PRE-DAM COMPARISONS

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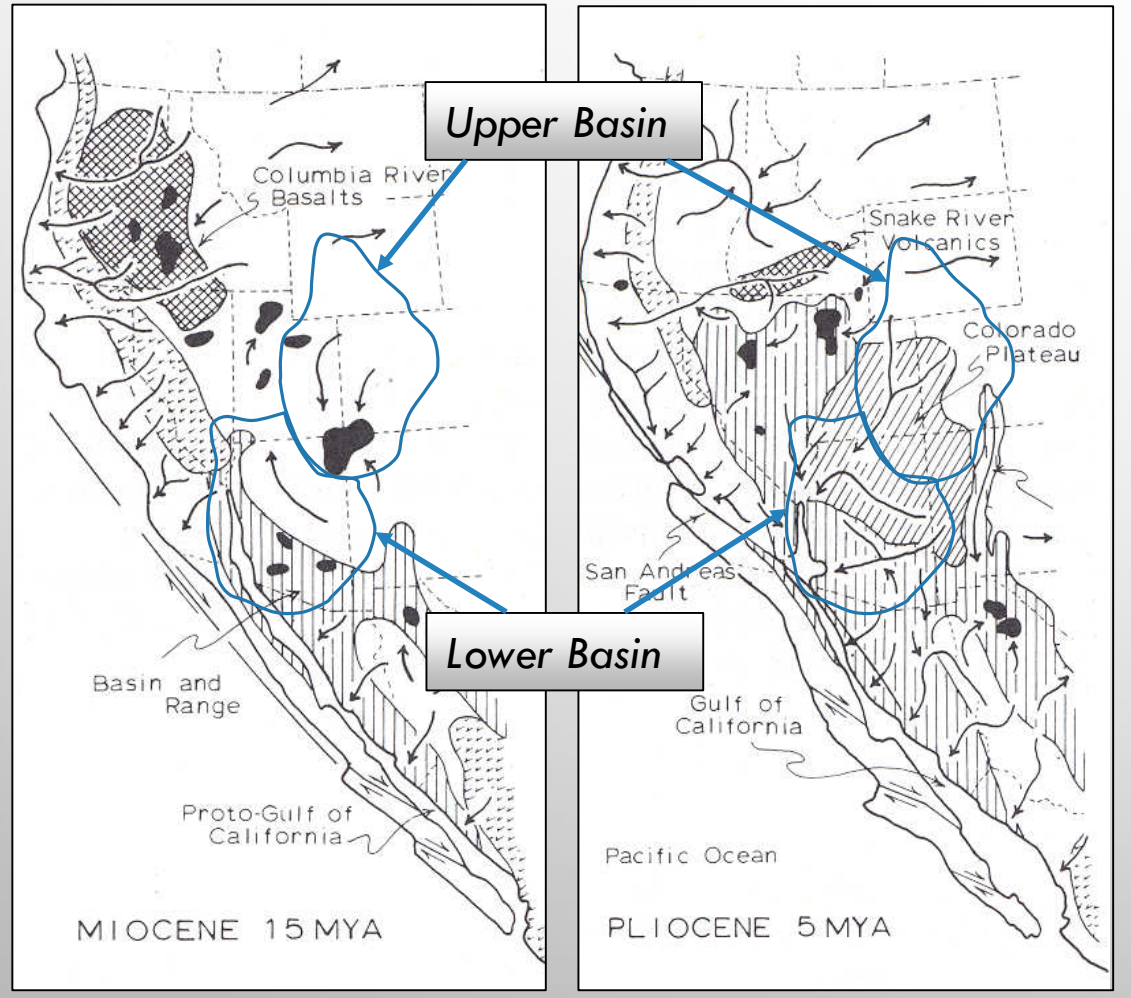
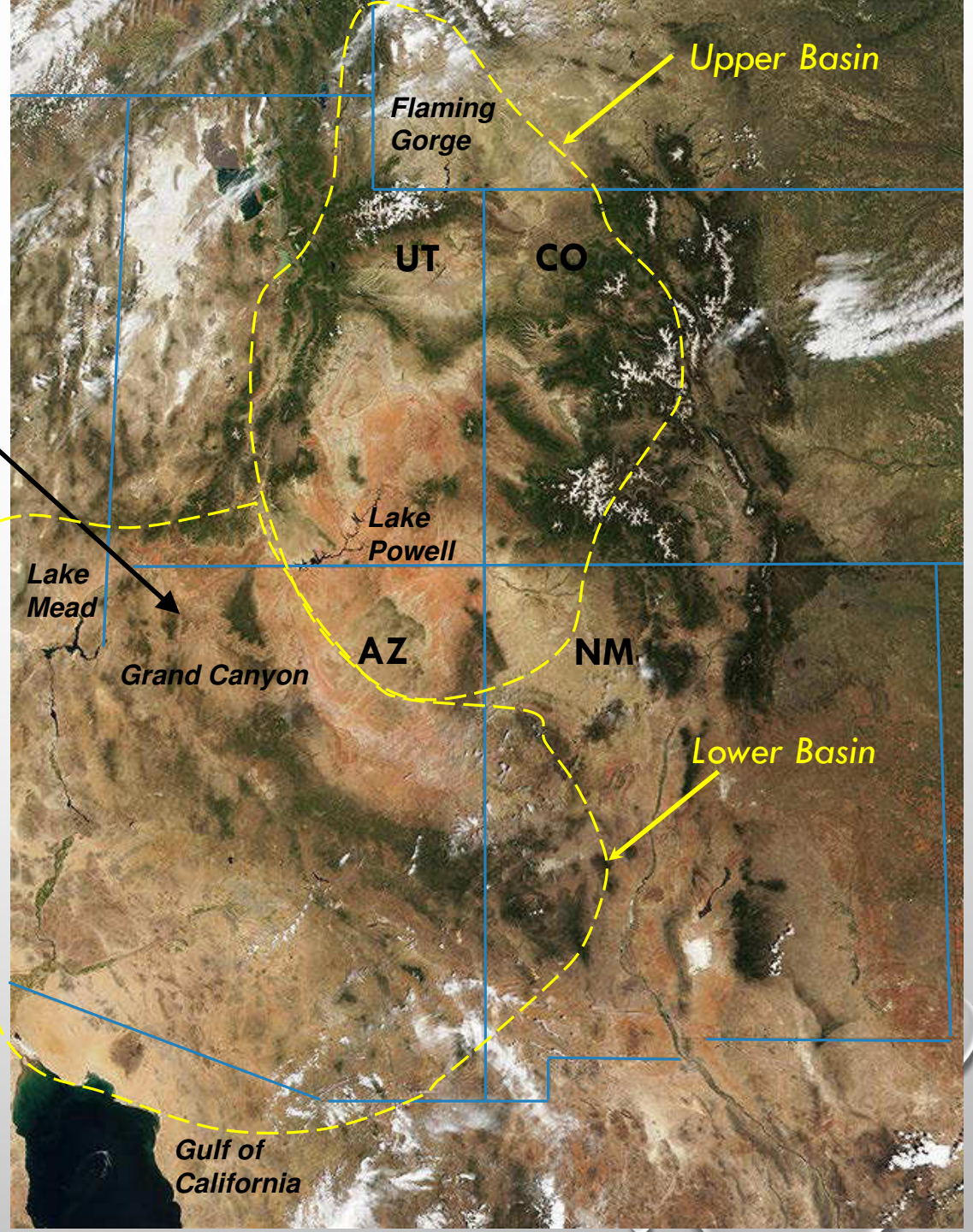
COURSE OUTLINE

- Geologic History of the Colorado Plateau
- The River Continuum
- Cornerstones of the Colorado River
- River Channel and Sediment
- River Flow
- Water Temperature
- Woody Debris
- The New Ecosystem Paradigm

