6 The Colorado River: What Prospect for 'a River No More'?

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Introduction

The Colorado River of the American Southwest is among the most studied, contested and valued rivers in the world, annually providing water and electricity to roughly 30 million residents, generating 11.5 billion kWh of hydroelectricity, and irrigating more than 3 million acres (1.2 million ha) of crops (Adler, 2007). This is remarkable in many ways, not least of which being the observation that, just 150 years ago, Lieutenant Joseph C. Ives (1861:110) concluded his exploration of the basin with this remarkably misguided assessment:

> The region last explored is, of course, altogether valueless. It can be approached only from the south, and after entering it there is nothing to do but to leave. Ours has been the first, and will doubtless be the last, party of whites to visit this profitless locality. It seems intended by nature that the Colorado River, along the greater portion of its lonely and majestic way, shall be forever unvisited and undisturbed.

How does a river change from being 'altogether valueless' to becoming critically important in, roughly, the span of two human lifetimes? The answer lies not so much with the river itself, or even in the lands drained by the river, but in how human ingenuity and institutions have shaped how value is created and measured. The combination of an arid, sunny climate with abundant lands having good soils would, without irrigation, indeed be only of limited human value. But irrigation – aptly deemed 'reclamation' in the American West – has transformed the region, first for the benefit of farming, and more recently for booming sunbelt cities such as Las Vegas, Phoenix, Los Angeles and Denver. As part of this transformation, the jagged mountains, massive canyons and vast deserts that once made the region inhospitable are now viewed as amenities worthy of reverence and protection. It is a region, and a history, full of contrasts and paradoxes, with a future being shaped by a continuous stream of newcomers, including 37 million visitors annually to Las Vegas and 5 million to the Grand Canyon, and welcoming nearly one million new permanent residents annually to the seven Colorado River states.

Given the rate of change in the Colorado River basin, it is difficult to predict the future with any confidence, especially since an unwelcome new era is emerging: an era of limits. It is increasingly unrealistic to accommodate new demands in the basin simply by drawing on unused supplies, as users already exist to utilize every drop of the Colorado; the river has not consistently reached the ocean for decades. Rather, meeting new, mostly urban, demands requires actions that resonate through the water community in some way: for example, drawing on surplus flows in wet years, transferring water from agricultural to urban users in normal years, and tapping reservoir storage in dry years. This last scenario has been particularly evident in recent years; reservoirs that were 90% full in 2000 were less than half their capacity by 2004.[1] While much of this decline can be rightly attributed to the onset of drought (particularly severe in 2002), other conspirators have been population growth and the corresponding expansion of the water infrastructure to serve these new populations. From 1920 to 1990, the population of the Colorado River basin states increased more than sevenfold, giving way to an even more explosive growth in the 1990s, when four basin states (Nevada, Arizona, Colorado and Utah) led the USA in percentage population growth, while another (California) led in terms of absolute population growth (Census Bureau, 2001; Grand Canyon Trust, 2005).[2] In 2004, one senior official estimated that the size of the population relying on water from the Colorado River had increased by 26% in the past decade (Griles, 2004). Also impressive is population growth in the final reaches of the river, across the border in Sonora and Baja, Mexico. While drought conditions may end at any time, rapid population growth is expected to continue, and, additionally, the wealth of recent research suggests that climatic change will hit this region harder than most – reducing streamflows anywhere from 11 to 45% by 2100 (Christensen and Lettenmaier, 2006; Hoerling and Eischeid, 2007).[3] This is the backdrop against which irrigation, urbanization and environmentalism are now colliding, all within the context of laws, customs and values shaped over a remarkably short time-frame.

Physical and Environmental Setting

The Colorado River is primarily fed by snowmelt originating high in the Rocky Mountains of Colorado and Wyoming. Every spring and summer, this water races downhill in a generally south-west direction, pulling in tributaries from New Mexico and Utah to form the main channel slicing through arid lands in Arizona, Nevada, California and a small section of Mexico (Fig. 6.1) (for general summaries, see Carothers and Brown, 1991; Pontius, 1997; Gleick *et al.*, 2002; Project Wet, 2005). Many maps of the Colorado show the 632,000 km^2 basin as ending at the US–Mexico border – undoubtedly a politically motivated decision, but actually not terribly inaccurate as over 95% of the basin is in the USA. The overwhelming majority of management decisions and engineering works are located in the USA, and the river ends soon after crossing the international border, disappearing completely in most years into waiting fields before it can reach its natural terminus at the Colorado River delta along the Gulf of California.

One of the few qualities of the Colorado River that is not on a grand scale is the flow of the river. For legal reasons (discussed later), main-stem Colorado River flows[4] are reported at Lee Ferry (or adjacent to Lee Ferry), the midpoint of the river just downstream of the Glen Canyon dam (see Fig. 6.1). Gauging records are interpreted with respect to known upstream patterns of water storage and consumption to estimate the natural (i.e. unaltered) flow. The total annual natural flow of the river at this point averages approximately 15 million acre-feet (MAF)[5] (roughly 18 billion m^3).[6] None the less, while not among the top 20 US rivers in terms of flow volume, the Colorado is still an impressive and welcome asset in what is primarily an arid basin. Much of the lower basin, home to the most productive agriculture, receives only 100 mm of precipitation annually. An ambitious programme of hydraulic engineering has taken full advantage of these modest and highly variable flows (see Fig. 6.2). Along its course, the river is now harnessed by roughly two dozen significant storage and diversion projects, most notably the Glen Canyon dam (forming Lake Powell) and the Hoover dam (forming Lake Mead), bracketing both ends of the region's signature natural attraction, the Grand Canyon. Water storage facilities on the Colorado River can hold roughly 4 full years of flow, a tremendous asset in terms of water supply management, but achieved at the expense of transforming the river from an unpredictable and sediment-heavy, warm-water stream to an elaborate plumbing system of relatively clear and cold water, flowing in highly predictable (and tempered) patterns – described by Fradkin (1981) as 'a river no more'.

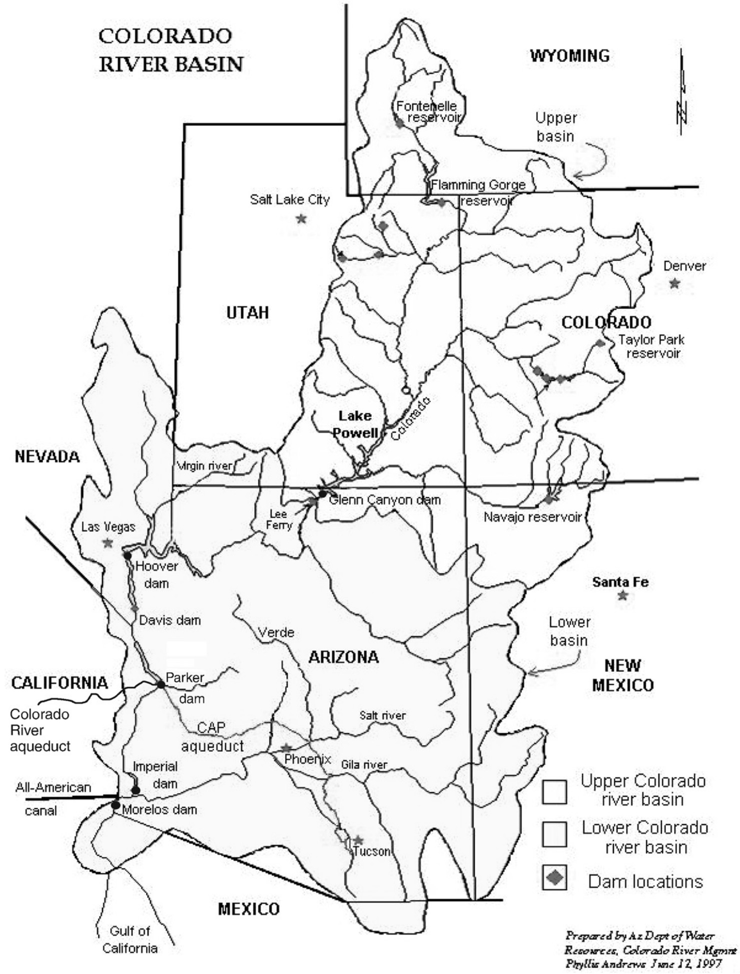

Fig. 6.1. The Colorado River basin.

The environmental consequences of this modified hydrograph are felt throughout both the basin and the local ecosystems, with native fish species providing perhaps the best indicator of the environmental costs of river development. The construction of water infrastructure, particularly the Hoover and Glen Canyon dams, has created an environment where non-native species have displaced most native species; four remaining native fish species (humpback chub, razorback sucker, bonytail chub and Colorado pike minnow) are listed as endangered (Carothers and Brown, 1991; Adler, 2007). Of particular salience has been the removal of both sediment from the river by the storage reservoirs and water from the system by out-of-basin exports. Many of the major users of Colorado River water – including those in southern California, Colorado's Front Range, central Utah, and the Rio Grande valley in New Mexico – are located outside the Colorado hydrologic basin. The ecological impact of the resulting changes to the volume, timing, temperature and chemical composition (especially the enhanced salinity) of flows is further compounded by the introduction of exotic species, including trout (for the cold-water fisheries), horses and burros, tamarisk (aka salt cedar), and plant and animal species associated with farming and ranching (Adler, 2007).

