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# LARGE-SCALE RIVER MANAGEMENT – THE COLORADO

The Colorado River drainage basin covers an area of 621,597 km$^2$ over seven states of south western USA and Mexico. It rises close to the Continental Divide in the Rocky Mountains of Colorado, and is divided into Upper and Lower basins at Lees Ferry below Glen Canyon Dam, close to the Utah/Arizona border. Stretching from the high mountains of the Rockies in Colorado, Wyoming and Utah, it flows for 2,304 km and falls over 4,376 m from its source to the Gulf of California. Its chief tributaries in the upper basin are the Green, which rises in Wyoming, the Gunnison and the San Juan rivers. Main tributaries in the lower basin are the Virgin, Bill Williams, Gila and Little Colorado rivers.

The river is now one of the most regulated in the world. More water is exported from the Colorado basin than from any other river basin in the US. It provides water for urban and industrial

*Figure 1: The Colorado Basin*

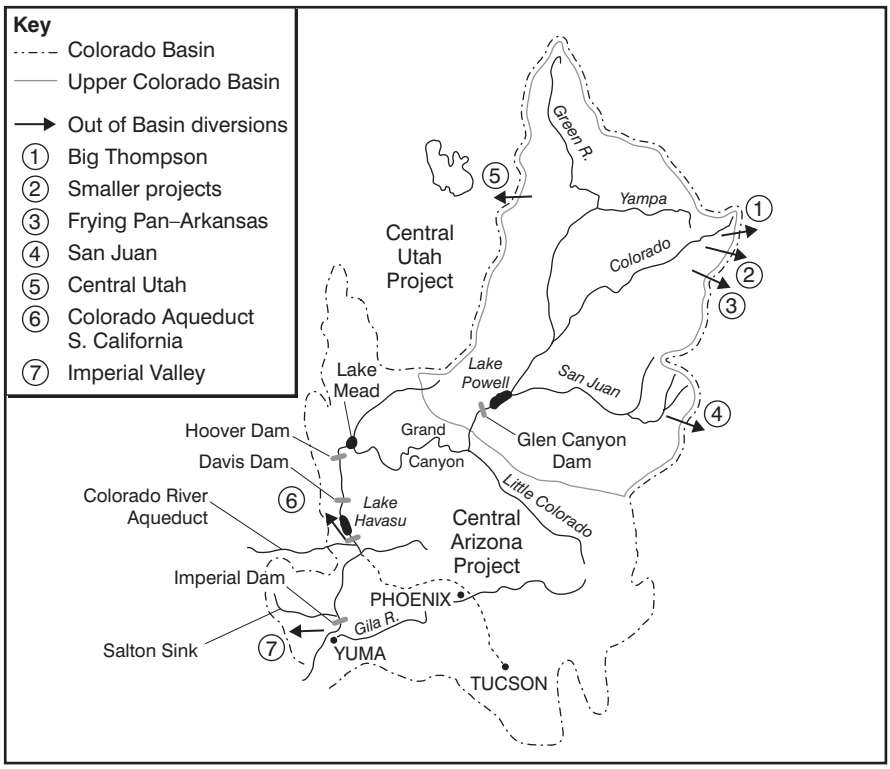



*Figure 2: Agricultural uses of the Colorado River water*

| State | Water allocation | Irrigated area from Colorado Water | Average annual precipitation | Crops | Major projects |
|---|---|---|---|---|---|
| Arizona | 3,453 m cu m | 226,624 ha | 5–30 cm | Cotton, alfalfa lettuce,wheat, barley, citrus fruits,vegetables, melons | Central Arizona Gila project, Wellton-Mohawk, Yuma . |
| California | 5,427 m cu m | 364,217 ha | 6.5–35.5 cm | Canteloupes, dates, grapes, oranges, lemons, avocados, lettuce, tomatoes, vegetables, onions, carrots, alfalfa, wheat and grasses (forage) | Colorado River Aqueduct, All American Canal, Coachella Canal, Imperial Valley |
| Colorado | 4,748 m cu m | 768,900 ha | 17.8–147cm | Hay, alfalfa, grains, vegetables, fruit | Transbasin transfers, Big Thompson |
| Nevada | 370 m cu m | Water used for urban needs. Agriculture uses ground water. | 10-16 cm (more in north) | Vegetables, fodder | |
| New Mexico | 1,040 m cu m | 24,685 ha (San Juan) | 15- 30 cm | Alfalfa , corn, wheat, barley, potatoes, onions | Navajo-Indian and 10 smaller projects, San Juan-Chama-Rio Grande |
| Wyoming | 1,295 m cu m | 133,546 ha | 18–152 cm | Alfalfa and small grains, pasture, fruit | |
| Utah | 2,095 m cu m | 178,000 ha | 30–35 cm | Pasture, alfalfa, grains, fruit | Central Utah Project, 12 smaller projects |
| Mexico (Delta Region) | 1,850 m cu m | 73,000 ha (delta) | 7 cm | Alfalfa, cotton, vegetables | |

