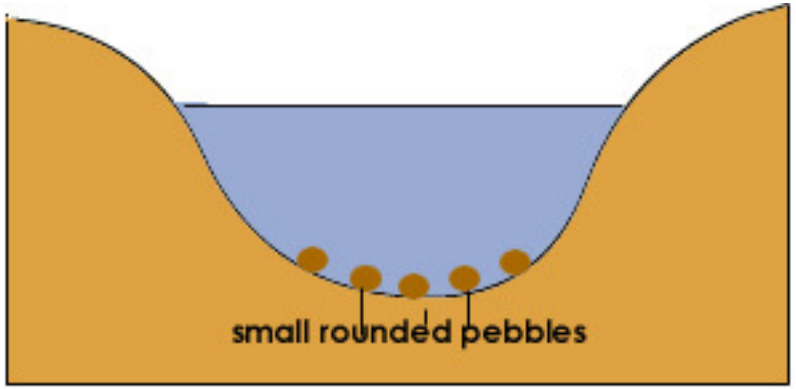
Sediment Deposition

- When flow velocity decreases…
  - Competence is reduced and sediment drops out.
  - Sediment grain sizes are sorted by water.
    - Sands are removed from gravels; muds from both.
    - Gravels settle in channels.
    - Sands drop out in near channel environments.
    - Silts and clays drape floodplains away from channels.

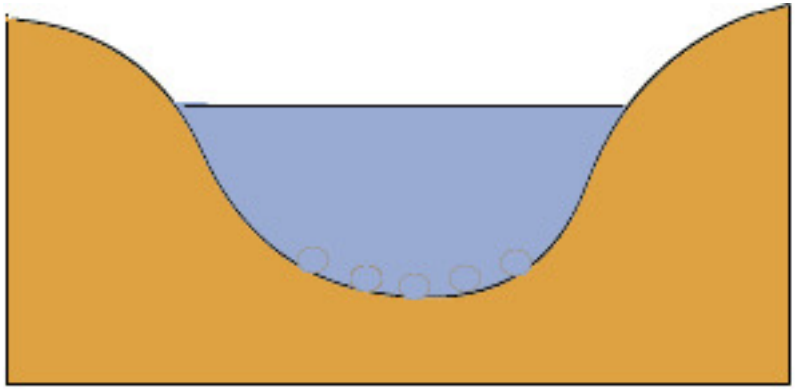
Contrasting river landforms from source to mouth



Upper Course



- Channel features
- Valley features
- Long profile

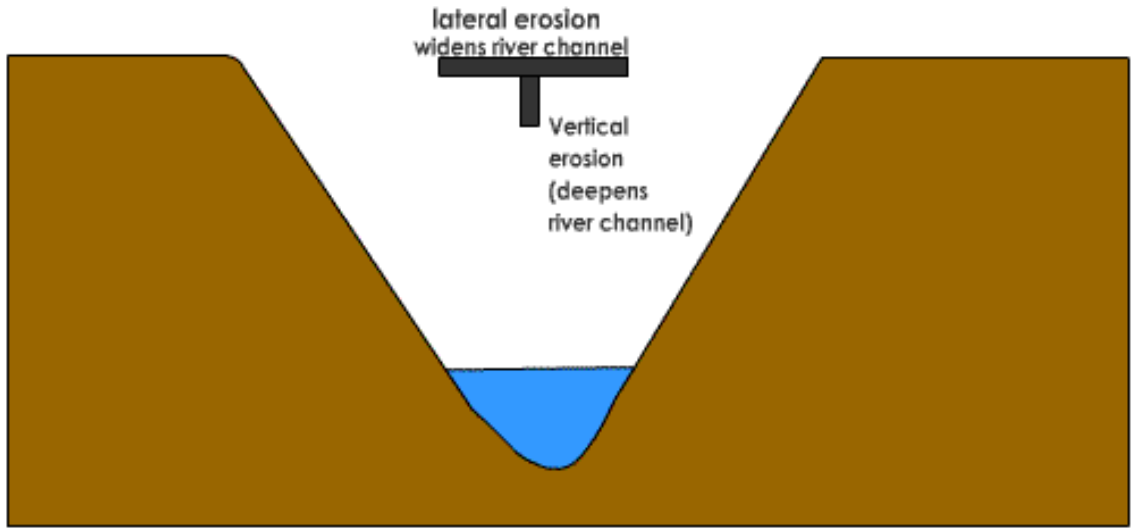


Lower Course

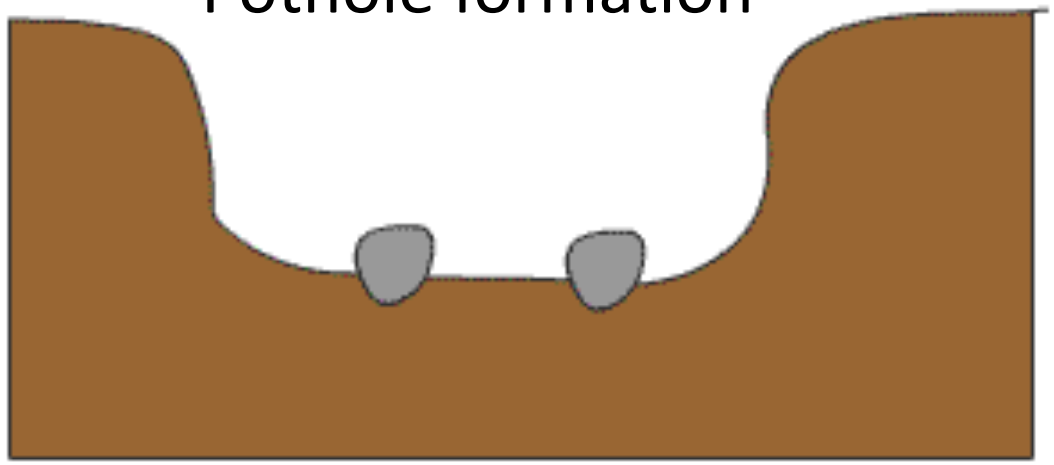
Upper Course - Channel features

- River channel is rocky.
- Covered with various shapes and sizes of boulder.
- Discharge is low.
- Under flood conditions rivers energy is expended on vertical erosion with hydraulic action and corrosion processes at work.
- Potholes may form.

