

The Colorado River

An Ecological Case Study in
Coupled Human and Natural Systems

edited by

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Note: In PDF format most of the images in this web paper
can be enlarged for greater detail.

“Ten years or a hundred years or a hundred thousand years from now, the world's supply of freshwater will remain much the same. Such an assertion cannot be made about the world's population or about mankind's capacity for devising technologies to use-and abuse-the limited water supply. Put another way, the fate of all natural bodies of water is inseparably tied to human values about the quality of life and the number of people any part of the world can properly support.

Seen from this perspective, the Colorado River is a microcosm of the world's water supply. Lessons learned from its past and policies adopted for its future are of fundamental importance not only for those dependent on the river, but also for people everywhere.”

Norris C. Hundley from *The West Against Itself:
The Colorado River-An Institutional History*

<http://www.movingwaters.org/hundleychapter.html>

Introduction

In studying humanity's impact on the world's ecosystems there are few better examples than the use and misuse of the Colorado River in the American southwest. This web paper introduces the Colorado as a case study in how humans have changed their world and the lessons that can be learned from those changes.

The story of the Colorado River is a study in complex environmental systems where human and natural systems are coupled in complex loops of cause and effect. It is also the story of coupled biological and physical systems. The geological history of the Colorado River has played a central role in the evolution and distribution of the plants and animals in this region. And it is the story of humans and their use of technology. The Colorado is "the most dammed, diverted, and depleted river in the United States..." and is thus an unintended experiment in how we should, and should not, manipulate the natural world with our technology.

Over its entire basin, the Colorado River has been changed from its natural state perhaps as much as any river system in the world. The demands for water and power in the arid West have drastically altered the system by impoundments, irrigation diversions, diking, channelization, pollutants, and destruction of bank habitats by cattle grazing and other practices. Some reaches, ranging from desert spring runs to main rivers, have been completely dewatered or, seasonally, their flows consist almost entirely of irrigation return laden with silt and chemical pollutants. The Gila River of Arizona, one of the Colorado's largest tributaries, has not flowed over its lower 248 miles (400 km) since the early 1900's. Only a few small tributaries, mostly at higher elevations, retain most of their natural characteristics.

The Colorado River watershed encompasses 244,000 square miles, including portions of seven U.S. states. Major tributary streams include: the Green River in Wyoming, Utah and Colorado; the Gunnison River and Yampa River in Colorado; the San Juan River in Colorado, New Mexico and Utah; and the Gila River in Arizona and New Mexico. Thirty million people in the seven-state Colorado River Basin use water taken from the Colorado River for household needs—drinking water, bathing, toilets, lawn watering. The majority of municipal users are in Southern California.

The Colorado is the most dammed, diverted, and depleted river in the United States, with more than 40 Bureau of Reclamation dams, reservoirs and diversions making up its plumbing system. The river's average annual flow is about 15 million acre-feet. An acre-foot is about 326,000 gallons. Because of the many reservoirs, evaporation and seepage account for between fifteen to twenty percent of this annual flow.

However, most of the Colorado River—about eighty percent of what's available after evaporation—is used for agriculture. Because so much water is taken from the river for agricultural and municipal use, the Colorado no longer reaches the Gulf of California, except in floods. In fact, the river has been over-allocated, meaning that more water has been claimed by users than actually exists.

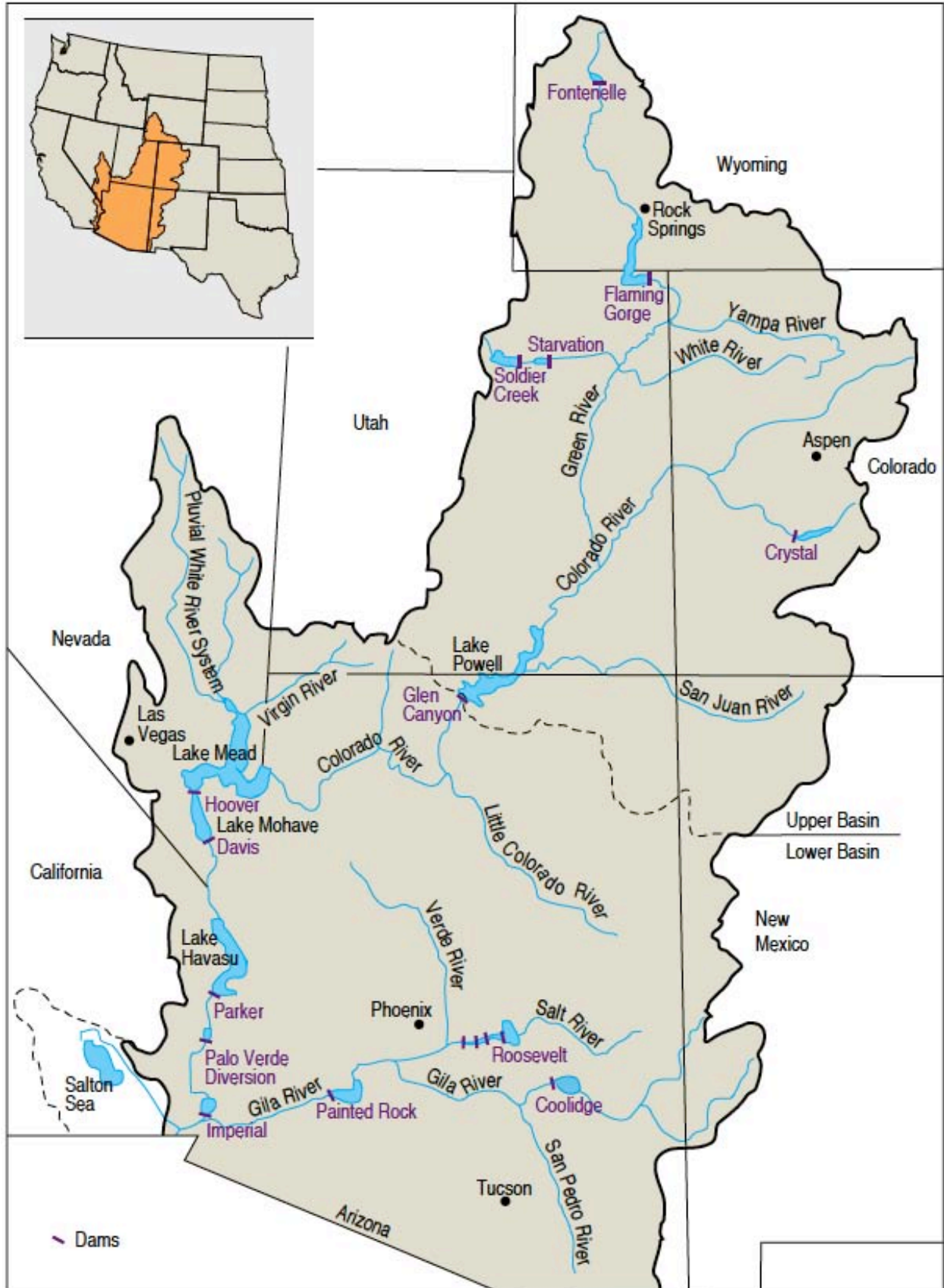
The environmental impact of taking every drop of water is that riparian habitats and their dependent species are dying all along the river. In the Grand Canyon, four of the eight native mainstream fish species are either endangered or extirpated, partially due to the depleted state of the ecosystem. The Salton Sea, a large agricultural drainage basin in southern California, is polluted by toxic run-off. International treasures such as the Grand Canyon, Dinosaur National Monument, and the Colorado River delta are all suffering. Over ninety percent of the delta, once a vast 1.9 million-acre wetland, has disappeared.

