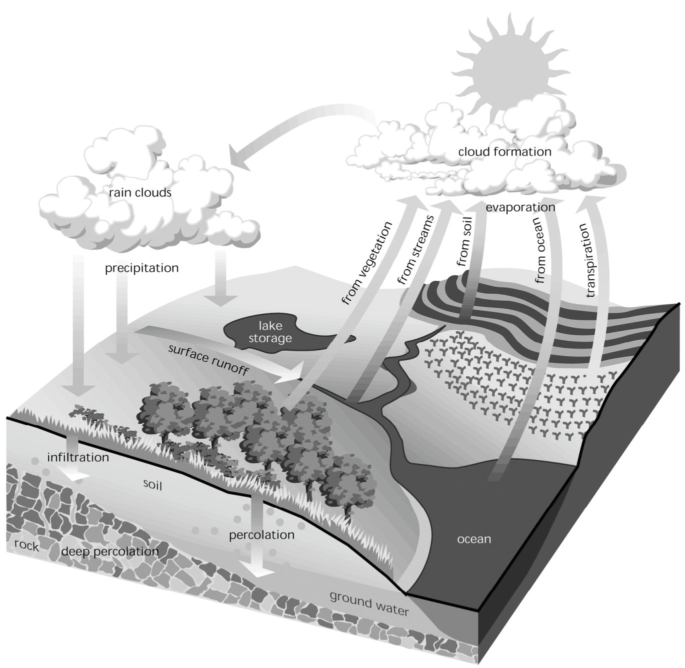
Introduction to the HYDROSPHERE

World Water Budget

- Global hydrosphere: 326 million cubic miles (1.36 billion cubic kilometers)
  - 97.2%: Oceans.
  - 2.15%: Glaciers and ice sheets
  - 0.62%: Groundwater
  - 0.03%: Lakes, streams, soils, atmosphere
    - 0.0001%: Rivers
    - 0.017%: All lakes



Hydrologic Cycle

- Each year, 320,000 km^3 of water evaporates from the oceans, most of which rains back down into the oceans. . .
- . . . and 60,000 km^3 of water evaporates from the land.
- But 96,000 km^3 of water rains down on the land.
- That leaves a net 36,000 km^3 of water that must somehow return to the ocean eventually.
  - Most flows over the Earth back to the oceans.
  - Some sinks into the Earth and forms groundwater, which in turn eventually returns to the surface and flows out.

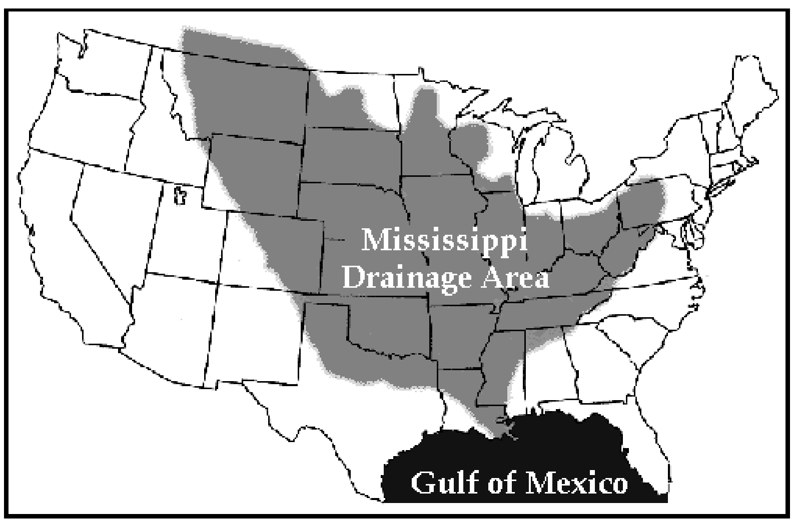
What makes a stream flow?

- Ultimately, it's gravity pulling the water downwards. How fast the water flows is influenced by:
- *Gradient*—the downward slope of a streambed
  - Lower Mississippi: ~10 cm/km
  - High mountain stream: ~40 m/km
- Channel size and shape
  - Large and/or smooth channel means less friction, faster flow
  - Small and/or irregular channel means more friction, slower flow

What makes a stream flow?