Vertical erosion

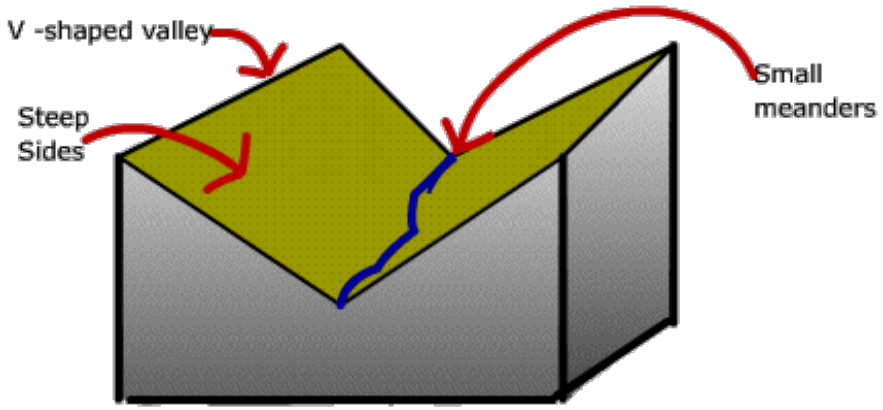


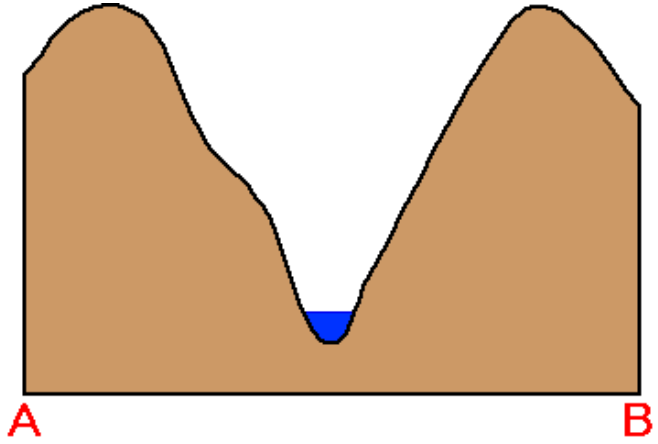
Pothole formation



Upper Course - Valley features

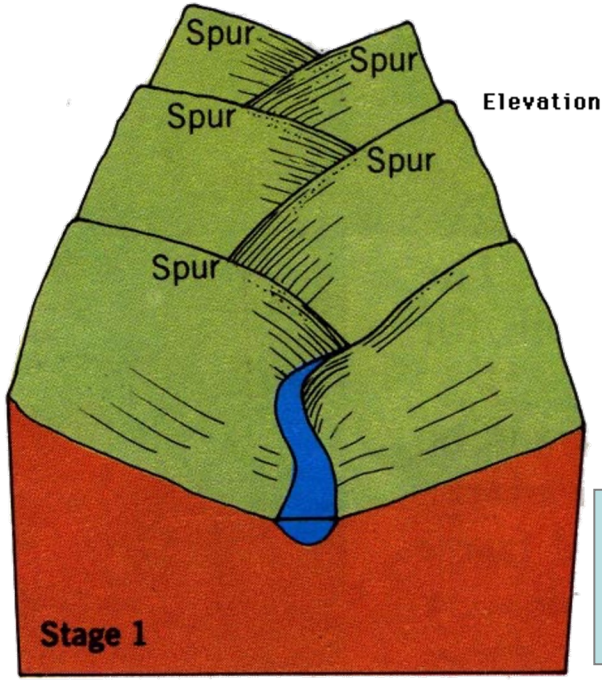
- Valley sides are steep and form a ‘V’ shaped cross section.
- Interlocking spurs.

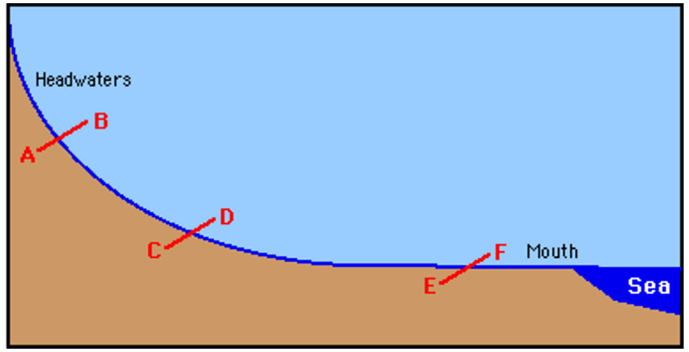




Form due to a combination of the following processes:

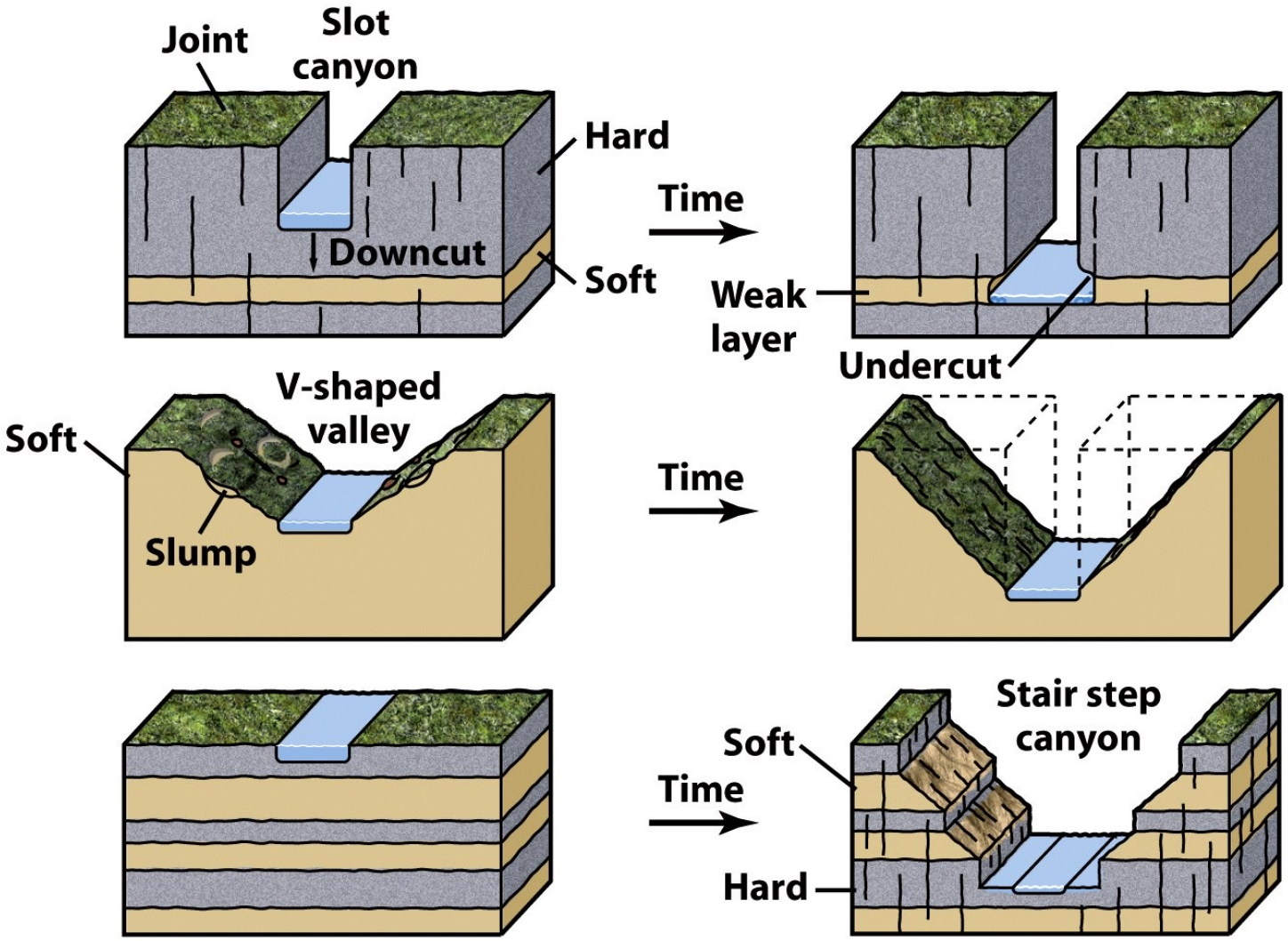
- Vertical erosion by the river itself.
- Physical weathering (eg: frost action) which provides debris to move down slope.
- Mass movement (including soil creep & landslides) to move debris down slope.