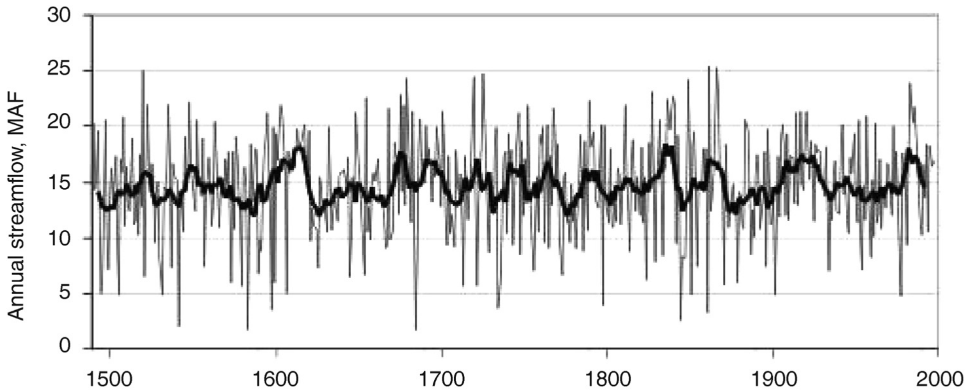

Fig. 6.2. Reconstructed natural Colorado River flows (at Lees Ferry) (Courtesy, Jeff Lucas and Connie Woodhouse). (Dark line indicates 10-year averages.)

Environmental restoration programmes in both basins – the Upper Colorado River Endangered Fish Recovery Program and the Lower Colorado Multi-Species Habitat Conservation Plan – exist to coordinate mitigation but, ironically, both efforts are explicit in allowing still additional river development and consumption. No ecosystem is more threatened by this accumulation of storage and diversion facilities than the Colorado River delta, primarily located in Mexico. Diminished flows due to upstream consumption, including long time periods during the initial filling of the Mead and Powell lakes, have starved the delta of flows, reducing the area covered by wetlands to less than a tenth of its original 728,000 hectares (Glennon and Culp, 2002). The delta now survives on roughly 1% of the river's natural flow, this water originating mostly as agricultural return flows and occasional reservoir spills – such as the El Niño-inspired floods of the early 1980s (Fig. 6.3). Given the increasing water demands, likely decreased flows due to climate change and currently low storage levels, major reservoir spills may never recur (Gertner, 2007). Current efforts to improve the efficiency of upstream water-delivery systems threaten further reductions in flow.[7]

An Institutional History of the Colorado River Basin

The institutional arrangements of the Colorado River basin have evolved over several decades of conflict and compromise. Most histories of the basin focus on the evolution of the so-called 'Law of the River', a collection of federal and state laws and court decisions that, collectively, apportion the flow of the river among the seven basin states and Mexico (e.g. see Lochhead, 2001, 2003). However, while the Law of the River is undoubtedly important and is central to understanding both the basin's past and future, it is only one component of the overall institutional framework. There are many political, social, cultural and environmental factors which not only fill out the legal skeleton provided by the Law of the River but also frequently articulate a competing set of values. The result is that the modern institutional arrangements of the Colorado River are bifurcated, and the primary source of this bifurcation is paradigmatic. Specifically, the institution features an odd balance of a 'private commodity' paradigm, featuring an emphasis on water development and the rights of individual rights-holders, with a 'public value' paradigm, emphasizing resource protection, value pluralism and democratic (i.e. collective and participatory) decision making. Not surprisingly, given their inherent incompatibility, these paradigms did not evolve simultaneously or in a coordinated manner, but evolved rather sequentially and incrementally. It is against this backdrop that new institutional arrangements are now being sought, pushed by the harsh reality of a limited water supply but constrained by the lack of a coherent vision regarding the appropriate goals of water management.

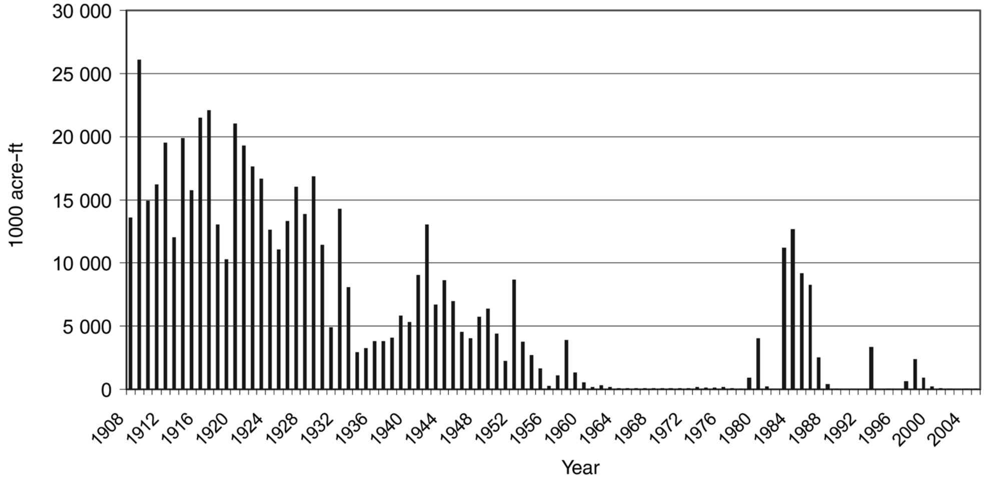

Fig. 6.3. Colorado River flows to the delta (adapted from data compiled by Kevin Wheeler).

In what follows, the institutional history of the Colorado River is reviewed in eras defined by these two dominant paradigms, focusing primarily on the major portion of the basin that lies within the seven US Colorado River states. In contrast to a traditional Law of the River history, which begins with the Colorado River Compact of 1922, this review begins with the arrival of the first Europeans in this part of the New World, as this provides the origins of the private commodity paradigm, which still largely shapes the institutional arrangements in the Colorado. In these early decades, the conflicts between countries, and, later, US states, for the bounties of the Colorado occurred within this dominant paradigm. Conflicts thus typically did not feature fundamental disagreements regarding values or ideologies but were primarily distributive in nature – i.e. each party wanted to secure as much of the river's benefits as possible – and were focused on issues of apportionment, development and consumption, while systematically devaluing non-monetary, public and systemic values of the river.

Evolution and reign of the private commodity paradigm

Early exploration and settlement

The origins of the region's private commodity paradigm can be traced back to the post-Columbian era of European expansion into the New World. The first wave of European explorers in the 1530s comprised the Spanish conquistadors, most prominently Francisco Vasquez de Coronado, who led the ultimately unsuccessful search for the mythical Seven Cities of Cibola, thought to contain mineral riches similar to those in the Inca Empire of Peru and the Aztec Empire in Mexico (Waters, 1946; DeVoto, 1952; Brandon, 1990). Finding no gold, these excursions ultimately gave way in the 1600s to Spanish missionary *entradas*, aimed at bringing Christianity to the region. Much like the conquistadors, the missionaries greatly improved the geographic knowledge of the lower Colorado basin but were otherwise unsuccessful, as the padres could claim few souls and only one mission (San Xavier, near modern-day Tucson, Arizona) survived after missionary efforts were abandoned in 1781. By the 1800s, the English and French had replaced the Spanish as the major European influences in the region, this time concentrated in the upper basin. Like the Spanish earlier, these were not immigrants looking for homesteads but were entrepreneurs looking to extract wealth – in this case, beaver skins for the European hat industry (Waters, 1946; DeVoto, 1952).

By the 1840s, the fur industry was in decline, but global forces were still shaping events in the Colorado River basin. As Waters (1946:185) writes:

> Across all Europe – in France, Austria, Germany, Hungary, Italy – geysers of unrest broke out. In an unparalleled outpouring of human emotion the tide swept over Europe, and kings ran before it in terror. All of South and Central America rose in revolt against their Spanish masters, establishing their independence. In North America, Mexico broke free from Spain and then the Republic of Texas from Mexico. The United States, declaring war against Mexico, took most of the Colorado River basin including what was to become Nevada, Utah, California and most of Arizona, New Mexico, Colorado and Wyoming.

Soon, almost the entire Colorado River basin became the legal domain of the USA, with the obvious exception being the failure to acknowledge the sovereign rights of the indigenous peoples (known as Indians or Native Americans). Dozens of tribes are indigenous to the region, including Apaches, Navajos, Hopis, Zunis and Utes. Beginning with the conquistadors, each wave of Anglo settlement occurred with little regard to native peoples, cultures and rights, a tradition that improved only marginally under US control, as wars and treaties forced great reductions in territories under tribal control. Addressing the so-called 'Indian problem', however, was insufficient by itself to stimulate Anglo settlement of the basin, and if the USA had learned anything from the European competition for the New World, it was that the key to holding land was promoting settlement (DeVoto, 1952). Given that settlement of arid territories is innately tied to water management, water policy thus became a tool of national security and national economic development.