1. GEOLOGIC HISTORY OF THE COLORADO PLATEAU

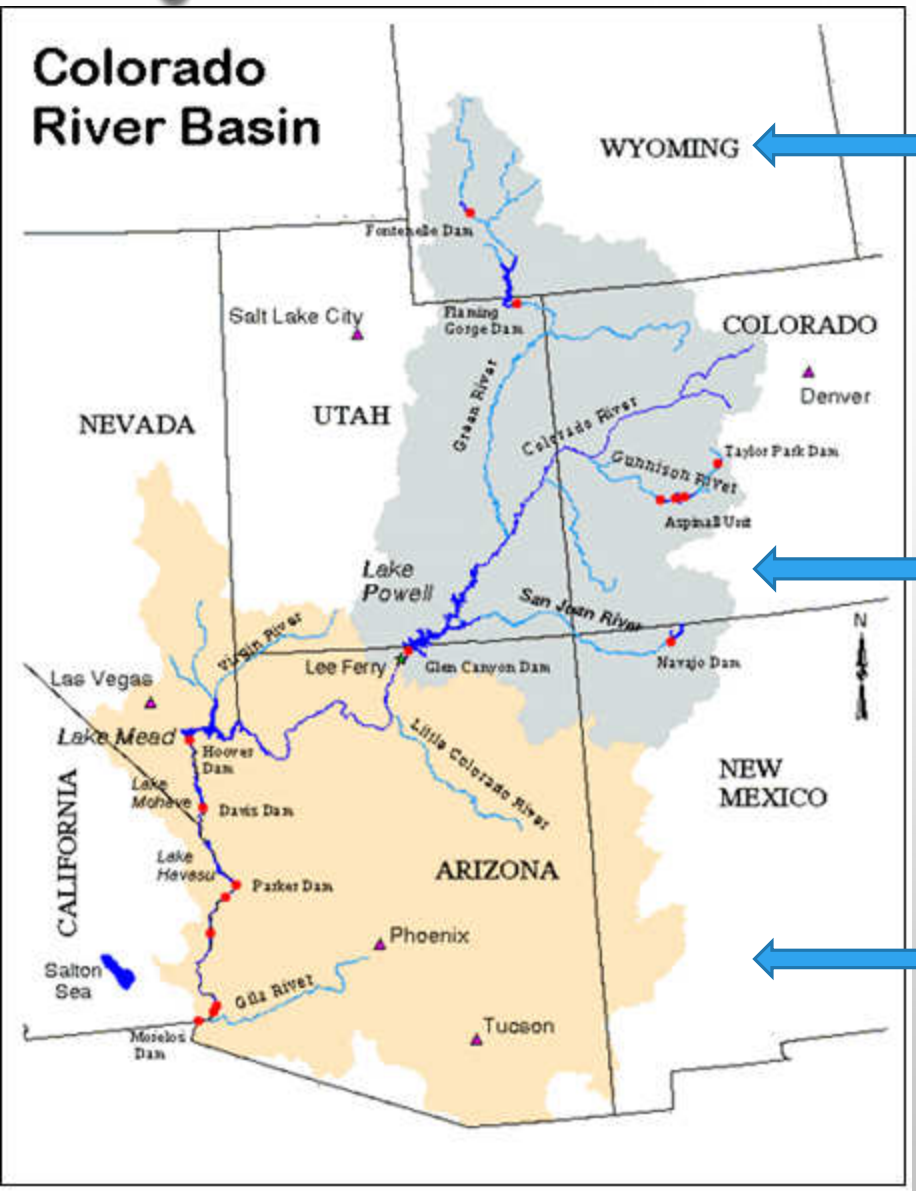
- The Colorado River is two historic basins:
  - The Upper Basin is ancient – formed in the Miocene ~15 mya
  - The Lower Basin is younger – formed in the Pliocene within ~5 mya
  - The two basins connected when the river carved through the Grand Canyon





THE RIVER CONTINUUM

The physical, biological, and chemical structure and function of rivers transition with elevation



High Mountain Streams

- Clear water
- Cold temperatures
- Diatoms, algae, seasonal leaf litter (autochthonous)
- Trout and whitefish

Mid-Elevation Rivers

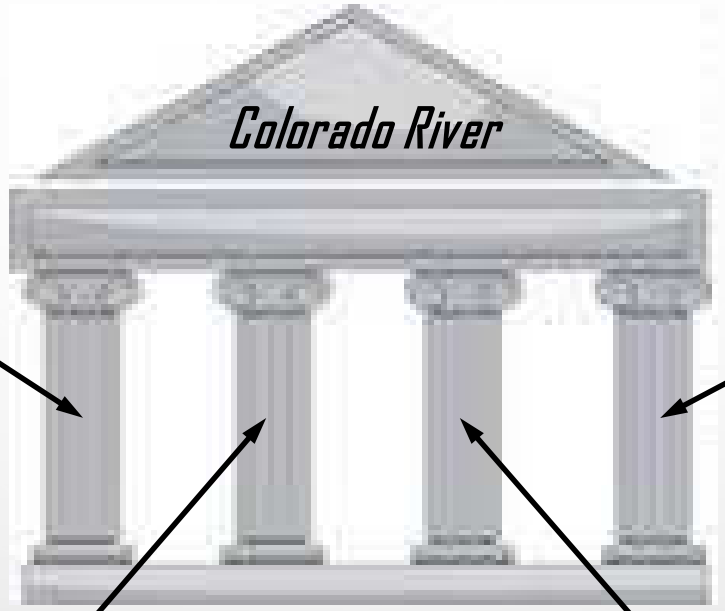
- Moderate water clarity
- Cool temperatures
- Diatoms, algae, leaf litter, woody debris (autochthonous/allochthonous)
- Trout, suckers, dace

Low-Elevation Rivers

- High turbidity
- Warm summer temperatures
- Woody debris (allochthonous)
- Suckers, chub, minnows

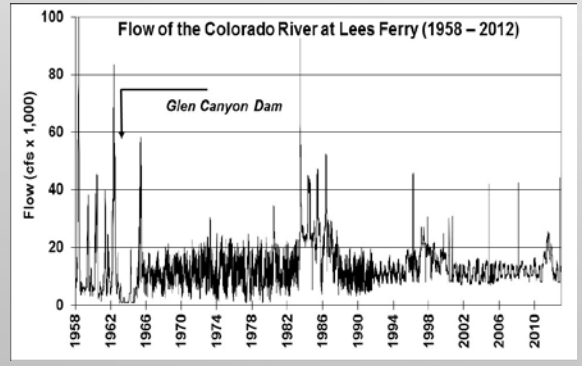
CORNERSTONES OF THE COLORADO RIVER

The structure and function of rivers are based on four fundamental components

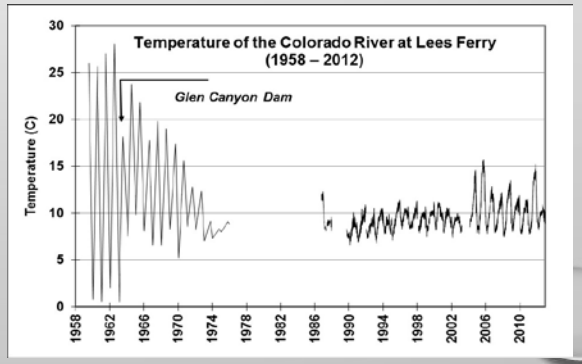


1. River Channel and Sediment (Geomorphology)

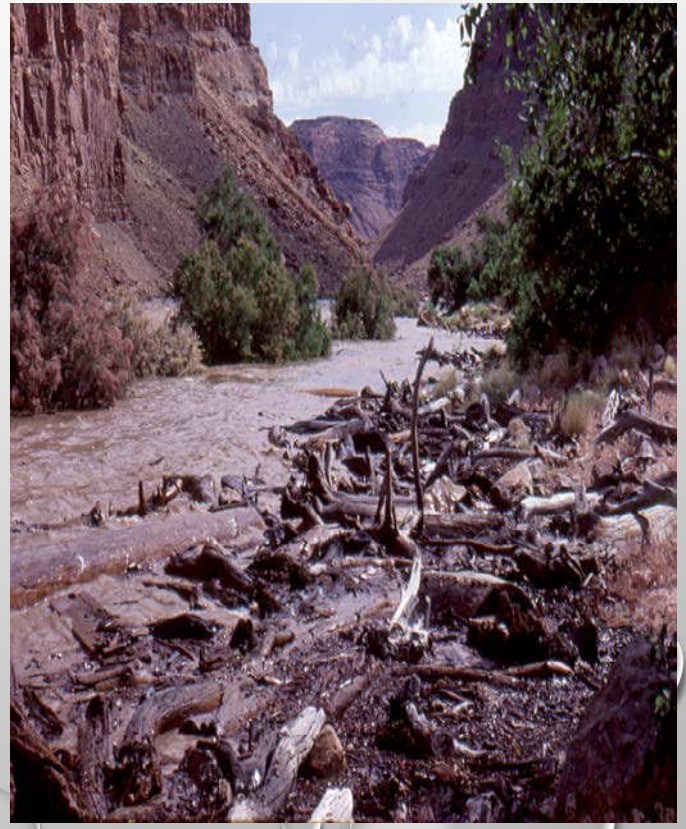
2. River Flow (Hydrology)