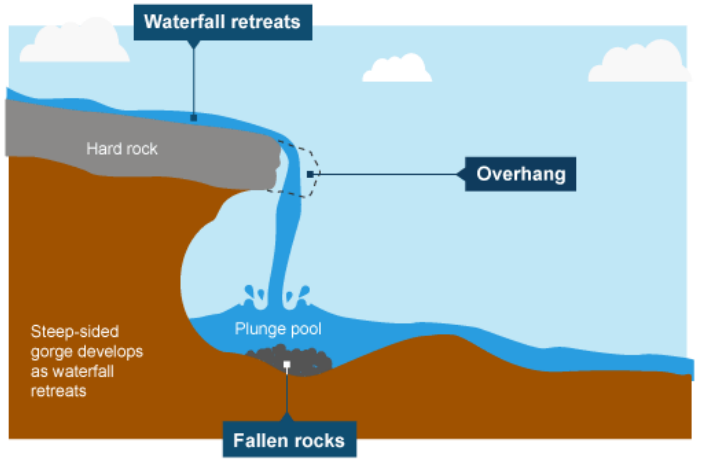


River flows around interlocking spurs

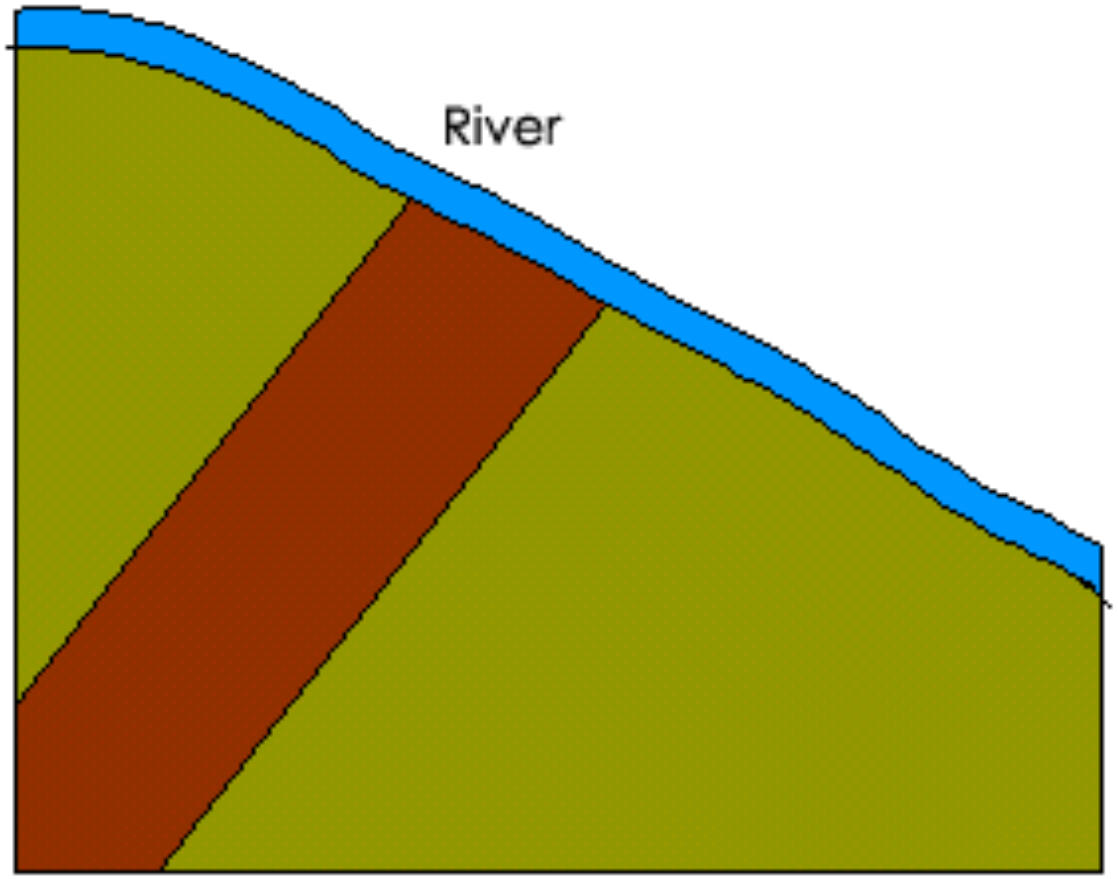
Erosional Landforms



Waterfalls

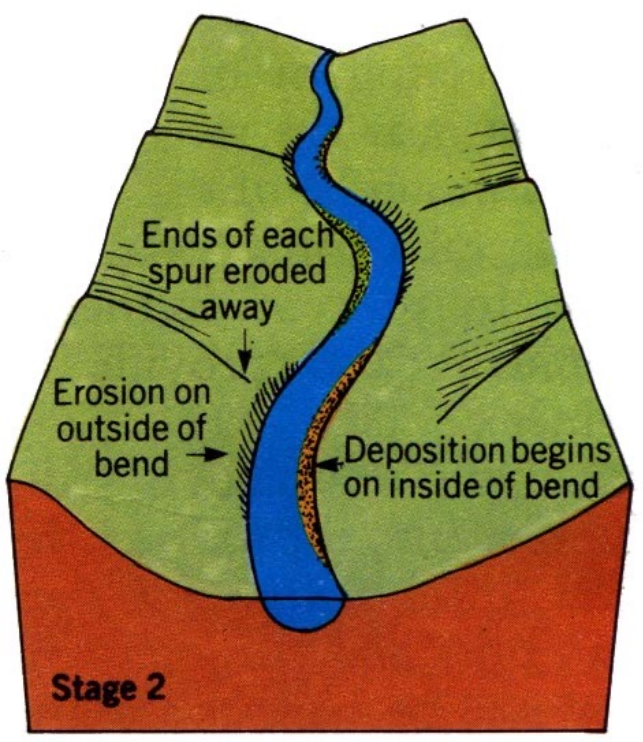


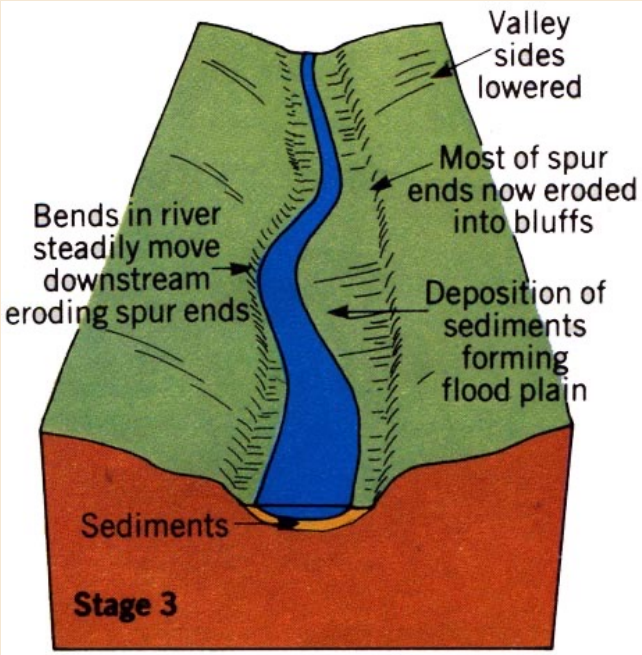
Raneh Falls, Khajuraho
(Grand Canyon of India)



1. The river flows across rocks of different resistance.

Middle Course - Channel and Valley features



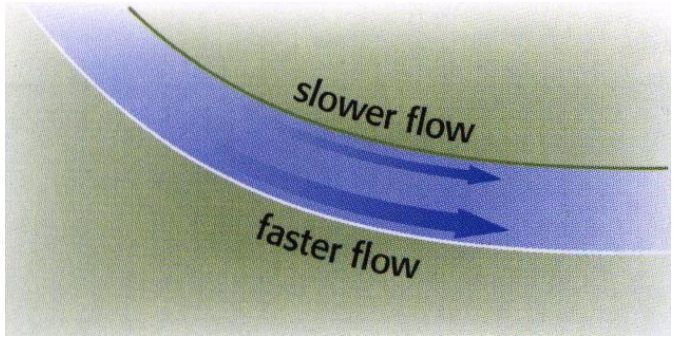


- Channel is now wider and has smoother banks and bed compared to the upper course.
- River erosional energy is now increasingly expended horizontally rather than vertically.
- Lateral erosion by the river's meanders broadens the valley floor into a narrow flood plain.
- Meanders gradually shift their course downstream.