use to 24 million people living in major cities including Los Angeles, Phoenix, Albuquerque, Las Vegas, Salt Lake City, Denver and San Diego. In addition to providing irrigation water for 810,000 ha of agricultural land, water is pumped through tunnels in the Continental Divide to Denver and cities on the eastern side of the Front Range. Within the river basin there is 74 billion cubic m of storage behind 11 major dams, providing 4,000 megawatts of hydro-electric power generation capacity.

## Major out-of-basin diversions of Colorado River water

**1 Southern California and Mexico** Rapid development of agriculture in California's Imperial Valley in the 19th and early 20th centuries created a high demand for irrigation water. 'First in time, first in right' was accepted as a principle of water usage. Water from the Colorado bordering Arizona and California was transferred to the Imperial Valley by a canal that passed through Mexican territory. Mexico permitted this in return for a portion of the river water. Disastrous floods occurred in 1905 and again in 1910 when the Colorado broke its banks, destroying farmland in the Salton Sink. For two years the river filled this inland depression, creating the Salton Sea. This led to demands from the California state government and from farmers for a canal within US territory, a flood control dam on the lower Colorado and the possibility of hydroelectric power to supply Los Angeles. Agreement was needed from upstream states, who resisted strongly until the Colorado Compact was signed in November 1922.

In normal years the river flow and storage is adequate for demands being made for water from rapidly growing populations and irrigated areas of Southern California and also Arizona. 9,250 million cu m annually were allocated to both the upper basin states and the lower basin states in the Compact. The allocations were decided on the average flow of 21,585 cu m at Lees Ferry in 1917. In retrospect, this was an above average year, which created difficulties in future allocations of water.

Mexico was not at first included in the Colorado River Compact, though the United States had tried to provide a minimum of 925 million cu m per year which was the highest amount used up to then by Mexican farmers. The Mexican Government wanted a guaranteed 5,500 million cu m to improve agriculture in lands around the Colorado delta and Baja California. Eventually (1944) Mexico was guaranteed 1,850 million cu m of Colorado water, and in return agreed to provide water from Mexican tributaries of the Rio Grande for farmers in west Texas.

However no provision was made for water quality, which has now become a contentious issue. Water now delivered to Mexico has already been used in the Wellton-Mohawk Irrigation district close to the USA-Mexico border. It is often of high salinity before its transfer to Mexico. A desalination plant was completed in 1992 at Yuma, Arizona at a cost of $25 million(£15.6 million), but until early 2004 this was still not fully operational as it was considered too expensive to run. The long drought has now made it necessary to commission the plant.

When the Colorado is flowing at normal level the speed of flow and amount of water are sufficient to maintain the salinity at an acceptable level. Salty drainage water is diverted to the Gulf of California creating a marsh area, the Cienga de Santa Clara. Additional water is drawn down from Lake Mead to help to flush out the salt concentrations before the water goes to Mexico. However during periods of drought this reduces the storage available for Arizona.

Little water now reaches the Colorado delta. Prior to the construction of Hoover Dam and Glen Canyon Dam, completed in 1935 and 1964, over 24,669 million cu m passed to the 809,000 ha of wetlands in the delta, but now less than 10% of the original wetlands remain, approximately 73,000 ha.

In both the Upper and Lower Colorado basins, attempts are being made to control salinity and reduce the amounts of salts reaching the river. Sources of salt inputs are being identified and farmers helped to alter their methods; such as using sprinkler irrigation more extensively, relining canals in irrigation districts to avoid waste, piping more water, and carefully observing and recording levels of salinity on individual farms.