3. Water Temperature (Thermal Regime)



4. Woody Debris (Organic Matter)



1. RIVER CHANNEL AND SEDIMENT

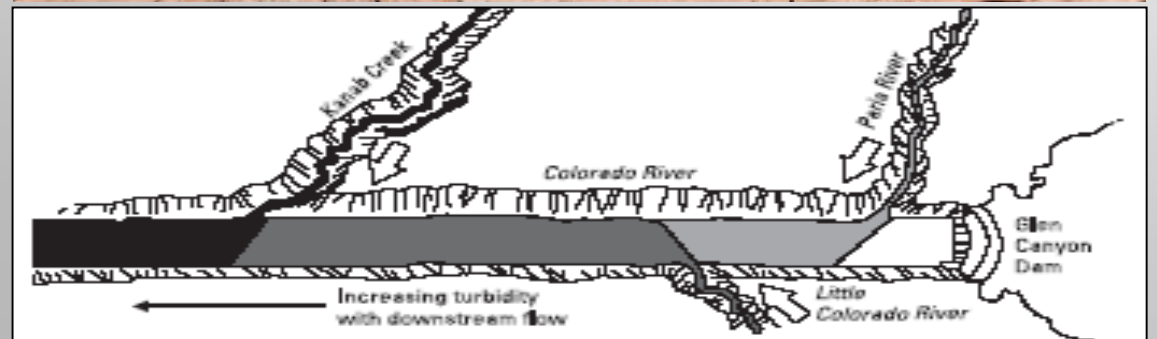
The Spanish Explorers called it "El Río Colorado" because of its muddy nature

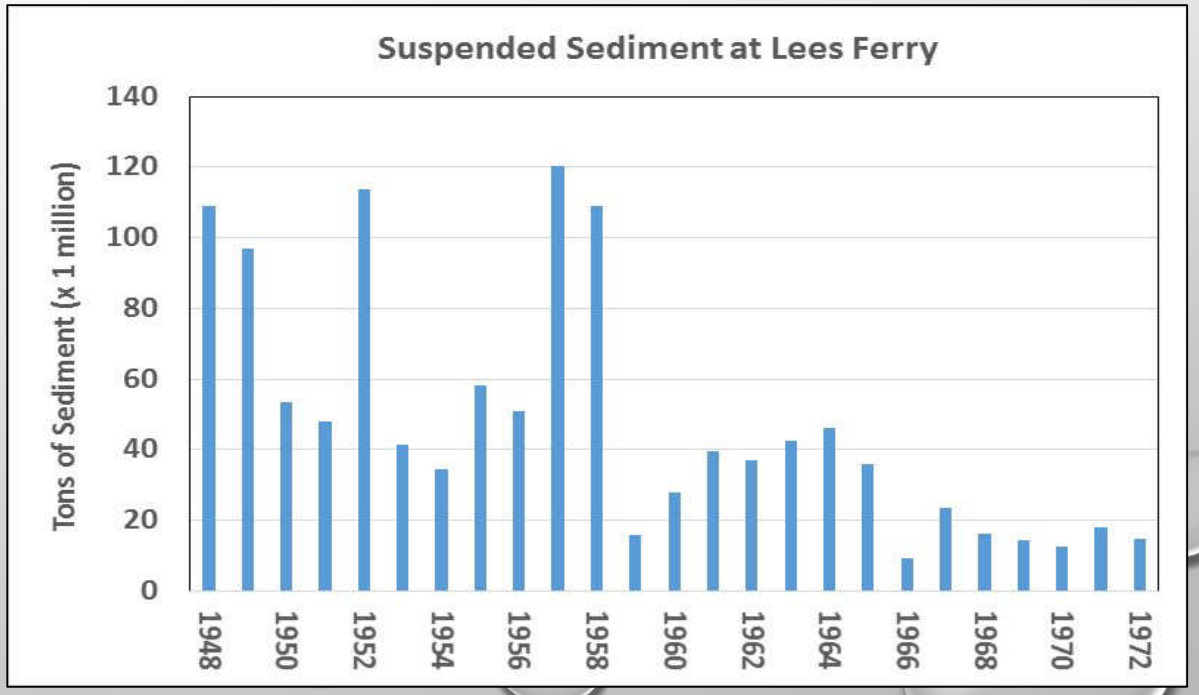
- The Colorado River carries an estimated 45 million tons of sediment annually at Glen Canyon (~ 85 tons/minute)

- Early settlers said that the Colorado River was "*…too thick to drink and too thin to plow…*"

GLEN CANYON DAM

- When Glen Canyon Dam (GCD) was built in 1962, all sediment was trapped in Lake Powell.
- The river below the dam was transformed from muddy to clear—reminiscent of a high mountain stream.
- The dam disrupted the river continuum and a new “ecosystem paradigm” developed.





SOURCES OF SEDIMENT IN GRAND CANYON

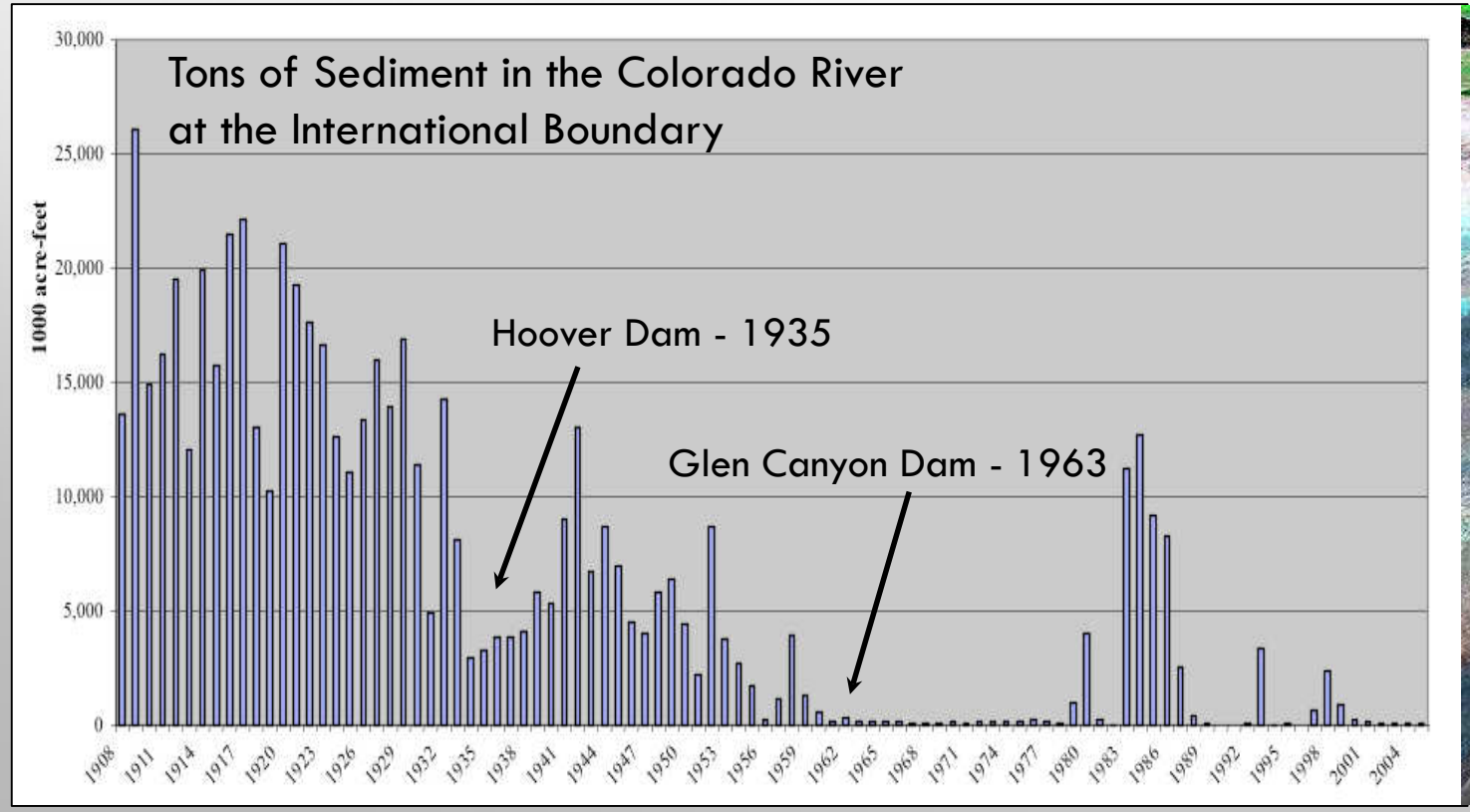
Principal source of sediment in Grand Canyon is tributaries—mostly the LCR and Paria River