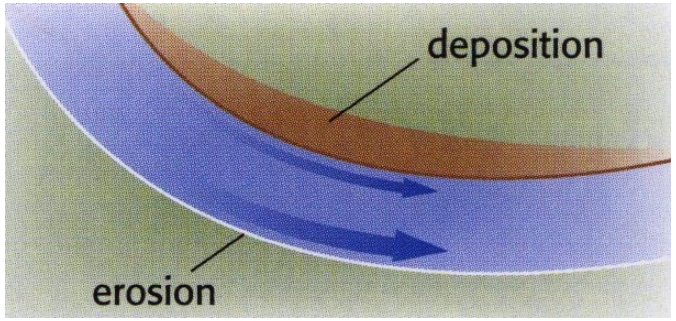
Meanders

A meander starts as a slight bend:

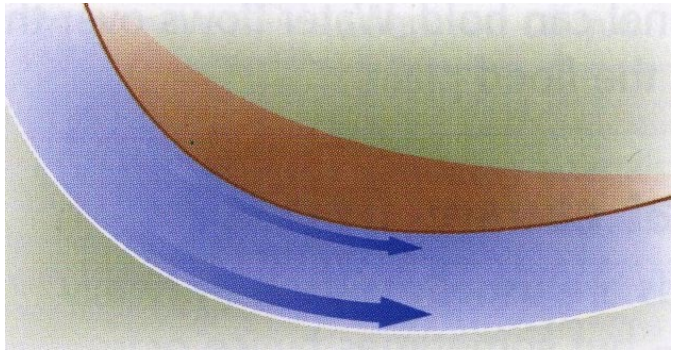
- Alternating series of irregularities develop
- Pools – **deeper** stretches of **slow** moving water
- Riffles – **shallower** section of **faster** flow, flowing above coarser material
- River develops a **winding** or sinuous course
- **Faster** flow on **outer bend** results in erosion and formation of River Cliff
- **Slower** flow on **inside** of bend results in deposition and formation of Slip-off Slope



Water flows faster on the outer curve of the bend (more energy), and slowest on the inner curve (less energy).



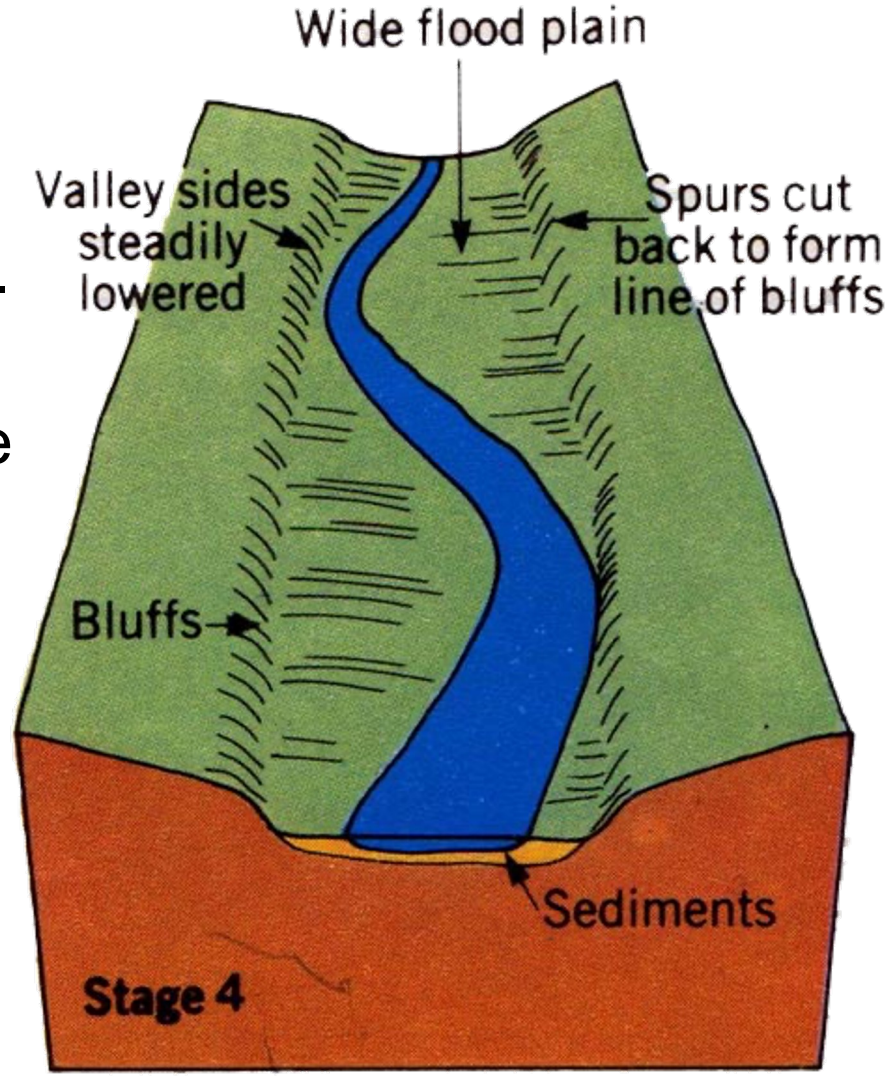
So the outer bank gets eroded while material is deposited at the inner bank.