In October 2003 California state and the southern water authorities agreed on the Quantification Settlement agreement, meant to last 75 years. This should reduce over-dependence on any available surplus water from the Colorado. California frequently extracts more than the allocation because of demands from both the urban and agricultural areas. The Agreement:

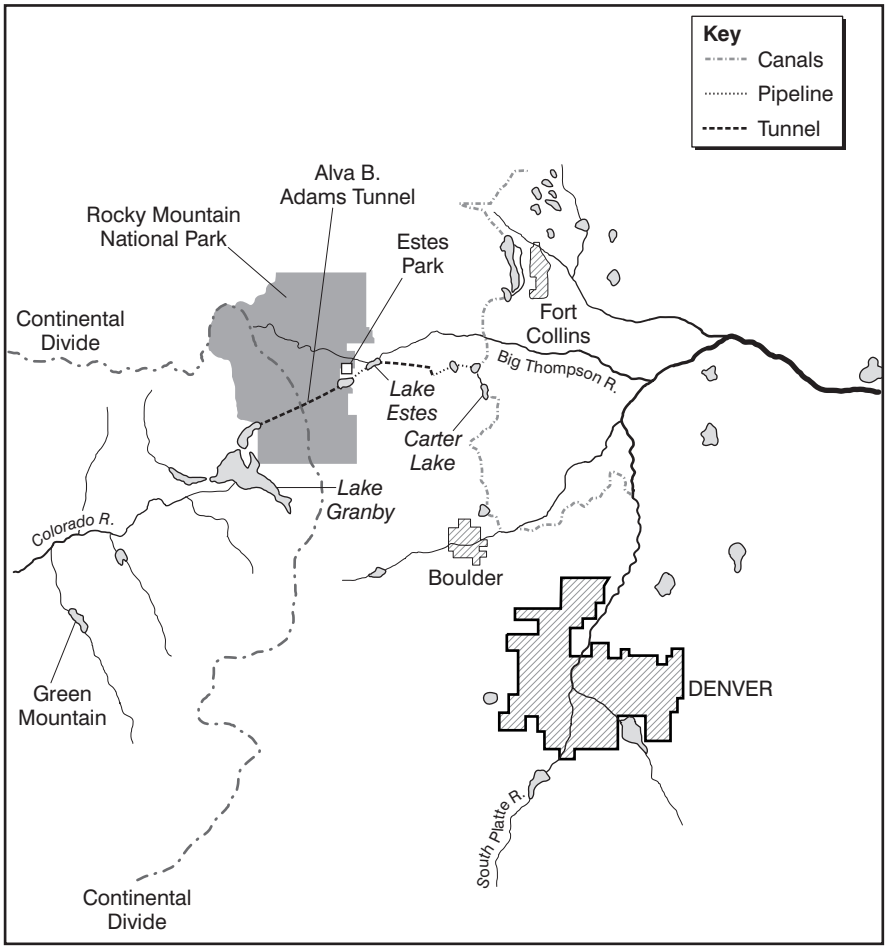
- reduces the draw down amount to 5,427 million cu m,
- makes special provision for the restoration of the Salton Sea

This is necessary because of increasing salinity and massive die-off of wildlife that occurred in 1996. The Salton Sea is at present replenished by return water flows (i.e. water originally taken from the Colorado River, used in the Imperial Valley and then returned) and the discharge of wastewater into the New River.

- The State of California is to buy 1,973 million cu m of water from the Imperial Irrigation District and then sell it to the Metropolitan Water District of Southern California for urban use, making $300 million (£187 million) to help pay for the Salton Sea restoration.
- The All American and Coachella canals are to be relined to prevent further seepage, saving 95 million cu m of water to be transferred to urban San Diego County. This should provide a reliable water supply for the future.
- Imperial Valley is also to take conservation measures to save present losses in transfers to San Diego. It will also have more finance available from the transfers to help to revitalise its economy, which depends so heavily on irrigation agriculture.