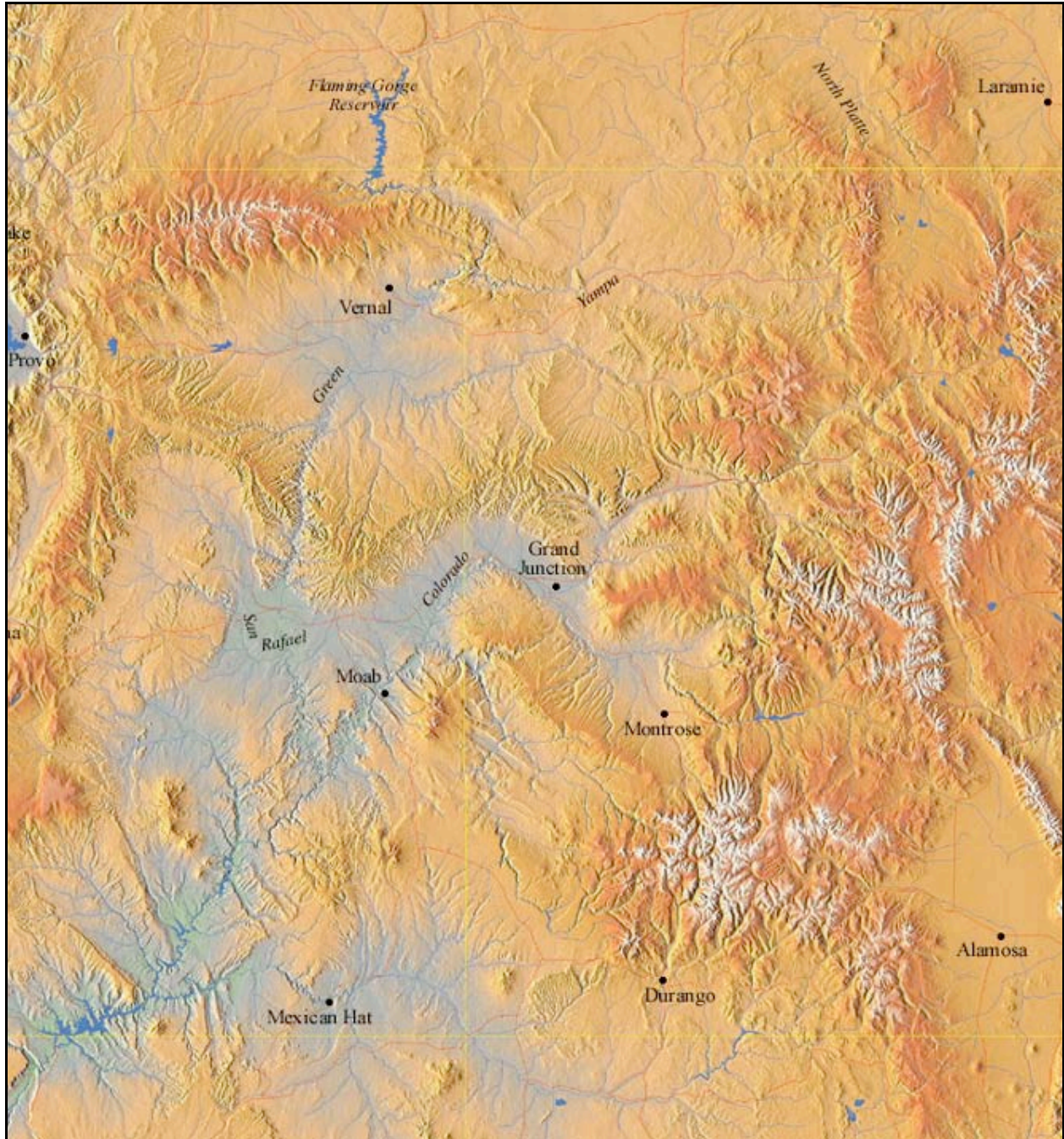
Territories with rights to the Colorado River are divided into the Upper and Lower basins. The Upper Basin states are Utah, Wyoming, Colorado and New Mexico. The Lower Basin states are California, Arizona and Nevada. Each basin is allocated 7.5 million acre-feet annually under the Colorado River Compact of 1922. From there, numerous compacts, agreements, treaties and court decisions— known collectively as the Law of the River—divide the waters of the Colorado even further.