Over time the outer bank gets worn away (river cliff) and the inner one builds up (river beach). The bend grows into a meander.

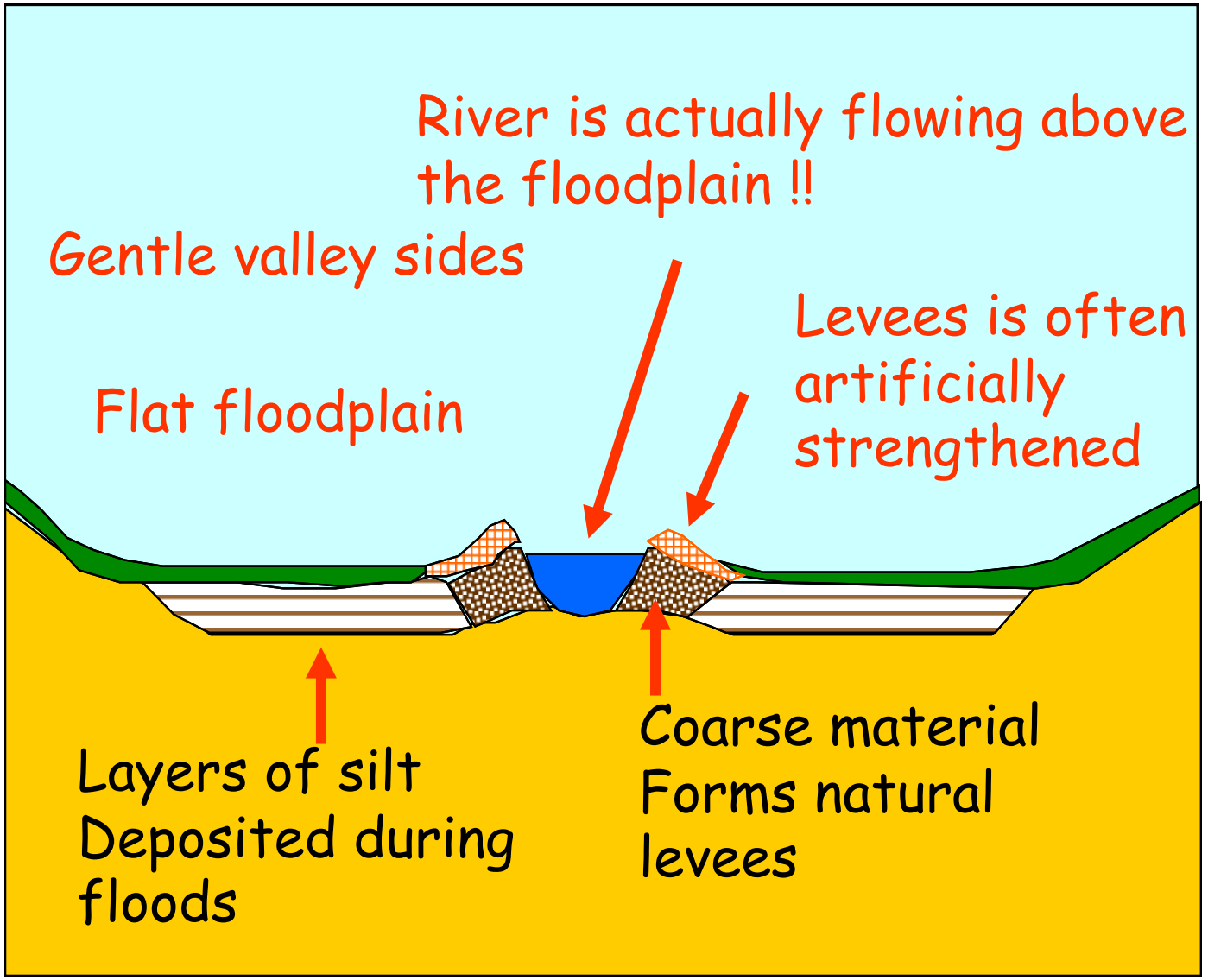
Lower Course – Channel and Valley features

- The channel is now at its broadest and deepest.
- Bedload is carried entirely in suspension and is solution.
- Deposition now dominates – particularly during floods.
- Erosion also occurs – in the formation of meanders
- Thanks to lateral erosion, the valley sides may now be several kilometres away.
- Typically, it may also contain the following features:
  - Floodplain & natural levees
  - Braided channels
  - Meanders
  - Oxbow lakes
  - Estuaries and deltas

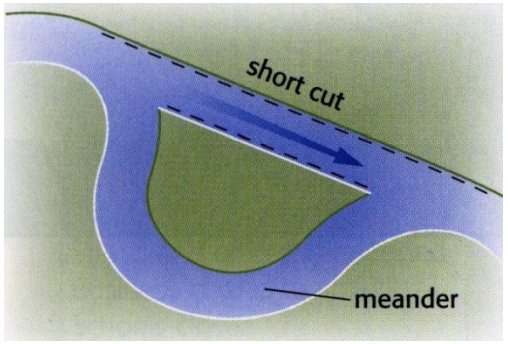


Natural levees

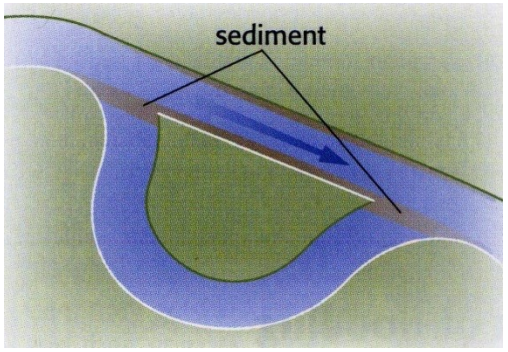
- As the river floods, sediment is dropped over all the flooded areas but most falls along the river channel itself.
- This sediment raises the height of the banks is flooding occurs regularly
- Levees themselves do not prevent flooding because as the banks are raised, more sediment is dropped on the river bed, raising the water level.