**2 The Central Utah Project (CUP)** is part of the Colorado River Storage Project (authorised in 1956) to divert water from the Colorado River westwards into the Bonneville basin of Central Utah. The project area was divided originally into six units of which the largest – the Bonneville unit south of the Great Salt Lake and surrounding Utah Lake – started in 1967 is now almost complete. The project relies on the transfer of water from the headwaters of the Colorado River, including the Duchesne in the Uintah Basin to the east of the Wasatch Mountains, to the lands around Utah Lake south of Salt Lake City. Ten new reservoirs have been constructed with 320 km of aqueducts, tunnels and canals. The whole project will provide water for 80,937 ha of new farmland and additional water for 96,719 ha of land.

*Figure 3: Colorado-Big Thompson Project*




CUP supports the growing of fodder crops for livestock on irrigated land and provides additional water for the rangelands in the dry Central Basin, as well as supplying water for urban and industrial use.

**3 Colorado-Big Thompson Project**
This federally funded project was completed in 1959 to divert water from the headstreams of the Colorado River to irrigate 291,400 ha in North East Colorado, supply power, and create recreational use on the dams constructed. Started in 1938 but delayed by the Second World War, water is diverted by several dams including the Granby Dam on the Colorado and Green Mountain on the Blue River. It is stored in Granby Reservoir, Shadow Mountain Lake and Grand Lake before being pumped through the Alva B. Adams Tunnel (13m/21km) at 15.5 cu m per second to fall 215m via tunnels and conduits to Estes Power Plant and down the eastern slope of the Continental Divide into the Big Thompson River, a tributary of the South Platte river.

Dams near Forth Collins and Estes Park divert water by canals for agricultural and municipal use.

Flatiron, Estes, Pole Hill and Green Mountain Dams generate hydro-electric power for the rapidly growing urban and rural populations on the Eastern Slope including Denver, Boulder, and Fort Collins.

In normal years irrigation water is important in late summer, but in drought years it becomes essential throughout the year. Crops produced under irrigation include sugar beet, potatoes, beans, corn and small grains, fruit, alfalfa (lucerne), vegetables, dairy products, poultry and eggs. Crops such as sugar beet are used to fatten lambs, pigs and cattle.

**4 Frying Pan-Arkansas Project**
This was completed in the 1980s and diverts water from the Gunnison River through a tunnel under the Continental Divide into the Arkansas Valley. The largest of five storage reservoirs is close to Pueblo in southern Colorado. This has become an important recreation area in addition to providing hydro-electric power, and the whole scheme provides irrigation water for 113,000 ha and municipal and industrial water for 430,000 people in the upper Arkansas Basin.

## Native American rights to Colorado River water

Tribes on Indian reservations close to the Colorado and its tributaries have interests in the waters, mainly for agriculture in the bottomlands close to the river. They claim 'senior rights' i.e. prior users' rights to the water. The Ten Tribes Partnership, formed in 1992, is now a strong political voice for the majority of the tribes in the Colorado Basin. The Federal government recognised their importance by allocating money for irrigation canals on reservations as early as 1867. When Parker Dam was constructed in the mid-1930s to provide water for Southern California, the traditional lands of the Chemuevi Indians were taken for the dam and reservoir, although suitable alternative land was provided. Rights of the Native Americans were not written into the Colorado Compact, but were accepted informally. In later discussions between states the Federal government has intervened to protect the rights of the tribes.

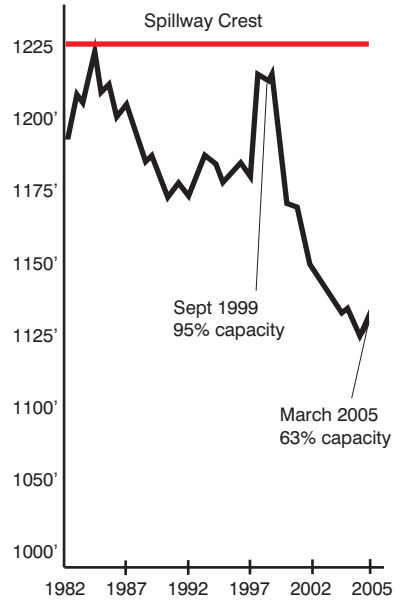
## Impact of six years of drought

In January 2005 the south western states of the US were into the sixth year of a drought, which is the most severe since the 1953–56 drought and could become the driest period since records began over 100 years ago. It is already worse than the Dust Bowl period of the 1930s (US Dept of Interior).