It was in this context that gold deposits were first discovered in the West, prompting the California Gold Rush of 1849, followed a decade later by similar gold rushes in Colorado and Arizona (Waters, 1946). Succeeding where the conquistadors had failed over 300 years earlier, thousands of entrepreneurs flooded into the region from across the globe in search of mineral wealth. Eventually, the mining 'boom towns' evolved more diversified economies or went bust as mineral reserves were exhausted or spread too thin among competing miners, but the legacy of the boom on water resources has endured, largely due to the evolution in the mining camps of the prior appropriation doctrine of water allocation, since adopted and practised in all of the Colorado River states (and beyond) (Pisani, 1992).

Four elements of prior appropriation are particularly noteworthy (Tarlock *et al.*, 2002; Kenney, 2005). First, unlike the riparian doctrine practised in the eastern USA, water rights established under prior appropriation are not linked in any way to land ownership, thereby ensuring that western development was not limited to stream corridors but can, instead, reach wherever the combined forces of engineering and economics can provide water services. Second, water rights established through prior appropriation are limited to legally recognized 'beneficial uses', which until recently only included industrial, agricultural, municipal and domestic uses, while excluding most environmental uses. Third, prior appropriation water rights are a form of private property right, which can be bought and sold with relatively few restrictions, the primary one being that no transfer can be permitted that 'injures' other legally established prior appropriation rights. Fourth, and most significantly, the prior appropriation doctrine is based on the tenet of priority and, specifically, the notion that the first person to beneficially use a water source should, in perpetuity, retain the right to continue to use the same volume of water (and for the same uses) every year.

Perhaps the best way to understand prior appropriation is to consider how a 'call on the river' works. A 'call' is the term used to describe a situation when insufficient water is available in a given year to satisfy the needs of all parties with recognized water rights. The origin of these rights can be traced back to the initial settlement of the region and the first uses of water for recognized purposes. Over time, an inventory of these uses was developed, and each 'right' was recorded with respect to the location of use, the amount of use, the purpose of use and the first date of use. While the details vary somewhat among the western states, each generally established a water management agency to record and monitor the exercise of these rights, with these efforts organized at sub-state scales defined by the major river basins. A call is most likely to occur in a drought, and begins when a water rights-holder complains to the state agency about the unavailability of water. To satisfy the call, the administrator orders some users to completely cease diversions, beginning with the most junior (the youngest rights), followed by the second most junior, and so on, until the available supply again matches the volume of the remaining rights. Note that this is not a system based on sharing or proportional cutbacks; junior water rights are cut off in their entirety, one by one, until the remaining rights-holders can use their rights in their entirety. In practice, this can be highly complex, as seniors and juniors are scattered throughout a basin, in different reaches and sub-basins. A particularly challenging situation arises when the most senior users are far downstream, as this requires the upstream juniors (perhaps in a different sub-basin) to allow water to flow past their diversion structures to ensure that the downstream senior is satisfied. Administering these programmes is a challenge to legal institutions, engineering systems and social systems, but provides the benefit of encouraging and protecting early investments in water projects (Kenney, 2005).

The priority concept not only provided a strong incentive to rapid settlement but also enshrined the key elements of the private commodity paradigm – i.e. the notion that water is an economic commodity which should be privately owned and manipulated for the benefit of entrepreneurial capitalism. It is worth noting that this approach to water allocation and management differs significantly from what was observed in many of the first agrarian settlements in the West, particularly the Mormon communities that sprang up in Utah in the late 1840s, the Hispanic *acequia* communities of northern New Mexico, or any of the Native American communities (Waters, 1946; Maass and Anderson, 1978). These communities all featured collective or centralized control of water resources, an approach strongly endorsed by western visionary John Wesley Powell. Powell – best remembered for his exploration of the Colorado River in 1869 – was one of the first men to openly question the logic of the private commodity paradigm, instead arguing for small communal societies nourished by the careful and sustainable utilization of the region's limited natural resources (Powell, 1890; Stegner, 1953). Powell's well-reasoned argument in favour of moderation and community control was widely ignored.

Following the US Civil War of the 1860s, a large and restless eastern population was ready to heed Horace Greeley's famous advice and head west, and did so at the urging of a national government that provided a variety of homesteading programmes designed to promote an agrarian West, a popular national goal (Pisani, 1992). Many homesteaders soon discovered, however, that the small land allotments (often just 160 acres, or 65 ha), lacking reliable water supplies, were simply not suited to farming. It is estimated that two-thirds of all homesteaders failed, often leading to the consolidation of land in the hands of banks and other 'empire builders', who found large tracts well suited to low-density ranching (Stegner, 1953). Where agrarian communities flourished – particularly in pockets of California, Arizona, Utah and Colorado – it was because of their location along perennial streams that were well suited to the construction of water storage and diversion works. If agrarian settlements were to take hold on a large scale, then water development on a large scale seemed the obvious answer.

Apportionment and lower basin development

By the early 1900s, it was apparent that the dream of an agrarian West – viewed by the progressive national government as more ideologically desirable than mining or ranching economies – would require development of the West's large river systems, particularly the Colorado River. The Reclamation Act of 1902 was thus enacted to bring the financial and technical resources of the federal government to task, initially under a funding mechanism designed to recoup costs from project beneficiaries, but eventually evolving into a programme of blatant subsidies and political favours (Worster, 1985; Reisner, 1986; Wahl, 1989). Many of the initial targets of the federal reclamation programme were in the lower Colorado River basin, where fertile soils, long growing seasons and favourable topography provided an ideal opportunity for large-scale irrigation, if only the flow of the river – once termed a 'natural menace' by the Bureau of Reclamation

(USBR, 1946) – could be controlled by upstream storage. Existing irrigation developments along the Palo Verde, Yuma, Imperial and Mexicali valleys (in the Arizona–California–Mexico border region) had not only already demonstrated the potential for irrigation but had also shown the vulnerability of these operations to flooding and siltation.

Large-scale river development could not proceed, however, until an understanding was reached regarding the legal apportionment of the river's flow among the seven US states and Mexico. Owing to political unrest in Mexico and a reluctance of water interests in the USA to acknowledge any obligation by the upstream nation to maintain flows to Mexico, it was quickly decided that an apportionment was needed just between the states of the upper basin (Colorado, New Mexico, Utah and Wyoming) and the lower basin (Arizona, California and Nevada) (Hundley, 1975). Despite the fact that the prior appropriation system was already in effect (intrastate) in each of the seven US Colorado River states, it was argued by the upper basin that this approach would not be equitable at the interstate scale, given that the lower basin was being settled at a much faster rate. The upper basin states thus wanted a permanent reservation of water for their use (regardless of when that use would eventually occur), and unless they got this, they would use all means necessary to block any apportionment and, more importantly, any of the desired lower basin developments – particularly the Hoover dam. Thus, the seeds of a very hard-fought compromise were sown, and a new institutional mechanism – the interstate compact – was unveiled to produce the Colorado River Compact of 1922, the first of nearly two dozen water allocation compacts now in existence in the American West (Hundley, 1975; Tyler, 2003).

As case-specific solutions to interstate water allocation disputes, each compact is unique, but the Colorado River Compact is particularly unusual, in that it features an apportionment of specific, long-term (decadal) volumes of water rather than annual percentages or standards requiring the maintenance of a constant minimum flow rate at the state line. The key element of the compact is found in Article III(d), which requires the states of the upper basin to release 75 MAF of water every 10 years past Lee Ferry (see Fig. 6.1) to the lower basin (or an annual average of 7.5 MAF), which seemed a modest burden, given that the annual flow of the river was estimated at this time to at least exceed 16 MAF and perhaps to be as high as 20–22 MAF (Hundley, 1975). The roughly two decades of gauging data available suggested an average flow of 16.8 MAF. However, as shown earlier in Fig. 6.2, this estimate has proven to be highly flawed, as gauging records and tree-ring studies both suggest the long-term flow of the river is approximately 15 MAF (Woodhouse *et al.*, 2006).

This error can potentially work to the disadvantage of the upper basin states, given the downstream release requirement. In a manner very analogous to a call on a prior appropriation regime, in an extended dry period, if satisfying the lower basin delivery obligation meant insufficient water remained to serve upper basin users, then those users would presumably be prevented from diverting and using the water as it flowed through these headwaters states. This situation has never happened, in part due to two protections provided to the upper basin. First, the compact's 10-year accounting method allows reduced deliveries in dry years, as long as they are offset by higher deliveries in wet years (within any 10-year period). Second, as discussed later, a major storage reservoir (Lake Powell) now exists just upstream of the delivery point, allowing the upper basin to maintain steady downstream deliveries even when faced with highly variable inflows – at least as long as water remains in storage. This capability has been exploited to create a hydropower-focused water management regime that keeps releases relatively constant, which ironically eliminates much of the flexibility inherent in the 10-year accounting method.