Web Reference

<http://www.sierraclub.org/rcc/southwest/coreport/index.asp>

On the following page is a map from Starnes, Wayne C. (1995) of the Colorado River basin showing the major tributaries and dams.

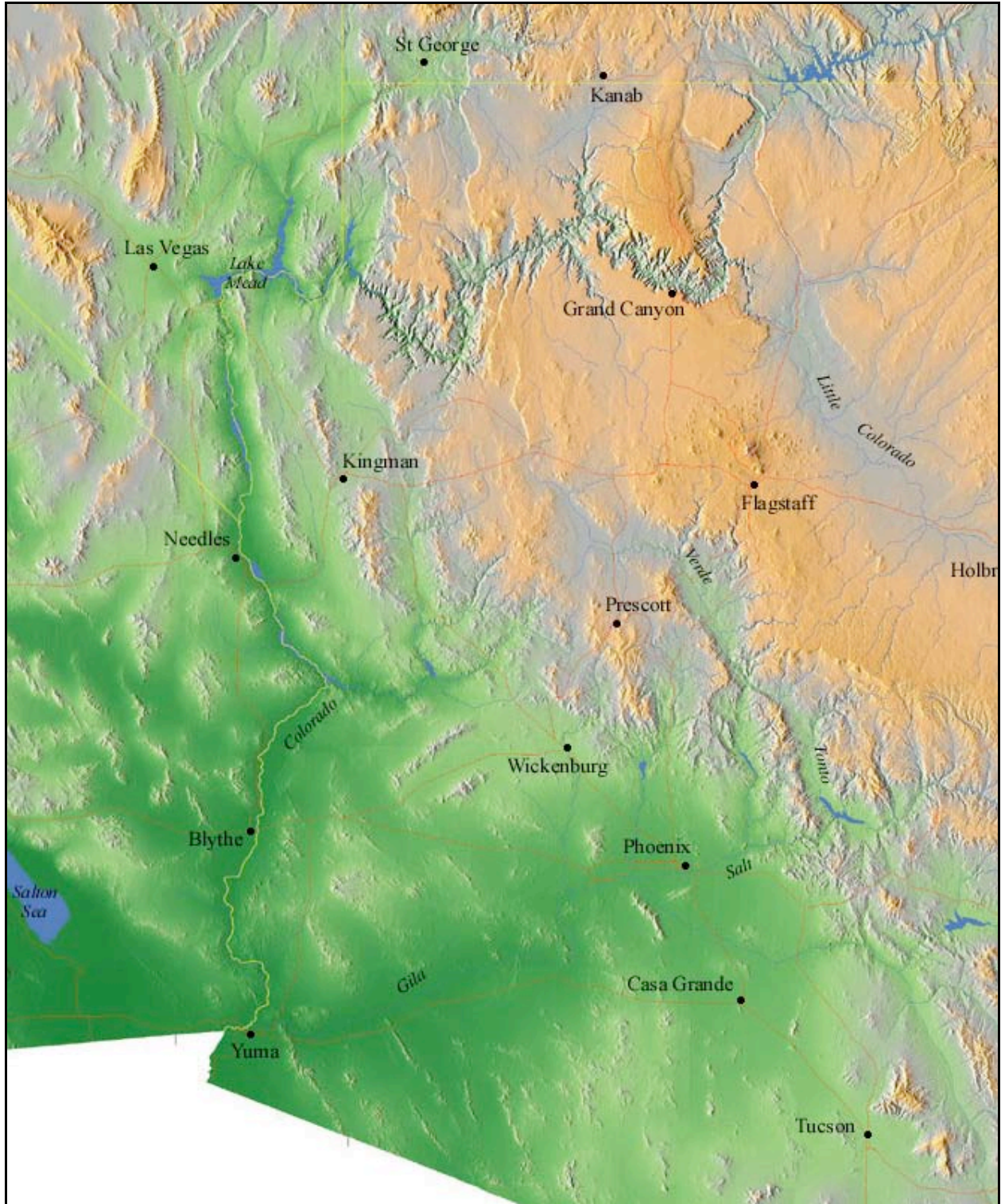




Colored Relief Map of the upper portion of the Colorado River

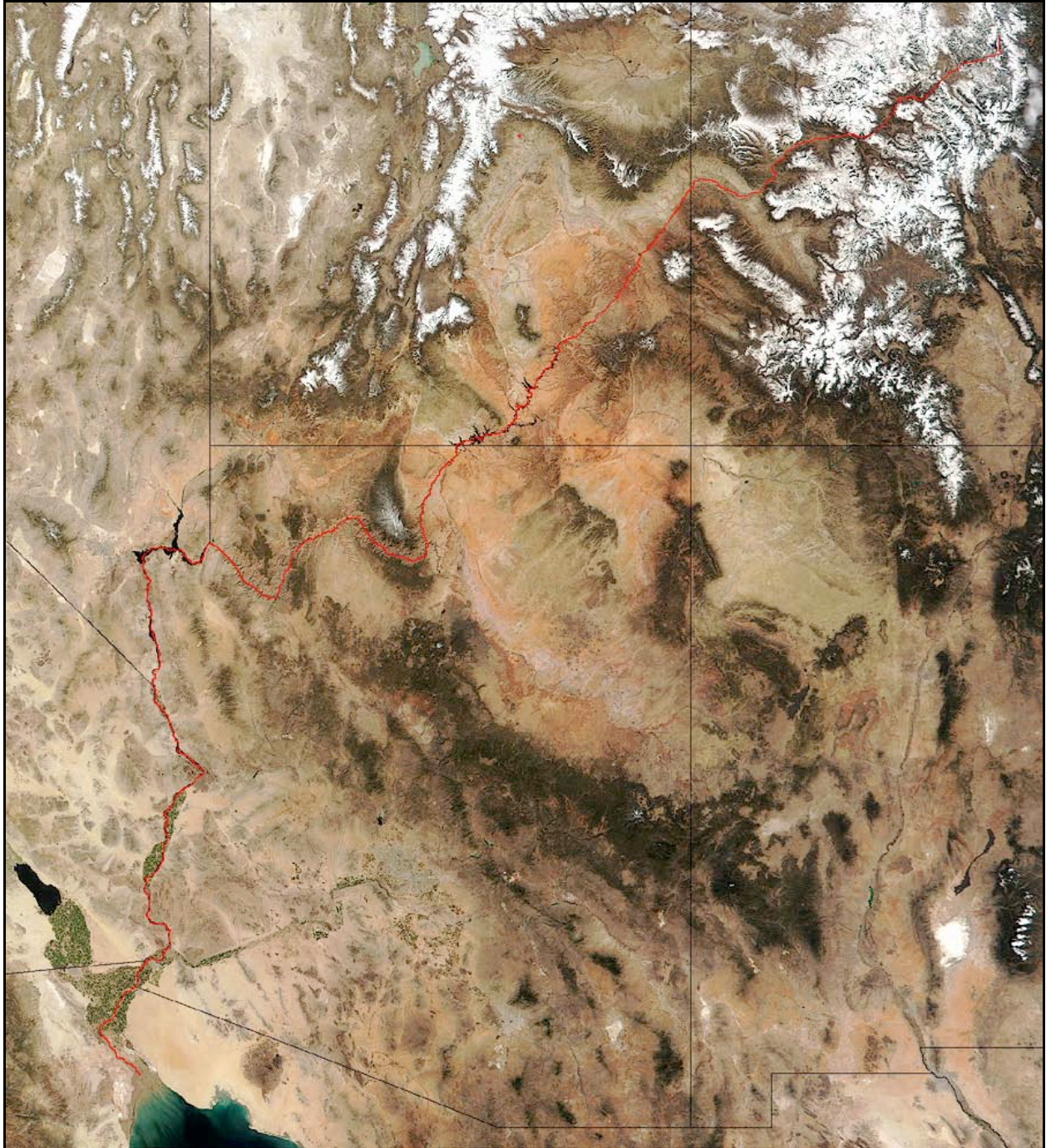
In PDF format this map can be enlarged for greater detail.

(Relief Maps courtesy of Chalk Butte Inc.)



Colored Relief Map of the lower portion of the Colorado River

In PDF format this map can be enlarged for greater detail.



The Colorado River (red line) flows from the Rocky Mountains (top right) southwest for 1,470 miles (2352 km) traversing three major desert regions and the states of Colorado, Utah, Nevada, Arizona, and California in the U.S., and Sonora and Baja California in Mexico, before reaching the Gulf of California (bottom left). In this March 31, 2002, satellite image the entire length of the river can be seen.

(MODIS image courtesy of NASA)