Little Colorado River
(~ 75 mi from GCD)

Paria River
(~ 15 mi from GCD)

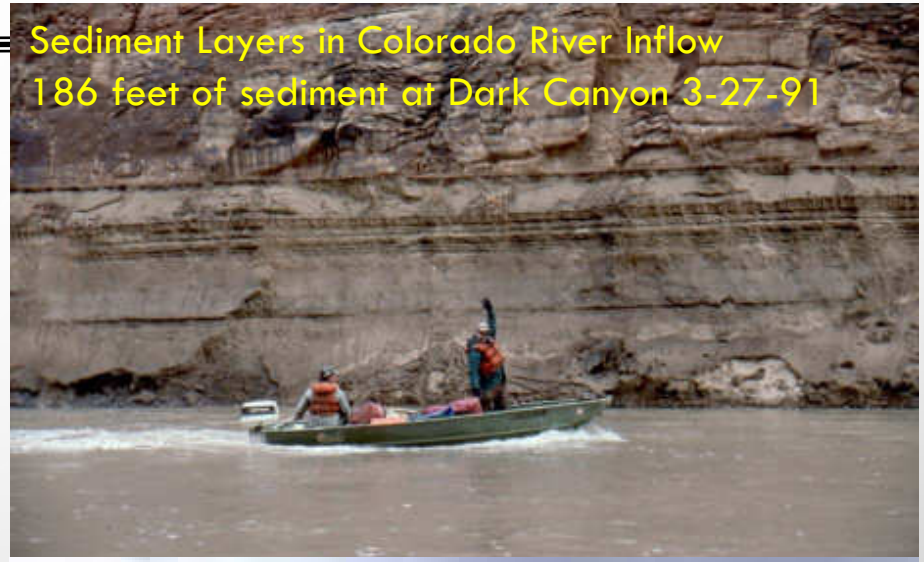
SEDIMENT TO THE GULF OF CALIFORNIA

- Sediment in the Colorado River built a grand delta at the outflow to the Gulf of California.
- Hoover Dam in 1935 substantially reduced total sediment load.
- Glen Canyon Dam in 1962 virtually eliminated all sediment to the delta.
- Record high flows in 1983-85 caused water to spill at the dams and sediment reached the delta.



HOW FAST IS LAKE POWELL FILLING WITH SEDIMENT ?

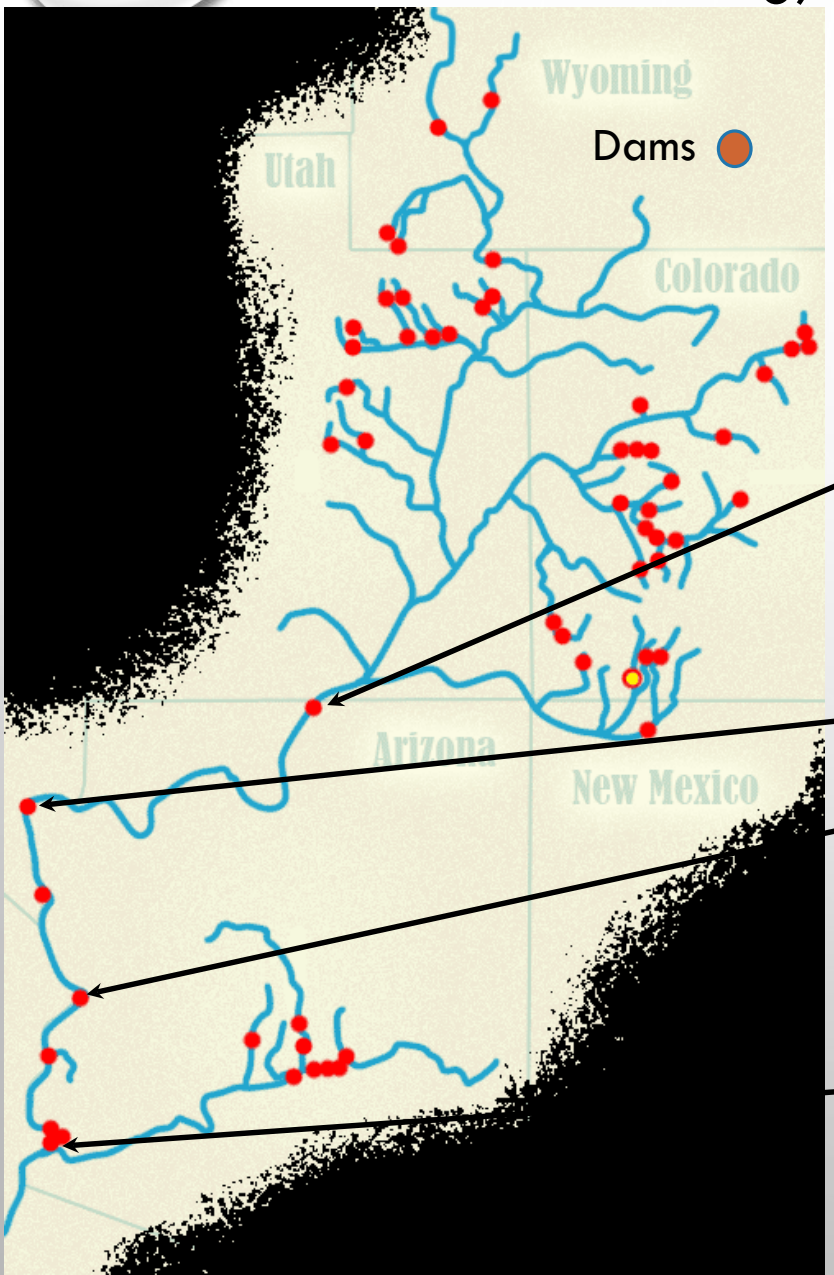
- Lake Powell (LP) is the 2nd largest man-made reservoir in the country, storing ~ 26 maf of water.
- From 1963 to 1986, a total of 868,231 af* of sediment had accumulated in the lake = 3.3% of capacity in 23 years.
- At a rate of 37,749 tons/yr:
  - LP has 1,925,208 af by 2014 (7.4% in 51 years), and
  - LP would fill with sediment in ~ 689 years.
- Declining reservoir levels starting in the year 2000 have exposed much of the sediment at the inflows.