The compact was ratified[8] as part of the federal Boulder Canyon Project Act of 1928, which authorized the Boulder dam, renamed the Hoover dam, and the All-American canal, so named since it would divert water from the river to agricultural users in southern California, in a structure that would not cross over the international line (unlike an existing canal, which was being used by both Mexican and American interests). It also provided an interstate apportionment among the lower basin states of 4.4 MAF to California, 2.8 MAF to Arizona and 0.3 MAF to Nevada.[9] This element of the Boulder Canyon Project Act has been the subject of considerable litigation, mostly resolved in Arizona v. California (1963), but has survived intact. With these provisions in place, construction of the Hoover dam (along the Arizona–Nevada border) was completed by 1935 at a cost of US$49 million (in 1935 prices) and at least 96 lives. The project has dramatically reduced the flood danger downstream, while providing over 26 MAF of storage capacity (in Lake Mead) and 2000 megawatts of hydropower capacity. Soon thereafter, in 1941, the Parker dam was built downstream on the river (along the Arizona–California border), to provide a diversion point for the Colorado River aqueduct, which provides municipal and industrial water to southern California cities (Fig. 6.1). As seen with the other lower basin projects, the Parker dam was fraught with controversy, with Arizona unsuccessfully using both litigation and the Arizona National Guard in a futile attempt to slow California's use of the river (Mann, 1963).

The apportionment of the Colorado River was completed in the 1940s in two separate actions. First, a 1944 Treaty with Mexico (Mexican Water Treaty of 1944) apportioned a minimum of 1.5 MAF/year (roughly 10% of the river's natural flow) to be delivered at the international border. This is water in addition to the 7.5 MAF allocated annually to both the upper and lower basins, and thus increased the overall annual apportionment of the river to 16.5 MAF. Initial discussions with Mexico in 1910 had been based on a potentially equal division of flows at the border, an arrangement that had disintegrated by 1923 to the point where the USA suggested it was not obligated to provide any delivery (based on the infamous but ultimately insignificant Harmon Doctrine) (Hundley, 1966). The deal enacted was, thus, yet another hard-fought compromise and was tied to another apportionment decision regarding the shared Rio Grande River, where Mexico has the strategic advantage of being the upstream party on the critical reach (Hundley, 1966).

The second apportionment decision of the decade came in the Upper Colorado River Basin Compact of 1948, which apportions the upper basin share among the four states as follows: 51.75% to Colorado, 23% to Utah, 14% to Wyoming and 11.25% to New Mexico. Percentages are used since the amount of water reserved for the upper basin is theoretically 7.5 MAF/year, but due to the flawed flow assumptions used in the Colorado River Compact and the new delivery obligation promised to Mexico – both of which must be satisfied before the upper basin can take its apportionment – it is widely assumed that the flows available to the upper basin may not consistently exceed 6 MAF (Tipton and Kalmbach, 1965).[10] This compact also featured the establishment of an Upper Colorado River Commission to monitor consumption levels and, if necessary, interpret and enforce complex rules for sharing upper basin shortages. This has never been necessary; upper basin consumption has never exceeded 4 MAF/year (see Table 6.1). Exactly how the Upper Colorado River Commission would calculate and enforce shortages among the four states remains to be seen, especially since no curtailment of upper basin uses is likely to be initiated by the commission until legal ambiguities regarding the full Colorado River Compact are first addressed. The rules of the upper basin compact generally call upon each state to curtail water uses in proportion to levels of use in the preceding years, although exactly how this would be implemented by state agencies within each state is a further source of uncertainty. Given recent drought conditions, several upper basin states have initiated these discussions.

Omissions in the apportionment scheme

Before moving forward with a discussion of upper basin and Arizona water development, still nested within the private commodity paradigm, it is worth noting that the seven-state and international apportionment of the Colorado River, as completed in 1948, left many issues unresolved for future generations. The apportionment framework is not only based on flawed flow assumptions and ambiguities about how future shortages would be handled, but also contains several notable substantive omissions. Many of these omissions have not been fully addressed as yet, with progress delayed for

Table 6.1. Colorado River main-stem consumption and deliveries to Mexico (thousand acre-feet).

	1975	1980	1985	1990	1995	2000	2005
			Upper basin (UB)				
Colorado	1,789	1,754	1,993	2,102	1,711	2,383	1,856
New Mexico	293	424	393	362	387	337	466
Utah	616	670	759	784	792	774	853
Wyoming	278	353	351	520	436	421	405
UB total	3,001	3,220	3,541	3,803	3,366	3,953	3,618
			Lower basin (LB)				
Arizona	1,208	1,035	1,032	2,117	2,029	2,643	2,429
California	4,937	4,680	4,710	5,163	4,837	5,258	4,344
Nevada	154	228	373	311	350	450	292
LB Total	6,299	5,943	6,115	7,591	7,216	8,351	7,065
Evaporation	2,093	2,063	1,841	1,598	1,703	2,102	1,360
Total USA consumption	11,393	11,226	11,497	12,992	12,285	14,406	12,043
Delivered to Mexico	1,656	6,143	13,396	1,676	1,838	2,145	1,725

Note: UB totals include minor deliveries in north-eastern Arizona (not shown). Data for 2005 are provisional; evaporation losses, in particular, are very rough estimates. During the current drought, inflows have been approximately 62% of the 30-year average in 2000, 59% in 2001, 25% in 2002, 51% in 2003, 49% in 2004, 105% in 2005, 71% in 2006, and 68% in 2007; 2008 was expected to be an average or above-average year. Data are compiled from the Bureau of Reclamation statistics, primarily the *Consumptive Use and Losses* reports and *Decree Accounting* statements.

decades until crises and changes in the paradigm provided a more conducive policy-making environment. Four of these omissions include Indian water rights, environmental flows, groundwater and water quality.

The basic apportionment is nearly silent on the issue of Native American (Indian) water needs, with the exception of language in Article VII of the Colorado River Compact – later repeated in many subsequent compacts – stating that 'nothing in this compact shall be construed as affecting the obligations of the United States of America to Indian tribes'. This language was inspired by the landmark Winters decision in 1908 (Winters v. United States, 1908), which established as precedent the federal responsibility to provide tribes relegated to reservations with the water resources needed to sustain these new tribal homelands. Translating this principle into actual water management in the Colorado River basin is an ongoing process, subject to considerable debate and litigation, especially in the lower basin, where the vast majority of the basin's large reservations are located. Arizona, in particular, features several tribes with Colorado River rights of great seniority, as these rights are defined as originating with the dates of the Indian treaties or the establishment of reservations, actions that typically took place before widespread homesteading by Anglos. Additionally, these rights can be quite large, as they have since been defined as the amount of water that would be needed to irrigate all the 'practicably irrigable acreage' within the reservation.[11] By some estimates, large reservations – such as the Navajo reservation in north-eastern Arizona – could conceivably be awarded the entire flow of the Colorado River under this calculus. Politically, this outcome is unacceptable to the non-Indians that would be displaced, so the 'solution' has been to withhold from tribes the financial resources needed to develop water projects until they agree to settlements that dramatically scale-back the size of their rights (Burton, 1991; Thorson *et al.*, 2006).

While the ethics of this approach are certainly debatable, the effectiveness is undeniable; many Navajos, for example, still do not have potable domestic water supplies in their communities. In contrast, several tribes have negotiated settlements tied to the Central Arizona Project (discussed in the following section), which now delivers approximately 0.55 MAF annually (about one-third of project capacity) to tribal lands in central Arizona.[12]

Another largely unresolved issue is the need for environmental flows. As suggested earlier in the discussion of the Colorado River delta, the reservation of water for environmental flows was not explicitly provided for in either compact or treaty, with the exception that each jurisdiction retains great latitude in how apportioned water is used internally. States can, theoretically, reserve a component of flow for environmental needs, but the incentive to do so is limited by the lack of any assurance that other states would follow suit and, more importantly, by the evolution of water allocation rules during an era and paradigm where environmental protection took a back seat to water development. In the Colorado basin (as in many other places), protecting the environment was seen as something that could wait until the basic sustenance needs of homesteading populations could be assured. As discussed later, this era did not arrive in this basin until the 1970s.

Groundwater is also not mentioned in the apportionment scheme, a common (and often problematic) omission in western water compacts generally, but one that has thus far been tolerable in this case, since the centrepiece of the Law of the River is the requirement to deliver a fixed volume of surface water at a given point (Lee Ferry) and, subsequently, the apportionment of that surface water to three states (and eventually Mexico) downstream. From the standpoint of the overall basin, how groundwater is managed upstream is largely irrelevant as long as the delivery obligation is satisfied. Similarly, groundwater use in the lower basin is an important issue – overdrafting in Arizona is a chronic problem – but is largely outside the scope of the Law of the River, which has been interpreted by the courts as not applying to lower basin tributaries. Groundwater law is extremely complex and non-uniform across (and sometimes within) the basin states, with most regimes awarding rights based on either priority (as done with surface water) or land ownership, or some combination thereof (Bryner and Purcell, 2003).

Finally, water quality is also omitted from the apportionment scheme, which has primarily been an issue due to the accumulation of salts as the river moves downstream. This is a result of natural processes and human activities, including out-of-basin imports of freshwater in the upper basin, saline irrigation return flows and evaporation from reservoirs. At one point in the 1960s, excessive salt in the river resulted in a brief international incident with Mexico, which convincingly argued that its apportionment could not be satisfied with water too salty for irrigation. In response, the treaty was modified in 1973 to reflect this understanding, and an ongoing remediation programme was established under the Colorado River Basin Salinity Control Act of 1974 (Holburt, 1975; Adler, 2007).