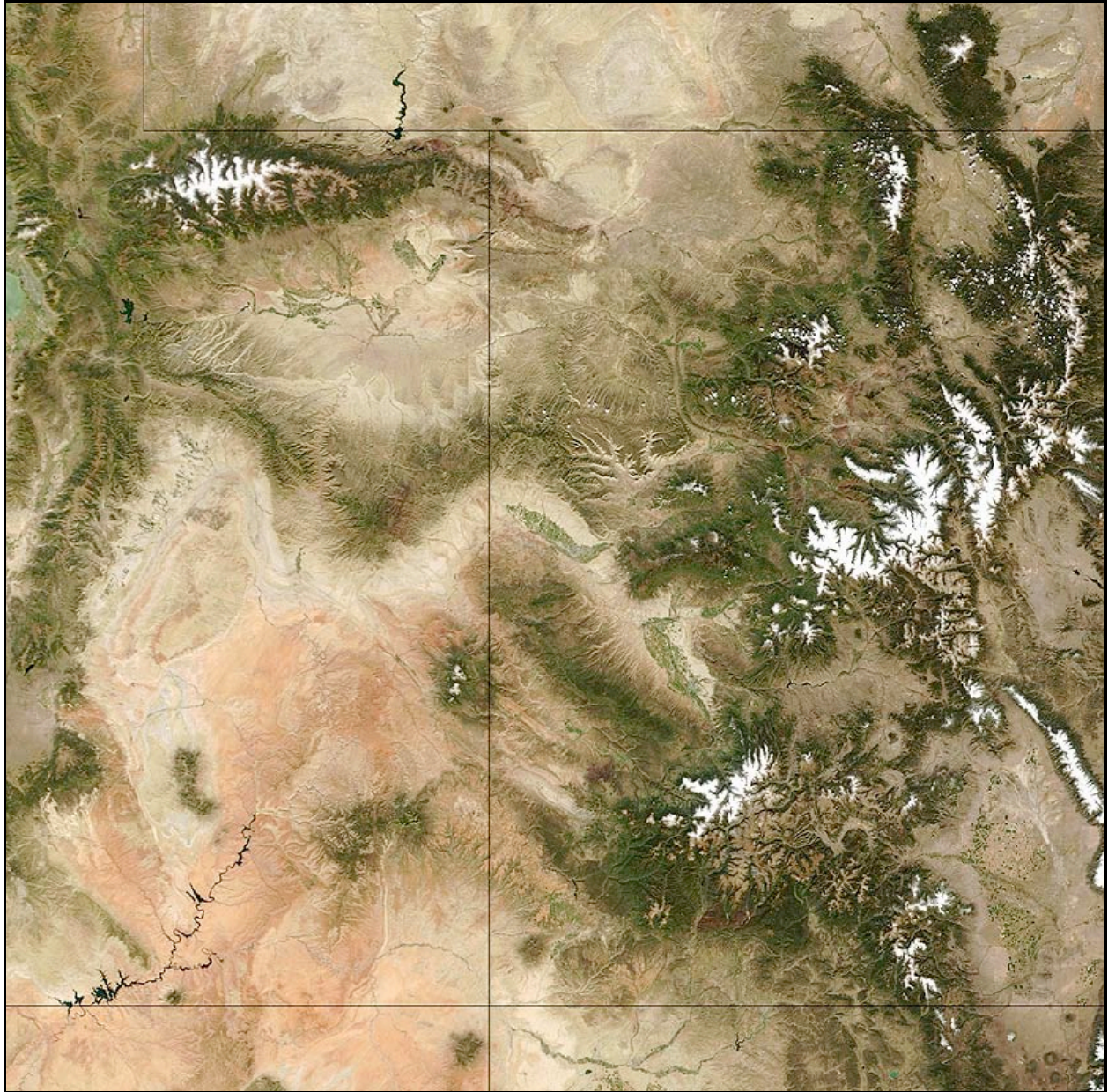


Never Summer Range in Rocky Mountain National Park, Colorado

The waters of the Colorado River originate in the Rocky Mountains of Colorado in Rocky Mountain National Park nearly 13,000 feet (3960 m) above sea level.



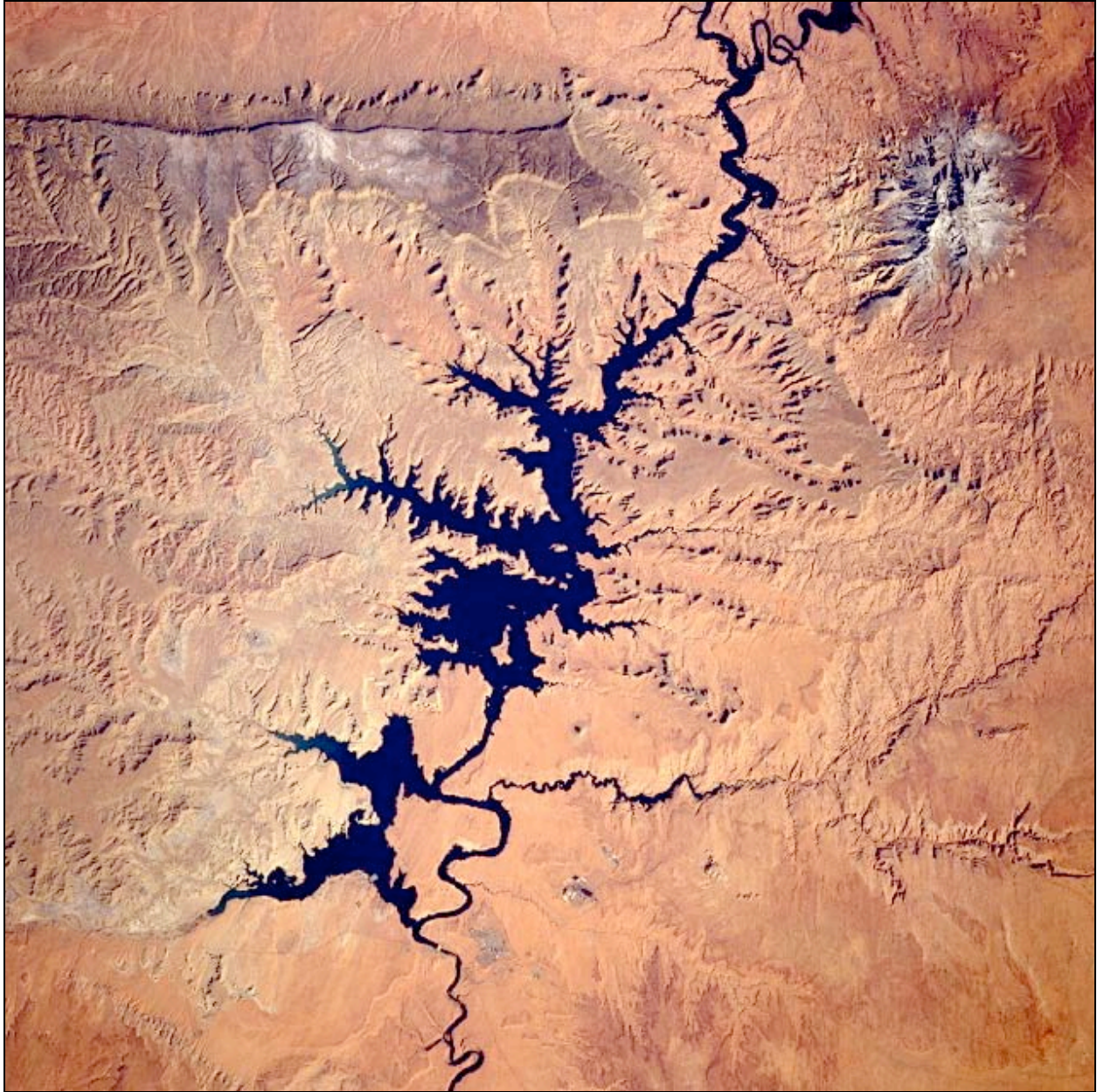
At its headwaters the Colorado River is a quiet mountain stream flowing through the meadows of the Kawuneeche Valley. In this picture of the river, note the horizontal scar on the mountainside to the right. The scar was made in the early 1900s building the Grand Ditch. The Grand Ditch, located on the eastern slope of the Never Summer Range, diverts water that would normally flow into the upper Colorado River across the continental divide into the Cache La Poudre River for eventual use in the Front Range of Colorado. It is the first, but certainly not the last, man-made water diversion along the length of the Colorado River.