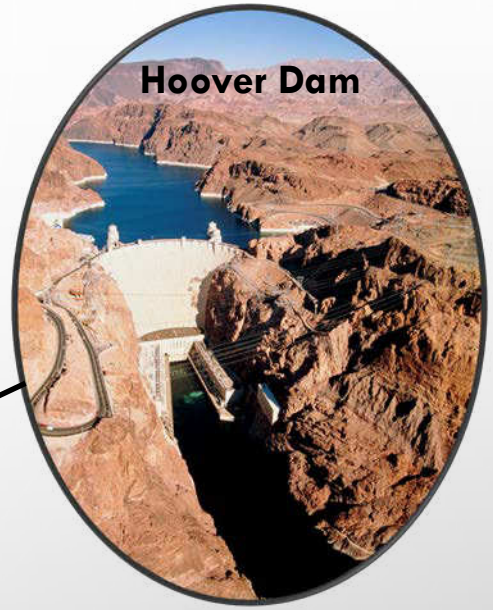


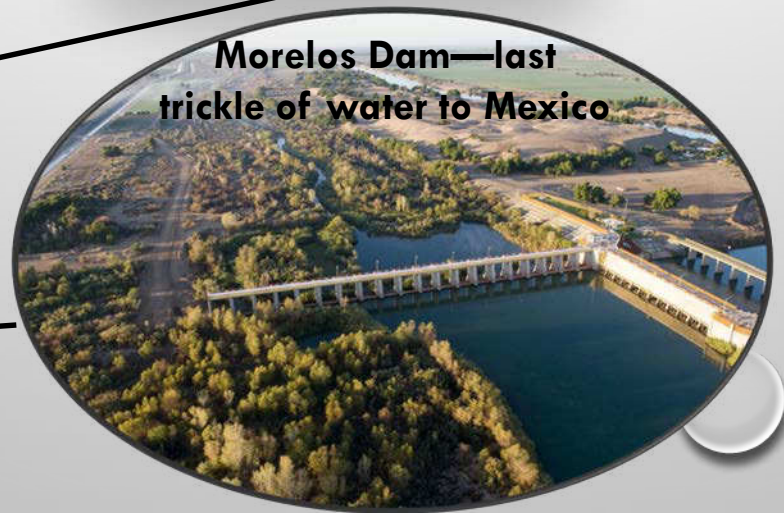
*Ferrari, R.L. 1988. 1986 Lake Powell Survey. REC-ERC-88-6. Bureau of Reclamation, Denver, CO.

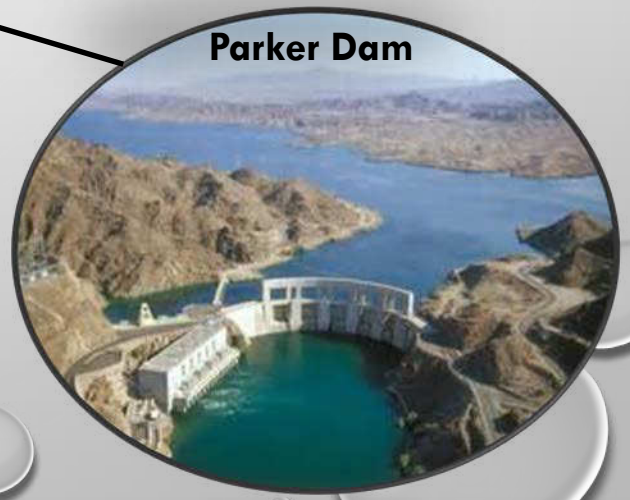
DAMMING THE COLORADO RIVER

57 major dams were built on the Colorado River in the 1900s transforming the river into a series of reservoirs and short cold clear reaches







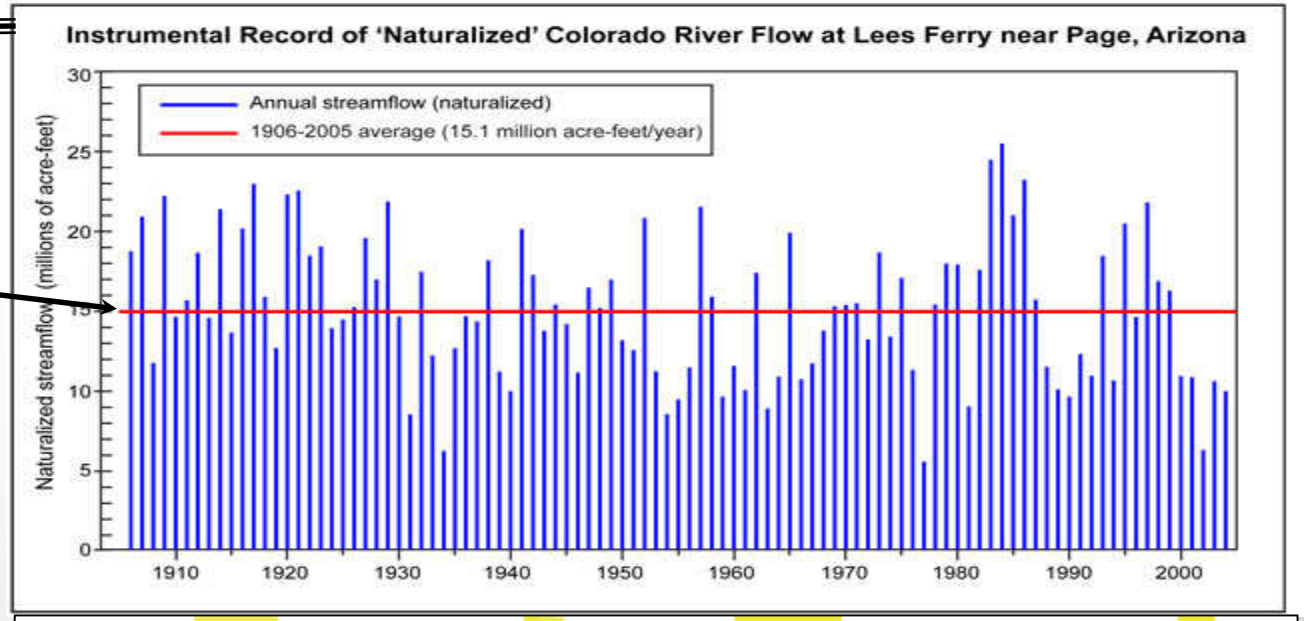


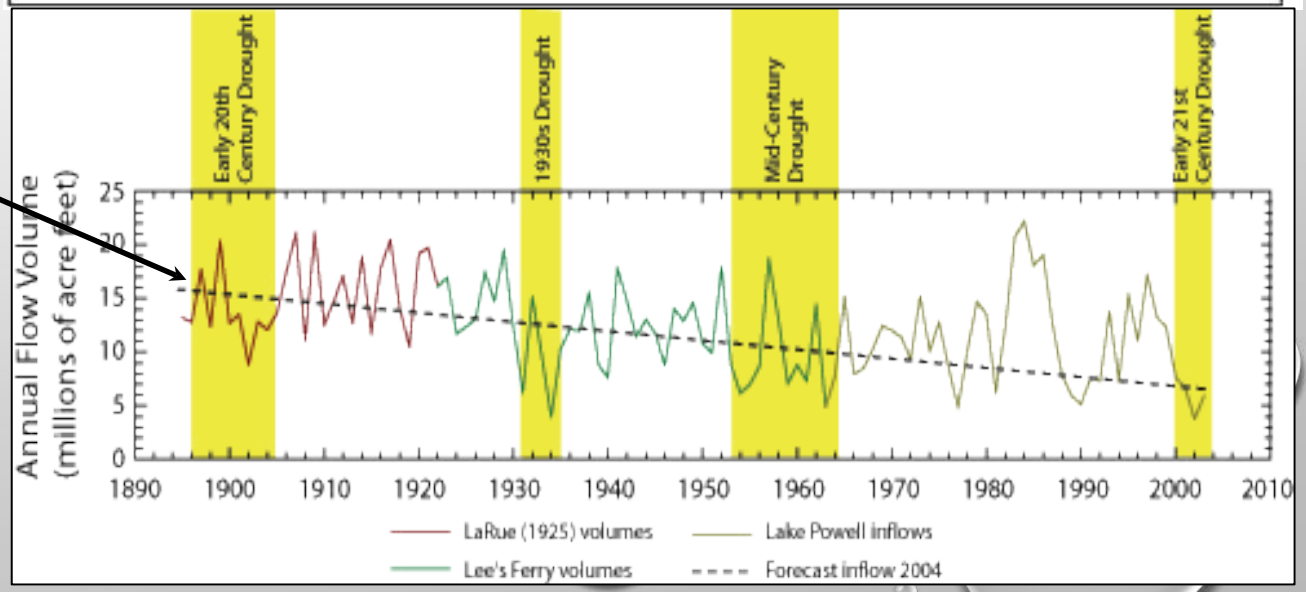
2. RIVER FLOW

- Long-term average flow of the Colorado River at Lees Ferry is ~ 15.1 maf.

- However, annual flow volume has decreased from ~ 16 maf to < 10 maf.