- *Drainage basin:* Region that's drained by a given river (a.k.a. *drainage area*)
  - Mississippi River: 1,244,000 square miles (third largest in the world)
  - Amazon River: 2,231,000 square miles (largest in the world)
- *Discharge:* Volume of water flowing past a point in a given unit of time
  - Mississippi River: 17,300 cubic meters per second (seventh largest in the world)
  - Amazon River: 212,400 cubic meters per second (largest in the world)

Mississippi River drainage area



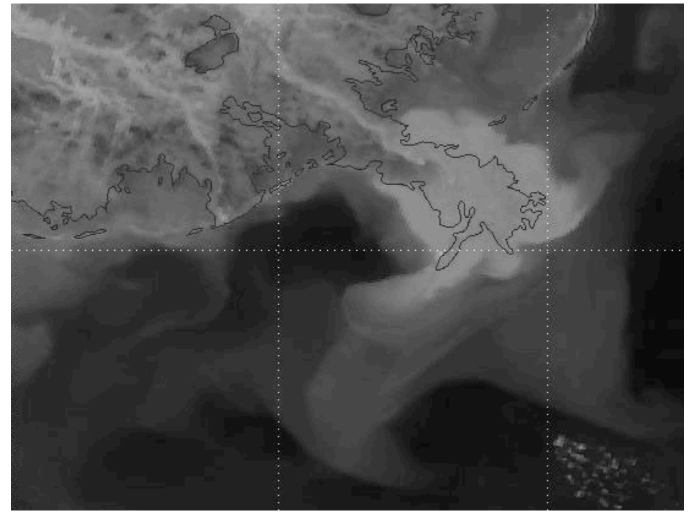
As you go downstream, from *headwaters* to *mouth*. . .

- Discharge increases
- Gradient decreases
- Channel width and depth increases
- Velocity increases
- Left alone, a river would eventually erode down to *base level* (which is ultimately equal to sea level) and flow would stop because there would no longer be any gradient

Stream transport

- *Dissolved load:* Material carried by a stream in dissolved solution
- *Suspended load:* Material carried as fine particles (silt, clay, etc.)
- *Bed load:* Material carried as larger particles intermittently rolling along the bottom
- Each year, Mississippi River carries into ocean:
  - 500 million tons of solids in suspension
  - 200 million tons of dissolved load
  - 50 million tons/year as bed load

Satellite image of Mississippi River mouth, showing sediment load (mostly suspended)