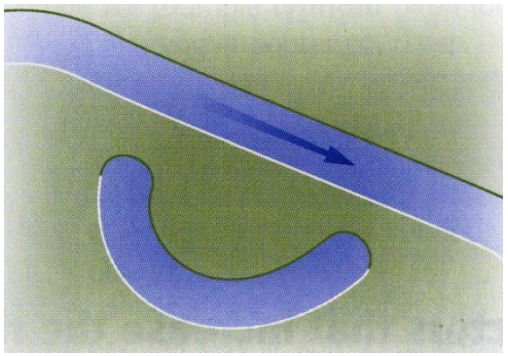
Oxbow lakes



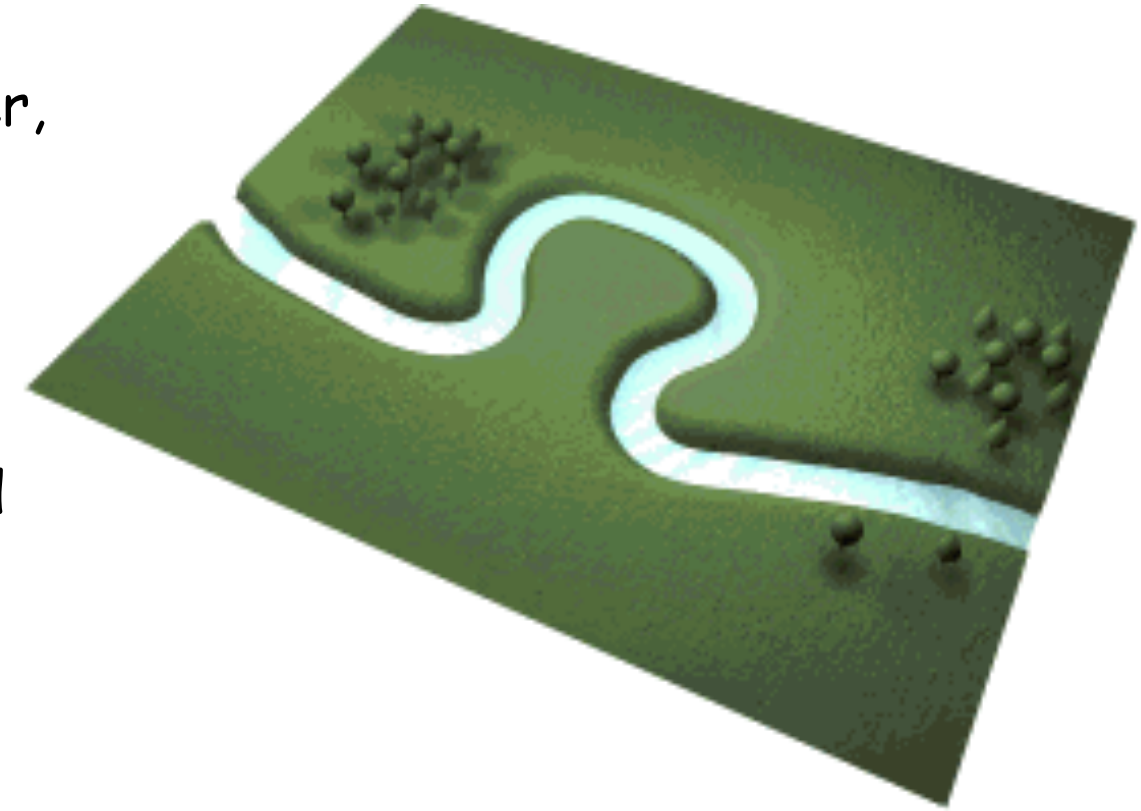
An Oxbow lake starts as a meander. During a flood the river cuts across the meander, forming a new channel.



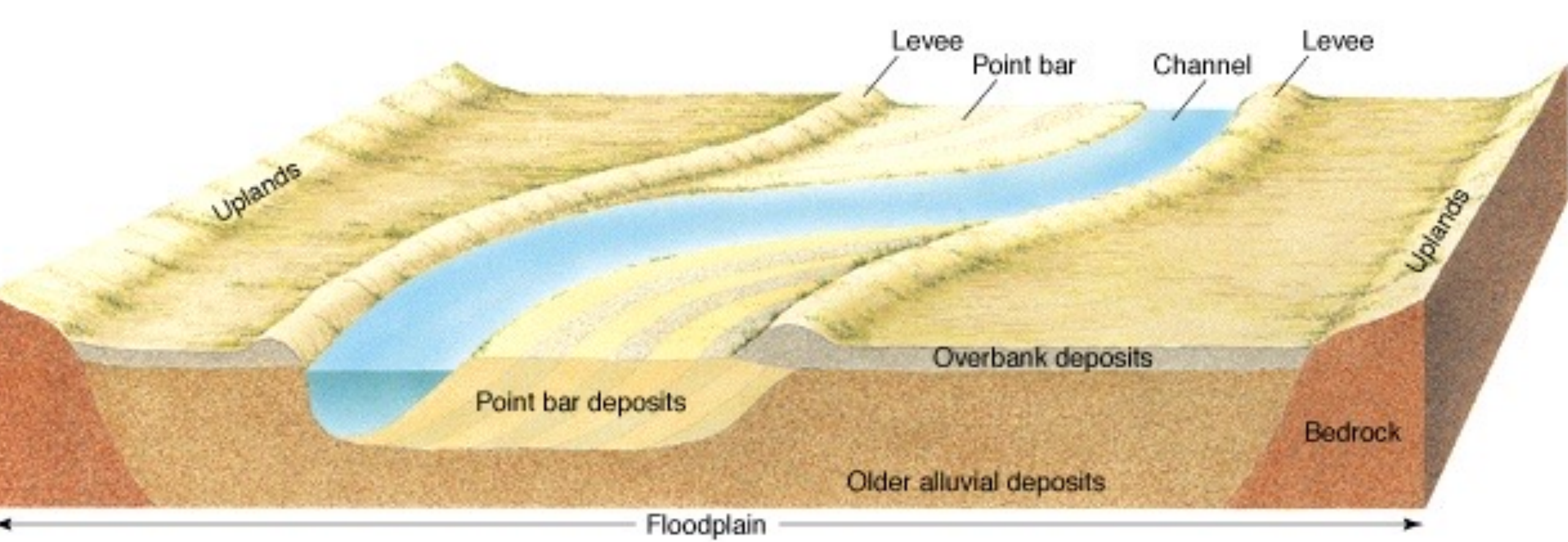
Sediment is deposited along the sides of the new channel. The loops gets sealed off and an oxbow lake forms.



The water in it becomes stagnant. The lake will remain sealed of until either the river floods into it or it dries out.