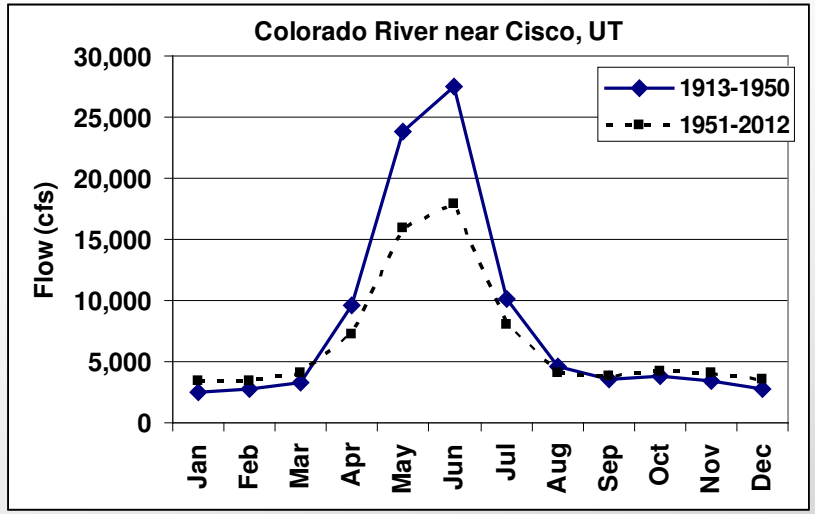
- The Colorado River Basin has experienced 4 periods of drought:
  - Early 20th Century
  - 1930s
  - Mid-20th Century
  - Early 21 Century



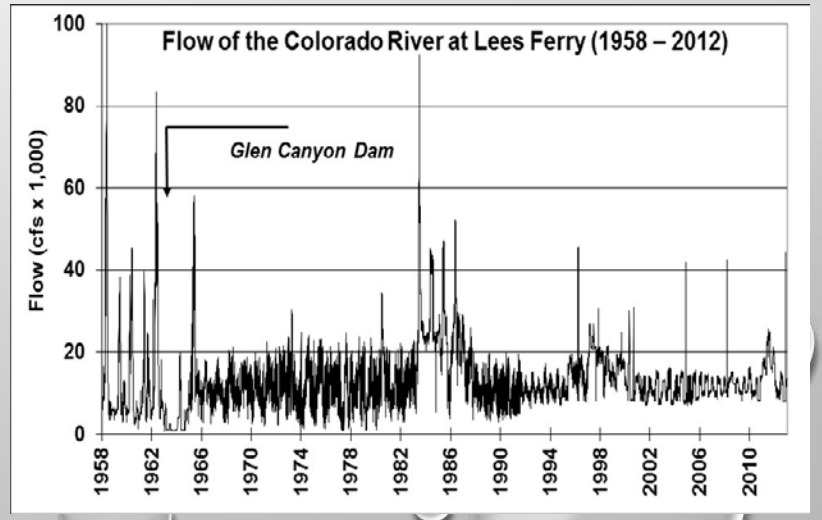


DAMS HAVE DRAMATICALLY ALTERED RIVER FLOW

- Dams transformed the river from seasonal flooding to reduced spring peaks and increased base flows.

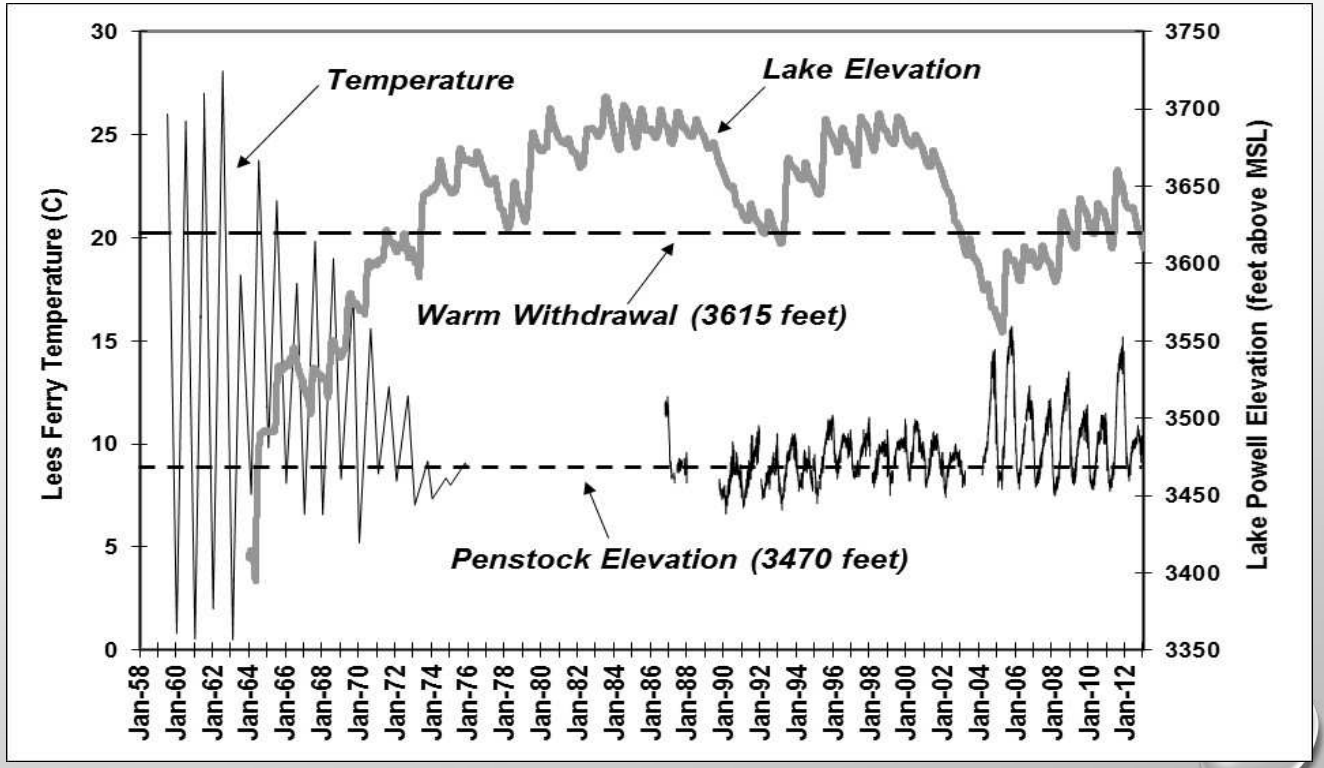


- Below Glen Canyon Dam, spring peaks of > 100,000 cfs were reduced to < 30,000 cfs.
- Dam releases have fluctuated from 3,000 to 30,000 cfs in 1 day.