Mountain areas within the Colorado Basin recorded exceptional drought conditions by early January 2004 but expected further snow falls. Snow pack conditions, which are essential for raising reservoir storage levels, had improved in the Upper Colorado Basin through winter and spring 2004. However, severe to extreme drought persisted. Snow pack conditions in March 2004 were between 90 –130% of normal, following very heavy falls in December and January. This was not enough to break the drought .

Throughout 2004 pastures remained poor or very poor throughout the region. On western rivers early snowmelt allowed earlier use of storage and distribution systems to meet water requirements. Premature melt means that maximum discharge occurs earlier and then river levels recede into the summer when water supplies are most needed.

*Figure 4: Reduced levels at Lake Mead (feet)*




Lake Mead Elevations at Hoover Dam 1982–2005 (March)
(Bureau of Reclamation data)

Drought is ever present in the South West. There is competition for the melting snow between lowered reservoirs and the drought parched soils. The warm March weather causes snow to be lost directly to the atmosphere. Trees and grass start growth earlier so further draining scarce soil moisture (*US Drought Monitor* 23 March 2004). This situation was to remain until late summer 2004 when severe thunderstorms and later more continuous heavy rain (thought to be linked to a weak El Nino in the Pacific) occurred.

There has now been a five-month period when the South West was wetter than normal bringing the drought to an end. By the end of January 2005 snow conditions were better than the previous two years (NOAAnews).

Water levels in Lake Mead and Lake Powell are still at record low levels although there have been slight rises since December 2004. The level of Lake Mead at Hoover Dam was 347m (59% storage), its lowest level since 1955 (332 m) and a 21 m drop since June 2000. It is the first time in 40 years that the level has fallen below 359m. In winter 2003/4 ramps for pleasure craft were extended in anticipation of the tourist season, and knowledge that the drought would persist. There are restrictions on the use of water in cities such as Las Vegas and the prospect of severe restrictions on the use of irrigation water for the next agricultural season. These continued and have not yet been lifted.

Run-off into Lake Powell was only 53% of average in 2003. The elevation of Lake Powell had dropped to 1,086 m, almost 30.4 m from full, at the end of the summer 2004, and in 2005 was now only at 43%. In spite of this there is at present enough water to meet water requirements of the Lower Basin states and Southern California, as long as demands do not increase. The reduced head of water for power production means that the turbines can only produce 31% capacity (cf record year 1984 – 93% capacity). Between April and July 2004 the Colorado had 76% normal flow.

One advantage of the present situation on Lake Powell is that many interesting sites flooded by the water when the dam was created, such as Cathedral of the Desert and Gregory's Natural Bridge, may now be visited by boat. Fishermen welcome the improved natural fishing for bass and other native fish. Large amounts of sediment are retained behind Glen Canyon dam which means a decline in sediment along the Grand Canyon. The reduction in numbers of native fish such as the humpback chub is serious. Introduced species such as the rainbow and brown trout thrive in the reservoirs and in the river below Glen Canyon Dam.

## Conclusion

Hydrologists believe that it will take at least five years of average or above average rainfall to refill the Colorado system. Farmers in the Upper Basin have already been warned to expect a 20% drop in their water allocations for the current year. In 2004 agricultural production in Upper Basin was down 40%. Impact on the Lower Basin farming was less due to the Colorado Compact law. It is now recognised that attitudes to water use from both urban and agricultural communities will have to alter significantly. In 2003 the US government launched a major programme, 'Water 2025: Preventing Crises and Conflict in the West'. $21 million (£14 million) initial Federal funding for 2004 will help co-operation between states with conservation projects, research into desalination, and improvements in water management to avoid future water supply crises. All states in the Colorado Basin must provide a strategy for more serious water shortages.

Population throughout the basin has risen rapidly, increasing by 47% between 1980 and 2000. Arizona's population has quadrupled since 1950. This puts increasing pressures on the available power and water supplies.

## Focus Questions

1. What methods could be used to reduce the consumption of water in cities such as Las Vegas and Los Angeles? Can the allocations of water to urban areas be justified?

2. 'A River No More' has been used to describe the Colorado. Is this fair? Are there more environmentally acceptable ways in which this river could be used?