Upper basin and Arizona development

With the completion of the basic basin-wide apportionment through the Mexican Treaty and Upper Basin Compact, and given the economic boom that followed the end of World War II, the states of the upper basin mobilized to pursue their share of federal water development funds. Arizona was also now in line for water projects, having seen the futility in spending decades unsuccessfully fighting Californian projects. In fact, the first of the big post-war project proposals was for the Central Arizona Project (CAP), a vast aqueduct that can convey approximately 1.5 MAF of water from the main stem (on the Arizona–California border) to interior regions, including the cities of Phoenix and Tucson, traversing over 541 km and 732 m in elevation. The project was designed to ease groundwater overdrafting problems throughout the state. Included in the CAP proposal were dams at Bridge (or Hualapai) and, later, Marble canyons, bracketing Grand Canyon National Park, to provide the hydropower (and the hydropower revenues) necessary to support the project in terms of both electricity (for pumping) and economic subsidies for the intended market of both agricultural and municipal users (Terrell, 1965a).

This idea of using 'cash register' hydroelectric dams to subsidize water deliveries was eagerly embraced by upper basin users, who sought to implement the concept on their own forthcoming projects.

While the economic and environmental merits of the CAP were debated in Congress, the upper basin pursued projects, first gaining resumption of work on the Colorado–Big Thompson Project[13] (initiated in 1938 but delayed by World War II), and then initiating congressional consideration of the multi-faceted Colorado River Storage Project (CRSP). After initial discussions, it was determined that the CRSP would consist of five cash register dams and 15 'participating projects' (i.e. regional irrigation systems), and would use the new economics proposed in the still-pending CAP bills to achieve what the General Accounting Office has since calculated as a 100% subsidy for the participating projects – truly a stunning fall for a programme that still claims to be fee based, but only a slightly larger subsidy than the system-wide reclamation project average.[14] In Congress, the CRSP bill enjoyed the support of the upper basin states and Arizona, but was opposed by a coalition of southern California water interests, fiscal conservatives and environmentalists (Terrell, 1965b).

The emergence of environmentalism as a political force in Colorado River politics was largely a new phenomenon, foreshadowing the eventual emergence of the public values paradigm. At issue in the CRSP bill was the proposal to build the Echo Park dam inside the Dinosaur National Monument (along the Utah–Colorado border). Ultimately, securing passage of the Colorado River Storage Project Act of 1956 meant abandoning the Echo Park dam proposal in exchange for an enlarged project at Glen Canyon – a Faustian bargain that is now widely regretted among environmental interests, due to the submergence of the spectacular canyons that characterize the Glen Canyon region (Terrell, 1965b). The dams authorized by CRSP provide nearly 34 MAF of storage capacity in four major units – Glen Canyon on the Colorado River in Arizona, Flaming Gorge on the Green River in Utah, Navajo on the San Juan River in New Mexico, and the Curecanti (now the Aspinall) Unit on the Gunnison River in Colorado. Eleven participating projects were also authorized to use the stored water, a great irony to many, given that the US Department of Agriculture was actively working elsewhere in the country at this time to take 40 million acres out of production to ease national crop surpluses (Terrell, 1965b).

Still additional projects in the upper basin (and elsewhere) were authorized in 1968 when the CAP legislation was finally enacted. As seen in the CRSP process, the passage of the Colorado River Basin Project Act meant abandoning the environmentally controversial 'Grand Canyon dams', this time traded for a massive coal-fired power plant (the Navajo Generating Station), which ironically impedes visibility of the canyon spared from the dam builders. Perhaps more than any other example, the coalition building and deal making associated with the act embodies the distributive politics epitomized by western water conflicts, as Arizona got its long-desired CAP only by conceding to California a junior water priority for Colorado River flows serving the project, and adding language authorizing projects in Nevada (the Southern Nevada Supply Project), Utah (re-authorization of the Dixie Project and provisional authorization of the Uintah Unit of the Central Utah Project), New Mexico (authorization of Hooker dam or alternative), and Colorado (authorization of the Dolores, Dallas Creek, San Miguel, West Divide, and Animas–La Plata Projects) (Ingram, 1990).[15] Overall, the Colorado River Basin Project Act legislation features a palpable lack of internal consistency or financial integrity, and marks the high water mark for the private commodity paradigm.

The Era of the public values paradigm

The successful efforts to block the Echo Park and the Grand Canyon dams were the precursors of a larger movement which fundamentally altered the legal, political and ideological foundations of the Colorado River. Until this point, the battles for the Colorado River, while heated and protracted, were among parties that viewed the resource through a common lens, emphasizing development, entrepreneurialism and private control. Sustaining the political viability of this paradigm required strict adherence to three related myths: (i) the economic argument that the federal reclamation programme pays for itself in user fees, a claim that is more than true for the multipurpose dams but only rarely a reality for the irrigation projects; (ii) the notion that these efforts worked to the benefit of the family farmer and other individual entrepreneurs, when in reality the benefits largely accrued to empire-builders such as banks, railroads and corporate agriculture; and (iii) the notion that the economic benefits of water development were so vast and fundamental as to render any concern over ecological impacts, the loss of environmental services, or the deterioration of other instream values as inconsequential (Fradkin, 1981; Reisner, 1986). Adhering to these now discredited myths fuelled numerous political careers and widespread economic development, and undoubtedly helped achieve the national goal of western settlement, but it also created something heretofore missing from the region: an urban constituency drawn to the aesthetic and environmental amenities of the region, supportive of public lands and other collective resources, and emphasizing quality of life over return on investment. It is more than a little ironic that aggressive water development activities in the West have created the infrastructure necessary to support approximately 55 million residents in the Colorado River basin states – up from 4 million just a century earlier (see Fig. 6.4) – and the subsequent rise of an 'ethic of place' (Wilkinson, 1990), based primarily on a public values paradigm.

The federal environmental movement

Efforts to reconcile these two competing worldviews take place in several arenas. One of the most controversial has been the evolution of federal environmental policy. Unlike the conservation movement of the early 1900s and the associated focus on the scientific utilization of natural resources (Hays, 1959), modern environmentalism has a strong preservationist ethic, which questions the underlying logic of utilitarianism, and also has a strong urban, aesthetic and public-health orientation (Paehlke, 1989). These threads run through several national laws enacted in the late 1960s and early 1970s, including, among others, the Wild and Scenic Rivers Act of 1968, the National Environmental Policy Act of 1969, the Clean Water Act of 1972, and the Endangered Species Act of 1973 (Rasband *et al.*, 2004). These acts, all applicable in the Colorado River basin, are forceful articulations of preservation, moderation and deliberative decision making, and all feature new opportunities for citizens to participate in decision making through both formal decision-making processes and a rapidly growing variety of ad hoc collaborative efforts (Kenney *et al.*, 2000). Of particular salience in

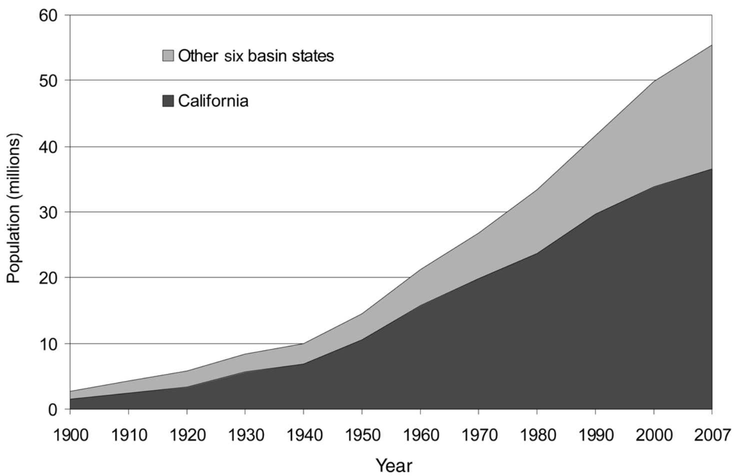

Fig. 6.4. Population growth in the Colorado River basin states (1900–2007). (Courtesy Brad Udall.)

the basin has been the Endangered Species Act, which effectively blocks new developments found to jeopardize the continued existence of threatened and endangered species, and which has forced many operational modifications to existing projects. Federal legislation enacted in this era and focusing on public lands management also articulates similar public values principles, a notable observation given that over half the Colorado River basin is federal public lands – a figure that jumps to almost three-quarters if tribal lands are included.