The Upper Colorado River Basin

The Colorado River is divided by the Colorado River Compact of 1922 into upper and lower basins at Lee's Ferry, fifteen miles below the Glen Canyon Dam. Lake Powell, created by the Glen Canyon Dam, can be seen in the lower left corner of this image.

(September 24, 2002, MODIS image courtesy of NASA)



The Colorado River and Lake Powell November 1994

Lake Powell, part of Glen Canyon National Recreation Area, is featured in this spectacular photograph. More than 180 miles (290 kilometers) long, Lake Powell has more shoreline than the United States west coast because of the many small canyons feeding off the main canyon. Southeast of the lake stands snowcapped Navajo Mountain 10,388 feet (3,168 meters) high. Visible is the northwest-southeast-trending Kaiparowits Plateau, part of the vast Colorado Plateau. Horseshoe Bend on the Colorado River below Glen Canyon Dam is the sharp bend shown at the bottom of this image.



Upper Lake Powell with Navajo Mountain left of center in skyline and the Kaiparowits Plateau in the upper left.



Lake Powell, May 2007

Note the prominent "bathtub ring" caused by low water.

Web Reference

http://en.wikipedia.org/wiki/Lake_Powell



Page Arizona and the Glen Canyon Dam

This Astronaut photograph of Page, Utah (center), the Glen Canyon Dam (below right of center), and the west end of Lake Powell (bottom center and left) was taken from the International Space Station.



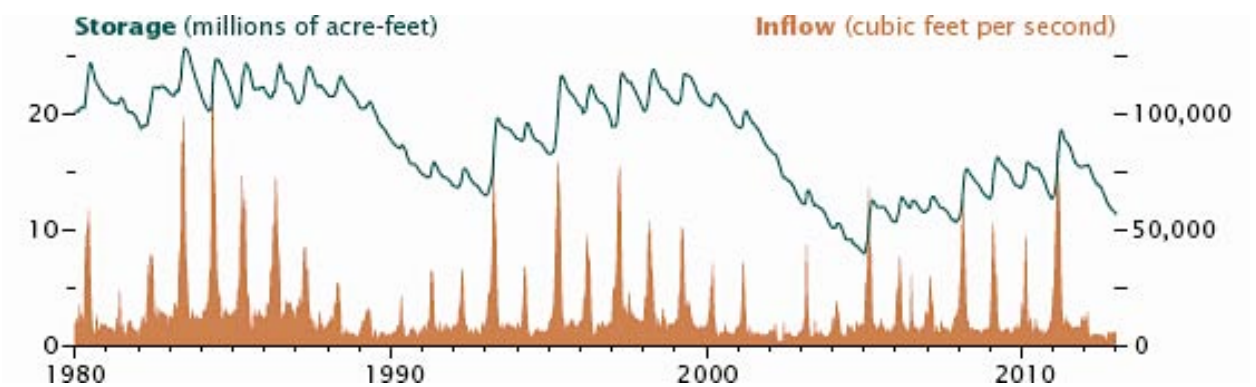
This isolated community near the northern Arizona border is of special interest because of its origin and location. Unlike other towns in the area, Page was created in 1957 to house workers and their families during the construction of nearby Glen Canyon Dam on the Colorado River. Its 17-square-mile site was obtained in a land exchange with the Navajo Indian tribe. The town is perched atop Manson Mesa at an elevation of 4,300 feet above sea level and ~ 600 feet above Lake Powell.

After the dam was completed in the 1960s, the town grew steadily to today's population of ~ 7,200. Because of the new roads and bridge built for use during construction, it has become the gateway to the Glen Canyon National Recreation Area and Lake Powell, attracting more than 3 million visitors per year.

Page is also the home of two of the largest electrical generation units in the western United States. Glen Canyon Dam has a 1,288,000 kilowatts capacity when fully online. The other power plant to the southeast is the Navajo Generating Station, a coal-fired steam plant with an output capability of 2,250,000 kilowatts.



Lake Powell and the Glen Canyon Dam



The last decade has been rough for the key reservoir in the intricate water storage system that sustains much of the American Southwest—Lake Powell. Inflow between 2000 and 2012 has been the lowest 13-year period on record since the lake was created in 1963.

http://earthobservatory.nasa.gov/Features/WorldOfChange/lake_powell.php



Looking upstream at the Glen Canyon Dam

The Colorado River below Glen Canyon Dam to Lee's Ferry 15 miles downstream is the only section of Glen Canyon left that is not inundated with the waters of Lake Powell.