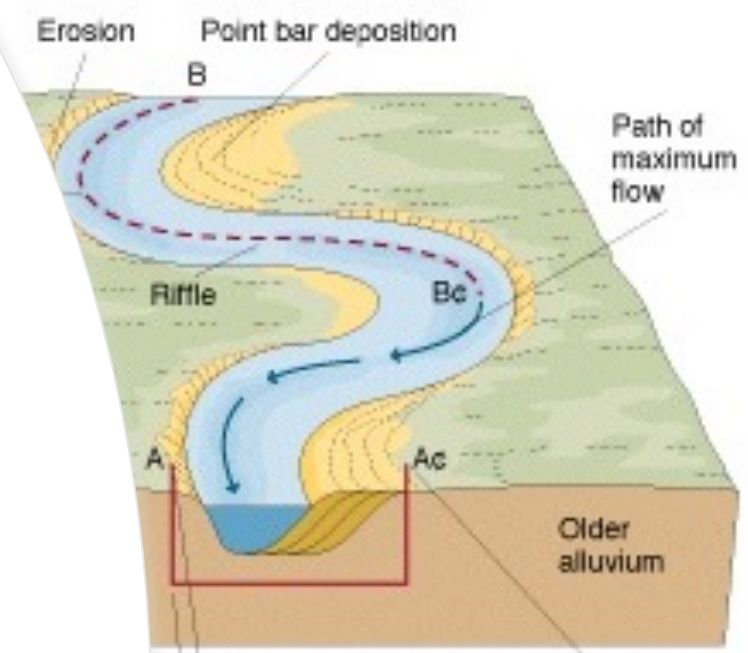


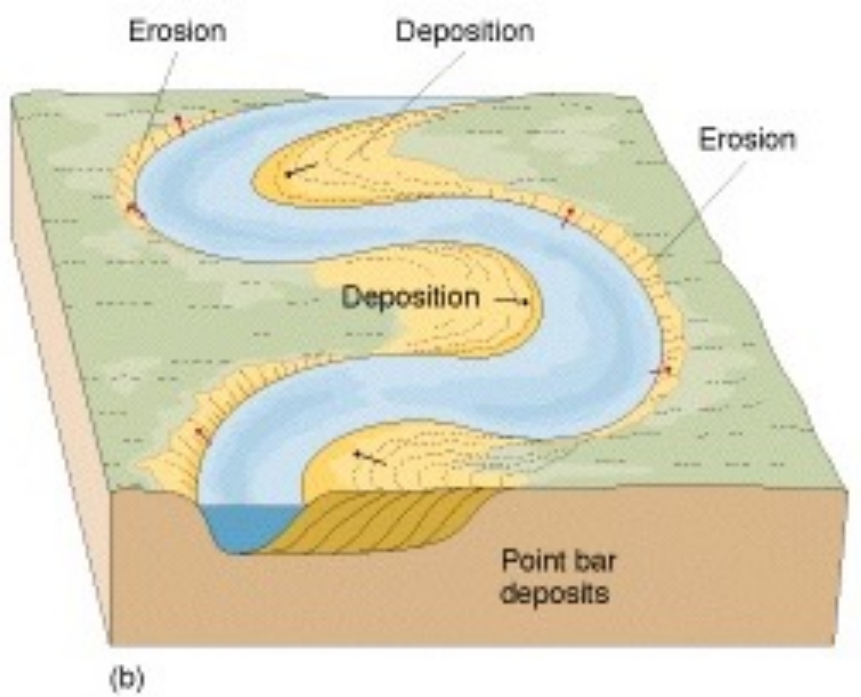

NARROW MEANDER NECK
FUTURE
OX-BOW LAKE

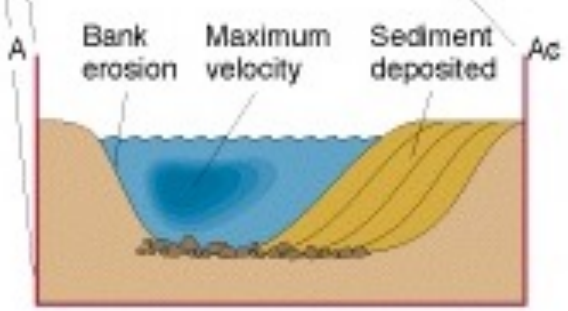


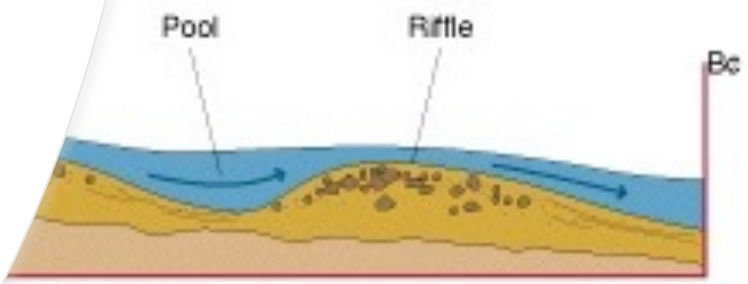
Floodplains

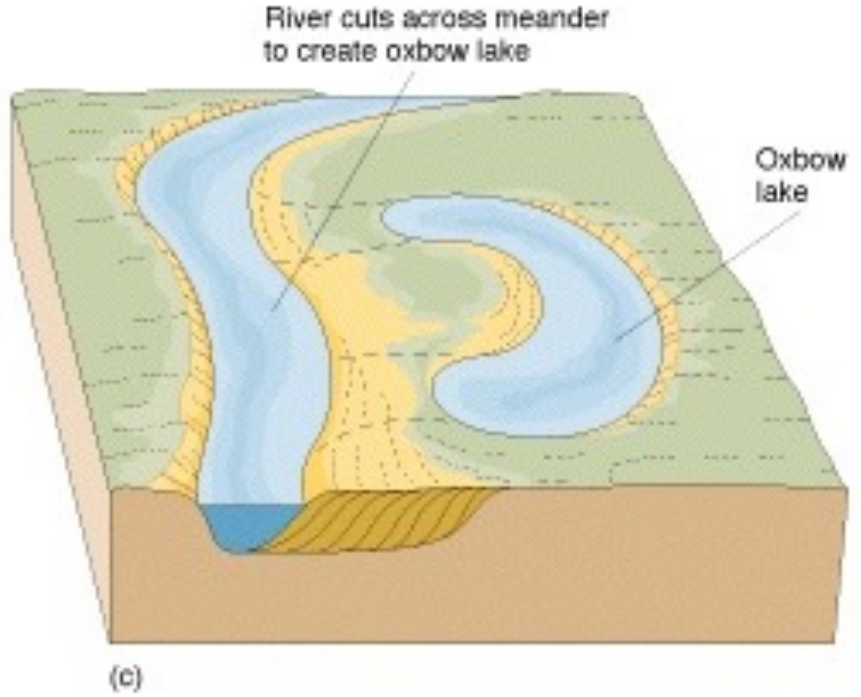
Meandering River Landforms: Summary





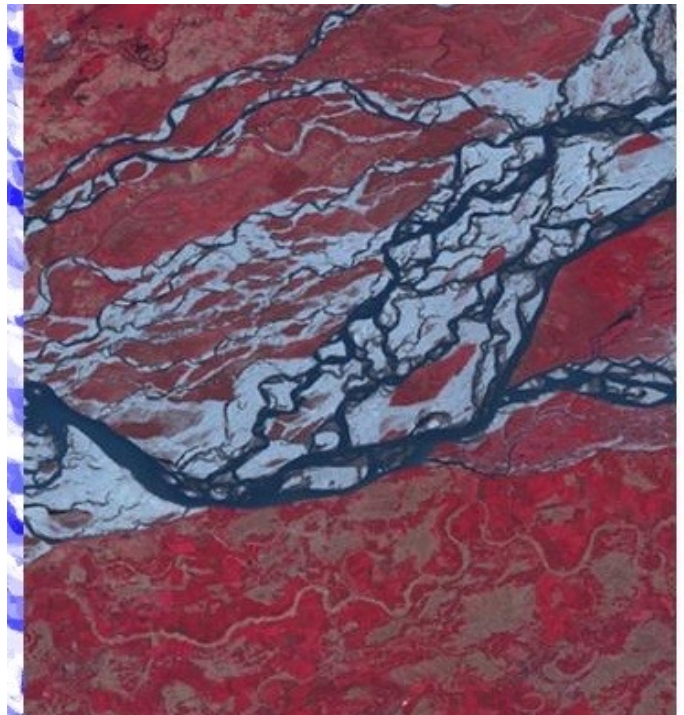




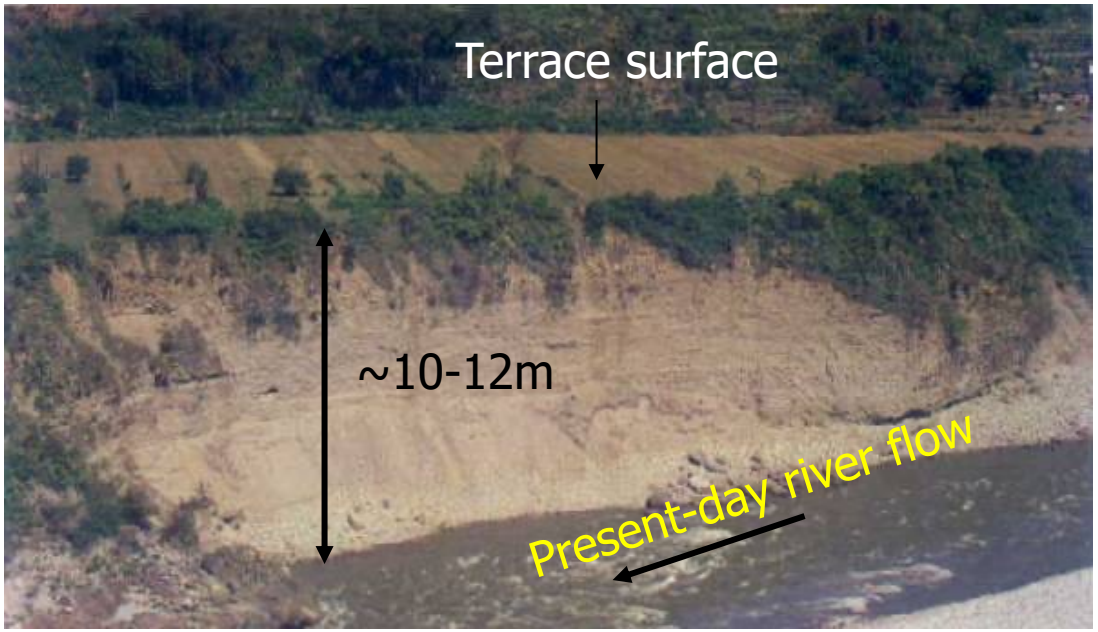


Braided channels

- Formed by the choking of the main channel by the deposition of a considerable amounts of the river load.
- The channel splits into several smaller channels which flow around fresh ‘islands’ of deposited material before rejoining.



River Terraces