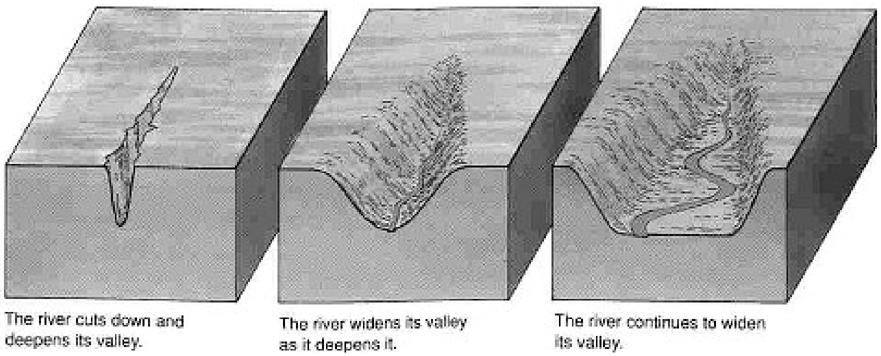
Stream erosion and deposition

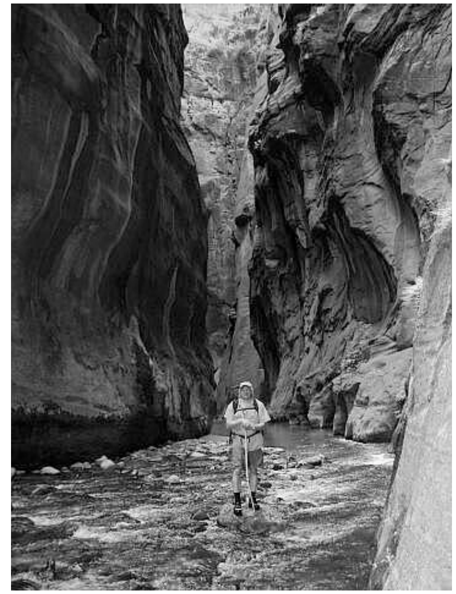
- *Competence:* the maximum *size* of particles that a stream can transport
  - Competence is a function of the square of the velocity. The faster a stream flows, the larger the particles it can transport
- *Capacity:* the maximum *load* a stream can transport
  - Capacity depends on discharge: the larger the volume of flow, the greater the load capacity

Stream erosion and deposition

- Streams erode
  - by picking particles up directly
  - by abrasion by the bed load
  - by dissolving soluble materials
- When a stream or any part of a stream slows down, its competence goes down, and particles begin settling out
- This creates *sorted* deposits called *alluvium*.
- Examples:
  - Delta formation
  - Natural levees
  - Meanders

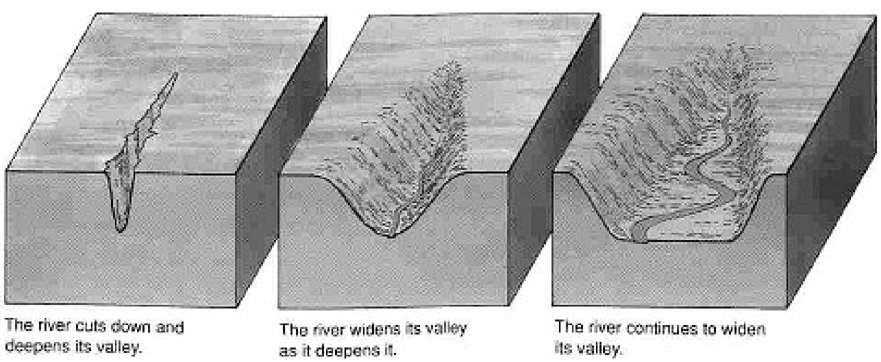
Younger parts of a river drainage begin with sharp downcutting, forming a *V-shaped valley*. . .



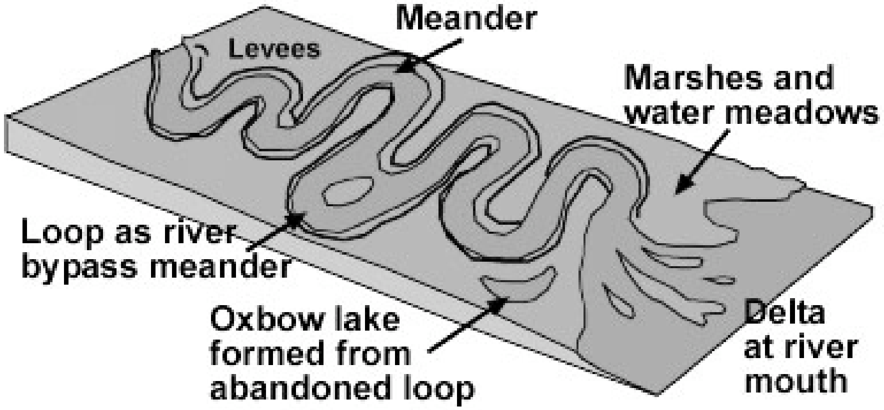


. . . one nice example of a V-shaped valley is The Narrows, in Zion National Park in south Utah—so narrow it's probably better called a *slot canyon*. . .

As the valley widens, the river begins meandering back and forth, eventually creating a *floodplain*.