(Photograph by Nick Wheeler)



Looking downstream from the Glen Canyon Dam

(Photograph by Nick Wheeler)



Horseshoe Bend on the Colorado River below Glen Canyon Dam

(Photograph by Kevin Korell)

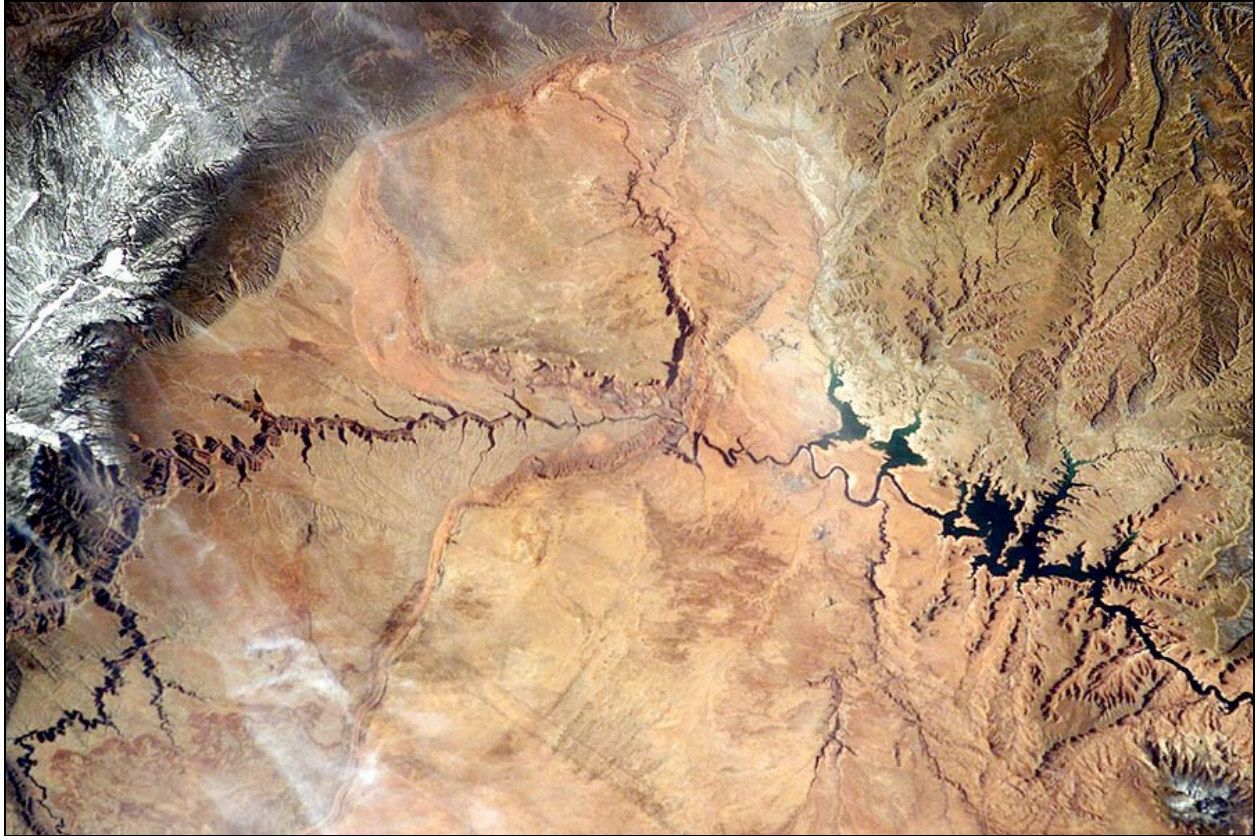


Looking downstream from Horseshoe Bend



Downstream from Horseshoe Bend as the Colorado flows toward Lee's Ferry

(Photograph by Nick Wheeler)



Lee's Ferry Overview

This International Space Station image spans the length of the Colorado River from just north of Navajo Mountain (lower right corner). Then on to Lee's Ferry almost exactly in the center of the image. The Colorado then flows westward from Lee's Ferry down Marble Canyon to the confluence of the Colorado River with the Little Colorado River. The canyon of the Little Colorado can be seen in the southwest corner running north to the confluence.

(February 23, 2003, ISS image courtesy of NASA)



The Colorado River begins its meandering 277-mile journey through the Grand Canyon at the entrance of Marble Canyon just south of Lee's Ferry (shown above).

(Photograph courtesy of Western Treks and USGS)

Web Reference

<http://3dparks.wr.usgs.gov/grca/river/index.html>



The Grand Canyon as it cuts through the Kaibab Plateau

The eastern end of the Grand Canyon can be seen in this spectacular photograph taken from the International Space Station late in 2003. The view is almost directly overhead of the portion of the Grand Canyon that cuts through the Kaibab Plateau with Marble Canyon bottom center. The confluence of the Colorado River with the Little Colorado River is in the lower left.

(ISS image courtesy of NASA)