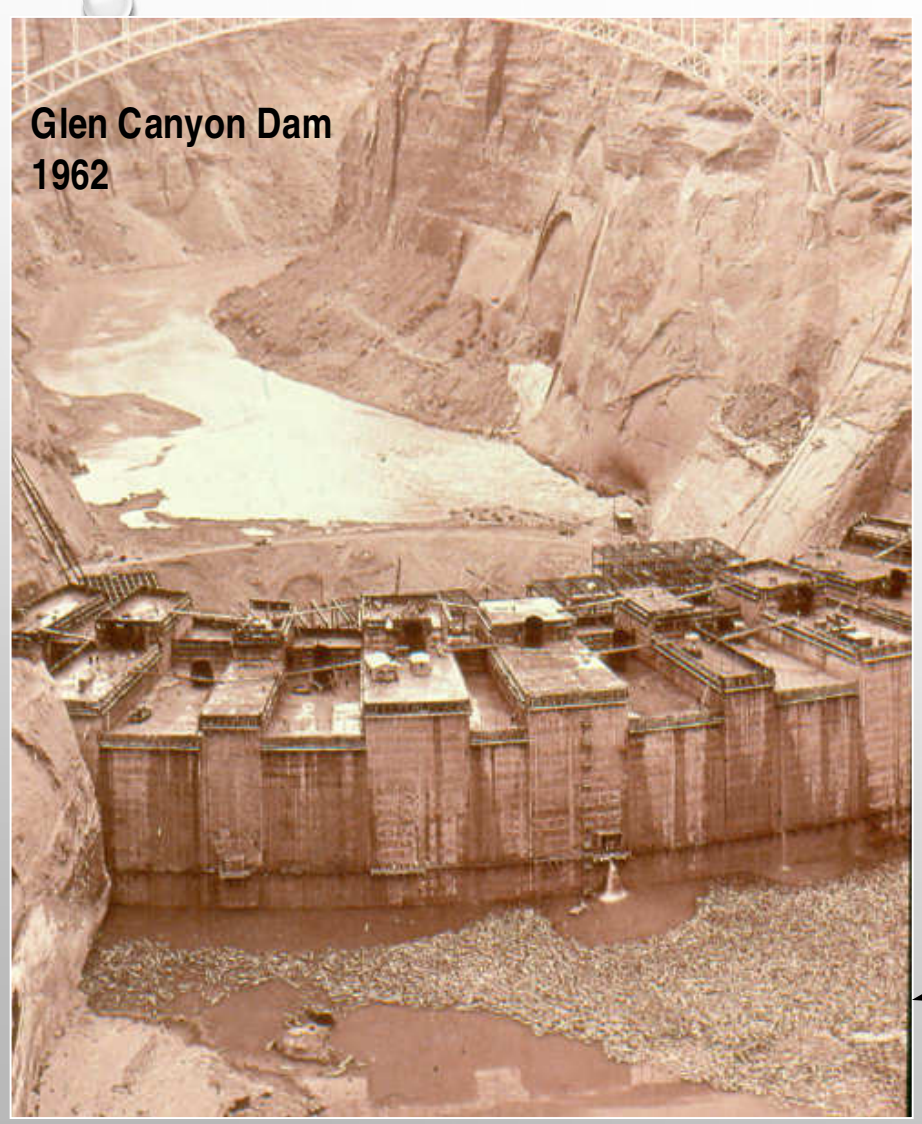


3. TEMPERATURE

- Glen Canyon Dam began impounding the Colorado River in March 1963.
- It took about 10 years—until 1973—for Lake Powell to reach a sufficient depth to release only cold water from the penstocks (3470').
- After 1973, dam release temperature was ~ 7-12°C.
- When lake elevation dropped in 2004, warmer water of 8-16°C was released.
- Temperature change has dramatically affected plants and animals:
  - Pre-dam = 0-30°C
  - Post-dam = 7-16°C



4. WOODY DEBRIS



- The Colorado River carries millions of tons of trees, logs, branches, limbs, leaves, uprooted plants (woody debris).
- Woody debris is ground up by the river into fine and coarse particulate organic matter (FPOM and CPOM) which becomes the energy (carbon source) for all aquatic life forms.
- This organic matter is broken down by molds and fungi so it can be consumed by aquatic insects and crustaceans.
- The aquatic insects and crustaceans are the primary source of food for fish.
- All of the woody debris is trapped in Lake Powell; only some is brought into the Grand Canyon by tributaries like the Paria River and the Little Colorado River.

Woody debris in Cataract Canyon during record spring flood of 1983.

Woody debris trapped behind Glen Canyon Dam as it was being built in 1962.

AQUATIC INVERTEBRATES

- Historically the Colorado River in Glen, Marble, and Grand Canyons supported an invertebrate community largely dependent on woody debris as a food source and as shelter.
- Principal forms included mayflies, stoneflies, caddisflies,* dobsonflies, damselflies, and midges.

The **mayflies** were adapted to swift currents and some burrowed into the mud and sand.

The **stoneflies** were also adapted to swift currents and clung to rocks and wood with graspers and claws.

The **caddisflies** were either in attached cases—or clung to rocks with large hooks and spun a web to trap food particles.

**mayflies, stoneflies, and caddisflies are members of the orders Ephemeroptera, Plecoptera, and Trichoptera (EPT)*

THE NEW FOOD BASE

Clear water has allowed algae species to thrive:

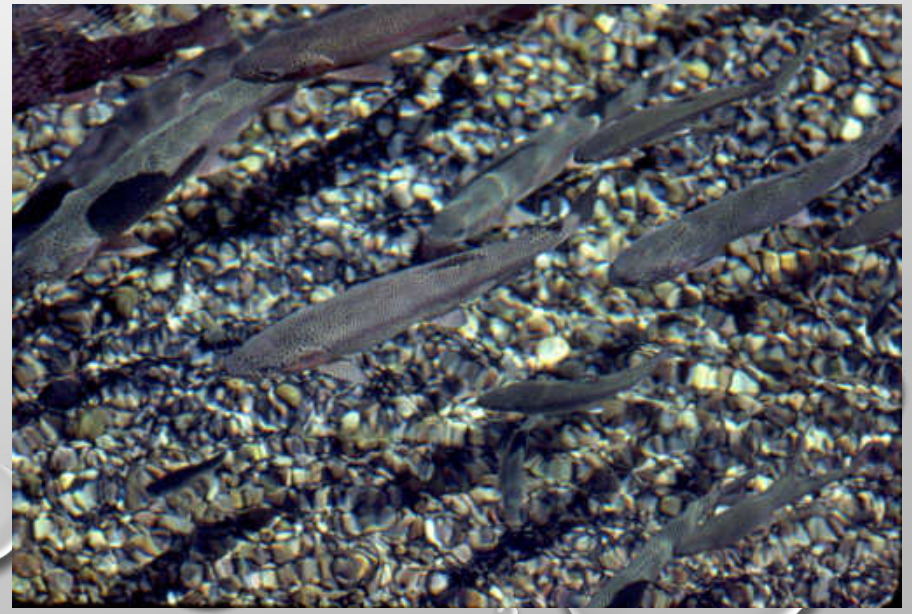
- *Cladophora glomerata* can grow up to 1 foot per day.
- Diatoms high in lipids (fats) graze on the green algae.
- The introduced amphipod *Gammarus lacustris* feeds on the diatoms.
- The *Gammarus* is an important food for fish.

THE NEW ECOSYSTEM PARADIGM

- A new ecosystem has become established downstream of large mainstem dams that we do not fully understand.
- The river continuum has been disrupted and segments of clear cold streams now occur where the river was historically muddy and warm.
- The four fundamental cornerstones of the river ecosystem have been altered:
  - Much of the sediment is stored in reservoirs and only a fraction is transferred through the entire river system.
  - Spring floods has been reduced and low summer and winter base flows have been increased.
  - The large water temperature range of 0-30°C has been replaced with a smaller cooler year-around range of 8-12°C.
  - Much of the woody debris is retained in reservoirs and the carbon energy source has been altered.

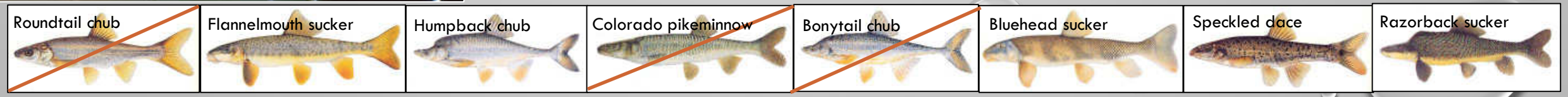
FISHERIES

- Cold clear releases from Glen Canyon Dam have created a blue-ribbon trout fishery at Lees Ferry that is known world-wide.
- Anglers spend an estimated 10,000 user days annually at Lees Ferry.
- The Lees Ferry trout fishery is a big part of the $26 million dollar recreational industry in the Grand Canyon.



NATIVE FISH POPULATIONS

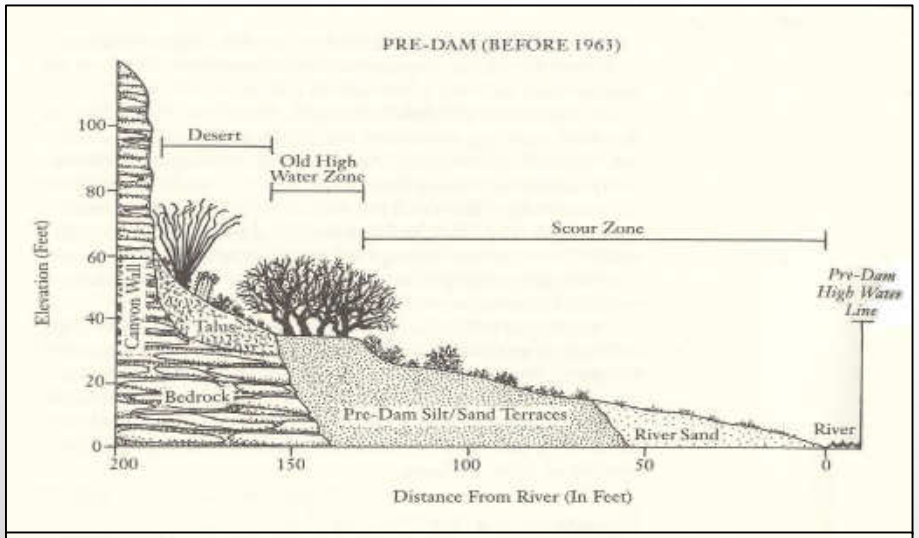
- Cold clear releases from Glen Canyon Dam reduced or eliminated native fish populations, including the top predator.
- The humpback chub population in Grand Canyon is the largest in existence…
- and the razorback sucker is beginning to invade the lower Grand Canyon from a population in Lake Mead.
- Of 8 native species, only 5 remain in Grand Canyon.