Still notably absent from this body of federal environmental legislation are rules requiring, as a matter of course, the reservation of water instream for environmental flows. Unless necessary in a given river stretch to protect an endangered species or to sustain the purposes of a federally reserved area (e.g. a waterfall associated with a national park), federal laws generally defer to the tradition in state water law of allowing water users to consume rivers in their entirety. Western states now provide some mechanisms for devoting water rights to instream flows, but these tend to be very limited in scope, often relying on water rights that are junior to traditional consumptive users (Gillilan and Brown, 1997). To the extent that rivers in arid regions of the American West retain some perennial flows, the cause is often the presence of senior water rights-holders downstream, which precludes some upstream (junior) diversions, or, on a larger scale, the existence of interstate compacts that require the maintenance of specified flow levels downstream. Since most demands on the Colorado River are in the lower reaches of the river, both legal requirements and economic patterns ensure that water flows remain relatively high (compared with unaltered flows) until reaching major diversion structures, mostly in California and Arizona. What is not maintained, however, are the peak flows needed to sustain the geomorphology and habitat characteristics required by native species. Major environmental restoration programmes in the upper basin, in the Grand Canyon reach (of the lower basin), and proposed efforts in the delta, for example, are all based around the desire to restore periodic peak flows, a goal that often runs counter to the purpose of constructing and operating water-storage reservoirs (Adler, 2007). To the extent that progress is made on these environmental issues, it usually takes the form of reservoir operational changes, including well-publicized (but very isolated and temporary) flood releases from the Glen Canyon dam. The actual removal of dams has been discussed, but is not an idea that has taken root in the Colorado basin.

In addition to substantive changes in water management, federal environmental laws also reshape the governance landscape. A strong theme running through most modern environmental legislation is a distrust of federal natural resource agencies, especially those accustomed to producing natural resource commodities. As a result, agency decision-making processes were reformed to be more specified and transparent than ever, with public participation, benefit–cost studies and environmental assessments as required elements, and with abundant opportunities for judicial review of decisions. Additionally, many natural resources agencies at all levels of government have found it increasingly worthwhile to work collaboratively with groups of public and private stakeholders on a variety of natural resource issues. The so-called 'watershed initiatives' are one expression of this phenomenon, mostly of the 1990s (Kenney *et al.*, 2000). These groups have been much more active in the small watersheds of the Pacific Northwest than those of the Colorado basin, and have found much more success dealing with water-quality issues than the water-supply disputes that characterize the more arid regions of the West, including the Colorado River basin, where the seniority concept is often viewed as an impediment to collaborative problem solving. None the less, they are one additional element of the Colorado's evolving institutional framework, encouraging a greater consideration of environmental and other public values as part of water management.

These changes in law and governance, combined with the demographic transformation of the region associated with its sudden urbanization, have presented a particular challenge for the region's primary dam builder and traditional enabler of the private commodity paradigm: the Bureau of Reclamation. A reorganization and temporary name change to the Water and Power Resources Service

(1979–1982) was one attempt to publicly embrace an evolving focus from water development to management. Similarly, the agency's need to rethink its constituency was perhaps firstly and most clearly articulated in its *Assessment '87* report, in which it noted:

> As irrigated agriculture becomes a smaller part of its mission, the Bureau needs to identify all of its constituencies. At the same time, however, it must assure agricultural interests that they are not being abandoned where there is a legitimate need for a continuing Federal presence. By working with new constituencies in potential partner arrangements, the Bureau can make an easier transition to an effective resource management organization.
>
> (USBR, 1987)

Although still an agency dominated by water resource engineering, by most measures the Bureau of Reclamation has been successful in evolving its mandate to include substantial foci on water-system efficiency, environmental mitigation, conflict resolution and urban water issues. A similar evolution has taken place in the other branches of the federal government. In Congress, key natural resource committees, once routinely dominated by powerful western defenders of reclamation programmes, now often feature members sceptical of (if not openly hostile to) environmentally and economically unsound reclamation programmes that are blatantly contradictory to the values expressed by their increasingly urban constituencies. Also, since the federal environmental movement, support for additional subsidized western irrigation projects has been spotty at best among most presidential administrations, first, and perhaps most famously, demonstrated by President Carter's 'hit list' of reclamation projects unveiled in the late 1970s, followed soon after by President Reagan's much less-publicized, but ultimately more effective, efforts to discourage questionable projects by the use of less-generous federal cost-sharing requirements (Reisner, 1986). To be politically viable, modern federal reclamation projects typically need to be small, feature extensive environmental mitigation elements, and be tied to Indian water rights settlements, such as the Animas–La Plata Project, nearing completion in south-western Colorado (Pollack and McElroy, 2001).

States, markets and the evolving role of agriculture

Although the Colorado River states have enacted several state laws consistent with the public values paradigm, the level of activity has generally trailed that of the federal government, perhaps in part due to the very fact that federal programmes now effectively cover issues of pollution and species protection, and also due to the observation that the state's role in water issues has generally been limited to administering prior appropriation rights, established, in most cases, decades before the modern environmental movement. Layering public interest protections and new efficiency standards on top of already established rights is a difficult task, which most states have been reluctant to tackle; rather, the more common focus is on establishing modest instream flow programmes (within the framework of priority rights) and adding terms to newly established or modified rights (Kenney, 2001). Of particular concern are rights transferred from one user to another – often in the modern era from agricultural to urban users. Outside some so-called 'water banking' activities, the legal transfer of water rights between Colorado River states is nearly non-existent and remains a highly delicate topic, but market-based water transfers within states are commonplace, and are the primary tool used to adapt the allocation of water in this region transitioning from rural to urban.[16]

The growing frequency of water transfers in the western states says a lot about the past, present and future of irrigated agriculture, although the message is far from clear (MacDonnell, 1999). Despite the emergence of several large cities highly dependent upon Colorado River flows (e.g. Las Vegas, Los Angeles, San Diego, Phoenix, Tucson, Denver, Albuquerque, Salt Lake City), the greater part – probably more than two-thirds – of Colorado River flows are still used in agriculture.[17] The most productive areas are in southern California and western Arizona, which produce roughly 80% of the winter vegetables of the USA (Project Wet, 2005). In the upper basin, much of the agricultural activity is focused on producing cattle feed; it has been argued that cattle are the single largest consumer of Colorado

River water (Fradkin, 1981). Thus, while the political might and economic importance of the agricultural sector have declined significantly, agriculture is still an important player in Colorado River water issues. Increasingly, agriculture plays two, largely contradictory, roles in western water issues: first, as a 'water source' for cities wishing to purchase rights to sustain ongoing population growth; and second, as a cultural and aesthetic amenity that urban dwellers often wish to sustain. Similarly, the viewpoint of irrigators towards water markets features two seemingly incongruent threads: first, that water markets provide an essential revenue stream for financially strapped or retiring farmers; and second, that the collective impact of markets can be a detrimental force undermining the viability of rural communities (Howe *et al.*, 1990). Not surprisingly, western state legislators are frequently caught in a dilemma of trying to streamline water transfers (to increase the efficiency and utility of transfers) while trying to ensure that transfers offer protection to third parties and public interests, typically defined to include rural communities dependent on farming economies and, less frequently, on environmental resources (National Research Council, 1992).

Living with Limits: a New Era for the Colorado?

The challenge

For several decades, water demands on the Colorado River have roughly matched the full available yield of the river, with most consumption happening in the last third of the basin. According to records provided by the US Bureau of Reclamation, from 1996 to 2000 (prior to the current drought), annual water consumption (depletion) averaged approximately 15.5 MAF: 8.0 in the lower basin, 3.7 MAF in the upper basin, 1.8 MAF in Mexico, and 2 MAF lost through reservoir evaporation (USBR, 2004).[18] Table 6.1 provides additional statistics on patterns of water consumption at 5-year intervals (not averages). Particularly noteworthy in Table 6.1 is the rise in demand throughout the 1980s and 1990s and, conversely, the sharp decline (evident by 2005) after the onset of aggressive drought-coping measures. Figures provided for Mexico are for deliveries, not consumption, although in most years the two values are comparable, given the tradition of full use in the basin.

Notwithstanding the important long-term challenges of finding water for environmental restoration and for some Indian communities with unresolved water rights claims, in most other respects, this tradition of full use is not inherently problematic, as long as the least reliable component of water yield is only used as a supplemental supply (ideally for low-valued uses) and not as the baseline supply supporting urban growth. Unfortunately, this is not the situation in many pockets of the basin, as rural uses generally precede urban uses (and thus rank higher within states' prior-appropriation systems). This is an unusual situation, but it is one that can be remedied. As noted above, state water laws provide an important mechanism to reallocate water (and the risk of shortages) through voluntary agricultural to urban water transfers, ranging in form from the dozens of small transactions occurring each year along Colorado's Front Range to the massive deals in southern California that have weaned urban areas off surplus flows (i.e. flows in excess of the state's apportionment) through complex conservation and transfer arrangements with major irrigation districts. But, ultimately, the efficacy of this strategy for managing water supply risk in particular locales in the Colorado River basin is shaped and limited by the larger interstate rules of water allocation codified in the Law of the River and, perhaps more importantly, by the realization that the overarching challenge in the basin is to acknowledge and live within the limits of the river. This challenge has a particularly complex flavour in the Colorado River basin due to the river's overallocation.