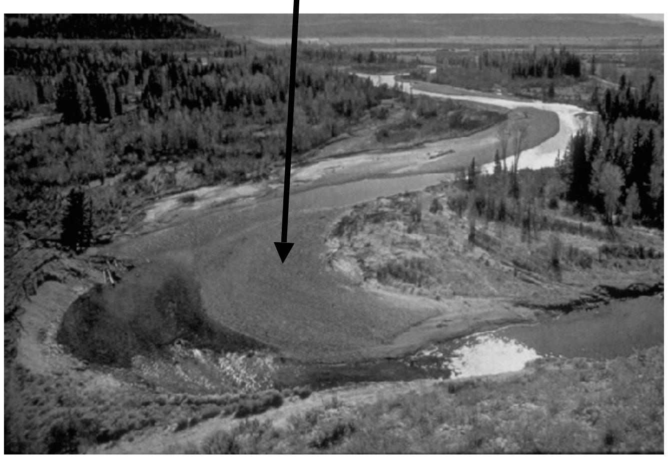
A mature floodplain with numerous *meanders* (Yellowstone National Park).



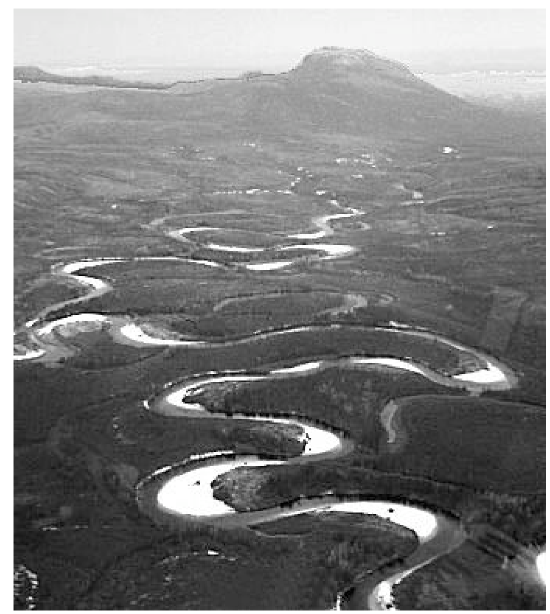
Old age river characterized by a broad flood plain and ox-bow lakes

If you have a meandering stream running over land that gets uplifted relatively rapidly, the uplift increases the gradient, which increases the speed of flow, which increases downward erosion. . . and you get *incised meanders*, like these.

Flow is faster on the outside of a meander. . . meaning that erosion happens on the outside of a meander (forming deep pools and sharp bluffs), while *point bars* build up along the inside.

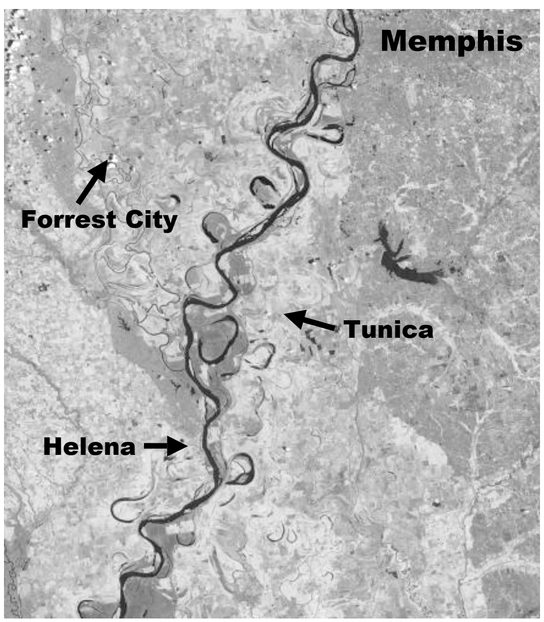


Lots of meanders, with point bars (whitish areas on the insides of the curves), on the Sebaskachu River in Labrador, Canada. . .



Erosion on a meander eventually causes the meander to cut across the *meander neck*, forming a temporary *backwater* (Ontanagon River, Michigan)