A Cable Stream Gauge Station over the Colorado River in the Grand Canyon

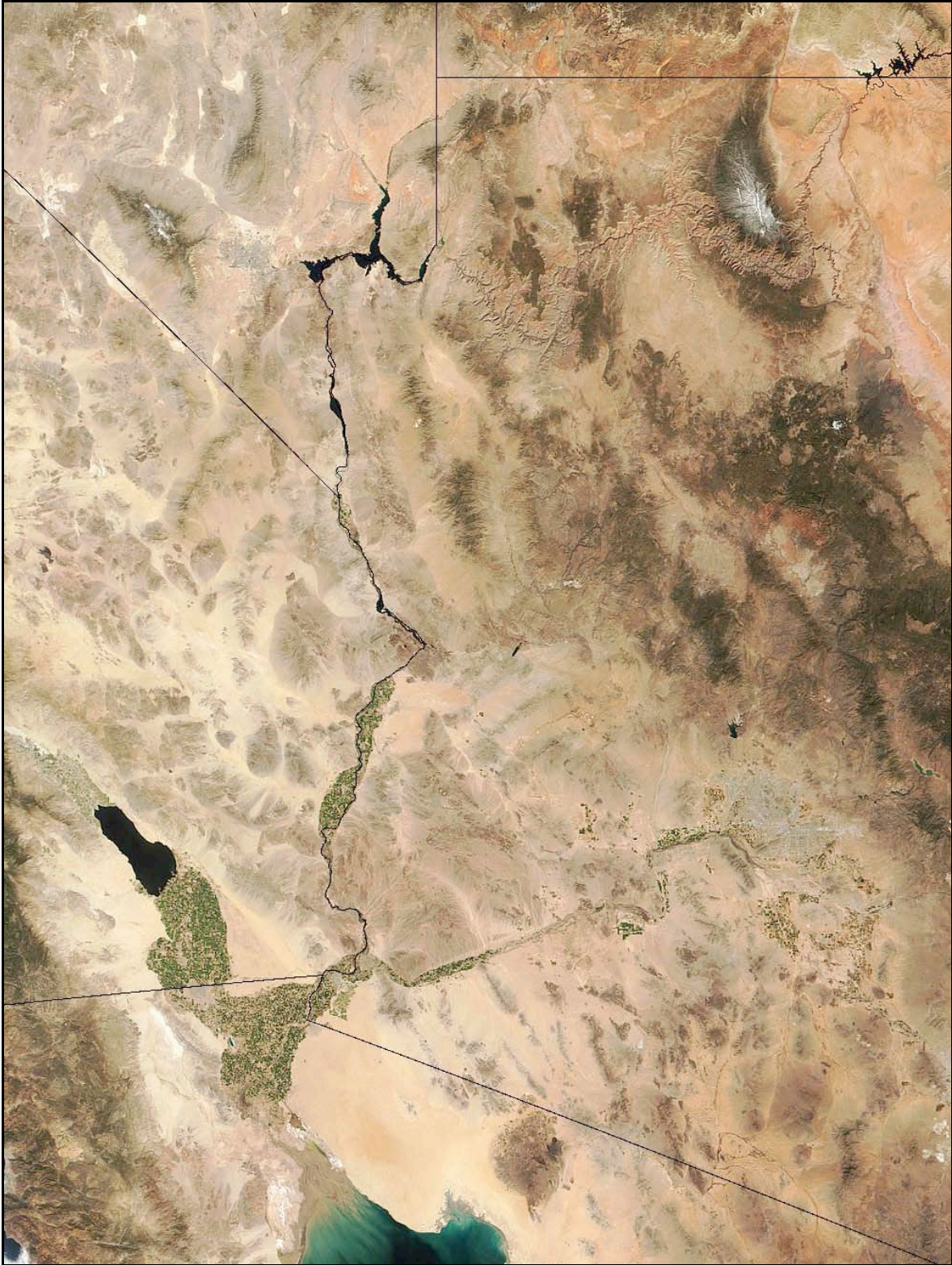
Seven states and a portion of Mexico depend upon the water of the Colorado River. No other major river in the United States is so thoroughly depleted by human consumption. As testament to this fact, the river has not flowed regularly to the Gulf of California for almost four decades.

This stream gauging station near Phantom Ranch in the Grand Canyon is one of the locations where river flow is closely monitored. A cable across the river carries a cage from which a hydrologist can lower instruments into the water to measure a variety of parameters, including water height and velocity. (Note the commercial rafts on the river.)

Web Reference: <http://epod.usra.edu/> (search for 2012-6-28)

Colorado River water allocations ^{[161][162][170]}		
User [↕]	Amount (MAF) ^[n 5] [↕]	Percent ^[n 6] [↕]
 United States	15.0	90.9%
 CA	4.4	26.7%
 CO	3.88	23.5%
 AZ	2.8	17.0%
 UT	1.72	10.4%
 WY	1.05	6.4%
 NM	0.84	5.1%
 NV	0.3	1.8%
 Mexico	1.5	9.1%
Total	16.5	100%

The Colorado River Compact of 1922 specifies how much water can be used by each state and Mexico. Unfortunately, the terms of the Compact were based upon river flow during the previous 30 years, a period of unusually abundant river discharge. Storage behind the Glen Canyon Dam and Hoover Dam help even out the supply water in years of drought. But if storage in the reservoirs falls below an established “trigger” level, which nearly occurred in 2010, the Compact specifies how states must cut back on their water usage. (MAF = million acre feet)



The Lower Colorado River Basin

This MODIS true-color satellite image from March 31, 2002, shows the passage of the Lower Colorado River through several southwestern states. In the image the river

begins in Utah at the far upper right, where Lake Powell is visible as dark pixels surrounded by the salmon-colored rocks of the Colorado Plateau. The Colorado flows southwest through Glen Canyon to the Glen Canyon Dam on the Utah-Arizona border. From there it flows south into Arizona, and then turns sharply west where the Grand Canyon of the Colorado cuts through the Kaibab plateau. The Colorado flows west to the Arizona-Nevada border (upper left), where it is dammed again, this time by Hoover Dam. The dark area at the bend in the river is Lake Mead. The river flows south along the border of first Nevada and Arizona and then California and Arizona. The river, which begins in Rocky Mountain National Park in Colorado, empties into the Gulf of California bottom left of center in this image.

(MODIS/Terra image courtesy of NASA)

In addition to this introduction, there are five other papers in this series on the Colorado River, each highlighting a different aspect of the complex ecological, physical, social, and political interactions that have produced the current state of the Colorado River ecosystem.

The Grand Canyon of the Colorado River

<http://fire.biol.wvu.edu/trent/alles/GrandCanyon.pdf>

The Lower Colorado River

<http://fire.biol.wvu.edu/trent/alles/LowerColorado.pdf>

The Geology of the Salton Trough

<http://fire.biol.wvu.edu/trent/alles/GeologySaltonTrough.pdf>

The Colorado River Delta

<http://fire.biol.wvu.edu/trent/alles/TheDelta.pdf>

The Sea of Cortez

http://fire.biol.wvu.edu/trent/alles/Sea_of_Cortez.pdf

For further information on related topics go to:

Global Ecology and Remote Sensing

<http://fire.biol.wvu.edu/trent/alles/GlobalEcologyindex.html>

Alles Biology Home Page

<http://fire.biol.wvu.edu/trent/alles/index.html>