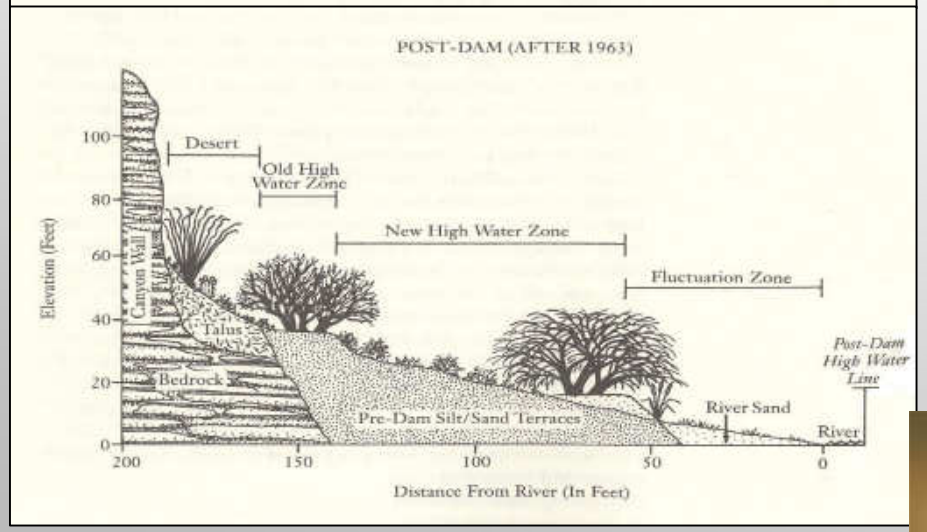


RECREATIONAL BOATING

- The Grand Canyon is world renown for whitewater rafting made possible year-around by regulated dam releases > 8,000 cfs compared to historic summer-time lows of < 5,000 cfs.
- Raft trips through the 225 miles from Lees Ferry to Diamond Cr. are capped at 115,500 user days annually.
- Recreational boating also takes place from the dam to Lees Ferry and a rafting operation by the Hualapai Tribe is also conducted from Diamond Cr. to Pearce Ferry.

RIVER-SIDE PLANTS AND ANIMALS





*Figures from Carothers and Brown . The Colorado River through Grand Canyon.

- The channel of the Colorado River within the 100-yr flood plain was scoured of vegetation by high sediment-laden flows.
- Dams reduced the high spring flows and removed the sediment, allowing vegetation to invade the once barren shoreline.
- This changed the nature of the riparian vegetation and the animal life along much of the Colorado River.

*Photos from Stephens and Shoemaker 1987. In the footsteps of John Wesley Powell. Johnson Books, Denver, CO.

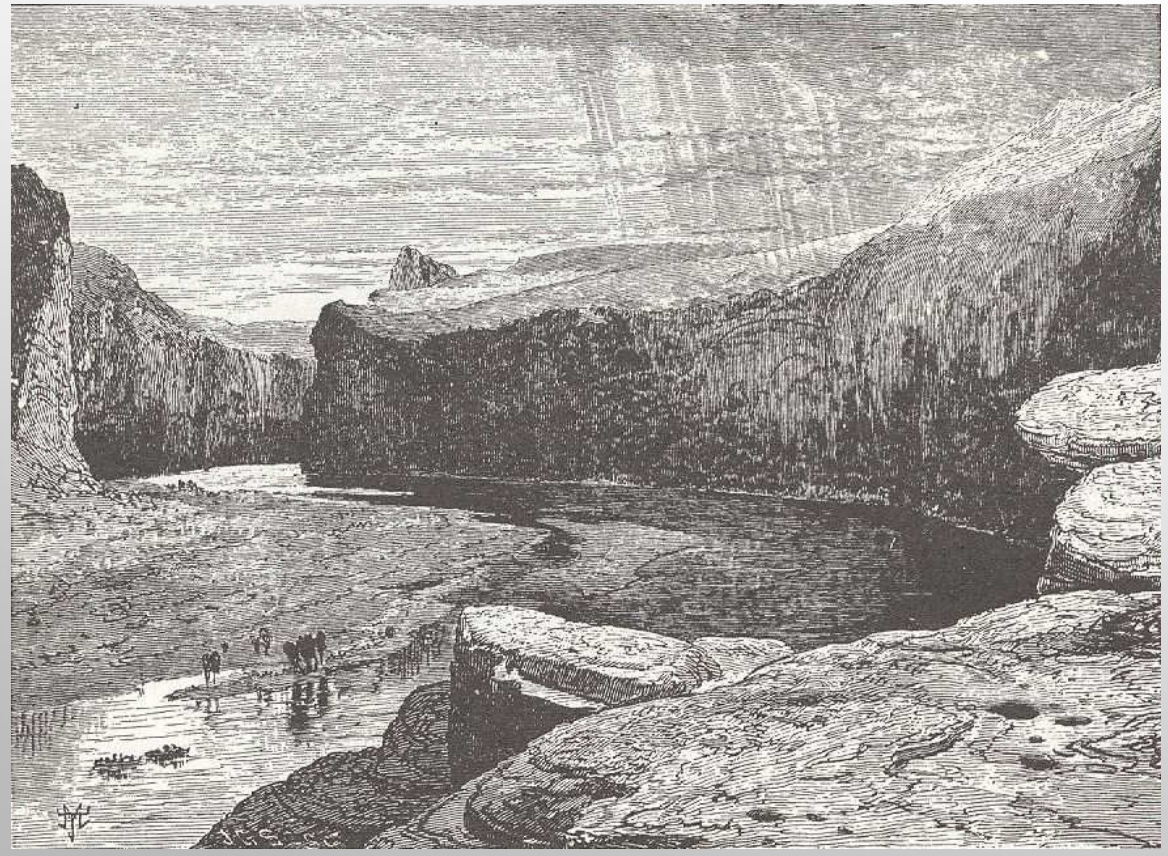
"You cannot see the Grand Canyon in one view, as if it were a changeless spectacle from which a curtain might be lifted, but to see it you have to toil from month to month through its labyrinths. It is a region more difficult to traverse than the Alps or the Himalayas, but if strength and courage are sufficient for the task, by a year's toil a concept of sublimity can be obtained never again to be equaled on the hither side of Paradise."

J.W. Powell 1895

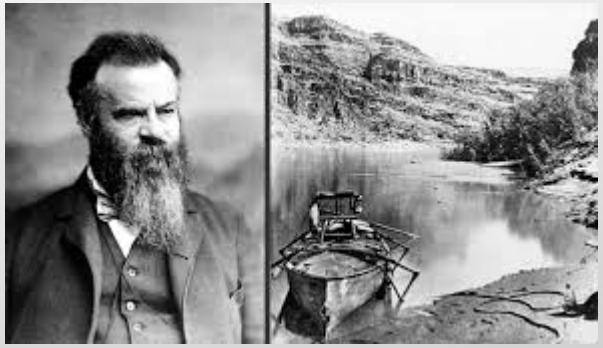
GLEN CANYON

"On the walls, and back many miles into the country, numbers of monument-shaped buttes are observed. So we have a curious ensemble of wonderful features—curved walls, royal arches, glens, alcove gulches, mounds, and monuments. From which of these features shall we select a name? We decide to call it Glen Canyon."

J.W. Powell 1895



Glen Canyon



Island Monument

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