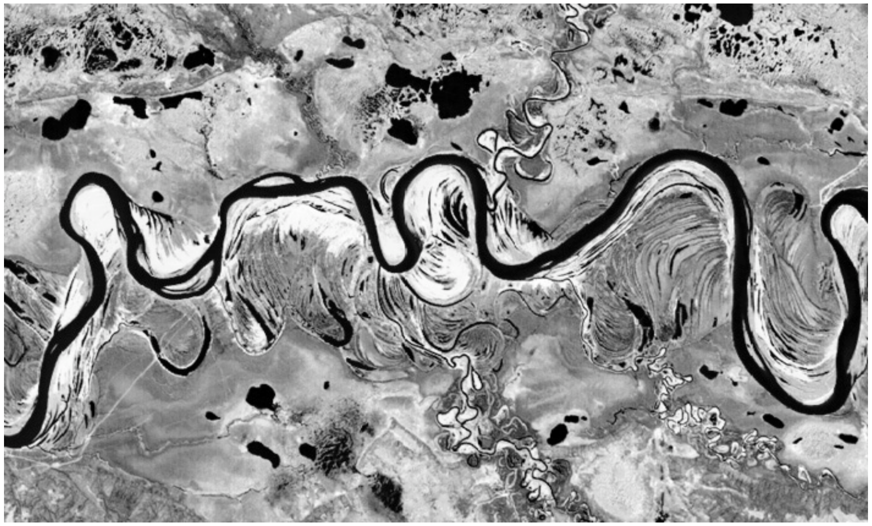
Backwaters soon lose their connection to the new main channel and form typical horseshoe-shaped *oxbow lakes*, which, given time, eventually silt up and fill in.



Oxbow lakes on the Mississippi River (with a few landmarks indicated so you can orient yourself. . .)

Solimoes River, Brazil. Note filled-in oxbow lakes and *scroll pattern* of old point bars. . .

Usa River, Siberia. Again, note the oxbow lakes (some almost filled in) and *scroll pattern* of old point bars. . .



Rivers build the land. . .

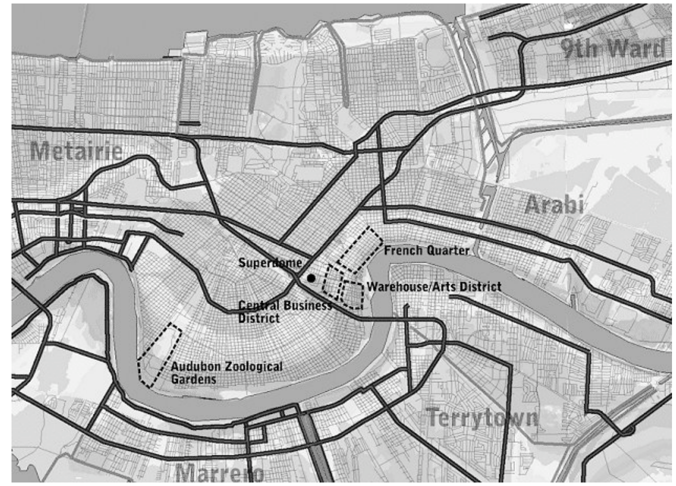
- When a river overflows its banks, the water right along the banks slows down
  - This happens for the same reason that flow from a hose is slower if you don't squeeze it: flow slows down as the size of its channel increases
  - When it slows, the water starts dropping its suspended load, and you get *natural levees*.

Beyond the natural levees of a river lies a stretch of low, often flooded ground, the *backswamp*.

Consider the current Mississippi River delta. . . an example of a *birdsfoot delta*. The *natural levees* extend along the main channel—they're the only place where roads and normal buildings can be placed. . .

Natural levees on either side of the Mississippi River, with backswamps beyond them, at Venice, Louisiana

The neighborhoods of New Orleans that *didn't* flood after Hurricane Katrina were those that were built on the old natural levees of the Mississippi River (shown in orange), the only real high ground.