In theory, the Law of the River provides the framework within which water budgets can be established and shortages allocated, if necessary, between the Colorado River states and Mexico. However, as noted earlier, the apportionment found in the Law of the River is flawed in many ways, as it annually allocates 16.5 MAF (7.5 MAF for each basin and 1.5 for Mexico) from a river that yields, at best, 15 MAF. The fact that the Colorado River is over-allocated has been widely understood for many decades but has become more difficult to ignore as urban growth results in larger (and firmer) water demands and as drought conditions have gripped the basin. Several trends suggest this situation could worsen; population growth, climatic change and energy development all suggest further stress on water resources. Faced with these pressures, states such as Colorado and Arizona, which historically have not used their full apportionments, continue to pursue additional development and consumption of the river. To not do so would ease stress on the river but only by imposing burdens (limits) on their own residents for a situation that others have primarily created and benefit from, and from which the Law of the River is supposed to provide protection. Somewhat ironically, this expansion of use has become more realistic as problems of overuse have forced California to scale back its use to its legal apportionment (from 5.2 to 4.4 MAF/year).[19] But the calculus remains unchanged: if all states pursue plans that target consumption at the level of their legal apportionments, and if those apportionments are collectively more than the river provides, then the situation is inherently unsustainable. This reality is particularly troublesome in an era of climatic change; even a modest 10% reduction in flows would provide a tremendous challenge to the regional water budget.

Solutions?

The twin forces of drought and growing demands, and the net impact of declining reservoir storage (see Fig. 6.5), prompted the federal government in 2005 to warn the states that they needed to develop a plan for sharing shortages or the federal government would do so independently. Ironically, despite all the nuanced language in the Law of the River, there had always been much ambiguity in how shortages in the lower basin should be handled. While the Upper Basin Compact provides some rules and establishes a commission to calculate and enforce shortages in that part of the basin, the legislation apportioning lower basin shares does not explicitly address the allocation of potential shortages and does not establish a commission to address the issue. The Supreme Court in the Arizona v. California (1963) litigation appointed the Secretary of the US Department of Interior to make these decisions when necessary, and, in 2005, the Secretary made it clear that her preference was to ratify a scheme developed by the states rather than to impose her own solution.[20] For the states, this was a formidable political challenge, as no state official wanted to agree to a reduction of its apportionment or to any change in the management of reservoirs or water accounting that modified the reliability of that apportionment. Political careers in the

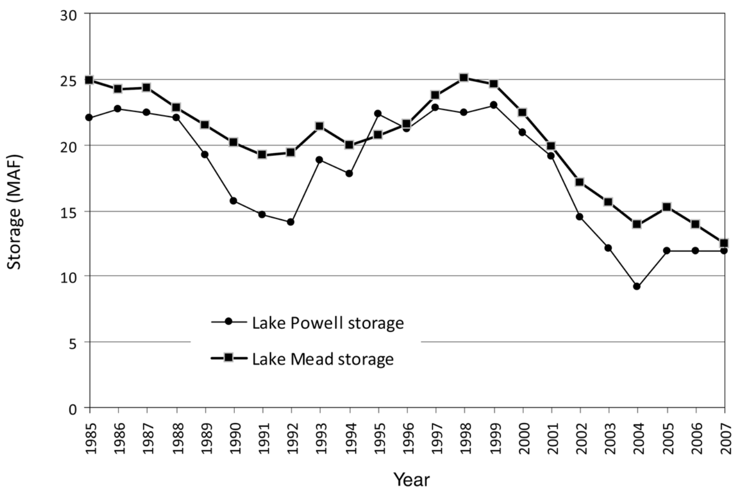

Fig. 6.5. Storage in Lakes Powell and Mead, 1985–2007.

American West have been historically built on the ability of leaders to obtain more water (Reisner, 1986; Ingram, 1990). Voluntarily agreeing to take less could be viewed publicly as failure and even as immoral, as the 'rights-based' tradition of water law in the West makes it very difficult to consider compromise or sharing (Wolf, 2005). The situation was, at best, a zero-sum game and explained why resolving the problem had been deferred for decades.

Through an elaborate planning and decision-making process centred around a document known as the Environmental Impact Statement (EIS), the states and federal government in 2007 concluded a contentious negotiation modifying reservoir operations (for Lakes Powell and Mead) and specifying rules for sharing shortages in the lower basin (USBR, 2007). The new rules call for water storage to be balanced more equally between the two main reservoirs, and prescribe a schedule of lower basin curtailments should storage in Lake Mead fall below specific elevations. Following the political compromise made back in 1968, which subordinated the water right to the Central Arizona Project to other lower basin users, it is the CAP that will bear the brunt of shortages. As before, the Secretary of the Interior is empowered to administer the programme and retains sole decision-making authority should water levels drop below the levels described in the shortage-sharing schedule. Although many issues about apportionment and shortage sharing remain, these new rules address the most pressing omissions in the legal framework.

The reservoir operations and shortage-sharing rules were the most debated elements in the EIS process; however, the new rules also address mechanisms (and incentives) for supply augmentation and conservation (USBR, 2007). These elements may be the linchpins to future progress, as including these elements allows the states to maintain the goal of additional development and use of the river, and transform the politics back to a positive-sum situation. In the past, the key to positive-sum bargaining in the basin was to expand the available benefits (i.e. water and power) through new storage and conveyance facilities, and by excluding public value proponents from decision making. Today, the situation is more complex, as far fewer opportunities exist for increasing yield through new storage, and environmental interests are an entrenched stakeholder, empowered by both law and public sentiment. The result has been the emergence of an unusually rich suite of strategies for increasing yields and avoiding (overcoming) limits, highlighted by efforts to eliminate reservoir spills (and associated overdeliveries to Mexico), marketing of water salvaged through conservation programmes, the eradication of water-loving tamarisk and Russian olive trees, weather modification (i.e. cloud seeding), desalination, the proposed importation of water from neighbouring basins, and compensated fallowing of agricultural land.[21]

Each of the augmentation and conservation strategies raises a host of difficult legal and political issues; by comparison, the engineering and economic challenges are almost inconsequential. One emerging issue is best expressed as the 'efficiency paradox', which refers to the observation that 'inefficiencies' associated with leaky canals, reservoir spills, inefficient irrigation practices and other system losses are often the primary source of water for valued environmental resources, such as the Colorado River delta, the Salton Sea (in southern California) and many other sites of high ecological importance. If these interests are considered – i.e. if the paradigm of decision making is broadened to include environmental values – then these efforts are not truly an augmentation strategy offering mutual benefits but are merely a zero-sum reallocation from public environmental interests to water users. Thus, while not as obvious as a debate over a new dam, this movement toward 'conservation and augmentation' strategies on the Colorado River is none the less another paradigmatic conflict and brings into question whether the full meaning of limits, restraint and sustainability will ever take hold in this basin.

As seen in intrastate water politics, the role of agriculture is also a prominent consideration in the future of regional (interstate) water management. For example, California's recent efforts to scale back its overall consumption to its legal apportionment has primarily been achieved through the reallocation of water from agricultural to urban users, with damages to agricultural interests offset by cash payments (these are voluntary transactions) and by efficiency programmes that allow most farming operations to continue with less consumption (but with less recharge of the Mexicali aquifer used in Mexico and less runoff for regional sinks, such as the Salton Sea, which is a critical habitat for migratory waterfowl). Agricultural interests in California and the other lower basin states are also implicated by the emerging ICS (Intentionally Created Surplus) programme, which allows water saved through 'extraordinary' conservation, efficiency projects, land fallowing and river augmentation to be transferred to other, mostly urban, users (USBR, 2007). Notwithstanding the environmental issues associated with the efficiency paradox and the hesitancy of regional leaders to embrace concepts of limits and sustainability, these ICS efforts offer many benefits to cities struggling to serve growing populations and farmers looking to stabilize (or even augment) revenues while responding to concerns about the high level of water use in agriculture.

Concluding Thoughts

The Colorado River of the south-western USA remains one of the world's most intriguing natural resources, valued as a critical water supply in an arid and suddenly populous region, and a source of natural beauty and grandeur few other rivers can match. It is also one of the world's most overstressed rivers, burdened by high expectations and by an institutional framework lacking in vision, coherence and sound assumptions about what is, and what should be, available to the community of farmers, cities and other water interests. Once immersed in these institutional issues, it is difficult to be optimistic about the river's future, particularly as growth and climatic change further challenge traditional management solutions, and regional (basin-wide) forums of planning and action are largely non-existent. Many organizations – including the Upper Colorado River Commission – exist with an interest in particular Colorado River issues and subregions, but there remains no river basin organization within which to study, consider and facilitate fundamental change in the basin. This institutional deficiency has been noted by several authors, who argue that the establishment of a basin-wide commission would be a valuable first step in framing, debating and ultimately addressing the issues in the Colorado basin that transcend the interests and authorities of any given state or interest group (e.g. see Kenney, 1995; Morrison *et al.*, 1996; Getches, 1997). The basin states have not been receptive to these proposals, in part due to concerns about establishing mechanisms that may increase the influence of Indians, Mexico, the federal government or environmental interests in basin politics.