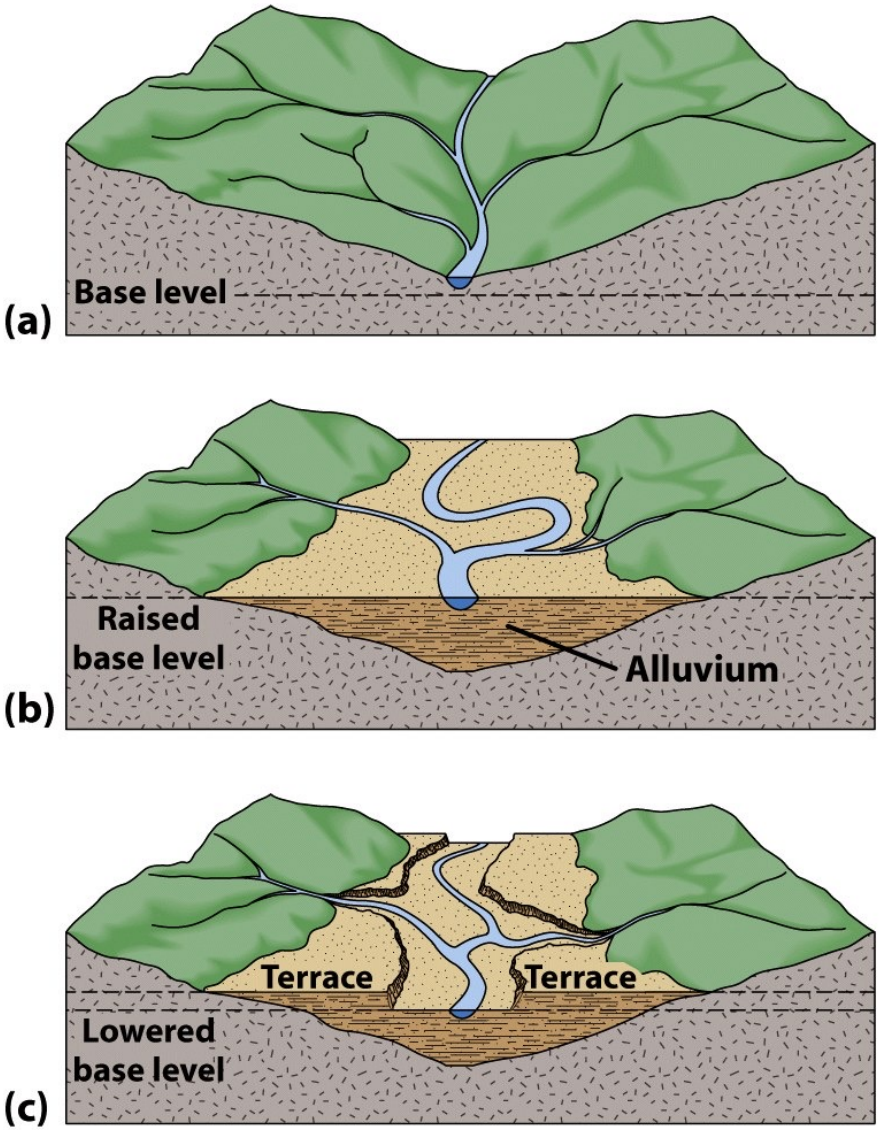


Aggradational terraces:

Aggradation + downcutting

Degradational terraces: Incision of bedrock channels (strath terraces)

Paired/unpaired



Summary

- Rivers produce a variety of landforms produced by erosional and depositional processes.
- These landforms are specific to the terrain through which the river moves – distinctive landforms in upper, middle and lower reaches.
- Meandering and Braided rivers are the two most distinctive types in terms of channel morphology.
- A river is a dynamic geomorphic agent, and it keeps on adjusting its form and position through time in response to natural as well as anthropogenic perturbations.