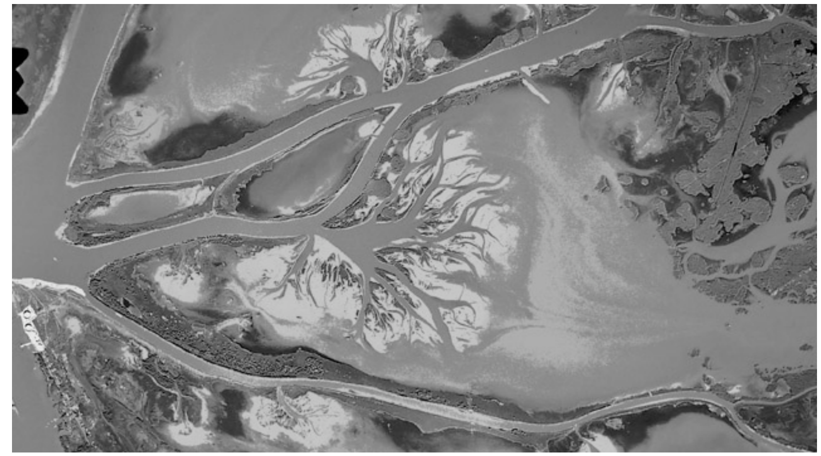


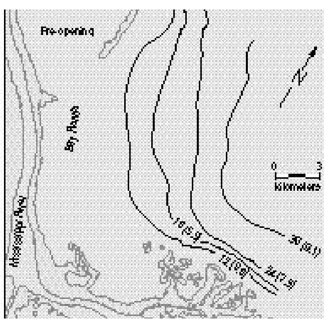
The worst-flooded parts of New Orleans were the old backswamps—some of which, such as the Ninth Ward, were *still* mostly swamps less than a hundred years ago.

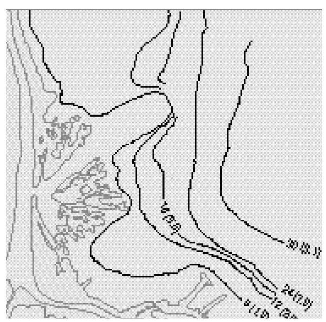
Tributaries of a river may not be able to break through the natural levees, so you'll see streams running in parallel with a larger river for many miles before they can get through a gap. Such a parallel stream is called a *yazoo* (after the Yazoo River, Mississippi)

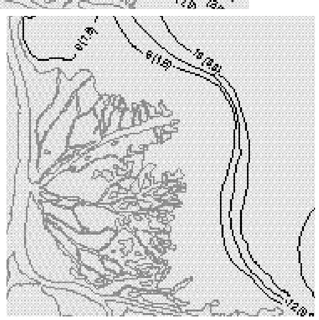
A breakout through a levee can lead to the formation of a *crevasse splay* (this one's actually in Wyoming).

Two more *crevasse splays* are visible in this satellite image of a channel in south Louisiana (and you should also be able to spot the natural levees).

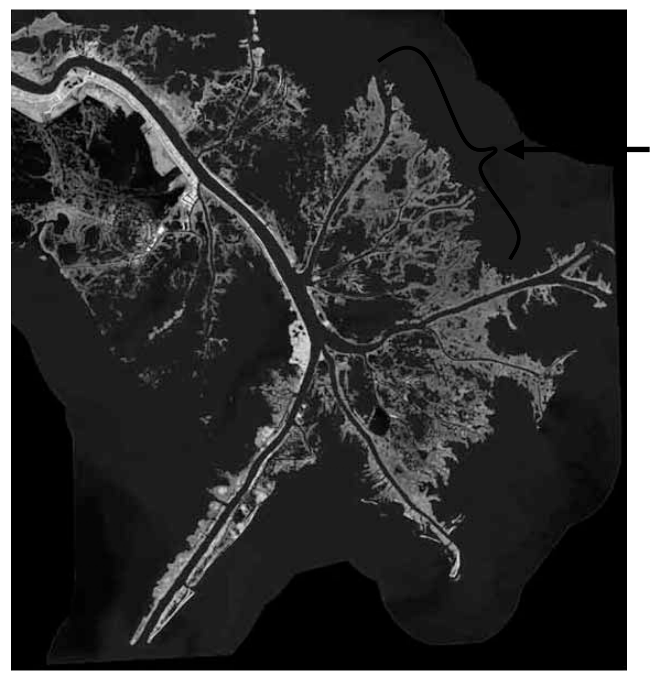








Birth of a *crevasse splay:* Cubits Gap in the Lower Mississippi Delta, in 1838, 1862, and 1905 (clockwise from top left)



Cubits Gap *splay* today, in a satellite image of the lower Mississippi (the area shown is roughly fifty miles wide). Most of the splay now makes up the Delta National Wildlife Refuge.