Ultimately, a new way of doing business will need to emerge in the basin – either incrementally or in a dramatic rush, perhaps triggered by empty reservoirs – and regardless of what that 'new way' looks like, it seems certain that few interests will be transformed as fundamentally as the agriculture sector. Even today, in a service area of over 30 million residents and a period of water stress, agriculture still consumes the greater part of the Colorado River water, often for uses that, in economic terms, are of low value. Ironically, this is perhaps the best long-term hope for this basin, as this provides an opportunity for market-based water reallocations, which could sustain cities and the most profitable farms for several decades. Agricultural to urban water reallocations are already seen throughout the basin, especially in southern California, and are finally emerging at a larger regional scale in the lower basin, through water-banking schemes and, potentially, the emerging ICS programme.

Water marketing, however, while probably more ecologically benign than the efficiency projects, comes with several hidden costs. Disentangle markets from legal constraints, and economic subsidies and the cities, industrial users and some instream uses (particularly hydropower) would find ample supplies; some farmers would enjoy needed revenue; and the highest-valued agriculture, particularly for fruits and vegetables, would continue uninterrupted for decades as lower-value feed crops were first phased out. Probably fairing less well would be non-market and public values (e.g. environmental resources) and rural communities dependent on lost farming economies. Additionally, the promise of the Colorado River Compact would be lost – i.e. the idea that a certain amount of water should be reserved for each region of the basin, in perpetuity, to support local lives and lifestyles, regardless of whether they were economically competitive with those in other regions. If not for this arrangement, farmers in Wyoming, for example, would never be competitive for water with casinos in Las Vegas. Perhaps that is fine; at the least, it is explicit in identifying that trade-offs need to be made if the region is ever to live within its means. That, after all, seems to be the biggest omission in the current arrangements, and in the current discussions on how to move forward. What should Colorado River allocation, management and use look like, given inherent limits in water supply and the imperative to consider traditionally excluded parties – the environment, tribes, Mexico – better in decisions? If history is a guide, then this is a question that is likely to exceed the capabilities of existing institutional decision-making forums, political leaders and paradigms. There is work to be done.

Notes

1 These statistics are compiled from data recorded by the US Bureau of Reclamation: http://www.usbr.gov/uc/water/crsp/cs/gcd.html.

2 Population statistics are compiled by the US Census Bureau and distributed online at www.census.gov.

3 These figures come from recent studies using the general circulation models (GCMs) associated with the fourth Intergovernmental Panel on Climate Change (IPCC) assessment. A summary of these and other relevant studies is provided in Appendix U of USBR, (2007).

4 Lower basin tributaries are much smaller, perhaps 2–3 MAF (million acre-feet) but are, more importantly, legally considered as outside the apportionment and management scheme of the Colorado River.

5 Estimating long-term natural (i.e. unaltered) streamflows at Lee Ferry is an inexact science, coloured by technical and political complications. Generally, these efforts fall into two general categories: those based on actual stream gauges (usually beginning in 1906) and those based on tree-ring reconstructions (which can go back as far as the year 762) (see www.colorado.edu/resources/paleo/lees/). Estimates based on actual stream gauges are primarily offered by the Upper Colorado River Commission and by the US Bureau of Reclamation, and usually fall in the range of 15.1–15.3 MAF/year (e.g. see UCRC, 2004; USBR, 2006). Slight differences generally reflect how many of the recent drought years are included in the analysis. Those based on tree-ring reconstructions suggest a lower long-term average. For example, the landmark study by Stockton and Jacoby (1976) suggested an average as low as 13.4 MAF/year. More recent reconstructions from 1490 to 1997 by Woodhouse *et al.* (2006) and from 762 to 2005 by Meko *et al.* (2007) suggest an annual value of 14.7 MAF.

6 Water volume in the western USA is measured in acre-feet. One million acre-feet (MAF) = 1.233 billion m3. Throughout the rest of this chapter, the MAF unit is used exclusively, despite its unfamiliarity outside the western USA, as the flow and apportionment numbers expressed in MAF units have great familiarity and significance in the region, and are of a convenient scale.

7 Of particular concern are efforts to line the All-American canal to reduce cross-border seepage and to construct a Drop 2 reservoir to catch main-stem overdeliveries to Mexico (with most of the 'conserved' water going to San Diego and Las Vegas). On the Colorado, seepage, reservoir spills and other 'inefficiencies' are often an important source of water for environmental resources. In most cases, water managers are under no obligation to continue these flows, and face powerful incentives to capture this water to serve growing human demands.

8 In order to take full effect, a compact must be signed by the negotiators, ratified by the legislatures of each of the participating states, and then be ratified by the federal government. The Colorado River compact was signed by the states in 1922, but was not officially ratified until it was accepted (ratified) by Congress in the 1928 legislation. The process was highly unusual in that Congressional ratification occurred before Arizona ratified the agreement, which did not occur until 1944. The delay, in large part, could be traced to a long-standing dispute between Arizona and California, which was not resolved until the conclusion of the Arizona v. California litigation many years later.

9 As noted later, rules for allocating shortages were not established until 2007.

10 The 6 MAF value is produced by subtracting 7.5 MAF (the lower basin apportionment) and 1.5 MAF (the Mexican apportionment) from a likely average yield of 15 MAF. It is only if the river's yield is 16.5 MAF or higher, as originally believed, that the upper basin receives the full apportionment of 7.5 MAF. The most controversial part of this analysis is the treatment of the

Mexican apportionment, which is to be reduced in some proportional (but otherwise unspecified) way to uses by the USA in a drought crisis. Since the Mexican obligation is a relatively small amount of water, any interpretation does not invalidate the observation that the upper basin is the primary entity harmed by the overallocation of flows.

11 Many of the key elements of tribal water rights in the Colorado River basin were established as part of the Arizona v. California (1963) litigation, which established the 'practicably irrigable acreage' standard for measuring rights, reiterated the great seniority of these rights and quantified rights for five lower main-stem tribes at over 900,000 acre-feet. Since tribal water rights are subtracted from the apportionments of the states in which they are located, there is a zero-sum competition for Colorado River flows among Indians and non-Indians within each basin state.

12 CAP allocations are listed at http://www.cap-az.com/docs/SubcontractStatusReport_03_13_08.pdf.

13 As the name implies, the Colorado–Big Thompson Project diverts water from the Colorado River main stem in western Colorado to the Big Thompson River in eastern Colorado, using the Adams tunnel to avoid the necessity of pumping water over the continental divide. The exceedingly complex project, completed in 1956, exports roughly 260,000 acre-feet/year to a mix of agricultural and municipal interests along Colorado's Front Range (Tyler, 1992).

14 Overall, the General Accounting Office (GAO, 1981, 1996) and Water Resources Council (1975) estimate federal irrigation project subsidies in the range of 82–98%.

15 This type of political behaviour is often called logrolling, and occurs when legislators from various jurisdictions all agree to support each other's proposed projects in their home districts. In this way, a project with only local appeal can gain the support of a broad base of legislators.

16 It is worth noting that Nevada has been the primary entity promoting interstate water transfer mechanisms, such as the water banks and the intentionally created surplus (ICS) programme (discussed later), as it is the only basin state that already uses its full apportionment exclusively for municipal uses (e.g. Las Vegas), and is thus very limited in its ability to support urban growth based on water transfers from agriculture.

17 Compiling water and water-use statistics in the Colorado River basin is notoriously difficult for many reasons, including the separation of administrative responsibilities between the upper and lower basins, and the differing traditions regarding the inclusion (or exclusion) of tributaries and the accounting of water (and water uses) once exported from the hydrologic basin. Additionally, patterns of water use can change significantly year to year; figures are updated frequently, and there is rarely agreement on any single set of statistics as being 'official' or formally accepted. With these caveats, the best available data come from the *Consumptive Uses and Losses Reports* issued by the Bureau of Reclamation (see www.usbr.gov/uc/library/envdocs/reports/crs/crsul.html). Unfortunately, these reports are not very useful for tracking main-stem use of Colorado River water in lower basin agriculture, which is shifting rapidly – particularly in southern California. Statistics for the upper basin suggests that agricultural land area and water consumption have both increased by about 10%, from the 1981–1985 to the 1996–2000 period, comprising in both periods about 68% of all upper basin consumption. These values have probably dropped in recent years due to drought conditions.

18 During the current drought, this total level of use has been reduced by efforts in California to scale back overuse (to its legal apportionment), by a reduction in the amount of spills and overdeliveries to Mexico, and through reduced evaporation from reservoirs that are currently at unusually low levels. Collectively, these efforts have re-balanced the system-wide water budget at least temporarily, assuming average yields – a condition that has existed in only one year between 2000 and 2007.

19 The so-called '4.4 Plan' is implemented as part of the Quantification Settlement Agreement (QSA) and is described in *The Colorado River Water Delivery Agreement* (text available at www.saltonsea.water.ca.gov/docs/crqsa/crwda.pdf).

20 As part of the litigation, a Special Master employed by the court suggested that lower basin shortages be apportioned in ratios matching the apportionment; thus, California's share of reductions would be 4.4/7.5, Arizona's 2.8/7.5 and Nevada's 0.3/7.5. The court rejected this approach as being overly rigid.

21 An inventory of augmentation options was recently compiled in research commissioned by the Southern Nevada Water Authority and is summarized at: www.snwa.com/assets/pdf/augmentation_summary.pdf.

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